LEADING THE ELECTRICITY DISTRIBUTION INDUSTRY

AMEU

27th Technical AMEU Convention

13 to 16 October 2019

The 4th Industrial Revolution ("4IR")
Building the Power Utility of the Future, Today

Special AMEU Convention Proceedings edition

energize

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Contents

Front cover story – *Information from ArmCoil* 3
Welcome address by the AMEU president – *Refilwe Mokgosi, AMEU president* 4
Welcome address by the host city – *Councillor Phindile Maxiti, City of Cape Town* 6
Keynote address – *Gwede Mantashe, Minister of Mineral Resources and Energy* 10
Keynote address – *Xolile George, SALGA* 11
Address by Nersa – *Christopher Forlee, Nersa* 13
Women in electricity 15
AMEU VIPs and Awards 16
Panel discussion: "4IR - Are we fit to face the future?" 17
Closing address 18

IMPACT OF THE 4IR

Low cost intelligent outage management – *by Warren Mathers, City of Ekurhuleni* 20
Relevant skills required to survive and thrive in the fourth industrial revolution – *by Heino van Jaarsveldt and Corrie van der Wath, Matleng Energy Solutions* 24
Electrical master planning for the fourth industrial revolution – *by Hilton Boartman and Steyn, GLS Consulting* 28

ENERGY STORAGE

Energy storage on municipal grids: Why this makes sense – *by Paul Vermeulen, City Power* 34
Price parity of solar PV with storage? – *by Aradhna Pandarum, Eskom* 42

TECHNOLOGY & INNOVATION

The utility of the future: Distributed power generation enabled by the Internet of Things – *by Dr Cathy Pickering, FuseForward South Africa* 48
Public lighting: Lighting the way to smart city development – *by Bjorn Smidt-Hart, SMEC South Africa* 52
Early detection of impending failure in HV cable terminations – *by Samantha Chimunda and Cuthbert Nyamupangedengu, University of the Witwatersrand and Patrick O'Halloran, City Power* 57
Challenges of planning future high voltage power system networks – *by Vasu Chetty, eThekwini Electricity* 60

SMART TECHNOLOGIES IN THE EDI FOR BUSINESS SUSTAINABILITY

Making smart grids smart makes smart cities smarter – *by Martin Kuhlmann, Siemens* 65
Evolving 4IR technologies and digital substations – *by Stuart Michie, ABB South Africa* 70
IoT based smart grid communication for metropolitan electricity distribution networks by – *Gerhard Brown, City of Cape Town* 74

SMALL SCALE EMBEDDED GENERATION ("SSEG") & ASSOCIATED TECHNOLOGIES

Impact assessment of a high penetration of rooftop PV in Cape Town – *by Johanette van der Merwe, City of Cape Town; Trevor Gaunt, University of Cape Town; and Karen Kritzinger, University of Stellenbosch* 82
Solar PV investment decisions in the residential sector in SA: A technical analysis – *by Nikkie Korsten and Karin Kritzinger, Stellenbosch University and Centre for Renewable and Sustainable Energy Studies; and Louise Scholtz, Urban Futures WWF-SA* 85
Incorporating embedded generation into municipal networks – *by Poonam Lutchman, Schneider Electric* 91
The impact of small-scale embedded generation on municipal revenue – *by Tanaka Shumba, Hlengiwe Radebe, Josh Dippenaar and Megan Euston-Brown, Sustainable Energy Africa* 98
Leveraging open source technologies: A remote monitoring case study – *by R Singh, and G Nkomo, eThekwini Electricity* 102

ASSET & REVENUE MANAGEMENT

Competence in an ever-changing asset environment – *by Tim Beavon, Pragma* 110
TID rollover checklist and timeline – *by Don Taylor, STS Association* 112
Condition monitoring for asset management in MV switchgear at eThekwini Electricity – *by MP Lokothwayo, Sheila Cele Diploma, N Zulu and PM Ntombela, eThekwini Electricity* 115

AMEU Utility and Engineer Members 119
AMEU Affiliate Members 121
AMEU Past Presidents 124
AMEU Honorary Members 124
AMEU Deceased Members 2019 124
PeopleScene 125
Advertisers list 128

the team

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New minisub design boasts internal bunding wall

Information from Armcoil

Armcoil is now offering the market a sophisticated minisub which incorporates a bund wall and storage tank to retain oil should the oil-filled transformer leak. This new design addresses the environmental risk and clean-up costs associated with oil spills from minisub transformers.

Minisubstations (minisubs) can be defined as substations which comprise a transformer, low voltage and high voltage switchgear, connections and auxiliary equipment in an enclosure to supply low voltage energy from a medium voltage network.

Every oil-filled transformer must be installed in such a way as to contain oil should it leak from the transformer. Transformer oil – especially mineral oil – is harmful to the environment and increases the risk of fire. Oil spills are largely due to slow oil leaks, attacks from metal thieves or vandals, or result from human error at the time of maintenance or installation. Bund walls allow for the containment of spilt oil.

Protecting the environment against an oil spill, and air pollution produced by an oil fire, is not only the responsibility of the people doing the installation or the routine maintenance, but it is also the responsibility of the design engineer to mitigate all possibilities of oil spills and fires contaminating the environment in the event of a failing transformer due to human actions.

Fig. 1: Flash chute and lifting lugs visible on the roof of the minisub.

Fig. 2: Minisub with doors open, showing the RMU.

Armcoil, a rapidly growing electrical equipment company based in Roodepoort, west of Johannesburg, manufactures and repairs transformers, motors and other electrical equipment. The company recently developed an innovative minisub enclosure design which incorporates a bund wall and storage area for transformer oil should the transformer leak. This important feature helps the company's minisubs to comply with environmental regulations, and also removes the need for oil clean-up mitigation equipment and procedures to be put in place when the minisub is installed.

The enclosures are designed to be robust and built to protect all the equipment they house and can also be ordered with built-in fire suppression units. These locally designed and manufactured minisubs offer tamper-resistant features including a sophisticated door-locking mechanism which makes forcing the doors open virtually impossible.

These minisubs are available in a wide range of capacities ranging from 200 to 3150 kVA; with primary voltages ranging from 6,6 to 33 kV, and secondary voltages from 415 to 3300 V.

Special features include a "flash chute" on the roof of the unit which will blow off in the event of an explosion inside the minisub guaranteeing operator safety; as well as pre-fitted lifting lugs and built-in skids which can be fitted with wheels should the client wish to be able to move the minisub without having to order a mobile crane or rigging team.

The units are designed to be used anywhere – including corrosive environments. The cabinets are made from either mild steel or 3C12 – a form of stainless steel – and treated with a special "coastal" coating which protects them from corrosive sea air. Their modular design makes the repair or upgrade of internal equipment easier and therefore less expensive.

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Welcome address by the AMEU president

I welcome you to the 27th AMEU Technical Convention 2019 and express my sincere appreciation to the City of Cape Town for hosting this prestigious event.

This convention provides a unique opportunity for all of us to engage in dialogue over several issues which affect our way of life.

We have ahead of us a three-day programme packed with key topics aimed at assisting us in dealing with the opportunities facing the electricity distribution utility businesses.

The economic climate in our country, in fact globally, hasn't been that favourable yet despite all the challenges we have remained resolute and committed.

Albert Einstein did not speak until he was four, and was told he would never amount to anything, Oprah struggled as a small-town journalist and Michael Jordan was cut from his high school basketball team, so it's important for us all to remember that it's not how we start that matters but its how we finish.

With that said, I would like to encourage all of us to always look on the bright side of life, always remembering that every cloud has a silver lining.

That our efforts especially during trying times like the ones we are currently facing, will yield the desired results, only if we could work together, with commitment and focus.

As you will experience over the next three days, while dynamics might vary from one geographical area to another, we are not unique in South Africa and we can therefore learn from the rest of the world and from the rest of the Africa continent.

The challenge is for us as leaders to capitalise on the opportunities and to shape a sustainable future for the electricity and energy utilities.

Providing a world class service to our customers, building sustainable and ethical relationships within the industry, with our customers, suppliers, government, financiers, and regulators, while taking care of our environment and planet, must be among our key focus areas.

I do not suggest that this is an easy task, but I am convinced that working together we can do it.

There's been a public outcry in South-Africa about the poor performance of municipalities. That many are not living up to expectations and hopes of their communities.

Globally the electricity supply industry is confronted with various disruptors forcing the industry to consider options which will contribute to sustainability and which will lay the foundation for the attainment of inclusive economic growth.

Refilwe Mokgosi, AMEU president

CoGTA has previously developed a turnaround strategy in an attempt to address areas riddled with poor performance within the local government sector.

It can be argued that turning around municipalities calls for a degree of knowledge and innovation, in particular from senior officials, around the implementation of appropriate theoretical perspectives that are informed by the local conditions and needs.

The local government turnaround strategy identified key developmental areas of change for our municipalities as such the local government turnaround strategy compelled the municipalities among other things to:

- Reflect on their own performance and design turn around strategies to focus on establishing positive councils with visionary and accountable leadership
- Concentrate on properly constituted corporate services, technical services and financial management functions, including recruitment and skills retention policies ensuring "right people in the right job".
- In the same breath improve on internal or micro-environment as well and optimise revenue collection and improve billing, customer care, indigent and credit control policies – "balance the books"..., the list is long.

Customers owe municipality billions of rand for services, while municipalities owe Eskom about R23,5-billion for bulk electricity procured.

This situation is clearly not acceptable and as the industry we must collectively find innovative ways to effectively address this challenge, including the structural problems that are the root cause.

The loss of sales due to the introduction of energy efficiency initiatives and customers pursuing effective alternative energy options such as rooftop PV, do have an impact on the traditional business model.

Therefore as the industry we must find ways to adapt to these ever changing circumstances or our very survival is threatened.

The steep tariff increases experienced from Eskom for bulk electricity is not helping municipalities. While municipalities must improve revenue collection, search for additional revenue streams, improve efficiencies and reduce their operating costs if there is no intervention to curb the tariff increases associated with bulk electricity, it must not come as a surprise to anybody that more and more municipalities will default in respect of paying for bulk energy purchases from Eskom.

To avoid this disaster waiting to happen, requires a structured intervention where, municipal leadership both politicians and administration, Eskom, industry leaders, the regulator and National Treasury urgently meet to address these challenges.

Without taking away anything from what I have just said, municipalities must also as a matter of urgency conduct a comprehensive cost of supply study.

There are many examples of tariffs which are not reflective of the real costs while many municipalities do not have a good handle on their cost structures.

Without doing proper ringfencing of the electricity utility business it will not be possible to get a good control over income and cost, thus negatively affecting the sustainability of the service we provide.

We do have an obligation towards all customers and from a support perspective we must look after the customers who cannot afford cost reflective tariffs.

However, we must demonstrate transparency where cross-subsidisation is applicable. This is also an area where the AMEU and SALGA have started to play a leading role.

From a technical/infrastructure perspective, the industry must give urgent attention to the infrastructure performance and ability to meet customer requirements.

It is by now common knowledge that in the case of South Africa and based on the Approach to Distribution Asset Management (ADAM) 2014 updated report, that the distribution infrastructure investment backlog was R68-billion in 2014.

It is therefore clear that as an industry we have lost control over the investment in the

Continued on page 6...


Kratos Family
Floodlights
GEN Series
Street and Floodlights

Welcome address by the host city

I would like to welcome you all to this, the oldest city in South Africa, which is rich in history with a diverse culture. It is the most beautiful city in the world.

It is a privilege and honour for us to host the Association of Municipal Electricity Utilities' 27th Technical Convention 2019, "Building the power utility of the future, today."

I have recently returned from the C40 Mayors Summit event in Copenhagen, Denmark, where various countries and cities discussed and showcased their climate action plans and measures. Seeing the effects and the impact posed by climate change, one is left with no option but to understand that this is the reality we face today.

A local case study, being the recent "day zero" that Cape Town experienced less than a year ago, is just one example how climate change is a reality and needs to be taken seriously.

As mentioned and endorsed by the United Nations as part of the Global Goals for Sustainable Development 2030, known to many as the 17 goals, climate change remains a catalyst that cuts across all other goals.

Listed as one of the global goals is energy, which plays an important role, from decent work and economic growth, industrial, innovation and infrastructure to sustainable cities and communities. Partnerships is the most important of all, because without partnership nothing can achieved, as history has shown.

Phindile Maxiti, Councillor

South Africa is currently grappling with shortages in energy which poses a threat to its economy if not dealt with urgently. Illegal connections and the vandalism of infrastructure is costing cities a lot of money. Increases in electricity tariffs are a huge burden on our citizens.

This is but a few of the challenges faced by the City of Cape Town's electricity generation and distribution department.

The City of Cape Town is now looking to innovative smart technologies and other various alternatives, including small scale embedded generation (SSEG) for solutions.

Having achieved so much in the past in the electricity provision space, from the conversion of the old system to prepaid meters, to the electrification of informal settlements and backyarders, the City of Cape Town believes that IPPs are another way of solving the energy crisis in the country.

As the 4th industrial revolution dawns upon us, many questions must be asked:

- Are we really ready for this change?
- In what way will it affect our livelihood?
- How will it affect our environment?
- Is it an answer to the poor of the poorest?

The honest answer is, we do not know but we can try!

I stand here today in front of men and women who continue to strive to find solutions to the energy challenges faced by our municipalities, not only for today but for future generations too. Standing here in front of you all, knowing the work that has been achieved and the work that lies ahead, it is our call that we continue our partnership in building sustainable communities with sustainable and clean energy.

Phindile Maxiti, Councillor, City of Cape Town

...*Continued from page 4*

infrastructure which is aimed at serving our customers.

Considering the current financial position of municipalities as well as the regulators guideline in respect of the minimum investment in maintenance of infrastructure, all indications are that the infrastructure performance will not improve.

It is my humble opinion that this matter must receive urgent attention and be driven as a national priority. Economic growth cannot take place without sound and reliable distribution infrastructure.

The AMEU remains committed to providing guidance in respect of prudent asset management practices and the identification of appropriate training and skills transfer mechanisms.

As the industry we must then broaden our discussion extensively to touch on how 4th industrial revolution will speak or is already speaking to the utilities space.

Ladies and gentlemen fasten up your seat belts as we are about to dive into the unknown.

Over the last three decades it has been about the IT revolution, which has already radically transformed our working and living environments.

This interconnection between several worlds is very powerful 4th industrial revolution is not the first big change in human history, but its extraordinary with the respect to the speed of the transition.

The disruption is happening much faster than what we anticipated. We must think about the customer of the future and how we should respond to their needs.

From an AMEU executive leadership perspective we formulated the challenge as: "How might municipal power distribution utilities respond to the current challenges and emerging disruptors in the energy landscape, so that they excel in service delivery for all on a sustainable basis?"

While I am not for a moment suggesting that as an industry, we should be waiting for the policy makers and the regulator to first get everything in place before we can embrace the future, it is essential that the industry enablers from a policy perspective be addressed.

It is essential that we get clarity on the future market arrangement and that the status of municipalities be recognised as a participant in the industry from a generation, distribution, trading and retail perspective. This "middle-man model" is just introducing additional cost with limited benefits.

Furthermore, it is now needed more than ever before that the municipal funding model be reviewed.

In all honesty we don't have all the answers to some of these questions, which is why it's so important now, more than ever before to work together as various stakeholders towards developing and implementing sustainable solutions to effectively and efficiently address our current challenges for the benefit of our customers and our country's economic growth and development.

In conclusion it is important to note that the 4th industrial revolution is not just about technologies.

May you enjoy the 27th AMEU Technical Convention and when you leave here go back to your place of work, re-energised and full of new ideas to capitalise on the opportunities at hand.

Refilwe Mokgosi, AMEU

EThekwini Electricity scoops top awards at AMEU convention

It takes over two thousand six hundred employees of eThekwini's Electricity Unit, and technical teams working around the clock to provide safe, affordable and reliable electricity to every home in our city.

Maxwell Mthembu

Recognition for work well done is always appreciated. The electricity department of the eThekwini Metropolitan Municipality's efforts were singled out for particular recognition at this year's AMEU convention when they were awarded the association's coveted "Top performing metropolitan municipality" award.

Last month, their hard work was lauded through two prestigious awards won by the unit in the Association for Municipal Electricity Utilities (AMEU) president's Legacy Awards. EThekwini municipality's electricity unit won the inaugural award for "Top performing metropolitan municipality".

The unit's head, Maxwell Mthembu, thanked the AMEU for recognising eThekwini Electricity's efforts, by saying, "This hard earned award comes at a time when the country as well as the electricity distribution industry finds itself crippled by a series of challenges from dwindling sales, constantly rising electricity prices, challenges around renewables and self-generation, a stagnant economy as well as infrastructure theft, among others."

"It is under these difficult circumstances that our resilience and perseverance against adverse conditions, are forged. It gives me great pleasure to note that the majority of our staff have risen to deliver the best possible service the unit can offer under trying circumstances."

Excellent papers were presented by three of the unit's technical staff.

Sheila Cele, a technician who specialises in diagnostics and maintenance, spoke on the topic "Condition monitoring developments for asset management in MV switchgear"; Vasu Chetty, a chief high voltage planning engineer, gave a presentation on "Challenges of planning future high voltage power system networks"; and Resham Singh, a chief engineer, who specialises in SCADA, automation and control, presented a paper on "Leveraging open source technologies in the municipal landscape: A remote monitoring solution case study."

Jayshree Pershad

The Municipality's project executive for electricity, Jayshree Pershad, who has over two decades of experience in electricity transmission and distribution, was awarded the inaugural "Top performing woman in electricity" award.

In her speech after receiving her award, Pershad applauded the unit's programmes which continue to break gender barriers in this largely male dominated industry and its success in attracting, developing and retaining competent women.

"I thank the AMEU for awarding me the honour of receiving this award," she said. "I would also like to take this opportunity to also thank the eThekwini Electricity executive team and my previous director, Tony Dold, colleagues, friends and family for their support and encouragement."

Pershad's message to young engineers and those aspiring to join the industry is "hard work, perseverance and performance are the keys to success." Pershad is also the AMEU's president-elect and will be inaugurated as the association's president at its next convention, which is to be held in Durban in October 2020.

EThekwini Metropolitan Municipality
www.durban.gov.za

Keynote address by Minister of Mineral Resources and Energy

It is a great privilege for me to interact with you today as of the Association of Municipal Electricity Utilities at this, your 27th Technical Convention under the theme "The 4th Industrial Revolution – Building the Power Utility of the Future, Today".

This convention takes place a day before I table the updated Integrated Resource Plan 2019 to Cabinet for approval. As you might be aware, the IRP2019 update has been long coming. I believe that its approval will create the much-needed policy certainty within the electricity generation sector of the industry.

The National Development Plan identifies the need for South Africa to invest in a strong network of economic infrastructure, designed to support the country's medium and long-term economic and social objectives. Energy infrastructure is a critical component that underpins economic activity and growth across the country. It needs to be robust and extensive enough to meet industrial, commercial and household needs.

Municipalities play an important role in the electricity delivery value chain. They provide the interface with the end-user of electricity and thus without technically competent municipalities, the delivery of electricity will be hampered.

The government has, since 1994, made significant progress in providing access to electricity. In 1994 access to electricity stood at 36%. Since then, through the government's Integrated National Electrification Programme (INEP), access has increased to over 90% of households. The programme is implemented annually by transferring allocated funds to licensed municipal distributors and Eskom, to undertake the infrastructure programmes for electrification.

The department of Mineral Affairs and Energy spends over R5-billion per annum in this regard. Progress made is commendable. However, there is concern about the increasing under-expenditure by municipalities in the current fiscal constrained environment.

The programme has over the last financial years seen budget reductions. These are likely to continue if municipalities do not execute projects and spend their electrification budgets as planned.

The department is also rolling out non-grid electrification solutions through solar home systems. Communities have gradually begun to embrace this type of solution, compared to their initial reaction.

Gwede Mantashe,
Minister of Mineral Resources and Energy

Municipalities play an important role in the electricity delivery value chain. They provide the interface with the end-user of electricity and thus without technically competent municipalities, the delivery of electricity will be hampered.

Falling solar panel and battery prices provide an opportunity to scale up on non-grid solutions for rural areas with difficult terrain for economical construction of grid infrastructure as well as informal settlements.

Incorporation of these solar home systems into the municipal service basket is critical for the sustainability of service to rural households, as well as municipal electricity business models.

The electricity generation and distribution landscape in South Africa, and globally, is changing rapidly. World-wide electricity innovation, technology advancements and associated technology cost decline make it possible for end-users to generate their own electricity. This is a significant shift from the traditional vertically integrated power generation, transmission and distribution model of the past. We need, therefore, to contextualise this shift in our own environment.

South Africa's increasing electricity prices compound the energy industry evolution. Substitutes such liquid petroleum gas (LPG) are now viable alternatives for cooking and space heating whilst rooftop solar photovoltaic are viable for lighting.

The revenue model for municipalities will have to be reviewed in the light of the changing behaviour of the electricity consumer. More and more consumers choose to generate their own electricity. This will lead to the reduction of customers of municipal electricity. It is not necessarily wise to make up for this reduction by increasing tariffs. A better proposition could be for municipalities to amend their revenue model by introducing more services, in the context of the fourth industrial revolution.

Within the three major areas of the value chain (electricity generation, transmission and distribution) municipalities play a key role of distribution and interfacing with end-users.

It is critical that municipalities are technically capable to service the electricity consumer and in a cost-effective manner. We need to focus on building technical capacity and re-train at municipality level to prepare for the next revolution within this sector. Municipalities must be able to adapt to global trends.

Once the IRP2019 has been approved, I will issue a ministerial determination in line with section 34 of the New Generation regulation to initiate procurement of additional electricity generation capacity. This will be preceded by detailed work that the department will undertake to identify areas of improvements from the previous procurement.

In terms of the embedded generation opportunities in other words, generation within the municipal grid the department plans to issue an updated Small Scale Embedded Generation Regulation once the National Energy Regulator of South Africa (NERSA) has concurred. I am acutely aware that the industry is also awaiting this regulation. This will further provide policy certainty once promulgated.

I wish you all the best in your deliberations in the course of this convention.

Gwede Mantashe,
Minister of Mineral Resources and Energy

Keynote address by SALGA

The energy transition and the 4th industrial revolution are already taking place in South Africa and have for quite some time.

The electricity customers now have a suite of options for their energy needs, customers are no longer captive: decentralised generation allows customers to not only generate their own electricity but also the opportunity to sell excess power to the grid.

Improved energy storage technologies, digitisation and smart systems enable customers to more effectively manage and reduce their electricity consumption.

The growth of renewable energy technologies is also re-shaping energy systems across the whole electricity value chain. This trend suggests a critical shift in dynamics, generating numerous risks and opportunities at all levels of the value chain.

Increasing integration with the information and telecommunications (IT) networks have allowed electricity systems to become "smart". Better communication and information with the electricity industry has allowed for a more productive system overall. Integration with IT has also allowed for consumers to become more informed and actively involved in the electricity sector.

As the industry, we can dare try to resist these changes and remain in our old traditional ways, or we can embrace and define the energy utility of the future that brings "just" energy transition for all. Together we need to recognise the energy transition, and 4th industrial revolution, and jointly engage on a vision for the future which is sustainable and where we also achieve low carbon emissions, economic growth and job creation, transformation and development of local communities. This means reconfiguring the energy business model and redefining the role of government, state-owned entities and other sectors in the energy space.

The 4IR presents immense opportunities for municipalities and the energy utility of the future. To unlock its value within the electricity and energy sector we need to engage on some of the key issues below for the utility of the future, today.

Development of new business models and services relevant to the 4IR which means new and more revenue streams, e.g. services for charging of electric vehicles, providing 4IR energy advisory services to customers as well as O&M to customers, etc.

Reskilling of existing employees and creation of 4IR jobs and tasks within the system.

Xolile George, SALGA

Quicker demand management response due to automation of services. Demand flexibility creates value for customers and the grid by shrinking customer bills (by as much as 40%), reducing peak demand and shifting consumption to lower price, off-peak hours. Demand flexibility also can help providers, in some cases, to avoid or defer investments in central generation, transmission and distribution, and peaker plants.

Increased quality of service and supply to customers. The increasing deployment of advanced metering infrastructure presents clear opportunities for improving quality of service, low voltage network observability and data gathering (this data offers opportunities for automated outage detection, more detailed demand forecasting, etc.

Reliable, affordable electricity supply

Reliable electricity supply is critical to a 4IR economy and society. Digital infrastructure enablers such as connectivity, internet of things (IoT), smart machines, devices etc. need electricity to function. Digital services and e-commerce also rely on electricity. As such, stable electricity is critical and needs to be achieved through a combination of grid solutions and the incentivisation of off-the-grid electricity solutions especially in rural areas.

Deploying of the 4IR enabling infrastructure where several actions can be taken to ensure that the necessary infrastructure is in place to enable new business models and the future energy system, including:

- Defining the model to deploy enabling infrastructure that is flexible, open and interoperable.
- Ensuring customers and third parties can benefit from data generated by Distributed Energy Resources and the digital grids.
- Define innovative financing schemes for services, infrastructure etc.

There is no revolution that comes without risks and complexities.

As electricity grids increasingly become smart and interdependent the impact of a cyberattack also becomes more severe and wide-reaching. The World Economic Forum's Global Risk Report 2019 suggests that large-scale cyberattacks rank fifth among the risks most likely to occur in the next ten years. Currently cost of a cyberattack on the US smart power grid is estimated to be $1-trillion.

Rising joblessness due to digitalisation and automation of the services that 4IR is bringing. Some of the jobs may become redundant and there would be urgent need of reskilling utility employees for the 4IR jobs and opportunities

New technologies may threaten to amplify current inequalities, both within and between countries. That means driverless trucks and robots, all fully digitised. Rising inequality and income stagnation are also socially problematic.

New technologies may further concentrate benefits and value in the hands of the already wealthy. Those who didn't benefit from earlier industrialisation risk being left even further behind.

The introduction of distributed energy resources (small scale embedded generation) at scale will increase the complexity of system governance, and system planning needs to be modernised.

The 4IR must find us ready, we do not have enough time - we must prepare for it while mitigating the possible risks that comes with it. We have an advantage in that we have identified some of the risks and challenges.

I am confident that this convention will discuss key enablers (e.g. policy, regulatory, etc.) that should be in place to facilitate the future readiness in order to grab the opportunities and to position the business to be fit to face the future.

At policy level there will be a need for redesign of regulatory paradigm by changing the rules of the game, enabling new roles for utilities, innovation and full integration of distributed resources, participation of customers in the industry.

The regulatory entities must be independent, with the ability to clearly define and track outputs and performance metrics, including technical, commercial and operational KPIs for reliability, power quality, workforce, system losses and other aspects of the electricity system.

For the leadership of utilities, we will have to discuss embracing of new business models and how the utilities will pursue new revenue sources from innovative distribution and retail services.

Discuss strategies for deploying enabling infrastructure and ensuring that the infrastructure enabling new business models can be timely deployed.

Redefine customer experience: Incorporate the new reality of a digital, customer empowered, transactive electricity system, etc.

The key primary technologies to be focused on by South Africa based on an Accenture report on unlocking the 4IR value for South Africa, include:

- Internet of Things and connected devices with a potential value of R1,4-billion.
- Artificial intelligence with a potential value of R1,3-billion.
- Digital platforms with a potential value of R1,1-billion.
- Big data analytics and cloud with a potential value of R800-million.
- Robotics with a potential value of R260-million.
- Wearables, block chain and autonomous vehicles with a combined potential value of R332-million.

As municipalities and the industry we must see to it that we are part of the above agenda.

Conclusion

The energy technological advances are paving the way towards a new energy system that will unlock significant economic and societal benefits. However, there is a great risk for value destruction if we fail to efficiently capture the value of distributed energy resources, which could leave generation or network assets stranded and see customers defect from the grid. This risk represents one more reason to identify and take the right actions that will accelerate and make the transition cost effective.

The speed of adoption and the success in shaping the transformation in the most beneficial way for the society and the system overall will depend on a broad range of factors, which fall under four main dimensions: regulation, infrastructure, business models and customer engagement.

The public and private sectors will need to contribute to successfully accelerate adoption of grid edge technologies, as neither can do it alone. Policy-makers will have to redesign the regulatory paradigm, adapting the network revenue model and tariffs, planning the electricity system (taking into account both utility scale and distributed energy resources), and using price signals.

Regulators will have to foster agile governance by adopting stable long-term regulation that includes faster reaction cycles, involving more stakeholders and including an urban regulatory dimension.

The private sector will have to acknowledge the new reality of a digital, customer-empowered, transactive electricity system by embracing new business models and simplifying and redesigning the experience of residential, commercial and industrial customers. All stakeholders will have to deploy enabling infrastructure that is flexible, open and interoperable.

Public-private partnerships will help build enabling infrastructure, even if it is not yet commercially viable and thus requires initial public intervention. Emerging markets that may be less encumbered by existing infrastructure, investments, or system structure may have the opportunity to leapfrog some of these challenges and head straight to mass adoption of these new technologies.

It is important to note that the 4th Industrial Revolution is not just about technologies. It will impact on society and all human life. We have to make sure that our technological cooperation and development have contributed to the enhancement of people's lives and it must continue in the future. Energy will continue to play a key role in this.

The focus of technological developments in the 4th Industrial Revolution should be the human beings mostly. This has nothing to do with pessimism or aversion against technological progress, on the contrary. We need progress and development but we should steer and control it. All involved researchers, innovators, policy-makers and citizens need to be well informed, adequately trained to ensure that we build a better future.

Xolile George, SALGA

Address by NERSA

It is my pleasure and honour to be given the opportunity to say a few words on behalf of the National Energy Regulator at this convention. Congratulations on this convention being held under the stimulating theme of: The 4th industrial revolution: building the power utility of the future, today.

I would also like to congratulate the AMEU for the work it does in promoting uniform approaches and technical excellence in the industry. Conferences such as this are to be valued for their contribution to the creation of awareness and professionalism in the industry.

The National Energy Regulator of South Africa (NERSA) is a vital role-player in the electricity supply industry. The very nature of NERSA's role requires that it balance the interests between a myriad of role-players. It cannot favour one and ignore another. It is required to execute its mandated role without fear, favour or prejudice to look after all stakeholders in the best interests of the South African public. This includes especially those end-users who might not have a voice or a proper understanding of the technicalities of the industry.

Similarly, municipalities have a critical role to play. You are the face and arms of service delivery to the South African public. This service delivery includes the electricity industry and thus NERSA and the municipalities are well aligned and have many of the same goals.

The 4th industrial revolution about which we are speaking at this conference is sometimes a difficult concept to grasp, terms such as big data, artificial intelligence, robotics, the Internet of things and blockchain amongst others are often bandied about to describe the 4th industrial revolution. Sounds a lot to me like the digital age, which is the one I most readily identify. This is no surprise as I understand that the 4th industrial revolution is enabled by and built upon the technology and infrastructure of the third revolution.

So, then, what is this 4th industrial revolution? The World Economic Forum describes it as the advent of "cyber-physical systems" involving entirely new capabilities for people and machines. While these capabilities are reliant on the technologies and infrastructure of the third industrial revolution, the fourth industrial revolution represents entirely new ways in which technology becomes embedded within societies and even our human bodies. Examples include genome editing, new forms of machine intelligence, breakthrough materials and approaches to governance

Christopher Forlee, CEO, NERSA

that rely on cryptographic methods such as the blockchain.

The pace and change of technological advancement is orders of magnitude greater than when I was growing up and even my studies and early working life.

We are so connected now, to everyone, everything and anything, and whilst our society has changed, in ways I could never fathom, I believe it is still set to change even further in ways that we still cannot fathom today and during our lifetimes still. We seem to have so much access and data at our fingertips, literally, just have a look at your smartphone if you want evidence of that.

With so much information available and accessible, the 4th industrial revolution is characterised for me by the notion of big data. In the old days we used to call it data mining, I guess it would be a major field called data analytics today. The interconnected, technological world we live in today generates vast amounts of data. Remember the days when we used to speak about megabytes, today we speak about terabytes, a factor of a million.

To gain the promised benefits we will require accurate and verified data and lots of it.

If data is as the heart of the 4th industrial revolution, let's ask ourselves, how clean and accurate is our current data? I know that as NERSA we struggle to obtain accurate D-Form information. There is an old saying that says to err is human but to really mess things up takes a computer. Can you imagine, with the assistance of artificial intelligence and the internet of things devices how we could really mess things up.

We must recognise that great care needs to be taken in the implementation of the systems of the 4th industrial revolution. The data must be clean and verified and accurate. No matter how good the technology, the old adage of garbage in, garbage out remains valid.

With the theme of this conference in mind, I urge that, in the year to come, that we make it a priority to clean up and physically verify our data. Starting with your customer list, their meters and the correctness of the meter installation.

While on the subject of data may I point out that there is a need for uniform back office systems starting with a uniform data structure and definition for all municipalities.

The IEC common information model

A unique customer number for each customer would allow customer information to be easily integrated into a national database. Such a published system will establish the standardisation that will enable us to leverage off economies of scale to make the 4IR transition more affordable. It will also promote national planning and enable developments and innovation in one municipality to be used in another.

Complete visibility and control of your systems is an imperative. Surely, you cannot apply intelligence, artificial or otherwise, to what you cannot see and there is no point in applying intelligence to what you cannot control. Isn't this the point of walking down this road towards a modern grid that is flexible and smart. There has to be some benefit as a result of all the effort or it just becomes an exercise in futility. All the benefits accrue as a result of these two things whether it is shorter restoration time or a better understanding of customers in pursuit of better, more efficient service delivery.

I think we all anticipate that we are standing on the cusp of massive and dramatic changes in the industry. Visionaries describe a wonderful future with all the magnificent benefits, sales people are only too willing to support them with the latest and greatest technology. The managers, all of us, however, must work out the practical implementation to achieve these benefits. They don't just happen by chance.

In our context, there will need to be a transitional path to this new and wonderful land that the visionaries see.

Looking at some of the lessons learnt from when businesses transitioned from manual to computerised systems that may assist us to transition through to the 4th industrial revolution whilst avoiding some of the pitfalls along the way.

As observed by the World Economic Forum, 4IR will be reliant on existing infrastructure and technologies. It will also be reliant on existing processes. In the sixties they learnt that if these processes are in a mess the computer makes the mess really an enormous mess. So a utility is not ready for it with sound processes and procedures, the 4th industrial revolution can make it an even worse situation. For example if your billing system is in disarray, then unless you make special effort to resolve the issues before, your automated billing system will be in disarray, automated disarray, which will probably be an even more complex problem.

Management will need to take ownership and responsibility. You need to lead the process because to be successful there must be collaboration across many departments. Objectives and goals must be clear. Implementation must be properly managed. In the sixties and seventies companies almost went under computerising. In the nineties the same situation occurred when companies converted to databases and ERP systems.

The best preparation for the coming 4IR is to get your existing processes and systems working well and properly understood by

We need to get the basics right and that 4IR technologies to be introduced should be focused on achieving that first. For municipalities what are some of these basics? It is suggested that the whole measurement of power flow from first meter to last is one of those. Think of electricity as an invisible product that needs to have stock control procedures even more than other commodities. It is not a luxury to know where every kWh is. It is a necessity for good business which is now entirely possible technically. Once again, big data, but how to analyse and utilise it is key.

For all its benefits, 4IR also brings with it different and new risks

The World Economic Forum Global Risks Report of 2019 cites "technological vulnerabilities" among the top five global risks. Cyber risks, along with environmental risks, are in the high-impact, high-likelihood quadrant of the global risks landscape. The breadth and impact of cyber-risks and cyberattacks – affecting business, economies, national security, international stability, individual privacy and employment opportunities — are only beginning to appear. They undermine overall trust in technology and grow exponentially as interconnectivity and technological advances accelerate in the fourth industrial revolution.

Thus cyber security has to be built in from the very start. It is not an add-in it has to be part of the system from scratch.

In the context of this conference, we need to ask, how can and will municipalities effectively respond to these changes in our industry?

Perhaps the starting point is that there needs to be more of the highly skilled person than are currently required and employed. Vacant positions cannot accomplish anything.

This requirement will be driven by more complex networks, smarter more demanding customers, the need to secure revenue and a changing business model. As NERSA we can only urge municipalities to invest your people. Create storehouses of human capital that will yield dividends for your municipality in this fast changing world.

The advent of embedded generation will make municipal networks a lot more difficult to plan and operate. Bi-directional power flows will bring voltage control and metering issues to the fore. It will require more careful planning, faster reacting equipment with more intelligence built in.

Customers are also getting smarter in the sense they are becoming more tariff aware and more aware of their own loads. Tariff aware customers are a natural evolution because of higher prices and the opportunity of "going off grid", although for most they will still remain grid-tied.

This will mean that the municipality will have to have proper, carefully calculated tariffs based upon facts and evidence. In the first place to justify the tariff and in the second to recover the required revenue.

Without adequate skills of both the required quantity and quality, our dreams of the 4th industrial revolution will remain just that, dreams.

We would be trapped in a scenario where we will have tariffs that do not recover costs, Network planning will be inadequate with the resultant exceedances of Notified Maximum Demands with associated penalties, Catastrophic failure of equipment that should have been maintained or replaced and Incorrect metering with associated loss of revenue.

Speaking of revenue, the advent of small scale embedded generation is a good example of 4IR in motion and is a disruptor to our traditional operating models. As SSEG gains momentum, tariff structures will need to change to accommodate them, but these will need to be based upon sound cost of supply studies. Recovery of the fixed costs for the network and maintenance thereof is vital to municipal sustainability and it requires a properly structured fixed cost component of the tariff. The infrastructure has to be properly maintained and refurbished and this cost has to be recovered regardless of the amount of product delivered. However, when this approach is taken it needs to be understood that the customer will then expect reliable and uninterrupted supply when needed.

In this context of exponential technological change and disruption, there are challenges, but also great opportunities. Transformation leadership will be needed to access the opportunities and mitigate the challenges. Let us recognise that this is uncharted territory that we are headed into and even the leaders present here today will need to navigate their own personal journey along this uncertain path, whilst guiding their organisations and the people that they are responsible for through it.

Our business models will need to adapt and transform to maximise the opportunities presented by 4IR and I urge you to put your people first in this endeavour by investing in the knowledge, skills and mindsets required for yourself and the people you lead to enable you to embrace the new context.

We must recognise that 4IR offers the municipal business a "whole new world" of opportunities for business improvement and efficiency gains and even new revenue streams. Conferences like this one offer a great opportunity for these to be showcased and for those intimately involved in the business to take a moment to reflect on what is possible and how it could be effected.

I would like to conclude my remarks by saying that the South African electricity supply industry is a complex space with many facets and stakeholders all of whom need to play their role effectively for the country to succeed and in the interests of the South African public whom we all serve. Our industry has already become more complex due to the changes brought about by 4IR and the so called disruptive technologies. It is set to become even more so. This makes the topics and discussions of this conference of paramount importance as we try to envision the impossible possible future.

I wish you successful and fruitful discussions and deliberations as you share your insights and thoughts on these important issues.

Chris Forlee, NERSA

Women in Electricity - panel discussion

A group of women, all of whom are involved in the electricity sector, addressed the topic of "the role of women in the fourth industrial revolution" on the second day of the convention.

They spoke from personal experience and discussed the challenges they face at their places of work and how the industry is likely to change as new technology introduces new ways of working.

The panelists included Punkie Majola, City of Ekurhuleni; Betsia Masemola, City of Tshwane; Tumisang Gabriel Maphumulo, Eskom; Mary Haw, City of Cape Town; Canninah Mapena, GE Electric; Karabo Masekwameng, GIZ; and Corrie van der Wath, Matleng Energy Solutions. Lomile Modiselle, from the City of Tshwane, chaired the panel.

The panel agreed that it is not easy for women to work in what is traditionally a male-only environment. Often, facilities at sub-stations are designed to cater for men only so it is difficult to find a bathroom women could use. Another challenge some women artisans face relates to the physical strength certain tasks require. This is particularly true when a woman is pregnant. However, modern equipment, based on new technology, is generally smaller and lighter, making it possible for a woman to undertake any task a man can do, the conference heard.

Modern technology makes it possible for a certain amount of monitoring to be done remotely, meaning that visiting the site becomes less necessary. This offers women the convenience of working from home after bearing their children.

Corrie van der Wath, the only male participant on the panel, said that most problems can be categorised in one of two groups: "tame" problems or "wicked" problems. Tame

problems, according to Wath, are generally of a technical nature and are relatively easy to solve. Wicked problems, on the other hand, are people-based problems which require more work and care as they are often more complex and therefore more difficult to resolve, he said.

Often, there are more interpersonal problems in teams which contain both genders. This means that special care must be taken when building teams. Collaboration and partnership in the team is vital, Wath said.

Women are particularly good at interpersonal relationships, Wath said. This ability proves useful as technology automates more procedures, either through the introduction of robots or other tools, which will reduce the number of human beings working on a site.

New technology often brings with it a fear of the unknown, so it is here that management need to keep motivation and enthusiasm for the job in hand, high.

New management styles which employ coaching and mentoring rather than monitoring and controlling will be required. Since women are generally strong in this area, one can expect to see more women employed as supervisors and managers in such settings.

The industry has already changed a great deal. There has been a huge growth in the number of women working at renewable energy facilities, or in the offices where such equipment is designed. Women are also working in so-called "green" building design, improving both the efficiency and aesthetics of buildings.

The panel agreed that engineering will play an important part in building South Children of both genders should be encouraged from a young age to take an active interest in science, technology, engineering and mathematics (STEM) and to study these disciplines in high school and university to increase the number of skilled people the country will need to develop its infrastructure and make the most of the benefits inherent in the fourth industrial revolution.

The concern that the fourth industrial revolution might decrease the number of job opportunities applies to both male and female employees, the panelists said, but while the public sector and some large privately-owned companies might reduce their staff headcount, other opportunities will arise for small businesses owned by both men and women.

Women in Electricity – WiE workshop feedback

Punkie Majola, the chairperson of Women in Electricity (WiE), told the audience that Women in Electricity hold workshops to assist women working in the electricity industry. The workshops seek to document and analyse specific challenges women face and to develop an action plan to update WiE's strategy.

eThekwini Electricity is in the process of developing implementation plans for two of the organisation's programmes, viz., the development of technical staff, which includes guidance on professional registration, training and the assignment of mentors, and career planning; as well as addressing gender-based discrimination, which includes sexual harassment awareness and human resource diversity workshops.

Majola said that 71% of those invited, attended the workshop. In all, 149 women from eThekwini and neighbouring municipalities were present for the workshop. Most of those were electricians (46%), followed by technicians (33%), technologists (12%) and engineers (9%).

Most of the training centres around core competence (30%), followed by technical competencies (21%), with the balance being made up of soft skills, leadership and management, business administration, computer skills and organisation software, and language proficiency, Majola said.

A highlight was the visit the women made to the Murray Primary School, and the Sisonke and Jolobe High Schools in the Eastern Cape where they presented talks on the importance of science, technology, engineering and mathematics to the learners.

Honourary AMEU membership (L to R): Marius vd Westhuizen, Johan du Plessis, Selwyn Scholtz, Nelisiwe Magubane, Jacqui Burn, and Moferefere Tshabalala.


Cigré best paper: Poonam Lutchmon, Schneider Electric.


Best large stand: Schneider Electric.


Best paper in Experienced Professional category: Paul Vermeulen, City Power.


Best paper in Emerging Professional category: Samantha Chimunda, City Power.


Best medium stand: CBi-electric.


Best small stand: CT Lab.

President's legacy Award 2019: Jayshree Pershad, eThekwini Electricity.


President's legacy Award 2019: eThekwini Electricity.

2019 AMEU Executive Council

Panel discussion: "4IR – Are we fit to face the future?"

The conference heard that rapid urbanisation, demographic and social change, climate change and resource scarcity, technological breakthroughs in the energy sector, and economic shifts are major disruptors in South Africa's energy and social structures.

Panelists: Dr Willie de Beer (chair); Jonathan Cawood, PWC; Christopher Forlee, Nersa; Xolile George, SALGA; Nelisiwe Magubane, Eskom; Polelo Mphahlele, City of Tshwane; Ayanda Noah, Eskom; Prof. Daniel Plaatjies, Finance and Fiscal Commission.

Energy has always played an important role in all industrial revolutions. It started by moving from animal power to steam power, which then moved to electric power. The digital computer age introduced the third revolution, while the age of artificial intelligence enables higher levels of automation, data processing and robotics. Utilities are likely to see fewer large-scale generation projects as flexible small-scale embedded generation becomes popular. This will require higher levels of investment in distribution networks to make sure they are flexible enough to cope with sudden changes in load and supply.

The industry should use technology to get visibility and control to improve customer service and reduce non-technical losses. Utilities should use modern technology to improve customer service: drones can monitor transformers and sell drone monitoring services.

"Data is the new oil," Xolile George said. People should appreciate the value of data. New technology can gather and analyse data and provide utilities with trends which can be modelled to help them to make more informed decisions in their planning. It can also assist in the maximisation of revenue collection.

"There are two worlds in SA: the haves and have-nots," said Prof. Daniel Plaatjies. New technology should be used to bridge the gap between the education and material advantages enjoyed by the haves, to upskill the have-nots. New technology, if used incorrectly, will entrench poverty. Public investment in technological innovation must serve the entire population, Prof. Plaatjies said. Utilities may have to rethink the way the distribution systems are managed, but they should be willing to challenge the status quo.

Ayanda Noah reminded the conference not to lose sight of the fact that the electric supply industry exists to serve the public. Smart meter rollouts may suit the utility, but not necessarily the users of electric power. This calls for a mind-shift to solve customer problems and prevent the fourth industrial revolution from becoming nothing more than a pipe dream which is unable to deliver the expected results.

While certain municipalities may be gearing up to benefit from the fourth industrial revolution, Polelo Mphahlele said, the changes are not spoken about enough. Employees need to be reskilled to ensure that they can continue to add value as technology makes jobs change, she said. It may be necessary for national government to take a lead in getting the municipalities right, she said, adding that the municipalities will not be fit enough to cope with the challenges the fourth industrial revolution will bring until they get the basics right.

Jonathan Cawood said that international research shows that most municipal utilities in most countries are concerned about the main challenges which accompanies the fourth industrial revolution: decarbonisation, decentralisation and digitalisation.

To meet these challenges, municipal utilities cannot continue doing things in the same way and change is often difficult. While there are some pockets of excellence, he said, most utilities are struggling to change their way of working.

Decarbonisation means using cleaner generation technologies such as wind, solar and hydro together with some form of storage or gas-fired (rather than diesel-powered) peakers. The idea of decentralisation too relates to rooftop solar PV systems feeding into electric distribution grids which were designed to carry power from a central point to multiple points of load and have always been operated in this way. The idea of multiple points of supply and multiple points of load is often a serious challenge to municipal utilities. At the same time, digitalisation, adds new ways of doing things which municipal employees can find daunting.

The panel wrapped up their discussion by saying that we must rethink the municipal utility of the future. They will need to focus on putting their customers ahead of their processes – processes must be designed to offer excellent customer service. This means that even with the rollout of a digitalisation programme, municipalities should invest in

Nelisiwe Magubane

Dr Willie de Beer

Jonathan Cawood

Christopher Forlee

Xolile George

Ayanda Noah

Palelo Mphahlele

Prof. Daniel Plaatjies

human capital – training – and modernising their infrastructure to accommodate new technologies and systems.

Regulation and legislation should support and encourage the use of electricity by the public and should be used to protect users rather than limit them. Society needs to be free to use modern technologies, such as solar PV, safely, but without having to comply with complicated rules and regulations.

Xolile George said that work is being done to define the extent to which the introduction of the fourth industrial revolution will affect municipal utilities' workstreams and how it can be commercialised to assist to bolster a municipality's finances. The study will also consider what impact the fourth industrial revolution will have on employment figures and the types of work human beings will do in the future. The new revolution will, no doubt, have an effect on how new infrastructure will be designed and what changes might be necessary to existing infrastructure.

The municipal utility business model may need to change, but, according to Magubane, South Africa has the intellectual capital to make the changes necessary for the fourth industrial revolution to benefit the country. To enhance that capital further, she said, more training and education will be needed to encourage and support innovation at municipal utilities.

In closing, Chris Forlee said that we need not chase the technologies of the fourth industrial revolution, but we should seek the benefits these new and developing technologies can bring to the country. "Let's implement those elements of the fourth industrial revolution which fit real needs," he said.

Closing address

Ladies, gentlemen and distinguished guests, I am sure you will agree that we had a very successful AMEU Convention starting off with a sports day on Sunday and culminating in excellent keynote addresses, papers and presentations. From the comments I have heard from a number of delegates, this was one of the best conventions in respect of the quality of papers and presentations that were presented.

I think the topical nature of the 4IR theme also helped in enhancing the value-add of the convention. As you would have also noticed, the speakers who presented came from different backgrounds and with different experiences. The time and effort put in by each of the speakers was also noteworthy and commendable.

Besides the speakers, a number of other stakeholders also contributed to the success of this convention. In this respect please allow me to thank the following people on behalf of the leadership of the AMEU:

- The keynote speakers and the other speakers.
- Our hosts the City of Cape Town, Hoosain Essop and Siyabulela Gqwede and the rest of the local organising committee.

Refilwe Mokgosi, AMEU President

- The City of Cape Town did a wonderful job and a token of appreciation will be handed over at the end of the convention.
- The AMEU secretariat which, as always, did a sterling job in putting this convention together, which as you can appreciate is not an easy task.
- The affiliates, as always, made a tremendous contribution to the success of this convention which includes the exhibition area and sponsoring the various activities, sessions and gifts at the convention.

I also want to take this opportunity to thank you the delegates for your contributions in making this convention a success. Your participation by the number of questions you fielded during the various sessions was also noteworthy and appreciated.

I must point out that the software app SLIDO, which we used for the first time, was a huge success and we will continue to use the same going forward to field questions.

With that said ladies, gentlemen and distinguished guests, and with the power invested in me I now declare this convention duly closed. Have a safe journey and travel safely back home.

Refilwe Mokgosi, AMEU President

Low cost intelligent outage management

by Warren Mathers, City of Ekurhuleni

The City of Ekurhuleni (CoE) is the industrial hub of Gauteng, contributing 8,8% of the national economy. Strengthening its industrial competitiveness is a priority for the CoE. Africa's largest and busiest airport also fall within its boundaries. It is home to approximately 3,5-million people, with 18,7% of the approximately 1,3-million households in CoE being informal dwellings. Currently there is a backlog of 115 375 informal dwellings that are not yet supplied with electricity. Supplying electricity to the informal settlements forms an important component of the pro-poor focus of the current term of Council (City of Ekurhuleni, 2019).

A reliable distribution network is vital to ensuring that customers receive a high standard of electricity supply with minimal power outages. Numerous challenges to achieving this exist, which include, inter alia, aging infrastructure and illegal connections overloading the network. An important component of managing the reliability of the distribution network is to be able to identify potential problem areas and frequently failing distribution equipment.

Municipal customers affected by power outages are negatively impacted in several ways ranging from revenue lost by businesses through to the inconvenience of a home without electricity. Municipalities also lose revenue over the duration of a power outage.

To respond to a power outage as soon as possible, in order to minimise downtime, it is desirable to have automated notifications of power outages. Additionally, reliable statistics on power outages can be used to identify circuits experiencing frequent outages so that remedial action can be taken.

Supervisory control and data acquisition (SCADA) is a solution that can, inter alia, meet the requirements described in the above paragraph. However, SCADA is costly and for South African municipalities faced with a high demand to expand service delivery to customers lacking basic services expenditure on an item of this nature can be seen as a luxury.

The need for a cost effective and efficient system for alerting staff to power loss events so that they can be rapidly responded to, as well as displaying current power outages and logging power loss and return events was identified by the CoE's: energy department.

The energy department investigated the feasibility of implementing automated notifications of power outages, as well as recording of power outage statistics, using existing modems used as a metering communication medium for remote metering together with open source software, available at no cost.

The implementation of the system, and the benefits obtained will be discussed in the following section.

Discussion

Factors influencing adopted solution

The coverage provided by the installed base of meters being remotely read was deemed to be acceptable for the intended purpose for the following reasons:

- Key customers and large business customers are all metered remotely.
- Residential complexes with bulk connections are metered remotely which will provide notifications of area outages in residential areas surrounding the complexes.
- Modems with the capability to generate notifications of power loss and return events could be retrofitted to sites to be monitored within the existing contract with the remote metering service provider.

Suitable open source software, for which the necessary in-house skills to develop a system to geographically display received power loss events and to log received power loss and power return events was available.

