The role of smart grid technologies on demand response in a power system with embedded wind power generation

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Abstract

Around the world, energy regulators and power utilities have set medium and long term targets to meet gross electricity production aided by the employment of a number of renewable energy sources such as wind energy. These targets are in response to climate change, reduction of emissions produced by conventional electricity generation methods and increasing prices of oil and fossil fuels.

Due to its intermittent nature, wind energy has adverse effects with limited predictability which can compromise the security and reliability of a power system with a high penetration of embedded wind power generation. These effects include the availability of wind, accommodation of its variability and managing capacity reserves, managing costs and regulating the balance between supply and demand. These effects can be managed through the use of real-time Demand Response applications. This paper presents the challengers which have been faced by other utilities on a global scale to combat the adverse effects of wind energy by using Demand Response. A number of smart grid enabling technologies in the automation and control plant discipline which are currently being tested and implemented in other countries are described and these applications and their challengers in the South African context are outlined. The objective of this paper is to aid utilities when developing their business plans and strategies for the next generation smart-grid framework

Keywords: DSM, Demand Response, ICT, Smart Grids, AMI, metering

1 Introduction

In South Africa, the state of the power system and the balance between supply and demand is tight, thus further emphasizing the need to invest in cleaner energy to meet South Africa's future demand. The inception of independent power producers (IPPs) generating cleaner energy to support the existing power system coupled with Eskom's intent on building wind farms will lay the foundation for South Africa to embrace wind energy technologies and contribute towards the reduction of emissions on a global scale.

The output wind power of the electrical system is governed and determined by prevailing meteorological conditions which falls outside the dominion and control of the system operator. Reduction of wind in power grids with large scale wind energy penetration can introduce severe consequences on the security, reliability and integrity of the power system predominantly where no additional resources are available to respond to significant ramp rates [1]. Many countries encompassing a substantial install base of integrated wind power generation have experienced extreme positive/negative ramp rates. Ramp rates between 4% - 7% of the installed capacity can be experienced in a second and rates between 10% to 14% can be experienced in minute intervals for the same installed capacity [2].

The intermittency of wind energy can be managed by a number of resources including grid integration, energy storage technologies, complimentary renewable energy systems, improved forecasting techniques and conventional spinning reserves.

One of the key enablers of managing the intermittency of wind in a power system is through the institution of smart grid technologies and programs. These include Demand Side Management (DSM) and Demand Response (DR) programs. These programs and techniques can facilitate the reduction of load on the demand side during peak times and can be used by utilities to decrease demand to match available supply as opposed to the conventional method of increasing supply to meet current demand by operating spinning reserves.

DSM and DR programs are being explored and implemented by many utilities around the world including South Africa. However, the intermittency of wind require near real-time variation in the load in order to not compromise the security of supply to the grid. In this case, it is important to introduce DR initiatives and there supporting smart grid technologies to supplement DSM and manage the power-system.

In the next few years in South Africa, the building and integration of large-scale wind farms on the transmission and distribution networks is inevitable. This outcome necessitates the investigation of South Africa's current DSM and DR practices in order to determine the most optimized approach in managing the power system. It is fundamental that this approach incorporates the correct implementation of smart grid technologies such as advanced metering infrastructure (AMI) coupled with various demand response technologies. These technologies need to be aligned with the countries smart-grid strategy going forward and should contain the appropriate means to compensate the effects of wind variability.

2 Demand Side Management / Demand Response

To provide supply to an uncontrolled demand, power utilities around the world are required to ensure that sufficient capacity reserves and ancillary services are provisioned in order to provide generation security especially in cases where integrated renewable energy systems exists. Additional reserves can be provided through the use of DSM and DR.

Over the past few years, Eskom's DSM program has been primarily focused on load shifting and actively managing and reducing electricity demand profiles [3]. Public education and awareness on energy efficiency is a major contributor to the DSM program. This program is aimed to achieve a target of 10% reduction in power demand and a savings of 8000 MW by 2026 [3]. Part of Eskom's DSM program includes the replacement of incandescent lights with CFL, providing rebates to customers wishing to replace the use of electric geysers with solar water heaters, mass-rollout of geyser blankets and efficient shower heads, incentives to replace electric stoves with gas-operated stoves and endorsing the use of smart metering devices.

