Evolution of future electrical network in Eskom

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Technology Strategy and Planning: Eskom research

Abstract

The electrical network will undergo several changes over the next few years. The development of new technologies would support the existing network and provide business with tools to improve their present processes and operations. Eskom are assessing several technologies with specific focus on leveraging the benefits of existing assets. The deployment of renewable energy technologies needs to be made with a strategic framework on value creation for the business. Through research and evaluation of new technologies the utility can make decisions to determine the most effective solutions for the business. Due to the large investments required for deploying the future grid it becomes an incremental process driven by different needs in the business.

1. Introduction

Eskom the South African electricity utility is facing a diverse range of social and economic challenges. This is hampering business progress and infrastructure growth, which are elements key to the long term sustainability of the utility. The key to having a sustainable business is the alignment of processes and technologies to meet the demands of present and future network uncertainties. Success will depend largely on the optimal use of assets and strategic investments.

Challenges Eskom faces include corporate social responsibility issues (like managing carbon emissions) and ensuring world class service delivery to key customers. The electricity system of the future needs to deliver high levels of customer service through providing reliable, accessible and flexible means to

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meet the changing demands from our customers. At the same time, Eskom needs to manage the consumption of electricity.

Traditional electrical networks deliver power through transmission systems which actively control the supply and demand process. The future of the electrical network will include renewable energy source from both the supply side and distribution side. Generation sources will essentially fall behind the customer's meter. This would mean the future distribution network would have to be controlled actively. Essentially a distribution system operator controlling distributed generation on the network

Smart grid development is a global initiative in power engineering. The purpose of smart grids is to ensure that utilities start to provide a future systems architecture that will integrate all of the processes and systems required for a highly intelligent electricity network. The benefits of smart grids can be realised through the right investments by choosing appropriate technologies to meet business needs.

As Eskom embarks on the development of new power stations what remains crucial is the sustainability of the existing electrical network. The strategic choice of renewable energy and smart grid technologies will ensure that Eskom has a future network that will utilize its existing potential and be supported by new emerging technologies.

2 Challenges going into the future of electricity provision

The present electrical network faces many challenges. Electrical networks been designed with the purpose of providing electricity to the end consumer. Supporting technologies are growing to ensure that the system is no longer just an end to end connection from generation to the consumer but a more intelligent system managed by data flow within the different processes.

The present electrical network is limited by design and cannot provide the intelligence required to fully develop into a smart grid. Eskom's electrical network is supported by an interconnected telecommunication infrastructure which has both EMS and DMS functionality. This provides control and supervisory to the electrical network with SCADA.

The electrical network has only one interface with the customer - metering. The purpose of the existing metering system is to collect energy consumption data. This data is used for billing and basic load and forecasting analysis. There is a gap between what is required to have fully integrated intelligent connectivity with the customer and the electrical network. The data network at present is limited. It does not provide bi-directional information about energy consumption patterns, which can be utilized for better decision making.

The constraint on the existing energy generation capacity and social pressure to replace or carefully manage aged existing infrastructure are further challenges in the South African energy market. Access to funding for these projects is a key issue. With global trends showing an increase in the cost of producing energy (specifically dormant with the higher costs of producing energy from renewable resources), Eskom needs a significant revenue injection to ensure that any build programmes can be supported.

The global warming crisis adds further pressure to Eskom to reduce its carbon footprint. Each plant needs to reassess the way in which processes are managed.

It is clear that a holistic view is essential in steering the business forward in terms of managing assets responsibly, in a timely manner and with limited resources. The fundamental issue is deciding how Eskom should address these short comings and improve the present infrastructure to support growing demands.

