24th AMEU Technical Convention

6 to 9 October 2013

"Supporting SA infrastructure and service delivery objectives"

Special AMEU Convention Proceedings edition

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2013

Wireless field area networks in smart grids

Information from ABB

Smart grid applications need real-time, bidirectional communications between the utility's data centre, substations and utility devices in the field to provide instantaneous information of the network's status.

Wireless field area networks (FANs) link smart meters and intelligent electronic devices (IEDs) in the distribution system to substations and the utility's data centre. IEDs usually connect directly to the FAN. Smart meters generally use a lower bandwidth neighbourhood area network (NAN) to communicate with an advanced metering infrastructure (AMI) collector that aggregates data from a large number of smart meters. The collectors, in turn, connect to the FAN. The FAN transports information between NANs and IEDs and the utility's core IP network. The core IP network connects to the data centre, where the smart grid software systems are located. Fig. 1 shows the overall network architecture.

One network, many applications

Many utilities implement single-purpose communications in their distribution system with, for example, one network serving an AMI, another serving a distribution area (DA) and yet another being used for mobile workforce automation. Unified networks provide better return on investment, lower operating costs due to standardising on fewer hardware and software products, the ability to centrally manage the network for improved reliability, the ability to enforce consistent security and quality of service (QoS) policies and efficiencies. Utilities can reap similar benefits if they adopt a one network, many applications model in their FANs.

Field area network requirements

To support many applications concurrently, FANs need to:

- Have high data capacity and low latency
- Be able to prioritise various applications
- Ensure reliable data communications by automatically using multiple paths, channels and frequency bands to route around failures
- Be able to support a wide variety of applications and devices using industry standards and automation protocols
- Keep data secure
- Be scalable

Tropos mesh networks for field automation applications

Tropos wireless mesh networks from ABB enable utilities to build one network that aggregates communications for all smart grid applications and systems. FANs based on this architecture provide the following of benefits:

Interoperability/open standards

Smart grid deployment requires collaboration among vendors and technologies. Based on open standards, these FANs interoperate with other smart grid components.

Highly available

High resiliency is provided with multiple redundant communication pathways to ensure that there is no single point of failure. Dynamic channel selection, adaptive noise immunity and other advanced RF resource management techniques provide added flexibility.

Multi-use network

These FANs enable the creation of multiple virtual networks, each with their own QoS and security policies, completely segregating the traffic of different applications and user groups.

Secure

A multi-layer, defense-in-depth approach is implemented using embedded IPsec virtual private networks and firewalls, RADIUS authentication and AES encryption.

High capacity and low latency

This architecture can support >10 Mbps throughput at each router with <1 ms latency per hop.

Application QoS

These FANs support IETF and IEEE QoS standards in addition to mesh extensions to deliver application-based QoS.

Distributed architecture

Since they do not rely on a centralised controller for their operation, functions such as network optimisation, path selection and routing, and enforcing security and QoS policies are performed separately.

Scalable

These networks scale to large coverage areas, with a large number of users transferring massive volumes of data and large numbers of routers.

Centralised management

A comprehensive and scalable network management system supports network implementation and optimisation as well as ongoing management of key performance indicators.

Summary

As smart grids evolve, the vision of a self-healing distribution grid that effectively and efficiently balances supply and demand comes closer to reality. Intelligence and bidirectional communication are key enablers of this. Wireless FANs, smart grid systems located in utility data centres and substations can collect up-to-the second information from the distribution system, be used to adjust system operation, automatically read meters, reduce peak loads, integrate distributed generation and energy storage systems, proactively engage customers and predict pending failures, enabling preventative maintenance forecast and planning.

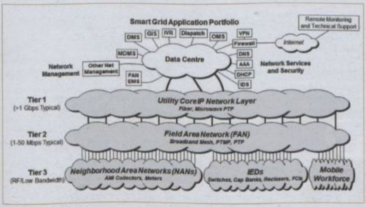

Fig. 1: Overall network architecture.

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Welcome address by the AMEU president

I have great pleasure in welcoming you to the 24th AMEU Technical Convention here at ICC East London, hosted by Buffalo City Metropolitan Municipality.

I trust that you will enjoy your time with us and that the AMEU convention programme for the next three days and the affiliate's sports day will fulfill all your expectations. I want to thank the 2013 convention team for their effort in ensuring that this event is a resounding success, taking into account the increased challenges year by year to keep up with the standards set by our predecessors.

A special thank you must go to our affiliate committee and the many sponsors of this wonderful event. We always say it and I want to say it again, it would not be possible to host such a professional event without their support and in the same breath I want to thank the Buffalo City Metropolitan Municipality for supporting me as president and for their financial contribution as the host city.

All delegates please enjoy your stay in East London, the convention and the networking with colleagues. Thank you for your support to the AMEU and the role you as delegates play to make our conventions a major success year after year.

Hannes Roos, AMEU President

Hannes Roos, AMEU president

Message from the AMEU president elect

It is truly a great honour and privilege to welcome all of you to the beautiful Buffalo City Metropolitan Municipality, which holds its place in the country's history as having been named after a river (Buffalo River), at whose mouth lies the only river port in South Africa.

That we have chosen Buffalo City Metropolitan Municipality to host this year's technology convention is quite fitting with the theme of the conference which seeks to focus our attention to how best municipal electricity utilities can support South Africa's infrastructure and service delivery objectives.

Buffalo City, like many municipalities across the country, is facing a number of infrastructure and service delivery challenges. These are hindering its ability to increase its contribution to the country's economic growth and providing a better life for all. This is after all, part of the reason we exist.

While as utilities we can be proud of the great progress we have made in improving access to basic services for millions of South Africans, the reality is that a significant percentage of the country's population either still cannot access electricity or cannot afford it. Therefore our work is far from done. The fact that you have all taken the time to gather here says you will not rest until every South African has access to basic services. This includes adequate, reliable and affordable electricity.

The importance of achieving this objective cannot be understated.

A recent study by the UCT Graduate School of Business reveals that service delivery protests will continue to be a key feature of the South African landscape until utility organisations find new ways of solving the challenges they face. These, as you all know, include aging infrastructure and its poor maintenance, insufficient capacity, and the skills and expertise deficit within our organisations. As South Africa endeavours to improve the quality of life of its citizens and continue to be top of mind for foreign direct investment, it has become pressing that utilities resolve their challenges.

Sicelo Xulu, AMEU, president elect

The country's economic prosperity and indeed its social stability is dependent on our ability to provide adequate and reliable electricity not only to households but also to businesses across the different sectors. To do this, we need to start being innovative in how we do things more so because unlike other entities, municipality utilities do not have the luxury of withdrawing their services if continuing to offer them is either difficult or no longer financially viable.

As many of you are aware, Johannesburg City Power recently had to manage illegal strike action by its employees who were protesting

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Keynote address at the AMEU Technical Convention 2013

by Dr. Wolsey Barnard, Department of Energy

A good working relationship has been established between the Department of Energy (DoE) and the AMEU, and this longstanding relationship is appreciated. The important role that the AMEU is playing, not only in keeping the lights on at a municipal level, but also as a professional association that is operating on different levels within the energy environment, is recognised and valued.

This is reflected in the fact that you are not rendering assistance at a political/governance municipal level with service delivery aspects, but also to be a resource basic for influencing national standards, policies and strategies. This is not an easy task given the ever changing environment; either it has been political, technical, as well as structural challenges that are inherent within all spheres of government and the energy environment.

This convention is technical in nature and it is interesting to note the various themes to be deliberated upon during the next three days. It indicates the changes and challenges that are faced by the electricity distributors in the country and globally. The theme of "Supporting infrastructure and service delivery objectives" is very relevant and it is good to see that the AMEU is after 98 years still as relevant and directional as it was when it was established. The keynote address will focus on some aspects that will be covered by experts in the respective fields.

IEP

Firstly I would like to share the background view on the issue of future energy planning in South Africa.

Energy is one of the key elements in production processes. A lack or shortage of energy has a serious effect on the economy and gross domestic growth. By virtue of its size and economic importance, the energy sector periodically requires considerable investments in new and replacement supply capacity. Historically, such decisions were primarily driven by concerns regarding maintaining supply security, without giving full consideration to the economic, environmental and social impacts of all alternatives. As a consequence, the tendency has been towards the construction of large-scale capital-intensive supply facilities and the neglect of alternatives that might have been more cost effective in the long term with greater employment benefits and more favourable environmental impacts.

Over recent years, the contribution of different sectors to the country's gross domestic product (GDP) has changed significantly. In the past few years the industrial policy has shifted towards a greater focus on knowledge-intensive sectors and human resource development, placing less emphasis on comparative advantage based on natural endowments. Primary production like agriculture and mining now contribute less to the economy than the tertiary or services sector. The tertiary sector now contributes almost two-thirds of our GDP. This implies a lowering of overall energy intensity, as generally the energy required per unit product (measured in rands) is less for the tertiary sector compared withthe primary sector. This shift is similar to what has occurred in most industrialising nations. This does not mean that agriculture and mining are becoming unimportant, but that the energy sector may re-focus efforts on how to further exploit South Africa's endowments. Such re-focusing may be based on integrated energy planning.

The development of a National Integrated Energy Plan (IEP) was

Dr. Wolsey Barnard, Department of Energy

envisaged in the White Paper on the Energy Policy of the Republic of South Africa of 1998 and, in terms of the National Energy Act, 2008 (Act No. 34 of 2008), the Minister of Energy is mandated to develop and, on an annual basis, review and publish the IEP in the Government Gazette. The purpose of the IEP is to provide a roadmap of the future energy landscape for South Africa which guides future energy infrastructure investments and policy development.

Integrated energy planning entails understanding the current and future energy requirements of different types of consumers (e.g. industry, commerce, mining, agriculture, households, etc.) and then determining the most optimal mix of energy sources and technologies to meet those energy needs in the most cost-effective, efficient, socially beneficial and environmentally responsible manner. Delivering energy to end users requires multiple processes (production, conversion, transmission and distribution) and involves many participants, from both the public and private sectors. Today's choices about how energy is extracted, harnessed and used will determine the sustainability of the energy system in the future and thereby influence the extent of socio-economic development.

This is the background to the development of the IEP that was approved by Cabinet in June 2013 to be discussed with all role-players in the energy environment. The first workshop was ten days ago in Johannesburg, but two more workshops have been planned for 24/25 October in Cape Town and 30/31 October in Durban. I want to invite the AMEU and its members to actively participate in this process. This is the first policy paper to obtain a balanced view of supply and demand balance with regard to the diverse energy environment in SA.

Because a reliable network depends on safe, flexible, and maintenance-free switchgear

Introducing Premset MV switchgear, flexible architecture designed to improve peace of mind.

Switchgear designed for enhanced peace of mind

Because business relies on the availability of electricity, buildings need their medium voltage distribution systems not only to be reliable, but also to be energy efficient, durable, and able to adapt to changing business needs.

But the operators of these systems require more. Peace of mind is paramount, and can only be achieved with low-maintenance switchgear that helps ensure the safety of both people and assets. Switchgear that enables monitoring and lowers the total cost of ownership is critical.

Stress-free installation, upgrading, and maintenance

By combining proven technologies with a modular architecture and the Shielded Solid Insulation System, Premset™ MV switchgear represents a breakthrough innovation in MV distribution. Additionally, its compact and easily upgradeable design optimizes your costs through:

> Maintenance-free operation
> Extended life
> Easy installation and upgrades
> Compact size

The 3-in-1 architecture means its operation is not only intuitive — it's the safest switchgear in its class. And, due to an SF6-free design, end-of-life is made easier, with no need to worry about future legislation.

High modularity with total insulation

Premset architecture is based on type-tested assemblies of functional blocks which are designed to work together in every combination to improve cost savings while facilitating modifications.

1. LV cabinet
2. Cable test
3. Top connection
4. Core unit
5. Bottom connection
6. Bottom compartment

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Over recent years, the contribution of different sectors to the country's gross domestic product (GDP) has changed significantly. In the past few years the industrial policy has shifted towards a greater focus on knowledge-intensive sectors and human resource development, placing less emphasis on comparative advantage based on natural endowments. Primary production like agriculture and mining now contribute less to the economy than the tertiary or services sector. The tertiary sector now contributes almost two-thirds of our GDP. This implies a lowering of overall energy intensity, as generally the energy required per unit product (measured in rands) is less for the tertiary sector compared withthe primary sector. This shift is similar to what has occurred in most industrialising nations. This does not mean that agriculture and mining are becoming unimportant, but that the energy sector may re-focus efforts on how to further exploit South Africa's endowments. Such re-focusing may be based on integrated energy planning.

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With the IEP being out for public comments, it is also important to note that the AMEU should start considering the "E" in AMEU to become energy. The challenges for local authorities are not only limited to the supply of electricity, you have to become more involved in energy supplies. This has also been foreseen in the constitution with regard to the supply of gas.

IRP and future generation projects

As one of the pillars of this IEP will be the IRP, which is focusing on the electricity supply options and direction to be taken with regard to future technology options and timeframes.

Government has embarked on an electricity infrastructure capacity path to ensure security of electricity supply, and pursuing energy to meet the needs of our fast growing economy without compromising our commitment to sustainable development by utilising our fossil resources responsibly.

The IRP2010, as promulgated in May 2011, proposed various technology options that address the additional capacity requirement of 42 000 MW by 2030.

• Wind	8400 MW
• Solar PV	8400 MW
• Concentrating solar power	1000 MW
• Open cycle gas turbine	3900 MW
• Gas closed cycle gas turbine	2400 MW
• Import hydro	2600 MW
• Nuclear	9600 MW
• Coal	6300 MW

It has the effect that about 18 000 MW of the new build generation will be regarded as RE, which results in about 42% all new build will come from RE sources.

In converting the IRP as a plan, into action, one of the first actions taken by the Department of Energy was to initiate a process to allocate 3725 MW renewable energy resources by 2016 to independent power producers. The first and second "window" of successful bidders resulted in over 2600 MW being allocated to various renewable energy resources in December 2011 and May 2013 respectively. The overall foreign direct investment into the renewable energy generation will be over R70-billion by 47 IPPs. The third window closed at the end of August.

The current reality is that more than 65% of South Africa's total energy needs are met through coal as the primary energy source. This is followed by crude oil at around 22%, while the remaining 13% of our energy needs are met by gas, nuclear, hydro and renewable energy sources combined. Coal therefore plays the dominant role in our supply of energy, especially in the electricity sector where approximately 90% of the country's electricity is produced in coal-fired power stations, the country's biggest source of greenhouse gas emissions, while nuclear, gas, hydro and renewable energy sources make up the remaining 10%. We cannot, however ignore the fact that we are a coal-rich economy, nor can we ignore the significant contribution of the coal mining industry towards the economy. In 2010 South Africa had an estimated 32-billion t of coal reserves (which at current local consumptions rates could last us more than 100 years).

Irrespective of the fact that we are a coal-rich economy, government is committed to having increased focus on the advancement of clean coal technologies through projects such as underground coal gasification, as well as carbon capture and storage (CCS). If we are serious about diversification towards a low carbon economy, then we cannot ignore the role that natural gas and nuclear power can play as a bridging gap in this transition.

I would like to urge municipalities to become actively involved in the REIPP programme. It can be a benefit to your maximum demand and become an attraction for future investment into your area. Nelson Mandela Bay Metro (NMBM) has taken the lead in this regard with the first wind farm that will generate RE by means of wind to be supplied into the grid, and then to the distribution grid network of NMBM.

It is important to note that the Minister of Energy has already made another determination for 3200 MW RE – which includes CSP, solar PV, biomass, biogas, landfill gas, and hydro by 2020.

Infrastructure development

This brings me to the issue of infrastructure development. Cabinet adopted the National Infrastructure Plan which intends to transform the South African economic landscape. In the context of the National Development Plan (NDP), and with the vision set about through the National Infrastructure Plan, we have set our country on a course towards meaningful and sustainable development.

- The Presidential Infrastructure Coordinating Commission (PICC) was established to integrate and coordinate the long term infrastructure build programmes (Infrastructure Plan) over all three spheres of government.
- Eighteen Strategic Integrated Projects (SIPs) have been developed and approved to support economic development and address service delivery in the poorest provinces.
- The SIPs cover a range of economic and social infrastructure.
- All nine provinces are covered, with emphasis on poorer provinces.
- The focus of each SIP:
  - Localisation
  - Job creation/skills development
  - Research and technology development
  - Stimulate green economy and
  - Empowerment improvement

Some of the SIPs that are central to the Department of Energy's scope of operation and of the AMEU are the following:

- SIP 6: Integrated municipal infrastructure: To address all the maintenance backlogs and upgrades required in water, electricity and sanitation bulk infrastructure in the 24 least resourced district municipalities, covering 23-million people, in a project that is nationally managed but locally delivered.
- SIP 8: Green energy in support of the South African economy: RE IPPs, SWH, etc.
- SIP 9: Electricity generation to support socio-economic development.
- SIP 10: Electricity transmission and distribution for all.

A number of government departments and SOE are currently working on skills plans for all SIPs. Concrete actions are also developed for the use of infrastructure to industrialise South Africa. I know that AMEU has also been asked to become involved in the PICC process, and I want to encourage you to participate in this programme to ensure that South Africa's infrastructure is upgraded to support a growing economy. This is in line with the theme of this 24th AMEU Technical Convention.

It is impossible to consider the security of supply situation without critically addressing the problems facing the electricity distribution infrastructure specifically. It won't help the country if the new build programme ensures adequate supply of electricity that cannot be effectively and efficiently distributed to the end-users.

EDI

In parallel, DoE will implement the Approach to Distribution Asset Management (ADAM) programme which forms part of SIP 6 and 10, to address the distribution industry infrastructure and resource challenges.

ADAM is in essence a three-legged approach:

- Addressing the infrastructure challenges, which include the financial shortcomings

- Manage these challenges by strict programme and support by means of a project management practices
- Addressing the skill shortage within the EDI

The ADAM roll-out has been structured into different phases. The first phase is the so-called "mini-ADAM" phase, in which the roll-out will be tested at about seven different municipalities and two metros. The steering committee has made the allocations and currently contracts are being signed between DoE and the respective LA entities.

It needs to be emphasised that this is a once off "mini-ADAM" pilot process to test the ADAM methodology. Currently different financial models are being considered to address the financial challenges in the EDI. I want to emphasise that the assistance that has been envisaged through the ADAM process, will not mean that the current backlogs in the EDI will be funded in full or the EDI skills challenges will be resolved by national government. The management of the municipalities and metros has taken some burden of this challenge. Hence, all spheres of government will have to make a contribution. The ADAM process is not and will not become a hand-out programme, where municipalities will receive funding to solve a very serious problem.

National treasury is currently busy with legislation with the ringfencing application of administrated allocations, such as tariff allocations that are earmarked for specific applications such as allocation applications by municipalities for upgrading and maintenance of networks. These allocations will in future then be managed separately from normal operational revenues.

Lastly I would like to deal with the electrification programme, but specifically with the New Household Electrification Strategy that was approved by Cabinet at the end of June 2013.

Electrification is a cornerstone of social and economic upliftment, and has been proven to positively contribute to South Africa's development goals. Progress to electrify South Africa has so far been good, with more than 5,7-million connections made between 1992 and 2011, confirming South Africa's electrification leadership role in the sub-Saharan region and its positive development path compared to other emerging economies However, much more is to be done to reach universal access in SA.

There are still 3,2-million households without electricity, despite just over 203 000 new connections being made in the last financial year.

DoE has developed a new implementation strategy to ensure that the rate of delivery will be improved by utilising the following measures:

- It is recognised that electrification can not only be defined as a grid connection, since it is in some cases just too expensive to build infrastructure for a few households in deep rural areas. It is suggested to implement more non-grid solar systems, but systems with a higher electricity capacity than what is installed currently (50 W systems vs 95 W DC systems), to address this challenge. Currently about 62 000 solar systems are in use by customers in rural areas (50 W systems), where gird is too expensive to reach. This will not only release some electricity from the national grid and generators, but can also increase the electrification rate at which an electricity service can be delivered, since the non-grid roll-out is cheaper and quicker. We need strong support from the AMEU with the non-grid programme.
- The future roll-out of the electrification programme will have to done in accordance with a National Electrification Master plan that will be developed through municipalities' IDP inputs and assistance from Eskom. It is foreseen that the first draft will be finalised by end 2013. The respective electrification projects in the country will have to follow this plan. If such a holistic plan is not being followed, it will not be possible to reach universal access in the country.
- Improve the inefficiencies in the delivery of the electrification programme by managing Eskom and the municipalities more tightly. Some success has been obtained by managing the programme holistically; to manage or allow the respective entities to share the internal processes with INEP. In this regard inefficiencies have been identified and highlighted.
- The current electrification programme funding allocations will have to be increased, if the electricity programme delivery rate is to be improved, but the improved INEP programme will first have to be implemented. This can be achieved by international grants which are available for non-grid programme, improved efficiencies which are already resulting in more connections, additional fiscus funding and the top up of funding shortfalls with "soft loans" in order to prevent the long time it takes to connect houses due to the slow delivery of important infrastructure projects.
- Considering the above proposals with respect to an improved electrification implementation plan for the future, universal access to all existing households and future households is possible by 2025.

I also want to make use of the opportunity to thank the AMEU for their positive contribution to the development of the new implementation strategy over the last four months.

I would like to end off by urging the AMEU to continue with the positive contribution that it has made over years to the energy environment in general and especially the electricity industry.

Dr. Wolsey Barnard, Department of Energy

...Continued from page 4

against a new shift system introduced as part of our efforts to improve efficiencies. While we are glad that the situation is behind us, we have not let the experience deter us from our vision, and that is to create a profitable high performance organisation. It is important that we achieve this objective if we are to be a true and meaningful partner to the City of Johannesburg.

Our plans include modernising City Power's infrastructure to improve network stability and enhance customer experience. This strategy includes the rolling out of smart meters, whose advantages include the ability to communicate with the central command room as soon as a network fault is detected. This improves response times and allows other energy efficiency initiatives.

The utility is also engaged in a process to improve its service delivery. This is so that the utility can address performance gaps, reduce any inefficiency, and ensure effective distribution of electricity to Johannesburg residents.

As a province, Gauteng is also investing heavily on the installation of solar panels. Last month, MEC for Infrastructure Development, Qedani Mahlangu, announced that the province intends to spend R11,2-billion on installing solar panels on all its state-owned buildings. This is the equivalent of 8-million m² of roof top space. The investment is in line with the province's integrated energy strategy.

Therefore, as we discuss solutions to our challenges and ponder how best we can support our cities' and indeed South Africa's infrastructure and service delivery objectives, let us remember what Finance Minister Pravin Gordhan said in his budget speech early this year: "All of us have a patriotic duty and responsibility to build and promote our country." This, I believe, we can only do by remembering to always put the needs of our customers first, and also the country's.

Sicelo Xulu, City Power

Speech by Phindile Baleni, CEO of NERSA

On behalf of the National Energy Regulator of South Africa, NERSA, it is my pleasure and honour to be given the opportunity to say a few words at this Convention under the theme of "Supporting SA infrastructure and service delivery objectives." This is indeed an important theme to explore over the next three days, particularly in light of the current infrastructure development programmes on which our country has embarked upon as well as quality of supply challenges as they are being experienced by customers. It is true that almost twenty years into democracy, the country still faces the triple challenges of poverty, unemployment and inequality. The country still remains a highly unequal society where too many people live in poverty and very few work. To eliminate poverty and reduce this inequality, there is an urgent need to grow the economy faster and in ways that benefit all South Africans.

Governments around the world rank modernisation of infrastructure as being critical to future economic competitiveness and crucial to accommodating expanding populations in urbanising environments. South Africa is no exception. Infrastructure lies at the heart of government's stimulatory fiscal package and is a pivotal component of the new growth path accounting for just less than 8% of gross domestic product (GDP) in the 2012/13 fiscal year. According to the report on the state of South Africa's economic infrastructure, 2012, "Infrastructure development is an enabler of socio-economic development". The report also states that "state capacity is a pivotal determinant of successful infrastructure development".

Successful infrastructure development will indeed play a critical role in growing the economy to address the identified triple challenges of poverty, unemployment and inequality. There is little disagreement about what should be done to reduce poverty. Economists agree that a market-oriented and growth-inducing approach that expands opportunities for production, employment among the poor and development strategies that improve access to social services such as health, education and other poverty alleviation initiatives are key to any poverty reduction strategy. Access to these services is only possible through physical infrastructure that does not happen by itself. Investment in infrastructure that improves access to these services is imperative for both economic growth and development. Infrastructure has a positive impact on productivity and thus on economic growth and development, particularly in developing countries where infrastructure is still insufficient.

The National Development Plan (NDP) states that South Africa needs to invest in a strong network of economic infrastructure designed to support the country's medium and long term economic and social objectives. This economic infrastructure is a precondition for providing basic services such as electricity, water, sanitation, telecommunications and public transport, and it needs to be robust and extensive enough to meet industrial, commercial and household needs. The NDP further observes that even though South Africa has a relatively good core network of national economic infrastructure, the challenge is to maintain and expand it to address the demands of the growing economy.

In the transport and energy sectors, (dominated by state-owned enterprises), the economy has already been constrained by inadequate investment and ineffective operation and maintenance of existing infrastructure. In the telecommunications industry, policy and regulatory uncertainty and lack of capacity remain barriers to infrastructure investment and to achieving affordable, quality services, especially for the poor. In the water sector, delaying critical investments may result in water shortages during a drought period. For many

Phindile Baleni, CEO of NERSA

South Africans, particularly in poor rural and peri-urban communities, accessing electricity, safe water, sanitation, telecommunications and public transport remains a daily challenge.

For infrastructure to have the desired impact on poverty, there has to be a proper infrastructure plan with clear objectives that are linked to a country's development strategies. However, an infrastructure plan on its own is not adequate; it needs to be accompanied by another plan that details the way in which the infrastructure plan is going to be financed. The role of economic regulators such as NERSA is critical to the success of these initiatives. The need for a robust regulatory environment that is responsive to government goals and objectives cannot be overemphasised. Indeed, economic regulation plays a pivotal role as all backbone infrastructure sectors such as telecommunications, transport and energy tend to be natural monopolies. It is therefore important to regulate these sectors in order to mitigate the negative impact of monopoly pricing.

There is a strong theoretical justification in favour of economic regulation in backbone infrastructure sectors such as energy, telecommunications, transport and water. Economic regulation in these sectors is widely regarded as necessary in order to prevent market failures in the absence of effective market forces; to ensure that essential infrastructure services are provided, and ultimately to achieve optimal social welfare.

The NDP has identified two challenges confronting regulators in South Africa. Firstly, to make sure that there are adequate levels of investment to ensure customers get reliable services, and secondly, to ensure that pricing levels are managed in a way that creates certainty and militates against shocks. To address these challenges, there is a need for a closer working relationship between regulators, utilities and government departments, better management of financial requirements through economically viable pricing levels and a greater climate of certainty and an avoidance of economic shocks. In this regard, improved regulatory performance is vital for national development. Capacity building remains a core challenge, requiring sustained training to improve both technical and leadership capabilities.

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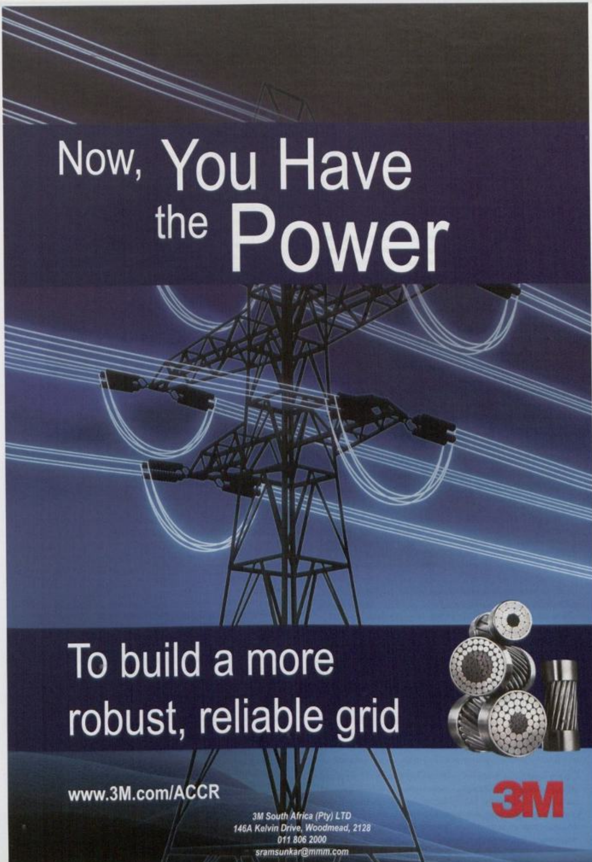
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Keynote address at the AMEU Technical Convention 2013

by *Malusi Gigaba, Minister of Public Enterprises*

It gives me great pleasure to address you on this important occasion of your convention, assembling as it does during the important period in our country when we have resolved to make the important and yet decisive turn towards more meaningful, radical and faster economic transformation.

Addressing himself to this matter, President Zuma said in 2011:

"We must make the decisive shift to meaningful economic transformation and set in motion a very deliberate programme that will ensure that the benefits of our political liberation are shared amongst all our people. Our people have struggled selflessly for freedom from oppression. We cannot fail them when it comes to the struggle for the elimination of poverty... We have to live the promise of the Freedom Charter, which states amongst others, that all our people will share in the wealth of the country. Political emancipation without economic transformation is meaningless."

In this regard, President Zuma raised both a moral as well as political imperative to ensure that we address poverty and inequality by spreading the benefits of political liberation to all our people, recognising that they had struggled selflessly for freedom. The president then made the bold and yet fundamental assertion that – "Political emancipation without economic transformation is meaningless."

Having struggled, suffered and sacrificed so immensely against colonialism, the peoples of Africa are yet to live the dream and true meaning of freedom.

We cannot be simplistic in our appraisal of the task ahead if we are to make significant headways, as President Zuma directed us, in the pursuit of this meaningful economic transformation.

Quite clearly, none amongst ourselves gathered here this morning can doubt the fact that together with the people of South Africa, we have achieved a lot in political and socio-economic transformation during the past 20 years. Today, South Africa is a better country and place for our children than it was in 1994 at the advent of the new democratic dispensation. As a result of the massive progress we have made, we have reason not only to celebrate what we have achieved, but to be more positive about the future, confident that we have a real possibility to bequeath our children an even better society that is more equal and just, with a thriving and sustainable economy and quality basic services.

This is precisely what the National Development Plan (NDP) exhorts us to do, building on this confidence that we have accumulated. The NDP is not merely a set of economic plans or sectarian formulations about what we need to do; it is a comprehensive vision and plan to develop our country comprehensively into the future. It articulates a vision to pursue full employment, achieve high growth rates on a consistent basis, eliminating income poverty, reduce inequality, ensure quality education, health and social safety for all and build an efficient, capable and corruption-free state.

This has been supported by the overwhelming majority of the peoples of South Africa. However, some of the critics of the NDP have not outrightly rejected the plan, but highlighted issues which require further engagement and debate, with a view to improving them as we march forward with its implementation. The plan itself is not sacrosanct or cast in stone, but is a living document.

Malusi Gigaba, Minister of Public Enterprises

However, the NDP recognises that in spite of the significant progress we have made since 1994, massive, deep and brutal poverty remains the daily reality for many South Africans, and we are duty-bound to address this if we must make the decisive turn towards meaningful economic transformation that the president directed us to make.

In effect, we must turn our backs on poverty, inequality and unemployment and strive towards a more socially just and equal society. In this regard, the New Growth Path recognised infrastructure development as one of the key jobs-drivers necessary to take our economy to a new level. The fact is that we cannot achieve social justice unless we create jobs for all and, towards this endeavour, infrastructure development will play a decisive role. The development and modernisation of infrastructure remains critical to South Africa's future economic competitiveness, facilitating domestic, regional and international trade, and enhancing South Africa's integration into the regional, as well as the global economy.

South Africa's infrastructure needs point to the existence of untapped productive capacity potential which will be unlocked through scaling up investments in the sector. Coupled with better human development outcomes that improved infrastructure promises, the spill over effects and the dynamism that would be generated will support South Africa's economic growth and poverty eradication efforts. Similarly, improved infrastructure will help eliminate some of the structural constraints in various markets in the economy.

Some among the critical lessons for infrastructure rollout in Africa include that we must never stop planning for future infrastructure capacity, and having gained the momentum, the infrastructure development programme must not stop; and that we must service and maintain our infrastructure so that we do not neglect it for future generations to have to maintain, service and even replace it at exorbitant cost.

One of sub-Saharan Africa's top developmental challenges continues to be the shortage of physical infrastructure, which serves as a major impediment to growth and development. Greater economic activity, enhanced efficiency and increased competitiveness are hampered by inadequate transport, communication, water and power infrastructure. The world is eager to do business with Africa, but finds it difficult to access African markets, especially in the interior, due to poor infrastructure. Physical infrastructure facilitates growth through its backward and forward linkages. Africa's economic growth and development are intrinsically linked to infrastructure development, but it is the push-pull relationship with commodities that has become the driving force for infrastructure development in the region.

Large commodity finds, like oil and gas in east and south-east Africa, as well as the huge demand – particularly from Asia – for agricultural and natural resources, including minerals such as iron ore, platinum, coal and copper, are driving the need for infrastructure. In turn, investments in infrastructure needed to extract and move these commodities to global markets, such as the rail and port infrastructure, continue to drive Africa's economic development. Infrastructure development is an important pillar for regional integration, trade competitiveness and development. The magnitude of Africa's infrastructure needs requires transformational approaches. Regional integration has the potential to lower costs and boost output in all sectors.

Regional power generation projects will increase economies of scale leading to cheaper electricity; whilst the transport and road infrastructure will reduce delays and costs caused by poor road infrastructure and disharmonious border and customs management. While inadequate infrastructure may be the single biggest threat to Africa's long-term growth, at the same time it also represents a significant opportunity for investors. With governments across the continent committing billions of dollars to infrastructure, Africa is at the start of a 20 to 30-year infrastructure development boom. We are aware that there are, however, certain preconditions that private investors typically require before committing themselves to projects with the lengthy payback periods that attach to infrastructure assets. For example, they want to be involved in projects that are high priority for governments and thus are likely to come to a conclusion.

They do not want to be involved in projects where there are no clear implementation timelines or where the timelines, are repeatedly moved out. They will also focus on markets where there is a guarantee of long-term policy stability and revenue certainty and where there is institutional capacity within government to make projects happen. Accordingly, long-term planning that creates a longer horizon as well as the capacity of the state, including coordination and integration at state level, are fundamentals which cannot be overlooked when seeking investments in infrastructure development as investors will most certainly focus on these before they make their decisions to invest.

Through the Presidential Infrastructure Coordinating Commission (PICC), as well as the Strategic Integrated Projects (SIPS) involving various government agencies – departments, agencies and state-owned companies (SOC), the South African government addresses the above and thus seeks to limit execution failures.

The PICC seeks to correct government failures, coordinate the allocation of resources in the economy, improve intergovernmental relations and accelerate the execution of the national infrastructure plan in a coordinated and integrated manner. Ultimately, the infrastructure programme would amount to a dismal failure if all it did was merely leave behind it a trail of physical infrastructure, which whilst it would make it easy to do business, but would merely and narrowly be about that – making it easier and cheaper for business to conduct its affairs and make profit and wealth.

In this regard, President Zuma stated during the 2012 State of the Nation Address that: *"The massive infrastructure investment in infrastructure must leave more than just power stations, rail-lines, dams and roads. It must industrialise the country, generate skills and boost much needed job creation."*

When our children stand at the end of 2030 and look back to what we achieved when we implemented the current infrastructure programme, they must see a trail of skills, jobs and local industries lying in the wake of the physical infrastructure we erected all along the way! To achieve this requires political will and capacity on the part of government and buy-in from the private sector investors, particularly the global suppliers and original equipment manufacturers (OEMs). And, the private sector will often not buy into new visions without being compelled to, as their inherent inclination is to chase the bottom-line and their natural tendency is to make a profit as quickly and as easily as possible. I know that the focus of this convention is on energy utilities, but it would be amiss of me not to highlight the areas of infrastructure that are interconnected to energy infrastructure.

In fact, no energy infrastructure will be developed without a road, water and ICT infrastructure. Reliable supply of electricity is essential to foster regional economic development. Whilst significant effort has been put to improving capacity on the electricity generation side, the present worrying state of our electricity networks, particularly at distribution level, remains a threat to the security and reliability of electricity supply in the region. There is therefore a pressing need for enhanced investment and maintenance of distribution and transmission networks to improve the reliability of power supply.

For some municipalities and SOCs, poor system reliability and the associated impact on electricity provision are far more serious than for others. Where municipalities or SOCs run operations on a continuous basis, that is, 24 hours per day, seven days per week, there is little room for unplanned shutdowns of the production equipment; any loss of production is often difficult or even impossible to make up. Where operations are not run on a continuous basis, the recovery can be easier, nevertheless time consuming and expensive, thus reducing revenue generation opportunities.

In the South African context and I suppose the region too, municipalities play a key role in the provision of electricity and hence it is critical that they possess the requisite capability and resources to deliver on this role. This is in view of the concerns we have noted in relation to some municipalities having challenges with the provision of reliable and quality electricity, a matter that needs to be resolved as a matter of urgency before it becomes a culture.

Some of the contributing factors to this include the high turnover of key municipal staff; poor revenue collection; misalignment of tariffs that Eskom charges to those charged by municipalities; revenue losses through energy theft and meter tampering; misalignment of financial year-ends between Eskom and municipalities; amongst other things.

We are exploring sustainable solutions for the energy industry. One of our policy priorities to address these challenges is to accelerate investment in infrastructure to correct the structural problems in the economy and lay the basis for higher growth and economic development. Infrastructure development will significantly contribute towards the economic and social development of our communities within each province. Delivering on social and economic infrastructure increases access by communities to basic services and will eliminate poverty and unemployment, and thus ensure that they share in the political benefits of our democracy.

The provision of access to basic services such as electricity, sanitation and water is therefore a key infrastructure delivery issue and a fundamental human right. Over the years, our economy has grown on the back of extractive industries and the retail sector.

The government has recognised that this is not sustainable for economic development and the global economic recession has pushed developing countries to develop counter-cyclical strategies to stimulate demand in the economy. Energy utilities are better placed to build domestic industrial capacity and support enterprise development.

Part of this infrastructure drive will contribute towards the objective of universal access to electricity. Electrification has both economic and social functions in that it stimulates economic activities, creates employment opportunities and provides basic energy services for households.

Over 4,2-million households are now electrified since the inception of the electrification programme, a feat achieved through working together with municipalities. This means that the ANC-led government has electrified more households in the last nineteen years than the entire colonial and apartheid regimes did in over three hundred years of their illegal and criminal existence. However, we note that there are still challenges towards meeting the universal access objective, and I hope that part of your deliberations will consider how we address these challenges.

The provision of electricity to all should improve the quality of life of South Africans, especially the marginalised, and as such, the "unaffordability" of electricity to households with no income should be addressed.

Government intends to counteract the adverse impacts of electricity price increases through the provision of subsidies and the continuous improvement of the effectiveness of the free basic electricity (FBE) programme. Government is also in the process of investigating ways to improve the free basic electricity programme further to ensure that every poor household is catered for. Continued collaboration between the three spheres of government in ensuring improved service delivery to all South Africans is critical in this regard. Our role, as the department entrusted to guide several SOC, is to ensure that initiatives aimed at fostering the developmental objectives of the country which are essential to the country's overall growth are undertaken judiciously, timely and responsibly.

As you aware, the South African economy is highly energy-intensive, and heavily dominated by the extraction of raw materials and primary processing. As the demand for energy grows, the energy sector is expected to play a central role in acceleration of the country's economic growth and development. Social equity and economic efficiency are crucial in energy production and we have developed appropriate policy instruments to minimise negative impacts of externalities associated with energy production and consumption. The Eskom capital investment programme will add 17 000 MW of new electricity generating to the national grid. I am happy to report that all the previously mothballed plants have been returned to service and almost all the units are operational. Despite the challenges in the construction of the new electricity generation plants, there has been significant progress and we are on course to receive first power by the second half of next year at Medupi Unit 6.

The increase in generation capacity is complemented by Eskom's large investments to expand and upgrade the transmission grid. Both Eskom and municipalities are investing in distribution infrastructure to replace or upgrade out-dated equipment. Through improved cooperation and coordination within the various spheres of government and other key stakeholders, it is possible to arrive at cost-effective, integrated and sustainable solutions to address service delivery challenges in South Africa and the region. However, the challenge for electricity utilities and other SOC will continue to be how they raise funding for their capital investments, particularly during this very constrained global economic environment which is expected to get even tougher as the US persists with the tapering off of its quantitative easing programme. Raising capital to address both capital and operational expenditure is going to prove more complex and difficult to surmount in the coming period.

It is therefore important that, for example, the issues of the payment for services by customers as well as the municipal electricity debts must be addressed as capital investments continue, so that we do not compromise on the "user-pay" principle. In our case in South Africa, both debts such as the one by the Soweto customers, which constitutes 90% of the debt owed to Eskom by residential customers, as well as the one by municipalities, which today stands at over R1,5-billion for the ten largest-owing municipalities, must be resolved. The risk is that a wrong culture of non-payment and defaulting is thus not only encouraged, but sustained, particularly when the ten largest-owing municipalities have the resources at their disposal to settle their debts. This creates a serious dilemma for Eskom as they must either make a business decision and switch the lights off for the debtors or a political decision and keep the lights without an end to the payment "boycott" in sight!

This is more important given both the current build programme as well as the electricity constraints as a result. However, the issue of energy efficiency must move beyond being a stop-gap measure to address electricity shortages into being a culture for our people and corporate customers. The negligent use of electricity merely because it is available must come to an end; and we must begin to make it our culture to be concerned both about the other person and the future. A continent without sufficient energy must be concerned about expanding capacity, making electricity available to all and yet conserving enough for future generations. Negligence is for us not a luxury.

There are big expectations placed on associations such as yours to be innovative in resolving the service delivery challenges and, as crucial partners and stakeholders, to participate in the programmes to build and sustain the infrastructure. I wish you all the best in your deliberations.

Malusi Gigaba, Minister of Public Enterprises

...Continued from page 10

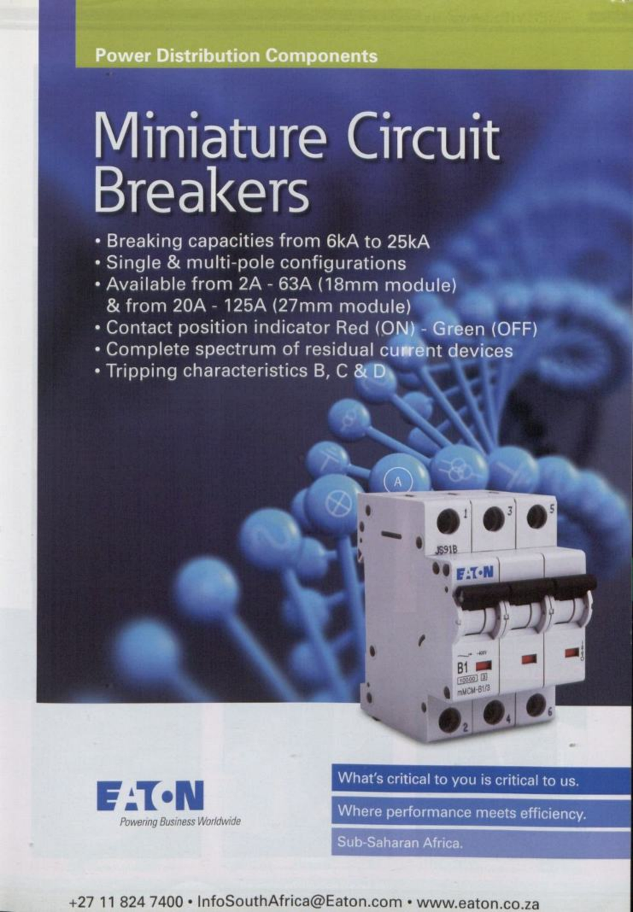
NERSA's mandate is to regulate the electricity, piped-gas and petroleum pipeline industries as enshrined in the National Energy Regulator Act, the Electricity Regulation Act, the Gas Act and the Petroleum Pipelines Act. The three industries we regulate are to a large extent monopolistic in nature and therefore the regulation of these industries is critical to ensure that the balance between the needs of the consumer and the industries are met.

NERSA is a key enabler in advancing economic growth and social development within South Africa. Energy forms the backbone of the South African economy, not only from a growth point of view but also for job creation and social upliftment. Our defining challenge as the energy regulator is to regulate the energy industry in a manner that balances the interests of the energy producers on the one hand and consumers on the other hand. This is never an easy task, for it is influenced by the greater economic environment both locally and internationally and as directed by government policy. Specific challenges that we have identified as NERSA, with this sector and the electricity distribution industry relate to the D-Forms, the number of municipalities that do not keep to the benchmarks (system losses, expenditure on maintenance/number of outages, etc.) We look forward to working with you to resolve these challenges, which are in line with the objectives of government, as articulated in the NDP.

The above observations bring me back to this convention. The convention has brought together technical experts in the electricity transmission industry to share knowledge and best practice on how to effectively contribute to support the country's infrastructure and service delivery objectives.

I wish you fruitful discussions as you share your insights on these issues.

Phindile Baleni, CEO of NERSA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Kim Dore, AMEU Affliates chair.

Daniel Kasper, Beka, receiving the Cigré Best Paper Award from Antony Falconer, Cigré.

eThekwini's Jayshree Pershad and Sandile Maphumulo receiving the AMEU Best Paper Award on behalf of Derek Morgan from Kim Dare, EE Publishers.

Carola Hantelmann, GIZ; Minnesh Bipath, SANEDI; and Chris Billingham, Eskom.

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The South African smart grid vision

by Dr. Minnesh Bipath, SANEDI

South Africa's electricity supply industry stands at the threshold of critical transformation. This moment presents an opportunity for innovation to improve service delivery and to enhance industry sustainability. However, it also requires important decisions to be made for the optimal deployment of available resources which will provide the best platform for the economic and technological needs of the country – now and into the foreseeable future.

The purpose of the vision is to describe the aspirational future state of the ESI in South Africa.

The vision defines, through a process of careful consideration and consultation, a common picture of a smart grid which is relevant to South Africa and the challenges the industry faces. Having an agreed definition or collective understanding of the smart grid vision in South Africa is imperative for alignment of effort and integration into a coherent national system. A clear vision will enable numerous role players and stakeholders involved in multiple solutions and applications over an extended period of implementation to be "pulling in the same direction".

The aim is to balance practical realism with a suitably ambitious and aspirational vision so that the economy and society can reap optimum benefit from the significant infrastructure investments that will necessarily be made in the immediate future.

In describing this vision it is recognised that the electricity industry is dynamic and that a level of "grid smartness" exists and is currently being pursued/implemented. It is furthermore recognised that energy supports and leads economic development and should be responsive to the ever-increasing complexity of power supply and consumption requirements. The vision may therefore continue to evolve in time, but is intended to describe, as best possible with current information, what the aspirations are amidst the changing landscape.

The vision forms part of a comprehensive framework that is being created for a smart grid in South Africa as illustrated in Fig. 1. In addition to the vision, the framework will consist of an "as is" analysis of the industry status at present; a gap analysis to identify the variance between the current status and the defined vision; a strategy and roadmap broadly suggesting the approach for achieving the ideal national position as described by the smart grid vision; supported by a business case or value proposition for establishing a national smart grid. The business case, combined with pilot findings and lessons learned, will inform clear direction on the required and prioritised functionalities and implementation guidelines to aid role players and stakeholders with appropriate technology' system selection and implementation where required.

The development of the vision will follow a consultative and inclusive approach to accomplish the necessary paradigm shift amongst all stakeholders. Consultation is inevitably an iterative process that requires time, but brings about a collective understanding, stakeholder alignment and the motivation for change amongst the relevant role players. The SASGI workgroup provides the platform for the process to develop the vision and, subsequently, also other critical aspects of the smart grid framework (e.g. the business case and roadmap): implementation experience and performance feedback from the industry will continually serve to refine the implementation approach, again following an iterative process to develop the most appropriate guidelines for South Africa.

While the strategy and roadmap will follow from the vision, the vision does assume that the implementation of smart grid applications can be approached in a modular way i.e. any role player has the freedom to prioritise the implementation of an aspect of the smart grid to suit specific leverage opportunities or areas of constraint or need. This suggests that while the national vision, strategy and roadmap will provide the overall direction, the respective utilities in the industry could start their specific journey at any point within the context of the vision that will create the greatest immediate benefit for them. Implementation of the full, envisaged scope and realisation of the full benefits of the smart grid may therefore be achieved over an extended, but non-prescribed, timeframe. The approach adopted must also be seen in the broader context of the structure of the electricity supply industry in South Africa. The industry currently consists of a dominant player who incorporates a vertically integrated business (generation, transmission, distribution and retail) and numerous autonomous bundled distribution utilities.

An analogy used by NETL for this "systems approach" is that of a catalogue versus a novel. A catalogue can be constructed by collating many technology data sheets and arranging them in some order, such as alphabetic. A catalogue may present valuable content, but no clear direction.

A novel is approached with an overall vision, followed by a storyline onto which the components and building blocks of the novel (characters, plots, chapters, and narrative) are built and integrated in a way that supports the vision and goals that were defined in order to deliver a coherent, meaningful story.

It is proposed that the South African grid should be advanced in a similar fashion; not by gathering a collection of interesting technologies and calling it modern, or smart, or intelligent, but by first defining a vision and then building the construct of a grid that serves a defined purpose. The vision will hold up a

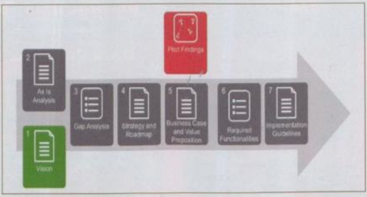

Fig. 1: Comprehensive framework to guide the smart grid implementation in South Africa.

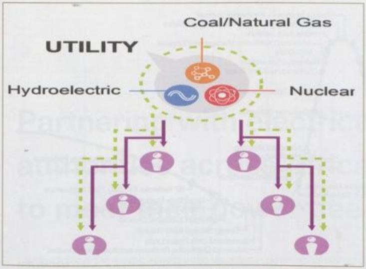

Fig. 2: Historic energy system (conceptual).

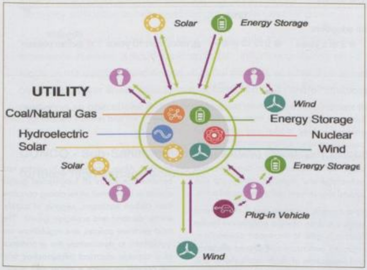

Fig. 3: Transformed energy system (conceptual). (As presented in Smarter Energy for Smarter Cities, by IBM Global Energy and Utilities Industry.)

view of the smart grid against which future decisions can be checked in terms of whether it "works" and whether it "fits" with the vision and will allow progress against the vision to be gauged along the long and arduous journey to realisation.

This means that the vision may be ambitious without compromising on critical requirements because of resource constraints. But, it also emphasises the need for the vision to give clear direction that will ensure that disconnected, independent implementation of applications are aligned and can be integrated into the national network/system.

Back ground and context to the vision

The South African ESI

The bulk of the South African electricity supply (generation, transmission and distribution) infrastructure was designed several decades ago in a vastly different political, societal and technology context, to respond to relatively "simplistic" supply needs (conceptually illustrated in Fig. 2). The same, ageing infrastructure is now struggling to support rapidly growing and changing "21st century" network requirements.

The ESI stands at a critical juncture requiring urgent and significant infrastructure investment to maintain security and quality of supply, to respond to growing supply needs and to new challenges. Perhaps the biggest challenge will be finding the right economic and environmental balance between these imperatives:

- Changing and more demanding customer expectations.
- Secure supply of electricity now and in the future.
- Diversified (and distributed) energy mix with a cleaner, more sustainable supply.
- Affordable infrastructure capable of supporting economic growth and rapid technology advancements.

The transformation required of the ESI to support this evolving landscape is illustrated in Fig. 4, in the growing complexity of the existing and anticipated demands on the energy system.

While the challenge of responding to the changing energy system requirements is not unique to South Africa, South Africa is in a favourable position where this coincides with the need for infrastructure investments to maintain a stable platform for current and growing economic activity.

Smart grids are an essential part of these inevitable industry changes (e.g. replacement of ageing infrastructure, clean energy, securing supply, introduction of electric vehicles and distributed generation), in addition to the other many challenges, and doing so while managing escalating energy costs.

Furthermore, being in a position as an industry to give consideration to the most appropriate, collective approach prior to making an investment of this magnitude presents a defining opportunity to leverage global and local knowledge, experience and technology for the most appropriate, integrated solutions before embarking on this journey.

Aligning on this vision may further present opportunities for leveraging economies of scale, localisation and the exchange of best practice.

Smart grids

The concept of the smart grid has been around for many years, has evolved significantly over time and covers a broad spectrum of technologies and functions. The electricity grid related challenges experienced during the last decade in countries such as the USA, Europe, UK, etc. did however significantly accelerate the deployment of smart grid applications. While the drivers might have differed from country to country, the smart grid applications were successfully used to overcome and address their challenges at hand. As a result there are many smart grid definitions and explanations.

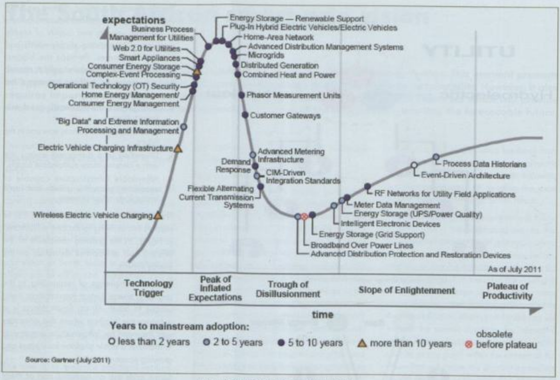

Fig. 4: Smart grid Gartner Hype Cycle (2011).

