The Integration of Smart Meters Into Electrical Grids: Bangladesh Chapter

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Abstract

The Smart Metering Technology paves way for increased utilization of green power through Renewable Energy Sources. With the introduction of Smart Metering Technology at Distribution level, the consumer shall have an incentive to switch on their appliances time specific, to have the benefit of choice of low cost power. This paper identifies specific issues that could be developed for Bangladesh's deployment of Smart Metering Infrastructure, recommends appropriate goals, key strategies, and critical objectives in solving those shortcomings, and outlines a practical program, identifying key tasks and necessary expert capabilities, to accomplish that solution in a timely and affordable manner.

Keywords: AMR, AMI, AMM, Power Line Carrier (PLC)

1. Introduction

Smart meter is nothing but an Interval meters on customer premises that measure consumption during specific time periods and communicate it to the utility, often on a daily basis. Smart meters will become ubiquitous over the next decade and will flourish as an important part of the electrical grids of the future. But it is such a nascent industry that there is not an abundance of information freely available. Many of the business cases are still to be proven especially when it comes to the integration of future functionality such as load shedding, the integration of renewable energy and electric vehicles. Especially from the point of view from Bangladesh it has to be deeply thought whether it is suitable or economically efficient for the third world developing countries like ours. So, first we've to think of its eligibility and cost efficiency as well to establish smart metering system in Bangladesh.

2. Smart Metering VS AMR, AMI, AMM

Smart Metering provides more detailed information than does the older, related Automatic Meter Reading (AMR) system. In AMR, meters communicate their monthly or daily consumption totals to a central collector using one of a number of different communications techniques, such as radio signals, power-line communications, or satellite reads. In other words, they are designed to replace house-to-house meter readers with centralized collection. AMI (Automated Metering Infrastructure) refers to system that measure, analyze and read energy consumption. These systems are also able to read electricity, gas, heat and water meters remotely. AMI system can be defined as an extension of the simpler AMR system. AMM (Automated Meter Management) or smart metering is another expansion of a remote reading system that

includes the possibility of performing technical measurements and functions and carrying out customer-oriented services via the system. 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 (e.g. down to a socially acceptable 6A or 10A for non-paying customers) or for reconnection of customers [1]. 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 response –for usage flattening or load shifting–, or for integration in home automation systems – for automatic response to varying electricity prices–, 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 [2].The question is not anymore how to get the data, but how to manage them and how to get the most information out of them. This is in fact the core function of the smart meter; it enables a sensible and economically viable allocation of the resources from data collection to analyzing data.

3.   Proposed Design for Bangladesh

Each appliance belongs to one household from where it consumes energy. The rate at which the energy is consumed is different for each appliance, within the average limits that several studies have found. Each appliance can have different states that affect its energy consumption profile. An appliance also belongs to an appliance category that holds information for the load distribution, presence and schedule for all the appliances of that category. The load is represented by a probability distribution function and indicates how much energy the appliance consumes over time.
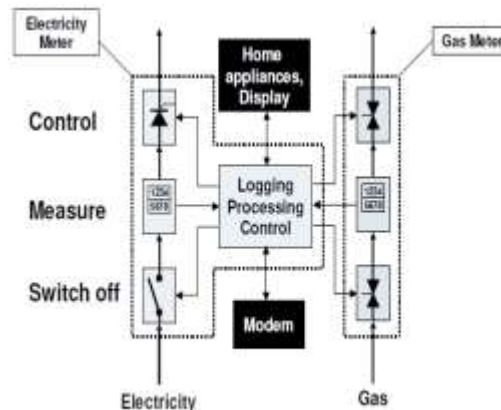

Figure 1: Schematic overview of a typical smart meter   configuration [3]

In the figure both electricity and gas control has been shown. Both the control is done by Logging processing control device and the communication is executed by modem. There are two measuring units by which Logging processing control unit will decide which load should be cut off or remain. Our Proposed smart metering system is similar to that of an EMS (Energy Management System)-type system. To popularize this smart metering system, we tried to find a method to enable its installation in existing buildings without extra construction. To achieve this, we considered PLC (Power Line Carrier) and wireless methods for system communication.