Power loss and return event alerting

Currently a total of 10 724 sites are remotely metered. Of these sites 1153 are equipped with modems capable of generating notifications of power loss and return events. The distribution of the remotely metered sites and sites with modems capable of generating notifications of power loss and return events between the nine distribution business units

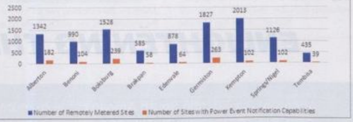

Fig. 1: Distribution of remotely metered sites and power event notification capabilities between DBUs.

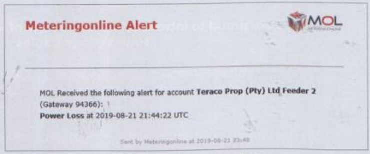

Fig. 2: Email content of a power loss notification.

4.3.2 Classification of unplanned interruptions

4.3.2.2.1 Momentary interruption events: Unplanned interruptions of LV and MV circuits that are longer than 3 s but less than or equal to 5 min shall be classified as momentary interruptions.

4.3.2.2.3 Sustained interruptions: Unplanned interruptions of LV and MV circuits longer than 5 min shall be classified as sustained interruptions.

Fig. 3: Unplanned power outage classification based on duration (Eskom, 2007).

(DBUs) within the CoE's energy department is shown in Fig. 1.

The modems installed at the sites that are monitored by the system can provide a "last gasp" notification, before powering down, of a power loss event that has occurred. When a power return event occurs, the modem is powered back up and provides notification of the power return event.

The notifications are received by the remote metering service provider, who then sends the following notifications to the energy department:

- SMS notifications to staff whose cell phone numbers have been included in the notification list.
- Email notifications to staff whose email addresses have been included in the notification list. An example of the content of an email notification is shown in Fig. 2.
- A hypertext transfer protocol (HTTP) post request to an energy department hypertext preprocessor (PHP) server for further processing.

Display and logging of power loss and return events

The display and logging of the power loss and return events is accomplished using a PHP server together with a script supplied by the remote metering service provider to process the HTTP post request sent to CoE, as well as the following open source software:

- A PostgreSQL database, an open source relational database (Postgresql.org, 2019), for the processing and logging of the power loss and return events received via PHP together with PostGIS, an open source spatial database extender for PostgreSQL (Developers, 2019) to spatially enable the PostgreSQL database.
- GeoServer, an open source server for sharing geospatial data (Geoserver.org, 2019), to publish the spatial data.
- Leaflet, an open source JavaScript library for publishing interactive maps (Leafletjs.com, 2019), to display the map showing current power outages.

The HTTP post request parameters are processed by the supplied PHP script residing on the PHP server and the status (power loss or return) of the site/s for which the event/s occurred is updated within the PostgreSQL database.

The update triggers a stored procedure which then logs the event after assigning a sequential (per site) event number to the event and, if a power return event, calculating the power outage duration and classifying the power outage in accordance with Fig. 3 for interruption durations longer than three seconds and as a voltage dip for interruption durations less than or equal to three seconds.

PostGIS is used to add spatial geometry to the relevant tables within the PostgreSQL database thus allowing the data to be geographically located. The Geoserver publishes the spatial data through connecting to the PostGIS database via a store and using styles to control the appearance of the various geospatial layers published. Leaflet is then used to display the map in a web server.

A map (Fig. 4) of the current power outages (overlaying the installed base of remotely read meters) can be displayed in any web browser from within the CoE ICT network using an intranet URL.

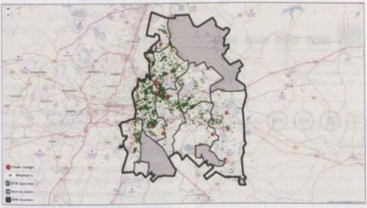

Fig. 4: Current power outages.

	event_number	action_tstamp	site_name	account_number	elec_depot	status	outage_duration	outage_classification
212	16	2018/12/11 16:37:08	Actom (Pty) Ltd	3501974695	Springs	Power Outage		
213	16	2018/12/11 17:01:17	Actom (Pty) Ltd	3501974695	Springs	Power Restored	00:04:09.622	Momentary Interruption
214	17	2018/12/28 14:16:57	Actom (Pty) Ltd	3501974695	Springs	Power Outage		
215	17	2018/12/28 14:39:03	Actom (Pty) Ltd	3501974695	Springs	Power Restored	00:22:05.989	Sustained Interruption
216	18	2018/12/29 14:33:02	Actom (Pty) Ltd	3501974695	Springs	Power Outage		
217	18	2018/12/29 14:33:02	Actom (Pty) Ltd	3501974695	Springs	Power Restored	00:00:00.148	Voltage Dip
218	19	2019/01/07 22:22:45	Actom (Pty) Ltd	3501974695	Springs	Power Outage		
219	19	2019/01/07 23:12:54	Actom (Pty) Ltd	3501974695	Springs	Power Restored	00:50:09.417	Sustained Interruption
220	20	2019/05/03 12:57:18	Actom (Pty) Ltd	3501974695	Springs	Power Outage		
221	20	2019/05/03 13:31:18	Actom (Pty) Ltd	3501974695	Springs	Power Restored	00:33:59.342	Sustained Interruption

Fig. 5: Power loss and return event history.

	site_number	account_number	site_name	elec_depot	power_status	status_date_time	outage_duration
2	33614302		POD310: Edenvale Town Supply Sub 2	Edenvale	Power Outage	2019/08/22 10:33:38	0.01:38:07.135
3	13546896	1708105655	Teraco Prop (Pty) Ltd Feeder 2	Kempton	Power Outage	2019/08/21 23:41:32	0.12:30:10.821
4	13662942	3000233682	I & W Van Der Merwe Boerdery	Springs	Power Outage	2019/08/21 21:01:37	0.13:20:06.080
5	13662893	2101071847	Solepnops 39 (Pty) Ltd	Alberton	Power Outage	2019/08/19 22:30:47	2.13:40:55.769

Fig. 6: Current power outages.

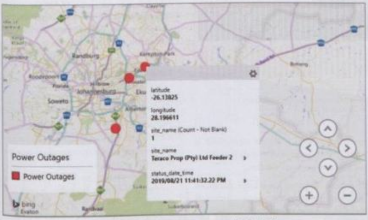

Fig. 7: Visualisation of current power outages within Excel 3D map.

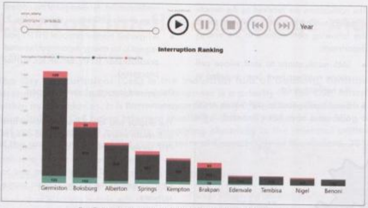

Fig. 8: Interruption ranking by DBU for number of interruptions from 14 December 2017 to 22 August 2019.

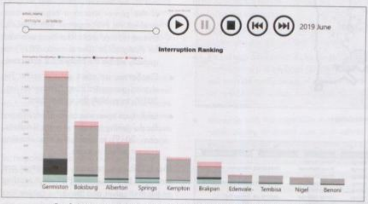

Fig. 9: Interruption ranking by DBU for number of interruptions in June 2019.

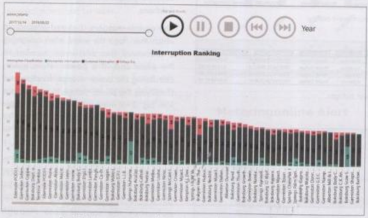

Fig. 10: Interruption ranking by site (customer) for number of interruptions from 14 December 2017 to 22 August 2019.

Reporting on and business intelligence from power loss and return events

Reporting on power loss and return event history is achieved using MS Excel (Fig. 5). The spreadsheet is automatically updated through a data connection to the PostgreSQL database when the spreadsheet is opened and updated every five minutes while the spreadsheet is open. The spreadsheet can then be used to analyse and report on the data.

A separate worksheet within Excel also shows details of current power outages including the date and time of the power loss and the duration of the current outage (Fig. 6).

The current power outages can also be visualised spatially within Excel using 3D maps (Fig. 7)

Business intelligence (BI) software, is also used to derive information from the data in the form of dashboards providing readily available visualisations of the information to employees to facilitate planning and decision making. Since the ICT department has indicated that it intends to standardise on Microsoft Power BI as the BI software for CoE Power BI was utilised for this purpose rather than one of the open source alternatives.

Fig. 8 shows the interruption rankings by DBU in terms of number of interruptions over the period since implementation, 14 December 2017 until 22 August 2019, while Fig. 9 shows the same statistics for the month of June 2019 against the backdrop of the total number of interruptions over the period in Fig. 8.

Drilling down on the interruption ranking shown in Fig. 8 shows the interruption rankings by site (customer) in terms of number of interruptions over the period since implementation, 14 December 2017, until 22 August 2019. The results are shown in Fig. 10.

The criteria for the interruption rankings can be based on any meaningful measure, e.g. the interruption rankings can be based on the sum of all outage durations per site over a period rather than number of interruptions over a period. Information of this nature assists in identifying problem areas and frequently failing distribution equipment that attention needs to be given to.

Fig. 11 is a spatial visualisation in Power BI of an area outage that occurred on 6 June 2019.

Limitation of method used to generate power loss notification

A limitation of the system is that the system cannot distinguish between unplanned or planned power interruptions as the only notification is for the absence or presence of power.

Future enhancements

Extrapolation of received notifications to identify the full extent of an area outage

The possibility of using available data on substation zones together with notifications of power loss events from modems located at check meters on substation feeders, as well as developing GIS based feeder connectivity models, to allow power loss and return events for customers downstream of feeder outages to be reliably logged is being investigated.

Fig. 11: Area outage on 6 June 2019.

Calculation of estimated energy lost due to a power interruption to a customer

The power loss notification includes the rolling 12-month maximum demand for a customer. The value of using this together with the interruption duration in hours and the load factor for the substation zone within which the customer falls to calculate an estimate of the energy lost as a result of the power interruption is being considered.

Conclusion

The system has shown itself to be an effective and efficient low-cost method for the display, monitoring and alerting of power loss and return events. It provides the underlying historical data to assist in identifying problem areas that contribute to network downtime thus providing valuable input to contributing to optimal reliability of supply to customers. There is potential to substantially enhance the value derived from the system through further innovation and development.

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Relevant skills required to survive and thrive in the fourth industrial revolution

by Heino van Jaarsveldt and Corrie van der Wath, Motleng Energy Solutions

The fourth industrial revolution is characterised by technologies which are blurring the lines between the physical, digital and biological spheres, commonly referred to as cyber-physical systems. The rapid technological innovations associated with the fourth industrial revolution will change the way we interact with the world and revolutionise the very nature of the work we currently do.

With the increased utilisation of robotics, automation and artificial intelligence, it is worth noting that in 2018 the global unemployment rate fell to 5,2%, the lowest level in 38 years [1]. The strong correlation between the fourth industrial revolution and high employment rates should therefore instil a sense of optimism as we move towards a time when jobs will be more accessible, more flexible and more liberating.

Our ability to not only survive, but to thrive during the fourth industrial revolution is dependent on the fundamental issue to understand what makes us as humans different from technology. This moulds the core from which our emotions and knowledge stem. It is essential to understand that technology does not foster a need for survival, nor does it possess any true emotions.

In an employment landscape that is rapidly evolving, it is important to understand that not only jobs are changing, but also the required skills to perform these jobs. It is therefore crucial that we prepare by continuously improving ourselves through strategic skills development.

It is inevitable that we will experience fundamental technological change. The challenge however will be to guide our actions to ensure the best, most inclusive outcomes for all.

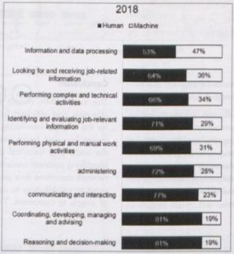

Fig. 1: Ratio of human-machine working hours for 2018 [9].

Background

The word "revolution" denotes abrupt and radical change. We can therefore say that various revolutions have occurred throughout history when new technologies and our perception of the world triggered profound change in economic systems and social structures [2].

The first profound shift in our way of living is referred to as the agrarian revolution. This revolution combined the efforts of animals with those of humans for the purpose of production, transportation and communication [2].

The agrarian revolution was followed by a series of industrial revolutions that began in the second half of the 18th century. For a better understanding of the principles of the fourth industrial revolution, it is important to understand the history and the origins of the other industrial revolutions that precedes the fourth.

The first industrial revolution

The first industrial revolution is characterised by the shift from our reliance on animals, human effort and biomass as primary sources of energy to the use of fossil fuels and the mechanical power this enabled [3]. Mechanisation, steam and the prolificacy of water power became the order of the day during the later stages of the 18th century. The first industrial revolution spanned from approximately 1760 to 1840 [2].

The second industrial revolution

The second industrial revolution occurred between the end of the 19th century and the first two decades of the 20th century [3]. This industrial revolution is seen by many as the period which introduced the most changes. The technological advancement which led to the second industrial revolution unlocked major breakthroughs in the form of electricity distribution. Rapid advances in the creation of steel, chemicals and electricity helped fuel production, including mass-produced consumer goods and weapons [4]. The second industrial revolution was characterised by the rapid growth of cities, prominence of public transport and the number of factories that began, people's lives became regulated by the clock rather than the sun.

The third industrial revolution

The third industrial revolution began in the 1960s. This revolution is often referred to as the computer or digital revolution because it was catalysed by the development of semiconductors, mainframe computing (1960s), personal computing (1970s and 80s) and the internet (1990s) [13]. The information technology (IT) age with the development of digital systems, communication and rapid advances in computing power enabled new ways of generating, processing and sharing information [4].

The fourth industrial revolution

We are in the inception stages of a new industrial revolution that according to Klaus Schwab (founder of the World Economic Forum) will not just change what we do

Technology drivers	Fields
Digital	The Internet of Things (IoT)
	Artificial intelligence
	Machine learning (AI)
	Big data
	Cloud computing
Physical	Autonomous vehicles
	3D printing
Biological	Genetic engineering
	Neurotechnology

Table 1: Technological drivers for the fourth industrial revolution [8].

and how we do it, it will change us [5]. The fourth industrial revolution is characterised by technologies which blurs the lines between the physical, digital and biological spheres, commonly referred to as cyber-physical systems [3].

The complexity of these technologies and their emergent nature makes many aspects of the fourth industrial revolution feel unfamiliar and, to many, threatening. The foundation of the technology of the fourth industrial revolution is reliant on the infrastructure of the preceding industrial revolutions. This revolution will however represent new ways in which technology becomes embedded within societies and even our human bodies [3].

Some of the most notable technologies shaping the fourth industrial revolution include genome editing, machine intelligence (AI), new materials, 3D printing, Internet of Things (IoT), big data, blockchain, genetic sequencing and synthetic biology. The technologies can all be clustered into three distinct categories: physical, digital and biological, hence the reference to cyber-physical systems.

The fourth industrial revolution (4IR) is often seen as a very abstract concept with massive disruptive potential. It is however a true reflection of our desires and choices to shape a better future.

Potential impact of 4IR

An industrial revolution is generally characterised by advancements in technology that is applied to improve the process of production. The fourth industrial revolution however has the potential to be so much more than just some improvements in a production process.

With every industrial revolution comes refining shifts to social, economic, environmental and political systems that truly alter the course of humanity [6]. It is important to understand that some of these shifts are foreseen, and other are completely unforeseen. It is therefore essential that we focus on upskilling with the aim of empowering ourselves to thrive in the fourth industrial revolution. As Schwab says: "There has never been a time of greater promise, or one of greater potential peril" [3].

While the fact that we are still at the beginning stages of the fourth industrial revolution means that it is impossible to know the precise impact, four key impact areas should be considered.

Technology

Some of the technologies that will shape the fourth industrial revolution and define the next-generation human enterprise, connectivity and lifestyles are already here, but have not been scaled to everyday utilisation. This is due to the fact that the regulatory environment, legal considerations and other issues currently outweigh the benefit to innovate [7].

The developments of digital, physical, and biological technologies are three fundamental technological drivers of the fourth industrial revolution. The basis of the fourth industrial revolution is not only vested in new breakthrough technologies within the respective areas of technology, but the fusion with each other. These three technological drivers are summarised in Table 1 [8].

Economic

The fourth industrial revolution will have a monumental impact on the global economy, of which the effect will be so vast and multifaceted that it makes it difficult to examine individual aspects. There are four factors of production that fuel economic growth: land, labour, capital and enterprise. Today, the world is attaining 52% of its entrepreneurial capacity, and this number is declining year on year [6].

The world's population is forecast to expand to 8-billion by 2030 and 9-billion by 2050 [2]. Another powerful demographic trend is the overall aging of the world's population. Ageing is an economic challenge in the fact that retirement ages will have to be increased so that older members of society can continue to contribute to the workforce.

Social

Technology and the fourth industrial revolution will continue to change societal values. More than 36% of the workforce in the United States of America currently functions as freelancers [6]. The shift in societal values are often fuelled by autonomy, flexibility and additional income. It is estimated that within the next ten years more than half of the American workforce will be freelancers. The societal shift introduced by the fourth industrial revolution will therefore not only change the way we work, but also how we interact with other humans.

Education and training

The technological advancements often associated with the fourth industrial revolution will impact our ability to access training for employment. Education and training is directly correlated to economic growth and will therefore be one of the major drivers for the fourth industrial revolution. We are also migrating to a system where students are less interested in stale curriculums and keener to take shorter, skills-based training that is more relevant to today's workplace. The acquiring of "on-demand" skills will become very relevant which will allow employees to adapt to their changing roles and responsibilities required by employers to ensure that they remain not only competitive, but relevant [6].

Future of jobs

With each new industrial revolution new jobs

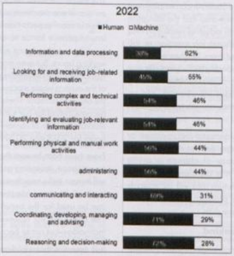

Fig. 2: Ratio of human-machine working hours for 2022 [9].

are created and old jobs destroyed. A much debated topic regarding the fourth industrial revolution revolves around the fear that with technological advancements and increased automation, the fourth industrial revolution might increase unemployment significantly.

Common to these recent debates is an awareness that, as technological breakthroughs rapidly shift the frontier between the work tasks performed by humans and those performed by machines and algorithms, global labour markets are likely to undergo major transformations. The challenge lies within the managing of these transformations to ensure good work, good jobs and improved quality of life for all. If the transformations are not managed wisely, the fourth industrial revolution poses the risk of widening skills gaps, greater inequality and broader polarisation. In many ways, the time to shape the future of work is now [9].

According to the latest *Quarterly Labour Force Survey* (QLFS) results released by Statistics South Africa (Stats SA), South Africa had an unemployment rate of 27,6% in the first quarter of 2019 [10]. Approximately 60% of the Country's unemployed, don't have a Grade 12 certificate, and those seeking further education are gravitating towards business, economics and social sciences [11].

It is further estimated that by 2020, as many as 80% of all future jobs will require a STEM (science, technology, engineering and mathematics) education [11]. The high unemployment rate of South Africa, accompanied by the relevant low level of education and further lack of interest in STEM education will leave a significant deficit in the country's skills reserve.

A common trend of the fourth industrial revolution is disruption. Disruptive changes to business models will have a profound impact on the future of the South African employment landscape. It is estimated that the disruptive nature of the fourth industrial revolution may range from significant job creation to job displacement, and from heightened labour productivity to widening skills gaps. By one popular estimate, 65% of children entering primary school today will ultimately end up working in completely new job types that don't exist today [12].

Many of the in-demand occupations or specialities of today did not exist ten years ago, and the pace of change is set to only accelerate. It is therefore essential to understand that future jobs will increasingly require complex problem solving, social, people and systems skills.

Triumph of mankind

Our thirst for knowledge is vested in our emotional intelligence that stems from our basic instinct to survive. As we expand our knowledge, we establish the ability to interact without exposing ourselves to the shortfalls of emotional weaknesses.

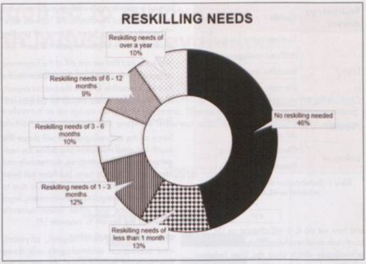

Fig. 3: Reskilling needs [9].

It is essential that we understand that we, as humans, are fundamentally different from machines. Humans behave according to their consciousness, whilst machines only perform as they are taught. Our actions are based on knowledge and therefore humans perform activities as per their own intelligence. In direct contrast to this, machines only have artificial intelligence. Maybe the most striking difference between humans and machines lies in our creativity, which allows us to do anything original whereas machines can't act on a set of creative skills.

The fourth industrial revolution will usher in an era where machines will replace human effort in more aspects than ever seen before. It is important for us to understand where machine working hours will replace human working hours. But even more important is our fundamental understanding and exploration of the aspects where machines will not replace the efforts of humans. These areas of skills will become critical for our survival. Figs 1 and 2 illustrate the ratio of human-machine working hours for 2018 and 2020 respectively.

From these it can be seen that communication, coordination, reasoning and decision making will remain tasks heavily reliant on humans. It is essential that we understand that technology can be used for the benefit of all mankind. The challenge will however be to embrace technology, but not to become it.

It is essential that we identify these relevant areas where we need to develop our skills for the complete integration of our emotions with our knowledge.

Skills development

In such a rapidly evolving employment landscape, the ability to anticipate and prepare for future skills requirements, job content and the aggregate effect on employment is increasingly critical for businesses, governments and individuals in order to fully seize the opportunities presented by these trends and to mitigate undesirable outcomes [12].

Performance evaluation is one of the most important communication tools an organisation can use. Performance evaluation creates awareness around key strong performance areas and less strong area that can be improved on. It also enhances team integration and performance [13].

Employers surveyed for the *Future of Jobs* report 2018 estimate that, by 2022, no less than 54% of all employees will require significant reskilling and upskilling. Fig. 3 shows the proportion of employees relevant to the scope of reskilling required [9]. Although the graph shows that 46% of all employees will require no reskilling, it also shows that approximately 19% of employees will require reskilling in excess of six months. It is therefore crucial that employers focus their attention on the reskilling of their employees to ensure that technological disruption does not sacrifice jobs.

The increase in the reliance on technology accompanied by automation poses the question whether or not robots will replace human beings. While experts have warned that there will be an increase in job automation and artificial intelligence, specialist agree that human beings will never be made completely obsolete [14]. It is however important to understand that there are certain skills that will grow in importance as technology becomes more influential. The following is a list of skills that when developed will form a holistic competence level which is required to address the challenges posed by the Fourth Industrial Revolution.

Critical thinking skills

To see the essence of what needs to be resolved and the ability to resolve it without a delay. Critical thinking skills refers to the analytical ability of a person, the talent to connect the relevant dots to see the bigger picture.

Technical skills

Superior practical technical solutions to correct standards and needs. Technical skills allow you to be the master of your craft. These skills refer to knowledge supported by relevant capability.

Project management skills

Delivering a successful product/project start to finish, including servicing its lifecycle purpose. Project management is the practice of initiating, planning, executing, controlling, and closing the work of a team to achieve specific goals and meet specific success criteria at the specified time.

People skills

Bringing out the best in people while achieving together. People skills create trusting relationships that do not discriminate in terms of gender, race, culture, politics, religion (or any other stereotyping). Well-developed people skills ensure that personal needs do not compromise professional relationships created in the work environment.

Personal skills

The ability to know, understand and manage your own emotions to deliver in the work environment. Personal skills are embedded in emotional intelligence, the capacity to be aware of, control, and express one's emotions, and to handle interpersonal relationships judiciously and empathetically.

Management skills

To deliver through people. Management skills entails the understanding of integration, planning, implementation, monitoring and feedback. The goal is to utilise skills to manage people to achieve required results within outcome indicators.

Leadership skills

To influence people to the desired outcome. The essence of leadership revolves around understanding the problem to be solved, whilst leading people to support the cause or action required to solve the problem. On your way to becoming a leader it is about you and your successes, once you are a leader, it is about the successes of those around you.

Business skills

People, product, profit and systems integration. The purpose of developing business skills is to create a business mindset, focussed on vision, mission, strategy, structure and securing the future. Relevant business skills will allow an individual to keep it simple and understand the value and contribution of every implemented system.

Financial skills

Refers to the efficient and effective management of money in such a manner as to accomplish the objectives of the organisation. Financial skills refer to those skills required to keep score for the company in the most beneficial way, whilst ensuring clean, legal and well documented systems and procedures.

Drive and will

To be aware, active, alive and participating in achieving company goals. Drive and will is directly related to understanding your passion and purpose, in essence doing what you love. A person with drive and will is energetically and enthusiastically engaged, an inspiration to others and future self.

Conclusion

The fourth industrial revolution is characterised by new technologies with disruptive nature which will change the way we work, live and interact with each other. The challenge is to ensure the best, most inclusive outcomes for all mankind.

The fourth industrial revolution is often seen as a very abstract concept with massive disruptive potential. It is however a true reflection of our desires and choices to shape a better future.

As we enter a new revolution we will experience refining shits to social, economic, environmental and political systems that will truly alter the course of humanity.

The fourth industrial revolution is associated with major technological advancements and the increasing reliance on machines. It is essential that we understand that we, as humans, are fundamentally different from machines. Our thirst for knowledge is vested in our emotional intelligence that stem from our basic instinct to survive.

It is however important to understand that there are certain skills that will grow in importance as technology becomes more influential. We therefore need to accept that we are migrating to an era of continuous upskilling in order to empower ourselves to take advantage of the innovation of the fourth industrial revolution.

Nelson Mandela famously said, "May your choices reflect your hopes, not your fears." There has never been a time where we had to make more important choices than the present. We all have a choice between fear for what the future and technological advancement might bring, or hope that through our unique set of skills we can embrace innovation to create a better world for all.

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Electrical master planning for the fourth industrial revolution

by Hilton Boartman and Steyn, GLS Consulting

Smart cities, driven by the fourth industrial revolution (4th IR), seems to be the buzzword in infrastructure development and procurement today - but what informs these decisions, and are we making smart ones? Existing methodologies are outdated and not sufficient to address long-term planning for the ever-changing power system.

A modern methodology for developing a full master plan, from LV to HV level, is presented in this paper. The master plan is developed in a modern software package which combines and consolidates several datasets into one geospatial master model viewer. Load analysis, demand patterns, the network model and GIS are combined into one tool to develop a comprehensive master plan using data aggregation and analytics. Load forecasting and analysis is done through analysis of the utility's billing system and MDs and ADMDs are thus based on the utility's own data. Each stand in the utility is geospatially linked to a supply point in the network model. The master plan is then finally presented through an auto-generated master plan report with projects and costing of said projects. All of this can be viewed on an online web view platform which enables users to interact with the master plan, instead of it just being a simplistic pdf document.

The 4th industrial revolution

The 4th industrial revolution (IR) centres on the communication, processing and analysis of large datasets to make informed decisions. The power system of the 4th IR is one that has constant monitoring via internet of things (IoT) devices, and is self-healing through supervisory- and control systems with built-in intelligence. Furthermore, in the future power system consumers can become prosumers through small-scale embedded generation (SSEG) with intelligent control units. Smart metering is also being rolled out to bulk-, credit- and prepaid consumers which allows for more accurate consumption- and demand statistics to be accumulated.

The status quo is that long-term power system planning, or master planning, is being done by utilising various independent systems with minimal data integration between the datasets. These processes over time cause several datasets, created for different purposes, to be developed as opposed to the development of one multi-purpose central database. This creates a situation where data analytics can only be applied to a limited extent on current planning datasets.

Traditionally, master planning has also focused on long-term power system infrastructure planning only. However, master plans for the power systems of the future should consider many more factors. These include:

- Load forecasting from a reticulation level upwards.
- Operational and maintenance planning for existing infrastructure to enhance asset life.
- Asset management plans which incorporate the underlying master plan data as well as additional asset failure and life cycle information about the assets.
- Asset replacement prioritisation plans which look at the risk of power system infrastructure failing and the consequence of failure.
- Revenue analysis and enhancement.

The above-mentioned factors or outputs are currently produced haphazardly and not from the same underlying dataset. The 4th IR has a large emphasis on data centralisation and this should be the main driver behind the master plans of the future. The need therefore exists for tools that centralise both our offline and online data into common, interchangeable datasets [1]. Master plans of the future should ultimately allow us to make smarter decisions on our infrastructure operations, maintenance and planning.

Fig. 1: Master model concept.

The World Bank reported that South Africa is ranked 109th in the world in terms of "getting electricity" in their annual "Doing Business" report [2]. On average, it takes about 112 days from application until installation for a new electricity connection. This is in part due to the lack of facilitating processes and systems.

There are thus the following areas of concern to address in terms of master planning in the 4th IR:

- How do we ensure maximum benefit from the various data sources we have?
- What is the optimal balance between risk and funds available to upgrade and renew our existing asset base going forward?
- Are our current load models telling us the full picture and can we plan our networks more effectively with more (and more representative) data?

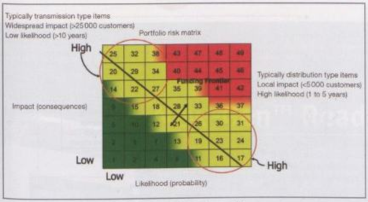

Fig. 2: Asset portfolio risk matrix [3].

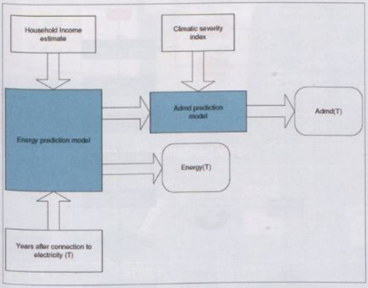

Fig. 3: Energy prediction model as input to ADMD prediction model [7].

- How do we raise the funding for the necessary plans of the future, when considering that the "kilowatt hour business" is dying?

This paper aims to explore these themes and in particular looks at how they are interrelated.

The master model

A master model combines all our various data sources and integrates into various other systems as an output. The master model proposed in this modern software package solution is a fully geospatial model which is formed with data sourced from the utility through various interactions. The master model must ultimately pull and push data from and to various other systems. Current master models are created in different, unconsolidated systems, resulting in out of sync datasets with limited benefit. Utilities need to invest into one consolidated master model which will deal with various planning needs. With advancement of technology, the master model should also interact and integrate with various other systems. For example, the master model must be able to export the full model or parts of the model into a format that can be imported into power system analysis tools as per Fig. 1. Ultimately, the master model must be a digital twin of the real-world network and should include the LV network where, arguably, the largest changes are happening and will continue to happen in the light of the onset of SSEG.

Asset management planning

South African distribution and reticulation networks are fairly aged and in most cases need urgent upgrading. However, utilities have limited budgets and still have to ensure reliable power supply to their customers. Going forward, utilities need to ensure that budgets are optimally allocated for:

- Asset creation
- Asset operations and maintenance
- Asset replacement prioritisation (ARP)

Traditional master plans only speak to the asset creation and to a degree, asset upgrades as well some refurbishment. However, a holistic view of the replacement prioritisation that should be in place to guide capital expenditure is not place. A technique to develop a replacement priority risk index has been developed. The asset replacement priority index score is:

where: $LF_{total} = \sum_{i=0}^{n-1} LF_i \times QF_i$ [1]

and: $CF_{total} = \sum_{i=0}^{n-1} CF_i \times QF_i$

This asset replacement priority index is informed by various weighted factors according to the relative severity of the factor. Some influencing factors include:

- Plant condition
- Current loading
- Future loading
- Age
- Theft
- Failures
- Cost of replacement

Asset operations and maintenance can be done more accurately once all of the asset condition information is captured in a centralised system with a clear plan on the maintenance requirements of the assets. If existing systems are in place with data for the asset operations and maintenance, then it is suggested that the O&M system integrates with the master model and plan. The outcomes of the ARP methodology provides a risk matrix as shown in Fig. 2 [3].

The ARP risk score should thus inform capital expenditure on upgrades, refurbishments or renewals for the utility over a predetermined planning period. This, however, cannot be done in isolation of the master plan as the two datasets need to inform each other.

Load modelling and forecasting

Load modelling is an established area of research in South Africa with various major contributions such as the NRS034-1 residential load models and the Herman Beta method [4 – 7].

The design and planning of networks are done with the after diversity maximum demand (ADMD) of a load class or usage group. This ADMD is fundamental to the sizing of the load and thus has a significant impact on the final design and consequent funding required to supply the load. The development of the load models has been based on a probabilistic method where the ADMD of the load is estimated based on the estimated energy consumption of a particular load class over a month. Energy consumption is related to demand (kVA) as shown in Fig. 3 and 4 [7,8].

The current geospatial load forecasting (GLF) method is not always as accurate as expected as per [9], but becomes more accurate with finer spatial subdivisions [9,10]. Modelling on a per stand/erf basis is the most granular and consequently most accurate spatial subdivision.

A proposed method to obtain the demand of a customer in a network, is now presented. This proposed method is summarised in Fig. 5. Energy consumption is metered at a house or stand level with either credit- or and prepaid meters. Credit meters can give a clear indication of the consumption pattern, on a monthly basis, of a particular customer. Prepaid customers' purchase history is analysed over a period of at minimum two years to determine their average energy usage. The average annual daily consumption (AADC) per stand is calculated to obtain a base energy value for a typical 24 hour day for a customer. Average load shape libraries from the GLF standard is used [4]. Some of the advantages of using a utility billing system database is that this typically also provides valuable information such as:

- Land use of the registered erf
- Zoning of the registered erf
- Usage and demand of other utility services such as water

At the onset of the forecasting model population, each stand within the utility supply area is populated with an AADC value and load class with a standard 24-hour load profile shape assigned to each stand. A key difference to the standard methodology is that where fixed apparent power (S) peak values are assumed for each load class, this methodology does not assume a peak value per load class, but rather calculates the peak value for each stand, in relation to the stand's actual, metered energy consumption (AADC) data.

The maximum demand (MD) for each stand is calculated as per the equation:

$$MD\ (kVA) = \frac{AADC\ (kWh)}{LF\ .PF\ .24h} \qquad [2]$$

A particular problem with South African LV networks is the lack of LV network data, and consequent lack of visibility in LV networks. Network SLDs are typically only captured up to the level of MV/LV minisubs, which leaves uncertainty as to which stands are supplied by a particular MV/LV minisub.

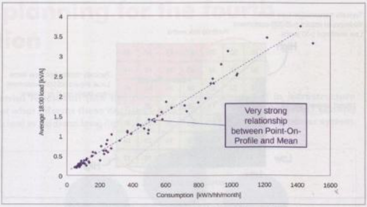

Fig. 4: Correlation between consumption (kWh) and demand (kVA) [8].

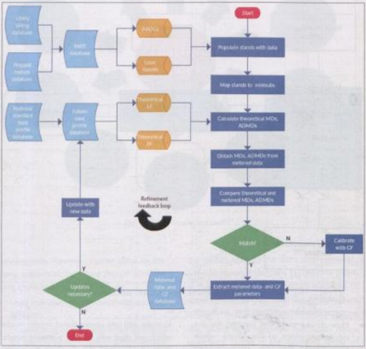

Fig. 5: Geospatial load modelling process flowchart.

The new proposed solution addresses this issue by employing a stand-to-minisub cross-referencing feature, which spatially maps each stand to its closest minisub or MV/LV transformer. Fig. 6 shows an example of the spatial mapping technique applied to a minisub. Fig. 7 shows a network view of the spatial mapping of stands to minisubs. A very useful extension of the capability of this feature, is that the same cross-reference mapping technique can be applied on LV networks, in order to map each stand to its nearest LV kiosk. This promotes the capability to model and perform studies on LV networks.

A composite or aggregated load profile can then be viewed at a minisub- or other supply point level (switching station, substation, etc.) with improved accuracy in the load mix representation, since estimation errors introduced by estimating the representation of load classes in a broad area is reduced. Figs. 8 and 9 demonstrate this aggregation concept.

The last step in the derivation of the network MDs and ADMDs is to calibrate the modelled aggregated load profile with that off the measured peak load of the network. The lowest point in the network where load data measurement is typically available, is at the

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New-Gen™ Ready Board System

Over the last two decades traditional ready boards have answered the demand for a rapid and safe way to create a very basic electricity supply to homes that were not previously connected to the grid. Due to the fact that the installation was only in one room there was an increasing risk of homeowners distributing power to additional rooms in "creative" ways.

The New-Gen™ ready board System is the worlds first expandable ready board system. The New-Gen™ ready board comes paired with a CFL bulkhead. The key feature that makes this ready board system unique is the fact that the "room extender" can be attached in a daisy chain method throughout various rooms in the house.

The room extenders are available in different cord lengths: 3m, 7m and 11m to ensure that there is enough cord for installation in different applications. The device plate at the back of the room extender makes installation easy & efficient as it can be done without the use of an electrician.

Room Extender mounting instructions:

STEP 1: Mount the mounting plate to the wall using 3x6mm screw/plug.

STEP 2: Hook the first unit at the top as shown above and close it.

STEP 3: Plug the first unit into the New-Gen ready board.

STEP 4: Repeat steps 1 and 2 and connect the second unit in a daisy chain as shown.

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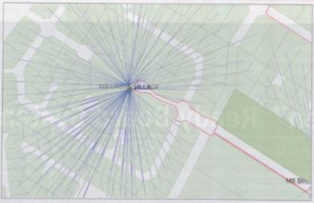

Fig. 6: Local view of spatial mapping of stands to a minisub.

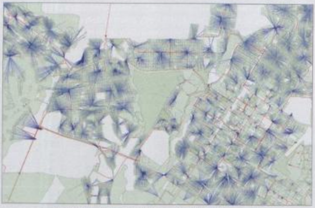

Fig. 7: Network view of spatial mapping of stands to minisubs.

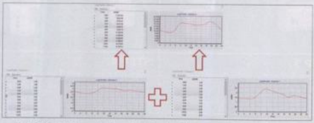

Fig. 8: Graphical example of combined load profile at a common supply point.

Fig. 9: Example of a de-aggregated view of a combined load profile.

HV/MV distribution substation, where 5- or 30-minute resolution data is typically monitored. The load mix and the amplitude of the downstream loads are then calibrated to balance with the actual measured profile. Once calibrated, a set of ADMDs for each load class in a specific zone is available. This zoning can be done on various levels of granularity, such as the entire supply zone of an HV/MV distribution substation, the supply zone of an MV switching station, the supply zone of a minisub, or even as granular as the supply zone of an LV kiosk.

The forecasting is done after establishing the network MDs and ADMDs. The municipal spatial development framework, growth trends, electrification-, housing- and other plans are all analysed and consolidated into a spatial layer which is superimposed onto the existing network model within a GIS environment. This allows one to visualise future growth pockets. All future developments are assigned a commencement year, a development duration, an associated growth curve and a corresponding land use and load class. Furthermore, a saturation scenario is considered where all stands within an area is occupied. The forecast is done for both outright demand as well as future projected energy consumption. This energy forecast is crucial to inform the funding of the master plan and system maintenance into the future.

Master planning from the master model

The master model introduced earlier in this paper allows the creation of a centralised system master plan, from one consolidated dataset, within one software tool. All necessary information can be easily layered, themed, visualised and analysed in this tool. Future projects can be sized from the future development geospatial shapefile which also allows for preliminary servitude requirements to be identified as demonstrated in Fig. 10. Various maps, plan books and spatial drawings can be generated via the tool, creating particular benefit for operations teams that require visibility on where infrastructure or assets are located.

Funding the future

Master plans have traditionally considered and provided a capital expenditure plan. However, there is very little informing where these funds would come from, considering the various threats utilities are facing in terms of revenue. Consumption trends across the country have shown that customers use less energy due to the high cost of energy. The high cost of energy and uncertainty in reliability of supply has also seen financially able customers opt to navigate towards distributed renewable energy technologies.

The master plan identifies the capital expenditure plan in terms of creation, upgrading, refurbishment and renewal of network assets. Funding of this expenditure plan should be funded through the revenues the utilities collect in the future. Various scenarios of the uptake of technologies such as solar PV and price elasticity should be considered for the estimated revenue over the planning period for the utility.

Utilities can ill afford to lose revenue they are supposed to collect and this makes loss prevention, or rather revenue enhancement, central to the sustainability of the utility. The same underlying data that informs the load modelling and forecasting can be used to identify loss recovery opportunities as well as future tariff requirements. The load forecast, due to its nature within this new integrated way of planning for utilities, will forecast the potential energy consumption in the network. This allows for various future scenarios to be tested with various tariff combinations which speak to the funding requirements of the utility. Furthermore, this same dataset should identify improvement areas that the utility can look at in terms of revenue collection and minimisation of losses. Fig. 11 demonstrates the use of a themed cadastral map to identify stands with meters but no consumption and various other anomalies. These themed maps make it easier to identify loss hotspots and allows for targeted revenue enhancement interventions.

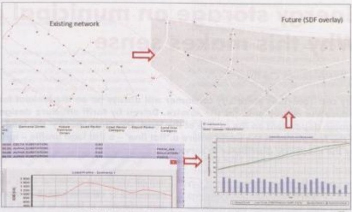

Fig. 10: Master plan with preliminary design and load growth.

Conclusion

This paper has looked a new way of absorbing the existing datasets we have and has proposed a master geospatial model solution for master planning in the 4th IR. The 4th IR will require integrated systems and planning. The paper puts forward an asset replacement prioritisation risk score index which makes use of various influencing factors to assist the utility to spend their limited budget for asset renewals and upgrades, optimally.

A new load modelling method that uses existing energy consumption of users in a utility network is proposed. The method uses billing system information to relate the energy consumption to the absolute demand of each stand. The land use and stand size is used to inform the load class of the stand and a load profile is then assigned to the stand. In turn, the stands are then linked to the closest supply point through the use of spatial correlation. The load profiles are then aggregated up to higher supply points in the network such as switching- or substations.

The load forecast is therefore based on MDs and ADMDs that are derived from the utility's own dataset. The future developments are captured in a shapefile as a layer to the master model to point out where growth will occur, what kind of growth and how fast that growth will be. The first saturation scenario tested is for all stands to be fully occupied. Future forecasting is then done for both absolute demand (VA) as well as energy consumption (Wh).

A master plan is then developed from the software with easily themed drawings and maps clearly showing the infrastructure requirements. Plan books can be generated easily for ease of use by the electricity operations or planning teams.

A new addition to the master plan is proposed which looks at where the funding for the networks of the 4th IR will come from. The proposed addition is to conduct an energy consumption forecast and use this as basis for the calculation of various tariff combinations with particular emphasis given to the new disruptive technologies such as solar PV, batteries and electric vehicles.

Future developments for the 4th IR master planning solution include:

- Integrating IoT device downloads into the dataset.

Fig. 11: Consumption and meters mapped to a themed cadastral map.

- Using mathematical constraint models to calibrate the energy consumption, peak demand and profile shape of the stand loads in a zone to the measured historical profile and peak of the zone's load higher up in the network.
- Calculation of the peak month daily consumption or peak month consumption and use these as basis for the energy model going forward.
- Machine learning to be used to enhance the algorithm for the replacement prioritisation tool.
- Using weather and micro- as well as macro-economic data to enhance forecasting of the load (algorithms can be used).

The possibilities are, in fact, endless.

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Energy storage on municipal grids: Why this makes sense

by Paul Vermeulen, City Power

Any cost-conscious electricity consumer will always be on the lookout for ways to optimise their energy use and reduce the money paid for the service. Driven by tariff structure design, the real costs have always been, and remain dependent on the profile of the load. The more "peaky" the load, the more it costs to service it. This is one of the few places in the world where a "flat line" – a flat load profile – turns out to be a good thing, as it is cheaper for the electricity distributor to service.

The load profile shown above is one of City Power's smaller Eskom intake points supplying an area where there has been rapid residential growth and the necessary upstream upgrades are planned, but still several years away in the Eskom pipeline. As a result, the intake point is subject to Notified Maximum Demand Penalties and over the 2017/18 financial year, the penalty amounted to R2,6-million for the year, while the "normal" component of the bill was around R20-million for the year. The penalty therefore inflated the price for that intake point by more than 10% for the year. This inflated cost is over and above the higher cost due to the "peaky" nature of the load.

In years gone by, the first action taken at the consumer level would been to manage peak demand by scheduling equipment start-up times. This was done in response to the distributor passing on, and applying their own additional demand charges onto the consumer. Second was to improve energy efficiency, and thirdly the implementation of power factor correction equipment to avoid reactive energy charges, also passed on to the consumer. These responses were possible because there was mitigating technology available to make an impact. Quite often however, even though the actions made economic sense, response was lethargic because the price of electricity was still relatively low and the technologies were somewhat limited, seemed complicated and "too technical" in nature.

At a distribution level, the focus has predominantly been to manage peak demand using geyser control systems, or focusing on converting large power users, who can shift load, onto time of use tariffs to manage the overall load profile. A few distributors had diesel fired gas turbines to "peak lop", however, these became uneconomical to run with the rising price of oil and the migration of most municipal distributors to the Megaflex tariff in the 1980s, where there was a shift from charging exclusively for peak demand, to a blended set of charges that have a component of demand and peak energy pricing from Eskom. Where possible, distribution design objectives were set to improve diversity through combining residential loads with commercial or industrial load connected to each substation, to flatten to overall load profile.

Things have really changed over the last two decades. The price of electricity has increased by over 500%, and improvements in energy efficiency options as well as alternative, distributed energy sources have been remarkable. Supply insecurity from centralised generation has also unfortunately crept into the picture. We have added many thousands of new "peaky" residential consumers to the networks and all the while, new technologies have matured and prices fallen, most notably in the cost of photovoltaics and of energy storage systems, particularly storage at "utility scale". What in the past seemed not worth the effort or was too "complicated" to do, are today imperatives for electricity distributors.

Across the globe, storage is being deployed at an accelerating pace, not only to improve the availability factor of renewables, but also to solve a host of electricity delivery problems distributors face. (Clean Horizon, 2019).

The deployment of energy storage at scale touches several of the convention's themes for this year: small scale embedded generation, smart distribution management and to some extent aspects the fourth industrial revolution as there is a need to prepare for the orchestrated digital control of all of the stored energy facilities across the country.

The theme of this paper is to explore the value-add of the various applications of storage, from utility scale to the aggregation of many small 5 to 10 kWh systems for individual houses as well as the dependence on where in the electricity distribution value chain the storage is placed. In an environment where the national generation industry may not have adequate reserves to balance the system over the coming years and the proportion of self-dispatched renewable energy sources feeding into the grid increases, the introduction of a significant quantum of energy storage can go a long way towards managing the reliability and cost effectiveness of the system.

How a fleet of storage assets can be grown in an economically viable and mutually beneficial manner is explored, as well as the added benefits of deploying energy storage as part of a small scale embedded generation program.

Today, all electricity end customers are interested in reducing the cost of using the product. The same must apply to any entity purchasing energy in bulk for resale to these end customers, particularly where there is a mutual benefit. This a key objective of

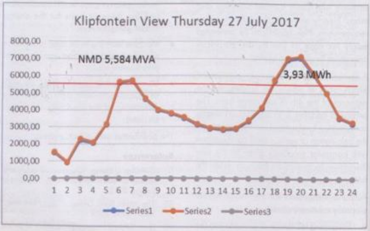

Fig. 1: Load profile of the Klipfontein View Eskom intake point, City Power.

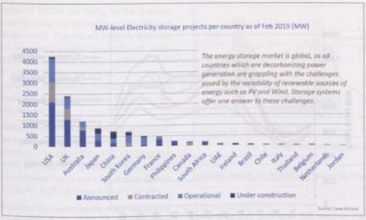

Fig. 2: Storage project capacity by country. (Source: Clean Horizon, Storage Status Overview and Survey, 2019).

the Municipal Systems Act that furthermore has the backing of the constitution. Any regulation or legislation (or lack thereof) that is inappropriately used or obstructs the realisation of this objective needs to be brought to the attention of the relevant ministry, to be resolved.

A recipe for reducing costs

The municipal distribution industry at present faces massive financial challenges and must find ways of reducing their costs and improving efficiencies, for the sake of their own sustainability. Those technologies that offer cheaper energy and those that could be used to avoid peak energy consumption as well as reduce network and demand charges and penalties must be deployed as soon as they become economically viable.

Where energy is already available at rates below those of Eskom, the municipality is obliged to pursue these in order to reduce the cost of their municipal services. This is in perfect alignment with Section 73 (2) of the Municipal Systems Act 32 of 2000, paragraphs a) through e).

It is incorrect to classify an energy storage system as an alternative source of energy. It is easy to fall into this trap because storage has quite often been included in renewable energy facilities to improve their capacity factor and this aspect of storage has been well publicised. It is also incorrect to think of energy storage as just a giant UPS system, because energy storage systems are grid-interactive – they can act as a load as well as a source of energy to both the grid and to priority loads.

In terms of the energy system, storage is a net load as there is an element of charge and discharge loss inherent in their use. Primarily, these systems are able to store cheap surplus energy from any source, at a time such surplus may be available, and to release almost all of the energy back to the system when there is a generation shortfall and peak energy pricing applies. In financial models, the stored energy should always be taken from the cheapest source available and may be either from off-peak coal derived Eskom energy at night or from any surplus or lower cost renewable energy in the middle of the day.

The load profile shown in Fig. 3 is the sum of the three 275 kV intake stations that supply the Johannesburg area of City Power. As mentioned in the introduction, the most cost-effective load to service is one that is a flat line. The question is, what can be done to straighten out the kinks in this profile and can it be done as a normal course of business?

Many municipal distributors have over the years deployed geyser control systems to manage the evening peak in particular. Geysers are in fact pretty good energy storage devices – a fully charged 150 litre geyser stores around 7 kWh of heat energy equivalent and is the principle on which the geyser control systems operate.

In effect, a signal is transmitted to control relays to interrupt the supply to the geysers. This reduces the instantaneous demand for power, and "holds off" the growing geyser load until the peak period has passed and capacity to re-charge the geysers becomes available. This action creates a deficit of energy within the energy distribution system which has limitations.

The power must be restored within at least an hour and a half, otherwise the result will be many customer cold water complaints. It takes only a few such incidents and the relay will be bypassed by the consumer. Despite these constraints, these systems have successfully been used to manage instantaneous demand and avoid recharging the geysers with costly peak energy, by delaying the re-charge so that it can be done with cheap off-peak energy. This is the basic financial arbitrage mechanism that reduces the cost of supplying energy for water heating purposes.

A grid connected battery energy storage system does not have this limitation as it can be recharged many hours after the peak has subsided and at the most convenient time that best suits accessing the cheapest form of energy the system has to offer. Storage systems are able to pre-create a reserve of energy for the system to manage demand rather than creating a deficit to achieve the same. So, a utility scale energy storage system is really more like a geyser control system on steroids.

Energy storage is also twice as good as a gas turbine at managing the peaks and valleys of any load profile. A gas turbine system can only ever behave as a generator of electricity. In contrast, a utility scale energy storage system can be both a schedulable generator and a schedulable load. It can both fill the valleys and clip the peaks, so it has twice the control range of a gas turbine generator.

In parts of the United States, PV plus storage has become a cheaper 'peaking' option and is displacing natural gas powered peaking plant. In some cases storage is competing not only with peak generation, but also with mid-merit generation plant (IEEFA 2019).

The load profiles in Fig. 5 shows the effect of introducing a total of 350 MW worth of PV generation and 250 MW worth of storage with a capacity of 1690 MWh to the Johannesburg grid (see Table 2). While this is a tall order and for storage may take over a decade to achieve, it demonstrates that the load factor can be improved from 0,78 to 0,94 which will significantly reduce the bulk energy purchases bill from Eskom. In the example, the total sales for the day was 23 942 MWh, and the evening peak at around 19h00 was 1232 MW.

The cascading benefits of energy storage

Utility scale energy storage is developing rapidly and can have significant negative disruptive potential for the EDI in so far as it is an enabler for those end users who have the desire and financial means to go "off grid". At present, the cost of going completely "off grid" is not economically viable. This will however change as the cost of storage eventually does reduce to the point where renewable energy plus storage reaches grid parity.

In contrast, when storage is put to use in support of the electricity distribution system as a whole, the so-called disruption to the industry can become immensely positive in a number of different aspects. It is important to realize that the value of utility scale energy storage is generally increased the further down in the grid energy value chain it is placed, provided it is still operated at a time that benefits the generation, transmission and distribution industry. This is due to the cascading value or "stacking" of both technical and financial benefits as the storage facilities are located deeper into the network.

For example, a 100 MWh storage system placed at a point on Eskom's high voltage transmission network can provide:

- A means to store surplus renewable energy at a national level.
- Avoid transmission network bottlenecks.
- Provide frequency support (reserve margin) for the national generation industry.