Some definitions describe the smart grid in terms of function and/or technology capability and/or benefits offered. From all these, a few key elements common to most definitions emerge: communication, integration and automation which are sustainable, economic and secure.

The European Technology Platform Smart Grid (ETPSG) defines the smart grid as follows:

A smart grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.

Based on ETPSG definition, smart grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies to:

- Better facilitate and manage the connection and operation of all sources of energy.
- Give end-users more choice so they can help to optimise energy use.
- Provide consumers with greater information and choice of supply.
- Significantly reduce the environmental impact of the whole electricity supply system.
- Deliver enhanced levels of reliability and security of supply.

Smart grids deployment must include not only technology, market and commercial considerations, environmental impact, regulatory framework, standardisation usage, ICT (information and communication technology) and migration strategy but also societal requirements and governmental edicts.

As a concept, the smart grid is intuitive and elegant and an obvious progression for the electricity grid to increased automation, improved performance, improved efficiency, and integration of more applications. But, as with most large movements of technology change, the development phases of the initial, emerging smart grid technologies were not without growing pains and hard lessons learned. However, by 2011 the Gartner Hype Cycle (Fig. 4) for smart grid technologies showed most related technologies had advanced far towards widespread adoption.

Until recently South Africa has mostly lagged behind the world in the adoption of smart grid technologies. As a result of this lag, South Africa now has the opportunity, at a convenient time in our investment cycle, to leapfrog several technology development cycles and lessons learnt by the front-runners in implementation. From this vantage position the focus should be on capitalising on the improved global understanding of smart grid and to adopt applicable best practices to realising full and relevant benefits for South Africa.

Policy context

In South Africa, the electricity sector has become the focus of heightened policy interest in the context of escalating concerns over carbon emissions, security of supply, energy demand and economic growth. The most pertinent policies and regulations are highlighted to demonstrate the importance of a capable electrical infrastructure and the context to which a smart grid would significantly contribute.

The National Energy Act, 2008 (No. 34 of 2008) sets out specific goals with respect to energy security and security of supply:

- Ensure uninterrupted supply of energy to the country.
- Promote diversity of supply and energy resources.
- Facilitate effective management of energy demand and its conservation.
- Promote appropriate standards and specifications for the equipment, systems and processes used for producing, supplying and consuming energy.
- Ensure collection of data and information relating to energy supply, transportation and demand.
- Provide for optimal supply, transformation, transportation, storage and demand

Driver
Growing energy demand
Capacity expansion and diversified mix
Energy independence and security
Environment and climate change
Economic growth
Policy and regulation
Technology advancement
Increased efficiency through grid operations
Advanced customer services
Infrastructure reliability and security
21st century power quality

Table 1: Drivers for change and relevance of the smart grid to South Africa.

of energy which is planned, organised and implemented in accordance with a balanced consideration of security of supply, economics, customer protection and sustainable development.

- Commercialise energy-related technologies.
- Ensure effective planning for energy supply, transportation and consumption.
- Contribute to the sustainable development of South Africa's economy.

The Energy Security Master Plan – Electricity (2007 – 2025) echoes these goals and provides for a good reference point to evaluate the current performance of the electricity supply industry against the defined vision expectations. The master plan presents the following priorities for South Africa:

- Supporting economic growth and development.
- Improving the reliability of electricity infrastructure.
- Providing a reasonably priced electricity supply.
- Ensuring the security of electricity supply as set by a security of supply standard.
- Diversifying the primary energy sources of electricity.
- Meeting the renewable energy targets as set in the EWP.
- Increasing access to affordable energy services.
- Reducing energy usage through energy efficiency interventions.
- Accelerating household universal access to electricity.
- Clarifying some of the policy issues in the context of an evolving electricity sector.

The ageing and stressed infrastructure of the ESI is challenged to deliver on many of these goals and national priorities. Investment in grid refurbishment and expansion, and particularly investment in support of a smart grid, will contribute directly to the realisation of the objectives and goals of both the National Energy Act and the Energy Security Master Plan.

The National Climate Change Response Policy white paper (Department of Environmental Affairs, 2011) reaffirms South Africa's undertaking and international commitments to slow down, and in due course, reduce carbon emissions. To achieve this necessitates a substantial integration of renewable energy into the electricity grid. It is important to note that the distribution grid, which includes all networks/grids operating at the 132 kV level and below, will be critical in the realisation of this objective. Without a substantial level of grid intelligence, the renewable energy opportunities cannot be effectively pursued.

Fig. 5: Smart grid as an enabler to address industry challenges.

Government Regulation (GN) 773, published in terms of section 35 of the Electricity Regulation Act, establishes norms and standards for reticulation services to:

- Maintain the quality of electricity supply.
- Ensure the stability of the electricity network.
- Minimise electricity load shedding and avoid blackouts.

The regulation includes specific measures for the roll out of smart metering to all customers with a monthly consumption of 1000 kWh and above and for a "time of use" (TOU) tariff to be applicable to these customers by 1 January 2012. The regulation is in effect since 2008, but the specified timeframe and details regarding smart grid and TOU tariff implementation as allowed for in the regulation is under review. This regulation establishes an important precedent for the introduction of a smart grid in South Africa and clearly demonstrates the national intent to move towards smart grid infrastructure.

During 2008 a comprehensive study was undertaken by EDI Holdings to determine the status of the assets in the electricity distribution industry. The study revealed, among other issues, that there is a significant underinvestment in infrastructure maintenance, refurbishment and strengthening. This was applicable across most of the electricity distribution utilities in South Africa. Furthermore, an urgent need was identified in respect of people recruitment and development while there was a glaring absence of business efficiency and the optimal deployment of technology. It is estimated that South Africa will have to invest approximately R35-billion (2012) in assets and management tools to address the current infrastructure related backlogs. ADAM was approved in 2012 by Cabinet (national government) to be introduced as an asset turnaround strategy for the electricity distribution industry. While ADAM is not an end solution, it presents significant opportunities to enhance the performance of the EDI. The introduction of a smart grid vision embedded in the roll out of ADAM could bring about significant cost savings while it will contribute to a more holistic and integrated solution.

Electricity presents inherent and unique safety risks, requiring stakeholders to prioritise the health and safety of employees and the general public. Smart grids offer the electricity industry opportunities to enhance employee and public health and safety by improving grid safety, providing better network information and reducing exposure time to faulty networks. With due consideration to training and change management, a smart grid will facilitate compliance with the requirements Occupational Health and Safety Act (No. 85 of 1993) and reduce electricity related incidences amongst employees and the public.

Operational efficiency	Enhanced energy efficiency
Integrated distributed generation	Reduced technical and non-technical losses
Optimised network design	Enables DSM offerings
Infrastructure visibility and control	Improved load and VAR management
Improved asset and resource utilisation and optimisation	Complements national energy efficiency policies and objectives
Skills development	Supports IRP 2
Sustainable job creation	
Knowledge management	
Improved customer satisfaction	**Supports national green agenda**
Reduction in outage frequency and duration	Integrates RE generation and embedded/distributed generation
Improved power quality	Enables wide adoption of alternative energy options
Empowers customers to manage consumption patterns	Further reduces GHG emissions via DSM, peak saving and electrification of public transport
Facilitates customer self service	Complements climate change policy and GHG legislation (inventory, reporting requirements)
Reduced energy costs	
Community upliftment	

Table 2: Smart grid response to industry challenges.

Key success factor	Description
The grid must be more reliable	A reliable grid provides power, when and where its users need it and of the quality they value and are willing to pay for. It provides ample warning of growing problems and withstands most disturbances without failing. It takes corrective action before most users are affected.
The grid must be more secure	A secure grid withstands physical and cyber-attacks without suffering massive blackouts or exorbitant recovery costs. It is also less vulnerable to natural disasters and recovers quickly from disturbances.
The grid must be more economical	An economic grid operates under the basic laws of supply and demand, resulting in fair prices and adequate supplies.
The grid must be more efficient	An efficient grid employs strategies that lead to cost control, minimal transmission and distribution losses, efficient power production, and optimal asset utilisation while providing customers with options for managing their energy usage.
The grid must support greater environmental sustainability	An environmentally responsible grid reduces environmental impacts thorough improvements in efficiency and by enabling the integration of a larger percentage of intermittent renewable resources than could otherwise be reliably supported.
The grid must be safer	A safe grid does no harm to the public or to grid workers and is sensitive to users who depend on it for medical necessities. It furthermore serves to improve the safety of the workplace.

Table 3: Key success factors for the smart grid.

A smart grid therefore represents an enormous opportunity to contribute towards and enhance delivery on these policy objectives and national initiatives.

Relevance to South Africa

South Africa's electricity industry is facing significant structural changes combined with the urgent need for major improvements to ageing and inadequate (as a result of growing demand and increased footprint) infrastructure in the power supply and delivery system. Incorporating a greater intelligence into the new infrastructure presents an opportunity to create an energy system which is economically, socially and environmentally ethical, durable and resilient in the face of on-going global change.

Table 1 shows the specific considerations driving the change to the electricity infrastructure for South Africa.

In response to these change drivers, the smart grid offers improved operational efficiency, opportunities for energy efficiency improvements, improved customer satisfaction and enhanced ability to respond to the National Green Agenda (see Table 2).

Increasing the intelligence of the grid will enable the ESI to better respond to situations such as when generation capacity constraints are experienced, to better leverage technology to complement other energy resource availability, to support the growing demand, projected economic growth and climate change commitments and to dampen the impact of electricity price increases through efficiency and reduction of system losses. The innovation and technology development due to a smart grid implementation may also spark a renewed interest in the electricity industry as a possible career opportunity, enticing new skills and employees into the market. Certainly a smart grid will require skilled people to manage the development and maintenance thereof.

It is acknowledged that a smart grid will not address all network concerns and challenges, but for a relatively small additional cost to the planned electricity system infrastructure investment, it offers potential to improve operational efficiencies and significantly enhance the electricity network infrastructure so it may support the changing industry requirements, the drivers for change and deliver on the vision described in the subsequent section of this document.

As such, a smart grid is a key enabler for the resolution of many of South Africa's described industry challenges as shown in Fig. 5.

Forfeiting this opportunity to modernise and introduce intelligence into the grid while in the necessary process of infrastructure upgrading and strengthening would be like expanding the nation's telecommunications system without taking advantage of today's digital and wireless technologies.

Scope of smart grid vision

With consideration of this document's context and the broad goal to transform the existing electricity supply infrastructure to a more intelligent system, this vision now crafts a smart grid aspiration with respect to the following system elements:

- Key success factors
- Principle characteristics
- Performance
- Applications (technical solutions)
- Metrics

This vision is intended to be outcome based i.e. the vision aims to create an overall picture of the aspired network qualities, capabilities and functionalities, but is not intended to be prescriptive in terms of the implementation approach, technology specifications or timelines. The expectation is that each role-player's need shall determine the applications prioritised for implementation. Not every industry role-player will start at the same point or follow a linear process, but rather will be guided by the vision and smart grid framework to select suitable applications and to build in the same direction towards the same national, integrated objectives.

In the subsequent section of this document the smart grid vision is described in terms of each of these system elements. This understanding of the vision is initially compiled for discussion and consultation purposes, but once consensus is reached it will serve as a key element of the national smart grid framework to guide coherent and focussed implementation.

Fig. 6: A systems view of the smart grid.

Fig. 7: A smart grid value contribution.

South African smart grids vision

The fundamental steps towards smart grid transformation begin with a clear vision of the objectives. The vision aims to describe an overall picture of the smart grid and in doing so, takes a systems view of the grid that will steer an integrated national solution.

To achieve this, the vision describes the smart grid in terms of key success factors, performance requirements, principle characteristics, applications and metrics necessary to realise the smart grid (see Fig. 6).

The vision for the South African smart grid is described comprehensively in subsequent paragraphs in terms of each of these system elements, but can be summarised into a smart grid vision statement such as:

"An economically evolved, technology enabled, electricity system that is intelligent, interactive, flexible and efficient and will enable South Africa's energy use to be sustainable for future generations."

Clarity is provided on the meaning of certain of the words in the vision statement.

- "Economically evolved" – affordable electricity system that meets the growing needs of the economy.
- "Technology enabled" – fit for purpose ICT, processes, sensors, systems and applications.
- "Intelligent" – from data to knowledge.
- "Interactive" – ability to monitor, control and manage using two way communications throughout the complete value chain
- "Flexible" – appropriate, scalable and adaptable based on common standards.
- "Electricity system" – the complete value chain of all interconnected equipment and components from generation to end use.
- "Sustainable" – optimised and affordable from environmental and economic perspectives.

Objectives

Implementation of a national smart grid in South Africa aims to enable the following objectives by 2030:

- 20% sustainable reduction in South Africa's peak energy demand relative to the 2012 national baseline projection.
- 100% grid availability to serve all critical loads as defined nationally and by each utility.
- 40% improvement in system efficiency (measured against the national and local 2012 technical and non-technical losses baseline) and asset utilisation to achieve a load factor of 70%.
- 8 GW electricity capacity integrated into the distribution networks from renewable energy sources.
- Improved service delivery and service reliability to customers to achieve a customer satisfaction index that exceeds 80%.

Cost and benefits

The transition to a smarter grid entails changes and enhancements to the complete grid value chain, from how the electricity utilities operate, to how the network is structured, to how the end user interacts with the grid infrastructure. It requires extensive alignment, cooperation and integration. But, as a result, it offers, and should offer, significant benefits throughout the value chain from the utilities to the customers and, importantly, to society as a whole.

The motivation for incorporating a smart grid solution into the planned infrastructure upgrades and expansions lies with the associated benefits to the respective stakeholders and the expectation that the benefits outweigh the costs. Estimated maintenance, refurbishment and strengthening backlog costs in the distribution network alone have been calculated at R27,5-billion (2008 values), growing at a rate of R2,5-billion per annum. This is a cost that must be incurred with or without smart grid implementation. Incorporating greater intelligence into the grid might add to these costs, but should deliver benefits commensurate with and in excess of the additional investment.

An investment of this magnitude does however require the associated value proposition to be compelling to all stakeholders.

The smart grid contributes value to stakeholders in four areas (see Fig. 7).

The expected benefits to all stakeholders are considered prior to the vision definition as this should guide and influence the envisaged goals/targets. Stakeholders can effectively be grouped into four categories of beneficiaries, namely: power generators, electricity utilities, customers and society. The values with respect to each of the illustrated areas are considered for each stakeholder category and the costs and benefits for each are briefly summarised.

Key success factors

The smart grid is expected to set the foundation to deliver on the anticipated electrical networks resilience, efficiency and environmental benefits. The transition to a smart grid should focus on achieving value with respect to six key success factors (see Table 3).

The key success factors for a smart grid establish a basis for specific performance requirements and for measuring progress and benefits.

Performance

The addition of intelligence to the electricity network must enable enhanced performance with respect to the items shown in Table 4.

Principle characteristics

Meeting the stated performance requirements requires the smart grid to include certain important characteristics or features. The vision describes seven broad principal characteristics which constitute the smart grid and Table 5 summarises these seven principle characteristics and allows a comparison between the existing grid and the vision of the smart grid with respect to these characteristics.

Key technology applications

Deployment of appropriate technology applications is the key to achieving the stated success factors, performance requirements and principle characteristics of the smart grid. Identifying the relevant applications will influence and improve how the smart grid is planned, designed, operated, and maintained throughout the value chain. The focus here is therefore on which technology applications to implement and at what pace to achieve a cost-effective, sustainable and beneficial smart grid solution for South Africa.

Performance	Description
Emergency response	The smart grid must provide advanced analysis to predict problems before they occur and to assess problems as they develop. This should allow steps to be taken to minimise impacts and to respond more effectively.
Restoration	It can take days or weeks to return the current grid to full operation after an emergency. A smart grid must enable faster restoration and at lower cost by making better information, control and communications tools available to assist operators and field personnel.
Routine operations	The smart grid must provide operators with an understanding of the state and trajectory of the grid, should provide recommendations for secure operation, and allow appropriate controls to be initiated. Operators should be able to depend on the help of advanced visualisation and control tools, fast simulations and decision support capabilities.
Optimisation	The modern grid must provide advanced tools to understand conditions, evaluate options and exert a wide range of control actions to optimise grid performance from reliability, environmental, efficiency and economic perspectives.
System planning	Grid planners must be able to analyse projected growth in supply and demand to guide their decisions about what to build, when to build and where to build. Smart grid data mining and modelling must provide much more accurate information to answer those questions.

Table 4: Performance requirements for the smart grid.

Existing grid	Principle characteristics	Envisaged smart grid
Customers have limited information and opportunity for participation with power system, unless under direct utility control.	Enables informed and greater participation by customers.	Informed, involved, and active customers – demand response and distributed energy resources.
Dominated by central generation – many obstacles exist for distributed energy resources interconnection and operation.	Accommodates all generation and storage options.	Many distributed energy resources with plug-and-play convenience; distributed generation with local voltage regulation capabilities to support high penetration on distribution systems; responsive load to enhance grid reliability, enabling high penetration of renewables; frequency controlled loads to provide spinning reserve.
Limited wholesale market, not well integrated – limited opportunities for customers.	Enables new products, services, and markets.	Mature, well-integrated wholesale markets; growth of new electricity markets for customers; interoperability of products.
Focus on outages and primarily manual restoration – slow response to power quality issues, addressed case-by-case.	Provides power quality for the range of needs in the 21st century.	Power quality is a priority with a variety of quality/price options – rapid resolution of issues.
Limited integration of operational data with asset management – business process silos limit sharing.	Optimises assets and operates efficiently.	Greatly expanded data acquisition of grid parameters – focus on prevention, minimizing impact to customers.
Responds to prevent further damage – focus is on protecting assets following a fault.	Addresses disturbances – automated prevention, containment, and restoration.	Automatically detects and responds to problems – focus on prevention, minimizing impact to customers, and automated restoration.
Vulnerable to inadvertent mistakes, equipment failures, malicious acts of terror and natural disasters.	Operates resiliently against physical and cyber-attacks and natural disasters.	Resilient to inadvertent and deliberate attacks and natural disasters with rapid coping and restoration capabilities.

Table 5: Comparison of the existing and envisaged grid in terms of principle characteristics.

Principle characteristic	CE	ADO	ATO	AAM
Enables informed and greater participation by customers.	✓	✓		
Accommodates all generation and storage options.	✓	✓	✓	
Enables new products, services, and markets.	✓	✓	✓	
Provides power quality for the range of needs in the 21st century.	✓	✓	✓	✓
Optimises assets and operates efficiently.	✓	✓	✓	✓
Addresses disturbances – automated prevention, containment, and restoration.	✓	✓	✓	✓
Operates resiliently against physical and cyber-attacks and natural disasters.	✓	✓	✓	

Table 6: Correlation between smart grid principle characteristics and functional areas.

These applications should incorporate and prioritise those technology solutions that will provide a positive return on the investment over the deployed asset life cycle. This is achieved through energy demand reductions, savings in overall system operation costs, delayed capital investment, requiring smaller generation reserve margins, lower maintenance and servicing costs (e.g. reduced manual inspection of meters), reduced grid losses, new customer service offerings and improved customer service levels.

The following applications are included in the identified smart grid solution for South Africa:

- Advanced metering infrastructure (AMI).
- Customer side systems (CS).
- Demand response (DR).
- Distribution management system/ distribution automation (DMS).
- Transmission enhancement applications (TA).
- Asset/system optimisation (AO).
- Distributed energy resources (DER).
- Information and communications integration (ICT).

The deployment of these applications directly correlates to achieving the key success factors of reliability, economics, efficiency, environmental, safety and security, as shown in Fig. 9.

The applications are roughly aligned to four functional areas of the smart grid. The four functional areas are defined as customer enablement (CE), advanced distribution operations (ADO), advanced transmission operations (ATO), and advanced asset management (AAM) and correspond with the applications as illustrated in Fig. 10.

The final realisation of a smart grid is a system that demonstrates all seven of the principal across all four functional areas as shown in Table 6.

The functional areas can be used to structure a "roadmap" of an ordered and cost effective strategy towards a smarter grid while keeping the vision goals/targets in mind.

It is possible to use each functional area to develop a business case and then integrate these four business cases to determine the most productive transformation plan for South Africa with its own limitations, priorities, and cost concerns. In a general sense, sequencing of the smart grid implementation within the functional areas with consideration of a "roadmap" can aid in the implementation and with maximising the benefits (see Fig. 11). A "roadmap", based on this proposed approach will be developed as part of the smart grid framework to provide

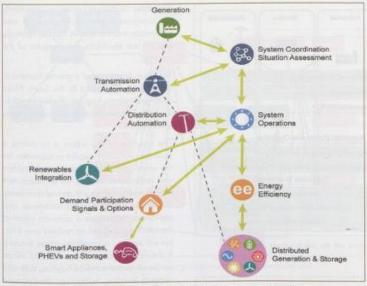

Fig. 8: Envisaged smart grid initiatives and interfaces for South Africa.

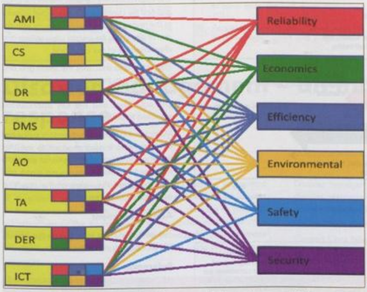

Fig. 9: Illustrating the correlation between applications and key success factors.

industry guidance in terms of the vision, but will not prescribe the journey that each utility should take.

It should be recognised that smart grid benefits are optimised when applications across the respective functional areas are combined across the ESI (from generation to residential) as shown in Fig. 11. As the functionalities from various applications combine, the potential benefits from the smart grid increases exponentially to all stakeholders. There is however a point when further investment in applications deliver smaller returns (see Fig. 12). The vision and overall SASGI smart grid framework aim is to assist with unlocking optimal benefits for the given investments.

As indicated previously, a cohesive smart grid framework shall allow each utility to identify functional areas with the most severe challenges in the utility network and to prioritise the selection of applications in terms of the most urgent need and greatest anticipated return. Each of the listed applications is therefore described briefly in the context of the functional area (CE, ADO, ATO, AAM) to which it is allocated (see Fig. 12).

Metrics

Metrics and targets provide a framework against which to monitor the transformation of the national electricity infrastructure into the envisaged smart grid and to gauge the value of the resulting contribution to the country. It is therefore a critical aspect of the vision.

At a high-level the smart grid objectives will serve as the metrics to track progress towards delivering on the South African smart grid vision. But it recognises that these metrics will be composed of several sub metrics that will require aggregation across industry sections and across entities/role players. It is also recognised that the metrics would represent an industry average, with varying targets and statuses for individual entities.

A monitoring system that can evaluate performance of the smart grid applications against these metrics should continually guide the national roll out. It is anticipated that performance against these metrics will be composed of a more detailed framework of KPIs across the industry that will be tracked and aggregated across the industry to report performance at this level. It is proposed that a standard framework and standard definition of metrics is agreed as part of the process to develop standards for smart grids.

It is furthermore recognised that the metrics would have to be reviewed as the national smart grid framework that SASGI is working on, unfolds to ensure the targets remain both aspirational and realistic.

Conclusion

South Africa's electricity network has provided vital links between electricity producers and customers for many decades. Historically, these networks and infrastructure were developed to support the large, predominantly carbon-based generation sources that were congregated around the coal resources in the country.

South Africa is now facing increasing economic challenges combined with a changing electricity landscape. The national drive for lower-carbon generation options (including renewable energy and distributed generation), combined with greatly improved efficiency on the demand side, necessitates more sophisticated and intelligent network capabilities.

Pressures to invest in the renewal and expansion of ageing electricity infrastructure across the country are mounting if South Africa is to ensure an acceptable quality of life for all South Africans and economic activity and future growth can be supported.

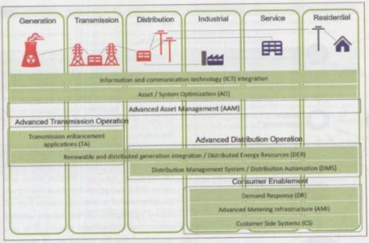

Fig. 10: Correlating the prioritised applications with the four functional areas.

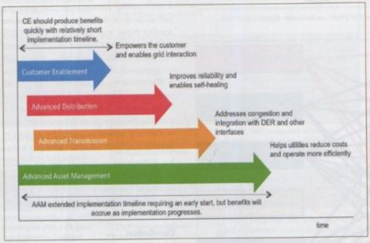

Fig. 11: Indicative smart grid sequencing roadmap.

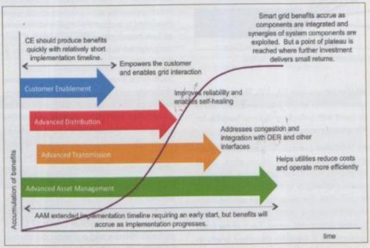

Fig. 12: Accumulation of benefits (conceptual) as smart grid components are incorporated.

With these challenges comes an opportunity to incorporate greater intelligence and automation into the network that can optimally support the electricity requirements of the country.

The vision forms part of a greater framework that is being developed by the South Africa smart grid initiative to guide effective transition to a coherent, modernised national electricity infrastructure.

The purpose of the vision is to define a common, national blueprint or aspiration for the smart grid before industry stakeholders and participants embark on an investment programme of this magnitude and complexity. The vision is intentionally ambitious and aspirational to provide a common vision of the smart grid that will be realised over time, but will serve to align efforts across industry. It should also serve to align national efforts across all related activities including skills and capacity building, technology development and localisation of industries where relevant.

The vision considers the objectives of the smart grid and the contribution it is expected to make to the respective stakeholder groups with the aim of identifying the priority interventions and characteristics of the smart grid.

The vision also describes the smart grid and the expectations thereof in terms of key success factors, performance requirements, principle characteristics and the key applications identified to deliver on these.

Metrics and targets are furthermore suggested as a framework against which to monitor the transformation of the national electricity infrastructure into the envisaged smart grid and to gauge the value of the resulting contribution to the country.

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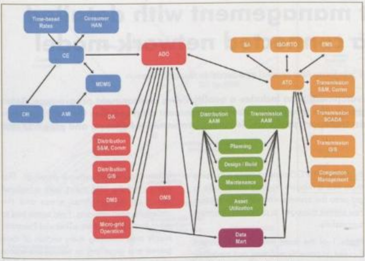

Fig. 13: Comprehensive view of smart grid applications in each functional area.

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Disaster management – an integrated response

by Chris Billingham, Eskom

A disaster can be defined as a progressive or sudden, widespread or localised, natural or human-caused occurrence which causes or threatens to cause death, injury or disease, damage to property, infrastructure or the environment, or disruption of the life of a community and is of a magnitude that exceeds the ability of those affected by the disaster to cope with its effects using only their own resources.

Disaster management is the discipline that involves preparing for disaster response (e.g evacuation, quarantine, decontamination, rescue, etc.) and supporting and rebuilding society after natural or human made disasters have occurred.

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Enhancing asset management with detailed asset data and a connected network model

by Jayshree Pershad, eThekwini Electricity; Coert Scherman, Attie Senekal, and Jonathan Hunsley, Aurecon

eThekwini Municipality's integrated development plan includes a quality living environment programme. Asset management is included in this programme. The integrated asset management plan includes the management of electricity, water and sanitation, roads, transport, parks and leisure, stormwater, solid waste and property and buildings assets.

The British Standards Institute's Publically Available Specification 55 and the International Infrastructure Management manual are the frameworks being adopted by the eThekwini Municipality. An asset management implementation plan (2/5/10 years) was developed in June 2008 and an integrated infrastructure asset management policy was developed in August 2008.

The eThekwini Electricity Department initiated a unit wide asset management project in 2009. NetGroup (now Aurecon) and Pragma were appointed as subject matter experts. Phase 1 focused on the strategic or high voltage assets and phase 2 the medium and low voltage assets. The purpose of both phases is to have detailed asset information for all network assets.

While most entities within the electricity supply and distribution industry have good asset information for their high valued assets which normally correlates to the generation, transmission and sub-transmission assets, few utilities have sufficient information at the distribution and reticulation network level to enable proper asset management. Distribution and reticulation asset data often does not correlate to the asset registers and it is in many cases not properly modelled within systems. This issue is mostly as a result of a long time period when systems did not exist and asset management and control was not deemed as important as it is today. It was never a requirement to have those networks modelled.

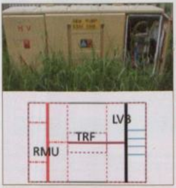

Fig. 1: Field equipment.

By the time the GIS systems came into being there was a massive backlog of networks to get onto the systems with very little control. Few entities managed to climb that mountain successfully.

Phase 1 of the asset management project focused on correctly recording and modelling the sub-transmission network assets. With these assets captured and correctly accounted for, the focus moved to phase 2 – the distribution and reticulation networks which are the bulk of the electricity department network assets. Aurecon was appointed to field capture and model the distribution and reticulation assets of eThekwini Electricity to a sufficient level of detail to enable proper asset management within the municipality. Secondary objectives included supporting other initiatives within eThekwini Electricity including system integration and establishing property-network-link for use within outage management.

Project approach

The main scope of the project was to field record all distribution and reticulation point assets to a sufficient level of detail to enable accurate asset and network modelling for upload into eThekwini Electricity systems. Point assets imply that the field teams did not record line/cable routes apart from the line/cable data recorded at the point asset locations (i.e. miniature substations, MV panels, meter rooms, etc.).

The project team decided that the field exercise was to be done in isolation of available network drawings as this would ensure field teams visit all assets and not only follow documented network drawings. This implies that the field teams were scheduled based on geographical areas and the underlying road networks. Field teams had to move through the entire eThekwini Electricity supply area following every section of road (paved and gravelled) as well as line routes where not along road networks and field record all eThekwini Electricity distribution and reticulation assets encountered.

Following field work, the office teams compared recorded data points to available information to identify missed assets. This was particularly important where assets were non-visible from the street front and "hidden" within buildings or behind walls, which the field teams might be ignorant about.

Breaking new ground

The project deviated from the conventional field data recording methods by taking a fresh approach that proved to reduce cost and enhance quality. This included:

Minimise time spent in the field

Field data capture exercises of a technical nature often contend with the following major challenges:

- Electrical network asset data is of a technical nature and often requires qualified field personnel to correctly record asset data. This greatly increases the cost of field exercises.
- Detailed recording of asset data in the field is time consuming (small input data screens, many assets) and places strain on resources due to harsh environmental conditions and at times hostile environments.

Fig. 2: GNIS for networked utilities.

Fig. 3: Actual field photograph of equipment captured.

Fig. 4: Existing GIS representation of equipment.

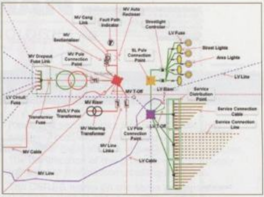

Fig. 6: Pole equipment model (maximum items).

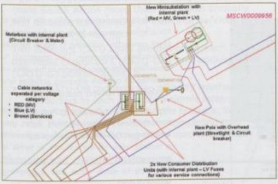

Fig. 5: Re-modelled representation of equipment in GNIS.

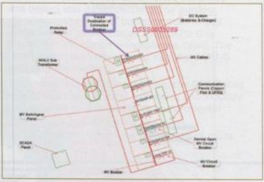

Fig. 7: Substation model.

- Field data capture errors frequently occur as a result of capturer fatigue and incorrect field interpretation. There is normally no way, apart from a re-visit, to identify such mistakes made.
- Where data queries exist (i.e. an uncommon transformer rating has been captured which is queried), there is no simple means of validating data apart from revisiting the specific site.
- No additional information is available post capture.

To address these issues the project team took a unique approach to limit field work to recording a GPS position, capturing detailed photographs of the assets and recording minimum attribute data. This resulted in significant time and cost savings as well as improved data quality.

Maximise utilisation of dedicated office based resources

Interpreting photographs to capture electrical equipment attributes and modelling the equipment in a GIS would require resources with technical background and skills. This was not feasible from a cost- and resource availability perspective.

The project team took a different approach whereby office modelling relied on domain specialists, a well-structured data capture process and state-of-the-art information systems in support of a largely unqualified, data capture and modelling team. The engineers and supervisors initially trained new data capturers and thereafter assisted with ad hoc queries and interpretation of data where the data capturers did not have the know-how.

At the peak of the project the office team consisted of 50 data capturers supported by two supervisors and four electrical engineers.

Field technology utilised

Apart from the GPS devices and high definition cameras deployed in the field the project also deployed iPads with the field teams. While iPads are considered too fragile for field work, it proved to be a valuable tool to the field teams. During the entire field capture phase (18 months, 30 field teams) only one iPad was damaged when a bolt fell onto it and cracked the screen. The advantages of deploying iPads included:

- Skype (direct communication to and from field teams)
- Field team tracking (Find my iPad)
- Field quality assurance process advantages
  - Data verification integrated with GIS backdrop
  - Large screen for easy data entry and more complex form designs

Modelling software

Data modelling was done in a geographical network information system (GNIS) supporting real connected network modelling. This greatly enhanced modelling quality and added value to the deliverable as a result of functionalities enabled from connectivity. Most municipalities in South Africa maintain a GIS model which simply represents equipment location but does not include actual connectivity that supports advanced functionality including capturing and managing property/customer network link (PNL) which is of utmost importance for network operations as well as smart grid planning and implementation projects. The model implemented allows full connectivity from the customer to any upstream device though network topology.

The GNIS environment allowed for the development of automatic placement routines for template equipment which generated the relevant equipment at the GPS location. As an example a miniature substation consists of MV breakers, LV switches, a busbar, transformer, container, etc. Using the office captured attributes and the GPS position the complete and specific equipment model is automatically generated in the GIS. This reduced the modelling component to mainly establishing connectivity by connecting networks between equipment.

Fig. 8: Attribute data.

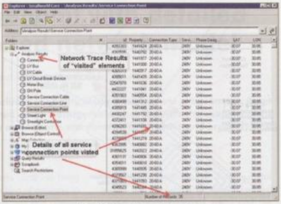

Fig. 10: Network trace data results.

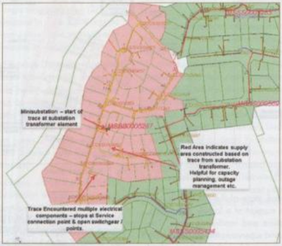

Fig. 9: Network tracing.

The decision to model asset data within a geographical network information system environment proved to have benefits beyond that initially envisioned and was a major contributor to the project success. The GNIS environment and advantages is elaborated on and explained in more detail in hereafter.

Social responsibility

Although not a direct contributor to the technical objectives of the project, a major social benefit was also realised. The project developed a large number of contractors from essentially being unskilled labourers into semi-skilled labourers. At the peak of the project 30 field teams (team leader and assistant) were deployed with 50 office data capturer and network modellers employed. Subsequent to the project completion many of the resources that proved their ability were retained for other similar opportunities at the sub-consultant.

The field teams consisted of a skilled team leader, semi-skilled assistant and general assistant. Semi-skilled assistants were trained to take over position of team leader, general assistant received basic safety training and various skills were transferred with regard to the operation of the GPS, iPAD and camera technology.

Most of the office data capturers did not possess any tertiary qualifications. The project trained the personnel in the use of data capturing software and the network modelling software. This increased the skill level of the contractors increasing their value in the job market. Some of the resources deployed elected to start career paths within the electrical engineering environment and subsequently commenced with studies funded from income generated by the project.

Advantages of a GNIS

What is a GNIS

A geographical network information systems is similar to traditional GIS but with added focus on connected network modelling. Network modelling includes rule sets with regards to connectivity enabling the utility to trace/follow networks from supply source to client connection adhering to actual network connectivity behaviour. This approach to modelling holds many benefits to the utility – it underlies all network planning activities and is essential for network operations.

As such GNIS is the application of choice for networked utilities (electricity, water, gas, telecoms) worldwide. GNIS software presents a realistic view on the network in terms of geographical location, how equipment connects to each other and supporting technical data.

Connected network modelling is unfortunately still a relatively new concept for many local municipal GIS departments who still do not model connectivity.

GNIS enhancement

The field data captured was modelled in a geospatial connected network model. Figs. 3, 4 and 5 show an actual field photo, which was transformed from the existing geographical represented model (GIS) into the geospatial connected information model (GNIS).

The existing GIS model representation has its origins from a CAD environment where information was ported directly into a GIS, containing basic attribute information about the elements. As can be seen from Fig. 4, the elements were "connected" at the same location without giving thought to the different equipment at the site and to separate different switchable elements and voltages at the same location. This representation makes network tracing for fault analysis, connected element counts, outage predication almost impossible, since the network trace will continue through connected points instead of stopping at switches or components of different voltage levels.

Fig. 5 shows how models were developed to represent the point features in Fig. 4. The result is a visually accurate and electrically connected model mimicking the actual equipment in the field.

Advertorial

AMAN TECHNOLOGIES (PTY) LTD

Clamping down on copper theft

AMAN Technologies introduced the CABLE ANTI THEFT UNIT (CATU) to municipalities at the recent AMEU Convention in East London. This South African company proudly introduced their Cable Anti-Theft Unit as a solution to the scourge of cable theft – a costly problem for most municipalities no matter what size. Latest figures suggest that the theft of electricity cables costs South Africa more than R5 billion annually and disrupts the delivery of essential services to industry and consumer.

Two different CATU units are designed each for overhead conductors (CATU-OH) and underground (CATU-G) power cables:

- The CATU-OH connects two adjacent overhead conductors to each other via a simple locking design that works with the cable tensions. When cut, thieves are deterred from completing their task, since a self-locking clamp mechanism then rotate and securely lock into position and they are then faced with trying to remove the entire network of cable instead of just a single conductor. The complication of this procedure will ultimately hamper the thieves from stealing the cable.
- The CATU-G works on the same principals as the CATU-OH but only having an anchor point to secure the cable firmly. Its inherent simplicity and design was developed with the purpose of reducing the theft of buried or submerged industrial and power cables. The CATU-G is installed in the trench alongside the cable. The cable is inserted and clamped into the CATU-G clamping mechanism.

Easy to install and maintenance free, the CATU units offer complete piece of mind to utilities and industry and a headache for any would-be cable thieves!

Contact Jif van Zyl, AMAN Technologies, Tel 011 609-0509, info@amantechnologies.co.za

AMAN TECHNOLOGIES (PTY) LTD

The CATU "Cable Anti-Theft Unit" available in South Africa to provide piece of mind for utilities and industry

The simple mechanical design can prevent underground and overhead cable theft.

- Internationally patented and trademarked
- SABS and CSIR tested and certified
- Quick to install and safe
- Non-conductive and non-corrosive
- Can withstand high temperatures and large shock loads
- Maintenance free

The CATU has been designed to save utilities and other essential service providers hundreds of thousands in capital costs, downtime and labour.

For more information and technical specifications:

Contact Jif van Zyl | Tel: 011 609-0509
Email: info@amantechnologies.co.za
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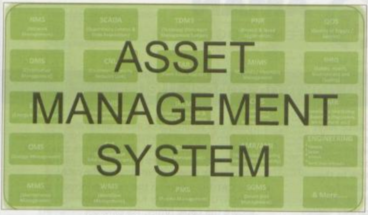


Fig. 11: Information systems relating to asset management.

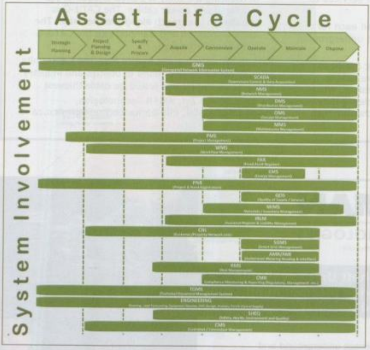


Fig. 12: Systems involvement – asset life cycle.

The modelled representation allows for equipment tracing based on switching points, voltage levels, functionality etc. and opens up doors for other engineering functions such as outage management fault predication, power flow analysis, network management, planned/grouping of maintenance (show affected/outstanding work orders connected to circuit breaker down-stream that can also be addressed when circuit breaker is maintained) .

Note the miniature substation model containing the medium voltage ring main unit (3-way) with isolating links, connected to medium/low voltage transformer, which connects to LV switch pillar containing the various low voltage cable rings supplying the reticulation network elements such as consumer distribution units, metering cubicles, etc.

Certain challenges were faced to enable correct model representation especially for OH equipment on the same pole, which is connected vertically and horizontally onto a flat GNIS model. A single pole structure can host various equipment of different voltages, and the model needs to visually separate and electrically connect them differently to allow for easy identification and accurate network representation. Fig. 6 shows the model implemented for the maximum number of placeholders for equipment attached to a pole to enable accurate modelling of the equipment.

The substation model (Fig. 7) was also challenging since the substation would host various assets that need to be electrically connected, and some supporting assets were added for representation only (e.g. DC system, communication panels, relays, etc.)

Fig. 8 illustrates some of the information that is populated as attributes based on the representation and connectivity of the element (in this case a medium voltage cable connected between two substations being DSSS0025289 and MJSS0011945).

Connected networks allow for electrical tracing which can be used for example to indicate all visited (affected) equipment, sites, customers etc., or to define impact zone/supply area. Fig. 9 shows the results of a network trace (yellow) for a miniature substation from its MV/LV transformer all the way to connected customers to highlight/construct a transformer supply area.

Information is available for all "visited" elements for the connected element trace (see Fig. 9). In Fig. 10 the results of the connected trace are listed, indicating 35 service connection points (customers) supplied from the source miniature substation.

Systems perspective – opportunity for data enhancement/integration between various systems

Vendors have a tendency to sell an "enterprise asset management system" to non-suspecting utilities, when in fact the requirements for a comprehensive asset management system is so rich, that no single vendor thus far has the ability to provide all the requirements to effectively manage all the information requirements of an asset throughout its lifecycle. Fig. 11 shows just some of the vast and different software systems involved to supportively function within an asset management system, admitting that this is still not comprehensive.

To highlight some of the implementations possible to assist in effective asset management let's explore the use of the GNIS' role in effective asset management.

Everyone would agree that before an asset is created, it should have been conceptualised or planned to a certain degree, and depending on the resources and complexity involved in addressing the problem, various systems could have been used to assist with the conceptualisation of the intended asset.

A network information system offers the planner various engineering and information tools such as network connectivity tracing (existing

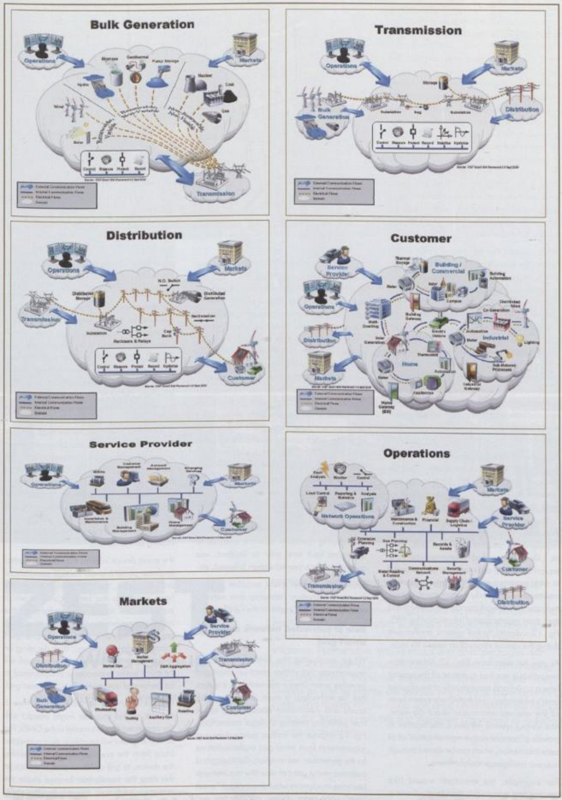


Fig. 13: Smart grid implementation perspectives. (Images courtesy of National Institute of Standards and Technology US Department of Commerce (NIST)).

network connections, capacity information, current connected consumers/equipment etc.), spatial analysis (access to various geographic information such as routes, geology, contours, vacant land, location of customers etc.) The GNIS should enable the planner to perform "what if" scenarios and represent the planned change to the network in the geospatial environment, the ability to perform various analysis can be performed on different design alternatives. Valuable information to support decisions on preferred design should be done in the conceptual design stage. The initial birth of information about the conceptualised asset is thus often found in the GIS/GNIS environment and not in a maintenance/ operational management system as is the case with many utilities which aren't utilising the strengths of a GNIS.

When using a GNIS the network is represented in both the as-built and intended future state, which can be shared with other users, systems and process as required. Often other planning and design tools are available to enable the planner to perform budget costing on solution alternatives, alternative site location and feeder routes, creating bill of materials (quantities and lengths), perform technical analysis on various alternative solutions/designs and compare them in relation to cost, financial return, impact on environment, power quality, reliability and customer and much more. Using these analysis and available information a preferred solution will be identified for implementation and actual asset acquisition/creation

From the GNIS initial information is already available to inform other systems about the intended asset. Information such as location (coordinates, planned route), capacity (size/ rating), connected elements (equipment, customers, supply area etc.), network information (dependency (connectivity) switching requirements, operational requirements, limits etc.), life expectancy and replacement cost (from equipment library) and more, can be forwarded to other systems such as the project planning, maintenance and works management, outage management, network management system and even asset register (partial information for WIP). Fig. 12 indicates typical systems involvement during the various stages of an asset's life cycle.

As can be seen from Fig. 12, information integration is required to ensure all the systems have a similar and accurate view of the required asset's information, and that no one system hosts all the required information about the asset. Also various systems will play a role together to provide a "comprehensive representation" of all asset information, which can be viewed through business intelligence tools/software.

For example, the manager would like to analyse a network incident where a transformer has exploded. He/she will utilise information from the SCADA (historian – what was the network status and load readings prior to the incident); network management system (how was the network switched during and after the incident); outage management system (how many customers were affected and complained); risk management (what damages were caused to neighbouring equipment, and what mitigation measures are now required to minimise the risk forward); insurance register (was the transformer insured, at what cost, what is the claim procedure or excess payable); maintenance management (when was it last maintained, by whom, what actions were done to avoid incident); QOS (did the incident affect power quality to sensitive customers (dip amplitude and duration); GNIS (show the connected network geographically just before the incident and affected customers, and potential network changed to repair incident – alternative network configuration); engineering (perform network analysis to determine fault level prior to incident, was code of practice/correct design followed, etc.

Clearly the above is not possible without proper information capturing and network modelling that originates in the GNIS.

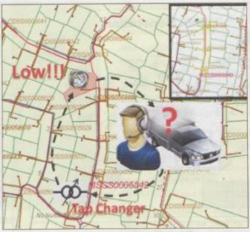


Fig. 14: Network engineer interaction.

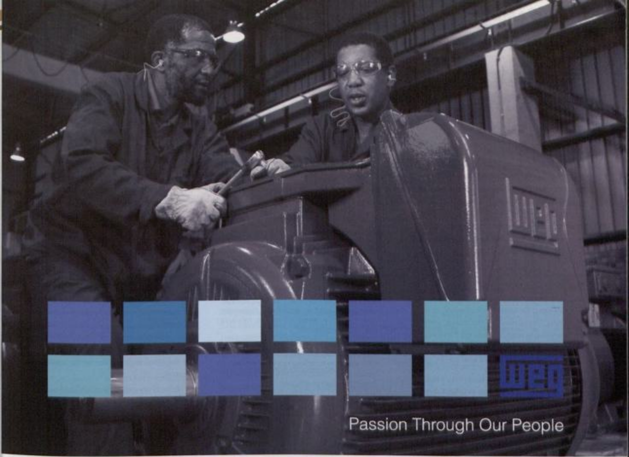
Role of connected network model in smart grid

When analysing the functionality and requirements that utilities place on smart grid (or rather smart cities) implementation, it is clear that the technology is more about managing assets and information about assets rather than protecting revenue or illegal connections. Fig. 13 displays the various perspectives and requirements from smart grid implementations for the generation, transmission, distribution and customer sector point of view (the requirements becomes much more when one looks at "smart cities" since more utilities, infrastructure and information sources starts playing a role, but for now let's stick with the smart electrical grid).

To enable the above inter-operability implementers often do not put sufficient emphasis on the requirement of the availability of network information and how the network is connected or related to the various devices in the field. As part of the data capture for medium and low voltage equipment, a connected network model was developed to ensure eThekwini Electricity has the ability to perform connected information analysis and thus unlock full smart grid requirements in relation to what is connected to what on the electrical network. Further enhancements can be implemented to ensure communication connectivity is also achieved to know which devices communicate through which routes to other devices. Smart grids are about having access to information about the network, communicating it to the right people, systems and customers and enable thus self-healing functionality and intelligent decision making on the network.

If a smart device informs the network control engineer about a under voltage experienced on the network, the control engineer should have access to the network model which portrays how the device performing the measurement (warning) connects to voltage regulating equipment (e.g. tap changers located higher up stream), thus deciding on mitigating actions (automatic or manual) will be much easier to execute or programmed to be performed automatically by the smart grid.

Fig. 14 illustrates as an example how a network control engineer might interact with the connected network model in the GNIS. The control engineer will be able to do a connected trace from the premise/location containing the device, to any up/down stream device (in this case the transformer located inside the miniature substation). He now has the ability and information available to dispatch crews to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the correct transformer location to change the tap position after confirming voltage levels at neighbouring premises through voltage drop analysis software.

Key take-away points

Motivation to perform asset management

Asset management is far greater than simply being compliant with GRAP17 or IFRS and gives the utility the opportunity to really understand, optimally plan, effectively manage, operate and maintain their assets. Major investment is often made to ensure reporting on assets is in compliance with regulatory requirements, and utilities often miss opportunities to really address proper asset management, through projects and funding available. eThekwini Electricity realised the effort involved in enabling proper asset management, and will in future reap the benefits of investing in data capturing, implementing processes, systems and continuous training ensuring that through the unequivocal support of management their journey towards excellence in asset management is successful.

Asset management requires extensive asset data

Proper asset management can only be implemented with good data about those assets both in terms of its location, technical attributes, dynamic attributes (loading levels, operation counts, etc.) and logical attributes (i.e. how it fits into the network to supply electricity). In electrical utilities this is a big dataset to extend and keep updated with asset counts that could easily run into the millions. It is impossible to stay in control of your asset data without proper business processes supported by relevant information systems influencing asset data.

Eating away at the elephant

Due to various reasons very few entities have all of their asset data under control, especially at the lower voltage levels. This can be corrected by:

- Developing and implementing asset and equipment structures that makes sense for your business and systems.
- Establishing business processes and workflow that will ensure any future asset changes (updates, additions, disposals) are correctly recorded in the relevant information systems.
- Utilising available electronic and hard copy data to capture historical asset data (the decision to follow this step should be made based on the quality and control of historical data available).
- Field exercise to capture and update assets with lacking data.

Data capture approach

Conventional field capture projects focus on capturing attribute data while in the field. With the low cost of high resolution cameras and the low cost of storage this changes the data capture landscape. The approach taken by the project team to reduce field time and moving most of the attribute capture work to office teams supervised by technical specialists proved very valuable in terms of time, cost and quality.

High resolution aerial photography also proved to be very valuable as many asset points could be identified on the aerial photograph assisting in verifying positional accuracy of field data recorded, as well as identifying missed assets.

Importance of the GNIS during data capture and modelling exercise

The use of a modelling environment that supported connected network modelling was essential to ensuring project success and enabling secondary eThekwini Electricity objectives. As a result of GNIS modelling, the project not only recorded asset data, but also delivered logical information regarding the assets:

- Network connectivity modelled from MV devices to LV networks
- Supply areas for devices is dynamic based on network open points
- Asset plant slot identification could be automated based on location within network
- Network portions completed by data modellers could be subjected to various test routines to ensure data and modelling accuracy.

Enterprise asset management system misnomer

An enterprise asset management system is firstly not just a single piece of software, but rather a system consisting of multiple parts being processes, resources and various technical and non-technical software applications working in unity to realise asset management. There is a significant dependence on supporting systems to keep asset data up to date. Any entity serious about asset management should work through an exercise to define what asset data they need for proper asset management. This should be based on a holistic view of the assets from where data attribute ownership mapping can be done which defines data ownership and responsibility for the various information systems including the EAMS.

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[1] NIST special publication – NIST Framework and Roadmap for Smart Grid Interoperability Standards Release 1.0 (Office of the National Coordinator for Smart Grid Interoperability) – January 2010

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Unified service, asset and work management in a spatial environment for better efficiency

by Bouke Spoelstra, Vetasi

Whether they are called cities or towns or municipalities, local government organisations of all forms around the world shoulder the same responsibility to provide essential services to their constituents. Amid flat or shrinking budgets, local governments today are expected to accomplish more with fewer resources. Municipalities are under pressure to rollout services to more constituents while maintaining good levels of service, but they often struggle.

To meet their responsibilities and achieve their goals, local government organisations must improve their internal operations and find efficiencies to free resources for other opportunities. The task of improving operations in local government is complicated by the very nature of the organisation. The breadth and scope of assets and services for which municipalities are responsible, when coupled with financial pressures, is unlike anything in the private sector.

Municipal service and asset management challenges are further exacerbated by the fragmented nature of most business solutions used today. The islands of data that these systems produce cannot be aggregated in a way that supports informed decisions. Similarly, standalone systems make it next to impossible to comply with recognised industry standards such as PAS 55 (PAS), now ISO 55001, and the Governmental Accounting Standards (GARP 17). The ideal solution should instead provide a unified platform to track and manage the full spectrum of municipal assets and service providers, addresses compliance, accounting and asset-related challenges across multiple departments, and integrates smoothly with key systems such as geographic information systems (GIS), enterprise asset management (EAM), customer information systems (CIS) and ERP.

A geographic location is a fundamental reference point in the physical world. As enterprise business systems evolve to more accurately reflect real-world conditions, the ability to represent a location has become increasingly critical. GIS software creates, organises, maintains, analyses and visualises information related to a location. Other fundamental GIS capabilities which are highly valuable in the asset management context include proximity functions to determine adjacency, relationships, nearness, shortest distance, shortest path distance to and other related functions more quickly.

The widespread popularity of web-based mapping tools like Google Earth, Google Maps, Bing Maps and Yahoo Maps, has caused an explosion of interest in making visualisation part of core business processes and workflows.

