A Framework of a Smart System for Prepaid Electric Metering Scheme

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Abstract— **In developing countries, the utilities are facing difficulties in collecting electric bill in full scale. Therefore, prepaid metering system is becoming popular for ensuring the collection of bill in advance. But it does not account for the unauthorized energy usage because those cannot be metered. In this paper, a framework of a smart system for prepaid electric**ity **metering scheme has been developed. This is based on collection of electric energy data hierarchically from the consumer ends to the source end. Similarly commands for the meters are communicated from the source end to the consumer end. The objectives of this development are to control and monitor the prepaid meters and at the same time to localize the energy pilferage and thereby bring the unauthorized energy usages under accounting.**

Keywords- ***Prepaid meter, Smart System, Framework for Smart System.***

I. INTRODUCTION

The idea of prepaid metering scheme is based on 'Pay first use later'. The concept is becoming very popular in developing countries. From the consumers' point of view, the idea is attractive because there is no hassle of disconnection and reconnection if he becomes defaulter for some reason. Moreover since the amount remaining in the meter gradually decreases as he uses electricity, every time he remains cautious to stop the misuse of electricity so his consumption and corresponding bill becomes less. On the other hand from the utility's point of view, it is beneficial because they do not have to engage meter reader, bill preparation team and bill server. Most importantly utility receives the payment in three months earlier than usual time. No record keeping related to bills for the individual consumer is necessary for prepaid metering scheme and thus the related manpower can also be reduced.

There have been a huge number of ongoing researches related to evolving protocol, methodology and implementation issues of prepaid metering scheme. Most of the researches focus on the development of meter itself. A number of features have been incorporated [1][2] in order to ease its use for the consumers and fulfilling the need for the utilities. But a few researches have been reported related to its system development. Most of the prevailing system follows the vending station-system master station based prepaid metering scheme. The great disadvantage of this popular system is its bundled feature. If some individual wants to install a prepaid meter on his own he cannot do that. He has to apply for a meter to the utility and the utility configures a meter to the system first and then install it in the consumer premises.

Moreover, the charging and recharging system of the advantageous type (smart card based) is not an open rather a closed one confined to a particular utility area. A consumer cannot recharge his meter from anywhere of his choice and not through internet. These are the main hindrances [3] for which the system is not spreading with the desired rate.

Additionally, prepaid metering scheme applied to a smart system has not been considered so far. Most of the smart metering scheme is based on post paid metering scheme and they are limited to one way communication. Additionally they are used mainly for energy accounting and not for load management. Limitation of a smart meter becomes prominent when its ability in dynamic data update [4] is considered. A limited number of schemes have discussed on the dynamic data update using smart meters.

The smart metering scheme [5] based on wireless communication from individual meter has been reported. It claimed its superiority over off-line data collection system but it did not provide any impression on cost of the system. Ref [6] claimed that their developed smart meters are capable of identifying electricity theft. But it can only identify the theft using tempering within the meter; external means of theft cannot be identified. GSM network based prepaid metering scheme [7] has also been developed. The solution although can accumulate the energy data in a central server but the solution is costly and the recurring cost for the bill of the GSM network is detrimental for the consumers.

This paper proposes a framework of a complete prepaid metering scheme which is not only an open system but also unbundled. The meters in the proposed scheme, if a consumer wishes, can install on his own following a certain guideline and he can monitor and control his meter using his smart phone with the help of a mobile Apps. The energy data of all meters under a distribution transformer is collected at a point through Power Line Carrier (PLC) and finally are sent to the server using a GSM network.

II. PREPAID ELECTRIC METERING

The prepaid metering scheme is a closed system involving a system master station. Under a system master station there are several vending stations which are used for recharging the meters by the consumers. All transactions are made through the vending stations. The system runs on the concept that except some exceptions there must be a positive balance in the meter if the continuity of supply is to be maintained. If the balance becomes zero or negative the meter automatically shuts down by a latching relay. The relay is residing within the meter and remains in series with the supply line. At that time if the consumer recharges his meter the reconnection of the supply line is restored by the closure of the relay.

The meter operates under a system comprised of (a) meter (b) vending station and (c) system master station. The interconnection between the three identities is shown in Figure 1.

