DEMYSTIFYING THE SMART GRID

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1. Introduction

The principles of the technology of today's power grids have not changed significantly in the past 100 years. Electricity is a product that has to be generated at the time of need. The level of power generation is set to match the instantaneous demand. With the constraints in power resources, this has to change, hence the development of the Smart Grid.

This paper investigates some of the concepts around the idea of the Smart Grid, with the purpose of showing that implementing a Smart Grid is not the application of a single technology, but the collective result of a system design with the application of many technologies and products. It is important that a utility takes a holistic view of individual Smart Grid related projects in order to get the many components to work together and achieve better utilisation on capital spent.

2. Vision of the Smart Grid

Around the world, and in South Africa, it has become evident that utilities need to do more with less. Constrained power availability, rising demand, environmental pressures, cost pressures, skill shortages and limited resources have all led to increasing pressure on the power grid.

The digital age has placed increased demands on the quality of supply, while new alternative sources of generation have made the reliability of supply more unpredictable. The configuration of the power grid is changing from having centralised generation (Figure 1) with one way power flow to end consumers to having distributed power generation and consumption (Figure 2). No longer can the assumption be made by a consumer that the power grid is an infinite source of energy that can be tapped at will.

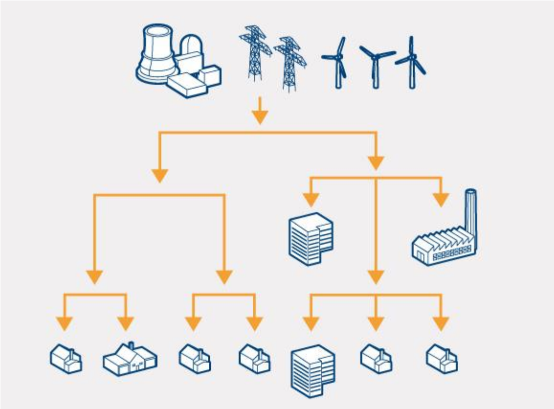

Figure 1 - Traditional Power Grid

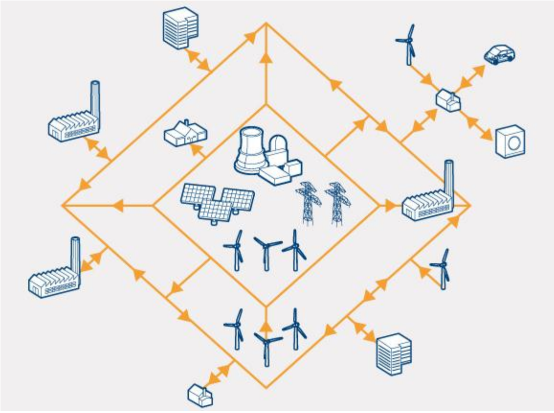

Figure 2 - Power Grid of the Future

To successfully operate a power system under these conditions a clear real time picture of the status of the system is needed. Better utilisation needs to be made of existing assets. More intelligent investment decisions need to be made. Knowing the real time status of the elements of the power grid are key to achieving this.

Integrating the realms of operational technology and information technology is essential to realise the vision of the Smart Grid.

The key concept is integration.

