The internet of things for a smart South African grid architecture

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Abstract

Energy demand in South Africa is fast exceeding supply, leading to instances of load shedding and high prices. An optimized energy supply environment has to be achieved if the country is to maintain reasonable pricing and universal access to energy for the majority of the population. This research showcases the adoption of the internet of things technologies in the management of energy and specifically the smart grid. The research focuses on the design of an architecture of a national smart grid that integrates distributed renewable and non-renewable energy sources in an effort to overcome the challenge of pricing of energy for the South African consumers. The research analyses literature on existing smart grid systems and the South African national grid environment and draws lessons from the analysis that input the architecture design. When completed this system will enable the national grid to tap into distributed energy resources and also allow homes not only to connect to the national grid but also to connect to renewable energy sources and store energy on batteries. Excess energy from each home, if any, is sold to the utility company. The utility companies have the ability to compare supply and demand and determine the prices for the period which is then communicated to the consumers.

Keywords
Smart grid, smart energy, internet of things

1 Introduction

This research showcases the adoption of the internet of things technologies in the smart management of energy. The term internet of things refers to the increasing integration of ICT into people's lives and environments made possible by the growing availability of microprocessors with inbuilt communication facilities. The internet of things is the idea that almost any devices, from clothing to tools to appliances to homes to the human body can be embedded with chips to connect the devices to an infinite network of other devices (Serbanati, 2011). The goal of the internet of things, which combines current network technologies with wireless computing, voice recognition, internet capability and artificial intelligence, is to create an environment where the connectivity of devices is embedded in such a way that the connectivity is unobtrusive and always available. Internet of things devices can be separated into three categories as: (1) sensors: input devices that detect the environment, (ii) processors: electronic systems that interpret and analyse input data, and (iii) actuators: output devices that respond to processed information by altering the environment via electronic or mechanical means.

This paper reports on an integrated smart grid system. By drawing lessons from various literature on smart grids, peak demand reduction, power scheduling, demand side management, and renewable energy the paper comes up with an architecture for a South Africa-specific smart grid.

The document is structured as follows: Section 2 is on the problem statement. Section 3 is on the definition of the smart grid and is subdivided into subsections on peak demand, renewable energy and power scheduling. Section 4 is on the components and architecture of the system. Section 5 is on the business benefits of the architecture. Section 6 is on the conclusion.

2 Problem statement

The pricing of electricity in South Africa has not always been a transparent process. Some utility systems adjust pricing according to the time of the day, some according to peak load pricing which shifts demand away from peak times, some according to zones, while others offer a blanket approach to pricing. This paper suggests a solution on pricing in the form of integrated smart grid system according to the load on the electricity network and the amount of energy generated from distributed resources.

The question that this research answers is:

“How would the architecture of a South African smart grid that enables electricity pricing that is dependent on peak load demand and distributed generation be structured”

The goal of the research is to design the architecture of a smart grid that ensures transparency in pricing of electricity supply. The objectives of this research therefore are:

- To review various literature on smart grid related information from both a South African and international perspectives
- Analyse literature and recommend solutions for the South African smart grid
- Design an architecture of the integrated smart grid from the analysis

3 Smart grid

According to Keshav (2011), the smart grid is a highly-interconnected, complex and interactive network of power systems, telecommunications, the internet and electronic consumer devices. This network is built on top of a two-way digital communication technology, intelligently delivering electricity from suppliers to consumers. Peak load pricing shifts demand away from peak times by raising prices when the demand for a service is at its highest. The smart grid features distributed energy production, vastly more storage, tens of millions of stochastic renewable-energy sources and the use of communication technologies both to allow precise matching of supply to demand and to incentivise appropriate consumer behaviour.

According to (DeGroff, 2012), the concept of a smart grid – is on an intelligent and active power distribution network that uses advanced communication technology to collect and use real-time operational information for efficient control of the grid. The modernisation is directed at facilitating greater competition between providers, enabling greater use of variable energy sources, establishing the automation and monitoring capabilities needed for bulk transmission across continent distances and enabling the use of market forces to drive energy conservation.

