Smart Meters for Smart Grid

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Abstract--*The need of an expanded and strengthened power grid is a fact. The power industry faces many major challenges in the coming years. So instead of using conventional power system, it is very essential to convert or change our power system to smart system and it is smart grid. As an important part of Smart Grid, smart metering attracts more and more attention all over the world. It is the way for energy consumer to sense the benefit of smart grid directly. It provides the users, a Digital Meter which displays the real time power consumption every time in very friendly and detailed format, and a website to check & analyze their consumption and expenses on energy, using different types of graphs, tabulated and manipulated data. It not only comforts their users but also give relief to the distribution company by minimizing power losses by using automatic Power factor maintenance technique, and providing anti-power theft capability. It also gives a control of power distribution through which Distribution Company can limit the user from exceeding usage of power in specific time duration. This paper discusses the structure of smart meter, smart metering system, communication of smart metering, smart meter government policies, role various issues and challenges involved in design, deployment, utilization, and maintenance of the smart meter infrastructure.*

Key word- Smart meter, smart grid, energy consumption, smart metering, advance metering, automatic meter reading

I.INTRODUCATION

Demand of electricity is increasing day by day and existing conventional grid is not able to fulfil the requirement of customer or electricity consumer. So utility and consumer wants a smart power system which meets the existing and future requirement of electricity which is done by Smart Grid. There is no perfect definition of smart grid. In smart Grid the smart meter is plays an important role. Smart meter employs two way communications and allows user to actively participate between energy utilization and energy consumption .Smart meter is an advanced energy meter that measures the energy consumption of a consumer and provides added information to the utility company compared to a regular energy meter. Smart meter is usually an electronic device that records the consumption of electric energy in intervals of an hour or less communication that information at least daily back to utility for monitoring and billing purpose. Smart meters can read real-time energy consumption information including the values of voltage, phase angle and the frequency and securely communicates that data. The ability of smart meters for bidirectional communication of data enables the ability to collect information regarding the electricity fed back to the power grid from customer premises. A smart meter system includes a smart meter, communication infrastructure, and control devices. Smart meters can communicate and execute control commands remotely as well as locally. Smart meters can be used to monitor and also to control all home appliances and devices at the customer's premises. They can also collect diagnostic information about the distribution grid, home appliances, and can communicate with other meters in their reach. They can measure electricity consumption from the grid, support decentralized generation sources and energy storage devices, and bill the customer accordingly. Data collected by smart meters is a combination of parameters such as a unique meter identifier, timestamp of the data, and electricity consumption values. Smart meters can be programmed such that, only power consumed from the utility grid is billed while the power consumed from the distributed generation sources or storage devices owned by the customers are not billed. Smart meters can limit the maximum electricity consumption, and can terminate or re-connect electricity supply to any customer remotely. Smart metering is the combination of energy metering and intelligence. Though the functions of different smart metering products may not completely identical, several basic abilities are contained: Multi-energy meters readings. E.g. electricity, water, gas. Real-time information of energy used and price of energy. Possibility to read meters remotely and locally. Possibility of auto fault detection instead of sending an engineer.

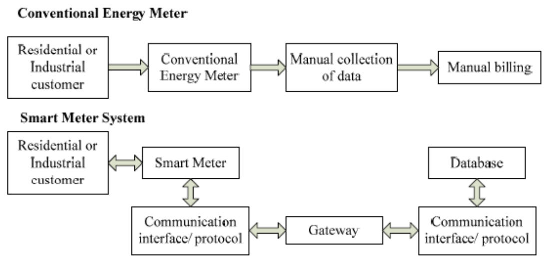

Figure1: Metering Architecture of conventional energy meter and smart meter

In future electricity distribution grids, smart meters would play an important role in monitoring the performance and the energy usage characteristics of the load on the grid. The utility companies are able to manage electricity demand more efficiently because of collection of energy consumption data from all customers on a regular basis. A smart meter system employs several control devices, various sensors to identify parameters and devices to transfer the data and command signals. Smart meters can be used to control light, heat, air conditioning and other appliances. Integration of smart meters helps utility companies in detecting unauthorized consumption and electricity theft in view of improving the distribution efficiency and power quality.

