ADVANCED METERING INFRASTRUCTURE IN SMART GRID: AN OVERVIEW

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ABSTRACT

Advanced Metering Infrastructure (AMI) is the most important technology used in smart grid. Apart from measuring energy consumption, it also provides additional information to the utility company and the consumers for effective energy management. Integration of many technologies provides an intelligent connection between consumers and system operators. This paper outlines the benefits, impacts and applications of AMI. In addition, it introduces some basic communication technologies used in smart grid like Power Line Carrier (PLC) , zigbee, wifi etc.

Key words*: *AMI, Home Area Network (HAN), Smart Grid, Smart Meter

I. INTRODUCTION

A smart grid is a modern electrical grid in which electricity and information flows in two-way to improve reliability, efficiency, sustainability and economics of the grid. By utilizing modern information technologies, the smart grid is capable of delivering power in more efficient way and it could respond to events that occur anywhere in the grid. One of the important way to modernize the present electric grid into a smart grid is by integrating AMI in to existing electric grid. AMI uses variety of sensors, control devices and supportive communications infrastructure. It gathers information from the users or load equipment and calculates the energy usage of consumers therefore provides additional information to the power company and / or the system operator [1].

AMI network is shown in figure 1. It is in fact the collective term to describe the whole infrastructure that includes smart meters, two-way communication network and control center equipment. The control center equipment is connected to all the applications that gather and transfer energy usage information in real-time.

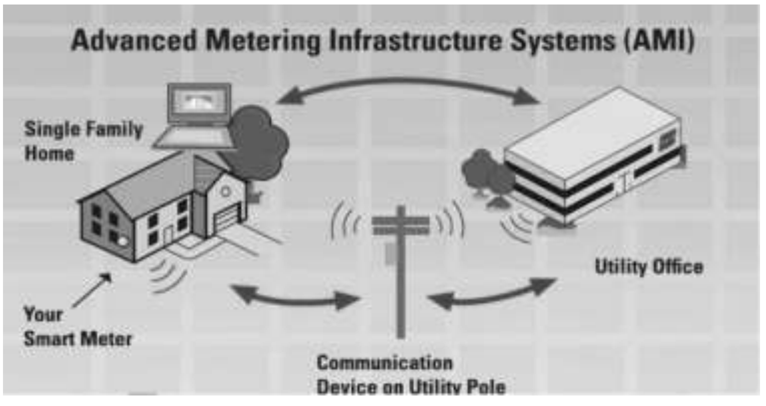

Fig.1 Advanced Metering Infrastructure

AMI makes two-way communications with customers and is the backbone of smart grid. The objectives of AMI are remote meter reading with error free data, network problem identification, load profiling, energy audit and partial load curtailment in place of load shedding [2].

The objectives of AMI are remote meter reading with error free data, network problem identification, load profiling, energy audit and partial load curtailment in place of load shedding. AMI is comprised of various hardware and software components which include smart meters, communication network, Meter Data Acquisition System (MDAS), Meter Data Management System (MDMS) and Home Area Network (HAN) [3].

The remaining paper is scheduled as follows. Section II describes smart meter design, functions and benefits; section III outlines different communication network technologies; section IV aims MDAS; section V explains about MDMS; section VI explains HAN; section VII gives benefits of AMI; section VIII explains the challenges of an AMI and conclusions are drawn in Section IX.

II. SMART METER

A smart meter is usually an electronic device that records consumption of electric energy in intervals of an hour or less and enables real-time communication of energy usage data between customers and their utility companies for monitoring and billing purposes. The vast majority of these meters are installed at the residential level. In order to carry out a meter reading using a conventional meter, the meter reader needs to physically visit the customer premise and take the reading. This reading will be sent to the utility company for billing. But in case of smart meters this can be done automatically. The system operator will create a meter read request from the utility company office thus avoids manual intervention during meter reading and provides more accurate, real-time data to the utility company.

A smart meter consists two units. One unit of the metering device is in the custody of the distribution or utility company and the other is the display unit which is at consumer's place. A smart meter has designed with built-in-technology to disconnect and reconnect certain loads remotely. Smart meters are implemented to monitor as well as to control end users and appliances to manage demand and load flow in the future. Smart meter's data comprises the unique meter identifier, data timestamp, the electricity utilized values and so on.

Fig.2 Smart meter

Smart meters can gather diagnostic information about the distribution grid and home appliances and measures energy consumption from them to identify parameters and transfer the data to utilities and send back to the command signals in order to calculate the customer's bill and power consumption accordingly. Sometimes, a smart meter can also communicate with the other smart meter. Figure 2 shows the original model of a smart meter. Smart meters, which enable real-time communication of energy usage data between consumers and their utility companies, generate electric usage readings for every 15 minutes or one hour[4].

The main functions of a smart meter

Generally, smart meters are expected to have the following features like:

1. Two-way communication
2. Data collecting, recording and storing
3. Load control function
4. Programming function
5. Security function
6. Display function
7. Billing function

III. THE COMMUNICATION TECHNOLOGIES

The AMI communication infrastructure supports continuous interaction between the utility and controllable electrical load. It must employ open bidirectional communication standard at highly secure. AMI various architectures can be employed with one of the most common being local concentrators that collect the data from group of meters and transmit the data to a central server.

