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A prepaid meter using mobile communication

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Abstract

Energy meters in India have dominantly been electromechanical in nature but are gradually being replaced by more sophisticated and accurate digital and electronic meters. A high percentage of electricity revenue is lost to power theft, incorrect meter reading and billing, and reluctance of consumers towards paying electricity bills on time. Considerable amount of revenue losses can be reduced by using Prepaid Energy Meters. A prepaid energy meter enables power utilities to collect energy bills from the consumers prior to the usage of power by delivering only as much as what has been paid for. This paper suggests a prepaid energy meter behaving like a prepaid mobile phone. The meter contains a prepaid card analogous to mobile SIM card. The prepaid card communicates with the power utility using mobile communication infrastructure. Once the prepaid card is out of balance, the consumer load is disconnected from the utility supply by the contactor. The power utility can recharge the prepaid card remotely through mobile communication based on customer requests. A prior billing is bound to do away with the problems of unpaid bills and human error in meter readings, thereby ensuring justified revenue for the utility. The proposed prepaid meter is implemented in a software model and Matlab has been used for simulation.

Keywords: Balance, Consumer, Energy Meter, Mobile Communication , Prepaid Card

1. Introduction

Electric energy meters, the direct billing interface between utilities and consumers for long, have undergone several advancements in the last decade. The conventional electromechanical meters are being replaced by new electronic meters to improve accuracy in meter reading. Still, the Indian power sector faces a serious problem of lean revenue collection for the actual electric energy supplied owing to energy thefts and network losses. One of the prime reasons is the traditional billing system which is inaccurate many times, slow, costly, and lack in flexibility as well as reliability (Devidas *et al*, 2010). Therefore, attempts are being made to automate the billing systems. Even though more accurate and faster meter readings have seen the light of day, bill payment is still based on an old procedure. They require an individual/agent to personally come down to customer place and note the meter readings and report the amount one has to pay to the household/office.

But the demand for computing power at all levels of electronic systems is driving advancements in semiconductor chip technology. The AMR and power quality monitoring systems manufacturers are taking advantage of these advances and integrating them into new meters and instruments. The networking technologies are driven by the demand for interconnection of computer users worldwide (Chandler, 2005). The AMR and power monitoring systems are using these advances to expand the monitoring systems.

A Prepaid Energy Meter enables power utilities to collect electricity bills from the consumers prior to its consumption. The prepaid meter is not only limited to Automated Meter Reading [AMR] but is also attributed with prepaid recharging ability and information exchange with the utilities pertaining to customer's consumption details. The idea of prepaid metering will be very important for the new research fields of Micro-grid and Smart Grid and is an inevitable step in making any grid smarter than it is now. Literature has witnessed quite an amount of work in this area. The use of electronic token prepayment metering has been widely used in UK for customers with poor record of payment (Southgate *et al*, 1996). A paper suggests a design of a system which can be used for data transmission between the personal computer and smart card. The device will transmit the data in half duplex mode (Kwan *et al*, 2002). The system designed in this project can be used to develop more complex system where a smart

card can be used to several applications including prepayment. Another paper features a 3-tier smart card secure solution for a novel prepaid electricity system. It uses an IP-based controller in addition to a power meter, providing efficient online control of the amount of electricity consumed by the user (Raad *et al*, 2007).

Prepaid meters can also make use of state of art technologies like WiMAX owing to the idea of centralized accounting, monitoring and charging. It brings telecommunication to the core of its activities to support more Smart Grid applications such as Demand Response and Plug-in electric vehicles (Khan *et al*, 2007). Prepayment polyphase electricity metering systems have also been developed consisting of local prepayment and a card reader based energy meter (Ling *et al*, 2010). In this paper, we have attempted to initiate a different idea of using mobile communication to remotely recharge as well as bill the consumer's energy consumption. A prepaid card capable of communicating with power utility using mobile communication is attached to the energy meter. The idea has been successfully implemented in Matlab and results obtained have been presented.

2. Design of Prepaid Energy Meter

The proposed idea is not to replace the existing energy meter and chalk out a completely new prepaid meter but up-grade the available energy meters to prepaid meters. Thus, our design primarily has an energy meter, a prepaid card and the communication module encapsulated and provided as an upgrading attachment along with a contactor and a liquid crystal display (LCD).