GIS technology has long been valued for its ability to display network features (such as pipes, wires and roads) and to help reduce costs by enhancing decision making. The deployment of these solutions is typically limited to back office functions such as infrastructure expansion. The end result is that GIS applications have largely been vertically integrated with very specific use and operated as an information silo.

The municipal challenge

Municipalities in South Africa are complex environments to manage, compared to municipal organisations in the UK and US which do not provide basic services such as water and electricity. In South Africa these basic services are the responsibilities of local municipalities, thus increasing the level of complexity. Managing this distributed asset intensive environment without proper business systems to identify, optimise, plan and predict work required to ensure continued service delivery becomes an unassailable obstacle.

In the South African municipal environment several business systems exist such as:

- Billing systems (account information)
- GIS/spatial systems
- Help desk environment
- Work management systems
- CAPEX processes
- Asset register/financial systems

The biggest single problem is that these systems are usually operated as silos in the organisation, hampering business processes that run across these environments. The end result is that each system must be maintained, updated and verified separately and the value of a unified environment is lost.

In recent studies, significant value was extracted for a process of combining and correlating the information from the data sources into a single environment without losing the single point of entry approach. Each of the above systems can contribute to an integrated environment:

- Billing: Providing accounts, property, customer information.
- Helpdesk using this information when capturing a call, also verifying customer information and geoplacing the service request.
- Asset register: Provides all asset data for

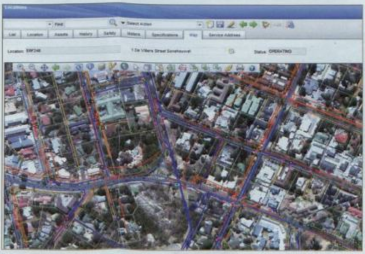

Fig. 1: An asset register is spatially enabled when loaded into the service and asset management system linked to the GIS.

service requests and maintenance, asset type, geoposition etc.

- The GIS/spatial system provides the backdrop on which assets, customers and networks are displayed, as well as service requests and work.
- CAPEX processes utilise the GIS and asset management environments for quotations and planning, providing componentisation and automated asset take-on.
- Work management: Planning, scheduling, dispatching, routing and tracking of crews using the map.

Fig. 1 shows how an asset register is spatially enabled when loaded into the service and asset management system linked to the GIS.

This environment now allows for a single user interface which drives the business process from:

- Registering service request on map (spatially defined).
- Create and plan the work.
- Provide an estimate and send for approval.
- Dispatch crew (to spatial enabled asset).
- Route and track vehicle spatially.
- Provide feedback and complete work – history spatially enabled for analysis.

These business processes are optimised in every step through spatial functionality.

Benefit realisation

Geospatial technology can extend the capabilities of service and asset management systems in a number of fundamental ways, including:

- *Enhancing spatial context:* Along with time, location is a fundamental reference point for countless human activities. In service and asset management systems, location data provides a useful context which makes other work/asset-related data more meaningful.
- *Having measurement capabilities:* Geospatial data can help us understand the physical relationships among assets, such as the distance between them for routing purposes.
- *Extending modelling options:* Analysing and visualising geospatial patterns can help identify trends and predict future events with greater accuracy.
- *Deeper knowledge about asset locations:* Municipalities with widely dispersed assets such as water utilities, electric utilities, and departments of transportation, find it useful to track the locations of assets over time.
- *Greatly improved visualisation capabilities:* Visually displaying location data on maps is the most familiar, and often the most valuable use of geospatial technology. Applying this capability to strategic assets has a vast range of implications for improving business performance.

Fig. 2: The value of historical data visualised in a graphic format.

Usage scenarios

Geospatially enabled asset management systems better support customer service, work order management, emergency (outage) response, mobile dispatch and more.

There are numerous other applications such as those described below, where the capability to combine GIS and service and asset management data dynamically is particularly powerful.

- *Work planning, scheduling and execution:* Using a map interpolated from GIS and asset location data, planners are able to visualise current and potential work locations for decision making purposes.
- *Locating assets for inspection, maintenance and repair:* At large facilities such as municipalities, it can be challenging to locate assets for preventive and corrective maintenance activities. A geospatially enabled service and asset management system combining geospatial referents with desired asset attributes helps coordinate inspection and maintenance activities and serves as a basis for planning routes and optimising resources.
- *Call centre:* Using a GIS-based map, call centre agents can pinpoint trouble locations more rapidly by entering a key identifer (nearest intersection or cross street, customer address, etc.). The agent can then check whether other trouble has been reported nearby, whether a crew is assigned, and on the status of the existing work order(s).
- *Decision support:* Integrated GIS-based mapping abilities, in combination with asset management data, can be used to facilitate investment planning or other forms of analysis.

Software suppliers working closely with geographic information systems (GIS) solutions, provide users with complex GIS information. These solutions provide a geospatial context of work, assets and relevant land-based features, which improve reliability, longevity and efficient work execution. In return, GIS users also gain acess to the business processes around work and asset management activities, which are equally important.

Benefits of a spatially enabled environment

By leveraging extended asset management abilities, government and commercial enterprises can derive fundamental, cross-functional benefits from geospatially enabling their asset and work management business processes. These potential benefits include:

- *Cost savings through greater efficiency:* Streamlining work and scheduling activities such as the logistics of maintaining assets can help organisations save labour, time and materials.
- *Better informed decision making:* Knowing more about where assets are located spatially and relative to one another naturally improves both tactical and

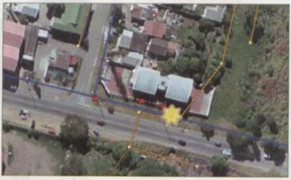

Fig. 3: Once the asset is identified, a new service request can be created in that location.

Fig. 4: The geospatial context enables the engineer to identify "hot spots" of repair activity, and to leverage other asset-related data to restore service.

strategic decision making, from better route selection to improved long-range planning of inspection, maintenance and repair activities.

- *Enhanced communication and collaboration:* Maps and visualisations created using GIS data make it possible for individuals and teams to view and understand situations more quickly and completely.
- *Creation of new business value:* Through its support for new forms of data analysis and insight, geospatially enabled service and asset management systems can help drive new sources of business value and possibly even change how business is done. By creating a single source of information, all disciplines in the organisation have access to the same information at the same time, eliminating the need to track data in multiple locations or synchronise asset attributes between the GIS and asset management systems.

While the integration of asset and work management with GIS is not a new idea, the technology approach available in the new architectures makes the power of desktop GIS directly available to enterprise service and asset management users. It offers a seamless user experience which incorporates map-based user interfaces, dynamic access to GIS data and interoperability with the enterprise service and asset management environment.

Spatially enabled service and asset management use case

The integrated service and asset management environment with GIS can help organisations identify and plan work by enabling call centre agents, supervisors and others to more easily locate assets geographically and select assets for work. Further, executives can leverage insight into the geospatial relationships among assets for stronger decision support and more meaningful reporting.

Consider a scenario in which a customer calls to report water in the street in front of her home. Using a service and asset management solution, the agent can quickly locate the problem based on an address search. Once the asset is identified, a new service request can be created in that location, as shown in Fig. 2. Viewing the infrastructure, they can then ask appropriate questions to better identify the location of the problem. This will help direct the crew to the specific location of the problem accurately.

The agent can easily view other assets in the area on the map. Notes and other redline information can be added to the map to provide additional details to the crew responding to the problem. The map with notes is then attached to the service request.

Upon review of the service request, it is determined that a work order will be required to resolve the issue; one is created easily from the service request. Next, the supervisor checks for other open work orders in the area, and so maximises the value of the truck roll. The geospatial context also allows an engineer to visually identify "hot spots" of repair activity and to leverage other asset-related data to make decisions on how best to restore service.

Going far beyond simply publishing static images of asset locations, the system provides access to the full power of GIS for spatial analysis, tracing, location-based services, etc., from within the enterprise asset management solution.

Conclusion

Spatially enabled enterprise asset management provides a valid geospatial context for all asset and location types: linear (roads, rails, pipelines, power lines, waterways); area/polygon (buildings, roofs, forests, service areas, campuses, offices) and points (poles, hydrants, meters, signs, transformers, houses). The integrated environment provides the following benefits to municipalities:

- *Supports geocoding:* The ability to convert street addresses and similar location data into latitude/longitude (GPS) coordinates, and vice versa.
- *Support tracing networks:* The ability to spatially relate the components of a pipeline system or network. This ability is the foundation for determining which customers will be affected by maintenance activities and other service interruptions.
- Support for enhanced routing or route planning abilities by providing core GIS routing abilities in combination with rich asset management positioning.
- Support detail and complex queries from a GIS or service and asset management point of view, and delivering the results spatially or in tabular form.
- Include GPS automatic vehicle location (AVL) feeds to track resources, assets, and tools and data.
- *Eliminating data duplication:* The new architecture moves away from an environment where it is required to copy or synchronise GIS data to work with it in other applications. Complex queries across database instances are supported without the need for data duplication or synchronisation.

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The evolution of medium voltage power cables up to 36 kV

by Patrick O'Halloran, City Power

This paper will cover the evolution of MV power cables over the last century and will cover some pros and cons of all the different types of insulation mediums utilised for MV power cables. In South Africa most utilities still install three-core paper insulated lead covered (PILC) cables and are considering three-core cross-linked polyethylene (XLPE) insulated cables. No utilities install three-core ethylene propylene rubber (EPR) insulated cables which are extensively utilised in the mining industries.

This is not the case internationally, where utilities predominantly only install either single- or three-core MV XLPE or EPR cables and have programmes to replace their existing PILC cables networks.

New HV cable projects in South Africa are all single-core XLPE insulated. The old existing fluid filled HV power cables are being replaced because of the intensive maintenance requirements of these pressurised systems.

Background

Ever since electricity was first transmitted over a century ago via MV power cables, their insulation mediums and designs have evolved. MV power cable networks make up the biggest asset that most utilities have to operate and maintain. These MV power cable networks are buried out of sight unless they become unreliable and faults are experienced. In many cases these networks are run to failure with very little maintenance or expected life diagnostic testing being conducted.

Utilities need to ensure reliability of supply and therefore MV cable designs have also evolved. MV power cable insulation ages due to the electrical stress and operating conditions that they are exposed to. The cable experts will also remind end users how critical it is not to overload their MV power cables, as increased temperatures are the quickest ageing mechanisms to reduce the remaining life of a MV power cable. When MV power cable faults occur they contribute to large area interruptions of supply and the fault may take time to be located and can be very expensive to repair. Depending on the MV network design, faulty cable sections could be quickly isolated and power restored to the healthy parts of the MV network.

MV power cable design changes have also been driven by changes in switchgear designs and higher voltages and loads that are required to transmit the increased power demands that utilities are required to supply.

The exact remaining life of an existing MV power cable network is complicated to predict. However, by performing regular condition assessment tests on the existing cables, the results will give utilities a good indication as to when the cable insulation system has reached its end of life and repeated failures can be expected.

On-line and off-line diagnostic testing can be applied to try and predict the remaining life of existing installed MV power cable networks.

The impact of theft on MV power cables is now starting to affect the performance of MV networks and repeated faults are causing stress on upstream power transformers and associated MV equipment which is reducing their remaining life.

Another big concern is the lack of jointer skills to repair all the cable faults utilities experience. Utilities are losing all their experienced jointers either to retirement or industry. Utilities now make use of contractors to perform the critical joints and terminations. To what standard should jointers be trained to and who can provide the required training?

The first power distribution system, developed by Thomas Edison in the early 1880s in New York City, used a cable constructed from copper rods, wrapped in jute and placed in rigid pipes filled with a bituminous compound.

Although vulcanised rubber had been patented by Charles Goodyear in 1844, it was not applied to cable insulation until the 1880s, when it was used for lighting circuits. Rubber-insulated power cable was used for 11 kV circuits in 1897 in the Niagara Falls power project. Mass-impregnated paper-insulated lead covered medium voltage cables were commercially practical by 1895.

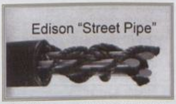


Fig. 1: First power cable that was developed by Thomas Edison in the early 1880s.

During World War II several varieties of synthetic rubber and polyethylene insulations were applied to MV power cables.

In the late 1960s cross-linked polyethylene (XLPE) insulation was introduced as MV power cable insulation and this technology changed MV power cable systems, but like any new technology had many teething problems and manufacturers spent lots of time and money in resolving the problems that were experienced in the industry.

The currently available MV power cables in South Africa are all manufactured and tested to stringent standards published by the South African Bureau of Standards (SABS).

These standards are reviewed periodically and the following SABS South African National Standards (SANS) are compulsory for MV power cables in South Africa according to VC 8077, the compulsory specification for the safety of medium voltage electric cables:

- SANS 97: Electric cables – impregnated paper-insulated metal-sheathed cables for rated voltages 3,3/3,3 kV to 19/33 kV (excluding pressure assisted cables).
- SANS 1339: Electric cables – cross-linked polyethylene (XLPE) insulated cables for rated voltages 3,8/6,6 kV to 19/33 kV.

Further to the above standards the Electricity Suppliers Liaison Committee (ESLC) has published the NRS 013 specification for MV cables. This specification makes recommended rationalised options for PILC and XLPE MV power cables.

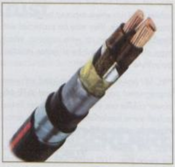


Fig. 2: Typical three-core PILC MV power cable.

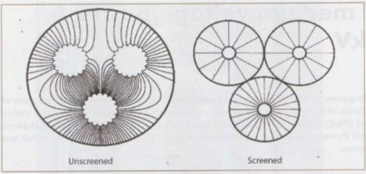


Fig. 3: Unscreened (belted) cable and screened cable PILC MV power cable.

Fig. 4: Typical single and three-core XLPE insulated MV power cables.

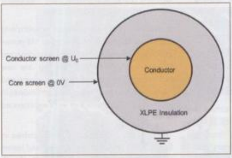


Fig. 5: The three critical layers in a XLPE insulated MV power cable which are applied as a triple extrusion.

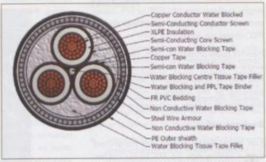


Fig. 6: CBI Electric African Cables longitudinal water blocked XLPE MV power cable design.

MV power cable construction

The construction of MV power cables needs to be understood to really appreciate the major technical differences between the two different technologies. Both are available in single or three-core and as unarmoured or armoured. The conductors are either stranded copper or aluminium depending on the end user's preference or power needs. The copper conductor has been preferred over aluminium for many reasons. The extruded outer sheaths vary depending on the final applications. Polyvinyl chloride (PVC) is typically flame retardant but can also contain low halogen for mining applications.

Cables intended for underground use or direct burial in earth will have heavy plastic or metal, most often lead sheaths, or may require special direct-buried construction. When cables must run where exposed to mechanical impact damage, they may be protected with flexible steel tape or wire armour, which may also be covered by a water resistant polyethylene outer sheath.

PILC MV power cables are insulated with mass impregnated paper insulation and XLPE MV power cables are insulated with cross linked polyethylene insulation. These two insulation materials are very different in many ways.

PILC MV power cables have been around for more than 100 years and subsequently make up the prominent installation base in South Africa and internationally. These cables have had many design changes over the last 100 years. Many of these changes were improvements to make the cable's performance more reliable at higher voltages. When PILC MV power cables were first utilised they were on 6,6 or 11 kV voltages only.

Paper insulation on its own does not provide a good enough insulation for power cables for the following reasons:

- Absorbs atmospheric moisture.
- Susceptible to cracking with ageing.
- When continuously subjected to local ionisation (partial discharge) during load cycling can result in irreparable damage during cable handling.

The paper insulation is currently impregnated with a non-draining compound. They are now referred to as mass impregnated non-draining (MIND) cables. In the past, oil-based compounds susceptible to draining (e.g. rosin oil) was employed. When the compound drained with gravity and temperature the paper insulation would dry out and many failures at terminations were experienced.

There are two types of "non-draining" compounds used by various manufacturers:

- Compound processed from a mineral based amorphous crystalline wax.
- Recently a synthetic compound better known as polyisobutylene (PIB) compound.

All single-core PILC cables have round conductors and an individually screened design. However, three-core cables have sector shaped conductors and initially had a "belted" construction design and one of the first improvements was to introduce an "individually screened" construction design. This equalises electrical stress on the cable insulation. This technique was patented by Martin Hochstadter in 1916; the screen is sometimes called a Hochstadter screen. The individual conductor screens of a cable are connected to earth potential at the ends of the cable, and if voltage rise during faults would be dangerous, at locations along the length. When a cable is screened, it can be touched safely without the risk of a potential build up occurring.

Unscreened belted design

A three-core cable, in which additional insulation (the belt insulation) is applied over the laid up core assembly. If air is introduced in a belted designed cable the potential for partial discharge (PD) to be initiated is increased. This is typically what happens at dry type terminations. If the air is removed as in a compound filled cable box joint, no PD should occur and therefore no crutch failure.

Screened cable

A cable in which, in order to ensure a radial electric field surrounding the conductor, each core is individually screened by a non-magnetic conducting tape that is in electrical contact with the metal sheath and in the case of three core cables in direct contact with the screens of the other two cores. The risk of a crutch failure is reduced with type of screened cable design. Special steps must be taken to ensure the electrical stress at the ends of the core screens are graded to prevent PD. Typically stress relieving mastic or stress control tubes are utilised.

Belt papers are removed when jointing and terminating. This reduces the phase voltage to earth to 5,5 kV at all accessories. Therefore screened designed cables are more reliable when being jointed or terminated.

Fig. 3 shows the electric field lines in belted unscreened and individually screened three-core cables.

Characteristics of unscreened cable (belted design) insulation comprised of core paper insulation and belt paper insulation:

- Only "collectively" screened.
- Reduced core insulation when compared to screened cables.
- Only useable up to 11 kV.

Many of these cable improvements were made to improve the PILC cables at higher voltages. When PILC MV power cables were first utilised they were on 6,6 or 11 kV supplies only. For voltages above 11 kV only screened designed cables are available.

PILC MV power cables are very susceptible to moisture ingress. Once moisture has penetrated through the lead sheath, the paper insulation is affected immediately leading to insulation failure. This moisture then quickly travels down the cores and eventually affects a bigger section of the PILC MV power cable. Therefore it is critical to prevent moisture from entering the cable at all. It is also then very important to perform a moisture crackle test on the paper insulation prior to any joint of termination being installed. If moisture is detected, the cable with moisture ingress should be replaced to prevent further failures. It is also critical that the PILC MV power cables are sealed at all times with the appropriate sealing caps. The use of a plastic bag or a plastic half litre cold drink bottle is not acceptable and will lead to moisture ingress.

When XLPE insulated power cables were first manufactured in the late 1960s they experienced many premature failures in the field. These failures were due to incorrect manufacturing leading to the presence of impurities and contaminants within the XLPE insulation. These failures gave XLPE insulated MV power cables a poor name in the industry and most South African utilities quickly changed back to PILC MV power cables.

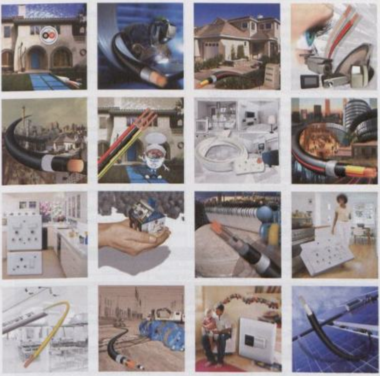
Subsequently the XLPE insulation cleanliness, designs and manufacturing production process technologies have considerably evolved. The manufacturers began to understand what was important when it came to making XLPE cables more reliable and with extended life expectancy. The three critical layers in a XLPE insulated MV power cables are now applied at the same time and is referred to as triple extruded.

These three critical layers are:

- The conductor screen which is at U_0 phase voltage.
- The XLPE insulation.
- The core screen which is at 0 V (needs to be kept at earth potential).

The conductor and the core screen are both made of conductive materials and the XLPE insulation is the pure insulating material. XLPE insulated cables always have a screened design and are round to ensure the equal stress distribution in the XLPE insulation.

Further improvements have now been made with regards to the XLPE insulation materials and for MV power cables tree retardant (TR) XLPE compounds (TR-XLPE) are now utilised to successfully pass the wet aging type test and required breakdown strength criteria which are specified in SANS 1339.



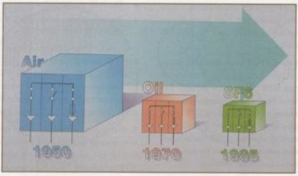


Fig. 7: MV switchgear trend as insulation mediums evolved.

Fig. 8: Compound filled cable boxes.

The quality of XLPE insulated cables is so high that it is becoming the preferred insulation at 500 kV, as XLPE insulation has lower dielectric losses and higher operating temperatures thus higher ampacities and lower environmental impact. Unaged XLPE insulated MV power cable has a typical breakdown strength of 50 kV/mm.

City Power and Eskom have changed their MV power cable specifications to longitudinally water blocked XLPE insulated cables as a standard. The concept is comparable to a baby's nappy, where water swellable compounds and tapes are included in areas where water could flow in the cable should it enter for reasons such as damaged sheath, lugs, existing cables, storage, etc.

The water penetration type test as per SANS 1339 shall be conducted to prove the design. This design will extend the life of the cable as water entering the cable it is stopped where it enters. This also then prevents the old problem that XLPE cables had of becoming water pipes.

Areas that have to be water blocked in a three core XLEP cable are:

- Conductors
- Core(s) and metallic screening
- Laid up cores for three-core designs
- Armouring

The international trend is to use single-core cables rather than three-core cables, as it is simple and easy to longitudinally block a single-core cable, as it does not have the big fillers between the cores. The risk of moisture entering all three phases is also reduced when three single-core cables are utilised as compared to a three-core design.

Eskom will be installing the first 400 kV EHV XLPE insulated cable in South Africa in early 2014. The cables and the accessories will be important for this project. One local HV cable company has invested in a new EHV XLPE production line to be able to manufacture 275 kV cable. This is really exciting for future projects and we will no longer have to import 275 kV EHV cable as it can be made locally.

The risk of DC pressure testing is also better understood these days and it is not recommended to use DC pressure test equipment on XLPE insulated MV power cables. DC pressure testing has been proven not to test the true resistive properties of the cable and at the end of the day is not really effective. DC pressure testing has been around for many years like PILC cables, but is slowly being replaced by AC, DAC and VLF source test equipment. DC source equipment is required for fault finding, but this is different to voltage withstand testing.

To prevent theft of cables in South Africa, suppliers are now adding special marking tapes with serial numbers, giving end users the ability to identify stolen cable. Furthermore end-users are also utilising these serial numbers for their asset register.

Table 1 summarises the key differences between PILC and XLPE insulated MV power cables.

Cable construction	PILC-insulated cable	XLPE-insulated cable
Conductors (either copper or aluminium)	Usually shaped conductor, but may be circular or oval.	Only circular.
Insulation	Wrapped impregnated paper insulation.	"Solid" dielectric XLPE insulation.
Screen	Belted collectively or individually screened. (Wrapped metallised paper tapes).	Always individually screened. (Conductive semicon with either copper tapes or copper wires).
Metallic sheath	Essential, typically lead.	Optional, either lead or aluminium.
Bedding layer	Extruded or fibrous (if armoured).	Extruded bedding (if armoured).
Armouring	DSTA/SWA/AWA (optional).	SWA/AWA (optional).
Outer sheath	Extruded (PVC/PE)/fibrous.	Extruded (PVC/PE).
Continuous operating temperatures	70°C	90°C
Short circuit temperatures	160°C	250°C
Longitudinally water blocked	No, normally only radially due to metallic layer.	Yes, if specified as it is not a standard.
PD free design	No	Yes
Diagnostic testing possible	- Tan delta diagnostic which is the overall circuit condition. - Pre-failure faults can't be located without breaking down the insulation system by applying a high voltage source.	- Tan delta and partial discharge diagnostic possible. - Pre-failure faults can be located without breaking down the insulation system. - Jointer errors can be identified before energising the cable.

Table 1: Comparison between PILC and XLPE MV power cables.

Other factors influencing cable technologies

With the improvements in insulation mediums and cable terminations, MV switchgear has drastically reduced in actual size. This means that the sizes of cable boxes have been reduced and special bushings have been introduced to accommodate the new cable terminations.

Things get really exciting on site if the wrong equipment has been specified and purchased. Typically most equipment has long lead times and instead of stopping the project,

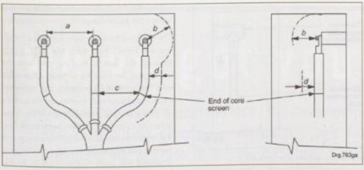


Fig. 9: Bare termination air-insulated (Type 1).

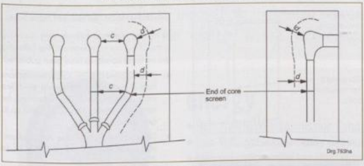


Fig. 10: Shrouded termination (Type 2).

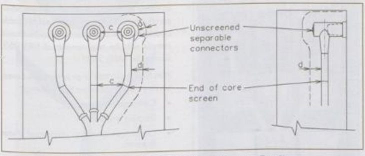


Fig. 11: Unscreened separable connector termination (Type 3).

people make plans on site to terminate the cable in to the switchgear that is supplied on site. Therefore from day one the installation is wrong and premature failures can be expected. These failures can be expensive to repair and could also involve replacement of the switchgear. Staff or members of the public could be injured or killed from the resultant explosion.

Cable termination beginnings (early 1900 – 1950s)

In the beginning, electrical equipment like switchgear and transformers were designed to have compound filled metal cable boxes. This way of terminating cables was not technically good, and was very difficult and hazardous to field staff. The MV paper insulated (PILC) cables at the time had belted construction and had wiped earth connections.

Compound filled cable boxes are designed to have no air inside, so creepage was not a major consideration when designing the cable bushing. This explains why the bushings of compound filled cable boxes are small compared to air filled cable box bushings found in metal clad switchgear and outdoor transformers.

Compound boxes were filled with many different compounds, but mainly a hot pouring compound was used. This hot pouring compound was difficult to manage and gave off harmful fumes while being heated up prior to pouring. Compound filled boxes were made of metal housing with porcelain bushings where the cables exited the compound box.

Some draw-backs of compound filled cable boxes are:

- Compound top-up is required to ensure proper insulation (no air voids).
- Long installation times.
- Cable box failures cause major damage when they ruptured (hot burning compound could be expelled).

New technology cold pouring compounds are now available, which are environmentally friendly, safe to install and re-enterable.

Air insulated MV cable terminations (1950 – 2000s)

With the introduction of tapes, heat shrink and later cold shrink terminations, compound filled boxes have been replaced over time with air insulated terminations. This type of MV cable termination is used by 95% of the South African market.

Screened paper insulated cables were introduced to control the electrical stresses in the cable designs, especially where increased voltage cable ratings were required. Currently, belted design paper insulated cables are limited to 12 kV. Screened paper insulated cables are normally rated up to and including 36 kV as per SANS 97. The screened cable design provides improved MV cable termination performance, especially in the crutch where in belted cables the crutch is a high stress area.

The belt design paper insulated cable is more likely to have crutch failures than the newer screen design paper insulated cable where the complete crutch area is screened. This is because of resistivity of materials and the introduction of air between to unscreened insulated conductors.

International markets (which are mainly 24 kV rated systems) tend to require smaller and smaller switchgear. This in turn equals reduced busbar clearances and cable boxes.

Air was the first insulating medium for busbars. This was replaced with oil and with the introduction of SF6 insulation, busbar clearances could be reduced tremendously. This allowed the cable box sizes to be reduced. Along with the reduced cables boxes, came reduced clearances between phases and phase to earth. The reduction of clearances required new MV cable terminations. When switchgear manufacturers design smaller air-filled cable boxes with reduced clearances, MV cable accessory manufactures have to redesign the bushings and MV cable terminations to make the cable box and cable termination compatible for these reduced clearance requirements.

In South Africa we have standardised on a type C 630A bushing with M16 thread. This type C bushing is found on all the new SF6 insulated switchgear that is currently used by City Power, Eskom and other utilities and industries. Type C bushing allows end users to move away from traditional putty and tape shrouds to factory made fully insulated shrouds. These shrouds are installed the same way every time and ensure that cables are terminated properly

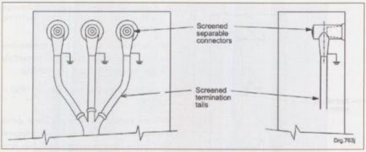


Fig. 12: Screened separable connector termination – outside cone (Type 4).

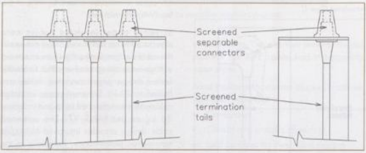


Fig. 13: Screened separable connector termination – inside cone (Type 5).

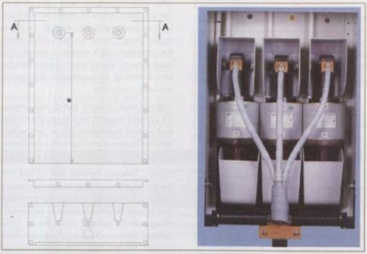


Fig. 14: Height of the cable box.

on type C bushings as well. This is a product that is designed to be used on South African paper insulated cable systems.

Paper insulated cables which are susceptible to moisture ingress that causes insulation breakdown, were also being forced to find new alternative cable designs. With the introduction of screened XLPE cables, heat shrink MV terminations evolved once again. Internationally it was decided to standardise the cable interface and to introduce screened cable terminations. Screened MV cable terminations could only be used on MV XLPE cables and when installed eliminated the problems of creepage, tracking and erosion and clearances experienced by most air insulated MV cable terminations. The term "screened" means earthed. Once a cable termination is completely screened it can be completely submerged in water without any flash over. Screened connectors are required when connecting to new 24 kV compact switchgear.

Internationally a lot of the bigger utilities have changed from three-core cables and now use single-core XLPE insulated cables. This is not an easy change to make as all electrical aspects of the network must be reviewed and employees need to be trained on how to install and terminate single-core XLPE insulated cables. The South African market mainly uses three-core cable designs for many reasons.

The design of the screened connector controls the electrical stress from the XLPE cable through the Type C bushing and into the switchgear. Because the surface of the cable and the screened connector are screened there is no leakage current along the surface of the screened connectors. With these screened connectors installed in the cable box, the cable box and all electrical clearances can be reduced drastically. The life expectancy of screened MV cable terminations is double the expected life expectancy of unscreened cable terminations, especially with reduced clearances inside new reduced cable boxes.

To try and eliminate failures from occurring in the MV cable compartment, the following two national standards have been published:

- NRS 012/SANS 876 – *Cable terminations and live conductors within air-filled enclosures (insulation co-ordination) for rated AC voltages from 7,2 kV and up to and including 36 kV.*
- NRS 053 – *Accessories for medium-voltage power cables (3,8/6,6 kV to 19/33 kV).*

These two standards are not compulsory yet, so it is up to the end user to specify them when purchasing any MV switchgear and MV cable accessories. All MV cable accessories should comply with the requirements of NRS 053, soon to be SANS 1332.

With the introduction of air in the cable boxes, we now have to consider the following:

- Creepage distances.
- Tracking and erosion.
- Clearances (phase to phase and phase to earth).

The above three technical considerations must be correct if an air-filled termination is to last in excess of 30 years. Inadequate creepage, tracking and erosion properties and air clearances will result in the MV cable termination failing prematurely. Failure of MV cable terminations are dangerous and cause long power interruptions.

NRS 012/SANS 876 has been developed to address these challenges. This standard is critical to understand and also to specify correctly when ordering new switchgear to accommodate the cable technology that will be installed.

In NRS 012/SANS 876 the following types of terminations are specified:

- Type 1 termination – lugs connected onto bushings or post insulators, uninsulated (bare) at the terminal fixing point (Fig. 9).
- Type 2 termination – lugs connected onto bushings or post insulators with a shrouded (unscreened) insulation termination (Fig. 10).

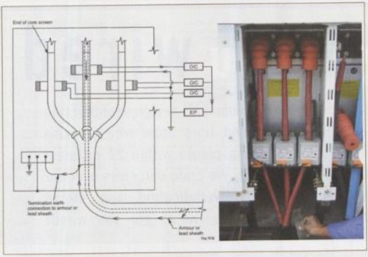


Fig. 15: Illustration of the correct earthing for ring type current transformers on each cable core used for overcurrent and earth fault detection.

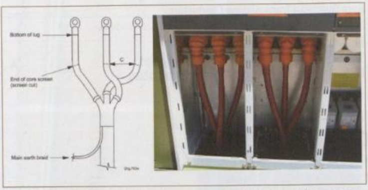


Fig. 16: Example of a cable termination where the core crossing is made below the end of the core screen.

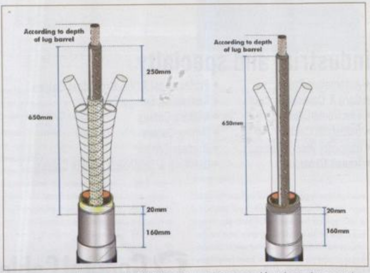


Fig. 17: Example of screened and belted PILC cable termination prepared from the top down principle.

- Type 3 termination – unscreened separable connector terminations (Fig. 11).
- Type 4 termination – screened separable connector terminations – outside cone (Fig. 12).
- Type 5 termination – screened separable connector terminations – inside cone (Fig. 13).

All critical dimensions and definitions are given in NRS 012/SANS 876.

Type 1: Bare termination (air insulated)

In a Type 1 termination, the interfaces are bare and:

- Cable cores are terminated with stress control appropriate to the cable design and voltage.
- Air is the sole insulation medium for the terminal connections.
- The minimum distance from any live bare metal (e.g. bushing, post insulator, live conductor, lug, fitting etc.) to an adjacent phase or to earth is determined by the impulse withstand voltage requirement.

Type 2: Shrouded termination

In a Type 2 termination, the interfaces are shrouded with unscreened interfaces and:

- Cable cores are terminated with stress control appropriate to the cable design and voltage.
- Unscreened local insulation enhancement at the terminal connections.
- The minimum distance from any unscreened, shrouded, live metal (e.g. shrouds, cable cores etc.) to an adjacent phase or to earth is determined by power frequency (e.g. corona inception and extinction) and impulse withstand voltage considerations.

Type 3: Unscreened separable connector termination (USC)

In a Type 3 termination, the interfaces are unscreened but utilise specially designed USC and:

- Cable cores are terminated by stress control appropriate to the cable design and voltage.
- USC at terminal connections.
- The minimum distance from any unscreened, live metal (e.g. USC, cable cores etc.) to an adjacent phase or to earth determined by power frequency (e.g. corona inception and extinction) and impulse withstand voltage considerations.
- Leakage current limited by quality of the interface between USC and bushing – interference fit.

Types 4 and 5: Screened separable connector interfaces (SSC) – inside or outside cone

In Type 4 and 5 terminations, the interfaces are screened and use specially designed SSC and:

- Clearances are determined by the mechanical clearance required to fit the SSCs within the cable box.
- Are safe to touch due to surface being earthed.
- The leakage current is limited by the quality of the interface between SSC and bushing (interference fit).
- Note: PILC cables could not use SSC especially above 11 kV because of sector shape cores and loose core screens.

Cable box sizes (heights)

It is also important to ensure that the correct size cable boxes are supplied, as nearly all MV power cables installed are three cores, so extra space is required.

LV current transformers in MV cable boxes

As technologies have improved with screened cables, the uses of low voltage current transformers have been utilised in MV cable boxes for metering and protection applications.

It is essential that these low voltage current transformers be installed in a screened area, otherwise discharge may occur if the air clearances are inadequate.

The dimensions from the top of the low voltage current transformer to the screen cut is covered by the dimensions in Type 2 and 3 terminations.

Core crossing for phasing within MV cable boxes

Core crossing for phasing within MV cable boxes is not recommended, however many crossed terminations exist in our networks. The risk with cross cores inside unscreened type terminations is that adequate clearances get reduced and this leads to increased electrical stress and partial discharge.

NRS 053 requires all terminations to be done with a top down principle. If the top down principle is followed, the screen's metallic area is increased and core crossing can be done easily without any risk of partial discharge. However with a belted design cable, there is no metallic screen and core crossing is very risky.

Fig. 18 shows the extra base that needs to be supplied with compact switchgear to ensure that the correct three-core cable height is attained. This would not be the case for three single-core cables. The whole evolution of MV power cables, switchgear and cable accessories has made it possible to reduce cable boxes significantly. The additional bending radius of three-core cables also has to be considered. Fig. 18 shows the special removable front covers which have been designed to make the jointer's job easier and in doing so will hopefully prevent jointer errors.

Fig. 19 shows a clever way of terminating three-core XLPE MV power cables into small compact switchgear. By performing a tri-furcating termination in the duct or ground, three single-core cables are achieved. Terminating single-core terminations in such small cable boxes is recommended. This small cable box has two cables terminated in it and there is no risk that a failure could occur. Core crossing is done under the cable box in the duct or ground. Special attention should be paid to using the right single cable clamps and gland plate material.

Fig. 20 shows an example of where things have gone wrong in the past. The SF6 insulated ring main unit was installed with additional metering low voltage and protection current transformers (CT). This happens often and it is because the wrong products were ordered because end-users have not understood the new technologies or wanted to stay with older technologies. City Power was able to locate this problem before a failure occured by using handheld detectors.

The installation should have been done with Type 4 terminations and single-core XLPE cables. Instead a Type 3 termination was installed and the CTs were installed over the unscreened areas of the termination.

This installation would have failed if nothing was done. PD takes a long time to cause a failure in terminations, but it is guaranteed to fail one day.

Fig. 18: Example of SF6 RMU with an additional raising plinth and removable front sections.

Fig. 19: Example of tri-furcating termination into compact MV switchgear.

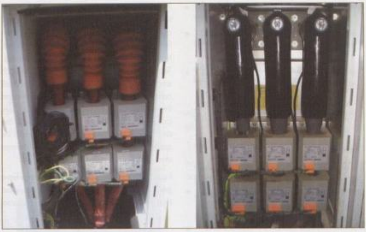


Fig. 20: Example of incorrect and correct termination into compact MV switchgear with LV CTs.

Testing to ensure reliability

Most end-users still use direct current (DC) cable pressure test equipment which gives no diagnostic results. This equipment has been available for many years, is portable and is affordable. The current test method is to apply a high DC voltage for a predefined period to the MV power cable. If nothing trips during the test, the cable is declared healthy to energise. This is referred to as "go or no go" testing. Why then do failures of the cable, joint or terminations still occur after energising? The answer is well documented. DC testing only tests the resistivity properties of the cable system. However when the cable system is energised with alternating current (AC) 50 Hz, the permittivity properties of the components are stressed. To ensure future cable system failures are avoided and to make an informed remaining-life decision with regards to possible replacement of the faulted or aged MV power cable, we need to test differently.

With the improved technologies in testing voltage sources, we can test the permittivity properties of the cable system, and simulate the same stresses as in service with AC system conditions. The following alternative test wave forms exist:

- Very low frequency (VLF).
- Damped oscillating waveform test voltage (DOWTS).
- Alternating current at power frequency.

A diagnostic test should also be conducted before energising a new cable or after a repair has been made after a failure in a cable system. Off-line tan delta (TD) and partial discharge (PD) results can be taken during the pressure test. The results are available on site and an informed decision can be taken with regards to the health of the MV power cable system.TD test results will give an overall cable system condition result. It will not isolate the problem area. PD test results will give the distance to the source of the PD (which is a potential failure point). Because new XLPE insulated MV power cable is PD free, if PD is detected it is typically in the joints or terminations where jointers have made errors. This now means that these joints need to be identified and corrected, prior to energising. We all know that PD will never go away and it will just intensify and eventually lead to a failure.

These results provide us with a fingerprint of the condition of the MV power cable system and when future diagnostic tests are conducted the results can be compared and the cabling ageing rate confirmed. The proposed revised SANS 10198-13 code of practice for MV power cable testing, now recommends integrated voltage withstand and diagnostic testing. These tests do not take longer to perform as they are now all integrated in the new available test equipment.

Conclusion

MV Power cables have definitely evolved over the years. The new third generation XLPE-insulated MV power cables are now reliable and make it possible to connect into the new compact switchgear which is now being installed.

The following recommendations need to be considered in the future to ensure improved reliability of MV cable systems:

- Install screened rather than belted designed PILC cables.
- Select and specify the corrected termination types up front as it makes no sense to install the wrong terminations from day one.
- If three-core cables are installed, ensure that the switchgear is suitably designed as per NRS 012/SANS 876.
- If three single-core cabless are installed there is reduced risk of termination failures. Tri-furcating terminations are perfect to convert three-core cables to three single-core cables.
- It is also possible to install a tri-furcating transition joint from three-core PILC to three single-core XLPE.
- Ensure clearances are kept at all costs if screened terminations are not installed.
- Ensure jointers are well trained to install the MV power cables and accessories, to prevent unnecessary failures.
- If PILC insulated cable are installed always test for the presence of moisture and cut out affected sections.
- If XLPE insulated cable is installed utilise the right screen removing tool.
- Consider single core cables instead of large three-core cables.
- Always perform combined voltage withstand and diagnostic testing, so that the actual condition of the cable system is known and future faults can be avoided.

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The benefits of using high-temperature low-sag (HTLS) overhead conductors

by Tony Hill, CTC Global Corporation

As growing demand for electricity continues to stress the electrical transmission grid, many transmission lines have become thermally constrained. These constraints are due to the subsequent sag that occurs as bare overhead conductors are operated at higher loads and temperatures, due to their high coefficients of thermal expansion.

An innovative conductor has been developed and commercialised to mitigate high temperature sag through the use of aerospace derived carbon fibre composites. These high performance materials have excellent thermal stability and have been widely deployed in several other demanding applications due to their excellent resistance to cyclic load fatigue. Over 22 000 km of this conductor has been installed in over 250 projects worldwide. The conductor aluminum conductor composite core (ACCC) was developed not only to replace thermally constrained lines, but also to reduce the costs associated with new installations by reducing the number of supporting structures required, as the ACCC conductor's composite core is 25 to 40% stronger than its steel counterparts. This additional strength and thermal stability enable far greater spans (or lower structures) to be utilised without jeopardising clearance requirements. The higher strength composite core, which is significantly lighter than steel, also allows 28% more conductive aluminum material to be incorporated into an equivalently sized conductor (in terms of diameter and weight). This contributes to greater throughput and a substantial reduction in line losses. While the ACCC conductor is rated to operate at up to 200°C, it actually runs substantially cooler than an all aluminum or steel reinforced conductors of equivalent size, under equivalent load conditions. This can enable line loss reductions of 25 to 40%. These capabilities help improve the efficiency, capacity and reliability of the grid.

Background

On 14 August 2003, the northeast United States and Ontario, Canada, experienced the second most widespread blackout on record at that time (after Brazil in 1999), affecting 55-million people. Six weeks later, on 28 September 2003, a similar outage occurred in Europe which affected 56-million people. According to the final NERC report, the US/Canada blackout of August 2003 was caused by a number of factors. These included inaccurate telemetry data used to operate the Midwest Independent Transmission System Operator (MISO) "state estimator" (and a subsequent computer re-boot failure); a "race condition" computer bug in FirstEnergy's energy management system; and three 345 kV transmission line trips (outages) due to excessive conductor sag, which led to a cascading of similar sag-trip outages on their 138 kV system. These events and lack of effective communication between other utilities ultimately shut down 508 generating units at 265 power plants. The economic impact was estimated to approach US$10-billion.

On 30 and 31 July 2012, a similar series of cascading outages in India impacted more than 670-million people. At the time of writing, it is not known what sequence of events caused these blackouts, but initial reports suggest a shortage of generation capacity and substantial grid limitations including excessive conductor sag.

For these and several other reasons, it is well known that excessive conductor sag can lead to catastrophic grid failure. While demand for electricity continues to grow and further strain our electrical grids, the use of high-temperature, low-sag (HTLS) conductors is becoming increasingly essential, especially as new sources of generation continue to be brought online.

Overhead conductors

For over 100 years, electricity has been delivered to end-users using bare overhead conductors that were made up of conductive aluminum strands often wrapped around a core consisting of steel wires to improve the conductor's overall tensile strength. This type of conductor is commonly known as aluminum conductor steel reinforced (ACSR). As demand for electricity continues to grow and new sources of generation continue to be brought online, many transmission and distribution lines have become thermally constrained. This is due to the fact that, as electrical current increases, the temperature of the conductor rises. The increase in conductor temperature is a function of the electrical resistance of the materials used. Unfortunately, as aluminum wires are heated to above 93°C, they begin to anneal, which causes a substantial loss of strength. However, certain aluminum alloys can operate at higher temperatures and do offer higher strength, but these generally increase the conductor's electrical resistance and so reduce their efficiency. On the other hand, pre-annealed aluminum, which offers minimal tensile strength – but excellent conductivity – can be operated at higher temperatures, as required. A comparison of conductive aluminium properties are presented in Table 1.

In addition to the various aluminium alloys used in a number of bare overhead conductors, a number of core technologies have evolved which offer additional performance advantages. Table 2 offers comparative values.

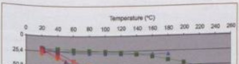

Fig. 1: Sag comparison of several overhead conductor types.

Aluminum conducting materials				
Decription	Name	Conductivity (% IACS)	Tensile strength (ksi)	Max cont. op. temp. (degrees C)
Hard drawn	1350 – H19	61,2	23 – 25	90
MS alloy	5005 – H19	53,3	36	90
HS alloy	6201 – T81	52,5	46 – 48	90
Fully annealed	1350 – O	63	6 – 14	250
Thermal resistant	TAL	60	24 – 47	150
HS thermal resistant	KTAL	55	27 – 36	150
Ultra thermal resistant	ZTAL/UTAL	60	24 – 27	200
Extra thermal resistant	XTAL	58	24 – 27	230

Table 1: Comparison of aluminum strands commonly used in bare overhead conductors.

Core materials				
Description	Weigh (lbs/ inch^3)	Modules of elasticity (msi)	Tensile strength (ksi)	Coefficient of thermal exp. (x 10 – 6/°C)
HS steel	0,281	29	200 – 210	11,5
EHS steel	0,281	29	220	11,5
EXHS steel (Galfan coated)	0,281	29	285	11,5
Carbon hybrid expoxy	0,070	16 – 21	330 – 375	1,6
Alum clad (20,3 IACS)	0,238	23,5	160 – 195	13,0
Galv. Invar alloy	0,281	23,5	150 – 155	3,0
Mishmetal std	0,281	29	200 – 210	11,5
Mishmetal HS	0,281	27	220 – 235	11,5
Al oxide metal matrix	0,120	31,2	190	6,0

Table 2: Comparison of core materials used in overhead conductors.

Fig. 2: Conventional ACSR and modern ACCC conductor.

While various combinations of these materials have been used to create a number of conductor types including AAC, AAAC, ACAR, ACSR, ACSS, Invar, Gop, ACCR and others, ACCC offers the highest performance combination of materials. ACCC conductors use high-strength, light-weight carbon fibre core that enables the use of an additional quantity of fully-annealed (low resistance) aluminum without a weight or diameter penalty. The added aluminum content decreases electrical resistance under any load condition compared to all-aluminum or steel-reinforced conductors. This serves to reduce line losses by 25 to 40% or more depending upon load conditions. Fig. 1 offers a thermal sag comparison of several "Drake" size conductors where each conductor was placed in a 65 m (215 foot) test span and an electrical load of 1600 A was applied.

While HTLS conductors such as ACSS are commonly used to replace AAC and ACSR conductors to increase the capacity of thermally constrained transmission lines, the degree to which they can increase the transmission line's capacity is still limited by conductor sag in spite of the HTLS conductor's ability to potentially operate at higher temperatures. For instance, looking at Fig. 1, if you consider that ACSR conductor can only deliver about 1000 A at 100°C (emergency operating temperature assumption), its sag would correlate with the X-axis (horizontal line) represented by '40". If an HTLS conductor (of the same size) such as ACSS, ACCR or Invar were used to replace the original conductor, they would appear to reach the same sag level well before they reached their rated capacity.

While it is easy to see and compare the differences in sag between the various conductors tested, what is most remarkable about the ACCC conductor besides its extremely low sag compared to the other conductors tested, is the fact that it operated at 60 to 80°C cooler than any other conductor of the same diameter and weight under equal load conditions. The substantially cooler operating temperature reflects a substantial improvement in efficiency. Being able to deliver high levels of current with very low thermal sag and comparatively low line losses offers several important advantages. Fig. 2 offers a visual comparison between ACSR and ACCC conductors.

When faced with the need to increase the capacity of an existing transmission line, many utilities have resorted to raising or reinforcing existing structures to enable increased conductor sag or to accommodate larger, heavier conventional conductors. In some cases, structures have required full replacement. One of the advantages of ACCC conductors is that it can be used to replace a conventional conductor (of equal size) without requiring structural modifications, and because of its very minimal thermal sag, line capacity can be virtually doubled without suffering the degree of line losses that would be inherent if another HTLS conductor were selected.

When new lines are built, the ACCC conductor's greater strength, dimensional stability, and excellent self-damping characteristics can be used to increase spans between fewer and/or shorter structures. This can reduce overall project costs and environmental impact.

As global efforts continue to be made to improve the efficiency of generators (in an effort to reduce generation costs), and the drive to improve the efficiency of demand-side appliances (to reduce generation capacity requirements) continues, several utilities are now also using ACCC conductors to achieve similar goals.

In the United States, for instance, several utilities including Duke Energy, have estimated that their T&D losses represent about 8 to 10% of all electricity they produce. Approximately 3 to 4% is associated with transmission losses. The ACCC conductor's ability to reduce losses by 25 to 40% can dramatically reduce these losses. So, the energy which would otherwise be lost now becomes available. This can have the same effect as building new generation.

For example, if one considered a 100 km (62 mile) 230 kV transmission line that had a peak capacity of 1000 A (assuming a Drake size conductor, 30°C ambient condition, 2 fps wind, and other common assumptions) and a load factor of 53%, the use of ACCC conductors would reduce line losses by 20 329 MWh per year. Assuming a generation cost of $50/MWh, this would equate to a savings of just over $1-million per year. This also equates to a generation savings of 8 MW. If you assumed the cost of new generation was $1-million per MW, you could easily see that the ACCC conductor upgrade would save the equivalent of an $8-million generation investment. Reconductoring this hypothetical line would cost much less.

If you considered the same assumptions, but increased the peak amps from 1000 to 1600 A, the reduction in line losses offered by the ACCCC conductor would save 72 976 MWh per year. In this scenario (with the same 53% load factor), the savings would amount to $3,65-million per year. From a generation capacity standpoint, this would reflect a savings of 28,8 MW or $28,8-million.

When considering the cost of developing a renewable resource, if line losses are considered and ACCC conductor employed, the economics regarding the overall cost per delivered MWh become more favourable. Perhaps the ACCC conductor is one technology that can reduce the need for government funded incentives to develop renewables?

Conclusion

Considering that the efforts to increase the capacity, efficiency, and reliability of the grid continue globally, the ACCC conductor offers an outstanding alternative to other conventional methods. This is why, in just eight years, more than 22 000 km of ACCC conductor has been deployed by more than 100 utilities at 250 project sites. At this time, American Electric Power is currently reconductoring 240 circuit miles (386 km) of a double bundled 345 kV line while it remains energised. Upon project completion this single project will incorporate over 1440 miles (2300 km) of ACCC conductor.

Reference

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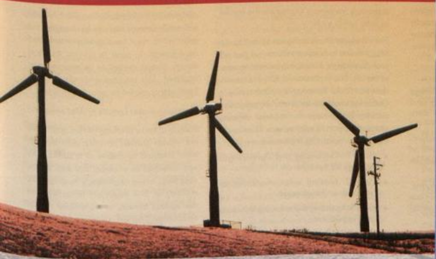

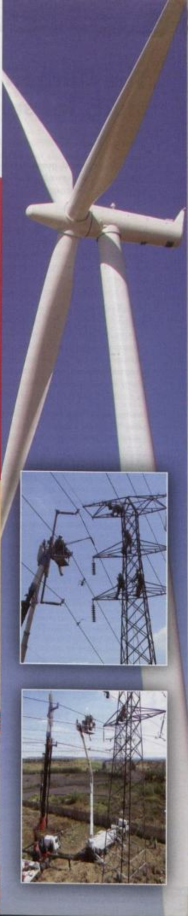

The Durban Solar City Framework as a case study for small scale embedded generators

by Derek Morgan, eThekwini Municipality; Amy Marshall, Camco Clean Energy; Nathan Williams and William Hove, EAB Astrum Energy

China introduced ground-breaking legislation in 2005, the Renewable Energy Law of the People's Republic of China. The "Renewable Energy Law" was a national framework to promote the uptake of renewable energy (RE) throughout the country.

It included: national renewable energy targets and local RE planning; mandatory connection and purchase policies; a national feed-in tariff system; and a cost-sharing mechanism funded by a surcharge on electricity sales, to pay for feed-in tariffs, grid connection projects [1].

The different components of this framework approach complimented each other and have resulted in large scale implementation of renewable energy on an unprecedented scale. More recently, the Chinese leadership have taken the framework approach to renewable energy support a step further in supporting the concept of "the third industrial revolution".

Jeremy Rifkin, in his New York Times best-seller, *"The Third Industrial Revolution; How Lateral Power is Transforming Energy, the Economy, and the World"*, argues that the world is undergoing a fundamental economic change as new internet communication technologies converge with new renewable energy systems. The book, which was formally endorsed by the European Parliament, lists the five pillars of the third industrial revolution as:

- Shifting to renewable energy
- Buildings as power plants
- Deploying hydrogen and other storage technologies in every building and throughout the infrastructure to store intermittent energies.
- Using internet technology to transform the power grid of every continent into an energy sharing Internet that acts just like the internet.
- Transitioning the transport fleet to electric, plug in and fuel cell vehicles that can buy and sell electricity on a smart continental energy Internet.