These are the only benefits that can be realized in the case the storage is connected to the transmission network.

If the same energy storage capacity of 100 MWh was deployed by strategically placing fifty smaller 2 MWh systems further downstream on the municipal distributor's medium voltage distribution networks, not only could the abovementioned benefits still be realized, but the storage systems could add further value through:

- Eskom energy purchasing arbitrage and demand charge reduction.
- The alleviation of distribution network bottlenecks and overloads.
- The avoidance of Eskom notified maximum demand charge penalties.
- The deferment of network refurbishment or network upgrade capital expenditure.
- Improvement of the power factor across the entire transmission and distribution networks.
- Realising a significant improvement in the security of supply for end customers.
- Providing a measure of standby power to end customers as an alternative to expensive diesel power.
- Through digital co-ordination, operate as a proxy to peak power generation plant to maintain the reserve margin.

This increasing value effect or "stacking" is critically dependent on where in the network the storage system is located. The highest value of all to the end customer and the economy as a whole would be realised where these energy storage systems are strategically placed at the so called "grid edge", as close to the customer as possible and designed to run as independent power islands or mini-grids to maintain supply to one or a group of end customers in the event of load shedding or other unplanned grid outages. It is important to remember that 60% of the "grid" edge is in the hands of the municipal distributors.

Another subtle benefit of rather installing the storage on a distributed basis, is that the reliability of the storage function within the

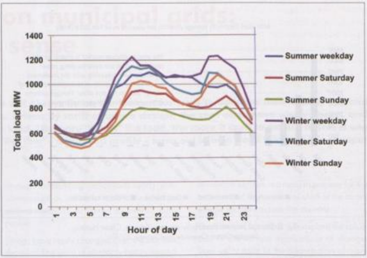

Fig. 3: Johannesburg: Eskom intake summer and winder load profiles.

system is made more secure. Diversity brings this added reliability for the storage, as the chance of all of the smaller facilities all failing at the same time is far less than the possibility of a single large installation failing at an inconvenient time. The distributed approach is able to include a reliable element of demand reduction that can confidently be factored into the demand charge reduction financial modelling for storage.

So, it is in the space between going completely off-grid with PV plus storage, and using PV plus storage plus the cheaper "off-peak" grid energy available by staying on the grid that is much more interesting to the system as a whole. Customers remaining part of the grid community will be provided backup on those occasions where sunshine is unreliable for days at a time, and on good solar days, they will still reasonably provide a cross-subsidy to support those customers that cannot afford a system of their own.

Real, practical benefits of storage

Utility scale energy storage systems are rapidly becoming economically viable and can provide demand side flexibility like never before. They can be deployed where networks need strengthening, can defer costly network upgrades and in most cases do this permanently. As an added benefit they can be sited at key customer premises and used as an alternative to diesel generation in the event of both forced and unforced grid outages. This ability to offer enhanced security of supply is a potential new revenue stream for the distributor.

It is not unreasonable that a distributor should aspire to be in a position to control at least 10% of their peak demand liability using energy storage systems, specifically to manage the winter evening peak demand caused by residential load on a daily basis. Such a quantity of storage capacity can also be used to insulate the distributor from Stage 1 load shedding, should the need arise in the future.

The various applications of energy storage can be described in terms of the benefit they bring to the municipal distributor. We will unpack a few of the applications to identify how they benefit distribution systems they are connected to:

- Optimising energy procurement costs – arbitrage and demand control.
- Avoiding NMD penalties.
- Protecting the economy and enhancing the security of supply.
- Preserving overloaded distribution infrastructure and extending its lifespan.
- Unlocking property development and supporting densification.
- Optimising investment in renewable energy systems.

Optimising energy procurement costs – arbitrage and demand control

Tariff arbitrage is the practice of using load shifting techniques to reduce energy procurement costs where the energy is available on a time-of-use basis, such as the Eskom Megaflex tariff. This is done by storing cheap off-peak energy for later release during peak times when the cost of energy is much higher. Table 1 shows the daily arbitrage value of 1 kWh's worth of storage to a municipal distributor (yellow highlight) when applied to an 11 kV intake point on the Eskom Megaflex Local Authority tariff for 2019/2020. The table shows the average value over a whole year.

The table also shows the maximum cost of the energy storage system (pink highlighted value of R4309 per kWh) for the business case for using the storage for arbitrage alone to be viable. The site will begin to generate an increasing surplus should Eskom prices continue increasing at above inflation rates. In addition to this, the actual cost of storage systems is expected to continue reducing to levels significantly lower than this figure over the next ten years.

Daily tariff arbitrage is the "base business case" for energy storage in the hands of a municipal distributor. Based on Eskom's 11 kV Megaflex tariff, the value to a distributor of having just one kilowatt-hour's worth of energy storage to use for tariff arbitrage is R1,59 per day.

Provided the system works every day (except Sundays) for the next 15 years shifting just that 1 kWh of demand from peak to off-peak, a total savings of R7470 will be realised over that period in today's money terms.

As an added hedging advantage, these savings will increase at the same rate that any Eskom price increases do, which will most likely be at above inflation rates for several years yet to come.

This means that any storage system that today costs below $295/kWh already makes business sense even when it is used for arbitrage alone. Any additional benefits realised would be a bonus on top of this basic, self-sustaining business case.

In the event no local storage is introduced to the grid, the distributor will continue indefinitely to pay for Eskom peak energy and increasing maximum demand costs. The situation will get even worse if residential electrification projects continue at scale and the more affluent customers accelerate their uptake of renewable energy.

Where energy storage is introduced using arbitrage as the base business case, the distributor will be able to avoid peak demand and energy costs from Eskom and rather use the funds to pay for these new assets. These assets will not only provide a means to manage bulk energy procurement, but also, if strategically located, be able to overcome local network overload and constraint problems.

As the cost of energy storage further reduces, it will soon become viable for external parties to provide energy storage or "arbitrage" services to the distributor on a tailor-made Energy Arbitrage Agreement basis. If the same financial model shown in Table 1 is used and the capital loan interest rate is converted to a "rate of return" for an investor and is set to 15%, as soon as the cost of storage reduces to $160/kWh it becomes a viable business proposition.

From the municipal accounting perspective, the energy bulk purchases line item on the operating expenditure budget could (and perhaps already should) be split into the constituent components of the Eskom bill. These are: network and demand charges, off-peak, standard and peak energy line items. Arbitrage services, being functionally equivalent to the provision of peak-priced energy and a portion of the demand charges, could be paid for from these line items instead of the payments that would otherwise have been made to Eskom.

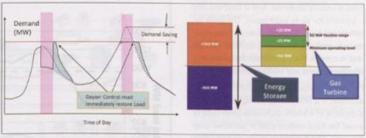

Fig. 4: Comparison of Energy Storage to Ripple Control and a Gas Turbine.

$$\textit{(Montly Penalty)=(MUC-NMD)*Event No*(Network Demand Charge + Low Voltage Subsidy)} \quad (1)$$

This amounts to procuring arbitrage services on a performance contracting basis, similar to the way energy efficiency projects can be funded from the savings that they yield. Unlike the complications that cast doubts on the measurement and verification of energy efficiency projects, the M&V of an energy storage system will be clear-cut. All that is required is to measure the energy going in against the energy that comes out, on a time discriminated basis with an ordinary smart meter. Beyond this, all that would be required would be a Section 33 exemption from Treasury to sanction a 15-year contract term with the service provider.

This arbitrage business case is at risk should Eskom significantly change the structure of its Megaflex (or proposed future Muniflex) tariff. At present the summer peak to off-peak price ratio for energy is 2,29:1 and the winter ratio is 6,08:1. While the value of daily arbitrage is directly dependent on the base cost of energy, it is far more dependent on the pricing differentials between peak and off-peak periods.

Avoiding NMD penalties

In the event the declared notified maximum demand on an intake point is exceeded in any month, the first billing effect is that the annual utilised capacity (AUC) figure is set to the higher recorded value. The AUC is kept at the highest value recorded over a rolling twelve month period, and it is the AUC figure that is used to calculate the transmission and distribution network charges on each monthly bill.

In the case an energy storage system is applied to the intake point and is programmed to operate whenever the NMD capacity limit is reached, then the ordinary network charge savings over a year that the system can realise will be twelve times (equal to the twelve months of the year) the demand reduction that the system is capable of delivering, multiplied by the applicable network charges. The saving will however only become effective after the storage system has been in service for a full year.

The penalty for the monthly utilised capacity (MUC) exceeding the notified maximum demand (NMD) really punitive and is determined by the following formula, (as interpreted from the Eskom NMD rules document) see Eqn (1).

Over the months in a year, the penalty "multiplies up" drastically because of the event number term. In the first month of an exceedance within a twelve month rolling window, the penalty on an 11 kV Megaflex intake point will be R28,99 per kVA exceeded for example. In the second month it will be doubled to R57,98 per kVA exceeded and by the third month will triple to R 86,97 per KVA exceeded, and so on.

The effective demand reduction capacity of an energy storage system is dependent on the shape of the load curve of the particular intake point to which it is connected. If the peak is relatively flat and sustained, such as a commercial or industrial customer, actual demand reduction will be at a minimum. Where the load curve is more "peaky" as is the case for residential loads, the greater the demand reduction the energy storage system will be able to deliver for a given storage capacity.

In general, the load reduction capacity of an energy storage system can be expressed as in Eqn (2).

The peak on an industrial or commercial

load is usually sustained over a business day – typically for six to eight hours. The peak on residential load is usually over a three-hour period, typically between 17h00 to 20h00 and is a more likely candidate for storage to effectively avoid any NMD penalties.

For the Klipfontein View NMD penalty example, a 2 MW energy storage system with a capacity of 4 MWh could have been used to avoid the R2,6-million paid in penalties over the year. This translates to an added value of R1,78 per day per kWh for the energy storage system.

Energy storage systems are ideally able to solve the problems of intake stations that supply residential loads that typically see exceedances of up to 20 % of the site's NMD capacity, perhaps only in the three winter months of the year. The potential added savings are site specific but will be between a minimum of 15 cents/kWh and the extreme R1,78 per kWh described above.

Protecting the economy and enhancing the security of supply

Customers have invested in diesel generators that have a high operating cost – typically R5/kWh – to defend themselves against the risk of load shedding or network outages. If those customers could have been persuaded to rather to invest in an energy storage system, the storage could have been used on a daily basis to reduce their overall energy costs and still provide the desired backup that the customer requires.

A diesel generator is a sunk cost, is expensive to use and is only ever used in an emergency. Today, an energy storage system would be a far better choice not only because it can pay for itself and deliver cost savings, but because the changeover from failed grid to the storage system is seamless, unlike the supply interruption that is experienced when the grid fails and time is needed for the diesel generator to start and stabilise before it can accept load. A beverage company running bottling lines for example would benefit most from this feature.

The seamless changeover also supports the participation of the customer in proper demand response schemes, where instead of load shedding, the distributor could rather request the dispatch of the energy storage systems on its networks to achieve the same effect.

At sufficient scale, storage is an ideal antidote to load shedding, it protects the economy by avoiding the cost of unserved energy and has the added benefit that the distributor also does not experience any loss of revenue due to supply interruptions.

This is different to the destructive power buy-

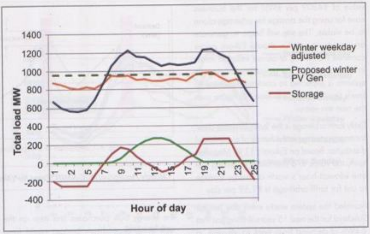

Fig. 5: Hypothetical adjusted Johannesburg load curve with PV generation and utility scale storage added to the mix.

$$\text{Load reduction capacity} = \frac{\text{Capacity of the energy storage system}}{\text{Average duration of the load peak}} \qquad (2)$$

back demand response scheme that Eskom proposed to introduce at the height of the load shedding crisis. In the case of the buy-back scheme, the result was a stoppage of a portion of the economy. In the case the demand response program uses stored energy to manage the reserve margin, there is no interruption to the economy.

Those companies that have already installed UPS units to ride through power interruptions are already reaping the benefits of having energy storage. Using the arbitrage business case, as many customers as possible need to be informed of using energy storage as a backup and convinced to invest in systems for their own purposes.

In the case a distributor decides to make utility scale storage investments, the best location for the facilities would be at the customer's premises. Modern inverters can be connected in a way that enables the system to operate as an independent power island – in a mini-grid configuration – to provide secure power to the participating customer or perhaps even a cluster of adjacent customers.

An internal benefit to the distributor is realised where there is a reduction in the net revenue lost to either unforced (overloads) and forced (load shedding) outages. In the case storage is used to reduce winter overload outages in residential areas the value of the revenue protection will be determined by the frequency and duration of the outages usually experienced on that specific network.

Preserving overloaded distribution infrastructure and extending its lifespan

Repeated stressing and overloading of distribution feeders shortens their operating lifespan. If an energy storage system was installed at the end of the feeder or at the mid-point of a ring feeder, it could be used to de-load the feeders at times when the load is excessive.

All that is required is a simple control system that measures the power flowing into the feeder at the source, and is able to signal the storage system when to charge itself and when to release the stored energy back into the system. The direction of power flow at the end of the feeder will change, and the effect will be to reduce the power flow at the source end of the feeder.

South Africa has a R70-billion backlog (De Beer, 2014) in distribution infrastructure maintenance. It is estimated a third (R23-billion) of this is for distribution network strengthening, often needed for only short duration peak loads which storage systems can easily deal with.

Upgrade work involves the physical replacement of existing distribution infrastructure transformers and cabling, an expensive and disruptive activity. This problem is constraining property development in municipal areas, also affecting economic development.

The life of aging distribution infrastructure is extended where the networks can be de-stressed through peak load reduction. A well-placed energy storage can permanently avoid or solve a fair share of these problems – particularly since it can already pay for itself from daily arbitrage savings and the correlation of the peak loading and the tariff peak period pricing periods will usually be very strong.

Fig. 6: Energy storage facility placed on the Eskom transmission network.

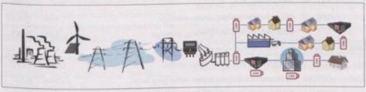

Fig. 7: Distributed energy storage facilities placed on the muicipal distribution network.

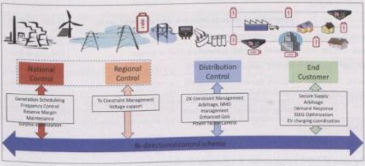

Fig. 8: A suggestion of the overarching, bi-directional control scheme required for energy storage.

Long term planning has got to begin considering energy storage systems as a viable option to costly and disruptive whole network upgrades. Distribution planning engineers are a sceptical lot, who have up until now (perhaps with fair reason) never trusted geyser control systems for example, to permanently solve distribution overloads. Energy storage systems will be under the direct control of the distributor and can be installed at separate, distributed points along the affected feeders.

With sufficient distributed energy storage installed within a given power network, it may also be possible to defer the upgrade of the Eskom intake points supplying the network, on a permanent basis.

Unlocking property development and supporting densification

The process of township development requires that sufficient bulk supply capacity be available to support the development. In the case of residential developments, enough energy may be available over the period of a day to supply the energy needs from the existing infrastructure, but the bulk supply transformer and distribution network capacity may be insufficient to support the evening peak that is characteristic of residential developments.

The problem can be solved by installing an energy storage system right in the middle of the proposed new development, to soak up energy when the overnight or midday load is low, and release the energy locally, when the peak needs to be serviced. No upgrade to the bulk infrastructure will be necessary.

Effectively, the energy storage system can be seen as a new 'virtual intake point' to unlock the development. Unlocking development brings with it additional rates revenues as well as new economic activity in the area. New service connections also bring an increase in overall volume of kWh sales, something that the generation industry desperately needs at present.

Exactly the same principle applies where it is desirable to increase the housing density without the need to go through a costly bulk supply and network upgrade. Containerised energy storage systems are the norm, and can be placed where necessary or even relocated if the bulk suplly infrastructure is finally upgraded.

It could even be the case that Eskom owns the energy storage facility and operates it as a virtual Eskom intake point, to both increase the volume of Eskom sales and assist the municipality with development.

Optimising investment in renewable energy systems

The introduction of an ever increasing quantity of photovoltaic energy onto the Johannesburg grid will alter the load profile into a shape similar to the California "duck curve", with a more pronounced morning and evening peak profile. This will worsen the load factor at the Eskom supply point and will increase the cost of bulk supply from them.

While photovoltaic energy may be cheaper than grid power in cost per kWh for a customer, the cost of supporting the flow of that energy within the system remains with the distributor. The distributor must still pay the full cost to operate the grid during peak periods and procure backup capacity from Eskom to cater for bad solar days. Including an element of storage within a renewable energy system so that some of the energy the energy can be released during the peak periods, will assist the distributor significantly.

In the case of City Power's residential customers, the SSEG feed in tariff is subject to the customer migrating to the Residential Time-of-Use Tariff. In this case, including an element of storage allows the customer to effectively remove themselves from the grid during the peak periods. The tariff is designed so that the overall cost of the balance of the energy consumed from the grid is lower than the flat rate tariff.

A lot of the residential systems that were installed in response to load shedding already have an element of storage built in. What is needed is for those customers to respond to the tariff signals and use the storage to reduce their consumption of peak energy and begin to benefit from the overall cost reduction.

From a city perspective, storage can optimise the use of all the photovoltaic installations on the grid by compensating for the negative effects of the "duck curve". It would not be unreasonable to consider a policy that requires a certain quantity of storage be included as a condition to granting permission for customers to connect their PV systems to the grid. The benefits are mutual in this case.

There are many customers who do not have a suitable rooftop for their own PV systems. There are also many warehouse type buildings that have an abundance of rooftop space but no load to consume the power. The grid can easily connect the two together – with a fair wheeling or offsetting tariff for providing the service.

This will become an important new revenue stream for the distribution industry in the near future, and what is becoming clear is that the charge for transporting the energy across the grid will be dependent on the time that the transfer takes place. Energy flowing behind the Eskom meter during

Analysis of break-even point of energy storage cost vs. maximum arbitrage potential of the local government Megaflex tariff					
1 kWh storage used for 6 days of the week, one shot per day, to shift 1kWh from peak to off-peak, all year around					
Plant parameters			**Megaflex tariff application**		
			11kV intake point, e.g. Rondburg		
Technology aspects	**Units**	**Value**	**Operational aspects energy**	**Units**	**Value**
Cost of storage system	$/kWh	295	HV distribution system losses	%	4,00%
Storage system expected cycle life	Number	7000	MV/LV distribution	%	3,00%
Efficiency of charge and discharge cycle	%	85%	Value of winter evening energy arbitrage	c/kWh	246,84
			Value of summer evening energy arbitrage	c/kWh	54,29
Capital aspects	**Units**	**Value**	Loss-less average value of daily arbitrage	c/kWh	102,43
Rand to Dollar exchange rate	Ratio	14,61	Average daily rate to re-charge system	c/kWh	43,72
Local cost of Storage	R/kWh	4309,95	Cycle cost to overcome system recharging losses	c/kWh	6,56
Capital loan interest rate	%pa	5,5%	Cycle savings due shift of losses out of peak	c/kWh	3,07
Capital loan term	Years	10	Net average value of daily energy arbitrage	c/kWh	98,94
Cost of Finance	R/kWh	-1303			
Total financed plat cost	R/kWh	5613	**Operational aspects network and demand costs**	**Units**	**Value**
Theoretical plant life, 6 days p/week, 1 cycle/day	Years	22,4	Peak Period duration	hours	2
Expected operational lifespan	Years	15	Demand reduction potential per kWh of storage	kVA	0,5
Charge/discharge cycles required	Number	4696	Monthly network charge per kW	R/kVA	7,63
Staff operating costs	R/kWh	1440	Monthly demand charge per kW	R/kVA	28,99
R&M plant costs @ 10% of capital costs	R/kWh	430,995	Daily network and demand charge savings potential operation during the annual half hour peak	c/kWh	60,23
Total cost of financed and maintained plant	R/kWh	7484			
LCOE over expected plant life 1 shot per day	c/kWh	159,37	Total potential daily arbitrage value of 1 kWh storage	c/kWh	159,17

Table 1: The value of 1 kWh energy storage to a municipal distributor.

Type of installation	Nominal storage capacity per participant (kWh)	Potential number of participants	Contribution to total (MWh)
Individual residential PV prosumers (kWh)	3	100 000	300
Sectional title residential (kWh)	50	5 500	275
Large power users <100 kVA	100	8 000	800
Key customers >100 kVA	1000	300	300
		Total	**1675**

Table 2: The effect of introducing 350 MWh PV generation and 250 MW storage with a capacity of 1690 MWh to the Johannesburg grid.

the peak period will be charged at a lower rate to encourage the use of any power generation – such as from and energy storage system – at the right time, that will reduce the need to over-depend on Eskom during the peak periods.

Does it matter who owns the storage assets?

Even as distributors, we often take the properties of the grid for granted and tend to think of it as simply an infinite source of energy. Its most important property is that it is a network, where what happens at one node of the network has an impact on other nodes at locations both above and below that point. With the advent of distributed energy sources, the grid is also in the process of transforming from a one-to-many type of network to one that has more of a peer-to-peer architecture.

One of the key characteristics of a grid is that of load diversity, which loosely equates into a kind of a community in which the grid designers only need to design for the average requirements of users of the grid rather than the maximum that each may require. As for as storage is concerned, as long as the operations of charging and discharging of all the assets on the grid can be done in a co-ordinated manner, it does not matter who owns the storage facilities as the system as a whole benefits. Of course, the owner of the asset will always benefit the most, but cannot realize any benefit without also benefiting others within the system.

This means that the storage system can be placed either at the intake substation or anywhere deeper into the network that will co-benefit from peak load reduction. Regulation of the industry will be needed as the facilities will need to include control systems that can respond to independent signals from the generation and transmission operator (national control) as well as signals from local distribution control centres. This type of control regimen will form the demand response part of the future smart grid, actively dispatching the storage assets as the need arises.

Where, in order to fully realise the "stacked" benefits and the storage assets are located behind the Eskom meter and also at the so called "grid edge", the opportunity presents itself for the distributor build the storage facilities, with negotiation with key customers, at their premises and to provide these customers with secure standby power in the event of a network outage. This new service and revenue source is possible because today's energy storage systems can operate in an islanded or "micro-grid" mode.

If the assets are located still further into the network – behind the municipal distributor's meter, an appropriate time differentiated tariff can be used to signal when the stored energy should be released and when the system should recharge.

The electric vehicle will be a new load that will improve sales volumes for distributors. While they are essentially mobile energy storage systems that will not feed the bulk of their energy back into the grid, they can be shaped into a schedulable block of load with intelligent charging systems to fill the load profile valleys, and perhaps in the future make a contribution to supplying energy back to the grid during peak periods.

Conclusion

Municipal bulk supply and distribution planning needs to begin including storage as a real alternative to costly network strengthening capital expenditure, particularly if the storage facilities can be funded through the operating budget. National Treasury should be approached to advise on the application of the MFMA to enable this mechanism.

Policy on renewables would not be unreasonable should it prescribe that a certain quantum of storage be included with renewable energy sources that are connected onto municipal distribution networks by prosumers. In this case the storage is self-funding when used for arbitrage and the use of a common grid-tied inverter for both the renewable energy and the stored energy further reduces the overall cost of these systems and delivers valuable benefits to the system as a whole.

The distribution environment needs to be opened up to all forms (all viable technologies) and applications of energy storage, including assets owned by the distributor where capital is available, all privately owned storage available to the distributor on a performance contracting basis as well as all privately owned storage that is operated in response to tariff signals.

In the Johannesburg example where a storage capacity of 1690 MWh across the grid could deliver an improvement in the load factor from 0,77 to 0,94 the breakdown of installed facilities may look something like numbers shown in Table 2. When broken down in this way it does not seem to be an unrealistic objective for the coming decade.

Distributors will also need to begin preparing for the control systems that the grid will require to integrate new alternative energy sources and storage facilities into their networks.

Most importantly, the distribution industry needs to encourage the wholesale uptake of energy storage systems in all forms as it will be key to the sustainability of the EDI in the coming years.

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Price parity of solar PV with storage?

by Aradhna Pandarum, Eskom

Globally, there is currently an installed capacity of approximately 140 GW of small scale solar PV. It is anticipated that this penetration will increase to 1391,9 GW by 2040.

Bloomberg New Energy Finance (BNEF) justifies this rapid growth by stating that it is due to the historical decrease of technology prices, a trend which will continue in future. Fig. 1 illustrates the global decline in the costs of solar Photovoltaic (PV) crystalline silicon modules – from \$80/W in 1976 to \$0,25/W in 2017.

The small scale embedded generation (SSEG) market in South Africa is predominantly owned by rooftop PV. In December 2017, it was estimated that there was ~285 MWp of small to medium scale embedded generation (SSEG) installed in South Africa [2]. This includes all installations with a capacity of <5 MWp. 5% of the installed capacity is considered to be off-grid installations. The sector that dominates the market was found to be the Commercial and Industrial sector with a penetration of 70% of total installed capacity.

The cost of storage technology is also declining at a significant rate. This is mainly due to developments and research initiatives into technology improvements for large scale roll-out into the transport sector. According to another report by BNEF, the average decline in capital costs for Li-ion batteries from 2010 – 2016 equates to 16,3% per year and a total of 73% reduction in just seven years [3].

Utilities and service providers have been reporting declining sales in electricity sold from 2008. One of the possible reasons for this trend is that customers are finding other energy efficient solutions to supplement their electricity needs and the use of solar PV could be a large portion of this supplementation. Furthermore, the impact of load shedding has also caused many customers to resort to alternative means for electricity supply. The International Energy Agency states that SSEG is increasingly attracting the interest of utilities and policy makers and there are 5 main contributing factors as to why. These are [4]:

- Increasing customer demand for reliable electricity.
- Liberalisation of electricity markets.
- Utilities facing constraints on the construction of new transmission lines.
- Developments in technology of SSEG and decreasing costs.
- Concerns about climate change.

An additional factor could also be electricity price uncertainty and/or increasing electricity tariffs.

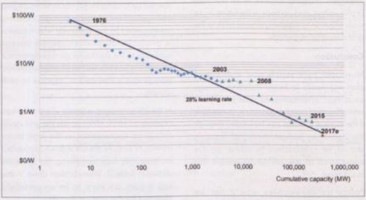

Fig. 1: Crystalline silicon solar PV experience curve [1]

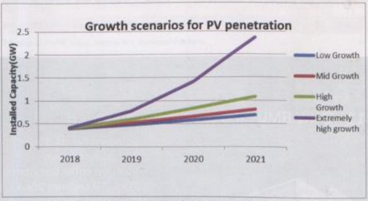

Fig. 2: Projected growth scenarios of SSEG in South Africa from 2018 – 2021 [5]

There are 4 scenarios that were evaluated for the penetration of SSEG (predominantly rooftop PV) in future years, including 2018; these are represented in Fig. 2 [5].

As the costs of PV and storage continue to decline it becomes more apparent that decision makers at utilities and municipalities be made aware of when customers would consider defecting totally of the grid as this would be the point at which mass sales reduction could occur. This paper provides some answers with regards to that topic. It provides 1) projected installation costs for solar PV without storage and 2) projected LCOE for solar PV with and without battery storage. This projected cost will be analysed with respect to the expected electricity price path to provide insight into the future of PV and battery storage for different segments. The assumption made is that no changes to tariff structures will be made during the years of projection.

Methodology

The steps and methodology used to project the LCOE of solar PV with storage is illustrated in Fig. 3 below. The LCOE of PV with storage includes the LCOE of PV plus the levelised cost of storage (LCOS).

Current and future installation costs for both PV systems and behind the meter storage technologies are documented in this paper. Future costs are determined by a mixture of extrapolation methods and data available. Using the installation costs, LCOE of PV with storage is computed for 2018 – 2021.

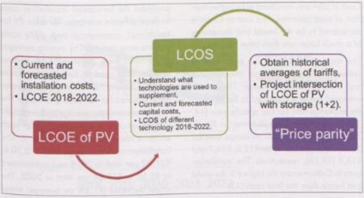

Fig. 3: Methodology used to determine LCOE of PV with storage

Module costs	Module make, size and cost
Balance of system (BoS) hardware cost	Inverter
	Racking
	Wiring and cables
	Monitoring system
	Battery
	Other hardware (transformer, protection devices, etc.)
	Duty and transportation cost
BoS soft (non-hardware) costs	Project development/feasibility study cost
	Customer acquisition (sales and marketing costs)
	System design and procurement
	Subsides (applications, fees, etc.)
	Permitting (application for permitting with utility provider and other authorities)
	Financing and contract (legal) fees
	Installation cost/civil works
	Interconnection
	Perfomance and warranty
	Commissioning cost
	Training and capacity building

Fig. 4: Cost breakdown of solar PV systems [6]

Cost component	Residential system (1 – 10 kW)	Commercial system (2 MW – 100 MW)	Utility scale system (10 kW – 2 MW)
Module	35%	45%	49%
Hardware BOS	16%	20%	14%
BOS soft costs	49%	35%	37%

Table 1: Percentage breakdown of cost components for PV systems [7, 8, 9].

Finally this LCOE is compared to average Eskom tariffs for the projected years to find intersection point. All costs in this paper are determined using literature that is available locally and internationally. The LCOE and LCOS calculation was computed using tools developed by the author. The projected electricity tariffs are represented in three different scenarios and this was determined using tariff data from 1996.

During the research phase of this work it was found that the installed costs of a specific technology is directly linked to the utilisation and implementation of the technology. Hence, as the demand increases for a specific technology the costs will decrease accordingly. The costs used in this paper are costs obtained from international and local research reports. The main referenced bodies include International Renewable Energy Agency (IRENA), National Renewable Energy Laboratory (NREL) and Greencape (representing the South African perspective). It must be noted that the "price parity" of PV with storage obtained does not necessarily represent the generation of electricity from a utility in its entirety as other costs such as availability of the grid, frequency support, voltage support, etc. is not considered. PV system costs

Installed costs of PV systems comprise of various component costs. These components are broken down into 2 major segments; the first being module and the second is Balance of System (BOS) costs. Fig. 4 presents a breakdown of all associated costs for the installation of PV systems [6]. The cost of meter exchange from conventional to four-quadrant is not included in these costs.

The average percentage distribution to all cost components that form an installed PV system, be it residential, commercial or utility scale system is represented in Table 1. This was calculated using cost distributions from United States of America and South Africa. It is evident that the majority of the costs are derived from procuring the modules and accounting for BOS soft costs.

Research shows that there are efficiency improvements in most of the components included in PV systems. These improvements lead to reduced costs and space required for the installation.

Module costs include costs involved in the manufacturing process of the PV wafers and the assembly process of the entire module. This specific cost has experienced a drastic decline and makes up a large portion of the entire system. According to [6] the decline in module cost experienced from 2009 to 2015 was around 80%. This statement is further supported by Bloomberg New Energy Finance [1], in which they articulate that module costs have decreased by 99,68% from 1975 to 2017. This is primarily due to the conversion efficiency improvements in the semiconductor materials used in the wafer of the modules. In 2017, the global manufacturing cost of modules was between $0,33/W and $0,35/W dropping by ~40% in four years [10]. National Renewables Energy Laboratory (NREL) predicts that the ASP of modules will decrease to $0,27/W by 2021 [10].

Inverters and balance of system (BOS) costs make up the rest of the costs associated with PV systems. Currently, the inverter costs, on average, between $0,06/W and $0,15/W AC [10] based on the application. There are different types of inverters used for different applications; central inverters are used for utility scale plants, string inverters for commercial sized plants and string or micro-inverters are used for residential applications. The cost of inverters are expected to drop by an average of ~34% from 2015 to 2025 based on application [11]. Balance of system costs (hardware and soft costs) is the last cost component involved in installation of PV systems. The hardware BOS costs are costs for structural and other electrical components, not including the inverter. In 2017, BOS costs in United States of America (USA) were, on average, between $0,71/W and $2,18/W depending on application [12]. In 2015, BOS costs in Africa were, on average, between $1,46/W and $2,8/W depending on application [6]. IRENA expects a 66% reduction in BOS costs for utility scale PV plants from 2015 – 2025 [11].

The aspects previously mentioned on the cost reductions for components in a PV systems being experienced is evidence enough to assume that total system costs are declining as well. In South Africa, the cost of residential systems have decreased by 36% from 2013 – 2017 [13]. The cost reduction for utility scale PV plants in various countries is considered to be ~72% on average from 2010 – 2017 [13]. The cost reduction for commercial scale PV plants in various countries is considered to be ~66% on average from 2009 – 2017 [13]. Currently, the average total system cost in USA ranges from $2,25/W to $3,83/W depending on the application [10]. The average system cost for utility scale plants ranges from $1,03/W to $1,11/W [12]. In Africa for 2015, average installed costs for residential PV systems were $2,9/W, commercial $2,27/W and utility scale $1,87/W [6]. In South Africa for 2018, Greencape's analysis concluded that installed costs for residential were between R13,5/W and R16,0/W and commercial systems between R10,5/W and R14,0/W. Costs in USA are considered to be higher than that of most countries. The cost in China is considered to be the lowest and decreasing at a much faster rate than other countries.

The total systems costs for each type of system were obtained from international and local literature reviewed. These were averaged out and converted to Rands using the exchange rate for that specific year [14, 15]; the final results are illustrated in Fig. 5. The average rand to USD exchange rates for 2015, 2016 and 2017 are R12,8, R14,7 and R13,3 [14,15], respectively. The installation costs in California are the highest in the world and hence skew the final costs [13].

Using forecasting techniques such as trend extrapolation (extrapolating the past trend for installed costs based on moving averages seen from previous research for those costs) and all the data previously analysed the forecasted installation costs in three different scenarios for solar PV for residential, commercial and utility scale systems were derived. The moving averages of all costs were computed from various sources and used to forecast for future years in Rands; hence no exchange rates were required for forecasting of costs. The forecasted optimistic, average and pessimistic installation costs in Rands per Watt for each sector is also represented in Table 2. The installation costs can range from R10,50 to R37,30 per Watt in 2018 and is decreased to R5,50 to R19,54 per Watt in 2022. The major decrease (41,5% on average) arises from the utility scale PV plants in costs in four years. Installed costs in the residential sector can experience a 30% decrease in four years and 9,5% decrease is expected for commercial PV system costs.

Installation costs in R/W	2018	2019	2020	2021	2022
1 – 10 kW optimistic	R 13,50	R 12,66	R 11,81	R 10,13	R 9,28
1 – 10 kW average	R 25,40	R 23,20	R 21,89	R 17,50	R 14,41
1 – 10 kW pessimistic	R 37,30	R 33,75	R 31,97	R 24,87	R 19,54
10 kW – 2MW optimistic	R 10,50	R 9,69	R 8,88	R 7,27	R 6,46
10 kW – 2MW average	R 18,98	R 16,43	R 15,59	R 13,93	R 12,67
10 kW – 2MW pessimistic	R 27,45	R 23,16	R 22,30	R 20,59	R 18,87
2MW – 100 MW optimistic	R 11,01	R 9,63	R 8,25	R 6,88	R 5,50
2MW – 100 MW average	R 16,07	R 14,43	R 12,33	R 9,54	R 8,02
2MW – 100 MW pessimistic	R 21,14	R 19,24	R 16,41	R 12,21	R 10,53

Table 2: Forecasted optimistic, average and pessimistic installation costs in R/W for PV systems for 2018-2022 based on Rands

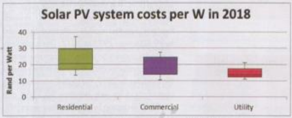

Fig. 5: Summary of average system costs per Watt in 2018 for each system in South Africa extracted from various literatures [16, 12, 17, 13, 6, 18].

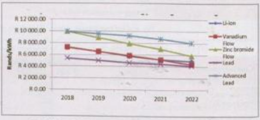

Fig. 7: Capital cost reduction in R/kWh for energy storage technologies 2018-2022 [25, 24].

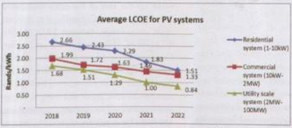

Fig. 6: Average LCOE (R/kWh) of PV systems from 2018 – 2022.

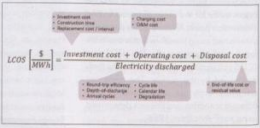

Fig. 8: Levelised cost of storage formula [20].

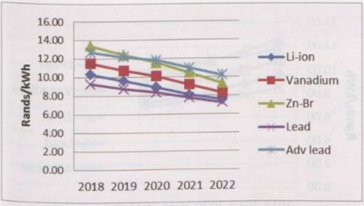

Fig. 9: Average LCOE reduction for residential PV systems with different storage technologies for years 2018 – 2022.

Parameter	Assumption
Life span of plant	25 years
Installation costs	Average value for each year
Nominal discount rate excl. tax	15,3%
Inverter replacement year	10
Inverter replacement as % of capital	3%
Energy yield	PVSyst (average 1770 kWh/kWp/year)
Degradation factor for PV modules per year	0,5%
Operations and Maintenance (O&M) cost	1,5% of capital cost per year
Inflation rate per year	5%

Table 3: Assumptions used for LCOE calculation for PV.

LCOE of PV

LCOE is a calculation that is used to compare various power plants with cost structures that differ from each other. The calculation entails summing all costs that are incurred during the lifecycle of the power plant and comparing it to the energy generated during that period of time. The LCOE for PV for each type of system was calculated using a tool that was developed by the author for years 2018 – 2022. The following formula is used to calculate the LCOE [18]:

$$LCOE = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{M_{t,el}}{(1+i)^t}} \quad (1)$$

where:

$LCOE$ = Levelised cost of electricity in R/kWh

I_0 = Investment expenditure in R

A_t = Annual cost per year (fixed and variable operating costs)

$M_{(t,el)}$ = Amount of electricity produced per year in kWh

i = Real interest rate in %

n = Lifetime of the plant

t = Year number (1, 2....n)

The assumptions tabulated in Table 3 were used during the analysis of LCOE for PV systems in South Africa.

Three scenarios of forecasted LCOE's for different sized PV systems in the years 2018 to 2022 were computed using the assumptions above and the final results for the average LCOE is illustrated in Fig. 6.

The optimistic, average and pessimistic LCOE ranges are tabulated in Table 4.

Battery storage

Battery storage technology has been utilised for many purposes for many decades. Lead acid batteries are known to be the oldest secondary battery technology and have been in operation for the past 150 years [19]. In 2017, there was a global installed capacity of 3.8 GW of battery storage of which, 67.7% is considered to be Lithium ion (Li-ion) technology [20]. As the demand for renewable technologies increase so will the demand for more efficient and durable battery storage technologies. This is due to the intermittent nature of renewables and grid impediments such as unavailability of renewable generation at peak experienced by utilities due to increased penetration of renewable technologies. Energy/battery storage is considered to become one of the key facilitating technologies of the energy transition [19]. Energy storage can provide a number of services to the grid and to the end-user. The main primary and applications that storage can provide are energy management, bridging power, power quality, renewable integration, transmission and distribution deferral, ancillary services, system capacity, renewable smoothing and reliability [21]. Apart from energy storage technologies being segmented into stationary and non-stationary [22], they are also classified into five different technology categories. These are electrical, mechanical, electrochemical, chemical and thermal [23]. There are various applications that different energy storage systems can be applied to due to their designs, attributes and make-up. The focus of this paper is on renewable integration consisting of behind-the-meter applications used mainly to reduce electricity consumption from the grid and these are considered to be the following (from most relevant to least) [19]: Li-ion (Nickel Manganese Cobalt), Li-ion (Nickel Cobalt Aluminium), Li-ion (Iron Phosphate), Li-ion (Titatnite), Vanadium redox flow, Zinc bromine flow, Flooded lead acid, Valve-regulated lead acid, Sodium sulphur and Sodium nickel chloride.

Battery storage installed costs include the following [24]: i) Capital costs which consist off – The storage system or otherwise referred to as the fuel costs, Power Conversion System (PCS), power control and management systems and balance of plant costs and ii) Additional costs consisting off – the structural cost, permits and engineering/design costs (engineering, procurement and construction (EPC) included), land acquisition costs, metering and network extension costs, if required. Operational and maintenance costs include component replacement costs (could include entire cell replacement, electrolyte top-up or mechanical system refurbishment), inverter replacement (generally ten years as with PV), control system upgrades or entire replacement and general operating costs for labour, etc.

From the analysis previously on application based technologies, it was concluded that the technology types that are being commercially applied to PV systems for back-up purposes are generally Lithium Ion, Lead acid, advanced lead acid and Redox flow batteries. Therefore, the future predictions will incorporate these costs only. According to IRENA, installation cost estimates for Li-ion Titanate are currently between $473 and $1260/kWh and between $200 and $840/kWh for other Li-ion batteries. Their installed costs declined by 60% from Q4 2014 and Q2 2017 in Germany [19]. These costs will further reduce by 54 to 61% ($80 to $480/kWh dependant on chemistry type) by 2030 due to the expected demand for transport applications. Installation costs for redox flow batteries ranged between $315 and $1680/kWh in 2016 [19]. These costs are expected to further decline by −66% to between $108 and $576/kWh in 2030.

The average projected capital cost reduction to 2022 for all relevant technologies for small scale use is depicted in Fig. 7 [25, 24]. This cost was calculated using the average cost reduction extracted from research for the years 2019 to 2022 for each technology and extrapolated in Rands/kWh for each technology.

LCOS with PV

LCOS is defined as the discounted cost per unit of discharged electrical energy [26]. This definition reduces to the calculation expanded in Fig. 8 and is in line with recent publications [22, 26,27].

The LCOS for five different technologies were computed using the above calculation. The assumptions used to compute LCOS were obtained from research on the respective topics and are as follows [3, 19, 22, 24, 25, 27 – 32]:

- The combination of energy storage with PV systems creates value through shared infrastructure such as of having only one Power conversion system (PCS), interconnection and balance of system in the combined plant. The assumption that was made as a result is that the cost of the PCS will be deducted from the installation cost of the battery system. This cost was equated to 30% of the total installation cost per kWh for each technology.
- The initial average BESS capital costs for each technology will be as per Fig. 7,
- Loss of efficiency costs as a result of charging from PV was not considered.

The LCOE of PV with different storage technologies were computed and these are illustrated for residential and commercial and industrial systems in Fig. 9 and Fig. 10, respectively.

Price parity point

The average LCOE of PV systems with different battery storage technologies were projected to identify a possible intersection point with 3 scenarios of Eskom average tariffs for residential and commercial customers (6%p.a., average year on year and 15% p.a.).

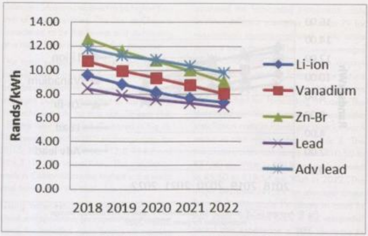

Fig. 10: Average LCOE reduction for commercial and industrial PV systems with – different storage technologies for years 2018 – 2022.

LCOE in R/kWh	2018	2019	2020	2021	2022
1-10 kW Optimistic	R 0,91	R 0,86	R 0,81	R 0,69	R 0,63
1-10 kW Median	R 2,66	R2,43	R 2,29	R 1,83	R 1,51
1-10 kW Pessimistic	R 2,52	R 2,29	R 2,16	R 1,68	R 1,33
10 kW-2 MW Optimistic	R 0,71	R 0,66	R 0,60	R 0,50	R 0,44
10 kW-2 MW Median	R 1,99	R 1,72	R 1,63	R 1,46	R 1,33
10 kW-2 MW Pessimistic	R 1,86	R 1,57	R 1,51	R 1,39	R 1,28
2 MW-100 MW Optimistic	R 0,75	R 0,66	R 0,56	R 0,47	R 0,38
2 MW-100 MW Median	R 1,68	R 1,51	R 1,29	R 1,00	R0,84
2 MW-100 MW Pessimistic	R 1,43	R 1,31	R 1,11	R 0,83	R0,72

Table 4: Optimistic, average and pessimistic lcoe in r/kwh for different sized pv systems for 2018 – 2022.

This "intersection" point is illustrated in Fig. 11. It is evident that there is no intersection of the average LCOE of PV with storage and forecasted Eskom tariffs before the year 2022, further analysis was completed to determine when this intersection could occur post 2022. This analysis included a very high level projection of the average LCOE of PV with storage using exponential trend extrapolation. The results show that a potential intersection can occur in 2028 for residential users and Lead acid systems if an increase of 15% p.a. for tariffs is implemented from 2018 to 2028 (which is highly unlikely). For commercial and industrial users in the same scenario, the intersection occurs in 2029. A more realistic view is that intersection occurs post 2030 for average tariff increases of 9 to 10% for customers with lead acid systems. However, this is still quite high for an average tariff increase in those years.

An analysis from a paper presented at the energy storage conference in 2018 indicated that by 2023 grid parity for mining applications would be possible [33]. This could be possible, only if, the customer falls into a municipal jurisdiction and is paying a tariff much higher than the average tariff being paid by Eskom customers. However, for an Eskom customer this cannot be concluded from the analysis provided in this report.

Conclusion

This paper details the projected installation costs for solar PV without storage, projected LCOE for solar PV with and without battery storage and a projection of LCOE of PV with storage plotted against three tariff increase scenarios for Eskom customers. The results provide insight into technology trends and costs for PV and storage technologies. Projection of sales can be further understood by taking these results into account. The possibility of customers installing PV systems to supplement energy needs is a reality already and as costs decrease this effect is to worsen the current state of the business

Parameter	Li-ion	Vanadium flow	Zn-Br flow	Lead acid	Advanced lead acid
Project life cycle	25 years				
Real Discount rate	8.4% p.a.				
O&M cost	2% of capital cost (PCS cost not included)				
Average battery system lifespan years	12	18	18	5.5	10
Degradation of battery systems per year	1,84%	1,23%	1,23%	3,98%	2.21%
Disposal cost of capital cost	11,50%	11,50%	11,50%	11,50%	11,50%
Number of cycles per year	365 (1 cycle per day)				
Nominal installed capacity each sector	1 MWh for commercial and industrial and 0,06 MWh for residential				
Electricity cost of charging the batteries	R0 as PV system will be used to charge				
Depth of discharge (DoD)	100%	100%	100%	50%	100%
Roundtrip efficiency	85%	85%	85%	74%	82,50%

Table 5: Assumptions used to calculate LCOS for different battery technologies.

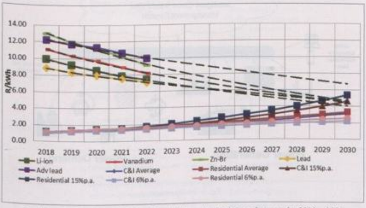

Fig. 11: Average forecasted LCOE of PV with different technologies of storage for 2018 – 2030 plotted with Eskom electricity tariffs in three scenarios.

in Eskom. The effect of battery storage on customer deflection is still very adolescent as the installed cost of storage for any technology is quite expensive as seen internationally. This could change in the next few years as a result of performance enhancements and demand increases causing installed costs to decrease and in turn appear as a more attractive solution to supplement energy needs and as a secure supply.

It is envisaged that post 2030, PV with storage may appear as a more attractive solution to migrate off-grid and not rely on Eskom supply. However, this may be true only for Eskom supplied customers. Even though this may be the case from the study completed in this report, factors such as loss of supply resulting in loss of revenue (load shedding) for a commercial and industrial customer may result in an off-grid solution being more feasible than having to pay for diesel during load shedding, for example.

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The utility of the future: Distributed power generation enabled by the Internet of Things

by Dr Cathy Pickering, FuseForward South Africa

Until now, Africa has chosen to meet its growing electrical grid requirements by focusing on large plant investments built and operated over long time-horizons. Consequently, about 91,2% of South Africa's power is currently generated by thermal power stations and only 8,8% is generated from renewable energy sources.

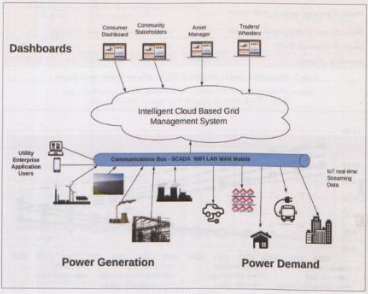

Fig. 1: Intelligent utility.

The intelligent utility of the future will make power generation, distribution, and management more responsive to the needs of the communities it serves. The intelligent utility will be composed of a combination of intelligent, dynamic power generation and distribution systems enabled by Internet of Things (IoT) devices. The utility will be managed by a distributed cloud-based grid management system, with an increasing percentage of its power being generated from smaller, more agile renewable energy sources.

The utility of the future, the intelligent utility, will be made up of centralised, regional, community and home power plants. It is comprised of interconnected systems (the power generation and distribution systems enabled by IoT) and managed by a distributed cloud-based grid management system. FuseForward sees municipalities playing an important role by helping their communities become energy self-sufficient with smaller, but modular and scalable, systems that can be deployed rapidly using pre-manufactured components. The major advantage of distributed plants is that it is easier to "ring fence" the data from the plant. Therefore, one important consideration for the intelligent utility is how to secure generation system and IoT information to protect this information from cyber-crime.

Research project

Working with academic institutions in Canada, FuseForward has set up and is part of the Intelligent Systems Research Network, a team of professionals with an interest in the application of big data in various areas. Led by FuseForward, the network is working to develop intelligent IoT and big data solutions that bridge the gap between academia, industry and technology. Our goal is to create new tools that enable operational managers to harness the power of big data and smart devices in a way that is innovative and practical.

The research covers all aspects of analytics for industrial campuses and building portfolios, including streaming data management, real-time facility analytics, and automated control. The smart campus research is looking at the requirements for sustainable buildings which are cooled and heated naturally and are energy efficient. Central to this research is the use of IoT devices.

A current research project focuses on applying artificial intelligence (AI) and machine learning (ML) to energy management on a university campus in Canada, as well as the development of algorithms and AI integration for deep learning and integrating user behaviour. The research and predictive models developed so far have resulted in the decrease in the use of HVAC (heating, ventilation and air conditioning) systems and 30% power savings on the university campus. The research involves calculating dynamic set points and providing dynamic control of the HVAC systems using machine learning methods.

The smart campus research and the conceptual model being developed informs the Intelligent utility research and the development of the Intelligent utility. The outcome of the smart campus research will facilitate power utilities to get started with the intelligent utility.

The intelligent utility model requires that a distribution management system is overlaid on the power distribution grid. Further research is underway regarding methods to deal with the dynamic power supply, how to govern the distribution of power and optimize its usage.

What is the intelligent utility?

To understand the intelligent utility, it is important to understand that the Intelligent utility is built on the smart grid. In 2014 the national Institute of standards and technology (NIST) in the US defined a framework and vision for the smart grid. NIST acknowledged that there are various definitions of smart grid but stated that "*...all notions of an advanced power grid for the 21st century include the addition and integration of many varieties of digital computing and communication technologies and services with the power-delivery infrastructure*". Bidirectional flows of energy and two-way communication and control capabilities will enable an array of new functionalities and applications that go well beyond "smart" meters for homes and businesses.

NIST gives nine priority areas for the

Attack type	Sub type	Part of intelligent utility to be secured against attack
Nefarious activity/abuse	DOS Malware manipulation of hardware and software of a device Targeted attacks Abuse of personal data Brute force	Control systems e.g. SCADA Software in cloud management system IoT devices Mobile devices Personal data within systems Communication networks People
Eavesdropping, interception, hijacking	Man in the middle/session hijacking Communication protocol hijacking Network reconnaissance	Communications network IoT devices Information
Physical attack	Vandalism/theft Sabotage	Power plants Data centers IoT devices Mobile devices Control systems e.g. SCADA People
Accidental damage	Misconfiguration Erroneous use or admin of devices Third-party damage	Power plants IoT devices Control systems Communications networks Information cloud computing services Data analytics Software and licenses Servers and systems People
Failures/malfunctions	Failure or malfunction of a sensor / actuator Failure or malfunction of a control system Exploitation of a software vulnerability Failure or disruption of service providers	Power plants IoT devices Control systems Software Cloud service providers Information
Outages	Communications network Power supply Support services	IoT devices Servers and systems Control systems Communications network
Legal	Violation of rules and regulations / breach of legislation / abuse of personal data POPI (GDPR in Europe) Failure to meet contractual requirements	IoT devices Cloud computing services Information Control systems Software and licenses
Disasters	Natural Environmental	Power plants IoT end devices People Control system Communications network Data centres

Table 1: Potential threats that can affect IoT devices.

application and requirements of the smart grid. These key areas are:

- Demand response and consumer energy efficiency.
- Wide-area situational awareness.
- Distributed energy resources.
- Energy storage.
- Electric transportation.
- Network communications.
- Advanced metering infrastructure.
- Distribution grid management.
- Cybersecurity.