2.1 Energy Meter: The electromechanical energy meter calculates the electrical energy or units consumed by the load based on the mechanical energy of the disk or rotor. The electronic meter has this existing structure attached with a microcontroller programmed to perform specific calculations and present it in terms of electrical energy units consumed to a prepaid card. The meter is also connected to a contactor apart from the consumer load.

2.2 Prepaid Card and Communication Module: The prepaid card is the most important addition to the design. The power utility sets the amount in the prepaid card to a measure that the consumer recharges the card to, called Fixed Amount. The tariff rates are already programmed and fed into the card. As the load is consumed, the meter sends the units consumed to the prepaid card which continuously converts these units into expenditure at each instant and then subtracts it from the fixed amount. The communication module uses mobile communication to share prepaid card balance with power utility at certain instants as required by utility for tracking the balance and also for any other application e.g. Demand Side Management (DMS) etc. The fixed amount in the prepaid card will go to zero eventually with the consumption. The consumer can recharge the prepaid card by prepayment through internet. The utility on receipt of recharge request and desired prepaid amount, recharges the customer's energy meter i.e. prepaid card. The prepaid card sends a signal to the contactor for monitoring the supply to the consumer. The communication module has prepaid card encapsulated inside the encryption authentication module which is Embedded Security Access Module (ESAM). It thus enables the card to use the mobile communication to communicate with power utility and share information regarding the card's balance details.

2.3 Contactor: A local contactor is the connecting link between the consumer load and utility supply. The opening and closing of this contactor depends on the balance present in the prepaid card at a moment. While the prepaid card has some fixed amount more than zero, it stays closed and keeps the utility supply uninterrupted to the consumer load. When the card runs out of balance, it opens and disconnects the load from the supply. Hence, even when the energy meter receives voltage supply, it does not reach the load while the contactor is open because the balance in the prepaid card is not available. Since the contactor too will consume some amount of electrical energy, it will be inclusive in the calculations made by meter and prepaid card.

3. Working Scheme

The scheme for working of the proposed idea has been explained with the help of a block diagram in Fig.1. As seen in the block diagram, the consumer level supply, i.e., the utility supply is fed to an energy meter which has a prepaid card embedded. The prepaid card feeds a low/high signal i.e. open/close signal to the local contactor depending on the balance left in it. The contactor thus controls the supply to the consumer load, disconnecting it when prepaid card runs out of balance. When prepaid card is short of sufficient balance, the consumer makes a recharge request to the utility by prepayment through internet. The utility having received the recharge amount recharges the prepaid card using mobile communication. The utility also receives information about the balance details from the card for the record purposes.

