Smart Grid and Smart Meters - A Beginner's Perspective

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Abstract

Energy crisis is a global problem which has started decades ago, continues to affect the existing generations and those in the future. Increasing population, change in lifestyle, comfort and automation has increased much more than the past decades, thereby increasing the demand. The limited energy resources are insufficient to meet the demand thereby worsening the demand-supply gap. Electricity is one of the most used forms of energy with a wide range of applications. Electricity Grid is the network of Generators, Transmitters, Distributors and Consumers of electrical energy. Modernization of Electricity grid by incorporating Smart and efficient methods have created a new generation of grids called Smart Grids. One attractive and important benefit of the Smart Grid compared to the conventional methods is the two-way communication facility connecting the utility and users. Monitoring of the energy consumed is done by Energy Meters which has undergone evolution through years from the basic Analog meters to the latest trend of Smart Meters. Besides providing the basic functionality of monitoring the energy usage, Smart Meter has several advantages. This paper studies the different aspects of Smart meter and Smart Grid from a beginner's perspective.

Keywords

Smart Grid, Smart Meter, Energy measurement, Microcontrollers, Renewable Energy Sources, Advanced Metering Infrastructure.

I. Introduction

Globalization has established an enhanced demand of energy in all sectors including industries, commercial, residential etc. With the ever-growing population and technology advents, energy utilization has increased manifolds over the past decades. All economic activities utilize energy. As the consumption increased, resources are getting perished. This energy crisis has affected our day to day life and it has profound impact on our future. Hence the conservation of energy has become a requisite in this current scenario.

Electrical energy deployment sector is undergoing an evolutionary change which includes modernization of the existing system of energy generation, distribution, transmission and consumption. Technology advancements in this sector have opened up the scope of improving energy efficiency as well as power quality which can be obtained by a collective effort. One important part of the complex system of Electricity grid is the energy monitoring module. Monitoring in the traditional way is to count the number of rotations of a disc in a magnetic field, where this count is proportional to the energy consumed. It has the important advantage of being simple, but can be tampered easily posing serious security issues. Moving to electronic meters, recording and displaying of consumption has changed its way. But still it requires manual reading by the staff visiting the premises. In this era of technology, innovations are happening to reduce human effort on operation and maintenance of different devices. Automated systems have been increasingly implemented in small household devices as well as industries.

Systems now act and respond automatically, and are Smart. Using the latest techniques, metering of energy consumed has become simple, accurate, reliable, real time, immune to security attacks, dynamic and demanding less human intervention. Such meters are called Smart Meters. Smart Meter is one of the pillar technologies in the Smart Grid. Smart meters have provided more information on all aspects of energy consumption, which has made the customer better aware of their demands, usage, wastage and billing. It gives a complete split up of the energy consumed rather than the traditional methods which can only provide a measure of total consumption. Fig 1. shows a Smart Grid.
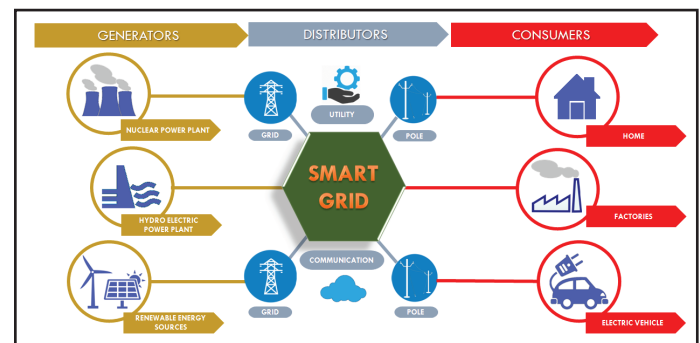

Fig. 1: Smart Grid

II. What is Smart Meter?

Smart meter is an automated, electronic measurement device used for measuring and recording energy consumption in short intervals. Smart meters are installed at the customer side both industrial and residential by the electricity distributors. It plays pivotal role in the electricity distribution system. Smart Meters are an integral part of Smart Grid for data collection and communication. Smart Meters are developed by combining electronic meters with two-way communications technology for information and control and is commonly referred to as Advanced Metering Infrastructure (AMI). AMI refers to the systems that collect, measure and analyze energy usage from networks that are connected to Smart meter. An AMI includes software, hardware, communication networks, customer-associated systems, and a meter data management system [1]. Some of the benefits of AMI are:

- Improved accuracy of meter reading
- Theft and Power outage detection
- Reduced maintenance
- Energy usage management by customer
- Improved Energy saving
- Flexible billing
- Improved security
- Better accuracy and Transparency in billing

AMI has evolved from Automated Meter Reading (AMR). So, the limitations of AMR like reduced energy management from Customer site, using only Conventional Resources for power generation, flat/fixed tariffs without any flexibility based on supply-demand curve, inaccessibility of electricity to the entire

population leaving some darker areas, can be eliminated slowly by installing AMI based systems. These systems allow live recording, storing and retrieval of information between remote servers and consumers. Central Utility can remotely monitor the energy usage information at any time, set tariffs, and upgrade firmware in the meter as and when required. Smart Meters provide information on the usage pattern of a customer.

