INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume3, Issue1)
Available online at: www.ijariit.com

A Comprehensive Review on Smart Meter Communication Systems in Smart Grid for Indian Scenario

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***Abstract:** In existing power grid, the currently used power meters, are either electronic energy meters or electro-mechanical meters and are limited to record power/energy up to KWh unit only. One of the drawbacks of these power grids is that out of the total power production, 26% of energy gets lost because of various reasons such as power theft, blackouts, etc. To fulfill the continuous drastic demand of energy production and consumption, a new generation power grid is required, which should include communication and information technology (ICT) along with distributed power generation (like solar power and wind power). The concept of new generation smart power grid, so called Smart Grid, has been gaining continuous rapid attention worldwide. Smart Grid is considered as system that can supply bi-directional flow of electricity and information, with better power grid reliability, security, and efficiency of electrical system from generation to transmission to distribution. To meet the requirement of Smart Grid we require the most fundamental components like Smart Meter, in the intelligent energy networks (IENs). Smart Energy meters are used to control and monitor home appliances and other devices by providing two way communications among them. This paper reviews the basics of Smart grid and development and deployment of communication technologies used among various Smart Grid components/networks and provides an insight into the current research on Smart meters with some guidelines and future directions for IENs.*

***Keyword:** Infrastructure (AMI), Intelligent Energy Advanced metering Networks (IENs), Smart grid, Smart Meter, Zig-Bee.*

I. INTRODUCTION

Power or Energy plays a big role in the economy of any country and for an economy like ours the energy requirement is increasing rapidly. In the present scenario, the old power structure seems ill suited in context to technical environment and needs to be upgraded to automatic and intelligent structure with new Information and Communication Technologies (ICT). Presently, for metering and billing, meters used in India are either electromechanical or they have been recently replaced by digital meters but these are stand alone and cannot be read and updated remotely. In 2012, the European Parliament (2012/27/EC) instruction defined a Smart Meter or intelligent metering system as a "New generation electronic Power system", with Machine to Machine (M2M) communication reducing human participation. To meet the requirements of advanced Metering Infrastructure (AMI), power grid system should be capable of real time consumption, should have high accuracy and reliability. Smart Meter using Information and Communication Technologies forms the basis of AMI that leads to conversion from old to new infrastructure, thereby providing more efficiency and two way communications which includes all the information to both consumer and utility. Henceforth, a lot of research and analysis of existing communication and information technology have to be done for the above mentioned development.

II. METHODOLOGIES AND RELATED WORK

1. Concept of Smart Grid :

One of the significant factors in the development of a nation is conversion of electrical power grid into an advanced digital infrastructure with two-way flow capabilities for communicating information, controlling tools, and distributes energy. This is challenging not only for a couple of scientists but for thousands of people all around the globe. The Information and Communication network that will be essential to the grid performance, reliability, transmission and distribution(T&D) losses and security of the electric power infrastructure has to be developed. Smart Grid is an upcoming Intelligent Energy Network (IEN) that can be described as an interconnected system of information, communication technologies and control systems , integrates all the supplies, Advanced Metering Infrastructure(AMI) ,Intelligent Devices , large number of sensors ,and digital technologies with two way measurement as smart meters generate a lot of data which enables higher resolution for entire electricity delivery system [5][6][11][32]. Fig.1 shows the components of Smart Grid.