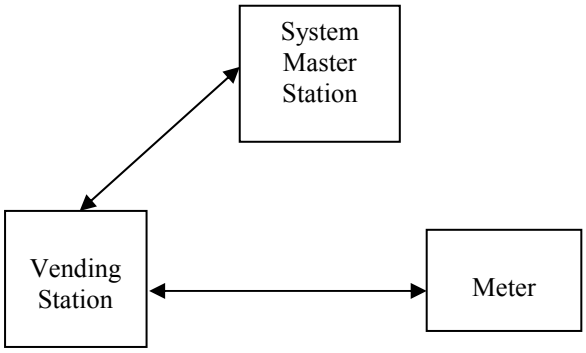

Figure 1. Interconnection between the identities

There are two well known method of recharging the meter. One is called scratch card method and other is called smart card method. In scratch card method upon payment by the consumer, a number is generated at the vending station and printed in a piece of paper. The consumer punches the number using the keypad in front of the meter. The number is an encrypted number and it is decrypted by the firmware written within the meter. The decoded charged amount is added with the previous balance and if the resultant balance is positive the meter reconnects or continues the supply line with the load.

In smart card method upon payment of an amount in the vending station the amount recharged is written electronically within the chip of the smart card. The consumer takes the card back to his home and insert to the meter for which the card is assigned. Once inserted, the meter reads the information within the smart card so the amount becomes known to meter. At the same time the information stored in the meter is transferred to the card. The information is downloaded to the vending station when next time the consumer hands over his card for recharging. The next steps are similar to that described above for scratch card method.

III. THE DRAWBACKS OF EXISTING PREPAID METERING SYSTEM

There are a number of drawbacks of the prepaid metering scheme that is described earlier. They are as summarized below:

It is a bundled system with the vending system (VS) and system master station (SMS). The capacities of VS and that of SMS is limited and if somebody wants to add some meters beyond the capacities a new set of VS and/or SMS has to be established.

All calculation, monitoring and control is made on the meter itself. If a meter becomes faulty all data upto certain period is lost. Because the data is transferred in an interval of charging the smart card.

Dynamic data can not be updated in the present system. For example, if load shedding data is required to be updated there is no mechanism to update the data to the meter.

At present, consumer has no easy means of observing, monitoring and controlling the meter and thus optimization of the usage of his electricity.

IV. THE FRAMEWORK OF A SMART SYSTEM

A. The network

A smart system is proposed for prepaid metering scheme. The system will be centered on the distribution transformers. A unit will be composed of all the consumers connected under a distribution transformer. A sub-unit will be recognized as the consumers connecetd under a pole. Each and every consumer will be recognized by a consumer ID which is numbered according to the ID of transformer of supply and the ID of the pole from which the service drop will be drawn to the meter of that consumer. Each pole will be fitted with concentrator.

There will be two types of concentrator. The concentrator which will be connected at the pole containing the transformer will be called concentrator-M and other concentrators will be termed as concentrator-S. The concentrator-M will communicate with the server and to the adjacent concentrator-S. And each of the concentrator-S will communicate with adjacent concentrator-M or with another concentrator-S or with the consumer meter. The communication between the concentrator and the meters or between a concentrator (-S or –M type) and an adjacent concentrator (-S or –M type) will be made by Power Line Career (PLC). On the other hand the communication between the concentrator to the utility server will be made by wirelessly using a GSM modem. The proposed frame work is depicted in Figure 2.

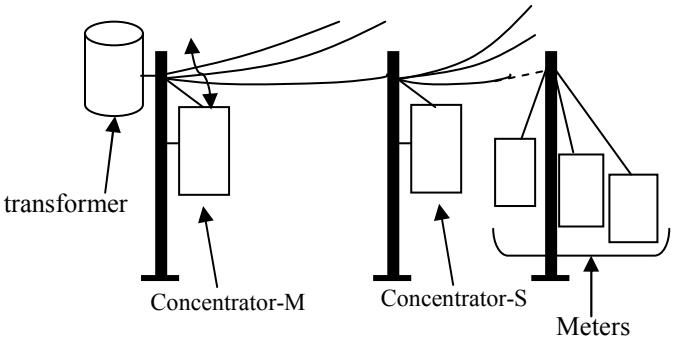

Figure 2. The proposed framework

Although for the sake of clarity the figure shows meters of the consumers at the furthermost end of the distribution line, in practice each and every pole will supply energy to the consumers at its vicinity. Therefore, every concentrator will collect energy of all the consumer meters under its jurisdiction and also to line travelling to the next concentrator, if any.