III. Benefits of Smart Meter
Smart Meter is advantageous to both customers as well as service providers.

A. For the Consumers
1. Monitors and Records the energy consumption accurately. Allows on-demand reading.
2. Provide information about the consumption and tariffs on real time request. Consumption can be seen instantly or in short intervals like hourly, daily, weekly or monthly.
3. More accurate and timely billing
4. Better awareness on energy usage and this allows the active participation of consumers in the management of power usage and wastage. Smart Meter gives information on the sources which uses energy the most, thereby allowing the customer to make energy saving decisions.
5. For a customer, a monthly or bimonthly bill provided by the energy providers always great an ambiguity about the consumption. Smart meter eliminates this hidden or unknown energy consumption by being transparent about the usage.
6. Rate flexibility: Consumers can select from a list of power plans provided by the utility based on the usage pattern. This allows better control and management of power.
7. Net Metering: Customers can act as the generators by installing solar energy system at their side. This allows them to feed electricity they do not use, back to the grid. Also, the customers can earn credits from this which can eventually reduce their bill. This is advantageous for the utility also.

B. For the Utility
1. Measurement of electrical energy parameters rather than total consumption alone
2. Two-way Communication facility enables remote monitoring and updations. Utility sender can receive and send data remotely and keep the logs recorded in the database. This allows instant retrieval of data for analysis.
3. Firmware updations in the Smart meter can be done remotely
4. Provides security against electricity theft, outage, tampering
5. Reduced cost of Meter reading. Eliminates the trips made by staff to visit and take the readings.
6. Load and Demand side management: Since the utility is getting live data of the demand, it is possible to make decisions on when to reduce and increase the supply. This avoids the additional infrastructure required to build new plants, and can rely on the existing plants
7. Issues like tampering, theft, power outage etc. in the consumer side can be detected and rectified in a short time
8. Remote connect and disconnect in case of non-payment of bills, power shortage or demand overshoot, isolating grid and meter for protection in case of meter damages.

IV. What is Inside the Smart Meter?
Traditionally Energy meters were mechanical or electromechanical type with minimal components. Next generation of meters were electronic type which can be digital or analog. These meters come under Automated Meter Reading (AMR). But they lack communication with the central utility. Smart Meters have metering as well as communication features. Basic architecture of Smart Meter has the following components – Microcontroller, Timers, Real Time Clock, Memory, Analog/Digital parts, Connect/Disconnect switches, Communication module, Sensors, Power management modules, Displays, User inputs. Fig. 2 shows the internals of Smart Energy meter.
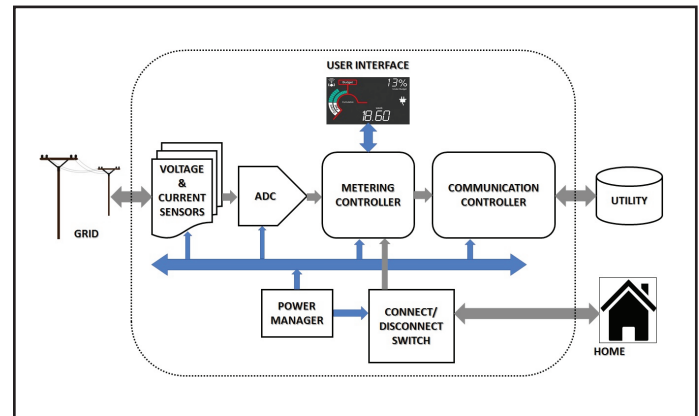

Fig. 2: Internal Blocks of Smart Meter

Smart Meter front end module is the sensor which gets the stimulus from Grid through current as well as voltage transformers. Metering is done using mains in normal mode and switched to battery mode on main shut off. Sensors will be providing the analog signal to the converters which outputs digital equivalent to a controller part. Controller is the heart of the system, which provides all the smart features to the system through various algorithms in the software running. Metering controller sends the digital data which gives the measured as well as calculated electrical parameters to the utility through Communication modules. Metering module also has the function to provide anti-tampering features against security attacks. The system may have some protection circuits to isolate grid from meter or vice versa in case of faulty loads and lightening surges.