Our vision of the intelligent utility encompasses these key areas and can be thought of as two interconnected systems; intelligent dynamic power generation and distribution systems, and a distributed cloud-based grid management system – both enabled by IoT.

The IoT devices continually feed data into the cloud-based grid management system. This information can be analyzed in real-time to provide automated control of the system, for example predictive algorithms could be used to increase or decrease the power generated based on predicted demand. The power is generated with centralised power plants, supported be regional power plants and home power plants. Both the electricity generation infrastructure and the cloud infrastructure will contain IoT devices and will be enabled by the IoT.

Current power generation is focused on large plant investments with long time-horizons, as mentioned previously. In South Africa, the current centralised power distribution by Eskom will provide the core of the system, the intelligent utility will augment this with smaller, modular systems that can be deployed rapidly with pre-manufactured components. The energy generation will be distributed between regional, community and house/building systems with differing power generation rates, such as 500 kW to 10 MW for regional generation, 50 – 300 kW for community generation and 5 – 30 kW for home generation. This distributed model will do away with the current need to "step down" the power for communities and home requirements, the distributed model will provide the correct power rating where it is required. The intelligent utility will provide dynamic load balancing across these generating facilities and enable full network optimisation encompassing the distribution grid and consumption management.

The intelligent utility is enabled by IoT, fibre connectivity and cloud-based digital control services that control, manage and analyse the information coming from the entire system. The system is also able to provide internet and application services to consumers, businesses and industry.

Smart meters are not the only IoT devices that are utilised in the intelligent utility. Devices such as surveillance cameras, remotely monitored real-time sensors, supervisory control centres and smart devices are also utilised. These devices are strategically placed in the power generation and distribution systems, the communications network, and at the point of consumption. These devices feed data into the cloud-based digital control system, which also has IoT devices for monitoring and securing the state of the cloud infrastructure.

Electric vehicles

A market intelligence report written earlier this year by GreenCape says that public transport in South Africa gives the best business case for electrification, more so than private transport. The South African bus market makes buses that are designed in South Africa for the local market. However, the local bus market is currently flat, the report cites that manufacturing intelligent, electric buses to provide additional services would be a way of achieving a refresh of the industry.

With the current centralised grid system, a municipality with a large electric bus fleet would have the problem of loading the grid when trying to ensure all the buses were fully charged at the start of the day shift. The intelligent utility and decentralised power generation provides the solution to this problem. The revitalisation of the local bus market is just one example of the types of innovation and business opportunities that can be created by the intelligent utility.

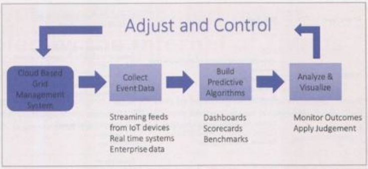

Fig. 2: Cloud-based grid management system.

Key considerations for implementation

Security

One of the key areas in the NIST framework is cybersecurity. Securing the information and the information systems of IoT devices connecting to the grid is a major challenge.

Globally, the power sector is the most frequently targeted sector by cyber criminals. Cybersecurity attacks threaten the power grid, enterprises, and consumer devices on a nearly constant basis, putting valuable digital assets, private information, and corporate secrets at risk, while also carrying the potential for physical harm. As IoT technologies become more popular, new threats are appearing and the need for stronger IoT security increases. Growing adoption of IoT devices and the systems that support them is increasing the number of vectors and surfaces for cybersecurity attacks against utilities and other enterprises.

In South Africa, a case in point is the recent (July 2019) Johannesburg City Power ransomware attack which took down most of their applications and network, affecting customers' ability to buy prepaid electricity. These attacks are prevalent worldwide – in March a major US utility experienced a serious "denial-of-service condition", and in 2015 an attack in Ukraine left a quarter-of-a-million residents without power for two days.

Although these attacks are not necessarily via IoT devices, research shows an increase in the amount of cyber-attacks targeting IoT devices as the number of IoT devices grows. In 2016, in what is known as the biggest distributed denial of service attack to date, hackers took control of thousands of IoT devices and brought down a European web host. Since then (2018) a global IT security firm reports that the number of IoT threats have doubled. Thankfully, many of these threats use predictable, known techniques to compromise devices, either targeting weak credentials, unpatched vulnerabilities or both. As a result, many threats are preventable by applying good cyber security practices.

The intelligent utility needs to have the relevant security systems in place, both for physical and IT/information related security. This security should not only deal with known security threats and vulnerabilities, but also to be able to deal with new threats as the cyber criminals develop them. As can be seen from Table 1, the security systems required to protect the intelligent utility from cyberattacks need to be multi-layered and protect all parts of the intelligent utility, not just the IoT devices.

Reliability

From the reliability point of view, failures in a centralised distribution model can lead to blackouts affecting areas as large as a country. The recent blackout in Argentina in June 2019 left the whole of mainland Argentina and parts of Uruguay and Paraguay without power, an estimated 48 million people were affected. In August 2019 a large blackout affected parts of England and Wales, affecting nearly a million people, causing travel disruptions and trapping people in trains for several hours. A distributed generation model, with its built-in redundancy, is inherently more reliable as the total failure of one power plant can be compensated by other plants in the network.

Large power plants require large distribution lines and power step-downs so that the correct power is distributed to the relevant electricity users. As a result, the power is not necessarily generated where it is needed, which means a failure in one part of the distribution network can potentially affect a widespread area, as in the examples above.

Reliability in the intelligent utility is provided both by the dynamic power generating systems and the cloud-based grid management system. With the intelligent utility model, smaller, independent systems at regional, community and house or building level can continue to operate when there is a power failure elsewhere on the network, providing the required reliability.

IoT devices continually feed data into the cloud-based grid management system. This information is fed into data stores for analysis and can also be put into a machine learning platform. These systems can identify problems before they happen by recognising failure patterns. This data can increase awareness of grid performance and can also be used for predictive analytics, further increasing system reliability and reducing expenses related to maintenance and outage hours.

Scalability

As identified in the NIST framework, demand response and consumer energy efficiency are key requirements for the intelligent grid. The intelligent grid must be able to scale to meet consumer requirements, deal with burst load requirements, balance domestic and industrial peak requirements. As before, artificial intelligence and advanced analytics in the cloud-based grid-management system can be used to predict expected demands and scale the provision of electricity accordingly. The information from this analysis also assists decisions regarding cost-savings and increased productivity. In competitive markets, optimising the purchase and sale of power based on instantaneous pricing information offers both tangible and commercial benefits.

As an example, smart meter data can be used for locational load forecasting. As a result, smart meter data becomes the "enabler" of the automated distribution grid. This data can be used to reconcile the activity of controllable devices against the utility's ability to provide the required capacity and adjust the capacity being supplied automatically.

The intelligent utility model encompasses smaller, modular systems serving regional, community and residential or building requirements. This model leads to the physical scalability of the intelligent utility. Small home or community systems can quickly be installed as demand increases.

The ability of the distribution grids in the intelligent utility to allow two-way distribution of power means that a small home solar system can provide power back to the grid if excess is generated. This leads to further scalability and provides an incentive for homeowners to invest in power-generation assets.

The cloud-based grid management system is also scalable, as it runs on cloud technology which enables IT infrastructure to scale to meet demands. For example, additional IT infrastructure can be provisioned to perform monthly billing runs and then de-provisioned after the billing cycle is complete, thus optimizing the cost of the IT infrastructure.

Role of the municipalities

The local municipality has a very important role to play in the intelligent utility. They can assist their communities to become self-sufficient with the power generated by the regional, community and home-based systems. They will have the role of managing the power generation and distribution systems enabled by IoT and the distributed cloud-based grid management system. They will be in charge of ensuring that the correct levels of security are in place, both physical and cyber, and of ensuring applicable regulations are adhered to.

A discussion paper commissioned by the South African-German Energy Partnership in 2017 reviewed the various business models that municipalities can adopt to benefit from the opportunities provided by domestic renewable energy, while also minimising the associated risks. These business models can be applied to the role of the municipality in the intelligent utility. The roles played by municipalities can be broken down into three classifications; building generation capacity, procuring energy and facilitation.

If the municipality has the role of building generation capacity, they will build and own the regional and community generation systems. By building them on municipal land and municipal buildings, they can make revenue from selling the power generated. If they have the role of procuring energy, then third parties (including IPPs and community groups) will build and own the generation systems.

In the third role, as facilitator, the municipality will procure electricity from the owners of the regional, community and home systems and on-sell to customers. Municipalities will also operate an electricity storage facility on municipal land to store power when there is excess supply and sell it when there is a shortage of power or a time of high demand.

Additionally, they may provide services such as installing the community and home systems, providing maintenance services and so on.

A business model that is appropriate for a large municipality will not necessarily suit a small one. The various municipal business models provided by the intelligent utility give scope for each municipality to decide which role best suits them. The municipality could choose to implement a combination of the roles, building generation capacity in some areas and playing a facilitation role in other areas. The South African-German Energy Partnership discussion paper outlines concepts that municipalities should consider when deciding what role to take on. The intelligence provided by the system will be an enabler to the municipalities for whichever role they choose.

Challenges

Worldwide the utility/energy sector is risk adverse. New technologies and systems need to be proven before utilities will adopt them. The intelligent utility comprises innovative technology which is enabled by IoT. These new and innovative technologies are present in both parts of the system, the intelligent dynamic power generation and distribution systems and the distributed cloud-based grid management system. Integration with legacy systems is another challenge.

Some of the challenges are technical, such as validating and testing the new technology. Some of the challenges are related to people, and whether they are willing and able to use the new systems and accept the changes. Currently many South Africans have smart meters, but in most cases the data that these smart meters provides is not being utilised to its fullest. Typically, the data is only being used for billing purposes and much of the data provided by these devices is simply being discarded. It involves a mindset change to take the available data and use it for predictive analytics and AI purposes. There are also regulatory and financial issues to be taken into consideration.

How to get started and next steps

FuseForward understands these very really challenges and follows a proven implementation methodology for its solutions and demonstration projects. Our methodology takes into consideration the ability of people and organisations to adopt and effectively use new technology and incorporates an agile incremental release cycle with validation and refactoring of solutions as required. Therefore, our intelligent utility implementation follows a phased, a four-step model.

Step 1: Pilot demonstration deployment

The initial phase of implementation of an Intelligent utility is the deployment of a pilot demonstration system. The pilot system focuses on the deployment, configuration and initial "template" implementation of the Intelligent utility for a small community with a small number of IoT devices. In the African context this "small community" could be a collection of homes within a municipality, a university campus, a small neighbourhood or a gated community.

A key part of the pilot deployment is the development of an operational business plan. This plan includes a revenue-based funding model to ensure that the solution does not become a cost-burden to the municipality or other involved players.

Step 2: Micro grid deployment

Step two expands the deployment of the pilot, using the lessons learned from the pilot phase. This phase focuses on expanding the use of the solution to all areas of a small town/rural area with a larger number of IoT devices. This phase also further develops the operational business plan to ensure that the solution generates a return on investment, meets its social objectives and does not become a cost burden to the municipality. Operations are designed to test the ability of the system to scale under operating conditions and tests the assumptions of the business plan.

Step 3: Regional grid deployment

The third step further expands the solution to deployment of the regional grid. This phase focuses on the ongoing operations of the intelligent utility, the continuous improvement and deployment of new innovations and the continued revenue generation of the intelligent utility. By this step the municipality involved will have decided the role it will play in the intelligent utility and will have finalised the business model, including development of key commercial contracts. Also, by this stage there will be enough time and data to prove the stability and reliability of the network.

Step 4: Integration with centralised generation and distribution system

This is the final phase which integrates the distributed power generation system with the centralised power generation and power system, ultimately completing the intelligent utility system. This step builds incorporates experiences from the first three steps, making appropriate changes to complete the Intelligent utility system.

Conclusion

This paper has described the intelligent utility of the future. The intelligent utility is made up of intelligent dynamic power generation and distribution systems, enabled by IoT and managed by a distributed cloud-based grid management system, with an increasing percentage of the power being generated from renewable energy sources.

It has covered three key considerations for implementation security, scalability and availability. Cybersecurity and the risks involving IoT are a key challenge in the intelligent utility. The intelligence in the intelligent utility comes from analysing the data being fed from the IoT devices and performing predictive analytics and artificial Intelligence predictions on that data and using this information to dynamically adjust and control the intelligent utility.

Continued on page 59...

Public lighting: Lighting the way to smart city development

by Bjorn Smidt-Hart, SMEC South Africa

Electric public lighting was introduced into the city landscape as early as 1878, with Yablochkov candles (early arc lamps) illuminating the Avenue de l'Opéra in Paris. Since then public lighting has become an almost unnoticed service which is implemented in most municipal masterplans or town planning development strategies.

So why has this service become so important to the point that it is vital to a city to have it implemented?

Public lighting is one of the services that is most visually seen by the general public within a city (though it almost goes unnoticed). Lighting provides a sense of visual safety and security. This improved sense of safety and security will often lead to an increase and further promotion of community activities, events, sport, trade, industry and commerce to occur beyond normal daylight hours. It is a service that has the power to indirectly promote stimulus into potential economic growth and state of wellbeing within a municipality.

Although public lighting may assist in generating revenue indirectly for a municipality, it does add to the electrical consumption and operational costs of a municipality, for which a budget needs to be reserved. This should include a budget for maintenance and improvements on a city's system which may need to expand as the community's demands grow.

So how can a municipality maintain or improve this service to the general public while reducing overall energy consumption and operational expenditure?

How does public lighting become a source of revenue generation opportunities?

Would securing and improving the public lighting service delivery improve investment opportunities into a municipality?

With all these questions we could agree that public lighting should no longer be considered a singular service, but should rather be viewed as a multi-discipline service; that through small initiatives, the public lighting infrastructure could be used to transform a municipality into a more sustainable and efficient entity that may better serve the general public.

The importance of public lighting

Public lighting is an important service to be implemented and maintained by a municipality. But what is public lighting?

Public lighting is any lighting installation or system that provides illumination at night, or during low light conditions (such as stormy weather), or in poorly lighted spaces (such as tunnels) in public places and places that the general public may have access to. These installations and systems form a connected infrastructure throughout a municipality. Thus, public lighting would comprise:

- The lighting of street and roads.
- Area lighting of developed areas such as residential areas, public transport nodes, trading facilities.
- Lighting of parks, zoos and recreational venues.
- Lighting of amenities such as a municipal stadium.
- Interior lighting of municipal buildings, municipal halls, libraries, clinics or theatre venues.
- Similar lighting installations that are necessary for public places used by the general public.

Public lighting is a service required by the general public and communities within the municipality. Darkness can create a sense of isolation within communities and may result in business areas becoming deserted through the lack of patronage if these businesses are situated in dark unattractive or unsafe environments. The purpose and importance of public lighting is to illuminate public places to allow the general public to carry out tasks safely, observe and react and to create a safer night time environment for the community through visual security while making many public spaces more usable and enjoyable for by the general public. Fig. 2 illustrates this importance in conjunction with the following question: Which alleyway is more inviting to walk down?

Fig. 1: Yablochkov candles illuminating Avenue de l'Opéra in Paris under the Exposition Universelle (1878).

Was the answer based on facts or on emotion? Take note that the only fact provided is that one alleyway is well lighted and the other not. No facts pertaining to the location, crime statistics, governing law nor municipal operations capabilities for maintaining these lighting installations were provided.

Although public lighting aims to provide practical illumination of public spaces, it is important that these spaces are illuminated to illumination levels in compliance with standards such as:

- SANS 10098 *Public Lighting (road and street lighting).*
- SANS 10389 *Exterior Lighting.*
- SANS 10114 *Interior Lighting.*

- Occupational Health and Safety Act, 1993 Environmental Regulations for Workplaces, 1987.

The way in which these public spaces are illuminated by lighting systems and how these systems are managed, operated and maintained may impact the visual perception and emotional wellbeing of the general public, rather than facts.

To reduce the risk of public lighting systems being perceived by the general public as poor indicators of service delivery, sustainable and accountable strategies in management, operational maintenance and installation projects of public lighting systems should be developed. These strategies should be implemented efficiently to provide safe and secure quality (good) lighting, not necessarily more lighting.

Through the responsible control of these public lighting system strategies, a municipality may have the benefit of persuading the emotional wellbeing of a community and possibly improving the status and visual perception of a municipality. This may further result in a municipality being more inviting to those looking to reside or invest within a municipality. Fig. 3 further illustrates this by comparing the night time visual perception of two areas located within Cape Town.

Fig. 2: Which alleyway is more inviting to walk down.

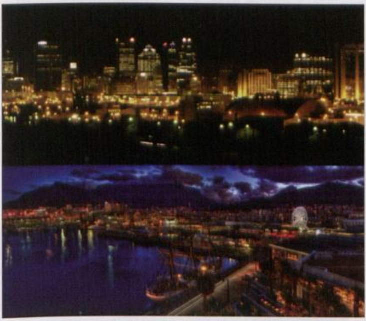

Fig. 3: Night time visual perception of areas within Cape Town, top: Zonnebloem area, bottom: Cape Town Waterfront.

Public lighting trends

As municipalities have developed and expanded, so has the demand for service delivery and the need for the associated infrastructure for these services. With public lighting being a visual service provided by a municipality, as a municipality develops the public lighting infrastructure should expand proportionally with the demands and needs of growing communities.

Two concerns that could be associated with ever-expanding service infrastructure are:

- How can the service infrastructure be sustainably maintained?
- How can the service infrastructure meet the demands and needs of growing communities?

There are two trends developing in public lighting that may attend to these two concerns. These two trends are identified as:

- The implementation of energy efficient LED (light emitting diode) luminaires.
- Improving the quality of lighting installations.

Both these trends promote a favourable service infrastructure and could advance the infrastructure to a status acceptable for IoT (Internet of Things) system implementation and integration. These advancements coupled with IoT systems could be used to further promote revenue generation and may assist in improving the delivery of other services to the general public.

Through the implementation of an energy efficiency initiative, energy efficiency could enhance the competitiveness of economies while helping to alleviate energy poverty as energy becomes more available within a municipality. Energy productivity gains may lower the cost for the economy as a whole, enhance the energy supply security and may reduce the need to develop new sources of energy supply to serve those without access to modern energy services for health and education enhancement. Accelerated energy efficiency could also create attractive green jobs and businesses within a municipality.

By improving the energy efficiency of the public lighting infrastructure, the initiative provides a cost-effective, least-polluting and readily-available energy resource available to a municipality to possibly re-invest into revenue generating opportunities. This initiative also assists in climate change mitigation. The South African Department of Minerals and Energy (DME) promotes energy efficiency initiatives. As an example, the DME requested municipalities to submit proposals for funding consideration for the 2017/18 Energy Efficiency and Demand Side Management (EEDSM) programme, which included the planning and implementation of energy efficient street light luminaires and new LED luminaires on high masts.

The basis of the energy efficiency initiative is to replace existing non-efficient luminaires with modern energy efficient LED luminaires and additionally implement energy efficient luminaires into new public lighting systems.

Quality energy efficient LED luminaires have longer operational life than existing non-efficient luminaires, thus the implementation of these LED luminaires would result in a longer lasting, consistent and affordable public lighting infrastructure with reduced maintenance and operational expenditure (excluding the impact of theft and vandalism to these systems). It is estimated that South African municipalities could save at least 40% of the total expenditure per annum allocated to the existing non-efficient public lighting infrastructure by replacing the existing non-efficient luminaires with energy efficient quality LED luminaires.

However, the concern with the energy efficiency trend is that the focus is on energy saving and not energy saving while maintaining quality and compliance to luminaire and lighting level standards. This may result in poor lighting installations, thus lending itself to the second trend.

The second trend, improving the quality of lighting installations, pertains to the improvement of the quality of illumination, thereby improving the visual ability and perception of the general public. The trend considers the illumination demands and needs on public lighting systems of growing communities and aims at fulfilling these by creating a safer night time environment for the communities and improving the "look and feel" of a city, town and municipality.

Improving the quality of public lighting installations and infrastructure could:

- Promote the better use of open spaces by supporting positive evening use of open spaces.
- Promote walking, cycling, public transport and safer driving through quality lighting providing higher visibility.
- Promote the use of open spaces by partially sighted persons and improve the visual facility to persons with universal access desires.
- Reduce greenhouse emissions through the use of fewer or more energy efficient luminaires.
- Promote urbanisation and aesthetic appeal by showcasing urban features.
- Improve safety and security through quality lighting improving visual ability of surveillance and monitoring systems.
- Promote economically sustainable lighting assets that are easy to install, have low maintenance requirements and are cost effective over the life of the asset.

By adopting and further developing these public lighting trends through the implementation of sustainable initiatives, a municipality should be able to overcome the associated risks and demands of an ever-expanding public lighting service infrastructure.

Should the sustainable initiatives be implemented, IoT systems could be implemented and integrated into the public lighting infrastructure. This integration would further promote the sustainability of the infrastructure while promoting an ability to deliver additional services, other than lighting, to communities within a municipality.

Sustainability of public lighting

Is it possible to maintain the quality of public lighting while reducing energy consumption and overall operational expenditure, while generating possible revenue opportunities? Various methods and strategies could be implemented to obtain this. These range from manual methods of testing to automated systems and control, security of assets, financially feasible and efficient energy and maintenance schedules, community involvement, personnel training and more.

One of the first steps to take when commencing the journey to sustainability is to identify, understand and mitigate the risks that may undermine and challenge the existing and future delivery of the public lighting service. These risks may predispose the public lighting systems and municipalities to reduced or impaired service delivery. More importantly, these risks reduce the safety of the general public in public spaces where these undermined public lighting installations are present.

Without firstly identifying the risks and understanding the causes of the risks impacting public lighting systems, it is not possible to implement effective strategies to mitigate the causes of these risks, to a sustainable level where the risks could be overcome and thereby promote a more secure and sustainable basis from which to improve the quality and efficiency of the public lighting service.

There is possible financial gain if some resources could be utilised to fully understand why the public lighting installations are being affected. Knowing these causes may reduce the costly exercise of continuously repairing and replacing these affected installations, or developing and implementing more resistant and secure lighting installations that may become more difficult and costly to maintain.

Elements of theft and vandalism, behaviour of communities and the ability of municipalities to operate and maintain public lighting infrastructure are some identifiable risks.

It is not possible to eliminate acts of theft and vandalism that may render the state's assets inoperable, but maintainable initiatives could be implemented to reduce the causes of this risk. Acts of theft and vandalism on the infrastructure could be attributes of poverty, criminal activities that require darkness or require the material to operate, community unrest, a game played by children or even an activity undertaken by some adolescents.

Communities are ever evolving as are the service delivery demands of these communities. Various risks influence a community and some of these risks may result in the public lighting service being affected by a community. Unrest within a community, elements of corruption, unemployment, socioeconomic status, education, access to services, crime and sense of being empowered are some factors influencing communities. It may be beneficial to a municipality to install a certain type lighting but it may not be beneficial to the wellbeing of the community in which it is installed.

The public lighting infrastructure is only as good as a municipality's ability to manage, operate and maintain it, thus influencing its service to the public. Some risks that may affect a municipality may include limited financial budget allocation; inability to pay for energy, material purchases and other expenditure; having limited or inoperable tools, equipment and plant to carry out the works; not having adequately trained and skilled personnel; shuffling of management due to the changeover of leadership which may result in the changing of directives; accuracy of inventory of the assets installed; various types of material stocked for maintenance and repair purposes; poor quality assets installed and possibly including the way in which the management, implementation and operational processes are carried out on a day to day basis.

Some may think why would it be necessary to change when a specific task has been done this way for years? Yes, this way of thinking may work for some tasks. However, if the public lighting infrastructure is to evolve with changing technology and changing community demands the same method cannot be used and there is no one-size-fits all solution. Furthermore, if the public lighting infrastructure is to merge with IoT systems and be used to assist in growing and advancing a municipality, new strategies and plans should be developed and implemented.

Continuing the journey to the sustainability of the public lighting infrastructure, a municipality may consider developing a set of sustainable public lighting guidelines. Although similar guidelines may exist within some municipalities, where some municipalities have adopted the recommended practice guidelines of ARP 035, it remains crucial that these guidelines should evolve and support a sustainable, intensifying and progressing public lighting infrastructure.

These guidelines should also consider the various demands of communities, which vary from municipality to municipality.

When developing or revising a set of sustainable public lighting guidelines, these guidelines should consider including the following significant measures:

- The overall aim of the guidelines should be to ensure that new and existing lighting is energy efficient, well designed, well located and that it complies with the South African standards applicable to lighting.
- Identify, understand and mitigate the risks affecting public lighting infrastructure. It is important that these strategies include constant revision and review so as to keep abreast of the changing risks.
- Know who the lighting is for. Communication is a vital tool to maintain, particularly with communities. Build and maintain community relationships. Informing, involving and educating a community may assist in improving the security of a lighting system, as will implementing efficient, reliable and responsive call centres.
- A municipality should maintain its commitment to sustainability. Ensuring commitment would promote service delivery, security of the service and maximise potential financial savings. Commitment may also assist in promoting community wellbeing.
- Develop or revise auditable management, implementation and operational processes. The aim is to ensure the efficiency and quality of these processes are upheld and prevent a backlog in service delivery that may impact on a municipality's commitment to sustainability.
- Ensure that the people appointed for the task are properly qualified and develop continual upliftment programmes to improve the knowledge and skills of personnel through higher education and training. Coupling upliftment programmes with resource planning and allocation would assist in providing a sustainable workforce for a sustainable infrastructure.
- Develop and define public lighting minimum efficiency and quality performance standards and standard design requirements. It is important that luminaires and other assets are tested by a municipality to verify compliance to these standards.
- Define the recommended lighting categories for open space lighting, referencing the applicable South African lighting standards. No one municipality is the same, thus identify the categories for open space lighting applicable to a municipality.
- The guidelines should assist in informing and guiding and municipality's decision making for public lighting installations. This may involve decisions of where and when public lighting is required, and if so, what sort of lighting should be installed to best serve the public space.
- The guidelines should assist municipal staff, lighting design consultants and others to consistently apply sustainable lighting principles to new public lighting installation implementation, replacement, maintenance and repair initiatives to existing lighting installations.
- Develop a design process for the lighting of public spaces. This guideline should assist municipal staff to develop bids and to easily evaluate designs and installations for compliance.
- Investigate the open spaces within a municipality that are accessible to the general public during the day. Consider promoting the use of spaces in the evening if beneficial to the community and economy.
- Assist in improving safety through illumination and proactive surveillance and monitoring to create a safer night time environment for the community.
- Use public lighting to promote walking, cycling, and public transport facilities. The quality of public lighting may promote the use of these facilities by partially sighted persons and persons with universal access desires. It may improve the visibility and safety of pedestrians and safer driving for motorists.
- Select assets and implement lighting installations that consider reducing greenhouse emissions and promote the environmental consciousness of recyclable waste, light pollution and sensitivity to biodiversity.
- Promote the acquisition and installation of economically sustainable quality assets, ensuring that the assets can be managed sustainably over their lifetime. These assets should promote an efficient circular economy.
- Identify, investigate and select urban features for aesthetic beautification or show casing in an efficient and sustainable way. This form of public lighting aims at improving the look and feel of a city or municipality with the potential of improving community wellbeing and promoting investors, tourists and new inhabitants.
- Identify the methods or systems by which the public lighting infrastructure is to be controlled and monitored through manual and autonomous telemanagement systems. These methods and systems should assist in risk mitigation, efficient maintenance scheduling and in tracking and auditing the efficiency of assets and operations.

- Undertake testing of lighting installations and the measurement of illumination levels to ensure that these installations continue to fulfil a municipality's commitment to sustainability, efficiency and compliance to lighting standards. It is important to verify that the public lighting installations continue to promote the use of a public space.
- Develop efficient cleaning, maintenance, repair and replacement operation schedules that evolve with the ageing and operational conditions of the assets. These schedules should be developed, managed and fulfilled to promote sustainability and feasible expenditure.

Lastly, the rate at which sustainability of the public lighting infrastructure can be achieved is inversely proportional to predisposing risks while being proportional to the amount of quality resources available. This is similarly applicable to the growth and evolution of the public lighting infrastructure.

Concluding with a look to the future

The efficiency and quality of a municipality's sustainable public lighting service could be seen as the municipality's advancement further into the fourth industrial revolution era.

By implementing even small initiatives, a more sustainable public lighting infrastructure may be obtained. As sections of the public lighting infrastructure become efficiently and reliably sustainable, there exists the potential of merging IoT systems with the infrastructure. The integration of various services into the public lighting service would transform this sustainable singular service into a sustainable and multi-discipline service that may enable a municipality to advance into a more sustainable and efficient entity that may better serve the general public.

By integrating various services into a sustainable and adaptable public lighting infrastructure, public places and road reserves no longer need to become additionally congested with new surface and underground infrastructure. This would avoid additional obstacles that may otherwise reduce public safety and a municipality's ability to efficiently sustain and gain access to other services.

Consider the possibilities that a sustainable and adaptable public lighting infrastructure could provide by supporting services such as:

- Municipality-wide surveillance systems used by local enforcement and emergency services.
- Micro-communication towers that could be leased out by the municipality to communication service providers.
- WiFi hot-spots that may connect communities, businesses and individuals.
- These same WiFi hot-spots could be used to retrieve real-time power and water demand from wireless metering devices or be used to assist in automated monitoring and control of these and other bulk services.
- Intelligent traffic systems that assist in reducing congestion, as well as monitoring pedestrian and motorist behaviour and volumes, which could be used in future town planning and developments.
- Climatology sensing instruments may assist in accurate weather indication.
- Waste sensing instruments which may assist in efficient waste identification and removal.
- Air pollution sensing instruments which may assist in informing individuals or investors which municipality has a higher quality of air. These same sensors could be used to impose greenhouse emission or air pollutant penalties on identifiable industries.
- Electronic advertising and news boards that may improve revenue generation for a municipality, as well as the local economy.
- Electronic vehicle charging stations that promote the use of hybrid and electric vehicles, as well as being a further source of revenue generation for a municipality.
- Available public parking indication could be implemented to assist motorists in safely identifying parking bays.
- Universal access assistance systems that further enable persons to navigate safely to a destination.
- Various other services that are able to be integrated and sustained on the public lighting infrastructure.

The importance and potential of the public lighting infrastructure should not be underestimated. The public lighting infrastructure should be considered a financial investment, the earlier one begins to invest, the greater the return on investment. The return on investment could be secured through the implementation of responsible initiatives and strategies that promote a sustainable and efficient quality public lighting infrastructure. These initiatives and strategies should be developed from a well-structured and evolving set of sustainable public lighting guidelines.

Through responsible sustainability and adherence to these guidelines, an adaptable public lighting infrastructure may evolve to support other services and sources of revenue generation for a municipality.

By bringing sustainable light into darkness, communities may no longer have a sense of isolation. This sustainable light may promote the upliftment of the emotional wellbeing of a community and may improve the status and visual perception of an advancing municipality. Where municipalities can be seen to be developing and advancing, these municipalities are seen to be more inviting to those looking to reside or invest within a municipality.

Thus, sustainable and efficient quality public lighting could ignite the possibilities of developing and advancing municipalities, communities, industry, businesses, families and individuals to an improved state of wellbeing or smart city status worthy of the fourth industrial revolution era.

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Early detection of impending failure in HV cable terminations

by Samantha Chimunda and Cuthbert Nyamupangedengu, University of the Witwatersrand and Patrick O'Halloran, City Power

In a case study municipal substation, there has been prevalent failures of 88 kV cable terminations after 29 years in operation.

All failed terminations were forensically investigated and the failure mechanisms within the cable termination were identified. Furthermore, an online data logging system had been installed in order to record the terminations operating parameters. In the present paper, firstly, the forensically identified degradation mechanisms are presented. A review of the condition monitoring methods in the case study substation is then presented. A possible intelligent solution which allows the identification of impending failure is then discussed.

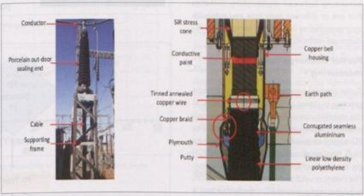

Fig. 1: Cross sectional view of an 88 kV XLPE cable termination [1].

The power cable termination design

The 88 kV XLPE power cable termination material and geometry and other design aspects are shown in Fig. 1. Such high voltage power cable termination design is in common use in most South African metropolitan power utilities. In that regard, it can be widely beneficial if problems encountered and solutions associated with the technology are shared among asset managers in the utilities.

The identified failure mechanisms

Through forensic analyses of the failed terminations, the predominant modes of failure were identified as corrosion, thermomechanical fatigue and electrothermal degradation [1]. Thermomechanic fatigue and galvanic corrosion occurred at the critical metallic interfaces of the cable termination. Fig. 1 and Fig. 2 show metallic interfaces that are subjected to fatigue fracture and corrosion. The cracked metallic interfaces due to the thermomechanic fatigue may cause current path disruptions and/or establishment of undesired electric potentials. Arcing and corona discharges ensue. In the event of a fault surge, current erode and thermally degrade the underlying semi-conductor material. As an example, the fault current path can be diverted towards the stress cone, which exposes it to accelerated electrothermal degradation. Fig. 3 shows examples of failure at the copper braid and aluminium sheath interface.

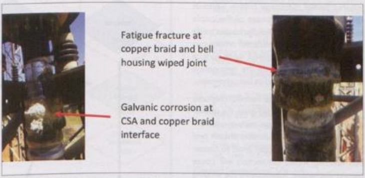

Fig. 2: Metallic interfaces subjected to thermomechanic fatigue and galvanic corrosion.

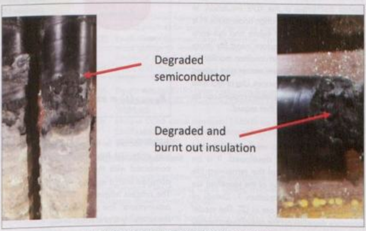

Fig. 3: Semiconductor erosion and thermal degradation.

The cracked metallic interfaces in the termination also allow water and/or moisture ingress into the termination which in turn initiates corrosion process. The aluminium sheath (shield) can get corroded beginning in the termination and extending for meters along the cable length. An example of such degradation is shown in Fig. 4. The degraded ground sheath result in discharges between the CSA and the outer semiconducting layer. Such discharges further erode the semiconducting layer and eventually the XLPE insulation leading to complete failure. The partial discharges occurring between conducting surfaces that are at different potentials can easily be misinterpreted as harmless in conventional PD diagnosis methods.

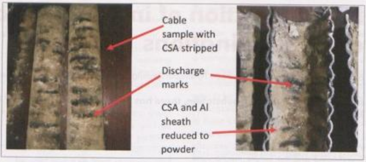

Fig. 4: Completely disintegrated and dissolved aluminium foil sheath.

Partial discharge condition monitoring

Partial discharge measurements are a common practice in power cable systems diagnosis. In the present case study, the PD diagnosis protocol shown in Fig. 5 is employed. The PD signal acquisition is through a hook-on high frequency current transformer (HFCT) on the connection lead of the termination. The criterion used to differentiate terminations requiring replacement from those that are in good condition (Fig. 5) is based on the intensity and location of partial discharge activity. Internal partial discharge activity warrants the immediate replacement of the cable termination. Surface partial discharges inside the termination are considered ambiguous and further testing is required, while surface partial discharges outside the termination and corona are discarded as being harmless.

The primary failure of the metallic interfaces will most likely be discarded given the above-outlined partial discharge testing criterion. Sharp edges on the aluminium sheath and fracture solder at the copper braid to copper bell housing wiped connection will cause corona discharges. Subsequently the eroding semiconductor layer will be subjected to surface partial discharges and then finally leading to partial discharges in the XLPE insulation. In the context of the termination under study, PDs only indicate imminent failure and not early warning. There is therefore need for more comprehensive and smart condition monitoring system for the cable termination and indeed other power cable accessories. Use of real-time continuously updated reliability models can be a promising solution in that regard.

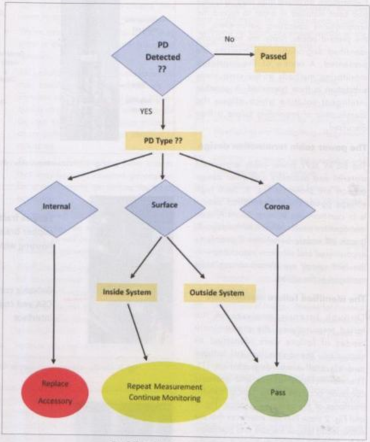

Fig. 5: Partial discharge test decision chart.

Reliability model

In the present work, a weakest link-based reliability model was developed. It is an analytical expression of the remaining life probability as a function of the identified life factors as shown in equation 1. Details of the model formulation are in [2]. The model accuracy depends on the ability to accurately determine the various parameters constituting the life factors. In the present work, the data was obtained from onsite measurements combined with the parameters that were obtained from a wide search in the literature. The process inherently entails making some assumptions. The graphical presentation of the reliability is presented in Fig. 6.

$$R_{E,T,N,C}(t) = exp\left[-\left(\frac{t}{\alpha_0 \cdot \alpha_{E,T}}\right)^{\beta}\right] \cdot exp\left[-\left(\frac{t}{\alpha_0 \cdot \alpha_N}\right)^{\beta}\right] \cdot exp\left[-\left(\frac{t}{\alpha_0 \cdot \alpha_C}\right)^{\beta}\right] \quad (1)$$

where $\alpha_{E,T}$ is the electrothermal life factor, α_N is the thermomechanical life factor and α_C is the corrosion life factor (see Eqn 1).

The concept of intelligent asset management

The instrumentation and online data logging systems can be used to obtain real-time operating parameters which together with

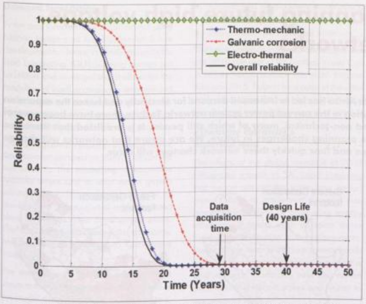

Fig. 6: The graphical representation of the reliability probability of the cable termination under thermomechanic, electrothermal and galvanic corrosion life factors [2].

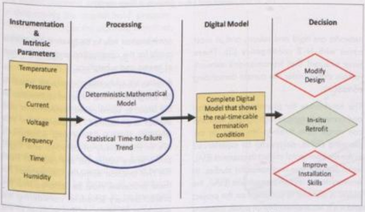

Fig. 7: Intelligent cable termination asset management solution.

material specific parameters, make up the mathematical deterministic models. When the degradation models are combined with statistical time to failure data, an estimate of the remaining life of the cable terminations can be made [3]. Furthermore, an intelligent distributed multiphysics "digital twin" [5] can be developed. This would allow the complex synergistic degradation mechanisms to be observed in real time. The real time operating condition of the cable terminations will assist the maintenance engineer and influence future designs.

Conclusion

The failure modes of a type of 88 kV XLPE power cable termination have been identified through forensic analyses of failed terminations. The forensic investigations show that not all degradation mechanisms can be identified through partial discharge testing. An intelligent digital twin solution has been proposed. The digital twin solution combines the statistical time-to-failure data, measured operating parameters and real time multiphysics simulations to inform maintenance and design decisions.

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...Continued on page 51

The paper discussed the role of the municipality in the intelligent utility. FuseForward believes that the intelligent utility offers many benefits to the municipalities in Africa.

Participate in a pilot

We have opportunities available for an interested municipality or university (or other interested party) to work with us on a pilot demonstration deployment. Not only will this pilot prove the solution, it will demonstrate that the utility of the future is available today in Africa, enabled by IoT and current cloud infrastructure.

If you are interested in helping your organisation be a part of this leading-edge initiative, please connect with us on the provided contact details.

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Challenges of planning future high voltage power system networks

by Vasu Chetty, eThekwini Electricity

Steady growth and development in South Africa has led to increased demand for electricity and hence the expansion of electric power networks and an evolution to the current power system network. To date, there have been several planning challenges, both technical and non-technical, many of which still persist. It is predicted that there is a likelihood of further increased complex planning challenges in future. We are aware that networks will change but the difficult questions are how, when and how quickly these network changes will occur.

This paper focuses on the planning of future high voltage power system networks supplying cities, municipalities and large power users, as well as smaller communities and rural networks. The increase in electricity tariffs, load-shedding, introduction of renewable energy and the drive towards "clean energy" sources are among the key aspects that will impact the energy sector. Policy and regulatory changes will further significantly affect network planning consequently leading to either a positive or negative evolution.

South Africa is largely supplied by power stations that are located in Mpumalanga province. There is a change to the supply of energy from power stations with the introduction of the renewable energy independent power producer (REIPP) programme initiated by the Department of Energy (DoE). This program has procured around 6400 MW of energy from 106 independent power producers (IPPs) [2]. Renewable energy is generated chiefly by wind and solar sources in the Eastern Cape, Western Cape, and the Northern Cape. As part of the integrated resource plan more renewable energy (around 4000 MW) is likely to be introduced in the next ten years. Fig. 1 provides a general overview on the current and future footprint of power generation in South Africa.

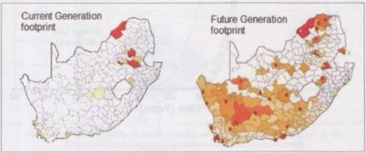

Fig. 1: SA's current and future generation footprints [2].

The South African power system comprises largely of the Eskom owned and operated transmission network with voltage levels ranging from 220 to 765 kV. These networks supply municipalities, cities, towns, mines, industries in South Africa as well as neighbouring countries. Countries such as Namibia, Botswana, Zimbabwe, Mozambique, Swaziland, and Lesotho are currently connected to the South African transmission grid. In an effort to trade more power, more interconnection is planned in the long-term plan between southern Africa and neighbouring countries.

The high voltage planning process

The current high voltage planning philosophies are based on the transmission grid code, together with policies and codes of practice that are specific to utilities. As a transmission networks are rigid and robust, and in most cases with N-2 contingency [3]. These have ensured that transmissions network remain stable under the current demanding conditions.

The timeframes for planning, construction and commissioning of high voltage networks can range from three to ten years. In the planning phase, delays can be experienced in the environmental impact assessment (EIA), water use licences and specialist studies. In environmental impact assessments (EIAs), the public is allowed to comment on the project and it is a requirement that all public concerns are satisfactorily addressed before approvals are granted.

In most cases objections to projects are raised by residents in the vicinity of the project leading to implementation delays. Land acquisition can also be a lengthy process leading to further delays if owners are not willing to sell land or servitudes rights required for projects. When required, the expropriation of land can delay projects if there are lengthy legal battles.

The construction of overhead lines requires 35, 45, 55 m of servitude for 132, 275, 400 kV respectively for the full length of the line. Depending on the utility, a single or double servitude would be required for the new overhead lines. Substations require between 6400 and 60 000 m^2 of land. The cost of land varies depending on the land-use, zoning and terrain. Further careful consideration has to be given to the access roads for the construction and maintenance of towers and substations.

Prior to construction, approvals need to be sought from the affected authorities in the area. In some cases, assessments and studies are required. An example of this situation is where lines and substations are in the vicinity of airports and flight paths where approvals are required from the civil aviation authority. Timeframes for these processes must be factored into the project delivery schedule, considering the possibility of delays on one or more of the items mentioned.

Bulk infrastructure projects require large amount of land that is difficult to acquire in built up environments. Urbanisation requires a secure, reliable and resilient source of power in order to sustain development into the future. The projects are planned with supply developments for a minimum of 40 years. Maintenance and refurbishment of infrastructure would take place as and when required after construction.

In addition components would need to be replaced as they reach their end of life. Current planning looks at life cycle costing when choosing components. Maintenance practices are now moving to a "condition based" maintenance regime rather than "time-based" regimes. Online monitoring equipment are also becoming common for large value assets.

Demand forecasting

In the past forecasting was carried out using historic trends and known/planned future developments. More recently geographic load forecasting (GLF) is being carried out by utilities and municipalities. It allows for the modelling of loads according to daily demand curve. Loads can be classified as industrial, commercial and residential with each justifying a specific demand load for planning purposes.

GLF programs require an economic development perspective study to be carried out prior to the modelling. It identifies spatially where and to what extent growth will take place. The study makes use of all stakeholders' plans, spatial and integrated plans as well as other development plans. The population statistical data, economic and land-use data is used to formulate a model.

The data derived from this model are direct inputs to the GLF program. The output data of the model depends on the input parameters, therefore good quality data is required. The results of the models become the key inputs the master planning process and is crucial in determining the 'capital bold' program. However the longer the planning time-lines, greater is the uncertainty in the forecast data.

Fig. 2 indicates the measure of uncertainty against time. The area within the red ellipse indicates the planning period for the network development plan (NDP), while the blue is for the network masterplan (NMP). Beyond ten years, the uncertainty increases exponentially. In planning high-voltage projects, planning can begin in excess of ten years prior to the project being required. Hence, forecast in general is based on current data and hence there will always be factors of uncertainty in forecasting. Plans have to be reviewed regularly and adjusted if required.

eThekwini Electricity's load forecast

eThekwini Electricity completed its first forecasting exercise in 2011 the results of which are shown in Fig. 3 [4]. The forecasts were seen to be higher than what was being experienced within the network. An update of the economic development study was carried out in 2015 and subsequently the GLF model was updated accordingly. This process was completed in 2017. The results are shown in orange in the results are shown in the graph below.

The results indicate that there is a significant difference in the forecasting between the 2011 and 2016 load modelling. Factors that influence modelling are:

- Load data used.
- Economic development perspective.
- Statistical data (census data).
- Growth and development materialising as planned.
- Government and municipal initiatives.

The larger variance in the results indicates that pre-2010 (the year of the Football World Cup in SA) economic outlook was much brighter than pre-2015. Projects forecasted in the initial study did not take place as planned, but where stretched out over a longer period of time.

eThekwini Electricity's historical load

The effects of the global recession of 2008 influenced growth in SA. Load shedding that began around the same time period drove Eskom to implement demand side management (DSM) by promoting energy efficiency. Projects such as solar water heating, incandescent bulb replacements, geyser timers, energy efficient shower heads and education on saving power reduced the load demands. Customers have also moved away from the electric stoves and heater to gas powered ones.

One of the most significant changes in the power industry is the introduction of renewable energy and the drive to produce clean energy. This has led to commercial, industrial, and residential customers installing generation units within their facilities for the production of power to either use or import into the network. Industrial customers are now able to generate power from existing processes. Even though companies are seeking to become carbon neutral in their production lines there still has to be a business case for this. Small to medium customers have become more energy efficient and are using less power.

The decrease in load demand [3] has been as a result of:

- Increase in tariffs by Eskom.
- Load-shedding.
- Demand side initiatives and customer awareness.

The electricity tariffs have been increasing steadily from 2008 to present. Year-on-year

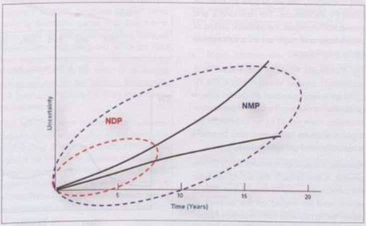

Fig. 2: Forecast uncertainty over time [4].

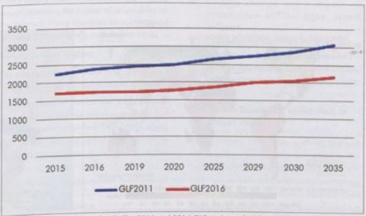

Fig. 3: The 2011 and 2016 GLF study results [4].

increases have varied between 4,95 and 26,2%, the latter being for the 2009/2010 financial year. An overall increase of 59% was levied over the last ten years. Fig. 4 is a plot of historical load data against an S-curve. S-curves are used to trend loads over time, accordingly, a load reaches a point of saturation.

Between the years 1978 and 2008, the load curve closely followed the S-curve. Since 2008/2009, a deviation from the S-curve is seen and there are slight increases and decreases in eThekwini Electricity's peak loads.

Embedded generation

Within the eThekwini Municipality embedded generation has taken the form of photovoltaic (PV) systems. There has been an increase in the number of residential units that have installed solar PV in the last 5 years. Municipalities are still in the process of regulating the installations. A new tariff scheme [5] has been introduced this year. It has introduced a grid connection charge to customers who wish to generate power and still want to be grid connected. This would have an effect on future PV installations. The new tariff's grid connection increases the payback period of installations and might act as a deterrent to future installations.

Fig. 5 indicates the daily usage curve of a residential customer, shown in black. The PV curve is shown in purple and indicates a peak generation at midday. Thus, as PV penetration increases, there would be an increase in the amount of power being generated by small-scale embedded generation (SSEG).

However, if significant amounts of SSEGs are present in the network this would increase the amount of power in those areas. SSEGs would have an impact on the amount of power being required from upstream Eskom supplies to municipalities. The result will be that the transmission grid load would decrease. The solar irradiation map, Fig. 6, indicates that along the east coast of SA, between 1700 and 1900 kW/m² radiation is received. This, when compared to the central and west between 2100 and 2300 kW/m², would be generated and is equivalent to 20% more power. Thus for the similar capital investment large scale solar plant are not likely to be constructed in the KwaZulu-Natal, unless for reasons other than obtaining the maximum return on investment. Thus currently there are such plants that have been in operation in these areas for the last few years a part of Eskom's REIPP program.

The drive towards renewable energy and reducing greenhouse gases is likely to see a change in the current power sources. This would mean that the traditional supply chain of transmission lines and substation would have to be reconfigured. This is shown in Fig. 7 which are Eskom's proposed corridors for transmission lines going into the future.

Municipalities are governed by the Municipalities Act [7], while Nersa regulates

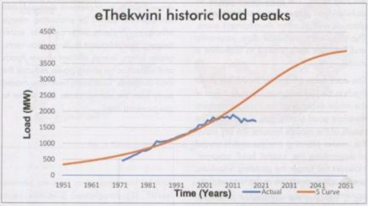

Fig. 4: The Historic demand graph for EThekwini Electricity.

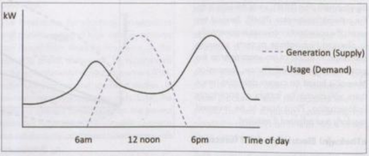

Fig. 5: The daily load curve with PV generation.

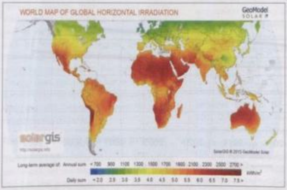

Fig. 6: The Global Solar Horizontal Irradiation Map [6].

Fig. 7: Eskom's future servitudes [2].

power generation in the country and regulates tariffs. Policies and regulations have to be put in place for the purchase of power from SSEGs and other generators. Eskom is committed to purchase power at set rates for the IPPs. The lack of policy gives freedom to participant but the lack of certainty make it hard to find funding.

Challenges

The challenges in SA are both technical and non-technical in nature. However both affect the quality of supply of the customers.

Technical

- Embedded generation: More small scale and large-scale renewable energy generation.
- Power flows that will change.
- Changing power quality due to the increase of renewable energy generation: fault current levels, flicker, harmonics etc.
- Cyber-attacks and cyber security.
- Variable operating conditions and currently only a few small modifications having been carried out to the current network planning and operations.
- In-depth knowledge of the MV network and changes within the medium voltage network.

Non-technical

- Sites and servitudes are becoming harder to acquire, especially in built-up areas.
- Theft of electricity, cables and overhead lines.
- The constant pressure to reduce carbon emissions and produce green energy.
- Long project planning and execution timeframes.
- Variance in the demands of the customers, due changing usage patterns.
- Changing the way in which they use energy, the move to gas and energy efficiency.
- High costs for the transmission projects.
- Effects of climate change on infrastructure.
- Human resources and changing of skill set of employees.

We are currently at a junction and must decide what energy demands to plan for going into the future at transmission level. Thus the historical methods of transmission planning has become more complicated. The data sets used in the past have to be modified and the planning methods change to suit the current situation. Older planning methods were based on distribution forecasts.

Planners need to do more active long-term forecasting in order to keep up with the trends of the power system network. There are various factors that affect the load forecasts such as population growth and migration, the economy, public and private developer and industry plans. In the future, the introduction of renewable energy, vehicles would be major factors in affecting the way in which power is consumed by customers, both residential and industrial.