DSM can further acts as a remedial balancing action to manage the unpredictability and variability of wind power. Applications of DSM can provide additional system stability and support and can be seen as an alternative ancillary service.

a) Benefits of DSM

- Increase the utilization factor of generation network and capitalize on network investment. The conventional method of having a number of spinning reserves operating at partial load degrades the efficiency of the power system [4].
- Provides flexible capacity to stabilize and balance the power system.
- DSM can indirectly educate the consumer in managing their overall energy consumption and provide consumers a greater role in the value chain of energy trading.

- Climate challenge and environmental protection.

b) Challengers of DSM/DR

DR can assist abrupt variations by adjusting load in near real time. However, in order to fully conceptualize and benefit from the load reduction that can be achieved, a number of prevailing challengers need to be carefully considered. These primarily include:

- There is a lack of ICT and metering infrastructure required to deploy DSM/DR on a national scale.
- The ability of the billing system to efficiently manage dynamic pricing with fluctuations and billing to customers based on their responses is very limited.
- There is a challenge to justify the upfront capital investment required to install technologies for DR. These costs need to be weighed against the benefits derived from its correct institution.
- Quantifying costs and benefits derived from disaggregated smart grid technologies/applications associated with DR.
- Lack of skills and confidence in different smart grid -enabling technologies which support DSM/DR. Utilities are encouraged to continue piloting and investing in research and development as the system complexity increases considerably when implementing DSM/DR applications and management of these applications is paramount for its success.
- There is a lack of incentives for consumers to change their consumption/behavior patterns and compromise their convenience for efficiency.
- Loads which require sufficient operational and startup time make load-shifting a challenge [2].
- Inactive loads can operate when supply is high, however, these can only operate over a specified period of time.

3 Current Smart Grid Enabling Technologies

A number of techniques and tools centred on demand response are currently being researched and implemented in countries with a high penetration of wind energy.

The Federal Energy Regulating Commission (FERC) estimates that DR programs can alleviate US peak demand by up to 20% within 10 years.

In Portugal, investigations and tests were conducted against various DR programs using the industrial, domestic and tertiary sectors. Reduction of 13% of peak load was observed when instituting these programs [1]. Their research estimated that peak load reduction of 17.4% can be achieved by 2020 by continuing to apply DR programs with smart grid technologies [1].

In the United Kingdom, the “Demand for Wind” research project was introduced to investigate the use of DR programs in order to address the variability of wind energy in a power system. The scope of the research included the development of smart grid enabled technology to perform a number of functions including: diverse forms of controls in the residential environment; monitor household energy, communication of usage data and control signals between the control centre and the household; measuring consumer energy usage patterns using DSM/DR programs; develop a small scale home automation system with embedded web technology enabling direct communication to consumers through web-forums [6]. The key objectives of this project was to promote renewable energy sources by creating a demand for wind energy, prevent wind curtailment, enable consumers to use a larger load when surplus of wind energy was available and change customer behaviour patterns by allowing consumers the flexibility of responding to electricity price fluctuations by managing the energy usage accordingly [6].

The Belgium transmission system operator, Elia has contractual agreements with industrial customers to temporary permit the interruption of large power components in order to ensure grid security [7]. New England's ISO ancillary services market project enables utilities to bid DR capacity into the energy markets which is perceived as capacity reserves [8].

Scandinavian and UK markets manage short-term energy trading based on supply forecasts and predictions. These incentives are offered to consumers for both load reduction when wind energy is low and for increases in load when wind energy is high [2]. In these markets, much research has been done in analysing the technical properties of different loads in the domestic sector which can assist in time shifting and during generation peaks [2]. Two major groups of high energy consuming appliances in the domestic centre exists: appliance operating for short periods which are typically used for during generation peaks and appliances that operate as and when required [2].

Utilities in the United States have committed to investing in over 40 million smart meters over the next 5 years [8]. The U.S. government has demonstrated its support with a number of acts, regulations and policies being introduced which are directed towards the development of the next generation smart grid. A substantial portion of the funding of this smart grid development is sourced from the American Recovery and Reinvestment Act of 2009 (ARRA) [11]. One of the main objectives is to upgrade the power system to enable consumer choices, create jobs and generate clean and secure energy from renewable sources. Nine states are estimated to have over 50% penetration of advanced meters [13]. FERC's latest annual assessment indicated that the potential demand response resource contribution from all DR programs is nearly 72 GW which is nearly double the generation capacity available in South Africa [13].

The city of Tallahassee in Florida has spent 8.8 million dollars to implement a smart grid based DR program that allows users to remotely cycle off their air-conditioners.