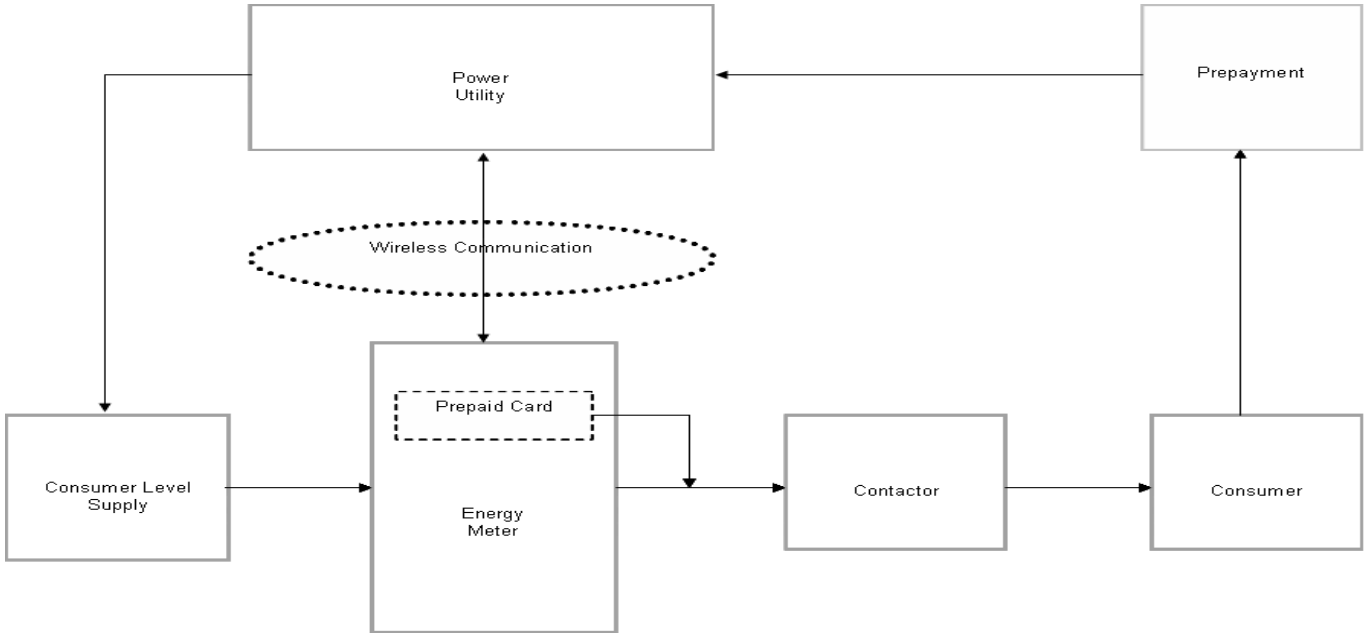

Figure 1. Prepaid meter working schema

4. Simulation Model

The complete idea and scheme of work has been modeled and simulated successfully using Matlab environment. The model is shown in Fig.2.