3. Future Energy sources impact on electrical network

PV systems

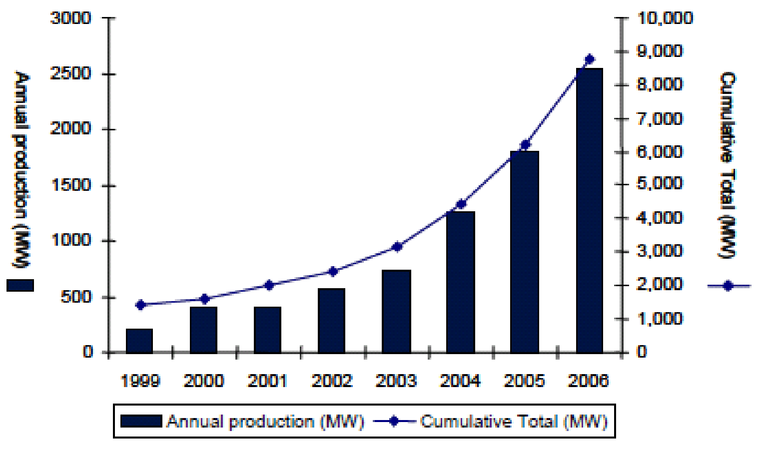
The largest source of energy is from the sun. Solar energy equates to over 700m TWh of energy spread over the earth in a year. This equates to over 14000 times more energy that we presently consume as a year. Photovoltaic are solid state silicon devices that absorb photons of energy to energize and electron to produce a current.

Table 5.13: Annual solar cell production and cumulative capacity (MW), 1999-2006

	Annual production (MW)	Cumulative Total (MW)
1999	202	1,405
2000	395	1,607
2001	401	2,002
2002	562	2,403
2003	742	3,145
2004	1,256	4,410
2005	1,815	6,216
2006	2,536	8,752

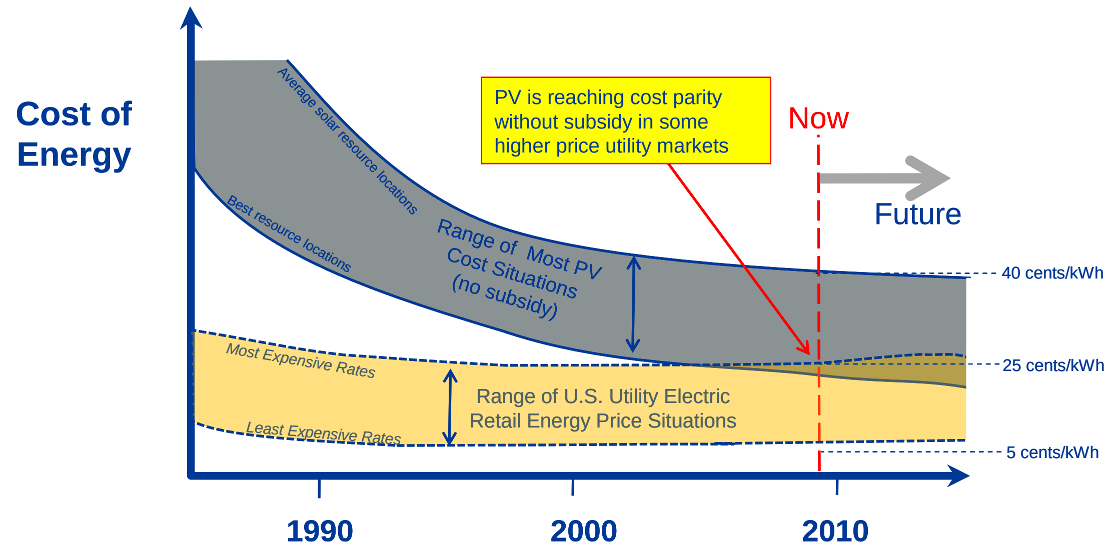
Source: Photon International, Business Insights[35] Business Insights Ltd

