ISSN (Online): 2455-7838
SJIF Impact Factor : 6.093

EPRA International Journal of

Research & Development

(IJRD)

Monthly Peer Reviewed & Indexed
International Online Journal

Volume: 4, Issue:1, January 2019

Published By
EPRA Publishing

SJIF Impact Factor: 6.093 Volume: 4 | Issue: 1 | January | 2019 ISSN: 2455-7838(Online)
EPRA International Journal of Research and Development (IJRD)
Peer Reviewed Journal

OVERVIEW, RESEARCH CHALLENGES AND OPPORTUNITIES IN SMART GRID COMMUNICATION TECHNOLOGIES

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ABSTRACT

Nowadays, requirement of electricity is increased tremendously. However available energy is not sufficient to fulfill requirements in modern civilization. Especially in Big malls, System house, big societies and corporate offices. Renewable energy sources are expected to increase highly for energy conservations. The depleting fuel resources, deteriorating environmental conditions and ever increasing power demands make imminent the modernization of the electricity transmission and distribution networks. The future of power distribution relies on utilities to maximize their efficiency and optimize the network to consistently deliver power to consumers at minimal cost and smart grid technologies are a promising solution for dynamic optimization of grid operations and resources, metering, distribution automation in response to demand, etc. Smart Grid systems allow End user (building/ office owner) to (1) monitor & control any activity (which consumes energy) from anywhere (2) Utilization of own generated renewable power (3) Buy and sell can be possible from anywhere. The communication infrastructure is critical for the successful operation of the modern smart grids. The use of communication technologies ensures the reduction of energy consumption, optimal operation of the smart grid and coordination between all smart grids' components from generation to the end users. The future smart grid is based on combination of legacy grid with advanced smart metering, remote sensing, remote control of all key components and equipment. The success of the smart grid depends directly on reliable, robust and secure communication system with high data rate capability. In Future work should be concentrated on development of improved security algorithms that could be adapted for the smart grid communication and protocols and methods for interference reduction and elimination.

INDEX TERMS— *Smart grid, communication protocol, Energy conservation.*

I. INTRODUCTION

Electricity is fundamental for development in current economy. There is a need of major revamp in current electric power system (from generation to consumption).The present Electric Grid is network through which generated electricity transmitted and distributed to consumers. It has generation system, Electrical transmission lines and Switching power stations. This existing system has some problems. Like, when demand of energy goes on increasing then one generator get loaded and hence not able to fulfill their demands. In other hand, due to some technical problem one could not maintain the reliability, efficiency of the system. So to overcome these limitations, we can make a grid system which can connect different types of generating companies and consumers. The grid system can become a Smart Grid when we make some advancement in generation, transmission and distribution.

The communication infrastructure is critical for the successful operation of the modern smart grids. The use of communication technologies ensures the reduction of energy consumption, optimal operation of the smart grid and coordination between all smart grids' components from generation to the end users.

The unidirectional nature of communication and centralized generation makes the traditional grids less efficient, thus reengineering of current grid is required in such a way that they are able to meet increasing demand, are less prone to faults and power loss, reduce electricity thefts and air pollution, extends life of equipment etc. This bidirectional grid with integrated communication system, highly efficient sensors and measuring units, advanced components and control methods, decentralized generation and smart distribution is called smart grid. They are self-healing, have efficient OMS, reduce greenhouse gas emission and focus on improving the PQ. Their main objective is smart and optimal utilization of all available resources.

The major characteristics of smart grid are –

- ❖ It allows informed participation of consumers to modify their use and purchase of electricity and monitor their consumption pattern.
- ❖ It allows use of all generation and storage options i.e. centralized as well as distributed (incorporates renewable energy resources also).
- ❖ It enables new services, markets and products.
- ❖ Provides real time pricing.
- ❖ It improves power quality by self-healing, load forecasting, fault prediction and control and monitoring of frequency.
- ❖ Asset utilization and operating efficiency is optimized by the use of latest technologies.

II. ARCHITECTURE OF SMART GRID

The bidirectional smart grid is composed of a smart generating system, smart transmission and smart distribution system and an advanced metering infrastructure with highly efficient meter data management system. Below figure shows the basic architecture of smart grid.