This concept of the third industrial revolution has found support around the world and is the foundation of the European climate and energy package , which has a legislated target of increasing the share of renewables in the energy mix by 20% and a 20% reduction in energy consumption by 2020.

In leading the transition to a renewable energy economy, China and Europe have demonstrated the need for a strategic plan or framework approach to developing the sector. The framework should consider different technical, legal and financial components of renewable energy that can complement and integrate with each other in developing the sector.

Solar City Framework concept

There are a range of tools available to assist local government in developing strategic frameworks that promote renewable energy. The United States (US) Department of Energy initiated the "Solar American City Programme" to help stimulate a solar market in the US. The programme focused on providing support to 25 large cities to promote the local uptake and manufacturing of solar photovoltaic (PV) technologies. Within this program, the Department of Energy developed a number of guidelines, including "solar powering your community: a guide for local governments". This guideline was designed with local government practitioners in mind and provides clear steps on how to design and implement a strategic framework to promote the uptake of solar within a city.

The eThekwini Municipality has elected to use this guideline to develop a framework that will provide strategic direction to promoting solar in the city. The Durban Solar City Framework draws on "Solar Powering Your Community: A Guide for Local Governments" by proposing six inter-linked steps that address different areas of support to solar uptake. The steps in the Durban Solar City Framework are:

- Step 1: Organising and developing a strategy for the solar city
- Step 2: Making solar affordable for residents and businesses
- Step 3: Updating and enforcing local rules and regulations
- Step 4: Improving local grid policies and processes
- Step 5: Educating and empowering potential customers
- Step 6: Leading by example with installations on government properties

The eThekwini Municipality drafted the first iteration of the Durban Solar City Framework and then procured consulting services for the implementation of the framework over a two year period, beginning in early 2013. The program has now been running for more than six months under the management of Camco Clean Energy and EAB Astrum Energy and some significant lessons have already been learnt from the process.

Durban Solar City Framework

The purpose of this paper is to outline the Durban Solar City Framework as a case study for local government in South Africa to apply a framework approach in facilitating renewable energy. The paper provides some detail of the current status of the steps listed above and outlines some of the lessons that have emerged to date.

Step 1: Organising and developing a strategy for the solar city

In order to achieve the outcome of an enabling environment for embedded generators, a key element of the overall approach is the strategy, or framework that will accomplish that goal. The Durban Solar City Framework has been designed as the foundation on which to build a dynamic strategy that can be changed and adjusted to meet varying local needs and requirements. In order to do this, the local energy context needed to be explored and analysed. This required understanding the local energy market for solar technologies.

Identifying market barriers to solar energy

Analysis of the local energy market, specifically the market barriers to solar technologies, were analysed by means of a survey. This was identified as a crucial first step before supplying a new technology to a specific market, as it is important to understand the various barriers to the uptake of that technology. The first phase of this process involved conducting a market barrier literature review. For the purposes of this review, "market barriers" were broadly interpreted to include all barriers that affect the likely uptake and demand for solar technologies, including technical and non-technical barriers.

The literature review found that while solar technologies have come a long way in recent years, there are still significant market barriers to the technology. However, as highlighted by the international and South African literature, these barriers are starting to decline.

Market barriers in the literature were classified into four themes: financial, information/awareness, inertia, and market perception barriers.

Financial barriers were identified as the greatest barrier to investment. This was found to be specifically true in contexts where the consumer tariff for conventional electricity is considered to be relatively low. This outcome is further exacerbated in contexts where solar irradiation is relatively low, thereby extending the payback period and making the return on investment less attractive. Added to this are the high initial investment costs and difficulties in obtaining the finances in the local market required for such an investment. However, as the price of the technology decreases and the cost of conventional electricity continues to increase, the attractiveness of such an investment increases proportionately.

Information and awareness are important in removing barriers to solar technologies. The two areas to be addressed in this regard are a lack of knowledge or awareness and inconsistent information or a lack of community involvement. Where these two factors exist, the potential market is unlikely to invest as knowledge gaps and uncertainties remain or increase.

However, even where communities or individuals are aware of nuances, consumers may still fail to invest due to inertia. This can result from the technical complexities of the solar technology, often combined with limited or inadequate policies and incentives to encourage investment.

Finally, perceptions towards the technology are an important fourth barrier. This can either be perceptions about the attractiveness of the actual physical system, or doubts about its credibility or reliability.

The literature review was used to inform the methodology and approach for a survey that would assess these market barriers on three levels within the eThekwini context: households, small and medium businesses and large industry. Electronic surveys were sent out to a large sample group of individual, business and industry databases. Industry surveys were followed up with telephonic interviews to minimise the complexities of an individual answering for a whole industry or company. The results from the survey will be analysed and a final report on the current context of market barriers in eThekwini will be produced.

Conducting an installation baseline and establishing solar targets

The next stages of the first step of the Durban Solar City Framework will include conducting an installation baseline survey, as well as establishing solar installation targets. The installation baseline will most likely be ascertained by means of a survey, verified with site visits. Key to this process will be the capturing of the data obtained in a database developed for this purpose. In order to establish solar targets, a literature review of international, as well as local best practice literature, will be conducted. In accordance with the data from the baseline survey, this information will be used to establish achievable targets.

While there are complexities in ascertaining the number of installations due to no central database or registration service, this information, combined with the contingent market barriers will help to continuously revise and fortify the framework and action plan to address the present context on the ground.

Continuous revision of the framework and action plan

The last phase of step one involves the continuous revision and updating of the framework and action plan for the Durban Solar City on an on-going basis. This is crucial in order to ensure that the framework is a dynamic, versatile tool that is able to not only meet, but potentially anticipate the needs and requirements of Durban as a whole, in achieving the status of a solar city.

Step 2: Making solar affordable for residents and businesses

Affordability is one of the main driving factors in consumer uptake of a technology. Although the cost of solar energy systems has and is expected to continue decreasing for the next few years, these systems still require a substantial initial capital investment for residents and businesses. Financial barriers were identified as the greatest barriers to the market uptake for solar technology in the literature review as previously mentioned. The eThekwini Municipality has engaged with this barrier through the Shisa Solar Programme and is beginning to understand the complexities of various aids to support the industry.

The eThekwini Municipality is looking at financial incentives and financing mechanisms required to make this an attractive technology for the local market. Developing incentives and financing programs to bolster local market demand attracts solar businesses and will establish a community in a growing industry. Financial incentives such as rebates and tax credits can reduce the up-front cost of solar energy systems. Loans and other financing mechanisms enable customers to spread costs over time.

The solar resource in the eThekwini Municipality is one of the lowest in the country with the global horizontal irradiation (GHI) at approximately 1450 kWh/m^2 average. The solar resource maps of KwaZulu-Natal show the potential annual electricity production from a photovoltaic system with optimally tilted c-SI modules at approximately 1400 kWh/kWpeak averaged over 1994 – 2011. This is much lower than other regions in the province such as Newcastle which have a potential annual electricity production of greater than 1800 kWh/kW peak. This has the implication of a longer payback period on the investment in comparison to other parts of the country. However, the resource is still sufficient for solar systems depending on the tariffs, incentives and finance mechanisms that are made available to consumers. The following options are being considered to facilitate the uptake of solar energy:

- Developing a renewable energy portfolio standard (RPS) or goal to stimulate demand. The portfolio standard will require the eThekwini Municipality and other utilities to use qualifying renewables or renewable energy certificates to account for a specific percentage of their retail electricity sales. This will allow for the creation of an economic development environment that is carbon competitive to the rest of the country. For a target of 10% of total capacity the municipality seeks to facilitate the additional generation of 250 MW renewable energy for sale through the billing system. An initial assessment of the current energy mix and identification of industries that have the capability to sustainably generate their own electricity using renewable sources will be conducted in order to assess the potential of reaching the target generation capacity of 250 MW. To make renewable energy more affordable to the market, the RPS policies should be enacted in conjunction with incentive programs such as upfront rebates. A renewable portfolio goal is similar to an RPS but is not legally binding and therefore not as effective in driving development in the sector. The renewable portfolio goal can be aimed at residences and small businesses.
- Facilitating cash incentives and feed in tariffs. The cash incentives may be in the form of rebates or grants based on either the capacity or the investment cost. Another possible cash incentive may be a production based incentive which encourages optimised system design and installation.
- Implementation of solar leasing rental model in industry This model can be attractive to consumers as it reduces the risk and complexity involved in owning and operating a renewable energy system. This usually provides for systems that operate more efficiently as the owner of the system is responsible for the operations and maintenance. The owner's earnings are based on system output thus it is in their best interest to ensure optimal performance of the generator.
- Implementation of community solar models to take advantage of the benefits

associated with communities of scale by reducing the cost of embedded generators on a per-watt basis. This model also allows individuals who don't own the property or whose property does not receive adequate irradiation to still invest in solar energy.

Step 3: Updating and enforcing local rules and regulations.

Legal and regulatory framework forms the foundation for building a sustainable renewable energy infrastructure. Effective and streamlined rules and regulations on a municipal level may help reduce installation costs and can significantly improve the market environment for solar energy technologies. With this in mind, the eThekwini Municipality conducted a legislative and regulatory review relevant to embedded electricity generators in the city.

The purpose of the review was to summarise all the key areas of legislation applicable to embedded generators and to identify areas where legal opinion or interventions are required to create an enabling environment for embedded generators. In addition to this, the eThekwini Municipality would like to investigate the legal options for purchasing electricity from electricity providers. In order to achieve this sustainably, eThekwini would need to enter into long-term (20-year) contracts to buy electricity. The legislation and regulations that formed part of this review were:

National legislation

- The Constitution of the Republic of South Africa
- Municipal Structures Act
- The Electricity Regulation Act 4 of 2006
- Standard conditions for small scale embedded generation (less than 100 kW) within municipal boundaries (SCSSEG)
- Regulations, rules, guidelines, directives and codes of conduct and practice
- Municipal Finance Management Act
- Municipal Systems Act

Local regulations

- eThekwini Municipality Electricity Supply By-law
- eThekwini Power Purchase Agreement
- Natal Local Authority Ordinance

The eThekwini Municipality currently has a system in place to enter into power purchase agreements (PPA) with embedded generators. The current PPA restricts the contract period to only three years with the option to renew for a further three years upon approval by council. This presents challenges in obtaining finance for the generator if required as the debt tenor period is usually longer than this resulting in low to no solar uptake. Only generators able to finance their projects off balance sheet are currently able to enter into these PPA. In order to allow for bulk 20-year PPAs within eThekwini Municipality, three legal options need to be investigated:

- Long-term contracts according to Section 33 of the Municipal Finance Management Act (MFMA)
- A by-law amendment/addition permitting the municipality to enter into 20-year PPAs
  - By-law amendment to extend or allow for longer power purchasing agreements
  - By-law addition to create a separate municipal entity, classified as an organ of state, to purchase electricity
- The licensing of embedded generators by municipalities.

In summary, there are three main areas of legislation that were identified that require further legal interpretation by an appointed legal counsel. The first area that requires attention is section 33 of the MFMA. There are three points that need further clarification under section 33. The first is the issue of whether many projects could be bundled into a single section 33 application as this would reduce the onerous nature of the process. The second point involves further guidance on whether the MFMA section 33 makes exemption for purchases with a "low value"and how low this value has to be in relation to the project. This may be most applicable for very small generators. Legal opinion would be required on the definition of "low value" in terms of section 33 MFMA by comparing it with other legislation. The third and final point of clarification involves legal opinion on what "future budget implications" in terms of section 33 of the MFMA means and whether a contract at which the rate of purchase does not increase can be classified as therefore not imposing future budget implications.

The second area of legislation involves additions or amendments to municipal by-laws. The electricity supply by-laws could be amended to include embedded generators (EGs). The by-laws could regulate the tariff for EGs, the PPA contract periods and ensure quality of supply for network integrity. The tariff may need NERSA approval and this needs verification. The contract period may be in contravention of the PPA and clarification on this issue will also be required. The municipality could levy a tariff or surcharge for services provided. The levy or surcharge could then be utilised for bulk purchases of renewable energy.

The second way in which by-laws could provide assistance involves using them as a potential legislative platform to circumnavigate supply chain management requirements. This involves the issue of whether or not it is possible to get around competitive bidding through using an entity which is classified as an organ of state to purchase electricity for the municipality. Specifically, whether this entity would have greater flexibility than the municipal administration currently holds. Also, the restrictions around what type of entities municipalities can establish and own needs further exploration.

The third area requiring clarification is the point of the municipality issuing generation licences. It seems that formal licensing by municipalities is very unlikely but considering that municipalities already "license" installations under 100 kW, this point is most applicable to larger installations. There is however an area that needs further verification regarding the requirements for a generation licence if the installation is under 100 kW but is for commercial use. It is not clear whether the small scale generator requires a licence if it enters into a PPA with the municipality as this may be interpreted as commercial use. The correct interpretation of the SCSSEG is required in order to ensure that PPAs are lawfully entered into by parties concerned.

The IRP 2010 sets capacity targets for different RE technologies. These targets have been applied to IPP projects under the REI4P. IPPs participating in the REI4P will enter into a 20-year PPA with Eskom at specified prices and get a generation licence from NERSA on this basis. Under the REI4P, the targets constitute limits for the different technologies. The most onerous part of the licence application procedures is not the administration but rather the process that needs to be followed in order for NERSA to grant, or refuse the licence. Legal opinion needs to be sought on the following:

- Do the IRP 2010 targets constitute absolute limits per RE technology for projects applying for NERSA generation licenses outside of the REI4P? This understanding would contradict the national economic policy objective to build a RE industry.
- The licensing by NERSA of PV installations over 100 kW. The possibility of a "right to a NERSA licence" if the municipality commits to purchase the generated electricity also needs to be investigated. This point concerns the issues of central versus decentralised electricity generation. Legal opinion in this regard would also cover the issue of whether it is possible to purchase renewable energy at a higher rate than Megaflex.

Develop a solar access and solar rights by-law

A potential legal intervention the municipality could investigate is the option of developing a solar access or solar rights by-law. These types of by-laws would provide some assurance for citizens to access sun-shine as a right. For example, if someone invests in a solar installation and a neighbour proposes a


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development that will cause shading on this solar PV installation, the by-law would restrict this development to ensure there is no shading. This would allow certainty in business modelling for solar developers by mitigating the risk of decrease productivity on the PV installation in the future.

Solar ready buildings in town planning regulations

Another legal intervention would be to develop solar ready buildings concepts in town planning regulations. The municipality can encourage or require homebuilders and developers to design and build solar-ready homes and commercial buildings, so architects and builders can choose viable sites for solar technologies. In the current national regulations there is no reference to the concept of solar ready buildings. The new building regulation in South Africa references SANS 10400-XA for the minimum requirements to be achievable for building energy efficiency. Although not mandatory, the regulations indirectly promote design principles taking orientation and local climatic conditions into account.

Solar-ready buildings need to be incorporated at a local planning stage during the establishment of communities. This will facilitate the concept being feasible once development of top structures commences. Planning for the eventual installation of a solar system when designing a building can significantly improve the economics of the investment. Solar-ready building modifications are low- to no-cost at the time of new construction or retrofit and often very costly later in the building's life. By understanding and accounting for solar energy system requirements during the building design phase, installation efficiency can be maximised, costs can be minimised, and system performance can be optimised. This can readily be done through the town planning scheme amendments at a local level. The proposed approach is to initially conduct a review of existing town planning regulations in countries which have already implemented these concepts with focus on countries with similar legal systems as South Africa. These regulations can then be adopted to be in line with international best practice and local regulations.

Streamlined solar permitting and inspection process

An additional step is to streamline the solar permitting and inspection processes with clearly defined requirements and expedited processing for standard installations. The outcome will be a guideline that will provide all the relevant information on how to get a solar installation approved through the municipal permitting system. The system will be such that all application processes will be consolidated into an online tool.

Step 4: Improving local grid policies and processes

In order for embedded generation to become a reality, local grid policies and processes require not only updating, but also further improvement. This step will involve an in-depth analysis of all local grid policies and processes to establish what improvements are required.

Facilitate implementation of new NRS for embedded generation

Embedded generators are different to conventional energy consumers in that they export electricity to the grid. This means that not only the connection process, but also the local tariff need to be analysed and understood to align with this. Further to this, general policies applicable to embedded generators need to be restructured and modernised to meet the changing context on the ground. The first stage involves the NRS development process. Once this has been finalised, this information needs to be made publically available so that potential embedded generators, and the public at large, are aware and able to tap into the system.

Design and implement a bi-directional metering pilot

Once the NRS development process is complete and made publically available, the second phase of step four involves designing a bi-directional metering pilot project. The project will need to be launched in stages, the first of which is the design of the different program elements. Once this is complete, the ToRs for the implementation need to be developed. The final stage will involve contracting the chosen service provide to implement the program.

Step 5: Educating and empowering potential customers

A key aspect of the programme is disseminating the information gathered through other aspects of the Durban solar city project in order to educate and empower potential solar energy technology customers. The overarching objective of this activity is to create market demand for solar products by overcoming the barrier of lack of access to information on and awareness of solar energy technologies.

Durban Solar Map and Information Portal

The centrepiece of this task is the creation of the Durban Solar Map and Information Portal (DSMIP). The DSMIP will be a powerful tool to assist potential customers in assessing the solar energy potential of their roof spaces, link customers and solar professionals and provide easy access to information on relevant regulations and permitting processes.

The key component of the DSMIP is the interactive solar map. This web based tool permits users to locate their buildings on a GIS interface, similar to Google maps, and quickly and easily obtain an estimate of the solar energy that could be produced on their rooftop along with data on the financial attractiveness of the investment.

Solar maps have been implemented extensively in countries such as the USA, the UK and Germany. The scale and functionality of these maps vary widely, from simple databases of existing installations, to three dimensional models of city buildings and structures containing volumes of data detailing solar potential on each and every roof façade. The costs and data requirements of more sophisticated maps can be prohibitive. Particularly in South Africa, three dimensional building data is not widely available and would require the commissioning of such modelling for specific sections of the city at great cost.

The eThekwini Energy Office has elected to develop a map that can be implemented cost effectively and universally within the municipality. Furthermore, once developed, the map will be easily replicable within other localities in South Africa. To provide high resolution images, basemaps will be constructed from aerial photography which is produced by the municipality on an annual basis.

Users will have the ability to search their address and visually identify their roof top. They will then be instructed to outline the roof façade that they would like to assess using a simple polygon tool. Users are then prompted to enter data on the tilt and orientation of the façade (e.g. north facing with a 30-degree tilt). Basic information is then presented on the size (kWp), energy yield (kWh per annum) and carbon emissions reductions (tCO_2 per annum) that could be achieved by installing a photovoltaic system on the selected surface.

Interested users can then click on to the next window to assess the financial feasibility of the system using a financial model embedded in the map. The municipal electricity tariff at the building must be entered in the financial inputs window. Advanced users can adjust parameters such as system size and cost per Wp. By clicking on a link, users will be directed to a financial results window that will provide a calculation of return on investment and payback period.

The final window will prompt users to submit their contact information to a panel of solar energy professionals who can contact the customer to arrange an on-site assessment and quotation. Alternatively, users can obtain contacts details of the panel to contact them directly.

Replication of the map in other municipalities would require the creation of a new basemap and alternation of solar resource and tariff data. The eThekwini Energy Office intends to develop the map on a platform that can easily be implemented for different communities.

Further consumer outreach and education programmes

In addition to the DSMIP, the energy office intends to disseminate the knowledge generated through the Durban Solar City programme through many other channels. These activities will draw on lessons learned through eThekwini's Shisa Solar Campaign. The campaign will incorporate elements of:

- Public workshops
- Advertising campaigns
- Educational brochures
- Information website (through the DSMIP)
- Call centre
- Emailing list and social media
- Exhibition and market stands
- On-site presentations in the market place

These activities will centre on the DSMIP which will act as a "one-stop-shop" for everything solar in eThekwini. It will serve to ensure the widespread dissemination of the knowledge and resources generated by the Durban Solar City programme. The overarching objective is to address barriers to solar energy technology implementation related to the lack of information relating to solar.

Step 6: Leading by example with installations on government properties

The eThekwini Municipality is implementing a range of sustainable energy programmes within the city. These projects have provided invaluable learning opportunities for both municipal staff and the community at large. Municipal renewable energy installations provide the opportunity to test and showcase technologies as well as stimulate the market for local production.

Pilot project identification

In this activity, the Durban Solar City team will identify and implement several solar photovoltaic pilot projects within the municipality. The energy office has identified a broad range of potential installation sites on municipal infrastructure, from open land parcels to municipal building rooftops to water reservoirs. The first step in this activity will be to short-list the best sites.

Initial short-listing based on predefined criteria will utilise GIS tools and will leverage the Durban Solar Map to identify technically suitable sites. Short-listed sites will be subject to professional site assessments. Once technical feasibility has been established, the financial attractiveness of the investments will be investigated.

Pilot project financing

The method of financing pilot projects will depend on project size and the availability of public funds. For large projects or a bundle of small medium sized installations, third party finance models will be considered. Small projects which are funded directly from the municipality operational budget must achieve a five year payback period. The eThekwini municipality utilises RETScreen for the purpose of determining payback periods. Projects that pass financial thresholds will then be ranked and prioritised for funding.

Conclusions and observations

Promoting the uptake of renewable energy at a local municipal level in South Africa is currently complex. The legislative mandate of local government is unclear, the legislative requirements for solar PV are unclear, the technical requirements are not standardised and the entire electricity supply system is not geared for small scale embedded generators. There is however increasing demand from the market for local government to play an active role in streamlining and promoting renewable energy technologies such as solar PV.

In order for local government to make an impact in this environment, and be seen as an enabling agent rather than a blockage, it is critical for a strategic plan to be in place. The Durban Solar City Framework has gone a long way to providing that plan for the eThekwini Municipality. It has systematically listed the areas of intervention that need to be addressed and provides useful direction on how best to prioritise and implement these interventions.

The Durban Solar Cty Framework does however have some weaknesses. Most noticeably, it does not address capacity constraints in the municipality and in the sector as a whole. Having the necessary skills and people in place to deal with the various technical, financial and legal requirements of embedded generators is a serious constraint for the municipality. In future iterations of the framework, a section on building local capacity will be included in the document.

The framework also does not address the interplay between renewable energy and the internet, as outlined in the concepts of the "*Third Industrial Revolution*". The "energy internet" and "smart grids" are still quite new concepts in South Africa, so including this element on the framework may only come after some initial research has been completed in the city.

On the whole though, the Durban Solar City Framework has proved to be a very useful tool for the eThekwini Municipality to create an enabling environment for solar installations in the city. It has provided a clear road-map on some of the key barriers that need to be addressed in promoting RE in the city and can be used to check progress over time. Currently a similar document is being developed for the promotion of biofuels and biomass in the city and in the future the concept may be rolled out to all renewable energy resources in the eThekwini Municipality.

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Renewable generation reactive power capability and grid code compliance

by Mick Barlow, S&C Europe, Middle East and Africa

Most renewable generation will have the ability to either generate and/or absorb reactive power. However, that does not necessarily mean that the plant (wind or solar) will be grid compliant. This paper will illustrate the relationship between the plant capabilities and the grid code and identify some of the key factors that determine if auxiliary compensation equipment is needed to obtain compliance.

It will also discuss some of the options available for providing grid code compliance when the plant on its own is not compliant. In this paper we concentrate on the voltage and reactive requirements of wind energy (which also applies to most renewable generation) to comply with the grid code. These are probably the least understood aspects of grid code compliance.

Wind farm connection

Often smaller plants can be connected at the distribution level, while plants generating over 20 MW are generally connected at the transmission level. In distribution connections, the system may be underground or overhead, while transmission systems are almost always overhead.

Key technical requirements for wind power plant interconnection include protection, voltage control and reactive power capability, voltage and frequency ride through, frequency control, and communication and supervisory control and data acquisition (SCADA). Through their inherent capabilities, some wind turbines can meet some/all technical requirements, while other wind power plants require additional equipment known as balance-of-plant (BOP) equipment to achieve compliance.

Distribution interconnection

Traditionally, utility electric power systems were designed to accommodate active power generation at the transmission level, not the distribution level. As the distribution system is also becoming a collection system of different distributed power resources, the one-way load flow is becoming a two way street, and the traffic rules are changing. In this shifting environment, integrating distributed power resources into the grid can be challenging because the requirements are still being worked out in many regions.

A typical utility substation has three or four distribution feeders. Wind turbines generating 10 MW of power or less at voltage levels of 1000 V or less can be connected on a distribution feeder or at a substation. To do so, their power output needs to be stepped up to the distribution medium voltage level. In South Africa, that medium voltage is typically 11 or 22 kV.

When connecting wind turbines on distribution feeders, various issues may arise at or near the ends of the feeders. Voltage rise effects, especially at the end of long feeders, can become unacceptably high. In addition, variation in wind energy generation can cause flicker, which occurs when available fault system strength is so low that variations in

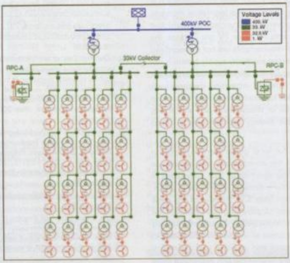

Fig. 1: Typical large wind farm configuration.

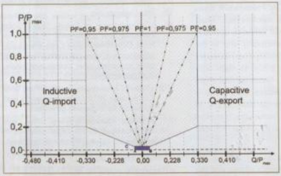

Fig. 2: Reactive power requirements for category C renewable power plants.

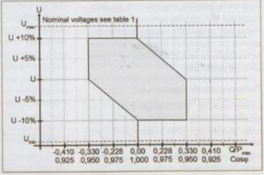

Fig. 3: Requirements for voltage control range for RPPs of category C.


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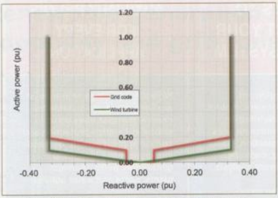

Fig. 4: Wind turbine capability superimposed on grid code requirement assuming no interposing network.

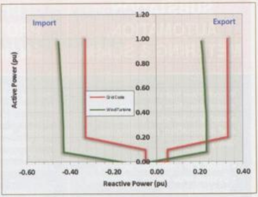

Fig. 5: Wind turbine capability reflected to the POC.

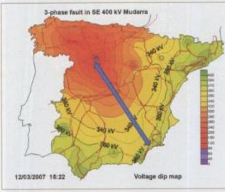

Fig. 6: 400 kV fault 640 km from the coast.

power production cause significant variations in voltage.

The feeder ampacity, the maximum amount of electrical current a conductor can carry, may also be lower toward the end of feeders as feeders are often tapered. The ampacity limits the amount of power generation that can connect to a feeder: segments of a feeder may need to be re-conductored with larger conductors to accommodate turbines.

At the distribution level, wind turbines producing power over 10 MW can typically be connected only at substations. There, the limiting factor becomes a specified percentage of the substation transformer rating.

The higher levels of distributed renewable generation create challenges for controlling voltage due, for example, to the limited reactive power produced, but many grid codes currently have no minimum reactive power requirements. When the standards were developed, utilities were controlling voltage levels on feeders. To avoid conflicts, wind farms were not required to regulate voltage, but the increase in distributed generation means renewable energy generators may need to. The standards will eventually evolve to accommodate these developments.

Transmission interconnection

Connecting at the transmission level involves a larger scale version of the concepts used for distribution interconnection. Larger wind farms have multiple circuits, typically four or more with 15 – 20 MW per circuit. Voltage is stepped up twice: first to collection system voltages, typically 33 kV, and then to the transmission voltage level at the point of interconnection: 132 kV or above.

Multiple collector feeders, which are usually underground but may also contain overhead line sections, bring the power output from the wind turbine generators to a collector substation with one or two large power transformers. A wind plant can be interconnected on the high-voltage side of the transformer in the collector substation, or it can be connected some distance away via a transmission line through an interconnect substation.

Developers need to provide plant design information modelling how the injected power from the wind plant will impact the existing power system.

Grid codes

With a significant increase in wind generation and other forms of renewable generation the performance of both transmission and distribution networks are changing significantly from the traditional model of large centralised fossil fuel generation. In order to accommodate these higher levels of renewable generation, often at relatively weak locations in the network, Utilities are developing more demanding grid codes so that the operation, reliability safety and security of the network are not compromised.

In order to meet these rigorous grid code requirements it is often necessary for additional equipment (balance-of-plant) to be installed to meet the grid code criteria. It is important that the developer and his major contractors are aware of these requirements early in the project cycle as they will have an impact on both cost and space requirements. Without them the developer may not be allowed to start up the generating plant, thus causing significant economic penalties to the plant owners and stakeholders.

If we look at some of the aspects of the grid code we will start to understand the issues.

Many grid codes categorise generators based on size. In South Africa there are three main categories:

- Category A: < 1 MVA
- Category B: 1 to 20 MVA
- Category C: > 20 MVA

There are some sub-categories within these main categories but that level of detail is not required for this paper.

The reason for these categories is that the grid code requirements are proportionate to the size of the wind form i.e. the impact of a single turbine on the network is much less than that of a large wind farm and therefore does not need such extensive controls.

For the purpose of this paper we will just concentrate on category C requirements, power plants over 20 MVA.

Many of the requirements for renewable power plants (RPPs) are defined at the point of connection (POC). This is the point at which the wind farm interfaces with the rest of the network. This is normally defined in the connection agreement. In Fig. 1 this is shown to be at 400 kV but it could it could be at lower voltages e.g. 132 kV.

Grid code – steady state requirements

Fig. 2 defines the reactive (Mvar) requirement at the POC. This can be summarised as the wind farm's requirement to either generate or absorb a constant Mvar value between 20 and 100% of the windfarm MW output.

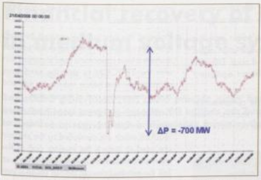

Fig. 7: Resultant loss of generation due to wind farm tripping.

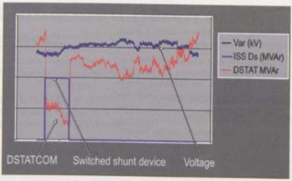

Fig. 9: Measurements of a hybrid STATCOM scheme.

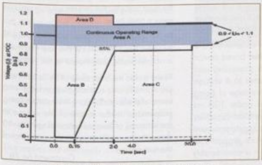

Fig. 8: Fault ride through requirement in South Africa.

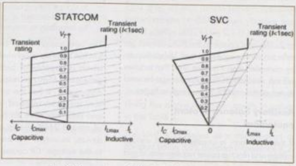

Fig. 10: Comparison of STATCOM and SVC characteristics.

At 100% MW output this equates to a 0,95 pf, e.g.100 MW windfarm needs to provide ±33 Mvar. Below 20% output that requirement is dramatically reduced.

Fig. 3 shows that there is also a requirement to operate within the defined voltage ranges, in this particular case it is defined for ±10% of nominal voltage.

What is important is that these requirements are at the POC and not the wind turbine terminals. So the question to the manufacturers is not if their wind turbine is grid compliant but will it be grid compliant at the POC when accounting for the effects of the network between the wind turbine and the POC.

Grid code – impact of collector network

The network between the wind turbine and the POC has a major impact on the turbine being able to meet the grid code.

If we examine a simple network comprising of a number of wind turbines connected to the POC via their turbine transformer, collector network and a main grid transformer. Assume the wind turbine is capable of 0,95 pf at its terminals and the grid code requirements are 0,95 pf at the POC as defined earlier.

If we examine Fig. 4, assuming that there is no interposing network, it looks like the chosen turbine is grid compliant. However, this is not the real world. When we add the interposing network we get the result shown in Fig. 5 which is clearly no longer grid compliant.

This solution is now not acceptable to the utility and additional balance of plant is required to achieve compliance.

Of course there are a wide choice of turbines to choose from and some will be better suited to specific grid code requirements. So one could argue that you just need to select a different turbine with a greater reactive capability and this might be the case. However, these aspects are not always fully understood by developers and often the choices are made based upon turbine size (MW) and price without due consideration that the wrong turbine is likely to encounter additional BOP equipment. Also, turbines with additional capability are likely to be more expensive so it could be a trade off between the two approaches.

There are also a number of additional factors that need to be taken into account such as voltage and dynamic performance.

Impact of voltage

As mentioned in an earlier section it is required that this reactive capability is supplied over a range of voltages. This is not always considered in the early stages of wind farm design but can have a significant impact on the ability of the wind turbine to supply reactive power.

Many wind turbines are controlled by power electronics which are susceptible to voltage variation, specifically high voltages. Therefore at 10% voltage above nominal they are very likely to reduce their reactive output significantly or even trip. In South Africa where the wind farm is required to stay connected for voltages up to 1,2 pu (+20%) this could be significant and must be taken into account.

Low voltage and high voltage ride through

As mentioned earlier one of the main purpose of grid codes are to ensure that the wind farm behaves as much as possible like a conventional generator. It is therefore important that the wind farm stays connected for variations of system voltage following a network disturbance. Before specific clauses for fault ride through were introduced it was quite common for wind farms to trip for voltage excursions outside normal limits.

Fig. 6 shows the voltage contour across Spain following a three-phase fault at a 400 kV substation in the middle of the country. It can be seen that at the coast the voltage dropped to 0,9 pu (360 kV).

Because this was prior to the introduction of fault ride through to the grid code to accommodate renewables, this voltage dip tripped 700 MW of renewables as shown in Fig. 7. Whereas this may be tolerated for a small number of renewables, it is not acceptable for larger levels of penetration.

For this reason most utilities introduced a fault ride through requirement into their grid code which specifies the behaviour of the windfarm for system disturbances outside the normal operating range. This is always a low voltage ride through (LVRT) requirement but may also include a high voltage ride through (HVRT) requirement.

Fig. 8 shows one of the aspects of the fault ride through requirement in South Africa. There are two important points that can be brought out from this. Firstly, the wind farm must be able to remain connected at zero volts for up to 0,15 and secondly must be able to stay connected when subject to 1,2 pu (+20%) voltage for up to 2. This is of course at the POC but will get reflected into the wind farm itself. Unless this can be controlled then it is quite likely that turbines will trip. Auxiliary BOP equipment can be used to reduce the impact of these high voltages.

Auxiliary balance of plant equipment

If the wind farm is unable to meet various voltage and reactive power requirements of grid compliance on its own, then it may be necessary to provide additional reactive compensation.

This may come in various forms and the correct solution will be a combination of the compensation capability and price. Different grid codes will result in different equipment being suitable.

The simplest form of reactive compensation is switched capacitors and reactors. These are relatively inexpensive but have two disadvantages:

- They do not provide continuous voltage control, each time they switch they will cause a step change in voltage,
- Their output varies with the square of the voltage (V^2) e.g. if the system voltage drops to 0,9 pu the capacitor output will reduce to 81% of its rated output. It may therefore be necessary to oversize these devices.

The next equipment to be considered is a STATCOM. This is an inverter based device which is capable of both absorbing and generating Mvars in response to a voltage disturbance. It has the advantage of being very fast, can respond in under 100 ms and also may have an overload capability of around 260%. Being a constant current device, its output is therefore proportional to the voltage. Of course it is considerably more expensive than a switched capacitor/reactor solution.

However, this cost can be reduced by using one of its variations. A bias capacitor solution is where a fixed capacitor is used in conjunction with the STATCOM to shift the wind farm characteristic and hence reduce the size and cost of the inverter part of the solution.

Another approach is to install a hybrid scheme where switched devices (capacitors and reactors) which are controlled by the statcom are used to reduce the inverter part of the solution. Because the inverter controls are so fast the switched devices do not cause a step change in voltage and can be considered as a continuous voltage control. This is normally the most cost effective inverter solution and can reduce costs by up to 40%.

Fig. 9 illustrates that when a shunt device is switched the STATCOM is that fast that there is no noticeable disturbance to the voltage.

There is also the alternative of SVCs but these are normally only cost effective on large wind farms and also suffer from their output being proportional to the square of the voltage at the extremes of their operation range. Fig. 10 shows the comparison in the characteristics of the two devices.

Continued on 78...

Financial recovery of embedded generation in medium voltage systems

by Ravi Moonsamy, Eskom

Embedded generation (EG) could provide many benefits in terms of reduction of system technical losses and increased load carrying capacity. EG options are being focused on by users of electricity in South Africa in order to improve energy savings and increase revenues derived from the sale of electricity.

The release of feed-in tariffs (FIT) by the Department of Energy in South Africa has increased the viability of renewable energy technology applications. The economic studies have to be based on localised parameters as the nature of the program is based on price bidding with the average cost effect of all the renewable energy assessed only after the program has been concluded in 2015 [1].

The Eskom wholesale tariff is the average cost of generation and is increasing at a rate greater than inflation per year. The wholesale rate is the rate at which non Eskom generation power suppliers can be paid in South Africa for energy supplied into the national grid. This implies that eventually an economic point will be reached where the cost of investing in localised generation, becomes viable at the wholesale rate. This breakeven point varies across the available technology spectrum but it is possible to calculate the capital investment amount that would be available based on the revenues derived from selling power at the South African wholesale rate, i.e. the system marginal price (SMP).

The electrical system used in the study consisted of a radial system with distributed load and generation. The distributed loads were modelled using the average load capacity supplied by the utility in a medium voltage system. The average volume of sales lost as a result of non-technical losses was included in the load model so that the overall accuracy of the revenue effect by EG on the utility, could be increased.

Simulation model

Load model

The study required that the total energy P_T be split up into the time of use categories as shown in Table 1. In order to achieve this split, the methodology described below was used.

$$P_T = P_P + P_S + P_{OP}$$

where

P_T = Total energy (kWh) in the system

P_P = Total peak period energy (kWh) in the system

P_S = Total standard period energy (kWh) in the system

P_{OP} = Total off peak period energy (kWh) in the system

TOU	(kWh/day) avg (total feeders)	LPU demand (kW)	SPU demand	PPU demand (kW)	Total demand
Peak	2078	1213	628	415	2256
Peak (loss adj)	2127	1300	757	503	2559
Std	4937	500	259	171	930
Std (loss adj)	5054	808	467	376	1651
Off-peak	1985	201	104	69	374
Off-peak (loss adj)	2032	325	188	151	664

Table 1: Energy per point and co-incidental demand per customer category.

$$T_T = T_P + T_S + T_{OP}$$

where

T_T = Total time (hours) in the month

T_P = Total peak time period (hours) in the month

T_S = Total standard time period (hours) in the month

T_{OP} = Total off peak time period (hours) in the month

The total energy sent out in the system is then separated into the time of use (TOU) categories as calculated in the methodology below.

The instantaneous base case losses for a three phase distribution system can be expressed in Eqn. 1 below as [2]:

$$Loss = \frac{rL(P_i^2 + P_i^2)}{3V_p^2} \quad (1)$$

where

r is the system resistance per unit length, L is the total length of the line, P_i and Q_i are the real and reactive loads at the i^{th} bus respectively, and V_p the system phase voltage. Using the square relationship of losses to load in the above equation:

$$LR_T = LR_P + LR_S + LR_{OP} \quad (2)$$

where

LR_T = Total loss ratio

LR_P = Total peak loss ratio

LR_S = Total standard loss ratio

LR_{OP} = Total off peak loss ratio

$$LR_T = \frac{T_P}{P_T}\cdot\left(\frac{P_P}{T_P}\right)^2 + \frac{T_S}{P_T}\cdot\left(\frac{P_S}{T_S}\right)^2 + \frac{T_{OP}}{P_T}\cdot\left(\frac{P_{OP}}{T_{OP}}\right)^2$$
$$= \frac{P_P^2}{P_T T_P} + \frac{P_S^2}{P_T T_S} + \frac{P_{OP}^2}{P_T T_{OP}} \quad (3)$$

Based on the sales per month per category an average kWh consumption per feeder (number of feeders in KZN) is calculated. Using the above equations results in values in the Table 1.

The load is modelled as a combination of constant power (CP), constant impedance (CZ) and constant current (CI). The parameters for the ZIP model used are not discussed in any detail in this paper. The largest component of constant current load comes from the residential customer category as well as the non-technical losses. This is important for the study because with changes in nodal voltages, the non-technical loss load changes, and this affects the results in the financial recovery within the system.

Electrical model

The general electrical network framework to be used for analysis is a 22 kV network with load points whose composition is structured as a ZIP model. The generation points will be located at the load points. The load points and generation points are used at the same point to represent the generator supplying an average load point i.e. the generator is located in the mid-point in the average load density around it. The points were chosen to get a sufficient spread of points along the average feeder length.

The load at each of the points will tested for three conditions, namely:

- 0,5 MVA (0,96 power factor) per load point which is 2,5 MVA total load excluding technical losses. This represents the peak load carrying capacity of the system as indicated in Table 1
- 1 MVA (0,96 power factor) per load point which is 5 MVA total load excluding technical line losses. This represents the capacity increase in the system as a result of all generators being in service at the

same time i.e. the generators have created enough capacity to double the load demand without changing the net load supplied in the system. The robustness of the extra capacity created on the system will then be tested against the various generator availability combinations.

- 0,12 MVA (0,96 power factor) per load point which is 0,6 MVA total load excluding technical losses. This represents the off-peak load scenario to be tested against the various generator combinations.

The maximum size of the generator is kept at the maximum peak load capacity per load point i.e. 0,5 MW and overall net generation capacity on the system is to be obtained by changing the load size.

Impact of EG on system losses

The equations below represent the weighted average effect on losses for using the same number of EGs dispersed by different distances. This is used so the average effect for losses for similar number of EG combinations can be attributed to the cost study [2].

$$S_{Gi} = P_{Gi} + jQ_{Gi} \qquad (4)$$

The above is the equation for the EG supplying complex power and therefore the output current from the EG is [2]:

$$I_G = \frac{(P_{Gi} - jQ_{Gi})}{3V_P} \qquad (5)$$

The effect on line losses as a result of having a single EG in the system can be broken up into the sum of two parts [3]:

- Line losses from the source to the location of the EG
- Line losses from the EG location to the location of load

With the EG exporting current into the grid, the feeder current I_s will be the difference of load current I_L and EG output current I_G. Therefore the total line losses with a single EG at "x" distance from the source can be expressed using the equation below as [3]:

$$l_T = \frac{R}{3V_P^2}\left[P_i^2 + Q_i^2 + (P_{Gi}^2 + Q_{Gi}^2 - 2P_iP_{Gi} - 2Q_iQ_{Gi})\left(\frac{x}{L}\right)\right] \qquad (6)$$

where, $R = rL$; total resistance of the line. The instantaneous loss savings (LS) at any point "b" on a feeder is the difference between losses without EG and losses with the EG and can be represented as [3]:

$$LS = Loss_{(b)} - Loss_T \qquad (7)$$

Hence [3],

$$LS = \frac{R_x}{3V_P^2L}\left[(-P_{Gi}^2 - Q_{Gi}^2 + 2P_iP_{Gi} + 2Q_iQ_{Gi})\right] \qquad (8)$$

If LS is positive then this indicates that the system loss reduces with the introduction of the EG into the system, and if LS is negative then the EG causes higher system losses in the system [4]. For multiple loads, the most amount of loss savings will occur when the EG is equal to the average load and is physically located at the point from the source where the length weighted load point, is located. This is subject to [5]:

$$V_i^{min} \le V_i \le V_i^{max} \qquad (9)$$

where

V_i^{min} and V_i^{max} define the voltage limits for the system

Capital recovery methodology

An important function of economics considered in this study is that it is project specific. The system is scrutinised for cost-effectiveness based on recovery at the SMP. Any project that is economically driven should be able to recover its capital and an acceptable margin of profit, with an acceptable risk profile. The market will determine whether the technology being invested in goes against the long term social benefits. Excessive investment in overly expensive energy projects through governmental subsidies will lead to higher energy costs for the public. So will underinvestment in, and neglect of the existing stock of energy infrastructure. The margins to which this can be done will be analysed.

The input fields into the study will be as follows [6]:

- *Term of the project:* This will be expressed as N number of years
- *Initial cost:* This is a onetime expense incurred in the first compounding period. The constructability of all projects on the medium voltage network will have to be done within one financial year.
- *Annuity:* An annual increment of cash flow related to a project. In this case it is for the lifetime of the project. Annuities can either be positive (e.g. annual revenues from the sales of energy from a project) or negative (e.g., annual expenditure on maintenance). In this study these values will be shown separately and the analysis will show the costs based on sensitivity values. The specific values per technology are not considered as part of this study.

In this study discounting of cash flow analysis will be used and it starts with the premise that the value of money is declining over time and that therefore values in the future should be discounted relative to the present. Two terms that pertain in particular to discounted cash flow is:

- *Interest rate:* This is the percentage return on an investment, or percentage charged on a sum of money borrowed at the beginning of a time horizon. In this study the interest is compounded at the end of each year, that is, the unit of 1 year is referred to as the "compounding period" [6]. The interest rate will be the current REPO rate of 4%.
- *Minimum attractive rate of return (MARR):* This is the minimum huddle rate at for which investors and bankers will invest into a project [6].

As a basis for calculating the time value of money, a relationship between the present, annual and future values of elements in cash flow analysis is needed. Given the interest rate, i, time horizon of N years, and a present value P of an amount, the future value of that amount F is given by [6]:

$$F = P(1+i)^N \qquad (10)$$

To translate a stream of equal annuities forward or backward to some fixed point at present or in the future the equivalent present value P is [6]:

$$P = A\frac{(1+i)^N - 1}{i(1+i)^N} \qquad (11)$$

In order to discount a set of non-uniform annuities to its equivalent present worth value PW, each annuity is treated as a single payment to be discounted from the future to the present and then summed [6]:

$$PW = \sum_n^N 1\frac{A_n}{(1+i)^N} \qquad (12)$$

Here A_n is the value of the annuity predicted in each year n from 1 to N [6].

The levelised cost per unit of energy output is the method that will be used as a measure to compare the cost effect across energy technologies [6].

$$Levelised\ cost = \frac{Total\ annual\ cost}{annual\ output}\ (in\ units\ of\ R/kW) \qquad (13)$$

where [6]:

Total annual cost = annualised capital cost + operating cost + return on investment (ROI)

This study also takes into account the external benefits of direct cost support in the form of subsidies. These subsidy values are known from the existing government determinations on the renewable feed in tariffs.

Results

EG combinations

The structure of points of the analysis will occur as per the Table 2.

The load flow studies were conducted to evaluate the network performance of a

Condition	Status of Gens on
1	No Gen on
2	Gen 1
3	Gen 2
4	Gen 3
5	Gen 4
6	Gen 5
7	Gen 1 & 2
8	Gen 2 & 3
9	Gen 3 & 4
10	Gen 4 & 5
11	Gen 1 & 3
12	Gen 2 & 4
13	Gen 3 & 5
14	Gen 1 & 2 & 3
15	Gen 1 & 2 & 3 & 4
16	Gen 1 & 2 & 3 & 4 & 5

Table 2: System status of generators.

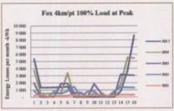

Fig. 1: Energy losses per month for Fox network.

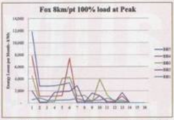

Fig. 2: Energy losses per month for Fox network.

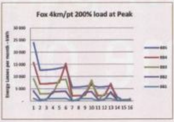

Fig. 3: Energy losses per month for Fox network.

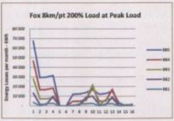

Fig. 4: Energy losses per month for Fox network.

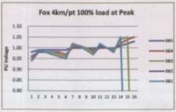

Fig. 5: Energy losses per month for Fox network.

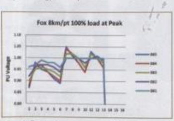

Fig. 6: Energy losses per month for Fox network.

Fig. 7: Energy losses per month for Fox network.

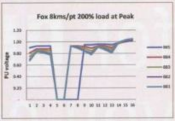

Fig. 8: Energy losses per month for Fox network.

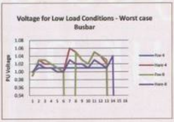

Fig. 9: Energy losses per month for Fox network.

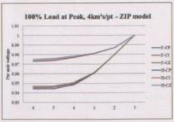

Fig. 10: Energy losses per month for Fox network.

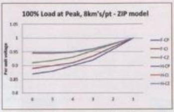

Fig. 11: Energy losses per month for Fox network.

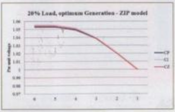

Fig. 12: Energy losses per month for Fox network.

one year timespan with the impact of EG assessed for:

- Losses
- Voltage constraints i.e. voltage rise by 5% or decrease by 5%
- Effect on different load models taking into account that non-technical losses are made up of mostly constant current type loads.

Effect on losses

See Figs. 1, 2, 3 and 4 for effect on losses.

Effect on voltage

See Figs. 5, 6, 7, 8 and 9 for effect on voltage.

Effect of different load types

See Figs. 10, 11, and 12 for effects on different load types.

Revenue effect for different load types

Table 3, indicates that average revenue change with the EG generators varies across the system and that the effect is worst when the impedance is highest. This is either caused by increasing length or type of conductor. This revenue effect is applied to all practical cases where the generation set can successfully fulfill all boundary conditions.

Sales and cost of sales for MV system

Fig. 13 shows the gross contribution (%) to sales and cost of sales with and without non-technical losses.

Minimum condition for failed state combinations per busbar

For the cells that are shaded in brown in Table 4, the busbar fails with the minimum generation set on, for the lower voltage boundary condition. For the cells that are shaded in red, the busbar fails with the minimum generation set on, for the upper voltage boundary condition. Using this table the minimum practical income that is possible is then calculated.

Levelised cost

The levelised cost is calculated for all TOU periods combined with all generator combinations that are within system performance criteria. The MARR was calculated over 20 years and the 90% of the income attributed to the EGs, was associated to operations and maintenance of the facilities.

Conclusion

The overall network reach is increased with EGs but a very high switching configuration would be needed from the generator in order to stick to the times of operation in order to be within regulation limits. The times of operation would have to be split

TOU	Conductor type (F – Fox, H – Hare), length (4 km or 8 km)			
	F4 – 100%	F4 – 200%	F8 – 100%	F8 – 200%
Peak	-2%	-10%	-10%	-10%
Std	0%	0%	0%	0%
Off-peak	2%	2%	5%	2%
TOU	Conductor type (F – Fox, H – Hare), length (4 km or 8 km)			
	H4 – 100%	H4 – 200%	H8 – 100%	H8 – 200%
Peak	-1%	-3%	-4%	-5%
Std	0%	0%	0%	0%
Off-peak	1%	1%	5%	3%

Table 3: The revenue effect of using 50% constant current for domestic supplies rather than constant power type loads.

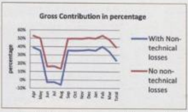

Fig. 13: Energy losses per month for Fox network.

into commercial payment schedule of peak, standard and off-peak. Invariably, the highest volume of generation that is supplying power into the grid while maintaining the operating conditions, will always lead to the highest amount of capital that can be raised. However, as per Table 5, the per unit cost, or levelised cost per MW (rand per MW), indicates that the highest capital can be raised from the least amount of generators operating on the system. In order to have economies of scale benefit, these generator stations should be owned and operated by single entities in order to maximum investment capability. It is not always practical to have the stations owned by single entities and this would probably result in high competition for becoming the first operator in the system and locking in a contract for as many time periods as possible. Entry of new participants will then see a decrease in the amount of operating time available and hence the amount of seed capital that can be raised. There are currently not enough regulations around these values and significant disputes could arise once operation has begun, without formal network contracting. Multiple generation sets that operate in various time sectors are exposed to network performance issues. The performance of the network was not factored into the calculation but will materially affect the predictability of the profit margin. The yearly planned and unplanned outage performance of the network for the utility is about 47,5 hours but this could affect operating profit by more than +5% – 10% for Fox networks because of the low time penetration of EG. The closer a Fox network is to its operating voltage margin the lower the volume of sustainable generation. Even with the correct operating condition it is still not possible to secure enough capital for a generation scheme and achieve a minimum MARR of 5% when the values in Table 5 is compared to the actual values of alternative technologies e.g. solar PV ranges from (R17 to R25-million per MW). This means that it is not possible to fund new generation assets at the utilities system marginal price. However, if the EGs are used as part of existing processes and or capital subsidies are made available to them by FITs, medium voltage EG projects would then become economically viable.

The impact of having a high volume of non-technical losses affects the overall margin that is available to EGs. The cost impact of non-technical losses as a result of modelling some of the load as a constant current load, compared to that of conventional constant power load, varies on the time pattern that is used for the EG and the related improvement in voltage parameters. The actual cost impact varies within a small range extending from +R9000 to -R7000 per year. This impact should also be factored into the apportionment of technical losses savings to the EG. For various generator and TOU combinations, the income to the utility goes negative, implying that the utility is paying more money to the EGs than what it is making from the sales of its billed customers. There would therefore also have to be a minimum threshold of non-technical losses on the system before the utility can allow high penetration of EG into an MV system.

The highest number of permutations that are available to the EGs comes from a network that is loaded to its maximum reach in voltage performance. For the Fox network, there were 31/88 (31 out of 88) permutations when it is close to its voltage regulation limit, without any generators. This is significantly different when the network depends on EG operating, in order for the network to be within its voltage limits. The number of permutations decrease to 7/88 and 8/88 for a network that doubles its length for same load volume and for a network that doubles its peak load value.