II. SMART METERING

Advanced metering can be implemented with different levels of intelligence associated to the meter. Typically three types can be distinguished, in order of increasing interaction level and feature contents. AMR (automated meter reading) implies the remote reading of the measurement registers of a (electricity, gas, water,) meter without physical access to the meter. It can be implemented via a temporary RF (radio) link to the meter from a car passing by in the street while interrogating the meters, or as an (always connected) communication link to the meter from the data collecting devices. Such link may use wireless or wired communication media. AMM (automatic meter management) extends AMR with the ability to manage meters remotely. For instance, it allows for disconnection of customers, for dimming their usage or for reconnection of customers (except for gas because of safety issues). Smart metering extends AMM with control abilities. For instance, it allows to shut down several customers simultaneously on short notice - in order to balance the grid in case of an incident -, or for demand side management- for usage flattening or load shifting -, or for integration in home automation systems - for automatic
Response to varying prices in real time pricing or time-of use pricing scenarios - etc. As such, smart meters are an indispensable enabler in a context of smart grids which deploy advanced information and communication technology to control the electrical grid. Many different types of advanced meters are on the market, from classic electromechanical Ferraris meters with an external pulse output to fully digital electronic power and energy meters. mainly comprises of two major section (1) first one includes an electronic device which measures the real time energy consumption and all the power parameters, then display on the 4x16 LCD. (2) All data will be transferred to the controlling/monitoring room through PLCC (Power Line Carrier Communication) or GSM (Global System of Mobile Communication) depending on the availability of resources. (3) After receiving data, it is manipulated by software application for preparing monthly billing report which is then uploaded on the internet and is up dated twice in a day. (4) It includes the measurement of apparent power along with the power factor measurement using zero crossing method. Also, energy in KWH (Kilo-Watt Hour) is calculated using related formulae of calculus as done in.

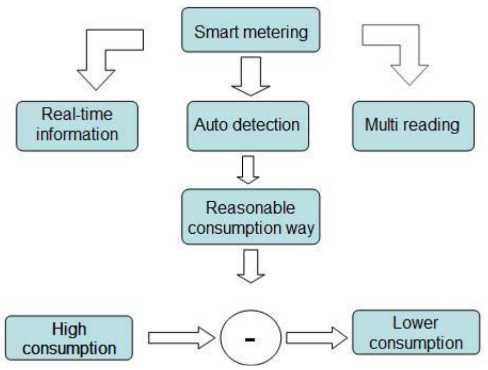

Figure2: Structure of Smart Metering

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III.COMMUNICATION MEANS FOR SMART METER

Three categories of communication media to smart meters have been studied in detail: power line carrier, communication over telephone and cable infrastructure, and wireless communication (mobile phone, RF, PMR), discussing technical aspects and the concerned situation in Flanders. The following sections elaborate major advantages and disadvantages of these communication media for advanced metering applications. A. Power Line Carrier Power line carrier, or power line telecommunication, uses the power grid for data communication. Digital data is modulated on a carrier at a specific frequency. Its usage is standardized and limited to specific spectra (EN 50065-1). The spectrum reserved in Europe for PLC lies between 3 and 148.5 kHz, in which the A-band (3-95 kHz) has been reserved for utility communications. This allows small band communication only; realistic communication bandwidths reach up to about 4 kbps (kilobit per second). PLC has already been used for a long time for lower bandwidth applications e.g. to switch public lighting or to switch between tariff periods. Each advanced meter requires a PLC modem which communicates with data concentrators which are often located in medium/low voltage substations. In Flanders, a typical distance of the meter to the substation transformer is about 400 m. In city areas, each transformer serves about 400 households; in rural areas this is often less. Hence, many concentrators will be required to serve all meters.