The communication structure can be wired like Power Line Carrier (PLC), Broadband Over Power Lines (BPL) or wireless like Global System Mobile (GSM), ZigBee and Radio Frequency (RF). The chosen way must take into account the distance between the devices and existing infrastructure [5].

3.1 Power Line Carrier Communication (PLCC)

PLCC systems consist of a high frequency signal injection over the electrical power lines. This technology has been widely developed mainly due to the new modulation techniques used for wireless telecommunication systems. An advantage is that there are no additional cost pertaining to cables and related infrastructure. Disadvantage is that it may require several mega watts for information transmission [6].

3.2 Broadband over Power Line (BPL)

Communication system can deliver high speed voice data and video communication to end users by transmitting radio frequency, BPL technology is more practical in recent years. The existing infrastructure for BPL is the most considerable area of this technology .BPL is also used in management of power distribution grids by monitoring and facilitating control of them remotely. The advantage of BPL technology is its vast geographical coverage. Access BPL technology can potentially provide broadband services for rural areas which do not access to such service now. Another interesting aspect of BPL is its ability to potentially connect all electric devices in a communication net work [7].

3.3 Radio Frequency (RF)

The collected data from end users is transmitted to data collector through wireless radio frequency using smart meters. Then, the data is processed and delivered in several methods to utility data systems at a central collection location. The utility billing, outage management and other systems use these data for operational and business purposes [8].

3.4 Cellular networks

Public cellular networks use in smart grid is slowly gaining a acceptance and acceleration across the world. Cellular network is now commonly seen as an additional connectivity option just like PLCC and RF mesh. Global System for Mobile communication (GSM) is a digital mobile telephony system that digitizes and compresses data before sending it. The main advantage of the GSM is its widespread use throughout the world and the use of Subscriber Identity Module (SIM) cards to send Short Message Service (SMS).

3.5 ZigBee

ZigBee is a low-cost, low-power, wireless mesh networking standard. It is best suited for local coverage such as Home Area Networks (HANs). Smart grid considers ZigBee as a main communication as it controls the appliances automatically. ZigBee installation and upgrade cost is low, in addition it offers meter-to-meter communication and remote monitoring ability of whole home conditions [10].

Smart energy meters using both ZigBee and GSM technologies should have a transmitter and a receiver with both technologies. The meter can read the energy and send it to the receiver using GSM or ZigBee. The data management system collects and stores the data and uploads it to the internet. So, the consumer can check his information from the internet using a developed android program or through a website portal. The receiver can also send the consumption information to the user by an SMS message through the GSM network [9].

IV. METER DATA ACQUISITION SYSTEM (MDAS)

MDAS will do real-time data acquisition from the deployed Data Concentrator Unit (DCU)s, and organize the data in the database in a Common Data Format (CDF). It will do real-time monitoring, summary reports and Graphs. MDAS application mainly consists of three components [10]:

(1).Communication server application: Communication server application will establish communication with modem associated to DCU and process the data sent by the device.

(2). OPC Server application: OLE for Process Control (OPC) where OLE stands for Object Linking and Embedding. OPC server will read the raw data which was received by communication server application and convert the raw data to actual meter data.

(3). User interface using web based application: Web server provides web based user application which will access using public IP where user should be able to login and get to know the details of their meter status and data. Utility Operation/Dashboard user will have the interface for supervisory activities involved in meter data acquisition, processing and analysis. The business logic tier would service the requests made by the client tier.

These requests could be automated, based on user-defined schedules or on-demand from the user. The collected data can be viewed in the form of customized reports. User can take print outs of these reports, export the data into spread sheets, or convert the data in the form of flat files.

It has two modules. One is User module and the other is Meter Module. The user module has feature to Add/Delete/Modify user and the rights. Each user can read the meter to see the meter data. Each user can generate a report for meter information for a single meter with graph. Meter module has feature to Add/Delete/Modify meter information. Meter Master Information contains Meter type, make, date of manufacture and the modem.

V. METER DATA MANAGEMENT SYSTEM (MDMS)

This system analyzes the data collected and sent by the Smart Meter to set electric power costs and to let consumers use energy efficiently. Collecting the metered data from consumers in real time makes it possible for electric power suppliers to understand how electricity is being used. Plus, it improves the efficiency of recovery work after natural disasters or accidents happen to the power grid itself. Consumers can use the data managed by MDMS to help them use electricity more efficiently. MDMS will do real-time data acquisition from the deployed "DCU"s, and organize the data in the database in a Common Data Format (CDF). MDAS will do realtime monitoring, summary reports and Graphs. Online Alerts, dynamic formation for observation groups of suspicious meters or just area, zone, consumer indices etc. in normal circumstances.