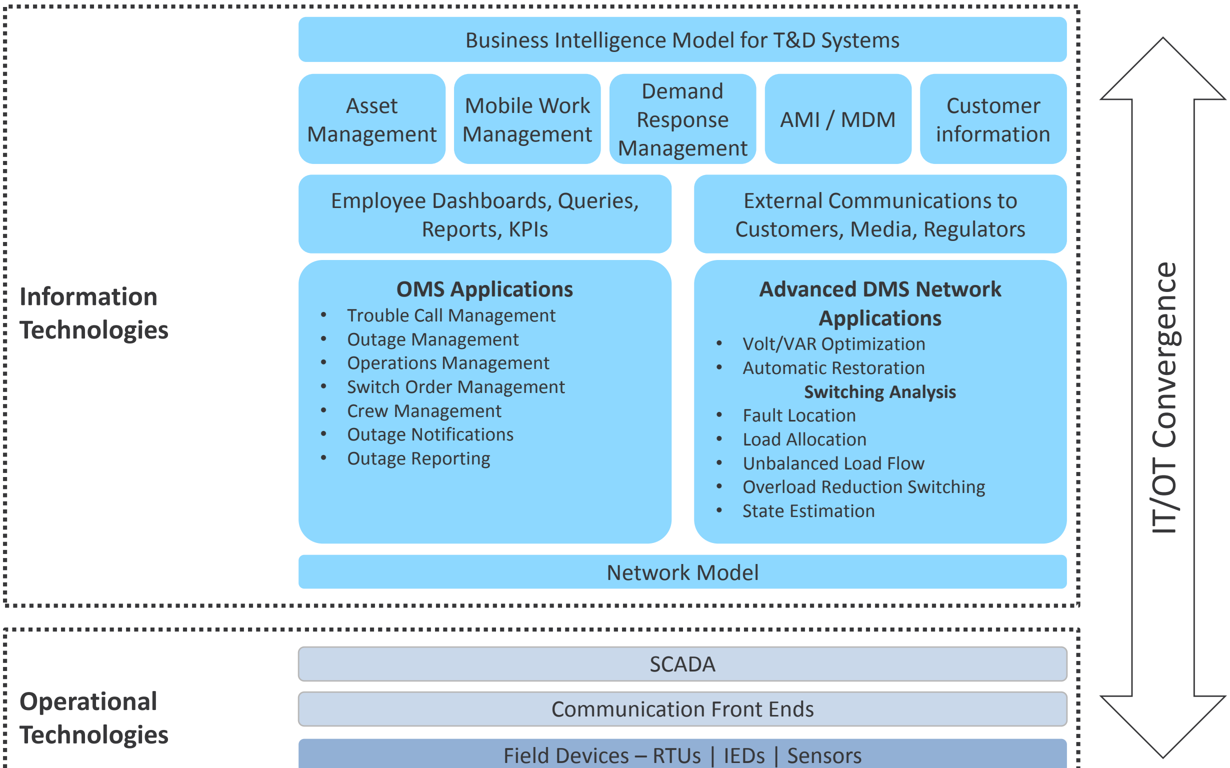

Figure 3 - Integration of Operational and Information Technology

3. Technology

3.1. Operational Technology

Operational technologies are the systems and devices that allow the physical monitoring of a power system, such as basic SCADA, RTUs, protection relays, meters and communications.

Operational technologies provide the measurements, indications and control interfaces to physical plant in the power system. The more detailed information provided, the better a power system can be modelled and controlled.

3.2. Information Technology

Information technologies are the enterprise software systems that enable the management and operation of a power system. Examples of information technology systems are Outage Management, Distribution Management, Asset Management and advanced SCADA (Figure 3).

Integration of the Operational Technology world and the Information Technology world brings significant benefits to a utility.
As an example, a sophisticated Outage Man agement system can exchange information with a SCADA system, a geographical information system, a metering system, a customer management system, a crew management system and a call centre to provide a dynamic, real time fault and planned outage management for a utility.

3.3. Systems Thinking

When planning an investment in a technology, it is advisable to take a "systems view" approach. For example, installing an automatic meter reading system (AMR) to manage payment and customer connections provides useful functionality. Broadening the scope to an advanced metering infrastructure (AMI) with two way communications provides more possibilities for Smart Grid integration and associated benefits.

Making the meter information available from the AMI system to provide customer outage information to an outage management system increases the value of the investment.
This requires the correct specification up front to realise these synergies (e.g. meters report outages within a short time period rather than only reporting metering data once a day).
Using the same system to feedback information to consumers adds another benefit, while using the same infrastructure.