The concept of advanced metering infrastructure (AMI) is central to various definitions of the smart grid. AMI refers to a network that allows for two-way communication between the electricity provider and the customer meter. Smart meters, built on top of AMI are utility meters that record real-time electricity consumption and report this data back to utility providers. A smart meter is an electric meter that records consumption of electric energy at intervals of an hour or less and communicates that information at least back daily to the utility for monitoring and billing purposes (Agarwal, 2011). There is a major approach to improving the overall efficiency of the power grid called demand response (DR). DR refers to a variety of programs and actions that involve customer/user response to particular conditions within the electricity system such as peak period network congestion or high prices (Pierce, 2012). Demand response programs aim to transfer customer loads during periods of high-demand to off-peak periods, a strategy referred to as load shifting. Load shifting can improve the overall efficiency of the power grid by flattening load curves and allowing more electricity to be provided by less expensive base load generation.

The primary benefits associated with the typical smart grid initiative include (Sarfi, 2010):

- Realisation of conservation and energy efficiency goals such as enable demand response, demand and overall consumption reduction and reduce distribution losses
- Improvement in system reliability such as increase capacity, enable ‘self-healing’ automation, enable reliability-centred maintenance paradigm and support for micro-grids
- Provide greater service flexibility to consumers related to consumption and tariffs
- Achieve greater control required to leverage distributed generation including green power and renewable resources
- More effective use of resources
- Realisation of considerable labour efficiencies, in particular reduction of overtime

According to the smart grid vision, any electronic device connected to it will be able to communicate its consumed or produced energy almost in real time. Based on the analysis of this newly acquired information, a new generation of services and decision support systems can be realised, enabling more intelligent decisions, and ultimately a more efficient energy system. (Karnouskos, 2011) build a web-based advanced metering infrastructure of simulated smart meters, concentrators and a smart metering platform, all interconnected via web services. Metering data collected from various sources is gathered at strategically positioned concentrators. The concentrator is the interface between much low-speed, heterogeneous, usually asynchronous channels and one or more high-speed usually synchronous channels. It acts as the interface between the smart meters and the enterprise. It is also responsible for aggregating the meter reading data and submitting it to the metering server. The metering data management layer collects the data for long term storage, analysis and management. This is typically used by enterprise services in order to empower applications such as billing, forecasting, etc.

The functionality offered by the networked embedded devices that would realise the monitoring and control part is crucial for the success of the smart grid. A smart grid will be a collaborative service ecosystem (Karnouskos, 2011). In the green economy, for example, prediction for sunny and windy weather will probably mean that more energy will be produced as green generators. In parallel, homes can plan to schedule energy hungry tasks during time that electricity is available from local generators (e.g. photovoltaic panels).

There are many research areas that can be applied to smarten the grid. Local matching of supply to demand in a micro-grid, detecting illegal tapping, modelling of stochastic energy generating sources, delay-tolerant networking, latent indexing, i.e., collecting monumental amounts of data and using data mining techniques to extract useful information from them, incentive compatibility, i.e., making end users behave in a way that is beneficial to the network, congestion control and distributed algorithms for control (Keshav, 2011).

3.1 Peak demand

Demand response is a crucial aspect of the future smart grid (Liu, 2013). It has the potential to provide significant peak demand reduction and to ease the incorporation of renewable energy into the grid. Data centres' participation in demand response is becoming increasingly important given the high and increasing energy consumption and the flexibility in demand management in data centres compared to conventional industrial facilities. (Liu, 2013) describes work on two demand response schemes to reduce a data centre's peak loads and energy expenditure: workload shifting and the use of local power generation to avoid the coincident peak and reduce the energy expenditure. The first algorithm developed optimises the expected cost and the second one provides a good worst-case guarantee for any coincident peak pattern. One popular demand response program is charging a very high price for usage during the coincident peak hour in order to control and reduce usage during peak hour. Data centres usually resort to backup power generation since it can be automated easily although it can be very dirty.

Smart grid technologies require algorithms and mechanisms that can solve problems involving a number of highly heterogeneous actors e.g. consumers with different demand profiles or generators with volatilities. Thus, the key artificial intelligence challenges in demand-side management are: (1) designing automation technologies for heterogeneous devices that learn to adapt their energy consumption against real-time price signals when faced with uncertainty in predictions of future demand and supply, the individual users' preferences and the constraints of the overarching system, (2) developing the means by which automated decisions of the systems can be effectively communicated to and controlled by their human owners while allowing a varying range of autonomous behaviours and (3) developing simulation and prediction tools to allow the system wide consequences of deploying pricing mechanisms and energy management agents to be assessed by grid operators and suppliers (Sarvapali, 2012).