4.   Detailing Key Parts

Generally, a smart meter consists of three elements or units: a metering unit, a communication unit, and an open/close unit (see block diagram in Figure 1). The metering unit tracks the customer's utility usage and processes the billing. The communication unit enables two-way digital communication with the utility company. The start/stop unit starts and shuts down the utility supply. In an electronic power meter, the

metering unit consists of a metering section that measures the current and voltage; a microcontroller section that calculates power usage and billing data based on these measurements; a display section that shows status and other information; and an EEPROM section those stores billing data. There is also a photo-coupler that provides line isolation, while interconnecting with the communication unit that transmits and receives data and commands.
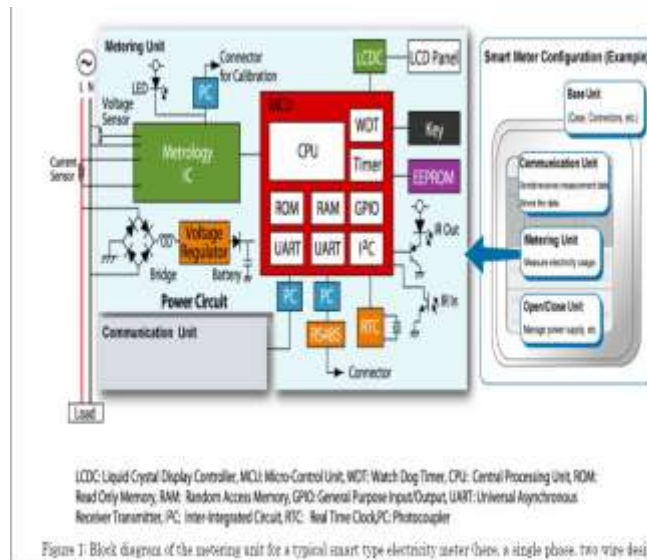

Figure2: Block diagram of the metering unit for a typical smart-type electricity meter (here, a single-phase, two-wire design). [4]

4.1 Home Area Network (HAN):

The Home Area Network (HAN) provides utilities a powerful platform to establish two way communications with the consumer premise. HAN helps Consumer to Utility Communication having Actual energy usage information and response to device energy management control signals. It also helps Utility to Consumer communication having near-real time energy usage information, time of use pricing information appliance control/energy management signals.

4.2 Two way communication:

Other countries such as Australia and US use Zigbee wireless communication. But in the context of Bangladesh either Wi-max or zigbee communication is too much expensive and is not affordable to the common people as well. As we have said earlier that we don't want to make extra construction for communication, we will use the GSM network established by our mobile operators and the fiber optic communication chain which has been already set up by PDB (Power Development Board) among 132KV substations. We can also use the fiber optic communication set by Bangladesh Railway as well. PLC (Power Line Carrier) will be the most versatile medium for two way communication for Bangladesh. Various coding techniques may be used for wired PLC; however OFDM is rising in popularity due to its robustness against time-varying noise. This is the key to high throughput as many commercial products introduce a number of high frequency components onto the transmission line that is highly attenuated at the MV to LV transformer but present in adjoining properties next to the source.

4.3 W –LAN:

Wireless LAN uses the 2.4 GHz, 3.6 GHz and 5GHz frequency bands for signaling according to the IEEE 802.11 standards. In Europe, this frequency band is open to public use, and is divided into 13 channels. The W-LAN technology is used widely in computer networks. Current W-LAN systems can provide data rates of typically 11 Mbit/s for 2.4 GHz band, 54 Mbit/s for 5 GHz frequency band. But, the W-LAN rates might go even up to 600 Mbit/s with the latest IEEE802.11n specification. For use in home automation systems,

other standards are more suitable, however. ZigBee uses the same frequency band as W-LAN, but in contrast also specifies auto-routing of information packages from one node to any other node allowing reaching devices within the entire building, as long as all nodes can contact any other node of the network. For using W-LAN, direct radio signal connectivity between all nodes (clients) and the central access point is required unless special repeaters are used. This would increase cost and power consumption of the system. For this reason, W‑LAN is not further considered for home automation in this project. W‑LAN can be very helpful for the connection between the customer interface and the display, however.

4.4 Power line carrier (PLC):
One of the most widely used technologies for advanced metering; power line communications makes use of the existing electricity wires to transfer data. Its spectral position is about 1.6MHZ-80MHZ and its estimated bandwidth is almost 256Kbps-2.7Mbps. The diagram below illustrates how a smart meter could be connected to the Data Transport using power line carrier:
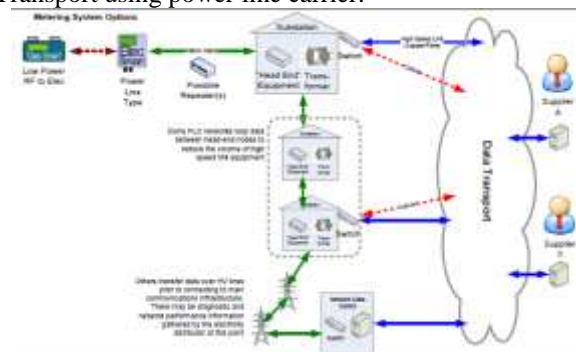

Figure3: Power Line Carrier [5]