B. Small band Communication over Telephone Lines

For analog telephony and Integrated Services Digital Network (ISDN) (digital telephony), a connection is made over the public switched telephone network between an advanced meter and the data collection point. The modem at the meter needs to be connected to the telephone line, which is often not in the same place. Communication bandwidth is up to 56 kbps (analog) or 128 kbps (ISDN) for a duplex connection. Setting up a connection (dialling in) takes a non-negligible time. The communication medium is very reliable, but multicasting is not supported. Flanders has a very high penetration rate of telephone (45 connections per 100 inhabitants), hence about 98% of the meters are connectable. This communication network remains functional in case of power problems, if the modem does not need a grid-connected power supply.

C. Broadband Connection over Phone Line or TV Cable.

The Digital Subscriber Line (DSL) technology provides a
broadband connection over a PSTN line, while a cable based connection uses the cable that carries television and radio signals to bring data communication to the home. These implementations allow for a bandwidth of hundreds of kbps to several Mbps. When this communication medium is already existing in a home, it can be shared with the metering application. It is operated by a telecom provider or internet service provider (ISP). For research purposes, we also include a dedicated broadband connection that is used for advanced metering only. In both cases, it is required to make a connection from the meter to the phone or cable equipment. Cable based broadband also allows for broadcasting data to all meters on the cable segment. Flanders has a high penetration rate for television cable, which serves about 9500 of the households. If this is coupled with the high penetration of telephony, it is clear that it is a potentially widely available communication medium for smart metering. The reliability is assumed to be somewhat lower than small band communication over telephone lines.

IV.COMMUNICATION MEANS FOR SMART METER

Selection of the communication network and design of the communication devices are very important and must satisfy multiple complex requirements. Utilization of the smart meter system involves a huge amount of data transfer between the utility company, smart meter, and home appliances in the network. This data is sensitive, confidential and access to this data should be restricted to a few personnel. With these restrictions on data, security guidelines are formulated for transmission, collection, storage, and maintenance of the energy consumption data. The communication standards and guidelines were formulated to ensure that data transfer within the network is secure. It is equally important that this data must represent the complete information regarding the energy consumption by the customer and status of the grids without any potential manipulations or miscalculations. So, this data must be authenticated and should reflect information about the target correct devices. Fig. 2 shows the generic architecture of communication network that is capable of performing all the features discussed above. This figure illustrates the directionality of communication between the devices at the customer premises, utility, neighbour's smart meters, and other power system components. In this figure, devices in the transmission sector ensure proper transmission of generated energy, control systems in distribution sector ensure monitoring and controlling faults, communication devices like protocol gateways, data collectors and repeaters and network operations coordinates data and control signals between all the devices in the communication network. A smart meter or an appliance that belongs to a customer can be identified by a unique identity assigned to it. In general, identities given to all components are secured by cryptographic techniques. The communication network selected has to support operation of the smart meter system even on power outage detection and support distribution automation. In addition, the selected network and its components must be cost effective and must support "traffic prioritization" i.e., prioritize the delivery of data based on its time and direction sequence.