In (Lee, 2011), as a networked appliance, the home controller basically coordinates the interaction among utility companies, home appliances and monitoring devices. The controller exchanges the information on price and demand with the utility company via the WAN connection. The utility company sends a residential load change to the consumer's home, activating load control, demand response, and price adjustment. Next, the controller interacts with home appliances, mainly by the home area network such as ZigBEE, triggering their operation and metering their power consumption. Finally, the smart grid home controller sends a message to the user through mobile phone or web portal to inform them of price change. The home power management system makes decisions to control power consumption by scheduling the devices. The schedule can be generated and modified according to a task set change any time the customer wants.

In the 'smart grid city' (Weiss, 2009), on the demand side the hub of a smart grid system is digital, two-way power metre. A two-way digital power meter reports usage directly to the utility. Beyond that, it provides real-time data to users (through a web browser) about power consumption. A digital meter can maximise the use of variable pricing models, where power is cheaper when demand is lower. Variable pricing also allows customers to choose their source of power. Looking at the reverse direction, smart meters promise to make it easier for buildings to supplement their power draws using on-site sources like

An intelligent charging system called SmartCharge (Mishra, 2012) uses an on-site battery array to store low-cost energy for use during peak periods. SmartCharge's algorithm reduces electricity costs by determining when to switch the home's power supply between the grid and the battery array. The algorithm leverages a prediction model which forecasts future demand using statistical machine learning techniques.

nPlug (Ganu, 2012) is a demand-side management system based on smart plugs called nPlugs that 'sit' between deferrable loads and wall sockets. An nPlug senses line voltage and frequency to infer the load level and supply-demand imbalance in the grid respectively. It processes the sensed data using simple data mining algorithms to identify the peak and off-peak periods of the grid. It runs the attached load(s) during off-peak periods as much as possible without violating user-specific constraints. To ensure grid and application safety, it avoids scheduling appliances during periods of supply-demand imbalance. Furthermore each nPlug runs a decentralised load rescheduling algorithm that contributes to peak load reduction by distributing the loads over time.

To reduce peak demand, utilities are introducing variable rate electricity prices. Recent efforts have shown how variable rate pricing can incentivise consumers to use energy storage to cut their electricity bill, by storing energy during inexpensive peak periods. Variable rate pricing can be augmented with a surcharge based on a consumer’s peak demand. The surcharge encourages consumers to flatten their demand, rather shift as much demand as possible to the low-price peak period.

PeakCharge (Mishra, 2013) is a system that includes a new peak-aware charging algorithm to optimise the use of energy storage in the presence of a peak demand surcharge and use a closed-loop simulator to quantify its ability to flatten grid demand as the use of energy scales. The system reduces upfront capital costs since it requires significantly less storage capacity per consumer and also increases energy storage’s return-on-investment since the surcharge mitigates free riding and maintains the incentive to use energy storage at a scale.

(Ramchurn, 2013) is a prototype agent-based platform to solve tariff selection problems for homeowners. AgentSwitch incorporates novel algorithms that work on the coarse data provided by smart meters to make predictions of hourly energy usage as well as detect and suggest to the user deferrable loads that could be shifted to off-peak times to maximise savings. The algorithms include i) novel extensions to Bayesian Quadrature (a machine learning technique) in order to generate predictions of yearly consumptions at hourly level and help select the best tariff traditionally available from retailers, (ii) a novel mechanism for collective energy purchasing, (iii) non-intrusive appliance load monitoring algorithm that works on coarse energy data, (iv) a novel provenance service that allows the tracking of data throughout the system in order to provide accountability for its recommendations.

3.2 Renewable energy

Energy management strategies in homes powered fully or partially by renewable resources such as solar are lacking. (Banerjee, et. al., 2011) explore home automation techniques for achieving better utilisation of energy generated by renewable technologies. They propose a recommendation-based system that monitors energy harvested and consumed and provides users with feedback and advice on how to adjust energy consumption patterns via a smartphone application. The study demonstrates three recommendation components: an early warning system that allows users of renewable technologies to make more conservative decisions when energy harvested is predicted to be low; a task scheduling system that advises users when high-power appliances should be run to optimise overall energy utilisation; and an energy conservation system that identifies sources of energy waste and recommends more conservation usage.