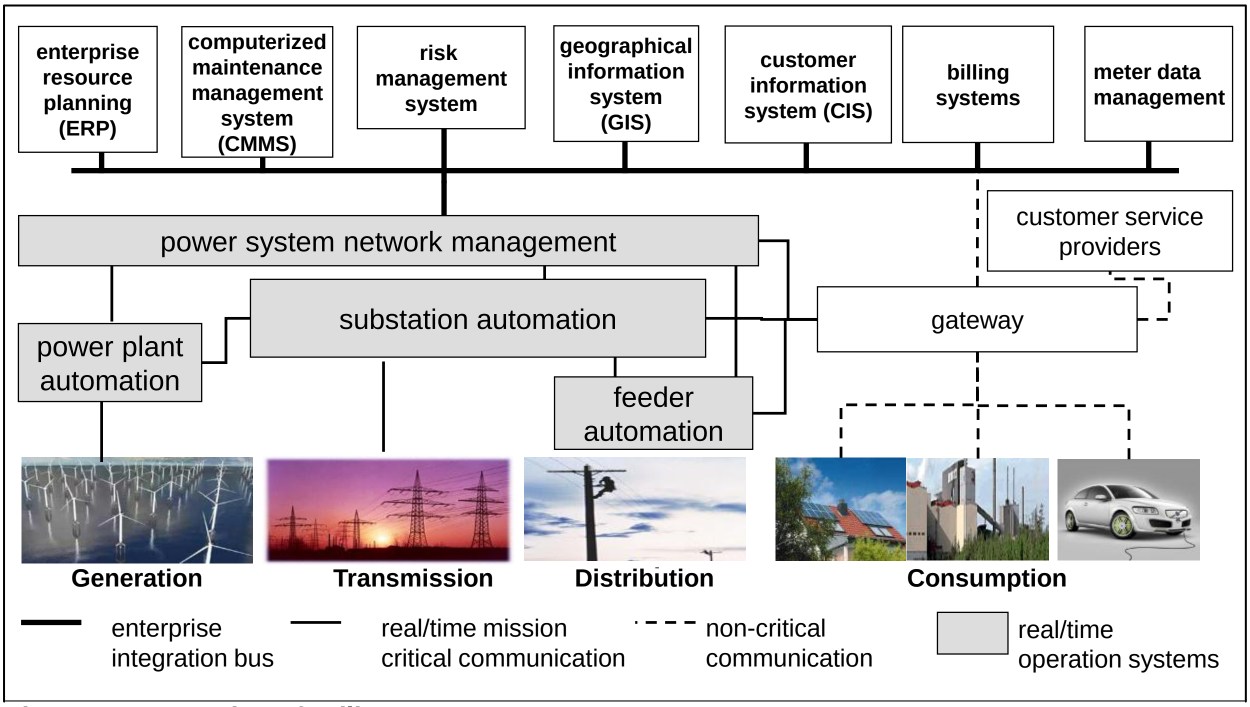

Figure 4 - Integration of Utility Systems

4. Four Key Areas

There are four key areas that must be considered to implement the Smart Grid

4.1. Communications

Communications is key for enabling the Smart Grid. Without a reliable, all-reaching communication network, it will not be possible to realise the full benefits of the Smart Grid.

Our daily lives are being improved by the continuous improvement in mobile communication technologies, which are enabling whole new applications such as live traffic enabled GPS and personal instant messaging.

The same is needed to enable the Smart Grid, with the ideal being to have two-way communication enabled right to the end devices in each consumer's installation.

There is no one size fits all communications solution. Different technologies are applied to the core network, the Distribution Area Network, the Neighbourhood Area Network (NAN) and the Home Area Network (HAN) (Figure 5).

New technologies are being developed and existing technologies are being improved in ways that allow the implementation of communications for the Smart Grid. For the backbone there are the existing multiplexer type network technologies (SDH, PDH) using fibre optic and microwave radio. For the NAN there are wireless mesh technologies that create a self-configuring and healing network. For the last mile there is Power Line Carrier (PLC) and for the HAN, short range radio technologies such as Zigbee and Bluetooth

At the medium voltage level, a good communications network supports the implementation of Distribution Automation.