The Turkish electricity market is undergoing rapid growth and large capacity increases are expected from renewable energy sources. A projected target of 30% of demand to be supplied by wind and solar is anticipated by 2023 [13]. In light of this, Turkey has made the development of a smart grid a priority and will be investing $5 billion on smart grid technologies in order to meet their targets [13].

Recent reports have also shown that a number of countries in Asia are investing significantly in the development of the smart grid. China projects that their installed base of smart meters in China will reach $377 million by 2020 resulting in a penetration level of 74% [15].

In Ontario, 4.3 million smart meters have been installed with a 1000 homes having a complete integrated smart-grid solution. The intention behind this investment was to reduce peak demand, improve energy efficiency and increase visibility and control. This solution incorporates: a utility management system capable of managing demand by load shaping; a consumer portal accessible over a web interface, mobile application or tablet allowing consumers to conveniently manage energy usage; the core network infrastructure communicating to smart meters using broadband power line carrier (BPLC) and digital area radio; a home energy manager that the consumer uses to communicate with the control centre on DR applications.

Eskom's current smart metering strategy does incorporate the accommodation of DR programs including Time of Use Tariffs (TOU) with load limiting capabilities and remote disconnection [11].

4 Role of Smart Grid Technologies

Utilities are currently investigating various smart grid enabling technologies and developing strategies which describes the new smart-grid paradigm envisioned for their countries electrical infrastructure [9]. This is being done with the idea of improving the efficiency and utilization of the power system.

The next generation of smart grid technologies will support DR programs and applications in allowing consumers to make smarter and informed decisions on energy efficiency and conservation. In many parts of the world, deregulation of the electricity industry and energy trading has provided the consumer with many choices thus making the consumer a key component in the value chain of the power system.

The management of the intermittency of wind energy in South Africa's electrical system requires a number of technical and practical challengers which need to be addressed. Amongst others, these include demand response programs, the power system's pricing model, the advanced metering infrastructure and the ICT infrastructure.

a) Advanced Metering Infrastructure

One of the prominent smart grid technologies that support DR applications is advanced metering infrastructure (AMI) with smart meters. This includes a master station, a full duplex communications network, smart meters, data concentrators, a load switch, appliance control devices (ACD) and a customer interface unit (CIU). The type of communications media for the full duplex network is not specified in the NRS specification for AMI's for use in South Africa.

Currently, AMI systems and smart meters that have been deployed in the South African power system are capable of providing the following minimum facilities:

- Event reporting with time to the AMI master station.
- Local/remote appliance connect/disconnect.
- Meter/data concentrator configuration change
- Control a minimum of two appliance devices
- Load limiting
- TOU Tariffs configurable through messages from the AMI master station
- Sending commands to meters to remotely operate a number of ACD's.
- The ability to remotely curtail demand and provide load control during system emergencies.

It should be noted that a smart meter is not a smart grid [14]. A number of enterprise systems including resource management, outage management, asset management, customer service constitute a smart grid. Specific needs of the industry should be considered and a strategy with a roadmap towards the end-state should be clearly defined prior to commencing the journey towards a smart-grid [14]. This becomes more critical when mission critical services are involved.

In order to enable the transfer of information to various stakeholders within the utility, it is necessary for the AMI master station to integrate into the utilities enterprise systems. This can be achieved using an adaptive interface that uses a common information model (CIM) described in IEC-61968 primarily structured in extensive markup language (XML).

Inter-application integration is paramount for the exchange of real-time information used in the corporate network. Systems which use adaptive interface supporting CIM will prevent replacement of existing applications and systems and secure the current investment.

IEC 61968 that the domain model of each enterprise system interface be defined in Unified Modelling Language (UML) and that XML be the data format for document interchange. Having a common architecture will enable various systems to inter-communicate and facilitate data exchange between a variety of business functions. These business functions include: sales, network operations and support, distribution management system, fault management, records and asset management, customer services, operational planning, maintenance and construction etc. Data acquired from smart meters can then be fed into these business functions.

The economic benefit of employing this smart-grid technology includes: outage detection, load management, device management, credit management and tamper detection thus avoiding loss of revenue and providing revenue protection.

The complete solution for smart metering should accommodate a web-interface which provides customers with their metering data, historical trends, usage profiles, costs, a forum allowing consumers to exchange ideas and information on energy efficiency and demand side management and provide a portal for utilities to communicate and update consumers on a real-time basis.