The demand for electricity and the requirements for its generation pose a challenge. The vision of an electricity grid that makes use of renewable generation challenges this situation. Renewable energy is both intermittent and distributed, with the output of such generators being determined by local environmental conditions (such as wind speeds and photovoltaic (PV) solar panels). Thus it will no longer be possible for supply to continuously follow consumer demand, but rather the demand side will be managed to ensure the demand for electricity is matched against the available supply. The increased demand for renewable generation may require a lot of generators, distributed across both the transmission and distribution networks.

Distributed generation, especially solar and wind power collected across different small generation locations is gaining considerable importance and their deployment is perceived as vital in achieving carbon reduction goals. Extracting the maximum value from a time varying and intermittent renewable energy source requires intelligent scheduling of both generation and loads (Narayanaswamy, 2012). Intelligent generation scheduling is the process of scheduling different generation sources to minimise cost while meeting physical constraints of the electricity system. It involves genetic programming and other non-convex optimisation techniques.

As a major consumption source and a renewable energy source, water management systems and wind power generators make operation plans for their facilities based on temporal predictions of target objects (Lee, 2012). The massive daily ground water levels readings and daily wind speed records, which are accumulated over a 10 year period, are fed into a 3-layer neural network for modelling the change pattern. The neural networks yield an accurate prediction on ground water levels and wind speed. These predictions are fed into an electric vehicle charging system to shift the peak load to less loaded intervals

One way to decrease both transmission and distribution (T&D) losses and carbon emissions is through distributed generation (DG) from many small on-site energy sources deployed at individual buildings and homes. However in practice, DG has drawbacks that have prevented its widespread adoption. For instance, DG uses renewable wind and solar energy sources which buildings cannot dispatch at any time to satisfy their energy demands. Since the energy consumption density of buildings is higher than the energy generation density of solar and wind deployments at most locations, buildings must rely heavily on the electric grid for power. More importantly, larger centralised power plants benefit from economies-of-scale that cause their generation costs, even accounting for T&D losses, to be significantly lower than DG. As a result, today's DG deployments rely heavily on net metering – where consumers sell the unused energy they produce back to the utility company, to offset their cost relative to grid energy. One other reason for the strict laws limiting DG's contribution is that injecting significant quantities of power into the grid from unpredictable renewables at large scales has the potential to destabilise it by making it difficult for utilities to balance supply and demand. (Zhu, 2011) explores an approach that combines residential time-of-use (TOU) pricing models with on-site renewables and modest energy storage to incentivise DG. The system architecture and control algorithm efficiently manages the renewable energy and storage to minimise grid power costs at individual buildings.

3.3 Power scheduling

In (Chen, 2011), the authors propose a power scheduling protocol for demand-response in smart grid systems. They developed a joint media access and appliance scheduling approach which allows appliances to coordinate with each other about their power usages over a home network so that the total demand for the home is kept below a target value. Other system oriented work in this area focus on developing mashups of electricity sensors, which allow for both, monitoring on device-level and providing an overview on the total load attached to multiple outlets. (Lifton, 2007) embedded a multi-modal sensor network node into a power outlet to monitor the electricity consumption and infer the appliances being used in the house. (Jiang, 2009) developed a wireless networked sensor node that measures the power consumption at the outlet and uses the communication interface to automatically transmit data to an application tier that stores the readings in the database. The approach consists of a three layer architecture that builds on a wireless current sensor per outlet.

4 Components and architecture of system

The following section describes the components and architecture of a smart grid system. The first subsection draws lessons collected in the preceding sections on how the architecture should be structured. The next subsection describes the architecture itself.

4.1 The South African grid environment

In the South African system, transmission of electricity is one-directional, from the generating company Eskom, to the consumers. This means that currently consumers who generate solar energy in their homes cannot sell it to the utility company or back to Eskom. It would even be more beneficial for them to sell their excess energy to their neighbours. The closer the consumer is to them, the lower the cost of transmission, hence a reduction in price. The utility bill is higher the further one is from the generation source.