State	Condition	BB1	BB2	BB3	BB4	BB5
Fox 4 km – 100% load	Peak	Gen 1 & 2 & 3 & 4	Gen 1 & 2 & 3 & 4 & 5	Gen 1 & 2 & 3 & 4 & 5		
	Std	Gen 1 & 2 & 3 & 4	Gen 1 & 2 & 3 & 4	Gen 1 & 2 & 3 & 4		
	Off-peak	Gen 1 & 2	Gen 1 & 2	Gen 1 & 2 & 3	Gen 1 & 2 & 3	Gen 1 & 2 & 3
Fox 8 km – 100% load	Peak	Gen 1 & 2 & 3	Gen 5	Gen 5, Gen 4	Gen 5, Gen 4, Gen 3	Gen 5, Gen 4, Gen 3
	Peak	Gen 1 & 2 & 3	Gen 1 & 2 & 3	Gen 1 & 2 & 3	Gen 1 & 2 & 3	Gen 1 & 2 & 3
	Std	Gen 1 & 2	Gen 1 & 2	Gen 1 & 2 & 3	Gen 1 & 2 & 3	Gen 1 & 2 & 3
	Off-peak	Gen 1 & 2	Gen 1 & 2	Gen 1 & 2 & 3	Gen 1 & 2 & 3	Gen 1 & 2 & 3
Fox 4 km – 200% load	Peak	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1	Gen 5, Gen 4, Gen 3, Gen 2	Gen 5, Gen 4, Gen 3
	Std	Gen 1 & 2 & 3	Gen 1 & 2 & 3	Gen 1 & 2 & 3	Gen 1 & 2 & 3	Gen 1 & 2 & 3
	Off-peak	Gen 1 & 2	Gen 1 & 2	Gen 1 & 2 & 3	Gen 1 & 2 & 3	Gen 1 & 2 & 3
Fox 8 km – 200% load	Peak	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1	Gen 5, Gen 4, Gen 3, Gen 2, Gen 2	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1
	Std	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1
	Std	Gen 1 & 2 & 3	Gen 1 & 2 & 3	Gen 1 & 2 & 3	Gen 1 & 2 & 3	Gen 1 & 2 & 3
	Off-peak	Gen 1 & 2	Gen 1 & 2	Gen 1 & 2 & 3	Gen 1 & 2 & 3	Gen 1 & 2 & 3

Table 4a: Minimum conditions for failed state combinations per busbar for BB1 to BB5 (with Fox conductor).

State	Condition	BB1	BB2	BB3	BB4	BB5
Hare 4 km – 100% load	Peak					
	Std					
	Off-peak	Gen 1 & 2 & 3 & 4, Gen 1 & 2 & 3 & 4 & 5	Gen 1 & 2 & 3 & 4	Gen 1 & 2 & 3 & 4	Gen 1 & 2 & 3 & 4	Gen 1 & 2, Gen 2 & 4
Hare 8 km – 100% load	Peak	Gen 1 & 2 & 3 & 4 & 5	Gen 1 & 2 & 3 & 4 & 5	Gen 1 & 2 & 3 & 4 & 5	Gen 1 & 2 & 3 & 4 & 5	Gen 1 & 2 & 3 & 4 & 5
	Std	Gen 1 & 2 & 3 & 4, Gen 1 & 2 & 3 & 4 & 5	Gen 1 & 2 & 3 & 4, Gen 1 & 2 & 3 & 4 & 5	Gen 1 & 2 & 3 & 4, Gen 1 & 2 & 3 & 4 & 5	Gen 1 & 2 & 3 & 4, Gen 1 & 2 & 3 & 4 & 5	Gen 1 & 2 & 3 & 4, Gen 1 & 2 & 3 & 4 & 5
	Off-peak	Gen 1 & 2 & 3 & 4, Gen 1 & 2 & 3 & 4 & 5	Gen 1 & 2 & 3 & 4	Gen 1 & 2 & 3 & 4	Gen 1 & 2 & 3 & 4	Gen 1 & 2, Gen 2 & 4
Hare 4 km – 200% load	Peak					
	Std					
	Off-peak	Gen 1 & 2 & 3 & 4, Gen 1 & 2 & 3 & 4 & 5	Gen 1 & 2 & 3 & 4	Gen 1 & 2 & 3 & 4	Gen 1 & 2 & 3 & 4	Gen 1 & 2, Gen 2 & 4
Fox 8 km – 200% load	Peak	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1	Gen 5, Gen 4, Gen 3, Gen 2, Gen 1
	Std	Gen 5, Gen 4, Gen 3	Gen 5, Gen 4, Gen 3	Gen 5, Gen 4		
	Off-peak	Gen 1 & 2 & 3 & 4, Gen 1 & 2 & 3 & 4 & 5	Gen 1 & 2 & 3 & 4	Gen 1 & 2 & 3 & 4	Gen 1 & 2 & 3 & 4	Gen 1 & 2, Gen 2 & 4

Table 4b: Minimum conditions for failed state combinations per busbar for BB1 to BB5 (with Hare conductor).

System configuration	Statistic	MARR 5%	MARR 7%
Fox conductor, 4 km 100% peak load	Max R'000/MW	R5700	R5008
	Min R'000/MW	R1707	R3508
	Avg R'000/MW	R2087	R1834
Fox conductor, 8 km 100% peak load	Max R'000/MW	R5700	R5008
	Min R'000/MW	R1707	R1500
	Avg R'000/MW	R1751	R2259
Fox conductor, 4 km 200% peak load	Max R'000/MW	R2013	R1768
	Min R'000/MW	R2013	R1768
	Avg R'000/MW	R2013	R1768
Fox conductor, 8 km 200% peak load	Max R'000/MW	R3993	R3508
	Min R'000/MW	R1591	R1397
	Avg R'000/MW	R2080	R1827
Hare conductor, 4 km 100% peak load	Max R'000/MW	R5700	R5008
	Min R'000/MW	R1707	R1500
	Avg R'000/MW	R2232	R1929
Hare conductor, 8 km 100% peak load	Max R'000/MW	R1500	R5008
	Min R'000/MW	R1707	R1500
	Avg R'000/MW	R2283	R2006
Hare conductor, 4 km 200% peak load	Max R'000/MW	R5700	R5008
	Min R'000/MW	R1707	R1500
	Avg R'000/MW	R2232	R1929
Hare conductor, 8 km 200% peak load	Max R'000/MW	R3993	R3508
	Min R'000/MW	R1707	R1500
	Avg R'000/MW	R2127	R1850

Table 5: Marginal average rate of return.

For a Hare conductor network the length of time for operation as well as the number of generators that can be added to the network significantly improves from that of the Fox conductor network. When a network is performing higher than its operating voltage limit, it is able to have significantly more number of permutations of EG. The number of permutations varies from 42/88 for a non-optimally loaded system to 29/88 for an optimally distributed load pattern. This means that there can be significantly more stable financial conditions, for capital investment and recovery for a Hare conductor network. The effect of load composition is much greater in a hare network because of the higher number of permutations of operation. The cost effect of having 50% constant current loads instead of 100% constant power loads results in a maximum and minimum range from R22 000 to – R12 000 per year. Improving the system capability for EG, also creates the negative effect on increasing costs related to non-recovery of sales. The technical losses savings as a result of EG is also significantly lower than that of Fox conductor.

Should the spare capacity created by the EG be attributed to new load, with long term fixed operating time contracts for EG, the upper limit of connecting new customers would decrease significantly i.e. there would be a limitation on the amount of new load customers that can be connected. This situation would then warrant the introduction of voltage control devices dispersed in the network. This only becomes relevant when the network is operating at, or beyond its voltage boundary condition. Performance of the network will be critically linked to the EG availability index.

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Alternative energy to deliver services to unproclaimed urban informal settlements

by Clive Hardwick and Grant Mashile, Energy One

Globally the developing world is characterized by large inflows of people into urban areas giving rise to large informal settlements. In South Africa government estimates that around 10% of South Africa's 51-million people live in un-proclaimed urban informal settlements. This equates to more than 5,1-million households. In May 2010, the President's Coordinating Council estimated that South Africa has a housing backlog of 2,1-million housing units, affecting 12-million people in 2700 informal settlements.

This housing backlog continues to grow despite the delivery of 2,7-million subsidised houses in the past 18 years. Informal settlements have grown at 4% per annum in line with urbanisation trends and government budgets are hard pressed to cater for this growth.

Although informal settlements are generally considered to be temporary, once established they tend to become long-term realities. Some informal settlements in South Africa have been in existence for up to 30 years and there is little indication that they will be formalised in the near future.

Infrastructure, in the main, has generally not been rolled out to these informal and low-income settlement areas. These settlements are often unauthorised or illegal and as such do not usually form part of official infrastructure planning. Further planning complications arise through the fact that these informal settlements are often by their very nature in a constant state of change and thus accurate, reliable and up to date information is often not available.

The Integrated National Electrification Programme (INEP), has, until recently, focused only on electrifying formal housing in rural and urban areas. However, according to the constitution, every citizen has a right to basic services, including electricity, regardless of location. Government and municipalities, as an extension of government, therefore have a responsibility to ensure electrification of all citizens within their boundaries.

Apart from the fiscal pressures that this presents, there are also a number of logistical and safety issues. Such safety issues include settlements that are in low-lying flood prone areas and where density is extremely high.

In addition, electrifying formal areas that are adjacent to informal settlements also pose safety concerns through the ever-present threat of shack fires, together with concerns surrounding the theft of electricity and cables.

This not only compromises safety issues for such electrification – it also results in being extremely costly to the State for a multitude of reasons – loss of revenue for electricity, loss of resources from cable theft, additional costs in terms of emergency services.

For the communities themselves the dangers presented are very real and often tragic. They often lose all their possessions in shack fires, get burnt and in the worst case scenarios, lives are lost.

In view of these considerable challenges and dangers it would be worthwhile to consider alternatives means of providing basic electricity services. Such alternatives require a carefully considered consultative approach and implementation strategy to enable the all-important community buy-in, without which these alternatives would not be possible.

In an attempt to provide a solution to theses challenges we have consulted with a broad range of strategic partners with considerable experience in these communities and the findings of this research is the subject of this paper.

High/low choice for informal settlements

Once it is agreed that electricity services must be provided for informal settlements the decision of how best to service these communities must be considered.

Informal settlements are by their very nature unplanned. This also means that every settlement is different and therefore each one needs to be evaluated individually.

The basic factors to be taken into account when evaluating an informal settlement are:

- Settlement layout and population density.
- Drainage and flooding risk.
- Relocation timeframes.

These factors will determine the initial decision, that being, whether or not it is safe and financially viable to provide traditional grid electricity connections to the community.

It is clear that where safety of the consumers is in doubt, as it is in many informal settlements, there is simply no option but to look to low voltage DC power as the ultimate in alternative power solutions.

Where traditional grid connections can be safely implemented, 220 V AC connections, may still not be the best choice due to financial considerations which will have to be considered, especially where relocation plans have or are being made.

One of course has to consider the message these decisions will send to the communities. Does the provision of a permanent solution to a temporary settlement solve or compound the informal settlement problems and what precedent does it set for other and future settlements?

It would be, we would argue, a safer and more prudent route to offer lower cost, portable DC solutions as a temporary solution for a temporary settlement.

Safety first

Whilst it is true that the constitution of South Africa requires that all citizens have a right to basic services, the health and safety of individuals and communities is also a basic human right. When it comes to the provision of electricity to informal settlements these two rights provides a seemingly impossible conundrum.

As was raised earlier in this paper, it is often simply not safe to provide 220 V AC power into the many communities in low-lying areas that are prone to flooding. Most informal settlements do not have acceptable storm water drainage and this, coupled with the fact that the dwellings themselves are neither waterproof nor structurally sound, makes the provision of traditional services unsafe.

Over crowding and lack of access for emergency vehicles increases the risks of any disaster management that may be required as a result of such unsafe practices.

For many of these communities it is necessary to consider alternative technologies which will provide poverty relief and lifestyle improvements through the use of low voltage systems which will provide lighting, cell phone charging and can also power radios, television sets and other small appliances.

For some communities the only really safe alternative is low voltage DC power. We would argue that for these communities suitable and acceptable solutions must be found.

The cost of indefinite time lines

Apart from the health and safety issues facing the provision of electricity to informal settlements, we have the additional layer of complexity that is brought about by the impermanent nature of these settlements.

Informal settlements are by definition unplanned and therefore it is never certain how long a settlement will exist before relocation. Whilst it is generally the intention to relocate settlements sooner rather than later, this is not always the case.

If it is not certain when the community is to be relocated it is difficult to make capital expenditure decisions. This is particularly true where the relocation of networks and equipment will be a significant cost factor.

If a community requires infrastructure upgrading before grid connections can be safely implemented, then this decision becomes even more onerous.

It should be remembered that significant investment in long term infrastructure for informal settlements sends a message to the community regarding the longer term planning for the community and its possible relocation time line.

We would argue that where the relocation of the community is uncertain it is prudent to provide solutions that require less expensive infrastructure and are easily relocated if required.

Low voltage DC alternatives are therefore more appropriate solutions in these cases.

This conclusion and apparent solution, when examined more closely, raises many more questions.

The central challenge is: *"How can we get these communities to accept these alternative off-grid technologies when they may perceive these to be less attractive than traditional grid services that are available to the rest of the population?"*

This challenge, no matter how daunting, must be addressed simply because, for some communities, there is no practical alternatives.

The solution we believe lies in a three-pronged approach:

- Exciting product design offering compelling lifestyle choices.
- Communications strategies to correct consumer perceptions of these technologies.
- Financial models that make the technologies affordable for consumers and service providers alike.

Technology choices

Once the decision to provide low voltage DC power has been made, one has to consider the available technology choices.

The provision of low voltage DC power does of course require near field battery storage and a reliable means of recharging. It also requires supplementary energy solutions that provide for the consumers' thermal needs, which cannot be provided for through the use of low voltage DC systems.

The Department of Energy has come to the same conclusion regarding informal settlements in that it is agreed low voltage systems are required. They have further concluded that solar PV provides the most suitable recharging source. We agree with this conclusion. Liquid petroleum gas has been identified as the preferred source of thermal energy.

We all appear to be in agreement up to this point, but before we rush to implement this let us consider the following questions:

If the only safe solution will be low voltage DC power, then the development of products and services which will provide a sustainable and acceptable long term solution for these communities, is urgently required.

Technology choices need to be made that will not only ensure that the products offered are of sufficient quality and durability, but these solutions also have to be cost effective for both the consumer and government, both on a national and municipal level.

In order to achieve this we believe that not only do we need to find a sustainable business model using all the available technological advances, but we also need to change the way that we think about and fund these initiatives.

Community and consumer perceptions

The most fundamental problem facing the introduction of low voltage DC solutions to informal settlements, is the all-important community buy-in. Without this it is almost impossible to succeed in such a venture.

The size of this challenge should not be under estimated, and it is critical that the expectations of the communities are managed.

When speaking to people who do not have access to traditional grid electricity and who rely on candles and kerosene for their energy needs, we have found that they are surprisingly unenthusiastic in PV solutions.

We believe this can be attributed to three common misperceptions, namely:

- Many believe that PV solutions are an inferior alternative and that they are only offered to those who are not able to get "proper grid connections".
- Most believe that PV is only good for lighting and perhaps cell phone charging.
- Many people believe that if they accept any PV alternatives they will never get a 220 V grid connection.

The inferior product perception has come about, we believe, as a result of many of the products on offer being inferior in design, durability and performance. The solution to correcting this perception is to ensure that the products look good, have a long lifespan and perform in a way that exceeds the consumer's expectations.

There are now a number of products available which will be very attractive to this market. Not only do they provide well-designed lighting and other accessories that members of these communities will be proud to have in their homes, there are also high quality TV and audio systems that will provide very real lifestyle improvements.

We believe that the selection of products offered to these consumers is a key success factor in getting low voltage DC products accepted. If the quality of the lives of these people is improved there will be a compelling reason for them to go with DC alternatives. If they do not like the products that are offered to them and which do not offer them quality of life enhancements, they are unlikely to accept them.

Solar PV systems that are suitable for informal settlements should be restricted to 35 W panels which can be easily and safely mounted on the roof of these dwellings. Anything larger will bring the structural integrity of the dwellings into question. Systems of this size and design are by definition portable and could be considered temporary. The discussion of the finality of the decision therefore can be more easily addressed and total flexibility can be included in the planning for such projects.

It should be noted that a 35 W panel is sufficient to provide six internal lights, an external cell phone and small appliance charger, and which would be able to power a low voltage 17 inch LED TV set. Such a system would certainly improve the lifestyles of those living in informal settlements and would thus go a long way to providing the compelling reason for these communities to approve such solutions.

In order to achieve the necessary switch in perceptions, we need to embark upon an awareness campaign that will correct the negative perceptions about solar energy in general. We should be highlighting the many up market first world PV installations around the world. Germany's widespread acceptance of these technologies can be used to accurately portray PV alternatives as a desirable contemporary technology for all consumers.

Perhaps the most compelling argument will be found in successful local pilot projects. The problem is that there are not enough relevant examples of these at present. The first step we believe is to embark on pilot projects that will clearly demonstrate the suitability and the desirability of low voltage DC solutions. Only then can we be bold enough to roll these solutions out on a large scale basis knowing that the chances of broad community acceptance will be good.

Pilot projects which prove both the acceptability and choice of products must therefore be undertaken as a priority. The results will prove invaluable in the communication of future offerings to informal settlements around the country. Energy One is currently embarking on a few such pilot projects and we look forward to sharing the results in the near future.

Pilot project strategic considerations

It is critical that pilot projects be carefully planned and implemented if we are to have the best chance of success. The following are all important considerations:

- Selecting the best locations. It is important that communities are selected where there is strong but co-operative leadership.
- Community communication is carefully planned and implemented to ensure that the purpose of the project is clear. Support of the community is important.
- The correct products are selected for the project and technical support should be available.
- The test should, if necessary, be run by or with a NGO experienced in such community work. This will increase the chances of initial success.
- The test should be run on a small scale. Ideally less than 500 dwellings and where possible, communities which are geographically isolated from similar communities should be preferred.

Financial considerations

In recent years there has been considerable discussion on the erosion of revenue that would arise if solar costs reach grid parity, and consumers who are currently paying for their electricity adopted this technology.

This fear becomes a real one when one considers the fall in the revenue collected from electricity usage across the board.

Whilst this may be an issue for existing paying consumers, especially those who are heavier consumers, this is not a consideration for informal settlements for the following reasons:

- These are not existing customers and therefore there will not be a negative impact on revenues.
- They are not heavy users and therefore are potentially very profitable.
- They are potentially payment avoiders and therefore are not necessarily profitable customers

In addition to the above considerations we also need to take into account the cost of providing safe grid connections to these communities.

These would include:

- The upgrading of infrastructure such as drainage and roads.
- Relocating some of the houses to provide emergency vehicle access.
- Grid extensions and additional transformers.

When considering the above costs it must be remembered that some of these communities will be earmarked for relocation and thus these costs may be wasted in the short or medium term.

Perhaps the most exciting development in solar home systems are the pay as you go systems that have been developed which allow for the monetisation and repayment of investments into these technologies. Some of these systems offer high security encryption, making it very difficult for consumers to by pass the metering mechanisms as they are protected by a full system authentication process covering all components.

This not only offers a secure payment environment, but also allows consumers to purchase additional components such as TV sets through a secure financial gateway.

A pay as you go system such as the one

described above, together with a free basic electricity allowance, will make the roll out of such systems financially attractive for both consumers and local governments.

We would further recommend that a results-based finance program for lighting should be considered. It ought to have five main principles:

Fund services, not watts: Efficiency is the name of the game when you are off the grid. An inefficient 100 W system and an efficient 35 W system can deliver exactly the same service level. Fund outcomes that can be objectively measured: lumens of light, hours of TV viewing, number of phones charged, etc.

Fund durability: It is easy to deliver a high level of performance with a cheap or poorly designed system. It is much harder and more expensive to provide a system that delivers at a high level for years. Technical analysis can identify high quality systems and reward the investment in quality. Funding through the Free Basic Electricity allowance can be dispersed a long time period and discontinued when systems cease to function.

Only fund on audit-able data: Any organisation seeking funding should provide exact data, including GPS coordinates of customers and detailed system specifications, so that a random audit can be conducted. In addition the monitoring based on monthly fee payments can provide continuous real-time usage reports. This should form the basis of any funding.

Release funding quickly and transparently: A well-designed program cannot subject entrepreneurs to a yearlong opaque process and grueling reporting requirements. It must have a transparent funding protocol with rapid turnaround and personalized service.

Build a broad market: No more than 20% of the fund should go to a single company, or organisation, and funds should be distributed pro rata if there is more interest than funds available. Special effort should be made to fund local small solar dealers as well as ambitious high-growth startups. Competition should be built into the process as this will ensure that ongoing technology improvements which be for the benefit of all concerned.

Conclusion

The challenges facing the delivery of electricity to informal settlements is enormous.

The problem however cannot be ignored, as it is unlikely these settlements will become less prevalent in the future. In fact the problem is likely to grow.

Additionally, the members of these communities have a right to such services and will become increasingly more impatient and demanding.

In many instances low voltage DC solutions are the only safe options and in many more cases financial considerations make these options attractive. More attention should be given to these solutions and serious studies should be undertaken to find the right solutions.

A significant challenge lies in getting the communities' acceptance and support. This can be done if properly handled, but in order to do this we need to:

- Select the correct products carefully and test these for design, quality and performance.
- Test the products in a carefully monitored and prepared pilot projects.
- Carefully consider and test payment systems to ensure efficient and cost effective revenue possibilities.
- Conduct a comprehensive communications campaign.

The provision of such solutions is technically simple, quick and relatively inexpensive and the astonishing advances made provide all the tools, not only to provide the level of service required, but also to provide the support required for exciting new funding and business models.

Perhaps the most exciting reward in tackling this challenge is that a solution for the whole of Africa can be born here in South Africa using South African designed and built systems.

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Rural electrification challenges and opportunities

by Mohamed Peer, GIBB

This paper describes GIBB's experience and presents some of the key challenges in undertaking projects of this nature in deep rural communities. Some of the major benefits which have arisen due to these undertakings are presented.

New access to household electrification potentially affects both home and market production in ways which change the nature of work in the home and in ways that increase market labour. Providing new public infrastructure to a location may also induce employed and unemployed individuals to migrate into the area.

South Africa is very different from other African countries in that grid connected electrification has already reached more than 65% of the population compared to the average rate that is still below 30% in sub-Saharan countries. Due to the massive electrification led by the national electricity utility since 1994, more than 2,5-million households have been connected to the grid. Even with the tremendous electrification effort of the post-apartheid government, there are still around 1,5-million households in rural areas which are unlikely to be connected in the near future.

The electrification programme in South Africa is managed by a unit within the Department of Energy – Integrated National Electrification Planning (INEP). Between 1994 and 2010 over 5,2-million households were connected to the grid. Currently 76% of all households are electrified and there is a backlog of 3,4-million households.

At the beginning of 2012, the Eastern Cape government went on a drive to change 49 schools from mud to solid structures and also provided them with sanitation, water and electricity – R675-million has been earmarked for the programme. Of the 49 schools located in Libode, Lusikisiki and Mthatha, GIBB is involved in the electrification of 49.

GIBB has been involved in rural electrification projects in the Eastern Cape and KwaZulu-Natal since 1994. The financial constraints and budget availability throughout the years have resulted in a backlog that is currently being attended to. Our clients for such projects are usually Eskom and local municipalities and their funding comes from the national Department of Energy and then channelled down to service providers such as GIBB.

The projects that GIBB has been involved in, in this field vary in size. They range from 200 to over 2000 free-standing households dependant on the project.

Because electrification requires specialised skills, job creation and skills transfer are created by giving local residents jobs on sites where they are trained in excavation and on how to install pre-paid electronic meters. Another way in which skills are transferred is through the training and development of contractors because there is still a major shortage of skilled contractors in the construction field.

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Demand response applications for municipal utilities

by David Ellis, Comverge

An Eskom-funded demand response (DR) pilot, for which Comverge provided aggregator and CSP services from 2011 to March 2013, achieved significant outcomes proving that the market is ready for DR. Municipalities, using ripple control relays, played an important role during the pilot but there is still much more value to be gained.

This presentation showed key lessons learned, challenges encountered, and incremental benefits to municipalities well beyond conventional DR including:

- DR as a complement to EE
- DR to enhance AMI infrastructure investment
- DR advancement in smart grid offerings
- The maximisation of municipal utility revenues by the use of DR

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Conclusions

Increased requirements of grid codes are putting greater demands on wind farms and their individual turbines. Whereas, some turbines will already be capable of meeting the grid code and others will be developed, it is important that this is examined at the early stages of the project to avoid potential delays and unexpected cost.

Where there are problems concerning reactive/voltage requirements, auxiliary reactive compensation equipment can be installed. The optimum type of equipment chosen will depend on the individual characteristics of the wind farm and the requirements of the grid code.

There will be circumstances where the grid code can only be met with the use of additional reactive compensation, and also cases where it might be more cost effective to use reactive compensation instead of buying a more expensive turbine which has an extended reactive capability.

The most important point is to consider these options at the start of the project. To do this it is likely to require the undertaking of some power system studies.

This paper only considers a few small design aspects of developing a wind farm which is grid compliant. There are many other aspects which need to be considered which have not been discussed.

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The electrification planning report – the process, content and result

by Mikie Khumalo, Eskom

Eskom, acting as the electricity agent of the government, through the Department of Energy (DoE) and Department of Public Enterprises (DPE), has been mandated to execute the on-going government-funded electrification programme to meet the extended goals of the Universal Access Plan.

The South African President, in his presidential address to the nation, declared in 2005 that all South African citizens would have access to electricity by 2012. This date was later extended. The mandate was to become known as the Universal Access Plan (UAP) for electricity. The government's intention with this plan was to improve the basic living standards of its people and stimulate economic activity through the delivery of other related services and infrastructure, which in turn will stimulate further growth.

In 2005, Eskom undertook to identify the national back log of un-electrified connections in South Africa. A study known as the UAP quantified approximately 1,5-million connections that made up the backlog that needed to be electrified. The backlog was defined as all households not yet connected by 2000.

Eskom has, since the inception of the electrification programme, been managing the execution and commissioning of these electrification projects through the existing network asset creation value chain with all processes and protocols required for the approval of electrification projects following the same approval process.

Eskom's network planning section is responsible for the development and approval of the development plan approval (DPA) and concept release plan (CRA), which are two functional activities in the project life cycle process. During these activities, network planning is guided by the body of knowledge contained in the planning standards and guidelines, good corporate governance and project motivation in order to recommend capital expenditure through infrastructure development to support the required electrification connections to the Eskom grid.

With the rising cost of electricity and the pressure felt by the shortage of Eskom's generating capacity in 2007/8, the need for innovative, streamlined and standardised processes is now greater than ever, where low household densities escalate the electrification programme's cost. Distribution network planning and counterparts in electrification planning need accurate consolidation demand side and supply side its information in order to optimise infrastructure cost.

The network planning section is completely responsible for the bulk infrastructure requirements to support the electrification programme, and have the task of ensuring that the network is correctly sized to provide an adequate and reliable supply. In addition, the motivation of capital for bulk infrastructure requirements must adhere to good financial practices in order to sustain the future networks through the tariff recovery and subsidy mechanisms. Failure to successfully implement a long-term sustainable programme will imply that the future maintenance of the network will suffer under financial constraints.

Eskom's current electrification process makes use of a multitude of disciplines to ensure delivery on the electrification programme. Not all operating units have access to the same technology, resources and information, and this affects the operating unit's progress of meeting the targets.

The process

Fig. 1 illustrates the interaction between network planning and electrification planning in developing a supply side electrification plan that supports the demand side request for electrification connections. The process that supports this interaction is mostly tacit agreements between the sections, and will be described in step-by-step form, so as to document the generic process.

The electrification process has both internal and external stakeholders. The external stakeholders are:

- The Department of Energy (DoE).
- The Department of Public Enterprises (DPE).
- The Department of Provincial and Local Government (DPLG) under which the Metropolitans and local municipality Authorities fall.
- The Department of Local Government and Housing.
- The Department of Education – Schools.
- The Department of Health – Clinics
- Private Developers

These external stakeholders are responsible for identifying and formulating an electrification demand side connection plan for the country's electrification needs, and the connection plan for the country's schools and clinics. Certain areas in the country may have up to date energy sector plans that may identify the need for electricity and other services in their area of jurisdiction. Integrated development plans (IDPs) have become a high priority with the Department of Provincial and Local Government. These plans identify the need for infrastructure requirements, which include the identification of electrification areas that have been budgeted for in the coming financial years. The blind side of the demand side plan is that there is no knowledge of the electrical

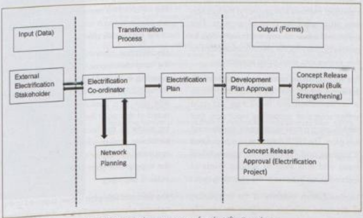


Fig. 1: Network planning process for electrification plans.

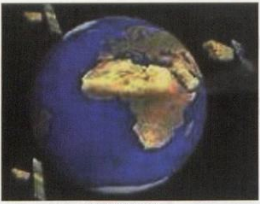


Fig. 2: SPOT technology.

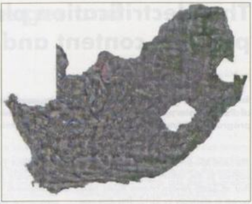


Fig. 3: SPOT technology.

constraints of the network such as resources, network capability and network availability.

The electrification planning section under the asset creation department within the distribution division is responsible for managing the relationship and liaising with the above external stakeholders. The purpose of this liaison is to ensure that the electrification needs for the present and future years are documented in order to compile an electrification demand side plan. This plan should have all the envisaged electrification prepaid connections, schools and clinics as consolidated per Eskom operating unit or municipal boundary.

Usually this information is collated by electrification planning from all the local authorities. This list is often compiled in a non-spatial format and relies heavily on the intrinsic knowledge of the electrification coordinator. Eskom does not have a national system, but is currently working on a model that has its roots in a system developed by the eastern region called "Spaceman", which is short for "spatial manager". This system manages all the prepaid electrification, schools and clinic connections spatially, and removes burden of individual memory with respect to the location and other attribute data of projects. This system will allow all internal stakeholders to visually account for the electrification plans as they evolve into executable projects.

The housing electrification programme (HELP) database (which may be in various formats at an operation unit level) may act as a further source of supporting input data that electrification planning can use in the demand side plan. The HELP database was populated to capture and document all un-electrified areas and may exist at various levels of updated states in some of the operating units.

Another Eskom initiative is the acquisition of digitised satellite imagery to identify densification of households in electrification areas. This technology makes use of satellite data from the Satellite Pour l'Observation de la Terre (SPOT) 5 satellite and is currently being managed by electricity supply industry – geographic information system (ESI-GIS). Sample data of both the HELP database (where applicable) can be obtained from the local land development sections and SPOT5 images from ESI-GIS. Eskom also makes use of national systems such as Smallworld and the land and rights geographic information system (LARGIS), to support the input to the demand side plan. Figures below contains a high-level summary of the nature of the SPOT images. A building count has been performed using the SPOT 5 images, and should become part of a standardised way of operating.

Formulation of a demand side plan using the inputs from the above institutions and functional tools should be used to identify and position all of the connections required, together with their priorities and timing of their connections. This should be represented in single-source spatial database to avoid data being misinterpreted and creating problems that will affect project deadlines. It must be noted that this plan has multiple dependencies that will affect the manner in which the villages are connected as a result of the development of the supply side plan.

Electrification planning should make use of the land development sections of network planning in order to produce this electronic working copy of the electrification demand side plan in a spatial format. It should be noted at this point that no commitment can be made to the local authorities, as the suitability and availability to electrify the requested connections need to be tested with the supply side plan that is formulated by network planning.

The demand side plan is then supplied to the network planning section for the evaluation and formulation of the supply side plan that will inform the prioritised time frames of the demand side plan. This evaluation takes into account the technical network requirements based on the location of the connection as well as the supply side capacity constraints, in order to determine the extent to which the subsidised budget will be suitable for the number of connections requested. Eskom has previously developed, in conjunction with the Department of Minerals and Energy (DME), an electrification planning model, which has various inputs and produces on a high level the extent to which electrification can penetrate an area based on an allocated electrification subsidy. This tool, however, needs to be updated and maintained in order to render results that can be used by network planning in compiling the supply side plan.

In the absence of electrification planning model in the regions, the classical planning approach should be adopted in order to evaluate and formulate a supply side plan that suits the demand side plan in order to achieve a mutually agreed electrification plan. Network planning will need to consider various connection strategies to achieve the required connections in the most cost-effective way. This iterative process will result in feedback to the electrification coordinator, indicating the proposed plan based on the availability and suitability of the network. It should be noted that this supply side match to the demand side request has costing confidence levels of approximately 50%, as this is at the development plan stage. This being equivalent to the development plan approval stage as defined by the Eskom Standard Project Life Cycle Model Policy in the distribution business. Only once the plan is supported by all the stakeholders and projects identified for the three-year rolling plan and pre-engineering fees are made available, can the process to develop the costing and scope be completely more accurately.

Electrification Project: Network Planning Report

Sikhulu electrification area

Project summary

No. of connections:	704
Feeder and TRFR detail:	Ingeli NB1 near TGG25
GPS co-ordinates:	29°41'46,1"E 30°25'33,33"S
Income level:	0 to 750
Network constrained status:	Constrained
Existing customer base:	6571

ADMD, Herman Beta, and MV System Parameter Calculation and Assumptions

Elect. Proj. Name: Sikhulu *Classification:* Rural settlement

Parameter	Final (year 15)
ADMD (kVA)	1,0
Alfa parameter	0,461
Beta parameter	1,661
Circuit breaker size	20
Statistical current	AMEU
Network classification (C1=102%, C2=98%, C3=95,5%, C4=92,5%)	C2
Maximum allowable LV volt drop	7,5%

Calculated ADMDs, Herman Beta parameters and MV system voltages.

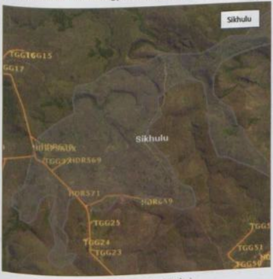
Recommendation

This project may not go ahead.

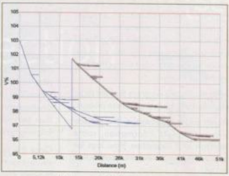
Dependency: This project is not to go ahead until the following infrastructure project is completed:

Job ID:	STM-1107-2053
Job description:	Ingeli NB1 Split
Projected completion date:	30 June 2013

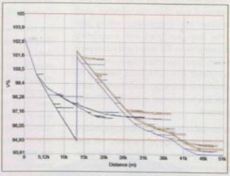
MV Backbone Technology and Conductor Selection



Overview of area to be electrified.



Voltage profile before Sikhulu.



Voltage profile after Sikhulu.

Notes

The information provided in the planning report is based on relatively high level information as provided to the network planning department. Should any of the inputs and assumptions on which the recommendations are based change, the recommendations will need to be adjusted accordingly. Whilst this report provides recommended design parameters based on this high level information, these parameters will need to be verified by the designer as part of the design. The responsibility still lies with the designer to ensure that the income levels/Herman Beta parameters are indeed representative for the customers to be supplied. Any deviation from the recommended values must be discussed with and approved by the network planning section.

The contractor needs to verify the validity of the census data results before completion of the design.

Any other lines longer then 1 km long are to be constructed in three phase FOX.

Income level per household per month provided by electrification planning department.

Classification based on zone no. MV recovery voltage from the substation to end of the network.

All transformers are to be locked in nominal tap for both initial and final design, with the no-load boost used to differentiate between the use of 400/230 V and 415/240 V transformers. For projects utilising 415/240 V transformers the no-load boost will be 3,75% (three phase transformers) and 4,35% (dual and single-phase transformers). If 400/230 V transformers are used (recycling existing transformers) the no-load boost will be 0%. Any 380/220 V transformers in the electrification area must be replaced as part of the project.

The Herman Beta parameters stated above are based on the specified circuit breaker rating. In reality a smaller circuit breaker may be installed, but the network must be sized based on the specified circuit breaker rating in order to cater for the anticipated loading levels.

Should the number of connections or income level vary by more than ±10% then the parameters provided in this report will need to be re-evaluated by Eskom's network planning section.

Electrification project classification: deep rural, informal settlement, rural, township.

This report is valid until 30 August 2013.

Report by: Mikie Kumalo, distribution network analyst, Eskom, KZNOU

Fig. 3: An example of an electrification planning report

Electrification planning is now in a position to negotiate the re-prioritised demand side plan and supply side plan with the external stakeholders for their support and endorsement. Naturally one has to make allowance for certain project delays that may materialize, as follows:

- Political changes on areas that are to be electrified and the timing of these projects.
- Project delays – planner initiating projects with incomplete information, route selection and acquisition (time lags for approvals), design reworks, construction delays.

The endorsement of the supply side plan and demand side plan (electrification plan) materialises into a three-year rolling plan with the first year fixed with supporting municipality/metro IDP letters and subsequent years semi-fixed. Updates to the business plan are completed on a yearly basis, pending the prioritisation of connection and changes in the projects due to changes in the electrification programme.

These annual or biannual updates, depending of the rate of change of the plan, will also account for ad hoc commitments that arise. These connections may have to follow a queuing system, as capacity on the network needs to be assessed according to their priority. Here tools such as "Spaceman" or similar tools will support the decision-making process, as the requester of this new connection will have to discuss the impact with the input stakeholders. Ideally, the three-year rolling plan should be fixed with approved execution release approvals (ERAs) completed in a staggered release format at least twelve months before the required commissioning date of the project. This will allow for adequate time to meet the commissioning dates as well as report within the DoE time frames.

Network planning must ensure that all network dependencies to support the connection plan are identified during the network development planning stage, either by a minor network extension or major bulk infrastructure development. These network expansions can then be released timeously from the DPA following the trigger from the electrification plan.

Once the project enters the asset creation value chain (ACVC) process, all normal business practices and processes will apply as defined by the Eskom Standard Project Life Cycle Model Policy in the distribution business.

In a perfect world, the preceding process would progress seamlessly and effortlessly. However, data is often the single largest factor that impedes the progress of the programme. In reality, not all connections are known to all the internal stakeholders, and existing plans often need to be revised in order to accommodate new connections. These revisions create additional work for all parties and, for obvious reasons, are undesirable. One can appreciate the turmoil that is caused when a network extension plan is developed with various load flows to the networks to test compliance to voltage constraints under normal and abnormal conditions, only to have to rework the plan due to newly discovered connections that alter the manner in which the network extension is required to evolve.

Further complications can be appreciated if projects are released without long lead items, only to have the newly prioritised connections requiring bulk network upgrades which require long lead items.

It should be noted that CRAs can be released by both electrification planning as well as network planning. However, all bulk infrastructure projects are released by network planning.

The content

- All MV conductor sizes are to be specified unless inside the village.
- Only use two phase technology for supplies to small villages.
- Squirrel conductor can be used as it is still an Eskom standard conductor.
- Voltage levels are specified for peak and light loading for the medium term (10 years from date of connection).
- Voltage levels are provided at the end of the MV lines inside the group of villages (project).
- Fault levels are specified for the time of connection and for the future if strengthening is planned for the network.
- Fault levels are provided for each village.
- Further system development indicates future strengthening planned for this network.
- Voltage support (voltage regulator, capacitor bank, conductor upgrade) required within three years of connecting the electrification project must be included in the electrification project.
- Requests for electrification reports must come from project engineering and these reports must be sent to project engineering when completed.

Fig. 5 illustrates an example of an electrification planning report:

The result

Upon the endorsement of the supply side plan that meets the requirements of the demand side plan by the external stakeholders, network planning would be in a position to finalise the DPA in order to compile the three-year rolling plan and five-year business plan.

The electrification plan should be available, spatially indicating all connections that need to be connected to the Eskom grid on a project (village or settlement) or geographical area basis. This electrification plan and capital projects that support the connections constitute the DPA and will be required to be taken to management forums for approval. These projects would then inform the NDPs as they are updated, to provide senior management with a holistic view of the development and capital requirements of the networks for the NDP area and period.

The electrification plan and NDP will highlight the dependencies on bulk infrastructure projects required by the demand side plan. This includes the strengthening projects and their associated electrification projects. This plan must indicate preliminary routings of MV backbones and technology selection, as this affects the total connection plan. This is required to ensure that the optimum equipment sizing is done to ensure optimum thermal loading, back feeding, voltage apportionment and voltage regulation of the MV network.

The electrification plan can now be accepted by all internal and external stakeholders, and the three-year rolling plan and five-year business plan can be extracted from the plan with the necessary capital projects being released in the ACVC for execution.

Conclusion

In conclusion, Eskom is fully committed to the United Nations Millennium Goals towards eradicating poverty. As 2012 has been declared the International Year of Sustainable Energy for All, Eskom is in full support of developing long-term plans to provide access to sustainable energy for all by 2030, as envisioned by the United Nations.

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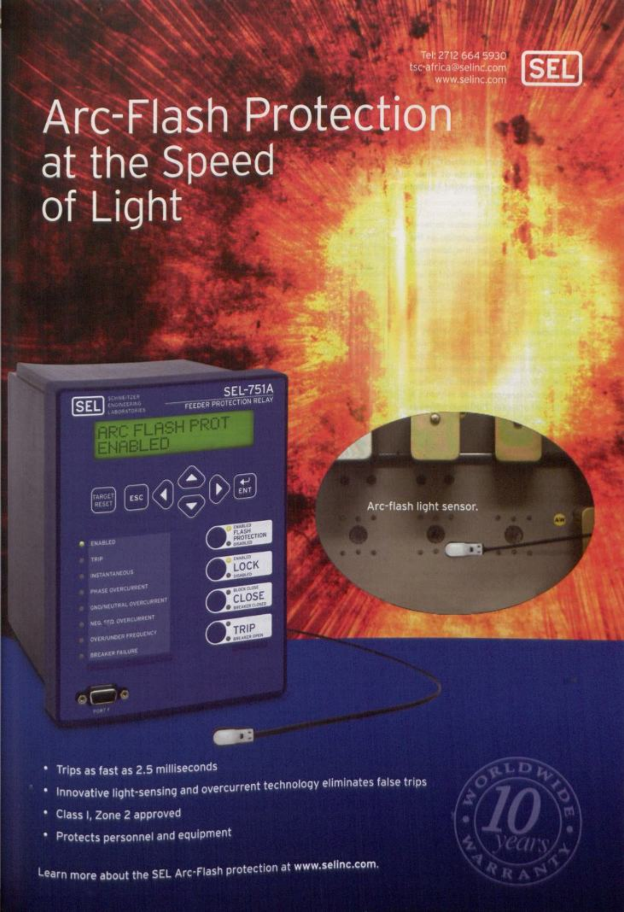
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OVER/UNDER FREQUENCY
BREAKER FAILURE
FLASH PROTECTION
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Utilities: self regulation for self-sufficient electricity distribution

by Nhlanhleni Lucky Ngidi, NERSA

Most South African electricity utilities, especially within municipal jurisdictions, only monitor performance and compliance requirements of their business processes against the requirements of the Integrated Development Plan (IDP). Other important business aspects are ignored because they are not mentioned in the IDP.

It has become general practice to leave almost all aspects of regulation to the statutory, regulatory bodies. It is, however, a fact that, should utilities not have compliance management systems in place to interface with regulation and compliance, regulation will always be viewed as merely an unnecessary burden to industry.

This paper promotes proactiveness in terms of knowing and monitoring one's business, leading to a self-regulated and efficient business. Implementation of these systems will create an environment where regulation is integrated into the utility's operational businesses. This paper addresses the development and implementation of internal compliance and quality management systems which allow business managers to perform self-evaluation and diagnosis of their businesses, based on the identified areas of improvement. An example of a self-compliance system implemented by a South African utility ("Utility A") will be discussed briefly here.

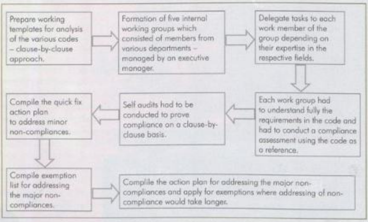

Fig. 1: The steps taken by Utility A in conducting the compliance self assesment.

Operational excellence

Utilities must operate as businesses and not just as service providers or revenue generators for municipalities. Proper strategic business planning should be at the order of the day. The Safety, Health, Environment and Quality Management (SHEQ) systems should be integrated into the business planning processes. While it is generally accepted that it is not easy to operate an electricity utility which is not ring-fenced and to operate it as a standalone business, everything will fall into place if the strategic planning ideology is brought into and championed by the shareholders.

Achieving world-class performance

The utilities should be focused on safe and reliable delivery of electricity to empower human and economic progress in South Africa. Utilities should consider the following questions when conducting business planning and its execution:

- How can we deliver electricity reliably and safely to empower human and economic growth in South Africa?
- How can this be done in the face of inherent risk?
- How do we deliver electricity across our demarcated and licensed areas, day after day, year after year, with zero tolerance of poor quality of service?
- How do we keep our customers, employees, contractors and shareholders happy and safe?
- How do we protect the environment and the communities around us while operating reliably and efficiently?
- How do we become a valuable input to the national government's twelve outcomes?

To meet these challenges, all businesses should be governed and operated in accordance with the legislative requirements. These are developed in the interest of the economy, the business operational efficiencies to stimulate growth, as well as to ensure that the customer's interests are protected through proper service delivery and availability of essential services such as electricity, water etc.

Utilities should ensure that systems are in place which support a culture of high performance, efficiency, reliability, safety, and environmental stewardship that strives to achieve world-class performance. This is called operational excellence (OE), and it drives everything the business does. Operational excellence is not impossible to achieve; there is legislation, as well as rules, regulations, codes, standards, policies and processes in place to assist in achieving these goals.

Mostly, the issue with the impression that governance and regulation are a hindrance is because proper understanding of the intent, embracing it and championing it going forward, is not properly looked at, and this is where management commitment within the utilities comes in.

Tenets of operation

OE requires constant attention to countless details and to how work is performed. It should be based on several tenets of operation, a code of conduct which employees and contractors use and which supervisors and managers reinforce. These tenets are based on two key principles:

- "Do it perfectly, reliably and safely, or do not do it at all."
- "There is always time to do it right."

These tenets address a wide range of behaviour. The key word in the tenets should be "always":

- Always operate within design and environmental limits.
- Always operate in a safe and controlled environment.

Code	Clause	Description	Comply Yes/No	Responsible department(s)	Comment by	Supporting documents/ comments	Action plan	Apply for exemption (Yes/No)
System operation code	3(8)	The distributor shall ensure it has sufficient resources to continuously monitor and operate the distribution system.	Yes	Operations	Lucky Ngidi, manager: operations and maintenance.	The utility has operations and maintenance division comprising of network control, dispatch, field services etc.	None	No

Table 1: Example of how each code was analysed and how compliance was reported.

- Always ensure that safety procedures are in place and implemented.
- Always follow safe work practices and procedures.
- Always meet or exceed customers' requirements.
- Always maintain the integrity of dedicated systems.
- Always comply with applicable rules and regulations.
- Always address abnormal conditions.
- Always follow written procedures for high-risk or unusual situations.
- Always involve the right people in decisions which affect procedures and equipment.

Business planning and strategic objectives should emphasise how all these tenets would be achieved, but more emphasis should be placed on complying with the rules and regulations. In fact, this should be instilled as an operational culture at the utilities, as this forms the basis of how the efficiency and effectiveness of the business plan will be achieved. A business that operates outside the scope of legislation can never prosper; it will be always be run in "fire fighting" mode, which actually means focusing on visible problems and emergencies while ignoring their root causes and fact finding models which yield preventative and proactive operational models. Utilities must develop operational excellence systems to address issues of compliance assurance and quality management in order to achieve operational excellence and improved performance.

Assuring compliance

Utilities must assure compliance with their operational excellence requirements by verifying conformance with applicable company policies, government laws and regulations. The current operational culture in the industry leaves all of that to the regulator and other bodies mandated to perform such activities, e.g. the auditor general and others. This, however, is a compromised culture. A regulator would conduct compliance and technical audits on a three-year cycle and these audits do not go into details and the crux of the business processes and performance, but only zoom into the license conditions, which do not address the holistic picture of the business. Many things may go wrong in the three years during which the regulator is not "in the picture".

An electricity licence holder cannot afford to wait for the regulator to tell them how their business is doing. This is very risky and not a very efficient way of conducting the business which, in the case of most municipalities, is a main revenue generator. The required compliance assurance process should establish requirements, procedures and tools to:

- Identify and record applicable laws, regulations and company policies.
- Assure that employees and contractors understand and comply with the requirements.
- Develop and implement programmes to verify that effective controls are in place.
- Conduct self-audits and independent audits to verify compliance on a regular basis.
- Provide for anonymous reporting of violations.
- Define and track actions when instances of non-compliance are identified etc.

Self-audits by operating units and independent audits are key drivers of compliance assurance. Utility operations should undergo corporate audits every second year at least. The ISO quality management standards requirements are based on a three-year cycle. Corporate audit teams should be comprised of employees and external parties with experience and subject matter expertise in each operating unit's risk areas. These teams should assess the design of processes and the effectiveness of operations consistent with these processes and always refer back to applicable laws, regulations, codes and standards.

Basic management requirements

In relation to developing processes and structures of assuring compliance and quality management for the organisation, the management of the utilities need to ensure they are aligned with the following management requirements:

- *Purpose:* establish the organisation's purpose, as well as the needs and expectations of stakeholders relative to this purpose.
- *Policy:* define, document, maintain and communicate the overall intentions, principles and values related to compliance assurance.
- *Planning:* establish objectives, measures and targets for fulfilling the organisation's purpose and its policies, assessing risks and developing plans and processes for achieving the objectives which take due account of these risks.
- *Implementation:* resource, operate and manage the plans and processes to deliver outputs which achieve the planned results.
- *Measurement:* monitor, measure and audit processes, the fulfilment of objectives and policies and satisfaction of stakeholders.
- *Review:* analyse and evaluate the results of measurement, determine performance against objectives and determine changes needed in policies, objectives, measures, targets and processes for the continuing suitability, adequacy and effectiveness of the systems.
- *Improvement:* undertake action to bring about improvement by better control, better utilisation of resources and better understanding of stakeholder needs. This might include innovation and learning.

The basic organisation's compliance assurance and quality management systems requirements demonstrate:

- That it has effective policies for creating an environment which will motivate its personnel into satisfying the needs and expectations of its customers and applicable statutory regulatory requirements.
- That it has effectively translated the needs and expectations of its customers and applicable statutory and regulatory requirements into measurable and attainable objectives.
- That it has an effective system of interacting processes for enabling the organisation to meet these objectives in the most efficient way.
- That it is achieving these objectives as measured, that they are being achieved in the best way, and that they remain consistent with the needs and expectations of the customer and the applicable statutory and regulatory requirements.

Management and the organisation as a whole must demonstrate their commitment to the achievement of compliance to rules and regulations.

Code type: Distribution system operation code	
Total clauses	117
Total compliant	112
Total no compliance	5
Notes to NERSA (Request for clarity on clauses)	14
Percentage compliance	98%
Remedial action plans to address non-compliance	5

Table 2: Example of summarising findings and level of compliance.

Conclusion

A compliance-driven business is a business which is always ahead, able to detect the risks quicker and to respond to them by always ensuring that their operational processes and performance are audited, monitored and reviewed to align with the best international norms. It has been proven that compliance-driven entities also enjoy high turnovers and profit margins and attract skilled employees, while other companies underperform and are always "putting out fires", a model which is only reactive and which faces problems when they arise, rather than identifying risks prior to their becoming problems.

It goes without saying that waiting for regulation to remind you of how your business is doing is an indication of poor business management. This mentality slowly eats away at the business and will eventually devour the whole concern. More effective streamlining of processes across the entire business and assessing their compliance provides for more effective use of resources and increased productivity for the business.

Example of a self-regulated utility: How self-compliance assurance against one of the licence conditions (distribution code) was implemented by a South African utility using compliance assurance and quality management systems:

The distribution code was approved by the National Energy Regulator of South Africa (NERSA) in August 2007. The code comprises six different codes within it: governance, network, system operation, metering, tariff and information exchange codes. In 2008, NERSA presented at the AMEU Convention, communicating the approval of the code and stating that it was to form part of the licence conditions. The expectation was that licensees would make preparations during in 2008/09 to ensure compliance with the code.

The requirements were that all utilities would:

- Conduct a critical review and have an understanding of the code requirements.
- Assess areas where there is non-compliance so that a licensee can apply for temporary exemptions where necessary.
- Assess where amendments to the code may be necessary.
- Follow the appropriate process (governance code of grid code) to apply for amendments or exemptions.
- Provide an action plan for non-compliance, to address these by improving their business code of practice by aligning with the distribution code.

Process followed by the licensee

In complying with these requirements, the particular licensee, ("Utility A"), implemented the process and was aligned with the ISO 9000 and 9001 frameworks for quality management and compliance assurance systems.

Management endorsement and commitment

The top management of Utility A proved its commitment to implementing the requirements of the distribution code and to its self-compliance assurance process. The commitment was also to ensure continued improvement of the effectiveness of the compliance assurance process through communicating to the organisation the importance of meeting customer as well as statutory and regulatory requirements, of establishing compliance assurance policy, and ensuring that compliance objectives are established. Management also appointed and mandated a workgroup which would be responsible for the development of a compliance matrix. This formed part of resource allocation and loading for the project.

Time frames and coordination

It was considered important to appoint a project champion to ensure the successful completion of the distribution code assessment process. The candidate should ideally have a good understanding of the business process and operations. It was equally important to appoint a project manager to oversee the overall co-ordination. An executive member was tasked to oversee the overall co-ordination of the project.

Formation of the distribution code compliance working group

Utility A formed working groups to conduct compliance monitoring and to investigate the enforcement of the distribution codes of practice. This was done by conducting internal and on-site audits. This methodology of monitoring allowed the utility to compile a self compliance framework that reflected the status quo of the utility in terms of compliance with the respective codes. The workgroups were assigned tasks depending on their expertise, i.e. the team would analyse a certain code and investigate the areas of non-compliance of that specific code. Once non-compliance has been identified, recommendations for compliance would be documented and this information would be shared accordingly with NERSA.

Steps taken by Utility A to conduct self compliance assessment

Fig. 1 depicts the steps taken by Utility A in conducting the compliance self-assessment. Table 1 provides an example of the codes analysed and how compliance was reported.

Results, lessons learned and the way forward for Utility A

Utility A found that they were above 90% compliant with the code and that no funds were needed to conduct the self compliance assessment. All that was needed was to resource the project team with skilled members. Time was the only commodity needed.

This utility performed the self assessment and managed to identify the clauses that were unnecessary and irrelevant to utilities of its type. Amendments to the code were proposed by the utility and these were also a lesson for the regulator with regards to reviewing the code in future. The other lesson learned was a better understanding of what exactly the code requires from the utilities.

