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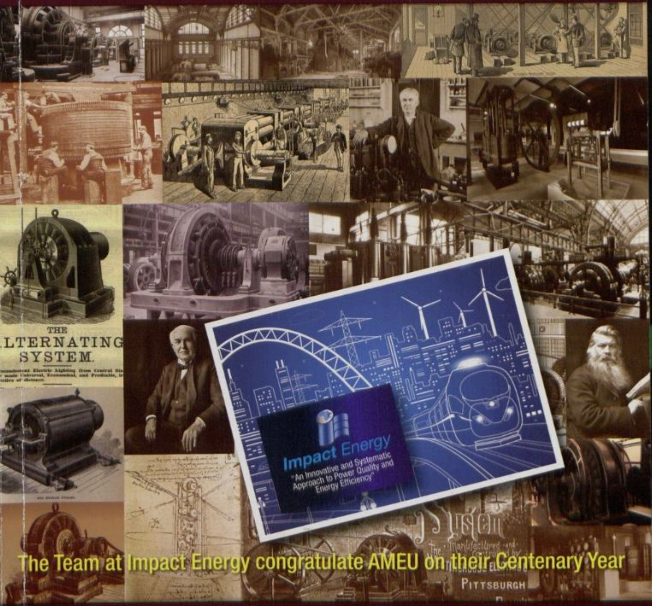
4 to 7 October 2015

"Alternative trajectories towards the SA electricity regime"



Special AMEU Convention Proceedings Centenary Edition

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AMEU Proceedings

2015

Impact Energy: Power quality, probability and profitability – energy saving the Elspec way

by Sishal Kuwar-Kanaye, Impact Energy

Estimating the financial losses associated with power quality disturbances can be complex as there are many uncertainties involved. Where effective analysis has been conducted, these costs have been found to be significantly high compared to the overall cost base of an organisation.

The effects of poor power quality (PQ) for any business are established by critically examining two core areas:

- Operational losses such as downtime, equipment failures, scrap, rework, etc.
- Power bill demand (kVA) related costs/ penalties as a result of poor power factor.

Probability

This is defined as the extent to which something is likely to happen or be the case. And the likelihood of the occurrence or event is usually expressed as a percentage. This likelihood can also be referred to as a "confidence level" and forms a pivotal aspect of any energy saving project.

The burning questions

Elspec have made the linkage between power quality and probability through several years of research and development of their leading edge PQ measurement and solutions technologies. The uncertainty associated with historical burning questions are now answered with confidence with the Elspec tools in hand:

- What are the areas or opportunities for energy saving?
- How much can I save and what is the payback?
- How confident are you that the savings can be achieved?

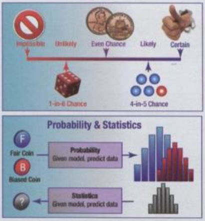
Technical losses (kWh)

Technical losses are an inherent facet of any power network resulting in losses and inefficiencies across key components on the network. These losses have historically been an acceptable and ignored cost implication for all business types. In the current and future context of power constraints and business profitability impact, ignoring any opportunity for optimising efficiency is unacceptable.

The technical loss considerations and associated implications are tabled and hold true for almost all types of industry, regardless of customer perceptions. Energy (kWh) savings potential of up to 13% can be estimated with a confidence level of 80% or greater. This, together with any form of quantified operational loss analysis, serves as a sound basis for investment into power quality solutions.

The innovative and systematic power quality approach

The high confidence levels as tabled in estimating PQ losses and proposing benefit/ saving opportunities can only be made possible if power quality is approached in a systematic manner and backed by technologies that can "deliver the goods".



Energy is supplied on a continuous cycle-by-cycle basis, so naturally PQ analysis and loss analysis should be done on the same basis for an accurate representation of the performance of a power network. This is the principal distinctive offering by Impact Energy, brand ambassadors and exclusive agents for the Elspec product and service portfolio.

Profitability

The energy constraints and rising costs facing South African power users impose a critical examination of all inefficiencies within the operation, specifically within power networks, in order to drive profitability and ensure sustainabilty.

The leading-edge Elspec Energy Saving Concept, backed by proven PQ measurement and solution products, takes the guesswork out of quantifying the PQ energy cost blueprint.

Several other Elspec energy optimisation projects are in process around the country with energy users embracing the concept of turning PQ technical losses into saving PQ rands.

Contact Sishal Kuwar-Kanaye, Impact Energy, Tel 086 135-7732, sishal@impactenergy.co.za

Energy saving (kWh) typical values:

Description of change in supply conditions		Range of saving (typical values)		Accuracy of estimation using continuous cycle-by-cycle measurements (error in %)
Savings due to reactive current and harmonics reduction				
Transformers - Current reduction - Harmonics reduction (skin effect, hysteresis)		0,25% – 0,75% 0,25% – 1,0% (*)		±(5 – 10)% ±50%
Cables - Current reduction - Harmonics reduction (skin effect)		0,5% - 1,0% (**) 0% – 0,1% (*)		±15% ±(5 – 10)%
Load - Harmonics reduction (skin effect, hysteresis, negative sequence field due to 5th, 11th etc.)		1,0% – 3,0% (*)		±30%
Saving due to optimal voltage control				
	One step – 2,5%	2,0% – 4,0%		±(5 – 10)%
	Two steps – 5%		6,0% – 8,0%	±(5 – 10)%
Total range saving		(4 – 9)% Approximately	(6 – 13)% Approximately	±20%

(*Depending on the THD(V) and THD(I) level.) (** Depending on distance.)

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Welcome address by the AMEU president

On behalf of the AMEU, I would like to extend a warm welcome to all of you, and wish to extend our heartfelt gratitude for making time to be with us at this event which coincides with the centenary celebrations of the association.

The association has come a long way since its formation 100 years ago. It has borne witness to a number of seismic historical events that have radically changed the world as we knew it then. To mention a few:

- The association witnessed the genesis of the aviation industry after the Wright brothers defied gravity and took to the skies in a man-made machine.
- The association survived the devastating Spanish flu pandemic that decimated millions of lives across the world.
- The association lived through both world wars.
- It witnessed the winds of change blowing across the continent when African countries broke off the yoke of colonialism.
- It saw the enactment of apartheid and its painful era spanning decades.
- It witnessed the end of the cold war, the dawn of democracy and the ushering-in of the digital age.

The association's achievements are enormous and to mark this occasion we have introduced a commemorative book that documents the history of electricity and the association. We are confident that this coffee table book will be a collector's item for those who are passionate about the development of the industry.

These achievements would not have been possible if it had not been for the inspirational men and women who played a role in ensuring the survival of this association. We would like to thank all those involved with the association from its inception in 1915 until today.

We would also like to thank our affiliates who have played a significant role in the growth of AMEU: the Department of Labour, the Department of Energy and the Department of Co-operative Governance and Traditional Affairs, government departments, the private sector, NGOs and relevant institutions that have been part of the journey.

I would like to thank the City of Johannesburg under the leadership of the executive mayor, Cllr Parks Tau; the MMC of Environment and Infrastructure Services, Matshidiso Mfikoe; the City Manager, Trevor Fowler; and City Power, which allows me run this organisation and to participate on various boards and the AMEU in the interest of the country.

The City Power board, its executive management and employees on the support they have given me and their continued support and holding the fort while I'm away; as well as the AMEU's standing committee and executive committee for its guidance and support. The role that Peter Fowles, my strategic advisor, plays and the sterling work he is doing for the organisation; Jean Venter and the councillors who are part of the executive committee for their political guidance ensuring that we work together in transforming the organisation.

I am grateful to the office of the Presidency for the support received; Refilwe Mokgosi and Moferefere Tshabalala for their support in creating a sense of team work and doing the day-to-day running of the organisation.

Sicelo Xulu, AMEU president

The AMEU is made up of various branches within South Africa. I would like to thank the chairperson in all branches for ensuring the organisation is self sufficient.

Thank you to the affiliates for your positive support to the AMEU and your sponsorship. With the work the organisation is doing, I hope you can see value that will translate into your organisation from what our members learn.

I am also grateful to my family for their support. Sometimes they complain about my unavailability because of work yet they still rally behind me.

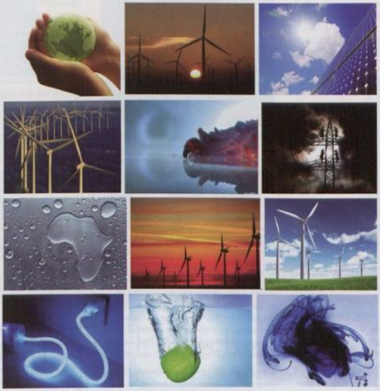
Thank you to all the standing committees as well as the secretariat for their unwavering support over the past twelve months

I am glad to have achieved so much in the first year of my presidency, and I wish to express my sincerest gratitude to all the people who have worked tirelessly to make this event a success.

This is the team that has burned the midnight oil by ensuring that the centenary convention of the association runs as seamlessly as possible. I wish to make special mention of Melindi Snyman, Yumna Sheik and Lebo Maroane for the hard work they have invested into this project. Your contribution is highly appreciated. Your perseverance and attention to detail has boded well for the success of the conference.

The last 100 years have been eventful, challenging and equally exciting. I am sure that working together, the next 100 years will be equally exhilarating and electrifying.

Sicelo Xulu, AMEU president



Speech by Mpho Parks Tau, executive mayor of Johannesburg

On behalf of the city of Johannesburg, I wish to welcome you to this momentous occasion when we mark a historic milestone in the history of the Association of Municipal Electricity Utilities.

Indeed, this is not just a centenary celebration for the association, but the convention that the city of Johannesburg is hosting also marks an important stride for thousands of municipalities and utilities who have contributed to the growth of the association.

We are honoured and privileged to once again host this important and momentous occasion.

This event is of historic significance to the city as it symbolises the coming into full circle of the symbiotic relationship between the association and the city. It was in the city of Johannesburg where the association was formed in 1915, and it is in Johannesburg that the association celebrates its 100th year of existence.

Since the launch of the association at the turn of the 20th century, the city of Johannesburg has grown significantly, both in stature, population and economic importance. The city has evolved from humble beginnings as an arid and desolate wasteland to become the financial hub on the continent that is home to what is regarded as the richest square mile in Africa.

Since it was founded in 1886, Johannesburg has grown to become the second largest city in Africa, a bustling metropolis that is home to approximately 4,8-million residents, 90% of whom have access to electricity.

The city has become the magnet that continues to attract people from the country's rural outskirts and beyond the country's borders who are in search of jobs, education opportunities and better economic prospects.

Johannesburg has developed to fit its moniker of city of gold: it now contributes more than any other city in South Africa to the country's gross domestic product, with the contribution of a whopping 14,98% according to the findings of a paper authored by Potchefstroom University statisticians, Willem Naude and Waldo Krugell.

According to studies by the Centre for Development and Enterprise, around 74% of all corporate headquarters are based in the city, and so are 60% of South Africa's top 100 companies.

The growth of the city of Johannesburg carries with it challenges of providing a reliable supply of energy to sustain the city and fuel economic growth. The electricity generating

Mpho Parks Tau, executive mayor of Johannesburg

constraints the country is faced with have had a debilitating impact on the residents and businesses in Johannesburg.

The incessant bouts of load shedding necessitated by generating constraints on the supply side have seen thousands of potentially productive man hours lost in gridlocked traffic and businesses incurring lost revenue.

I am pleased with the strides that have been made to shield and insulate Johannesburg residents against the impact of load shedding. In partnership with City Power, the city has tapped into the transformative power of technology to minimise the potential onset of load shedding by ensuring that we curb excessive consumption on the supply side.

Through the rollout of approximately 65 000 smart meters across Johannesburg, we have created a platform that enables the city to manage the demand side of energy through the deployment of technologies such as load limiting and ripple control.

These smart units also allow for the integration of added capabilities that foster residents to generate savings by opting for dynamic tariffing system such as time of use. In the future, we foresee the city incorporating smarter technologies that will give residents the ability to turn their households into smart homes.

I am gratified with the positive outcomes that saw us sparing the residents of Johannesburg from load shedding through the innovative deployment of these solutions.

However, as commendable as these achievements have been, we have no intention of resting on our laurels and basking in the shadow of past achievements. We are acutely conscious of the mandate we have of lessening our carbon footprint and ensuring that we strike the balance between security of supply and conserving the environment.

The city has committed to implementing a number of initiatives going forward aimed at augmenting generating capacity while ensuring minimal impact on the environment.

The city is in the process of harnessing energy from water flowing through the vast labyrinth of the waste water pipes network traversing the city using in-pipe turbines. We are working with the University of the Witwatersrand to develop ICT solutions to meet the challenges that the city is facing and that we anticipate in the foreseeable future.

We envisage the ICT sector playing a catalyst and central role in developing solutions for a cosmopolitan city such as Johannesburg. We intend to make technology and smart solutions an integral part of everything that we do.

The importance of preserving the environment is rapidly changing the way we conduct ourselves, the manner in which we do business and also ways in which the economy and businesses operate.

Correspondingly, the economy is going through a transition phase, which, in turn, also prompts the city to review the ways it conducts business. What has grown the city of Johannesburg over a hundred years ago cannot sustain it.

We need to conduct our business in line with environmental considerations and the demands of a new economy. This is the rationale behind the partnership we have forged with the University of Johannesburg. The partnership proactively seeks to identify opportunities for growing a green economy and to incubate enterprises and the ecosystem that is being spawned by this economy.

In my State of the City address, I emphasised the importance of turning chapllenges into opportunities. When faced with the potentially crippling impact of load shedding, the city refused to yield in to a state of incapacity and helplessness.

A lot has been achieved in enhancing security of supply, but there is potential to do more.

I hope this conference will stimulate thought-provoking discussions and deliberations that will benefit not only the city of Johannesburg, but the multitude of metros and utilities and thousands of municipalities that the association serves.

Clr Mpho Parks Tau, executive mayor,
City of Johannesburg

Women in electricity: Launch

Today marks an important occasion in the history of the electricity and engineering sector. It symbolises the dawn of an important chapter for the industry and heralds a season of hope for the future of women in the electricity and engineering sector.

I am pleased and honoured to announce the launch of Women in Electricity (WIE), an initiative that is the first of its kind to facilitate and advance the development of women in the electricity and engineering sector.

The creation of this noble initiative is borne by the slow pace of transformation in the electricity and engineering sector. The President of the Association of Municipal Electricity Utilities, Sicelo Xulu, made a firm undertaking at the 64th Convention of the AMEU that one of the key mandates of the AMEU is to implement programmes that will fast-track the advancement of women in the electricity sector.

The AMEU Executive Council approved the initiative as it was in line with its mandate to develop its members. As WIE is a women initiative, by women and for women, it is only fitting that it is led and driven by women leaders.

As the first vice president elect, I wish to take this opportunity to acknowledge and thank the following people for providing support and resources to this initiative: Lungi Mbewu from City Power who used all her resources within City Power to make this noble objective a reality. I also wish to thank Elsie Moshigo who represents AMEU affiliates and Bertha Dlamini from EON Consulting for their dedication, support and invaluable contribution to the realisation of this ideal. I also wish to express my heartfelt gratitude to Dikeledi Ndlovu, Lebo Maroane, Rosemary Naidoo and the AMEU secretariat for the diligent and hard work they invested to implement the ideas.

The hard work by the AMEU members culminated in the pre-launch event that was hosted by Sandile Maphumulo, eThekwini's head of electricity on 3 August 2015 at the Durban International Conference Centre.

I wish to thank the City of eThekwini for the support they have provided to WIE. I wish to make special mention of the deputy mayor and city manager of eThekwini, Councillor Nomvuzo Shabalala, AMEU president Sicelo Xulu, and MMC of service and infrastructure in the City of Johannesburg, Councillor Matshidiso Mfikoe, for the unwavering support they gave us throughout this process and at

Refilwe Mokgosi, AMEU vice president elect.

the pre-launch of the WIE. The speakers and panelists at the event consisted of Sy Gourrah, Jayshree Pershad, Canninah Mapena and Azwi Mamanyuha.

The pre-launch event was a roaring success and was attended by 145 women from different organisations, including but not limited to, the municipalities, Eskom, SALGA and AMEU affiliates.

Following the fruitful discussions, a pragmatic programme was designed to guide WIE initiatives to enable the organisation to reach its goals.

To that end, a task team sponsored by the vice president elect was formed to facilitate the implementation of the programme at the pre-launch event. The members of the task team are: Adeline Maleka, Jacky Ramailane, Malerato Mohlala, Mokwape Lekganyane, Orene Maposa Mnguni, Prisha Harigen, Rachel Seabela and Rindzani Nkanyani.

The task team will be supported by Lungi Mbewu who is the lead of the support group, Elsie Mashego and Bertha Dlamini. The support team were later joined by Refilwe Buthelezi from the South African Institute of Electrical Engineers and Selina Velaphi from City Power who will provide assitance on human resource issues.

We therefore segmented the programme into three values, pillars and a mandate that will guide the work of the WIE. As much as we are mandated by the AMEU president and executive council, we believed that WIE should have its values as foundations which are progressive service excellence, agility, stewardship and astuteness.

WIE has a three-pronged mandate which is to accelerate gender transformation in the industry, create tangible programmes that are designed to groom women in the electricity sector and to maximise the positive contribution that woman can make in the industry.

To kickstart its activities, WIE will compile and create a database of women professionals in the sector, create a mentorship and leadership programme and embark on a career awareness campaign in schools. The second leg of the WIE activities, which will commence next year, includes establishing international exchange programmes, career days and competitions.

The WIE is anchored on the pillars of mentorship and fostering leadership development. This is anticipated to be achieved through the successful development of mentors, increasing the number of professionally registered women in the industry and facilitating technical development training for women professionals in the sector.

The other pillar that will be hoisting the WIE programmes is the identification of partnerships and sponsorships, facilitating the international exchange programme and heightening awareness among women of careers in the electricity generation and distribution sector.

We will also be working closely with the Department of Higher Education in ensuring that there internships and apprenticeships are available to ensure the right skills sets.

In conclusion we would like to thank the AMEU president and executive council for actively advocating for the establishment of the WIE and for the support they have provided.

I wish to make special mention of the following organisations which contributed generously to make the pre-launch event possible: Schneider Electric, Jolobe Trading, EON Consulting, Zedek Trading, Colsto Projects, Matleng Energy Solutions, Indosi Investments, Dodwana Construction, Aberdare Cables and Buonomano Capital Construction.

I wish to encourage everyone here to actively participate in the WIE programmes where possible and support women in their different organisations by creating an enabling environment that allows them to thrive and prosper in this sector.

Refilwe Mokgosi, AMEU vice president elect.


Mpho Parks Tau, executive mayor of Johannesburg.


Sicelo Xulu, AMEU president.


Dr. Sean Phillips; DG, Dept. of Performance Monitoring in the Presidency.


Len Richardson received the honorary membership award from AMEU president Sicelo Xulu.


Silas Zimu received the honorary membership award from Jean Venter.


Jan Malan received the honorary membership award on behalf of Gerrit Teunissen from Jean Venter.


Dr. Clinton Carter-Brown received the AMEU Best Paper Award.


Brian Sibiya was awarded the Cigré Best Paper Award.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ENGINEERING OVER 200 YEARS of EXCELLENCE

Investigation and mitigation of electric power losses within City Power distribution

by Sibusiso Bakana, City Power

The national grid is more constrained, influenced by the growth in population and electricity usage, in addition to Eskom's load shedding scenario due to generating constraints. As the distribution network changes its normal business, energy efficiency is the dominating term and the reduction of technical losses is one of the sections that need attention in the emerging economy of South Africa.

This paper evaluates different loads (residential, commercial and industrial), using calculations through load factor improvement and simulation (DigSilent) methodologies in order to develop accurate and authentic results. These results are further analysed to develop an optimum solution, mainly around improving the load factor with battery energy storage by peak shaving. The paper focuses on improving technical losses due to circulating current (I^2R), thereby improving the overall energy efficiency that can further boost the operational efficiency and planning equipment of the electrical network when a battery energy storage is involved.

South Africa like any other developing country, in an electricity crisis and normally termed "load shedding", this crisis causes economic treats to the country's economic growth, as the country's economy is electricity-driven. After the new government of democracy, the utilisation of the electrical energy increased and is still increasing. Electrical energy, is generated, transmitted through some resistance, and transformed to a required level of utilisation. What naturally occurs in practise is that the generated electricity is not equally delivered to the destination required for use generated and that implies that, between the source of electricity and the load, there are losses accumulated.

The losses found in electrical system are unavoidable and cannot be ignored but only reduced through different approaches and on system components connected to the system reviewed. Before reducing these losses, what constitute these losses should first be understood, as this normally directs the determination of an authentic approach and upon understanding the formation of losses, an investigation has to be undertaken, then later a mitigation approach is determined as a solution to reduce the losses. With literature mostly complimenting the transmission systems and where the literature in distribution systems are still based on the transmission literature, this research aims in contributing to the distribution system literature.

Power losses are divided into two and referred to technical and non-technical power losses, where technical losses are found to be those influenced by the load current and non-technical losses being influenced by theft and faulty meters. The approach is to investigate the technical losses found in the distribution network. This research will focus only on technical losses formation, what constitutes them and how they can be reduced using an approach that will address the energy crisis while addressing the energy efficiency problem. This topic contributes to the distribution system literature, where these losses are investigated in three different scenarios, the residential, commercial and industrial loads fed by the John Ware substation 88/11 kV. This research is structured as a guide to technical loss reduction which focuses on improving the load factor and framed in chapters that are logically connected in resolving technical loss problem.

Theoretical framework

As distribution components deliver energy to customers, the loads differ and this cannot be controlled as it depend on customers' needs for a particular period. The attempt adopted for this subject is one of analysing the loads of customers with the view of improving the load factor, which will be an advantage in determining a loss load factor in order to produce authentic results of technical loss being constituted and corresponding flexible methods available to improve load factor.

The distribution system loss has become a concern due to the growing load demand and the wide area it covers [1]. Adding to that, applying a detailed system modelling is difficult and impractical, as the distribution system designs has numerous equipment and that lead to voluminous data being involved [1]. Previously, researchers have developed different methodologies to find ways on how these losses are constituted and ways to reduce losses. When analysing power losses, it should be firstly defined as two types and NetGroup has indicated that total losses equate to a sum of technical losses and non-technical losses [7]. Where technical loss is influenced by the load and the function of electrical equipment's and non-technical loss is characterised by billing challenges and theft.

Technical losses

The framework of this study is based on calculating technical losses for all customers (residential, commercial and industrial), separating losses through sections as that one of conducting and that of transformation. Davidson [9], technical losses represent 6 to 8% of the cost of electricity generation and a 25% of the cost to deliver the electricity to the consumer. These losses are composed of several components, such as the ohmic

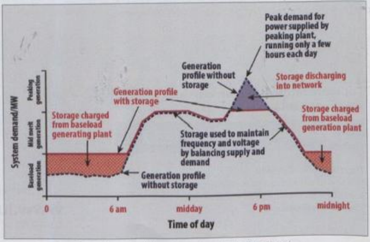


Fig. 1: Illustration of where system demand is handled efficiently.

Distributor's name	Load factor	Load loss factor	Technical loss calculated (W)	Technical loss simulated (W)
Commissioner	0,85	0,73	0,081	0,097
Fox	0,73	0,55	0,0096	0,0101
Market	0,81	0,68	0,077	0,082

Table 1: The results prior to an energy storage system.

loss in power distribution and losses due to leakage current, weak connections, distribution transformers, metering device, incorrect designing and by harmonics in power distribution network [2]. Further is to propose a flexible method to reduce the technical loss found.

This research in summary, should determine the actual magnitude of distribution losses, their location and components constituting distribution technical losses. In most of the distribution feeders, losses occur for different reasons and are [3] line losses on phase conductors; line losses on ground wire and ground; transformer core and leakage losses; excess losses due to lack of coordination of var elements; excess losses due to load characteristics and excess losses due to load imbalances on the phases. Ideally a system that can respond to all of these reasons influencing the occurrence of technical losses can be applied, as that is not material, a method that can respond to most when compared will be tested and presented.

Determining technical losses with relevant components: These technical losses are not occurring at the same level of loading and are further divided as fixed and variable technical losses and are [4] technical losses that do not change with load current, such as transformer no-load losses and are technical losses that change with the load current, such as copper losses respectively. There are sections in a distribution system that theoretically defines these losses; those sections are those made of conductors to transport the electrical energy and those that transfer energy to any level required by the load. The mostly influential components that yield technical losses are transformers and conductors of the distribution network. In transformers during on load both copper and core losses are found and in conductors only during on load conditions where copper losses are presented.

Conductor losses: Conductor losses are a result of a circulation current through an imperfect conductor such as copper. The characteristic impedance that produces a voltage drop along the conductor proportional to the current flow is found in conductor's material. From the impedance, only a restive component that contributes to the active power losses. In order to calculate conductor losses, measured current load is based on the formula:

$$P_{loss} = I*(I*[r/l]*L) = I^2R$$

where:

I = current (A)

r/l = resistance per km

L = length of the cable in km

As the system solved is three phase system, the losses for each phase are calculated separately according to the measured current:

$$P_{loss\ total} = P_{loss\ a} + P_{loss\ b} + P_{loss\ c}$$
$$= I_a^2R_a + I_b^2R_b + I_c^2R_c$$

Transformer losses: In order to logically define the transformer losses, an addition of power dissipated by the cores magnetising inductance and winding impedance will yield to transformer losses. The power dissipated by the cores magnetising inductance is the iron loss found in a transformer and result as a function of the applied voltage and mostly referred to as no-load losses and are even induced when there is no-load current. The winding impedance also referred as copper loss, these losses are a function of the winding current and known as load losses. These types of losses in a transformer can be calculated for any operating condition when few parameters of the transformer are known.

How to mitigate technical losses

While factors and components that constitute electric technical loss are known, then a respond on how to reduce these electric technical losses is essential and is achieved when power factor correction; voltage upgrade; re-conductoring in primary and secondary feeders; feeder reconfiguration; using high efficiency transformers; reduction of secondary network length with larger number and optimal location of distribution transformers; sub-transmission substation placement near load centres; load balancing between three phases and feeders and load factor improvement with demand side management. Technical losses can also be reduced by introducing a battery storage system as part of the distributed generation solution to enhance the operational efficiency of power utility which is found diverse and flexible.

In improving the efficiency of the distribution system, the reconfiguration for loss minimisation was firstly proposed by Merlin et al. [6] using a discrete branch and bound technique. This method allow that all the network switches be closed to form a meshed system and again opened successively to restore the radial configuration. While conscious that the method of reconfiguration involves approximations. With the advancement by Shirmohammadi et al [7], a

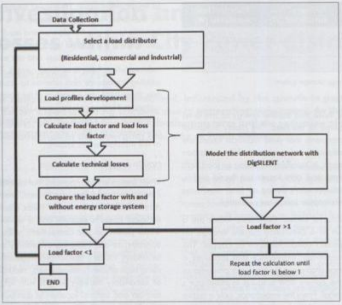


Fig. 2: Process of collecting data from the power flow.

proposal to overcome these approximations was introduced. With this method switches are opened one by one, based on an optimal flow pattern. A method for optimal operation of distribution system was developed by Peponis et al [8] where loss minimisation is obtained by installation of shunt capacitors and reconfiguration of the distribution network.

Salam et al. articulated [3] the results of distributed generation on voltage regulation and power losses in distribution systems. Then a technique to evaluate the impact of distributed generation size and placement on losses, reliability and voltage profile of distribution systems. Davidson *et al.* have presented an optimisation model with distributed generation for loss minimisation. Mutale et al [10] have presented a methodology to measure the impact of distributed generation on power loss minimisation, through observing loss allocation coefficient. Kashem et al [11] represented techniques in a distribution feeder by optimising distributed generation model in terms of size, location and operating point of distribution generation in order to minimise losses. Sensitivity analysis for power losses in term of distributed generation size and operating point has been performed by XP Zhang et al [12] in a paper that articulate issues of energy loss minimisation in electricity systems with large renewable generation.

Pavlov et al [13] reported on enhancement of the operational efficiency of electric power utilities, and energy storage units were reported to be diverse and flexible in solving distribution system challenges as part of the distributed generation solution. While at first, pumped hydroelectric energy storage were used for that purpose and later on, old lead acid battery storage systems were revised. The battery storage system has been proven to be a system that its art internally and externally is not a disturbance in disconnecting critical loads. This is achieved, through its fast de-coupler that separate network in case of overcurrent conditions in direction of the supply network or and under-voltage and under-frequency; bus bar fast switch over which is a method helping to quickly restore sensitive or critical loads and under-frequency and under-voltage load shedding where mostly used as a method of restoring power balance. Battery storage system also referred as energy storage system is mostly applied in industrial networks for active power balance, peak load lopping or and load levelling and frequency control.

Gustufson et al defined load factor as the ratio of the average load during a designated period to the peak or maximum load occurring in that period. The magnitude of this factor should be between 0 and 1 and minimising technical losses using a load factor it then implies improving the load factor and that is achieved through peak load reduction as a peak load is determined by power or current, consequently reducing the I^2R losses.

The research presents a method of calculating load factor using Pande et al's approach of dividing the distribution network load factor for distributors or and feeders and transformers, the focus of this research will be minimisation of technical losses utilising a battery storage system, as the battery storage system is found with beneficial characteristics that brings high energy density, fast load following, air emission credits, good efficiency of energy storage and this characteristics have been emphasised by the fact that energy storage has real possibility to be implemented in future.

With the ignored or lightly mentioned literature, in regards to impacts of peak shaving by the battery energy storage system, Nourai et al [15] presented a paper that evaluated the load levelling of the battery energy storage system that reduces transmission and distribution losses, because of the sensitiveness to the ratio of the off peak load and peak load. This ratio is not like load factor, it is not dependent on load profiles. The level of loss minimisation when implementing battery energy storage systems depends on the maximum storage designed size for a particular load levelling, because when the load peaks again a designed system of loss reduction should keep the load as a base for such integrated battery energy storage system. The literature available with regards to battery energy storage system as a means to reduce technical losses of a power system presents that losses are reduced when a number of small loads are shifted to multiple sites rather than a larger load shift at a single site.

Since these losses are proportional to the square of the current flow, using energy storage to shift some of this current or load from peak to off peak periods decreases the net resistive losses, which can offset some of the storage losses. Nourai et al [15] indicate that not only concentrating on the squared current relationship which assist in reducing transmission and distribution losses, through shifting a fraction of load from the peak to off-peak periods. There are other two factors that enhance the loss minimisation and increasing its value which are the resistance of transmission and distribution wires and transformers being lowered at off-peak periods, yielding low temperature and that of cost in energy and losses, is generally lower during off-peak periods. A theoretical approach is being evaluated for this research to reduce technical losses with the analogy that the load levelling approach reduces peak current as per the literature. An evaluation of technical losses here is to be presented by a ratio of peak power and maximum power during that period, improving this ratio for loss minimisation with the implementation of the battery energy storage system for peak shaving purposes. This paper appears to be one of the literature to minimise losses in a distribution network, through load factor improvement by peak shaving of a battery storage plant.

As this research proposes to evaluate

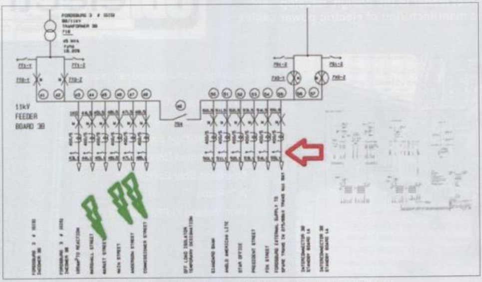


Fig. 3: Illustrates the John Ware substation 80/11 kV, three 45 MVA transformers, feeding three loads for this case (Commissioner, Fox and Market in green).

different loads of the distribution system, that of residential, commercial and industrial customers. The evaluation is presented in the next chapter as the investigation part of technical losses, how to calculate this losses in a system and a simple approach in approximating technical losses by investigating the load factors of this different customers. The heart of the paper include minimisation of the found technical losses from load factor, the minimisation of technical losses has been presented by different researchers and indeed are practical. What differentiate this study is the level at which the system proposed to reduce this losses, is found to be the most flexible and diverse among all available in improving load factor, while battery storage system found advantageous in improvement of load factor, with the current load shedding it can also be a proper solution for minimising load shedding, as the system mechanism charge during off peak periods and discharge stored energy back to the grid during peak times.

Research design and methodology

Fig. 1 indicates a level where system demand is handled efficiently when storage system is incorporated into the distribution network.

Basically the storage is charged from the base load generation during morning hours as this graph shows a daily curve that simplifies off peak hours as indicated by red to be charging period for the storage system and that is achieved when demand is low and typically is during early hours of the day and towards midnight of that day. While the demand is rising during the day, the generation plant belongs to mid merit category, which accounts for the demand as Joseph et al presented for this graph. As from the graph, a system incorporated with the storage system during peak, compared when there is no storage, it is cut through during that high demand period, and a storage system is activated to supply the peak for a few hours of the day. We then observe that when the generation profile with storage is taken, there is a much controlled demand graph, as storage take care of peak shaving, after it performs the shaving it get charged again.