South African electricity prices differ between day and night, and between industry, suburbs and townships and also from municipality to municipality. The higher the demand for electricity, as in industry for example, the higher the electricity tariffs. As a result industry goes for renewable energy to maintain their systems during peak demand periods of the day. The disadvantaged areas such as the townships have lower price rates.

In the homes that tap into renewable energy such as solar, the advantage of batteries is that they store up as much energy as their carrying capacity, although they do not have the capacity to send out the energy stored. The longevity of a battery use depends on the levels of current drawn from it frequently. Each device that is fired from a battery has its own current. The more frequently a battery is overloaded with current, the shorter its life span. The renewable energy generated in a home should ideally be sold directly to the nearest substation to it, instead of back to the distribution system, which is further. The substation is aware where the deficit is and is closer to the grid the home belongs to

In South Africa the smart meters in homes are linked to the service provider's system. A user purchases units from an agent against their meter number. In turn, recharge occurs when substations calculate supply against the meter number. For those who are not on prepaid electricity, a meter reader collects meter readings manually on a monthly basis for generation of the bills. In Australia, on the other hand, the utility company gets data from customers wirelessly instead of sending personnel to collect the data. The vehicle which carries a meter reader drives through the streets and smart meters are read wirelessly. In Europe there is the GSM-based smart meter. SIM cards send bills at the month-end to the utility company which in turn sends information to the customer via SMS. This is expensive as a result and not a viable approach for South Africa since it requires that households connect on the net and only a few can afford such. The GSM meter is precise though. With no cell phone linked to the GSM meter there is no hacking and reduced tampering. The issue is how to link the GSM meter to the grid so that the consumers can sell excess energy to the utility. Where the GSM meter is used, there is a direct link to the user's phone and to the utility company separately. Communication is two way. Since the information is duplicated, the consumer is not taken advantage of by the utility company in terms of communication costs.

4.2 Lessons drawn from literature

In the technologies identified are a number of characteristics that our architecture should have:

- Distributed energy production by the service provider, in order to tap into various forms of energy sources (Keshav, 2011)
- Distributed renewable energy sources in homes that store energy in on-site batteries and feed into the grid during peak demand or when there is excess (Mishra, 2012), (Keshav, 2011), (DeGroff, 2010).
- Metering infrastructure to enable homes to switch between the batteries and national grid, depending on energy demand and availability of renewable energy generated (Agarwal, 2011), (Pierce, 2012).
- Two way digital communication between consumer and provider (Agarwal, 2011), (Pierce, 2012).
- Real-time energy information generated for monitoring and control of the grid and information dissemination to consumers (DeGroff, 2012).
- Load detection for peak load pricing, load matching of supply to demand and load shifting to flatten load curves and schedule appliances (Keshav, 2011), (Ganu, 2012), (Liu, 2013)
- Algorithms to optimize costs in demand-response systems (Sarvapali, 2012), (Mishra, 2013), (Zhu, 2011), (Lee, 2011), (Ramchurn, 2013), (Chen, 2011)
- Accounting for energy to detect illegal tapping (Keshav, 2011)
- Visualisation of the grid performance (Karnouskos, 2011)