Since the assessment is done by looking at your practices against the requirements of the code, the utility was then able to develop operational and training procedures that are aligned to the code of practice. This helps a great deal even when there are new employees who are supposed to be introduced into the utilities' operational procedures, providing seamless transition for them.

As a way forward, Utility A committed itself to conduct an audit in compliance with the codes bi-annually to check if it still complies with them, and to stay abreast of the changes in the codes as these documents are amended regularly.

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MUNICIPAL SECTOR CONSULTANTS

Achieving optimal benefits with a demand response system

by Rodney Swartz, Siemens

Mention the word "Medupi", and faces go red with embarrassment, angers flare and all kinds of comments and explanations are offered. The reality is that we need additional supply capacity, that we are facing all kinds of challenges to build new power stations and implement renewable IPP solutions.

An interim solution to run concurrent with new build programmes is to focus on managing the demand of electricity. This is known as demand side management (DSM) and Eskom has implemented various programmes since 2005.

One of these programmes, namely demand response (DR), was introduced early in 2007 and is still running today.

What is demand response

Demand response is a programme in which utilities incentivise consumers to reduce their non-essential electricity load upon request (DR event) during critical system conditions and/or when the cost of electricity becomes too exorbitant.

Consumers become participants of the DR programme by entering into a contract that agrees on the amount of load that can be reduced, how many times, for how long, the notice period required and most importantly the incentive amounts.

Incentives differ mainly according to:

- The notice period, whether 10 minutes or 30 minutes
- The accepted and scheduled time on stand-by
- The MWh of load reduced

DR events are not only called during peak demand periods, but can also be called anytime during the day should a critical system condition occur.

Why demand response

As opposed to load shifting that incentivises consumers with part of the capital costs to permanently shift load from peak to off-peak periods (Fig. 1), DR focuses on having consumers (participants) on stand-by to reduce huge amounts of load whenever requested (Fig. 2).

DR can therefore be seen as bringing peak generation on-line when needed for a period of time.

The costs to incentivise participants for a DR event are considerably lower than the costs per MWh from a peaking power station.

The South African situation

Eskom's peak demand in 2012 was 35 525 MW and the total nominal capacity of the 27 power stations was 41 919 MW.

The current installed capacity expansion plan amounts to 11 126 MW by end of March 2019.

Various challenges have been hampering the expansion plan and future challenges cannot be ruled out.

DR therefore becomes a very attractive interim solution because of the short lead times required to sign-on new participants as compared to the time required to build a new power station and the risks of delays thereof.

Most of the mega electricity consumers (20 – 80 MW) have already been signed up for DR directly with Eskom, totaling to approximately 900 MW of available load to reduce for DR events.

To cater for smaller consumers, Eskom requires at least 100 kW to 10 MW of load that can be reduced.

Eskom will also consider the aggregation of smaller loads from various participants as one load made available to Eskom as an aggregator. Eskom will therefore only deal with one participant (aggregator) as opposed to numerous individual participants, making it possible for smaller consumers to also participate and getting incentivised via the aggregator.

Applications for municipalities

This creates the opportunity for municipalities to participate in Eskom's DR programme as an aggregator of the consumers in the municipality's area of supply (Fig. 3).

The benefits for Eskom to have the municipality as an aggregator are multiple, such as drastically reducing Eskom's administrative and logistical burdens.

Having control over which loads are reduced when, municipalities benefit by ensuring value is added by reducing strain on specific networks as well as gaining a share of the DR incentives.

A great example is by utilising existing ripple control systems that manages hot water

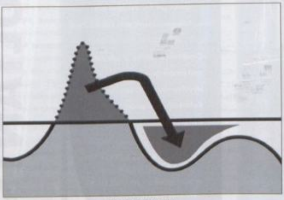

Fig. 1: Load shifting.

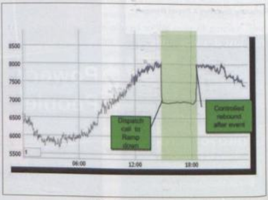

Fig. 2: Demand response.

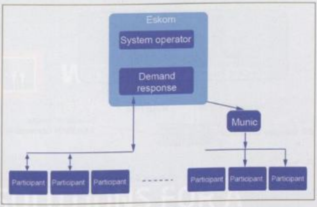

Fig. 3: Municipality as aggregator.

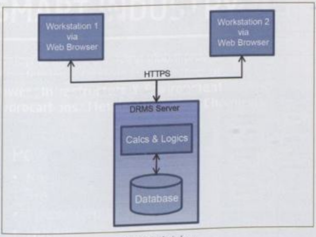

Fig. 4: DRMS platform.

cylinders of residential customers as a load reduction mechanism.

Not only will these municipalities save on their energy costs during peak periods, but will also get incentivised for the reduced MWh by aggregating multiple smaller loads that would otherwise not have qualified for the DR incentive.

Municipalities know their consumers best and already have existing relationships with them. Hence, when it comes to signing on new participants, the municipality would be in the best position to accomplish this activity.

Achieving optimal benefits with a demand response management system

A simplistic DR process involves the following:

- Market DR and sign-up participants
- Register participants and available loads
- Receive one day ahead forecast from Eskom of load required
- Verify how much load can be provided by participants and offer bid to Eskom
- Eskom calls a DR event
- Notify participants to reduce load
- On instruction from Eskom, notify participants to restore load in a staggered fashion and not all at once
- From meter data, determine exactly how much load was reduced by the participants and for how long
- Pay incentive to participants based on the delta between the baseline and reduced load
- Ensure that each participant has a fair chance to reduce load, not too many times and also not too little

This might sound complicated, but by automating the tasks and by integrating into existing utility and participant systems, it becomes a demand response management system (DRMS) and a pleasure to implement.

To ensure optimal benefits, points to consider for an effective DRMS should be:

DR program constraints

- How many times can a DR event be called during a program period
- How many consecutive hours can a DR program be called for
- How many consecutive days can a DR program be called
- Will the program allow a participant to opt-out of an event
- What days and time periods can a DR event be called
- How much advanced notification will a participant receive prior to a DR event
- What baseline calculation will be used to validate M&V and DR settlement

DRMS platform

In essence, a server will be required to do all the computations and storing of the data. The latest methods available for accessing the server allows for a secure connection through HTTPS with a web browser acting as a client workstation (Fig. 4).

This creates the possibility to either have the server in-house or hosted elsewhere in a data centre (cloud).

Different access levels with relevant user rights should be controlled by an administrator assigning usernames and passwords to the authorised users.

Sending of DR events

A standard pathway to follow would be to start with sending DR event notifications via email, text message or automated phone call to the participant contacts. Participants will then manually respond to the DR events by switching off or reducing load as agreed. The DRMS should therefore be able to interface automatically to these email, text or phone systems when a DR event is called.

Utilities then progress to more sophisticated automated methods that entail sending DR events to end devices at participant locations. This could be done either through advanced metering infrastructure (AMI), ripple control systems, or through DR gateway devices installed at participant sites. An AMI or ripple control system will already have some means of communication in place that will need triggering and control from the DRMS. It is therefore fundamental to consider a MultiSpeak interface that will enable communication with many AMIs that comply with this standard.

By installing DR gateway devices at participant sites, the reduction of load can be automated with control of the load (PLC) being wired to the gateway device. The most cost and operational effective communication medium between the DRMS and participant sites needs to be selected. This could range from radio, GPRS, power line carrier, etc. OpenADR is a communication standard that will facilitate communication and control of various DR gateways. It is thus just as essential that this standard be considered for the DRMS and DR gateway devices (Fig. 5).

Other interfaces

Numerous commercial buildings already have building management systems (BMS) installed. The BMS could control the HVAC and lights as an example. The DRMS should be able to have access to a variety of BMSs (e.g. Honeywell, Johnson Controls, Siemens) by utilising multiple adaptor interfaces for communication.

An interface to the utility's SCADA system will make it possible to receive consumption data from specific substations or feeders to measure and display the impact of the load being reduced. DNP3 is a typical protocol that is used for this application.

Restoring of loads

To avoid another critical system condition, load should be restored over a period of time and not all at once. The DRMS should be able to schedule restore messages via the email, text or phone systems. Where DR gateways are used, the DRMS should schedule the restore commands to have a gradual ramp up process.

Grouping of loads

In order to only reduce the required amount of load or to reduce loads in a specific area, it is advisable to identify and group loads accordingly by substation, participant, or participant site for scheduling and sending DR events.

With loads grouped by participant, DR programs can be customised according to the group participants' contracts stating how many times they may be called for a DR event per day, week, month or year.

By grouping loads per substation or feeder, utilities are able to reduce strain on overloaded networks and ultimately prolong the life of equipment.

Loads can also be grouped by participant sites, like a group of supermarkets where participates aggregates the smaller sheddable loads of their different supermarkets.

Baseline calculations

Many disputes can be avoided by using tried and tested algorithms for baseline calculations. Some of the best are the PJM and ERCOT baseline algorithms. Not only should historic meter data be used to do once-off baseline calculations, but it should also be recalculated on a regular basis using the latest measured data.

For participants with unique load profiles, the DRMS should have the ability to add baseline calculation methods. This functionality should be controlled and assigned only to specific users.

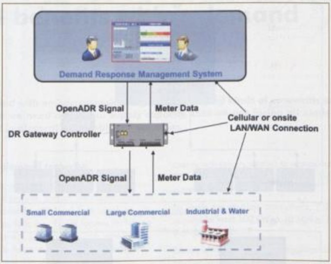

Fig. 5: Open ADR via DR gateway.

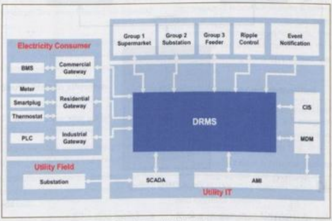

Fig. 6: Typical DRMS solution.

Calculation of settlement data

Accurate settlement data for billing and energy payments can be calculated by accessing revenue grade meter data from an existing meter data management system (MDM). This is calculated based on the delta between the participant's baseline usage (kWh) and the participant's actual usage during a DR event.

By sending the settlement data back to the MDM, a billing system should be able to access it from the MDM for calculation of energy payments to the participants.

Scalability

It is not always financially viable to start with a fully fledged system containing all the bells and whistles. The DRMS should therefore offer the flexibility to start at a smaller scale and add functionality as required (Fig. 6).

Conclusion

Municipalities can execute their own DR program and act as an aggregator for the national Eskom DR programme by implementing their own in-house DRMS.

By taking the few key points into consideration and in-depth discussions on objectives and requirements, a flexible and scalable DRMS can be developed.

This gives the municipality the opportunity to achieve optimal benefits such as increased revenues, better control over resources and ultimately improved customer satisfaction.

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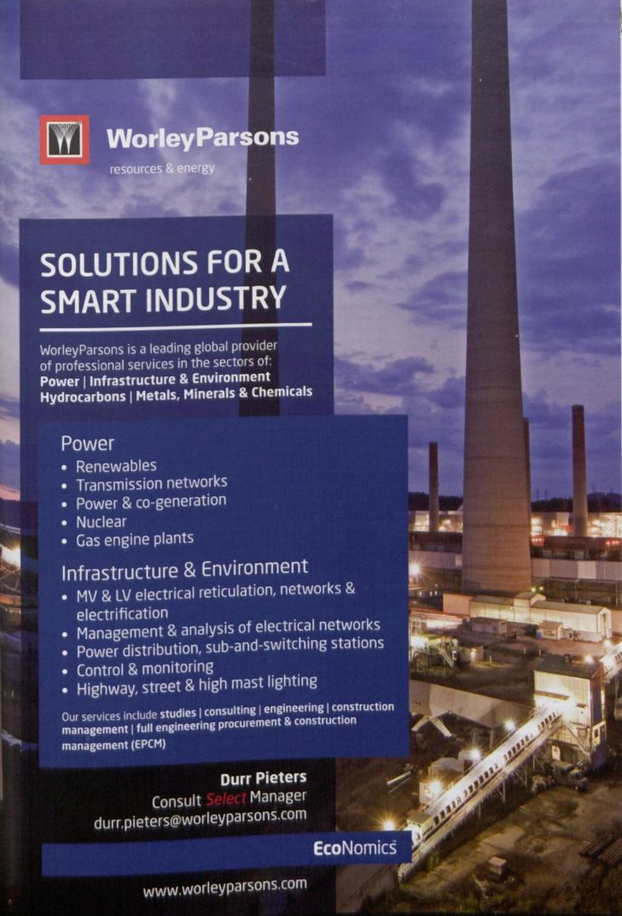
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Grid connection code for renewable power plants South Africa

by Target Mchunu and T Khoza, Eskom

Regulations have and still play a major role in the successful penetration of renewable energies in the power grid. In South Africa, the White Paper on Renewable Energy of 2003 has set a target of 10 000 GWh of energy to be produced from renewable energy sources (mainly from biomass, wind, solar and small-scale hydro) by 2013 [1]. The incorporation of these renewable technologies, especially wind and solar, can only happen through unlimited access to the power grid.

However, a high penetration of renewable energies harbours the risk of the grid instability in case the generating plants are not able to support the grid. On this background, the National Energy Regulator of South Africa (NERSA) approved in November 2012 the new grid code for connecting renewable power plants (RPPs) to the transmission system (TS) or the distribution system (DS) in South Africa. This paper provides an overview of the grid code for the connection of RPPs to electric power systems.

In many countries, renewable energy technologies, which include photovoltaic (PV) and concentrated solar power (CSP), wind, small scale hydropower, landfill gas and biomass, expands and covers a steadily increasing part of these countries' power demand. This is as a result of the policies and incentives given by governments around the world which has caused the inclusion of renewable energy as a significant part of the power system network. Although South Africa predominantly makes use of coal-fired power stations to supply over 90% of the electricity needs of the country, the government has committed itself to increase the generation mix to include more sustainable and environmentally friendly forms of generation.

In South Africa, renewable energy technologies will be integrated into the utility grid and due to its nature; this type of generation will be not only geographically dispersed but also distributed across several voltage levels, at either the transmission level or distribution level, depending on the scale of generation. Both types of interconnections present different type of challenges that must be carefully analysed before systems are designed. The connection of RPPs to electrical power systems influences the system operation point, the load flow of real and reactive power, nodal voltages and power losses [2]. At the same time, RPPs must maintain uninterrupted generation throughout power system disturbances, supporting the network voltage and frequency, and therefore, extending features such as low voltage ride through or reactive and active power capability.

Low voltage ride through is particularly important to maintain the voltage stability, especially in areas with high concentration of RPPs i.e. wind and PV power generation [3].

The aim of the grid connection code is to keep the safety and reliability of the network operation with a growing share of decentralised generation plants and keep the voltage quality in accordance to the limits formulated in applicable standards.

Challenges faced by electricity distributors with increasing growth of RPPs

As more and more RPPs added to the distribution system, the nature of the medium voltage (MV) and low voltage (LV) system is changing from a traditional passive radial network to an active network with power flows in both directions from and to the transmission system. This presents particular challenges in terms of network protection, system operation and safety as more faults on the network may now be energised by multiple sources. The majority of new RPP being added to the South African distribution system is in the form of inverter-interfaced generators, with very specific technical characteristics which are quite different to those of traditional large-scale thermal generation.

There are many potential challenges faced when large amounts of RPPs are connected to a distribution network [4]:

Protection co-ordination: Risk of under-reach of existing impedance protection. Also, selectivity between series overcurrent or impedance protection can be lost unless RPP is considered when calculating settings.

Voltage regulation: Control of system voltages can become difficult on weak systems where generation may be intermittent in nature (e.g. wind turbines). Can lead to overvoltages or undervoltages following connection or loss of RPP.

Islanding: Issues of safety and power quality on islanded power systems fed by RPP that may be created following system disturbances or operation of protection.

Power factor: Under conditions of light local load demand and high levels of renewable generation, power can be exported from the distribution system to the transmission system. However, reactive power may still be required from the transmission system. Under these conditions, this can cause a low power factor to be measured at the feeding transmission substation and can cause spurious protection trips if it is not considered in the protection relay settings at the substation.

It is therefore with these challenges that the industry has provided the RPP code which sets out technical framework for integrating renewable energy into the electricity grid, especially distribution system. The following sections outline some of the technical aspects proponent generators must identify and ensure that are incorporated early during project development phase

Objectives and scope

The primary objective of the grid connection code is to specify minimum technical and design grid connection requirements for RPPs connected to or seeking connection to the South African electricity grid. This grid connection code, at minimum, applies to the following RPP technologies:

- Photovoltaic
- Concentrated solar power
- Small hydro
- Landfill gas
- Biomass
- Biogas
- Wind

The requirements of the RPP grid connection code are organised according to defined categories as illustrated in Table 1.

Sub-categories	Rated power range
A1	0 < A1 ≤ 13,8 kVA
A2	13,8 kVA < A2 < 100 kVA
A3	100 kVA ≤ A3 < 1 MVA
B	1 MVA ≤ B < 20 MVA
C	≥ 20 MVA

Table 1: RPP categories.

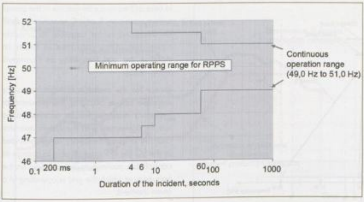

Fig. 1: Minimum frequency operating range of a RPP (during a system frequency disturbance).

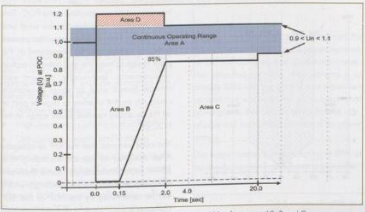

Fig. 2: Voltage ride through capability for the RPPs of category A3, B and C.

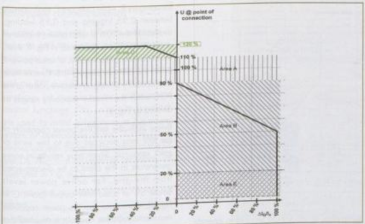

Fig. 3: Requirements for reactive power support, I_Q, during voltage drops or peaks at the POC.

The code is to be fulfilled by all RPPs that are to be connected through high-voltage transmission level and the medium-voltage distribution level either directly or through a dedicated transformer. This scope also includes some RPP units, which are typically connected to the low-voltage level such as PV inverters if they are clustered to achieve larger power levels. In addition, all thermal and hydro units shall also comply with the design requirements specified in the SA Grid Code (specifically section 3.1. of the Network Code) [5].

Overview of South African RPP code

South African renewable power plant code for generating plants connected to TS and DS networks came into effect on November 2012 [3]. The new code is one of the efforts of network service providers (NSP) whose role is to provide network services through the ownership and maintenance of an electricity network towards the integration of renewable technologies into the network. The requirements deemed relevant are voltage and frequency operating ranges and the corresponding trip times. For mitigating voltage suppression and power surges in the wake of transient faults, the active power and reactive power control requirements are also taken into account. The voltage and frequency operating ranges determine the limits within which the RPPs must not disconnect from the grid and have to sustain operation. The active and reactive power control requirements determine control capabilities under various fault and system situations.

Tolerance of frequency and voltage deviations

The RPP shall be able to withstand frequency and voltage deviations at the point of connection (POC) under normal and abnormal operating conditions described in this grid connection code while reducing the active power as little as possible [4].

Normal operating conditions

RPPs shall remain continuously connected to the TS or DS at maximum available active power output in normal system conditions. This range will be defined by the NSP for different elements in the grid. Also, the RPP shall have the capability to operate continuously at normal rated output at frequencies in range from 49 Hz to 51 Hz and to remain connected to the power system at frequencies within a bigger range (for example from 47 Hz to 52,0 Hz) for a certain duration as shown in Fig. 1 [5].

Abnormal operating conditions

RPPs shall remain connected to the grid for system voltage dips on any or all phases, where the system voltage, measured at the HV terminals of the grid connected transformer, remains above the heavy black line in Fig. 2.

Fig. 2 shows that RPPs of category A3, B and C, shall remain transiently stable and connected to the system without tripping for a close-up solid three-phase short circuit fault or any unbalanced short circuit fault on the TS or DS with a total fault clearance time of up to 150 ms. Throughout the operating range of the RPP, these type of faults must not result in instability or isolation from the network. Furthermore, Fig. 2 shows that the RPP shall be capable of continuous operation down to 90%

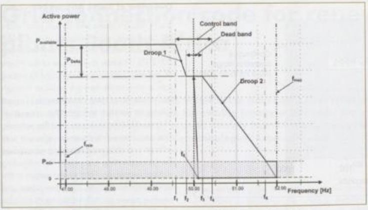

Fig. 4: Frequency response requirement for RPPs of category B and C.

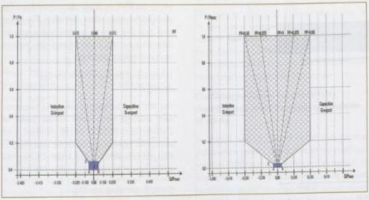

Fig. 5: Reactive power requirements for RPPs of category B & C.

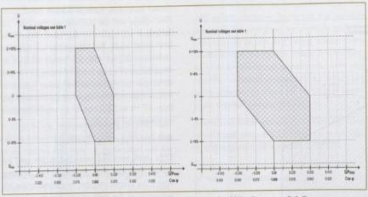

Fig. 6: Requirements for voltage control range for RPPs of category B & C.

of rated voltage at the POC. Furthermore, RPPs have to provide a mandatory voltage support during voltage dips. The required reactive current in terms of dynamic voltage support is defined as shown in Fig. 3.

Frequency response

All the generating equipment in an electric system is designed to operate within very strict frequency margins. Grid codes specify that all generating plants should be able to operate continuously between a frequency range around the nominal frequency of the grid and to operate for different periods of time when lower/higher frequencies down/up to a minimum/maximum limit. Operation outside these limits would damage the generating plants. The loss of generation leads to further frequency deviation and a black-out may occur [6].

In case of frequency deviations in the power system, category B and C specifically shall be designed to be capable to provide power-frequency response in order to stabilise the grid frequency as illustrated in Fig. 4 [5].

Except for the mandatory high frequency response (above 50,5 Hz), the provision of frequency response will be entered into a specific agreement with the system operator (SO). At a given frequency range provided by the SO the RPP must be able to change its controllable power output depending on the frequency at which the grid is operating at a given moment.

Reactive power capability

Reactive power requirements for interconnection are specified at the POC. This is an important consideration for wind and solar plants. First of all, it means that several technical options can be considered in the plant design to meet the grid interconnection requirements. Technically, a plant with inverter-based wind or solar generators could rely on the inverters to provide part or all the necessary reactive power range at the POC [3].

The code requires that the RPP of category A be designed to operate according to a power factor characteristic curve (between 0,95 lagging and 0,95 leading), which will be determined by the NSP or the SO. Category B and C shall be designed to supply rated power (MW) for power factors ranging between 0,975 lagging and 0,975 leading for category B; while category C shall operate between 0,95 lagging and 0,95 leading, available from 20% of rated power, measured at the POC. This is illustrated in Fig. 5. Also, when operating above 20% of rated power P (MW) the RPP of category B & C must have the capability of varying reactive power at the POC within the reactive capability ranges as defined by Fig. 6.

Below 20%, the reactive power capability of the RPP may decrease due to low wind or solar resource, which may results in some generators in the plant to be disconnected from the grid. For active power levels below 5% of rated MW output (point C in Fig. 5), there is no reactive power capability requirement. In this range, it is required that the RPP operates within the tolerance range specified by point A and point B in Fig. 5.

In addition, RPP of category B & C must be designed with the capability to operate in a voltage, power factor or reactive power control modes. The actual operating mode (V, power factor or Q control) as well as the operating point shall be agreed with the NSP [5].

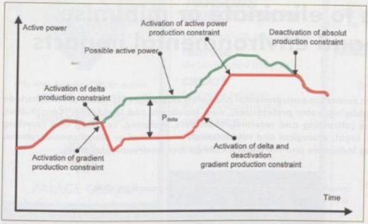

Fig. 7: Active power control functions for a renewable power plant.

Power quality

Power quality and voltage regulation impact shall be monitored at the POC. Impact assessment shall include amongst the disturbances at the POC.

- Voltage fluctuations
- High-frequency currents and voltages
- Unbalanced currents and voltages

Voltage and current quality distortion levels emitted by the RPP at the POC shall not exceed the apportioned limits as determined by the relevant NSP. Maximum allowable voltage change at the POC after a switching operation by the RPP (e.g. of a compensation devices) shall not be greater than 2% [5].

Active power constraint functions

In order to cope with different scenarios in the grid and for system security reasons, additional power control strategies may be necessary. Depending on the local state of the grid, the RPP shall be equipped with constraint functions, i.e. supplementary active power control functions. The constraint functions are used to avoid imbalances in the power system or overloading of the TS and DS in connection with the reconfiguration of the TS and DS in critical or unstable situations, as illustrated in Fig. 6 [5].

The required constraint functions are as follows:

- Absolute production constraint
- Delta production constraint
- Power gradient constraint

Conclusions

Intermittence nature of renewables brings about a different challenge to the power system, hence NERSA has introduced new grid code requirements to minimise these risks. In this paper, a couple of the minimum technical requirements were presented for the connection of RPP to the power systems, at the transmission and distribution level. The objective of these requirements is to provide RPPs with the control and regulation capabilities encountered in conventional power plants that are necessary for the safe, reliable and economic operation of the power system.

The major concerns in connection of RPPs at the distribution level are related to protection, voltage control and power quality. The reserve requirements, reactive power and the grid support during the fault ride through are among the major issues to be considered in grid integration of RPPs at HV level.

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Utility strategies to eliminate or minimise safety incidents and environmental impacts

by Troy Govender, Eskom

Electricity utilities in Africa are faced with numerous environmental and safety challenges [1]. Some of these include public pressure (consumer pressure, lobbying, voter preferences), new standards and legislation (Constitution, ISO14001), new business opportunities (attracting and retaining customers, reducing, re-using and recycling materials), reduction of risk (financial, legal, ecological and reputational) and ethical or moral considerations, given the current safety concerns across industries and the climate change and environmental crisis.

These safety and environmental challenges are heightened by activities involved in the distribution of electricity. These include employee and public injuries and fatalities, waste (hazardous and general) disposal, wildlife interactions (collisions and electrocutions with infrastructure), oil spills or leaks from electrical equipment, herbicide or pesticide spillage, the removal of indigenous and protected trees, habitat destruction and the damages caused to sensitive or protected areas particularly during construction and maintenance activities [2].

Safety, environmental management in business/industry

Safety and environmental management is not about the management of the work environment by a safety specialist or an environmentalist, but rather about the organisation controlling its activities which have or could lead to safety incidents/ accidents or have a negative impact on the environment [3].

Business and safety, environment challenges

There are many reasons for businesses, including electricity utilities, to respond to the safety and environmental challenges in South Africa [4], some of which include:

- The nature of activities at electricity utilities often lead to a range of safety related injuries/fatalities such as slips, trips and falls, electrical contact incidents, motor vehicle accidents, animal interactions, etc.
- Great impacts on the planet such as global warming, ozone depletion, desertification, waste, pollution, over-population, destruction of forests, killing of animals, over-fishing, hazardous chemicals, water scarcity, erosion, litter, etc.
- There is a strong link between poverty, safety and the environment. When a breadwinner from an improvised community is injured or killed while working, the family is left destitute. The poor suffer the most in highly degraded environments; damaged environments mean less natural resources for poor people. Environmental care is a low priority for poor people due to other life threatening needs such as food, shelter and clothing.
- Health and safety issues are related to and are influenced by the environment because the quality of the environment impacts on the health of a nation (and its ability to manage disease and epidemics).
- There are moral or ethical reasons why all have to respond. Employees have families who rely on them. Injury to or death of an employee while on duty has far reaching consequences for families and communities.

Mankind has caused much of the destruction through development and greed, and is therefore obliged to do something positive for the environment [5].

The business drivers for improved safety and environmental practices include:

- Public pressure, e.g. consumer pressure, lobbying, influencing, voting, etc.
- New standards and legislation, e.g. Constitution, OHSA, NEMA, etc.
- New business opportunities, e.g. attracting and retaining customers, reducing, re-using and recycling materials, consultancies, etc.
- Reduction of risk, e.g. financial, legal, ecological and reputational (publicity).
- Ethical considerations.

Strategies

The main challenges for safety and environmental management improvements in the electricity industry are to:

- Make business more effective and its safety performance and environmental impact more acceptable.
- Identify and realise potential areas for safety and environmental good practice.
- Change (traditional) management practice to address these new challenges, especially with tighter budgets.
- Ensuring safety and environmental care within the organisation against a backdrop of a high risk culture externally and low environmental ethic.

A paradigm shift

- Trust + control = k where k = good safety and environmental performance.

Trust: honesty, transparency, disclosure.

Control: laws, policies, directives, instructions, job compacts.

High trust requires low controls and vice versa.

High trust is much more desirable than high controls.

If trust is lacking, high controls will be required.

- Risk = hazards + outrage.

Risk: financial, legal, and publicity risks.

Hazards: injuries, fatalities, environmental incidents.

Outrage: media, community, government, NGO response, anger, dissatisfaction.

A company's risk is directly proportional to the sum of its hazards and outrage. Outrage can be managed through better relations with communities and all stakeholders.

- Shifting the focus from the bottom line to the triple bottom-line (profits, social responsibility, environmental care).
- Sense of community.

Conclusion

The last decade has witnessed a remarkable public awakening. There has been revolution in awareness and understanding of safety and environmental issues, a growing sense of urgency, a knowledge that environmental protection is not the luxury of the rich, a realisation that we share one, finite earth and that all of us are responsible for what happens to it. A growing number of people – ordinary citizens, executives, government officials, religious leaders, and journalists – are beginning to recognise that their long-term aims and activities and environmental conservation are mutually dependent, not mutually exclusive.

Effective management of environmental, health and safety (EHS) issues entails the inclusion of EHS considerations into corporate

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Serious incident in the Boksburg area of Ekurhuleni Metropolitan Municipality

by Dave Jamieson, Ekurhuleni Metropolitan Municipality

A summary report on the investigation and proposals following an electrical incident that occurred on 11 March 2013 at a switching station in Boksburg that resulted in the injury of four council employees.

An incident occurred on 11 March 2013, causing serious injury to four Ekurhuleni Metropolitan Municipality (EMM) council employees.

The purpose of this paper is share what an internal departmental investigation team determined to be the cause of an electrical incident that occurred in the Energy Department on 11 March 2013 at approximately 18h50 on the corner of Lea Road and Kent Street, Anderbolt, Boksburg, when four staff members sustained serious burns whilst attempting to restore the electricity supply following a medium voltage outage in the Anderbolt area.

Fig. 1: Switchgear damaged in the explosion.

Investigation team

The team instructed to investigate the incident consisted of the following :

- Chief area engineer: Boksburg.
- Operations and maintenance engineer: Boksburg.
- Senior operations officer: Boksburg.
- Chief area engineer: Alberton.

EMM employees involved in the incident

- Electrician A – Approximately 8,5 years' experience
- Electrician B – Approximately 2 to 3 months experience.(Helping out in the section).
- Special workman – approximately 25 years' service.
- Artisan assistant – approximately 36 years' service.
- Senior operations officer

Sequence of events

Electrician A and Electrician B were called out to attend to an outage in the Anderbolt area. They found that a medium voltage circuit breaker in switching station S16 had tripped. They racked the circuit breaker out and proceeded to test the circuit. They found the circuit to be without a fault "clean". They then racked the circuit breaker into position. Electrician A instructed the other personnel to exit the switching station. Electrician B stood outside the door of the switching station, the special workman outside the door against the perimeter fence and the artisan assistant was walking towards one of the vehicles. Electrician A then closed the circuit breaker. The circuit breaker failed catastrophically, causing a fire that injured Electrician A. Electrician B, the special workman and the artisan's assistant (the three men that had just walked out of the switching station) ran back into the switching station and dragged Electrician A out of the building. The special workman then phoned the senior operations officer for assistance. The senior operations officer immediately made his way from home to the switching station and at the same time called for help from the emergency services. All injured personnel received emergency treatment at the scene and were transported to different hospitals.

Electrician A suffered burns to approximately 50% of his body. He was airlifted and admitted to the Milpark Hospital for treatment and observation. Electrician B suffered burns to his body. He was transported to the Glynwood Hospital and then transferred to the Milpark Hospital for treatment and observation. The special workman suffered burns to his hands, arms and face. He was transported to the Glynwood Hospital for treatment and observation. The artisan's assistant suffered burns to his hands. He was transported to the Glynwood Hospital for treatment and observation.

Observations

The findings of the internal investigation conducted was:

- The oil circuit breaker ruptured its oil tank when it was closed.
- The moving contacts on the cable side of the circuit breaker were melted.
- The fixed contacts of the circuit breaker on the busbar side showed damage due to arcing.
- The rose joints on the busbar side of the circuit breaker were melted away.
- The busbar bushings on the panel were burnt extensively and the busbar chamber of the panel together with adjoining panels was filled with carbon and soot.
- A cable fault was located on the relevant circuit which when excavated was found to be burnt back from a transition joint by approximately 300 mm.
- The tripping time of the feeder cable circuit breakers was set at 0,45 seconds and a circuit breaker operating time of 0,045 is assumed.
- Oil from the faulty circuit breaker was tested for insulation breakdown voltage and a value of 33 kV was observed.
- Oil from an adjacent circuit breaker was tested and a value of 42 kV was observed.
- The circuit breakers of sub 16 had a short circuit current rating of 150 MVA = 7,873 kA.
- The calculated short circuit current at the time of the fault was 9,208 kA (A 40 MVA transformer with 22,8% impedance at 11 kV was supplying the switching station at the time of the incident).

Considering the observations made the following is deemed to be the most likely sequence of events that led to the incident on 11 of March 2013.

- The medium voltage cable in question failed causing the protection system to operate and open the circuit breaker.
- On arrival of the standby personnel racked out the circuit breaker and proceeded to test the circuit.
- The test indicated no fault as they were testing between the earth and the cores of the cable. The fault most likely being a fault between cores or an open circuit

fault of which the tester could not arc over the air gap.

- The personnel then racked the circuit breaker into position and the circuit breaker was closed. The resulting in-rush current caused the fault in the cable to draw a fault current that is calculated at 9200 A. This fault current was enough to melt the moving contacts of the circuit breaker on the cable side and the resulting arc then flashed over onto the fixed contacts of the circuit breaker.
- The fixed contacts sustained damage and the rose joints between the circuit breaker and the busbar contacts melted.
- The intense heat and release of energy caused the busbar bushing to burn and the oil tank of the circuit breaker to rupture. The resulting fire destroyed the circuit breaker and caused damage to adjacent panels including the secondary wiring, the protection relays and ammeters.
- The fire also injured the personnel on site.
- The circuit breakers at the supply substation tripped isolating the supply to sub 16.

Conclusion of investigation

The investigation points to the following:

- The short circuit current rating of the circuit breaker was exceeded sufficiently to cause a catastrophic failure of the circuit breaker.
- The resultant fire caused enough damage to make the equipment in the switching station unsuitable for use.
- The standby personnel omitted to utilise the personal protective equipment supplied to them for the functions that they were performing.

Contraventions

Part B of the EMM Energy Department's General Instructions, Operational Procedures and Policies, Section no 14, Substations Sub Section 14.4.5. and 14.4.6 states the following:

"14.4.5. No MV/HV/EHV switching, linking and earthing shall be carried out unless there is a minimum of two people present, an authorised person and a responsible person.

14.4.6. Before any switching, linking, earthing, etc. either MV/HV/EHV or LV is carried out the appropriate protective clothing and equipment must be worn under all circumstances."

OHSA General Safety Regulations

"2(6) An employer shall not require or permit any employee to work unless such an employee uses the required safety equipment or facility provided in terms of this or any other regulation.

General duties of employers to their employees

Section 8

As far as is reasonably practicable, not permitting any employee to do any work or to produce, process, use, handle, store or transport any article or substance or to operate any plant or machinery, unless the precautionary measures contemplated in paragraphs (b) and (d), or any other precautionary measures which may be prescribed, have been taken... taking all necessary measures to ensure that tire requirements of this Act are complied with by every person in his employment or on premises under his control where plant or machinery is used; enforcing such measures as may be necessary in the interest of health and safety."

The EMM Energy Department's budget for protective clothing during the 2012/2013 financial year was over R4-million. A tender is in place so as to ensure that only the best quality and highest rating protective clothing is supplied to personal. By having a contract, there can be no excuse given as to why the specified protective clothing/equipment is not supplied.

Departmental recommendation

- That for the sole purpose of preventing incidents of this nature in the future, the Executive Manager: Support Services, Electricity and Energy be instructed to include, in conjunction with the Director: Operations and Maintenance, in the induction course/training related to safety, first aid and the general instructions, operational procedures and policies, to all existing and newly appointed employees, students, apprentices and contractors in the electricity and energy department, the approach to similar incidents.
- That for the sole purpose of preventing incidents of this nature in the future, the chief/acting chief area engineers be instructed to reiterate and workshop the wearing of protective clothing and equipment as defined in the standard operational policies and procedures documentation.
- That for the sole purpose of preventing incidents of this nature in the future, the council be instructed to amend the disciplinary procedure in order to empower the chief/acting chief area engineers to suspend, without pay and without disciplinary enquiry for a period of one week, any person that does not comply with the wearing of protective clothing and equipment as defined in the standard operational policies and procedures documentation.
- That for the sole purpose of preventing an incident of this nature in the future, the chief area engineer (Boksburg) be instructed to refurbish the switching station with switchgear capable of withstanding at least 20 kA fault current.
- That for the sole purpose of preventing incidents of this nature in the future, the chief/acting chief area engineers be instructed to compile a basic safety checklist of actions that should be taken before switching is to happen and for such a checklist to be affixed to the wall of every substation and switching station.

There is no mention of disciplinary action to being taken against the four persons injured for not wearing the personal protective equipment supplied to them for the functions that they were performing as defined in the standard operational policies and procedures documentation. This point was discussed at the corporate occupational health and safety committee meeting where consensus could not be reached as to whether or not disciplinary action should be taken. One view was that the injuries were serious and that to then put the four through the further stress/trauma of a disciplinary would not be the correct thing to do. The argument against not taking disciplinary action was that others who also do not always wear the correct protective clothing for whatever reason would assume that action would not be taken and possibly continue not to wear the protective clothing.

At present to enforce such measures as may be necessary in the interests of health and safety, chief/acting chief area engineers may send home without pay, any person that does not comply with the wearing of protective clothing and equipment as defined in the standard operational policies and procedures documentation for a period of one day.

An additional concern that all staff need to be made aware of is that should they be injured on duty and they are not wearing the required protective clothing there is a possibility that workman's compensation may not pay for the treatment.

Conclusion

- Whenever possible all switching must be done remotely. (There are portable units available that can be used where the breaker itself does not have opening and closing coils.)
- Chief/acting chief area engineers must do more workshops with all staff on EMM Energy Department's general instructions, operational procedures and policies.
- All staff must do written tests following the workshops to ensure they understand the requirements of the operational procedures and policies with specific emphasis being put on safety and the wearing of safety clothing/ equipment. (If a person is unable to write, oral tests can be done.)
- Any staff member found not wearing the required protective clothing/equipment whilst performing any task must be sent home immediately without pay for that day or part thereof.

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Distribution automation sets network standards and smart grid roll out

by Tim Spearing, Lucy Switchgear, UK, and Rick St. John, Lucy Switchgear, SA

The challenges of electrification of many new and existing distribution networks are at the cusp of the evolution of the smart grid. Utilities are charged with meeting network performance measures and improving network infrastructure whilst facing cost down pressures.

Distribution automation techniques will become an integral part of network design, and will align with many smart grid initiatives. Minimising cost whilst maintaining performance expectations is a driving issue which can be managed by a staged approach of understanding the network and carrying out minor improvements before making potentially further investments.

An approach of using "automation ready" switchgear and modular automation solutions are discussed in this paper as an efficient means of enhancing a distribution network. This approach affords the flexibility for future upgrades providing an efficient smart grid roll out.

Automation techniques are an enabler for outage reduction of distribution networks. The key decisions are in choosing the right automation points that have the most impact and also having the appropriate means at each automation point to provide the most cost-effective solution. This requires investing in sufficient distribution automation proportional to the number and location of feeders, and how they are divided in order to provide the best outcome.

Network automation techniques such as changeover schemes, auto-isolation and fault detection, isolation and restoration (self-healing) will become an integral part of future network designs. However, there will be a tipping point between the automation intensity and the benefit a utility receives from investing in automation. The tipping point may be different depending on the distribution network, the available communications infrastructure and the stage at which the utility is in automating their distribution network.

Different feeders may have different characteristics such as load, length, potential connections and sources of generation. The design of the MV network plays a significant part not only in the cost of the overall network but also how the network performs. A radial feeder supplied by a primary substation has no method of connecting to any alternative supply. For a fault on any one section of cable, customers downstream of that fault must wait for repairs to be made before supplies can be restored.

Feeders which form an open loop network, as illustrated in Fig. 1 are able to mutually support each other. For any cable fault, the customers downstream of that fault do not need to wait for repairs because they can be reconnected to a supply by switching the network around. This means that the normally open point (NOP) switch between the two feeders will need to be closed after downstream disconnection.

In order to manage an active distribution network there is a need to dynamically reconfigure grids to help reduce losses, increase electrical headroom and to improve the reliability. Dynamic network reconfiguration contributes to these through being able to shift the NOP, reducing the number of switching actions (and travel of personnel) and allowing different load profiles to be exploited. It also allows deferment of investment (in primary plant). Note that in allowing deferral a solution must not result in lock-in to a specific technology or product (unless standards are in place).

The challenges of reliability

The challenges facing utilities in building modern electrical distribution networks is how to achieve reliable power delivery whilst lowering the capital and operational costs. Therefore, effective capital investment strategies are needed to maximise the asset life of the installed equipment and to add automation and control in a cost effective and timely manner.

As utilities manage a more active distribution network, handling more dynamic power flows and integration of renewable energy sources, they will need to overcome aging assets as well as introducing new installations and facilitate a smarter network through remote and automatic control of MV down to LV installations.

As these networks become more dynamic then matching supply and demand will become more of an issue as an increased network capacity is not always available. The use of distribution automation to manage the network more efficiently in order to maximise the "electrical headroom" will become more important. However, the benefits of the investment must be greater than the cost of developing a distribution automation solution.

Stages of automation

Basic automation

This would essentially be the local automation of the switch. This could be an automatic isolation scheme or an automatic changeover scheme. This could function without indications to the control room although the control room would really need to be aware, and thus this scheme could fit in-between the next two stages.

Indications

The manually operated ring main unit (RMU) can have some intelligence by way of local fault passage indicator (FPI) indications. The FPI is a device that gives an indication as to

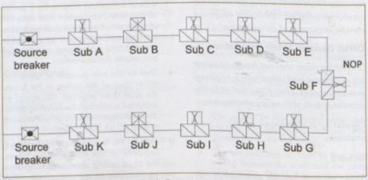

Fig. 1: Open ring network.

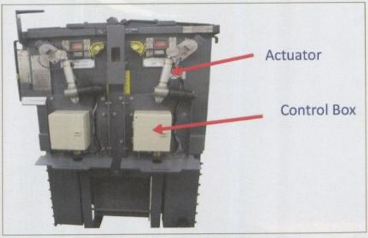

Fig. 2: Retrofit actuator on oil RMU (Long & Crawford).

Fig. 3: Retrofit actuator on SF6 RMU (Lucy Switchgear).

whether fault current has passed the point where it is located. Secondary substations are unmanned and require travel to site in order to operate or as a minimum to determine if the FPI has operated. Automation at this stage is to transmit fault passage indicators to the control centre in order to allow fault location to be achieved quicker than physically investigating each FPI manually.

Development of brownfield substations can be achieved in two ways; installing new switchgear or applying retrofit actuator kits to existing switchgear. Fig. 2 shows a linear actuator that has been retrofitted to an existing oil RMU. This provides position indication as well as control facilities, and when connected to a remote terminal unit (RTU) can be controlled remotely.

With some foresight it is also possible to have "automation ready" switchgear (pre-wired looms), as illustrated in Fig. 3. This means that an actuator can be easily added whilst the switchgear is live.

Remote control

The next level of automation is the remote control of switches, including automation functions such as reclosers and sectionalisers. Driven by the need to meet performance expectations utilities are already investing in solutions to reduce restoration times and eliminate temporary outages through the deployment of remote control and distribution automation techniques.

Self-healing

This level of automation is the "self-healing grid" where the fault detection, fault clearance and re-supply to customers is achieved automatically without manual switching and without operator intervention. This can be achieved with various degrees of control from centralised to decentralised with peer-to-peer communications. There are degrees of functionality with their respective advantages and disadvantages between the centralised approach and a distributed approach.

One of the key observations is that there is currently a greater degree of situational awareness with a centralised approach. For example, some utilities may interconnect their LV networks. This level of information may not be available for a decentralised self-healing approach and thus a centralised approach may be more suitable.

Migration to the smart grid

An active distribution network will support self-healing (fault detection, isolation and restoration). Current developments in self-healing will reduce SAIDI[1], but the benefits will not increase proportionally with the penetration of automation. This is illustrated by the top curve (no interconnection) in Fig. 4 which shows the reduction in SAIDI as more points are automated. This is explained further here after, but highlights that it is not essential to control all points on a network because of diminishing returns. Some established networks may have a meshed structure and will also have interconnections at MV. The bottom curve (interconnection) in Fig. 4 shows the improvement in SAIDI when there is a single interconnection (at substation D). As networks develop, the complexity of the network will also be an influencing factor. The tipping point in this scenario would suggest the optimal level of automation intensity is around 20 – 40%.

A network with low automation intensity would be more suited to a centralised approach of self-healing. This is because the SCADA/ distribution management system (DMS) will be able to take a wider view on the network and carry out a situational analysis before continuing with the self-healing. As the automation intensity grows then a regional approach is required, essentially to reduce the amount of communication traffic and to distribute the risk of a single failure. For a network with high automation intensity then peer-to-peer communications on a small regional level may be appropriate, although the merits of this are unclear regards the level of return from the investment.

The benefits of self-healing will be dependent on the state of the network and on the character of the connected loads, generation sources etc. (i.e. time based, weather or seasonal based), and so utilities should look for an optimal placement of the equipment. However, there is a need to monitor because most utilities report they have very little visibility of the MV/LV network.

Incremental development of the smart grid

There is a balance between performance expectations and cost, and the tipping point that helps decide what solution to invest in depends on the characteristics of the distribution network at that time. Typical decisions will be to make a full investment in automating a network, to defer investment to

Note 1: SAIDI – System average interruption duration index is the average duration of all interruptions per utility customer during the period.

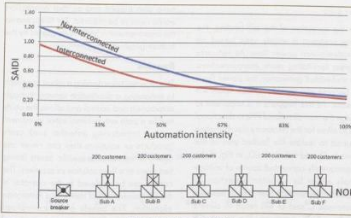

Fig. 4: Improvements in SAIDI[1].

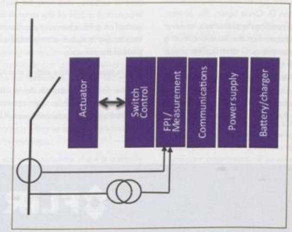

Fig. 5: Typical RTU structure.

another time or control period, or to make incremental investments providing a more immediate return. However, any of these solutions may also depend on the amount of information available from the network.

The solution to provide an effective, efficient and sustainable solution for a control and monitoring system is based on an incremental approach to developing the distribution network into a smart grid. The assets deployed have a relatively long lifetime and will not preclude future work. However, this approach allows solutions to be developed in a relatively short time, and affords an effective means of monitoring the network providing more information to help decide on which automation points would have the most impact as the system is developed.

This proposal considers the automation intensity and network complexity as a means of justifying the level of distribution automation through an incremental approach. In order to show improvements after the implementation of an automation solution, and to calculate the savings made as a result of the investment, it is necessary to identify key indicators. Factors to consider include average cost of operations, SAIDI, SAIFI[2], customer distribution and feeder lengths. For the purposes of illustration this paper will consider theoretical values of SAIDI and customer distribution.

Incremental investment

This is based on having or enabling "automation ready" switchgear and providing a modular automation solution which affords the flexibility and upgradeability to allow further incremental enhancements. This solution, if used for self-healing, would be based on a centralised approach. The aim is to help with cost savings in planning and implementation of networks where the full scope is unclear or too expensive to achieve without a longer term solution.

Remote monitoring

The approach is to deploy monitoring onto the MV network, initially at known key points but this can grow as and when more information is required. The minimal investment would be to monitor the flow of current with communicating fault passage indicators. This would typically comprise RTUs, FPIs, GSM/GPRS[3] modems, and an uninterruptable power supply. The GPRS/GSM is a relatively low investment approach and will allow the network to be monitored to help make future decisions. The options available are illustrated in Fig. 5.

This is not precluding other communications options such as radio, power line carrier and fibre optics. In fact, the communications protocol may be chosen to suit the purpose, but would operate within a virtual private network (VPN) and have appropriate security measures in place such as firewalls and secure authentication. This approach benefits towards developing a more reliable grid because it is possible to identify the fault vulnerability of the network in advance of further investment. This can also apply to LV as well as MV measurements (for when the RMU is connected to the LV network).

Switch control

Upon analysis of the network and the frequency of faults it may be required to remotely control the NOP and to add a single switch control to a disconnector on an RMU mid-way along the open ring dividing the customers into roughly equal halves. For this it would be necessary to add a control module to two of the installed monitoring units, and unless the switchgear is "automation ready" (as shown in Fig. 3), to retrofit a means of physically controlling the disconnector (as shown in Fig. 2). Retrofitting a remote-control facility to legacy RMUs is a means of implementing distribution automation but it is dependent on the physical ability of the switchgear to accept a retrofitted actuator.

Referring to the top curve of Fig. 4, and the under laying network of a source breaker supplying a ring of six RMUs up to the NOP, consider a fault has occurred between substation C and D. The primary source breaker is tripped by the primary protection, the down steam network is isolated from substation B, and the primary circuit breaker is then reclosed bringing 400 customers back on line. Adding further control points

Note 2: SAIFI – System average interruption frequency index is the average number of interruptions per utility customer during the period.
Note 3: – GSM (Global System for Mobile Communications) defines the entire cellular system. GSM uses digital technology and is the second-generation (2G) cell phone system. GPRS (General Packet Radio Services) is a wireless communication service for GSM that offers high data rates for continuous connection to the internet.

may not have any significant benefit unless the normally open point is used as a means of restoring power onto the network from another source. Applying remote control to points B, E and F gives an automation intensity of 50% and improves the situation dramatically as shown in Fig. 6. Thus considering another fault between substation C and D, the primary breaker is tripped by the protection, the disconnectors at substations B and E are opened thus the faulted section of the network is isolated. However, the customers supplied from substation F are on an unfaulted part of the network but no longer receive power and so the final control action is to close the normally open point and restore power to the remaining customers. Even by using remote control alone almost halves the SAIDI.

The remote operation of the switchgear and disconnectors, in this instance is performed by the control room operator. However, central decisions can be made by the DMS and communicated to the SCADA so that the operations are performed automatically. This is the path to developing a smart grid and can be part of a centralised fault detection, isolation and restoration algorithm.

Smart grids

With the exception of the self-healing, the above scenario is widely used based on a unidirectional power flow. As networks progress facilitating more interconnections and embedded generation the power flows will become directional and fault levels will increase. As this happens it is important to change the non-directional FPIs to directional FPIs to allow for the necessary discrimination required to isolate the faulted part of the network. Should substation D, in Fig. 4, be a permanently connected source of voltage supply either by an interconnection or embedded generation then a fault between substations C and D will result in current flow from both directions. The source CB will be supplying fault current as would the distributed generator/interconnector via substation D. Once again, the primary breaker is tripped by the protection; however the FPIs indicate that the faulted circuit is between substations C and D. The power is restored to most of the customers by opening the disconnctors at substations B and E, and closing the normally open point at substation F. The circuit breaker protecting the embedded generator would have also tripped and so that connection would need to be restored. For this scenario the improvement in SAIDI is illustrated by the bottom graph in Fig. 4.

Benefits

This proposal helps develop a robust approach to enhancing a distribution network through automation and control and allows the utility to take a path with minimal initial investment without introducing potential sunk costs (products or solutions they can never use again) or relationship-specific assets (being tied down to a fixed solution or supplier). The control can be achieved by the operator in the centralised control room, or a restoration algorithm. The benefit of the centralised control is that the DMS can make a situational analysis of the network before taking any control actions. This may be particularly important if a part of the network is being worked on or have temporary connections that may inadvertently link what would be isolated parts of the network.

Distribution automation setting standards

As the feeders become more complex, the number of tied connections increases. Network automation techniques will become

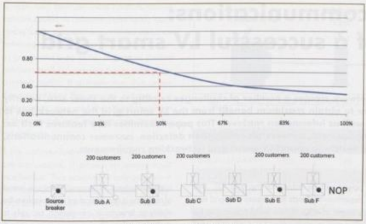

Fig. 6: Improvements in SAIDI (2).

an integral part in migrating to active networks because they support the network in becoming more complex. The complexity of the network not only influences the resultant performance, it also facilitates integration of distributed generation/ renewable energy sources. However, this complexity may introduce bi-directional flows thus introducing higher fault levels which will have to be managed.

In most electricity networks, there is a steady increase of load, but at the same time a network may be subject to a more sudden and specific load growth such as new industrial plants. Although load growth can be foreseen and planned over a long time scale, it would be possible to have a reinforcement plan based on a shorter time scale that could lead to a firm construction plan. Therefore, by using a NOP on the secondary network to reinforce a primary substation on a temporary basis would allow deferral of capital expenditure. The incremental approach proposed allows this to happen.

Smart grid roll-out

The method proposed helps utilities to understand their networks and where to place control points. In doing so, they can achieve significant improvements in reliability with a minimal investment. In addition this will bring an enhanced insight into the MV/LV networks. The utilities decision to implement such technologies may be bounded by the expected levels of network congestion, distributed generation, regulatory changes or changes in government policy. However, the incremental solution suggested means that utilities can maximise economies within the constraints of this bounded information and does not tie down the utilities to a specific technology or solution.