Research instruments

The investigation of technical losses is achieved by the determination of load factor, this factor as a ratio of average power in a period to the maximum power in the same period. This ratio from literature has been used to minimise technical losses but there is no literature thus far indicating its usage for minimising these technical losses through applications of a battery storage system. Even with battery storage system literature, the literature in minimisation of technical loss by peak shaving is only found to solve this problem through a ratio of the off peak load to peak load, not with load factor. This ratio is independent of load profiles, while this study will be analysing load profiles, load factor proves to be authentic for this study, as the data to be analysed is that of load profile from a case of John Ware substation 88/11 kV and load factors are dependent of load profiles. A load profile will be generated by a Microsoft Office Excel tool to computerise the curves, where the data is being extracted from Spectrum PowerCC-HIS, and for

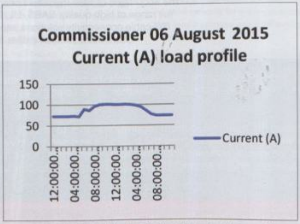


Fig. 4: Illustrating the load profile of a typical mix load of commercial and residential, with an average peak of 100 A.

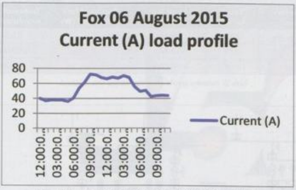


Fig. 5: Illustrating the load profile of a typical load of residential, with an average peak of 70 A.

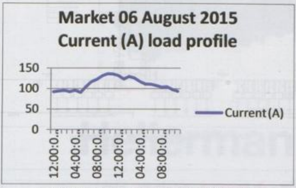


Fig. 6: Illustrating the load profile of a typical load of light industry, with an average peak of 138 A.

the level of presenting the concept, only one day profile is considered with an hourly interval for Commissioner, Fox and Market distributors which are their length is considered up to the first point of supply.

When load profile is generated, technical losses generated for that load are calculated by the utilisation of the calculated load factor from the extracted data to calculate the load loss factor for that load profile. As load differs, the load factor should differ for the said customers of residential, commercial and industrial, and here in this paper what is being presented, is based on the assumptions that lesser current from load profiles indicate residential or both residential and commercial customers and for higher currents load profile, assumed is for industrial loads. This assumption makes sense here, because of lack of data for specific loads, as distributors are not dedicated to a particular load customer but what it can handle. Below indicate steps to follow in determining technical losses, the steps outlined in this document are to be used to calculate the loss components for the various categories in the distribution systems which are the line and transformer losses.

LF (load factor) = Average load/max. load (1)

LLF (load loss factor) = Actual loss (during period)/Loss at maximum current (2)

In order to calculate losses, it is then required to calculate the exact relationship between load factor and load loss factor and is given by the empirical equation below. For presenting results, it was assumed that the value of the coefficient of K to be 0,08, as Gustafson *et al* indicate that this value is constant when no analysis is performed. Previous work has proven the exponential value to range within 1,91 to 1,93 and a recommended 1,912 if no analysis is performed independently by the utility and for simplifying this study, this value will be 2, as depicted by the literature.

$$LLF = K^{*} LF + (1 - K)^{*} LF^{2}$$

where K is the coefficient

The line losses are calculated below respec.

Line technical loss in a month =
$$I^{2} * R * L * LLF * 24 * 30 \times 10^{9} \quad (3)$$

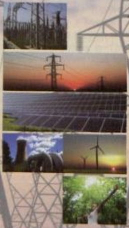
where:

I = load current in A,

R = resistance of the conductor in Ω/km

L = length of the feeder in km

LLF = load loss factor



Distributors name	Load factor	Load loss factor	Technical loss calculated (W)	Technical loss simulated (W)
Commissioner	0,69	0,44	0,0	0,059
Fox	0,71	0,47	0,0	0,0034
Market	0,84	0,66	0,0	0,0186

Table 2: Indicates results when the storage was involved.

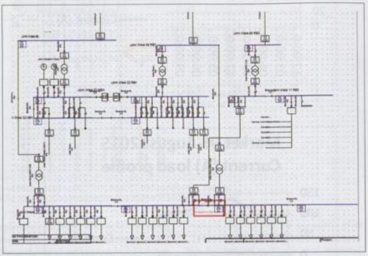


Fig. 7: DigSilent schematic of John Ware substation.

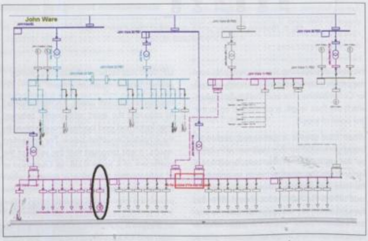


Fig. 8: Illustrates when the battery energy storage is connected.

After determining the technical losses with a load factor, a sized storage system is introduced to peak shave, in order to observe the impact of energy storage. This storage system is tested by the utilisation of DigSilent power factory software tool, this tool will be used to model the John ware substation before energy storage and after storage and observe the impacts. The impact should indicate whether the battery storage improves or does not improve the load factor. With data as collected, the software power factor is assumed for system model, for simplicity. The different in load factor after this model network, will be generated from the new data found from the power flow before and after battery storage system. The technique is presented by the diagram in Fig. 2.

As part of the procedure employed for this study in order to minimise technical losses within a distribution system through improving load factor by means of a battery energy storage system, the daily data was downloaded from Spectrum PowerCC – HIS, where only one weekly day of the winter month was used for testing the proposal of reducing load factor with battery energy storage just for simplicity and nothing will affect the analysis or results when say a weekly, monthly or yearly load profiles where analysed. With the daily measurement with intervals of an hour, this assumption stands to simplify this analysis.

As problems associated with distribution systems are those of lack of data and scares resources to collect this data and sometime data that does not correspond or logically documented, this study is not immune from those problems and as it is contribution towards the ignored distribution system literature as articulated from the literature above, this study contribute in structuring your data for technical loss minimisation through load factor improvement found in the battery energy system when controlled for peak shaving. The size of the battery energy storage assumed is in the range of 0,5 to 1 MW, this system is only tested in DigSilent during system modelling to evaluate the impact of peak shaving for technical loss minimisation.

Peak shaving is applied as a technique that is used to reduce electrical power consumption during periods of maximum demand on the power utility. Peak loads of consumers during the daily load curve are decisive for maximum power, which is expected to be generated and usually power tariffs weight these maximum demands at a high rate. Here the sizing of the battery energy system will not be relevant, but a suitable battery size will be required for peak shaving and this investigation focuses only on the impact of the load factor in reducing technical losses with the use of a battery energy system. Understanding the diverse level and multi-function of a battery energy system, the system has advantages in also minimising the energy crisis of load shedding and carbon footprint reduction, as battery energy systems charge during generation base load at cheaper tariffs.

As the research objectives is that of reducing technical losses in a distribution system, the case study was selected because after the collected data, that was a station found to have immediate data required, including when downloading from Spectrum PowerCC-HIS, John Ware substation is found to be also serving different customer loads and that simplify the complication of involving different stations, as trying to separate loads. Most assumptions made here can still be improved as the literature advances and currently are utilised based on the level of literature exposed to till thus far. The objective is testing load factor with and without battery storage, in a distribution system and the impact of technical loss.

Results

The results presented here, represents three different loads through an 11 kV distributors of John Ware substation, which is a distributor that its length and distribution point end at the load point of the customer. Fig. 3 illustrates how technical losses are behaving when a storage system is composed in an electrical system by playing with the load factor, improving it and seeing the impact of losses.

This substation feds ranges of customer loads and the distributor supplying the load is found delivering a mixture of customers and some have dedicated load customers. From the Spectrum PowerCC-HIS, its historical information downloadable, with a variety of options of organise the system performance and it is only selected for current actual values, so that from this actual, an average can be derived including the maximum current for the selected period. Periods are in a range from minutes, hours, month and a year and specifically the downloaded data was based on a one winter week day. The current is used to calculate the technical loss found in the distributor, by firstly determining the load factor and load loss factor before the storage plant. As from the literature that a load factor depends of load profiles, the load profiles for these distributors are presented in Figs. 4, 5 and 6 before storage was considered.

From the three load profiles (see Figs. 4, 5 and 6), the goal here is to reduce the peak current with a battery energy storage system, by comparing the load factor, then an impact from a load factor can be drawn, while this curves provide a clear daily curve of such loads, this profiles assist in determining the calculated load factor, load loss factor, technical loss of a distributor before the storage (see Table 1).

The John Ware substation was then modelled in a DigSilent power factory, that was the only method used to test the battery storage when connected. The battery storage system was assumed to be of a capacity of 1 MW with four hours charging and recharging period. The amp hour of this storage as is connected to the 11 kV bus bar, is 363,64 Ah storage. The diagram in Fig. 7 shows the connection of system components from the power factor software and is followed by the diagram in Fig. 8 which includes a battery storage connected where the loads are connected.

Fig. 7 shows the distribution substation of John Ware substation modelled in DigSilent without a battery storage. The technical losses found from the simulated data, are not strongly differing with the calculated, and using load profiles, as the load was also used in simulation, to assist determining system technical losses of the distribution system.

When a battery energy storage system is considered as it is the goal to reduce the technical losses of this system. Fig. 8 shows the position of the energy storage system.

When the battery energy system is considered, a peak shaving is anticipated as is the focus for this study, regarding the battery energy storage technology. While the profiles with storage are presented, what should be noted is the level at which this currents reduce. What was observed from calculations values, the technical loss found when the battery storage is involved where zero in all the cases. It does make sense as this are only conductor losses and they do not represent the whole distributor losses in a conductor, what was noted is that a significant drop in current in a distribution load reduce losses to a level that are unnoticeable. Table 2 gives the results when storage was connected.

Conclusion and recommendations

The battery energy storage system has indicated positively in responding to the research question. While the specific task was that of evaluating technical losses with load factor, the load factor as shown from Table 2 have shown improvement and with Commissioner, Fox and Market, after the storage of 1 MW with 4 MWh energy, the technical losses reduced from load profiles, as load profile are a dependent of a load factor, a percentage indication of this distributors load factor was 60,61%, 36,36% and 22,73% respectively.

While when using a new value of current to calculate technical losses when a battery energy storage system the value was zero and that might be influenced by the assumptions for the co-effient value when determining the load loss factor. It is understood that this results are a preliminary for the load factor improvement, while this research is still at its early days, authentic impacts with recent new assumptions as the technology advances, the load factor improvement of a battery system in a distribution network should be not ignored in the distribution networks.

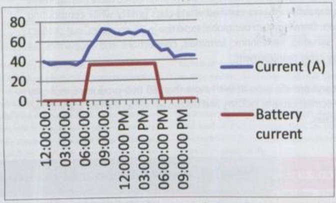


Fig. 9: Indicates a profile of Commissioner distributor with a battery.

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Combating power theft

by Mary Parker, PageMark Africa

Combating power theft initiative using Pelta Code through kWh meter authentication and its Track-and-Trace application

Electricity theft is costing sub-Saharan Africa billions of Rands per year [1]. Apart from the cost of the theft other maintenance costs are sometimes incurred, thereby exacerbating the expense. Repairs to electricity lines after they have been tampered with, are often required [2]. To add to the economic cost of this crime, power utilities cannot effectively manage demand and supply when electricity is being stolen.

But how is electricity being stolen?

Electricity is being stolen using the following methods [3]:

- Illegal connections
- Meter tampering and bypassing
- Stolen CDUs (credit dispensing units)
- Sale of illegal pre-paid electricity vouchers to consumers

Although thieves cannot be stopped from stealing electricity some preventive measures can be put into place to minimise crime and help to convict electricity thieves. In the case of illegal connections on distribution boards, tamper evident labels could be strategically stuck onto connectors. When the board is tampered with, the label disintegrates. Even when the connection is restored, the criminal would not be able to re-stick the label. Inspectors can immediately establish that an illegal connection has been constructed for further investigation.

In a similar vein, tamper evident or resistant meter seals are currently being attached to electronic meters to prevent meter tampering and bypassing.

In some instances, the material used to secure the meters, would resist some form of tampering due to the material composition of the seal. This method is not always effective as criminals tend to find innovative ways in which to break these seals. At the very least, inspectors would be able to establish that the meter has been tampered with and possibly bypassed.

Although the prevention of criminals bypassing meters or making illegal connections is not always possible, an innovative technology may be able to extend the security of the tamper evident seals and labels. The Pelta technology can be leveraged to do so. It is suggested that relevant labels and seals are marked with a Pelta 2D code. A Pelta 2D code is a secure code that has overt (accessible) and

Fig. 1: Distribution board with tamper-evident labels.

Fig. 2: Pelta 2D code in a QR code.

covert (hidden) layers of information. Due to the covert layer of information inspectors are able to authenticate the meter, the seals and labels. When the inspector scans the Pelta 2D code with a scanning application on his or her smartphone, the application will indicate that the meter, label or seal is an authentic item (should criminals find the means of imitating the meters, labels or seals).

Another benefit of using the Pelta code for this application, is that this technology allows the inspector to see information from the database (such as power usage and the latest payment) and it will enable the inspector to update the information using his mobile device. Customers would be able to access the latest payment due by using a common QR code reader on their smartphone. This functionality is mobilised due to the overt layer of information that is expressed in code format.

Perhaps the Pelta technology's functionality would be most beneficial when it comes to the theft of CDUs and the sale of fake or stolen vouchers. Often, criminal syndicates are involved in the theft of CDUs and supplying fake vouchers, and in most instances the public are unaware that they are purchasing these

Fig. 3: Validating a kWh meter.

voucher [3]. Now a solution is available to help consumers establish whether the voucher that they have purchased is stolen or fake. In addition, and depending on the business rules of power utilities, vouchers issued from stolen CDUs could be deactivated - once the power utility becomes aware of the stolen CDU. Power utilities could make use of the Pelta technology to achieve this.

The Pelta technology is mobilised for this particular application through ensuring that each electricity voucher and CDU is marked with a Pelta 2D code. Unique numbers can be allocated to each vending machine and voucher, and once stolen, the vouchers can be flagged on the Track-and-Trace software platform.

If an unsuspecting consumer purchases the voucher and scans the 2D code on the voucher with the smartphone, the application on the smartphone will indicate either that the voucher is authentic, fake or is part of a stolen batch. In addition, due to geolocation functionality on smartphones, the power utility would be notified of where the person scanned the fake or stolen voucher. The location of the scanning would provide law enforcement with important information as to the whereabouts of the stolen vending machine and thieves.

Lastly, as an incentive to electricity customers to report stolen CDUs, power utilities could activate a reward and loyalty program. When customers scan a fake or stolen voucher and provide authorities with information relating to the whereabouts of the criminals, they are rewarded.

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Load shedding from a municipal viewpoint

by Dennis Mokoala, Polokwane Municipality

Load shedding means controlled load power rotational sharing to avoid the total country's black out due to the fact that demand is more than supply. This is because Eskom has little reserve generation capacity and the loss of more than 1200 MW will always demand load shedding after all other reserves have been exhausted.

The influence of load shedding on municipalities

Even though municipalities understand the importance of load shedding and participate to avoid a total black out, they are affected in the following manner.

- *Loss of income to council:* During load shedding, municipalities loose the revenue which they are supposed to generate.
- *Loss of investors:* Investors require minimum power interruptions for their businesses.
- *Security risk:* It is a risk during load shedding that most security majors without a backup will loose monitoring and sometimes the operations as well. Criminals started to prepare their attacks during load shedding as well.
- *More overtime:* Employees are expected to work more hours, especially where switching is done manually due to the absence of SCADA, or manual switching to keep critical loads such as hospitals, water pump stations and major events.
- *Maintenance costs:* This is due to weak points on the network, and overloads after switching on. Where we have ageing infrastructure, the more you operate it the more you expose weak points on your network. Municipalities are exposed to major breakdowns due to this. The more you operate, the more maintenance is required.
- *Fear of the countries' black out:* They operate because they fear the total black out. This is done for compliance.
- *Community uprisings:* More claims are coming to municipalities due to the damage caused by over voltages that occur after sectional switching. Overloads are also experienced, coupled with damages to equipment even though communities are warned about these.
- *Water shortages:* Sometimes it is difficult to avoid load shedding for water pumps and this leads to community uprisings.
- *Sabotage:* It is commonly thought that sabotage occurs once load shedding happens.
- *Consumers with home medical needs (oxygen machines):* Consumers under medical support also suffer during load shedding. Most are individual households which cannot be excluded from load shedding.
- *Travelling costs:* Travelling costs by officials and technicians who respond to load shedding activities are not budgeted for.
- *Utilising equipment (breakers) beyond their design capacity:* More operations happen and sometimes too soon to budget for their maintenance, and one ends up operating it even if the apparatus is due for service.
- *Increased exposure to danger of switching personnel:* Sometimes it is difficult to adhere to maintenance programs, and this become a risk to technicians who are expected to operate.
- *Negative economic impact on businesses in community:* Some businesses end up closing once load shedding is pronounced.

Municipalities have the following frequently asked questions

- Why load shedding?
- Why is it done now?
- Why was it not foreseen?
- How long are we going to continue shedding load?
- When will the new power stations be operational and reduce the current load shedding risk?
- How can municipalities help Eskom to generate enough for its customers and avoid load shedding?
- Can the country build power generation capacity at a faster rate than demand is increasing?

People are so tired of load shedding that they are prepared to reduce load rather than being shed. Municipalities who could, cannot do load shedding themselves without facing a situation where the whole town comes to stand still and businesses close due to load shedding.

What could be done to avoid load shedding?

Several mechanisms and plans are in places, a few of which are:

- Consumers can reduce their consumption by 10%.
- Introduction of embedded generation mechanisms.
- Energy efficiency and demand side management processes.
- Emergency preparedness plans.
- Load control through smart metering, ripple controls, etc.
- Alternative generation mechanisms.

Load shedding to critical loads

NRS048-9 identifies the following criteria for the implementation of load shedding: the safety of people, the environmental, the potential damage to plants associated with critical national product (for example wastewater treatment works) and technical constrains on executing load shedding and curtailment or restorations. This is the reason why places like hospitals and wastewater treatment plants and occasions like games in stadia are excluded from load shedding. Households situated next to the above mentioned places sometimes boast that they are exempted from load shedding. This requires municipalities to inform its clients and avoid misunderstandings, thus another cost for municipalities.

Municipal network systems were not designed to accommodate load shedding. When shedding in such a way to avoid critical loads like water pump stations and hospitals, more switching work is done on the rings, and risks explosions where there are maintenance constrains and where dry joints and weak points are exposed in the process. A major issue is also the ageing infrastructure that in some cases is beyond its useful life expectancy. Some critical loads like traffic lights are unavoidable. This also causes traffic congestions within municipalities. There are general influences affecting municipal customers differently and are categorised as follows:

- Influence on domestic customers
- Influence on industrial customers
- Influence on commercial customers
- Security risk
- Traffic congestions
- Maintenance costs

Recommendations

- The AMEU can engage the Department of Energy to fund municipalities for participating in load shedding or even replace dangerously old switchgear.
- NERSA can provide clear guide lines for embedded generation.
- Eskom can improve notifying clients in time for load shedding.
- How to identify good performing companies for solar farm, bidirectional meters etc.

Conclusion

Load shedding causes constrains on the existing municipal infrastructure. Municipalities should be compensated for participating in load shedding.

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Creating a virtual power station to avoid load shedding through customer participation

by Rob Surtees and Deborah Blane, Enerweb EOH

Eskom allows some customer classes, including for municipalities (under certain conditions) to opt for voluntary curtailment and reduce load in order to avoid forced load shedding.

Given that the generation supply shortfall very rarely exceeds 20% of demand (stage 0 to stage 3), and most often only a 10% reduction (stage 1 and stage 2) is required, this can be achieved through the implementation of a number of "smart utility" initiatives with minimal impact on the customer base.

"Load shedding would not be necessary if an additional 3000 MW could be fed to the national grid" – Eskom acting chief executive Brian Molefe.

Municipalities can, through a collaborative effort with its customers, avoid up to 90% of all load shedding events in full compliance of the national standard (NRS048-9). Residential, commercial and industrial customers can co-operate and collaborate to ensure a more stable and predictable supply of electricity.

To assist with managing the demand, the system operator (SO) calls upon municipalities and large industry to assist with load reduction during emergency periods according to a defined set of rules.

"Load shedding or curtailment is a last resort to managing imbalances between supply and demand and supply network constraints – implemented in order to protect the power system from collapse." (NRS048-9:2010)

The disruptive impacts of electricity load shedding in municipalities and industry are enormous, with significant loss of production, income and extreme inconvenience to all customer groups.

"With South Africa being highly capacity constrained for the next three to four years, load shedding is expected to remain a regular occurrence in the country" – Eskom press statement.

This paper addresses the potential for municiplalities to minimise the impact of load shedding on their customers by adopting the NRS048-9 recommendations and implementing broader curtailment programmes for its customers.

By adopting a load curtailment approach instead of load shedding nobody is "left in the dark".

What is NRS048-9?

While NRS048-9 is not a prescriptive national standard, it is intended to support legislative and regulatory requirements when defining the roles of the various stakeholders. It is essentially a national code of practice for emergency load reduction and load restoration after a blackout. It is also updated from time to time with the next update expected in March 2016 and will include changes based on the learnings and developments over the past few years and learnings during the past year of national load shedding.

It was compiled and is regularly reviewed by an extensive stakeholder working group appointed by the Electricity Suppliers Liaison Committee (ESLC).

According to the NRS048-9 the definitions are as follows:

Load shedding: Load reduction obtained by disconnecting load at selected points on the transmission or distribution system.

Load curtailment: Load reduction obtained from customers who are able to reduce demand on instruction.

According to the NRS048-9 standard, customers may offer load curtailment instead of being shed, subject to some criteria such as:

- The customer shall be able to offer at least 10% of normal load for curtailment under stages 1 and 2, and 20% of normal load under stage 3.
- This curtailment shall be maintained for the duration of the emergency.
- The curtailment can be effected within an agreed time frame (typically under two hours).
- The required load curtailment can be measured and verified.
- An agreement between the customer and the licensee etc.

Emergency conditions

Eskom is highly capacity constrained and is compelled to embark on a load shedding programme when electricity demand outstrips supply and all other options have been exhausted. Emergency conditions are declared and pre-defined stages of load shedding commence i.e. stages 1 – 4, depending on the severity of the generation shortfall. In this way, Eskom, through its pre-planned schedules, is able to equitably "rotate" the available electricity between all customers to ensure the stability of the national electricity network.

Other Eskom demand response programmes (such as supplementary and standby generation) where large customers are contracted (and compensated) for reducing load on request from the system operator via Eskom's "virtual power station" are implemented before emergency conditions are declared.

Managing load shedding

The South African business community is finding it increasingly difficult to operate under the current high levels of supply uncertainty.

Typical business manager comments include:

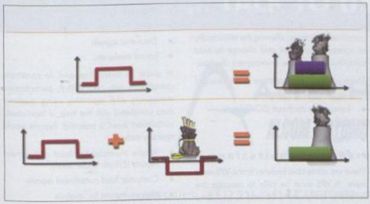


Fig. 1: Demand vs. supply.

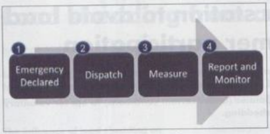


Fig. 2: VPS load curtailment flow.

"It would be better if we all knew when and for how long load shedding would happen, than to have the current situation where the grid is "stable'" in the morning and later in the day we have emergency load shedding; or when the outlook for the day is that the network is under pressure and we are warned to expect load shedding and then nothing happens!"

While load shedding is the most extreme measure a utility or municipality can adopt to manage a capacity shortfall, other initiatives based on voluntary customer load curtailment have been widely implemented internationally as well as in South Africa for many years.

Municipalities can, through a collaborative load curtailment effort with its customers, avoid up to 90% of all load shedding events in full compliance of the NRS048-9 standard.

The key is that individuals, businesses and municipalities work together and collaborate to ensure a more stable and predictable supply of electricity to a municipality.

Technology based solutions such as the implementation of intelligent load limiters and smart metering with remote connect/ disconnect capability are currently being trialed in a number of municipalities to achieve the requisite load reduction (curtailment). While these approaches may ultimately prove to be effective for the residential sector, they may not be appropriate for commercial and industrial customers. Smart metering roll-out programmes are also costly, frought with customer service challenges and take a long time to implement.

It is proposed that a "virtual power station" (VPS) approach be adopted, with a view to ultimately include the smart metering or other technology solutions in its "dispatch options" but initially operates by simply communicating with customers and reporting on their load curtailment performance. Customers in all sectors can thus participate. The VPS is essentially a centrally co-ordinated demand response (DR) programme being run by the municipality in response to Eskom's load curtailment/shedding requirements. A VPS is typically enabled via a custom demand response software platform/s.

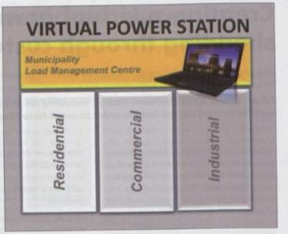


Fig. 3: A VPS should cover all sectors.

Customers are not load shed completely, but rather switch off a portion of their load, with the aggregated impact being sufficient for the municipality to achieve the requisite load reduction of 10% or 20%.

However, the issue that municipalities face is the management and administration of the programme as there are many customers involved.

A VPS operated by a municipality can assist in managing and optimising a load curtailment programme.

Virtual power station (VPS) – how it works

A virtual power station is an integrated demand response solution that enables multi-customer participation in a load curtailment and load shedding management program.

The VPS is essentially the "central brain" that ensures load curtailment initiatives/options are managed and optimised from the view of the municipality i.e. when considering its total load (all feeders), the curtailment objectives are achieved.

Most importantly, a VPS enables monitoring and reporting across all municipal load curtailment initiatives, allowing the municipality to constantly enhance and change its load curtailment mix as the environment changes.

There are four primary steps in a municipal load curtailment programme:

- Emergency declared (SO/Eskom)
- Dispatch
- Measure
- Report and monitor

There are some core features that a VPS must have. A VPS must be able to manage the following components for end-to-end load curtailment:

- Load curtailment options
- Planning and optimising
- Dispatching
- Monitoring and reporting

To maximise municipal response, the VPS should be able to manage all customer sector load curtailment requests:

- Residential
- Commercial
- Industrial

A VPS must be able to send curtailment requests through multiple channels and technologies.

The technologies may include:

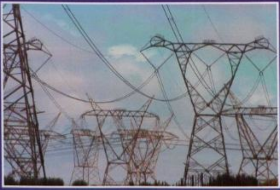
- Direct smart meter system interfacing
- Load management including ripple control
- Customer control units
- SCADA systems etc.

Communications methods may include:

- SMS
- E-mails
- Automated voice telephone system
- Web services messages
- GPRS
- Electronic signals
- Social media etc.

In order to determine and demonstrate compliance with NRS 048-9, performance measuring and reporting using metered data correlated with the time of load-shed/ curtailment event is essential. Reports would typically include:

- Whole municipality load curtailment reports (Eskom feeder level).
- Customer load curtailment reports
- Historic reports for analysis
- Detailed extracts for analysis



A VPS should ideally be managed and operated by a dedicated team with the following skills and attributes:

- Electricity distribution system knowledge
- Ability to work under pressure
- Excellent customer level understanding

The load curtailment approach would vary from municipality to municipality as the mix of customers varies considerably, with some municipalities having more industrial and commercial load than residential load and others having primarily residential customers.

VPS components

There are four primary components making up typical demand response VPS software/ platform:

- A (quantified) mix of load curtailment options
- Load curtailment planning and optimising
- Load curtailment dispatching
- Load curtailment monitoring and reporting

The primary VPS components can be described as follows:

VPS load curtailment options (mix)

This is where the municipality captures the load curtailment programmes and customer information in one place. It is here that each curtailment programme, customer's individual constraints, contact method, etc. are stipulated and then used in the daily load curtailment planning/optimising and dispatching.

A municipality decides what type of load curtailment programmes best suit its mix of residential, commercial and industrial customers. A municipality can also decide to implement load curtailment programmes in phases and/or target certain types of customers, depending on the technology and infrastructure available. Once the technology/ infrastrucure and processes are implemented in the field, the load curtailment details are captured. New options can be added at any time.

VPS planning and optimising

This is where the municipality decides on a daily and/or hourly basis which of its load curtailment options it will use to meet the load curtailment requirements. Municipalities need to ensure that the customer load curtailment requests are managed effectively and that they are:

- Fair
- Planned
- Measured
- Reported
- Minimum impact to customers

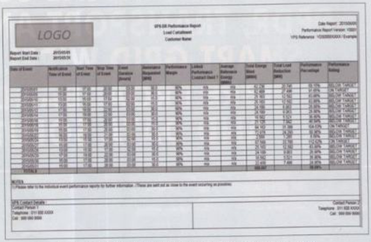


Fig. 4: Example of a customer load curtailment performance report summary.

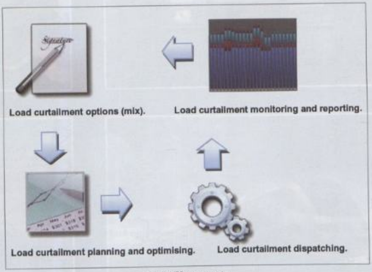


Fig. 5: VPS components.

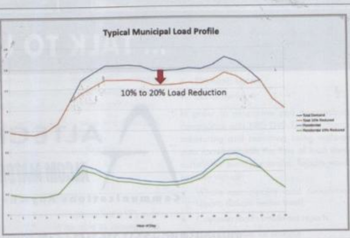


Fig. 6: Typical municipal profile showing reduction percentage.

A municipality looks at what load curtailment options are available across the various customer sectors. It balances them against various factors such as time, ecomomic cost, usage, flexibility, notification time etc. and plans ahead what it will do if it is called upon to curtail load.

VPS dispatching

This is where the municipality manages the dispatching of the load curtailment requests to customers. Once the municipality receives a notification of a system emergency, it can dispatch its own customers to meet the load curtailment requirement.

There are various methods of dispatching that can be used depending on the customers and/or type of load curtailment technology implemented. Typically this would be automated to ensure quick and consistent results. Types of dispatch methods can be SMS, e-mails, automated voice telephone system, web services messages, GPRS, electronic signals, social media etc.

VPS monitoring and reporting

This is where the municipality can monitor and measure its load curtailment achieved vs. load curtailment required. Typically metering data is collected to see what type of load curtailment was achieved by the municipality overall and what contribution was made by the customers dispatched. Once this information is available, a municipality can review the results and decide on how to optimise or change its load curtailment options.

A VPS should provide a comprehensive logging and audit trail. The detailed load curtailment dispatch records, meter data and performance results make the entire process completely transparent for all participating parties. This information provides management with the information to make decisions going forward.

Load curtailment measurement

Measuring overall municipal load curtailment

The NRS048-9 standard requires curtailment customers to reduce load by a fixed percentage. A municipality must reduce consumption by either 10% or 20% depending on the system emergency declared by the system operator.

There is some debate as to how this percentage load reduction should be calculated for municipalities and the current NRS048-9 does not currently provide this detail. The determination of the customer base line (CBL) as the reference for determining actual load reduction (curtailment) can be very complex as most customers don't have perfectly predictable and repetitive loads from day to day.

Measuring customer load curtailment

"What is measured improves" – PF Drucker.

There are various ways that a municipality can measure a customer's percentage load curtailment. This may differ depending on the type of sectors, customers and metering data available.

This measurement can be complicated as most customers do not have "flat" profile, where it is simple to determine any load reduction on an hour-by-hour basis.

In Fig. 7, the load reduction is calculated using historic consumption based "base-load". The difference between this base-load and actual load over the contract period is the amount of load curtailment achieved. Half-hour metering is thus essential for this method.

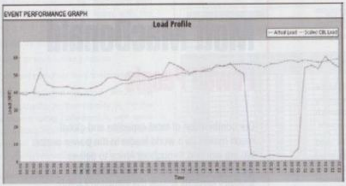
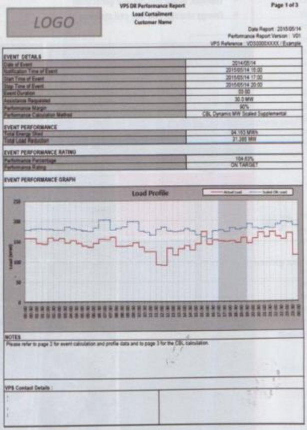


Fig. 7: Example of a VPS dispatch.



LOGO

VPS DR Performance Report
Load Curtailment
Customer Name

Page 1 of 3

Date Report : 2015/05/14
Performance Report Version : V01
VPS Reference : VD000XXXX / Example

EVENT DETAILS	
Date of Event	2014/05/14
Notification Time of Event	2015/05/14 15:00
Start Time of Event	2015/05/14 17:00
Stop Time of Event	2015/05/14 20:00
Event Duration	03:00
Assistance Requested	30.0 MW
Performance Margin	90%
Performance Calculation Method	CBL Dynamic MW Scaled Supplemental
EVENT PERFORMANCE	
Total Energy Shed	94.153 MWh
Total Load Reduction	31.385 MW
EVENT PERFORMANCE RATING	
Performance Percentage	104.63%
Performance Rating	ON TARGET

EVENT PERFORMANCE GRAPH

NOTES
Please refer to page 2 for event calculation and profile data and to page 3 for the CBL calculation

VPS Contact Details :

Fig. 8: Example of a customer load curtailment performance report.