Figure 5.2: Annual solar cell production and cumulative capacity (MW), 1999-2006

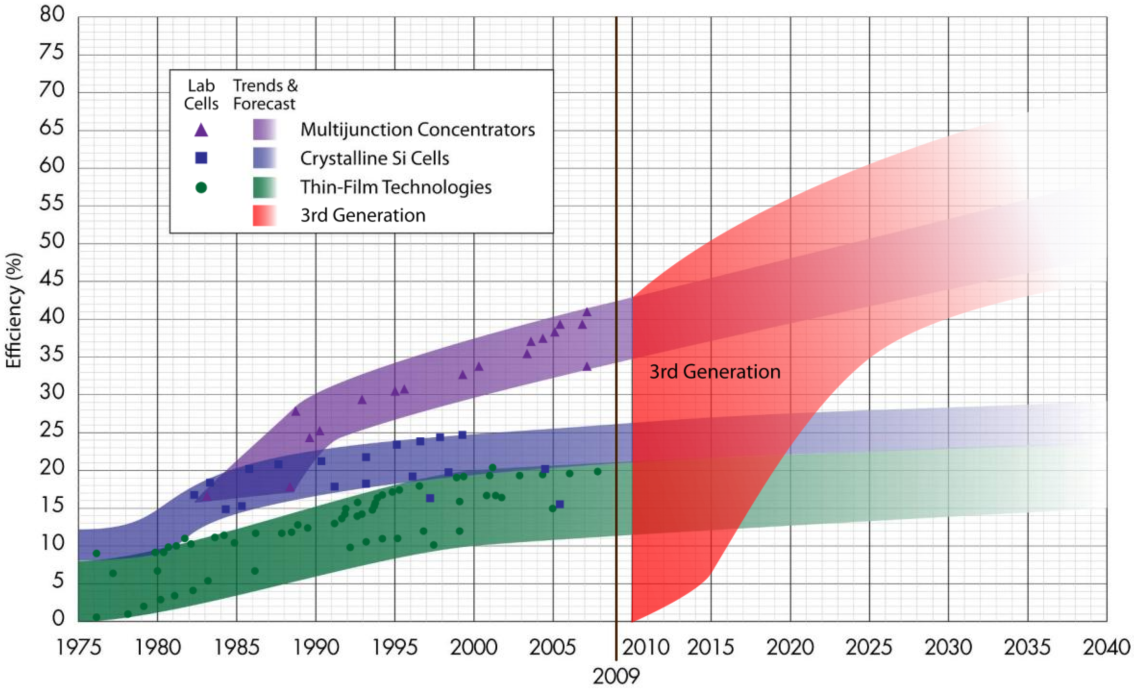


Source: Photon International, Business Insights Business Insights Ltd

PV will eventually reach a point where it becomes cost effective to use as a technology for both as large scale implementation and particularly becoming a effective source of energy as a distribution power sources. The trend in PV systems show the cost of energy of PV are soon starting to reach a point that the cost per kWh is starting to reduce dramatically and eventually reach a “ignition” point where PV becomes a viable option.