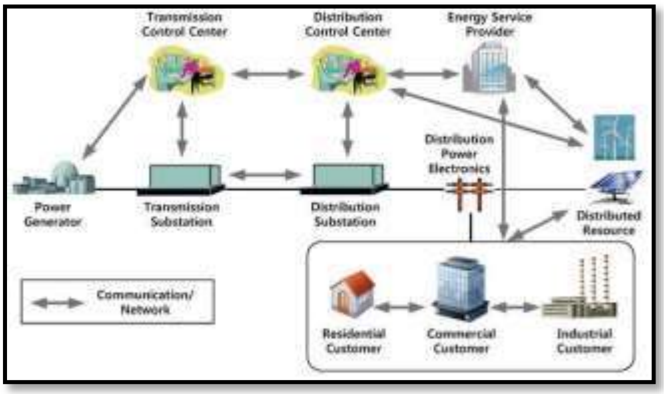

Fig.1 Architecture of Smart Grid

Table 1 Brief Comparison of Between Existing Grid and Smart Grid

Parameter	Existing Grid	Smart Grid
Generation	Centralized	Centralized and distributed
Communications	None or one way	Two way, real time
Customer Interaction	Limited	Extensive
Metering	Electromechanical (only for billing not much control)	Digital (Enabling real-time pricing and net metering)
Operation	Manual equipment checks, maintenance	Remote monitoring, predictive, time-based maintenance
Power flow control	Limited	Comprehensive, automated
Reliability	Prone to failures and cascading outages	Automated, prevents outages before they start
Restoration following disturbance	Manual	Self-healing
System topology	Radial, generally one way power flow	Network, Multiple power flow paths
Distributed Generation	Limited grid accessibility for new producers	Full and efficient grid accessibility

III. SMART GRID REQUIREMENT

The key requirements that are necessary to make the fundamental changes of the present distribution networks are as follows.

A. Self-Healing Grids

- ❖ Network with high reliability and inherent security in all levels.
- ❖ Decentralized control and wide spread use of sensors and measuring equipment.

B. Economical Grids

- ❖ Optimum use of assets and applying the concepts of demand response and demand side management
- ❖ Non-hierarchical distribution of electric power production and use of distributed generation driven by the consumers.
- ❖ Extensive use of network automation and reduced human intervention.

C. Low carbon network

- ❖ Integration of multiple energy resources.
- ❖ Electrification of transport sector.
- ❖ Management of pollution and carbon dioxide emission.

D. Two-way communication and advance software

- The smart devices transmit the information over a two-way communications pathway
- A key aspect of the smart grid will be its use of the same information technology that enables two-way communication between the consumers and utility.

IV. OVERVIEW OF COMMUNICATION TECHNOLOGIES USED IN SMART GRID

There are several technologies that can be applied to the smart grid:

A. ZigBee

ZigBee is based on an IEEE 802.15 standard. ZigBee is used in applications that require a low data rate, long battery life, low cost and secure networking. Applications include wireless light switches, electrical meters with in-home-displays, traffic management systems, and other consumer and industrial equipment that requires short-range wireless transfer of data at relatively low rates. ZigBee allows connection of up to 60000devices to its network.

ZigBee has a defined rate between 20 to 250kbs, best suited for periodic or intermittent data or a single signal transmission from a sensor or input device. The technology defined by the ZigBee specification is intended to be simpler and less expensive than other wireless personal area networks (WPANs), such as Bluetooth or Wi-Fi. ZigBee networks are secured by 128 bit symmetric encryption keys.

There is a "ZigBee Smart Energy" application that allows integration of smart meters into the ZigBee network together with other devices. By using this application, smart meters can collect information from the integrated devices and control them. Moreover, the consumers can view their energy consumption in real-time. It also allows better energy consumption and real-time dynamic pricing.

The advantages of ZigBee application in smart grid are low price, small size and it uses relatively small bandwidth. The disadvantages of the ZigBee are small battery that limits its lifetime, small memory, limited data rate and low processing capability. Moreover, its operation in unlicensed frequency of 868MHz and 2.4GHz may have interference with other Wi-Fi, Bluetooth and Microwave signals.

B. WLAN

A wireless local area network (WLAN) links two or more devices using spread-spectrum or Orthogonal Frequency Division Multiplexing OFDM and usually providing a connection through an access point to the wider Internet. This gives users the ability to move around within a local coverage area and still be connected to the network. Most modern WLANs are based on IEEE 802.11 standards, marketed under the Wi-Fi brand name.

WLANs have become popular in the home due to ease of installation, and in commercial complexes offering wireless access to their customers. WLAN could be easily integrated into smart grid due to its vast deployment around the world. WLAN works in 2.4GHZ-3.5GHz frequencies.

The advantages of WLAN are low cost, vast deployment around the world, plug and play devices. The major disadvantage of WLAN is high potential for interference with other devices that communicate on the same frequencies.

C. Cellular Networks

Cellular networks are largely deployed in most countries and have well-established infrastructure. Moreover, they allow high data rate communications up to 100Mbps. Therefore, the cellular networks can be used for communication between different components and devices in smart grid. There are several existing technologies for cellular communication such as GSM, GPRS, 2G, 3G, 4G and WiMAX.

The WiMAX technology is the most interesting for smart grid implementation. It is working on 2.5 and 3.5 frequencies, with data exchange rate of 70Mbs and coverage up to 50km. The WiMAX chips are integrated inside the smart meters that are deployed through the smart grid.

The advantages of the cellular networks are already existing infrastructure with wide area of deployment, high rates of data transfer, available security algorithms that are already implemented in the cellular communication.

The major disadvantage is that cellular networks are shared with other users and are not fully dedicated to the smart grid communications. This can be serious problem in case of emergency state of the grid.