4.3 The proposed architecture

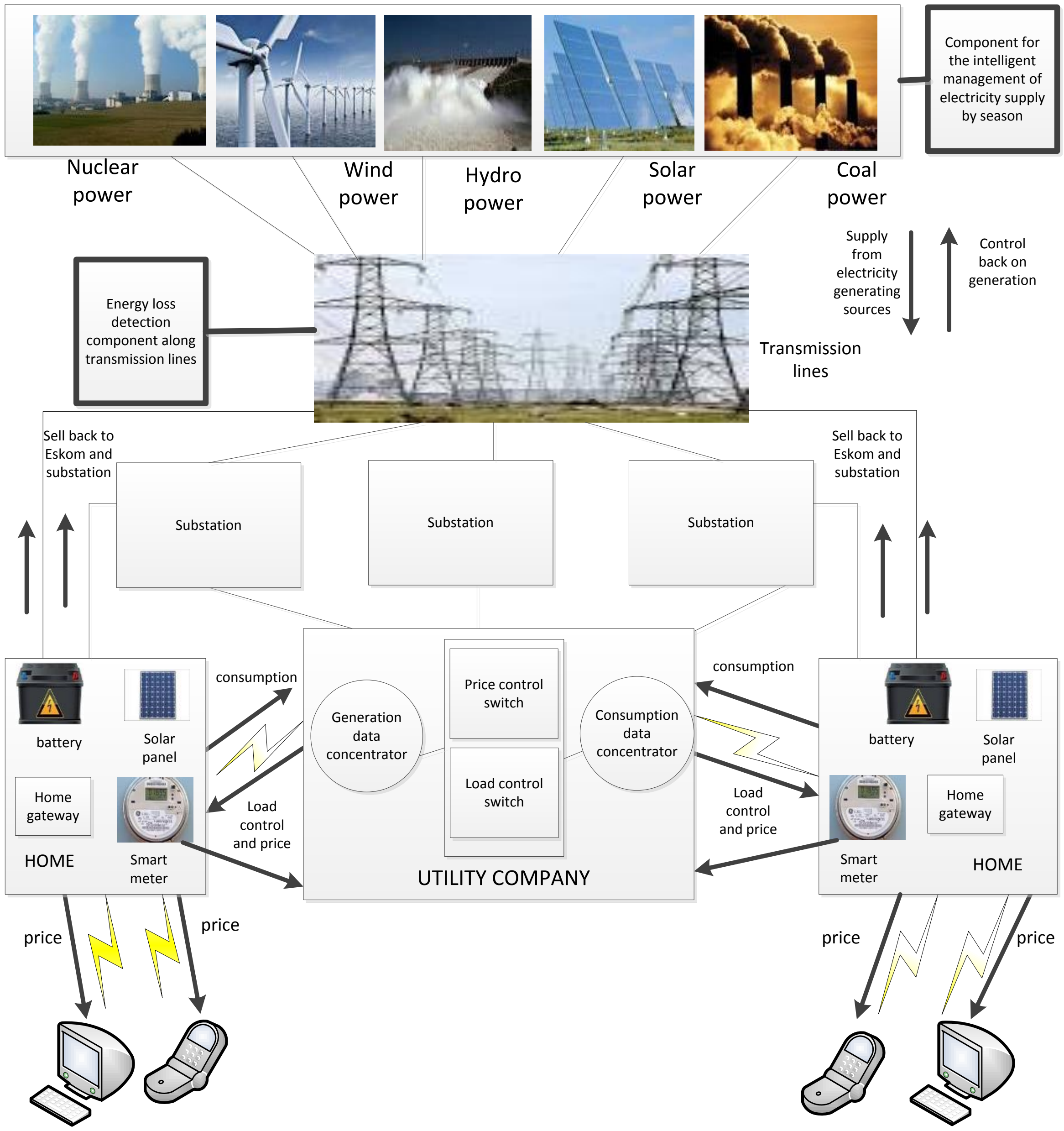

Figure 1: Architecture of the smart grid

- Smart meters to communicate usage to service providers and real-time data to consumers wirelessly (Weiss, 2009)
- Concentrator between smart meters and service provider for billing and forecasting
- High communication through TV whitespaces
- Home power management system to schedule devices in the home (Sarvapali,

2012), (Chen, 2011)

- Optimising generation by putting into consideration the various seasons. Networked embedded devices are required to predict the amount of renewable energy according to weather patterns (Karnouskos, 2011)
- Communicating consumed or produced energy in real time through metering (Karnouskos, 2011)
- Recommendation system to monitor energy harvested and consumed and provides users with feedback on how to adjust energy consumption patterns (Banerjee, 2011), (Narayanaswamy, 2012), (Lifton, 2007).

The smart grid is about the management of the supply of electricity. In Figure 1, electricity is generated from distributed sources of energy such as solar, nuclear, wind, hydro and coal power. This generation capacity has to be optimized because excess energy cannot be stored in the grid. Consideration should be given to the fact that, for example, less solar energy is generated in winter due to less sunshine due to cloud cover, solar power technology underperforms once temperatures rise above 30 degrees, in winter there is less flow of rivers for hydro-generation, wind power is available in coastal areas more than in inland areas and coal deposits are only found in certain and not all regions of the country. As a result, intelligence should be incorporated to optimize supply and demand by putting into consideration seasons and resource availability.