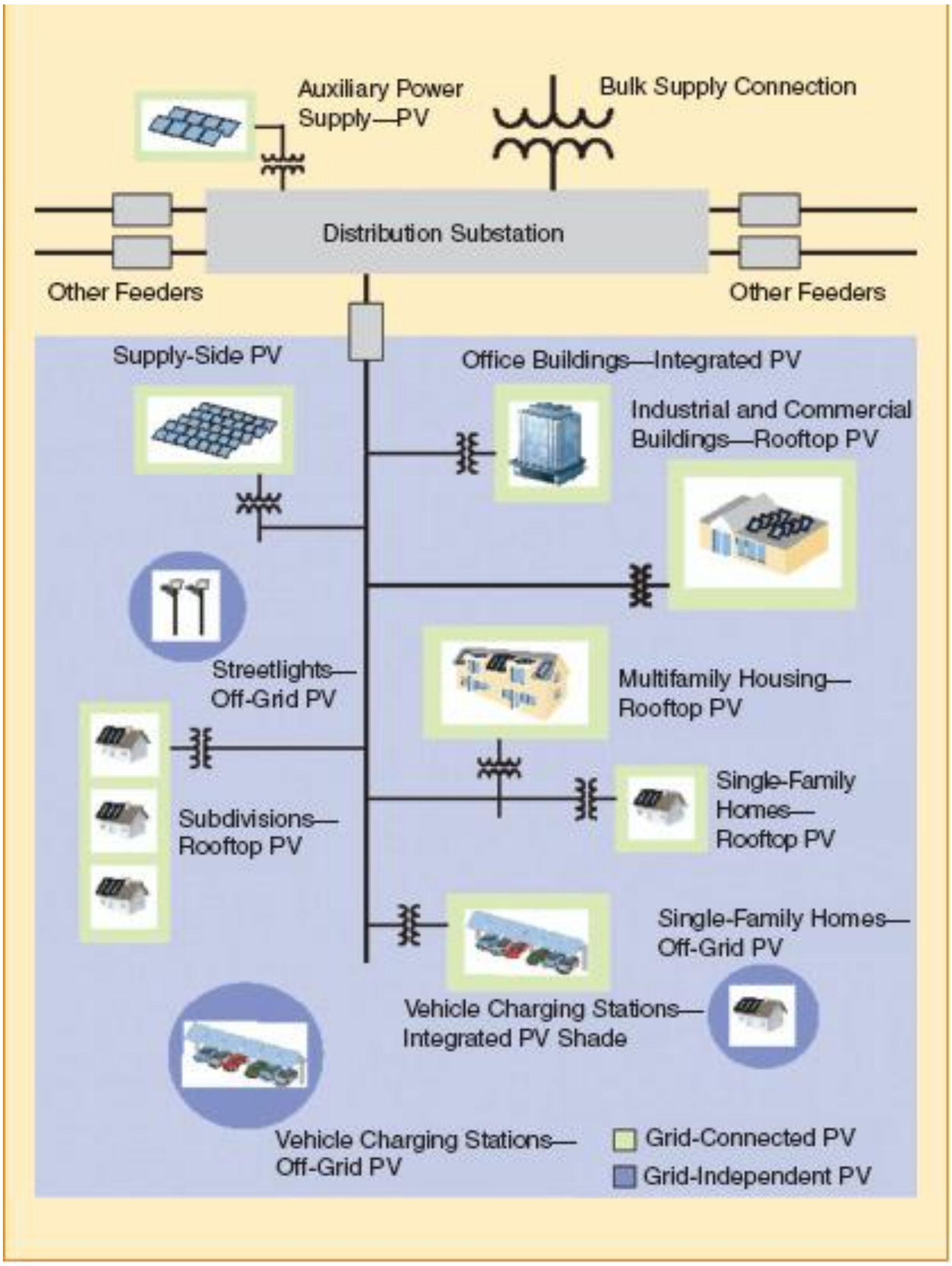


The trends in the utility industry show that it has become essential for utilities to be proactive on the opportunities for PV systems. As a business the large portion of customers are at risk moving towards PV systems. The efficiency of PV systems is improving as the development of the technology to new third generation cell systems starting to show efficiency of over 40%. The increase cost of energy would put utilities under pressure as a new market will be created for PV systems installed at home and thus the loss of markets share. The electricity industry is evolving and will become competitive in nature with the risk that utilities will have to create value proposition for consumers specifically in the residential sector.



Traditional solar cells are made up of silicon however the science in the area of semiconductors show that newer materials are being developed which operate at better levels of efficiencies. The PV is essentially an array of cells commonly known a solar panel usually rated between 5W to about 200W per panel. The power produced is DC in nature and converted to ac through and electronic inverter. These are usually deployed on rooftops or as large arrays for utility sources of generation. Rooftop installations are growing in Japan Germany and California. These systems generate electricity during the day and use some form of energy storage (batteries). The distribution network will evolve and result in new challenges as we start to integrate intelligent technologies and renewable energy on the distribution side of the network.

The basic functionality of the distribution network is to ensure the utility supply a stable voltage and frequency and coping with the demand needs while maintaining an acceptable level of power quality. The diagram below depicts a possible picture of electrical network in the near future.


