Understanding the Benefits of the Smart Grid in Distribution Networks: eThekwini Electricity Case Study

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***Abstract*—Understanding the benefits of a smart distribution network for eThekwini Electricity is reported. The requirements of transitioning from a legacy distribution network towards a smart distribution network is derived by identifying the user requirements of a smart distribution network. A smart grid maturity model is applied as a management support tool that provides a common language and framework in the assessment of eThekwini Electricity's readiness to develop a smart network. A smart grid vision is used to consolidate the integrated development plan goals with smart grid drivers. The paper concludes by showing how good governance by various standards and regulations will play a significant role in successfully implementing a smart grid.**

***Index Terms*—smart distribution network, SGMM, technology deployment, smart grid**

I. INTRODUCTION

The transition from legacy distribution networks to smart grid distribution networks is due to availability and affordability of technologies in the market. A smart grid is about using technology to operate and control a distribution network smarter. Objectives of a smart distribution grid is to provide resilient, reliable, stable and secure electric power with self-healing capabilities [1]. The benefits of a smart grid on eThekwini Electricity distribution network includes but are not limited to, improving customer service, improved grid operations, introducing embedded generation, asset management and enhancing safety of employees as well as the public. Moreover, it addresses growing consumer requirements and expectations. eThekwini Electricity's main responsibility is to provide continuous and reliable power supply to it stakeholders.

II. DRIVERS OF A SMART DISTRIBUTION NETWORK

A. Problem Statement

Residential consumers are the force that drives our economy as well as the strongest political constituency [2]. A fast growing population has resulted in high demand of electricity worldwide. Aging electric infrastructure has led to distribution networks becoming harder to manage and more complex. Population growth and power systems operating at their full potential resulted in a need to look for alternative methods to generate electric power while maintaining reliability and stability in a power system. The growth of the City's economy is heavily dependent on eThekwini Electricity's ability to keep the lights on. To enhance the overall performance of the power system improved usage of existing infrastructure is required. Furthermore, the implementation of more reliable and value adding technology functions that directly address consumer needs are required to supplement this goal.

A smart network is normally defined as an electrical network that uses modern advanced information techniques, communication techniques, and computer science to improve energy efficiency, reliability of power supply, reducing impact to environment and reducing power loss on the network [3]. Intelligent Electronic Devices (IEDs) are needed. Distributed intelligence at different levels of the electrical grid integrate behaviour and actions of all users connected to it to realize the objective of efficient and reliable power delivery.

B. Benefits of a Smart Distrubution Network

The transition from legacy distribution networks to smart grid distribution networks is due to availability and affordability of technologies in the market. The smart grid is about using technology to operate and control a distribution network smarter. This allows for a better control, more efficient and resilient operation such that it improves safety and customer satisfaction. A smarter distribution grid will help eThekwini to realise the benefits in Table 1 [4]:

Table 1: Smart Grid Benefits [4]

Area	Utility	Consumer	Society
Improved Reliability	Reduced operational and capital cost	Improved level of service with fewer inconveniences	Reduction in cost ultimately help keeping the prices of goods and services lower than they would be otherwise
	Increased employee safety	Reduced out-of-pocket costs resulting from loss of power	Virtual elimination of blackouts
	Higher customer satisfaction		Improved infrastructure boosts economic development
Improved Economics	Opportunities to leverage its resources and enter new markets	Opportunity to interact with the electricity markets through home area network and smart meter connectivity	A more robust transmission grid will accommodate larger increases in wind and solar generation i.e. green energy.
	Improved cash flow from more efficient management of billing and revenue management processes	Downward pressure on energy prices and total customer bills	Downward pressure on prices — through improved operating and market efficiencies
	A flatter load profile will reduce operating and maintenance (O&M) costs	Increased capability, opportunity, and motivation to reduce consumption	Creation of new electricity markets — enabling society to offer its electricity resources to the market and creating the opportunity to earn a revenue stream on such investments as demand response, distributed generation, and storage
Improved Efficiency	Increase asset utilization and reduction in lines losses on both transmission and distribution	Increased capability, opportunity, and motivation to be more efficient on the consumption end of the value chain	Deferral of capital investments as future peak loads are reduced and more accurately forecasted through the combined efforts of consumers and delivery companies
	Reductions in peak load and energy consumption leading to deferral of future capital investments	Increased influence on the electricity market	Reduced consumption of kWh's through conservation, demand response, and reduced transmission and distribution (T&D) losses