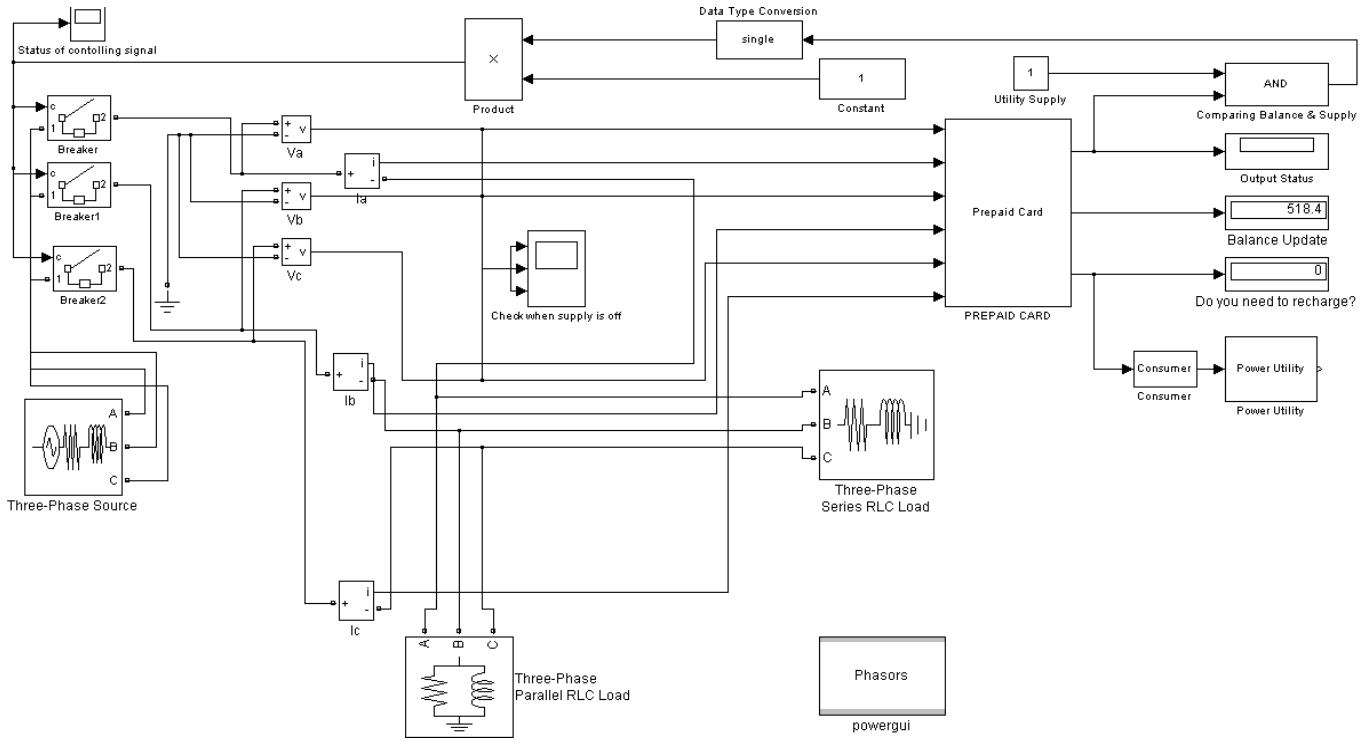

Figure 2. Matlab simulated model of prepaid energy meter

As seen in the MATLAB Simulink model, the input voltage is three phase supply and so is the contactor. The three phase parallel and series loads are used to represent the domestic loads. The block named 'Prepaid Card' is a Simulink block in itself with an M-file program embedded in it to imitate the electronic meter. The simulation outputs are balance left in the prepaid card, signal to contactor, and indication to consumer so as to indicate a need to recharge. The breakers simulate the contactor which remains closed provided the supply exists and the balance is not nil. The indication to consumer prompts him to request the power utility to recharge the card. The prepaid card sends a digital signal to the three phase local contactor to disconnect and reconnect the utility supply with the consumer load. The model does not explicitly show the presence of an energy meter owing to the fact that its functions have been aptly programmed and embedded into the prepaid card block.

5. Simulation Results

The simulation results from the proposed model depict output statuses of electricity supply, opening and closing of local contactor and phase voltage magnitudes over the intended simulation time. The prepaid card is recharged on the consumer's request to the power utility which can be made as soon as balance finishes in the prepaid card.

The variation in the output of electricity supply depending upon the prepaid card balance is as shown in Fig.3. The variations during the opening and closing of contactor are shown in Fig. 4 which is very much in synchronism with Fig. 3. It shows that opening (status 0) and closing (status 1) of contactor is in sync with prepaid card recharge and discharge. The individual phase voltage magnitudes shown in Fig. 5, Fig. 6 and Fig. 7, appear in coordination with the prepaid card running out of balance and gaining a recharge, respectively.