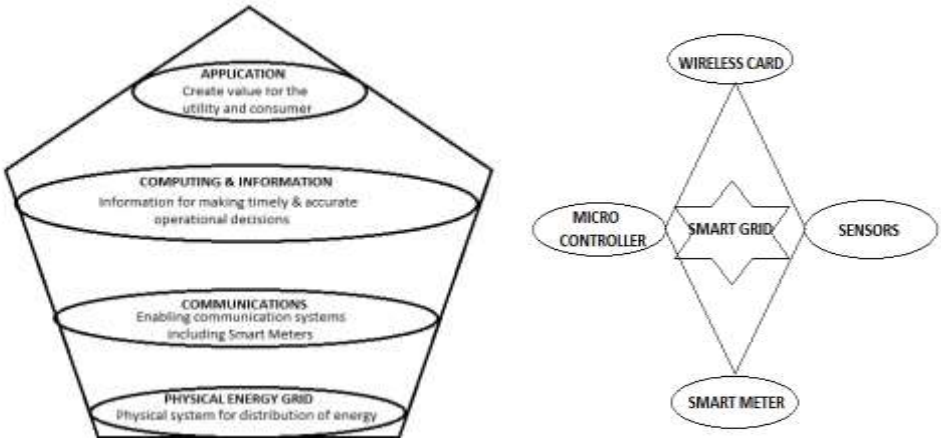

Fig.1 Smart Grid Infrastructure

One major need for implementing Smart Grid in Indian environment is because of the increasing complexity and necessity of the power sector, which requires well balanced and synchronized operation of tremendous power/energy transmission, along with planned and scheduled flow of power.

a) Smart Grid's Benefits[13][32][29]

Implementation of Smart Grid will bring abundant benefits to both the utility as well as to the consumers. Some of them are mentioned here under-

- Reduction in Transmission and Distribution losses
- More Efficiency , Reliability and Sustainability
- Reduction of Peak Time and pricing
- Tremendous Asset Management for whole system
- Integration of Renewable Energy
- Self healing Grid and reduction in power theft
- Two Way communication
- Demand Response and Time of use traffic
- Advanced Servicing and Load Balancing

b) Smart Grid Features [4][13][9]

- Smart generation of power from a mixture of resources, maintaining voltage and power factor (Renewable & non renewable energy)
- Smart Transmission of power with latest intelligent devices, wireless and wired communication techniques (Two way communication Infrastructure).
- Smart Distribution of power with various new automated capabilities using intelligent appliances such as self healing, self optimization, automated monitoring and analysis technique etc Outage Management System(OMS).

- Advanced Metering Infrastructure (AMI) having Smart measurement and billing capabilities with smart home appliances using two way communication and information technologies between utility and consumer.

c) Smart Grid Development in India [12][29]

- **India Smart Grid Task Force (ISGTF):**In order to initiate the deployment of Smart grid in India, Ministry of India has taken steps towards the Smart Grid activities and has establish ISGTF as an inter-governmental body.
- **India Smart Grid Forum (ISGF):** In August 2013, the government notified ,for a future smart grid rollout in the country and in this direction Realizing the rising value of Smart Grid technologies in Indian power sector, the Ministry of Power(MOP) constituted the ISGF in 2010 as an inter-ministerial task force
- **National Smart Grid Mission (NSGM):** It develops under a government institutional policy made for the planning, implementation and monitoring of grid and programmed for Smart Grid activities with an initial layout of Rs 980 Crores.

In India, in June 2013 Central Electricity Authority (CEA) released the first edition on Smart Grid specification for technical and functional requirement under the guidance of Ministry of Power (MOP). The most key initiative towards smart grids has been the allocation of 14 pilot projects in India, estimated approximate of $60-65 million for in which governments sharing is 50% of project cost and rest has to be borne by utility and technology providers. A proposal of 100 smart cities to base on large-scale smart metering has been already initiated and stared. [Ref- Alchemy Research and Analytic [29]

III. ADVANCED METERING INFRASTRUCTURE(AMI)

Advanced Metering Infrastructure (AMI) forms the base of Smart Grid, responsible for measurement & collection of data, transfer and analysis of energy usage, and for communication between metering devices. Basic tools of AMI are metering, telecommunication and information technology. AMI is under the agency called, Metering Service Agency (MSA) that manages and controls all the functions, maintenance and installation of AMI including testing and certification of meter, communication devices, installation and maintenance of software, IT system formation of middleware, incorporation of MDMS etc. AMI enables end users to participate in reducing peak demand load and in contributing to energy management process. Further, meters can also capture, receive and execute remote commands like load disconnect/connect. The main enabling features of an AMI include smart meter, communication medium, MDAS/MDM, load monitoring, Demand response, Load control, Alarm handling, Real time energy audit, Time of Day (ToD) tariff etc.[3][10][23]

a) *AMI Component*[5][11][25]