Table 1 above highlights some of the advantages of deploying a smarter distribution network. The smart grid benefits incorporate distributed intelligence at all levels of grid by integrating behaviour and actions of all users connected to it. Therefore, smart networks ensure an efficient and reliable supply of power.

III. SMART GRID MATURITY MODEL (SGMM)

The original development of the SGMM which dates back to 2007, was initiated by a group of key electricity industry representatives in the United States of America (USA). SGMM is fundamentally a management support tool that provides a common language and framework; for defining key elements of smart grid transformation and helping utilities in developing a programmatic approach and to track their progress [5]. The SGMM is composed of eight domains and five maturity levels. A maturity progression defined in SGMM covers eight domains that are logical groupings of smart grid related capabilities and characteristics [7]

This initiative was taken by eThekwini Electricity with help from South African National Energy Development Institute (SANEDI). Figure 1 below represents the results of the assessment as well as aspirations.

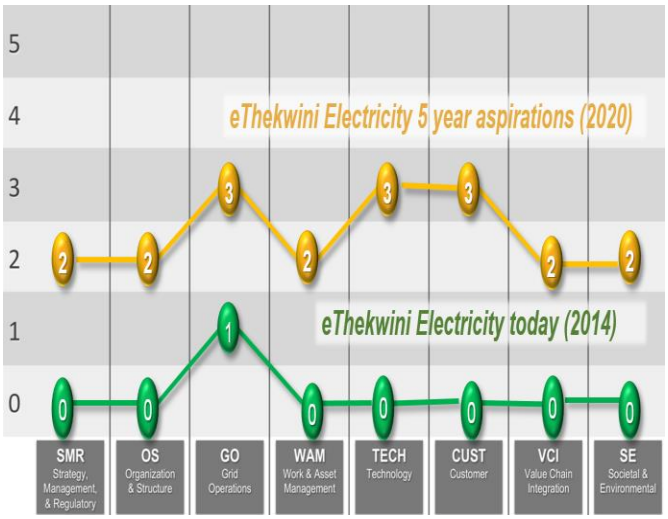

Figure 1: eThekwini Electricity SGMM Assessment [4]

The study was conducted using a first world management tool to assess a third world's country problems. This study is somehow not a true reflection of maturity of an African utility grid (eThekwini Electricity). A SGMM management tool need to be designed such that it addresses key third world country problems. It shall focus on Social Technical Economical Environmental and Political (STEEP) and benefit the local content.

IV. A SMART GRID JOURNEY

A. *eThekwini Electricity Smart Grid Vision*

In developing the smart grid vision for the utility, it was crucial to consider a few elements that would assist in this process [4]. The vision also needed to inspire and motivate the utility to push forward with vigour to achieve its objective of modernising its grid. Having an appreciation of what a smart grid looks like helps shape the thinking and inspire confidence in the utilities ability. These characteristics of a smart grid can be classified as follows:

a) Self-healing;
b) Resists attack;
c) Accommodates all generation and storage options;
d) Eco-sensitive;
e) Interconnected;
f) Affordable; and
g) Efficient.

The eThekwini Electricity smart grid vision for the distribution network is as follows:

"*It is to provide resilient, self-reliant, reliable and sustainable grid, enabling instantaneous access to customer and grid information [4]".*

B. *eThekwini Electricity Smart Grid Strategy*

eThekwini Electricity has implemented, and is implementing, various projects with the aim of improving the smartness of the grid and managing the grid more effectively [4]. The approach currently would seem to be fragmented. Hence, the need to consolidate all efforts to achieve a common objective. The smart grid strategy document contains all the projects within the unit that covers smart grid related issues.