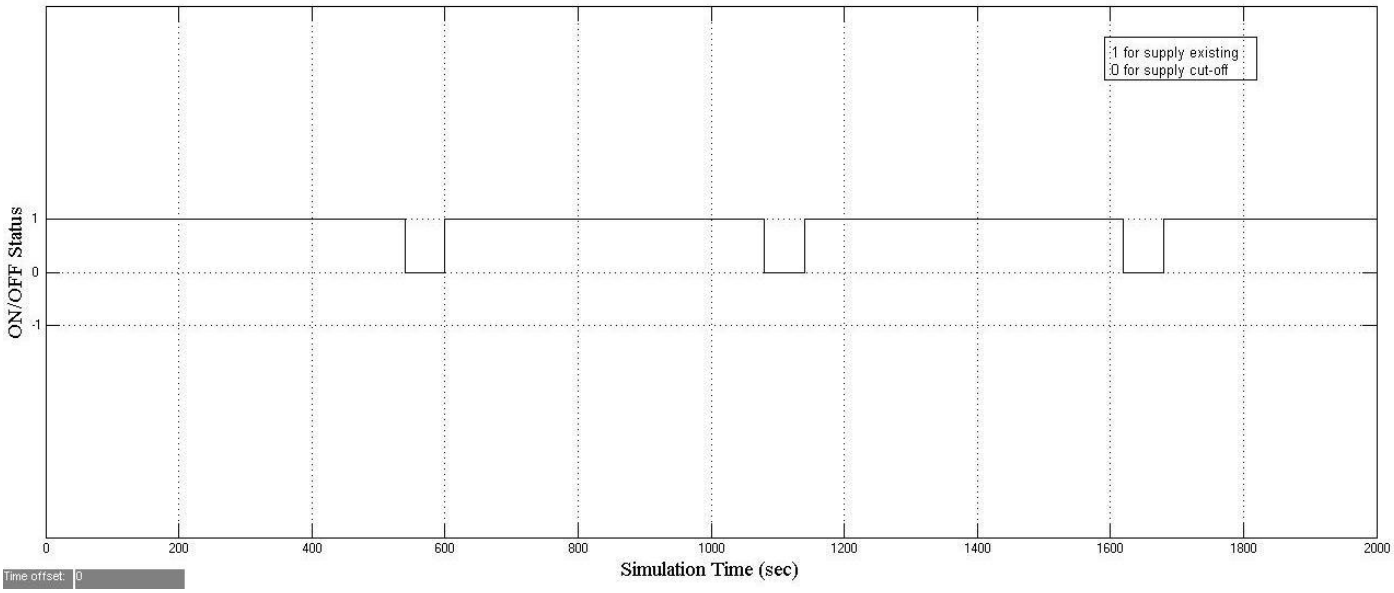

Figure 3. Output status of electricity supply based on prepaid card balance

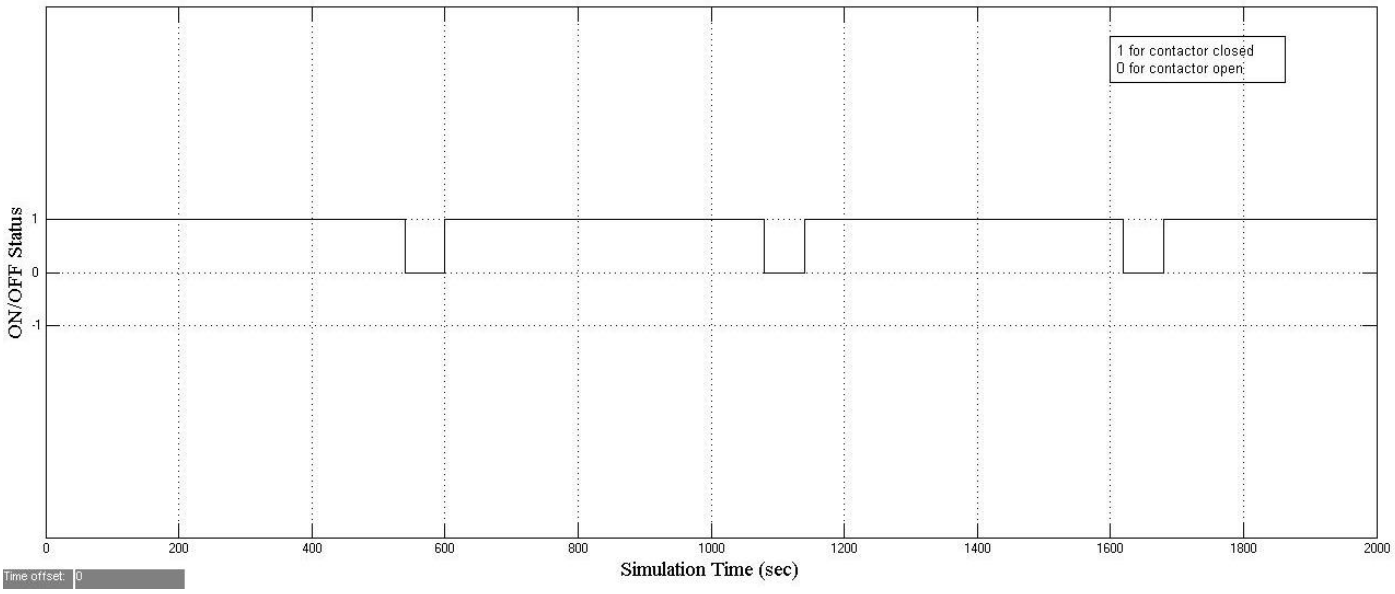

Figure 4. Working on contactor based on prepaid card balance