Auxiliary Power Supply—PV
Bulk Supply Connection
Distribution Substation
Other Feeders
Other Feeders
Supply-Side PV
Office Buildings—Integrated PV
Industrial and Commercial Buildings—Rooftop PV
Streetlights—Off-Grid PV
Multifamily Housing—Rooftop PV
Subdivisions—Rooftop PV
Single-Family Homes—Rooftop PV
Single-Family Homes—Off-Grid PV
Vehicle Charging Stations—Integrated PV Shade
Vehicle Charging Stations—Off-Grid PV
Grid-Connected PV
Grid-Independent PV

Evolution of future electrical networks

Traditional distribution systems have flow of electricity from the transformer through a transmission or distribution network to consumers . Networks are either radial or ring systems and the flow is in one direction to the consumer. Once PV or any other source of generation is added to the distribution network there is a potential to change the flow and thus change the complexity of the network. The interesting situation arises when there is more generation capacity on the network from the consumer side compared to what the demand is at that moment. This would result in net flow back into the network which traditional systems are not designed to manage. This may affect the voltage levels and may increase voltages beyond acceptable levels.

When distribution networks become active the way the distribution network is controlled becomes a new challenge. Traditional SCADA systems operate to monitor and control the passive network and not power flow. In order to maintain stability on the network the “Distribution System Operator” would need to control and balance the network. As the equipment such as PV is owned by the consumer the distribution network provider would need to have some form of energy storage to control and have ability to absorb power from renewable sources which could be used on the power system for balancing when the need arises.

The benefits however are huge when it comes to present and future demand constraints. The dispersed range of distributed generation would support the system operator nationally in managing the reliability of the network by controlling the peaks and daily load management. The grid of the future is thus changing to a more intelligent system. This gives rise to ‘Smarter’ electrical networks. The Source of power has largest impact on distribution networks when embedded directly on the distribution networ

3. The Grid of the future

What is it?

Several definitions exist on smart grids but they essentially all have the same meaning. Eskom's perspective on smart grids is summarised as follows:

"*Intelligence built into the existing electrical network to provide visibility, automatic control and intelligent decision making over the entire electrical architecture from generation to the end user*"

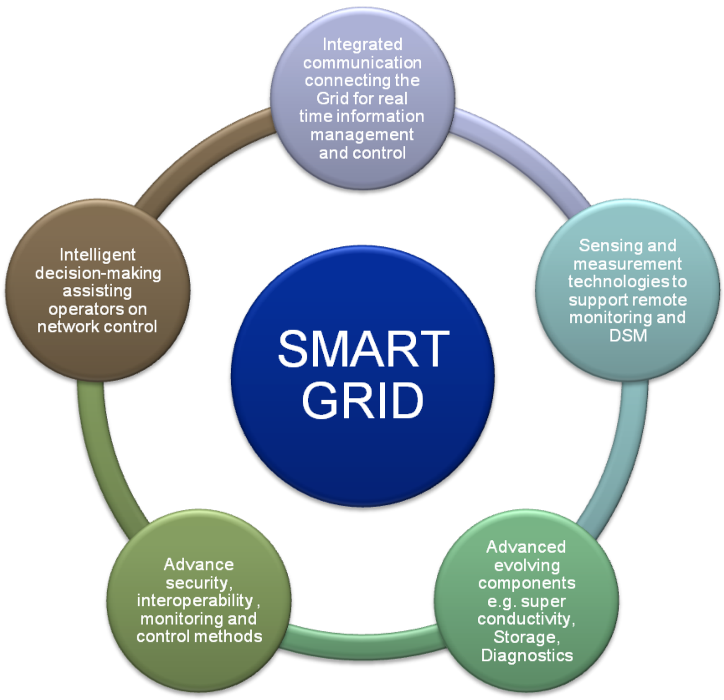


Figure 1: The elements of a smart grid

Benefits

It is important to note that although smart grid is a basket of potential technologies, it delivers more than just advanced technology to the business. The benefits include network optimisation, increased asset lifecycle, better interfacing with customer, improved reliability of network, and flexibility and adaptability by intelligent decision making.

The full benefits of smart grids can only be realised through proper planning, design and strategic implementation. There are two fundamental blocks to ensure that a smart grid has a future in South Africa.