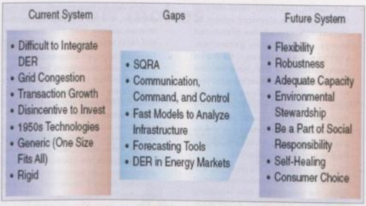

Fig. 8: The transition from the current grid to the future grid (SQRA: Security, Quality, Reliability and Availability; DER: Distributed Energy Resources) [8].

Due to the fact that the criteria has changed planners need to be more careful when making decisions going into the future. They need to gather information from all stakeholders and using model to do load forecasting. The existing models need to be modified to include the effect of renewable energy sources on the network. Renewables will have an effect on the daily load curves of customers.

This will vary from customer to customer depending on the amount of energy the system is producing. All factors that affect PV systems need to be taken into account. Eventually a bottom-up approach must be looked at in order to assess how the transmission network will be affected. The distribution model has to be maintained in order for accurate modelling to be carried out.

The forecasting method methods need to be tested before used. Case studies are a good way of assessing the impact of renewables on the network. Many countries have integrated renewables successfully included network.

Future power system

The transition to the future grid is described by Gellings et al. [8] and is shown in Fig. 8.

An assessment of the current system would have to be conducted and the gaps for that particular system identified. These gaps would differ across networks and utilities. Essentially the future power system should enable utilities to [9]:

- Be more competitive with their overall strategies.
- Provide better service.
- Better manage their assets.
- Extend equipment life.
- Improve diagnostics.
- Develop reliability-based maintenance.

Planning and development consider the ultimate inter-connections and progress towards it. EG would be part of the solution, but should be practically assessed together with traditional generation sources [11].

The drivers for the transition of networks are:

- *Rapid urbanisation:* whether or not we are ready for it, will place services placed under strain.
- EG costs have been decreasing steadily, an uncontrolled surge in EG will affect the networks.
- Smart mobility and the reduction in fossil based vehicles together with the move towards electric and autonomous vehicles would increase the demand for power and change the conventional daily load curves.
- The cost of battery storage is decreasing and would be a game-changer in the near future.
- Climate change and it impact on infrastructure will test power system resilience.
- Customers are becoming more discerning as to the products they purchase and the services they receive, hence products and services have to become more customer centric.

The fourth industrial revolution in the power sector

Power systems have been evolving and are not only becoming more connected at the high and medium voltage levels but also in information and communications technology sector. The World Economic Forum's Grid Edge Transformation Initiative developed the following key findings [13]:

- The fourth industrial revolution is transforming the electricity system by increasingly competitive distributed energy resources (like generation, storage, efficiency, demand management and EVs) have become widely available, empowering customers to become active elements of the system. Systems are becoming fully digitalised, customers can have real-time interactions, operations can be fully automated, and capable of managing flexible and mobile resources.
- The rules of the game are changing with blurred boundaries between sectors and along the value chain and increasing the complexity of system governance. The role of the network evolves beyond supplying electricity, becoming a platform that maximises value of distributed energy resources. The revenue model sees smaller shares of income derived from centrally generated electrons, which is compensated by new revenue sources from new distribution and retail services.
- Transformation will bring massive value creation with opportunity for creation of $2,3-trillion of value for industry and society – increasing reliability, resilience, efficiency and asset utilisation of the overall system, reducing CO_2 emissions and creating new services for customers. However, there is a great risk for value destruction if the system fails to capture the value of distributed energy resources, potentially resulting in stranded network assets and customer defection.

Conclusion

Policy makers must re-design the regulatory framework, adopting a new revenue model, planning the electricity system to include embedded generation with renewable energy sources. Regulators have to adapt faster to change, involve more stakeholders and include the urban regulatory dimension onto their models.

Private sector embrace the new reality of a fully digital, customer-empowered, transactive electricity system and transformation is inevitable. All stakeholders must deploy enabling infrastructure that is flexible, open and interoperable. Consider public private partnerships to build enabling infrastructure that is not yet commercially viable and requires initial public intervention.

Big data, machine learning and artificial intelligence should be explored to solve some of the existing challenges and be will central to the planning, operation and maintenance of future power systems.

The fourth industrial revolution is taking place much faster than the first three, adaptability, resilient, flexibility are key for success.

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Making smart grids smart makes smart cities smarter

by Martin Kuhlmann, Siemens

Today's energy challenges are causing modern cities to curtail their dependence on traditional energy sources and adopt smart grid technology.

Smart grid is the effective digitisation of field assets and respective communication of an electrical grid and water infrastructure into a central digital management system that:

- Manages grid control systems such as Protection devices with SCADA.
- Manages load/consumption systems such as power quality meters and commercial smart meters with MDMS.
- The integration of the above to effectively unify data.

MDMS load data will enable a typical SCADA system to understand load profiles etc in a "electrical digital twin" system so that unnecessary overloads can be avoided as an example.

Smart cities will use smart grid data to heighten operation management of the Smart city and provide feature rich data for Industrial zones, commercial zones, public and consumer zones etc.

Unified reporting and operation dashboard display of data in a "smart city" will enable effective management and efficiencies, as well as encourage consumer behaviour and trust.

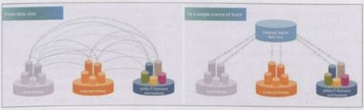

Fig. 1: The electrical digital twin.

"Smart grid" vs. "smart city"

"A smart grid is an electrical grid which includes a variety of operation and energy measures including smart meters, smart appliances, renewable energy resources, and energy efficient resources[1]."

"Smart grid" is the effective digitisation of field assets and respective communication infrastructure into a central digital management system that:

- Manages grid control systems such as energy protection devices with SCADA[2].
- Manages load/consumption systems such as power meters and commercial smart meters with MDMS[3].
- The integration of the above to effectively unify data.

"A smart city is a designation given to a city that incorporates information and communication technologies (ICT) to enhance the quality and performance of urban services such as energy, transportation and utilities in order to reduce resource consumption, wastage and overall costs[4]."

"Smart city" effectively uses all available system data to manage an efficient and functional city.

"Smart grid" overview

Smart grid can be interpreted differently from one provider to the next. However, it is the effective combination of focused areas in a typical grid as follows:

- Substation automation, protection, and smart communications.
- Grid operation and control.
- Grid applications and analytics.
- Grid planning and simulation.
- Grid security.

A short description of these topics above can be illustrated as follows:

Substation automation, protection, and smart communications

Flawless operation of an entire grid in an increasingly distributed energy landscape is the basic prerequisite for any network operator, electricity supplier, and industrial enterprise today.

Substation automation

Today power system operation is becoming more and more dynamic – which requires flexible, tailored solutions for reliable operation and efficient project management.

Protection for digital substations

High-performance protection makes power supply future-proof and is essential for network operators, electricity suppliers, and industrial enterprises in every sector.

Optimisation of power quality

The availability of energy is obviously an important contribution to power quality, but it's not the only one. In addition to the quality of service, quality of voltage is particularly crucial for an efficient power quality. More than €150-billion in annual losses due to downtimes in production and IT can be attributed to poor voltage quality in Europe as an example.

Smart communication

Digitalisation demands communication. Proactive response to digitalisation and the decentralised structures in energy supply using end-to-end telecommunication networks for the digital grid provides communication solutions for transmission and distribution networks as well as for industry specific applications.

Grid operation and control

Digitalisation and decentralisation are transforming the energy landscape right down to its very foundations and at amazing speed. Smart solutions help exploit the benefit of grid operators by digitally enabling products, solutions, and services that enhance the operation of grids of any size with valuable information, this way ensuring economic and energy efficiency, reliability and resilience, and a higher degree of sustainability.

- *Microgrids:* Microgrids contain all the elements of complex energy systems, they maintain the balance between generation and consumption, and they can operate on and/or off grid. They are ideal for

Note 1: https://en.wikipedia.org/wiki/Smart_grid
Note 2: SCADA - Supervisory Control and Data Acquisition
Note 3: MDMS – Meter Data Management System
Note 4: https://www.techopedia.com/definition/31494/smart-city

supplying power to remote or poorly developed regions with no connection to a public network. In addition, more and more industrial operators are using microgrids to produce the electricity they need cost-effectively, sustainably, and reliably. Microgrids use a variety of energy sources, including photovoltaic and wind-power plants as well as small hydropower and biomass-power plants. Biodiesel generators and emergency power units, storage modules, and intelligent control systems ensure the security of supply.

- *Distribution automation:* Keeping your grids up and running. Distribution Automation improves significantly the reliability and availability of power distribution grids. The functionality ranges from remote monitoring and control to fully automated applications
- *Digitalised substations:* The energy systems of the future are increasingly decarbonised, distributed, and digitalised. This fundamental transformation is in full swing and poses a wide range of challenges for all stakeholders. Only digitalisation will allow us to master these challenges. Ensuring that the digital transformation succeeds in the energy sector requires decisiveness, flexibility, and intelligent investments in smart digital technology. This is the only way to manage current tasks while creating enough leeway to actively shape the future. Investments in innovative technologies today create future-proof power grids characterised by reliability, efficiency, and sustainability.

Grid applications and analytics

Meeting the growing demand for power of our global, increasingly digital society is a challenge. On the other hand, digitalisation helps DSOs and TSOs master this challenge in its entirety and at the same time create added value through optimised efficiency, transparency, and reliability.

- *Grid applications:* Decarbonisation, decentralisation, and digitalisation are major factors driving the revolution of energy systems. Utilities, energy providers and industrial players all over the world need to adapt their technological base as well as their business processes to the new requirements of the energy sector.
- *Grid analytics:* Grid analytics such as fault reporting requires a fast, flexible, and direct system. Fast and efficient fault management was previously bound to the control room, but with MDMS and SCADA system analytics makes it possible to send fault information – including the fault location – directly to the maintenance crews, without the need for a grid control center. The result is that fault messages are enabled even without a control room or complex IT hardware – making it a mobile and surprisingly cost-effective alternative.
- *Data analytics:* The energy system is changing dramatically – and this is posing new challenges but also new opportunities to distribution grids. Transparency about generation and consumption, costs, and power quality, are becoming increasingly important as a result. It is this knowledge that will pave the way for making the adjustments needed to optimise grid efficiency and supply security. Rolling out an advanced metering infrastructure is costly, but now the time has come to create value from this meter data. The key to this lies in analytics.
- *Grid diagnostics:* Grid diagnostics allows grid data to be processed transparently so that reactions to grid conditions behave more quickly and planning predictive maintenance is enabled.
- *Cyber security:* With the onslaught of digitisation, cyber security has become a central planning aspect to any grid. Cyber attacks can happen directly to the central system, or via field devices and communication infrastructure. Strong cyber security is a must.
- *Managed Services:* In all IT systems, specialisation and application experience are very sought after. Unfortunately, utilities are constrained in providing suitably qualified engineers trained to manage and operate these complex systems. The question becomes: can a utility afford not to engage in a managed services contract?

Grid planning and simulation

From power generation all the way to distribution, power systems have never been more complex than today, and demands are continuously rising. Grid operators and utilities require powerful, flexible, and intuitive software tools, expertise, and global experience to compete in this dynamic environment and simplifying data maintenance and data exchange, as well as planning ahead, both in technical and business terms.

- *Power system consulting:* Power system consulting services range across technical, economic and regulatory disciplines delivering power system studies, field measurements, disturbance investigations, e.g. post-event analysis. Power system consulting provides expert software tools for power system simulation and analysis.

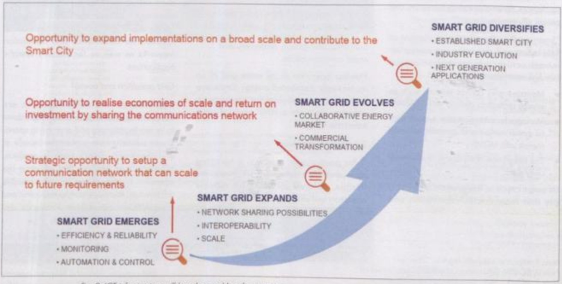

Fig. 2: ICT infrastructure will be a key enabler of smart cities.

Dry Type Mini Substation

Cast Resin Transformer

Complete Solar Substation

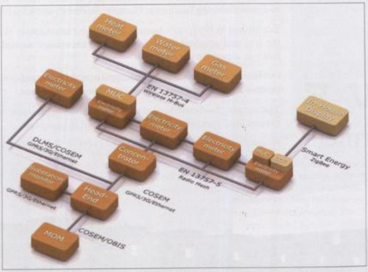

Fig. 3: Electricity and water meter integrated into a communication infrastructure.

- *Power system simulation and modelling:* The utility industry is undergoing a transformation, and utilities need to adapt their business processes and tools in order to continue to achieve their objectives in a sustainable way. Power system planners and operators require powerful, flexible and intuitive software tools to support their daily grid simulation and analysis work.
- *Electrical digital twin:* Data is at the centre of the power grid. It is exchanged between a large quantity of different software systems which enables utilities to properly plan, operate, and maintain their grid.

Utilities are spending a lot of time and resources to manually maintain, update, and exchange information among different systems. Inconsistencies during data exchange and even the lack of data exchange can lead to dramatic consequences, like excessive costs, duplicated labour, suboptimal system performance, and even system wide blackouts. Industry trends (such as distributed energy, renewables, and digitalisation) are only increasing the number of data points that need to be considered to achieve optimal system performance.

In this new digital world, data accuracy, model complexity and automation are the foundation to maintain operational excellence and maximise future investments. That is why Siemens has developed the Electrical Digital Twin, utilities are able to harness the power of transparency with a single source of truth for data across their entire utility IT landscape (see Fig. 1).

Grid security

Cyber security is a highly sensitive area that demands a lot of trust. Technology providers need to understand how products, systems, and solutions integrate with the processes and people behind them and how people interact with them. From this, complex grid/cyber security planning is developed to maximise overall security on all levels of grid operation and management.

"Smart city" overview

What makes a city smart? Smart city solutions contribute to the effective management of urban areas, improving connectivity, sustainability, and liveability. Across all areas of city life, technology and data are used to analyse and optimise functionality and efficiency, thus enhancing outcomes and improve quality of life to those living in the city.

Dimensions of smart city development

Our cities continue to grow at unprecedented rates, and we are living in an increasingly urban world. How do we manage environmental impact, urban resilience and financing? Different dimensions of smart city development have the potential to guide cities in the right direction.

Unlocking the potential of cities

How can we improve city life? The quick answer is: data.

Cities, in all their complexity, generate huge volumes of it, all the time. We can use these insights to optimise the systems that support our urban lives – from transportation and health, to energy consumption and safety. And these are real, tangible changes: by utilising data, it's possible to improve emergency response times, reduce greenhouse gas emissions, and improve commutes. Dedicated solutions help leverage smart data to maximise city potential.

City air management

City air management is designed to help conurbations reduce air pollution. It gathers emissions data in real-time and simulates measures that improve air quality – enabling decision-makers to remedy high emissions using reliable data. Highly accurate air quality forecasts are projected for the next five days, using a sophisticated algorithm based on historical data, weather input and current data.

City air management tools and consulting help cities identify methods to avert poor air quality in the short term and to build a strategy for longer-term technology change. City air management monitors and forecasts air quality and simulates actions that a city can take in the short term to avert breaches of air quality standards and limit respiratory stress on the most vulnerable citizens.

By ensuring data-driven decision making, cities are able to save on costs, maximise efficiency and foster long-term air quality improvements.

Smart city digital hubs

Smart city digital hubs allow researchers to gather data and develop solutions in the fields of data analytics and smart infrastructure. The aim? To create a technology ecosystem that will benefit smart cities in the future.

Typical smart city digital hubs digitalise its urban infrastructure as much as possible. The digitalisation hub brings together data specialists, software engineers, solution architects and domain specialists to pilot digital innovations.

Urban mobility solutions

Connected mobility data, and AI-driven applications and services, are developed for an even smarter management of road traffic, fleets such as eBikes and intermodal mobility. The goal is to optimize mobility for citizens.

Digital logistics – airports

Aviation industry in smart cities facilitate the development of future-oriented analytics and Internet of Things (IoT) solutions for airports, airlines, cargo service providers and ground handlers. It supports customers to continually improve the passenger experience, simplify processes and increase efficiency.

IoT services

The world is rapidly changing. Digitalisation and the Internet of Things (IoT) have a tremendous impact on our world. It is obvious that organisations need to address the issue of digital transformation, yet few have a concrete strategy. Those that tackle digital transformation and IoT will be the leaders of tomorrow, shaping the future of their industries.

City performance tools

All over the world, cities are shaped by profound forces: their population, their technologies and their infrastructures. Even today, these forces collide, and urbanisation and climate change will spur dramatic changes in metropolitan areas. Cities need to pave the way for constant evolution: digital technologies are becoming increasingly important and urban infrastructures and buildings require a more efficient and sustainable setup.

These changing environments set free a swarm of urban challenges: Developed cities for instance need to focus on cutting carbon emissions, improving efficiency in infrastructure and buildings, stimulating a market shift towards cleaner vehicles and more efficient and environmentally friendly public transportation. At the same time, infrastructure quality in many advanced economies is deteriorating. Looking forward to 2030, more than $50-trillion will need to be invested in infrastructure globally to keep up with GDP and population growth.

Cities in emerging markets on the other hand face issues such as power outages and inadequate public transport and roads, which brake on growth and development. Infrastructures cannot be built fast enough to keep pace with economic and urban development. In times of constrained budgets city leaders need to identify their infrastructure investments carefully, ensuring that their investments address their environmental and economic priorities. Technologies need to be adapted to serve local needs to ensure that the right technologies are applied in the right environments, tailored to the specific characteristics of the individual city.

Creating resilient cities

Population growth, rapid urbanization and climate change put our urban infrastructure under pressure. Siemens' technologies can help cities respond to these challenges with innovative solutions and our expertise in the areas of electrification, automation, and digitalization.

Making smart grids smart makes smart cities smarter

The topic of this paper is an interesting one, as an immediate question comes to mind – "Aren't smart grids smart anyway?"

That there are a lot of similarities between smart grids and smart cities.

However, it is clear that smart cities without any smart grids have a limited functionality and benefit.

Smart grids enhance smart cities

So, to what level or proportion does the "smartness" of a smart grid make a smart city smarter? The answer is simple, a smart grid provides a direct and 100% proportion to the "smartness" of a smart city.

"To meet the goals of a smart city in supporting a sustainable high-quality lifestyle for citizens, a smart city needs a smart grid. To build smart cities of the future, information and communications technology infrastructure will be a key enabler, and strategic choices made by utilities today have the power to transform society tomorrow (see Fig. 2)[5]."

"Security of revenue" business model for smart grids and smart cities

"Security of revenue" is a powerful term and is a big focus on utilities in South Africa, Africa and the world.

The utility business is changing:

- The end-to-end energy business value chain is affected by change.
- Technology and ICT are playing a huge role in modernisation within the industry.
- In the last 10 to 15 years we have seen emerging international trends focused on:
  - Better service delivery.
  - Improved system operation.
  - A greater customer centric focus => the "Energy Prosumer".
  - Big data – the Internet of Things (IoT).

In today's world a lot of utilities (electricity water gas) in Africa are struggling to make ends meet, blaming electricity/water/gas theft and "non-technical losses" (NTL) as a main contributor to their negative financial issues. This has a direct impact to a smart city.

"Security of revenue" is really a term that ensures maximum revenue for a utility is secured so that the aggregate technical, commercial and collection losses (ATC&C) is minimised and profitability and financial viability of the Utility enhanced!

To make this a reality, the utility needs to tighten up its administrative and technical departments so that every cent is accounted for. Administratively, this is easy to do, but technically this is a major challenge.

One key point is that utilities are moving from an OT (operational technology) centric strategy to an IT (information technology) strategy – this means a huge shift in resource focus and management.

- *IT*: refers to anything related to computing technology. Some examples are CRM, ERP, and email.
- OT: Gartner refers to OT as "hardware and software that detects or causes a change through the direct monitoring and/or control of physical devices, processes and events in the enterprise." Some examples of OT are SCADA, PLCS and HMIs.

For smart cities, smart metering is the latest buzz word to fix the technical and revenue divide, but is it financially viable? Well, the easy question is: if ATC&C losses are dramatically reduced by implementing a smart metering system, can the utility afford not to have such a robust and proven system?

"Security of revenue" needs careful planning and strategic understanding, but if implemented well, can instantly bring in much needed results.

Smart grid vs. smart cities – why billing is important

Technology really enhances the "smart grid" world by introducing the concept of "smart billing". Making smart cities smarter is not only the technical and digital management of a smart grid, but also making sure hat the services delivered to a consumer and the eco-system of the smart city enjoys the features and benefits of a "smart billing" business model to enable accuracy, affordability, easy-access, trust and efficiency.

Examples of a "smart" electricity and water metering infrastructure

Fig. 3 shows how both electricity and water meters are integrated into a communication infrastructure so that the MDMS receives both data, allowing for "security of revenue" models using a single back-end system incorporating both electricity and water data.

Conclusion

The buzz word of today, "smart city", is a very intricate, technical and a concept to deliver a new heightened the level of efficiency, human and environmental benefit, and a functionality that installs positive behaviour and trust in the new cities of the future.

To make cities smart, the reliance of digitalisation and the effective management of data is crucial.

Smart grids contribute to this model by making the utility supply of respective services modern, data enriched and most of all efficient – a must in the new world!

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Note 5: Discussion Paper – Ericsson – March 2012

Evolving 4IR technologies and digital substations

by Stuart Michie, ABB South Africa

The world of electrical energy provision is transforming at a rapid pace. The convention of centralised generation, transmission and distribution is fast changing with the ever-increasing adoption of renewable generation technologies, battery energy storage and new electric applications, such as electric transport.

These changes bring new challenges and opportunities for the operation of power networks, where reliability, the security of supply and cost-effectiveness needs to be maintained.

The need for increased visibility and management of power networks, both technically and commercially, can be met through digital technologies. According to the World Economic Forum, the electricity sector can realise significant value from digital transformation, at the estimated value of US$1,3-trillion globally over ten years. This paper explores some of the concepts and technologies that are available to achieve this.

The changing dynamics of power systems

Up until now the generation of electrical power has been managed to meet the demand, whatever it may be. A shortage of generation capacity results in load shedding, which is a blunt tool to manage demand. As the increasing adoption of renewable energy sources increases the unpredictability of generation, new ways need to be implemented to manage demand to match the available electric power generation.

The core themes that are seen in today's changing electricity system include:

- Bi-directional energy flow
- The major need for information exchange
- More power electronics, for both AC and DC
- Storage for grid stability
- New market designs, rules and regulations
- New grid protection concepts in order to cope with the characteristics of renewable generation
- New environmental and energy efficiency regulations
- Increased capacity and efficiency of assets
- Increased stakeholder involvement in the development of future requirements for grid infrastructure.

These themes require new ways of thinking and use of technology to manage electricity systems of the future. Power utilities have the opportunity to be more actively involved in the management of their networks and to access new commercial opportunities that are available today.

From the field to the boardroom

Electricity networks are becoming increasingly dynamic. There is a need for faster decision making and increased business agility. This requires greater visibility and automated management of the power network.

The adoption of digital technologies is the key to achieving the agility and speed of decision making needed across the enterprise. For increased efficiency of operations and the improvement of capital to be employed, the integration of digital information and analytics across the timeline of operations is essential.

In the field is where real-time measurements take place. Real-time data at the millisecond level is used for functionality such as power system protection, which is implemented in the substation. The same devices that implement real-time functions also provide the data that is needed for longer term applications. It is important to note that the data needed to drive applications that operate in a longer time frame is not necessarily the data that is provided by today's real-time devices. An example is condition monitoring data that should be provided by the protection IED, since the measurements are derived from the same raw data, but is not always available on all such devices. It is at this level that a proliferation of new devices and sensors are needed to fill the gap, including devices that connect directly to the Internet.

Power system operations management takes place in the control room in the second to minutes time frame. Applications include manual power system operation by operators, and operations driven by algorithms such as distributed energy resource management. It is here that the application of artificial intelligence (AI) can support the decision making needed to manage the power system. New applications include network analytics, theft analytics and outage analytics.

In the hours, days, and weeks timeframe is where the maintenance and asset management applications are situated. At this level, data is used from many different sources to maintain and improve the assets in the power network. Asset performance management (APM) analytics identifies problem assets and automatically initiates corrective action. AI has a role to play here in the analysis of the data and assessment and prediction of asset health. This proactive grid management improves not only the customer experience but the network efficiency too.

The board room is where long-term decisions are made. These decisions can now be driven by the aggregation and analysis of data over time, which avoids the need for lengthy and costly manual data gathering exercises.

The key here is the integration of data and applications. Devices should be selected on their capability to provide the data needed for applications across the time frame. For example, a protection IED should provide condition monitoring information, such as circuit breaker travel time. Data from transformer gas analysers should be fed into an APM application, where it can be managed and analysed properly. It is not scalable to access web pages on individual measurement devices or feed what is longer term data into a SCADA (Supervisory Control Data Acquisition) system.

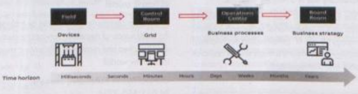

Fig. 1: Integration timeline.

Embracing the fourth industrial revolution

Digital technologies

Central to the theme of the fourth industrial evolution is the application of digital technology to integrate historically isolated components and provide new applications and new value.

Technologies such as the Internet of Things (IoT), advanced communications, standardisation of communication protocols, artificial intelligence (AI), blockchain, the digital twin and hyper-scale cloud computing are all tools that are available to realise the connected and visible power grid.

Integrating historically isolated systems such as SCADA, maintenance management, workforce management, customer information systems and metering systems as shown in Fig. 2 enables the creation of new applications to manage utility operations. New insights are unlocked through analytics and reporting, such as automated reporting for regulatory requirements that provide auditable information.

In this integrated landscape, it is possible to improve business continuity through the codifying of resources and the automation of institutional knowledge and best practices. AI is used to achieve the mapping of an expert's thought process to make knowledge and problem solving available widely.

Visualising digital insights

A useful way to visualise data and insights collated from the many different sources that exist in the utility landscape is to use a map-based view. Rather than using screens full of sterile forms, a map provides a visual and intuitive way for a human to access data within the organisation and make informed decisions. It is an ideal way of realising the digital twin for a power network, which can cover activities across all stages of the network lifecycle.

A maintenance worker can access a view of the network in the as-operated a real-time state. The health status of a piece of equipment in a substation can be accessed, along with its maintenance manual. An expert can then be brought into the maintenance activity using augmented reality to assist with troubleshooting and provide assistance to make the correct diagnosis and repair of a fault. The same worker can also see where his or her colleagues are and what activities they are up to, which increases safety.

A planning engineer can use the same view to look at network loading and power flow information, both historically and in real-time. Access to substation information can assist

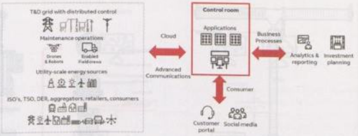

Fig. 2: Integration of utility operations

Fig. 3: Cross-functional access to information, systems, people and analytics.

with network expansion and refurbishment activities. Being able to visualise a substation in 3D can help with space planning and equipment information and optimises the decision-making process.

For the commercial manager, visualisation of energy sold against energy consumed over time can highlight the effectiveness of revenue management activities in different areas.

The operations engineer can see network performance and identify areas of concern where network reinforcement needs to take place.

For management, the integration of data across the organisation into a map-based view solves the dilemma that today, such information is contained in many different sub-systems.

Distributed energy generation management.

IoT will have a significant impact on the area of Digital Energy Resource Management.

Today, rooftop solar inverters provide only real power, which is dependent on sun irradiance. With no reactive power component being generated, these inverters cannot be used to maintain voltage control in the networks to which they are connected.

Looking forward, autonomous inverters can provide watts and vars depending on sun irradiance and local voltage. However, these operate in isolation to the rest of the network and can result in network instability. Adding IoT gives the capability to remotely control these inverters. This allows real and reactive power to be managed on command in real-time, thereby ensuring the stability of the connected networks and increasing the amount of renewable generation that can be connected to a network. Remote communication to inverters allows the pushing out of new grid code settings to manage the grid according to current conditions.

The same concept can be applied to the management of electric vehicles. The charging of electric vehicles connected via IoT can be managed to take into account the network conditions. This will mitigate the need to reinforce distribution networks and take into account the available generation in real-time.

To achieve the scale required for these deployments, utilities cannot rely only on self-managed communications network infrastructure. Mobile data networks and public cloud infrastructure will be important components in the rolling out of DER functionality. It will be important to separate the power system applications that are mission-critical from the applications that affect the efficiency of network operation and apply the appropriate technologies for each.

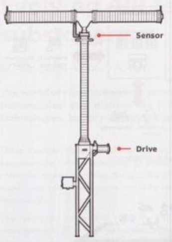

Fig. 4: DCB with integrated fibre optic measurement

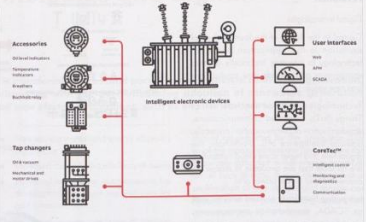

Fig. 5: The digital transformer

The digital substation

The substation as a data source

A significant source of real-time data is the power substation. It is here that power is managed and distributed and where the most expensive components of a power network are situated. The digitalisation of measured quantities allows substation applications to be implemented in software, with a resultant decrease in design decisions that need to be made at specification time.

Medium voltage

At the medium voltage level, sensors are replacing conventional current and voltage transformers. Apart from the physical benefits of lower weight and lower energy usage, the digital data provided by these sensors can be easily distributed using IEC 61850 process bus to enable the required applications. A complex, multi-winding current transformer can be reduced to one sensor with sufficient accuracy to drive all the required applications (protection, metering), with a second sensor added for redundancy if required.

The next step is to combine the protection devices into a single hardware unit, which can be duplicated for redundancy if required. Here, all the functions needed for the substation are implemented in software. If additional functions are needed, such as providing condition monitoring data, these can be added later. Upgrades can be deployed, and centralised backups done, automatically to a remote backup repository. Remote management and support and diagnostics are further features that enable better usage of experts in the organisation.

All of these technologies allow standardised medium voltage switchgear to be deployed, where the application can change through software configuration. The only parameters to be specified at order time are the physical parameters, such as voltage, insulation level and primary current ratings.

High voltage

Digitisation of measurements is also available at higher voltage levels, either through new sensor technologies such as fibre optic measurement devices or digitisation at the source current or voltage transformer. The indications and controls are also digitised in the primary device, removing the requirement for most of the control cabling used in a conventional substation. All these technologies enable the design of the protection system to be done in software. Due to the improved measurement capabilities and the ability to broadcast data to multiple devices, it is no longer necessary to specify in detail the current transformer characteristics at the specification changes. Design changes can be easily taken into account. The data required for upstream applications is available and can be transmitted by way of a suitable edge device.

Transformers

As the most expensive piece of equipment in a substation, today transformers too can be digitalised. A range of available sensors enable the effective monitoring and management of transformer health. Measurements include various temperatures, oil level and health through gas analysis, tap changer information and cooling information such as fan status (Fig. 5).

This information needs to be sent to and analysed in the appropriate systems. Real-time data can be managed and reacted to in the utility's SCADA system, while health information should be managed in an asset performance management (APM) system.

Given that transformer health usually deteriorates over a long period of time, analytic tools in the APM system determine and predict the health status of the transformer fleet. These status points are presented in a heat map and provide an overview of the health of the transformer fleet. Thereafter, corrective actions are identified and appropriate actions are suggested to be taken before failure occurs.

Integration through digitalisation

Fig. 6 shows the evolution of the substation, from conventional to modern to digital. The widespread adoption of IEC 61850, an industry-wide standard, has enabled the transition to the digital substation.

Digital technologies should also be leveraged to exploit the advantages that can be obtained at a substation level. For example, the combination of circuit isolation and current interruption into one circuit breaker device, with integrated optical measurement can reduce the footprint of a substation bay significantly (Fig. 4). The reduction in secondary cabling and the ability to test a bay fully off-site means that deployment time can be significantly reduced, with a reduced overall footprint and overall cost.

The way forward

Digital innovation is happening faster than the regulatory environment can keep up. Enabling regulation is needed that maintains power security and safety while allowing innovation to occur.

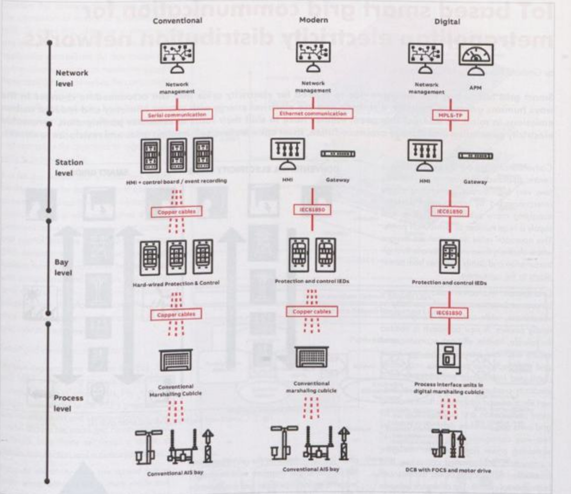

Fig. 6: Evolution of the digital substation

Skills and resources need to be developed to cope with this new digital age. Allowing a new generation of engineers, the freedom to innovate and implement ideas is important, to be ready to meet the challenge of the changing landscape. Utilities must stay involved and innovate to prevent grid defection. Digitalisation will help organisations be more aware, adaptive, responsive, collaborative, insightful, predictive and safe. This brings with it the agility to cope with the rapidly changing environment.

A key characteristic of digital solutions is that they can be purchased and used based on demand. This thus minimises the requirement for large capital projects and allows concepts to be tested and proven before scaling occurs.

It is quite clear that it will not be possible to implement a fully digital landscape in one go. It is important to develop a digital strategy, looking at the end goal and plan future investments with this strategy in place. Any investment should consider eventually integration into a digital platform and not be isolated.

For example, a smart meter investment strategy should, apart from the revenue management requirement, take into account the possibilities of power system operation (customer outage information) and customer interaction (demand pricing).

Conclusion

Why should utilities embrace digital technologies and the new applications enabled by the fourth industrial revolution? The main reasons are to protect the revenue stream, reduce costs through improved efficiency and to stay involved in the process of electric power provision.

Developing a digital strategy is important. It is best to avoid the "shiny toy syndrome" and implement a digital technology without considering the business impact and the potential return. Digital investment should be done with the big picture in mind.

Digitalisation can provide significant operation and performance improvements, improving employee and customer experience, enabling utilities to meet the challenges of today's world.

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IoT based smart grid communication for metropolitan electricity distribution networks

by Gerhard Brown, City of Cape Town

Smart grid technology has emerged due to a need for electricity grids that can accommodate changes in the ways humans generate, transfer, distribute and use electrical energy with energy efficiency and reduced carbon emissions in mind. To address this need, utilities have to shift their focus to consumer participation, renewable electricity generation and storage accommodation, asset optimisation, self-healing grids and resistance to attacks.

Conventional grids are developed using a centric approach that consist of relatively few, very high-output, generating plants interconnected by transmission systems supplying many substations, that in turn supply a huge number of distribution points. This approach relies on centralised designs where electricity flows unidirectionally through transmission and distribution lines from power plants to the consumers.

Grid data and information is also concentrated in central locations and only partially in substations, while consumer equipment is totally passive. A new approach is needed for reliable, flexible, efficient, economic, and secure electricity provision. This new smart grid approach uses more data and widely distributed intelligence embedded in local electricity production. It makes use of two-way electricity and information flows enabling more participation and collaboration for all grid users and therefore depends a complex two-way communication infrastructure, sustaining power flows between intelligent components, sophisticated computing and information technologies as well as advanced business applications. The difference between conventional electricity grids and smart grids is illustrated in Fig. 1.

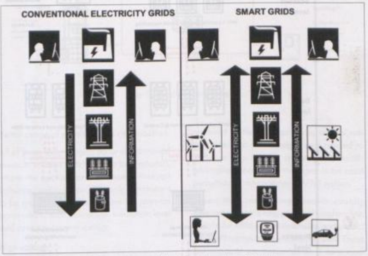

Fig. 1: Conventional electricity grids and smart grids [1].

Smart grids create opportunities for utilities to leverage the benefits of new technologies such as smart sensors, renewable energy generation, electricity storage, electric transportation and advanced metering infrastructure (AMI) more effectively. Implementing smart grid technologies comes with many challenges however, most of which stem from the fact that smart grids can be classified as complex systems in systems engineering terms [2] because they are vast and very dynamic.

Data communication is the cornerstone of any smart grid system and as more data generating devices are added to the grid, more opportunities emerge for smart grids to use this data in specific applications. These devices can provide data that can be used to determine energy production, grid efficiency, asset condition and consumer behaviour. For applications to have access to this data, it has to flow to various points in a massive communication network that is often just as complex as the grid it supports. Major challenges therefore exist in design, implementation, operation and maintenance of smart grid Information communication technology (ITC) networks that have to be addressed by further research.

Smart grid design

In its fundamental form, a smart grid design can be presented as a framework consisting of four layers as illustrated in Fig. 2. These layers are integrated to work in unison for the smart grid to perform optimally.

The energy infrastructure layer represents the grid technology responsible for electricity generation, transmission, distribution and ultimately consumption. It also includes the devices that generate and use grid data to perform specific functions. The communication infrastructure layer is responsible for transferring data in the smart grid over networks using ICT, while the information technology layer represents the elements that deal with the data structuring, processing and storage. Users utilise grid data and information to perform or automate certain grid functions using various smart grid applications, represented by the top layer of this framework.

Fig. 2: Smart grid framework adopted from [1].

A more detailed reference architecture for smart grids was developed by the CEN-CENELEC-ETSI smart grid coordination group [3]. Their reference architecture includes the smart grid architecture model (SGAM) presented as a three dimensional framework with five interoperability layers on the y-axis, five grid domains on the x-axis and six grid zones on the z-axis and is shown in Fig. 3.

This framework builds on the four layer framework by adding a fifth layer called the business layer that considers the objectives of the smart grid. As an example one may consider the business objective to monitor the condition of assets in a distribution grid. To meet this objective a smart grid design should include the monitoring application users will use, the data models and communication protocols needed to support these applications, as well as the components in various grids zones that will be monitored using collected grid data. Each one of these interoperability layers usually contains a series of complex designs that require regular review and change as the objectives an organisation aims to achieve evolve.

It is for this reason that a smart grid should be designed to be as flexible and adaptable as possible. Besides the energy infrastructure, which is usually already established, the data communication systems are the most complex and capital intensive parts of any new smart grid development. These communication systems form the crucial links between smart grid components and the users that monitor and control them. The communication infrastructure therefore requires the same level of management and oversight as the grid infrastructure itself.

Smart grid communication networks

Various organisations such as the IEEE, IEC and NIST are working towards standardising communication in smart grids. Fig. 4 shows a high level model of the IEEE's proposal for end-to-end smart grid communications. This model divides the smart grid communication network into three sections: a WAN, a distribution section and a customer section.

Because electricity grids are spread across wide geographical areas they make use of wide area networks (WANs) to connect generating units and transmission networks with distribution networks. The WAN usually consists of a high-bandwidth backbone communication network that handles long-distance data transmission interfacing with various plant networks, substation networks, MANs and a utility's LANs. Electricity distribution networks consisting of NANs, EANs, FANs and AMI networks make use of a backhaul network to interconnect networks in distribution substations, microgrids and distributed generation plants to the smart grid communication network while the customer section includes HANs, BANs and IANs for connection of customer appliances, equipment and devices. Smart meters communicate either through the distribution networks or customer networks, depending on a utility's design standards.

The communication network in an electricity distribution grid acts as a bridge between a utility's WAN and its customers' networks and therefore becomes a crucial part of the end-to-end communication network. Consisting of many sub-systems, equipment and components the distribution network is often the largest and most complex part of the utility communication network. Electricity distribution grids vary from location to location as grid designs have to cater for thousands of customer's that are densely clustered in towns and cities as well as those in rural areas with only a few widespread customers. Metropolitan areas often contain the most intricate collection of distribution grid designs that tend to follow a hierarchical network topology with main substations at the top and smaller localised distribution equipment such and mini-substations, ring main units (RMUs) and low voltage distribution panels at the bottom.

Conventional communication networks that support electricity distribution applications such as SCADA and SAS often follow similar hierarchical topologies. Historically, these network designs favoured dedicated wired connections over wireless technology resulting in grid designs where power cables are often installed with accompanying communication cables. Many metropolitan electricity distribution grids therefore have existing communication infrastructure in place, although some of these installations may be based on dated technology not capable of meeting the requirements for some smart grid applications especially those that rely on big data.

Some of the critical areas where these conventional data communication networks fall short are network management and security. In addition to grid operations, data communication needs to be monitored regularly to identify anomalies and to allow

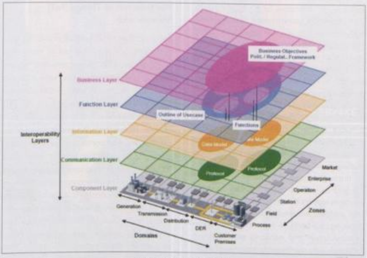

Fig. 3: SGAM framework [3].

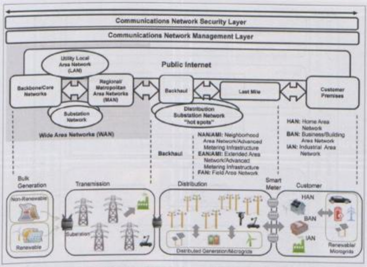

Fig. 4: End-to-end smart grid communications model [4].

network administrators to do fault analysis and correction, performance management, and network provisioning while controlling the quality of service. Administrators also have to set security policies that can prevent unauthorised access, misuse, modification, or denial of a computer network and network-accessible resources. This can include policies for access control, behavioural analytics and installing antivirus and antimalware software. If data is stored remotely, storage management is required to manage storage resources and data structures while device management applications may be required to manage smart devices connected to the gird as well as their interactions. These functions may be straightforward to implement and perform on smaller single application networks, but because of the complex nature of most smart grid networks administering these networks can become a mammoth task.

The Internet of Things (IoT) frameworks

Rapid advances in telecommunication, IT and manufacturing have led to many new innovative ways that allow computers, tablets, smart phones and other smart sensor devices to communicate, bringing with it different architectures and frameworks for IoT [5]. Similar to the framework for smart grids, most of them find unity in the presentation of an architecture that contains three layers as a minimum: An application layer for applications that provide services to users; a network layer representing the interconnection between devices and applications while responsible for all data transfers between these elements; and a device layer representing devices able to generate, store, transfer and process data or execute control actions.

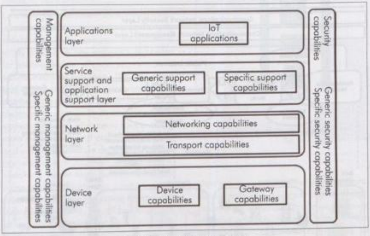

Fig. 5: ITU-T IoT reference model [6].

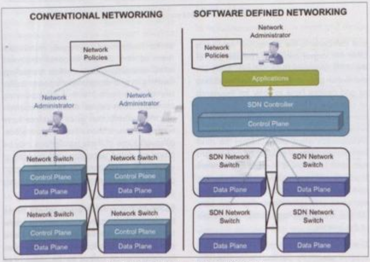

Fig. 6: Conventional networking and SDN [7].

Building on this, some standard reference models such as the International Telecommunications Union's (ITU's) IoT reference model shown in Fig. 5 adds a service and application support layer as well as multi-layer capabilities for crucial functions such as management and security. Applying this IoT architecture in ICT system designs creates new opportunities to transform physical "things" into equivalent software representations and to automate "actions" using software algorithms. Examples of how these software defined approaches have improved our daily lives can be observed in the abundance of mobile devices and device applications for personal use as well as the emergence of new IoT based home automation, self-driving cars and the creation of virtual environments using augmented or virtual reality.

This virtualisation of the real world has also found new applications in industry, especially in the IT and telecommunication industries. IoT paradigms such as cloud computing have already contributed significantly towards alleviating some of the problems associated with resource allocation, utilisation and management in massive data networks. Cloud computing is however facing new challenges regarding flexibility, dependability and security. The software defined systems (SDSys) paradigm addresses these challenges by adding software components that help to abstract physical hardware from other layers. This abstraction provides opportunity for system administrators to more easily construct and manage their systems through flexible software layers.

A popular example of this abstraction is found in software defined networking (SDN). Conventional networks rely on hardware such as network switches to manage network traffic with pre-programmed control functions configured on the physical device according to network policies. These control functions execute in the switch's control plane, controlling the data flowing through the network switch's data plane. Network switches have limited visibility of the entire network, impacting the overall network performance. Any changes to the network configuration or network policies that require changes to these control functions require network administrators to manually reconfigure each switch individually. In SDN, control functions run as applications in logically centralised SDN controllers.

These SDN controllers provide the network administrators with a global network view, as well as programmatic interfaces to allow direct control of the network's forwarding devices using SDN applications. This architecture therefore decouples the control plane from the data plane, allowing the switches to become simpler traffic forwarding devices that allow the SDN switches to run on normal

computer hardware while the SDN controllers can run on general purpose servers or even as a distributed set of servers using cloud computing principles with more scalability. The difference between conventional networking and SDN is illustrated in Fig. 6.

Network functions virtualisation (NFV) is another IoT framework which complements SDN as it decouples network functions from hardware so they can run in software on virtual machines (VMs). Because the network functions are virtualised software applications, they can be dynamically created, configured, migrated and replicated, thereby eliminating the need for physical, on-site installations of hardware. Using NFV, network functions such as network address translation (NAT), firewalling, intrusion detection, domain name service (DNS) and caching can be deployed as virtualised network functions (VNFs) on substrate infrastructure that includes the hardware resources (computation, storage and networking). A virtualisation layer, which can be realised by VMs or container virtualisation, provides virtual computation, storage and networking resources.

This approach of abstracting network functions using software layers can also be applied to other functions such as storage management (SDStore), security management (SDSec) and device management (SDIoT) to name a few possibilities.

Machine-to-machine communication (M2M)

M2M is a combination of various technologies, including wireless sensor networks (WSN), cyber-physical systems (CPS) and the Internet of Things (IoT), that enable machines such as computers, embedded processors, smart sensors, actuators and mobile devices to communicate with each other with limited intervention by humans, thus automating and optimising the processes these machines support. M2M relies on data communication achieved through standardisation of the communication interfaces that can exist between machines in a network. This is usually implemented by the introduction of a middleware layer in the communication network architecture that supports standardised data models, encoding and serialisation of data for exchange between machines through services. This approach is shown in Fig. 7.

Two organisations have made significant contributions to M2M standardisation. ETSI published its first M2M standards in 2011, focussing on horizontal service platforms and related application interfaces (APIs) which aim to improve and maintain globally applicable, access independent technical specifications for M2M, with an initial focus on the service layer. The global oneM2M organisation also released a series of standard M2M specifications in 2014. The oneM2M standard describes application entities which make use of a set of service functions common to the M2M environment that can utilise underlying network capabilities and can interact with each other.

An example of a reference implementation of the oneM2M standard available as open source software is OpenMTC. The OpenMTC reference architecture consisting of internetworking proxies (IPEs), gateways and a backend is shown in Fig. 8.

The IPEs are application entities that translate data from one domain to another. An example of an IPE could be an application that reads out sensor values from sensor devices by using a vendor-specific binary interface and translates it to a common standard such as oneM2M.

A gateway is an M2M software node that is central to a particular field domain, such as a section of a grid in a suburb or industrial area allowing it to collect data from various IPEs. Local applications in this domain can access resources via the gateway without the need to interact with a central server. It is possible to create a hierarchy of gateways in a grid network allowing data to travel from one part of a field domain to another.

A central backend server acts as the M2M root node within a hierarchy of gateways and is the main software node within the infrastructure domain. The backend provides access to data and services to a central group of applications such as other IPEs or industrial and enterprise applications at a control centre or grid administration offices.

IoT in smart grids

Smart grid technology can have various applications in electricity distribution. Most of these applications are focussed on monitoring and control of the grid or specific grid elements, while others support grid objectives such as revenue collection and energy management. Table 1 summarises some of the most common smart grid applications with their network performance requirements.

Because all smart grid applications rely on data communication, the use of SDN and NFV in smart grids has received a lot of research attention. This focus can be attributed to the past successes of these paradigms in data centres, WAN and enterprise networks. The benefits of implementing SDN and NFV in smart grids include:

- Simplified network management by providing remote monitoring and control of ICT network devices and network activity.
- Reduced dependence on specialised network hardware and the amount of effort required for remote fault finding and network maintenance.
- The ability for different smart grid applications or users to have different network views while sharing the same physical network infrastructure, known as network slicing.

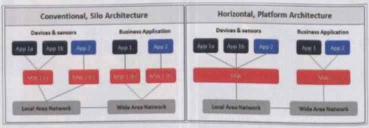

Fig. 7: Conventional silo architecture vs. horizontal platform architecture used in M2M communication [8].

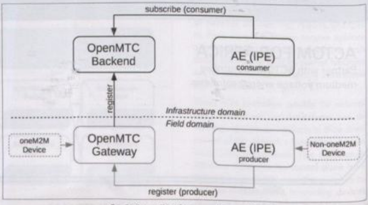

Fig. 8: OpenMTC reference architecture [9].

- The ability to configure smart grid networks to become contextually aware and automate actions that support grid stability.
- The ability to create self-healing networks with network resilience features such as fast failover recovery (FFR).
- The ability to automate network optimisation, improve network traffic flow and reduce network congestion using load balancing applications.
- The ability to virtualise protocol conversion functions on available computer hardware, controllable from a network management application that allows the ICT network to adapt quickly to connection requests from unrecognised networks or devices using unrecognised protocols. Protocol conversion is vital for incorporating exiting grid networks based on existing grid communication standards, for example substation networks based on IEC 61850 communication standards.

In addition to these benefits, other IoT frameworks also hold potential benefits for smart grid implementations. SDSec has been shown to be a viable solution for intrusion prevention, data security and malicious attack detection and prevention, while SDStore offers various improvements over cloud storage approaches, especially when used in conjunction with multi-access edge computing (MEC).

M2M standards offer a means for standardising the communication interfaces and data models used in smart grid networks. By implementing M2M middleware on devices at appropriate points in the network edge and core, the smart grid will not only become much more flexible in terms of the machines and applications that can interface with it, it will also be much easier to deploy and maintain. This is because M2M makes use of common libraries that provide common functions for diverse use-cases and allows developers to focus on applications, rather than underlying communication. M2M also promotes cross-sharing of resources and data between different applications and devices that creates new opportunities for solving many grid problems and improving existing functionality.

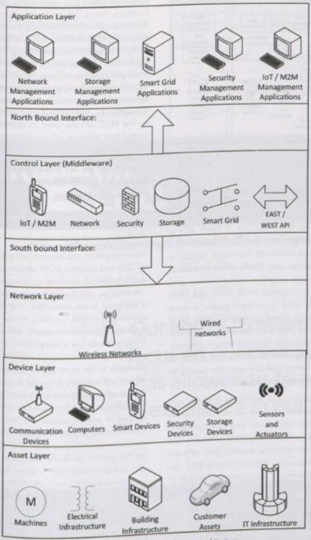

Fig. 9: IoT based smart grid reference architecture.

Reference architecture for an IoT based smart grid ICT network

In support of streamlining designs for smart grid ICT networks, a five layer reference architecture for IoT based smart grid designs is presented in Fig. 9. The five layers in this proposed architecture include:

The asset layer

All assets that are fitted with sensors and actuators, and that interface with the smart grid network using processing devices, are described in the asset layer of this reference architecture. This layer usually consists mainly of electrical infrastructure, but also includes buildings and other infrastructure that support grid operations. Because the distribution network acts as the main grid interface for customers, this layer can also contain customer assets that produce and use data where data communication network integration is required.

The device layer

In most modern electricity grids smart substation devices are used to provide data processing, storage and communication capabilities to the grid. Other substation technologies that offer similar features can include intelligent electronic devices (IEDs) and remote terminal units (RTUs) usually implemented with systems such as SCADA or SAS. The device layer represents all these devices that allow grid infrastructure to interface with the smart grid ICT network to exchange data. These devices interface with sensors and actuators connected to grid infrastructure that measure and control temperatures, current flows, voltages, vibration, pressure, motion or positions of things like doors or switches. The embedded processing capabilities in these devices can be used to translate or filter collected data and trigger control actions.

