CONSEIL INTERNATIONAL DES GRANDS RESEAUX ELECTRIQUES
INTERNATIONAL COUNCIL ON LARGE ELECTRIC SYSTEMS

http:d2cigre.org

STUDY COMMITTEE D2
INFORMATION SYSTEMS AND TELECOMMUNICATION

2013 Colloquium
November 13-15, 2013
Mysore – KARNATAKA - INDIA

D2-01_21

Integration of 4G Communication Network Technologies with Smart Grids

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IN

SUMMARY

In the smart grid operation and management, reliable and real-time information and communication networks play a very critical role. By integrating the appropriate information and communication technologies (ICT) infrastructure, automated control, sensing and metering technologies, and energy management techniques, the smart grid has emerged as a solution that empowers utilities and consumers to share the responsibilities of operating and managing the power grid more efficiently. The leverage of the Fourth Generation Communication Network and Technology provides a distinct possibility of the fourth generation Smart Grids Solution. For this purpose, the SmartMeter and SmartGrid Router need to be integrated with the next generation fourth generation communication standards. In this paper, it is proposed to investigate about the various ways in detail through which integration of 4G Communication network technology will play a vital role in the Smart Grids. This study is expected to facilitate robust communications and network management which will lead to reduction in cost, number of operators required, and the difficulties associated with increased data from Smart Grid applications and networks.

KEYWORDS

Smart Grid, Intelligent Communication, WiMAX.

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I. Introduction

The smart grid is a modern electrical power grid infrastructure for better efficiency, reliability, with possible integration of renewable and alternate energy sources. In order to achieve those broad objectives, smart grid integrates advanced information and communications technologies (ICT), automation, sensing and metering technologies, and energy management techniques based on the optimization of energy demand and supply into traditional power grid in order to make it more efficient in many ways. Smart grid offers better communications among all stakeholders in the system. Smart grid requires communications to be real-time in many cases. The ICT infrastructure in the smart grid environment needs to be reliable, highly-available, scalable, secure, and easy-to-manage.

Two-way seamless communication is the key aspect of realizing the vision of smart grid. There are several standardized wired and wireless communication technologies available for various smart grid applications. With the recent growth in wireless communication, it can offer standardized technologies for wide area, metropolitan area, local area, and personal area networks. Moreover, wireless technologies not only offer significant benefits over wired, such as including low installation cost, rapid deployment, mobility, etc., but also more suitable for remote end applications. Several activities are going on to explore specific applications of these technologies in smart grid environment.

4G Technology is ideal for smart grids, as it allows for the two-way communication, remote monitoring and control of the grid, quick and easy installation as well as broadband speeds. Furthermore, with 4G, utilities can remotely locate, isolate and restore power outages, thereby increasing the stability of the grids. The multiple megabits supported by 4G significantly outpace the bandwidth supported by outdoor Wi-Fi, Digital Cellular or proprietary solutions – this gives grid operators an ability to not only address the primary meter communication requirements of the network, but also the ability to leverage a common platform for real property management, mobile workforce connectivity (including VoIP support) and CCTV camera security backhaul.

II. Requirements for Communication Infrastructure for the Smart Grid

- **Standards-based:** The communication infrastructure needs to be based on standards to ensure support for the diverse set of utility applications and to provide investment protection. Applicable standards pertain to radio communication protocols, networking interfaces (TCP/IP) and industry standard security specifications.

- **IP network:** A network that is based on IP provides the broadest possible platform for the delivery of a wide range of applications.

- **Real-time:** The network needs to provide the real-time low latency communication capabilities that are needed by such applications as distribution automation and outage detection.

- **Scalable:** The network and its network management system need to be capable of scaling to the large deployment footprints typical of many large IOUs.

- **Resilient and High Availability:** To meet the reliability requirements imposed on utilities, the network architecture must be resilient and capable of continuing to operate even in the presence of localized faults.