The authors suggest that the percentage load reduction for municipalities be calculated based using a "dynamic" CBL. This is when the CBL is calculated based on previous days or weeks consumption patterns where there was no load shedding. Actual consumption during load curtailment is then compared to the CBL to determine the percentage reduction achieved.

This is very similar to the method used by Eskom to measure the demand response reductions of its large customers.

There is also some debate as to how this percentage load reduction is calculated for customers and the current NRS048-9 does not provide this detail.

The authors suggest that performance methods get agreed per customer sector and customer type e.g. a method for mining, production, smelters, supermarkets, households, shopping malls etc. so that all customers are treated and measured fairly and equitably and in alignment with their own particular load profile characteristics.

The updated NRS048-9 standard due to be released in 2016 will hopefully provide greater clarification.

Benefits of a VPS

A virtual power station operated by a municipality can assist in managing and optimising load curtailment requests and enables the following:

- Regular and consistent measurement of load curtailment customers.
- Automated "standard" detailed customer load curtailment performance reports and monthly and yearly summary reports showing load curtailment performance over set periods.
- Automated "standard" detailed emergency event load curtailment performance reports and monthly and yearly summary reports showing load curtailment performance over set periods.
- A quick way to see the load curtailment/ performance per customer for an emergency event.
- Load curtailment customers will be contacted via one source, allowing standard process and consistency.
- Historic and summary load curtailment reporting for emergencies per customer or group of customers enabling a clear audit trail and NRS 048-9 reporting.
- Easy monitoring of adherence across the various customers to the NRS048-9 standard.
- Ensure that all load curtailment customers are treated and measured fairly and consistently.

Current VPS applications

Eskom currently runs a VPS to manage its demand response load, with over 1300 MW of demand response "dispatchable" load managed and used to assist with system constraints almost daily.

With over 100 of Eskom's largest customers (primarily industrial) participating in the NRS curtailment program, the VPS has been shown to be an invaluable operational mechanism.

VPS and the smart grid evolution

There has been much focus in recent years on the "smart grid" which achieves distributed control through a network of automated real time load monitors and switches e.g. smart meters which automatically limit or shed load under certain network conditions. In future, the VPS would simply interface with these systems, enabling municipalities to further add to the MW available for load curtailment.

Electricity grid management in general is moving from a traditional load-following approach towards load-shaping strategies in which demand-side resources are managed to meet the available supply. With the integration of more and more renewable and variable generation technologies onto the network, this flexibility becomes critical.

Conclusions and recommendations

The disruptive impacts of load shedding on customers can be largely mitigated should a municipality adopt measures to become "curtailment" enabled under NRS048-9. This can be achieved through the implementation of a number of "smart utility" initiatives with limited impact on the customer base. Municipalities can through a collaborative effort with its customers avoid up to 90% of all load shedding events.

A VPS can play a key role in the smart grid architecture of municipalities in the future, enabling municipalities to balance demand and supply, leveraging off new technologies and customer participation.

The key is for individuals, businesses and municipalities to work together, to co-operate and to collaborate to ensure that, together, they achieve the requisite load reduction under national grid emergency conditions.

While good communications and reliable emergency event notification to its customers can make an impact, a VPS demand response approach is recommended particularly when there a large numbers of customers and a number of different load reduction options to consider.

Based on experience in with Eskom's current curtailment and demand response customers, the authors recommended that NRS048-9: (2010) be revised to include specific methodologies for the customer base line (CBL) determination.

Specific recommendations include:

- The percentage load reduction for municipalities be calculated based on a dynamic customer base line (CBL). This is when the CBL is calculated, based on previous day's or week's consumption patterns unaffected by load shedding. This scaling factor accounts for temperature related impacts etc. Actual consumption during load curtailment is then compared to the CBL to determine the percentage reduction achieved.
- Load curtailment performance methods should also be customer sector dependent. eg. a method for mining, production, smelters, supermarkets, households, shopping malls etc. so that all customers are treated and measured fairly and equitably.

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Energy efficiency and renewable energy initiatives in South African municipalities

by Aurelie Ferry, SALGA

The objective of this paper is to demonstrate, through a series of case studies, that great initiatives are taking place at the local level in the energy efficiency and renewable energy sectors. Through the profiling of existing projects, our aim is to encourage more municipalities to walk this path. Analysing existing initiatives and opportunities have also assisted in identifying some regulatory barriers which, if removed, would unlock a greater potential of energy efficiency and renewable energy within the local government sphere.

Traditionally, the role of municipalities in the energy sector was limited to electricity distribution and electrification through the use of the INEP grant. In the last ten to 15 years, a broader role in strategic management of energy supply and the use of all forms of energy has emerged for municipalities, mainly led by the metropolitan municipalities. The benefits of integrated sustainable energy at the local level are recognised as being multiple. The current energy supply crisis and the regular load shedding exacerbate the need for sustainable energy initiatives. Energy management is a transversal topic and closely relates to other infrastructure and planning sectors, such as water and sanitation, roads and transport, building management, waste management or community and local economic development.

Alternative trajectories is not a theme for the future but today's reality. The transition has begun and several initiatives are underway. The road, however, is still long and there is a need to create a framework to enable municipalities to grasp these opportunities and ensure they can sustainably deliver services to their communities.

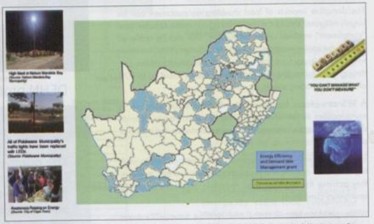

Fig. 1: Illustrative map of municipalities which participated in the EEDSM grant and illustration of interventions which took place within the programme [2].

Existing energy efficiency projects

Energy efficiency interventions have taken place in municipalities since 2009/10 with the Energy Efficiency and Demand Side Management (EEDSM) grant, DoRA, funded and administered by the Department of Energy. To date about 60 municipalities (Fig. 1) have participated in the programme and implemented projects resulting in the saving of approximately 500 GWh of electricity and avoiding the emission of over 500 000 t of CO_2 [1].

Other energy efficiency initiatives have been undertaken by municipalities and are not included in Fig. 1, for example the promotion of high pressure solar water heaters or the organisation of local energy forums to raise awareness on the need for all customers to save electricity. Even though the focus so far has been linked to the existing grant, there are other opportunities and huge potential to scale up energy efficiency initiatives at the local level, particularly when engaging on energy efficiency in the water sector.

It is equally critical to not only retrofit existing infrastructure but also to integrate energy efficiency into the design of new installations. For example, new street lights and high mast lights should be equipped with LED lighting from the onset, and new waste water treatment works or fresh water pumping systems should aim to reduce electricity consumption. This often results in higher upfront investment costs but the operational costs are reduced over the lifetime of the infrastructure, leading to overall lower life-cycle costs. An opportunity exists to integrate the life-cycle costs in the financial evaluation of tenders, instead of evaluating tender only based on upfront investment costs.

Existing renewable energy projects

It is often less known that municipalities have been proactive in the renewable energy sector as well. Some existing projects are historical or have been in operation for almost ten years, such as the hydroelectricity project in Bethlehem or the landfill gas to electricity in eThekwini. Other projects have recently been commissioned showing a growth in the number of existing projects and participating municipalities.

Several categories of renewable energy projects have been identified:

- Municipal own renewable energy projects
- Small scale embedded generation initiatives
- Other initiatives, often with the municipality playing a facilitating role (wheeling of electricity) or buying the renewable electricity through power purchase agreements
- Green buildings (with the inclusion of electricity generation from solar panels)
- Access to energy through alternative energy initiatives

The existing projects are illustrated in Fig. 2 and are not discussed in more detail in this summary paper.

Municipalities are encouraged to share information about other projects which may not appear on the map.

Possible business models for municipalities in renewable energy

The objective of this section is to have a closer look at the most used business models for renewable energy projects in municipalities to identify the success factors and potential barriers inhibiting a deployment at a larger scale.

Fig. 2: Illustrative map of existing renewable energy projects with municipal participation.

Municipal own generation

In this business case, the municipality develops, invests in and owns the renewable energy installation. The installation may be procured through a supply, operate and maintain contract during which the appointed service provider would be responsible for the operation and maintenance of the plant for the medium term. It is recommend that the maintenance period extends beyond the major maintenance cycle, so that the service provider has the obligation to refurbish the installation, if needed, before the end of the contract (for example, overhaul of gas engines). Skills transfer to municipal officials and operators should also take place during this period. The remuneration of the service provider should be (partially) performance based. This is a balanced mechanism to share some of the risk of the project, even though only to a certain extend.

More and more municipalities are investigating the concept and several projects are operational for a wide range of technologies, such as landfill gas to electricity, biogas or photovoltaic panels in waste water treatment plants, hydropower in the water reticulation systems or photovoltaic panels on municipal buildings. A series of case studies conducted by SALGA, GIZ and Sustainable Energy Africa (SEA) unpack these existing projects, their success factors and lessons learnt. These case studies look into more detail at the processes followed by municipalities and the legislation followed.

These projects have been implemented thanks to a clear strategy, strong political leadership and a dedicated project manager. Having an investment by the municipality on their own premises simplifies the business models and enable these projects to be developed in reasonable timeframes. However, financing restrictions and lack of capacity and resources to manage the sometimes complex procurement of advanced technologies are some of the barriers to a more widespread implementation.

Small scale embedded generation/ net-billing

Given high increases of electricity tariffs and regular load shedding, municipalities identified the need to allow residents and companies to generate their own electricity through solar panels and feed-back their excess electricity into the grid in a safe and sustainable manner. Municipalities pushed for feeding to be allowed as illegal installations endangers safety of staff and security on the grid. The price of solar photovoltaic electricity is now below the retail prices. It is thus economically viable for customers to install solar panels, and these customers will most probably install solar panels on their premises without a formal go ahead from the utility if they have no incentive to register their installations.

SALGA, together with AMEU, Eskom and with the support of GIZ has had extensive engagement with municipalities over the past years. This group has developed a common position on small scale embedded generation, which was approved by SALGA's national executive committee in July 2014. This position provided a skeleton of a framework to ensure a safe and sustainable development of roof top panels and other embedded generation technologies.

The position proposed by SALGA has three main objectives. Firstly, it aims at encouraging the uptake of private renewable energy installations to relieve the grid by saving consumption and providing the much needed additional capacity. While doing so, it avoids

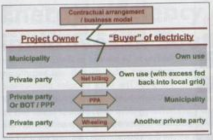

Fig. 3: Some of the identified business models for municipalities in renewable energy.

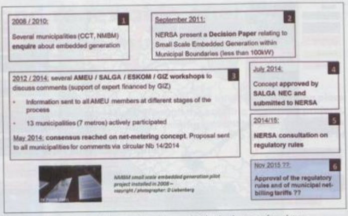

Fig. 4: Process followed to date with regard to the development of regulatory rules for small scale embedded generation.

informal connections thus ensuring the safety of staff and operations. Finally, the tariffs to be developed should limit the impact of such installations on municipal revenues, to ensure that municipalities have the resources necessary to keep maintaining and operating the grid.

To date, three municipalities are allowing net-billing on their grids while several others are eagerly waiting for their tariffs to be approved. Additional municipalities, of all sizes even in rural areas, are facing similar issues with some of their customers investing in solar photovoltaic installations and are seeking guidance.

NERSA has completed a consultation process to develop a set of rules on small scale embedded generation. It is becoming extremely urgent to give guidance to municipalities on how to deal with small scale embedded generation and to approve the submitted tariffs.

Private producers selling to municipalities

In this business case, a municipality wants to buy renewable electricity from a private generator through a power purchase agreement (PPA). There might also be a build-own-operate-transfer (BOOT) contract or a public private partnership (PPP) between the municipality and the private producer, should the energy be generated using public infrastructure.

Existing examples are scarce. In eThekwini, the municipality may enter into PPAs with private producers, however only at megaflex tariff and for a period not longer than three years. This model may assist some private producers who wish to sell their excess production, however, it would not assist new projects in getting the bankability assurance required to raise financing.

One of the barriers identified is finance. The Municipal Finance Management Act (MFMA) indicates that municipalities must spend according to a "best value for money" principle and that there must be financial and economic benefits to contracts longer than three years. In the case of renewable energy, the unit price of electricity produced from alternative sources is, in most cases and probably only for a limited period of time, still higher that the megaflex tariff paid by municipal utilities to Eskom for bulk purchase of electricity. Finding a funding source for the gap (between the cost of RE and megaflex) would enable several projects to come on line.

Wheeling of electricity, from willing seller to willing buyer

Finally, in a wheeling situation, a private generator of electricity sells electricity to a private buyer and uses the municipal grid to transport electricity from the point of production to the customer.

The City of Tshwane has signed such an agreement with the Bronkhorstpruit Biogas Project which produces electricity from biogas and sells it to BMW. The electricity is also partially wheeled through the national grid. Nelson Mandela Bay Municipality has signed a 20-year wheeling agreement with Amatola Green Power to allow for a maximum of 10% of the municipality's total energy consumption to come from privately traded renewable power, most of which is generated locally. These projects have been documented in a series of case studies conducted by SALGA, GIZ and SEA.

In 2012, NERSA published regulatory rules for third party transportation of electricity and a working group (comprising representation from utilities, private generators and industry) is currently reviewing the rules under the leadership of NERSA. When the review is completed, a public consultation process will be initiated.

Conclusion

The paper and the presentation aimed at profiling existing energy efficiency and renewable energy projects in municipalities, analysing the different business models and the barriers to increased uptake. Municipalities were encouraged to share information about their projects if they do not appear on the maps. The presentation was an opportunity to showcase innovations in the municipal space and profile good initiatives, which are often unknown.

Through studies and initiatives undertaken by SALGA and GIZ, several main barriers and opportunities to change – from a regulatory perspective – have been identified:

- The need to integrate life cycle costs in tender evaluation instead of only upfront costs.
- The difficulty for municipalities to sign PPAs, mainly because cost per kWh is higher than megaflex.
- The urgent need for NERSA to finalise the regulatory rules on net-metering/net-billing (small scale embedded generation).

Change is happening in the electricity and energy sectors and the regulation is lagging behind, creating barriers to municipalities. There is a need for more coordination between a wide range of stakeholders to unlock these barriers.

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Legislative imperatives – A legislative roadmap for energy challenges in SA

by At van der Merwe, Aurecon, and Adriaan van der Merwe, CDH

This paper provides a critical analysis of the legislative development and main business drivers for the current energy supply industry in South Africa, with specific emphasis on private sector participation. This analysis is then benchmarked against best practice for energy supply industry reform in other countries. Parallels are drawn with the current challenges (and disrupting forces) experienced in South Africa, and a roadmap for proposed enabling legislative and business interventions to address the current power shortages are put forward.

There is a growing consensus that the successful development and management of utility infrastructure depends on the adoption of appropriate policies and the effective implementation of same. The survival of an industry which is reliant on vast infrastructure is dependent on this infrastructure being functional and well developed. Only if this is the case can it be ensured that services are supplied in an affordable and cost effective way – without which the economy of a country cannot strive.

In Africa, as elsewhere in the world, clear energy sector policies, which are implemented through comprehensive and enforceable legislation and regulation, are key to unlocking investment, improving efficiency and increasing electricity access.

The question however, is whether this restructuring sufficiently supports the recent developments in the Southern African ESI, and what level of change in market design and regulation needs to be planned for, as there are no successful examples of "reform by default".

The future of the market structure of the South African ESI is uncertain. The vast interest in self-generation, on small and large scale, smart grids and green technologies to name a few, will redefine the industry and lead to catastrophic effects for the supply sector (including municipalities) if not sufficiently catered for.

This paper outlines the main driving and defining factors in the development of the South African ESI. A comparison to other countries is then provided in order to benchmark the South African experience and to understand what the future may hold.

Current electricity supply industry in South Africa

Main business drivers

According to Eberhard [4] three main ESI drivers for reform can be identified internationally. These are:

- The requirement to improve investment and operational efficiencies
- The requirement for new capacity investments that necessitates private sector involvement, as financing is not always available from public sources
- Privatisation, which creates the opportunity to unlock economic value and reduce government debt.

In a nutshell: The history of ESI reform in South Africa

The history of the ESI reform is summarised in Fig. 1.

Summary

The earlier years (phases one and two) are characterised by no private sector participation and focus on getting the regulatory system in place and a focus on some social requirements (electrification) going. The third phase was a preparatory phase for getting private sector in IPPs into the market in the last phase. The question then is how the future will unfold as far as possible reform in the ESI.

Current South African legislative framework

A snapshot of South Africa's energy legislation

The South African ESI is marked by a tapestry of policy, legislation, regulations and permitting requirements. Some of these are outlined in Fig. 2.

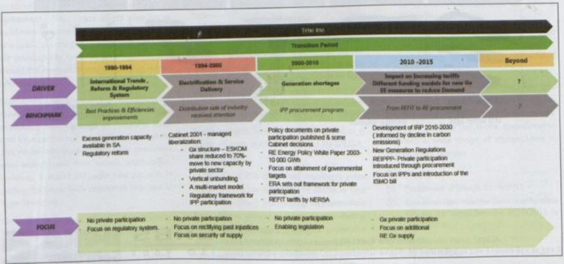

Fig. 1: History of power sector reform in South Africa.

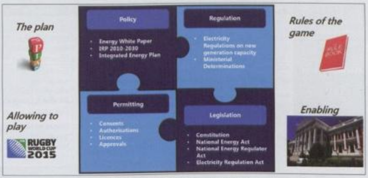

Fig. 2: South African ESI's energy legislation.

The timeline of the South African ESI's legislative reform

When a timeline is constructed for South African ESI's legislative reform, a clear trend can be detected in the development towards a more developed and open market for private sector participation. Fig. 3 depicts this timeline.

Summary

In summary then, and for the purpose of this analysis, private participation in the South African ESI can currently be realised as follows:

- Pursuant to a procurement programme, for which the Minister of Energy will make a section 34 determination under the ERA and in line with the IRP.
- Generation outside of the IRP, pursuant to a deviation application submitted according to section 10(2)(g) of the ERA.
- Any generation plant constructed and operated for own use, according to Schedule 2 of the ERA.
- A non-grid connected supply of electricity, except for commercial use, according to Schedule 2 of the ERA.

Drivers for reform – a benchmark

To understand South Africa's power sector's development a benchmarking exercise was undertaken to determine how private sector participation was introduced in the United Kingdom, Kenya and Nigeria. The benchmarking was undertaken to identify similarities, to determine whether the power sector models are the same, to identify elements unique to South Africa's power sector and to identify how the power sector develop further.

Tables 1, 2 and 3 provide a summary of this analysis.

Current challenges in South Africa

Disruptive forces

The future of the South African ESI's structure is uncertain, and as such it is important that utilities take a clear view on the way their marketplace is likely to evolve due to the business drivers at play.

As certain business drivers have the ability to shape the electricity industry as described above, new business drivers are disruptive forces to the current sector that will almost certainly shape the new power sector model and will lead to associated policy and legislative changes.

These forces (to highlight a few) that will result in some reform (either by default or in a managed way) can be summarised as follows:

- *The green revolution:* Where the economic usage of green power sources like solar and wind used to be more academic than every day practise, the reality is that the cost per unit of energy produced is steadily decreasing, leading to greater interest from both a commercial and a technical reliability point of view. The barriers of entry to the distribution sector are also declining. Soon the affordability of these technologies will become so attractive that customer choice, in the residential market, will react on the price signal from distributing utilities and exercise choice on usage that will first benefit the more affluent customers with some detrimental effects on the ability of the distributors for cross subsidisation within tariff classes as well as a deterioration on their revenue.
- *Distributed generation and mini-grids:* This is a growing market covering a wide spectrum from small- embedded to larger embedded generation, focussing on own use, local networks or distributing to the grid via wheeling arrangements. Included in this space is distributed storage to shift load – all affecting the traditional way of delivery. The penetration of such distributed generation schemes will depend on a variety of business factors amongst others the reliability of current infrastructure and the price signal. No longer are distributing companies shielded by the fact that their business is a monopolistic business where they do have captive customers.
- *Regional super grids:* Power pools play a much more dominant role in countries

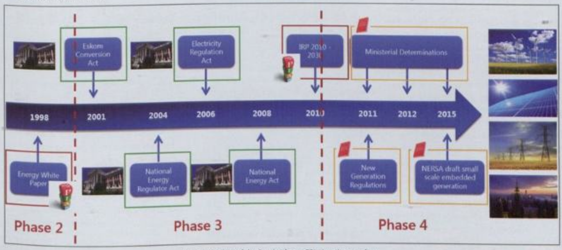

Fig. 3: Timeline of the South African ESI's legislative reform.

where the grid is interconnected, like is the case in Europe. In sub Saharan Africa the four established power pools are receiving increasing attention as possibilities to interconnect the power grids of countries and to operate in the retail market and to get access to amongst others contestable customers. The SAPP is already playing a role to support landlocked countries to get access to energy sources in southern Africa.

- *Increased urbanisation – shortage of supply:* One does not have to go far to notice the shortage of energy supplies in Africa, amongst others caused by underinvestment in infrastructure and a growing population in urban areas. The contrary of this would be a greater focus on off-grid supplies and mini-grids as suggested earlier in this paper. It is estimated that the net population growth is expected to occur in urban areas over the next two decades. Power companies will be challenged to provide infrastructure in a way to support orderly urbanisation and economics growth
- *Smart technologies:* The development of smart grids is essential if the global community is to achieve shared goals for energy security, economic development and climate change mitigation. Smart grids enable increased demand response and energy efficiency, integration of variable renewable energy resources and electric vehicle recharging services, while reducing peak demand and stabilising the electricity system. The "smartening" of the electricity system is an evolutionary process, not a one-time event.

	South Africa	United Kingdom	Kenya	Nigeria
Form of private participation	Procurement via RFP Licencing under ERA	Privatisation of ESI Electricity Act	IPPs Geothermal Development Corporation	IPPs NIPPs (National Integrated Power Projects)
Market reform	Private participation (ERA) Ministerial Determinations REIPPPP Restructure ESI (ISMO)	Restructured Industry (via Electricity Act) Privatised by selling state shareholding to private participants	Reform in 1990s, separating regulatory and commercial functions Facilitate restructuring Promote private-sector investment	Create competitive wholesale market (Market & Systems Operators). Create retail competition (long term vision)

Table 1: Types of private participation.

	South Africa	United Kingdom	Kenya	Nigeria
Focus	Introducing private participation Alleviating the energy shortage	Introducing competition	Creating a common energy sector regulator Ensure cost-effective, affordable, adequate and quality services	Private sector participation and eliminate government involvement Competition
Energy security	South Africa has to be self-reliant to ensure energy security	The UK can import electricity from EU member states	The East African Power Pool provides access to other energy sources	WAPP, but current Gx shortage Adequate gas supplies

Table 2: Types of legislation for private participation.

	South Africa	United Kingdom	Kenya	Nigeria
Competition	Private participation introduced to attract funding. No competition focus (but attained through a IPP procurement process)	Common market ideal led to the a competitive ESI, which is ensured and enhanced by the EU Competition Commission	Minimal competition	Unbundled and privatised to attract private investment MO and SO established and in operation
Regulation	Regulation via NERSA	Regulation via GEMA, and informed by EU policy	Energy Regulatory Commission (ERC)	Federal Ministry of Power and NERC

Table 3: Degree of legislation induced private participation in the power sector.

A power sector model

Various disrupting factors have necessitated that the existing utility business model be reviewed.

These developments have introduced various "non-utility" players into the traditionally vertically integrated market of the utility. As a result there is new competition at various stages of the value chain, resulting in the introduction of new business drivers in the vertically integrated business model. There is an increased risk for utilities of stranded assets for particular services in the vertical value chain. New and alternative energy options are becoming available to the customer and the result is the early signs of a changing market model where the status quo of a complete captive market is being challenged by the entry of IPPs and special service providers.

In this changing model, focus should be placed on customer contact, satisfaction, service and sales (with utilities being in an ideal position to leverage their existing customer base). The role of the distributor/utility is migrating from electricity (kWh) supplier to electricity partner providing only the networks. While traditionally, utilities only provided few products to all customers, utilities will need to become more flexible, providing multiple products and services to specific segments (e.g. support for distributed generation, rooftop solar, metering services etc.), including appropriately structured pricing options. Tariffs will also need to be restructured (unbundled) to allocate the appropriate fixed and variable costs and reflect the cost of supply.

The utility can take on various "new" roles relating to distributed generation, including planner, builder, installer, operator, facilitator, partner, financer, leaser or risk manager, amongst others.

Fig. 4 provides an overview of these changes.

The future of the South African ESI

The future of the South African ESI may require some of the following arrangements outlined in Fig. 5.

A legislative roadmap for intervention

It is not the intention of this paper to offer a comprehensive analysis of all legislative and/or policy aspects, but rather to highlight some enabling aspects identified during the benchmarking research. Specific challenges can be identified, especially for municipalities. As such a road map for intervention must be cognisant of the following:

- Procurement regulations are limiting municipalities in providing reticulation services in innovative ways.
- Uncertainty regarding regulations for small scale embedded generation to allow exporting to the grid (PV rooftop installations, net-metering, unbundled tariffs).

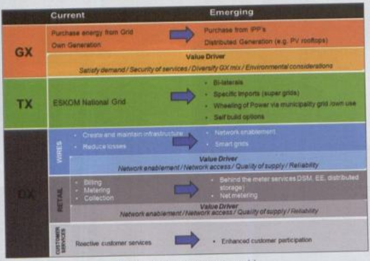

Fig. 4: The changing power sector model.

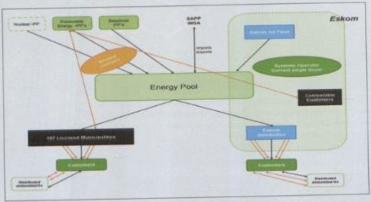

Fig. 5: A future outlook for SA for the changing power sector model.

- Regulations with regard to trading is unclear (how, who and when can traders enter the market.
- The market is developing from a single buyer to a multi buyer model.
- Uncertainty on how to allow for generation outside the IRP (deviation applications).
- Lack of tried and tested financial models for private participation in the municipal sphere.

Conclusion

Adequate infrastructure investment and the ability to attract investors are of paramount importance for economic development. Learnings from various countries suggest that ESI reform will take place either by design or by default. Reform by default is clearly not a preferred option. Therefore sufficient enabling policy and relevant legislation is of critical importance to direct the reform and to ensure the appropriate level of infrastructure investment.

The development of ESI reform in South Africa is characterised by specific business drivers that have influenced the way in which reform occurred. This paper's analysis has indicated that various disruptive forces cause business drivers that impact the current power sector model. It is therefore important that the reform process be effectively planned and managed to present the desired outcome.

Utility managers and policy makers need to be cognisant of these disruptive forces, to ultimately ensure that market reform occurs in an orderly and planned fashion. It is held that business drivers will reform the South African ESI, either by default or by design, to ensure that there is sufficient private sector participation for infrastructure development in South Africa.

It is held that market reform benefits an economy and a country's ESI, if said reform occurs according to a well-developed roadmap.

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Establishing a market for electricity at the distribution level

by Eustace Davie, Free Market Foundation

An efficient market for electricity at the distribution level cannot be brought about without making fundamental changes to the entire electricity, generation, transmission, and distribution system. It can also not be established without creating facilities for trading in electricity, competition between generating companies and electricity retailers, with the ultimate objective of providing consumers with a choice between competing suppliers at competitive prices. In addition, for the system to function at all, the transmission grid or grids must be independent of the generators, which in turn, must have unbiased access to the grids.

In South Africa it is taken for granted that a single distributor, whether Eskom or a municipality, will have a monopoly in a specified area and that the only constraint on their prices will be exerted by the regulator. The South African municipal retailer, on the other hand, is dependent on the regulator to control the prices charged by the generation and transmission company, Eskom, which also carries out about half the retailing. The regulator, in turn, cannot possibly have access to the information necessary to set prices similar to those that would have come about in a fully competitive market for electricity.

Given the structure of the South African generation, transmission and distribution system, it is not possible to know what the price of electricity could or should be. We do not know for sure whether the price is higher or lower than it would have been in a competitive market. However, if we examine what has happened in other markets for electricity, we find that wherever open competition has been introduced into the various sectors of the business, there has been downward pressure on the price of electricity and a better deal for consumers.

Transforming the South African electricity industry

For South Africa to have a robust and competitive electric power supply system, its electricity generation, transmission, distribution and control processes should be reformed as rapidly as possible. Security of short-term and long-term electricity supplies demand that government take immediate action to remedy what is obviously a faulty structure.

The best structure is not a single government monopoly such as Eskom, with centrally controlled oversight and direction. Much better structures are those that have evolved and continue to evolve in the European Union countries (based on the UK example) and the structure that has developed in North America.

An economic or business-driven structure for the delivery of electric power consists of an electricity grid made up of inter-connected high voltage transmission lines supplied by a multiplicity of electricity generating entities that feed electricity into the grid. An even greater multiplicity of distributors purchase electricity from the generating companies or from wholesale intermediaries, draw it from the grid, transform it from high to a lower voltage, and distribute and sell it to end users. For all or most of these functions to be carried out by a single organisation such as Eskom is not a good idea, especially when that organisation's very existence depends on a legislated monopoly that prohibits competitors from entering the business of generation, transmission and supply of electricity.

Countries that have abandoned vertical monopoly systems

There is ample evidence that South Africa's electricity generation and supply structure needs to change. One of the electricity producers in the EU reported, for instance, that "until the late 1980s, the structure of the electric sector in most countries was based on the idea that the most efficient way to provide electricity was to have a national electricity company which was a natural monopoly and so needed to be state-owned to protect consumers. However, now experience shows it is possible to divide electricity companies into those parts which are still natural monopolies (for example, high voltage and low voltage networks) and those parts where it is possible to have competition (for example, power stations) and to create a market for electricity. This experience is now being used all over the world to create cheaper electricity by means of competition among power stations and among companies that are in the business of purchasing and reselling electricity. Western Europe has shown that prices to consumers can fall by up to 20% when the market is fully operational".

European Union

According to a May 2000 European Commission report, marked decreases in the price of electricity from 1996 to 1999 occured in Finland (19,6%), Sweden (17,6%), and Germany (9,6%), all countries with 100% market opening.

Significant price reductions were also experienced by Spain (16,2%), Portugal (14,0%) and France (12,7%) – countries with a lower level of market opening (between 30% and 45%). These reductions were achieved as a result of conditions imposed by the European Parliament requiring all member countries to open up their electricity markets to alternative suppliers.

North America

Other markets are equally, or even more, open. The North American Electricity Reliability Corporation (NERC) reflects the openness of the electric power business in the US and parts of Mexico and Canada. NERC sets and maintains "effective reliability standards that are clear, consistent and technically sound, coupled with a strong standards enforcement program, to help maintain and improve the reliability of North America's bulk power system". NERC is a 501(c)(3) not-for-profit organisation with official backing from the US and Canadian governments. It oversees the grid which supplies electricity to 334-million people, a total electricity demand of 830 000 MW, utilises 340 000 kms of high voltage transmission lines, and represents $1-trillion in assets. NERC has twelve different member categories ranging from small and large electricity consumers, electricity marketers, private and co-operative electricity generators to US and Canadian municipal, state, provincial and federal government entities. Trustees, elected by members, run the organisation. What is clear from the North American experience is that the grid should be separated from the generation and distribution functions and that all the entities directly involved in the operation of the bulk power system should have a say in maintaining the integrity of the system.

New Zealand

In 1985, New Zealand had 61 statutory monopolies, or electricity supply authorities (ESAs), distributing electricity to consumers. A government-appointed Electricity Task Force issued a report in 1989 recommending the total restructuring of the electricity industry that included the corporatisation and privatisation of the ESAs, separate ownership of generation and transmission, and the possibility of creating a wholesale electricity market.

These recommendations have been implemented and the Electricity Authority now urges consumers to shop around for the best prices and to switch from one electricity retailer to another if it will save them money. There are more than 50 generating plants, most owned by five major and eight smaller grid-connected companies. To improve efficiency, increase competition and bring down prices to consumers, management and ownership of the various components of the system were separated. The electricity sold by competing retailers is carried by separately-owned distribution grids that are debarred from being involved in retailing. The high-voltage grid, split off in 1994, is owned by Transpower, an independent state-owned enterprise.

Spot and hedge markets, together with ancillary services comprise the wholesale market. Reconciling transactions on the retail and wholesale markets has been contracted out to the New Zealand Stock Exchange. Transpower, as the owner of the national grid, is the system operator responsible for all the functions that provide security of supply and maintain the integrity of the grid. These New Zealand reforms prove that there are positive benefits for consumers when the measures adopted increase competition and improve efficiency in electricity generation, transmission and distribution.