- **Smart Meter:** Smart meters have the capability of two way communication for receiving and collecting data at specific time intervals, measuring and recording, displaying and billing purposes.
- **Communication Network:** Communication Network serves as a gateway between Home Area Network (HAN), Neighborhood Area Network (NAN), and Wide Area Network (WAN) to allow the flow of information between utility, meters and consumers.
- **Meter Data Acquisition:** Data collector for collection and receiving of real time and periodic data from various smart meters using software
- **Meter Data Management:** The system where the collected data can be stored, analyzed and processed

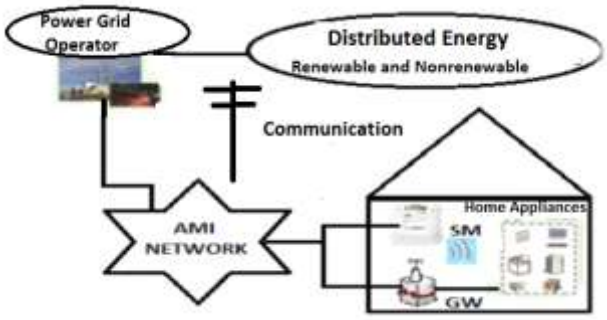

Fig.2 Advanced Metering Network

b) Smart Meter [30][38][39]

Today India has one of the highest transmission and distribution (T&D) losses. The average network losses in India is approximately 27-28%, varying from 70% in the north-east to about 15% in other parts of the country .In July-2014 CEA, India submitted a report about electrical energy supply and demand which showed the figure was -3.9% (MW). The difference in both supply and consumption can be managed by accurate metering and billing, detection of illegal activities and implementation of proper tariff. The traditional electromechanical and digital meter require a recurring visit by manpower to collect the data periodically in order to note the meter reading which is not only time consuming, but also tiresome and less accurate . Additionally, there may also be certain problems in the process of data collection because of bad weather conditions, absence of the consumer, theft of power , pending billing etc .India is facing energy deficit during peak hours , Low voltage during peak hours, and Load shedding have been reported as major power quality issues. Introduction of Smart meters in next generation power grid will become a milestone to overcome all these problems and communicate information more correctly and effectively, however, it will take almost a decade for this to fully implement in India. The Share of Smart meter in USA , Australia and Canada is 30.7 , 31.6 and 49% whereas India has it is less than 1%[25][30][38].

Smart meters are the most significant part of new emerging Smart Grid infrastructure and have been designed to meet a variety of features like remote monitoring of energy consumptions, remote turn ON/OFF of power supply, remote detection of energy theft, time varying pricing system, remote fault detection, capable along with smart metering and billing. Before the deployment of Smart Meter devices these must meet with some national, state and local code standards to ensure proper functioning and operation.(73)Primarily Smart Meters are used to save large amount of energy hence saves money for both utility and consumers. Recently in India, Tata Power Delhi Distribution Limited (TPDDL) installed 99000 smart meters, out of which 75000 are single phase and 24000 are three phase meters and Ericsson provided 15000 smart meters under AMI project and also won the best Smart Meter project in Assam [29].In Fig 3 we have shown some images of meters from different companies. Recently the following states initiated to implement prepaid meter deployment to improve billing and collection. ref-(Alchemy Research and Analytic) Table1 :

Table-I

S.No	**State**	**Prepaid smart meters (planned or under implementation)**
1.	Mizoram	60,000 Nos
2.	Arunachal Pradesh	32,000 Nos
3.	Maharashtra	25,000 Nos
4.	Uttar Pradesh	8,000 Nos
5.	Assam	3,500 Nos

Fig.3 Some Images of Smart Meters

c) Advantages of Smart Meters[25][30][40]

Following are the several advantage of installation of Smart Meter for both utility and consumer (24):

- Better management of data and energy in Home Energy Management System
- More reliable and accurate data for metering and billing purpose
- Reduced cost and trips for off cycle reads
- Eliminating human efforts for reading and billing
- Reduced cost for collecting load research data
- Introduction of data from renewable energies
- Improved and increased rate options and power quality data
- Reduced connectors and disconnectors.
- Early detection of meter tempering, billing errors and theft
- Improved efficiency, reliability of services, losses and loading
- Reduction in regulatory complaints
- Improved environmental benefits