The same infrastructure as shown above could support narrowband or broadband data services. The key difference would be in the sophistication (and cost) of the equipment installed in the infrastructure and the meters to support higher bandwidth data connections. For the purposes of defining Power Line Carrier, this document does not distinguish between narrowband or broadband applications of the physical media. Theoretically, a power line carrier network should be as capable as any other fixed network of supporting interoperable communications protocols– IP, HTML, SSL etc. However, it has generally been the practice for a utility to contract with a solution provider who then uses proprietary hardware or software within the network to deliver the service. There are international examples of investment in Broadband over Power Line (BPL) infrastructures allowing a much higher bandwidth. However, these are usually implemented with the intention of providing non-utility services such as internet connection or multimedia services. All power line communications systems operate by impressing a modulated carrier signal on the wiring system. Different types of power line communications use different frequency bands or modulation techniques, depending on the signal transmission characteristics of the power wiring used. There can be differing terminology - Power Line Communications could refer to data transferred over the High and Medium Voltage wires, with Distribution Line Carrier referring to the Low Voltage connection to individual meters. Initially in a metering context, PLC was used to deliver 1 way information transmission, with meters sending consumption information according to configured schedules. Technology is now widely available that allow for bi-directional use of PLC to and from meters. A number of existing solutions use mesh networking, sending information from meter to meter to reach a concentrator – this can affect the overall speed of the solution. Implementations in other markets do not attract a 'per kilobit' commercial cost model (unlike cellular), meaning that the cost to use a PLC network will not flex with the volumes of data transferred. As PLC communicating Smart meters utilize the electricity mains wiring, the hardware within the meter will include a transponder or transceiver to deliver communications capability, with some associated microelectronics to provide coupling to the wiring, power management etc. The scale of infrastructure required by a PLC implementation varies by the commercial solution selected. Some include substantial equipment within the electricity distribution network, others are less intrusive. All PLC deployments will require some network infrastructure equipment. The 'speed' of data transfers varies by commercial solution, and will depend on the 'quality' of the low voltage network. Traditionally PLC has been viewed as a narrowband communications link, with speeds lower than 10kbps. However, technology

continues to offer alternatives, with much higher speeds available with more expensive components within the infrastructure and meter. One of the 'narrowband' PLC systems reviewed stated a time of 20 seconds for an enquiry from a utility billing system front end to receive a response containing a meter read from an individual meter. Some technologies use PLC connections that offer speeds of 14MBps, 85MBps and 200MBps – it is thought that these high rates are only possible at reasonably low cost by the 'closed' nature of mains wiring within a home. The power usage implications of any PLC system will be largely dependent on the type of infrastructure installed. Data concentrators will all represent 'new' equipment that will consume power. The power consumption of the PLC communications system itself – the transmission and processing of the carrier signal – is also dependent on the signal, frequency, level of amplification etc. Shown below are illustrations of PLC equipment as may be installed in an electricity substation to provide communications connectivity to meters (transponders) on the low voltage network.

Figure4: PLC Substation Equipment

4.5 Home Smart Controller:

For the basic, type-1 configuration meter designs for example, we recommend the economical chips in the R8C family, as well as 78K0 devices, which integrate a power-calculation unit for single-phase power. For the more-capable type-2 and most-capable type-3 configurations, we currently propose the microcontrollers in 78K0R, V850, and H8S families. Moreover, this lineup soon will be augmented by chips in the RX200 family Our tailored system designs can include not only microcontrollers, but also current/voltage metering sections, display sections, EEPROM (for storing billing data), and other types of support ICs, as well as reliable power devices (MOSFETs, etc.).

5.   Ensuring Secured Operation

The incorporation of a communication capability within a meter creates some risks—most particularly, the risk of attacks by hackers. In the worst case, such an attack might cut the lifeline of a utility's metering system, crippling its power distribution infrastructure and thus causing a catastrophe. To reduce the huge potential danger entailed by this type of situation, communications must be encrypted. In particular, two types of data protection are probably required. First, high-level encryption should be implemented—at the router level, for example—to block remote hacking attempts. Second, anti-tampering features are necessary to ensure that any hackers who get direct access to the meter itself will not be able to steal confidential information from the smart meter's microcontroller section.

6.   Variable Tariff Plan

The overall load patterns of electricity consumption are quite well predictable. Characteristic peaks occur at some time intervals and other time intervals are characterized by low consumption, especially during night-time. Also, the availability of renewable energy resources can be predicted with certain accuracy, giving an indication of probable situations in the electricity system for the next day. Tariff Planning can be done by choosing some suitable time wise (peak and off pick) tariff planning. It can be fixed by announcement or smartly calculated hourly by the utility depending on prevailing load forecasting data Variable tariff plan will make the user conscious about their electricity consumption. They will be able to realize when heavy loads should be on or totally off. The key idea of the business case is, thus, to provide the customer with a variable price profile on the day before power delivery. This profile, calculated by the retailer, should be