- Supporting telecommunication infrastructure and IT systems.
- Strategic business model for utilizing the right technologies.

Despite all the benefits of transitioning to smart grid, it would not be viable for Eskom to deploy all smart grid type technologies. Technologically, the existing electrical network can be made smart, but financially it may not be viable, since the implementation of a smart grid would require a large capital investment.

The business needs to make a strategic decision on what technology is applicable for the business. The value gained from implementing smart grid technologies must have a considerable benefit to the business and needs to demonstrate value to the customers. The figure below illustrates the difference between the present and future grid.

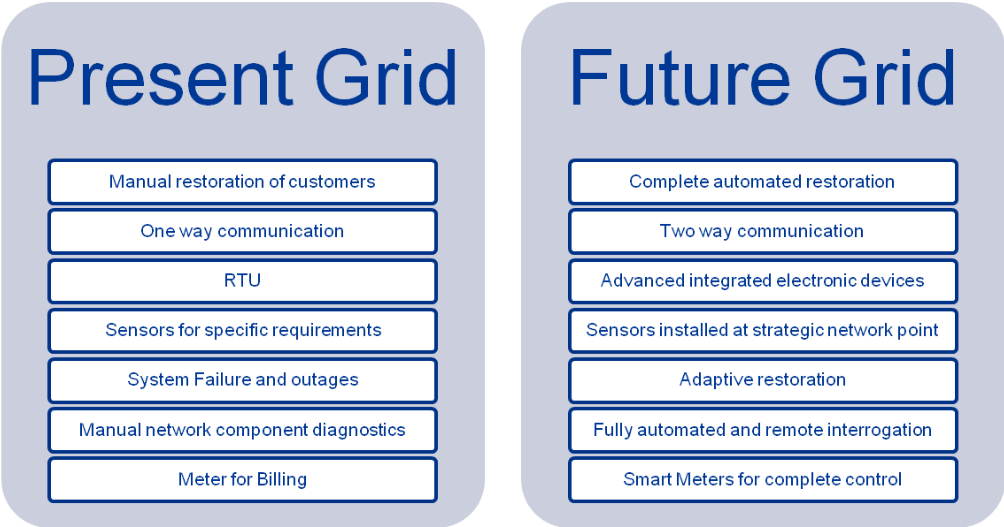


Figure 2: Present grid versus future grid, outlining intrinsic benefits

Technology exists to address and optimise business processes. By providing enabling applications that would provide asset management across the entire value chain, the smart grid can aid the electrical network. The smart grid is a process underlying the network – it is an ecosystem supporting the different business operations by improving its present functionality and increasing the reliability of the network.

Eskom and Smart Grids

The development of smart technologies is relatively new and several key issues need to be resolved within the different standards for interoperability. The level of risk is low as huge investments are made internationally on defining standards for interoperability between different vendors and technology concepts.

As Eskom would be a fast follower of these technologies it would assess those which are applicable and whether they make business sense before implementation.

4. Transition from today's grid to the future grid

The grid as we know it today will be very different in the next 15 years. This is largely due to the push of new technologies in the market place. It is also due to customers demanding a more efficient, reliable electrical network that can assist the customer in managing his consumption.

The transition from present network will largely depend on the deployment of an integrated communication platform. The platform would create the support required to exchange data in real time between plant devices, customers and intelligent software analysing the network.

The grid as we know it today is a combination of legacy technologies and new innovative applications which are used to control and manage the electrical network. Eskom's network is controlled by Energy Management System (EMS) at system operator level and Distribution Management System (DMS) at an operational level. These technologies assist in managing the electrical network in terms of supervisory control and data acquisition. Eskom also has several technologies adding more intelligence to the network. These are presently being implemented and tested. The figure below describes the present initiatives