Eskom has recently completed phase 1 of its AMI implementation with two suppliers which included the installation of more than 3000 smart meters on the network [16]. The intent of this project was to improve Eskom's experience with smart metering and AMI's and meet the objectives outlined for phase 1 [16]. This includes the implementation of DR programs; promoting customer behaviour change by offering incentives (real-time energy usage information and supporting TOU tariff/Load Shifting); improve efficiency and customer service and understand the requirements and challengers which exist with the implementation of AMI's in order to derive a standardized solution going forward.

This required integration into the utilities existing Customer Care & Billing system. The AMI master station and CC & B required interface adaptors for integration and data transfer. This resulted in the development of a multi-vendor integration layer (MVIL) using CIM which allowed the integration of both vendors AMI back-end systems into the enterprise network [16]. In addition, a consumer web-based portal was developed that accessed CC&B and provided consumers with energy usage information [16].

Eskom has experienced much success from Phase 1 of the AMI project. Their reports indicate that a number of benefits were derived from this pilot. These include:

- Customers which were initially not on the billing system were added as a result of the meter installation [16].
- Errors found on the billing system were rectified [16].
- Meter tampering and illegal meter bypassing were identified [16].
- Detailed specifications and installation procedures on smart meters were documented as a result of the experience gained during the implementation. This laid the foundation for developing the skills in smart metering for Eskom [16].

b) Demand Response Programs

Using DR programs and technologies will enable utilities to provide automated DR programs and offer the energy capacity of the grid to the energy trading market as a resource [8].

The economic benefit for the system operator is to provide incentives to the consumer and remunerate the consumer for reducing energy consumption as opposed to paying additional operating costs to match the available demand by employing the use of spinning reserves.

The DR applications that can assist load reduction by providing incentives during times when wind energy is low include:

- Direct Load Control: remotely cycles of a customer's electrical supply after receiving participation consent from the consumer. This is often used during load limiting programs. Load limiting can assist in load reduction, however, a consumer is forced to use a pre-specified amount of energy or supply will be disconnected.
- Interruptible load: this program is typically used in a commercial/industrial environment. This has been a program that has been deployed in South Africa over recent years. Load is curtailed during peak periods. Supply to the consumer is typically remotely switched off after notification is given. Incentives are usually given to a consumer for their participation which is governed by a contractual agreement between Eskom and the consumer.
- Emergency demand response: this program serves as an emergency contingency when load reduction is required near real-time. This event may typically arise during a high responsive

negative ramp rate of wind energy. Incentives will need to be provided to consumers who subscribe to this event.

- Demand bidding and buyback: This program allows the system operator to offer load reductions at a price and identify how much load the consumer will be willing to forego for the price offered. With demand bidding, consumers have the option of enrolling on programs which offer incentives if loads are sacrificed during peak times and when wind production is low. This provides an opportunity to load shift and increase the utilization on the power system.
- Time of Use Tariff: this is a pricing model that is designed to encourage energy efficiency and conservation by inflicting a high price for energy during peak periods.
- Real – time pricing: this pricing model fluctuates hourly or more often in order to indicate changes in the energy trading market. These changes can be in response to a loss of renewable sources.

When developing the smart grid strategy, careful consideration needs to be given on the type of DR program applicable for the power system. Appropriate statistical and load research techniques need to be applied when evaluating which DR program and application to implement on the network. This requires quantification (measurement and verification) on the amount of load reduction which can be achieved on different DR programs. A number of methods exist which can be employed to calculate the required baselines and load reductions possible in different DR programs. This should be investigated during the implementation of AMI's on a small scale. This enables the utility to monitor consumer behaviour and experiment with a number of DR applications in order to evaluate the optimum cost-effective solution offering the most reduction. Furthermore, this research will pave the way forward on the choice of DR program to be used in conjunction with AMI's for the large-scale rollout of the technology.

Initially, this approach might seem costly and time consuming as opposed to choosing a DR program based on best practiced approaches chosen by other ISO's and utilities. However, not all utilities share the same experience and encompass the same demand behaviour. Meteorological conditions and the economic circumstances of a country are key factors which can affect consumer behaviour patterns and energy consumptions. Hence, each utility is required to invest significantly in understanding their consumer's energy trading requirements. For example, the use of air-conditioning system's in South Africa is moderate when compared to countries situated near the equator which experience higher temperatures in the summer months. In addition, choosing a DR program without understanding the consumers energy requirements can lead to utilities paying incentives in excess of customer responses and/or no load reduction being recorded during a DR event which can lead to consumers not-participating in future events.