Conclusion

The levels of distributed generation or other forms of congestion may need to increase substantially for the economic justification to fully deploy distribution automation and control techniques in active network management. As utilities need to cater for the maximum contingency in the design of their distribution networks their decisions are bounded by having to accommodate the maximum possible load. This in itself is inefficient especially if the maximum possible load is infrequent. Moving towards an active management of the network would allow utilities to make more efficient use of their network because they would be able to manage the electrical headroom through dynamic reconfiguration of the network and applying time related constraints to generation and demand customers.

Fault detection, isolation and restoration can be achieved without communications, such as when the RTU is configured for a changeover scheme. However, a centralised approach allows integration of different vendors thus avoiding lock-in on the secondary equipment (accepting that there may be lock-in on the SCADA/DMS). If the infrastructure exists a modular approach will help in providing a solution for different system conditions and configurations, allowing integration of existing equipment.

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and facility-level business processes in an organised, hierarchical approach which includes understanding what is driving successful businesses to incorporate EHS issues into their culture, and tackling the key challenges for improved safety and environmental performance.

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Secure reliable communications: The backbone of a successful LV smart grid

by Andrew Goedhart, Util Labs

Deploying the smart grid into the LV network creates a number of challenges relating to the sheer size, security and reliability of the network. If we are to obtain maximum benefit from the LV smart grid the network has to support both command and control as well as information retrieval. This paper examines how features such as: operations and maintenance, asset management, network planning, theft detection, customer communications, tariff structures, load management and matching impact LV smart grid networking requirements.

The smart grid is being driven by the global need of utilities and government to increase reliability and security of supply in the face of constrained and ageing distribution, transmission and generation infrastructure and variable intermittent generation from renewable energy sources [1]. This is coupled with an increased variability in demand.

The focus in the utilities has mainly been on the HV and MV portions of the grid. This is in part because it is better understood, logistically simpler to implement and wholly under their control. The integration of the LV network has been largely limited to the roll-out of electronic meters. For the purposes of this paper the LV smart grid is defined as the portion of the distribution network from, and including, the LV transformer and extending into the customer's home (Fig. 1).

The impact of renewables

Historically the majority of South Africa's generation capacity has been made up of coal fired and nuclear power plants that provide a stable generation capacity. This means that in the face of constrained supply the focus is shifting to controlling and reducing demand. Demand peaks during winter are typically from 06h00 – 09h00 and 18h00 – 21h00 and driven primarily by residential demand [5]. These peaks are driven by household demand located in the LV distribution network. Traditional peaking solutions of pump storage and gas turbines are expensive to build and operate.

With increased constraints in supply likely to continue for the foreseeable future there is increased focus on residential demand side management (DSM). Grid stability requires that the DSM devices implement reliable two way communication that can support real-time control functions and feedback.

The South African Department of Energy has completed two rounds of the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) and is continuing with a third round. Under this programme 1850 MW of wind and 1650 MW of solar power will be added to the grid [3]. The department intends to increase this and has a target of 42% of new build capacity to be allocated to renewables [2]. Only 200 MW of the current renewables include grid tied storage. This means that the output from this generation capacity is variable and highly dynamic as well as wasted if not utilised.

As more renewables come online the focus will have to change from removing demand in times of constrained supply to matching demand to supply.

Multiple strategies to implement load matching that are currently being piloted include real-time peak pricing [4], two way ripple [9] and residential demand market participation [10]. This change to load matching has huge impacts on the underlying communications protocols because it forces the LV smart grid to be able to respond to changing events in real-time or near real-time. It also means that the LV smart grid extends into the private homes where the loads are situated. This has direct impacts on system security, data and customer privacy and ultimately, if not implemented correctly, can affect grid reliability by causing oscillations in the grid's dynamic response.

Increased customer communication around dynamic tariffing or billing requires a secure audit trail [8]. This is particularly important where customer connected devices incur cost as they respond automatically. Security concepts such as identification, authentication and non-repudiation become critical for such communications. In dynamic situations, speed of response is very important and therefore the ability to broadcast information securely to multiple parties with one message is required.

Increased distributed micro generation from solar, ageing distribution infrastructure and changing load profiles due to changing standards of living and increased electrification [7] require local control to ensure load matching and avoid stressing of the LV transformer. This local control must function even in the event of link failure with the central back end.

Operations and maintenance

Optimal operations and maintenance strategies require real-time feedback from the LV network to locate the source of fault during an outage. Faster fault categorisation and localisation leads to better response times in group faults. Better identification of fault location during initial customer contact allows for faults on customer premises to be identified and closed during the initial contact (see Fig. 2). This reduces call outs that have to be handled by the field staff by up to 30% and allows faster resolution due to proper vectoring and reduction in "no fault found" calls. Real-time feedback requires a protocol that supports pushing of alarms from the underlying network. Polling of a large number of devices increases the underlying network response time and load, especially when locating group faults. The mechanism used in the physical and network layers to control access to the underlying network

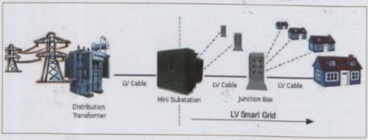

Fig. 1: The location of the LV smart grid.

is important because most random access network protocols collapse under heavy load. Heavy loads in operations and maintenance networks typically happen during events such as group and area faults. In general control networks tend to have very bursty rather than constant traffic. It is imperative that under these conditions the network behave in a deterministic way and that the throughput of the network and the response times do not collapse.

If the communications and power network are co-located, it allows for easier fault localisation. This however is only possible if the nodes in the network continually monitor each other, because the link between devices may be inoperable during fault conditions. Co-location of communications and power allows for better mapping of the customer network link (CNL), especially under changing distribution topologies. The co-location also allows for accurate mapping of the LV grid. If the network topology is tracked accurately then the loss of communications can be used to accurately locate faults. In most municipalities the customer configuration below the LV transformer is largely unavailable. Even where it is available, the 27 000 supply points sampled during the field trial conducted by Util Labs shows that it is only about 75% accurate. More accurate CNL allows for better maintenance planning as well as better fault location and shorter response due to more accurate dispatching of field team.

The reliability of LV smart grid is critical to its efficient function. The LV smart grid needs to implement sufficient mechanisms to enable it to function reliably even when the underlying communications channel is inherently unreliable.

Asset management and network planning

Accurate CNL tracking is required for both network planning and asset management. Better CNL allows more accurate tracking and prediction of network and transformer loading. Accurate prediction allows better planning when allocating new builds. Accurate tracking requires both co-location of network and power networks and energy balancing to ensure new builds, missed points, phase changes and other network topology changes are tracked. Energy balancing and phase tracking requires millisecond accurate time to be distributed between the field devices. This requires either a separate time source such as GPS receivers on every device or for the underlying communications network to guarantee and provide accurate packet timing when broadcasting time synchronisation packets. It also requires that all nodes in the same LV distribution network are reachable in a single hop as multi-hop networks add variable delays that interfere with extracting the required millisecond accurate timing information.

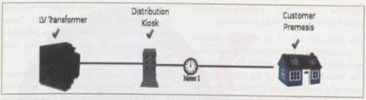

Fig. 2: Real-time customer network link status feedback used by customer care from the field trials.

Frequency (MHz)	Power (mW)	Duty cycle (%)	Channel space (kHz)	Regulations	Restrictions
169,4 – 169,475	500	10	50	EN300 220	Meter reading
173,23 – 173,28	10	100	25	EN300 220	
433,05 – 434,79	10	10	None	EN300 220	Digital modulation
433,05 – 434,79	10	10	25	EN300 220	
868,00 – 868,60	25	1	None	EN300 220	LBT
868,70 – 869,20	25	0,1	None	EN300 220	LBT
869,40 – 869,65	500	10	None	EN300 220	LBT
869,70 – 870,00	25	1	None	EN300 220	LBT
2400,0 – 2483,5	10	None	None	EN300 440	

Table 1: Gazetted open bands for SRDs.

Fraud and theft detection

Fraud detection requires accurate configuration management and change tracking. It requires constant auditing of configured parameters and high levels of security around change management. Users and network devices need to support proper security measures in line with FIPS 200 [12] and EN 62443-2-1. This includes proper identification, authentication, non-repudiation and data/packet tamper detection as well as audit trails on the individual devices. Because security is a holistic endeavour the network and protocol implementation needs to support these measures to ensure the compliance of the system as a whole. Careful attention needs to be given to system security boundaries especially where there is a hand over of responsibilities between system components.

To minimise the window for fraud, the deployed devices need to perform regular audits of their own configuration and push the results to a central server for checking and verification against centrally stored and authorised configurations. Typically this needs to be done at 06h00 and 24h00 hours. This requires the network protocols to support push, and increases network traffic.

Theft detection requires energy balancing of supplied energy with consumed and paid for energy. This is the only method of reliably detecting theft in a network. Both detecting and identifying energy theft requires accurate CNL information. This information needs to be kept up to date during network maintenance, new builds etc. The quality of data captured by manual processes is usually low. Even if a huge effort is expended to ensure a high input quality during the initial roll out, the quality tends to decay over time due to network maintenance. The only way to reliability obtain the information is to ensure the underlying network monitors and reports on this automatically. This requires that the communications network be co-located with the power distribution network. Ensuring that the energy balance and subsequent theft detection can be performed with a low false alarm probability, requires that phase information of the metering points be tracked accurately. It also requires accurate clocks to ensure proper synchronisation of the measurements. This requires that the underlying communications network be able to distribute and report on timing information in the millisecond range. Ensuring that energy theft is detected within 24 – 48 hours of it occurring requires very frequent measurements (<5 minute intervals). This also increases load on the underlying communications network.

Physical environment

The topology of the LV distribution network in South Africa is hierarchical. Typically a ring mains feeds a number of LV transformers. From the LV transformer a number of overhead or underground LV distribution cables are run. At points along the cable a distribution kiosk services a number of supply points. In overhead lines the number of supply points serviced from a single pole is usually lower.

From the kiosk or pole, a cable or overhead wires runs to each individual customer.

The physical layout of the distribution infrastructure impacts the choice of underlying technology and communications protocols. The maximum length of the cable runs is especially important as it impacts whether the underlying physical technology needs to employ a multi-hop network or not. Multi-hop networks decrease the bandwidth and increase the complexity of installation and maintenance of the underlying communications network. Fig. 3 shows the distribution of maximum distance between LV distribution transformers and furthest kiosk for all the networks in the field trial. The maximum distance required by single hop networks is roughly double the distance to the furthest kiosk because normally more then one cable is run from the LV transformer and usually in opposite directions to minimise cable cost and maximise coverage. If the underlying communication protocol wants to avoid packet collisions and heavy performance degradation under load due to multiple nodes transmitting at the same time, the nodes at the furthest points on the network need to hear one another. This issue applies equally to radio and PLC networks and is known as the hidden node problem [11].

Regulatory environment

Deploying a communications network for an LV smart grid impacts on regulations and standards outside of those controlled by NERSA. These include the Electronic Communications Act (36/2005). ICASA is responsible for issuing regulations in terms of this act. The Act requires all communication networks to be licensed by ICASA. This is separate from the licensing of radio, PLC or other spectrum. Currently a network can be exempted from licensing if it is "a private network used principally for or integrally related to the internal operation of the network operator." [15] (Section 6.40). This requirement means that the network must be owned by the operator and does not carry any traffic on behalf of third parties.

Under this Act ICASA can publish regulations in the government gazette around "Approval of Type" for network communications equipment [15] (Section 35) ICASA has published "Regulations in Respect of Technical Standards For Electronic Communications Equipment" [17] that determine the standards the telecommunications equipment has to comply to.

Radio

In terms of the Electronic Communications Act (36/2005), all radio based communications require a radio equipment type approval certificate to be issued before being allowed to be marketed or sold. In addition a spectrum license is required unless the device operates in one of the current open bands. These bands are defined in regulations published in Government Gazette 31290 [16]. (See Table 1.)

Currently there is a mismatch between EN, SADC and RSA regulations in regards to the usage and allocation of the 863 – 868 MHz non-specific short range device (SRD) bands. The regulations state that all SRDs are operated on a non-interference/non-protection basis. This makes high reliability of such network difficult to ensure. Listen before talk (LBT) is defined in EN300 220 [19] and is currently the only regulated mechanism to ensure co-existence between transmitters in the SRD bands. LBT is only applicable to the 868 MHz spectrum. Duty cycle requirements where the duty cycle is high and there is no channelisation leads to heavily congested bands. The 169 MHz band reserved for meter reading is only able to accommodate a single channel given the requirement for 50 kHz channelisation. This means the complete deployed network is required to share a bandwidth of less then 25 kbps.

SRD equipment in the 2400 MHz band competes with other equipment in the same band that the regulations allow to transmit at much higher power outputs (100 mW and 500 mW). The main water absorption frequency of 2450 MHz is located in the middle of the band. This makes devices operating in the band very susceptible to adverse weather conditions. This is one of the reasons this band was originally allocated to SRDs as it was deemed not suitable for fixed microwave links.

The Radio Frequency Migration Plan issued by ICASA [18] intends to migrate fixed links out of the lower frequencies to free this up for mobile communications. This means existing licenses in the lower bands for exclusive point to area spectrum will be migrated out and

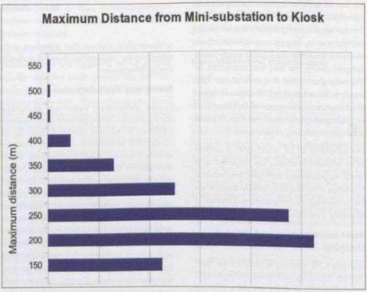

Fig. 3: The distance from LV transformer to the furthest distribution kiosk in the trial sites.

Identification and authentication	Verify the identity of the user
Access control	Does the person have the rights to do what he has requested ?
Audit and accountability	What did the person do ?
Configuration management	How should the system be configured?
Maintenance	Is the security system kept up to date
Personnel security	Vetting of personnel and notifying the system of terminations and transfers
Physical and environmental protection	Are installations protected
System and communications protection	Monitor, control and protect information
System and information integrity	Identify, report and correct data tampering and protect systems from malicious code

Table 2: Basic security requirements.

new licenses will become increasingly difficult to obtain.

Narrow band PLC

Currently narrow band PLC is not regulated outside of the normal requirements for compliance with SANS 222 [21] and SANS 224 [22]. These standards cover radiated and conducted emissions above 150 kHz and EMC susceptibility. The only published SANS standard is SANS 50065-1:2012 [23]. Whilst the standard deals with 10 – 149 kHz PLC, the forward of this standard reserves the band up to 500 kHz for utility use.

Currently low cost grid tied inverters and active power correction devices pose a huge threat to the <150 kHz band due to SANS222 and other regulations only covering emissions starting at 150 kHz.

In Germany due to the interference being experienced from solar converters, the regulator has accepted a number of "technical files" for G3-PLC operating using FCC-1 profiles (150 – 480 kHz). As more solar comes on line this trend is likely to spread to other areas of Europe.

Regulations on cyber security

Electronic Communications and Transaction Act, 2002 [14] covers issues around automated transactions (Section 20). It specifically requires careful examination of the measures taken to ensure the privacy, integrity, source and authenticity of transactions and data when submitting electronic evidence to court (Section 15). Its definition of personal information does not directly cover measurements or information normally transmitted during the operation of LV smart grid, unless that information is used as a basis for correspondence, billing and automated transactions. This is particularly important where customer actions lead to billable or refundable events and where connected devices incur cost or obtain credit as they respond automatically.

NRS057 [8] is part of NERSA licence conditions and requires secure audit trails for all billing.

The Protection of Personal Information Bill [25], first tabled in 2009 and awaiting final approval by parliament, requires organisations holding personal information including information around financial transactions and communications to take appropriate reasonable technical and organisational measures to prevent loss, damage or unlawful access to such information (Section 18 (1)) and to identify all reasonably foreseeable risks and implement safeguards for them (Section 18 (2)).

Basic security concepts

Currently there exists no SANS standards that cover security required for smart grids. The USA has taken the lead in this area with the publishing of NISTIR 7628 [26] – "Guidelines for smart grid cyber security". Core to these guidelines are FIPS (Federal Information Processing Standards). Of particular interest is FIPS 200 [12] that outlines the basic minimum security requirements for all federal information systems. These are broken into three areas: users, management and protection and are shown in Table 2.

The evaluation of a security system must always be done in the context of an organisation. Technology and systems can aid in the deployment of a secure system, but the procedures used within the deploying organisation are critical in ensuring the security of an operational system. In fact FIPS 800.53 "Guide for assessing the security controls in federal information systems and organisations" [13] looks almost primarily at how the security is implemented from an organisational context and views technology in supporting but critical role. Central to this belief is that security systems are complex and therefore a single technology or implementation cannot cover all the various aspects as listed in FIPS 200 above.

Another central theme is that security should be layered and compartmentalised to ensure that a single successful attack does not lead to the compromise of a large part of the system or organisation. Because security has both social and technical aspects a compromise in some part of the system is almost guaranteed. Regular audits ensure such compromises are discovered early and compartmentalisation and layering ensures that their effects limited and recoverable. Audit trails and proper authentication and identification then ensure that the responsible party can be identified. It is critical that the organisation then takes action to ensure that the perpetrators are dealt with appropriately. There must be consequences for one's actions or the entire system falls apart.

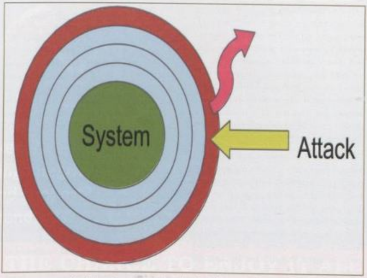

Fig. 4: Layering as a security mechanism to limit security breaches.

Existing AMI protocols

SANS/IEC 62056-21 "Electricity metering – Data exchange for meter reading, tariff and load control" [24] defines one of the most commonly used protocols to configure, control and extract data from a meter. It was initially designed to configure and query a stand alone meter via a local serial port. Over time it has been adapted and extended to cover many different transport mediums and additional aspects suchas alarming.

Unfortunately it suffers from major draw backs around security, scalability and standardisation.

SANS 62056-21 is session based. Every time contact with a meter is required, a session has to be established, the communications completed and the session torn down. This set up/tear down process is slow and requires a large amount of communications overhead and state tracking. Links cannot be kept open indefinitely because of a 60 s time-out in the protocol. This makes it difficult to scale in situations where a back-end needs to communicate with millions of devices simultaneously over a short period of time such as during an emergency demand response incident.

SANS 62056-21 defines four levels of security which are based around passwords and physical access. The protocol does not provide for any means of identifying the user. This means compliant implementations do not meet basic security requirements around identification, authentication and audit trails making it impossible to hold people accountable. This lack of accountability is listed as a specific concern with existing meter deployments in NISTIR7628 [27].

The standard also leaves critical aspects of the implementation such as the authentication algorithms undefined. This is problematic because many of the algorithms are proprietary and not open to public review. Some of these are not secure. This variation lead to incompatible implementations. This results in meters having to be configured and managed through vendor specific master stations.

Implementing a LV smart grid protocol

Between 2009 and 2011 Util Labs rolled out a 40 000 device network to do emergency demand side management. The majority of the devices were installed in Northern Suburbs, Johannesburg but sites in Cape Town and Durban were also included. The functionality grew over time to include metering, fault detection and outage management, customer disconnect/reconnect, energy balancing, network planning, transformer monitoring, messaging, and customer network link mapping.

The system was designed to use PLC as the communication medium in the LV network and GSM GPRS was used for back haul from the LV transformer. Radio was initially considered but was eventually discarded in favour of PLC. The reasons for this included:

- The distance from the distribution kiosk to where the display was located in the house was in some cases greater than 70 m.
- The fact that some of the kiosks were made from CR12 stainless steel and would require external antennas that were susceptible to tampering.
- The difficulty in penetrating multiple layers of re-enforced concrete used in the construction of some of the customers' houses.
- The duty cycle requirements for the system as a whole.
- Difficulty in managing public sentiment towards radio due problems with competitor AMI installations in neighbouring Blairgowerie.
- PLC was able to properly map the customer network link.
- PLC was able to provide better information regarding fault location and detection.

PLC physical layer

Currently narrow band PLC in South Africa is not regulated. ICASA is accepting PLC equipment for type approval that transmits at frequencies up to 500 kHz provided that it can be shown that it does not cause interference with existing radio licenses and meets requirements of SANS 222. The process is similar to the 'technical file' process allowed by regulators in Europe under the IEC regulations.

The 150 – 500 kHz (FCC) band has a number of advantages over the CENLEC bands (10 – 149,5 kHz) These include:

- Less noise due to FCC band being covered by the existing conducted emissions framework of SANS 222. Currently CENLEC A bands have no regulations limiting conducted emissions from other devices such as grid tied inverters which is problematic.
- A much larger bandwidth available. 350 kHz vs 60 kHz in CENLEC A.
- Higher and more stable line impedance. This is typically around 5 Ω for FCC and varies down to less than 0,5 Ω for CENLEC A. Low impedance requires higher driving power and leads to bigger power supplies and greater cost. Variation in line impedance leads to greater channel non-linearity, increasing signal distortion.
- CENLEC A requires considerably larger line couplers. This is due to the size of the safety capacitors in the line coupler circuit being inversely proportional to the lowest transmitted frequency.

The move to SANS 50065 specifically reserves the frequency band from 150 – 500 kHz for utility use. The increased bandwidth available is critical for robust communications as it allows modulation techniques to work around noise sources whilst still providing sufficient bandwidth for command and control. Due to when it was implemented, the PLC implementation used in the field trial is a modified version of home plug command and control. Currently however there are FCC variants of G3-PLC implemented by Maxim, TI and Enverv that operate in the same band providing greater throughput and similar robustness. During the field trial we tested the Enverv implementation on some of the worst sites in the field trial and received throughput of >160 kbps even in the presence of active interferers at distances of >500 m.

Robustness of communications is a crucial component of any blanket roll out as the reliability of the network is critical. Such a roll out does not allow for careful placement of network components and fine tuning of the network parameters. The devices must just work when place in the field at the predefined locations by the installation team. Experience gain during initial roll out of the field devices during the field trial indicated that the success of the installation was inversely proportional to the amount of human intervention required during set-up. Eventually the set-up process was completely automated through a hand held device with the only operator intervention being the selection of the network master if more then one master was detected on the network.

Protocol level optimisations

The network and application level protocols were designed for a bad communications environments. It was assumed that links would not always be available and certain cases there would be high error rates on the PLC network due to noise and interference. It was also assumed that the noise would result

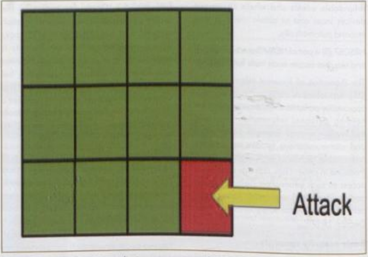

Fig. 5: Compartmentalisation as a security mechanism to limit security breaches.

in lower available bandwidth and that traffic would be bursty resulting in a requirement for determinism in network access.

The first optimisation was to minimise packet sizes. Assuming that the probability of a unrecoverable bit error is constant for a channel, the chance of bit error will cause a packet to be discarded increases with increasing packet length. Minimising packet size reduces the chance that packets have to be discarded.

Packet size can be minimised by reducing routing and packet overhead and also by using binary payloads and data compression techniques where appropriate. It is also better to split large packets into smaller ones where the average packet loss rate due to bit errors exceeds the packet overhead due to framing. For home plug the this was typically less then 100 bytes on noisy networks. The packet overhead is very much dependent on implementation of the physical layer and will change for protocols such as G3-PLC that transmit multiple bytes per data symbol. This optimisation was critical to ensuring reasonable link throughput because on certain PLC links the packet loss rate for long packets was as high as 50%.

Smaller packets also aid in ensuring better response times because on average other devices have to wait less time to get access to the channel. This makes the network more deterministic for command and control applications.

If the links are frequently dropped and multiple links exist between the device and the server, then the chance of a session based protocol succeeding decreases with the number of links as shown in Fig. 5. To work around this two technique were used to increase reliability of the communications. The first was to use store and forward mechanism similar to SMS where packets are held at a device and only forwarded onto the next device when the link is available. Provided the buffers on each device do not overflow, there is no time limit as to how long each packet is held as would be the case with a session based protocol.

The second technique is to get devices to push messages to the server rather then being polled. The removal of the request messages reduces overall network traffic. Since processes executing on the server are not forced to wait for response, this results in less state tracking and therefore greater scalability.

Store and forward coupled with push also help with bursty traffic because they can be used to smooth out the bursts. However most random access networks collapse if the network utilisation rises above 40% due to the high number of packet collisions during

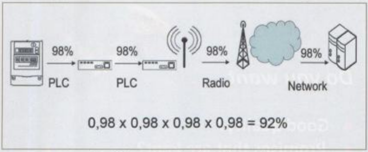

Fig. 6: Chance of session based protocol succeeding.

transmission. Ensuring that all network devices hear one another allows collisions avoidance techniques to be used by transmitting nodes and this substantially increases throughput under heavy load. In the field trial the home plug command and control protocol was adapted to given each node on the network a unique priority which resulted in a completely deterministic access scheme for the network and completely avoided collisions during transmission. This allowed the devices on the network to utilise 95% of the available bandwidth under heavy load [6].

System optimisations: designing for communications failure

If the system is designed to handle communications failure gracefully it can substantially mitigate the effects of such a failure. In the LV network the devices that make up the nodes of the network have limited resources. This means that if a link is down for extended periods buffers can overflow and messages will be lost.

Messages can be lost in both directions. The server needs to have a way of identifying when messages are lost and recovering automatically. Typically messages sent to the device relate to requests for information or configuration. Requests will time out and can be resent. If all configuration areas are checksummed and the checksums are pushed to the server on a regular basis, then any discrepancy between the configured setting and devices current state can be detected and rectified. This requires the server to be the single master data source for all devices and network configurations. This provides an added benefit that if a devices local configuration is tampered with, it will be detected and resolved quickly.

To allow for the detection of lost messages pushed from the device, sequential transaction IDs are added to all messages containing critical data such as alarms and measurements. These messages are first written to logs in permanent storage before being sent. The logs are implemented as circular buffers and can typically store six months worth of data before oldest entry in the log is overwritten. On receiving a pushed message, the server checks for gaps in the received sequential ids and requests any that are missing.

Security boundaries

When applying security techniques it is very important to understand the concept of the system boundary. All traffic that crosses the boundary need to be secured. Not correctly identifying the system boundary and securing it correctly can lead to a compromise of both systems. Sometimes where the system boundary is located changes due to the context in which a device is used. For example most PLC modems can be setup to encrypt traffic it receives in clear text on the serial link before it sends it out on the PLC network. If the modem and the host processor are used in an unsecured environment, the whole system may be compromised because traffic injected into the serial link is seen as authentic by all other devices on the PLC network.

GSM SIM attacks

During the field trial, devices containing GMS modules were targeted by criminals for their SIM cards. The SIMS were placed in phones and used with USSD to enter competitions to win airtime. The air time was then sold. Though all services other then GPRS were meant to be blocked by the network operator, USSD could not be blocked because it was used to setup GPRS sessions.

The SIMS had very low credit limits. Unfortunately the service provider only receives the SIM's call data records once a day from the network. This allowed the criminals up to 24 hours to run up very large bills before the SIM was disabled due to it exceeding the credit limit.

The use of a pin code as a mechanism to protect the SIM from unauthorised use does not work in this context because the pin needs to be sent to the modem in clear text during power on. Using a chip SIM embedded on the modem also does not work because the criminals removed the modem from the device and used a custom board with the standard modem connector to talk to the modem and issue the USSD commands.

The devices could not be physically secured in the field to prevent concerted attempts to gain access to the device. The solution had to be to remove the incentive for theft. A three pronged approach was tried and proved successful. All SIMs were moved to prepaid with limited funds being transferred to the SIM at the beginning of each month. Up until this incident network operators did not allow prepaid to be used with private APNS, however due to the fact that they could not block the USSD service from being exploited they have subsequently allowed this. This limited the liability associated with the SIM. To make the SIM less of a target a chip SIM was used and bonded to the PCB along with the modem in such a way that removing it led to significant damage to the chip SIM. The phone book in the SIM was set up to only allow a limited set of USSD codes to be dialed. This set only included the commands required to set up a GPRS session. The SIM has a separate pin to allow access to the SIM's phone book. This pin was randomised and discarded to ensure it could not be recovered and any of the numbers in the phone book changed. A label was stuck onto the device to notify thieves that no SIM was present in the device.

After this was done the number of device thefts decreased substantially and for the last three months leading up to September no devices were stolen.

Conclusion

The LV smart grid is changing from a network used to retrieval daily measurement data to one that needs to support and enhance the utility's day to day operations. Operations and maintenance, theft detection, asset management customer communications, network planning and load management and matching require that the network support command and control type functionality in addition to normal data retrieval.

With increased functionality comes increased risk due to security breaches. Mechanisms that were used previously such as multi-level passwords are no longer adequate and need to be replaced with an holistic security model that combines both technical and organisation aspects to meet FIPS 200 and 800.53 requirements and ensure safe secure operation of the LV smart grid.

The field is a hostile environment covering a large area and uses communications networks that are inherently unreliable. By taking a holistic system view and including mechanisms at multiple levels, from the physical to the application layer, the effective reliability of the communication network as seen by users of the system can be substantially increased.

This increased reliability is critical to ensure that the gains from the LV smart grid due to increased organisation efficiencies are not offset up by increased maintenance of the LV smart grid and the underlying communications network

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How software adds intelligence to the smart grid

by Torben Cederberg, Ventyx and Karen Blackmore, energy and industry analyst

Smart grids are seen as a combination of technologies, not just the power products and systems forming the physical transportation of electrical energy. Information technology such as smart meters, advanced SCADA systems, forecasting tools, business intelligence and many other examples of modern software solutions are adding smartness to the power system parts of tomorrow's smart grid networks.

The reader will learn from examples dealing with the operation and optimisation of the smart grid but also an example dealing with the smarter asset management of the electrical networks. The latter is of special interest since it is a very evident way of tying investments in the network (enterprise asset management) with the performance of the assets as measured in safety, reliability etc. (network operations).

Finally an example of how forecasting and smart data management is used by a utility in Europe will conclude this paper by showing how they are using software adding intelligence to their current network operations.

Smart grids are dynamic and information rich

As a result of worldwide promotion and investments in green energy as a way of having sustainable growth in the demand for electrical energy, tomorrow's electrical grids need to be smarter than those of today. Why is this? Many smart grids, unlike traditional networks, contain a larger proportion of renewable and distributed generation such as wind and solar power. These new sources of energy production are much more unpredictable since they are dependent on the elements for their production capacity and availability. Traditionally, it was enough to simply predict the load and then size the production accordingly. Adding a dimension by the introduction of volatile energy production in the distribution grid leaves a challenge for the grid operators to operate their networks under much more dynamic and changing conditions. Power flow, as just one example, may change direction and amplitude several times over the course of a day, putting security of power delivery to a real test.

Still politicians are putting pressure on the industry to grow its fleet of green power sources, while still keeping tariffs low, and are also increasing pressure for a stable and predictable service.

Changes in the power flows of distribution networks is just one smart grid challenge. Another, and perhaps one that is more urgent to resolve, is the huge amount of data produced and readily available, (as depicted by the ones and zeros in Fig. 1). Many utilities already today experience an avalanche of data, most of which is simply stored, but not properly processed. The valuable information is contained in the data, but not made visible or obvious to the utilities. This is where smart grid software can make a significant difference and, used correctly, can turn the massive amount of raw data into invaluable information to help the utilities in making better business decisions and to master the operation and ownership of tomorrow's smart grids.

Smart grids require both intelligent power systems as well as intelligent system support. This is quite a challenge for the industry. Understanding what these challenges are is a first step, but what are the components of a blueprint to master the challenges of tomorrow's smart grids?

How technology can enable a smarter grid

There are three key components that form the blueprint for the most successful smart grids of tomorrow:

- *Intelligence:* unlocking the wealth of new data along with existing knowledge to drive actions and automation
- *Integration:* optimise the entire electrical value chain in a responsive and responsible manner
- *Innovation:* incorporate new technology as it comes about in an agile manner and recognise possibilities as additional knowledge is gained from current implementations

These components will enable utilities to adopt collaborative, responsive and heuristic business models that give new meaning to the term "smart grid" – providing the energy for tomorrow while preserving the environment.

Intelligence

In order to fully unlock the wealth of new data, utilities are investing in sensors and monitors. The data from these sensors coupled with industry specific key performance indicators, algorithms and existing knowledge form the basis of increasing smart grid intelligence. While big data is often talked about in terms of intelligence, smart utilities will be looking at targeted data. Utilities will want the data to answer questions such as:

- What do we want to know?
- Where do we need to learn more about the grid and its functions?
- How much do we trust the data and the systems within the grid?
- How do our customers trust the information we supply them and how do they trust us to do what we say we are going to do?
- What components within the grid are missing that would supply more answers?

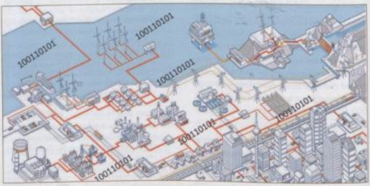

Fig. 1: The smarter grid is rich with data.

- How much do we "don't know that we don't know"?
- What is the next step?

As a utility continues to drill into the data and gain valuable insights into the significance of applied intelligence, it will unlock answers to the above questions and be able to act upon situations that are happening within the grid.

Integration

Many utilities currently working on smart grid projects are spending time on information technology, IT and operation technology, OT convergence. Blending these two technologies to provide true integration is a key to the puzzle of "connecting the dots" in the network. In addition to the integration of the technologies, processes must be integrated to take advantage of the automation that can occur once IT and OT are integrated. These processes allow smart automation to take place without intervention and alerts for responses that require manual intervention, additional decision-making and actions that cannot be completed with the current systems in place. Once the processes are integrated, there is another integration that involves customers and their responses to events such as outages or peak demands and the employees who help the customers understand what is involved. This integration of customers and other stakeholders is as important as the convergence of the technologies.

Innovation

The third "I", innovation, is fed by intelligence and integration. Innovation is what led to astronauts walking on the moon. However, to get to that point, people had to solve the problems of traveling in space and then landing on and returning from the moon. They had to solve problems at hand, but had a vision of the greater picture and goal. Utilities today that are innovative about smart grid solutions dream about a better planet and conditions for quality of life and fully sustainable systems for electric resources that supply all people regardless of location or income. But those utilities are aware that the problems of today must be solved first in order to reach the energy needs and dreams of tomorrow. VaasaETT[1], while doing the research and analysing the results from their smart grid global research project, found that innovation was a deciding factor in successful smart grid projects.

As we will see next, the three "I" components, intelligence, integration and innovation are all essential for building the solutions for tomorrow's smart grid applications.

What are the solutions that add intelligence to the smart grids?

The areas described will all exemplify how software solutions are processing data, in many cases, already existing and readily available, for utilities to form strategies and execute both in asset management as well as in operations in a more optimised way.

Several vendors are offering solutions in all mentioned areas. This paper will be describing the general principles in each area and will use examples, nomenclature and illustrations using examples from ABB and Ventyx. Other vendors may offer similar solutions using other names or configurations, however the principles are similar. The utility reader of this paper is encouraged to research what solutions are available and how they can be applied to its unique network and company structure, taking into consideration company (and network size) as well as business impacts.

Asset health

The value of a utility is very much dependent upon its assets. Many utilities struggle today with a set of assets that are near or even past their end of life data and a lot of money is put into various "prolong the equipment lifetime" programs. Many of the maintenance programs are still done in a time based manner, and therefore the optimal usage of the power equipment may not be achieved. The good news is that there is a better way – an asset health approach to maintenance.

Today, asset maintenance approaches typically rely on an ad-hoc mix of information from multiple sources like time and usage based inspection data, alarms from remote sensors, and industrial enterprise systems. All this data tends to get lost in different organisational silos. Often, utilities rely heavily on human experts to manually review this data, identify trends, and address the risks of the asset portfolio. As more of these experts retire, utilities will need to preserve this expertise as part of the ongoing maintenance data process.

Asset health centre merges the subject matter expert knowledge with historical and real-time data. By integrating an organisations operational technology (OT) with its information technology (IT), organisations have the ability to consolidate the wealth of data on systems loads, markets, inspections and equipment sensors. This solution helps identify trends with industry-leading performance models that capture decades of experience building and maintaining critical equipment. Asset health centre doesn't just alert the utility when assets are about to fail, it also helps anticipate issues before they turn into problems.

In practice, asset health centre will lead to a state of knowledge where the most valuable assets are mapped and categorised according to their current states and expected lifetime. Proactive maintenance is part of this as well as risk-based decisions of updating, prolonging life time or exchange of equipment is performed. The result is a reduction in risk of critical asset failure by combining many types of asset data to form predictive and actionable intelligence around the health of critical assets.

Using this improved level of insight, utilities can take action now and prioritise their response and resources. Organisations can optimise their maintenance spend to get the most from their assets and budgets, build business cases for repair/replace decisions and codify the expertise of their staff in order to make it accessible for new employees and maintenance outsource partners.

Fig. 2: Asset health centre.

Note 1: VaasaETT, Smart Grid Global Impact Report 2013, www.smartgridimpact.com.

Outage lifecycle management

The relationship the utility has with its customers is often just as important as the health of its assets. Customers value a reliable (and inexpensive!) service of uninterrupted electrical power and if it has to be interrupted for maintenance reasons they will want to know for how long – and be able to trust this information.

Outage handling, whether planned or unplanned, easily stands out among the most commonly performed tasks by operators in any control room of a modern utility. The difference between working with planned outages and unplanned outages is quite significant. In the first instance, the operator knows what is planned and lies ahead and the challenge is to optimise the work meeting deadlines and budget. In the latter instance, outage management in terms of system restoration is quite different with a much more stochastic process. What the two share is the need to make quick decisions minimising the number of affected customers when doing maintenance and system restoration works. It also needs to keep customers (and other stakeholders) informed of what is going on and when normal service will be resumed. Luckily for the utilities, but also for their customers, planned outages by far outnumber unplanned outages. Still the overall goal of restoring any outage remains the same, which is to resume service quickly and safely for improved customer satisfaction and reduced outage duration and frequency.

How can this be done in the most efficient way and what is the difference in doing this in a more conventional network compared with a smart grid environment?

An outage usually follows this life cycle: planning – pre-event preparations – restoration – closeout. Also in most, if not all, utilities these life cycles are managed by different people using various computer systems. So a first attempt would naturally be to map these systems and the flow of data to see how this can be smartened up and made more efficiently. We have done extensive studies on this together with a few selected solution partners and drawn a map (Fig. 4).

This illustrates a typical map with the different functions performed during an outage life cycle mapped on the horizontal axis while the utility departments supporting the (job) functions are mapped on the vertical axis. Highlighted using different colours are the point solutions that perform the various functions. We can see that the management of outages, both planned and unplanned, is quite complicated and involves many steps, people and exchanges of data. Wouldn't it be a nice idea to put all these functions into one single system or solution? There are vendors that are about to do this by integrating its point solutions and already in the research and development stage of a solution develop it as a part in a bigger picture. Naturally the point solutions can still be used as stand-alone tools and also integrated with other vendor tools using third party integrators in the classical manner. The take-away from this is that now for the first time there is also the option of a much more holistic solution that will have advantages when it comes to both capacity and more importantly, efficiency, compared with traditional build solutions.

The second part of the question related to outage management in smart grid versus conventional networks, what's the difference? First of all, most networks are still traditional so there is not a lot of field experience yet but through the early work of our innovation partners we have gained insights of problems that are foreseen when moving forward into the smart grid network structures.

The most obvious challenge is the distributed renewable resources introduced in or near the edge of the grid. An outage is no longer only affecting the disconnection of loads but possibly also production sources (PV-panels and smaller wind generators), making an even more complicated impact to the system restoration or outage planning process. The real-time analysis of the optimal vs. actual power flow must now be taken into account as well as safety precaution when having islands of the network perhaps still being energised.

Again the solution to this is even more integration and innovative sharing of data. As this tends to get more and more complex there is also a need to build safety and rule based management into the systems responsible for managing outages. Outage management is actually part of a bigger scheme called distribution system optimisation which is taking the same principles to the total distribution system management.

Distribution system optimisation

The ability to apply predictive analytics to a combination of operational and information system data helps enable control room operators to have better awareness of capacity and demand situations. The key is to better manage peak demand. Continually increasing demand places additional strain on the aging grid infrastructure. Much of this demand is relatively short (peak) duration such as a cold snap and may not require additional long term investment in generation if other measures can be applied. In 2006, a study was performed under the Independent Electricity System Operator, in USA, which showed that the top 2 GW of load were served

Fig. 3: Outage life cycle.

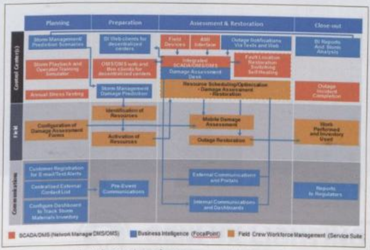

Fig. 4: Functional map of outage management system support.

during only 32 system hours (less than 0,4% of the time), underlining that the large amount of capacity that is used is very infrequently.

There are a number of strategies available to utilities looking for innovative solutions to this issue. One smart approach involves attacking the issue from both sides – managing the peak using conservation voltage reduction, and bringing new capacity online through distributed generation and demand response. These strategies are brought together under the distribution system optimisation solution.

Conservation voltage control

Where regulation permits, conservation voltage technologies offer utilities at the forefront of technology significant advantages. During pilots in a large North American utility, their estimates placed reduction in peak demand at between 2 – 4% correlating to a saving of $80-million per year.

Historical voltage control methods have had significant limitations. Local-based controls were highly labour intensive and had difficulty allowing operators to take changing network conditions into account. Centralised radio-controlled systems did not permit systematic optimisation of voltage and var controls for maximum effectiveness in loss reduction and also involved significant human oversight.

In contrast, model-based volt/var optimisation utilises mathematical optimisation supported by detailed network modeling and customer load modeling. The benefit of utilising a dynamic model is that the volt/var optimisation always uses the "as-operated" state of the network. As outages and system reconfigurations occur, the controls adapt to maximise conservation benefits.

The savings in deferred generation plants or capacity procurement costs, lower system losses, lower customer energy consumption, and reduced operating and maintenance costs results in model-based volt/var optimisation having one of the strongest business cases for smart grid functionality.

Distributed energy resources

Distributed energy resources can alleviate overloaded areas and reduce the impact of critical peaks. To facilitate streamlined utilisation of distributed generation, utilities need ways to manage registered resources, forecast requirements, and bring resources online. For example, a peak demand time during a summer heat wave may require generation above normal demand response and local wind farms may need to be brought online if wind is projected or excess PV generation from the local school. With the integration of information technology used to manage the requirements and operational technology to manage on-boarding of the resources, utilities can quickly activate these "virtual power plants". Distributed energy management systems provide real-time tracking, forecasting and aggregations of demand response and distributed energy resources into virtual power plants, enabling improved forecasting and optimisation of these assets.

Demand response

Effective demand response management solutions need to communicate with demand response devices, signaling an event and gathering data. Demand response management system (DRMS) supports commercial and retail utility operations that are required to deliver effective demand response programs and distributed energy management for their smart grid deployments. Using the demand response technology, utilities can give their customers the ability to make more informed choices about how and when they use power by providing them with incentives for controlling energy loads on the network. This enables utilities to better manage peak demand periods, minimise the impact of outages and decrease investments in additional generation, transmission and distribution assets.

DRMS solutions communicate with demand response devices, signaling an event and gathering actual data. DRMS enable utility portfolio optimisation by supporting unit commitment and dispatch for complex portfolios that include the full range of portfolio components, including generation, storage, renewables, virtual power plants and complex contracts but also industrial and residential loads. When many units are collectively signaled and managed from a single point it is often referred to as a virtual power plant, VPP.

Demand response dashboards facilitate

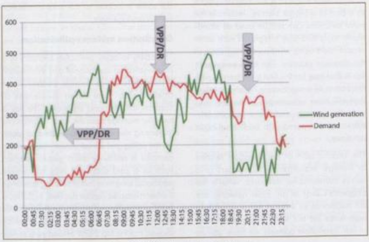

Fig. 5: VPP/DR signaling for peak clipping.

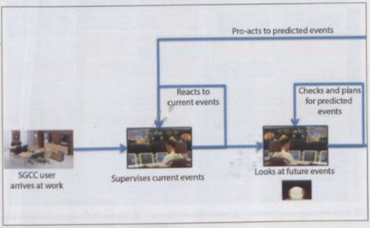

Fig. 6: Forecasting predicts events in the near future.

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the speed of decision making to dispatch distributed energy resources and provide a comprehensive portfolio view. Finally, a DRMS management solution should include an operations dashboard that brings all portfolio elements into a framework to help final decision making as well as reporting on forecast and execution results.

Utility example

The E.ON smart grid project in short:

- *The situation:* The company is one of the world's largest investor-owned power and gas companies serving more than 26-million customers in over 30 countries.
- *The challenge:* The grid company in Sweden servicing a geographically very large and disperse network with close to 1-million network customers, needed to prevent instability issues, minimise grid losses, and reduce operator stress by increasing the situation awareness ahead of time.
- *The answer:* Combining information (IT) and operational technologies (OT) in the smart grid control centre (SGCC) will deliver a higher degree of grid automation, sensing and visibility; achieve greater control of distributed generation; and further support regulatory compliance.

Innovative, integration and intelligence – it's all there

One of the innovative parts of this project is to work with scenario based simulations of what is foreseen to happen in the near future. The idea is very much trying to address the challenge of "wait and see what happens and then react". Monitoring alarms and then react is fine for some processes in the traditional grid but in the much more dynamic smart grids it is not good enough. Fig. 6 illustrates the closed loop control process that will be implemented in this project.

What building blocks are needed to do this type of advanced forecasting and analysis in real-time? First of all we need a well-functioning SCADA system with a high resolution of measuring points in the grid. The next crucial building block is the network model (simulator) with network calculations being performed continuously in the background to simulate the real network. It is this simulator that runs the different scenarios and tests the "what-ifs" being ordered by the operators. When we have the network components in place and integrated, we need behavioral data. Weather, load and generation forecasts need to be feed into the system, this data is the input. Based on the topology engine and the forecast data, the simulator is able to "run the network" for two hours or longer and check for predicted events and also suggest corrective actions. Can a possible overload in a feeder be detected based on forecasted data? What if a generator is down during high load conditions? Can we allow a temporary overload of 10% at this cable for two hours in the afternoon? All these and many more questions could be answered with a fair precision and therefore make the operators run the network more efficiently and adding capacity and reliability without additional network investments.

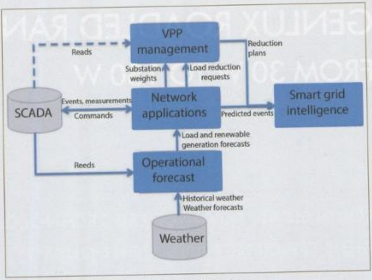

Fig. 7: Block diagram of the solution.

Smart grid intelligence solutions like this allows network companies to optimise their distribution systems at a very moderate investment compared with adding additional power system components. Software can prove very effective when the necessary data is made available and correctly analysed.

Summary and take away

Software solutions can add intelligence and produce significant value for utilities planning for the next generation of smart grids. There are three key components that form the blueprint for the most successful smart grids of tomorrow:

- Intelligence
- Integration
- Innovation

The blueprint contains the increased use of advanced software solutions. Turning the vast amount of data into actionable insights is a big challenge for any utility. Areas of smart grid applications to consider for rapid deployment are: asset health solutions, distribution system optimisation and outage lifecycle management. These areas address some of the top challenges of tomorrow's smart grid and the best software solutions combine intelligence, integration and innovation components to form a holistic solution.

Utilities have a lot to gain investing in these solutions starting already today. The process is not a one time, big bang, project but rather a transformational process with many smaller steps. A first step is to map existing system support and data flows.

The market is offering several solutions from different vendors. Even if the challenges are global, the implementations can be slightly different locally, with Europe and USA being early out but soon to be followed by utilities in other parts of the world.

The solutions discussed cover both asset management (asset investment optimization) as well as the efficient and reliable operation of the network. Because of this it is highly recommended utilities form a companywide strategy before engaging in any point solution. Having this strategy in place and executing accordingly, will lead utilities to additional business gains including; more agile network operations handling the dynamic power flows, servicing the customers with a more predictable and reliable outage management and deferring additional investments while using existing capacity closer to its limits.

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Johannesburg's smart meter implementation programme: from concept to reality

by Sicelo Xulu, City Power

As municipalities struggle with revenue collection, the issue of accurate billing and credit control is becoming more and more important. This calls for intelligent systems to help the billing team to minimise billing errors and to cope with the volume of additional customers coming online on daily basis. This paper outlines the approach adopted by City Power, a Johannesburg municipal owned entity, to address current challenges as part of the smart grid concept.

Most utilities are experiencing various problems ranging from poor revenue collection, capacity constraints, electricity theft and poor customer awareness regarding proper energy usage. South Africa has limited alternatives to electricity, which makes it the main energy source in most industrial and domestic environments. Economic growth mainly depends on the availability of electricity and with the unprecedented rate of development in the city of Johannesburg, according to the 2011 South African census [8], the population has grown by 37% over the past ten years. This is attributable to international and national migration and requires the city to continuously expand infrastructure to ensure reliability of supply. Alternative energy sources are still limited and very expensive. As the world's non-renewable energy resources continue to deplete, there is an increasing need to protect them and produce renewable sources of energy. There is also a need for systems to distribute this energy via an intelligent and efficient energy distribution system, thus the birth of the term "smart grid" as illustrated in Fig. 1.

A smart grid offers significant benefits for both utility companies and their consumers. For utility companies, it offers the ability to distribute energy more effectively and efficiently and to disconnect services for non-payment remotely as part of the credit control process. For consumers, it would enable them to get real-time information of their energy consumption, and with that information manage their loads accordingly to lower their utility bills. In order to move towards the smart grid, it is necessary to replace prevalent electromechanical electricity meters used to measure power consumption with advanced meters – smart meters. Smart meters enable various applications required by a smart grid [5].

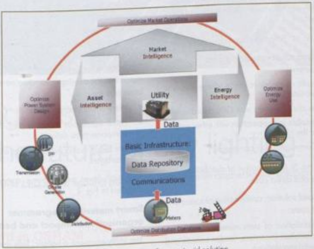

Fig. 1: Block diagram of a smart grid solution.

City Power's smart metering programme

Smart metering is a prerequisite for any effective demand response or demand-side management programme. A smart meter is an advanced electronic device which identifies consumption in detail, and which might be able to load profile data and implement complex time-of-use tariffs, and even measure quality of supply. These meters may be connected to some form of automatic meter reading system (AMR) and have the ability to communicate with the local utility for monitoring and billing purposes. Smart meters on their own might make marvelous ornaments for an electricity panel with cute displays and flashing lights, but are merely expensive replacements for simple electro-mechanical meters. In order for smart meters to be of any practical use, they have to be integrated into a comprehensive smart metering system which involves much more than simply putting a clever meter on a customer's wall or distribution panel, even if it does have a high-tech modem attached.

One of the most critical components of any smart metering system, and one that distinguishes it from a simple AMR system, is the ability to communicate directly with the customer. It is vital that customers see the connection between their lifestyle (in the case of domestic users) or business processes (in the case of commercial and industrial users), what they are paying for electricity, and how this affects the overall state of the electricity supply grid, particularly in times of crises.

City Power's smart metering strategy: the need for change

City Power at a glance

City Power is a municipal owned entity, its sole shareholder is the City of Johannesburg. City Power's vision is to be a "world class electricity utility".

The utility has over 460 000 customers segmented in the following way:

- Large power users (LPU), which account for approximately 1% of the city's population and contribute over 60% of the total revenue.
- Prepaid customers, which account for approximately 62% of the population and contribute less than 10% of the total revenue.
- Conventional domestic and business customers, which account for approximately 37% of the population and contribute over 30% of the total revenue.

City Power has annual revenues of R13,8-billion, employs 1700 people, is the only utility in Africa that holds three ISO

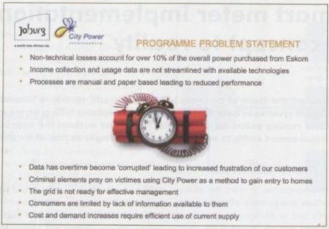

Fig. 2: Programme problem statement.

accreditations (9000, 14001 and 18001), and is the first utility in Africa to have undertaken the smart meter deployment in this magnitude.

Why the change to smart metering now?

The smart metering deployment programme is designed to respond to specific challenges faced by the utility and the city of Johannesburg.

It is anticipated that reducing the non-technical losses will allow the utility to see a return on investment within the first five years of operational life of the smart metering solution.

The solution is not only focused on financial aspects but also on the urgent need to ensure an improved service is delivered to its customers taking into consideration the most critical concerns:

- Risk of criminal activity when they need to allow "strangers" into their homes.
- Cost of electricity will only increase and they have limited visibility of their own usage patterns.
- The city and the utility do not have correct billing information and the so-called "billing crisis" needs to be resolved.
- How the city will cater for the renewable energy market when the grid is not ready to incorporate it.

To respond to these challenges, the utility has designed six-point plan, which has resulted in a foundation for the smart metering deployment programme, the six pillars of the plan are as follows:

Pillar no. 1: Split prepayment

Proposed solution: customers consuming <1000 kWh/month:

- To be converted to split prepaid meters with bidirectional communication.
- Installation of independent load management controllers, where necessary.
- Installation of protective structures, ground and pole mounted.
- Installation of remote meter monitoring systems, equipped with the back office.

Pillar no. 2: Domestic smart metering

Proposed solution: smart meters for domestic customers consuming >1000 kWh/month:

- Convert to smart meters (equipped with load management, ToU tariff functionality and the ability to be on pre-payment or conventional metering with fraud detection capability).
- Bidirectional metering infrastructure.
- Scalability and the ability to support outage management functionality.