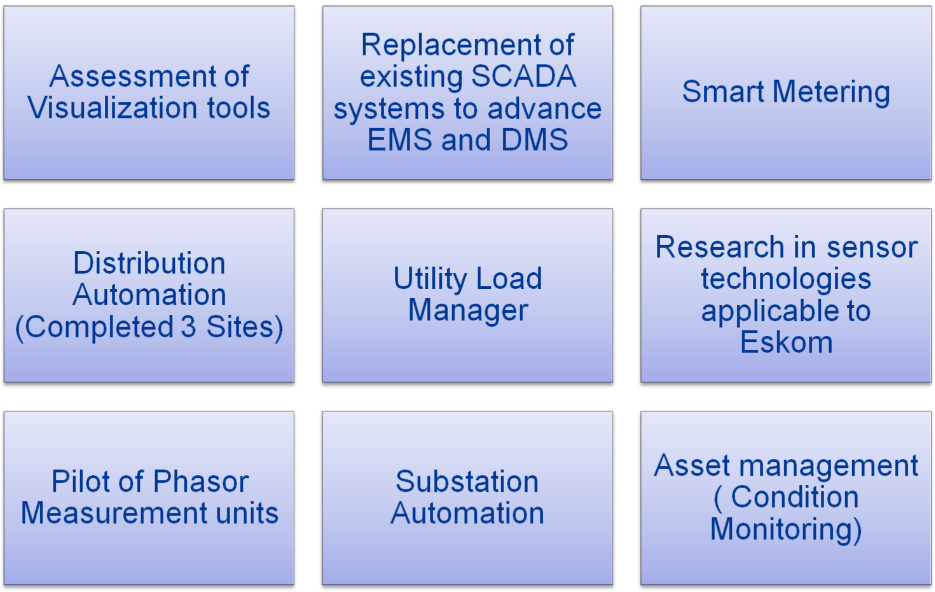


Figure 4: Some of Eskom's current technology initiatives

Figure 4 describes technologies which are components of the future system architecture. All of these are being tested and implemented. The intention of the testing is for Eskom to have an appreciation for the potential of the technology – the research process will ensure close evaluation and in depth analysis – before implementation on a larger scale to the rest of the electrical network.

There is a risk in implementing technology. Research will be responsible to manage the process to evaluate the different technologies.

One of the key challenges facing Eskom is to reduce the overall demand on the grid. This can be achieved through two channels

- Technology intervention
- Communication and marketing

The consumer of energy plays a vital role in the value created by smart grid. The first step for Eskom in terms of a technology intervention is to understand customer behaviour and usage patterns. Eskom has embarked on two strategic projects to establish a data network between Eskom and it customers. These technologies include the rollout of Advance Metering Infrastructure (AMI) and the utility load manager, both subsets of smart grids. AMI solution for Eskom customers is to encourage demand management and promote energy efficiency. The focus of the proposed implementation is in a phased approach to Eskom's qualifying customers whose average monthly consumption is in excess of 1000KWh. A target of 10 000 qualifying customers installation is intended for the first phase and the remaining qualifying customers in subsequent phases allowing customers an AMI solution with Time of Use (ToU) and supply capability control.

The future grid however will need to increase its grid efficiency to ensure optimal operations on managing the electrical grid in real time. The advancement of different sensor technologies will find its space within the electrical network for monitoring and control of the grid at a lower intensive. Eskom is presently evaluating the potential options of different sensors technologies. These will provide nodes into the grid for predictive situational analysis, assessment of assets and early warning systems to model the impact if subtle changes on the electrical parameters of the network.

A flexible AC transmission system support power flow and is now mature technology for higher power ratings with several applications in the business. This is becoming more important with the increase in distances of transmitting power at higher voltages. The technologies provide benefits of improving the voltage quality and increasing the stability of the electrical network. By correct application of SVC, series capacitors and deployment of new compensation technologies would allow for better voltage and reactive power control. These technologies supported by different sensor applications with provide real time information, modelling and providing optimized grid control. Phasor measurement units and wide area measurement are critical components of the smart grid from the perspective of grid control which provide grid dynamics for improving the stability and reliability of the network.