The electricity generated goes through transmission lines to substations. These substations supply power to the utility companies which in turn supply electricity to households. The smart grid has an accounting component along the transmission lines to account for loss of electricity from the grid to the local station and to the household. This assists identify areas of illegal tapping into the grid and leakages.

At the moment Eskom, the South African energy company, supplies power to substations in bulk depending on the average demand by the substations. Eskom reads the bulk supply meter from the substations to measure the consumption level by the utility company. Therefore Eskom generates electricity according to demand and has an average consumption demand for each utility. There is control back on the generation required by the utility at any point in time. This means that some of the generation sources can be switched off when demand is low. Renewable energy generation stations are less likely to be switched off over coal stations since coal is a resource that is depletable and is expensive. In this architecture consumers can sell excess energy back to the substations or to Eskom.

At the moment the utility companies buy bulk electricity from the substations and add their top-up to the price. The utility company calculates the average consumption for postpaid households. The price is divided among households at the ratio of the average consumption for billing purposes. It is transparency in billing that is required, as some households pay for what they didn’t consume.

The homes in the grid have solar panels for renewable energy sources. The solar panels store energy onto batteries during the day. Any excess energy from the home solar batteries is sold to the utility company. The home gateway calculates how much data is required by the home minus the data on energy available in the battery. The smart meter communicates the information on data required to the utility company should netional grid energy be required. The consumption data from several homes is aggregated by a consumption data concentrator. The data on the available energy from substations is also concentrated. The differences between the consumption and generation data are calculated, and a special algorithm calculates the price when supply/demand is uneven. The new price is communicated to the home gateways to allow users to control consumption. The home gateways in turn communicate the prices to the user's cell phone or web browser.

5 Business benefits of the architecture

The development of this integrated smart grid architecture is to overcome the challenge of pricing for energy consumed. The architecture looks at both demand-side management and generation and transmission issues, unlike other systems which look at only one aspect. The architecture affords the opportunity to integrate both renewable and non-renewable energy resources. Each of these types has its uses and benefits at different times of the year and places. For example, energy from wind is higher in coastal areas, solar energy in sunny regions, and coal is needed when other alternatives aren't generating enough capacity.

The distributed nature of the energy generation also means that when one system fails, the other energy sources can take over. When demand is low, other sources can be excluded. This improves energy efficiency as demand/supply is controlled. No energy is generated when no demand calls for it. Precise matching of supply to demand is a huge component of the smart grid. Energy is stored in the homes for usage during peak hours. This shifts energy generation to the consumer. Both transmission and distribution losses to homes are reduced if solar power is generated within the homes. Consumers sell unused energy back to the utility company to offset costs of the power grid.

Demand/response is an attempt to transfer customer load from high demand to off-peak period to avoid blackouts. Load curves are flattened. System reliability is improved. The architecture also tracks electricity usage. It incentivizes appropriate consumer behaviour. The customer is involved in the management of electricity. The benefit is the ability of the grid to be measured in realtime and visualized, manipulated and optimized, automated, interoperability of existing systems, communication between components and communication with the user. Large amounts of data are collected and processed for decision-making, that is, controlling the behaviour of consumers and controlling congestion. Variable pricing also allows customers to control their energy consumption behaviour and distribution agents to choose their source of power. The smart grid is about the interoperability of once standalone systems, that is processes, data systems, consumer management, deployment, operation and maintenance. Monitoring and control is crucial for the success of the smart grid. Detecting illegal tapping and congestion control are some of the mechanisms.

6 Conclusion

The literature on smart grid spans the areas of peak demand, renewable and non-renewable energy and power scheduling. This literature was analysed to come up with solutions for a South Africa – specific smart grid with its unique characteristics e.g. the pricing models, weather impact on renewable energy generation, the wide range of energy generation sources, collection and processing of energy data and energy transmission issues. The problem of transparency in the pricing of electricity can be eliminated through the introduction of a smart grid whose features cover peak load demand, generation and distribution. The smart grid is made smarter through the integration of internet of things technologies. This means that the smart grid is a network of power systems, telecommunication and electronic consumer devices. The architecture of the smart grid that is proposed in this paper results in conservation of energy, reliability of the grid network and effective use of resources. Since the future of energy generation lies in greening the economy, this calls for a move to more and more renewable resources as sources of energy supply.

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