- **Secure:** Since the grid and its components comprise critical infrastructure, the communication infrastructure for the Smart Grid needs to provide a secure foundation for information flow and conform to industry-standard security specifications.

- **Supports traffic prioritization:** The communication network must be capable of prioritized delivery of latency-sensitive mission critical applications such as distribution automation, over latency-insensitive traffic types such as metering data.

- **Mobile:** The network must support mobility to enable mobile workforce connectivity applications.

- **Future-proof:** In view of the long network lifetimes, the underlying network architecture and network elements must be selected so as to provide broad investment protection.

- **Cost competitive:** The communication infrastructure must be cost-competitive (CAPEX as well as OPEX).

- **Broad coverage**: The communication network should be capable of delivering broad coverage over thousands of square miles.

The description about the effects of the Smart Grid on the different primary functions of Generation, Transmission, Distribution, Energy Trading and Consumers has been tabulated. Besides that, it will show how an intelligent communication infrastructure will help the smart Grid to accomplish those functions.

Generation			
Primary Functions	**Description of Functions**	**How Smart Grid Affects These Functions**	**How an Intelligent Communication Infrastructure Enables and Amplifies the Smart Grid Impact**
Load Control and Dispatch	Economical load dispatch scheduling & optimization helps to select the right dispatch for the right load at the right time, reducing the cost of generation (start-up, operations and wind down).	Smart grid helps with the scheduling of the committed generating units so as to meet the required load demand at minimum operating cost while satisfying all units and system equality and inequality constraints.	Economic load dispatch during unforeseen events warrants robust real-time communication infrastructure between the demand and the generation functions.
Load Shaping	Shaping the load during peak demand times reduces the idle and stand-by generation capacity.	Demand-side management (DSM) helps to manage and accurately estimate demand so as to meet demand without extra generation.	Load shaping with DSM involves reliable communication between AMI, CIS (Consumer Information Systems), and generation functions.
Distributed Renewable Generation	Integration of Micro-grids as well as generation at customer premises with the utility infrastructure.	Smart grid enables distributed generation and automated adjustment of feed-in tariff regulation to receive premiums in the case of forced switch-off of distributed-generation asset for balancing energy.	Infrastructure is needed to confirm, analyse, and dispatch available load to distribution generation sources.
Generation Equipment Maintenance	Diagnoses and maintenance of the generation equipment reduces faults and prevents their propagation.	Smart grid helps asset management and conditioning in preventive maintenance It also helps accessing newly sensed data.	Data from turbines needs to be transferred to the generation control centre for better equipment conditioning and monitoring.

Transmission			
Primary Functions	**Description of Functions**	**How Smart Grid Affects These Functions**	**How an Intelligent Communication Infrastructure Enables and Amplifies the Smart Grid Impact**
Transmission Grid Monitoring and Control	Energy Management Systems (EMS) and transmission SCADA for data acquisition needed for the following functions: ●Outage management ●Volt/VAR management ●State estimation ●Network sensitivity analysis ●Contingency analysis ●Automatic generation control ●Phasor data analysis	●Automated regulation of load tap changer and capacitor banks for voltage regulation. ● Wide-area phasor measurement and control for grid optimization and control ●Volt/VAR management using capacitor switches and controls	Substation automation results in two-way communication between transmission SCADA equipment and EMS. Communication between transmission and generation units is necessary for automatic generation control.
Maintenance of Transmission Control Centre	The transmission control centre is the first layer of defence for transmission fault detection and prevention.	Automated operations eliminate human intervention in fault prevention, detection, isolation and correction.	Real-time communication between primary and backup transmission control centre, transmission, generation, and distribution units is necessary for control-centre operations. Security technology deployment provides for secure data sharing between transmission and other utility functions.
Equipment Maintenance	Maintenance of transmission equipment, including breakers, relays, switchers, transformers, and regulators, prevention of faults.	Smart grid helps asset management and conditioning for preventive maintenance	Data from transmission equipment needs to be transferred to the generation control centre for better equipment conditioning and monitoring.