The eThekwini Electricity smart grid strategy document covers initiatives and milestones to modernise the grid. These objectives includes improved asset management as well as improve customer satisfaction and participation. Moreover, to also improve reliability, efficiency, security, safety, observability and control of the network by implementing technology based solutions [4]. This is set to assist the city with improving service delivery and address Integrated Development Plans (IDP) goals.

In recognition of the City's IDP which serves as a strategic driver for the delivery of services as a municipality and understanding the views of Utilities from around the world, eThekwini Electricity undertook its own survey to understand what the motivating drivers are in moving towards achieving a smart grid. Below are the top five smart city as well as smart grid drivers [4];

a) Improving operations awareness
b) Improving safety
c) Reducing theft, peak demand and unmetered losses
d) Improving system reliability
e) Customer participation and choice.

The motivation for achieving a smart grid is crucial however, but cannot be viewed in isolation. Successful achievement of a modernised electrical grid needs to feed into the achievement of the City's vision of being Africa's most liveable city. Figure 2 present how these motivating drivers link with the city's IDP.

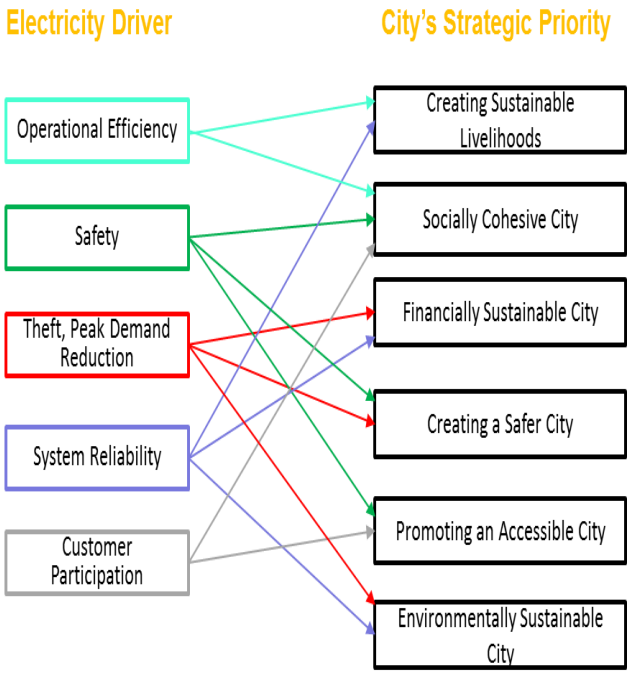

Figure 2: Drivers to IDP mapping [4]

This strategy set high-level targets specific to each of the eight main smart grid target areas. The individual targets combine to an overall target for eThekwini Municipality (Electricity Unit). This allow the impacts of action plans and interventions to be tracked over time, enabling an ongoing assessment of the success of the smart grid strategy.

C. *eThekwini Electricity Smart Grid Implementation Plan (SGIP)*

The SGIP is the implementation tool that focuses on both financial and non-financial measurable performance objectives in the form of delivery targets and other performance indicators. It is essentially the management and implementation tool which sets in-year information, such as quarterly delivery and monthly budget targets, and links each delivery output to the budget of the Electricity Unit, thus providing credible management information and a detailed plan for how the Electricity Unit realises the grid modernizing strategy.

The SGIP is structured for easy reference to the smart grid strategy according to the programs and projects of the eight focus areas. It mainly focuses on various action items that need to be achieved in order to meet SGMM expectations.

V. ETHEKWINI ELECTRICITY SMART GRID PROJECT INITIATIVES

A. Communications Network deployment Plan

The primary objective of communication networks is to provide communication links for all technical systems or equipment that monitor, control and protect electrical plants and equipment in the HV transmission and MV distribution networks from which all customers are supplied. Demands on the transmission and generation of power continue to rise drastically due to growing power consumption. In order to satisfy these demands, power systems are required to supply power in a manner which is reliable, efficient and sustainable. It is apparent that this multidirectional power flow requires real-time communications to maintain the stability of the grid and protect electrical infrastructure.