Smart Meter can be considered to have a two-layer protocol i.e. first layer convert meter data into Advanced Metering Infrastructure recommended protocol like IS/IEC 62056, IS 15959 and second layer converts Smart meter protocol compatible with communication module protocol like GSM/GPRS/Wi-Fi. A Smart Meter to be implemented in the customer side should be compliant with certain standards. In a developing country like India, some of the standards followed in the development of Smart Meters are IS 13779, IS 16444, IS 15959, IS 15884, IEC 62056 (Parts 21, 42, 46, 47, 53, 61 and 62) [2].

V. Communication
Inside and Outside of a Smart Meter employs different communication methods. Different household devices and appliances in a home are connected via Home Area Network (HAN). Depending on the meter population density in a locality, suitable networks can be used like WAN, LAN etc. which connects the Smart Meters to the Utility. The HAN can communicate using ZigBee, wired or wireless Ethernet, or Bluetooth.
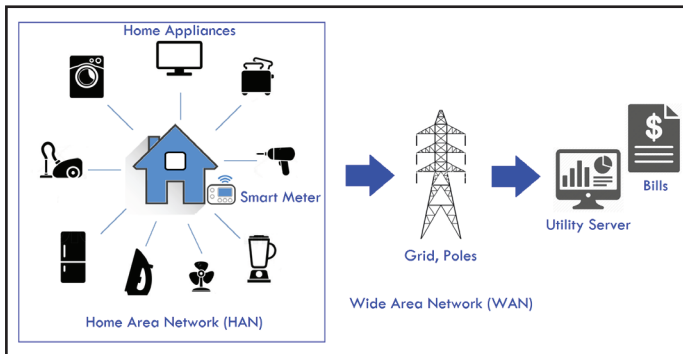
Fig. 3: Communication between Smart Meter and Utility

A WAN is a bigger network that connects the Smart meters, service providers, and electric utility. The WAN can communicate using WiMAX, 3G/GSM/LTE, or fiber optics. The Smart meter acts as a gateway between the in-house devices and the external parties to provide the needed information. The electric utility manages the power distribution within the Smart grid, collects sub-hourly power usage from Smart meters, and sends notifications to Smart meters once required. The Smart meter receives messages from devices within HAN and sends them to the appropriate service provider [3]. Fig. 3 shows the communication between Meter and utility. The system is using "Device Language Message Specification (DLMS)" - a generalized concept for abstract modeling of communication entities and "COmpanion Specification for Energy Metering (COSEM)" - sets the rules, based on existing standards, for data exchange with energy meters. Smart Meter having GPRS/3G/4G facilities should accommodate SIM card of any service provider. Power Line Communication (PLC) and Radio Frequency (RF) are the most commonly used technologies for LAN/NAN communication for AMI networks in Europe and North America. However, most of the utilities in these regions rely on cellular communication technology for the Wide Area Network (WAN) communication [4]

VI. Threats and Security issues in Smart Grid
Smart Grid has changed the way electrical energy is being transmitted and utilized. It has created easiness in its usage and thereby improved the participation of customers in a better way to reduce energy wastage. Along with the enhancements, Smart grid is highly vulnerable to attacks and thefts. Implementing the security protocols against malicious attacks is a necessity in these systems.

1. Smart grid is advantageous because of the two-way communication of data between utility and customers. This situation is highly vulnerable to attacks and thefts, since the data contains much private information of the consumers, thereby demanding high degree of security. If the communication network is not secure and authorized, the data will reach the hands of attackers or hackers.

2. Another type of attack is by the introduction of malware which can infect the software in the smart meters as well as utility. This can change the features of the system. A hacker can also introduce wrong information into the system which can give false usage and price details. Also, if the system gets shut down for some time, this will affect the working of the entire Smart grid, loosing large amount of sensitive data.

3. Since there are several access points and physical devices outside the customer sites in a smart grid, it is open to many physical attacks like tampering, damage of device, loss of packet data etc.

VII. Smart Grid Implementation
Smart Grid is getting implemented in many developed countries like USA, Canada, and Australia etc. This has reduced the human intervention in billing, reduced consumption and allows flexibility in tariffs. In a developing country like India, the scope of smart metering has numerous possibilities, but at the same time there are bottle necks too. Firstly, there is a need for huge investment for its installation. Secondly, standard communication protocols should be used in a Smart grid. Many pilot projects are being launched for the modernization of electrical grid. Government has also taken initiative to support such systems. Availability of renewable resources and its utilization can be advantageous in India, if the existing grids are modernized [5].

VIII. Conclusion
New invents and rapid growth in Technology has triggered the development and installation of smart and intelligent systems in various sectors. Electrical energy deployment sector is one important area which is undergoing evolutionary change to become a dynamic system with lots of features and capabilities. Many countries have triggered the onset of Smart Grid projects which has the potential to reduce the global electricity consumption and hence reduce the wastage of energy. This paper studies the basics of smart technology which includes smart grid and smart metering.

IX. Acknowledgement

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