Distribution			
Primary Functions	**Description of Functions**	**How Smart Grid Affects These Functions**	**How an Intelligent Communication Infrastructure Enables and Amplifies the Smart Grid Impact**
Feeder voltage regulation and phase balancing	Regulation of distribution voltage to prevent overcurrent problems. Maintain phase balance with the variation of customer load demand (unbalance will lead to equipment overloading and malfunction of protective relays).	Load consumption information from customer information systems will help in phase balancing. Information from distributed-generation Assets will help with voltage regulation.	Distribution automation through low-cost Distributed Network Protocol 3 (DNP3) helps in monitoring and control. Communication between Distribution Management System (DMS) and distribution equipment is necessary for automated distribution operations
Trouble call and Dispatch	Analysis of distribution trouble-ticket analysis and dispatch to increase customer satisfaction.	Provisioning an automated outage notification and automated dispatch system. Equip mobile field force with data.	Real-time data, voice, and video into distribution trucks resulting in fewer trips and quicker restoration.
Planned and Emergency Switching	Automation of fault detection and correction at substations and feeders.	Automation of switching sequence for emergency switching.	Provides effective communication from the relay, breaker, and the feeders to the distribution control centre
Power-quality Maintenance	Maintain the right voltage levels across the distribution system.	Improvement of power quality by fast and effective use of information from devices that cause those events (transformers and motors).	Real-time communication from transformers and motors and power analytics systems is necessary for power-quality maintenance.

Energy Trading, Consumers, and Others				
Other Utility Functions	**Primary Functions**	**Description of Functions**	**How Smart Grid Affects these Functions**	**How an Intelligent Communication Infrastructure Enables and Amplifies the Smart Grid Impact**
Energy Trading	Forecasting Market Modelling Demand-response Programs Energy trading Risk management	Energy trading enables a utility to buy energy to meet peak demand or to sell excess capacity	Smart grid provides real-time demand and generation information for energy-trading decisions	Real-time communication between analytics, demand, and generation units is necessary for effective decision making regarding energy trading.
Consumer	Home energy Management	HEM helps users to monitor and control the time, amount, type, and level of energy usage.	HEM data can ride on the neighbourhood area network when smart grid is employed.	Low-cost backhaul communication methods are necessary for HEM traffic.
	Metering	Meter data is used for billing purposes.	Advanced Metering Infrastructure (AMI) allows for remote meter reads, connects and disconnects an automated outage detection.	Scalable, reliable, low-cost backhaul communication methods are necessary for AMI traffic.
	Demand-side Management	Management of demand side load	Smart Grid enables sophisticated demand side managed by integrating HEM, AMI data with demand response techniques.	DSM needs communication between HEM equipment, AMI, and generation units.
Inter-grid Communications	Communication between regional coordinators	Coordination is needed for better information flow between grids for fault isolation and prevention of fault cascading.	Smart grid enables communication of real-time data between regional control centres.	Secure communication are needed for ICCP (Inter-Control Centre Protocol) infrastructure

Core Infrastructure			
Primary Functions	**Description of Functions**	**How Smart Grid Affects These Functions**	**How an Intelligent Communication Infrastructure Enables and Amplifies the Smart Grid Impact**
Preparing, planning and designing a network to support a common, converged infrastructure that supports all functions of a utility with support for smart grid	Smart grid requires communication between all functions of a utility, namely generation, transmission, distribution, consumer, and energy trading. Thus, a highly available common communication infrastructure is required.	Smart grid can increase the return on investment (ROI) if all the utility functions use a common converged infra-structure with all the advanced technologies including: ●Unified communication (data, voice, and video collaboration) ● Physical security ● Management tools	A secure, scalable, resilient, and manageable network that will be compatible with future versions is a necessity for the core infrastructure that supports all smart grid functions. Selecting technologies that are common across utility functions will help in the manageability of operations.

