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Smart Grid: An Overview

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Abstract: The electric grid system is evolved into a smart grid using advanced technologies. The smart grid acts on various information and data in a systematized fashion. It includes an advanced metering infrastructure system that is responsible for the communication between the smart meter and the utility. The reliability, efficiency, sustainability and economics of the production and distribution of electricity will greatly improve with a smart grid. Overall the smart grid will help save energy.

Keywords: Smart grid, advanced metering infrastructure, smart meter.

I. INTRODUCTION

Smart grids comes with real time monitoring that helps one know when and how much electricity one is using. It is an advanced version of the existing electric grid as it provides additional information about energy usage and allows a two-way communication between the utility and the electric grid.

This two-way communication allows the information collected regarding energy from the customer premises to be fed back to the power generation utilities. The enhancements also include a real time pricing structure. According to it, the customers can minimize the use of electricity when the cost of electricity is high or the electricity demand is at its peak.

II. COMPARISON BETWEEN EXISTING GRID AND SMART GRID

While the existing grid is an electromechanical one, the smart grid uses digital technology to function. The smart grid allows a two-way information flow unlike the one-way communication in the existing electric grid. This bidirectional communication will help create an advanced distributed energy network. One can manage the energy usage in the smart grid by choosing the best time to purchase electricity as the pricing signals from utilities are displayed on the smart meter.

One can save even more money by generating power on their own according to their needs. The smart grid is more computerized and automated with sensors throughout. The existing grid requires manual restoration incase of any power failure, whereas, the smart grid is a self-healing grid.

It can isolate power outages and still continue to supply electricity in order to meet the existing demand. Failure of the conventional electric grid can result in a blackout and requires manual monitoring.

The smart grid is self-monitoring. A smart grid is more economically feasible than the conventional electric grid. Fig. 1 shows an architectural model of the Conventional Energy Meter and a Smart Meter.

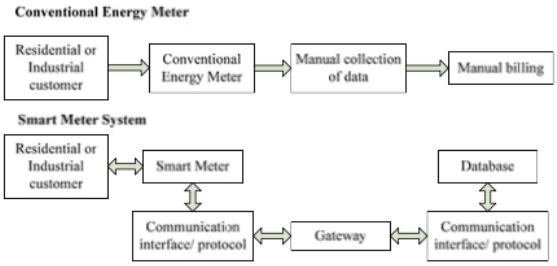

Fig. 1. Architectural model of conventional energy meter and smart meter [1]

III. SMART METERS

Obtaining information from the end users' load devices is the function of the smart meter. It is an advanced energy meter that measures the consumption of energy by the consumer. It provides additional information to the power generator plant or utility so that it can improve its monitoring and billing if required.

Smart meters help consumers to manage their bills by showing them timely measurements of energy usage. Hence in the phase of peak load, users can try and condense their demand. With the smart meter, electrical data such as voltage and frequency are measured and real-time energy consumption information is recorded [3].

A. Functions

A communication infrastructure integrated with different sensors and controls forms a smart meter. Smart meters can also be wirelessly connected to the different home appliances and monitor them at the customer's premises. The functions of a smart meter include bidirectional communication; collection, storing, recording of data; load control; security against power theft; display information and billing. In order to manage demands the smart meter has a built-in ability to disconnect and reconnect certain loads remotely. It can be used to monitor the customer's devices and appliances. Smart meters transfer the information collected about the energy usage to the utilities and send back command signals. This helps the consumer

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to optimize the power consumption. Since the smart meter collects energy consumption data, it helps the utilities to efficiently manage the energy demand and also provides its customers with cost efficient ways to use their devices.

B. Technologies

Technology and design varies through different smart meter systems but the overall design process is not that complicated. The data about the energy consumption is collected from the end users by the smart meter and transmitted to the data collector at the utility company through the Local Area Network (LAN). The requirement of the data demand determines the frequency at which this information is transmitted. On receiving the data, the utility further processes it by using the Wide Area Network (WAN). Fig. 2 shows the basic operations of a Smart Meter System.

Fig. 2. The basic architecture of Smart Meter System [3]

In order to design the smart meter, superior levels of safety and reliability must be ensured. There are several design implications like digital communication, distributed intelligence, decision and control software and communication standard that need to be linked together.

The smart meter communication includes two basic technologies, namely, Radio Frequency (RF) and Power Line Carrier (PLC).

In RF technologies, the data measured is collected from the end user's load and transmitted to the data collector by the wireless radio. Various methods are used to process this data. RF technologies can further be of two types: Mesh technology and Point-to-Point technology. The utility company determines the technology to be used after a thorough analysis and evaluation of the requirements.

In PLC technologies, the data is transferred from the meter to the utility through the utility power lines. PLC technology is beneficial when long distances are involved and this proves to be cost effective. However, it requires longer data transmitting time when compared to wireless technologies.