In New Zealand, nine or more retailers compete for the business of consumers in any given area. New Zealand's electricity system has been transformed to the point where it has room for over 20 electricity retailers. The country has 28 network owners that own the networks that deliver electricity to consumers. This would be equivalent in South Africa to Eskom and municipalities providing the networks for the delivery of electricity but not being involved in retailing. New Zealanders take pride in the fact that if customers are dissatisfied with the service they receive from one retailer they can switch within 24 hours to another supplier.

The New Zealand Electricity Authority reported on 3 March 2015 that the latest international research shows New Zealand's electricity retailers are competing fiercely for customers compared with those in selected overseas markets with competitive retail markets, but New Zealand consumers are relatively passive about exercising their option to choose between providers.

The Electricity Authority released results from a survey investigating international consumer activity, behaviour and attitudes towards the electricity industry. The survey compares New Zealand to Australia, Texas (US) and Alberta (Canada). These four regions have comparable cultures and competitive retail electricity markets.

Dr. Brent Layton, chair of the Authority says, "the results show New Zealand is at the forefront of promoting retailer switching and it is the easiest place in the world to switch. The competitive rivalry in the New Zealand retail market is significantly stronger than in the other markets we looked at. But, consumer switching activity is largely driven by retailers, not consumers."

The New Zealand Stock Exchange has recently once again won the contract to reconcile the quantities of electricity supplied by generating plants, transmitted across the transmission grid, distributed by the distributors, and sold by the retailers. They calculate the division of the proceeds of the sale of electricity to the various parties from information gathered from network supply points.

Conclusion

How should the electricity industry develop, in as short a time as possible, so that it can best serve the interests of all South Africans? Is it in our interests that government should continue to dominate as is apparent from the Draft 2012 Integrated Energy Planning Report? A fatal flaw in the report is that no mention at all is made of open competition in the generation and supply of electricity.

All developed and many developing economies of the world have, or are in the process of introducing competition in all possible aspects of their energy industries. This draft report, however, which outlines development plans through to 2050, seems to suggest that in South Africa the government should continue on the current path with a state-owned vertically integrated monopoly, Eskom, in the generation and supply of the bulk of the country's electricity. There is no sound economic or any other reason for this.

An electricity environment that would be far superior is one in which independent power producers (IPPs) compete with Eskom for the business of consumers. Even more important would be the establishment of an electricity market in which generating companies compete with each other in the supply of electricity. The problem faced by government would be how to introduce private generation capacity into the mix in a manner that will be of greatest benefit to consumers.

The 1998 White Paper adopted by government but not implemented, set out the following goals that needed to be achieved to modernise this country's electricity sector:

- Giving customers the right to choose their electricity supplier.
- Introducing competition into the industry, especially the generating sector.
- Permitting open, non-discriminatory access to the transmission system.
- Encouraging private sector participation in the industry.

But if those laudable goals are compared with what has transpired during the past 17 years, we find that:

- Customers have no choice of electricity supplier and there appears to be no intention to give consumers that choice.
- Competition has not been introduced into the industry (producers of alternative energy are suppliers to Eskom and not competitors).
- Open, non-discriminatory access to the transmission system is not available. If it was, independent power producers would be selling electricity across the transmission system directly to large energy users or into the energy market.
- Private sector participation in the industry has been actively discouraged and not encouraged as envisaged in 1998.

If government welcomed the participation of private firms in all aspects of the electricity business, it could rapidly create the environment necessary for the development of a market for electricity. There is no reason for government to incur further liabilities or burden taxpayers in order to increase the capacity of the electricity supply system.

The generation of additional electricity can be financed by private firms who could also build and operate the new generation plants. The private sector would do this with alacrity if they were confident that government is intent on encouraging the development of a fully functioning market for electricity. Such a market would provide competition in every possible part of the system, price electricity according to demand and supply, increase the efficiency with which generated electricity is utilised by differential pricing between high and low demand hours, and provide end consumers with a choice between competitive suppliers.

Most importantly, the generating companies that are investing their own money in new generating plants, with no guarantees from government except open access to the electricity transmission system and market, will make the decisions as to what kind of generating plant to build, and not government planners. Cost over-runs of whatever nature will be absorbed by the plant owners and the selling prices of the electricity they sell will be determined, in the final analysis, by consumers and not by regulatory officials.

South Africans do not only want the lights on; they want to know that all the productive sectors of the economy have access to the power they need to conduct their respective businesses as efficiently as possible. The livelihood of every single person in the country depends on them.

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Designing small scale embedded generation tariffs

by Kevin Kotzen, GreenCape

South Africa is currently experiencing an electricity supply crisis, with peaking plants having to be run outside of peak periods, pumped storage facilities being fully utilised, industrial load curtailment being requested and load-shedding being invoked more and more regularly. Customers have responded by investigating, and in many cases installing, small scale embedded generation (SSEG) systems such as rooftop solar PV.

These systems generate power on the customer's side of the meter and reduce the amount of electricity that is required and purchased from the utility. Thus far most municipalities lack the correct rules, regulations and tariffs for these systems.

This has resulted in sub-optimal installations with customer-utility relationships also being strained. Utilities which rely on revenue generated from electricity sales need to protect net surplus in a way that is fair and sustainable; supporting relevant government greening objectives and contributing towards resolving the energy shortages.

This presentation is focused on developing tariff ideas for utilities in the changing energy landscape. We present a number of principles that should be considered when designing these new tariffs.

It is essential that tariffs are transparent. Changes to the tariff structure or the introduction of a new SSEG tariff need to be done with a high degree of consumer engagement.

The introduction of a feed-in rate (cost vs. value) should not be accompanied by additional charges. The only difference between a regular electricity tariff and an SSEG tariff should be the addition of a feed-in component.

Economically optimised PV installations should be encouraged. All tariffs should be designed to promote installations that are economically efficient. The tariff needs to ensure that customers install a system that results in the lowest possible levelised cost of electricity for that customer and the municipality.

A guaranteed feed-in payment duration should be set. The risk involved in SSEG project development can be reduced by ensuring that the payment stream will not end before the SSEG customer or developer has had a chance to recover their investment.

Any customer must be allowed to be on a SSEG tariff (reduce the impact of tariff switching). SSEG tariffs should be designed so that customers cannot reduce their bill by simply switching to that tariff (without adding SSEG).

Time-of-use (TOU) metering should be enforced for all SSEG customers. A TOU tariff is more cost-reflective than a flat or two-part tariff in that it accounts for the varying costs of generating and supplying electricity. The TOU tariff should be designed to be revenue neutral when the SSEG is excluded.

All of these principles are designed to ensure municipalities remain part of the electricity value chain, support the growing SSEG market and ensure grid connection remains the most appealing option for SSEG customers (financially and for security of supply). Grid defection would be the worst case scenario for the municipality and the grid as a whole.

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Energy, demand and revenue impacts of rooftop PV in Namibian distributors

by Dr. Gerard van Harmelen, Enerweb, and Pinehas Mutota, Electricity Control Board of Namibia

This paper presents the methodology, process and high level results to determine energy, demand and revenue impacts of rooftop photovoltaic (PV) penetration in the Namibian environment. A detailed bottom-up engineering model approach was followed, where hourly impacts of PV installation penetration were computed explicitly per three customer classes, namely residential, commercial and industrial. The resulting energy and demand modifications were applied to the cost-of-sales components for each redistributor's cost-of-service components which inform the proposed tariff models. Modifications in revenue requirements were consequently computed and reported for various PV scenarios.

In this paper, the background is initially discussed, after which the proposed methodology is given. In the subsequent sections, the results of the hourly disaggregation profile modelling are described as being from a sample distributor, to maintain their confidentiality. However, actual detailed results per individual distributor were produced and are available on request from the ECB. There is an explanation of how the PV profiles were sourced (from ground station measurements) and the data processed to be useful at an hourly level. Details are provided on how the PV hourly profiles were modelled together with the disaggregated customer load profiles, to result in total hourly demand profiles feeding directly into the required revenue analysis model (i.e. converting cost-of-service elements to proposed tariffs). Once again, the specific cost-of-service components and tariff configuration were unique per distributor, but an example case is presented in this article. Required revenue reduction, as well as relative sectoral pricing movements (i.e. between different tariff categories), is finally presented, after which a summary is given and proposed new work is described.

Background

During the first quarter of 2014, the Electricity Control Board (ECB) of Namibia embarked on an analytical modelling study on energy, demand and revenue impacts on Namibian distributors, as a consequence of rooftop PV installations. Such installations had been gaining in popularity, and a draft set of net metering rules had been proposed. This study was to further inform these rules. While using PV generation for self-usage had always been the primary intention, its usage as distributed generation for the overall consumer base required careful analysis and additional rules and regulations [1]. The outputs of the study were to consist of an overall report specifying methodology and detailed level results and interpretations, accompanied by individual, distributor-specific models and analysis, using each distributor's customer segmentation, load profiles and proposed tariff structuring as per their yearly tariff application processes.

Methodology

In determining future impacts of PV penetration in general, an extremely large count of interactive variables and effects is involved, making any averaging, high-level simplification unsuitable. The two most important effects, and those concentrated on in the proposed model, were firstly the (unique) hourly sectoral (residential, commercial and industrial) profiles, and secondly, the (unique) proposed tariff structuring, with both these components being modelled separately for each redistributor (RED).

Whereas the first could be overcome with detailed (disaggregation) numerical modelling, the second relied on sectoral sales splits, unique cost-of-service components per distributor, and unique revenue requirements and indicative tariff structures, present for each. All of the latter are however used by the ECB during an annual standardised

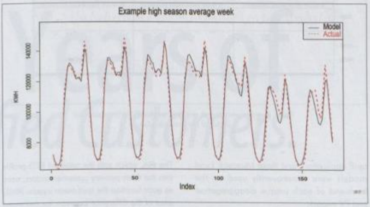

Fig. 1: GA modelled vs. actual metering data for total supply to the distributor example.

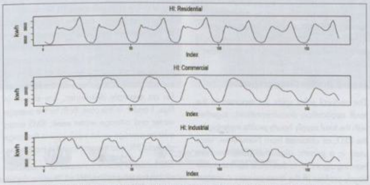

Fig. 2: Individual sector profiles (average winter week), for the distributor example.

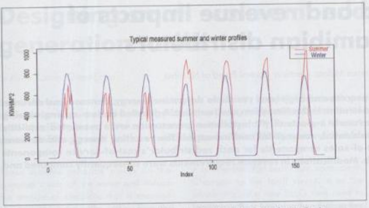

Fig. 3: Typcial summer and typical winter hourly solar radiation data for Windhoek.

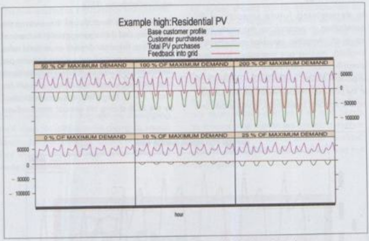

Fig. 4: Average winter week profile impact of PV in the residential sector of the example case.

tariff application, and those Microsoft Excel models were consequently used on the back-end of each unique disaggregation and PV impact.

Furthermore, the models were constructed using 2013 as the base year and performed in nominal terms (in percentage change terms), so that factors such as different future penetration rates, customer segment growth rates and different tariff configurations could be applied according to the modeller's discretion.

Supply profile disaggregation

The sectoral sales splits (as reported in the tariff application documentation), together with the total supply hourly profile metering for the RED, as obtained from NamPower, were used in a genetic algorithm (GA) machine learning algorithm to determine representative hourly profiles of the three primary customer category sectors [6].

The GA, which split the totalised RED profile into the three primary customer sectors, used as error function the root mean square (RMS) error of the difference between the measured hourly profile, and the GA generated total profile. This was done such that the sales in each sector (of the generated profiles) were equal to the sales volume splits as reported in the tariff application, and the hourly demands of the three sectors, when summated, were thus the minimum square error to the actual measured profile. The totalised comparison (actual vs. simulated), as well as individual sectoral profiles, together with the RMS error for an example distributor, are shown in Figs. 1 and 2. In this case, both for the average winter and average winter week, RMS errors over an average winter week were in the range of about 5%, and this was found in most cases.

The totalised profile consisted of a selection of customer profiles taken from a South African profile database, classified according to residential, commercial and industrial categories. The selections were made such that the individual sector sales aggregation added up to the reported sales category totals, and were chosen by the GA such that the error between actual and model was minimised. The individual profiles, for the case as in Fig. 1, are shown in Fig. 2.

The type of disaggregation was also applied to the low season, resulting in disaggregated profiles for the three customer categories during an average summer week. Depending on the specific distributor sales splits (per category) and their unique supply profile, the sectoral splits for summer and week were unique per distributor.

PV data management

Due to the high emphasis placed on PV and solar during the past years, a large body of simulated and measured data for solar irradiation is available, usually in the form of energy maps with monthly values being very common. NASA [2] and NREL [3] are popular sources, making use of atmospheric, and geometric and satellite data. In this study, actual ground station measurements (at five minute intervals) were used from the free weather service, WeatherUnderground [4]. Although the primary interface to their data is via a website, application programming interfaces (API) are freely available, allowing mass downloads to be automated. In this case, this was achieved using the R statistical environment [5].

A typical winter week and a typical summer week of five minute solar radiation data, aggregated into hourly values, are shown in Fig. 3.

Supply profile impacts of PV

Therefore, given the sectoral and PV solar generation profiles, and under the assumption of no storage, profile impacts for the sectors, at the sectoral level, for 0%, 10%, 25%, 50%, 100% and 200% PV penetrations could be superimposed on an hourly basis. PV penetration percentage is being reported as the total PV installation demand in a sector, as compared to the sales maximum demand of that sector (sales profiles). The results of this superimposition, for the residential sector, of the distributor example for an average winter week, are shown in Fig. 4.

As the percentage penetration of sectoral maximum demand increased, the green solar generation increased up to around 100% of sector maximum demand (middle in top row of the graph). At this point a red curve, namely the sectoral overall nett generation, started occurring. This means that at a sectoral level (not an individual house level), the sector was starting to generate back into the network.

In the actual modelling, results were computed at 1% increments, from 0% – 250%, resulting in overall statistics (such as percentage maximum demand impact, percentage load factor impact, and so on), and these were plotted on a single graph for each of the sectors, for the range investigated. In this case, the specific impact (e.g. percentage of maximum demand impact), became a single point on a line graph, at an x-coordinate of the penetration at which it was computed. Such a graph, which summarises hundreds of graphs resembling Fig. 4, is shown in Fig. 5.

The graphs as shown in Fig. 5 were generated for all sectors, for both seasons, resulting in six overall statistical outputs per distributor. The low season (summer) impacts, on a sector level, for the distributor example, for the industrial sector, are shown in Fig. 6.

Step	PV installed %	Revenue (million)	Revenue lost (million)
1	1,0	1381,6	0,0
2	2,5	1376,9	4,7
3	5,0	1370,6	11,0
4	7,5	1363,3	18,3
5	10,0	1352,5	29,1
6	15,0	1334,9	46,7
7	20,0	1319,7	61,9
8	25,0	1300,6	81,0
9	30,0	1282,6	99,0
10	35,0	1262,9	118,7
11	40,0	1252,1	129,5

Table 1: Installation vs. revenue losses.

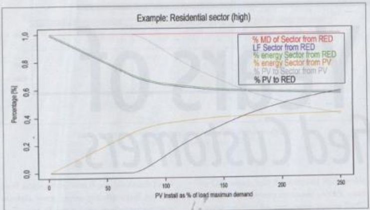

Fig. 5: Statistical summary of PV penetration of residential high season PV impacts.

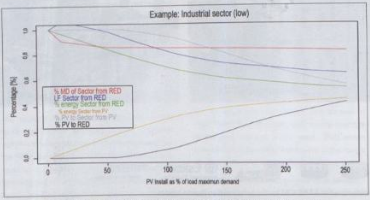

Fig. 6: Statistical summary of PV penetration of industrial low season PV impacts.

In terms of revenue impact modelling, PV penetration affects both energy and demand of purchases, namely the variable cost-of-sales go down due to energy reductions, and fixed cost-of-sales go down according to demand reductions. The reduction statistics, Figs. 5 and 6, for example, were used to affect the input (cost-of-sales) revenue requirements in a linear fashion (as percentage of reductions), after conversion to annual values.

Profile impact statistics (energy and maximum demand) of the PV penetration were modelled per sector and per season over the average winter and average summer week. When the tariffs sheet calculations were applied, however, only annual values were used, and consisting of a summation of the sectors and weighted according to the seasonal lengths, in moving from average winter and average summer week to annual values. High season impacts thus accounted for 25% (three months), whereas low season impacts (for energy), accounted for 75%.

The input revenue requirements (during tariff application) were thus modified linearly as per the reduction in requirements computed in the previous graphs. These revenue requirements were translated into tariffs via the regulatory tariff approval process, given a set of assumptions around the other cost of service items (e.g. operation and maintenance charges, etc.). It thus remained to specify a most likely PV penetration rate per sector, and then the rest of the tariff determination worked as before, computing proposed tariffs as per the ECB process.

PV penetrations

In this modelling, PV penetrations were given in percentage of sectoral maximum demand and computed to follow the Gompertz or well-known S-curve formulation for growth over time [7]. All revenue and price impacts were computed along nominal principles for the year 2013, meaning that the PV penetrations of between 0 – 50% for example, would be applied for revenue and tariff calculation to the same year, and all impacts calculated for revenue in that same year. One should thus read the output values relative to each other and convert to percentages. This means that the given PV penetration trajectories and the revenue drops associated with these (to be shown next) from starting value to ending value, are applicable, irrespective of the time period and the year chosen. It is left up to the reader to thus multiply by revenue or growth in a future year, according to the reader's assumptions of those; however the PV impact can then be applied as a relative percentage application.

In moving from one penetration value to

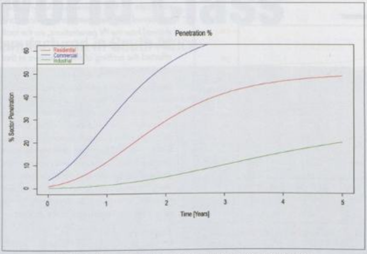

Fig. 7: One future scenario, showing PV penetration percentages per sector.

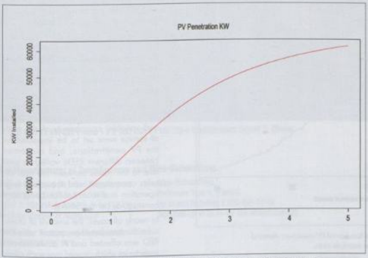

Fig. 8: Overall impact in demand (in MW), given the scenario as shown in Fig. 7.

another, these were allocated to a specific time progression, but this penetration rate over time needs to be estimated and is currently somewhat subjective (i.e. how long will it take to reach 10% PV penetration) due to insufficient data being available during the development of this study. However, using the nominal approach as described above, and applying them to the same year, one is able to compare everything in 2013 dollars, and those with better estimates or forecasts of such projections can then use the lookup tables/graphs, all keyed by percentage penetration, to derive the impact for any given year.

A given set of sample penetration growths, (Fig. 7), converted via the actual maximum demands per sector (Fig. 2), will result in an overall penetration curve, in MW, as shown in Fig. 8. For each of the sectors however, the asymptote, displacement and growth rates, being controlling parameters of each growth curve, can be set independently [8].

Required-revenue impacts

In computing the revenue requirement impacts, the analytics team used the tariff determination model, as is unique per each distributor's tariff application model, and as submitted to the ECB. This contains specific values for revenue requirements as well as a distributor specific revenue recovery allocation model. In terms of revenue requirement modelling, all cost-of-service values were kept constant, except cost-of-sales (variable) which was decreased as per energy percentage reductions, and cost-of-sales (fixed) which was reduced as per demand percentage reductions, in response to a specifically configured PV penetration scenario, as shown in Fig. 8.

The tariff determination sheet was processed via Excel macros for the PV penetrations as configured, from zero through to the final penetration value, in steps of 1%. This method allowed modifications to be found for the change in revenue requirements using the nominal modelling principles. This method was chosen in order to give results pertinent and specific to each distributor's sales splits, cost-of-service components and tariff determination method. Results could thus avoid being too generic to be of value, and also avoid getting trapped in too much detail for individual REDs. For the example distributor, as is being treated in this paper, the revenue requirement reduction trajectory was obtained over the time period for penetration, and is shown in Fig. 9.

As per the methodology set forth in the previous paragraphs, the time axis here is dependent on the reader's point of view as to penetration rates; however the time dimension can be removed, and the revenue requirement may also be plotted as a function of penetration percentage (percent of redistributor metered supply maximum demand). This is shown in Fig. 10.

A tabular example of the trajectory progression as shown in Fig. 10, is also shown in Table 1. Whereas before, PV installation was measured as the installed capacity of PV as a fraction of total distributor supplied maximum demand in percentage, total revenue and absolute values of revenue loss were found by multiplying the nominal values by the absolute values of the distributor example.

Indicative pricing trajectories

Given the indicative tariffing model referred to above and the revenue requirement driving mechanism formulation as present in the distributor specific spreadsheets, indicative trajectory modifications in price movements could thus also be obtained (indicative of subsidisation effects). The trajectories (seen in Fig. 11) showed relative price increases and reductions in percentage, relative to their own category starting prices at zero PV penetration. It did not show relative price differences between tariff groups. A trajectory value of 1,00 was the price as it was in the original (zero PV) case, and computed by the tariff determination sheet. The trajectory showed how that initial price moved as the PV penetrations increased. This gave some indication of relative percentage price

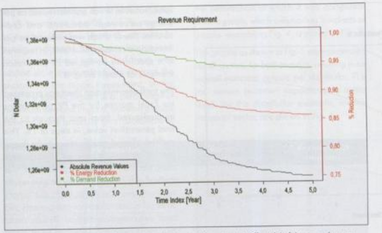

Fig. 9: Required revenue reduction according to cost-of-service to tariff model of the example case.

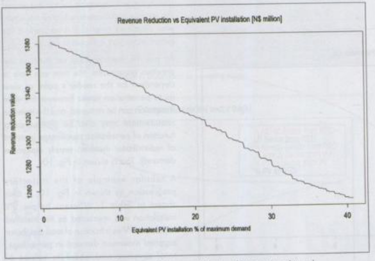

Fig. 10: Required revenue reduction as a function of PV maximum demand penetration rate for the example case.

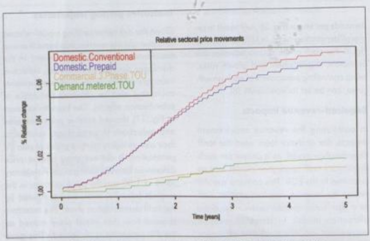

Fig. 11: Relative pricing movements due to PV penetration over five time periods.

increases of the segments/category when compared with their own starting prices, and showed how the PV penetrations, via the tariff allocations mechanisms present in this sheet, affected the tariffing of the customers in that segment/category.

Bearing in mind that the nominal approach was used and that the x-axis, although showing a 1 – 5 years' time lapse, rather represented the progression along time in terms of penetration concentrations, the time lapse could thus be longer or shorter than five years, but due to the nominal computations and scaling percentage applied, remained valid for other time spans as well, e.g. five decades, or five months, depending on the rate of penetration present in the market.

Summary

At a generic level, the following conclusions are proposed, as shown by the models:

- Maximum demand effects in the residential sector were negligible, with minimum and slightly increased effects in the commercial and industrial sectors.
- Nett energy started being fed back into the grid for a sector (nett), when PV penetration levels reached between 75% and 100% of the sector maximum demand, with details found in the specific graphs.
- During the revenue requirement calculations, only cost-of-sales (fixed and variable) components of the cost-of-service were set to be impacted by the PV penetrations, and outcomes between different REDs varied in part due to the ratios between the cost-of-sales components, and the others (e.g. operation and maintanance being kept constant, as per the others).
- In nearly all cases, the amount of cross-subsidisation between sectors with the RED was affected and in cases showed trajectories which crossed over each other, i.e. altering their (possible) original intent.

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Independent power producer procurement: integrating with municipal distributors

by Dr. Clinton Carter-Brown, John Samuel and Seaga Molepo, Department of Energy, and Shirley Salvoldi, Eskom

The South African Department of Energy's Independent Power Producers Procurement Programme (IPPPP) was established at the end of 2010 as one of the government's urgent interventions to enhance South Africa's power generation capacity. The programme is managed by the IPPP Office, and the primary mandate is to secure electrical energy from the private sector for renewable and non-renewable energy sources.

IPP procurement commenced with the Renewable Energy Independent Power Producers Procurement Programme (REIPPPP) which primarily involves the creation of utility scale renewable energy generation plant connected to the South African grid. The spatial locations of these plant (as informed by renewable resources, land and environmental impact) are such that these plant are primarily connected to the Eskom transmission and sub-transmission grid in predominately rural areas. There is hence limited impact on the municipal distribution networks.

The REIPPPP has resulted in the procurement of some power generation from IPPs located within municipal electrical supply areas. Municipal electricity distributors hence play a key role in facilitating the grid connection of these sources of new power generation.

This paper provides an overview of two areas that have particular relevance to municipal distributors given the strong inherent linkages to the customer base supplied by municipalities in South Africa; the IPP cogeneration programme, and a possible demand response programme. The paper provides an overview of the key concepts, with the intention to create awareness and ensure that the municipal distributor dependencies are well managed for the success of all parties involved in the development and implementation of these important initiatives.

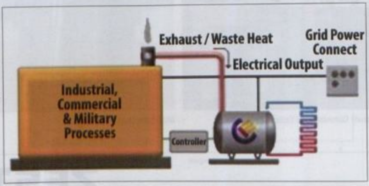

Fig. 1: Cogeneration – waste to power.

Introduction

The DoE's Independent Power Producers Procurement Programme (IPPPP) was established at the end of 2010 as one of the South African government's urgent interventions to enhance South Africa's power generation capacity. The programme is managed by the IPP Office, and the primary mandate is to secure electrical energy from the private sector for renewable and non-renewable energy sources. With regard to renewables, the programme is designed to reduce the country's reliance on fossil fuels, stimulate an indigenous renewable energy industry and contribute to socio-economic development and environmentally sustainable growth.

Energy policy and supply are not only about electrons, fuel and carbon technologies. In reality, it is rather an issue of socio-energy system design, as energy systems are deeply embedded in broad patterns of social, economic, and political life and organisation. The IPPPP has been designed not only to procure energy, but has been structured to also contribute to the broader national development objectives of job creation, social upliftment and broadening of economic ownership.

The programme is contributing to alleviating the electrical energy shortfall South Africa is facing. In this context the DoE is in the process of procuring significant additional renewable energy, coal, gas and cogeneration capacity from the private sector to fill the electricity supply gap up to 2022. This implies a sharp ramp-up in procurement to 17 GW. To contextualise this capacity, it is equivalent to introducing 3,5 times the Medupi plant capacity, within a period of only ten years.

IPP cogeneration programme

Cogeneration

Cogeneration, or "CoGen", is the generation of electricity from a generation facility that is integrally linked to a host industrial process and is classified under the technologies described below. Cogeneration is known internationally as combined heat and power (CHP), where steam generated for use in the industrial process is raised to a higher temperature and pressure and then first fed through a turbine before being used in the industrial plant.

NERSA expanded the definition of cogeneration to include Type I technologies, waste to energy and Type III technologies being combined heat and power using renewable fuels. Under Type I cogeneration technologies, waste includes discard coal which was seen as a waste energy resource [1].

The IPP programme has adjusted NERSA's definition of cogeneration by removing the use of discard coal from the cogeneration programme and including it under the coal IPP programme. The definition of Type III has been changed to include as a primary fuel the biomass trash associated with the production of renewable biomass fuel used in the host industrial process, removing the need for a steam supply from the boiler and removing any efficiency requirement.

Due to CoGen facilities being integrally linked to the host industrial process, the power generated will be self-despatched.

CoGen is an attractive supply side generation option as the inherent efficiency gains (due to the use of waste by-product and/or the use or supply of steam for industrial processes) reduce green-house gas emissions. The location of CoGen plant in close proximity with host industrial process electrical load

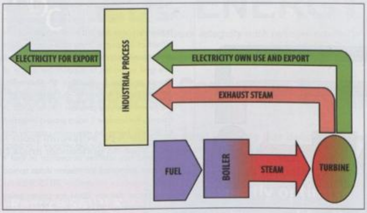

Fig. 2: Cogeneration – combined heat and power.

also reduces the grid impacts and reduces grid losses.

The CoGen IPP programme technologies are described below as:

Waste to energy facilities (Type I)

Waste to energy facilities are characterised by an energy resource that consists of waste heat or gases from an industrial process. These energy resources may be either high temperature exhaust gases that feed a heat recovery steam generator, or gases that may be used as a fuel as they contain a combustible component. Discard coal is excluded from the waste to energy categorisation, but is permissible in combined heat and power category.

Waste to energy facilities will utilise waste energy or waste gas as their primary fuel, but it is noted that they are allowed to augment this with up to 40% of other fuels, either renewable or non-renewable.

Waste to energy facilities are relieved of any mandatory obligation to simultaneously feed "useful thermal energy" back to the host, as the waste energy from the host ("free fuel") already satisfies the efficiency objective of the CoGen programme.

It is expected that the waste to energy facilities will operate whenever waste heat or gas is available. When the energy source is not available, they will not be able to operate. As a consequence these facilities will have little control over their despatch except to the extent that they can reduce output by not consuming fuel which fuel will then be wasted as the underlying host industrial process will continue to operate.

Combined heat and power (CHP) facilities (Type II)

Combined heat and power (CHP) facilities must simultaneously produce heat/steam for the underlying host industrial process (host) and electricity for host consumption, with any excess electricity available for export. The fuel for CHP facilities is defined as being a primary fuel, namely, coal (including discard coal), natural gas or oil which has the characteristic of being available for use as required and not being wasted when a plant does not run.

The main characteristic of CHP facilities is to achieve efficient use of the natural resource (fuel) and hence such facilities will be required to supply at least 10% of its energy production as heat (typically steam), and be designed to operate at a combined electrical and thermal efficiency of greater than 65%. In addition, the power facility is likely to depend on the host's industrial facility to condense all or part of its useful thermal energy (steam) within the industrial process. The result is that in the absence of the industrial process, the power facility cannot run unless another means to condense steam is made available.

Industrial biomass facilities (Type III)

Industrial biomass facilities utilise renewable fuel such as by-products from the pulp and paper industry or the sugar industry and can use agricultural or forestry residue of the primary inputs to the industrial process. The CoGen IPP programme requires the industrial biomass facility to burn at least 75% of its total annual fuel consumption from a renewable fuel that is linked to the host industrial process.

Cogeneration projects

The cogeneration projects are self-despatched generators supplying power primarily to the host plant, with any excess exported to the utility grid. Essentially most CoGen plants will be load relief projects.

The IPP CoGen procurement programme is based on the successful Renewable Energy Independent power producer programmes

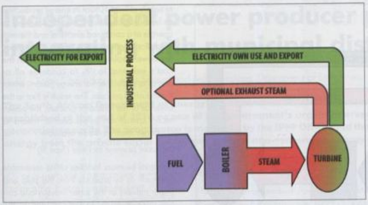

Fig. 3: Cogeneration industrial biomass.

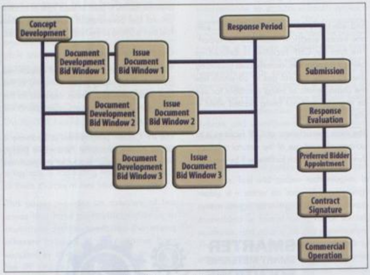

Fig. 4: CoGen procurement process.

(REIPPP) wherein bidding documents, a power purchase agreement and implementation agreement are issued to the market for their response. The IPP bidder responses identify how and where the plant will be established and the required tariff which tariff must be at or lower than a predetermined tariff cap. For the CoGen IPP programme a tariff cap has been set for each of the three cogeneration technologies, which cap acknowledges the difference in nature between the three different technology types.

The bid responses received are then subjected to a rigorous evaluation process held in the secure environment established at the IPP Office. The bids that are compliant, are within the tariff cap and the lowest priced will then be appointed as preferred bidders and will have a few short months to sign the power purchase agreement with Eskom, the buyer. From the contract signature date which cannot be more than four months post the submission date, the IPP supplier has (for the first bid window) just twelve months to achieve commercial delivery of electrical power or the PPA terminates.

As was the case with the REIPPP, the Cogeneration IPP programme will have a number of sequential bid windows for IPP bidders to offer electrical power to be purchased. The first bid window is targeting those bidders who are able to provide additional generated electricity over and above that which they have been generating from existing plant.

The second bid window will target new generation capacity. Each of the bid windows will have specific requirements with which a bidder must comply in order to have their bid accepted.

The first bid window is aimed at purchasing new power above a previous generation baseline. These first bid window projects are aimed at utilising existing grid infrastructure which is already connected to a host plant. Any grid upgrades to support the export of power and synchronisation of generation will need to be agreed to and delivered with the network service provider (municipality or Eskom). Bid window 1 has a project limitation of 50 MW being the maximum capacity that can be developed for bid window 1 projects and also has another innovation in that it has four sequential submission dates spread from August to November 2015 with the commercial delivery dates for power being from November 2016 to April 2017 (note, dates are correct as of August 2015).