From the above tables, we can infer that communication plays an important role in transformation of conventional Grid into *Smart Grid.* For the Smart Grid, the most suitable technology is the Fourth Generation Communication Technology.

III. Fourth Generation Communication Technology: WIMAX

Worldwide Inter-operability for Microwave Access

WiMAX clearly has an impressive set of compelling advantages that make it worth serious consideration by any utility planning a Smart Grid deployment, which are as follows:

- IP-based technology
- Much higher capacity and lower latency than 2G and 3G
- Genuine standards-based technology
- Full ecosystem of suppliers and equipment assure competitive pricing
- Proven interoperability between suppliers guarantees the supply chain
- Large installed base of carriers “future proofs” the technology

- Best Business Case
  (i) Cost effective, low OPEX, end-to-end solution
  (ii) Enables both build and lease options

- Best Feature Set

  (i) Full QoS regime assures utility traffic is given proper priority

  (ii) Strong security features safeguard grid and customer information

  (iii) Licensed spectrum assures that interference will not affect network performance

  (iv) Private or Virtual Private Network support isolates utility traffic from that of the public carrier

  (v) All-IP Architecture assures feature transparency

- Carrier-grade, high availability network assures system availability

- Scalable for very high and very low device densities

- New technology just beginning its service life (i.e., will not be replaced in the coming decade as is the case for 2G/3G)

Comparing Wireless Access Technologies: WiMAX emerges a clear winner

Technology	Advantages	Disadvantages
900 MHz Proprietary	Several suppliers Field proven	Proprietary wed to a single supplier Interference issues
2G/3G Cellular	Widely deployed Open standard	Limited capacity Limited service life
WiMAX	Highest capacity, Best feature set Supplier ecosystem, Open standard	Deployments in process

Requirements	4G Broadband	Proprietary AMI Narrowband
Security	✔	?
Interoperability	✔	?
Information Sharing / Data Exchange	✔	✔
Investment Leverage	✔	?
Scale & Flexibility to innovate Rapidly	✔	?
Enhanced Grid Reliability	✔	?
Reduce Obsolescence and Stranded Assets	✔	?
Shovel Ready	✔	✔
Transform/ Revolutionize Customer Relationship	✔	?
Near Real-Time Device Management/ Decisions	✔	?
High Bandwidth Network	✔	?
Network Latency	✔	?
Capacity for Growth	✔	?
CAPEX Cost: OPEX Cost	Higher Capex, Lower Opex	Lower Capex, Higher Opex

COMPARISON OF POSSIBLE WIRELESS TECHNOLOGIES

Customer Need	WiMAX	Wi-Fi Mesh	GSM/UMTS
Cost	High	Medium	High
Range	Rural 4 km Urban 500-900m	200 – 400 m	1.6-3.2 Km
Max. Data Rate	70 Mbps	54 Mbps	20-800 kbps
Frequency Band	2-11 GHz and 10-66 GHz	2.4 GHz and 5 GHz	700 MHz – 2.1 GHz
Band License	Free and Licensed	Free	Licensed
Flexibility	High	Medium	Medium
Robustness	Medium	High	Low

IV. Conclusion:

Smart Grid is an intelligent future electricity system that connects all supply, grid and demand elements through an intelligent communication system. The backbone of a successful smart grid operation is a reliable, resilient, secure, and manageable standards-based open communication infrastructure that provides for intelligent linkages between the elements of the grid while participating in the decision making that delivers value to the utility and supply and demand entities connected to it.

The ability of a utility to create ubiquitous connectivity between all of its current data sources and decision-making points is critical to the success of smart grid. A communication infrastructure that can efficiently move disparate types of data with varying degrees of transport, security, and reliability requirements is indeed a central requirement.

The fourth generation communication network technology is the most advanced and compatible technology for being the indispensable component of the Smart Grid.

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