The device layer also includes PCs, laptops, servers or other computer devices that are used as hosts for specific applications. These applications can include the software required for SDSys implementation, M2M

Application	Bandwidth	Latency	Reliability
Substation automation	9,6 – 56 kbps	15 ms – 200 ms	99% – 99,999%
Overhead transmission line monitoring	9,6 – 56 kbps	15 ms – 200 ms	99% – 99,999%
Wide-Area situational awareness	600 – 1500 kbps	15 ms – 200 ms	99% – 99,9999%
Distribution automation	9,6 – 56 kbps	20 ms – 200 ms	99% – 99,999%
Distribution management	9,6 – 100 kbps	100 ms – 2 sec	99% – 99,999%
Home energy management	9,6 – 56 kbps	300 ms – 2 sec	99% – 99,9%
Renewable distributed energy resources	9,6 – 56 kbps	300 ms – 2 sec	99% – 99,99%
Demand response management	14 – 100 kbps per node	500 ms – 5 min	99% – 99,99%
Advanced metering infrastructure	10 – 100 kbps per node	2 sec	99% – 99,99%
Outage management systems	56 kbps	2 sec	99%
Electrical vehicles and vehicle to grid	9,6 – 56 kbps	2 sec – 5 min	99% – 99,99%
Enterprise asset management	56 kbps	2 sec – hours	99%
Meter data management systems	56 kbps	2 sec – hours	99%

Table 1: Network requirements for smart grid applications (Adapted from [1]).

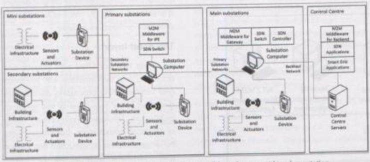

Fig. 10: Example of a system architecture for an IoT based smart grid implementation.

middleware or applications that support specific gird functions such protection settings management. Other hardware in the device layer may include network devices such as switches, routers and gateways as well as security devices and storage devices.

The network layer

The network layer represents the data communication interfaces between all networked devices. Design of the network layer starts with selecting the optimum communication mediums while considering performance requirements, available infrastructure and potential risks in network coverage areas. Wired communication mediums such as copper, PLC and fibre provide the advantages of physical connections between devices that are less susceptible to interference and more secure, although they are usually more costly to install in large coverage areas. Wireless communication is more flexible and can cover greater distances if long range wireless communication methods such as low powered wide area networks (LPWAN) or cellular networks are used. In most cases a combination of wired and wireless networks needs to be considered to cater for different requirements in different parts of a smart grid.

The network layer design should also define the different networks that will exist in a smart grid. Metropolitan distribution grids will likely include a MAN with a high performance backhaul network that connects different networks across a metropolitan area. NANs will be established in specific neighbourhoods where gird assets are located, while EANs and FANs may be used to connect assets in more rural areas. Some customers' HANs, BANs and IANs may also require interface with the smart grid communication network. Communication standards and protocols used in smart grid networks also need to be considered in network layer design.

Most smart grid devices will come with a predetermined set of communication standards they support and communication networks will have to be designed to interface with heterogeneous devices from different manufacturers. Protocol conversion can be implemented using gateway devices or virtualised translation applications. Interface requirements with other networks such as enterprise networks and the internet also need to be considered in the network layer design.

The control layer

The control layer represents the capabilities that support the smart grid services and applications by controlling and interacting with the underlying layers. SDSys controllers and M2M middleware are great examples of functions that reside in the control layer. The control layer elements rely on southbound interfaces to interact with devices in the device layer via the network layer. The Openflow protocol is an example of a southbound interface used to control network switches in a SDN implementation. Different control layer elements can also interface with each other using east and west bound interfaces.

The application layer

The application layer defines the various applications implemented in the smart grid network, aligned to the functions grid operators perform to meet specific objectives. Smart grid applications can be divided into two categories. Functional smart grid applications perform functions linked directly to the smart grid objectives such as grid monitoring and control, metering, grid protection or data acquisition for analytics to support decision making. Support applications manage systems that support the smart grid applications. Examples of these are network management, storage management, security management and device management applications. Northbound interfaces such as the REST API are used to connect the control layer elements with applications in the application layer.

Example of an IoT based smart grid design for a metropolitan electricity distribution grid

An application of this reference architecture in a design for a metropolitan electricity distribution smart grid is presented in Fig. 10.

Assuming specific requirements best addressed by SDN and common M2M services, a city's electricity distribution network consisting of mini-, secondary-, primary- and main substations is designed to be connected in a network consisting of a MAN, backhaul, smaller NANs and substation networks in specific grid sections. These networks use a combination of wired and wireless communication mediums. Each substation in the smart grid is equipped with sensors and actuators connected to substation devices with embedded processors and storage. These devices connect to substation computers located in primary substations that act as internetworking proxies (IPEs). The substation computers also serve as local SDN switches for the greater SD-MAN. Main substations also include a substation computer, but these computers are configured to offer M2M gateway services in addition to SDN switching. The main substation computers also act as SDN controllers for the respective grid sections in their areas, monitoring and controlling the SDN switches in the network. The use of multiple SDN controllers in a network eliminates the risk of controller failure disabling a network. All main substations connect to a control centre through the backhaul network. The servers in the control centre offer the services of a M2M backend and also host the SDN applications used for monitoring and controlling the smart grid ICT networks. Smart grid applications that control field devices and make use of the data acquired from sensors in the field are also hosted on the control centre servers.

Conclusion

Smart grid technology is needed to improve our electricity grids so that they can accommodate the rapid change from electricity consumers to electricity "prosumers" and the introduction of disruptive smart technologies. The uptake of smart grid technology depends on the development of methods that will simplify the design, implementation, operation and maintenance of their complex ICT networks.

IoT offers many opportunities that improve on conventional grid ICT network implementations, especially in metropoliton electricity distribution grids that consist of designs with the potential for vast numbers of sensors and actuators. Decoupling the management and orchestration of crucial grid support functions, such as networking, from field hardware simplifies grid operations and maintenance. This results in reduced operating expenditure and reliance on specialist ICT expertise to perform these functions. In addition, streamlining the design of smart grid ICT networks through standardised and repeatable functions and approaches simplifies smart grid implementation, making these systems less capital intensive for utilities to develop. The benefits of using IoT frameworks in smart grid designs should therefore be a prioritised consideration for any electricity utility.

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Impact assessment of a high penetration of rooftop PV in Cape Town

by Johanette van der Merwe, City of Cape Town; Trevor Gaunt, University of Cape Town; and Karen Kritzinger, University of Stellenbosch

There is an increasing global trend of grid connected rooftop PV systems in urban networks. Despite the possibilities offered by the uptake of PV, its increased deployment often comes with technical constraints such as voltage variations, reverse power flow, and equipment overload. This has resulted in a growing concern among municipal engineers on how the increasing customer-owned rooftop PV systems will impact existing networks. Impact studies therefore have a crucial role for distribution system operators who need to maintain specific network parameters within permissible limits and also to facilitate further uptake of residential PV systems [1].

In South Africa, the standard for embedded or distributed generator connections (NRS 097-2-3: 2014) specifies the capacity limitations for shared LV connections. This standard limits households (single phase customers) to 3,5kW/household distributed generation (DG) systems. Overly restrictive regulations can however limit the extent of PV penetration a network can accommodate. A study was conducted by Eskom, University of Stellenbosch, University of Cape Town, Cape Peninsula University of Technology and City of Cape Town, to determine the limit of PV penetration in urban networks. The purpose of this study was to determine whether NRS 097-2-3: 2014 is too conservative and can be relaxed to enable further uptake of embedded PV systems. To the extreme, the study had to provide answers on whether the City of Cape Town will first run out of roof space, or wires, if no additional investment is made into the LV and MV networks to accommodate DG.

An existing urban network is considered where the PV allocation is randomly distributed and the PV system capacities are restricted by the available roof size.

The study assumes generation back into the network and no battery penetration. It is important to note that reverse power blocking and battery storage will allow for greater PVDG (subject to further study).

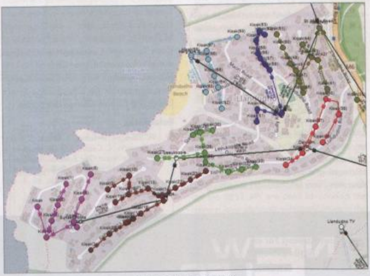

Fig. 1: Residential network [2].

Methodology

Network selection

An actual medium voltage feeder within the City of Cape Town supply area was selected for the study. The selection was based on areas with mainly residential customers, good solar availability, and customers that are highly likely to install solar due to their fairly high property value.

Network modeling

The selected residential network consists of seven separate LV networks, each radially supplied from an 11/0,4 kV MV/LV transformer. Each LV network supplies between 30 and 53 customers. The LV networks are modelled up to the 'kiosks' which are the points of common coupling (PCC). Each property is therefore not individually modelled. The load- and generation profile for each individual property is considered and lumped together, and represented as one LV load and one solar PV system connected to that kiosk. The kiosk is the first point in the network where solar PV distributed generation (PVDG) aggregation occurs, so it is useful to model the system up to this point in order to observe the influences of distributed solar PV generation on all parts of the LV networks. The residential network is shown in Fig. 1, where black lines are MV feeders and the round objects are kiosks. The seven LV networks are shown in different colours [2].

It is important to note that no data was available on which property is connected to each kiosk. It was assumed that:

- A property is allocated to the nearest possible LV kiosk.
- Connections are distributed across phases to minimise numerical phase unbalance.

Load modeling

The loading of individual MV/LV transformers, kiosk or individual LV loads is not available. The half-hourly load data for the MV feeder for 2016, as measured at the HV/MV substation, was therefore used.

The load data at MV level can be de-aggregated to LV customer level using deterministic load flow methods. These methods are mostly inadequate for analysing real power systems, due to uncertainties in power system variables, such as intermittent generation and stochastic customer load variations.

Probabilistic load flow (PLF) techniques can be used to model the uncertainties and provide a set of load flow results more representative of the range of probable network conditions. A probabilistic approach was therefore taken to analyse the network, such that the following non-deterministic characteristics of the problem are taken into account [4]:

- stochastic variability in the load
- variability in the PVDG output

- the uncertainty associated with PVDG location (or uptake).
- the uncertainty of the size of the installed PVDG system despite the knowledge of the maximum solar hosting capacity reflected by the roof-space area.

The first two items are dealt with by the statistical models of load and DG and will be analysed here through the Herman-Beta-Extended (HBE) transform capable of processing random inputs and reflecting the associated uncertainty at the outputs. However, the HBE transform can only calculate feeder voltages given the inputs, which include the location of loads and DG, on top of the other parameters. Consequently, the Monte-Carlo Simulation (MCS) is used for the process of random PV sizing and location.

The Western Cape Electrical Reticulation Technical Standards (a CCT internal document) that defines the estimation of the load variance associated with a given ADMD for residential customers was used to derive the statistical models. The probability distribution of the load currents, assuming a beta pdf with a scaling factor taken as the circuit breaker size (Cb) of 80 A (as is the norm for higher LSM customers), is defined by the shape parameters α and β [4].

Table 1 provides the results of the calculation, specifying the beta load parameters for each feeder for winter and summer.

Trfmr Name	ID	Rating [kVA]	Deaggregated Group Load Characteristics			Statistical Load Characteristics per household						
			Allocated Summer Demand [kVA]	Allocated Winter Demand [kVA]	Total Cust.	Summer ADD [kVA]	Winter ADMD [kVA]	CB limit [A]	Summer		Winter	
									α	β	α	β
Sunset Rocks		500	55.64	145.84	38	1.546	4.051	80	1.083	11.812	1.445	5.118
Fisherman's Bend		500	97.67	256.00	55	1.776	4.654	80	1.173	10.980	1.420	4.194
Leeukoppie		500	80.51	211.03	45	1.789	4.690	80	1.178	10.932	1.418	4.146
Oakburn		315	41.21	108.01	30	1.374	3.600	80	1.003	12.431	1.446	5.945
St. Mark's		500	72.03	188.80	46	1.566	4.104	80	1.092	11.738	1.444	5.029
Llandudno		800	80.51	211.03	53	1.519	3.982	80	1.072	11.908	1.446	5.237
Hargrave		315	101.22	265.30	44	2.300	6.030	80	1.317	9.217	1.296	2.658

Table 1: Load characteristics for LV feeders [4].

Direction	Area (m^2)	Percentage (%)	Installable capacity (kW_p)	Predicted energy production (MWh/year)
North	5 703.1	15	1012.5	1638.9
North East	2 433.1	6.4	432.0	660.7
North West	5 349.1	14.1	949.7	1490.6
East	2 386.9	6.3	423.8	575.6
West	5 039.6	13.3	894.7	1255.3
South West	3 931.6	10.4	698.0	838.1
Flat	13 090.8	34.5	2324.1	3306.1
Total	**37 934**	**100**	**6734.8**	**9855.2**

Fig. 2: Process of determining the maximum solar hosting capability of each property.

Generation modeling

PVDG is randomly located on the network, considering the node and phase of placement. Further, the allocation process is bounded by two factors; the desired penetration level, and the maximum solar hosting capability (MSHC) of a given node and phase, which depend on the MSHC of the respective properties connected to that point. To determine the MSHC of a given node, GIS software was used to determine the available roof space of each property, aggregated to each kiosk. The orientation of the roof was also considered. The process of determining the maximum solar hosting capability of each property using GIS software is shown in Fig. 2. The MSHC is then determined by the available roof space and the customer circuit breaker limit (80 A for single phase residential customer with a high LSM).

Simulation methodology

For the purpose of this study, the PV penetration is defined by the following equation:

Where:

$$\%\,PV\ Penetration = \frac{\sum_{i=0}^{N} PV_{Rated\,i}(kW)}{Feeder\ MD\ (kVA)} \times 100\%$$

$\sum_{i=0}^{N} PV_{Rated}$: Total PV capacity installed on the feeder;

Feeder MD: The maximum load that the feeder can supply before network violations (voltage or thermal) occur.

The simulation methodology followed is described in the steps below [4]:

- Load the feeder identified with the winter load model derived earlier for that feeder, and calculate the voltage profile on the feeder, applying a 10% risk (90% confidence interval) to assess the minimum voltages.
- Increasing the winter load models, model the feeder's highest passive loading it can supply without violating the design voltage limit (CCT allows 0,92 p.u.). This is termed the Feeder MD and is not the same as the allocated de-aggregated demand supplied by the feeder.
- Using the feeder loaded with the summer load model, randomly (to node and phase, by means of the Monte-Carlo Simulation) allocate PVDG modules on the feeder and calculate the voltage rise and conductor thermal loading conditions represented by a risk level (of exceedance) of 2,5% for the respective limits (1,1 for voltage conditions and 100% for thermal loading). For each scenario calculate the transformer loading.

Repeat this step for an adequate number of placement scenarios; in this study 800 runs.

- Successively add further PV modules, repeating steps c) with each increment, until the feeder is "full", having reached the limit imposed by the circuit breakers of all households.
- Plot the results of calculated voltages, line currents and transformer loading for all scenarios against the penetration ratio on a scatter plot. Derive the maximum hosting capacity of the feeder for both voltage rise and conductor thermal loading, again with a selected confidence risk; in this study a further 2,5%.

Results

The scatter plots of maximum voltages and currents (at 5% risk applied in the HBE transform) are shown in Fig. 3. The red line in the voltage graph and the blue line in the current graph indicates the 95% confidence level, with only 5% of the simulations having a voltage / current above the red line. As more simulations are done, the envelope looks fairly similar, but the 95% confidence line becomes smoother.

The maximum allowable penetration without violation is about 64% (the feeder being thermally constrained). Beyond this penetration level, the proportion of scatter points above the limits increases although, at the same time, placement scenarios that result in maximum voltages and currents within the regulatory limits exist. In this analysis, considering the stochastic variance of the load, the feeder gets full with PVDG at about 420% [4].

Several conditions of PVDG limits were investigated in steps of 2,9 kWp systems (1 PVDG system) until the circuit breaker limit of 80 A is reached. For this example, the limit was reduced to 75,65 A to accommodate six 2,9 kWp PV modules or 17,4 kWp per property. However, if this limit is higher than the maximum capacity by roof space, then the latter is used. The scatter plots for maximum voltages and currents are plotted in Fig. 4.

Looking at the marked 5% risk lines of maximum voltages, a common trend is observed. The envelope of voltages starts off with a positive correlation with PVDG penetration. The trend increases almost linearly until it approaches the 'filling' penetration (for an imposed constraint) and the trend of high voltages starts to decrease because the extreme placement combinations reduce as the feeder fills. For the full feeder, the variable random unbalance between PVDG module disappears. Moving from each penetration constraint to another, the feeders fill at different penetration values. The same applies to the envelopes of currents.

When the restriction is set to 2,9 kWp/hh, the maximum penetration of about 70% is achieved without any conditions of voltage or thermal violations. Increasing the uptake limit to 5,8 kWp/hh achieves an increased penetration of about 140% also without any violations. However, the limit of 8,7 kWp (~50% of the circuit breaker limit) introduces violations both for voltage and thermal conditions. Nonetheless, the proportion of voltages and currents above the regulatory limits is very low, and so is the extent of the violations.

As the uptake limit is further relaxed, the density of voltages and currents above the limits increase. For all cases above the 8,7 kWp limit, the allowable PVDG penetration without violations is between 65% and 70%.

From the results obtained for this particular feeder, it can be seen that a limit between 5,8 kWp (2 PVDG systems) and 8,7 kWp (3 PVDG systems), of about 7 kWp, would achieve penetrations up to 175% with 0% chance of violation (based on a 5% risk). Accordingly, the recommended uptake limit per household, avoiding mitigation measures or network reinforcement costs, for this feeder would be 7 kWp/household. However, the plots in Fig. 4 for the 8,7 kWp case (yellow trace) also show that a penetration level of up to 210% is achievable with minimal mitigation measures; the latter being as a result of the minimal extent of violation (magnitude of violation voltage and currents, and the density or chance of occurrence).

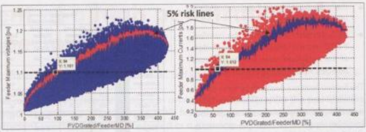

Fig. 3: Maximum voltages and currents on test feeder with increasing PVDG penetration: Stochastic loads.

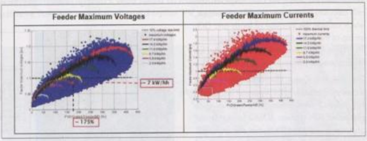

Fig. 4: Practical limits of installed capacity.

Conclusions

The following can be concluded from the study:

- Roof space exceeds the capacity of feeders, i.e. the City of Cape Town will run out of wires, long before all rooftops are covered with PV systems.
- Limiting households to about 7 kW per household (for a single phase 80 A customer breaker) increases the overall hosting capacity of the network. This is more than the NRS limit of 4,6 kW per household.
- Voltage rise limits on active feeders must consider correlated voltage rise on MV feeders:
- 45% – 60% PV penetration if 7% LV voltage rise is allowed (limiting LV voltage rise to 7% above nominal; allows for correlated MV voltage rise of 3%)
- 10% – 20% PV penetration if only 4% LV rise is allowed
- Some passive feeders are already overloaded and not all DG alleviates overloading, but it depends on its location:
- Thermal limits on PV depend on the margin of the passive feeder
- Every proposed installation would have to be studied before approval is granted.

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Solar PV investment decisions in the residential sector in SA: A technical analysis

by Nikkie Korsten and Karin Kritzinger, Stellenbosch University and Centre for Renewable and Sustainable Energy Studies; and Louise Scholtz, Urban Futures WWF-SA

The traditional model of energy provision by South African municipalities is being challenged by the increased uptake of small scale embedded generation (SSEG), mostly in the form of rooftop solar photovoltaic (PV) installations. These installations impact the existing municipal electricity business model and it is becoming increasingly important for municipalities to understand the drivers for the investment decision behind these installations in order to respond effectively.

The impact on the South African municipal business model, potential solutions to address it, as well as municipalities' role in the local renewable energy transition, have been studied extensively. In particular, many reports, articles and conference papers have been published that focus on the resultant threat to Eskom and municipal electricity income and the looming "death spiral" (Beer, Merwe & Merwe, 2018; Janisch, Euston-Brown & Borchers, 2012; Korsten, Brent, Sebitosi & Kritzinger, 2017; Kotzen, Raw & Atkins, 2014; Lekoloane, Wright & Carter-Brown, 2018; Mogemba, Jaarsveldt & Evert, 2017). In spite of this attention, there is still no clear-cut guide to follow to tackle this issue. Over and above general fatigue related to the issues raised above, it could also be because officials feel overwhelmed by the complexity of the problem that has no simple and implementable solutions, due to the interconnectedness of many factors.

What is clear is that rooftop PV reduces electricity sales of the utility and thus the income municipalities derive from sales. The challenge, however, is that this reduction in income does not necessarily go hand in hand with an equal reduction in the costs of electricity provision. Many South African municipalities have responded to this challenge by implementing rooftop PV policies, including tariff structures, to accommodate rooftop PV owners for supplying electricity to the grid and at the same time to safeguard municipal revenue. While this provides some operational comfort, it does not adequately address the future impacts of these installations which remain a pressing concern to municipalities.

Internationally, utilities have taken measures to both facilitate decentralised renewable energy as well to safeguard their own finances such as tariff changes to counter the negative financial impact. National government bail-outs of utilities under financial stress are, of course, also possible to prevent their financial collapse. However, in the South African context, the municipal concerns are different. Even though we

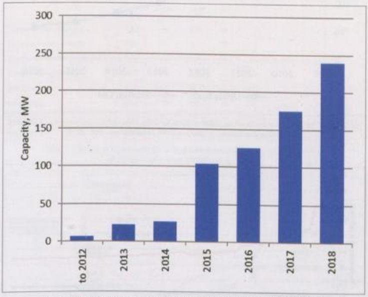

Fig. 1: Additional rooftop PV installed in South Africa up to 2018 (from AREP, 2019).

can learn from international best practise, appropriate interventions might look different in South Africa. It is therefore important to understand this problem in the local municipal context as well as to understand rooftop PV investment decision-making from the South African electricity consumers' perspective.

This paper contributes to existing knowledge by mapping out the South African energy transition, based on a household rooftop PV investment survey, conducted by WWF-SA and Stellenbosch University in 2018 (Korsten, Kritzinger & Scholtz, 2018) with a system dynamics modelling (SDM) approach. The South African case is contextualised and compared to investments in rooftop PV as well as the electricity tariff environment in Germany. Given the ability of SDM and specifically causal loop diagrams (CLD) to enhance in-depth understanding of causal relations within complex systems, it is an appropriate methodology to inform policy makers what interventions they could use to develop desired energy transitions scenarios (Qudrat-ullah, 2013). SDM has additionally been used in many studies to understand the complex dynamics in the energy and electricity sector (Ahmad, Mat, Muhammad-Sukki & Bakar, 2016).

Background

Electricity customers in South Africa are increasingly investing in rooftop PV (see Fig. 1). This is due to a combination of factors; the falling cost of the technology (see Fig. 2), the rising cost of electricity (Gucciardi Garcez, 2017; Islam & Meade, 2013) and continued load shedding (Korsten et al., 2018). The disruptive effects of this technology on a once robust and predictable electricity system are well known. South African municipalities, who are responsible for managing electricity service delivery, are feeling the consequences and some of them have taken measures to prevent potential

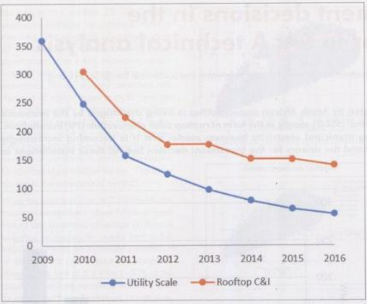

Fig. 2: LCOE for solar PV in South Africa, 2009 to 2016 for utility scale and for commercial and industrial (C&I) rooftop installations, in USD per MWh (adapted from DoE, 2018).

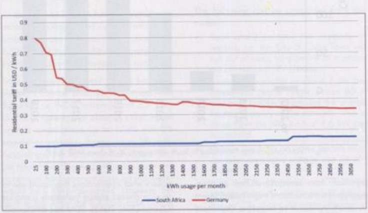

Fig. 3: Average household electricity tariffs in South Africa and Germany.

revenue erosion by implementing rooftop PV tariffs (Korsten, Brent, Sebitosi & Kritzinger, 2017; Kotzen, Row & Atkins, 2014).

While some residential electricity customers in South Africa are charged monthly set charges, the bulk of their electricity bill is made up of active energy charges (in kWh). It is also quite common in South Africa for municipalities to charge residential customers at an inclining block tariff (BiT), with low electricity users paying less than higher users. Indigent customers are also often provided with free basic electricity, and are charged at even lower rates for their electricity usage.

The practice of charging electricity customers largely for their active energy use leads to a fallacious belief on the part of consumers that their cost to the utility is accordingly reduced when they use less electricity. The utility cost, however, is not necessarily reduced in line with the lower active energy use. In addition the utility has to provide all customers with electricity when and if demanded. When a higher set tariff is charged, with an accordingly lower active energy charge, it limits the ability of the consumer to reduce the electricity bill by energy efficiency or rooftop PV and might in fact lead to higher electricity consumption. Thus, even though a higher set charge might be more cost reflective and economically appropriate to a utility, electricity tariffs evoke a behaviour response. The message received by customers from this tariff regime is that electricity saving as well as investments in energy efficient equipment and rooftop PV are actively discouraged.

Fig. 3 provides the average electricity tariffs in South Africa and Germany for different monthly consumption rates. From this it is clear that low electricity users in South Africa are charged a lower tariff than in Germany. In Germany, the set charge and the active energy charge are relatively constant, resulting in low electricity users paying substantially more per kWh than high electricity users. German households also have a number of electricity providers to choose from, leading to competition in electricity tariffs.

Stellenbosch case study

This challenge is clearly demonstrated when one looks at the data from Stellenbosch Municipality, a well-run, mid-sized municipality in the Western Cape.

With a Gini-coefficient of 63, South Africa is regarded as one of the most unequal countries in the world (World Bank, 2018). According to a study conducted by Orthofer (2016) the wealthiest 10% own around 90% of all wealth in South Africa while the poorest 50% earn only about 10% of all income and don't own any measurable wealth (Orthofer, 2016). This results in differences in economic purchasing power and affects the economic accessibility to basic goods such as electricity.

In terms of Section 152 of the Constitution of the Republic of South Africa, 1996 (Republic of South Africa, 1996), municipalities have a mandate to ensure the entire community within its jurisdiction is serviced in a sustainable manner. In order to do this, the municipality has to ensure it manages its finances well. This is documented in the Municipal Finance Management Act 56 of 2003 (MFMA) and the Municipal Systems Act 32 of 2000. The control of keeping up to the mandate of sustainable service delivery is weakened as more actors, in particularly high electricity consumers, are becoming co-producers of electricity that is used to generate the revenue to pay the costs of electricity service and to cross subsidise low tariffs for low income consumers.

The extent of both the contrast in electricity consumption and the extent of cross-subsidisation required are demonstrated for a municipality such as Stellenbosch Municipality is demonstrated in Tables 1 and 2. The tables show the differences in average and maximum electricity consumption per neighbourhood in Stellenbosch. When looking at the average pre-paid consumption in Table 1, citizens living in Kayamandi are using on average 156 kWh per month. This stands in stark contrast to households living in Uniepark and Karindal who consume 1071 kWh on average. Table 2 shows an even starker contrast in electricity consumption levels. Of the 160 meters located in Uniepark and Karindal, 106 consume more than 600 kWh per month. Despite Kayamandi having 1287 meters, only 19 of them consume more than 600 kWh per month.

Understanding the complexity

The paper has already alluded to the complexity of the problem and why mere tweaking of tariffs, whilst addressing short term revenue concerns, is not an adequate long term response. In the main this complexity relates to the increase of privately owned generation in the electricity system, which introduces a set of variables that falls outside the ambit of municipal control. These are explained in more detail below.

The causal relationship between variables in the municipal electricity system is depicted with a CLD in Fig. 4. Endogenous variables that influence the adoption of rooftop PV as well as the variables that impact the ability of the municipality to deliver electricity services in the future, are represented here.

R1 affordability loop

Rooftop PV is becoming more affordable to households. However, affordability is not only determined by the cost, but also by the economic status of households. This is an exogenous variable that cannot be influenced by the municipality, but that influences rooftop PV adoption. However, increasing investment in rooftop PV can reduce the installation cost, making it more affordable to more people.

R2 revenue generation loop

If the price of electricity goes up, at some point households will reduce consumption, which means the municipality loses sales on electricity, impacting its revenue. To counter this, the municipality will increase the electricity tariff in an attempt to compensate for this loss of revenue. Increased electricity prices in return leads to reduced electricity consumption.

R3 quality of service delivery loop

Rooftop PV adoption will lead to reduced electricity consumed from the municipal grid, resulting in a loss in revenue for the municipality. Grid maintenance and new investments in electricity services then become harder to justify financially, leading to the quality of service delivery being compromised. This reduction in the quality of municipal services might lead to the electricity grid becoming unreliable, resulting in households investing in rooftop PV to become more self-sufficient in their electricity provision.

	Credit	Prepaid	Credit	Prepaid	Credit	Prepaid
Uniepark and Karindal	1107	1071	9750	9080	79 103	44 550
Dalsig and Brandwacht	1048	963	7725	10 895	71 300	78 998
Die Boord and Paradyskloof	881	854	10 924	15 774	100 919	76 505
Onder Papegaaiberg	726	597	5032	50 645	36 379	17 588
Welgevonden	0	518	0	3117	0	18 786
Idas Valley	653	483	4518	3790	40 283	30 247
Cloetesville	571	242	6678	2648	21 529	19 647
Kayamandi	422	156	1198	2679	10 593	16 235

Table 1: Average and maximum consumption in different neighbourhoods (Korsten et al., 2017).

Suburbs		Electricity consumption (kwh)						
	No. of meters	>600	>1000	>2000	>3000	>4000	>5000	>10000
Uniepark and Karindal	160	106	73	34	18	8	6	0
Dalsig and Brandwacht	163	95	71	28	9	7	3	1
Die Boord and Paradyskloof	569	340	209	67	25	10	8	1
Onder Papegaaiberg	159	75	33	3	1	1	1	0
Welgevonden	546	258	63	3	1	0	0	0
Idas Valley	346	118	34	3	1	0	0	0
Cloetesville	728	197	37	1	0	0	0	0
Kayamandi	1287	19	12	1	0	0	0	0

Table 2: Number of households per suburb with a pre-paid meter installed and their electricity consumption (Korsten et al., 2017).

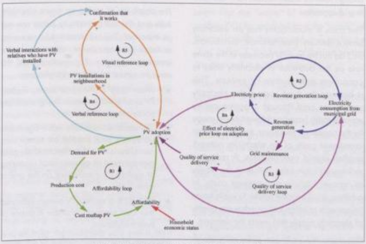

Fig. 4: CLD of impact of rooftop PV on municipalities.

R4 verbal reference loop

More conversations with people who have installed PV leads to a stronger confirmation that the installation of rooftop PV is worthwhile leading to an increase in rooftop PV adoption.

R5 visual reference loop

More rooftop PV installations in a neighbourhood results in a visual confirmation that these system are worth investing in.

R6 effect of electricity price on adoption loop

Higher electricity prices leads to more people seeking to reduce their electricity bill. One response is to invest in rooftop PV.

Making sense of the complexity

In Fig. 5, a CLD is presented that shows the disruption that rooftop PV could have on the electricity business model of municipalities. Electricity consumers, who used to contribute to municipal revenue from electricity sales, are now generating electricity for their own use, reducing the kWh bought from the municipality. The self-generation and consumption of electricity by households reduces the ability of the municipality to

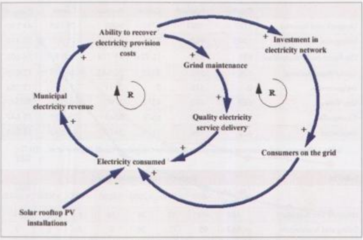

Fig. 5: Rooftop PV as a disruptive force in municipal electricity service.

recover costs of the electricity service. In order to recover the costs of the electricity service the municipality needs to make sure that enough revenue is collected to at least break even. This could be done by either selling more electricity or by increasing the tariff to existing customers. Enough revenue is also needed for investments in grid upgrades.

The costs a municipality has on electricity service delivery (maintenance, distribution, etc.) do not necessarily decrease at the same rate as the decrease in electricity sales to consumers with rooftop PV systems. This is because the fixed costs of the electricity service are paid through charging mainly variable tariffs based on kilowatt-hours usage by the consumer. Moreover, the high upfront investment costs of an electricity network is often repaid over decades. A reduction in kilowatt-hour sales will limit the ability to recover historic and present costs. In addition, it will become harder to justify future investments to safeguard an adequate quality of electricity supply that meets the demand.

This phenomenon, known as the utility "death spiral" has been well documented. However, context matters. As mentioned before, the "death spiral" in developing countries is different from that in developed countries, where there is a larger middle class who might be able to absorb the increased electricity prices. Given the lack of a "fat" in the system in a country such as South Africa, municipalities require a much more granular understanding of the drivers of both existing and future investment in household rooftop PV. In order to understand the investment decisions of PV owners and potential PV owners within the South African context, a national household survey was conducted in 2018 by WWF-SA and Stellenbosch University.

The main survey conclusions were that the investments are mainly financially driven, coupled with a fairly strong influence of the social environment of the potential rooftop PV investors. The high upfront cost was indicated as the biggest financial limiting factor for those who have not invested in rooftop PV yet and the possibility of saving on future electricity bills and the rising electricity prices are not as important. This indicated that future saving is not as important as the upfront cost in the investment decision. For municipalities, the most important take-home insights are:

- When costs of PV come down, rooftop PV uptake will increase. Rising electricity prices plays a lesser role.
- The social environment has a significant influence and should be taken into consideration for technical grid management as geographical clustering of rooftop PV installations on the grid is most likely.
- Only 25% of rooftop PV owners indicated that their electricity provider is aware of their installation.

Moreover, investments in rooftop PV are reliant on the ability to pay the high upfront costs, leading to investments by households with a higher disposable income. These households are also most often high electricity consumers who pay higher active energy charges. It will thus be the households in the highest income bracket who will first invest, as the initial investment costs is not so important to them. This phenomenon is also seen in practice.

Following the high income households will be investment by the middleclass, largely driven by increasing electricity prices. People who cannot afford the technology are excluded from making the investment, are thus unable to access the long term financial gain and are destined to use electricity from the grid that is increasingly becoming unreliable, expensive and inaccessible. Furthermore, even though rising electricity prices impacts the poor the most, they are excluded from investments in rooftop PV, and high electricity prices might even lead to them substituting electricity with other, dangerous and/or unsustainable energy sources.

Frequent load shedding also increases investments in rooftop PV as households are seeking self-provision of electricity. Almost 70% of the people who completed the *Household Rooftop PV* survey (both those who already have PV installed and others) indicated that not trusting the government or Eskom is a clear motivation for them to seek alternative and independent ways of energy provision (Korsten et al., 2018).

As people are influenced by their social environments (Korsten et al., 2018), this could lead to a clustering of rooftop PV in certain neighbourhoods and a non-linear, mushrooming effect on the uptake of the technology. This will exponentially increase the impact of rooftop PV over time.

The aforementioned blend of factors has financial, technical as well as governance implications for electricity service provision for municipalities in South Africa. In addition to the already mentioned issue of non-alignment between the cost of electricity provision and the reduction in income due to decreased sales, the lost electricity sales due to rooftop PV installations in South Africa is mainly from wealthier electricity consumers who can afford the upfront costs of the rooftop PV investment. These consumers are also most often high electricity consumers who consume electricity at higher tariffs and subsidised thee free basic allocation to indigent households. For high electricity consumers, it makes sense to reduce high electricity usage by investing in rooftop PV.

The loss of high electricity users in the South African context has implications. Firstly, high electricity consumers are often responsible for a higher share in revenue generation from the residential sector (Kotzen et al., 2014). Secondly, municipal efforts to keep prices low for low electricity users, mostly low-income electricity consumers, through a BiT, are now compromised. The BiT tariff evolved from an interim measure to protect the poor against the steep electricity price increases from 2010.

The BiT allows for cross-subsidisation from high electricity users to low electricity users, and is thus used as a financial mechanism to create more egalitarian access to electricity (AMEU, 2016). If the total electricity provision cost is not absorbed by increased tariffs, this burden might unfairly fall onto low electricity consumers, due to prices for all consumers increasing even more because affluent households are opting out of the common electricity grid.

Interventions and unintended consequences

In order to counter the effect of revenue loss and unfair cost distribution to non-PV owners, municipalities can implement "decoupling mechanisms" to break the link between the recovery of utility's fixed costs and the kWh sales (Eto, Stoft & Belden, 1997; Xue, Sullivan, Peltola, Peters & Leiber, 2014). One revenue decoupling mechanism is the increase of fixed tariffs for rooftop PV owners. Certain South African municipalities have a fixed electricity charge for high electricity consuming households only. If such households reduce their electricity consumption (for instance by installing rooftop PV), then the municipality not only loses the sale of the higher-tariff kWh sold, but also the monthly set fees. Most South African municipalities that have an SSEG tariff for rooftop PV owners have introduced an extra monthly set charge for these households, sometimes over and above the already existing set charge. South African municipalities also typically have different and separately measured tariffs for import and export of electricity for households with rooftop PV.

The introduction of a fixed monthly fee for rooftop PV owners might, however, lead to unintended consequences. The *Household Rooftop PV* survey showed that only 25% of respondents that have rooftop PV and who are consequently importing and exporting electricity at the new tariff rate have registered their system with their utility. The other 75% of survey respondents indicated that their utility is not aware of their rooftop PV system (Korsten, Kritzinger & Scholtz, 2018). This might indicate that rooftop PV owners are dissuaded to register their systems by what they conceive as a penalising SSEG tariff setting. In this case, the introduction of a fixed tariff to counter revenue erosion is an example of a "fixes that fail" archetype (see Fig. 6). The unintended consequence of the fixed tariff is that rooftop PV owners avoid registration and when forced to register, they might disconnect from the grid altogether.

In addition, households with rooftop PV could in the future invest in mini-grids and so collectively disconnect from the municipal grid. This would create islands in society in which households with the economic power can invest in private electricity generation and distribution. Municipalities are then left with a consumer base that is less able to absorb higher electricity prices.

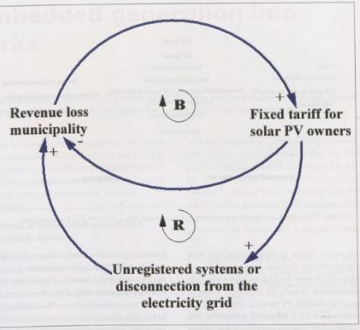

Fig. 6: Fixes that fail archetype: implementation of fixed tariffs.

The municipal governance of electricity service delivery and the financing system that worked well for decades is being disrupted with installations of rooftop PV that challenge the governance of the municipality. On the face of it, it seems as if the municipality and households with rooftop PV have very different wants with respect to rooftop PV. This is emphasised by the resistance to register household rooftop PV systems at the municipality and a general distrust from both sides.

The City of Cape Town launched an initiative at the end of 2018 urging rooftop PV owners to register their systems with the metro. This initiative came with a strict warning that failing to register will lead to being cut off from the electricity grid and a hefty fine of over R6000. Although the initiative received a reasonably good response, by August 2019 only an estimated 50% of households with already installed rooftop PV had applied to the City to register their systems.

This initiative is perceived in the press as an unnecessary and aggressive action, implemented without inclusive dialogue or informatively communicating the reasons for their actions (Businesstech, 2018; Caboz, 2019a,b; Keli, 2019; Sicetsho, 2019).

Municipalities and citizens function in an environment where sustainability, including the transition to a more sustainable electricity system is the end goal. So, although it may seem that the "wants" of households with rooftop PV is far removed from the "wants" of the municipality, this arguably may not be the case. In Fig. 7, the "wants" of the two parties are depicted in a Venn diagram.

From this image, it is quite clear that there is agreement on most aspects. The two parties already have a strong common ground on; wanting a technically stable and safe electricity system with no power interruptions: wanting to be seen as innovative, "green" and "good"; good governance; and a firm belief that rooftop PV is part of the future. This strong common ground might indicate that communication, including understanding of the impact of rooftop PV and the importance of registrations might resolve the matter in a more amicable way than with aggressive fines. Now might be the time to start a dialogue around the common ground of the "wants" to find the "hows" that benefits all fairly.

Conclusion

This paper discusses the unique South African municipal environment in the context of household rooftop PV installations and aims to understand the investment decision-making process from the household perspective. Municipalities and households alike view rooftop PV as a green, good, local and sustainable alternative to the remote generation of Eskom's coal-based electricity.

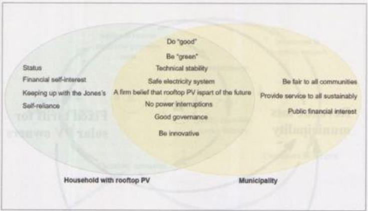

Fig. 7: Venn diagram depicting the "wants" of households with rooftop PV and the municipality.

However, there is little consensus how decentralised rooftop PV can support a win-win situation for both municipalities and households. In fact, the individual financial gain of rooftop PV owners often does not coincide with a financial benefit to the wider public. On the contrary, in the current South African tariff regime (excluding specific SSEG tariffs), it comes as the cost to the greater society, benefitting those that can afford investment in PV systems over those that cannot. This conflicts with the South African constitution that determines that electricity provision is a municipal mandate with no room for private sector engagement. In addition, municipalities have a responsibility to service all citizens in a fair and sustainable manner.

Internationally, government bail-outs, subsidies and electricity tariff regimes were often used as solutions to facilitate decentralised renewable energy, whilst safeguarding the utilities' finances. A similar implementation might not, however, work in the South African municipal context; the economic composition of the society is different with a smaller pool of tax-payers and a smaller pool able to absorb the costs of decentralised renewable energy.

It is clear that both South African municipalities and society at large want local decentralised rooftop PV. The way in which it is implemented currently, however, is often in conflict with the responsibility of a municipality to care for a common good. Fearing non-compliance with the municipal mandate, an aggressive approach is used by some municipalities to enforce rooftop PV registrations and shift these customers to an electricity tariff structure that safeguards municipal finances. This tariff structure, however, might not benefit the rooftop PV investor resulting in an avoidance of registration for personal financial gain.

Even though both municipalities and society at large want localised renewable energy that is reliable, there is, however, no common understanding of how this transition should be implemented in a financially and technically sustainable manner that benefits the entire community within the municipal area. In a pervading climate of aggressive stand-offs between municipalities and rooftop PV owners, this paper starts outlining a process of open dialogue between two parties (who already have a common goal and building on common "wants"), on how to implement local renewable energy in a financially viable, technically stable and safe manner.

Acknowledgements

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Incorporating embedded generation into municipal networks

by Poonam Lutchman, Schneider Electric

The demand for electricity consumption is expected to increase by 57% by 2050. This poses a dual challenge: There is a need to meet the increased demand for power while at the same time decrease carbon emissions.

Governments around the world have supported the Paris Agreement (COP 21) with the ambition to limit the global rise in temperature to below two degrees Celsius above pre-industrial levels. As a result of this, more countries are moving towards renewable energy as a carbon free alternative to providing electricity. According to a report by BP, electricity generation increased by 3,7% between 2017 and 2018 with renewables accounting for a third in the net increase followed by coal and natural gas [2].

Along with these challenges comes opportunities for transformation. The conventional power system is evolving. In a conventional power system, power is generated using centralised large-scale power plants and distributed to the end user on the demand side. In recent years this model is changing because of new technology advancements in renewables, the need for resiliency, the declining cost of distributed energy resources (DERs) and new smart grid technologies [3]. Globally the power industry is facing a transformation towards a more decentralised and decarbonised grid.

The economic viability for traditional forms of energy like coal and natural gas are declining. Consumers are looking for alternate forms of energy and are starting to generate their own energy for consumption and hence becoming prosumers [4]. Having onsite generation is desirable for security of supply, flexibility and moving towards a green economy [5].

This trend can also be seen in South Africa. Currently the falling cost for solar photovoltaic (PV) panels has been a key driver for embedded generation. Small scale embedded generation is on the rise as an alternative to electricity from the national grid [6]. The term embedded, or distributed generation is any form of generation which is connected to an electrical distribution network. These often include renewables, gas, fuel cells or cogeneration. This model of embedded generation into the electrical network is disrupting the conventional form of energy. Prosumers are causing utilities and municipalities to sell less electricity thus affecting their revenue stream whilst still having fixed costs.

This paper looks at the current state of embedded generation in South Africa, its market drivers and financial implications for municipalities. It also looks at the possible ways for municipalities to reduce the financial impact caused by privately owned microgrids and generate sustainable revenue in the process.

Status of embedded generation in South Africa

Electricity used in South Africa is generated predominantly by the national utility Eskom via centralised coal fired power stations. The current electricity supply chain is vertically integrated with municipalities purchasing electricity from Eskom and retailing it to end customers. Municipalities account for about half of the national energy consumption [7].

In recent years, the country has seen an increase in the number of embedded generation installations mainly attributed to the increase in demand for PV roof top systems [8]. In 2017, there were 90 260 roof top solar PV projects installed and commissioned totalling approximately 180 MWp with additional 48 067 projects identified but not yet commissioned. This is a significant jump compared to the 35 MW installed in 2016 [8, 9]. There has also been an increase in partnerships offering embedded generation to end customers using power purchase agreements (PPAs). In August 2019, Nedbank together with African Investment (company) partnered with SOLA, a company focusing on PV and storage solutions, to finance and build 40 MW of Solar PV across the country. Customers will pay for energy usage directly via PPAs. The proposed tariff rate from this agreement is expected to be 20% cheaper compared to Eskom and municipal rates [10].

Changes in national and local policy are also making it easier for companies to develop and offer embedded generation solutions to end customers.

The Integrated Resource Plan (IRP) which is the energy blueprint for South Africa makes provision for embedded generation. The draft IRP currently makes provision for 200 MW. On 2 May 2019 the ministry of energy sent a letter to the National Energy Regulator of South Africa (Nersa) granting a deviation from the existing IRP for licensing operation of generation facilities ranging from 1 MW to 10 MW, with a limit of 500 MW annually applicable for own use generation [11].

Factors influencing the increase in embedded generation

Several factors are driving growth in embedded generation in South Africa. These include the rising electricity prices from the central grid,

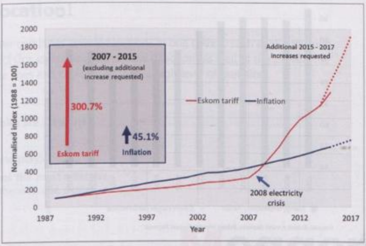

Fig. 1: Eskom tariff increase vs. inflation [13].

declining costs of renewable energy and the need for a more sustainable and reliable electricity supply [8, 12].

Electricity prices in South Africa

Over the last 15 years, electricity prices have increased by more than four times the rate of inflation [8]. Fig. 1 illustrates the electricity price tariff vs. inflation between 2007 and 2015 [13].

This trend is expected to continue. Nersa approved a 12,8% tariff increase (9,41% tariff increase with a 4,4% regulatory clawback) for 2020 and 8,1% and 5,1% stipulated for 2021 and 2022 respectively [14]. The clawback is part of the Multi Year Price Determination (MYPD) methodology by Nersa and allows Eskom to adjust for over or under recovery of revenue in any year of a tariff decision [15].

Eskom has suffered a financial loss of R21-billion in the 2018/2019 fiscal year which is almost an 800% increase in losses compared to the same period in 2017. Eskom is thus looking to recoup this loss and hence are challenging Nersa for an 80% increase in 2020 [16].

Sustainability and the declining cost of renewables

The 2015 Paris Agreement was a crucial driving factor for scaling up the use of clean energy technologies for embedded generation hence renewable energy technologies are featured predominantly on national policies. South Africa is one of the signatories to the Paris agreement and has committed to add 20 GW of renewables to the grid which represents 40% of the total generation capacity [6].

Renewables were initially supported by feed-in tariffs, however this soon changed with the falling cost of renewable energy. Prices has been dropping since 2010. The global average price for solar PV in 2016 was R1,78/kWh compared to R4,74/kWh in 2010. This represents a 62,5% decrease in six years. The same trend can be seen in South Africa [17].

Year	Period	Causes and Comments
2007/2008	Nov – Jan	Increased demand for energy resulted in the first spells of load shedding for the country.
2014	March	Depletion of coal stockpiles and the tripping of three generation units
2015	Jan – Sep	Maintenance backlog issues caused 99 days of load shedding in the country
2016		Although unplanned outages were reduced, there were still pockets of load shedding
2018	June	Stage 1 Load shedding – unexpected number of unplanned outages
2018	Nov – Dec	Stage 2 Load shedding – plant breakdown
2019	Feb	Stage 4 Load shedding – high number of plant breakdowns
2019	March	Seven consecutive days between Stage 2 and Stage 4 load shedding – high number of plant failures

Table 1: History of load shedding in recent years [18].
Note: Stage 1 allows for up to 1000 MW of the national load to be shed. Stage 2 allows for up to 2000 MW of the national load to be shed. Stage 3 allows for up to 3000 MW of the national load to be shed. Stage 4 allows for up to 4000 MW of the national load to be shed.

Fig. 2: Energy availability factor [14].

Need for resilient and secure power

In recent years South Africa has experienced significant spells of load shedding. This started predominantly in 2008. Table 1 provides a summary of the load shedding status in the country since 2008 [18].

Energy availability in South Africa is currently not where it should be. Although energy sales have fallen, and Eskom has capacity to meet the current demand but is not able to do so due to maintenance or breakdown issues. The company currently has 47 000 MW of installed capacity with an availability factor of only 66,8%, meaning that only 32 000 MW is available. The optimal availability factor that the company should have is 80%. Fig. 2 illustrates the availability factor from 2007 to 2018 [14].

It is thus expected that load shedding will continue to remain a possibility in the foreseeable future.

Impact of embedded generation

The increase in embedded generation has resulted in fallen energy sales from the national grid, which impacts revenue to municipalities and in turn Eskom. Embedded generation also results in increased pricing of electricity from the central grid which increases non-technical losses and may lead to a death spiral which impacts all stakeholders.

Energy sales

Fig. 3 illustrates the decrease in energy sales in South Africa. Embedded generation is one of the causes, though not the only one. Other reasons include lower economic growth and energy efficiency projects.

Demand profile and revenue impact

Municipalities are responsible for approximately 40% of electricity distribution in South Africa. They purchase electricity in bulk from Eskom which they mark up and sell to the end user [12]. They buy electricity on a time-of-use (TOU) tariff and sell at a flat rate to the end user [19]. The TOU applies different charges at different times. Most municipalities use the Eskom Mega-flex tariff that has a substantial price difference during peak and off-peak periods, peak tariffs are approximately 15 times more than off peak tariffs. [20]. Fig. 4 illustrates the profits generated during different time periods [20]:

Residential used of electricity represents about 18% of electricity demand, however at peak times it can be over 35% of the total demand. At present municipalities are supplying electricity to residential customers a loss due to standard fixed pricing. The loss at peak times are not fully recovered during standard and off-peak times. Higher tariffs mean that users are looking to save electricity via solar geysers and PV installations. Savings are achieved during standard and off-peak times where surplus are generated to cross subsidise the peak tariffs. Hence the losses during peak times (early morning and evenings) are expected to continue.

The increase in embedded generation results in an unpredictable altered electricity demand profile [21].

A study by Kotzen, Raw and Atkins in 2014 focused on the impact of solar PV on profit margins in municipalities. They modelled the PV load profile and compared it to residential power usage and time of use tariffs. The results indicated that up to 97% of the energy is generated between 09h00 and 18h00. The study indicated that given the electricity gross profit profile, solar generation only affects profits earned during sunshine hours. Only off-peak time gross profits are not affected by solar generation. The study indicated that most solar is produced during the standard billing time for municipalities. This equates to up to 60% of loss of profit for municipalities from customers that have installed solar PV systems [19].

Electricity sales cross subsidizes other municipal expenses and uses the net surpluses generated by high-consumption users through an inclined block tariff to subsidies free and low-consumption users. [20]. It is estimated that about 10% of annual electricity revenue generated is used to cross subsidise other important municipal services. This poses a risk as electricity revenue is under strain and high generating customers are looking at ways to spend less [20]. Municipalities are thus expected to run out of funds for other basic services due to loss in electricity revenue and profits.

The Death Spiral

High penetrations of renewables with legal priority over fossil fuels are driving down electricity sales from the central grid. Commercial and industrial customers are going completely off grid globally and in South Africa. This leads to the phenomenon called the Utility Death Spiral. As more consumers move off grid, utilities and municipalities are forced to raise electricity prices to cover fixed costs. This process ultimately repeats itself and results in municipalities and utilities having large overhead costs with not enough revenue to cover them, ultimately leading to "death". It should be noted that during the last five years, the top 20 utilities in Europe have lost half their value to this phenomenon [23].