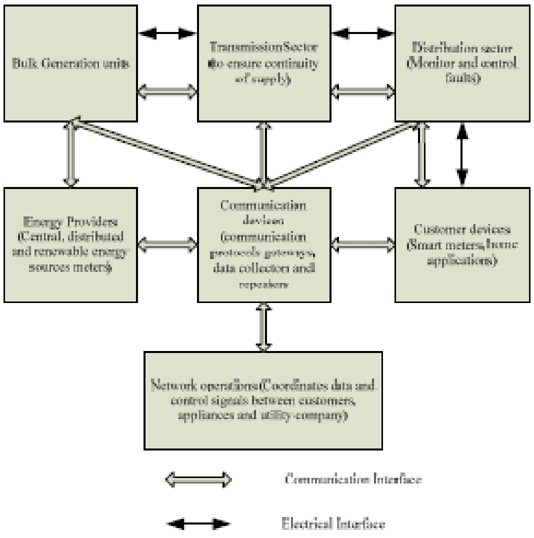

Figure3: Communication Network in Smart Meter System

Communication technologies to be chosen have to be cost efficient, should provide good transmittable range, better security features, bandwidth, power quality and with least possible number of repetitions. Bluetooth technology can be a possible option for communication of control signals and to transmit energy consumption data. In view the of implementing this technique, B.S. Koay *et al.* proposed a Bluetooth based energy meter that can collect and transmit the energy consumption data wirelessly to a central base station . Power Line Carrier (PLC) and Broadband Power Line (BPL) communication are the other possible options of data transfer supporting the higher level communication suites such as TCP/IP. One of the popular communication technologies is PLC, which uses the existing electricity grid, cellular pager network, mesh network, combination of licensed and unlicensed radio, wireless modem, existing internet connection, power line communication, RS-232/485, Wi- Fi, WiMAX, and Ethernet with protocol to upload data using IEC DNP. PLC technology is highly efficient for automation of data in smart meter applications. In spite of substantial overhead caused by the large IPv6 header; this protocol can be applied even at low PHY layer data rates. This technology, with the combination of the MAC algorithm can achieve satisfactory delay times and throughput. Though this combination might slightly reduce the usable data transfer rate, it will not affect the overhead at MAC layer. IP based network protocol would be another promising option for communication because of its advantages over other technologies while satisfying the security standards of the smart grid communications. In addition, TCP/IP technology can also be used as a common platform for multiple communication devices.

V.STANDARD AND POLICY FOR SMART METERING

As a result of introducing new technologies into metering and different understanding of smart metering, the application of this project appears to be multi-standard and incompatible. So setting up standards and limitation become one of the urgent affairs before used. No matter which standards or policies, the establisher ought to include the consideration of basic abilities of smart metering, such as a two-way communication between customers and energy providers, display of a flexible price and consumption details. Other than the basic demands, factors considered could be agile. Until now, different standards and policies have been established by countries, organization and companies, which are basing on the specific conditions and situations. This section provides a brief introduction of some smart metering standards and policies.

A. Standard and Policy in EU

The European Commission has made a investiture of the standardization requirement to CEN/CENELEC/ETSI, the main European Standard Organisations, for a structure of utility meters enabling interoperability and to improve the awareness of customers of low energy consumption. CEN/CENELEC/ETSI has established an organization, Smart Meter – Co-ordination Group (SM-CG), which constructed and cooperated with several technical committees, e.g. British Standard Institution. The SM-CG has listed suggested additional functionalities on Smart Metering.

1) Remote provision of metering data and related information to the supplier or other designated market organisations.
2) Two-way communications between the meter and the supplier or other designated market organisations.
3) Support for flexible tariffs.

Reference No.	Name
CEN/TC 92	Water meters
CEN/TC 171	Hear cost allocation
CEN/TC 176	Heat meters
CEN/TC 237	Gas meters
CEN/TC 318	Hydromotry
CEN/WS	DPP
CLC/TC	8X system aspects of electrical energy supply

Table 1: EU Committee on Smart Metering

4) Remote disablement and enablement of supply.
5) Provision of information to home and network.
6) Load management capability.
7) Exported electricity measurement.

8) Capacity to communicate with a measurement device within a micro-generator.

VI. ISSUES AND CHAGLLNGES FOR SMART GRID

In general view, efficient management of the grid can be an alternative solution instead of revamping the existing grid.