Bid Window 2 targets new generation capacity with direct grid connection to the utility grid allowed, and larger projects up to 200 MW of new capacity planned. While the larger projects will be permitted, it is still expected that the majority of projects will be smaller with the bulk being less than 10 MW. Projects will have to be integrally linked to a host industrial plant in order to qualify as CoGen with the linkage being the fuel supply being associated with the industrial process.

Legislative

The current regulations of the Electricity Regulations Act require that new generation capacity (MW) is purchased. An amendment to the ERA regulations has been signed by the minister, undergone a public comment process and promulgated wherein the requirement for new generation capacity has been adjusted to be new electricity generation capacity measured as MWh.

An amendment to the determination for cogeneration has also been signed by the minister and co-signed by NERSA wherein it is determined that the MW allocated to cogeneration will be increased from 800 MW by 1000 MW to a new capacity of 1800 MW.

CoGen and broader industrialisation and economic development

A fundamental difference between the procurement of electricity from cogeneration facilities as opposed to the other IPP procurement programmes currently running is that the other programmes have a focus going beyond the mere procurement of electricity in that they also have broader industrialisation economic development objectives, as well as the objectives of developing sustainable renewable energy or coal base load independent power producer sectors. The nature of CoGen projects typically means that there is limited opportunity for job creation (permanent jobs beyond the

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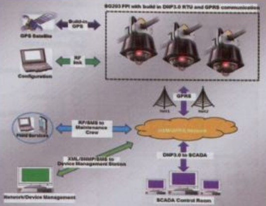

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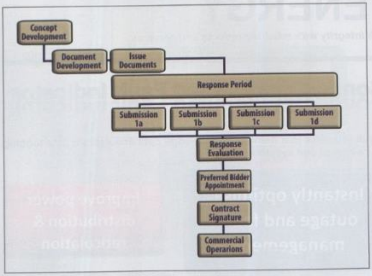

Fig. 5: CoGen Bid Window 1.

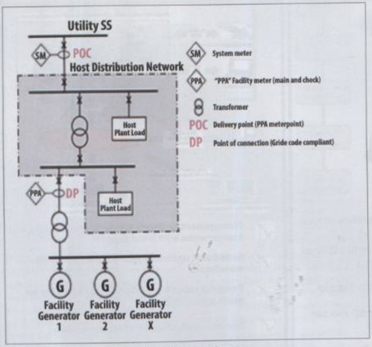

Fig. 6: Bid Window 1 electrical connections.

construction phase) and industrialisation, as these facilities are opportunistic in the despatch of power and are integrally linked to existing currently operating industrial processes with existing ownership structures and workforce in place. In addition, as cogeneration facilities are intrinsically linked to existing industrial processes, they do not have the potential for becoming a self-sustaining or independent sector.

Key features of the CoGen procurement process

The Cogeneration programme requires that IPP generation plants are reliant on a co-located industrial process because it provides either a collocated thermal load or fuel supply. A key distinguishing factor between the cogeneration procurement process and the renewable and coal procurement programmes is that the CoGen process is not stand alone, is a secondary process for the host plant and as a programme is focussed on the procurement of electricity as opposed to the establishment of projects or an industry.

The IPP Office has optimised significant aspects of the procurement and evaluation process to facilitate the procurement of electricity as opposed to the underlying facilities. Consequently, this programme has the characteristics of a programme simply directed at the acquisition of commoditised goods as opposed to a traditional energy and or infrastructure procurement programme. The procurement process is focussed on the bidder bidding its lowest tariff and providing its BEE verification certificate. It is expected that the IPP bidder will comply with the various legislative requirements such as compliance with NEMA, Water Act, Grid Code, connection arrangement requirements and various municipal bylaws which will have to be in place for commercial delivery of electrical power to take place.

Municipal involvement

In the CoGen programme, as compared to the other IPP programmes, increased project risk has been passed to the IPP bidder. The IPP Office will rely on the IPP bidder to comply with legislation and to interact and negotiate with the network service provider as regards all grid connection arrangements and agreements. The network service provider agreements include the amendments to the supply agreement and concluding a reconciliation agreement.

The first bid window for the CoGen programme requires the generation facility to connect to the host plant which itself connects to the utility grid. In the later bid windows, the opportunity for direct connection of the generation plant to the utility grid will be permitted. The IPP generator will be required to arrange and conclude connectivity with the network service provider. In the case of a municipal distributor appropriate arrangements must be made with between Eskom and the municipal distributor to assess impacts on the Eskom sub-transmission and transmission grid and to comply with the requirements of the codes. There are a number of agreements that would have to be concluded before COD i.e the supply agreement, the reconciliation agreement and connection and use of system agreement between Eskom or the municipal distributor and the host facility, and if the host facility is within a municipal supply area, the supply agreement and the reconciliation agreement between Eskom and the municipal distributor.

The network service provider will in consultation with the host plant and IPP need to understand what if any costs will be incurred by the IPP or host in connecting

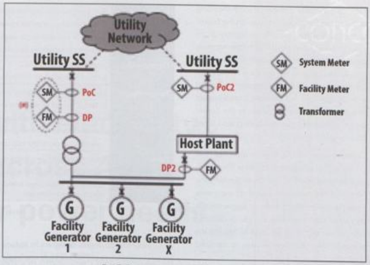

Fig. 7: Direct connection and facility connection.

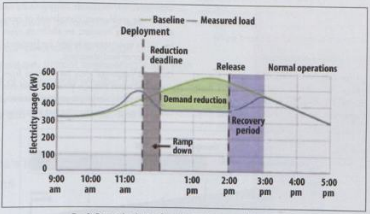

Fig. 8: Demand reduction from demand response deployment [4].

a generator to the grid, or increasing the exported power from existing generators. The IPP and host facility will need to ensure that the generator complies with the network service providers interconnection standards, and the grid code. Any grid upgrades need to be formally communicated to the IPP via the typical grid connection application and quotation processes. The IPP development timeframes and scheduled commercial operation date would need to consider such timeframes. The grid may hence be a key constraint of the CoGen programme delivery, and requires careful consideration. Even if there is no export of power into the utility grid (all CoGen power is consumed by the host plant), it is plausible that grid upgrades may still be required given that the generation may impact network fault levels, power quality and protection. Prospective IPPs have been informed of this potential dependency, and have been encouraged to engage accordingly with their network service provider.

A municipality apart, from approving building plans, could well be the water service provider supplying water to the host plant. While it is likely that the increased water requirement of the plant could be marginal, the IPP and host plant would also need to identify any additional water requirements and negotiate this with the municipality.

Account reconciliation

The energy produced by the CoGen plant is purchased by Eskom, partly or completely consumed by the host facility, and is not physically delivered over the Eskom network. The energy that is sold to Eskom and consumed by the host facility needs to be paid for by the host facility, and this must be documented in an amendment to the supply agreement – the reconciliation agreement. This reconciliation agreement sets out the terms and conditions on which the energy purchased by Eskom is to be added back onto the host facility's electricity account. Where the host facility is connected to a municipal network, then there will be two reconciliation agreements; one between Eskom and the municipality to add back the energy purchased by Eskom, and in turn the other between the municipality and the host facility to account for the energy that Eskom added back onto the account.

The Eskom policy on the charges to be raised for the purchased energy is well developed. An administration charge is payable but no use-of-system or network charges are raised on the energy not delivered over the Eskom network i.e. the electrification and rural subsidy charge, the reliability service charge and technical losses. The energy charges are based on the Eskom energy charge rates excluding losses.

There is no amendment of any network related demand charges. This means the cost of this energy is at a reduced price as compared to if Eskom had delivered the energy.

It is to the municipality's benefit to support the purchase by Eskom of energy from generators connected to municipality networks – as Eskom will sell this power back to the municipality at rates lower than if Eskom had delivered the energy at the municipality's point of supply. The municipality in turn will need to amend the supply agreement of the host facility to account for the energy added back by Eskom under the municipality/Eskom reconciliation agreement.

It is important that the municipality to develop its policy and rules as to how this energy will be charged for. Where municipalities have energy charges based on R/kVA this will complicate any reconciliation and the simplest approach may be to use the Eskom reconciliation account as the basis.

The reconciliation agreement does not deal with any charges payable by the host facility under the connection and use-of-system agreement. These charges will be based on the NERSA approved generator use-of-system charges.

Demand response

The South African situation

The South African power generation system is constrained. Planned generation plant outages (largely for maintenance purposes) require sufficient power system reserve margin. Eskom is faced with a difficult task of having to take plant offline for required maintenance whilst keeping the lights on.

In order to meet load demand, the system operator resorts to the utilisation of expensive peaking generation plants and load-shedding as measures to reduce pressure on the power system and allow for the necessary plant maintenance. Load shedding has a negative impact on the economic growth of the country and is disruptive to society as a whole. The addition of new generation capacity will assist in the longer-term but will have limited impact as a short-to-medium solution to the power system challenges due to the long lead times for new generation plant.

Demand side options may provide fast and cost-effective solutions to address the supply and demand shortfall thereby minimising the need for the extensive usage of expensive peaking generation plants or economically disruptive load-shedding. One such demand side option that may be used to reduce the pressure on the power system is demand response.

The current applications of demand response in South Africa are limited. There is prevalent usage of direct load control by distributors to change the consumption behaviour of customers to fit the load demand profile.

What is demand response?

Demand response refers to changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardised [2]. Demand response may be expanded, for the South African situation, to include involuntary curtailment of non-essential loads imposed on electricity users by utilities as a measure to limit the frequency and extent of load-shedding.

Demand response may be elicited from customers either through electricity rates that reflects the time varying nature of electricity costs or through a programme that incentivises electricity customers to reduce load at critical times. The incentive for involuntary but controlled curtailment by utilities is the possible avoidance of disruptive and costly load shedding. Demand response represents the outcome of an action undertaken by an electricity customer or utility in response to a stimulus, e.g. higher electricity rates, incentives or imminent load shedding, and its value is derived from its cumulative impacts on the electric power system [3].

Regulatory	Retail and wholesale price disconnect Market structure oriented toward accommodating supply side resources Ineffective demand response programme design Financial disincentives for utilities
Economical	Inaccurate price signals Lack of sufficient financial incentives to induce participation
Technological	Lack of advanced metering infrastructure Potential impact of aggregation activities on the distribution network Lack of cost-effective enabling technologies Concerns about technological obsolescence and cost recovery Lack of interoperability and open standards
Others	Lack of customer awareness and education Perceived lack of ability to respond, especially by small-sized distributors Uncertainty in customer retention for duration of payback period on enabling infrastructure investment

Table 1: Barriers to demand response.

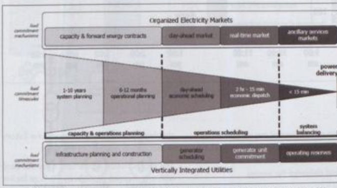

Fig. 9: Electric system planning and scheduling: Timescales and decision mechanisms [3].

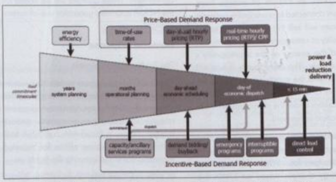

Fig. 10: Role of demand response in electric system planning and operations [3].

Voluntary demand response

There are two basic categories of voluntary demand response options i.e. price-based demand response and incentive-based demand response programs. Price-based demand response includes time-of-use (TOU), retail tariff pricing (RTP) and critical peak pricing (CPP) rates. These rates fluctuate in accordance with variations in the underlying costs of electricity production. Customers can reduce electricity bills if they respond by adjusting the timing of their electricity usage to take advantage of lower-priced periods. Participation is entirely voluntary and is typically driven by internal decision making processes [3].

Incentive based demand response programmes represent contractual arrangements designed to elicit demand reductions from customers at critical times called program "events". The incentives may be in the form of bill credits or payments for pre-contracted or measured load reductions. Participation is voluntary, although some programs impose penalties on customers that enrol but fail to fulfil contractual obligations when events are declared. Incentive based programmes typically require that a baseline energy consumption level be established in order to determine the magnitude of the demand reduction for which a customer will be paid.

A typical demand reduction against baseline is illustrated in Fig. 8 [4]. Incentive based demand response programmes include [3]:

- Direct load control
- Interruptible programmes
- Emergency programmes
- Demand bidding or buyback programmes
- Capacity market programes
- Ancillary services market programmes

Involuntary demand response

Direct load control using ripple control systems is widely practiced in South Africa. This form of direct load curtailment of non-essential loads by the utilities is involuntary and is generally informed by the fact that it ultimately reduces costs and therefore minimises tariffs charged to consumers.

It may be argued that it is better for the utilities to involuntarily switch off selected non-essential customer loads than to implement load shedding whereby customers are completely disconnected. A nationwide implementation of this form of demand response would require a regulatory framework supporting the equitable treatment of customers.

The role of demand response in the electric power system

The electric power system is comprised on the supply side by power generation facilities, transmission and distribution networks for transporting the power, and consumer loads on the demand side. The characteristics of electricity dictate an electric power system management regime that ensures a supply and demand balance in real time. This necessitates management of the electric power system to include long-term planning decisions, operations scheduling and system balancing as illustrated in Fig. 9 [3].

Capacity and operations planning includes long-term investment and planning decisions. Investment decisions within a vertically integrated utility system are typically evaluated in a planning process subject to regulatory review. Operations scheduling refers to the process of determining which generators operate to meet expected near-term demand. System operators evaluate and schedule generation plants on a merit order basis ranked according to their variable costs. System balancing refers to resource adjustments in the form of operating reserves (i.e. ancillary services) to meet last minute fluctuations in power requirements.

As illustrated in Fig. 10, demand response options can play a critical role in the management of the electricity system because they can be deployed at all timescales by coordinating the pricing and commitment mechanisms appropriate for when they are committed or dispatched. Demand response programmes designed to alert customers, of load response opportunities on a day-ahead basis should be coordinated with the system operator's generator scheduling process. Price-based demand response options may be incorporated into system planning timescales if planners and system operators have a good understanding how customers will respond to changes in the price of electricity.

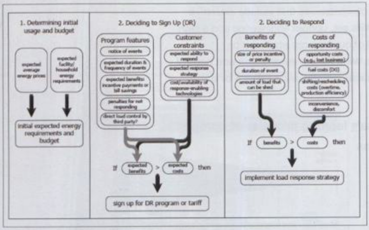

Fig. 11: Factors affecting customer decisions about demand response.

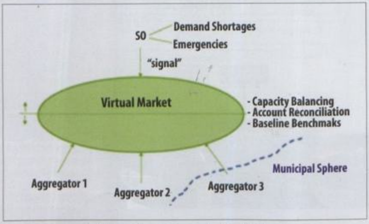

Fig. 12: Demand response aggregation in municipal areas.

Customer participation in demand response

Customer participation in voluntary demand response involves determining an initial budget based on their expectations of current and future average electricity prices and energy needs, deciding to sign up or not and subsequently deciding on whether or not to respond to program events or adjust usage in response to prices as they occur or the likelihood of load shedding. The decision to sign up for demand response options is typically informed by a cost benefit analysis as depicted in Fig. 11 [3].

Costs of demand response

Demand response costs are comprised of participant and/or system costs. Customers opting to sign up for voluntary programmes incur participant costs. These costs may include investment costs in enabling technology, costs for establishing a response plan as well as event specific costs e.g. inconvenience costs, rescheduling costs, etc. Costs incurred by third party aggregators, may in the absence of a licensing regime, have to be considered as participant costs.

System costs are typically borne by the implementing utilities which then typically pass through the costs to ratepayers through approved regulatory processes. System costs should be considered in assessing the overall cost-effectiveness of demand response and these costs include:

- Metering or communication system upgrade
- Utility equipment or software costs
- Billing system upgrades
- Customer education
- Programme administration costs
- Marketing

- Payments to participants
- Programme evaluation
- Metering and communication

Participant benefits of demand response

Customers who voluntarily participate in price based or incentive based demand response programmes do so primarily to realise financial and/or reliability benefits. The financial benefits include cost savings from using less energy when prices are high or from shifting usage to lower-priced hours as well as financial payments the customer receives for agreeing to or actually curtailing usage in a demand response programme. The reliability benefits refer to the reduced risk of losing service in a blackout. This benefit may be associated with an internalised benefit where the customer perceives benefit from the reduced likelihood of being involuntarily curtailed and incurring even higher costs [3].

In the South African context the benefit of mandatory load curtailment is realised in reduced or avoided load shedding.

Potential procurement of demand response

The potential procurement of demand response was identified by the DoE as a possible lever to assist in addressing the current system capacity constraints. A request for information (RFI) was then issued by the IPP Office to test market potential. Interested parties were invited to express an interest in participating in the development of strategies for demand response and/or distributed generation initiatives.

As many as 153 responses were received, representing a wide array of offers that included demand response aggregators and broader demand side management offerings. An indication from the RFI responses was that there is some demand response capacity available with a relatively short lead period. The majority of the untapped potential is within municipal supply areas, where individual demand response opportunities could be combined through the use of a municipal or independent third-party aggregator.

Aggregator role in the context of municipalities

Aggregators are entities that combine or aggregate smaller load reduction offerings by different customers in response to a signal from the system operator to reduce demand.

An aggregator may provide value to the electrical system and society through having to:

- Study which electricity customers can provide profitable demand response.
- Actively promote demand response service to customers.
- Install control and communication devices at customer premises.
- Provide incentives to the customers for providing demand response.

Barriers to implementation of demand response

The possible barriers to implementing demand response programmes are summarised in Table 1.

Potential benefits for municipal participation in demand response

The potential benefits to municipalities actively participating in a demand response programme may include the following:

- Cash payments or municipal debt offsetting
- Reduced network demand charges
- Reduced notified maximum demand penalties in proportion to load reduction contribution
- Reduced load shedding requirements from the municipality
- Optimisation of smart metering investment through broader functionality

Way forward

An indication from the request for information (RFI) issued through the IPP Office is that there is potential demand response capacity with a relatively short lead time. A significant portion of the demand response potential is expected to be within the municipal supply areas. In order to proceed with a national demand response programme a nationwide framework would need to be developed in consultation with stakeholders. The framework would need to consider the concerns and expectations of municipal distributors.

Summary and conclusion

This paper has provided an overview of the DoE IPP cogeneration programme, and provided some context and considerations regarding a possible national demand response initiative. The success of both of these initiatives is critically dependent on the municipal electricity distributors. The paper has sought to inform municipalities as regards related developments, with the intention to create awareness and ensure improved integration between the IPP Office and municipal distributors.

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Microgrid Shelter: ensuring stable, reliable off-grid load supply in remote locations

by Lorenzo Caldera and Maura Sinico, Siemens, and Stefano Nassuato, FIAMM Energy Solutions

Microgrids are an interesting alternative wherever a stand-alone grid is feasible or even necessary for reasons of infrastructure, security of supply, or geography.

Especially in remote locations where human maintenance activities are limited and have high cost impacts, one of the current technological challenges is to have very flexible infrastructures both in terms of operations and logistics. Here it is fundamental to have an off-grid system which guarantees energy production/storage and which can be monitored remotely. This is where Microgrid Shelter prototype comes into play.

The system developed is built up by different elements, all included in a twenty foot compact shelter comprising: a sodium nickel chloride ($NaNiCl_2$) storage technology; small renewable plants (photovoltaics and wind turbine); a diesel generator and a control center. The basic approach of the Microgrid Shelter is to maximise power production coming from renewable energy stored or supplied by an electrochemical storage system, ensuring off-grid stable and reliable load supply. The diesel generator guarantees black-start functionality and power generation in emergency conditions, while the control center monitors the whole system performance.

Thanks to its modularity, the system can be easily customised according to specific requirements related to unit sizes and energy mix, representing a reliable, environmentally friendly and cost-effective microgrid system.

The system architecture

The Microgrid Shelter is built up of the following elements:

- *Renewable generation:* two photovoltaic plants of 5 kWp each; one wind turbine of 10 kW.
- *Energy storage:* two electrochemical storage systems of 30 kW and capacity of 90 kWh each.
- *Traditional generation:* one diesel generator of 30 kVA and 750 ℓ tank.
- *Electrical loads:* base power 2,5 kW, peak power 5,5 kW at 400 V AC and 2 kW at 24 V DC (loads are in islands, not connected to the main national grid).

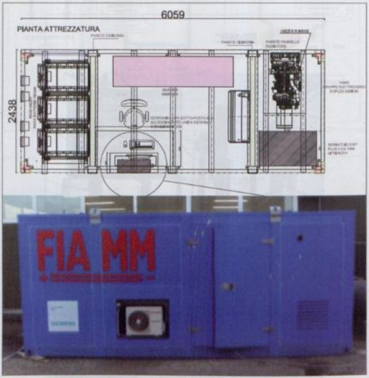

Fig. 1: Microgrid Shelter layout.

Although the number and size of the units were indicated by the customer, the system has been developed as a flexible prototype which can be customised both in terms of size and elements that can be installed depending on usage or environmental constraints.

All generation units that are part of the system (PV plants, storage, wind turbine) are conneted to a direct current bus at 690 V DC (DC bus) through Sinamics S120 converters.

Siemens Sinamics converters S120, usually used as drives for motion control, have been used in an innovative way. Managed by a dedicated control unit (CU), thanks to a firmware upgrade for bidirectional power flow management, converters allow the interfacing of static generation unit (battery and PV) as well as rotating machine. The CU also handles the AC/DC converter in order to support the island grid, maintaining required voltage and frequency.

The brain of the entire Microgrid Shelter, which co-ordinates the different units and converters, is realised through a PLC Siemens IM 151-8. The PLC acts as a control system supplying loads while maximising renewable generation. The basic approach of the control system is in fact to use the renewable energy (solar and wind) as a primary energy source, exploiting storage units to integrate the green production. On the other hand, the diesel generator has been included to guarantee charging functions for the storage system in case the charge level drops below a certain level or for black-starts/emergency conditions.

The innovation of this project stands in the central intelligence provided by the interaction between the control units and the PLC. This interaction makes possible the balance of the energy flow inside the DC bus according to the availability of the renewable generation, the needs of the loads, and the state of charge of the storage system.

The whole system has been developed compacting hardware (the converter, the

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power and auxiliary circuit, the control system) into one switchgear. This small size enables the system to fit with standard size containers (20 foot), facilitating transportation and delivery also in remote locations while a remote supervision via IEC 60870-5-104 protocol can be offered. The supervision is done thanks to Siemens Sicam CMIC RTU (remote terminal unit).

Renewable generation

The system includes two photovoltaic plants of 5 kWp installed out of the shelter (close or on top of the roof depending on customer needs/environmental conditions) and a wind turbine of 10 kW.

The wind turbine is installed on a traditional lattice tower 18 m high and the rotor blade is 6 m in length.

The brain of the Microgrid Shelter (CU and PLC) manages the renewable units at the maximum power available, disconnecting them from the system when the storage level reaches its highest capacity.

Energy storage

The electrochemical energy storage is based on Sodium Nickel Chloride ($NaNiCl_2$) technology which offers high energy density, which is completely recyclable and which works at an internal temperature of around 300°C, providing performances that are insensitive to the external temperature into a wide range (-30°C up to +60°C).

Once activated, this battery doesn't need a cooling system but just some power to stay at the right temperature if inactive, overcoming the main drawback of other storage technologies that have high auxiliary consumption for cooling needs.

The energy storage is divided in two branches of four modules with approximately 30 and 90 kWh. One branch is used to manage the system and the other as a backup.

The brain of the Microgrid Shelter uses the storage to maintain stable the voltage in the DC bus, managing the whole system's energy flows. For this reason, the system's is regulated to maintain the battery state of charge in an average range in order to guarantee the reserve up and down of energy. Batteries' rack and batteries' management system (BMS) are located in a dedicated room inside the shelter.

Traditional generation

The traditional diesel generator of 30 kVA is connected directly to the AC side of the system. The unit has been installed to guarantee the energy storage recharge in case the state of charge drops below a certain limit; the black start and batteries warm-up during the first start of the microgrid shelter. Finally, the diesel generator is also used in emergency conditions to supply loads directly.

The diesel generator and the fuel tank of 750 ℓ are placed in a dedicated room inside the shelter.

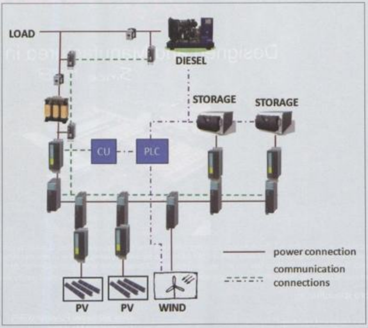

Fig. 2: Microgrid Shelter architecture.

Fig. 3: Microgrid Shelter switchgear.

Conclusion and future developments

The Microgrid Shelter is an innovative system engineered to be modular and easily customised. The use of more than one energy source allows a higher stability of the power supply, while renewable sources combined with energy storage allows the system to maintain the desired power output

Fig. 4: Microgrid Shelter wind turbine.

Fig. 6: Microgrid Shelter diesel generator.

Fig. 5: Microgrid Shelter energy storage.

and overcome the main drawbacks of the renewable generation in terms of availability of the primary energy source and fluctuating power output.

The Microgrid Shelter is the right answer to feed loads in remote environments where there the is no electrical grid available, where maintenance activities costs are high or where the electrical loads are not permanent and therefore building a fixed infrastructure is not justified. Customisable according to customer needs, the system can be monitored remotely and operates stand-alone minimising human workforce efforts and related costs.

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Transformer health assessment: the eThekwini experience

by Brian Sibiya, eThekwini Electricity, and Kamendren Govender and Luwendren Moodley, Doble Engineering Africa

To successfully convert data into valuable business intelligence is the key in managing the life of what is often the most critical and high valued asset to every electrical utility, the power transformer. With a fleet comprising over 250 transformers ranging from 275 kV to 11 kV feeding directly key customers as well as a distribution network of customers, eThekwini Electricity's (eTE) HV substations branch has employed a system that not only provides realistic risk and consequences of transformer failure at a very early stage but also identifies units that require repairs, refurbishment or replacement.

Asset information as per section 4.3 of PAS55 pinpointing critical assets as well as section 4.5 of PAS55 where the value of each asset is obtained are additional features of this system.

In 2011 eTE embarked on an asset management drive in order to ensure compliance with the electricity regulator's requirement that electricity utilities conform to NRS 093 (which requires all licensed electricity distributors to have an asset management policy in place) and the strategic decision taken by the organisation to ensure that they comply with PAS55. This led to the development of a long term asset management policy and strategy to guide all asset management improvement activities in line with the overall business strategy. PAS55 clearly defines hierarchical connectivity between the high-level organisation policy and strategic plan, and the daily activities of managing the assets. With power transformers being the most strategic asset in any power systems network, it is imperative for eTE to have a sound fleet strategy for managing power transformers that delivers directly to the organisation's overall asset management strategy.

One component of the transformer fleet strategy is the transformer condition assessement. The condition assessment of assets has a direct influence on a majority of the eTE asset management strategy's key performance area such as information management, risk management, asset care plans, work planning and control, performance measurement and focused improvement. It was for this reason that in 2013 eTE embarked on a transformer fleet condition assessment project thereby helping to accelerate eTE's asset management maturity. The project aimed at gathering condition assessment information and performance requirements for each transformer and establishing the planned actions required to meet reliability and performance targets.

eTE has a population of 252 power transformers, with power ratings ranging from 15 MVA to 315 MVA and comprising of 14 x 275/132 kV, 36 x 132/33 kV, 56 x 132/11 kV, 42 x 33/11 kV and four 33/6,6 kV voltage transformations.

Modern asset maintenance philosophies make emphasis on condition based maintenance which deals with understanding the probable condition of strategic equipment, such as power transformers. This approach is fundamental to prioritisation of maintenance spending and in establishing a condition-based reinvestment strategy for optimum system performance.

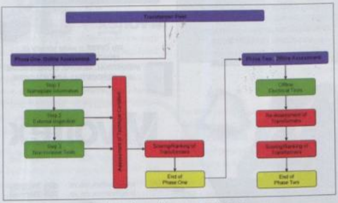

Fig. 1: Transformer fleet management process.

In order to embark on condition based maintenance, a complete assessment of the entire fleet is needed. Efficient assessments can recommend maintenance actions and strategies to extend transformer life, lower the risk of failure and use advanced diagnostics to augment missing data.

Transformer condition assessment

What we know about transformers is that their life expectancy can vary from a few cycles (ms) to more than 50 years. What we need to know is the life expectancy of a particular transformer in a given network. This fact is interesting and very useful. This is the essence of condition assessment.

Effective condition assessment is not just testing a transformer and reproducing the test results nor is it diagnosing the cause of a failure after the transformer has failed. The Cigré working group on life management techniques for power transformers has defined condition assessment as "A comprehensive assessment of the condition of a transformer taking into account all relevant information, e.g. design information, service history, operational problems, and results of condition monitoring and other chemical and electrical tests". This is an excellent definition that encompasses all aspects of the transformer's life. However, can effective condition assessment be implemented in utilities with little to no information? By using an innovative and proven two phase approach for condition assessment utilities with little documented information can enjoy the benefits of a comprehensive condition assessment on all types of transformers in the network.

The condition assessment process

The condition assessment technique followed is a two phase approach. Both phases include a proprietary risk scoring system and combine analysis of individual units of similar designs with similar operating conditions and age.

Phase one

The first phase is an online approach where the transformer is not removed from service for

additional testing. Phase one is a "scanning" approach and is more appropriate as a low cost assessment and step to provide "initial" risk assessment and ranking of transformers in a network. The first phase is essentially a review of available information. These include as much as possible of the following:

Step 1

Basic nameplate information from transformer and tap changer

Step 2

External visual inspection

Step 3

Review of all available documentation, such as:

- *Factory test report*: used to compare with current test results and operating ability.
- *Purchasing specification*: used to compare to current manufacturing standards.
- *Tests results (electrical and oil)*: current data can be compared to Doble database for industry norms.
- *Failure reports*: indicates the rate of aging, availability and performance.
- *Maintenance practices*: what are you doing?
- *Major modifications or rebuild*: indicates the rate of aging generally expected.
- *Substation fault level*: changes in fault rating.
- *Loading*: used to calculate loss of life.

Step 4

Consultation with all staff involved in the life management of transformers forms an integral part of this process in that this is a great source of information that has not been documented.

Step 5

Online testing

- *Oil quality indicators:* The oil quality indicators such as moisture (from which relative saturation is calculated), acidity, dielectric strength, and interfacial tension are excellent indicators of ageing oil. Poor results normally results in purification and/or regeneration of the transformer oil and it some cases oil replacement.
- *Paper condition:* The concentrations of the paper degradation product 2-furfural (2FAL) provide an indication of the condition of the paper. However, there are a number of factors that influence the concentration and stability of furanic compounds such as temperature, type of paper used, oil treatment, etc. The use of the rate of change in 2FAL rather than the conversion of 2FAL to degree of polymerisation results in an excellent indicator of paper ageing.
- *Doble DGA signature pattern:* Dissolved gas analysis (DGA) is the single most important test performed on oils from transformers. As the insulating materials in a transformer break down due to thermal and electrical stresses, gaseous by-products are formed. The by-products are characteristic of the type of incipient-fault condition thereby giving early warning signs of a developing fault that is an excellent trigger for further investigation. The Doble DGA signature pattern to analyse DGA results enabling earlier detention of faults, differentiate among thermal, dielectric and overheating faults and as well as stray gassing. The accuracy of the signature pattern increases substantially with DGA history.
- *Infra red (IR) scan:* IR scanning involves measuring radiated heat, not contact temperature. IR is effective in indicating external joint issues, bushing tap problems, oil levels in bushings and radiators, blockages in radiators, fan function and can also indicate tank heating from stray flux, or frame tank circulating current. See Fig. 3.
- *Partial discharge scanning:* Transformers like other high-voltage substation equipment are exposed to electrical, mechanical, and thermal stresses as well as environmental conditions. All of these stresses can act to accelerate the deterioration of the insulation and hence the electrical integrity of the HV equipment eventually leading to failure. Detection and measurement of partial discharge (PD) phenomena, which are symptoms of insulation deterioration, can provide early warning of insulation failure. PD occurs when the electric field strength exceeds the breakdown strength in a localised portion of the insulating material resulting in a localised breakdown of insulation (oil, paper) that results in a small current flow. Typical PD faults are shown in Fig. 4.

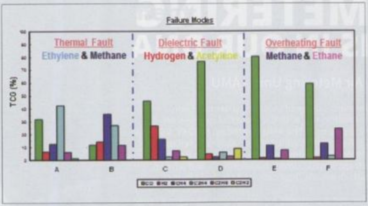

Fig. 2: DGA signatures for faulty transformers.

Fig. 3: Typical IR faults.

Fig. 4: Typical PD faults.

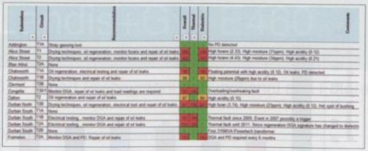

Fig. 5: Phase one assessment.