5. Enabling technologies for Smart grid applications

The future of smart grids lies in applications for the different business areas. The three essential areas of the utility is Distribution, Transmission and the customer. Various applications would provide the business with specific tools to deal with present issues both operational and strategic which affect the business. The table below highlights some of the applications that are essential for improving different areas of the business. It reflects some of the key areas that will need focus in Eskom presently and in the future.

Technology	Benefit	Key receivers
Variable frequency transformer	• Power transfer between non synchronized grids • Power transfer not interrupted when part of the grid experiences disturbances • No harmonics	Transmission
Phase shifting transformer	• Control active power flow	Transmission
Automatic capacitor switching	• Remotely configured for voltage support on network	Transmission and Distribution
Synchrophasor Technology	• High sample rate to measuring electrical quantities • Validating the operational models. • measurement of stability margins • system-wide disturbance monitoring	System operator
Condition monitoring technology	• Transformer monitoring • Circuit breaker monitoring • Hot spot monitoring • Overheard lime monitoring	Transmission and Distribution
Distribution and substation automation	• Improve restoration times • Performance improvement SAIDI/ SAIFI • Asset management	Transmission and Distribution
Advance metering	• Energy management • Demand response • Energy theft • Temper detection • Usage managements (appliances)	Business Value chain, DSM, Planning, revenue protection

6. Challenges in implementation of Smart Grids

Smart grids are being phased into the future of all electrical networks, internationally. The benefits will add value towards a more intelligent network but the actual implementation and transition could pose serious difficulties within the South African context. There is a clear need to improve the existing infrastructure in order to meet the demands of the future. This, however, needs a clear strategic framework. The biggest constraints are cost of deployment and adequate resources. From a business perspective, it is only viable to implement technologies which have already indicated an improvement in business performance. This, however, becomes a challenge as old legacy systems cannot always be retrofitted with new technologies and may need and entire technology solution.

The future electrical network will run as an IT system managing and controlling the data from Eskom Generation to the end user. Complex data and information processing will pose a real challenge in ensuring interoperability of different vendors as well as the ability to derive value from the data. The processing required and the supporting telecommunication backbone are two essential components of the smart grid. The present cost of telecommunication in South Africa is relatively high. The implication of deploying advance information architectures need to be clearly understood from a business perspective, before next steps are taken.

Although most technologies are in the development phase, it would be prudent for the business to take an approach of implementing a technology only once it has sufficient market penetration. This allows for controlled risk when making large capital investments. The biggest impact is on the present business model and operations. A completely defined and implemented smart grid solution would change the entire value chain within the business. It would thus require extensive change management within the business and realignment of processes and functions.

With the world moving to cleaner energy sources the generation mix will now include multiple renewable energy sources. These technologies need to be understood clearly in terms of its impact on the electrical grid. Multiple stakeholders will also integrate into the bigger electrical network. The stakeholders will include municipalities, vendors, IPP and consumers who could also feedback energy back into the network. The multiple sources of energy lead to complexity in the stability of the network. This will require a detailed study on its implications towards the management of a smart grid.

In summary, the challenges foreseen by the utility are:

- Cost of deployment
- Multiple levels of stakeholders (Consumers, vendors, Munics, Utilities)
- Complexity of SMARTGRID and Transition from legacy systems
- Security of system
- Finalization of standards and interoperability
- Installation of “Smart” Equipment
- Communication systems to support SMART GRID
- Data management (collecting storing , analysing, validation, accuracy, updating
- Re-defining Utility Business Models and Incentives
- Consumer Adoption of Smart Grid Service

7. Conclusion

As Eskom embarks on the journey towards developing its future grid it need to realise the potential of its existing network and enhancing present functionality intrinsic in the network. Leveraging the benefits of existing assets by fully utilizing previous capital investments will provide the utility the value inherent in smart grid type technologies. The implementation of a smart grid is an evolutionary process which will require a fundamental shift in the way the business in managed. The incremental changes to the network can be achieved by identifying key strategic investments to provide better customer value. Through research and collaboration with industry partners a strategic fit can be achieved for Eskom. The investment will require a phased approach with a large focus on driving training and change management to achieve a network of the future.