B. Power Line Carrier (PLC) Communication

The communication of energy and other associated data will be transmitted through the distribution lines using Power Line Communication (PLC) technology. The architecture of PLC technology is depicted in Figure 3 below. It consists of two trans-receivers connected at two ends of a line. In order to block 50Hz power signal to the communication devices coupling capacitors are used and to block the data embedded over high frequency carrier signal line traps at both ends of the line are installed. Again in order to match the impedance of the trans-receivers with the line impedance matching networks are connected at the trans-receiver ends.

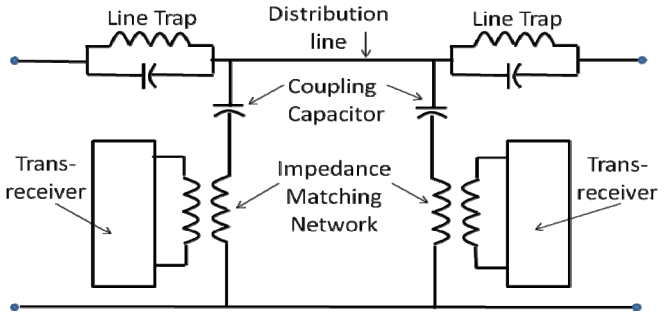

Figure 3. PLC Communication network

C. Detection of unauthorised electricity use

The proposed scheme will help the utility to pin point the unauthorized electricity, if any. The unauthorized use mainly occurs by making connections either from the input point of a meter or by tapping from overhead distribution line. This can easily be detected by adding additional information at the concentrators (both -S and –M types). The additional information will be the incoming energy at the concentrators. Since at every 15 second energy data from each meters are sent to the server, if at the same time the concentrators send their incoming energy, a balance sheet can be prepared from the data. If there is an imbalance between the incoming and summation of outgoing energy, this will be pointed out as pilferage and the location can easily be identified

D. The protocol

i. Each of the energy meters will send the energy data in every 15 sec to the concentrator-S from which its service drop will be drawn. This communication will be made using PLC.
ii. The cocentrator will send the energy data to the next concentrator-S and so on. This will also be communicated using PLC.
iii. At the remotest concentrator (i.e. concentrator-M) all the energy data will be sent to the server wirelessly using a GSM modem.
iv. On the other hand any command to be given to a particular meter will first be sent to concentartor-M and the data flow will be reverse in this case and reach to the particular meter using PLC communication in a number of hops.
v. In addition to the energy data status of the meter, i.e. any identified fault or attempt of temparing will be sent to the server using steps (i) to (iii).

E. The data format

(i) Data from meter/section of line

Bit 25-21	Bit 20-19	Bit 18-13	Bit 12-1	Bit 0

Specifications of the 26 bit data byte:

bit 25-21 - sender's ID (either a meter of a sub-section of distribution line)
bit 20-19 - type of the data, energy or status
bit 18-13 - time in minute-second
bit 12-1 - data (energy or status)
bit 0 - parity bit

(ii) Command from server

Bit 25-21	Bit 20-19	Bit 18-13	Bit 12-1	Bit 0

Specifications of the 26 bit command byte:

bit 25-21 - ID of a meter of a sub-section of distribution line for which the command is sent to
bit 20-19 - type of command, e.g. connect, disconnect etc.
bit 18-13 - time in minute-second
bit 12-1 - command detail (load shedding interval, etc.)
bit 0 - parity bit

F. The specification of Apps for the smart phone

A mobile application for the smart phones has to be developed. It will be used by the consumers. All communication with his meter will be made with the apps.