C. Benefits And Issues

In the long run, integration of smart grids rather than revamping the existing grid stands as a valuable solution. The interface that the smart meters provide between the consumer and the energy provider will enhance the economic conditions. Incase of a power distribution failure from the utility, the smart grid will allow the home to grab power from the local distributed resources, such as, solar rooftop and small hydropower and wind projects. Smart meters are consumer friendly as they eliminate the need of human meter reading and measuring the time of use of electricity.

However, the initial process of replacing the existing electric meters with smart meters will be a huge task for the utility companies. The devices that are integrated with the smart grid network can be used to the fullest extent only if they are in the metering network that is included in the communication network. With the increasing customers, integration of smart grid becomes difficult because of lack of proper infrastructure to synchronize this new technology with the existing one. The collection and transmission of energy consumption data is expensive and could be a tedious job. There might be maintenance issues involving network failure, communication network, smart meter and base server. The data transfer can pose challenges if the quality of implemented software is not appropriate. Also weak protocols and vulnerability in encryption and decryption can pose a difficulty. They also need to be protected from the insecure environment and need proper shelter.

Nevertheless, smart meters provide efficient power system control and monitoring. They can also perform allocation of energy cost, fault analysis and power quality analysis [1]. They also prevent billing irregularities.

IV. ADVANCED METERING INFRASTRUCTURE (AMI)

Power industry is facing unprecedented opportunities and challenges. The stability and security of the grid can be achieved by establishing an advanced metering standard infrastructure. The smart meter is an important component of the AMI. Formulation of standards for smart metering equipment needs to be done in order to meet the requirements of the AMI. The backbone of the smart grid network is its AMI. With the AMI, people can do some customized control with respect to the demand response. AMI is a system that collects, measures and analyses data by communicating with smart metering devices. AMI networks need to be built to scale and important requirements such as bandwidth, latency throughput and reliability need to be met. An AMI consists of the smart meter, two-way communication path, meter data acquisition system and meter data management system. Fig. 3 shows the basic architecture of an AMI.

A robust device management strategy needs to be deployed. Also a Power Quality Analyzer (PQA) is a part of the AMI for smart grid implementations. All the issues of power quality must be well defined.

The analyzer must be versatile and its real time applications are crucial. An efficient algorithm must be implemented and the PQA will be developed in an advanced embedded system [2]. The AMI can effectively

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respond to a power outage based on the levels of automation and communications present.

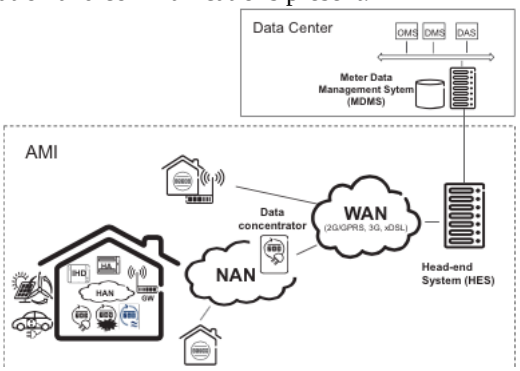

Fig. 3. Basic architecture of an AMI [5]

A. Energy Theft Issues

It is a challenging task to make AMI secure because of its complex communication network and unique characteristics. AMI must meet major security requirements. Efficient detection techniques must be developed in order to prevent the theft of energy. There are different types of energy-theft detection schemes.

Smart meter data, control data, bill information and customer's personal information need to be secured. Hence, the AMI must be equipped with confidentiality, integrity, non-repudiation and privacy [4]. Depending on the different types of attackers, various threat models are built to prevent stealing of energy. With the help of different schemes the problem of energy theft can be solved. The schemes are classified into three categories, i.e., classification-based, state estimation-based and game theory-based [4].

B. Secure Communications Of Ami

Authentication of data, confidentiality of data and message integrity must be ensured for the secure communication in the AMI. Advanced Encryption Standard (AES) mechamism and public-key infrastructure authentication mechanisms are used in AMI applications. Several key management schemes of AMI systems are being studied. The AMI comprises of a number of technologies that need to be secured. The messages transmitted need to be encrypted in order to provide more security. The signature of the encrypted data will be verified by the receiver and on passing the authentication, it will be decrypted. This ensures authentication and intergrity of information transmission [6].

Reliable and secure methods of wireless communications for AMI in Smart Grid are discussed in [8]. Also a network coding based encryption system is employed in [7] for the secure functioning of AMI.

V. CONCLUSION

This paper gives an overall view of the Smart Grid technology including its benefits and challenges that need to be overcome. The Smart Grid will help users to change their habit of consuming load from peak to off-peak hours. This will eventually equalize the network's load distribution. In addition, the different technologies used are also discussed. Consequently, the need for Smart Grid technology is emphasized.

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