B. Advanced Distribution Management System (ADMS)

An Advanced Distribution Management System (ADMS) is the software platform that supports the full suite of distribution management and optimization. It also includes functions that automate outage restoration and optimize the performance of the distribution grid.

The ADMS provides a unified software system that integrates modular functions of software systems that could exist separately in utilities in the past. It utilizes the electrical network model and a real time infrastructure.

C. Geographical Information System (GIS)

GIS at eThekwini Electricity provides a spatial platform for the technical records of all the existing network infrastructure. A new data model was designed to host the additional data from the Asset Management Field Verification project. This data model incorporates existing eThekwini Electricity's underground layers, (i.e. underground cables, communications infrastructure, cable ducts and cable joints and terminations) that were excluded from the asset verification project [6].

D. Asset Management

Asset Management is systematic and coordinated activities and practices through which an organisation optimally manages its assets and their associated performance, risks and expenditure over their lifecycle for the purpose of achieving its strategic business objectives. The Electricity Unit initiated the Asset Management Project in 2009 to comply with the Municipal Finance Management Act and the Generally Recognised Accounting Practice 17 (Property, Plant and Equipment) and the eThekwini Municipality's Asset Management Policy of August 2008 [6].

E. Distribution Automation (DA)

Distribution Automation is an integration of technologies and protocols that enables System Operations (Network Controllers/ Control Centre) to remotely control and monitor the electrical distribution network. EThekwini Electricity is to deploy distribution automation as part of the Smart Grid Initiative to Distributor Substations (DSS), Ring Main Units (RMU), Autoreclosers (AR), Through Fault Indicators (TFI), Kiosks and Mini Substations (MSS), in order to improve reliability, efficiency, asset utilisation and performance of the electric distribution system.

F. Supervisory Control and Data Acquisition (SCADA)

SCADA allows control officers to monitor and control substations remotely. Information from these substations are collected from field sensors and sent to a Remote Terminal Unit (RTU). This information is then transmitted over a communications medium such as optical fibre to the control centre. Sophisticated hardware and software elements influence this information and present it in a user friendly manner to the control officers. Control officers use this information to make important decisions about the electrical network such as customer outages.

The SCADA system is also used for load shedding in containing the impact of Eskom's national load shedding on local utilities. Load shedding is under the control of SCADA operators allowing remote switching operations.

G. Advanced Metering Infrastructure

The Advanced Metering Infrastructure (AMI) programme is responsible for the implementation of Smart Metering which entails installation of smart meters, associated equipment such as communications modem, Customer Information Units (CIU) and Data Concentrators (DC) as well as Multi-Vendor Master Stations (MVMS) and Meter Data Management System (MDMS). Integration of all these components will ensure a seamless end-to-end bi-directional communication flow. This initiative will enable eThekwini Electricity to achieve the broader objective of implementing smart grid in all areas of electricity supply. AMI also ensure consistency and optimisation of similar metering initiatives within eThekwini Electricity. The AMI programme align the overall eThekwini Electricity's smart grid objective of a sustainable and medium to long term strategy. This strategy is an essential part of eThekwini Municipality overall vision of creating, among other priorities, a safe, accessible, environmentally sustainable and economically sustainable city by eventually achieving a smart city objective.

VI. CONCLUSION

This paper provides an insight on eThekwini Electricity journey towards achieving a smart distribution network. It highlights the role of SGMM as the driver of change within Unit. The journey is based on the SGMM action items. Modern technology can produce information at much lower costs than before and has the potential to become smart grid enablers in a third world.

Deployment of technology solutions that achieve the characteristics discussed on this paper will improve how the smart grid is planned, designed, operated and maintained.

All the stakeholders have a role of substance in this journey towards a smarter distribution network. The deployment of these technology solutions is expected to create improvements in the six key value areas namely: reliability, economics, efficiency, environmental, safety and security.

Good governance by various standards and regulations will play a significant role in implementing a smart grid.

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