fixed once it has been communicated to the customer, so that the latter can rely on it for his further planning of generation and consumption. The price profile can look different for each day, however, to reflect market conditions that also vary from day to day. These variations will likely increase with increasing generation from fluctuating sources like wind and solar energy. The price profiles could be based on the wholesale prices that the retailer faces when procuring the energy amounts he sells to the customer. The exact relation between the spot market prices and the variable tariff profiles sent to the smart customer can be determined flexibly. The possibilities range from a direct adoption of the spot-prices (plus grid costs, taxes etc.) to more complex contractual relations specifying maximum price and average price levels of the customer. Moreover, in order to make the flexible tariff model more acceptable for the end-user, a ‚maximum average cost per kWh‘ could be guaranteed by the retailer, protecting the customer from unintended very high energy bills. It has to be noted, however, that each guarantee for prices decreases the customer's financial incentive to shift his consumption and generation in the desired way, thus weakening the demand response. At the customer's premise, an energy management system should receive the price signal and determine the optimal timing for the energy consumption of those appliances that can be shifted in time (e.g. washing machines or dishwashers) or that have a storage characteristic (such as fridges or deep-freezers).

7.   Flexible Demand Response

Demand response offers a variety of financial and operational benefits for electricity customers, load-serving units (whether integrated utilities or competitive retail providers) and grid operators. Electric power systems have three important characteristics. Firstly, because electricity cannot be stored economically, the supply of and demand for electricity must be maintained in balance in real time. From the definition of 'load factor', we know,

$$\text{Load factor} = \frac{\text{Average Load}}{\text{Peak load}}$$

Secondly, grid conditions can change significantly from day-to-day, hour-to-hour, and even within moments. Demand levels also can change quite rapidly and unexpectedly. It results mismatching in supply and demand. Thirdly, the electric system is highly capital-intensive and generation and transmission system investments have long lead times and multi-decade economic lifetimes.

8.   Load Forecasting

Load forecasting is divided into two parts. One is long term and another is short term. Extrapolation is used for long range load forecasting. It involves fitting trend curves to basic historical data adjusted to reflect the growth trend itself. Once the trend curve is known, the forecast is found by evaluating the trend curve function at the desired future point. Some of the functions used in trend curve fitting are:

Straight line $y = A + Bx$
Parabola $y = A + Bx + Cx^2$
S curve $y = A + Bx + Cx^2 + Dx^3$
Exponential $y = Ce^{Dx}$
Gompertz $y = \ln^{-1}(A + Ce^{Dx})$

Short term Load forecasting techniques generally involve physical decomposition of load into components. The expected hourly load forecast is divided into five components and written as,

$$Y(i,j) = ADP(j) + AWP(k,j) + WSC(i,j) + TR(i) + SEC(i,j)$$

Where, $Y(i,j)$ = load forecast for jth hour of ith day
$ADP(j)$ = average daily load pattern at jth hour
$AWP(k,j)$ = average weekly load increment pattern at jth hour and kth day of the week (k = 1, 2,…7)
$WSC(i,j)$ = weather sensitive component at jth hour of ith day
$TR(i)$ = trend component of load on ith day
$SEC(i,j)$ = stochastic error component which is assumed to be normally distributed.
Smart metering can give a load shedding architecture where important loads (light, fan, fridge etc) can be supplied from the grid where unimportant loads will be cut off by the user's predefined logic and sub-stations command. It will be done with the help of home smart controller.

9. Payback Analysis

Analysis should be done whether this project is economically efficient or not. If the payback returns within a few years, it will be profitable project. But if the payback returns after a very long period then it will be a great problem to implement this project. Government may impose extra tax on the users, so that the payback will return soon. We can calculate the NPV for the investment,[6]

$$C_0 = -I + \sum_{t=1}^{T} R_t * (1+i)^{-1}$$

Where I , i , t R , t = 1,...,10 denote the initial investment costs, the interest rate, the savings per year, and the year, respectively.

10. Conclusion

A Smart Metering infrastructure for Bangladesh will be an unprecedented technical undertaking involving millions of devices that must securely and effectively integrate with a variety of business entities. As envisioned, these systems will be an important and needed contribution to the country's existing and future energy infrastructure. The efficacy of these systems will depend upon the clarity of their functional criteria, the comprehensiveness of system architectures, and rigorous approaches to manage the entire scope of effort through all the steps of their life cycle. The success of Bangladesh's Smart Metering program cannot be simply assumed, but requires a Government-level technical integration and architecture development perspective, a perspective uniquely provided by this paper. Its development should be collaborative with a focus on bringing that vision together through open standards that enable interoperable equipment from a variety of manufacturers and industries. The program developed in this paper can help assure the success of that vision. Much is at stake. If done well, this system would provide substantial value, for all the stakeholders for years to come. However, if done without an appropriate level of technical rigor, the deployed systems could undermine public security and cost the country, utilities, and ratepayer's significant money, time, and public confidence.

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