Jobs and maintenance issues are at stake if municipalities and utilities do act to mitigate against the death spiral, thousands of jobs could be lost. This also has serious implications for lower income homes who cannot necessarily afford the upfront costs of embedded generation.

Non-technical losses

According to the South African Local Government Association (SALGA) total losses for municipalities accounts for R9,2-billion during the 2017/2018 financial year [24]. About 10% of this is attributed to theft or non-technical losses [25]. As grid electricity prices continue to increase, the average South African customers cannot afford alternative forms of energy as they are already under financial strain. This in turn is giving rise to illegal electricity connections, which further decreases municipal revenue [16].

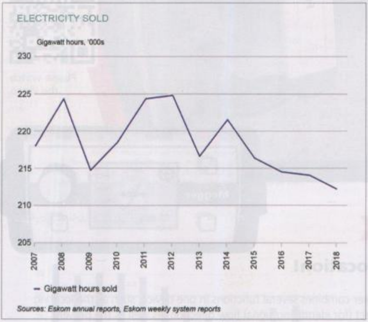

Fig. 3: Electricity sold in South Africa [14].

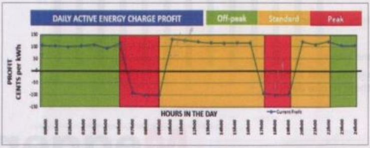

Fig. 4: Daily energy profit [23].

New roles for municipalities

The disruption caused by embedded generation can be leveraged as an opportunity for municipalities to take control of their pricing mechanisms and reduce losses during transmission and distribution.

Globally and in South Africa, utilities and municipalities are recognising that their conventional business model needs to change. In its own strategy document, EnBW (German utility) declared that "conventional business models of larger power supply companies no longer work" [23].

Action	Impact/comments
Introduce a TOU model where for commercial and residential clients	Instead of charging a flat tariff, municipalities can charge a surge amount for power consumed outside sunlight hours to minimise profit losses for customers with embedded generation. The aim is to align end uses with the same TOU tariff that municipalities are subject to. This would require the installation of smart meters. It should be noted that the TOU tariff was recommended before but did not gain much traction. This was mainly due to vendor specific tenders, over specifying the meters and the tender process itself [20]. Other obstacles include the high costs of installation of the smart meters which municipalities cannot afford [27]. A solution to these issues is to consider using Original Equipment Manufactures (OEMs) to supply and install the meters. The municipalities would only pay for the meters once revenue is collected. OEMs benefit from an OPEX business model [27]. Another option would be to pay the upfront costs of the meters via increased tariffs, Eskom has rolled this out in Gauteng. With the installation of meters municipalities would have access to real time data that can assist in developing innovative ways to increase customer satisfaction. They will be able to use and develop meter data and analytics engines to assist with pricing and demand response initiatives. Another option is to use TOU meters instead of smart meters which is expected to be much cheaper, costing about R800 per meter [20].
Increase fixed charges	This would eliminate the "Free rider effect" where currently residential and commercial customers with PV systems do not pay fully for their share of the system's fixed costs. This shifts the burden to households without PV systems. Companies using solar and the grid also need to contribute to the fixed charges for municipalities to cover grid maintenance costs. This is a key factor for municipalities to protect their revenue due to low electricity sales.
Grid availability charges – similar to an insurance policy	Most DERs are characterised by solar or other renewable energy resources. These sources are not dispatchable, hence if there is no storage or hybrid solution, grid power would still be required in certain conditions. Currently municipalities use a peak demand charge for the availability of certain kVA from the network. It is recommended that municipalities charge an additional amount for grid connection and usage above a certain value for energy consumers that have on site generation. This should be similar to an insurance premium with an excess amount paid for using the grid.
Feed in tariffs (FIT)	This would allow municipalities to purchase electricity cheaper from IPPs than Eskom. There might be contractual issues. Hence it is recommended that standard FITs should be implemented across to decrease the upfront project and admin costs.
Use of Network Tariff – Wheeling	To allow IPPs to connect with customers directly. This can be implemented within the current legislation. Municipalities can focus on the distribution aspects [27].

Table 2: Short term actions.

Action	Impact/comments
Legislation to prevent embedded generation	This would ensure continuous revenue to municipalities, but it is not practical or feasible. It would not meet the requirements of all stakeholders especially ensuring resiliency.
Construct and own RE PV plants at the end client's premises.	This option allows municipalities to own and operate the PV plants as well as sell power. It requires upfront capital which the municipalities may find difficult to raise as well as a change in legislation allowing municipalities to generate electricity.
Municipalities purchase power from small IPPs	This option is like the one above, with the difference of eliminating the up-front capital costs for municipalities to cover. It ensures resilient power to the end user from renewable energy. Plants can be located at the end-client's premises. The IPP would own and operate the facility, freeing up municipal resources. Most municipalities are already setup to purchase energy from IPPs and sell it to end customers, they are currently doing the same with Eskom. However current legislation in South Africa prevents them from purchasing energy from other resources [27]. Hence a change in legislation is required. This may even require guarantees from national treasury for the PPAs.

Table 3: Long-term actions.

In South Africa, municipalities around the country are also challenging the 'single buyer' model which restricts the purchase and sale of electricity to Eskom. They intend to purchase electricity directly from independent power producers [8].

A 2018 study done by SA TIED (Towards Inclusive Economic Development) to identify the main drivers for municipalities to implement their own embedded generation revealed the main driver is climate change mitigation, with going green as second and cost as the third incentive [6].

Interviews with municipal leaders indicated that they understand that the current model of electricity supply management is not sustainable, they see embedded generation as an opportunity as a service to provide to ensure their own and the overall sectors sustainability despite the current obstacles that they are facing [6].

Recommendations

Although the potential impact on municipal revenues still exist, municipalities still see embedded generation as an opportunity. They see embedded generation as an opportunity to break away from Eskom's dominance, much like the private sector.

Since embedded generation is on site generation, there is no real need for large transmission and distribution networks. It thus presents an opportunity to reduce technical losses by 5% [26]. Onsite generation could also assist municipalities to reduce non-technical losses if planned correctly taking all stakeholders into consideration.

Short-term actions

Table 2 summarises the proposed key actions that will benefit municipalities almost immediately in terms of revenue protection.

Long-term actions

According to PQRS, a local solar PV data and quality assurance entity, the commercial and industrial sector (C&I) represents the largest market for embedded generation in South Africa [9]. This is due to high energy usage and the need for continuous power. It is thus recommended that municipalities target these customers as clients for embedded generation. Table 3

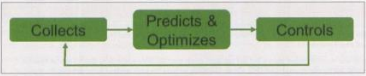

Fig. 5: Advisory control illustration.

Item	Comments
Remote monitoring & forecasting	Monitoring Power/Energy and other Key Performance Indicators for each DER using web access
Tariff Management	Control DERs according to variable electricity tariff rate
Demand Charge reduction	Control DER for reducing site consumption peak
Self-consumption	Control energy storage and PV system for maximizing the energy consumption from PV system
Off grid mode preparation	Control DER for anticipating on future off grid events
Sharing strategy	Aim to maximize renewables consumption the microgrid
ATO – Automatic Transfer Operation	Automatically manages connection / disconnection from the grid
Load sharing	Assure the stability for the tension and frequency by balancing the production and consumption in real time
Load shedding	Cut-off non-priority loads when the production cannot reach the consumption
Relay Settings	Manage the protection relays and if needed the global system protection when islanded.
Connectivity	Modbus and Modbus TCP IP, IEC 61850

Table 4: Benefits of using technology for operation and control of embedded generation [28].

summaries the proposed long-term actions for municipalities.

There are various challenges that impedes municipalities from the above recommendations. A 2018 study done by SA TIED (towards inclusive economic development) that interviewed key staff members and decision makers from various municipalities revealed the following key challenges [6]:

- *Current structure of the SA energy sector*: Highly vertically integrated with Eskom controlling most of the country's generation.
- *Regulatory environment*: Lack of national regulatory framework for embedded generation. Also, currently Eskom is the single buyer for IPP projects. Focus on large IPPs, note this is beginning to change with the inclusion.
- *Resources*: They are under staffed and often cannot meet with requests of embedded generation. They also often struggle to meet their primary mandate providing basic electric services.
- *Grid capacity*: Unable to adequately balance supply and demand PV generated during stand times – does not assist with peak, unless storage is included.

The distribution network in South Africa at both the municipalities and Eskom is not prepared for the introduction of embedded generation. The current model operates on a basis of one-way flow of electricity. The integration of DERs into distribution networks have led to the emergence of active distribution networks (ADS). ADS have systems in place to control a combination of DERs, grids and storage.

National regulations could not keep up with the recent uptake of solar PV systems. Hence there is a need for new regulations to guide and regulate this market taking all stakeholders into consideration. Though progress has been had at a municipal level, however this is not enough in mitigating the loss caused by embedded generation [8].

The South African Photovoltaic Association launched the PV Greencard Programme in 2017. The aim is to provide training and accreditation to PV installers to ensure safety and quality assurance. PQRS developed a quality assurance platform (P4) to score PV contractors on performance, knowledge and best practice [8]. These bodies will inspire investor confidence for development of PV embedded generation solutions. It is recommended that National Government looks at these initiatives and together develop a national framework that would be beneficial to all stakeholders. This will also benefit municipalities if they are permitted to purchase electricity from IPPs.

It is also recommended that local government and municipalities consider alternate means to generate profits and cross subsidise municipal services. Once such alternative they can look at is to monetise infrastructure through investment funds. This can apply to assets like rail and power distribution lines, substations, etc. The assets will be operated by the relevant local government or municipality, but ownership transferred to an investment fund. The investment fund will issue units or shares to investors with the price tied to the performance of assets. The revenue will be used to upgrade and maintain the infrastructure.

New technologies and original equipment manufacturers

Technology trends surrounding microgrids are driving prices down. These new technologies can also assist local government in providing electricity where there is no grid. OEMs have developed pre-built low cost microgrid solutions that are pre-tested. This would decrease installation time and assist municipalities to provide any access to users with no access.

Technology advancements can also assist municipalities to operate and control their DERs for embedded generation. they can be used for demand management, forecasting, and control of the various energy sources. Thus, enabling the municipalities to optimize their energy offer by always using the cheapest energy source first.

Data analytics would allow predictive analysis and automatic management of the DERs as illustrated in Fig. 5. Table 4 illustrates some of the benefits of using technology to advise and control DERs.

Advances in technologies can assist municipalities to improve customer satisfaction by providing advanced digital services that would assist customers to have continuous resilient power at the best possible price.

Conclusion

Embedded generation is on the increase globally and in South Africa. This trend is expected to increase as the costs for alternate forms of energy decreases and customers are looking for a more resilient form of energy. However successful implementation requires that all stakeholders get involved and benefit, else it could lead to negative disruption like the death spiral discussed earlier.

The disruptive forces of embedded generation together with increasing electricity energy costs can be seen as an opportunity for municipalities. They are distinctly positioned to benefit from the disruptive market elements. Municipalities are recognising that their business models require change to adapt to this new market.

It is recommended that they consider a TOU tariff model for residential and commercial customers. They should also consider increasing fixed costs to eliminate the free rider effect. Municipalities are also keen to purchase electricity from private developers as this would be cheaper than purchasing from Eskom. However, this would require a change in legislation. National government must also come to the party and play a role in this energy transition for it to be beneficial for all stakeholders involved. There has been progress, with the new draft IRP making provision for embedded generation, however this is not enough to take full advantage of the opportunities provided by the energy transition. New technology advances and OEMs can assist municipalities to provide enhance digital offers to their customers thus improving customer satisfaction.

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The impact of small-scale embedded generation on municipal revenue

by Tanaka Shumba, Hlengiwe Radebe, Josh Dippenaar and Megan Euston-Brown, Sustainable Energy Africa

Rapid small-scale embedded generation (SSEG) uptake provides potential benefits for municipalities via cheaper electricity and reduction of technical losses, but many municipalities have valid concerns around how these systems will impact their networks, technical operations and electricity-related revenue.

It is essential that municipalities address these concerns by developing and enforcing appropriate regulations and tariffs.

Many municipalities do not have detailed cost of supply figures – which should be the foundation of tariff setting. This paper explores the impact of some of the approved municipal SSEG tariffs on municipal revenue and customer 'business case' and outlines key tariff elements to balance access and cost recovery, until such time as detailed costing studies provide specific tariff building blocks. This work is part of the municipal SSEG support programme discussed below.

Four municipal case studies are presented where the revenue impact of growing SSEG on their distribution grids is investigated. The case studies are used to highlight the potential effect SSEG has on municipality revenue and draws out the importance of modelling impact as part of tariff setting and considers key lessons that could be learnt from the tariff structures in use. The paper will conclude by highlighting how revenue loss could be avoided by ensuring that the municipalities develop tariffs that account for the cost of supplying electricity to SSEG customers.

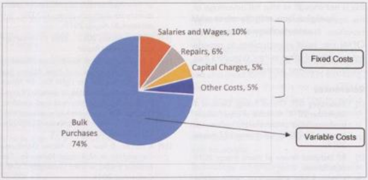

Fig. 1: Average cost structure of municipal electricity distributor.

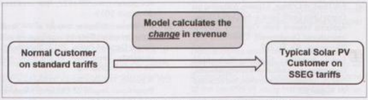

Fig. 2: Approach used to calculate revenue impact of solar PV.

Municipal SSEG support programme

As of October 2018, 41 of the 165 licensed municipal distributors allow SSEG installations – 29 of these municipalities have application systems and 25 have SSEG tariffs [1]. This reflects a strong upward trend from 2016 when only ten municipalities allowed SSEG (of which only five had formal processes), but indicates that many municipal distributors still lack the processes necessary to enable SSEG. In an effort to accommodate the inevitable growth in SSEG and stem the tide of illegal connections, support is being provided to municipalities to develop processes to formally include these embedded generators onto their networks.

The support work is part of the South African German Energy Programme (SAGEN) with co-funding from USAID South African Low Emissions Development Strategy Programme. SALGA and the Department of Energy are lead partners and implementation is being undertaken by Sustainable Energy Africa (SEA) with support from the CSIR and SunCybernetics. Support has included capacity building of staff and the provision of template documents which municipalities can tailor for their requirements. In the most recent phase of this programme 28 additional municipalities have been supported and trained to develop necessary processes and documentation.

The municipal SSEG document set is founded on the AMEU-SALGA Resource Pack - a set of template documents and forms that have been developed for use by municipalities and have been endorsed by SALGA and an AMEU SSEG Working Group. The AMEU-SALGA Resource Pack is available on the www.sseg.org.za website and not only has the function of facilitating the development of SSEG processes in municipalities new to SSEG, but also standardising the approach across municipalities.

The training component assists the municipalities to process SSEG applications, perform commissioning inspections as well as develop appropriate procedures and standards for SSEG integration to ensure grid stability and safety of systems. In addition, capacity is also developed around SSEG tariff development. On completion of the training, municipalities have a full set of customized documents for the entire SSEG application, approval and commissioning process which are ready for council submission for formal adoption. This includes customised SSEG Tariff recommendations for each municipality.

Structure of SSEG tariffs

South African electricity pricing policy indicates that economic efficiency/cost reflectivity should be the foundation of rate setting. Electricity tariffs need to cover the costs of supplying that electricity. Tariffs should therefore be built up from the associated costs. Fig. 1, shows the average cost structure across

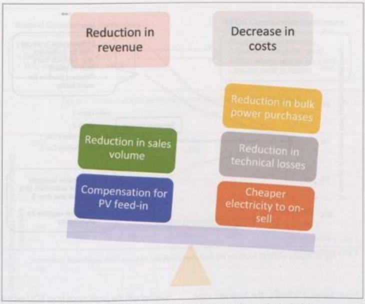

Fig. 3: Factors affecting municipal revenue with the installation of solar PV [4].

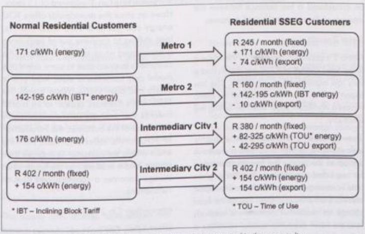

Fig. 4: Tariffs of the four municipalities which were used in the case studies.

various size municipalities, as determined from a survey of municipal D-Forms performed by NERSA [2]. It is important to note that some of these costs are variable (vary with the amount of energy sold) while others are fixed (do not change on a monthly basis).

Revenue recovery based on a single, volumetric charge (i.e. c/kWh) is common amongst municipal residential tariffs. This "bundles" both fixed network costs and volumetric energy costs into one charge. SSEG customers purchase less energy and under current tariff structures they contribute less to the fixed costs of the network and are not covering their share of these costs. To ensure residential SSEG customers cover these fixed costs, many municipalities are introducing a fixed charge, in Rand/month to be connected to the network and an energy charge for each unit they consume.

The final component of a typical residential SSEG tariff is the export tariff: this is the amount customers are compensated for electricity they export into the municipal grid.

A typical residential SSEG tariff therefore generally has three components:

Residential SSEG tariff = fixed charge (R/month) + energy charge (c/kWh) – export tariff (c/kWh)

Business and commercial customers are typically already paying demand charges and fixed charges, so they are often already contributing their fair share to the cost of the network. Therefore, many municipalities are simply introducing an export tariff for these customers to compensate them for any electricity they export into the municipal grid.

The challenge then, in the absence of detailed cost of supply studies, is how to cost each element within this tariff structure. The four case studies are analysed in order to explore how some of the approved tariffs have set these costs and the relative impact of this of municipal revenue and customer business case.

Municipal case studies: methodology

The analysis of the four case study SSEG tariffs which is summarised in this paper was done using a publically available Excel tool [3] known as the SSEG Tariff Tool. The tool is the product of extensive work around the effect of solar PV SSEG on municipal revenue. It investigates the impact of increased uptake of solar PV SSEG on revenue using customer and tariff data specific to the municipality in question. It does this by comparing the revenue generated per customer before the installation of solar PV and the revenue generated from that customer after they install solar PV. The SSEG tariffs can then be varied, and changes in revenue assessed, thereby allowing a revenue impact analysis of SSEG tariffs in specific customer categories in the municipality.

Solar PV can affect a municipality's revenue in a number of ways. Fig. 3, shows the basic architecture of the revenue impact of the model. Revenue is reduced in two ways: reduced sales volume to SSEG customers and compensating these customers for the electricity that is fed onto the grid. At the same time the municipality's costs decrease because of (i) a reduction in bulk power purchases from Eskom, (ii) a reduction in technical losses from these purchases, and (iii) cheaper electricity from SSEG customers can be on-sold to other customers with a slightly higher profit margin than from the bulk purchases.

When setting tariffs, it is important to balance cost recovery for services and utility sustainability with fair grid access and affordable tariffs. These are key objectives of South Africa's energy sector, as highlighted in the White Paper on Energy Policy (1998) [5] and the Electricity Pricing Policy (2008) [6]. Therefore, it is vital to understand the impact of SSEG tariffs on a customer's electricity bill. Experience suggests that if the tariffs are too unattractive, frustrated customers will be driven to invest in off-grid solutions or connect their SSEG installations illegally.

To consider the customer's perspective, the model indicates how favourable the customer's business case is to install solar PV under the proposed SSEG tariffs by calculating the payback period of the solar PV installation i.e. the time it takes the savings on the customer's monthly electricity bill to recover the initial cost of the installation. Favourable payback periods are typically considered to be less than five years, while a payback period of more than ten years is generally considered unfavourable.

Municipal case studies: results

To investigate how current SSEG tariff approaches are affecting municipalities' revenue, four South African municipalities have been chosen as case studies. All the analyses have been done using publically available data. The case studies are separated into residential and commercial customers. The tariffs considered and discussed are all excluding VAT.

The four municipal case studies cover different city characteristics – two are metros and two intermediary cities – as well as reflecting an array of different approaches to SSEG tariff setting.

Residential customers

Fig. 4, shows the selected tariffs of four municipalities which were used in the case studies. The revenue impact of customers migrating from the normal residential tariffs to the SSEG tariffs is then investigated.

Fig. 5 shows the forecasted impact of these tariffs on each municipality's revenue. The x-axis of the Fig. represents increasing percentage of customers installing solar PV while the y-axis of the Fig. shows the percentage change in revenue in that tariff category after the introduction of the SSEG tariff.

From Fig. 5, it is clear that SSEG tariffs can impact a municipality's revenue significantly. For example, under Metro 2's current SSEG tariffs if 10% of residential customers were to install solar PV, it would result in a 7% increase in revenue from this tariff category. On the other hand, Intermediary City 2 will see a noteworthy reduction in its revenue as customers install solar PV on their current SSEG tariffs.

Metro 1 results

Metro 1 introduces a fixed charge of R245/month and an export tariff of 74 c/kWh for SSEG customers. This results in a virtually revenue-neutral SSEG tariff.

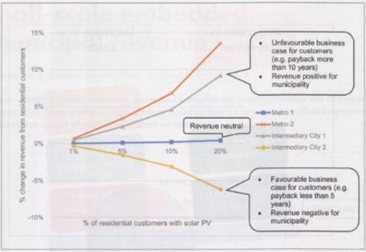

Fig. 5: Impact of SSEG tariffs on the four municipalities' revenue from residential customers.

Under Metro 1's tariffs, the business case for residential customers to install solar PV is 8 to 12 years, but because the SSEG tariff is revenue-neutral for the municipality, this can be considered a fair balance between the interests of the municipality and customer.

Metro 2 results

Metro 2's approach has been to introduce a lower fixed charge of R160 per month and a very low export tariff of 10 c/kWh. The low export tariff of 10 c/kWh means that the metro makes a significant profit when on-selling this electricity.

The customer's business case is highly unfavourable in Metro 2, with a payback period of 20 years. The low compensation for exported electricity (10 c/kWh) gives little encouragement for customers to export electricity onto the grid. Even though the fixed charge for residential customers is relatively low, the tariff does not appear to reflect a balance of customer and municipal interests. Furthermore, the unfavourable business case may drive frustrated customers to invest in off-grid solutions or to connect their installations illegally.

Intermediary City 1 results

This municipality has taken the approach of introducing a fixed charge for SSEG customers (R380 per month), as well as shifting them onto a TOU energy charge and a TOU export tariff. Since municipalities purchase bulk energy at TOU tariffs, selling electricity at TOU tariffs and buying from SSEGs at TOU tariffs is a well-founded principle, and results in more cost-reflective tariffs. In terms of the revenue impact of Intermediary City 1's SSEG tariffs, they are seeing a considerable increase in revenue. This is due to the high fixed charge coupled with the profit made from TOU export energy charges.

The business case is poor for SSEG customers in Intermediary City 1 – upward of 15 years. However, since this municipality offers TOU energy charges and TOU export tariffs, load shifting to consume out of peak times is encouraged which is likely to improve the customer's business case to some extent (the model only considers a static load profile before and after SSEG). While initially the SSEG tariffs therefore appear to be biased towards the interests of the municipality over those of the customer, the introduction of TOU tariffs reflects forward thinking which allows the customer to improve their returns, and is resilient into the future when storage becomes a common part of such installations.

Intermediary City 2 results

Intermediary City 2 already charges normal residential customers a fixed charge (R402 per month). This fixed charge is kept constant for SSEG customers. So when customers migrate from normal residential tariffs to SSEG tariffs, only an export tariff is introduced. This export tariff is equal to the energy charge – 154 c/kWh – i.e. net metering (meaning that customers get compensated for their exports to the same value as what they pay for electricity). This situation means that the municipality can purchase electricity from Eskom for much cheaper than what they are compensating SSEG customers. Considering the lack of additional revenue from introducing a fixed charge specifically for SSEG customers (it is already in place for normal customers) and the high compensation for exported energy,

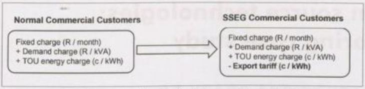

Fig. 6: Commercial tariff structures for the four case-study municipalities.

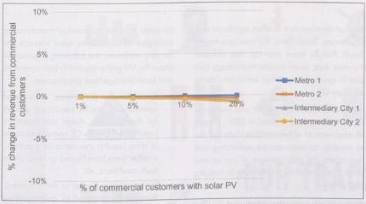

Fig. 7: Impact of commercial SSEG tariffs on municipal revenue.

Intermediary City 2 sees considerable revenue loss when customers install solar PV.

The business case for customers to install solar PV is very favourable – payback periods are in the order of 2 to 4 years. It appears that the balance of interests between the municipality and customer is biased towards the customer, although the resulting economic stimulus can be a sound reason for such an approach.

Insights from residential customers

The above case studies have shown that current approaches to setting SSEG tariffs differ greatly. Although all four municipalities are structuring their SSEG tariffs in a similar way – fixed charge, energy charge and export tariff – the value of these tariffs range widely between municipalities. This considerably impacts, either positively or negatively, both the revenue of the municipality and the business case for installing solar PV. Both need to be considered when setting SSEG tariffs.

The case studies help clarify some SSEG tariff setting pointers:

- A sensible SSEG tariff includes a fixed charge to recover most of the fixed costs – usually in the order of R200 to R400 per month. A few cost of supply studies examined suggest that fixed costs of between R200 to R400 per month are appropriate for residential customers. However, it is recognised that fixed charges are not always well-received by customers, and so phasing in the fixed charge over a few years may be a strategic approach.
- Regarding energy charges to recover variable costs, SSEG customers often are kept on the same energy charge as before for simplicity, however, since these volumetric tariffs generally are already recovering some fixed costs, the municipality should be careful not to double recover these fixed costs. Thus, the energy charge and the fixed charge are interdependent, and if the energy charge is indeed kept the same a lower fixed charge could be considered.
- The tariff for exported electricity should be related to the avoided bulk purchases less the technical losses. This is usually in the order of 60 to 80 c/kWh.

Looking into the future, it is important for municipalities to move towards TOU tariffs – this is reflected in the Electricity Pricing Policy [7]. When customers install solar PV, their daytime demand reduces, but when the sun sets, the customer still consumes expensive peak-time electricity. If this time-dependent cost is not reflected in tariffs, the municipality remains vulnerable to under-recovering.

Commercial customers

Unlike residential customers, virtually all municipalities charge normal commercial customers a fixed charge and a demand charge. Fig. 6, shows the commercial tariff structure for the four case-study municipalities. When commercial customers install solar PV SSEG, the only tariff modification is to introduce an export tariff.

Fig. 7, shows the impact of commercial customers installing solar PV and migrating to the SSEG tariffs in the four case-study municipalities.

The impact of commercial SSEG customers on municipal revenue is shown to be less of a concern than residential customers because commercial customers are already paying fixed charges. Although these customers reduce their consumption of municipal electricity when they install solar PV, the fixed costs of the network are largely still covered by the fixed charges.

Although the impact of commercial SSEG customers is significantly less than that of residential customers, the case studies show that revenue is slightly negatively affected by SSEG. This is can be because the fixed charges are not adequately cost-reflective. Such fixed charges should be informed by a cost of supply study to improve this situation.

The importance of Cost of Supply studies

The approach in this paper has been to investigate the impact on revenue of customers installing solar PV and migrating to SSEG tariffs. Currently it is common practice for these to be based on current tariffs, as with most of the case studies covered. This approach also allows municipalities to set sensible SSEG tariffs without detailed knowledge of their costs, but nevertheless feel secure around the revenue impact that could result. However, since the purpose of tariffs is to ensure the municipality covers the costs of providing the service, these tariffs should actually be based on costs, and not revenue protection.

This situation can result in income loss not proportionate with cost reduction, and less than optimal customer decisions e.g. leaving the grid due to incorrect price signals. While SSEG has the potential to deliver substantial benefit to the power system (decreased costs and emissions and increased reliability and customer choice), under a traditional tariff scheme SSEG may increase inequities through cost shifting by wealthy customers who can afford it. The NERSA requirement for municipalities to undertake cost of supply studies is increasingly important. Municipalities need to develop a thorough understanding of their costs as a basis for tariff setting. This

Continued on page 111...

Leveraging open source technologies: A remote monitoring case study

by R Singh, and G Nkomo, eThekwini Electricity

The 18th-century seafarers who conquered the oceans and invaded the lands to seek gold in a region that was once pivotal in trade route economics were met with a humble force that saw the end of more than a century-old colonial empire.

Unbeknown to many, the threat of colonisation beckons yet again but this time through a different guise. Under the nuances of Industry 4.0, Africa is fast losing its technical sovereignty.

In a technology article by the *Business Report* [1], a case about foreign backed companies recolonising Africa through technology prompts fears. The technology influence of foreign companies is beginning to surface through disruptions in transportation and monetary systems. Whilst digitisation makes for a good argument in 21st century economics, it requires thought leadership to strike a balance between modernisation and the prosperity of the nation. One solution to this conundrum is through better technology participation.

Specifically, within the Electrical and Electronics manufacturing sector in South Africa, the import-export ratio using GDP figures (in USD) for 2018 was 8,6:1,8 [2]. This figure raises questions about the structural changes for innovation that are needed if technology participation in the global market is a priority; given SA's unemployment rate standing at 26,6%.

One entry point to innovation is through open source technologies. Apart from fast-tracking product development, it offers significant cost efficiencies. Bank Zero, the new app-based South African bank start-up, has stressed the role that open source technology can play in spurring innovation within incubating start-ups [3].

Inspired by Enel's innovative and successful Open Meter project initiated in 2001, a team of engineers at eThekwini Electricity set out to develop an open-source monitoring unit that meets the requirements of the control room operator whilst conforming to industry best practice.

Monitoring opportunities and business case

Utilities are generally able to deploy remote monitoring equipment to tier 1 (high voltage (HV)) and subsets of their tier 2 (medium voltage (MV)) networks. As one begins to deploy monitoring equipment deeper into the grid, the costs begin to grow exponentially because of the sheer volume of infrastructure.

Several monitoring opportunities for both operational and asset management purposes exist. In order for operators to control the network, they require visibility regarding the state of critical elements on the network. Asset management practitioners are required to understand the operating characteristics of an asset in order to develop maintenance strategies throughout its asset lifecycle. At the very minimum, the following information about the MV grid is relevant to both operators and asset management practitioners:

- *Circuit breaker (CB) status:* These assist operators in quickly identifying a fault on the network. Asset management practitioners use the CB open/close count to drive breaker maintenance practices; whether these have tripped on load, under fault conditions, etc.
- *Isolator status:* Similar to the CB status, these assist operators in understanding the real-time network topology. Asset management practitioners use isolator open/close counts to drive condition based asset maintenance practices.
- *Earth fault indication (EFI):* These assist operators with the quick identification and isolation of a faulted circuit.
- *Load at strategic points:* These assist operators with load transfer strategies. It also assists planning engineers in understanding network growth and designing for future network capacity. Asset practitioners correlate load profiles and other independent variables such as temperature to better understand the operating performance of an asset.

Asset	Description	Count	Monitoring opportunities	Average cost to monitor	Total cost
DSSs	Incomers from major substations and feeders to local transformers and other DSSs.	731	Per Bay Digitals (6): Breaker status; breaker position; cable earth; overcurrent; earth fault; relay fail Analogue (1): Phase current Control (2): Open and close General substation: a.c. fail; d.c. fail; charger fail. Typically 6 feeders Digitals: 36 (6 bays) + 3 (station) = 39 Analogues: (6) Control: (12)	~ R 50 000 (2014 figures)	~ R 36 550 000
MSSs	Typically residential 11 kV to 400 V transformers.	5849	1 x EFI 3 x LV fuse fail (per circuit) x (1-6) circuits 1 x door open 3 x CTs (LV busbar)	~ R 28 000 (2015 figures)	~ R 163 772 000
Kiosks	Industrial, commercial and residential 11 kV to 400 V transformer with switchpillar and LV panel.	2835	1 x EFI 3 x LV fuse fail (per circuit) x (1-6) circuits 1 x door open 3 x CTs (LV busbar)	~ R 28 000 (2015 figures)	~ R 79 380 000
Pole top transformers	Residential (typically rural). Similar concept to MSSs.	6090	3 x 11kV drop-off fuse 3 x LV fail (per circuit) x (1-3) circuits 3 x CTs (LV)	~ R 28 000 (2015 figures)	~ R 170 520 000

Table 1: eThekwini Electricity distribution assets.

27 YEARS AND COUNTING
STELLENBOSCH
EMFULENI
LOCAL MUNICIPALITY
CENTLEC
CITY OF
TSHWANE
OUR TRACK RECORD
SPEAKS FOR ITSELF
City Power
ETHEKWINI
MUNICIPALITY
uMHLATHUZE
WE SERVE
Ekurhuleni
THIS CITY WORKS FOR YOU
Eskom
Polokwane
DRAKENSTEIN
nelson mandela bay
Western Cape
Postnet Suite 329, Private Bag X15, Somerset West, 7130
T: 021 841 4080 / F : 0866 892 718
Gauteng
Po Box 4172,Southgate, 2082
F: 011 494 3572
National Tel Number : 0861 777 769 (PPS POW)
michael@ppspower.co.za
www.ppspower.co.za
We hope you will either take the opportunity to meet with us, or afford our company the opportunity to quote against your requirements.
Should you require any further information please do not hesitate to contact us.
PPS
POWER PROCESS SYSTEMS
ECA
Eskom
PHILIPS

Fig. 1: Crestmore substation.

Name	Characteristic	Type
EFI	normally open	digital
Door	normally closed	digital
Red phase fuse fail	normally closed	digital
White phase fuse fail	normally closed	digital
Blue phase fuse fail	normally closed	digital
Red phase LV busbar current	0 – 400 V	analogue
White phase LV busbar current	0 – 400 V	analogue
Blue phase LV busbar current	0 – 400 V	analogue
Red phase LV busbar current	0 – 800 A	analogue
White phase LV busbar current	0 – 800 A	analogue
Blue phase LV busbar current	0 – 800 A	analogue
Ambient temperature	°C	analogue
Relative Humidity	0 – 100%	analogue
Transformer kVA	max. 500 kVA	analogue

Table 2: Signal list.

Characteristic	Requirement
Provisioning of digital inputs	Minimum 8 expandable
Provisioning of digital outputs	Minimum 2 expandable
Provisioning of analogue inputs	Minimum 4 expandable
Standard communications protocol over ethernet	DNP3 (slave), Modbus (master)
Provisioning of Human Machine Interface	Web browser
Should be easily configurable through a web interface	Web browser
Compliance with temperature and EMI regulations	IEC61850-3 CX3; IEC 61000
Compliance with cyber security requirements	IEC62351
Compliance to availability/uptime requirements	Five nines principle

Table 3: Technical requirements for open source RTU.

The above information also serves as an input into a state estimation engine within a distribution management system (DMS) at the control centre. More data collected from the filed improves the overall observability of the network. Apart from an operational and asset management perspective, information regarding the physical security of the asset can also be acquired viz., access to a cubicle through a door contact, tamper detection, etc.

Table 1 depicts eThekwini's distribution assets that are considered for remote monitoring within its distribution automation strategy.

The figures indicate that as one moves deeper into the grid the cost of monitoring acts as an inhibitor to increasing grid visibility. This is because of the sheer volume of assets that exist on MV networks. It is therefore reasonable to investigate alternative options.

Options to reduce such costs include:

- The deployment of monitoring equipment only at strategic points on the network and thereafter to use state estimation techniques to resolve at un-telemetered junctions.
- Changing the traditional concentrator type remote terminal unit (RTU) infrastructure to one that deploys lightweight sensors similar to those offered by internet of things (IoT) devices over low power wide area networks (LPWAN) technologies. This strategy becomes cheaper with volume as base station costs spread over the amount of sensors that are deployed; and,
- The use of open source technologies.

This paper focusses on the last option above. The objectives of this paper are therefore to investigate the following:

- Can open source technology offer a technically viable remote monitoring solution for the smart grid?
- What are the non-technical challenges that exist with open source technologies and how to overcome these?
- What are the cost advantages associated with the open source remote terminal unit OS RTU when implemented within the municipal landscape?

Technical requirements

As a case study, this paper investigates the use of open-source technologies at an indoor mini substation viz., Crestmore SS 3532. This substation supplies a block of flats in the Durban central area. Fig. 1 depicts the details of the station.

The station was wired for remote telemetry by in-house electricians. A signal list was developed based on the control room requirements and the wiring effort required. Table 2 depicts the signal list.

There is currently no private communications from the Municipal Control Centre to Crestmore substation. The use of General Packet Radio Service (GPRS) technologies was therefore provisioned. Some of the key requirements of a modern-day RTU extracted from eThekwini's specifications are detailed in the Table 3.

eThekwini Electricity is aligned to the IEC suite of protocols as are most other distribution utilities in South Africa. These requirements were used as a guide in the development of an OS RTU proposal.

Open source technologies

Open source: What is it?

Open source refers to a concept that is owned and modified by the public; a community of users that serve a common purpose. It allows for collaborative participation, rapid prototyping and transparency for open exchange of products and ideas [5].

Open source software vs. proprietary software

The source code for open source software is available for anyone to inspect, modify and enhance [5]. This differs from proprietary software wherein the team or organisation that developed the software has full or exclusive control over it. The Open Source definition describes the ten tenets of open source software [6]. These include:

- No fee for distribution.
- Uncompiled and compiled source code must be made available.
- Must allow for modifications of source code.
- Can allow for integrity of author's code through the distribution of path files.
- No discrimination against groups or people.
- No discrimination against fields for endeavour.
- The license must be technology neutral.
- The license must not restrict other software.
- The license shall not be specific to a product.
- The license must automatically apply to all to whom the software is distributed.

Licensing

Open source licensing allows developers and users to use, modify and share licensed software for any purpose, subject to the conditions that preserve the openness of the software itself [7]. The main two types of open source licenses in the market are discussed below.

Copyleft licenses: Developers are allowed to utilise the software under this license for commercial purposes and to modify the code provided that they disclose the source, state the changes that were made and preserve the copyright and license notices. The modification must however be under the original license and the developer shall make the complete source code available. An example of this license is GNU General Public License (GPL).

Non-copyleft licenses (permissive): Very similar to copyleft license but much less demands are made on the user or modifier of the source code. Developers can modify the source code and declare their work as proprietary. Examples of such licenses include Apache and Berkley Software Distribution (BSD).

Both licenses have limitations on liability and warranty.

Community based hardware development platforms

Several hardware development platforms exist in the market that compete on specifications such as power consumption, temperature performance, memory and storage capacity. For remote monitoring purposes, the key requirements are: a) temperature performance; b) provision of on-board digital inputs; c) provisioning of on-board digital outputs; d) provisioning of analogue inputs with at least a 16 bit ADC; e) provisioning of a real-time clock; and f) on-board storage. Some of the more popular development boards include the Arduino, Beaglebone and Raspberry Pi (RPI) and a comparison of these are shown in Table 4. Each board has its own merits depending on the functionality that is intended to be deployed on them.

Board	Arduino Uno	RPI	BeagleBone	Requirement
Model	R3	Model 3B	Block	Open Source eco-system
Flash	32KB	SD Card	4Gb Onboard	External/on-board
GPIO	14	40	69	At least 8 and expandable
Analog input	6	External	7	At least 4 and expandable
IDE	OS – Arduino	OS – Linux	OS – Linux	Open Source (OS)
Ethernet	None	Yes	Yes	Yes
Real-time clock	External	External	Onboard	External/on-board
Temperature performance	85°C (1)	85°C (2)	85°C	70°C
Project	Arduino LLC	RPi Foundation	BeagleBone.org	–
Cost	USD 30	USD 35	USD 55	–

Table 4: Development board comparison.
(1) ATMEGA chip
(2) Broadcom Application processor runs the hottest and can withstand temperatures of up to 85oC. RPI foundation is unable to qualify the exact operating temperature. COMPULAB offers RPI unit with maximum operating temperature of 80oC.

Based on the technical requirements discussed above, the BeagleBone Black and RPI fit the requirements well. Since the RPI is ubiquitous in the market; having been named the third best-selling general purpose personal computer after Apple and Windows PC [4], it was decided to be utilised in this open source project. It should be noted that since both the RPI and Beaglebone Black have Linux Integrated Development Environments (IDEs), the option to utilise the BeagleBone Black as the hardware platform can be achieved with similar effort. Both the RPI and BeagleBone Black boards operate on the open source software ecosystem.

Analysis

This section conducts an analysis of the objectives set forth earlier in this paper.

Objective 1: Can open source technologies provide a technically feasible remote monitoring solution for the smart grid?

This question is answered by investigating the Open Source technology market and whether such can match the technical requirements listed in Table 3. To investigate the technical performance of the proposed solution, three key performance metrics are suggested and explored viz., temperature performance, availability performance, and processor and memory usage. The potential failure modes of the proposed solution is also investigated as a means to understand the performance over the operating lifecycle of the asset.

Open source remote terminal unit proposal

OS RTU is an Open Source Remote Terminal Unit (RTU) based on the RPI hardware platform. An option for utilising the BeagleBone black industrial platform is also available.

To meet the technical requirements, a proposed hardware architecture is presented in Fig. 2.

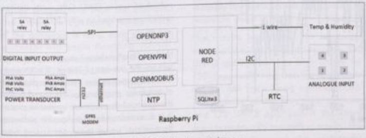

Fig. 2: OS RTU Hardware architecture.

The proposed architecture makes use of the RPI as the main hardware platform.

It utilises the one-wire protocol to communicate with a DH-22 temperature and humidity sensor. The Serial Peripheral Interface is utilised to communicate with an expandable Input/Output board viz., PiFace Digital. The PiFace is equipped with eight digital inputs and two 5A switchable relays. These inputs are expandable as required. 5000 Vrms isolation is achieved on the inputs through an opto-coupler circuit. As analogue inputs are not available as a default option on the RPI platform, the board communicates with an ADS1115 ADC chip using the I2C communications interface. The ADS1115 chip is equipped with four 16 bit ADC channels. For the specific implementation at Crestmore substation, the ADC chip is not utilised as the analogue values are interfaced through a power transducer.

In order to maintain time when the network goes down, a real-time clock (RTC) is integrated into the system. A DS3131 RTC is integrated into the platform using I²C communications.

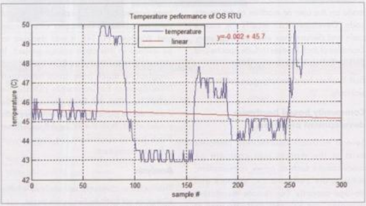

Fig. 3: OS RTU temperature performance.

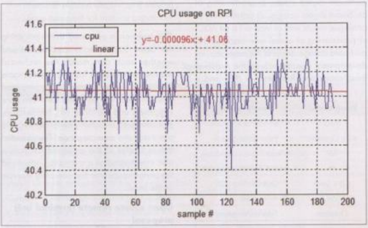

Fig. 4: RPI CPU usage.

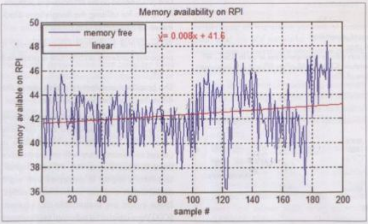

Fig. 5: RPI memory usage.

Communication protocols

DNP3

DNP3 is the de-facto communications protocol used for information exchange between a remote telemetry site and the control centre within electric utilities. DNP3 is often a preferred protocol as it supports buffered and unsolicited event reporting.

OPENDNP3 is an open source implementation of the DNP3 protocol as defined by IEEE 1815. This stack offers both master and outstation implementations of the DNP3 library as C++ code. This code is published under the GNU General Public License (GPL) implying, amongst other conditions, that there must be full disclosure of the source code within derived implementations.

MODBUS

Modus is an industry standard protocol used for digital communications between master and slave devices. For this application, the Modbus protocol is used for communications between the RTU and transducer devices.

The Pymodbus protocol is an open source implementation of the Modbus protocol as managed and maintained by the Modbus organisation. This code is published under the BSD license implying a more permissive utilisation of the source code.

Security

IEC62351-3 specifies transport layer security (TLS) as a requirement for machine-to-machine communication for virtual private network (VPN) connections.

OPENVPN is an open source application that implements VPN techniques using TLS security for point-to-point connections. VPN technologies allow for encryption of data thus ensuring the integrity of information traversing a third party network. It also allows for the authentication of remote devices thus ensuring that the master station is not communicating with a potential rogue device.

The OPENVPN client stack can be readily deployed on the hardware development platforms mentioned earlier. This code is published under GNU GPL, with similar restrictions imposed as with OPENDNP3.

Configuration

Node red is a flow based visual programming tool for the Internet of Things. It is browser based and open source with a large database of templates and libraries. Node-red has a strong social development interest in place. It is licensed under the Apache software agreement, i.e. a more permissive type license.

```
Last login: Mon Apr 10 22:27:49 2017 from 10.12.210.90
pi@raspberrypi:~ $ ps -ef | grep outs
www-data  1734     1 99  2017 ?        47721-20:24:18 ./outstation-demo
pi        7077  7066  0 13:48 pts/1    00:00:00 grep --color=auto outs
pi@raspberrypi:~ $ uptime
 13:53:13 up 499 days, 22:52,  2 users,  load average: 1.49, 1.45, 1.40
pi@raspberrypi:~ $ ps -o etime= -p 1734
499-22:52:32
pi@raspberrypi:~ $
```

Fig. 6: Uptime of open source RTU.

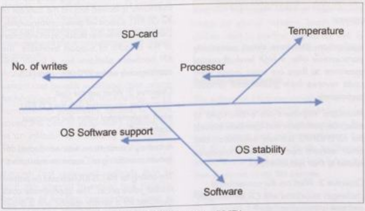

Fig. 7: Fishbone diagram – OS RTU.

Database

There are a plethora of database types available in the market. SQLite was chosen as the preferred database as it is lightweight, scalable, efficient and intuitive to use. It is a popular database that is built for embedded devices. SQLite source code is in the public domain. However, the general public is not able to openly contribute to the SQLite software itself. A team of developers regularly update the code based on community requirements.

An investigation into the performance of the OS RTU using the 4 key metrics viz. temperature, processor and memory usage and availability statistics follows below.

Temperature performance

In order to investigate the OS RTU for thermal runawdys, approximately 300 temperature samples were taken over a three day period. It should be noted that the core processor operates at a higher temperature than the ambient. The maximum operating temperature of the processor is 85°C after which the processor will begin throttling activity. Fig. 3 presents the temperature performance of the OS RTU. A linear basic fit is applied to the results. The small and negative gradient indicates temperature stability of the unit thus confirming no thermal throttling or runaways. The average temperature of the processor is also well below its thermal operating limit.

Processor and memory performance

In order to determine the stability of the code implemented on the RPi, processor and memory usage were monitored over a week. The results are presented in Figs. 4 and 5 respectively. A basic fit linear equation is superimposed onto the results. In the case of CPU usage, the small and negative gradient (-0,000096) confirms that the processor is well matched for its application. Regarding the memory availability on the RPi, whilst low, the small and positive gradient (0,008) confirms system stability. The illustrations indicate that there no runaways in processor and memory usage thus pointing to stability in the code and architecture of the system.

Availability performance

Prior to installing the OS RTU at Crestmore substation, a unit was installed at a high voltage substation to monitor critical battery charger alarms. The unit was installed in April 2017. The system uptime and the uptime of the key DNP3 process was investigated. The results are shown in Fig. 6.

The results reveal that the hardware was online for 499 days. The OS DNP3 application was also online for 499 days confirming that the application did not fail since being commissioned. The stability of the hardware platform and OS DNP3 application therefore provide technically compelling results. The availability performance also validate the CPU, memory and temperature performance statistics discussed above.

Electromagnetic interference (EMI)

Electromagnetic interference occurs when an external source affects an electrical circuit through electromagnetic induction or electrostatic discharge. Electromagnetic compatibility ensures that all electronic devices function reliably within their intended environments [8]. There is significant radiated electromagnetic disturbances within the power system environment and any electronic system installed within such an environment should be hardened such that it is immune from such disturbances. Whilst immunity to EMI disturbances are important, designers of hardware should also ensure that their products do not emit unintentional radiation that could possibly interfere with other electronic systems in the near vicinity. Devices should therefore be subjected to both emissions and susceptibility compliance tests.

Electronic devices that have no radio equipment are classed as unintentional emitters as they may contain a high speed clock which may introduce unwanted interference to local devices. The RPI 3B+ specifically has a Bluetooth and WiFi interface and is therefore considered an intentional radio transmitter. In South Africa, the RPI 3B+ has been approved by ICASA under Type Approval number: TA-2018/1426. This however, only ensures that the device does emit interference onto other devices within its immediate vicinity. In order to determine the impact of EMI on the device itself, certain immunity tests against electrostatic discharge, electromagnetic fields, fast transients, etc. within industrial environments as called for in the IEC 61000 standard is required. Research on EMC susceptibility of the RPI 2 platform was carried out in an IEEE paper by Mach, et al., [9] with findings revealing compatibility in industrial type field strengths of 10V/m across a wide frequency range. Consideration of EMC requirements when designing enclosures for the unit itself can assist with conformity requirements within such environments. Enclosure shielding through concepts like the Faraday cage effect can be taken into account. Stringent EMI susceptibility tests on the current implementation is further warranted.

Failure modes

As with any electronic device, there are many failure modes at play that could result in complete failure or reduced performance of the device. The main failure modes associated with the OS RTU is presented in the Fishbone diagram of Fig. 7. Each failure mode is discussed categorically.

Item	RPI	Vendor specific
Microprocessor with DNP3 license	R550	R22 000
IO board (8 inputs)	R650	R2000
Real Time Clock	R50	Included
Analogue board (3 inputs)	R100	R4000
Case	R150	Included
Temperature and humidity sensor (additional)	R50	R200
Cabinet and accessories	R1500	Included
Total (15 000 units)	R3050 (45 750 000)	R28 200 (423 000 000)

Table 5: cost Comparison.

Secure digital (SD) card

Flash memory has a limited amount of write cycles which is normally in the region of 100 000 cycles. This figure improves with the quality of SD card that is utilised. Some higher quality SD cards employ wear levelling techniques that prevent cards from pre-mature failure. In the manner in which this unit is designed, a wear levelling SD card is recommended. It is also not a difficult technical process to keep a backup image of the SD card. This SD card can be replaced every ten years at a minimum cost.

Temperature range

Whilst there is no official operating temperature of the RPI, thermal imaging of the device under heavily loaded conditions reveals that the broadcom chip (processor) runs the hottest on the board [10]. Temperatures above 80°C have shown significant performance degradations and the system is known to throttle performance at temperatures above 82°C. Heat sinks are available that can be attached to the broadcom processor chip. An industrial grade RPI is available from COMPULAB [11]. This supports industrial grade operating temperatures of up to 80°C.

Software

- Raspbian operating system

There are no known issues regarding the stability of the operating system. The operating system development community is very active in enhancing the performance of the system. There have been many iterations of the Raspbian operating system with each iteration providing performance enhancements. The fewer hardware devices attached to the system improves the overall stability figures.

- OS software applications

According to a 2015 Open Source survey, 78% of companies already run open source technologies [12]. Standard implementations of the open source applications will improve the overall reliability of the system. Custom implementations run the risk of the changed code not being vetted by third party independent sources. Open source applications that have strong community participation offer a high level of quality assurance as there are many independent code reviews from global and random participants.

Municipal engineers are encouraged to subscribe, participate and contribute towards the OPENDNP3 software application and other relevant open source technologies related to their specialist fields.

Objective 2: What are the non-technical challenges associated with OS technologies and how to overcome these?

Several non-technical challenges exist which include the resource constraints to assemble such units, the availability of spares and ongoing support. These are discussed below.

Human resource constraints

Apart from the technical issues there are also human resource constraints that need to be considered. Assembling a physical device requires effort and time. A business case and project plan will need to be thoughtfully constructed. This however, remains outside the scope of this paper. The system should be designed for ease of maintenance. As the intelligence of the OS RTU resides on the SD-card, a simple clone of the card should be kept as a spare.

Spares availability

Depending on the community development board that is chosen, the availability of spares will vary. In the case of the RPI and BeagleBone Black, the unit is available from many suppliers locally. Moreover, the BeagleBone hardware is built from open electronics. This means that the design is publicly available for modification and further development. Building of the hardware from the ground-up using readily available common of the shelf components, standard processes and open infrastructure is therefore possible. If a strong development community is built around the concept of the OS RTU, there will be no reason to be dependent on any specific supplier for spares.