An MDM system will typically import the data, then validate, cleanse and process it before making it available for billing and analysis. An MDM system performs long term data storage and management for the vast quantities of data delivered by smart metering systems. This data consists primarily of usage data and events that are imported from the head end servers that manage the data collection in Advanced metering infrastructure (AMI) or Automatic meter reading (AMR) systems. It provides Meter-to-Cash system, workforce management system, asset management and other systems. Also an MDMS may provide reporting capabilities for load and demand forecasting, management reports, and customer service metrics [11].

VI. HOME AREA NETWORK

HAN is a dedicated network connecting drives in a home such as displays, load control devices ultimately “SMART APPILANCES”seamlessly into the overall smart metering system. HAN extends smart grid capabilities into the home using different networking protocols. HAN technology enables to control many automated digital throughout the house. Integration of smart meter with HAN helps to communicate peak energy use times to digital devices.

Basic components of HAN are network portal or gateway that connects some information to the HAN and the access point or network nodes that form the wired or wireless network itself. Different technologies used in HAN are Zigbee and wifi [12].

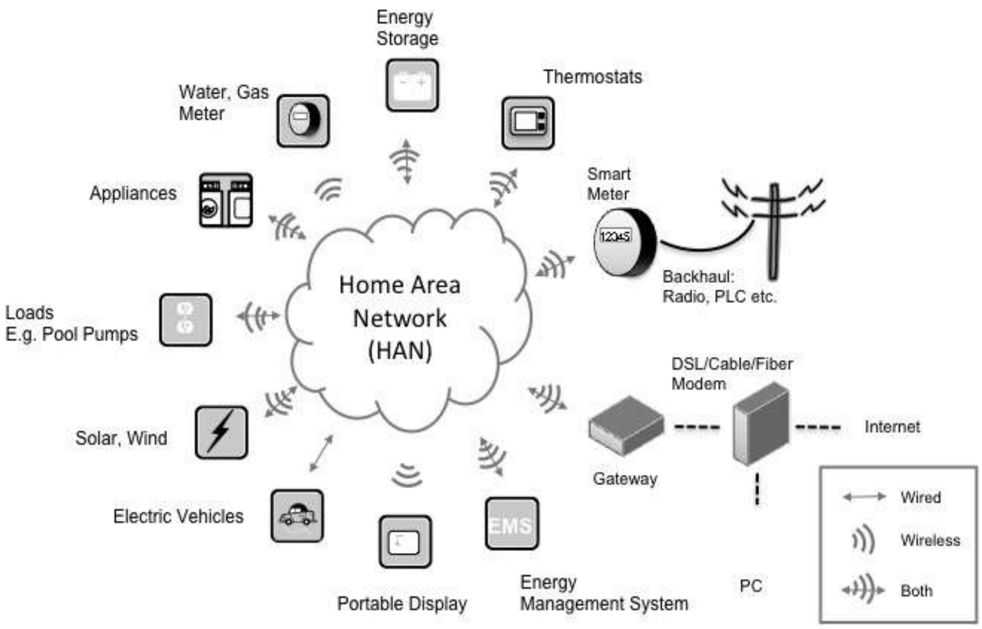

Fig: 3 Home Area network

VII. BENEFITS OF AMI

AMI advantages are multi-fold and can be generally categorized as:

1. Operational Benefits – AMI benefits the entire grid by improving the accuracy of meter reads, energy theft detection and response to power outages, while eliminating the need for on-site meter reading.

2. Financial Benefits – AMI brings financial gains to utility, water and gas companies by reducing equipment and maintenance costs, enabling faster restoration of electric service during outages and streamlining the billing process.

3. Customer Benefits – AMI benefits electric customers by detecting meter failures early, accommodating faster service restoration, and improving the accuracy and flexibility of billing. Further, AMI allows for time-based rate options that can help customers save money and manage their energy consumption.

4. Security Benefits – AMI technology enables enhanced monitoring of system resources, which mitigates potential threats on the grid by cyber-terrorist networks

VIII. CHALLENGES OF AMI

Despite its widespread benefits, deploying smart meters presents three major challenges that include:

1. High Capital Cost: A full scale deployment of AMI requires expenditure on all hardware and software components, smart meters, network infrastructure and network management software along with cost associated with the installation and maintenance of meters and information technology systems.

2. Integration*:* AMI is a complex system of technologies that must be integrated with utilities information technology system, including Customer Information Systems (CIS), Geographical Information Systems (GIS), Outage Management Systems (OMS), Work Management Systems (WMS), Mobile Workforce Management (MWM), SCADA system, Distribution Automation System (DAS) etc.

3. Standardization*:* Interoperability standards to be defined, which set uniform requirements for AMI technology, deployment and general operations are the keys to successfully connecting and maintaining an AMI based grid system**.**

IX. CONCLUSION

This paper reviews several important aspects of AMI. It presents various hardware and software components of AMI, which includes smart meters, communication network, Meter Data Acquisition System (MDAS), Meter Data Management System (MDMS) and Home Area Network (HAN). Moreover, research related to different communication technologies is presented in brief. Finally, the paper arises various challenges to be met by the AMI.

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