Two way communications with end customers gives better control of power system demand and the ability to match demand to available generation.

Good communications infrastructure also enables real time customer engagement for outage management. It is far better to be able to inform a customer that calls in to report a fault that the fault is known and when the estimated restoration time will be.

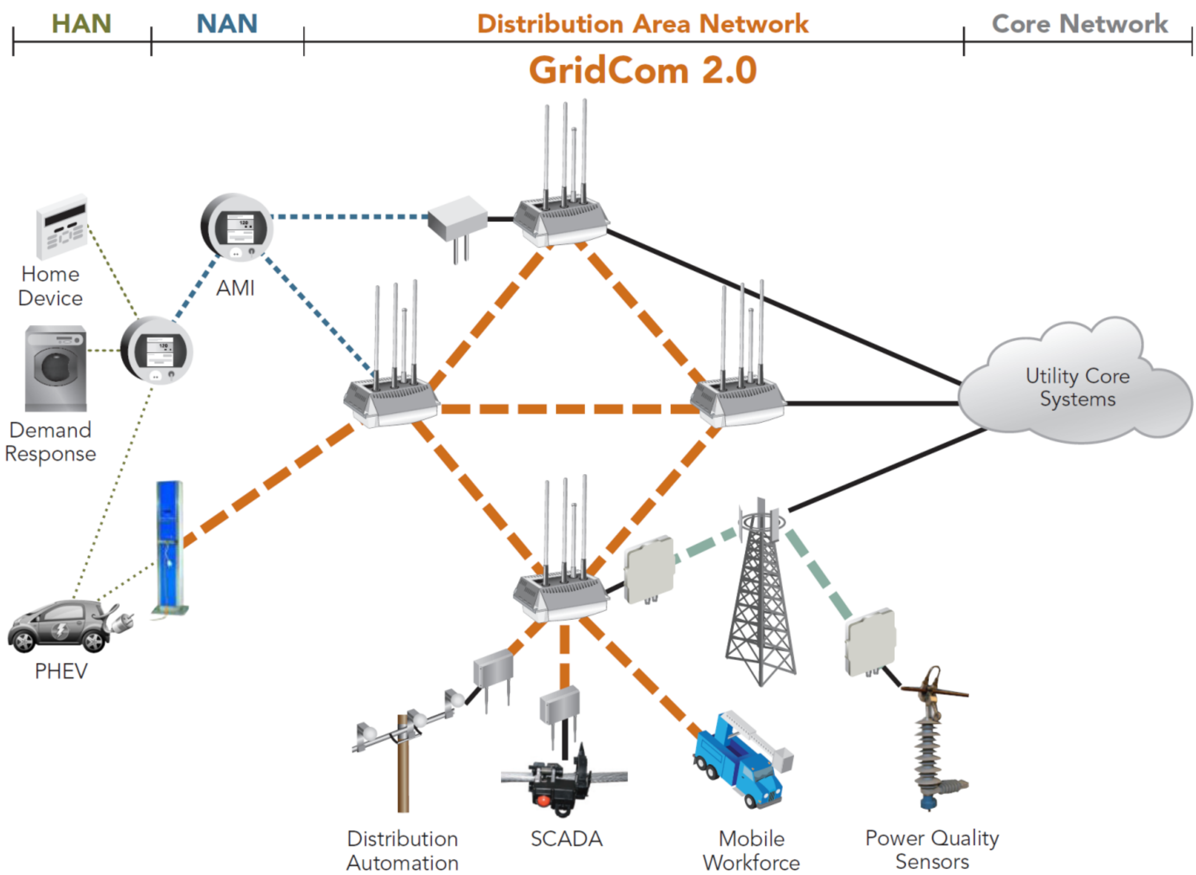

Figure 5 - The Evolving Grid - New Intelligence

4.2. Distribution Automation

The second key to the Smart Grid is Distribution Automation.