Support

Support is necessary throughout the operational lifecycle of the asset. Support for community based hardware platforms and open source software cuts across several industries and therefore far surpasses the cohort of support groups available from individual suppliers of proprietary products. However, whilst the breadth of knowledge is high, the depth of support may not be as detailed as those received from supplier product centric focus groups. Again, if a strong development community is formed around the concept of the OS RTU, support will grow commensurately. Using a forum member statistic as an indication of the breadth of support available, the RPI hardware platform has a forum with approximately active 270 000 users [13].

Objective 3: What are the cost advantages associated with the OS RTU when implemented within the municipal landscape?

A costing comparison was conducted for remote monitoring at Crestmore substation.

The costing for the OS RTU is based on present market value prices. The approximate costs illustrated for a vendor specific unit is drawn from recent public tender opening prices in 2015. This specific vendor product was the cheapest and most technically compliant. Table 5 depicts the cost comparison.

From a cost point of view, it is clear that for small stations with a low signal count, the OS RTU is very cost effective. In the case of eThekwini Electricity who maintains approximately 15 000 MV assets, the sheer capital cost savings based on volume immediately warrants further consideration.

From an operational cost point of view, there is no financial commitment to a specific vendor regarding support. Support is available within a virtual online ecosystem from a global user-space.

Discussion

The objective of this research was to investigate whether open source technologies can offer a technically appealing and cost effective remote monitoring solution for the smart grid. It also goes on to investigate the non-technical challenges in implementing such technology within a municipal landscape.

The research indicates that open source hardware and software technologies exist in the public domain that can meet the remote monitoring requirements of distribution utilities. The OS RTU proposal put forward in this paper offers a compelling option. The technical metrics investigated indicate stability of the open source code and overall system architecture. However, it is recommended that stringent immunity tests against the IEC 61000 standard is conducted as a design imperative.

The non-technical challenges associated with implementing OS technologies within the municipal landscape can be reduced through the formation of a strong open source community consisting of like-minded engineering practitioners. It is recommended that Utility Engineers collaborate on open source projects in order to share knowledge and where possible, contribute positively to code that ultimately resides in the public domain. Such collaboration spurs interest in research and development and reduces the financial commitments that larger equipment manufacturers place on customers with regard to support.

A cost analysis reveals that there are significant upfront cost benefits in utilising open source technologies for grid monitoring when compared to proprietary options. In some cases, the cost of proprietary systems act as an inhibitor to increasing grid visibility. The recommendation is that it is better to implement some level of monitoring through cost optimised methods than to omit any attempt to extend grid visibility because of funding complexities. There is also reduced operating costs associated with OS technologies as users have access to a large development community within a virtual ecosystem that is free-of-charge. Furthermore, there is no vendor lock-in and code is generally hardware agnostic.

Future research

The current implementation of the OS RTU is within an indoor mini-substation. A future implementation and subsequent evaluation will be on a pole-top transformer. OS technologies within the smart metering environment has already gained traction, viz. YOMO, the open source and open hardware metering board [14].

Conclusion

An investigation into the use of open source technologies within the smart grid for remote monitoring has shown that the open source market is mature enough to spur product innovation. It is recommended that utility specialists contribute, even at a functional level, to the open source knowledge base.

The OS RTU proposal put forward in this paper offers a compelling low cost remote monitoring solution for municipalities. The source code is available for other municipalities to adopt and implement where needed.

The use of open source technology removes vendor lock-in thus bringing flexibility and technology agility to the organisation. The collective power of crowd-sourcing from global communities introduce new ideas and concepts more effectively than rigid teams working on proprietary alternatives. Open source stands to democratise new technology and with the recent uptick in open source usage by global industry, South African utilities need to position themselves well to also harness the full benefits that open source has to offer.

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Competence in an ever-changing asset environment

by Tim Beavon, Pragma

How many times has it been said that people are our most valuable assets? Typically, assets are defined as items, things or entities that have potential or actual value to an organisation (ISO 55 000 definition). However, organisations rarely realise the true value of those assets without people.

This paper will look at the impact of the Internet of Things/Industry 4.0, the spread of technology and the impact it is having on people, how we train people and how we drive competence in our people in order to achieve the true value potential of our assets. So, let's have a look at these people that we rely on to deliver the value.

Challenge 1: Closing the competence gap

Every organisation faces the challenge of an aging workforce that has skills and experience, and young, enthusiastic, tech-savvy people entering the workforce but lacking the knowledge or experience in many areas. But even more challenging, these young people use technology that often the aging workforce has yet to understand. Now let's add another ingredient to our challenge – the concept of incompetence, which can be subdivided into:

Conscious incompetence: I know I don't know this and it challenges me or overwhelms me.

Unconscious incompetence: I believe that I truly know something and consequently make significant errors of judgement in my work.

Learning and development of people entering the work-force is critical to helping them overcome the barriers to competence. In 2018 research by David Perring of the Fosway Group showed that learning is the top reason why people want join your organisation or leave it. The risk is that, by focusing on the traditional way of learning (let's call it cramming – because three to five days of immersion in new ideas shouldn't be called anything else), is more likely to result in an increase in unconscious incompetence.

Perhaps our solution lies in ensuring that those people that recognise that they are incompetent are provided with the training and access to learning material that allows them to find the knowledge that they need to grow their competence. While this has always been the goal of training it is going to fail miserably if we keep pushing the cramming method.

Let us also recognise that formal training is necessary to push the boundaries of learning, and to create the awareness of unconscious incompetence but when used it needs to be followed up by smaller learning interventions that are extremely informal and supportive.

Challenge 2: The modern learner

Josh Bersin (Bersin by Deloitte) carried out extensive research on what he called "The Modern Learner". He described today's employees as overwhelmed, distracted and impatient. They are hungry to learn and keen to grow their skills and if their employer won't help them, they will leave.

Today's employees are untethered – they frequently work somewhere other than their employer's location, and they are frequently contracting or freelancing in order to accommodate their lifestyle. They are accessing information on-demand via their smartphone, collaboratively from peers and colleagues, and often not from the traditional training content because the learning content has to be useful and relevant to them in their immediate situation. Kirstie Greany of Elucidat noted in her paper on people centred e-learning that the average person gives a page of content around seven seconds to decide if it is for them and 70% of users will leave if it's not optimised for them and their needs.

Today's employees also are looking to the future; as job roles become more fluid and their lifestyle expectations more flexible, they are looking out for the kinds of skills that will do them well into the future. Bersin stated in The Modern Learner that the half-life of professional skills was between two and a half and five years and employees are constantly looking for integration between their learning and work – they want the learning to be as relevant and practical to their work situation as possible.

The problems of today and tomorrow

In my mind we need to satisfy the short-term challenge of providing our employees with the skills and competence to meet the challenges of today while also thinking of the long term and creating a work environment that can provide learning and knowledge to the employee that is relevant, available and adaptive to their personalised requirements.

Solving the problems of today

A starting point for many organisations is to ensure that there is an appropriate organisational design and structural clarity between the various role players. Unfortunately, there is no secret recipe to solving problems that can apply across industries and organisations, but the organisational systems must be aligned with the purpose and objectives of the organisation. Further, roles and responsibilities must be defined according to a RACI matrix (responsibility, accountability, consulted, informed) that clearly lists the applicable organisational management practices and the impact of the role. This process will highlight areas where competence gaps exist for the individuals in the role. The competence gaps can be used to manage career expectations and set targets for personal development.

Supporting this, there needs to be an enabling "ecosystem" for learning and development in the organisation – access to learning material that is easily available via smartphones, and the use of technology that enables employees to access information that is relevant and available in the moment of need. On top of that the content needs to bridge the seven-second rule because it is effectively curated.

Again, technology provides the organisation with the opportunity to set up communities of practice that will enable learning through on the job experience, mentorship programmes, and collaboration and knowledge sharing between peers. Tools such as Slack, LinkedIn Learning, Degreed, Axonify, etc assist in providing, enabling and reinforcing learning.

Above all the modern learner wants to apply and be confident in their application of learning and this is where mentorship programmes and grooming by the experts of the past are needed to support the modern learner in the workplace.

Solving the problems of tomorrow

Hagel, Brown and Wooll (Deloitte Insights) in their article "Skills change, but capabilities endure" report on how Toyota is compelling new employees to build motor cars by hand from scratch before they learn to assemble the vehicle on the assembly line. The intent is to ensure that these employees draw upon their imagination, creativity, problem-solving and experimentation capabilities so that they can ask the right questions when confronted by an unforeseen problem and develop new solutions.

At a time when the skill need is changing even more quickly, there is a focus on cultivating underlying essential human capabilities that will make the individual adaptable to the changing circumstances. Hagel, Brown and Wooll propose that organisations of the future will develop the following skills and capabilities:

- *Emotional intelligence*: Understanding other people's emotions and experiences and how they shape human interactions
- *Teaming*: Collaborating effectively across spatial, organisational and cultural boundaries
- *Social intelligence*: Understanding interpersonal dynamics and behavioural impacts of human interactions
- *Sense-making*: Creating awareness and meaning out of collective experiences
- *Critical thinking*: Analysing, evaluating, synthesising and reconstructing information
- *Adaptive thinking*: Recognising new patterns and applying patterns in new contexts

If one considers the skills and capabilities, they aren't new, they exist in all of us – we need to nurture and reward them because this will be the most sustainable way forward once we develop the critical mass that ensures our organisations enable these capabilities to thrive.

Conclusion

The fourth industrial revolution, internet of things, artificial intelligence and all the recent advances in technology will change the way we recruit, develop and retain skills and competence in the future.

What we need most is people with the skills and capabilities to be flexible and adaptable in a fast-changing employment environment; we need adaptable learning to support the modern learner and you need to assess whether your organisation is nurturing and encouraging growth in those skills and capabilities otherwise you're sure to lose them.

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...Continued from page 101

will be a focus of municipal support going forward.

NERSA's cost of supply framework utilises the cost plus methodology which allows for a surplus of 15% on total costs, inclusive of energy costs. This approach means that when customers consume less electricity after the installation of SSEG, the municipality loses the 15% surplus it was receiving from each unit sold. With cost reflective SSEG tariffs in place municipal revenue is substantially protected in terms of cost recovery, but overall revenue may decrease in the longer term. Municipalities and NERSA will need to address this particular revenue vulnerability.

Conclusion

This paper has shown that the rapid uptake of SSEG has the potential to significantly impact municipal revenue. Four case studies were explored where municipalities used varying approaches to SSEG tariff setting, and the outcomes ranged from significant revenue growth to considerable revenue loss. Some municipalities charge high fixed charges coupled with generous export tariffs, while other municipalities charge low fixed charges while offering very low export tariffs for exported electricity.

Although tariff setting should be informed by cost of supply information, an interim approach can result in a sensible SSEG tariff that balances municipal revenue interests with the customer business case. The analysis of the commercial sector revealed that it is robust in the face of SSEG due to the already existing separation of fixed network and variable energy costs. Metro 1, which closely approximates the recommended tariff approach for the residential sector (fixed charge between R200 to R400 and an export tariff that approximates the avoided bulk purchase costs), demonstrates that revenue can be protected whilst ensuring a reasonable (economically cost reflective) business case for SSEG customers.

A concern around revenue loss is not a valid reason to resist the adoption of SSEG into a municipal network given that it is easy to mitigate negative revenue impact, as illustrated in this paper. The SSEG tariff model provides a useful tool through which to explore tariffs that balance revenue protection with fair investment signals within each municipality.

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TID rollover checklist and timeline

by Don Taylor, STS Association

The token identifier (TID) is a 24-bit field, contained in STS compliant tokens, that identifies the date and time of the token generation. It is used to determine if a token has already been used in a payment meter. The TID represents the number of minutes elapsed since the base date of 1 January 1993. The incrementing of the 24-bit field means that at some point in time, the TID value will roll over to a zero value.

All STS prepayment meters will be affected by TID roll over on the 24 November 2024.

Any tokens generated after this date and utilising the 24-bit TID, calculated on base date 1993, will be rejected by the meters as being old tokens as the TID value encoded in the token will have reset back to zero.

In order to overcome the TID rollover occurrence, all meters will require key change tokens with the rollover bit set. In addition to this, the base date of 1 January 1993 will be required to be changed to a base date of 1 January 2014. This process will force the meters to reset the TID stack memory to zero. To avoid previously-used tokens from being accepted by the meter due to the TID stack reset, the key change process changes the meter key at the same time.

A process is therefore required to allow for the management of this TID rollover key change with the least impact to the utilities and equipment suppliers.

Definitions

- *HSM:* Hardware security module KLF: Keyload file
- *SGC:* Supply group code
- *SM:* Security module
- *STSA:* STS association
- *VSM:* Virtual security module
- *CTS:* Conformance test specifications

Benefits of a TID rollover and STS edition 2

The STS edition 1 specifications have been used successfully for more than 25 years, and with the recent launch of STS edition 2 specifications, significant benefits for the industry can be realised, these being:

- *Enhanced algorithms for vending key creation and protection:* The new system will use up to 192 bit encryption and state-of-the-art algorithms approved by NIST for use at least up to 2045.
- *Key expiration:* The new system will allow for a vending key to be expired after a certain time (chosen by the SGC owner). This ensures that even if a vending key has been compromised, the key will expire after a certain time. This will significantly reduce the risks associated with the theft of standalone vending systems or security modules.
- The longevity of the STS system is guaranteed.
- All STS prepayment meters that have been using tokens purchased from un-authorised vendors will reject these tokens after the TID rollover key changes have been performed.

Process overview

Overview

The process that should be followed to ensure that a smooth and successful the TID rollover is carried out to all meters is outlined in the sections below.

Update key management centre (KMC)

The KMC has been updated to support the upgraded security levels in compliance with STS 600-4-2 and also to support the updated security modules (see below). The KMC still supports the legacy key management protocols.

Update security module

Vending and manufacturing security modules have been upgraded to support the upgraded security levels and the generation of TID rollover key change tokens. The upgraded security modules have a new API (STS600-8-6), that requires additional vending and manufacturing software changes.

The upgrade path of the various security module models is given Table 1.

- *TSM210:* Replace with TSM250
- *TSM220:* Replace with TSM250
- *TSM250:* Send to Prism for firmware upgrade to STS6
- *TSM410:* Replace with TSM500
- *TSM500:* Send to Prism for firmware upgrade to STS6

Update vending systems

Vending systems to be updated to cater for multiple base date functionality in the security module. This will include the handling of a new key-load file specification as defined in STS600-4-2, and conformance to the STS600-8-6 HSM protocol.

All vending systems are to be re-certified to ensure compliance with these new requirements. Note that after June 2019, all vending systems must be compliant to the new requirements of the STS Edition 2 suite of standards (see appendix A).

Update meter manufacturing process

Meters are manufactured with a new base date of 2014 by selecting a vending key with a base date of 2014 – no further changes are required to manufactured meters. This will require updating of manufacturing security modules, software and processes to cater for dual base dates for the duration of the changeover period.

Utilities can only use meters manufactured on base-date 2014 after their vending software has been updated and should only do so upon specific request from the utilities.

The meter certification test facility could not test for TID rollover functionality prior to 2014, so there is a small risk that some of those meters may not correctly support the TID rollover key change. Utilities and meter manufacturers must select samples of these meters and resubmit them for testing. The STS Association will do the test free of charge. Those meters that do not comply must then be replaced in the field. A list of meters/suppliers falling into this category is available from the STS Association.

STSA test facilities

Accredited STSA test facilities are now able to certify all updated vending systems and security modules. These will be issued with new certificates and all prior compliance certificates will be revoked after June 2019.

Meter key-change programme

Utilities and sub-vendors must develop a programme to manage the TID rollover key changes to all installed meters operating on base date 1993. Those meters already operating on base date 2014 do not need their meter keys changed.

In certain cases this programme will be a huge undertaking and utilities are thus advised to start as soon as possible.

There are two possible options to follow:

- The end-customer may be issued with the key change token pair at the time when they next purchase credit at a vending station. They then enter the token pair into the meter themselves before they enters their newly purchased credit token.
- A dedicated field-service team may be used to visit each meter and then enter the key change token pair.

The STS Association is available to assist and advise utilities and sub-vendors on the appropriate approach to take.

Action plan

STS association

The STS Association (STSA) is putting in place the necessary infrastructure and has launched a campaign to make all STS users aware of the TID rollover requirements and to assist and advise users in the execution of the TID rollover key change program.

Checklist of actions required:

- STSA to communicate to all its members regarding the rollout plan – this process is under way.
- General assistance from the STSA technical support in respect to rollover queries.
- Development of CTS tests for the new SM and KMC – this has been completed.
- Manage the updated KMC project – this has been completed.

Secure module suppliers

Upgrading of secure modules (SMs) to cater for the rollover bit as well as the handling of multiple base dates has been completed. It is the responsibility of the SM supplier to communicate with their customers to inform them of the requirement to upgrade their SMs.

All SMs that do not support the STS6 protocol must be upgraded, this includes the TSM210, TSM250, TSM410 and TSM500 models.

Checklist of actions required:

- Upgrade SM to cater for rollover bit and multiple base dates – this has been completed.
- Test SM – initialisation, key-loading, and new firmware functionality to STS600-4-2 specification – this has been completed.
- Certify SM to CTS spec for STS600-4-2 (STS531-8-2) – this has been completed.
- Field test SM – code at KMC and test tokens with live keys – this has been completed.
- Deploy upgraded SM to the field – this has started.

Key management centre (KMC) suppliers

Upgrade to the existing KMC and rollout the new KMC supporting multiple base date functionality has been completed.

Year	2016				2017				2018		2023	
Quarter	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1-Q4		Q4	
SM Manufacturers												
SM update to STS6												
SM field test												
SM certification												
SM Deployment												
KMC manufacturers												
KMC update												
KMC data migration												
KMC UAT (+ field trial)												
KMC training												
KMC approval (STSA)												
KMC Deployment												
Meter manufacturers												
Update production processes												
Start meter manufacture to new base dates												
Vending Software Manufacturers												
Upgrade all SM's to STS6												
Upgrade vending software												
Software accreditation to CTS												
Update customer software in the field												
Utilities												
Update all field SM's												
Communications program Rollout												
Select SGC's												
Run pilot												
Generate program												
Rollout to all areas												
Sub-vendors												
Contact all sub-vendors												
Upgrade SM to STS6 with new base dates												
Perform key-changes												
Field KeyChanges												
Complete all key-changes												

Table 1: Overall project implementation timeline.
Note: Items in blue are completed. Shaded items started but not completed.

Key management centre

The key management centre has been upgraded in compliance with STS 600-4-2 and is fully operational regarding support for the TID rollover program.

Checklist of actions required:

- Issue new vending keys in the new key load file format to upgraded vending and meter manufacturer systems when so requested and are ready to receive them.
- Maintain support for legacy key load files until all TID rollover key change programmes have been completed.

Meter manufacturers

Meter manufacturers must update their production processes in order to cater for the new manufacturing security modules, and to enable them to manufacture meters on either base date as specified and so requested by their customers.

Checklist of actions required:

- Update manufacturing modules – this has started.
- Check rollover bit functionality in meters – this has started.
- Change production processes to cater for multiple base dates – this has started.
- Manufacture meters with new base date of 2014 when requested to do so by their customers.

Vending system manufacturers

Vending system manufacturers are required to update all the operational vending software to cater for the new SM API and key-load files and rules. They will also be required to contact all their customers to arrange for software upgrades to be performed in the field.

Checklist of actions required:

- Update software to cater for new key load file (KLF) specification – this has started.
- Update software to handle multiple base dates – this has started.
- Certify software to CTS test specs – this has started.
- Upgrade customer vending software in the field – this has started.
- Get contact details of all sub-vendors that use their vending systems and communicate these to the STS Association.

Utilities

Utilities are responsible for their own rollout plan of the TID rollover key-changes to the new base date. This program must be set up by the utilities themselves based on the timing requirements of their program timelines. This part of the project is naturally the most important and difficult of the entire program and must be thought out thoroughly before implementation.

Checklist of actions required:

- Request the vending system supplier to upgrade the vending system.

Appendix A (informative)

The STS Edition 2 document suite comprises the following documents:

IEC62055-41 Ed3 2018	Electricity metering – Payment systems – Part 41: Standard transfer specification (STS) – Application layer protocol for one-way token carrier systems
STS101-1	Physical layer mechanical and electrical Interface for virtual token carriers
STS101-2	Physical layer protocol for a two-way virtual token carrier for remote connection over DLMS/COSEM
STS201-1	Meter function object: Register table for payment meters
STS202-4	Physical layer protocol for a two-way virtual token carrier for direct local connection
STS202-5	Class 2 token extensions
STS202-6	Additional requirements for vending systems
STS203-1	Method for default payment meter values for conformance testing
STS531-0 (ED 1.9)	Compliance test specification – Quality plan
STS531-1-0-02 (ED 1.9)	Entity type A – POS to token carrier interface application layer protocol for POS devices supporting DKGA=02 and EA=07, and optionally: DKGA=04 and EA=07
STS531-1-0-04 (ED 1.9)	Entity type A – POS to token carrier interface application layer protocol for POS devices supporting DKGA=04 and EA=11, and optionally: DKGA=04 and EA=07
STS531-1-1-04 (ED 1.9)	Entity type A – POS to token carrier interface application layer protocol for POS devices supporting DKGA=04 and EA=07
STS531-2-1 (ED 1.9)	Entity type B – POS to token carrier interface physical layer protocol for TCT = 01 and TCT = 02
STS531-3 (ED 1.9)	Entity type C – Token carrier: Token carrier for TCT = 01 and TCT=02
STS531-4 (ED 1.9)	Entity type D: Token carrier to meter interface physical layer protocol for TCT = 01 and TCT = 02
STS531-5-0 (ED 1.9)	Entity type E - Token carrier to meter interface application layer protocol for TCT = 01 and TCT=02
STS531-6-1-07 (ED 1.9)	Entity type F – Meter application process for TCT = 01 and TCT = 02, Using EA=07
STS531-6-1-11 (ED 1.9)	Entity type F – Meter application process for TCT = 01 and TCT = 02, using EA=11
STS531-8-1 (ED 1.9) Entity type H – POS to security module interface	
STS531-8-2 (ED 1.9)	Entity type H – POS to security module interface supporting DKGA=01, DKGA=02, DKGA=04, EA=07, and EA=11
STS531-10-02 (ED 1.9)	Entity type H1 – Security module to POS interface adaptation layer protocol for POS devices supporting DKGA=02 and EA=07, and optionally: DKGA=04 and EA=07
STS531-10-04 (ED 1.9)	Entity type H1 – Security module to POS interface adaptation layer protocol for POS devices supporting DKGA=04 and EA=11, and optionally: DKGA=04 and EA=07
STS600-4-2	Key management system
STS600-8-1	Legacy security module API for STS03V
STS600-8-2	Legacy security module API for STS03M
STS600-8-3	Legacy security module API for STS04A
STS600-8-4	Legacy security module API for STS05V
STS600-8-5	Legacy security module API for STS05M
STS600-8-6	Security module API for STS6
STS600-15	Key management systems forms
STS1800-7	Manufacturing guidelines

- In the case where the utility had developed their own vending system, the utility must do the upgrade.
- Divide the installed base of meters into smaller manageable groups for processing one group at a time.
- Decide on key-change programme option.
- Compile a programme for the entire key change operation.
- Inform all role players (especially the end-customers) and regions of the programme details.
- Start the programme on a pilot site to test the processes.
- Roll out to other meter groups.
- Ensure that the entire programme is completed at least one year before the TID rollover date of 2024.
- As soon as the vending system has been upgraded, new orders for meters should instruct their meter vendor to manufacture those meters on base-date 2014.

Sub-vendors

Sub-vendors are responsible for the rollout plan of the key-changes to the new base-date on meters that are under their control. This programme must be set up by the sub-vendors themselves, based on the timing requirements of the programme timelines. This part of the programme is naturally the most important and difficult of the entire programme and must be thought out thoroughly before implementation.

Checklist of actions required:

- Request the vending system supplier to upgrade the vending system.
- Divide the installed base of meters into smaller manageable groups for processing one group at a time.
- Decide on the key-change program option.
- Compile a programme for the entire key change operation.
- Inform all role players (especially the end-customers) and regions of the programme details.
- Start the programme on a pilot site to test the processes.
- Roll out to other meter groups.
- Ensure that the entire programme is completed at least one year before the TID rollover date of 2024.
- As soon as the vending system has been upgraded, new orders for meters should instruct their meter vendor to manufacture those meters on base date 2014.

Tools/specifications requiring updates

Virtual secure module (VSM)

- The update of the VSM to cater for new base dates has been completed.
- Allow import of KLF using VSM allocated keys.
- Update VSM to handle new KLF specification.
- Release updated VSM for use.

Nedisys file specification

The specification (ST_240-76627071_Prepaid Meter upload standard Rev4) may be obtained from Eskom at www.prepayment.eskom.co.za.

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Condition monitoring for asset management in MV switchgear at eThekwini Electricity

by MP Lokothwayo, Sheila Cele Diploma, N Zulu and PM Ntombela, eThekwini Electricity

The aim of eThekwini Electricity is to operate electrical assets in the field without any defects at minimum cost; hence, improve service delivery, increase safety of personnel and equipment and ensure occupational health and safety environment. Electricity distribution assets comprise overhead lines, power transformers, instrument transformers, swicthgear and cables. This paper is centered around medium voltage (MV) switchgear.

MV switchgear is exposed to various stresses during operation. Partial discharge (PD) activity is considered the major source of defect in MV switchgear insulation [1]. Therefore, PD detection and location is an effective method to reveal the insulation condition in MV switchgear. The asset management (AM) plan that incorporate on-line PD detection allows for strategic decision based on assets' PD activity level to be taken and resources to be deployed effectively during planned outage.

The capital investment made to deliver electricity to the end users must correlate to the management of these assets throughout their life span [2]. Thus, the initial step in implementing a condition monitoring program is to collect and analyse historical failure records for similar types of asset. This help to determine the cause and magnitude of problems and resources are appropriately utilised in dealing with the causes. According to [1], a large number of substation defects originate from insulation failures as presented in Table 1.

This paper focuses on assessing the condition of the MV switchgear using on-line partial discharge detection technology. The overview of on-line PD measurements and MV switchgear defects which were identified are presented and discussed.

Asset management

According to [3], "AM is the process of maximising the return on investment of equipment over its entire life cycle, by

Component	Percentage of insulation failure
Transformers	84%
Circuit breakers	21%
Disconnect switches	15%
Insulated switchgear bus	95%
Bus dust	90%
Cable	91%
Cable joints	89%
Cable terminations	87%

Table 1: Insulation system failure statistics [1].

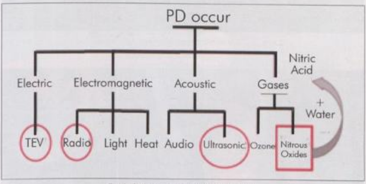

Fig. 1: Energy emitted during PD activity [7].

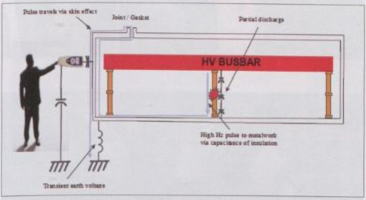

Fig. 2: Internal PD effect [7].

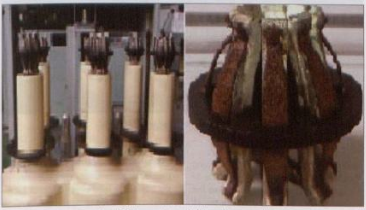

Fig. 3: Cluster contact on 11 kV switchgear panel.

Fig. 4: Cable termination on 11 kV switchgear panel.

Fig. 5: Tracking CTs on 11 kV switchgear panel.

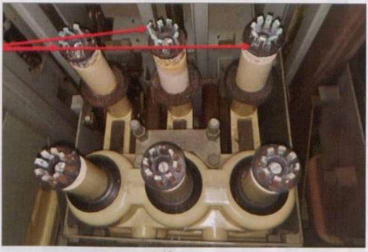
Fig. 6: Cluster contact on 11 kV switchgear panel.

maximising performance and minimising costs". AM is the well-organised use of resources, with focus on increasing the remaining useful life of the equipment. Its ultimate purpose is to effectively and efficiently use the equipment service life. It guarantees that critical assets will continue meeting the mandatory level of performance for the duration of the life of the equipment. From the electricity distribution perspective, AM is a systematic process of relating engineering practices and economic analysis to manage electrical assets in a cost effective manner.

There are five types of assets classification that need to be considered in achieving the organisational strategic plan successfully [4]. This includes physical assets, human assets, data assets, financial assets and intangible assets. Cost, risk and performance are three pillars in managing the life cycle of MV switchgear effectively. The attributes that impact switchgear remaining life are: insulation failure; mechanical problems; improper cable termination; failure on instrument transformers and malfunctioning. Risk evaluation and prioritisation most of the time poses a challenge in decision making process for AM system. CM approach based on PD detection in MV switchgear allows for proper decision making to either dispose or repair the matured switchgear completely and Capex available is used appropriately. It is in this way that CM supports the AM system and allows for optimising asset performance at a reduced operational cost.

Condition monitoring

Partial discharge concept

According to IEC 60270 [4], "PD can be described as an electrical pulse or discharge in a gas filled void or on a dielectric surface of a solid or liquid insulation system". PD can develop in electrical assets under normal working condition. It is caused by number of factors including improper installation, ageing, manufacturing defects, environmental and third party damage. PD in electrical insulation is caused by void or flaws and if left undetected can eventually manifest to full breakdown of insulation system.

PD phenomenon is an indication of degradation of insulation materials. Thus, the detection of PD at early stages plays a crucial role in increasing the service life of electrical assets [5]. By carrying out on-line PD testing in monitoring critical assets it is possible to provide an early warning of pending insulation failure. PD experience has shown that early PD detection followed by remedial action lead to simpler and lower cost solution maintenance [6].

The ability to comprehend theory of PD is very helpful in interpreting the PD measurement results. PD activity behaviour is greatly influenced by voltage and temperature (mainly humidity). Low humidity can cause PD activity to be undetectable and develop again when humidity increases. Fig. 1 show energy types emitted during PD activity:

PD classification

Two types of PD can be identified in MV switchgear, namely surface discharge and internal discharge [4].

- *Surface discharge:* When surface PD is present, tracking occurs across the surface of the insulation which is worsened by floating contamination and moisture leading to erosion of the insulation [5]. Often moisture combines with the NOx gasses to produce Nitric acid, which attacks both the insulation and surrounding metalwork, which can become seriously rusted. Insulation surfaces affected by such an acid attack produce an ideal surface for tracking to occur. Tracking is the result of carbonisation of the surface of insulation by the breakdown of contaminates in the early stages [6].
- *Surface discharge detection:* The high frequency sound waves generated by the partial discharge activity on the surface of the insulation can be detected using 40 kHz range ultrasonic detector [6]. Quantifying the seriousness of detected ultrasonic signals sometimes poses a challenge and therefore, further visual investigation is needed irrespective of the signal level. Table 2 presents risk interpretation for surface discharges [7].
- *Internal partial discharge:* Internal PD occurs within the insulation materials and is caused by age, poor materials or poor quality manufacturing processes [5]. If allowed to continue, eventually causes the insulation to break down catastrophically.
- *Internal discharge detection:* The discharge activity within solid insulation can be detected using Transient Earth Voltage (TEV) detection. The TEV measurement technique operates within a bandwidth of 3 to 70 MHz, to detect and locate the PD source from the phase terminations to earth usually caused by voids and surface discharge to earthed metalwork [6]. Fig. 2 illustrates the TEV practical concept.

When a discharge occurs a small quantity of electrical charge is transferred capacitively from the live conductor to the earthed metal-cladding. Due to the skin effect the transient voltages on the inside of the metalwork cannot be directly detected outside the switchgear. However, at an opening in the metal cladding, such as the gasket joint the electromagnetic wave can propagate out into free space. The wave front impinges on the outside of the metal cladding generating a transient earth voltage on the metal surface. Hence, the technique is called TEV for transient earth voltage. TEV signals will propagate from all types of chambers, i.e. the technique can be applied to gas insulated chambers, as well as oil, bitumen and air insulated chambers [6]. Table 3 present risk interpretation for internal discharges [7].

Ultra dB	Category	Comments
<6	Good background	No observable/measurable deterioration
7 – 10	Fair vary slight fizzing only just above the background	Minor deterioration which requires no specific action
11 – 20	Poor Heavy fizzing or cracking	Moderate deterioration item can be returned to service. Reinspect in 30 days.
>20	Action required. Spitting or sparking or heard with the naked ear	Serious deterioration items cannot be retured to service without shut down or engineering advise.

Table 2: Ultrasonic risk interpretation.

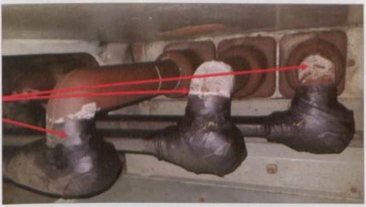

Fig. 7: busbar bushing connection on 11 kV switchgear panel.

Fig. 8: Tracking CTs on 11 kV switchgear panel.

Practical experience and analysis

Based on the risk interpretation in Table 2, serious discharge activity was identified on 11 kV switchgear cubicles.

The planned outage was scheduled via an Ellipse asset register. The visual inspection findings and analysis are presented next.

Case 1 – Distribution substation 413

- *Cluster contact:* Locator Reading 34 dBuV ultrasonic. Defects: Severe rusting. Possible cause: Nitric acid produced by combination of moisture and NOx gasses attacking insulation and surrounding metalwork.
- *Tracking cable termination:* Locator reading: 27 dBuV ultrasonic. Defects: carbon discharge and a bubble on one of the phases. Possible cause: Poor workmanship.
- *Tracking CTs:* Locator reading: 44 dBuV ultrasonic. Defects: treeing and tracking discharges. Possible cause imperfections in the insulation system.

Case 2 – Distribution substation 1123

- *Cluster contact:* PD locator reading: 32 dBuV ultrasonic. Defects: rust and loose cluster contact fingers compromises the mechanical strength of the cluster. Possible Cause: The loose cluster contact fingers and mechanic damage on the cluster contact creates an effective way for partial discharges to develop.

Fig. 9: 11 kV switchgear cable termination failure.

Fig. 10: 11 kV busbars failure.

TEV dB	Pulses/Cycle			
	<0,5	0,5 – 6	6 – 30	>31
0	No TEV detected			
10 – 19	No TEV detectnd	Possible low level internal PD	Possible low surfacePD	Interference or low level surface PD
20 – 29		Low level internal PD	Low level surface PD	
>30		High risk of internal PD	Likely floating object or poor contact PD	

Table 3: TEV risk Interpretation.

- *Busbar bushing connection: Tracking CTs:* PD locator reading: 43 dBuV ultrasonic. Defects: discharge traces in the busbar bushing connection. Possible cause: Water due to high humidity level treating a conducting level. Locator Reading: 38 dBuV Ultrasonic. Defects: water ingress on the CTs. Possible cause: design issues.

Case 3 – Distribution substation failures

- *Cable termination failure due to PD:* The PD was detected on this termination. However it was was not given attention on recommended time due to load challenges and it failed. Locator reading: 31 dBuV ultrasonic. Defects: cable termination failure. Possible cause: Poor workmanship.
- *Busbar failure due to PD:* The PD was detected on this circuit. The consumer refused a planned shutdown. Therefore this resulted to a busbars failure. Locator reading: 34 dBuV ultrasonic. Defects: 11 kV busbars failure. Possible cause: poor workmanship.

These failures would have been prevented if remedial work done was prioritised according to risk interpretation in Table 3.

Discussion

The PD measurement results in conjunction with defects identified clearly indicates that PD testing in MV switchgear is an excellent on-line monitoring tool. PD monitoring identifies risks of failure in MV switchgear. The use of on-line PD analysis can identify areas of immediate concern. The results can be prioritised and trended. Moreover, outages are planned and repairs can be budgeted.

Conclusion

This paper has presented a concept and implementation of asset condition monitoring in MV switchgear. The effectiveness of MV switchgear condition monitoring based on an online PD testing has been successful implemented. PD theory has been used to better understand the causes of defects in switchgear components. Visible evidence of PD defects and possible causes have been identified and discussed. The switchgear measurement results together with the identified defects were analysed and solutions actioned efficiently and effectively. Condition monitoring is an important element of power system asset management. The decision to replace or repair the asset is achieved better when the condition status of the asset is known. CM enhances reliability and aids in life extension of critical assets in power distribution system.

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Eya Bantu Professional Services	Mike Brown	043 726-2726	PO Box 19803, Tecoma, Berea, East London, 5241	Eastern Cape
Farad	Peter Gerber	011 726-4090	PO Box 31220, Braamfontein, 2017	Highveld
FIBCO South Africa	Yolandi Zeelie	010 110-0443	PO Box 1444, Gallo Manor, 2052	Highveld
Flash Mobile Vending	Neo Boabua	021 674-7620	2 Fir Terraces Building, Black River Park, Observatory, 7935	Good Hope
Flo Specialized Product Solutions	Fabian Oostendorp	021 982-7551	PO Box 5101, Kraaifontein North, 7572	Good Hope

AMEU Affiliate Members

Organisation	Name	Phone	Postal address	Branch
FuseForward South Africa	Wendy Scott	011 575-7609	Twickenham Bld, The Campus, Cnr. Main & Sloane Street, Bryanston, 2191	Highveld
GIBB	Paul Fitzsimons	011 519-4600	PO Box 2700, Rivonia, 2128	Highveld
GIZ	Karabo Masekwameng	012 423-6335	PO Box 13732, Hatfield Pretoria, 0028	Highveld
Global Spec	Paul Clarence	021 510-5202	PO Box 281, Paarden Eiland Cape Town, 7420	Good Hope
Hellermann Tyton	Claude Middleton	011 879-6600	Private Bag X158, Rivonia, 2128	Highveld
Hexing Electrical SA	Daisy Chen	011 078-0400	PO Box 593, Private Bag X29 Gallo Manor, 2052	Highveld
I.B Mcintyre & Co - Master Lock	Gregory Slater	021 508-1250	PO Box 342, Maitland, 7404	Good Hope
ID2	Phillip Loots	012 470-2200	PO Box 72614, Lynwood Ridge Pretoria, 0040	Highveld
Imvuselelo Consultants	Francois van Wyk	031 266-2707	PO Box 698, Westville, 3630	Kwazulu Natal
Infraset (A Business Unit of Aveng Africa	Mathemane Makhura	011 813-2340	PO Box 6062, Rivonia, 2128	Highveld
Inspired Interfaces	Tom Phillips	031 765-6650	PO Box 967, Hillcrest Durban, 3650	Kwazulu Natal
Integrity Control Systems	Imelda Mace	011 397-2508	Postnet Suite 126, Private Bag X4, Bedfordview, 2008	Highveld
IPES - Utility Management	Wouter Vermaak	012 665-4509	PO Box 11000, Centurion, 0046	Highveld
Iso-Tech Systems	Ben Wagner	011 466-3701	PO Box 13442, Vorna Valley, 1686	Highveld
iST (Integrators of Systems Technology)	Sean Cox	012 426-7200	Private Bag X95355, Waterkloof, 0145	Highveld
iX Engineers	Dürr Pieters	021 912-3000	PO Box 398, Bellville Cape Town, 7535	Good Hope
Izembe Technologies	Sipho Mthembu	012 667-1530	PO Box 10514, Centurion, 0046	Highveld
JoCastro	Miklos de Castro	021 577-1602	PO Box 1548, Dassenberg, 7350	Good Hope
KBK Power Solutions	Fred Peters	031 782-1329	PO Box 133, Cato Ridge, 3680	Kwazulu Natal
Kirkwall Holdings SA	Peter Horn	011 425-6372	PO Box 8053, Edenglen, 1613	Highveld
KoCos Measurement & Control	Hein Erwin	021 982-0016	PO Box 3585, Durbanville, 7551	Good Hope
Landis + Gyr	Nisha Chetty	012 645-3117	PO Box 4052, The Reeds Pretoria, 0185	Highveld
Lebohang Consulting Engineers	Leo Kober	011 784-0141	World Trade Center Johannesburg, 16Th Floor, Cnr West Road South And Lower Road, Morningside, Sandton, 2010	Highveld
LH Marthinusen (a division of ACTOM)	David Sullivan	011 615-6722	PO Box 27440, Benrose, 2011	Highveld
Lighting Structures	William Brough	087 310-1000	PO Box 1592, Nigel, 1490	Highveld
Lucy Electric South Africa	Tatenda Masawi	011 025-7490	PO Box 1078, Honeydew Johannesburg, 2021	Highveld
Lyners	Theo Potgieter	021 914-0300	PO Box 4901, Tygervalley, 7535	Good Hope
Lyon & Vennote	Martiens Lyon	016 981-6270	PO Box 3925, Vanderbijlpark, 1900	Highveld
Machine Assesment & Reliability Technology	Kim Dare	011 848-6940	Postnet Suite 181, Private Bag X121 Midrand, 1685	Highveld
Macrocomm Telecomunications	Marcellino Arendse	010 493-6871	20 Morris Street East, Woodmead Office Park Woodmead Johannesburg, 2191	Highveld
Major Tech	Werner Grobbelaar	011 872-5500	PO Box 888, Isando, 1600	Highveld
Malesela Taihan Electric Cable	Eurika de Lange	016 450-8200	PO Box 1643, Vereeniging, 1930	Highveld
Manelec Services	Dale Liebenberg	041 581-2262	PO Box 955, Port Elizabeth, 6000	Eastern Cape
Mapule Consulting	Christo Nortje	011 362-1829	PO Box 1300, Springs, 1560	Highveld
Matleng Energy Solutions	Corrie van der Wath	010 035-0230	PO Box 1444, Gallo Manor, 2052	Highveld
Medupe Distributors	Lemao Motaung	011 397-2913	PO Box 966, Isando, 1600	Highveld
Meso Utilities	Sisco Gweru	012 941-1252	576 Makou Street Monument Park Pretoria, Pretoria, 0181	Highveld
Metering Services International (SAFCONSULT)	Peter Harries	021 979-5315	PO Box 1369, Brackenfell, 7561	Good Hope
MI Materials South Africa	Victor Khubani	081 474-0033	Birchwood Court, 43 Montrose Court Johannesburg, 1686	Highveld
Motla Consulting Engineers	George Lotter	018 474-9000	PO Box 30, Robertson, 6705	Good Hope
Mott MacDonald Africa	Claudio Pierini	011 052-2408	Alice Lane Building 1, 3Rd Floor Cnr 5Th And Fredman Drive Sandton, 2146	Highveld
NAKO TRIOCON	Ian Botha	021 552-4949	11 Oxbow Crescent, The Estuaries Century City Cape Town, 8000	Cape Midlands
Norconsult Iyando	Nokululeko Holomisa	011 675-0303	Suite 50, Postnet X1 Florida Hills, 1716	Highveld
Nordland	Johann Lamprecht	011 662-4300	PO Box 522, Muldersdrift, 1747	Highveld
Nyamezela Metering	Motsotso Vuso	011 472-7335	PO Box 161, Strubensvalley, 1735	Highveld
Nynas South Africa	Alistair Meyer	011 675-1774	Suite 550, Private Bag X09 Weltevreden Park, 1715	Good Hope
Ompetha Power Projects	Johan van Staden	011 784-0170	PO Box 650187, Benmore, 2010	Highveld
Ontec Systems	Ivor Kilian	021 928-1700	PO Box 4059, Tygervalley Cape Town, 7536	Good Hope
Optron	Sean Dane	012 683-4500	PO Box 7911, Centurion, 0046	Highveld

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Organisation	Name	Phone	Postal address	Branch
Patch Industrial Supplies & Consulting	Michael Tyszowiecki	021 906-0600	PO Box 5123, Tyger Valley, Cape Town, 7536	Good Hope
PEC Utility Management	Frikkie Nel	021 948-0225	PO Box 3157, Durbanville, 7551	Good Hope
Pendo Energy Solutions	Rudolph Evert	010 035-0232	PO Box 1444, Gallo Manor, 2052	Highveld
PH Marketing	Ashwin Dhawakieram	011 867-6767	PO Box 1925, Mulbarton, Johannesburg, 2059	Highveld
Pienaar & Erwee Engineers	Johann Erwee	012 998-5219	PO Box 1831, Brooklyn Square, 0075	Highveld
Pofu Supply On Demand	Angeline Mabena	011 047-1681	13 Tamarisk Street, Ormonde Ext1 Johannesburg, 2091	Highveld
Power Measurement & Distribution	Johan de Klerk	044 873-0764	PO Box 4700, George East, 6539	Good Hope
Power Process Systems	Benjamin Roode	086 177-7769	PO Box 4172, Southgate, 2082	Highveld
Powerx	Derek Bottle	011 268-6735	The Firs, Office 301, 3Rd Floor Cnr Cradock & Bierman Road, Rosebank, 2196	Highveld
PQ Flow Solutions	Hylton Dettmer	031 261-1285	172 Queen Elizabeth Avenue, Manor Gardens, Durban, 4001	Kwazulu Natal
Pragma Africa	Nonette van Rensburg	011 848-6940	PO Box 3971, Tygervalley, 7536	Good Hope
Pricewaterhouse Coopers Advisory Services	Georg Boecker	011 797-4090	Private Bag X36, Sunninghill, 2157	Highveld
Progressive Energy	Greg Schaufelbuhl	021 511-5580	PO Box 495, Paarden Eiland, 7420	Good Hope
PSW Consulting Engineers	Juan-Dirk Voigt	012 349-2253	PO Box 146, Persequor Park, Pretoria, 0020	Highveld
Ramika Projects	Mirriam Rompopo	010 443-9149	PO Box 522, Muldersdrift, 1747	Highveld
Reinhausen South Africa	Kobus de Villiers	011 835-2077	PO Box 1395, Southdale, 2135	Highveld
Remote Metering Solutions	Francois Conradie	012 001-3600	PO Box 110, Persequor Park, Pretoria, 0020	Highveld
Revive Electrical Transformers	Dharmalingum Padayachee	011 613-1508	PO Box 83334, South Hills, Johannesburg, 2136	Highveld
Rocla	Kevin West	011 670-7600	PO Box 92, Roodepoort, 1725	Highveld
RPS Ilangabi	Regis Masuku	031 266-9505	PO Box 1670, Westville, 3630	Kwazulu Natal
RWW Engineering	Kyle Loss	011 433-8003	PO Box 2042, Southdale, 2135	Highveld
SABS Standards Division	Mogomotsi Motaung	012 428-6613	Private Bag X191, Pretoria, 0001	Highveld
Sandulela Technology	Nkululeko Mvulana	021 300-4560	PO Box 8046, Roggebaai, 8012	Good Hope
Schneider Electric	Brighton Mwarehwa	011 254-6400	Private Bag X139, Halfway Gardens, Midrand, 1685	Highveld
Sectional Poles	Morne van Zyl	012 348-8660	PO Box 17028, Groenkloof, 0027	Highveld
SGB-Smit Power Matla	Mariaan Irwin	012 318-9735	PO Box 691, Pretoria, 0001	Highveld
Signify Commercial South Africa	Nelisiwe Nkosi	011 471-5000	Woodmead North Office Park Block B, 54 Maxwell Drive, Woodmead 2191	Highveld
SMEC South Africa	Andre van der Walt	012 481-3800	PO Box 72927, Lynnwood Ridge, Pretoria, 0040	Highveld
Smith Capital Equipment	Fortunate Mdanda	011 873-9830	PO Box 165, Bedfordview, 2008	Highveld
Specialist System Engineering	Gert Bezuidenhout	012 663-4331	PO Box 7170, Centurion, 0046	Highveld
Spintelligent	Ricky Asher	021 700-3500	PO Box 321, Steenberg, 7947	Good Hope
Static Power (a div of ACTOM)	Nichola Fort	011 397-5316	PO Box 13424, Witfield, 1467	Highveld
STS Association	Franco Pucci	011 061-5000	PO Box 868, Ferndale, 2160	Highveld
Switchboard Manufacturers	Shane O' Reilly	031 508-1520	PO Box 40086, Red Hill, 4071	Kwazulu Natal
Syntell	Juanita Parsothum	021 204-6299	PO Box 30298, Tokai, Cape Town, 7966	Good Hope
SZZT South Africa	John Lin	021 591-6952	75 Vasco Boulevard, Good Wood, Cape Town, 8000	Highveld
Tank Industries a Division of ATC	Adriaan Theron	021 700-4380	PO Box 9, Steenberg, 7947	Good Hope
Tavrida Electric Africa	Andrew Sibiya	011 914-2199	Postnet Suite 64, Private Bag X4, Atlasville, Boksburg, 1465	Highveld
Terrapinn	Jenna-Lee Mcerlaine	011 516-4000	Private Bag X65, Bryanston, 2021	Highveld
TGOOD South Africa	Kobus Coetzer	010 010-5706	Unit 2, Sultana Park, 21 Roan Crescent, Corporate Park North, Midrand, 1685	Highveld
Tridonic SA	Trevor Milne	011 923-9694	PO Box 30542, Jetpark, 1469	Good Hope
Ulungeni Consulting	Gerrie Breedt	035 792-1026	PO Box 1521, Empangeni, 3880	Kwazulu Natal
Universal Cables	Rudi Labuschagne	011 769-1394	PO Box 21335, Helderkruin, 1733	Highveld
Utilities World	Dave Mason	031 833-0100	Unit 701, Strauss Daly Place, Ridgeside Office Park, Umhlangha, 4320	Kwazulu Natal
Verotest	Veronica Merry	011 805-8322	PO Box 50559, Randjiesfontein, 1683	Highveld
Voltex t/a Voltex Cape	Shawn Roets	021 530-3460	PO Box 291, Maitland, 7404	Good Hope
Wax Engineering Consultants	Howard Cengani Gewu	011 680-0126	82 Anson Street, Robertsham Johannesburg, 2091	Highveld
Women Effecting Change	Yolandi Zeelie	010 110-0443	PO Box 1444, Gallo Manor, 2052	Highveld
Woodbeam	Blaize Magee	086 196-6323	PO Box 526, Modderfontein, 1645	Highveld
YeboTech	Grant Martin	021 713-7260	PO Box 30761, Tokai, 7966	Good Hope
Zamori Engineering Services	Charles Marthinus	012 543-3487	349 Borage Avenue, Annlin West Pretoria, 0182	Highveld
Zwelamanzi Trading	Welile Dlamini		13 Strawberry Lane, Gibson Drive Buccleuch, 2066	Highveld

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	LJ 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
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
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 Whitehead	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
2012 – 2014	J Roos	Ekurhuleni
2014 – 2016	S Xulu	Johannesburg
2016 – 2018	T Tshobalala	Vanderbijlpark

AMEU Honorary Members

Date	Name
1915 – 1936	Dr HJ van der Bijl J Roberts E Poole
1938	LL Horrel
1944	GH Swingler AT Rodwell
1950	Dr JH Dobson
1951	HA Eastman
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1956	WH Milton A Morton Jaffray Maj. SG Redman Clr CEK Young
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1960	Clr FJ Castelyn Clr LP Davies
1962	AR Simpson
1963	CG Downie JC Downey RW Kane
1965	G Muller
1967	Clr JD Marais JR Telles
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1981	JDN van Wyk Dr RB Anderson J Morrison
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1985	AA Weich KG Robson Clr RL de Lange W Barnard
1987	AP Burger JC Dawson DH Fraser PC Palser
1989	PJ Botes MPP Clarke EG Davies JA Loubser
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1995	CE Adams B Madeley
1997	JD Algera HR Whitehead F van der Velde
1999	JG Malan CEBurchell
2003	AJ van der Merwe
2005	PE Fowles T van Niekerk J Ehrich
2007	DET Potgieter
2008	V Padayachee
2009	S Maphumulo JJ G Nel
2010	O Bothma JE Coetzee RS Wallis
2011	M Carry D Louw H Roos S Gourrah
2012	Michael Rhode Paul Johnston Louis Steyn Ferdinand Diener Roy Wienand Jorge Pereira
2014	Joseph Renney Neil Ballantyne Pierre van den Heever
2015	Silas Zimu Gerrit Teunissen Len Richardson
2017	Sicelo Xulu Stan Bridgens Roelof du Toit Dawie van Niekerk Kevin Grünewald
2018	Phindile Baleni Dr Willem de Beer Paul van Niekerk John Williamson
2019	Jacqui Burn Neli Magubane Johan du Plessis Selwyn Scholtz Marius vd Westhuizen

Deceased members 2019

Billy van der Toon	Joyce Toth
Charles Adams	Gustaf Kritzinger
Chris Vosloo	Willie Opperman
Dennis Palser	








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Genlux 5

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