Pillar no. 3: Smart meters, large power users

Proposed solution: smart meters for large power users:

- Convert to smart meters.
- Perform technical audit on metering accuracy.
- Implement Time of Use tariffs.
- Power conservation scheme through pricing signal.
- Opportunity to operate as prepayment through a meter data management system.

Pillar no. 4: Smart meters, large power users

Proposed solution: technical data completeness:

- Audit all stands in areas where supply is provided
- Locate all meters with GPS coordinates.
- Possible joint operation with other entities of the city
- Communication campaigns

Pillar no. 5: Confirmation of distribution losses and direct costs

Proposed solution: confirmation of losses and direct costs:

- Installation of stats meters at all of its substation incomers, feeder boards and switching stations.
- Installing bulk metering for intake points as check meters.
- Installation of capacitor banks in identified areas.

Pillar no. 6: Confirmation of distribution losses and direct costs

Proposed solution: establishment of a dedicated team to manage metering:

- Establishment of an energy management back office.
- Establishment of a revenue protection response team (to deal with bypass/faulty meters etc.).
- Introduction of energy champions to provide energy service to large power users.

Programme strategic placement and overview

Strategic placement

The pyramid in Fig. 3 describes how City Power intends to evolve to a smart grid utility in the portfolio of programmes currently being undertaken by the utility. The areas in green pertain to the smart meter implementation programme, the areas in red pertain to other related projects and programmes being run within City Power, while the areas in orange show the enhanced capabilities the city will have towards broader implementation of the smart grid (e.g. solar geysers, substation automation, etc.). It is therefore clear that the plan sees the smart meter implementation as a foundation of the longer term strategy, and the city and its citizens should see this programme in a 20-year context.

Programme overview

City Power is managing the process of programme management by virtue of managing successful programmes (MSP), an international best practice. The programme contains work being done by numerous contractors and service providers together with City Power. The service providers have been grouped according to various projects and activities into the listed "high-level" components for better control. Each of these report into the steering committee on a weekly basis and they:

- Have underlying structures.
- Have numerous intricate and detailed components to deliver.
- Are being managed by project and team managers.

The high-level programme overview is depicted in Fig. 4.

Smart metering programme: organisational impact and benefits

The utility envisions a holistic, fully integrated energy ecosystem in which smart metering


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information is used to optimise energy usage, distribution operations, power system design, and market operations. The end result being a self-managing, self-optimising, self-healing power system that is driven by the power of market economics and environmental requirements [1].

The implementation of a smart metering infrastructure towards the evolution of a smart grid is a clear example of the utility responding to industry challenges. By implementing advanced meter infrastructure (AMI), City Power can limit and control the demand for electricity thus impacting the environment with less pollution and/or CO_2 emissions. City Power can improve its environmental footprint by:

- The introduction of flexible time-of-use rates to encourage customers to use at off-peak times.
- Tailoring services to specific customer consumption patterns.
- Improving environmental protection through reduced carbon emission targets.

The reliability and quality of service will improve as faults and fraud can more easily be detected and addressed through improved operational efficiencies by means of:

- Automation of meter reading with smart meters and AMI.
- Reduction of the number of errors in the meter reading process and prevention of revenue leakage.
- Brown-out avoidance through better demand management.
- The rapid introduction of new services (customers' active cost control, health alarms, internet connection).
- Consolidation of management and monitoring platforms to reduce costs.

The use of AMI will enable City Power to cope more effectively with aspects of workforce productivity by means of:

- Automation of management of the smart grid.
- Intelligent deployment of maintenance crews and equipment to specific problem locations.
- Improved access to information as required by maintenance crews deployed in the field.

However, to achieve this, the smart metering deployment programme will have an impact on how the current business operates and the utility is aware of this anticipated change, as a result a working group with the sole purpose of studying the business impact and managing it for a successful outcome has been established. The output of the working group will result in:

- The organisational structures being realigned within two years.
- The processes being re-engineered as part of the programme.
- Underlying support technologies changing.
- City Power's capabilities changing.

There is no doubt that the organisation will have an improved business at the end of the implementation cycle.

Smart metering as load management tool

The city's networks and the national grid are experiencing overloading pressure as well as energy shortage from generation side. This calls for massive investment from the affected utilities and most of these utilities do not have the required capital to remedy the situation. Demand side management seems to be the quickest short-term solution to address the problem.

The city also experienced challenges with revenue collection and a solution to address both challenges has to be sought hence the development of a metering strategy that will address the demand side issues as well improving the revenue collection challenges.

The traditional load management programmes could not be abandoned as they become cheaper and quicker to install. These programmes have been combined with the resources that have been put in place to start rolling out the program. It is a very intense programme but more resources have been added to ensure efficient and fast execution. The potential savings that can be realised with the full roll-out/implementation of smart metering and a smart meter management solution will have a significant impact on City Power's overall business. Furthermore, South Africa is currently in a national crisis and cannot keep up with the demand for electricity – this project will also drive/promote energy conservation [1].

The strategy is also in line with the government's requirement on load control to address network constraints while new power stations are being built. The Department of Energy has gazetted Regulation 773 which compels all licensees to have installed smart meters with load management capabilities before 1 January 2012.

The extract of the regulation is stated below:

"In respect of existing buildings, where an electric water heating facility is required, a licensee should install a facility to remotely control the supply of electricity to any electric geyser that does not incorporate a solar

Fig. 3: Programme strategic placement.

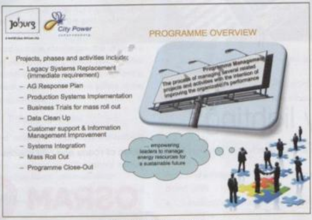

Fig. 4: Programme overview.

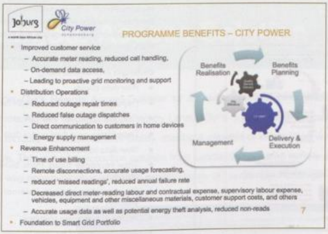

Fig. 5: Summary of programme benefits.

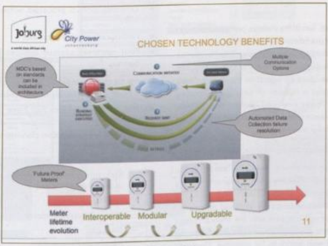

Fig. 6: Chosen technology.

heating water facility; (ii) sub-regulation (b) (i) must be in place not later than 1 January 2012; in respect of space heating, ventilation or cooling in existing buildings, to be in place not later than 1 January 2012, a licensee must, (i) install a facility to remotely control the supply of electricity to heating, ventilation and cooling system in its area of supply, (ii) link a swimming pool drive and heating system to a facility that enables the licensee to remotely control its supply of electricity; an end-user or customer with a monthly consumption of 1000 kWh and above must have a smart system and be on time-of-use tariffs not later than 1 January 2012; sub-regulations (b) and (c) do not apply in an event where the licensee can remotely reduce or increase the supply of electricity to the building using a smart system. In respect of sub-regulations (b) and (c), the licensee may remotely control the supply of electricity only during capacity or network constraints to avoid electricity blackouts. The system operator must issue a notice to the licensee declaring the constraints in terms of network or capacity and requesting distributors to reduce demand" [2].

Data management – customer profile

The system will help utilities to understand each customer's behaviour and will help to streamline efforts on customer awareness. It will also help with customer classification and the amount of resources required to look after those customers. All the attention has been on changing consumer behaviour but really it should be on boosting micro-generation by enabling accurate feed-in tariff information for upstream suppliers and providing suppliers with accurate demand information so they can optimise the grid by reducing the amount of spinning reserve required. Some have questioned whether energy utilities are equipped to deal with the flood of extra data which smart meters will bring. This is still a big challenge and will require utilities to invest more on data management centres and retraining of their staff and even hiring more expertise on data analysis and management.

Utility to customer communication

Depending on the utility's requirements, the technology can be used to the advantage of both the customer and the utility involved. The utility can communicate many messages to the customer and make setting changes remotely. Municipal communiqués can even be sent via this intelligent device. If the meter is integrated into an automated meter-reading system, it must be able to communicate with the data management system which is placed on a server either at the utility or at the system provider. Where the utility uses two different providers for meters and systems, the meters must be compatible with the system. This requires a kind of communication standard such as the device language message specification (DLMS). The utility can opt for a one-way communication (an AMR-solution) where consumption data are transmitted directly to the utility's central system; or they can choose two-way communication which gives the utility a comprehensive control of the meter with the possibility of enhanced customer services like the smart disconnect and remote upgrade of software [7].

Ease of billing

Smart meters will help the city to accurately get the customer's readings which will be automatically fed into the billing system to generate a bill to the customer. This minimises billing errors and reduces billing time to customers. This will also allow customers to view their bills online at any time of the month. This conversion improves the quality of both billing and collection levels while allowing customers real-time access to their consumption patterns, thereby facilitating demand side management.

Summary of programme benefits

Fig. 5 summarises the smart metering programme benefits which are outlined below:

- City Power will become more proactive with regard to customer service.
- The business operations will improve and reduce power wastage.
- Accurate data will allow for improved planning.
- Further smart grid applications will benefit from the smart metering implementation plan (SMIP) as the foundation.
- This is aligned to the problem statement and contributed to the decision to roll-out the programme.

Technology choice: "concept to reality"

City Power has been looking at a solution that will address both load management

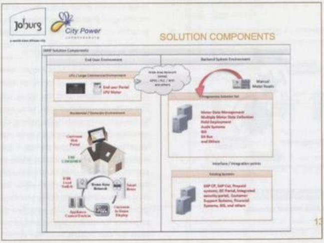

Fig. 7: Solution components.

and revenue collection challenges. The traditional methods have been tried but the utility has picked up too many challenges with those systems. The ripple relay can easily be bypassed by customers. In some cases the utility receives cold water complaints due to the malfunction of these ripple relays. With the old meter-reading methods, the utility deploys a number of meter readers but this system also has its own challenges as these readings have to be entered manually and inaccuracies have been picked up which lead to unhappy customers. The utility has also been experiencing problems with access to properties which leaves the utility with no choice but to estimate the readings. It is very difficult to manage these methods hence the increasing rate of non-payment and manual cut-offs resulting in a lot of unhappiness from customers. As a result, the technology choice had to deal with these issues and be agile and scalable. The selection of technology was key to the success of the short, medium and long-term strategy.

Fig. 6 shows the high level components of the chosen technology:

- It can implement third-party data collection services if they are based on standards.
- There are multiple communication options as the city has various challenges in different areas in terms of communicating to the back office.
- The systems have automated problem resolution features and notification functionalities.
- The meters themselves are upgradable which allows updates without full replacement.

Over and above the technology choice, it was equally important to choose a supplier/service provider with established credential and track record. Two of the strategic partners selected to assist are Edison Power and Itron, as they have excellent track records, are global leaders in this industry, and meet the criteria required by the country's legislative framework. There are also a number of suppliers supporting City Power over and above these delivery partners in areas of oversight and independent portfolio management.

Technology solution components

Fig. 7 provides a high-level extract of the solution components from the smart metering implementation plan (SMIP) document. The solution comprises the backend systems list which will integrate with the utility's current systems. The large power users will have access to a web portal to be provided. Domestic customers will get a customer interface unit (CIU) as well as a meter with access to an online portal. All these components will work seamlessly together. Further to the solution, customers can implement in-home devices to further capitalise on the smart grid into the future.

Highlights of project progress and lessons learned

The company is now over eight months into the implementation of the smart metering system, and significant progress has been made in the large power users environment. The next roll-out will be a prepaid smart meter for domestic customers that were identified as contributors to revenue collection challenges. Certain townships have been converted to different smart metering technologies and City Power is monitoring the progress while rectifying challenges with current technology. A decision has now been taken to gradually roll-out the technology starting with those areas with revenue collection challenges. The implementation is by no means issue free: the utility is dealing with various challenges. With a dedicated focus from the organisation it plans to overcome these and improve on processes wherever possible, some of the challenges encountered being:

- Poor data quality
- Prepaid customer information limited
- Out-dated customer information
- Dependency on a third-party's data
- Slow data update processes
- Slow response times from business resources
- Resistance to change (internal and external)
- Access to customer's premises
- Poor perception of the utility by customers
- Deteriorated "on-field" environment
- Extremely manual processes within the utility
- Limited documented processes
- Poor customer support services (call centres)

Despite the challenges significant progress has been made with noticeable improvements:

- Programme structures that have been implemented:
  - SMIP implementation plan has been completed
  - Toolkit developed
  - Risk and change management approach documented
  - Risk log
  - Impact assessment matrix
  - Issue log
  - Benefits document
  - Process documentation
- Business analysis and workshops, business solution design (BSD), technical architecture design (TAD), setup and configured development, test, interim and production hardware/operating systems and solution components.
- 9350 meters have been loaded onto the IEE MDM, 1925 domestic meters installed, just under 20 000 domestic meters audited, 6489 LPU AMR conversions of registers/meters were audited, 4582 LPU AMR conversions of registers/meters have been completed.
- Design of system architecture, installation of server to manage integration, interim integration between some systems, interim work order and commissioning sheet creation for domestic meter installations.
- Set up of warehouse, deployment of field deployment systems, deployment of two MDCs, preproduction smart meters installed, LPU meters – domestic meters and deployment equipment delivered.
- Set up of training facilities, training

Remote Access Solution

Landis+Gyr
manage energy better

Landis+Gyr's Remote Access Solution for its range of PLC2 prepayment meters, comprises of a three phase PLC Remote Access Terminal supported by Landis+Gyr's Suptalk communications controller. The Remote Access Terminal has modular communications facility, making it capable of being fitted with various communications modules in the future. This revenue protection solution from Landis+Gyr enables remote auditing and monitoring, fraud detection and two-way communications with the existing range of Landis+Gyr PLC2 split prepayment meters.

- Meter events (such as meter tamper) are immediately sent the administrators and utility response team
- Remote Access Terminal events (such as a power failure in a mini-substation) are immediately sent to the administrators and utility response team resulting in quicker response and improved customer service to the community
- Prepayment meter auditing can done by the utility from the comfort and safety of the utility offices
- Two way communication with existing Landis+Gyr PLC2 split prepayment meters, enabling the utility to send maintenance tokens to the meter, without the need to visit the meter –resulting in reduced operational costs and quicker response
- Quick and decisive response to bypassed or tampered meters, with the added psychological effect on the consumer and the realisation that the meters are being monitored, resulting in reduced meter bypassing and fraud
- Visibility of the Remote Access Terminal assets on the system dashboard
- Visibility of the prepayment meters and their status at all times, providing enhanced revenue protection capability for the utility

SwitchBoard: +27 12 645 3198 | www.landisgyr.com of installers, warehouse manager, administrative resources.

- Implementation planning framework developed, documentation of implementation processes, use cases for business trials developed.

It is important to note that the organisation has invested heavily in extensive planning and setting up of back end systems over the past six to seven months.

- Set up structures within the organisation:
- Extensive business analysis done
- Training facilities set up and various people in the end-to-end value chain trained
- Set up and implemented the warehouse and relevant processes
- Installed interim and production backend systems
- Replaced faulty meters and converted high value customers (LPU)
- Started the business trials

Conclusion and key milestone for the next quarter

As it proceeds, City Power plans to have better traction, as the initial resistance to change is subsiding, and the foundation for the programme has been set. Once all processes are streamlined the programme will begin to see more benefits surfacing. In the next quarter the following milestones will be undertaken:

- Transition from IEE MDM operations to City Power and the move from delivery to support
- The Auditor General's response to plan close out
- Business trials:
  - Complete field trials for customer experience
  - Final sign-off of field and back-office systems prior to roll-out
- Completion of business trials prior to mass roll-out
- Additional analysis workshops (business and technical) and phase one of production systems integration
- Communication and awareness:
  - Awareness campaign
  - Improved communication management structures
- Improved customer support centre
- Final planning for mass roll-out
- Completion of meter audits
- Business sign-off
- Mass roll-out implementation plan
- Updated SMIP toolkit
- City wide roll-out begins

In conclusion, City Power firmly believes that despite the challenges, it is pushing the organisation into a well-needed change. The programme has made good progress in eight months, is continuing at a fast pace and is continuing to expedite delivery.

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Bring city lighting to life: dynamic, intelligent and flexible control of city lighting

by Daniel Gooijer, Philips Lighting

It is expected that the global urban population will grow by about 44-million people every year. Of this world population 70% is expected to live in cities by 2050. This puts huge stress on resources and forces us to change the way we think and operate cities. We need to do more with less.

Lighting plays a key role in this transformation: 19% of world electricity consumption is consumed by lighting. Estimates show that around 40% of this is consumed by outdoor lighting. This makes lighting the obvious place to start: intelligent LED lighting can save up to 85% and can be a key driver in pushing back energy consumption and CO_2 emissions.

We need to act… and act fast. The intelligently connected, energy-efficient lighting solutions we need for a sustainable future are here today – the one thing we cannot afford is to delay their implementation.

Your challenges

Outdoor lighting presents many challenges for a municipality. You need the right levels of illumination to make the city safe, attractive and inviting, but you also want to be seen to be green. That means keeping up to speed with new lighting technologies, which could put increasing pressure on your municipal budget. With the right lighting solutions you can overcome all those problems and make the city more liveable, today and tomorrow.

Sustainability

One of the biggest challenges facing our cities is the increasing emphasis on environmental regulation. Acting responsibly towards the planet means finding the right balance between meeting your city's energy saving and CO_2 reduction targets and providing high quality lighting that can enhance modern city life. It's all about competing for the greenest image.

Energy savings

Legislation is putting pressure on municipalities to renew existing lighting infrastructures with more energy-efficient lighting sources. More than 35% of street lamp types will be obsolete by 2015, so you need to act fast.

CO_2 savings

Carbon neutrality is the aim of every modern city. To improve your carbon footprint you need to greatly reduce the amount of energy needed to run your street lighting. The challenge is finding out which new lighting technologies will maximise your CO_2 savings.

Smart grid

The smart grid is coming. The EU has already set 20/20/20 targets and municipalities will be required to balance energy production with demand soon. Make sure your street lighting is ready by choosing a future-proof solution today.

Budgets

In the current economic climate, many municipalities are feeling the burden of escalating debt. This is not the time for contemplating huge investments. In fact you're probably looking for ways to reduce the budget you need to manage your infrastructure investments, maintenance, manpower and energy costs.

Cost savings

Street lighting can represent up to 60% of a municipal government's electric bill, depending on the municipality's size, the services it offers and the efficiency of its public lighting. This makes it an attractive place to start to make cost savings.

New business models

With increasing cost pressure on capital expenditure as well as operating expenditure, you'll also be looking for smarter ways to use what budget you have. New business models such as energy performance contracts or outsourcing municipal services to a dedicated provider could provide a better solution.

Total cost of ownership

What's more, in addition to reducing on-going costs, the total cost of ownership of any lighting investment will be key to your decision. That's because any savings you make in this regard can be redirected towards making your city more safe and secure.

Future

As existing lighting becomes obsolete or phased out by legislation, you must embrace the challenge to move to intelligent solutions that can take advantage of smart grid technologies. These days, lighting technologies like LED are a far more affordable option thanks to their high energy efficiency and long reliable lifetime. So, when you upgrade to LED lamps it makes sense to invest a little more in an intelligent solution that will help you to maximise any energy and maintenance savings. So your city can look forward to a brighter, more prosperous future.

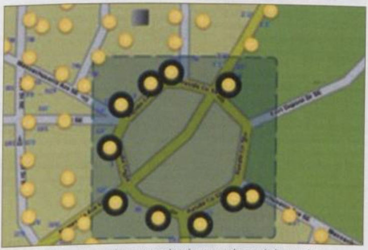

Fig. 1: The system provides an integrated interface to co-ordinate multiple types of lamp.

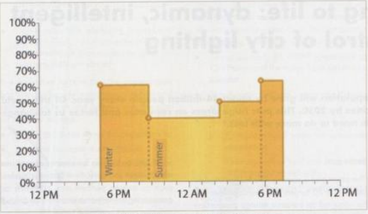

Fig. 2: Individual dimming schedules are created.

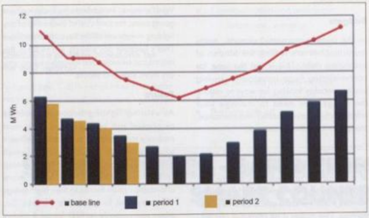

Fig. 3: The city's energy use can be evaluated and tracked.

New lighting technologies

LED is driving the move to digital in all lighting applications, including outdoor. The cost of LED has already decreased and will continue to do so in the future. But it is only in combination with intelligent lighting solutions that LEDs will achieve the highest possible energy and maintenance savings.

Hardware and IT

The cost of processing, storing and transmitting information has collapsed. At the same time, open standards and interfaces have increased. The result is a growth in cloud-based computing which relies less on hardware and more on software and intelligent solutions, something your city will need to embrace.

New regulations

The Energy-using Product Directive (EuP) will accelerate the move towards more energy-efficient solutions. More than a third of all street lamps will be obsolete by 2015. What's more, as an energy using product, street lighting must be connected to the smart grid for cities to achieve EU sustainable energy targets.

Safety

Lighting environments to make them feel safe and welcoming is key to creating a livable city. The challenge is to be able to provide lighting to suit each zone, from residential areas and public spaces to busy highways and industrial parks. Light when and where you need to, in precisely the right levels to make the city safer for drivers, pedestrians and residents.

Crime reduction

One of your major concerns will be to keep the city streets free of crime. Keeping light levels high will reduce the security risk in industrial zones and business parks outside office hours. In residential areas it can make people, shapes and objects easier to distinguish, reducing anxiety and making people feel much safer after dark.

Driving safety

Road and highways safety will also need consideration. High quality lighting improves visibility, a major contributor to road safety because drivers can detect roadside movement faster and at a greater distance. That gives them more time to stop, preventing accidents and serious injuries.

Management

Lighting your liveable city is not a short-term venture. As more people and businesses move in, you'll need to add extra capacity and light new neighbourhoods and business districts. The challenge is to choose a solution that can adapt and change to your city's needs, with the scalability to cope with rapid urbanisation. A future-proof way to bring your city lighting to life.

Future-proof

Costly legacy equipment is rapidly becoming an outdated concept and the trend is towards cloud-based service platforms. You'll need to explore ideas that shift the emphasis from hardware to software, shielding you from any advances in technology that may happen in the future.

Freedom of choice

Locking your lighting investment into one vendor or manufacturer may not be a good idea in the long term. To overcome any obstacles in the future you'll need a lighting solution that allows you to control heterogeneous lighting controls from different brands. So you have complete freedom of choice on how you light your city (see Fig. 1).

Software that grows with you

Cities typically deal with multiple systems to execute their workflows. The best solutions today integrate asset management and support all lighting-related workflows in a simple end-to-end solution. The software starts at the right size for your needs, grows with you along with the changing needs of your business and tailors around you over the years.

The solution: intelligent LED lighting

Why choose for an LED road lighting system?

An investment in LED road lighting heralds an efficient, brighter and safer future. A switch from conventional to LED lighting brings:

- Increased efficiency, enjoy 50 – 70% energy savings and reduced CO_2 emissions.
- Extended lifetime, good LED systems last 50 000 hours or more, providing enormous savings on expensive labour costs and replacement lamps. This compares favourably with the 15 000 to 20 000 hour lifetime of most conventional lamps.
- A superior quality of light, LED lighting is superior to conventional low pressure

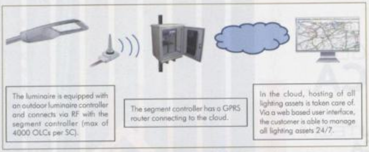

Fig. 4: The system consists of three components, all linked by network connections.

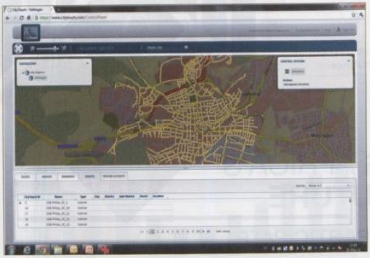

Fig. 5: A user interface provides access to all the system's features.

sodium lighting in its colour rendering, and offers enhanced night time visibility. Your roads are lit in easy-to-see white light – making them brighter and safer.

- Extended controllability. LED lighting is easy to control. You can make precise adjustments to brightness and monitor fixture operation from a centralised control room. It has big impact on a city, on its people and on its operators.

Why intelligent lighting?

Cities understand the advantages of branding themselves as unique, beautiful and secure places. Lighting plays a special part in establishing that identity. But with restrictive legislation and the United Nations' Kyoto Protocol, switching to energy-efficient light sources is high on every city's agenda. Intelligent lighting creates a unique identity and transforms the night scene with lighting solutions that also enhance your city's green credentials.

Sustainability

With concerns about climate change and the impact that our lives and actions have on the planet, the race for green is on. Intelligent lighting gives you highly energy-efficient lighting technology that you need to illuminate your city in the most sustainable way. So you can minimise your impact on the environment and maximise your green image.

Cost saving

Intelligent lighting gives you 21st century lighting with the most energy-efficient, liveable solutions. Intelligent lighting management could generate precious energy savings for your municipality. You'll also save on maintenance costs with lighting solutions that perform brilliantly for longer to extend replacement cycles and real-time fault detection in the event of unexpected failures.

Lighting can transform the city into a vibrant, exciting space that people want to spend time in after dark. But it must also respect the needs of its residents. Artificial lighting is responsible for 19% of all the energy consumed worldwide. It can also result in a night sky that is 500 times brighter than is natural. Intelligent lighting achieves the perfect balance between a beautiful city ambiance and preserving the darkness that makes our cities more liveable.

Safety

Automated lighting maximises safety in the city by providing the right light levels at the right times. With managed light levels on demand, intelligent lighting maximises illumination and safety during emergencies, maintenance programs or special events. High quality, white LED also makes the city feel safer. Its higher perceived brightness and superior colour rendering makes colours, shapes and people easy to distinguish, improving driving safety, reducing accidents and preventing crime.

Well-being

Artificial light has an impact on our sleep and natural rhythms which can affect our quality of life. With intelligent lighting you can limit light to when and where it's needed. Light on demand gives you the power to optimise light levels based on activities and events or dim street lights to reduce light pollution. So you can reclaim the dark skies that promote a healthy, restful sleep.

City beautification

Intelligent lighting solutions like Intelligent Lighting can enhance the streets, squares and parks that give each city its unique personality. They beautify and inspire, bathing the city with crisp white light or dynamic colour schemes to create attractive and inviting atmospheres. Enhancing life in the city and giving night-time socialising more sparkle and appeal.

Street lighting service companies are looking for value added services that they can provide to their customers. Intelligent Lighting is an attractive way of making the city more liveable through intelligent solutions that are enabled by information and communication technology. It provides flexible control with intelligent lighting that responds to the city's changing needs.

Future-proof

Intelligent lighting is fully scalable with a dynamic user interface that can handle millions of assets. The online service platform works with any mixture of multiple and co-existing hardware, so customers are completely protected from any changes in technology. Intelligent lighting is also prepared for future extensions too, like real-time weather data integration that could turn lights on when visibility is poor.

Savings

Intelligent lighting is a "one-stop-shop" solution including all IT and connectivity costs, making it much more cost-effective than in-house solutions. By achieving the highest possible energy and maintenance savings, it helps you to get a good return on your investment

Simplicity

Intelligent lighting is an end-to-end solution with a transparent "pay-as-you-go" service fee and no hidden charges. It makes smart lighting easy and simple for you.

How it works

Intelligent lighting is a dynamic, intelligent and flexible way to bring city lighting to life. It's a web-based ICT solution that connects light points, controls and cabinets with advanced lighting management applications. Intelligent lighting gives street lighting service companies detailed, real-time insight into the status of the lighting to enable them to respond quickly to the changing needs of the city. A seamless way to balance city ambiance with the challenges of sustainability and safety.

It controls and manages lights of an entire city and is not restricted to streets or certain areas. Its features empower you to control the light in your city dynamically, intelligently, and flexibly. You can actively dim or brighten corners, streets, or whole neighbourhoods – whatever the demands of the situation or the event are.

Remote lighting management

Take complete control of your daily lighting operations with interactive maps and detailed, real-time tracking of information and system activity. Create flexible dimming schedules to reduce light pollution or pre-configure light levels for different events. View charts and energy reports to see where you can make potential energy savings. Remote lighting management should be a flexible service that allows you to manage mixed controls hardware solutions, including third party, through one simple user interface. It gives you complete control over your city's daily lighting operation, including detailed analysis on system activities, tracking and energy reporting

Freedom of choice

The system provides a flexible, integrated interface to coordinate multiple types of lamp, luminaire and control. It allows customers to manage heterogeneous lighting controls from different brands, without locking them in to a particular hardware supplier.

Dimming schedules

The system enables you to create individual dimming schedules. It's possible to tailor light levels to suit every aspect of city life, helping to reduce light pollution and make valuable energy savings up to 40% (see Fig. 2).

Energy reporting

With the system you can evaluate the city's energy use (see Fig. 3) and track when and where any savings have been achieved. To optimise energy efficiency you can easily measure and compare the energy usage of single light points, certain groups of light points or entire city districts.

Asset management

Intelligent lighting should also support asset management for all the street lights and cabinets in your city that are connected to it. Complete data sets are imported with individual street lighting assets shown on a map view. It's a service with powerful search and flexible reporting capabilities to help you make the most of your lighting investment.

Asset handling

With intelligent lighting you can easily configure the asset management system to enable the street lighting operator to use his own asset properties.

Flexible query criteria

Flexible query criteria is an asset and component search editor that enables you to filter searches. It's clear and simple with drop down menus to help you navigate quickly through you assets by category, street and power.

Visualisation

Any assets related to your query results are listed in a detailed log and visualised on a map showing their exact location in your city.

Typical system setup

The intelligent lighting system essentially consists of three components, all of them linked by network connections.

Intelligent lighting web-based user interface

The user-friendly interface is your access to all features, just sign in to your account and perform one of the following tasks:

- Add and manage new hardware items in your lighting system.
- Control each hardware item of the system, down to the last street light.
- Monitor properties and measured values of each hardware item.
- Check the energy consumption of the system's hardware items.
- Adjust lighting individually and according to demands via so-called dimming calendars.

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LED street lighting: current and future trends, South African standards and case studies

by Daniel Kasper, Beka

Public policies, environmental and energy saving concerns are driving the local take-up of energy-efficient lighting. LED, or solid-state lighting solutions are becoming more and more popular, owing to their excellent levels of performance and rapidly falling prices. The lighting industry's need for proper international standards or local standards to ensure the safety and measure the performance of LED products is obvious. As new products are being introduced rapidly, new standards are required quickly. Manufacturers claim the standardisation of performance requirements is an important first step towards fair comparison of luminaires.

Among the many quality criteria to be considered when evaluating manufacturers' claims, the upcoming performance standard document lists the following:

- Rated input power (expressed in watt); that is, the amount of energy consumed by a luminaire, including its power supply.
- Rated luminous flux (expressed in lumens), which corresponds to the light emitted by the luminaire.
- LED luminaire efficacy (expressed in lumens per watt), which measures the initial luminous flux of a luminaire divided by its initial input power.
- Photometric code, which includes rates for colour temperature, colour rendering and chromaticity.
- Rated life of the LED module.

Some of these parameters, rated life in particular, are difficult to measure accurately now, as the technology is relatively new and the lifetime of LED products is expected to be much longer than that of other types of lighting system.

LED performance update

The LED market is showing highly dynamic development, particularly in the areas of general lighting. Leading market researchers continue to predict double-figure growth rates for this technology. Continuous investments in the technology and quality lead to higher energy efficiency and lifetime reducing energy costs and maintenance.

And the LED technology still holds a great deal of potential in terms of efficiency. It is still a young technology and records are continuously being broken. In the process, LEDs are steadily becoming the standard lamp solution in numerous fields of application.

- *Efficacy:* The LED efficacy will reach values of 200 lm/W within the next few years for commercially available LEDs. Calculations and science prove that values of even 300 lm/W could be achieved.
- Cost: LED prices, but especially the system costs of outdoor luminaires, are reducing by 20 – 30% each year. This will continue

1	2	3	4
Type of luminaire and lamp	Unit	Item 1 250 W HPSE/SE	Item 2 LED
Design criteria			
Lighting category		A3	A3
Arrangement		Single sided left	
Lanes per carriageway		2	
Width of each lane	m	3,7	
Mounting height	m	10	
Overhang of left-hand side	m	1	
Lamp lumen depreciation factor		0,8	
Dirt depreciation factor: for IP 6: 0,83*0,90 for IP 5: 0,76*0,90		 0,75 0,68	
Traffic volume for road without median	Vehicles per hour per lane	300	
Luminance	cd/m²	0,6	
Overall uniformity	U_o	0,4	
Longitudinal uniformity	U_l	0,5	
Threshold increment	%	20	
Design results			
1. System wattage, per luminaire	W		
Light source lumen	lm	27 000	
Angle of tilt	degrees		
2. Pole spacing	m		
Luminance	cd/m²		
Overall uniformity	U_o		
Longitudinal uniformity	U_l		
Threshold increment	%		
Price schedule, based on the following given criteria and costs:			
3. Number of years to be considered for evaluation	years	10	
4. Electricity cost per kWh, averaged over the projected period	R	1,3	
5. Cost of installed pole, inclusive internal wiring	R	3000	
6. Unit price of luminaire, inclusive of light source	R		
7. Scheme price: (1000/[2]) * ([5]+[6])	R		
8. Power consumption per km: (1000/[2])*([1]/1000)	kW		
9. Annual energy cost per km, [4]*4000*[8]	R		
Cost of ownership for the evaluation period: [7]+[3]*[9]	R		

Table 1: Tender form for design criteria, design results and price schedule. Group A street lighting – new installations. Values within grey shaded cells should be amended to users' requirements. (Note: This evaluation excludes the maintenance costs, which could substantially influence the cost of ownership. The grey shaded cells will be adopted to the criteria of the customer.)

1	2	3	4
Type of luminaire and lamp type	Unit	Item 1 250 W HPSE/SE	Item 2 LED
Design criteria			
Lighting category		A3	A3
Arrangement		Single sided left	
Lanes per carriageway		2	
Width of each lane	m	3,7	
Mounting height	m	10	
Overhang of left-hand side	m	1	
Existing pole spacing	m	45	
Lamp lumen depreciation factor		0,8	
Dirt depreciation factor:			
for IP 6: 0,83*0,90		0,75	
for IP 5: 0,76*0,90		0,68	
Traffic volume for road without median	Vehicles per hour per lane	300	
Luminance	cd/m²	0,6	
Overall uniformity	U_o	0,4	
Longitudinal uniformity	U_l	0,5	
Threshold increment	%	20	
Design results			
1. System wattage, per luminaire	W		
Lightsource lumen	lm	27 000	
Angle of tilt	degrees		
Luminance	cd/m²		
Overall uniformity	U_o		
Longitudinal uniformity	U_l		
Threshold increment	%		
Price schedule, based on the following given criteria and costs:			
2. Number of years to be considered for evaluation	years	10	
3. Electricity cost per kWh, averaged over the projected period	R	1,3	
4. Unit price of luminaire, inclusive of light source	R		
5. Annual energy cost per luminaire, as per formula: ([1]/1000)*4000*[3]	R		
Cost of ownership for the evaluation period: [4]+[2]*[5]	R		

Table 2: Tender form for design criteria, design results and price schedule. Group A street lighting – existing installation. (Note: Values within grey shaded cells should be amended to users' requirement.)

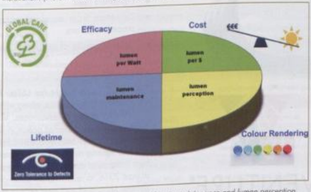

Fig. 1: Performance update: efficacy, cost, lumen maintenance and lumen perception.

until the system costs will be below the conventional luminaire costs (see Fig. 1).

- *Lifetime:* The lifetime of certain commercially available LEDs has increased substantially. Where claims of 50 000 h were the norm one to two years ago, the suppliers predict lifetimes of up to 100 000 h and sometimes even higher. These claims are nowadays proven by independent laboratories applying international standards.
- *Lumen perception:* The easy adaptation of the spectral distribution of LEDs offers great variety in different colour recognition indices (CRIs). This will be used in the near future to optimise the perception of light in various applications, like the food industry or offices.

Province	Qty of street light points
Eastern Cape	360
Free State	210
Gauteng	2060
KZN	6770
Western Cape	250

Table 3: Numerous installations in South Africa prove the benefit to the end-user.

Approved recommended practice (ARP035)

The SABS guideline for the installation and maintenance of street lighting has recently been revised and redrafted to include LED technology and give some guidance of how to apply this technology correctly when comparing and evaluating predominately outdoor lighting installations. Tables 1 and 2 provide guidance on new and existing installations, and emphasise that light sources should not be compared by the lumen value.

Reference installations in South Africa

Most end-users expect and assume that the LED technology is in its infant stage and not yet ready for roll-out to lighting installations in the public domain. Global sales statistics prove the opposite. Especially in North America, Europe and Asia, hundreds of thousands of LED light points are illuminating the outdoor environment with very high energy savings of up to 70 – 80%. Further cost savings like reduced maintenance are further reasons to switch to the LED technology. Even in South Africa various installations have been installed for a couple of years and prove the concept of benefit to the end-user. Table 3 illustrates this in more detail.

Performance SANS LED draft standard

The IEC has prepared and published various safety and performance standards for LED-related control gear, lamps, modules, luminaires and products. Some of them can easily be adopted in South Africa and published as SANS documents. But especially the performance IEC standards relating to LED luminaires cannot be adopted easily as not many international testing facilities including our local testing facility have the capacity and equipment to successfully and timeously conduct the required performance tests. The local lighting industry, end-user representatives and other key players have therefore founded a working group to address this and compose a local LED luminaire performance standard which will be available for public comment soon and published thereafter.

This locally developed standard covers the performance requirements for solid state lighting products including interior lighting, street lighting and floodlighting. It covers LED-based products incorporating control electronics and heat sinks for operation on AC or DC voltage power supply. It describes the procedures to be followed and precautions to be observed in performing reproducible measurements of:

- Total luminous flux or efficiency matrices
- Electrical power
- Luminous intensity distribution
- Colour temperature

Furthermore, it describes procedures to be followed and the information which needs to be provided where lifetime claims of operational performance are made. This includes:

- Rated life (in h) of the LED product and the associated rated lumen maintenance (L_x).
- Junction reference points (t_j) of LED product that corresponds to the rated life.
- Performance ambient temperature (t_p) for a luminaire.
- Ambient temperature (t_a) for a luminaire.
- Endurance test.

Each LED product will be issued with a final test report. This lists all significant data for each LED product tested together with the test results. The report lists all pertinent data concerning conditions of testing, type of equipment, LED products and reference standards. Items reported are:

- Date and testing agency.
- Manufacturer's name and designation of LED product under test.
- Measurement quantities such as total luminous flux, luminous efficacy, chromaticity coordinates and/or nominal CCT and/or CRI for white light products, input voltage (V), (clarify AC (frequency) or DC current (A), power (W) and power factor of LED product.
- Number of hours operated prior to measurement (0 h for rating new products).
- Total operating time of the product for measurements including stabilisation.
- Ambient temperature during measurement.
- Orientation (burning position) of LED product during test.
- Stabilisation time.
- Photometric method of instrument used (spectroradiometer, sphere-spectroradiometer, or goniophotometer).
- Designation and type of reference standard used (wattage, lamp type, intensity distribution type – omni-directional/directional) and its traceability.
- Photometric measurement conditions (for sphere measurement, diameter of the sphere, 4π or 2π geometry. For goniophotometer, photometric distance).
- Measured total luminous flux (lm) (absolute) or reference luminous flux (state parameters) and total lm/input W.
- Luminous intensity distribution (if applicable).
- Equipment used.
- Deviation from standard operating procedures, if any.
- Detailed results of tests, e.g. thermal, stress test.

Conclusion

The future looks bright for LEDs. Rapid improvement in economics, along with their fundamental technical advantages, will see them become the preferred option in almost all lighting niches – both indoor and outdoor. The LED lighting market is expected to grow by a compound rate of 20% each year until at least 2016, to reach market penetration in general lighting of well over 60% in most of the world's nations by 2020. Using the local reference street light installations and the availability of local performance standards will assist local authorities to more easily adopt and drive confidence in the technology and increasing economies of scale.

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LED floods with Bridgelux LEDs have 4 IEC certifications and Eskom approved

10w	R375
30w	R550
50w	R810
70w	R1275
100w	R1735
120w	R2200
150w	R2620
200w	R3150

20-72w solar LED street lighting models with dimming functions available.

German PV components and regulators. Autonomy from 2-4 days.

R9500 ex VAT for entry level model

LED HIGHBAYS

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100w	R2600
120w	R2900
150w	R3100
200w	R3550

LED TUBES

Our LED tubes with Samsung LEDs have 6 IEC certifications, SABS and Eskom approved

8w (2ft)	R195
12w (3ft)	R215
18w (4ft)	R250
24w (5ft)	R275

LED RECESSED

LED recessed with Samsung LEDs have 2 IEC certifications Eskom approved

20w	R870
30w	R1060
50w	R1165

Dimmable or non dimmable available

LED DOWNLIGHTS

LED downlights with Epileds LEDs and Cob Technology have 5 IEC certifications and Eskom approved

5w (MR16)	R85
5w (GU10)	R85
7w (MR16)	R105
7w (GU10)	R105

Dimmable or non dimmable available

Above pricing is not bulk or project based and excludes VAT. All of the above LED lighting have a 3 year warranty.

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Powertech Transformers	Jacqui Burn	P O Box 691, Pretoria, 0001	jacqueline.burn@pttransformers.co.za	012 318-9802
Pragma Africa	Alan Tait	P O Box 3971, Tygervalley, 7360	alan.tait@pragmaworld.net	011 318-0641
Preformed Line Products (SA)	Billy Oosthuyzen	P O Box 4015, Pietermaritzburg, 3210	sales@preformedsa.co.za	033 397-5800
PricewaterhouseCoopers	Jan Gey van Pittius	Private Bag X 36, Sunninghill, 2157	jan.gey.van.pittius@za.pwc.com	011 797-4134
Progressive Energy	Greg Schoufelbuhl	Suite 72, Cape Town, 7872	energy2energy@gmail.com	021 511-5580
Protective Structures	Connie Brooks	P O Box 1701, Rivonia, 2128	connie@mweb.co.za	011 917-3570
Quanta Services Africa	Fred Visser	P O Box 18598, Sunward Park, 1470	fvisser@quantaservices.colm	011 392-4761
Quiktrak Networks Africa	Clinton Lemmer	P O Box 1554, Stellenbosch, 7559	clint@quiktrak.co.za	011 253-3140
Reinhausen South Africa	Danie Venter	P O Box 1395, Southdale, 2135	c.mckenzie@za.reinhausen.com	011 835-2077
Reticulation and General Supplies	Louis Bezuidenhout	P O Box 1402, Sanlamhof, 7532	wolfgang@rgs-sa.co.za	021 982-7940
Revive Electrical Transformers	Dharmalingum Padayachee	P O Box 83334, Johannesburg, 2136	revive@global.co.za	011 613-1508
ROCLA	Kevin West	P O Box 92, Roodepoort, 1725	kevin.west@murrob.com	011 670-7600
Rotek Engineering	Gift Dladla	P O Box 40099, Cleveland, 2022	gift.dladla@eskom.co.za	011 629-4435
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Spintelligent	Andrew Dooley	P O Box 321, Steenberg, 7442	brigitte.hart@spintelligent.com	021 700-3500
SSI Engineers and Environmental Consultants	Buren-Schele	P O Box 867, Johannesburg, 7947	erict@ssi.co.za	012 367-5891
Static Power (a div of Actom)	Nichola Fort	P O Box 13424, Witfield, 2052	sales@static.co.za	011 397-5316
Stefanutti Stocks Power	Emmanuel Njapha	111 Mypark Drive, Parlock, 1467	emmanuel.njapha@stefstocks.com	011 254-5700
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Sure Engineering	Neil Jeffrey	P O Box 63, Steenberg,Cape Town, 1685	nj@suretech.co.za	021 701-8529
Surge Technology	Premesh Narismulu	P O Box 3109, Randburg, 7947	premeshn@mweb.co.za	011 792-1303
Switchboard Manufacturers	Ricky Rangiah	P O Box 40086, Red Hill, 2125	rickyr@switchboard.co.za	031 508-1520
Syntell	Cherelle Esau	P O Box 30298, Tokai, 4071	cherelle@syntell.co.za	021 710-2045
Tank Industries a Division of ATC	Adriaan Theron	P O Box 9, Steenberg, 7966	adriaan.theron@tank.co.za	021 789-2712
Telecom 180	Delio Senatore	P O Box 11106, Pretoria, 7947	delios@ansystelecom.co.za	012 360-0400
Thusani Brokers	Bernard Mberewere	Suite no 2 , La Lucia, 0181	bernard@thusanibrokers.co.za	031 566-2897
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Turnkey Metering Solutions	Navi Naidoo	84 Columbine Place, Durban North, 2136	navi@turnkeymetering.com	031 569-4085
Ulungeni Consulting	Jan Jordaan	P O Box 1521, Empangeni, 4051	ulungeni@iafrica.com	035 792-1026
Utillabs	Paroshen Naidoo	20 Thornhill Office Park, Vorna Valley, 3880	paroshen.naidoo@utillabs.com	011 805-0094
VAMP Solutions	Rodney Bristow	P O Box 11798, Selcourt, 1685	rbristow@vamp.co.za	011 818-2190
Velo VKE Consulting Engineers	Steyn de Lange	P O Box 72927, Lynnwood Ridge, 1567	delanges@velavke.co.za	012 481-3800
Verotest	Veronica Merry	P O Box 50559, Randjiesfontein, 0040	veronica@verotest.co.za	011 805-8322
Vetasi	Bouke Spoelstra	P O Box 39178, Pretoria, 1683	bouke.spoelstra@vetasi.com	012 348-4617
Voltano	Marius Schwartz	Postnet Suite 293, Lyttelton, 0043	marius@voltano.com	012 940-9272
Voltex t/a Voltex Cape	Corry Marinus	P O Box 291, Maitland, 0140	wcregional@voltex.co.za	021 530-3460
WDI Consultants	Accounts Payable	P O Box 3639, Randgate, 7404	louis.steynwdi@gmail.com	082 895-4899
Woodbeam	BV Magee	P O Box 526, Modderfontein, 1763	info@woodbeam.co.za	0861 966-323
WorleyParsons RSA	Corne Smith	P O Box 36155, Bellville, 1645	corne.smith@worleyparsons.com	012 452-6300
Y Wecan Environmental Trading	Norman Maharaj	B34 Platinum Junction, Cape Town, 7441	norman@nanolandsa.com	021 552-9855
Zest WEG Group	Jamie Wilson	Private Bag X10011, Sandton, 2146	jamiew@zest.co.za	011 723-6000

AMEU Past Presidents

Date	Name	City
1915 – 1917	JH Dobson	Johannesburg
1917 – 1918	J Roberts	Durban
1919 – 1920	B Sankey	Port Elizabeth
1920 – 1922	TC Wolley Dodd	Pretoria
1922 – 1924	GH Swingler	Cape Town
1924 – 1926	J Roberts	Durban
1926 – 1927	B Sankey	Johannesburg
1927 – 1929	J Mordy Lambe	East London
1929 – 1931	R Macauley	Bloemfontein
1931 – 1933	LL Horrel	Pretoria
1933 – 1934	LF Bickell	Port Elizabeth
1934 – 1935	AR Metelerkamp	Bulawayo
1935 – 1936	GG Ewer	Pietermaritzburg
1936 – 1937	A Rodwell	Johannesburg
1937 – 1938	JH Gyles	Durban
1938 – 1939	HA Eastman	Cape Town
1940 – 1944	IJ Nicholas	Umtata
1944 – 1945	A Rodwell	Durban
1945	JS Clinton	Harare
1945 – 1946	JW Phillips	Harare
1946 – 1947	GJ Muller	Bloemfontein
1947 – 1948	C Kinsman	Durban

Date	Name	City
1948 – 1949	A Forden	East London
1949 – 1950	DA Bradley	Port Elizabeth
1950 – 1951	CR Halle	Pietermaritzburg
1951 – 1952	JC Downey	Springs
1952 – 1953	AR Sibson	Bulawayo
1953 – 1954	JC Fraser	Johannesburg
1954 – 1955	GJ Muller	Bloemfontein
1955 – 1956	DJ Hugo	Pretoria
1956 – 1957	JE Mitchell	Bulawayo
1957 – 1958	JL van der Walt	Krugersdorp
1958 – 1959	CG Downie	Cape Town
1959 – 1960	R Wcane	Johannesburg
1960 – 1961	RMO Simpson	Durban
1961 – 1962	C Lombard	Germiston
1962 – 1963	PA Giles	East London
1963 – 1964	JC Downey	Springs
1964 – 1965	RW Barton	Welkom
1965 – 1967	D Murray-Nobbs	Port Elizabeth
1967 – 1969	GC Theron	Vanderbijlpark
1969 – 1971	HT Turner	Umtali
1971 – 1973	JK von Ahlften	East London
1973 – 1975	JC Waddy	Pietermaritzburg

Date	Name	City
1975 – 1977	E de C Pretorius	Potchefstroom
1977 – 1979	KG Robson	East London
1979 – 1981	PJ Botes	Roodepoort
1981 – 1983	DH Fraser	Durban
1983 – 1985	W Barnard	Johannesburg
1985 – 1987	JA Loubser	Benoni
1987 – 1989	AHL Fortman	Boksburg
1989 – 1991	FLU Daniel	Cape Town
1991 – 1993	CE Adams	Port Elizabeth
1993 – 1995	HR Whithead	Durban
1995 – 1997	JG Malan	Kempton Park
1997 – 1999	HD Beck	East London
1999 – 2001	AJ van der Merwe	Bloemfontein
2001 – 2003	J Ehrich	Pretoria
2003 – 2004	PE Fowles	Pietermaritzburg
2004 – 2006	D Potgieter	Polokwane
2006 – 2007	V Padayachee	Johannesburg
2007 – 2008	S Maphumulo	Durban
2008 – 2010	S Gourrah	Buffalo City
2010 – 2012	M Rhode	Drakenstein

AMEU Honorary Members

Period	Name
1915 – 1936	Dr. HJ van der Bijl
	J Roberts
	E Poole
1938	LL Horrell
1944	GH Swingler
	AT Rodwell
1950	Dr. JH Dobson
1951	HA Eastman
1955	W Ballad – Ellis
	JC Fraser
	C Kinsman
1956	WH Milton
	A Morton Jaffray
	Major SG Redman
	Clr. CEK Young
1957	DA Bradley
1958	Col. GG Ewer
	A Foden
	Clr. Holley
1960	Clr. FJ Castelyn
	Clr. LP Davies
1962	AR Sibson
1963	CG Downie
	JC Downey
	RW Kane
1965	G Muller
1967	Clr. JD Marais
	JR Telles
1969	W Beesley
	PA Giles
	D Murray-Nobbs
	EL Smith

Period	Name
1971	DJ Hugo
	ACT Frantz
	HT Turner
	R Leishman
	RMO Simpson
	W Rossler
	F Stephens
	JF Lotegan
1973	RG Ewing
1975	Clr. HG Kipling
	C Lombard
	DC Plowden
	JG Wannenberg
1977	Dr. RL Straszacker
	AA Middlecote
	GC Theron
	JC Waddy
1979	RW Barton
	Clr. HJ Hugo
1981	JDN van Wyk
	Dr. RB Anderson
	J Morrison
1983	TC Marsh
1985	AA Weich
	KG Robson
	Clr. RL de Lange
	W Barnard
1987	AP Burger
	JC Dawson
	DH Fraser
	PC Palser

Period	Name
1989	PJ Botes
	MPP Clarke
	EG Davies
	JA Loubser
1993	FLU Daniel
	JE Heydenrych
	B van der Walt
1995	CE Adams
	B Madeley
1997	JD Algera
	HR Whitehead
	F van der Velde
1999	JG Malan
	CE Burchell
2003	AJ van der Merwe
2005	PE Fowles
	T van Niekerk
	J Ehrich
2007	DET Potgieter
2008	V Padayachee
2009	S Maphumulo
	JJG Nel
2010	O Bothma
	JE Coetzee
	RS Wallis
2011	M Cary
	D Louw
	H Roos
	S Gourrah
2012	M Rhode
	P Johnson
	L Steyn
	F Diener
	R Wienand
	G Pereira

Deceased Engineering Members 2012

Johan Viljoen	Ockert Bothma	Fred Daniel
Koos Algera	Gert Mans	Wynand Viljoen


Lucy


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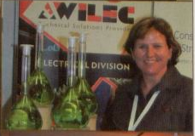


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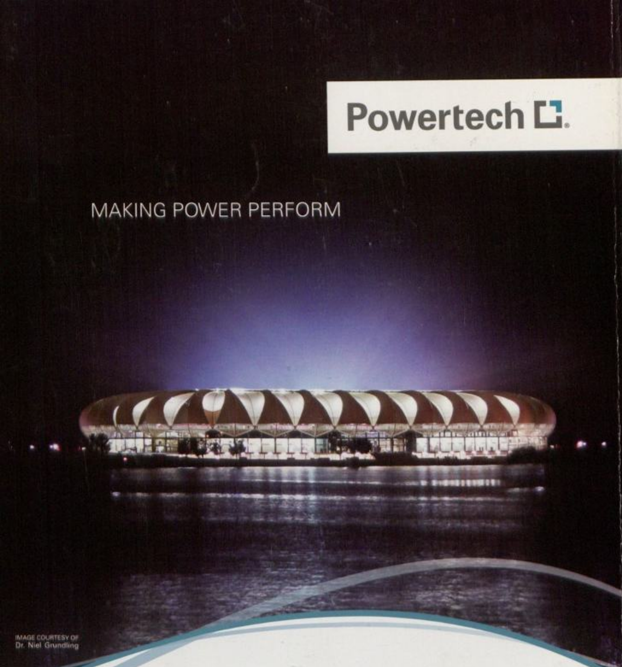

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