IV. SMART GRID COMMUNICATION

Traditional Power grid have one way communication infrastructure for power transmission and distribution but with the constant increasing demand of enhanced energy systems smart metering network design require more reliable, secure, efficient, robust communication infrastructure not only for metering and billing purposes but also to manage Home Energy Management System (HEMS) and remote metering data management with two way communication capabilities. In point of fact , new power grid communication structure is the backbone of Smart Grid and requires new research on existing communication technologies as well as inventing new ones that can better cope with new smart meter infrastructure and can handle a enormous amount of data. For smart meter communication technology requires both wired as well as wireless communication technologies for transmission of data, although wireless communication is more popular and important.(67) Data in Smart Grid is transferred through sensor to Smart meter via wired communication or wireless communication and from smart meter to data center via cellular networks and Internet. The communication network shall be based on standards suitable for Smart Grid from ITU/IEC/IEEE/CEN/ CENELEC/ ETSI for NAN and WAN network. In following section we are going to review some suitable existing communication technologies and some forthcoming communication technologies under research, which will be more appropriate for Smart Grid.[2][8][15]

a) Existing Communication Technologies for Smart Grid [17][31][36]

- **Zig-Bee- Zig:**Bee is a wireless communication technology having free radio frequency network and open global standard and may coexists with other technologies at certain bands. It is a simple, low power, low battery, Inexpensive, low data rate (20-250 Kbps) technology working with 2.4 GHz, 868MHz, and 928 MHz under IEEE802.15.4 standard within range of 10 meters. Zig-Bee has been realized as an ideal technology for communication between smart meter and appliances in home area network due to ease of setting up, and in commercial complexes contribution wireless access to their clients. In home area network, it can be effortlessly used among home appliances such as smart lightning, energy monitoring, home automation, and automatic meter reading, etc. In Smart Grid , HANs Zig-Bee can be used in various home appliances such as washer dryers, ac, water heater, PHEV etc. Zig-Bee is well suited for cyclic or intermittent data as in wireless personal area networks (WPANs) where as Bluetooth and Wi-Fi is not suitable for Smart meters.

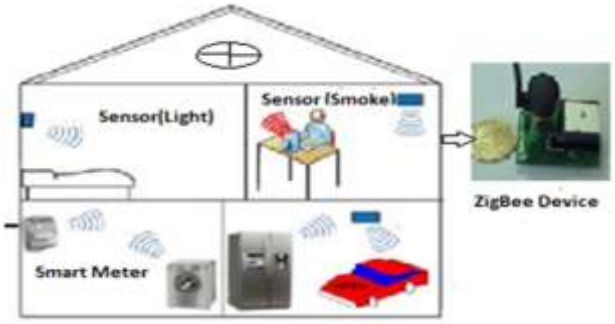

Fig.4 Zigbee For Home Area Network

- ***WMN (Wireless Mesh Network):*** It is a network composed of several wireless access point usually WiFi and Wi-Max router together forms fully wireless communication network to serve both mobile and fixed users. WMN can be connected to internet or other networks through a few gateway routers to their clients such as Laptop, Wi-Fi phone, RFID Smart Meters Sensors etc.

- **Wi-Max:** Worldwide inter-operatibility for Microwave Access (Wi-Max)is a very successful alliance capable of operating on various frequency bands from which SG 3.65 GHz and 5.8GHz for fixed communication and 2.3 GHz ,2.5 GHz and 3.5 GHz for mobile communication within the range of approximate 48 Km with data rate of 70Mbps. Wi-Max supports multiple connections to devices at the same time. In Wi-Max network that grid net selected, around 200 devices can communicate with a tower at one time. In Smart Grid, it is trying to gain a grip in Wide Area Network (WAN) because of its adaptability as it supports a wide range of devices compatible in any environment and remote connectivity of devices.