During this pilot, baselines are required to be continuously adjusted based on historical load-usage data and factoring the availability of wind energy during that time. This will allow the utility to create weather based consumer models of various DR programs based on the sample data recruited from participants of the pilot project and weather data retrieved from the wind farm controller system.

This result should then be weighed against the practical and financial feasibility of implementing different DR programs in order to ascertain the optimum solution for the power system.

c) Challengers facing smart grid enabling technologies

- Lack of infiltration of smart appliances to facilitate home automation systems.
- Extensive support and customer service will be needed to manage complex DR programs/applications. Customer queries need to be resolved and many customers will demonstrate resilience to the new technology due to a lack of knowledge and understanding of the system.

- The AMI system needs to accommodate all customer sectors including pre-payment metering. This particularly applies to the billing system. Many challengers require consideration when considering smart-metering on pre-payments systems. Utilities are required to investigate these issues and develop a strategy going forward with regards to pre-payment systems. Some of the issues include: the flexibility of having the billing system communicate with the pre-payment meters, pre-payment accounting to be achieved locally or centrally on the back-end system depending on whether transactions that will occur in currency or energy units, backward compatibility with existing token technologies, support for TOUT and other complex demand response applications etc. [18].
- The impact on the business by instituting a full-scale roll out of smart meters and AMI's needs considerable consideration. Issues which need to be considered include business operations, impacts on value chains, systems and stakeholders [12]. These need to be identified and a work-process flow with adapted processes and procedures need to be outlined.
- Defining and setting up an agreement with a customer. This needs to be clearly defined with customer acceptance prior to the rollout. Consumer input during the small-scale roll-out is suggested
- Managing and validating metering data. Phase 1 of the AMI rollout in Eskom showed that one of the critical challengers facing the implementation revolved around data inconsistencies on the meter data management system. Systems audits need to be conducted prior to rollout and the authenticity of all drawings needs to be verified during installations to prevent stranded meters and ensuring the accuracy of the customer network database.
- Network planning and roll-out strategy, billing for revenue collection, credit management, inspection, maintenance and repair philosophies need to be prepared.
- Outages are required during installation of data concentrators. Issues surrounding data concentrators will require additional outages. Customer notification and acceptance is required and key performance indexes will be affected during this time.
- Installation of smart meters requires approval from home-owners and this can only accomplished at their convenience. This can possibly delay rollouts and installations of CIU's, data concentrators and smart meters.
- Inventory count, monitoring of assets, project managing installations, monitoring of connectivity, resolving issues with suppliers, metering solution performance issues,
- Theft and vandalism which is often faced in a number of high risk areas. Eskom have added additional secure kiosks for the data concentrator in order to prevent further incidents of theft and vandalism.
- Regulations and existing government policies need to be amended in order to support DR programs in the domestic sectors.
- Control signals, data formats and protocols need to be internationally standardized and not proprietary. There is a lack of interoperability and open standards. The European standards organization working groups and technical committees mandated by the European Commission are reviewing and developing standards with the intent of harmonizing, standardizing and cater for interoperability in the smart grid architecture [17]. In the near future, we can expect a mapping between the Common Information Model message profiles defined in IEC 61968 and DLMS/COSEM (IEC 62056) message profiles thus allowing smooth integration of AMI master stations and the integration layer linked to utilities enterprise systems [17]. It is also envisaged that a translation between IEC 62056 and the IEC 61850 suite standards used for substation automation system will exist [17].

- There is a great need for consumer education. Creating awareness and including the consumer in the value chain during the infancy stages of the project can speed up adoption and acceptance of the new technology and prevent concerns and uncertainties arising in the deployment phase. This has been observed by utilities in Texas and California.

d) Ancillary Services

Under most conditions, spinning reserves are costly as generators are required to forfeit energy sales in order to respond to contingencies. Further costs are attributed towards additional maintenance and fuel costs of the generators.

Embedded wind power generation would undoubtedly affect the ancillary services requirements. These are required to be dynamic as demand resource can actively contribute towards the capacity reserves. In addition, the predicted wind power would impact the amount of variability on the power system. Hence, markets need to now plan ahead in order to ascertain what the ancillary service requirements will be based on the predicted conditions on an hourly basis.