D. Power Line Communication (PLC)

Power line communication allows data exchange between devices through electrical power lines. PLC is implemented by adding a modulated carrier signal to the power cables. The data rate of OFDM based communication can be up to several Mbs. Data rates and distance limits vary widely over many power line communication standards. Low-frequency (about 100–200kHz) carriers impressed on high-voltage transmission lines may carry one or two analog voice circuits, or telemetry and control circuits with an equivalent data rate of a few hundred bits per second; however, these circuits may be many miles long. Higher data rates generally imply shorter ranges.

Different types of power line communications use different frequency bands. Since the power distribution system was originally intended for transmission of AC power at typical frequencies of 50 or 60 Hz, power wire circuits have only a limited ability to carry higher frequencies. It is problematic to establish high frequency communication through power lines due to the dilution of high frequency signals. The propagation problem is a limiting factor for power line communications.

Furthermore, there can be interference of communication signals with high order harmonics produced by non-linear loads that present in the grid such as rectifiers, inverters, etc. In order to overcome this problem, advanced active filters should be used.

In smart grid applications, the PLC is used in Neighborhood Area Network communication for connecting between smart meters and Local Data Concentrator (LDC). However, the Wide Area Network communication, from LDC to other smart grid components such as operator control center, generation, transmission and distribution, is performed through cellular networks. The advantage of the PLC is already established, wide-spread infrastructure that reduces installation costs. The disadvantages are presence of higher harmonics in the power lines that interfere with communication signals and limited frequency of communication.

V. OPPORTUNITIES

The following are several research major programs in conduct till date,

A. Intelli Grid

Created by the Electric Power Research Institute (EPRI), IntelliGrid architecture provides methodology, tools, and recommendations for standards and technologies for utility use in planning, specifying, and procuring IT-based systems, such as advanced metering, distribution automation, and demand response. The architecture also provides a living laboratory for assessing devices, systems, and technology. Several utilities have applied IntelliGrid architecture including Southern California Edison, Long Island Power Authority, Salt River Project, and TXU Electric Delivery. The IntelliGrid Consortium is a public/private partnership that integrates and optimizes global research efforts, funds technology R&D, works to integrate technologies, and disseminates technical information.

B. Grid 2030

Grid 2030 is a joint vision statement for the U.S. electrical system developed by the electric utility industry, equipment manufacturers, information technology providers, federal and state government agencies, interest groups, universities, and national laboratories. It covers generation, transmission, distribution, storage, and end-use.The National Electric Delivery Technologies Roadmap is the implementation document for the Grid 2030 vision. The Roadmap outlines the key issues and challenges for modernizing the grid and suggests paths that government and industry can take to build America's future electric delivery system.

C. Modern Grid Initiative (MGI)

It is a collaborative effort between the U.S. Department of Energy (DOE), the National Energy Technology Laboratory (NETL), utilities, consumers, researchers, and other grid stakeholders to modernize and integrate the U.S. electrical grid. DOE's Office of Electricity Delivery and Energy Reliability (OE) sponsors the initiative, which builds upon Grid 2030 and the National Electricity Delivery Technologies Roadmap and is aligned with other programs such as Grid Wise and Grid Works.

D. Smart Grid Energy Research Center (SMERC)

Located at University of California, Los Angeles has dedicated its efforts to large-scale testing of its smart EV charging network technology - WINSmartEV™. It created another platform for a Smart Grid architecture enabling bidirectional flow of information between a utility and consumer end-devices - WINSmartGrid™. SMERC has also developed a demand response (DR) test bed that comprises a Control Center, Demand Response Automation Server (DRAS), Home-Area-Network (HAN), Battery Energy Storage System (BESS), and photovoltaic (PV) panels. These technologies are installed within the Los Angeles Department of Water and Power and Southern California Edison territory as a network of EV chargers, battery energy storage systems, solar panels, DC fast charger, and Vehicle-to-Grid (V2G) units. These platforms, communications and control networks enables UCLA-led projects within the greater Los Angeles to be researched, advanced and tested in partnership with the two key local utilities, SCE and LADWP.

CONCLUSION

The building automation and energy conservation through "smart grid & IOT" is upcoming advance technology to organize, monitor and control electrical activities. This mechanism regulates energy efficiently and overall promotes green energy. We can use renewable energy source in this mechanism (especially in Peak hours). And it requires a very small human interface to do activities. Which will overall reduces errors in building activities. The system works on internet and IOT server so that activities of Monitoring and controlling can be accessible from any part of world. Its ease will definitely helpful for End user and utility provider.

The grid modernization will lead to involvement of improved technologies in grid, fulfillment of consumer requirement of uninterrupted power supply, job creation with inclusion of new areas for research and development, increased asset life, improved power quality, increased security, reduction in forced power outages and blackouts, reduction in peak demands, energy efficiency, cleaner environment, new market for utilities etc. On the basis of requirements different countries have different benefits through grid modernization and accordingly they have made policies. Currently, in India main aim is providing uninterrupted power to all. The practical knowledge of possible hurdles in these technological advancements and associated benefits will be provided by the implementation of the above mentioned projects. Key challenges associated with the development should be kept in mind for widespread deployment. If these projects are implemented successfully, they will support the future goals and provide optimal solution.

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