But, in view of technical advantages and enhancements to operation capability, integration of the smart grid stands as a valuable solution in managing the existing grid. However, the design, deployment and maintenance of the smart meter system involve many issues and challenges. Implementation of smart meter system in the distribution system involves several billion dollars of investment for deployment and maintenance of the network. Indeed justifying the investment is difficult. So, this investment has to be realized as a function proportional to the projected increase in the energy demand and portion of the distributed generation. Initially, the process of replacing the existing energy meters with a smart meter system will be a challenge for utility companies. Lack of proper infrastructure for synchronizing this new technology with the existing ones might interrupt the introduction of smart meters. Though several devices are integrated with the smart meter system, they can be used to their fullest extent only when all the appliances and devices in the distribution and metering network are included in the communication network. Integration of the devices becomes even more complicated with an increasing number of customers. Collection and transmission of energy consumption data is a continuous process that is done automatically, but it is a tedious and expense job. In this context, a common notion might arise in several customers is that, smart meters they
might essentially create some privacy and security risks as the data and signals are being transmitted. Additionally, this data might also reveal the information about presence of people at their residence, when they were present, and what appliances are in use. In view of this, some customers might be unwilling to communicate their energy consumption data with their neighbour's meter. Fundamentally, it would be an issue about the choice of parameters to be transmitted and administrator authentication to access that information. Figs. 4, 5, 6 illustrate various issues and challenges in design, deployment, utilization and maintenance of the smart meter system. Apart from utility companies, there are certain sections of people who might be interested in collecting and analyzing the energy consumption data of a customer. They include revengeful ex-spouses, civil litigants, illegal consumers of energy, extortionists, terrorists, political leaders with vested interests, thieves, etc. for knowledge about people's presence at their homes. Quantification of the potential benefits from smart metering is very difficult due to the lack of historical data. Future of smart metering depends on the policies of utility companies and respective governments. Though customer gateways are intelligent and are easily compatible with other devices, they are prone to physical as well as cyber security risks. In addition, energy meters are located in open and insecure environments and need proper shelter to be physically secure.

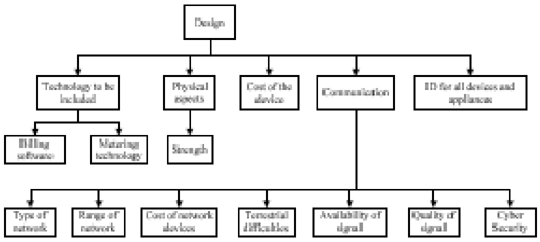

Figure 4: Design issues for Smart Meter System

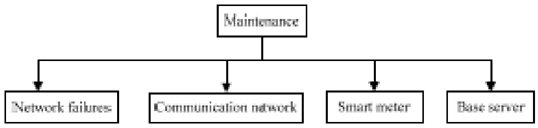

Figure 5.Maintenance issues for a smart meter system.

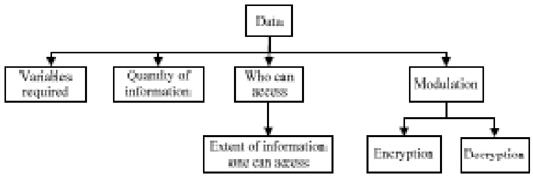

Figure 6. Challenges with data transfer for a smart meter system.

Fig. 4, illustrates several major design issues and constrains including the extent of technology to be included; this technology might include the kind of billing, control systems related software and other metering technology, the physical safety aspects such as positioning of the smart meter and physical strength of the structure that houses the smart meter components, cost of the smart meter devices, specific ID to identify all smart meters and other components in the smart meter network, and the type of communication infrastructure required, including overall cost for the data collectors, data repeaters, transmission, antenna system, type of network to be chosen based on terrestrial difficulties, availability of signal, cyber security, type of the signal and range of the signal. After deploying the required infrastructure, next major encounter would be the maintaining all the components of the network in case of any failure. Maintenance of network include issues with the base server that stores the energy consumption data, software and hardware issues with the smart meter, electric network as well as distribution network failures. Besides these issues, dealing with the data could be another major issue. They include quantity of data to be transmitted, what are the variables to be transmitted, the extent and quantity of information that the customer and the utility companies, can access parameters, parameters required to represent the energy consumption, modulation of the data before transmission, demodulation of the data at the reception.