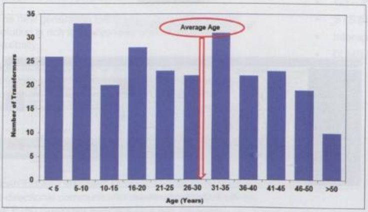

Fig. 6: Transformer age distribution. (Notes: The date of manufacture was obtained from the transformer nameplate during the visual inspection phase.)

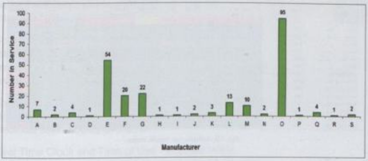

Fig. 7: Transformer manufacturers.

Step 6

Overall evaluation of phase one data

Once all the information has been gathered and the online tests performed, the transformers can then be scored based on condition. All units are assessed in terms of design groups with problems, overall condition, thermal and dielectric condition. Each aspect has its own score - a number between 1 and 100. Even with summation any aspect with a 100 score will be carried through and easily recognised. The results are assessed using this sum of the numerical scoring system and it is this sum that determines the position in the "league table" and summarised using a red-green colour traffic light code. It should be emphasised that the scores are not permanent but reviewed as new data is made available.

Phase two

This phase is a comprehensive analysis of the transformer and requires offline testing. The standard offline tests are as follows:

- Power factor and capacitance
- Sweep frequency response analysis
- Leakage reactance
- Insulation resistance
- DC winding resistance
- Exciting current
- Ratio test

Rescoring the technical condition

Once all the offline tests are performed the thermal and dielectric condition of each transformer can be re-scored with greater detail. The re-scoring now includes the mechanical condition of the transformer. With the final scoring for the condition of the transformer now in place, a total risk of each transformer can then be calculated.

Outcomes of phase two

Once the rescoring has been completed the following is made evident:

- High risk transformers in terms of the dielectric, thermal and mechanical condition.
- More accurate overall condition as a result of the offline tests.
- An action plan in terms of units that require replacement, repair or monitoring.

The results of Phase Two assessment are merely added to the Phase One assessment.

eThekwini assessment

ETE has currently performed the Phase One assessment to all their power transformers. Each of the assessed transformers were scored and ranked in terms of risk of failure. In addition to the risk of failure, recommendations were also formulated either to perform further tests to ascertain the extent of the fault or what immediate action is required to reduce the risk of failure. Fig. 5 is an extract of the summary of the assessment is given below. The condition of transformers was assessed in terms of their thermal and dielectric condition.

Analysis of data

Transformer vintage

The treatment of transformers by age is a matter of owner's internal policy. The age of a transformer can have a number of factors including the effect on the mechanical strength of the transformer's insulation and hence its ability to withstand common short circuit forces that are inherent in a transmission system. A further consideration is the relationship between advanced paper aging and transformer age. The relationship between the age of the transformer and its performance is a subject of great uncertainty. However, coupled with the other factors listed here the transformer's age can play an importance role in risk decision. It is common knowledge that transformers built and designed in the past have proven to be highly reliable with a low failure rate for many decades. The introduction of advanced computer programming for design purposes have resulted in modern transformers having a low loading capability. However, it is noticed that older transformers may lack adequate provision for leakage flux and have a higher probability of localised thermal problems. Further, industry standards (IEC and IEEE) were revised to ensure greater short circuit duty for modern transformers. Fig. 6 shows the eTE transformer age distribution.

This age distribution for the transformers is typical of what is seen in other utilities in South Africa of similar size to that of eTE. The eTE fleet has an average life of 29 years. This average life is also in line with industrial norms (utilities of the similar size in South Africa).

There is large installed base of transformers that are between 20 and 40 years old with a further significant population over 40 years old. This is a clear indication of an aging asset base. Due to the long service life of these aging transformers, maintenance records for these are not accurate as the information management was not advanced decades ago. Maintenance tactics were also of time based or reactive nature and these exposes the network to significant maintenance costs and high probability of failure.

Further, there is an increase in transformers between 0 to 5 years due to the replacement program possibly the result of failures of older transformers. This is a good indicator of transformer failures or an increase in demand of electricity.

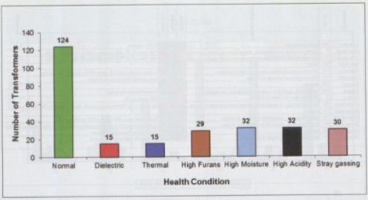

Fig. 8: Transformer condition classification.

Fig. 9: Overview of assets risk.

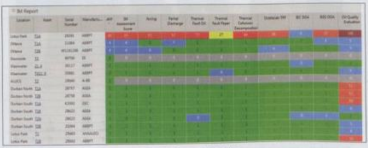

Fig. 10: Transformer health index.

Transformer manufacturer

The place of manufacture or the manufacturer is a key indicator of quality related issues. The identification of dominating deterioration and failure modes for each design group/ manufacturer can be used to identify the optimum diagnostic strategy to reveal the onset of failure modes.

Transformers of the same manufacturer and of same design (based on the serial numbers) have shown to have common fault characteristics. The fleet of eTE transformers, as shown in Fig. 7, comprises units from 19 different original equipment manufacturers (OEMs). This large number of OEMs results in a significant transformer fleet diversity in terms of designs or vintage.

Transformer faults

Fig. 8 illustrates identified different faults that are considered to increase the risk of a transformer. The date of manufacture was obtained from the transformer nameplate during the visual inspection phase.

All transformers were placed into the following condition classifications:

- *Normal:* Transformers that are considered to be in normal operation.

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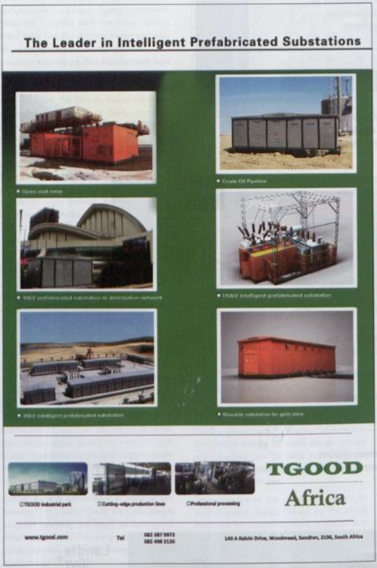
- *Dielectric fault:* Transformers that are considered to have some form of partial discharge which was detected by DGA and RFI scanning.
- *Thermal fault:* The thermal condition of the transformer is assessed by considering faults that result in excessive temperature rise in the insulation or other parts of the transformer.
- *High furans:* The levels of furans and the rate of increase of furans between samples is an excellent indicator of the age of paper insulation.
- *High moisture:* Moisture in the insulation influences the life of a transformer in many ways: accelerating aging, increasing losses, reducing insulation strength and introducing the risk of bubble formation during overload.
- *High acidity:* Acids in the oil originate from oil decomposition/oxidation products. Acids can also come from external sources such as atmospheric contamination. An increase in the acidity is an indication of the rate of deterioration of the oil, with sludge as the inevitable by-product of an acid situation which is neglected.
- *Stray gassing:* The gassing pattern which is generated when the oil is subjected to thermal stress under what is considered to be low temperatures.



Asset management tool

The data gathered from the transformer condition assessment will further be coupled with an implementation of the platform to integrate the online and offline testing data, online monitoring data and SCADA data into one centralised system that will monitor the risk associated with the asset. See Fig. 9.

This continuous process, will be able to monitor the assets in real time as well as update the asset management and operations management as to changes in the health and risk of an asset.

An asset risk management system is critical to showing an entire fleet's health and risk at-a-glance. The ranked asset health scores allowed for the utility to identify work priority and subsequent critical analysis helps to identify the consequences of failure and aided in scheduling work to mitigate the risk. Bringing data together and making it readily available, is a key to enabling tactical and strategic decision making. In addition this system will accept criticality metrics for safety, environmental impact, business interruption and financial loss, and is calibrated through a common denominator to ensure cohesion of analysis and results. By keeping track of the original risk quantities, eTE will be able to address risks as they develop and manage plans for intervention. See Fig. 10.

Conclusion

Transformer condition assessment program can be effectively introduced by using this two phase approach. This method of condition assessment can be implemented irrespective of the amount of information. ETE has achieved the following benefits from this assessment programme:

- Knowledge into the current health of transformers and identified normal, suspect and high risk transformers.
- How to effectively respond during trip or outage.
- Plan outages for maintenance or repairs.
- Put procedures in place to replace aged or suspect transformers.
- Identification of design weakness.

A further advantage is the risk assessment and residual life can finally be achieved through sound engineering principles.

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Consequences of auditing and project management misalignment

by Phetole Moagi, City Power

The misalignment between financial and performance auditing on engineering (infrastructure) management increases and perpetuates unethical behaviour, lack of transparency, unaccountability, lack of rule of law, unregulated interventions, weak quality controls, manipulation of the Municipal Financial Management Act (MFMA) and weak legal processes to name a few.

Underperforming state owned enterprises (SOEs), infrastructure developments or construction projects, ghost projects, and fabricated progress on abandoned capital expenditure projects are receiving pre-eminent appraisals and the current auditing controls are failing dismally to detect these.

The South African government adopted the National Infrastructure Plan (NIP) in 2012 and National Development Plan (NDP) vision for 2030. The plans are aimed at responding to "three horsemen" (inequality, unemployment and poverty); through planning and developing infrastructure that fosters economic growth (PICC, 2012). Cabinet has established a body to integrate and coordinate the infrastructure building across all spheres of government, the Presidential Infrastructure Coordinating Commission (PICC) to supports management structures (PICC, 2012).

Currently South Africa has eight metropolitan municipalities. The research is only limited to these, not all the 284 municipalities in South Africa. The City of Johannesburg has recently approved a programme called Jozi@work to also address the three horsemen. The Jozi@work programme has been designed in a way to align, support and achieve government priorities (job creation, education, skills development, economy). NDP provides a vision on where the country would like to be in 2030, and it serves as a planning and progress management tool (Fombad, 2014).

For South Africa to successfully achieve this vision for infrastructure development, it is critical that the current and future projects are efficaciously implemented. All projects must achieve their pre-set objectives and must be easily monitored and evaluated with the alignment of engineering management and auditing. According to Atkinson (2002) "real development requires on-going involvement with beneficiaries and communities, whether in the form of leadership development, institutional capacity building, public participation in planning or project implementation and frequent conflict management". In South Africa, municipalities in conjunction with community members are required to write the integrated development plans (IDP) (Atkinson, 2002).

The current system of IDPs places municipalities as development agencies within the government. Municipalities identify and undertake a variety of infrastructure projects, and construct or implement multifaceted social and economic development projects (Atkinson, 2002). Every financial year millions of rands are allocated or given to municipalities as equitable shares for the implementation of programmes and projects on the IDPs. During the implementation and monitoring of these projects it is evident that unethical behaviour goes unnoticed.

There is also a growing concern about misalignment between auditing and economic growth (infrastructure development). This warrants most countries, world organisations, and research institutions to intensify the focus on auditing and infrastructure development management and studies. Government has governance and oversight agencies, which provide monitoring and evaluation, and promote compliance with regulatory and ethical framework (Bruce, 2014). These agencies include the Department of Public Service and Administration (DPSA), Public Service Commission (PSC), Monitoring and Evaluation (presidency), the auditor-general (AG) which should be minimising the instance of "popular press accounts and congressional investigations of major corporations becoming insolvent shortly after receiving a clean audit" (Davis, 2001).

These investigations clearly demonstrate the misalignment between auditing and project management (engineering management), according to Davis (2001), and not only project management but also evaluation and technical auditing too. Audits (financial and performance) normally focus on management controls and compliance matters which lead to ticking boxes and missing crucial evidence on underperforming and fictitious projects. The ticking of boxes process perpetuates a fertile breeding ground for economic crimes such as fraud, deliberate bankruptcy, illicit financial flows, corruption, misrepresentation of project progress, bribery, bid-rigging, collusion, coercion, and extortion (Mukumbwa, 2012). These forms of corruption feed well into engineering management and auditing misalignment as they are hard to be detected due to tactics such as fronting, cover quoting and "javelin throwing" (Bracking, 2013). The current system lacks the strength, and

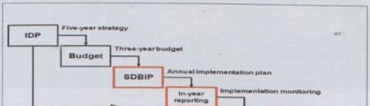

Fig. 1: 2011 local government budgets and expenditure review (National Treasury).

the checks and balances to effectively curb corruption, uncover unethical behaviour or expel corrupt officials (Vlasic and Atlee, 2014).

According to Vlasic and Atlee (2014), citizens of highly corrupt countries often believe that government efforts to fight corruption are ineffective. South Africa has the law enforcement and accountability mechanism to try and curb corruption activities (Bruce, 2014: p.51). These measures were supposed to reduce corruption in South Africa (Sampson, 2010).

Objectives

- To find the outspread of the problem and develop ways and recommendations: for government and authorities to try and develop polices to alleviate the misalignment and promote good governance and project management.
- To show government the need for development programmes and policies to harmonise, financial, performance, forensic, technical auditing with monitoring and evaluation and engineering management.
- Promote the social and technical audit, community or citizen based monitoring initiatives and advocate the principle of accountable governance though public participation as entrenched in South African Constitution, Section 195 of (1996).

Problem statement

There is a misalignment between financial, performance auditing and engineering management and it has an effect on the economy, infrastructure development and the fight against corruption, unemployment, inequality and poverty.

Literature review

According to Molina, *et al.* (2013:3) "millions of people around the world encounter administrative corruption in their daily interactions with public services". South Africa is rated number 69 out of 175 countries globally, and 44 out of 100 sub-Saharan Africa countries on the public sector Corruption Perceptions Index (CPI) 2014 (Transparency International, 2014). Failure to detect this misalignment increases corruption elements in the infrastructure sector and might increase the CPI rating of the country. Estimated amounts of 10 – 30% of the value publicly funded were reported as financial losses (Hawkins, 2013). Good auditing offices and clear rules on behaviour are ascribed as one of the solutions for addressing corruption (Hillman, 2003). This report aims to take it a step further and create awareness of the misalignment between auditing and engineering management. The article agrees with Sampson (2010:267), who states that "citizens and government must be made to understand that crime and corruption hurts everyone". It is often conducted in secret or hidden form authorities and exists in different sectors and all spheres of government.

"In particular, several empirical studies have shown that corruption impedes economic growth and shrinks investment (Brillantes and Ferndandez, 2010:90)."

It's evidenced that corruption can weaken national, provincial and local government institutions, it might increase inequality (increase the gap between the rich and poor), greedy, environment exploitation, unaccountable society and government, no transparency and no respect to the rule of law.

According to Coronel and Kalaw-Tirol (2008:17-22), the following are the five consequences of corruption:

- It impedes economic growth.
- It worsens income inequality and poverty.
- It damages political legitimacy and stunts democracy.
- It endangers public order and safety.
- It results in bureaucratic inefficiency and demoralisation.

From this article we see that corruption may emanate from infrastructure development in country or project construction and it is a contribution factor in the misalignments between auditing and project management.

According to the 2011 local government budgets and expenditure review, "Section 153 of the Constitution requires that a municipality must structure and manage its administration and budgeting and planning processes to give priority to the basic needs of the community, and to promote the social and economic development of the community". One can say systems are available in South Africa but departments or section management decides to operate in soles.

The process chart in Fig. 1 can be followed by the municipalities. However, it is a boardroom reporting process which clearly shows the misalignment between financial, technical, social auditing, project monitoring and

Load shedding										
Departments/municipalities			National development						Audit	
Projects	Description	Initiative	Technology	Economic	Political	Social	Cultural	Research	Financial	Perfomance
All	Interior/exterior/street lights (PV)	EEDSM	X		X	X		?	X	
All	Occupancy and motion sensors	EEDSM	X		X	X		?	X	
A – Project	Vandal proof structures	EEDSM	X	X	X			?	X	X
R – Project	Revenue recovery	SAPRA	X	X	X			?	X	X
S – Project	Revenue recovery	Municipalities	X	X	X			?	X	X
T	Smart metering	DSM	X		X			?	X	X
All	Solar water heaters	Renewable	X	X	X	X	X	?	X	X
All	Solar water pumps	Renewable	X		X	X		?	X	
Informal	Solar rooftop	Renewable	X		X	X		?	X	X
Eskom	Coal and diesel	Eskom	X		X	X		X	X	

Table 1: Projects vulnerable to misalignment. Load shedding presented opportunities (positive and negative). There are many technical offerings, and the capacity to correctly evaluate those technologies is limited. Hence most projects fall directly under the misalignment part, whereby projects are abandoned and auditors fail to detect them. This will definitely increase the extent of the corruption pandemic in society.

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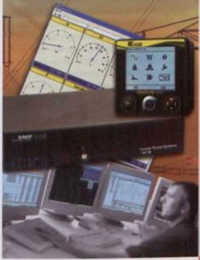

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evaluation. The structure is more of financial reporting, ticking boxes and compliance.

Current systems or process in South Africa

- Alignment to the Government Immovable Asset Management Act (GIAMA) – Act number 19 of 2007
- Structure of the Infrastructure Delivery Management Toolkit (IDMT)
- The Infrastructure Delivery Management System (IDMS)
- Planning and Implementation Management Support Systems (PIMSS)
- MISA (Municipal Infrastructure Support Agent)
- Local Government Turnaround Strategy (LGTAS) and Municipal Infrastructure Support Agent
- South African Monitoring and Evaluation Association (SAMEA)
- Public Service Commission Monitoring and Evaluation (PSCM&E)
- Department of Performance and Evaluation (DPME)
- Ministers and provincial members of the Executive Councils (MinMECs)
- Management Performance Assessment Tool (MPAT)
- Framework for frontline service delivery (FLSD)
- Government Wide Monitoring and Evaluation
- Auditor-General South Africa (AGSA)
- Departmental or SOE – Internal Controls
- Division of Revenue Act (DORA)

Tools to mitigate corruption risks throughout the project cycle

Weak oversight plus weak investigatory follow-up creates an environment where there is little chance of perpetrators being caught and punished for corruption. To change behaviour there must be mitigation measures in place where there is at least the threat that corruption may be discovered. The seven tools listed below can be used at different stages of the project cycle to help identify and mitigate the risks of corruption.

- *Audits:* can improve the fiduciary standard of an infrastructure sector programme and address weaknesses in the potential poor quality of the built infrastructure asset.
- *Construction Sector Transparency Initiative:* aims to address weaknesses in transparency and accountability within publicly financed construction projects.
- *Red flags:* provides a set of alert indicators and is applied to recognise and track vulnerabilities to corruption during the infrastructure project cycle.
- *Integrity pacts:* attempt to address the corrupt behaviour of procurement officials and potential bidders.
- *Project Anti-corruption System:* is an integrated and comprehensive system designed to assist in the prevention and detection of corruption on construction projects.
- *Citizen report cards:* provide systematic feedback from users of public services.
- Social and technical audit or accountability (through a board of professionals as proposed by this paper). DPME states that, "South Africa's democracy is founded on principles of accountable governance and public participation. Section 195 of the Constitution of the Republic of South Africa (1996) outlines the principles to which the public administration must adhere". These include:

  "A high standard of professional ethics must be promoted and maintained. Efficient, economic and effective use of resources must be promoted. Public administration must be development-oriented. Services must be provided impartially, fairly, equitably and without bias. People's needs must be responded to, and the public must be encouraged to participate in policy-making. Public administration must be accountable. Transparency must be fostered by providing the public with timely, accessible and accurate information" (DPME, 2013:5).

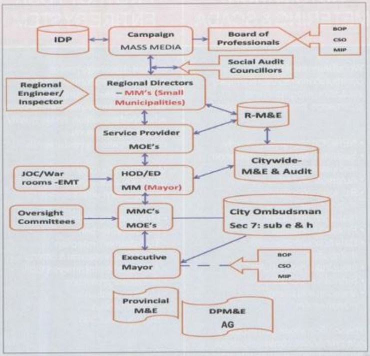

Fig. 2: Proposed citizen participation processes.

Community participation and accountability

South Africa has recently introduced the Department of Monitoring and Evaluation (DPME) which states, "the state's adherence to these constitutional principles requires approaches that are able to assess the reality of government services, as they are experienced by citizens".

Community participation of citizen-based monitoring (CBM) "is an approach to monitoring government performance that focuses on the experiences of ordinary citizens in order to strengthen public accountability and drive service delivery improvements" (DPME, 2011:7).

"It requires citizens to be active participants in shaping what is monitored, how the monitoring is done and what interpretations and actions are derived from the data. Many definitions of citizen-based monitoring are possible and citizen-based monitoring can be applied to a range of contexts – from frontline service delivery monitoring for improvements and public accountability; to assessing the impact and relevance of policy and legislation" (DMPE, 2013:8).

The literature has proven that social accountability can be a vital component of holding government officials responsible for service delivery and good governance. The paper proposed a way of doing things which "does not duplicate or replace existing public participation structures or processes, but offers the potential to strengthen the monitoring capacity in the country" (DPME, 2013:3).

According to DPME (2013:6) "the Municipal Systems Act (2000) (Section 16(1)) obliges municipalities to develop a culture of municipal governance that complements formal representative governance with a system of participatory governance and must for this purpose encourage, and create conditions for the local community to participate in the affairs of the municipality, including in the performance management system".

The National Development Plan (2012) highlights the need to improve state-citizen relations at the point of service delivery and positions this in terms of routine accountability, arguing for the delegation of authority to frontline managers to enable this. "Delegation presents an opportunity to strengthen mechanisms of routine accountability, enabling the state to be more responsive to public concerns. Service delivery protests stem from citizens' frustration that the state is not responsive to their grievances. This is unfortunate, as citizens are often best placed to advise on the standard of public services in their communities and to suggest possible interventions." (NDPs 2012:427)

Conclusion

It is prudent that a weak and vulnerable oversight committee on infrastructure development increases the risk of corruption in project management. The misalignment only benefits the few, who can manoeuvre around regulatory standards, policies and acts. It has direct effect on inequality, increasing poverty levels and the risk of corruption in different stages of project life cycle. The inability of financial and performance auditing in detecting irregularities, unethical behaviour and performance problems leads to an increase in corruption activities on infrastructure development. The following mitigation tools were developed to deal with infrastructure corruption:

- Auditing – social, financial, performance, technical, forensic, auditor-general
- Construction sector transparency initiatives
- Whistle-blowers (Secrecy Bill) or red flags (potential corruption indicators)
- Project anti-corruption system
- Project monitoring and evaluation
- Section 79 (oversight committees)
- Integrity and ethical committees and
- Chapter 9 instructions.

However, alignment, coordination and inter-departmental collaboration frameworks and procedures are a problem. Performance monitoring and budgeting presents opportunities for the South African government to build a sustainable budgeting system and a transparent resource allocation strategy. It promotes public participation, accountability, transparency, strengthening of links between current policy priorities and MTEF (public expenditure). In terms of service delivery projects in the country, performance budgeting and policy implementation can assist the country addressing the issue of inefficiency and ineffectiveness

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Tangible benefits of implementing smart metering technology at City Power

by Mdu Nzimande, City Power and Jayesh Pillai, EON Consulting

City Power has identified an increase in the energy loss trends experienced in recent years. The revenue loss equivalent of this increasing trend has reached significant proportions. In order to address this challenge, City Power has launched the revenue recovery programme (RRP) which comprises of a series of initiatives aimed at arresting this trend. These initiatives are to be rolled in conjunction with the existing smart meter implementation plans in the various customer segments that are to be targeted for loss minimisation.

This paper describes the programme strategy, planned initiatives, implementation approach and the key benefits to be realised by embedding smart metering technology to combat the challenges faced. Key highlights from the implementation are also presented in this paper.

Globally, it is estimated that electric utilities lose approximately $85-billion annually owing to theft of energy related services. Fuelled by poor economies and increased technical savvy, crimes such as meter tampering and meter bypassing are becoming easy to commit, lucrative in nature and hard to detect. In South Africa, the revenue losses attributed to the theft of energy services is estimated to be approximately R8-billion annually and is on an upward trajectory.

The municipalities that are tasked with the critical task of energy distribution to fuel the growth in the economy are faced with the dilemma of managing their revenue streams effectively in terms of accounting for what is sold versus what has been supplied. Only a portion of the revenue losses due to fraud is ever detected using historically available detection techniques [5]. This threatens the municipality's ability to properly invest in its system and provide stable supply, thereby creating a growing financial burden for municipalities, consumers and the nation alike.

Owing to this situation, municipalities are currently facing a large amount of internal and external pressures that require them to improve their revenue management practices. Poor revenue management has resulted in an increasing level of consumer debt, which in turn has resulted in the inability to meet the municipality's obligations to Eskom. As a result, Eskom is threatening to cut off electricity supply to the defaulting municipalities. As electricity revenues are one of the municipality's key sources of revenue, this is an undesirable status. The illustration below encapsulates the key factors of energy loss and revenue management that need to be managed effectively in order to unlock the benefits realisation phase of any initiative to be planned to counter the losses problem.

When the key areas within revenue losses and energy losses management are managed well, underpinned by an effective social awareness and change management strategy, the numerous benefits of a fully functional revenue management value chain within a municipality are visible.

Fig. 1: Key focus areas and benefits of revenue management.

Smart metering technology presents an opportunity for a paradigm shift owing to its ability to support various aspects of electricity distribution management to enhance customer service, improve reliability, combat energy theft and improve efficiency in operations. The increased deployment of smart metering and smart grid technologies, along with the ability to leverage powerful back-office data analysis from such deployments, provides utilities with new opportunities for identifying and analysing energy diversion in the distribution network [3].

City Power is experiencing an increase in its non-technical losses and is faced with the revenue collection challenge due to increasing levels of non-payment, energy theft and tampering with metering infrastructure across the customer base. In order to combat this challenge, City Power has adopted smart metering technology in conjunction with carefully devised initiatives to combat non-technical losses and improve the overall service delivery to their customers [4]. City Power launched a strategic programme titled the "Revenue Recovery Programme (RRP)" in a bid to implement a series of initiatives designed to specifically combat the increasing trend in losses. The RRP's initial focus is to target the large power user (LPU) base in order to maximise the impact in this customer class.

City Power's revenue recovery programme

City Power supplies electricity to the greater Johannesburg metropole and is faced with an increasing challenge in the realisation of the revenue owed for the energy supplied to its customer base. This is also evident in the increasing energy losses trend that has been experienced by the municipality in the recent financial years. Energy losses can be defined as the computational measurement of energy purchased versus the energy sold. Losses are comprised of two components, namely technical and non-technical losses. Technical losses naturally occur when electrical energy is transferred from the source to the load due to the resistance of the conductor. Non-technical losses are caused by actions external to the

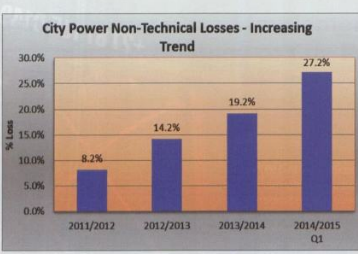


Fig. 2: Increasing non-technical losses trend.

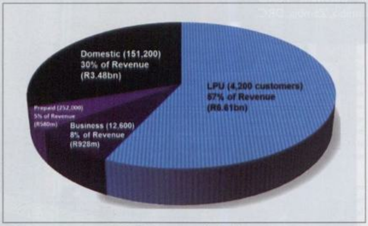


Fig. 3: City Power customer base breakdown.

network and primarily consist of energy theft, errors in the billing and metering system, non-issuance of bills and unknown electrical connections. Fig. 2 provides an indication of this increasing trend.

As can be deduced from the graph, the increasing trend of non-technical losses is immense as it threatens the survival of City Power as an organisation. Hence, it required a systematic shift in approach and drastic change in direction to set the organisation back on the path of financial sustainability. In light of this situation, the executive management at City Power opted to launch the revenue recovery programme with the strategic objectives of improving the revenue realisation potential, arresting the increase in the losses trend, improving meter reading performance and enhancing the overall customer service experience in the process.

City Power smart metering programme

City Power has pioneered the large-scale implementation of smart metering infrastructure in South Africa. The existing customer base exceeds 420 000 active customers across the different customer categories and jointly generates over R12-billion in annual revenues. City Power's challenges include meter reading, revenue recovery, accurate billing, and reduction of non-technical losses.

A high-level breakdown of the different customer categories in Fig. 3 provides a view of the scale of operations required.

In order to tackle these issues, the adoption of innovative technology with the utilisation of smart metering technology played a pivotal role. City Power appointed the Itron/EPG consortium to manage the implementation of smart metering infrastructure within the municipality. The smart meter roll-out programme aims to install over 250 000 smart meters, including approximately 12 000 demand meters in a 3-year programme, aiming for completion by the end of 2015. In order to ensure that the back-end is managed effectively, the meter data management system (MDMS) has also been implemented to integrate with the vast amounts of data received from the smart meters. This further links up to the other monitoring and billing systems within the retail services department. This integrated system makes provision for the large consumers to monitor and manage their consumption statistics in real-time on a dedicated web portal. Communication with domestic customers will also be enabled via SMS to notify them of power interruptions, consumption reduction requests, and provision of billing- related information.

The smart metering technology will provide City Power with advanced metering capability and some of the key benefits to be derived are:

- *Improved customer service:* Accurate meter reading, reduced call handling, on demand data access, proactive grid monitoring and support.
- *Distribution operations:* Reduced outage times, reduced false outage dispatches, direct communication to customers in home devices, energy supply management.
- *Revenue enhancement:* Time of use billing, remote disconnections, improved meter reading statistics, decreased meter reading costs, contractual expenses, supervisory labour expenses, vehicle roll costs and customer support costs.

Revenue recovery programme (RRP)

The revenue recovery programme has been strategically launched by City Power with the primary aim to ensure improved revenue recovery, meter reading performance, and a reduction in the energy losses trend. The RRP aims to leverage existing smart metering implementation programmes within City Power and combine the efforts in a bid to better to address these challenges.

Fig. 4 represents a snapshot of the various initiatives that have been designed to address the different customer segments to be targeted, various process enhancements and system integration requirements to stem from a massive programme of this nature. The journey map conveys the different phases of the programme and the initiatives that ensure sustainability into the future and the various performance areas of the business that the programme intends to impact. The RRP roll-out is of massive proportions and needs to be implemented in a well-structured and coordinated fashion. Table 1 depicts a snapshot of the key statistics of the programme in order to illustrate its scale in terms of costs, operational tasks involved and human

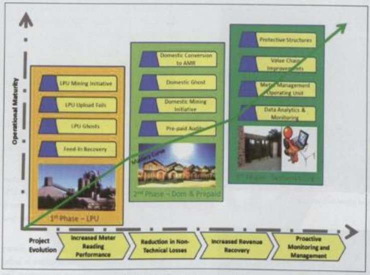


Fig. 4: City Power RRP journey map.

resource requirements that will be involved to ensure successful implementation and delivery within the prescribed timeframes.

Large power user (LPU) initiatives

Initial focus will be in the LPU domain and the various initiatives will be geared to maximise the impact created in this sector. The approach will utilise the functionality provided by smart metering technology and protective structures. Key initiatives are:

LPU mining

The LPU mining initiatives are conceptualised such that the following key objectives can be enabled:-

- *Top 200 key customers:* full detailed audit of all components of a metering installation including primary plant, wiring, meter programming, data and system associated with each account. The output of this exercise is three-fold: compliant metering infrastructure, accurate data and accurate billing.
- *6000 Plus AMR meters online:* diagnosis, fault- finding and field normalization of meters that are offline including the correction of installation data collected in the field. The output of this exercise is accurate billing upload files without exceptions.
- *LPU known issues:* represent a group of LPU customers that approached City Power with known under-billing installations.

LPU upload fails

The LPU upload fails initiative is aimed at normalizing meters that are not successfully uploading data to the billing system. The key objectives to be derived are:

- *System mismatches (4200):* a metering installation record is declared a mismatch if at least one of the key parameters (installation code, account number, location) between the billing system and the meter data management system (MDMS) is not the same.
- *Offline meters (4500):* due to its dynamic nature, the metering environment requires constant monitoring of meters to ensure that they are fully functional at any given instant. This initiative is specifically focusing on the improvement of meter performance.
- *Manual meter conversions (2800):* an identified group of meters, historically manually read LPU meters, must be converted to AMI metering to ensure improvement in the meter reading performance.

LPU ghosts

The LPU ghosts initiative is designed to locate, normalise and maintain LPU customers that are currently not in the billing system.

Feed-in recovery

City Power purchases electricity from Eskom power stations and the Kelvin power station. A strategic initiative to roll out statistical metering at all feed-in points in the form of "check metering" is being implemented to ensure accurate monitoring and measurement verifications between entities and payments thereof. Rectifying inaccuracies will result in significant revenue recovery opportunities and make significant strides in the energy losses measurements. The results obtained for two strategic feed-in points have demonstrated the value in this exercise and management have extended the analysis to be carried out across all 42 feed-in points that need to be monitored.