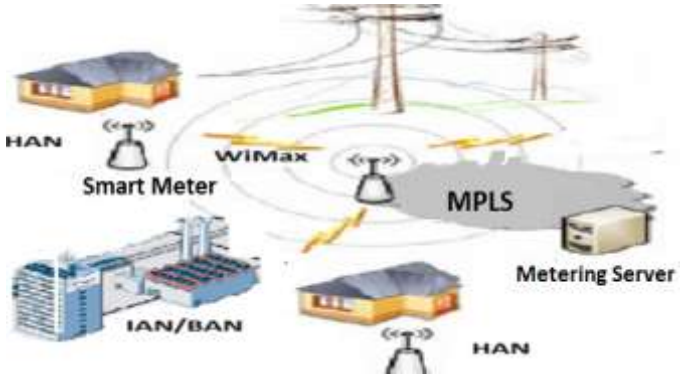

Fig.5 Smart Grid Communication Network

- **Cellular Network:**Cellular networks have deep routed infrastructure that allow high data rate up to 100 Mbps and used for communication among different components and devices in smart grid. GPRS,GSM, 2G, 3G, 4G and Wi-Max are various existing cellular technologies, out of which the Wi-Max technology is the most appropriate and of interest for smart grid implementation. The significant qualities of the cellular networks are wide area of deployment, high rates of data transfer, and available security algorithms in the cellular communication. The major drawback is that cellular networks are common with other users and are not fully dedicated to the Smart Grid communications.

b) Recent Communication Technology for Smart Grid-

- **Sub-GHz:**For wireless applications, Sub-GHz technology is a principle alternative for smart grid having long range of a kilometer or more and reduced power consumption, lower deployment and operating costs. In India 890-960 MHz frequency band is allocated for cellular services and 585-806MHz for broadcasting services. Zig-Bee (2.4GHz protocols) technology is profoundly marketed and used extensively in the present markets. However, for low data rate applications, such as home security/automation and smart metering, Sub-GHz wireless systems offer several advantages. Sub-GHz radios can offer comparatively simple wireless technology

that can function uninterrupted on battery power unaided for up to 20 years. The key reasons why Sub-GHz is a superior range over 2.4GHz technology can be summarized as following [1][14]:

- It is known that the radio waves after passing through the walls and other obstacles weaken. The 2.4GHz signal weakens faster than a Sub-GHz signal because with the increasing frequency, the attenuation rate also increases.
- We know that the 2.4GHz radio signals fade more quickly than Sub-GHz signals because they reflect off opaque surfaces, therefore in highly congested environments, the such transmission weaken rapidly, thereby adversely affecting the quality of signals.
- The radio waves travel in a straight line, but when they hit any solid edge like corner of any solid structure they bend and angle of diffraction increases with the decrease of frequencies.
- In the growing marketplaces, we observe that both 2.4GHz and Sub-GHz technologies are extensively used in day to day lives.
- In North America and Australia the frequency used is that of 915MHz, whereas in European countries 868MHz is being used.

- **LoRa:** It is a low power, long range wide area network for regional, national or global area wireless communication technology. LoRa targeted key requirement of Internet of Things(IoT) such as bidirectional communication ,mobility and localization services as LoRa is derived from "Long Range "communication .In Smart Grid this wireless technology is integrated into home appliances for M2M communication. LoRa has several key features such as long range up to 15km -20 km, millions of nodes, low cost chipset and network, long battery life in excess of ten years supporting Smart Metering applications. LoRa chips transmit in the Sub GHz Spectrum (109MHz, 433MHz, 866MHz, 915MHz- Sem-Tech)[19].

CONCLUSION

In this article we reviewed state of traditional power grid and realization of new era Smart power Grid with new communication technologies for Smart Grid as well as Smart Meter. This paper presented the background and motivational features along with various parameters of Smart Grid and review of suitability and adaption possibility of existing communication technologies for new generation Smart Grid and Smart Meters. In this paper, our survey shows that Smart Grid/Smart Meter is a new concept and need improvement and more research has to be done in the area of communication technologies especially for home area network. There is also a brief mention of governmental bodies for the development of Smart Grid in India.

POSSIBLE RESEARCH DIRECTION

In deployment of Smart Grid there is a nonstop and immense requirement of research and investigation as nowadays it is the biggest challenge for any nation to implement it completely. The implementation and completion of Smart Grid require a range of research and analysis in various fields separately like communication technologies, metering and billing requirements, topologies, and standards for Smart Grid, Middleware, and Security Issues etc. For future implementation, extensive research has to be done on Smart Meter and communication technologies since they form the significant part of Smart Grid especially in Indian scenario. Although implementation and deployment of Smart Meters in many Indian Urban areas have already been started but the same in rural areas remain a big challenge for researchers especially in India.

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