The following specification should be met by the Apps to be developed.

i. Once meter ID is entered, present status of the meter should be displayed.
ii. Consumer can recharge his meter using mobile or on-line banking facility or credit in his mobile.
iii. Consumer may disconnect the meter on his own during a long vacation when he does not want to use elecricity.
iv. Consumer may be able to lodge complaint, if any.

G. *Summary*

In summary, the followings are the salient features of our proposed frame work:

i. The meter will record only the energy data, no calculation will be burdened in the meter firmware.
ii. The load will be disconnected either for lack of balance for that meter or for a prescribed preplanned load shedding or for detecting tempering within the meter.
iii. All calculations of energgy bill will be made and actions to be taken (connection/ disconnection) will be decided at the server end.
iv. Consumer will be able to communicate with the server regarding his meter using an Apps to be developed for smart phone.

V. PROTOTYPE OF THE PREPAID METER

The main component of the proposed system is the meter. We developed a prepaid meter capable of handling the protocol mentioned in the previous article. The number of bare minimum components of the meter is six and they are: (a) Microcontroller (b) Input conditioning circuit (c) Energy Measuring IC (d) Latching Relay (e) PLC unit and (f) Power supply. The firmware has been developed only to cater for three functionalities they are (a) Normal calculation of energy (b) Reconnecting or disconnecting the supply line (c) communication via PLC.

A picture of the meter board has been shown in Fig. 4.

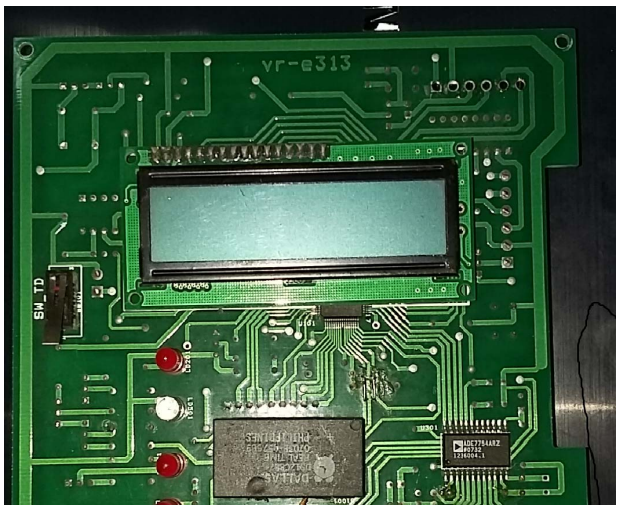

Figure 4. Picture of prepaid meter capable of handling the proposed frame work

For testing purpose LCD is provided in the prototype. In practice, there will be no LCD in the meter. For communication between meter and the connected concentrator, a PLC modem is used. The modem sends data and receives command from the concentrator in the data format described in the previous article. Atmel's AT89C51 microcontroller is used in the board. Since time of energy data has to be sent to the server a real time clock (RTC) is used in the board.

VI. COMPARISION WITH OTHER SYSTEMS

There are several advantages of our proposed system with respect to the conventional systems. They are,

1. In the conventional systems, all calculations of energy, bill amount, remaining amount etc. are made within the meter, but in our system no such calculation is burdened on the meter firmware. Hence the meter firmware will be simpler and robust in operation.

2. For data communication, in the existing systems, components like wireless modem are required. But, in the proposed system, the operation of PLC is implemented by the same microcontroller responsible for energy accumulation. So, the cost of the system will reduce drastically.

3. In oppose to the other prevailing systems, in our proposed system we shall be able to pin point any power pilferage caused by tapping or hooking any section of the distribution lines.

4. The load management can be implemented in our system. But in the conventional system one cannot do that.

VII. CONCLUSION

An open framework for prepaid metering scheme has been formulated and explained in this paper. A prototyping of the meter part is developed and the ways it will be incorporated in the whole framework has been explained in the paper. The disadvantages of the present prepaid metering scheme and how the framework is going to eliminate the drawbacks of present scheme have been discussed in the paper. The framework also explains how it will be beneficial in detecting an unauthorized use of electricity. The relative advantages of the proposed system over conventional systems have also been outlined in the paper.

The implementation of the full scheme is under process and it will soon be reported after a pilot project is up and running in the capital city of Bangladesh.

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