Domestic user initiatives

The domestic customer class forms a significant volume of City Power's existing customer base. The segment is comprised of over 151 000 customers and constitutes approximately 30% of total sales revenues for the municipality. The focus on the

Large power users cost components (Rand, millions)			
Capex	**Opex**	**Sustainability**	**Total**
300	600	200	1100

Domestic and prepaid cost components (Rand, millions)			
Capex	**Opex**	**Sustainability**	**Total**
1050	1065	350	2465

Programme task		
Initiatives	**Tasks**	**Total**
LPU recovery	1312	198 857
LPU losses prevention	1040	
LPU update fails	10 130	
Domestic conversions	139 801	
Clear audit	46 574	

Large power users staff complement	
Resource	**Numbers**
Directors	4
Programme managers	10
Back office staff	97
Field supervisions	40
Field contractors	265
Maintenance staff	40

Table 1: Key statistics of the RRP.

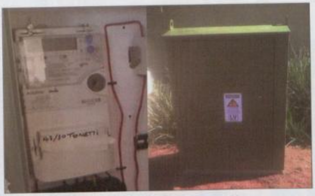


Fig. 5: Itron smart meter and protective structure.

Fig. 6: Hexing meter and protective structure.

domestic sector is twofold, the first being the revenue losses incurred and the other important factor is the opportunity to implement load limiting within this segment in a bid to ease the overall burden of load shedding. The key initiatives in this sector are:

Domestic conversions

The initiative is aimed at replacing the conventional domestic metering installations and associated data with smart metering in order to ensure accurate and timeous measurements and related billing so that the associated revenue accrues to City Power. The implementation of this initiative is geared to address historic challenges which include faulty meters, inaccessible meters, bypassed meters and meters that appear on the Auditor General (AG) lists for not having been read over a significant period. The approach looks at targeting specific areas that have been identified through pre-audits prior to the mass roll out of these conversions into the targeted areas.

Domestic AMR offline

The domestic AMR offline initiative is earmarked to address previously installed AMR meters that are recorded as being offline on the system and need to be rectified. There are approximately over 11 000 meters in this state and it has been identified that need to be addressed with field visits to test the cause of the meters being offline. The on-site visits will assist in the diagnosis of the problem and the rectification thereof. The resolution of the offline meters could see an impact on the overall number of meters that are being estimated.

Domestic/prepaid duplications

The issue of duplicate meter information for certain accounts have arisen owing to incorrect or inadequate system updates being carried out or a lack adherence to the prescribed system updates processes. In this scenario domestic customers that had been converted to prepaid metering still continue to receive estimated bills for their domestic meters. The normalisation of these accounts would need to be carried out through a series of site visits and system updates to be completed in order to resolve the issue of duplicates and irrelevant estimations that arise owing to this situation.

Protective structures

The initiative to roll out protective structures is important to ensure that the structure in which the metering infrastructure resides is robust in nature, withstands external intrusions and is monitored with access control mechanisms. This approach is expected to drastically reduce the energy theft experienced and maintain the integrity of the metering equipment.

Fig. 5 shows the Itron meter and protective structure that is typically utilised in the LPU domain whereby each individual customer is provided with a dedicated demand meter and protective structure.

In the domestic sector, Itron or Hexing meters are used to normalise the installations in order to obtain all the measurement information. The protective structures in this domain can each house multiple meters. This is particularly useful in urban areas. City Power's strategy to minimise access related issues for the technicians is to install these structures outside the properties on the pavements and common areas that fall under the municipal area of control. This will also assist in terms of minimising the access of the metering infrastructure to the customer and limit his opportunity to conceal any acts of tampering or attempts to bypass the meter from within his private premises.

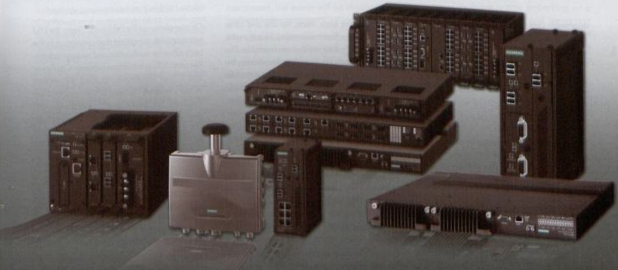
Revenue recovery programme structure

Large-scale programmes of this nature require experienced, well-coordinated, tightly managed and adequate resources (human and material) to deliver on its mandate. The RRP will require utility staff from various parts within the business, external service providers, contractors and the command centre resources to manage well-structured processes and to function in a well synchronised manner. In light of these requirements, a comprehensive RRP structure has been developed with skills and expertise procured from various operational divisions within City Power to form part of the implementation. The high-level view of the RRP structure is depicted in Fig. 7.

The RRP structure is headed by the engineering services director and is currently in full operation with the large power users and domestic customer implementation. The individual initiatives, currently focusing on the different segment are driven by the dedicated project managers (PMs) and their support teams in accordance with their schedules for delivery on the milestones and target deadlines.

Implementation approach

Implementation revolves around a five-stage



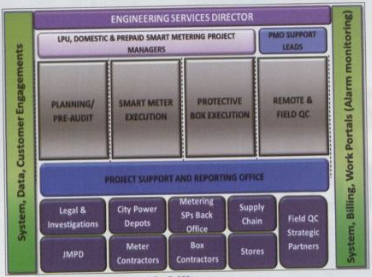


Fig. 7: RRP structure.

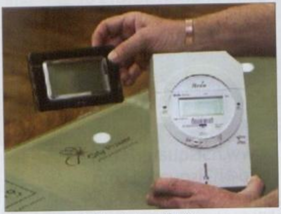


Fig. 8: Smart meter and CIU device.

approach that caters for the entire value chain. The complete process ensures that each metering installation will be normalised and the system updates completed. In doing so, the revenue to be recovered can be computed and the future revenue to be realised from the customer can be safeguarded effectively [5]. The prioritised roll-out based on the different initiatives under the RRP, are coordinated by the respective PMs and the teams that support the initiatives. The following section briefly describes the various stages of the approach.

Data analysis and prioritisation

The actionable customers within each initiative are carefully managed to ensure that the production rates in terms of the normalisations are not impacted by any delays that may occur with the simultaneous implementation of various initiatives in parallel. The LPU customers to be audited are targeted based on prior analysis in the back office, tip-offs and other lists that stem from anomalies found in the various system data sets that are available. The domestic segment approach varies whereby the implementation follows a mass roll out in order to normalise the problematic customers and obtain the required conversions to AMR meters.

Pre-installation audit

In the LPU customer segment, the planning teams are divided and assigned to specific initiatives per team and then mobilised to complete their audits. Depending on the nature of the initiative at hand, the planner goes to site and carries out a full visual inspection of the installation to determine the nature of the remedial work required there. The scope of work is then captured on file and brought to the back office. Further processing to the files is carried out to facilitate the material reservation, allocation to implementation teams, dispatch updates and scheduling of outages where necessary.

For the domestic customer segment, a pre-installation desktop linking exercise is carried out on all the customers that are earmarked for normalisation. The exercise involves linking of crucial information pertaining to the meter numbers, account numbers and customer address related information being verified and correlated. This step must be completed prior to the roll- out plans being put in place for the specific target areas.

Meter and protective structure installation

The smart meter installation phase is one of the most critical stages whereby the accuracy of the readings determines the success of the programme's revenue realisation effort. The scoped site contains the requirements for the installation such as the panel wiring, programming and the exact location in GPS coordinates. Site installations are carried out by teams that comprise of the meter installer and the box installer. Depending on the requirement, normalisation activities may include trenching, cable laying and the preparation for the protective structures to be mounted on site. On completion, the meter installer will test the remote availability of the meter(s) and then ensure that the protective structure is secure and poses no danger.

Quality assurance checks and verifications

Quality assurance measures are critical to ensure that the installations are correct and the integrity of the consumption data is maintained. The quality assurance checks are carried out in terms of system verifications and the physical aspects of the installations. This component of the programme is critical in ensuring future revenue streams for the utility.

System updates and interface confirmation

On completion of the field installations, the LPU teams provide completed documentation to the back office for verification and system updates. Required billing interfaces between City Power and City of Johannesburg (CoJ) are verified and any revenue recovery actions required are instituted. The system updates that are required per initiative are also accounted for and tracked. The domestic teams utilise hand held devices to capture the relevant information during the implementation phase and so electronic job cards are made available on completion of each installation. The downloaded information is then transferred through the interface to the City Power SAP billing system for customer billing related requirements.

Implementation of load limiting

The smart meter roll-out in conjunction with the RRP project has provided the means for City Power to enable their highly anticipated

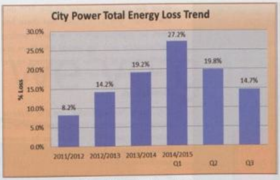


Fig. 9: Non-technical losses trend.

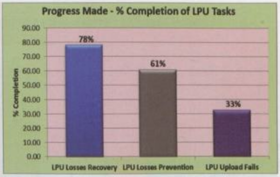


Fig. 10: Percentage of LPU tasks completed on RRP.

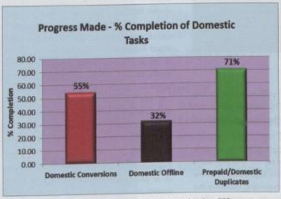


Fig. 11: Percentage domestic tasks completed on RRP.

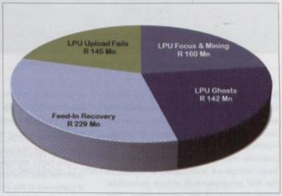


Fig. 12: Revenue recovered through the RRP.

load limiting capability to be deployed in the Domestic customer segments. The intent of the load limiting strategy is to provide customers an opportunity to mitigate the need for load shedding to be deployed during situations where energy supply constraints are experienced. Certain additional benefits to be derived with the introduction of this technology are management of load on the City Power grid to maintain plant health and remain within the available maximum demand requirements in accordance with the license agreements.

Load shedding is necessitated when the electricity demand exceeds the available supply. Currently, load shedding within City Power's domain is implemented by disconnecting supply transformers until the required quantum of load is shed. Load limiting is an attempt to reduce the need for disconnections because of load shedding, by making use of smart meters installed within the customer premises.

The process commences by a signal being sent to the customer through the customer interface unit (CIU) informing them to reduce their load to within a stipulated threshold. The smart meter will then monitor the load to verify compliance by the customer. If the request is not adhered to the smart meter will disconnect the main electricity supply to the customer. Another opportunity is provided within the next few minutes to reduce the load and reconnect the supply and monitor the situation. If the load is within the required threshold, the electricity supply will remain connected or else be disconnected once again. Once the requirement for the load shedding in the area has passed, the power will be automatically restored to the customer.

The approach provides the opportunity for a two-way interaction with the customer in addition to providing the choice for voluntarily participation in the exercise. Communication to the customer will be via SMS and the CIU, with the CIU being the primary means for notification. The approach is aimed to minimize the impact of load shedding by assisting City Power to balance the required load against the available supply. From a customer perspective, the key benefits are reduction in blackouts, continued utilization of critical appliances such as security systems, essential lights, chargers etc. City Power is currently testing the load limiting capability in a Domestic customer population of over 65 000 customers which is able to yield approximately 153 MW of load that can be made available during periods of supply constraints. The longer-term plan is to roll out over 450 000 smart meters which will significantly increase the load that can be made available through the load limiting approach. Hence, as the smart metering roll-out progresses, areas will be switched from load shedding to load limiting zones as the supply areas are saturated with smart meters. City Power is also embarking on a comprehensive education and awareness campaign in a bid to create the knowledge and understanding within the customer base to encourage participation and utilisation of the benefits provided by this technology. The use of several print and visual media platforms will ensure maximum outreach to the customers prior to the curtailment of loads in the different areas.

Meter reading performance

An important element of the RRP project is to enable the improvement of the meter reading performance for the existing customer base within the LPU and domestic sectors. These two customer sectors have been receiving increased focus by aligning the outputs of the various initiatives that run concurrently such as the Auditor General (AG) performance reporting and the RRP programme. In order to ensure efficiencies in the approach,

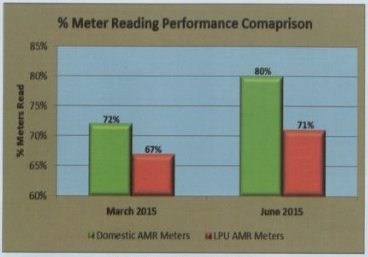


Fig. 13: Meter reading performance status.

the planning phase aimed to prioritise the customers that had overlaps on the estimation reports and the Auditor General's reports. During the implementation phase, instances where the meter readers identified customer installations that had potentially been tampered with were re-routed to the RRP programme to ensure immediate normalisation of the installations. The increased focus created through these interventions in the last few months has shown significant improvements. The next section provides the meter reading performance improvement evident during this period.

Results

Non-technical losses trend

The RRP has commenced in earnest and significant strides have been made to date in terms of the field implementation, system updates and account normalisations [5]. A significant achievement thus far relates to an arrest in the increases experienced in the energy losses trend that is evident because of the successful roll out of the RRP initiatives.

The losses trend is expected to reduce significantly through sustained efforts in the programme and the maintenance of the focus created. Efforts should then be geared towards maintaining the reductions achieved to within sustainable levels through a series of proactive monitoring and control mechanisms.

Revenue recovery initiatives

On the revenue recovery front, significant strides have been made and the RRP initiatives have managed to collectively secure over R696 million in revenue. The recovery rate also sheds light on the effectiveness of the prioritisation criteria utilised amongst the different initiatives. Fig. 10 lists tasks completed on the LPU side since the commencement of the RRP.

Fig. 11 lists the progress made to date on the tasks completed on the domestic customer side. There are significant volumes of customers in this domain and therefore the emphasis will be to ensure sustained effort over an extended period.

Fig. 12 shows the revenue recovery achieved to date as part of the LPU initiatives on the RRP. At this stage, the various initiatives have begun to gain the required traction and the focus created needs to be sustained in order to complete the remaining tasks that have been earmarked for the RRP [5].

The significant gain in the pilot feed-in recovery initiative has prompted verification exercises to be employed on the remaining Eskom and Kelvin supply points. The RRP has demonstrated the immense revenue recovery potential that exists and the importance of securing the revenue streams for City Power to ensure sustainability.

Meter reading performance

Meter reading performance is a key focus area for City Power in terms of ensuring that accurate and timely meter reading measurements are obtained for the purposes of billing as well as relating to the licensing agreement from NERSA. Hence this is a key performance area that requires much attention and improvement. With the commencement of the RRP, the planning of the different initiatives in the domestic and LPU sectors took cognisance of the requirement to improve meter reading performance. Fig. 13 provides a view of the meter reading performance since the commencement of the RRP and the current status. It shows that there has been an improvement in the meter reading performance over this period and there are healthy signs of further improvement as the initiatives progress with the roll-outs.

Conclusion

City Power has embarked on the revenue recovery programme to increase its revenue realisation potential as well as to create opportunities to improve its service delivery capability to its customer base. Efforts on the programme to date have yielded tangible benefits to the organisation. The interim results achieved thus far demonstrate the significant strides that have been made by City Power to deal with the revenue loss challenge in a coordinated fashion. With the deployment of smart metering and the immense potential to utilise the data analytics that are made available, the organisation aims to further streamline its revenue management activities into the future. This will ensure accurate measurements, billing and realisation of the revenue owed to the municipality that will enable the financial sustainability it strives to achieve.

The introduction of the load limiting initiative in a phased manner will significantly contribute towards easing the burden of the supply constraints that exist in the country. The initial roll-out has demonstrated the capability of load limiting that can be achieved with the use of smart metering technology. The opportunity for an alternative to load shedding has been eagerly received by the residents of Johannesburg who been part of the roll-out. This technology holds great promise into the future.

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The real smartness of a smart metering solution

by Christo Nicholls, Edison Power Group

Prior to addressing the issue of smartness, the author needs to provide a platform of what smartness really refers to in the context of this paper, namely: true smartness lies on the other side of achieving what seemed unlikely (even maybe impossible at times) not because of a well defined route or abundance of knowledge or absence of difficulty, turmoil or even resistance, rather because of a skillful convolution of clinging onto what only exists in its fullness in the realm of imagination at the start of the journey (not in the journals of past knowledge obtained) and the relentless, cohesive and collaborative effort until what was only once thought of finally materialised in the form of tangible benefits.

Hence, real smartness is not an attribute, but rather a skillful, well thought through and sweat-filled methodology of turning a wish into reality...

Now that a fairly elaborate definition and explanation of the concept of smartness has been presented, in the subsequent sections the author will not only provide some history around the smart meter solution, but also speak to the definition of such a solution and how this can assist in providing solutions for tough questions within the utility space in a smart fashion.

The realisation that having an end-to-end solution that can provide key information on electricity usage and events impacting the reliable supply of it, in a convenient, integrated, transparent and automated fashion, saw the light of day as early as 1972 when Theodore Paraskevakos developed a sensor monitoring system with digital transmission capabilities, while working for Boeing in Alabama, USA.

This he developed further to the point where he produced the first fully automated, commercially available, remote meter reading and load management system after obtaining a US patent on the solution in 1974. Hence, although the smart metering solution is recent in the country and the African continent, it is not new to the global village.

However, the aggressive adoption of this method of service provision within the utility domain really only started unfolding in the early 2000s and the biggest influence factor was not so much available technology, but industry accepted standards and regulations. Until today, the IEC 62053-21 specification addressing the core meter element still forms a key regulatory building block.

Fact is, from the start, the purpose of this technology was elevated above the basic provision of an accurate meter, but rather the full offering of a smart methodology to obtain critical information related to electricity supply and associated utilisation.

Smart meter solution: defintion

The smart meter solution was born within the aerospace domain. Alongside the military domain, the concept of solution vs.technology is extremely well-embedded and documented in specifications, e.g. ISO 15288.

Within the above-mentioned domains, solutions or acquisitions as they're often referred to, acknowledge the fact that, in order to materialise benefits (not necessarily producing defined deliverables only), it is imperative to have fit-for-purpose technology. However, it is equally imperative to have fit-for-purpose resources that can configure, deploy, operate and maintain the technology and fit-for-purpose facilities to assist the resources with the required pre-deployment, deployment and post-deployment activities. Fit-for-purpose policies and procedures which can guide the resources on various matters ranging from the basis of configuration strategies, (e.g. if we want to be future-proof, do we configure the meter as import only), bi-directional or uni-directional, as all metering configurations have a direct impact to which extent the four quadrant measurement capabilities of the smart meters can be used to assist with future electricity rebate programmes linked to alternative energy sources on the end-user side.

Lastly, to ensure the solution is properly defined, the technology, resourcing, facilities, and policies must be accurately positioned within an environment which is unique to each utility. Within this environment sphere, the utility is faced with interesting challenges directly impacting the lower tier choices of the solutions, e.g. due to budget does the utility buy host or the software suite or employ or outsource resources.

Questions surface such as "what are the various levels of customer engagements required to ensure access to premises?" as, in the USA, the concept of a communication liaison officer (CLO) is foreign, whereas in Johannesburg it is very often the difference between life and death for field workers.

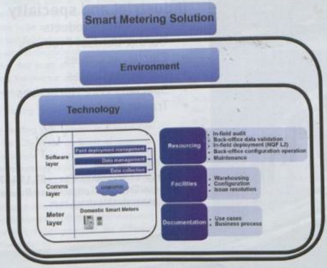

Fig. 1: An overview of typical smart metering solution architecture.

The same can be said of what is known as a magician in the favelas of Rio De Janeiro.

Fig. 1 shows a pictorial overview of a typical smart metering solution architecture.

Solution benefits

Assuming the full spectrum of a smart metering solution was implemented within the utility space, the solution as a whole has the potential to materialise the list of benefits as per the various areas within the utility space.

Firstly, within the sphere of the organisation, the solution directly contributes towards an imperative paradigm shift linked to:

- What benefits the organisation wants to see as opposed to what technology it wants to acquire.
- How we must manage a legacy resourcing structure and model to align with the smart metering solution and the benefits envisaged.

Next, within the billing value chain, the smart meter solution addresses issues such as:

- Legacy data issues, e.g. rectifying discrepancy between updated deeds office data and outdated billing account data.
- Implementation of smarter ways of addressing recurring queries and complaints

Within the customer engagement domain the solution encourages upfront focused customer engagements, awareness and education, ensuring the required customer buy-in is obtained, as access to customer premises is paramount. Also, integral to the solution and a direct contributor towards the customer service level experience is a functional and efficient call centre equipped with the required response capabilities which, in turn, provide the end-user with transparency on all billing matters, but also access to highly-skilled response personnel.

Within the growing domain of efficient load management, the smart metering solution does bring to the fore cutting edge methodologies of managing load on a mass scale, informing customers on what to expect and when, plus activating either mains control through limiting or disconnection of loads.

Another key domain within the utility space is the need to not only identify but exercise control related to alarms and field related events threatening the broader revenue collection value chain. Here, the solution implicitly not only records and reports time-stamped occurrences of unwanted events, but through trained resourcing and well-defined policies provides a sustainable solution addressing the ever-present non-technical losses within the utility space.

Conclusion

In conclusion, this article highlighted the fact that the notion of adopting an end-to-end solution that can provide a meter with smart functionalities, but more importantly a solution that marries the relevant technology with adequately trained resources, equipped facilities and well-defined policies and operating procedures in a seamless way so that a broad spectrum of benefits can be materialised, has made entry into the electricity world in the early 1970s through the aeronautical space.

However, as of the early 2000s the utility space latched onto these smart meter solutions to assist them in materialising key service delivery benefits in a smart fashion. Nonetheless, the biggest challenge still is for utilities to accept that, when implementing a smart meter solution, to extract the embedded smartness within it is imperative to accept the fact that they are implementing much more than just a meter and related software. If not, even the smart meters and their related software will ultimately join an embarrassing list of very expensive technology white elephants due to the lack of the other critical solution elements.

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Visual improvement and energy-saving in high-mast lighting installations in municipalities

by Daniel Kasper, Beka-Schréder

High mast lighting installations are to be found in almost all geographical locations in South Africa. It provides light to areas where either limited electrical reticulation is found or because it makes economic sense to provide lighting in these areas. The typical applications are township/informal settlement lighting or highway interchange lighting or huge industrial sites like harbours or mining sites. The provided level of light increases visibility and provides a sense of safety. It enhances the quality of life in those areas where no other artificial light is provided and increase the night activity and provides a safe environment.

During the last decades mostly high pressure sodium lamps (HPS) were used to provide the necessary lighting level. But with new lighting and control technologies emerging, a revolution can be expected in terms of the amount of cost savings and the quality of light.

LED light source and luminaire

Light emitting diodes (LEDs) have become a common used light source in the last few years. Whether low wattage LED lamps are used to replace halogen lamps in households, or high wattage streetlights, the LED luminaires are providing mostly high energy savings. Another positive aspect of LED lights is the high colour rendering and good visibility which is noticed due to the white light the LEDs emit. Furthermore, the long lifetime and instant full-light-output are just a few added advantages the consumer can benefit, when replacing conventional luminaires with LED luminaires.

With the ever increasing efficiency of LED luminaires and higher expected lifetime, the LED light source becomes the most economic choice for any high mast installation.

High wattage LED luminaires used on high mast installations need to sustain the environmental conditions which they are exposed to and they need to at least match the lighting criteria set by the conventional luminaires.

The luminaire housing, the LEDs and control gear requires to be:

- Corrosion resistant.
- Mechanically strong enough to sustain severe vibration caused by wind and vehicles.
- Survive surges to which the electronics and LEDs are exposed to by means of integrated surge protection.
- Survive in even the highest temperatures caused by daytime operation due to network faults etc.

Furthermore, the light distribution should be able to provide sufficient light at the nearest point at the bottom of the pole, while still providing sufficient light at the most furthest point from the mast. Typical distributions have a very high light peak intensity to be able to shine far enough.

Lighting calculation

Luminaires should only be replaced with an equivalent, if the replacement luminaire is equally performing and makes economical sense. With the current power shortages in this

System design
9 x luminaires per pole
30 m mast
300 m spacing
Required minimum lux level of 1 lx

Table 1: Spacing between high masts and the lighting levels are fixed values.

country, it is of further benefit if power savings are achieved to assist with the national aim of reducing power usage. A further benefit would be if the previous achieved lighting levels are not only matched, but actually increased. Adding to this is the ability to control the lighting and increase the lighting levels if needed, i.e. in the busy hours of the night, and reducing the light levels for the remainder of the night.

To summarise:

- Equal or higher lighting levels.
- Better colour rendering.
- Energy saving.
- Lower maintenance costs.
- Control of light.

Since most high masts are already existing and installed, the aim would be to directly replace each HPS or metal halide (MH) lamp, in either

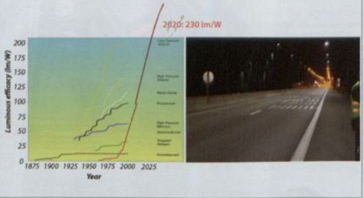

Fig. 1: Efficacy comparison of light sources (left) and visibility improvement (right).

Fig. 2: Omnistar High Power LED luminaire.

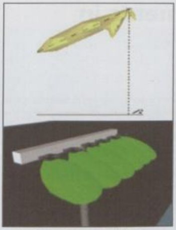

Fig. 3: Specific photometrical distributions designed for high mast lighting.

Fig. 4: Layout of high mast installation.

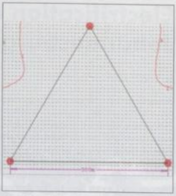

Fig. 5: Spacing between high masts and achieved lighting levels.

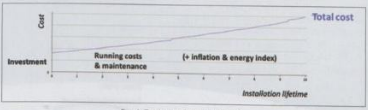

Fig. 6: Total cost of ownership graph.

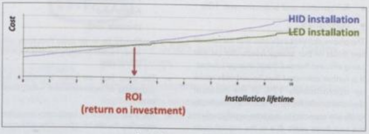

Fig. 7: Return on investment.

400, 1000 or 2000 W, with the equivalent LED replacement. The spacing between the high masts and the achieved lighting levels are fixed values (see Table 1).

Total cost of ownership

In most installations energy savings can be achieved. Additionally, the white light with its inherent higher colour perception could convince end-users to slightly lower the light levels while still having the perception of equal visibility. Therefore even higher energy savings can be achieved if light levels of the LED replacement are slightly lower than those of the LED luminaires. With the added benefit of maintenance reduction, the break-even point of an HID installation compared to an LED installation is further shortened.

Control system

There are a number of control systems available on the market and can be easily integrated into most luminaires. The main advantages of such a system are:

- Total energy savings of more than 50%.
- Savings on maintenance costs.
- The ability to observe the lighting installation remotely and act immediately when there is a failure or non-performance.
- The ability to add camera systems, which are technologies beyond the lighting concept but can easily be integrated.

Improving operations management

Very easy accessible and a clearly structured report system allows you to monitor and assess your lighting installation independently and provides the necessary information to wisely manage the network throughout its lifetime.

By limiting maintenance operations, you will reduce your operating bills and minimise lighting disturbances.

Light on demand and only when needed

Lighting public spaces when they are not being used is a waste of energy. Dimming scenarios and light-on-demand features can adapt the lighting to the real needs of the place and the time. Simple solutions like motion detection sensors that can operate on either individual lighting points or on a complete network.

Each luminaire level can be configured individually with several parameters such as minimum and maximum light output, delay times from minimum to maximum and duration of on/off times.

Reliability ensured

By monitoring every luminaire, the control system prevents failure by detecting problems (broken lamps, device temperature, surges...). If problems arise, the system switches to a default programme, ensuring that the lighting installation does not turn off.

Conclusion

With the recent technology improvements, LED floodlights are certainly able to equally replace HID luminaires while achieving substantial energy savings or at least matching the power consumption of the HID luminaire. With adding the remote control and monitoring options while also saving costs on the low maintenance on LED luminaires, the return of investment for the initial higher unit cost of an LED floodlight is quickly reached, sometimes in under 2 – 3 years.

With the added benefits of LED light such as the higher colour rendering and better perception of colours, areas lit with LED light are often perceived as being bright, friendly and safe, which certainly adds to the overall satisfaction of the citizens living in areas lit by this kind of lights.

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Electrification of informal settlements in Johannesburg

by Phetole Moagi, City Power

Electrification of informal settlements is aligned to sustainable human settlements priority. Access to electricity will have a substantial positive impact on the quality of life of the recipient communities. The programme will improve revenue collection; reduce electrical and nonelectrical losses, carbon footprint, and security of electricity supply, reduce illegal connections in and around informal settlements, etc. The investment by City Power in renewable energy and energy efficiency is significant to improve township economic, social, cultural and environmental impacts of energy production, distribution and consumption in South Africa. The current capacity constraints and load shedding, calls for additional measures. Currently, renewable energy contributes relatively little to primary energy and even less to the consumption of commercial energy. This paper examines alternative energy options for providing sustainable solution for informal settlements and promotes renewable electricity.

In the past, basic energy needs were adequately met by electricity utilisation in the household. In terms of the "Energy outlook" published by the Department of Energy in 2013, it is estimated that the energy use in a typical household is as follows:

- Cooking: 41%
- Water heating: 32%
- Space heating: 12%
- Refrigeration and entertainment: 10%
- Lighting: 5%

The above statistics indicates that the almost two thirds of our energy needs can be met using efficient thermal (heat) energy sources. It is further estimated that households make up approximately 17% of the national demand of electricity. In addition, electricity tariffs are expected to increase significantly in the next three years due to the capital costs of new generation capacity and higher costs of Eskom to maintain an old fleet of power stations as well as the increase in the cost of environmental compliance.

In line with the constitutional mandate and the commitment made by the City of Johannesburg's Mayor, Councillor Parks Tau, the City of Johannesburg intends to improve service delivery of energy to informal settlements. This will be done by ensuring that a package of innovative energy solutions is provided, while ensuring that the basic services meet the expectations of the residents.

City Power has developed a concept that brings together a number of technologies in order to assist government in this regard.

Electrification of formal households is traditionally funded by the Department of Energy (DoE). However, informal settlements fall outside of the DoE programme (grant) due to prerequisite conditions that must be met to qualify for the subsidy. The DoE criteria are listed below.

- The settlement should not be encumbered by:
  - Servitude
  - Under high voltage lines
  - Road or rail reserve
  - Fire-prone area, flood-prone area or flood plain
  - Environmental issues
  - Storm water retention or detention pond
  - Private land
  - Unstable land
  - Should be in an area that pose any other health or safety hazard such as dump sites
- The area has not been identified for upgrading or redevelopment within three years
- The ward councillors have been consulted regarding the electrification of the settlement
- The community supports the proposal and is willing to:
  - Co-operate with the opening up of access roads where necessary
  - Keep these access roads clear
  - Supply and organise local labour where required, and help prevent tampering with or on selling of electricity supplies

Policy implications

Some of the informal settlements are situated in private land. In these instances, it will be required of the city to negotiate with property owners to enable provision of electrical services.

There is a need to find solution on how to provide minimum acceptable electricity services at the current location to Category 3 informal settlements. The policy guidelines are based on the grounds that Category 3 informal settlements will, in future, be upgraded to Category 1 or 2 and thereafter services will be provided.

DoE - Non-grid electrification policy guidelines (19/03/2012): Criteria

Non-grid systems should not be installed with 2 km from a grid line.

The lowest capacity grid supply cannot be supplied within the capital expenditure limit. Consider future grid electrification plans. The area falls outside of the 3-year grid plan. The identified areas must be included in the Municipal IDP.

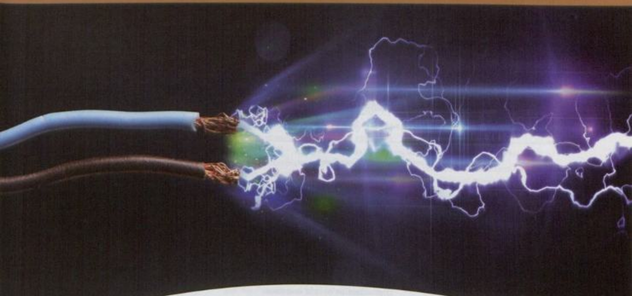
Eskom or licensed distributor in that area must confirm areas or households that would not receive grid electricity in the foreseeable future and grant permission that non-grid electrification be provided in those areas.

A cost benefit analysis will also be considered to determine whether an area will be electrified via non-grid or not.

Category	Condition/status	Response
Category	On suitable land (complies with the set criteria and is likely to go through in situ upgrading).	Will be subsidised for electrification.
Category	Settlements that do not need immediate relocation and will therefore go through the process of regularisation which is pre-formalisation (putting basic services with plans to relocate in future).	Will be subsidised if the settlement will not be relocated in the next 3 years.
Category	On unsuitable land (do not comply with the set criteria, areas such as on dolomite land, in toxic areas, or in a dangerous area) and need relocation.	Settlements that have been there for a reasonable amount of time will be considered on a case by case basis upon application by the department.

Table 1: Policy guidelines for the electrification of unproclaimed areas (DoE, p. 8).