Monitoring and automation of high and medium voltage plant allows better management and control of the power system plant, thereby leading to better reliability and better efficiency. Outages are detected quickly and can be dealt in a shorter time, thereby reducing customer minutes lost. Traditionally SCADA monitoring has been applied at the HV to MV substation level. Today equipment is readily available to extend monitoring down to the secondary distribution level, greatly extending the reach of monitoring to make Distribution Automation possible.

The provision of fault current measurements and earth fault indicator operation leads to the possibility to have a self-healing grid. Dynamic algorithms in the SCADA system can sense when a fault has happened and, based on real time loading and back feeding capabilities, devise and, optionally, execute a switching plan to restore supply to as many customers as possible.

Loss reduction through Volt-VAR control is another benefit of distribution automation. Best suited to rural networks, algorithms on a SCADA system can be used to manage capacitor switching on medium or high voltage networks to control the VAR flow, which in turn manages the voltage profile and the losses.

4.3. Grid Analysis

Improving the operations of power networks can be achieved using several tools in the Information Technology world to analyse the history.

From an Outage Management system, fault causes, durations and other statistics for performance measurement can be derived automatically. This provides better information that automatically leads to improved reporting quality to the regulator and the ability to manage future events better.

From an Asset Management system, non-operational data can be used to track the health of assets for condition based maintenance. This leads to better performance of assets and reduced maintenance costs. Scarce skills can be utilised more effectively.

4.4. Integrating New Technology

Integration of new technology is the final key area of the Smart Grid. While these might not be prevalent in South Africa yet, they will come as demand from customers grows.

When they arrive, electric vehicles will place significant new demands on power distribution infrastructure. This needs to be managed in real time, such as with real time pricing of electricity to manage the demand for charging. Electric vehicles can also be used as a source of storage for utilities, where power can be bought back from customers to assist with meeting demand at peak times.

Interconnection of renewables, such as wind and solar, will bring a new dynamic to the power system. These are variable sources of power that are not predictable. Consumers will also become producers with the management of distributed generation requiring incorporation into power system.

Local area power storage is another new technology being explored. Power is stored in a medium voltage network using a storage facility such as a battery bank. This is used to bridge short term variations between demand and supply and helps reduce the effect of intermittent renewables.

5. Advanced Meter Infrastructure

While the main purpose of an automatic meter reading system is the management of billing and payment for electricity, there are many other benefits that can be derived from installing an advanced metering infrastructure (AMI).

Using two-way communications systems, these systems can be used to provide useful information for other systems that make up the Smart Grid

Real time information can be used by an Outage Management system to provide indication of power outages and restoration. Before a customer is even aware of a fault, it can be identified and even repaired, with a corresponding improvement in the regulator measured indices.

Power quality information can be provided by an AMI system. This information can be used to identify problem areas and initiate corrective action.

Demand response control is another possible benefit of AMI. With the scarcity of generation resources and the growth of intermittent renewable sources, no longer is the power system a seemingly infinite source of energy. Therefore demand has to be dynamically tailored to meet supply constraints. An AMI system can be used to control consumer loads, either by involuntary disconnection or by indication to the consumer to initiate voluntary disconnection of loads.

6. Benefits of the Smart Grid

What are the benefits of the Smart Grid? Why should a power utility implement the previously mentioned technologies?

6.1. Capacity requirements

Demand for power continues to grow. New loads such as data centres and the continuing electrification programme are adding more load to the power system. Electrification has the worst demand profile as it contributes to the evening peak. Demand management can be used to manage this peak and reduce the requirement for new generation, saving on capital spending investment.

6.2. Reliability

Distribution Automation and the self-healing network make the power network more reliable. Outage Management systems lead to a reduction of customer outage minutes due to automated fault location and fault process management. This not only helps a utility meet the regulatory requirements, but also gives consumers a more reliable supply and a better experience.

Asset management helps a utility to maximise the use of its assets. One of the benefits is that maintenance is done when required, making best use of scarce maintenance resources, while at the same time extending the life of an ageing power system.