Research has shown that renewable technology will be participating in certain ancillary service markets. Through the inception of embedded wind power generation, the need to recognize additional ancillary services including frequency response, voltage and reactive power support.

e) Dynamic Pricing

Customer needs feedback on how much energy they have saved when they participate in events and how much they could have saved if they participated. It is rather challenging for the CIU of the smart meter to integrate pricing with energy consumption and provide real-time dynamic pricing updates. In addition, should this be achieved, its accuracy when compared to the electricity bill generated from the utilities billing system requires careful consideration. A more efficient method of providing such real time information is to provide customers with a web-accessed information portal which access the utilities billing system. This access to information is one of the supporting pillars based around DSM/DR [8].

The consumer needs to be compensated for being energy efficient and participating in DR programs. Furthermore, rebates and incentives should be given to consumers who partake in pilot programs. A duel benefit is derived from this approach as the learning experience is extended to the consumer creating awareness, and an opportunity for consumers to adopt energy efficient behaviour profiles [8].

Over recent years, South Africa experienced electricity price increases on a yearly basis. Escalating prices is now the reality for many consumers in South Africa. The realization of the increase in electricity prices can be the incentive required to accelerate the adoption and promotion of customer behaviour change by instituting dynamic pricing thus enabling the consumer to have control over his energy consumption and electricity bill.

f) ICT Infrastructure

In order to support these smart grid technologies, high up-front capital is required for network expansion and providing a network that is capable of supporting full duplex traffic allowing near real time communications to customers. A full duplex network will permit the transmission of signals, messages and events between customers participating in DR programs and the utility. In addition, there are a number of technologies available which need to be considered for the AMI. In addition, depending on bandwidth available and cost, a number of technologies can be used. For example, the communications technology between the meter and the ACD and the communications technology between the meter and the data concentrator or the data concentrator and the AMI master station do not need to be the same. Utilities are requested to test a number of these mediums during the small-scale implementation. These technologies are detailed below.

- Broadband over power line carrier (BPLC) can be used for high-speed internet access using existing residential electrical infrastructure. The technology is based on DSL which exploits un-used transmission capabilities on the wires and using signaling frequencies other than the power frequency. This is largely employed between the meter and the data concentrator unit.

- Going forward, with the inception of fiber to the home (FTTH), additional bandwidth may be available from 3rd party vendors who are operating VoIP, ipTV and internet services. However, this introduces a number of challengers and risks which need to be carefully considered before this option is recognized. These include: stability of 3rd party vendors and possibility of liquidation, service level agreements and availability of communications, costs, security etc. In addition, each concentrator communicates with a number of smart meters. This will be rather challenging to implement as there may not be availability of fibre between all devices required to communicate to a concentrate.
- At present, mobile service providers have achieved a large coverage for data communications using GPRS and 3G. Latency and throughput on GPRS can be variable as the network operates on a best-effort grade of service depending on the number of simultaneous data users on a service in making it inadequate for real-time services. However, for purposes of demand response applications and providing bi-directional communications between the utility and the customer/data concentrator, GPRS/3G is adequate. With the institution of LTE networks in South Africa, additional bandwidth will soon be available in major metropolitan areas with a number of LTE communications devices already available by 3rd party vendors. LTE will provide an increase in capacity and speed and reducing latency when compared to its predecessors and provides a packet switched Ethernet interface which is supported in many emerging smart meters.
- The use of wireless communications such as World-Wide interoperability for Microwave Access (WiMax) and wireless devices using the ISM radio frequency band which support high data rates is another medium which has recently been adopted in many AMI solutions.

Issues that need to be addressed when determining the optimum telecommunications medium include: determining the speed and the maximum no. of meters that can be used per data concentration unit (DCU), quality of the links, packet error rates and bit error rates, signal strength, availability, meter data management and web-based services, integration of customer interface portal with the billing system, scalability, affordability, reputable service level agreement with telecommunications service provider with end to end guarantees, possibility of differentiating between different classes and quality of services etc.

5 Conclusion

With the large integration of wind energy sources in the power system, utilities are expected to accelerate the pace of testing various smart grid technologies. Acquiring first-hand experience in best practices needed to overcome these technological and commercial challengers is a key enabler when implementing smart-grid technologies that can support Demand Response.

A cost-effective solution would be for utilities to deploy AMI on a smaller scale which includes a large portion of the DR applications and programs that is desired on the final network as outlined in there smart grid strategy and roadmap.

This paper presents the role DSM and DR plays in a power system and outlines a number of benefits and challengers associated with these programs. The current smart-grid enabling technologies which are being employed around the world in order to manage the intermittency of wind energy is presented and the role of these technologies is discussed with particular reference to ancillary services, the ICT infrastructure, advanced metering infrastructure and the challengers accompanying these technologies.

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