Make sure your Copper components are SABS approved



SABS APPROVED

Economic Sizing of Power Cables

While copper is an excellent conductor of electricity, it still has a degree of resistance to the flow of electrons through it. Therefore, some amount of resistance heating will occur in the cable. It is normal for a properly sized cable to feel warm to the touch after prolonged usage. However, if the diameter of cable is too small for the level of current flowing through it, then the cable will overheat. This can result in a potential fire hazard, as well as damage to the cable itself (and ultimately to cable breakage and failure). A breakdown of the insulation jacket can also be an electrical shock hazard.

Conversely, cable that is oversized for a given amperage level does not conduct current any more effectively than properly sized cable. However, larger diameter cable typically costs more per metre than smaller diameter cable, because of the increased amount of copper strands. Therefore, oversized cables may not be cost effective.

The cost of energy dissipated in cables is frequently ignored. Many cables are installed with a conductor size designed to be the minimum permissible size to avoid overheating and volt drop. The sum of losses due to resistance in conductors for renewable energy installations could be significant.

Only buy SABS approved copper cables and fittings

Technical and manufacturing improvements over the years have improved quality standards resulting in a product which is now certified by the South African Bureau of Standards.

In addition to buying only SABS approved cables, it must be kept in mind that there are other factors which will affect the performance of this unique material.

Even the best product will fail if poorly installed and it is important that the correct procedures are adhered to when installing copper cables. Use only registered electrical contractors.

Adhering to the rules will ensure that your copper cables will give you a lifetime of trouble-free electricity supply and protect you and your family against electrical faults which may result in electrical fires.

Roughly one quarter of all building fires have an electrical cause, many of them due to non-compliant installations. It has become clear that the need for correct copper cabling and quality components in your home is indisputable.

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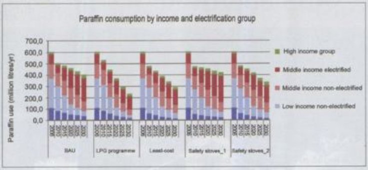

Fig. 1: Paraffin consumption by income and electrification group (Energy Research Centre, University of Cape Town).

INEP: The programme will contribute in achieving universal access to electricity.

In the Energy White Paper, cognisance is taken of the fact that many people informal settlements are living below the poverty line and have limited ability to pay for goods and services.

Illegal connections affects the surrounding areas, causes overload, interruptions, revenue losses, unaccounted electricity usage, electrical losses and compliance to NRS 047, NRS 048 and NRS 034. Section 101 is also affected; complaints and petitions are also received from the affected areas.

NUSP (government outcome 8): sustainable human settlements and improved delivery quality of life. Informal settlement upgrading includes national priority programmes such as NUSP.

Legal and constitutional implications

Environmental issues, unstable land, dolomitic, flood plains, unpleasant and harmful gases. Section 26 (2) of the Constitution identifies the rights to basic needs and the provision are found in the Bill of Rights, entrenches the right of each citizen to adequate housing, healthcare, food, water, social security and education.

Section 27 (1) (a) (b) and (c) endorses that each citizen has the right to access proper services and infrastructure such as health care services, water, electricity and social security.

Section 24 (a) (b) confirms the rights in a live a suitable environment free of harm to health or wellbeing, Bill of Rights (Chapter 2 of the Constitution).

Section 25 children's rights in terms of housing, shelter, basic health care and social services (sustainable environment).

Section 152 (1) (b) and (d) ensure the provision of services to communities in a sustainable manner; (d) to promote a safe and healthy environment.

Sections 9 and 25 of the 1996 Constitution equitable access to land, and to promote equality:

The South Africa Housing Act 107 of 1997 and Housing White Paper of 1994 (livelihoods) Section 2 (1) (iii) Eradicate informal settlements through, demolitions, evictions, controlled transit camps and criminalisation of land invasions.

The programme in its current form seeks to comply with Section 13.2.2 "Principles of the programme": qualification for benefits, stand sizes, suitable land, and demolition of shacks: from Department of Housing (2004b) National Housing Programme. *Upgrade of Settlements*

Currently the majority of these informal settlements are illegal connected (electricity theft), exposed bare wires, unsafe and not conform to electrification standards and specifications (NRS, SANS, Section 101, CoJ etc.).

Safety and capacity

City Power in conjunction with JPMD constantly removes these illegal connections. Illegal connections to infrastructure and non-payment of rates account diminish the revenue base of the City to provide services.

National Environmental Management Act, 2004 (Act 10 of 2004) (NEMA): services should be 32 m "from a river, tidal lagoon, lake, in-stream dam, floodplain or wetland" in the one in ten year flood line river, stream or wetland , or with 32 m, which is greater, from the bank of a river, stream or wetland.

New approach by City Power (gas and photovoltaic)

The scope of this section of the proposal is to provide alternative solutions for the supply of two plate gas stoves suitable for low cost housing in order to improve living conditions of home occupants and at the same time lower the demand on the electricity grid.

The following alternatives are provided as part of the scope described above:

- Cylinder sizes 6 kg and 9 kg
- Freestanding cabinet for gas stove and gas cylinder with or without small drop-in basin or removable plastic wash basin.

The scope also considers logistical options for the supply of LPG and LPG cylinders to the relevant communities.

Legal requirements on gas

The approach needs to be safe and comply with the relevant standards. These standards include the following:

- Occupational Health & Safety Act, 85 of 1993 and Regulations (OHSAS).
- SANS 10087-1: The handling, storage, distribution and maintenance of liquefied petroleum gas in domestic, commercial, and industrial installations. Liquefied petroleum gas installations involving gas storage containers of individual capacity not exceeding 500 l and a combined water capacity not exceeding 3000 l per installation.
- SANS 10087-7: The handling, storage, distribution and maintenance of liquefied petroleum gas in domestic, commercial and industrial installations. Storage and filling premises for refillable liquefied petroleum gas containers of gas capacity not exceeding 9 kg and the storage of individual gas containers not exceeding 48 kg.

Steps to ensure compliance to the relevant SANS codes

Based on the above-mentioned standards, the following will be done to ensure compliance of each installation:

- The two plate gas stove will be equipped with a flame-failure device as an additional safety feature. The flame-failure device shuts down the gas supply when the flame of the burners goes out for some reason or another.
- The two plate gas stove will be placed on top of a custom made free standing cabinet with an incombustible table top.
- The cabinet design allows for a well-ventilated and designated space for the gas cylinder.
- A leak test of installed gas cylinders and two plate gas stoves will be conducted.
- A certificate of compliance will be issued for each installation.
- Home owners will sign the COC to take cognisance of relevant safety standards.

Benefits to using gas for cooking compared to paraffin and electricity

Providing LPG to communities is beneficial in many ways. Many people use paraffin as their main fuel, especially for stoves. The following are some of the dangers experienced with the use of paraffin:

- Paraffin is highly volatile, much more so than LPG, which means accidents can happen more easily, resulting in devastating burns and fires.
- Paraffin is also often consumed by

Fig. 2: Typical gas detector.

children, who mistake it for cool drink, a mistake that cannot happen with LPG.

- Paraffin releases toxins into the environment, unlike LPG which is clean-burning.

LPG is also becoming an ever-increasing alternative to electricity.

Some of the benefits of using LPG for cooking:

- Less dependent on electricity. By keeping a spare cylinder of LPG on hand, the homeowner is assured of an uninterrupted, reliable source fuel for cooking.
- Using alternative fuel sources helps reduce the negative environmental effects of producing electricity.
- Reduced carbon footprint by as much as 50% simply by switching from electricity to gas for cooking.
- LPG is well suited for use indoors because it is inherently clean and burns without smoke or residual particulate matter.
- LPG is highly controllable and efficient with instant heat and immediate heat reduction for faster, more economical cooking.
- Reduced load on the country's over-stretched supply – especially during peak usage times.
- LPG is completely safe like electricity, when used correctly.
- LPG is becoming a more affordable alternative to electricity. "BAU" (Business as usual).

"There is a firm belief that electricity is more expensive than paraffin and beyond the affordability levels of many households, although research studies comparing the relative cost to cook with different fuels and their appliances show that electricity is significantly cheaper than both paraffin and LPG". "A major barrier to increased LPG use is fear that it is not safe, particularly that cylinders may explode, which ironically keeps many households continuing to use paraffin, a fuel with comparatively greater safety risks". (Sourced from: Energy Research Centre University of Cape Town.)

"The Energy Act elaborates on and makes specific mandates to develop programmes in relation to various aspects of energy supply". Some relevant parts of the Act are outlined below: The objects of the Act that are relevant to households and safety include: (h) provide for certain safety, health and environment matters that pertain to energy. (Energy Act 2008.)

Gas detector

A gas detector and alarm may be considered as an optional extra to detect leaks when the appliances are in use. Though not required by legal standards, it may further enhance the safe implementation of the project. The cost of a gas detector, with sensor and alarm only, is in the order of R2250 (excluding VAT). A detector with sensor, alarm and cut-off valve is in the order of R3780 (excluding VAT).

Cylinder exchange depot and/or cylinder filling premises

The properties of LPG and LPG containers provide a lot of flexibility in the handling, storage and distribution of LPG. Cylinder

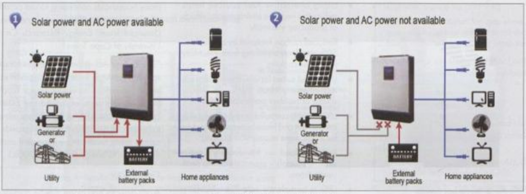

Fig. 3: Typical solar system configurations.

exchange depots and filling sites, whether large or small, are widely and effectively used in the LPG industry.

Large filling sites with bulk LPG tanks are highly regulated and controlled due to the risk of illegal and unsafe filling of gas cylinders. These large filling sites also have more gas on site and pose a bigger threat to the local community. Large filling sites are normally situated in industrial areas and are more suitable for the filling of 9, 19 and 48 kg cylinders on a large scale from a bulk LPG tank.

The nature of exchange depots and small filling sites lends itself positively toward the creating of sustainable SMMEs. As an alternative to large filling sites, smaller filling sites can be considered at already existing businesses within the local community. Examples of these can include filling stations, hardware shops, and general dealers. Small filling sites are more suitable for the filling of small household and camping cylinders (smaller than 9 kg).

The following are benefits in using existing SMMEs:

- The filling sites can be implemented on existing business premises.
- Local dealers have already established a client base.
- Local dealers are in accessible areas to the local community.
- Local dealers are already entrepreneurial.
- Filling stations already have fire department approval and amendments only will be required.
- A proper selection process can be implemented to identify the best local service provider.

It is recommended that small cylinder filling sites be established through already existing SMMEs in the local community. It is important that a reputable gas supplier be appointed to develop and support such filling sites. This will ensure that legal and safety requirements are adhered to.

SANS 10087-7 refers specifically to the storage and filling premises for refillable liquefied petroleum gas containers of gas capacity not exceeding 9 kg and the storage of individual gas containers not exceeding 48 kg.

Cylinder exchange depot

Cylinder exchange depots are widely and effectively used in the LPG industry. The nature of exchange depots also lends itself positively toward the creating of sustainable SMMEs.

Some of the relevant legal requirements for cylinder exchange and storage depots are:

The storage area shall:

- Not be located inside a building, but in an open, well-ventilated area, and shall be used exclusively for the storage of LPG containers.
- Be so located as to eliminate, as far as possible, exposure of the containers to any excessive rise in temperature, corrosive substances or vapours, other highly flammable substances, physical damage and tampering by unauthorised persons.
- Be kept clean and free from any accumulation of combustible matter, such as paper. Any possible source of ignition shall not be allowed in a storage area. An area of at least 3 m in all directions round the perimeter of the storage area shall be kept clear of grass, weeds and other combustible matter, including any electrical source of ignition that does not comply with the requirements of zone 2 equipment.
- Be provided with fire-fighting protection, and where this cannot be achieved, a rational design as given in SANS 10400 shall be applied.

Purposely designed containers/structures shall be acceptable, provided that the requirements are complied with. All potentially dangerous activities, such as the use of open flames, welding and cutting operations, the use of electric grinding tools, and smoking, shall be prohibited in the storage area, and symbolic safety signs.

Training and qualification for filling sites

- Qualifications, training and experience of operators: The employee carrying out the inspection, filling and handling of containers in terms of this part of SANS 10087, shall have had the appropriate technical and practical training for the type of work undertaken, the proof of which both employer and employee shall document.
- Record of operator training: A record shall be kept on the premises of the training undergone by an employee. This record shall contain the training course syllabus, the name of the trainer and the name of the trainee.
- Authority of qualified operators: No one shall inspect, fill or handle a container unless:
  - He has been duly trained.
  - His training has been recorded.
  - He has been found competent to fill containers in accordance with this part of SANS 10087.

Photovoltaic

Access to proper lighting is especially important for City Power, as pupils need proper light to do homework and to study for the exams.

A 230 V system consisting of a 3 kW micro grid system featuring PV panels, batteries, charger and inverter. The system is grid tied, feeding solar energy back on to the City Power grid.

This system can be used to put access solar energy back onto the national grid. The system can also be divided into 500 W and 375 W per shack (3 kW system will be used to feed six to eight households (shacks). It is important to further acknowledge that the "PV module's voltage output is actually a variable value that is primarily affected by temperature".

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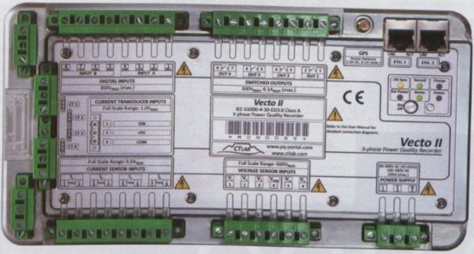

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"The relationship between module voltage and temperature is actually an inverse one" (Massawe, June 2013).

The higher costs of this system are due to the following:

- A costly four quadrant meter is required if energy is pushed back onto the national grid.
- Due to the fact that a 230 V AC off-grid system is installed in the same structure that a grid connection is installed, the installation are much higher due to the fact that precautions have to be implemented to prevent the two systems from coming in contact with each other.

3 kW system

- 12 x 250 W solar panel.
- 1 x 3 kW pure sine wave hybrid inverter.
- 2 x pole mounting structure.
- Accessories (cables, circuit breaker, isolator, fuses...etc.).
- 8 x 12 V/100 Ah battery.
- 500 W per shack after diversity.

Furthermore inverter interfacing PV module(s) with the grid ensures that the PV module(s) is operated at the maximum power point (MPPT). See Fig. 3.

Solar hot water

Government is committed to provide water and sanitation at most of the locations, and City Power proposes that this commitment is taken a step further by providing hot water.

In terms of hot water it is suggested that solar water heaters (SWH) be used in this specific informal settlement. Since very little roof space with adequate structural integrity is available, SWH cannot be installed per house but rather at centralised locations.

The idea is to provide hot water for washing and cleaning specifically, including kitchen utensils after cooking and eating, washing of clothes and specifically for personal hygiene.

The solution presupposes that there is a municipal water connection. If necessary, hot water can be installed at centralised locations or at individual houses depending on the specific location and installation possibilities. Centralised units can either be installed per 24 households, or per stand.

Conclusion

The new approach serves as a better option for the city and City Power. It presents opportunities for informal settlements dwellers and will generate revenue for the organisation. It also helps the organisation in avoiding load shedding and use photovoltaic (PV) power supplied to the utility grid. Integration of PV power generation systems and gas for cooking it plays an important role in securing the electric power and gas supply in an environmentally-friendly manner.

The organisation should continue investigating the impact of gas in areas that pose any other health or safety hazard such as dump sites (chemicals). City Power is working hand in hand with housing to successfully implement the new approach. Based on the prerequisite factors prior to electrification of informal townships, housing is critical in address the following requirements (e.g. relocation of houses, access roads, land ownership negotiations time, etc.), City Power will be able to mobilise its land ownership negotiations time.

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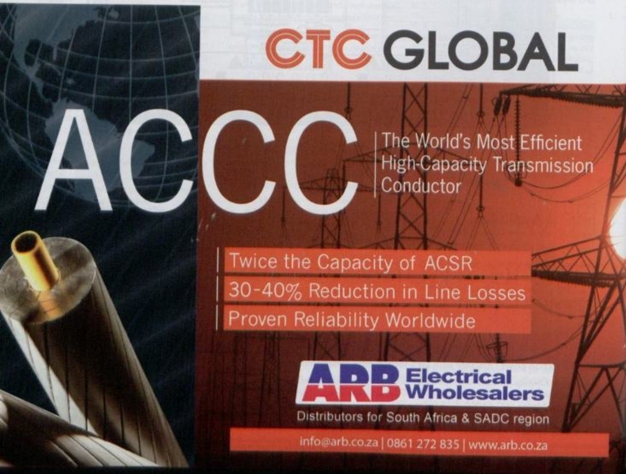

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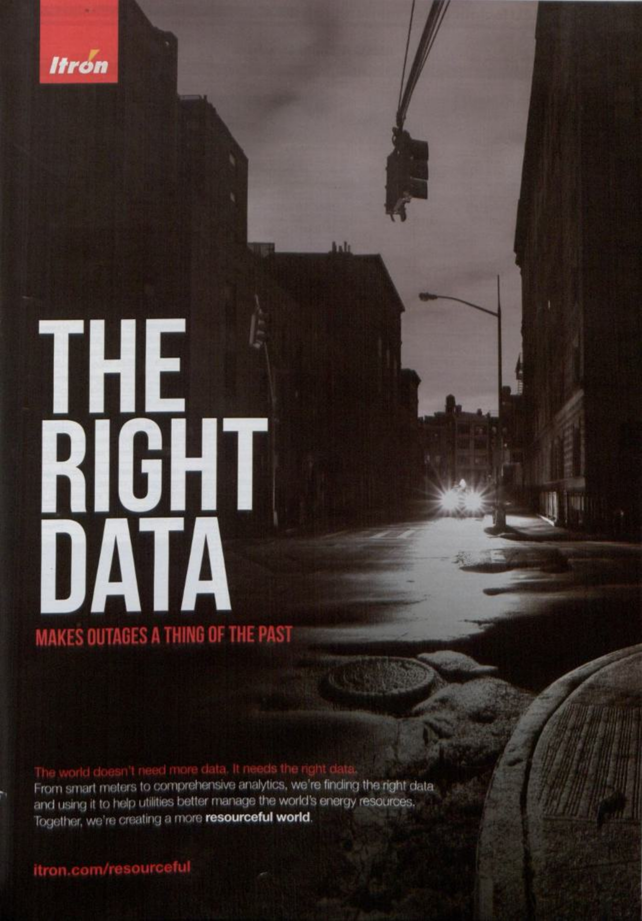
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Low life-cycle costs give concrete poles and masts the edge

South African municipalities and rail operators are making extensive use of prestressed concrete poles and masts manufactured by Aveng Infraset. The reason is quite simple. Low life-cycle costs and exceptional durability give precast concrete poles and masts a distinct advantage over other materials such as steel and timber.

Aveng Infraset poles and masts are being used countrywide, not only in rail and municipal applications, but in mining, private property development and industrial estates. They are manufactured to world-class quality standards in ISO 9001-2008 accredited factories in Gauteng, KwaZulu-Natal and the Northern Cape, and are available in a wide range of lengths, strengths and sizes. Designed to comply with most MV and LV line requirements, they also conform to Eskom's DTC 0106, various SABS and Transnet Freight Rail specifications.

Experience worldwide demonstrates that during their lifetime prestressed concrete poles are maintenance-free. Unlike other materials, concrete poles don't weaken over time and are resistant to insects, fire, rot and corrosion. The environmentally friendly nature of precast concrete also means that one is able to reduce the dependence on the use of hydrocarbons for treating timber poles used for similar applications. Concrete poles have no scrap metal value and are fire resistant.

Aveng Infraset prestressed concrete masts are being widely used for the replacement of steel rail masts for electrical overhead track equipment (OHTE) in the electrified railway environment not on only in coastal areas but also inland. The overall life-cycle costs, starting from construction cost savings and the long term maintenance savings make this an automatically viable alternative, especially when one considers the large capital investment and long term maintenance cost of owning and maintaining an electrified railway system.

For example, in the coastal areas of KwaZulu-Natal, the compnay has supplied prestressed concrete masts for the replacement of corroded steel masts on several sections of track. These include a ±30 km rail link between Mtunzini and Empangeni where 1235 masts were supplied to Transnet Capital Projects to support the OHTE systems on the line. Similar projects have and are being undertaken in the Richards Bay area.

Prestressed concrete masts have also been used by Transnet Freight Rail for the installation of a supplementary electricity feeder system to boost the power supply to the overhead track line on the Saldanha/Sishen ore line. As a section of the line runs adjacent to the Atlantic between Strandfontein and Saldanha, where sea spray quickly corrodes anything made of steel, the inert properties of prestressed concrete poles are especially valuable. In the drier, inland environment between Kimberley and De Aar, prestressed concrete masts are being used for the double line section of the Transnet Freight Rail network.

In addition, their high strength-to-weight ratios places them in a class of their own.

Aveng Infraset's prestressed concrete poles have been successfully deployed for medium and low voltage reticulation for major municipalities throughout the country such as City Power, EThekwini, Ekurhuleni and the Nelson Mandela Bay Metro. Most recently, Telkom in the KwaZulu-Natal region, has installed several poles to replace problematic support structures previously used for their fixed line telecommunication distribution network.

In the greater Gauteng area, many housing projects have been supplied with prestressed I-shaped poles by Aveng Infraset, some of which include: Fleurhof in Roodepoort (3000); Windmill Park Ext 16 and 17 in Boksburg (248); Palm Ridge, a township situated close to Katlehong (533); and Winnie Mandela Park in Tembisa (1000). Moreover, over 15 000 concrete poles have been used by the eThekwini municipality for the electrification of various townships. Although the programme is still being rolled out, concrete poles were first supplied for the electrification and street lighting of Illovo as long ago as 1994/5.

In Springs, the Ekurhuleni Metropolitan Municipality has replaced vandal-prone steel street-lighting poles with over 800 prestressed I-shaped concrete poles.

Mothemane Makhura, Aveng Infraset, Product Manager, Aveng Infraset, advises that poles and masts are designed for different ultimate loads depending on the strength and length required.

"However, we always manufacture them to guarantee maximum strength and this takes the guesswork out of line design," he adds. "We don't really just sell prestressed concrete poles, we do pre-construction training, advise on best practice stacking, handling and transportation, on site construction advice and... actually we sell sustainable solutions", he says.

OHTE masts manufactured by Aveng Infraset recently installed on the Transnet line between Bridge City and KwaMashu in KwaZulu-Natal.

The Brakpan/Springs road where vandal-prone steel street-lighting poles have been replaced with prestressed concrete poles.

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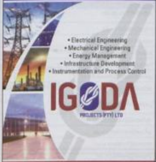

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RWW Engineering	Kyle Loss	011 433-8003	kjloss@rww.co.za	P O Box 2042, Southdale, 2135	Highveld
SABS Standards Division	Willa Breed	012 428-6613	willa.breed@sabs.co.za	Private Bag X191, Pretoria, 0001	Highveld
Schneider Electric	Brighton Mwarehwa	011 254-6400	brighton.mwarehwa@schneider-electric.com	1 Riverview Office Park, Janadel Avenue, Midrand, 1685	Highveld
Sectional Poles	Morne van Zyl	012 348-8660	morne@sectionalpoles.co.za	P O Box 17028, Groenkloof, 0027	Highveld
Siemens	Rodney Swartz	011 652-2306	rodney.swartz@siemens.com	300 Janadel Avenue, Halfway House, 1685	Highveld
Siyaphambili Electrical & Industrial Supplies	Imtiaaz Kader	021 981-8556	bksei@absamail.co.za	Unit B25, Icon Business Park, Brackenfell, 7560	Good Hope
SMEC SA	Andre van der Walt	012 481-3800	andre.vanderwalt@smec.com	P O Box 72927, Lynwood Ridge, 0040	Highveld
Solartricity	Jon Kincaid-Smith	011 548-7400	jon@ikat.co.za	Private Bag X138, Bryanston, 2125	Highveld
Solethu Energy	Neil Morris	021 530-8060	neilm@solethuenergy.co.za	P O Box 109, Eppindust, 7405	Good Hope
Specialist System Engineering	Gert Bezuidenhout	012 663-4331	gbez@sse.co.za	P O Box 7170, Centurion, 0046	Highveld
Spectrum Communications	Kevin Clack	021 551-5800	kevin.clack@spectrumcom.co.za	P O Box 36900, Chempet, 7442	Good Hope
Spectrum Utility Management	Gustav Kritzinger	012 991-3122	gustav@sutility.co.za	P O Box 38525, Faerie Glen, 0043	Highveld
Speedcraft Manufacturing	Melba Nzimande	033 397-5400	melba.nzimande@pfisterer.co.za	P O Box 4004, Pietermaritzburg, 3200	KwaZulu Natal
Spintelligent	Claire Volkwyn	021 700-3500	claire@spintelligent.com	P O Box 321, Steenberg, 7947	Cape Midlands
Spintelligent	Ricky Asher	021 700-3500	ricky.asher@spintelligent.com	P O Box 321, Steenberg, 7947	Good Hope
Static Power (a div. of Actom)	Nichola Fort	011 397-5316	nichola.fort@static.co.za	P O Box 13424, Witfield, 1467	Highveld
Switchboard Manufacturers	Shane O' Reilly	031 508-1520	shaneo@switchboard.co.za	P O Box 40086, Red Hill, 4071	KwaZulu Natal
Syntell	Julia Williamson	021 710-2044	julia@syntell.co.za	P O Box 30298, Tokai, 7966	Good Hope
Tank Industries a Division of ATC	Adriaan Theron	021 700-4380	adriaan.theron@tank.co.za	P O Box 9, Steenberg, 7947	Good Hope
Terrapinn	Tanya Boretti	011 516-4031	tanya.boretti@terrapinn.com	Private Bag x65, Bryanston, Johannesburg, 2021	Highveld
TGOOD Africa	Kobus Coetzer	011 064-1603	penny.alberts@tgood.com	140A Kelvin Drive, Morningside Manor, Sandton, 2146	Highveld
The Electrical Contracting Board of SA	Tony McDonald	012 804-9652	info@ecbsa.co.za	P O Box 912479, Silverton, 0127	Highveld
Thytronic S.p.a	Ivica Debeljkovic	011 787-3835	ivica@dipro.co.za	P O Box 131, Hurlingham View, Johannesburg, 2070	Highveld
Tisetso Dev Solutions	Popo Joda	082 543-4977	popo@tisetsodev.co.za	P O Box 1923, Johannesburg, 1610	Highveld
Tronsfix Transformers SA	Shannon Vraagom	051 534-1651	sales01@groupe-cahors.co.za	P O Box 5061, Botshabelo, 9781	Free State
Tridonic SA	Trevor Milne	011 923-9694	trevor.milne@tridonic.co.za	P O Box 30542, Jetpark, 1469	Good Hope
Ulungeni Consulting	Gerrie Breedt	035 792-1026	gerriebreedt@mweb.co.za	P O Box 1521, Empangeni, 3880	KwaZulu Natal
Universal Cables	Rudi Labuschagne	011 769-1394	sales@universalcables.co.za	P O Box 21335, Helderkruin, 1733	Highveld
Utilabs	Paroshen Naidoo	011 805-0094	paroshen.naidoo@utilabs.com	20 Thornhill Office Park, 94 Bekker Road, Midrand, 1685	Highveld
VAMP Solutions	Rodney Bristow	011 818-2190	rbristow@vamp.co.za	P O Box 11798, Selcourt, 1567	Highveld
Verotest	Veronica Merry	011 805-8322	office@verotest.co.za	P O Box 50559, Randjiesfontein, 1683	Highveld
Voltano	Marius Schwartz	087 805-5218	marius@voltano.com	Postnet Suite 293, Private Bag X1007, Lyttelton, 0140	Highveld
Voltex t/a Voltex Cape	Shawn Roets	021 530-3460	shawn@voltex.co.za	P O Box 291, Maitland, 7404	Good Hope
Woodbeam	Blaize Magee	0861 966-323	blaize@woodbeam.co.za	P O Box 526, Modderfontein, 1645	Highveld
WorleyParsons RSA	Durr Pieters	021 912-3000	durr.pieters@worleyparsons.com	P O Box 398, Bellville, 7535	Highveld
WPI Power Solutions	Alaric Pagel	012 666-8904	alaric@wpi.co.za	P O Box 635, Wierda Park, 0149	Highveld
YeboTech	Grant Martin	021 713-7260	grant.martin@yebotech.com	P O Box 30761, Tokai, 7966	Good Hope
ZEST Electric Motors	Russell Finch	011 723-6000	russellf@zest.co.za	Private Bag X10011, Sandton, 2146	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	IJ Nocholas	Umtata
1944 – 1945	A Rodwell	Durban
1945	JS Clinton	Harare
1945 – 1946	JW Phillips	Harare
1946 – 1947	GJ Muller	Bloemfontein
1947 – 1948	C Kinsman	Durban

Date	Name	City
1948 – 1949	A Forden	East London
1949 – 1950	DA Bradley	Port Elizabeth
1950 – 1951	CR Halle	Pietermaritzburg
1951 – 1952	JC Downey	Springs
1952 – 1953	AR Sibson	Bulawayo
1953 – 1954	JC Fraser	Johannesburg
1954 – 1955	GJ Muller	Bloemfontein
1955 – 1956	DJ Hugo	Pretoria
1956 – 1957	JE Mitchell	Bulawayo
1957 – 1958	JL van der Walt	Krugersdorp
1958 – 1959	CG Downie	Cape Town
1959 – 1960	R Wcane	Johannesburg
1960 – 1961	RMO Simpson	Durban
1961 – 1962	C Lombard	Germiston
1962 – 1963	PA Giles	East London
1963 – 1964	JC Downey	Springs
1964 – 1965	RW Barton	Welkom
1965 – 1967	D Murray-Nobbs	Port Elizabeth
1967 – 1969	GC Theron	Vanderbijlpark
1969 – 1971	HT Turner	Umtali
1971 – 1973	JK von Ahlften	East London
1973 – 1975	JC Waddy	Pietermaritzburg

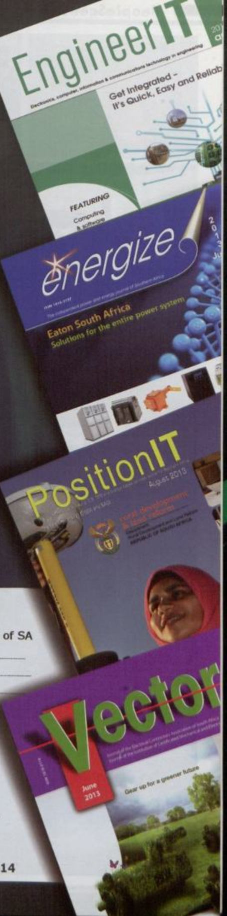
Date	Name	City
1975 – 1977	E de C Pretorius	Potchefstroom
1977 – 1979	KG Robson	East London
1979 – 1981	PJ Botes	Roodepoort
1981 – 1983	DH Fraser	Durban
1983 – 1985	W Barnard	Johannesburg
1985 – 1987	JA Loubser	Benoni
1987 – 1989	AHL Fortman	Boksburg
1989 – 1991	FLU Daniel	Cape Town
1991 – 1993	CE Adams	Port Elizabeth
1993 – 1995	HR 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	JJ Roos	Ekurhuleni

AMEU Honorary Members

Period	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
1955	W Ballad-Ellis
	JC Fraser
	C Kinsman
1956	WH Milton
	A Morton Jaffray
	Major SG Redman
	Clr. CEK Young
1957	DA Bradley
1958	Col. GG Ewer
	A Foden
	Clr. Halley
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
1969	W Beesley
	PA Giles
	D Murray-Nobbs
	EL Smith

Period	Name
1971	DJ Hugo
	ACT Frantz
	HT Turner
	R Leishman
	RMO Simpson
	W Rossler
	F Stephens
	JF Lategan
1973	RG Ewing
1975	Clr. HG Kipling
	C Lombard
	DC Plowden
	JG Wannenberg
1977	Dr. RL Straszacker
	AA Middlecote
	GC Theron
	JC Waddy
1979	RW Barton
	Clr. HJ Hugo
1981	JDN van Wyk
	Dr. RB Anderson
	J Morrison
1983	TC Marsh
1985	AA Weich
	KG Robson
	Clr. RL de Lange
	W Barnard
1987	AP Burger
	JC Dawson
	DH Fraser
	PC Palser
1989	PJ Botes
	MPP Clarke
	EG Davies
	JA Loubser

Period	Name
1993	FLU Daniel
	JE Heydenrych
	B van der Walt
1995	CE Adams
	B Madeley
1997	JD Algera
	HR Whitehead
	F van der Velde
1999	JG Malan
	CE Burchell
2003	AJ van der Merwe
2005	PE Fowles
	T van Niekerk
	J Ehrich
2007	DET Potgieter
2008	V Padayachee
2009	S Maphumulo
	JJG Nel
2010	O Bothma
	JE Coetzee
	RS Wallis
2011	M 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



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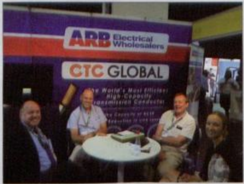
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