6.3. Efficiency

The Smart Grid leads to better efficiencies, both on the power system and the use of resources.

With ageing workforces and reduction of skills, it is required that the skills that are available to a utility are used more efficiently. Better management of faults on the grid and intelligent asset maintenance helps to achieve these efficiencies.

Dynamic power system optimisation reduces losses, gives better utilisation of equipment. Improved customer awareness increases efficiency as customers make better use of the power available to them.

6.4. Sustainability

For the power grid to be sustained in the future, the new technologies for generation will have to be successfully integrated.

Interconnection of renewables into the grid while reducing CO_2 emissions, is crucial to sustainability of the power grid in the future.

The Smart Grid will assist in meeting the challenges of the integration of renewables.

6.5. Customer enablement

Improvement in customer education and awareness through dynamic feedback of information is a large benefit of the Smart Grid.

AMI systems enable customers to manage their loads more effectively, with better understanding of the various loads that they have.

Outage Management enables a vast improvement in the utility response to customer calls, allowing call centres to provide useful information to callers.

Customer involvement in the power system operation removes the mystery of power. It is much easier to keep a customer happy that is informed.

7. Barriers

Deploying the technology needed for a Smart Grid is not a simple exercise. There are several barriers to its implementation.

7.1. Policy & Regulation

The Smart Grid is a tool that can be used to implement government policies around energy usage. Timeous implementation of policies that deal with energy efficiency and usage are crucial to the implementation of the Smart Grid.

In South Africa, energy saving is something that is high on Government's agenda. This supports Smart Grid investment decisions that will improve the efficiency of energy usage and reduce overall demand.

7.2. Market Uncertainty

A second barrier to the implementation of the Smart Grid is the financial disincentive to power utilities. Smart Grid technology can be expensive and, at the same, reduces a utility's revenue stream due to the reduction in use of energy.

The world economic crisis has also limited the amount of money available for Smart Grid projects, thereby adding a barrier to implementation.

7.3. Technology Barriers

While there is Smart Grid technology that has been in the market for many years, such as SCADA and Substation Automation, there is significant development effort that is on-going to bring new technology to market and to better integrate existing technologies.

New technology requires implementation and testing to become proven technology. Smart Grid systems can be complicated and not all solutions have been fully developed, so it is in a utility's best interest to select a proven technology partner that has the track record and experience to make systems work.

7.4. Security

As systems within a power utility begin to communicate, the issue of security is raised. Smart Grid solutions should be designed with appropriate security built into the system from the outset, rather than being bolted on later.

7.5. Lack of consumer involvement

Customer involvement is vital to the goal of managing power demand. Education, real time information with regard to pricing and live feedback of power system status are tools that are provided by the Smart Grid to get customers involved in managing the process of using energy more efficiently.

Until customers can see this kind of information, the assumption remains that, because the lights are on, there is no problem. This is a barrier to achieving the goals of efficient energy usage and matching demand to supply.

8. Standardisation

As with all new technologies, when new products are developed they start off being proprietary. This is due to standards often not being available to match the new technology developed.

It is in power utilities' best interests to demand standardisation. This is so that utilities are not locked into single vendor solutions, but are able to mix and match equipment to provide a suitable overall system solution.

Standards bodies such as the IEC and IEEE are in the process of developing standards for the Smart Grid (see www.iec.ch/smartgrid).

In the SCADA and Substation Automation worlds, IEC standards have long been in place and utilities are reaping the benefits of standardised solutions.

9. Conclusion

Implementing a Smart Grid is not a one time project but rather a transformation process. It is a journey that will be undertaken by any utility that will take time. Many of the components are available and in use today.

There are many areas to consider. Utilities must take into account their business needs and determine what overall outcome is required before selecting the right combination of technology to provide the correct solution.

Making the grid smarter will require coordination across the different disciplines within a utility to see the benefits of a truly integrated set of systems

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