VII.APPLICATION AND ADVANTAGES

Smart Grid System determines the need of aspects such as
daily workflow, workforce management, asset management, call centre philosophy, billing systematic etc. Smart meters can enhance the operation of SCADA system. As smart meter system provides several benefits such as efficient power system control and monitoring, operational decisions those are taken timely to minimize outages and losses . Particularly in micro-grids, smart meters can perform energy cost allocation, fault analysis, demand control and power quality analysis. Smart meters can schedule preventive maintenance, and support the operation of check meters for accurate billing. In addition, smart meters can detect the presence of unwanted harmonic component in current supplied from the de-centrally Smart Grid System determines the need of aspects such as daily workflow, workforce management, asset management, call center philosophy, billing systematic etc. Smart meters can enhance the operation of SCADA system. As smart meter system provides several benefits such as efficient power system control and monitoring, operational decisions those are taken timely to minimize outages and losses. Particularly in micro-grids, smart meters can perform energy cost allocation, fault analysis, demand control and power quality analysis. Smart meters can schedule preventive maintenance, and support the operation of check meters for accurate billing. In addition, smart meters can detect the presence of unwanted harmonic component in current supplied from the de-centrally generated sources, which helps in identification and rectification of the source of the problem. Micro generators integrated into the distribution network must be registered, so that they are under the access and control of the smart meter system. Pattern recognition techniques can also be employed as part of the smart metering system in order to gain access to the performance information of the devices and financial incentives to the customer. Manual energy meter reading is a tedious, continuous and an expensive job. In conventional metering system, meter reader has to go and take the reading manually to generate and issue the bill. This whole process can be simplified with the help of a smart meter and proper communication mechanism. Increased energy security as well as energy saving drives the installation and adoption of smart meters. Smart meters encourage consumers to conserve energy by helping them maintain the quantity and cost of their energy consumption. There are several models of smart meters proposed by several researchers. Of which a few models are discussed in this section. Power strip smart meters can be employed to monitor and control the appliances of customers. These meters provide data, identity and location of home appliances under operation. Generally, unbalanced loads cause fluctuations in the voltage profile of a distribution feeder located far-away from the substation. Smart meters can analyze and control these fluctuations in low voltage grids. Information about the load at the customer end and control of the maximum load demand helps utility companies in maintaining a flat voltage profile on the power supplied. Smart meters control the maximum load demand of a customer during peak load, and if any customer exceeds their limit, the supply of electricity will
be disconnected to that customer. Present electricity grids are designed for large scale generation, centralized control, transmission, and distribution of electricity. As such, these devices and system might not be efficient for housing intermittent power generation sources such as wind turbines and PV panels without compromising on the overall power system stability. In addition, present grid systems are designed for unidirectional power flow. Integrating additional devices to the smart meter system enhances the capabilities of smart metering technology. Geographic Information System (GIS) can be integrated to the smart meter system in order to obtain specific information regarding the geographical location of a potential fault. Quick identification and rectification of faults and other issues that demand the attention of utility company reduces the overall power outage duration. In addition, smart meters reduce the average power outage duration to 4 to 6 minutes due to their fast response and rectification to power outages and faults. C. Claudio and R. Emilia proposed a smart total harmonic distortion (THD) meter that monitors the quality of the power supplied from the grid and evaluates the THD. Particularly, when the distribution grid is integrated with wind turbines, occurrence of a fault similar to sudden disconnection of a generation unit or large load can alter the supply frequency. Smart meter system can quantify and maintain these parameters

within desirable range even under high wind circumstances.

VIII. CONCLUSION

It concludes that smart metering has a huge potential in improving energy efficiency and allow energy trading down to customer level. It explains advantages of smart meter system in utility company as well as in customer point of view. Various potential communication networks for smart meter communication are presented in detail. In addition, several challenges, requirements and issues in design, development, deployment, and maintenance of the smart meter systems are illustrated.

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