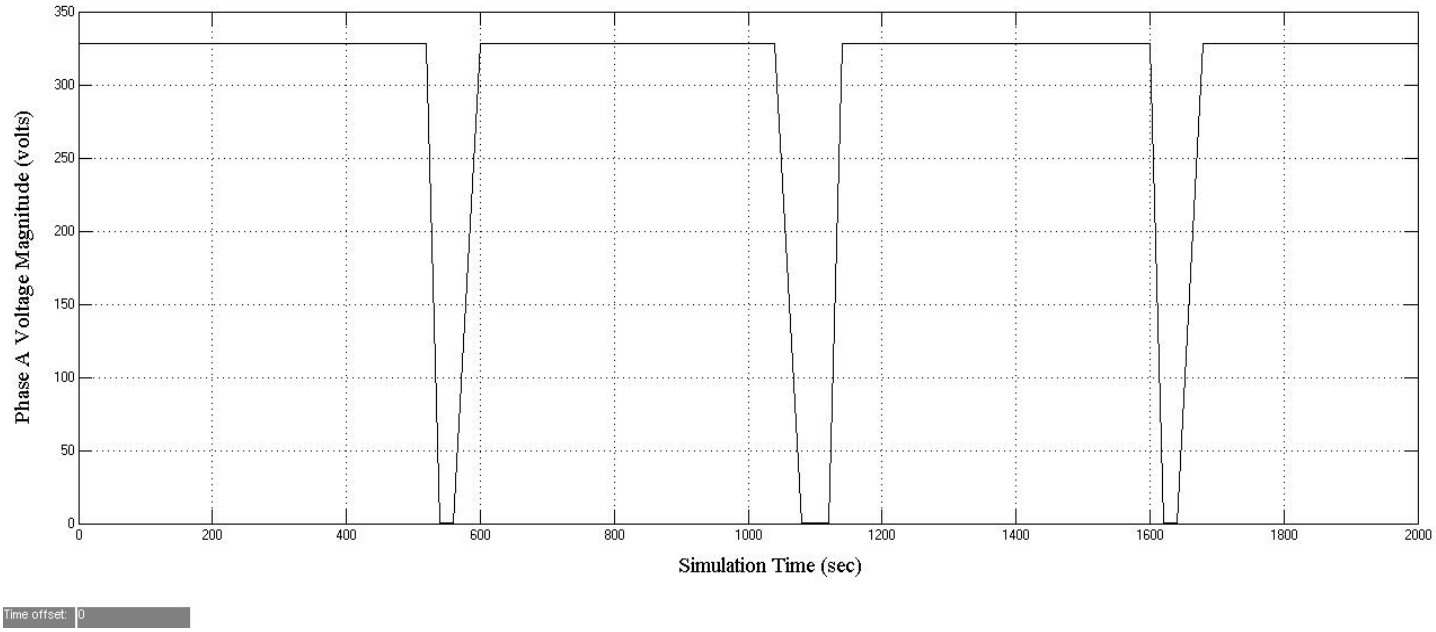

Figure 5. Variation in phase A voltage magnitude based on prepaid card balance

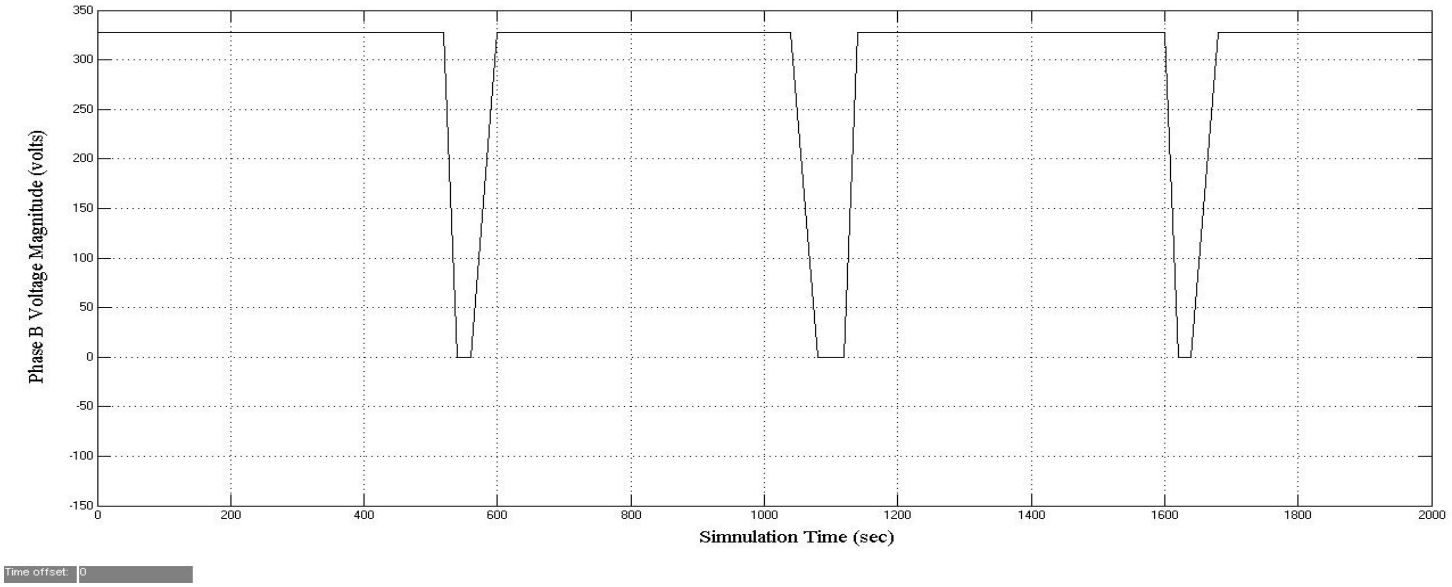

Figure 6. Variation in phase B voltage magnitude based on prepaid card balance

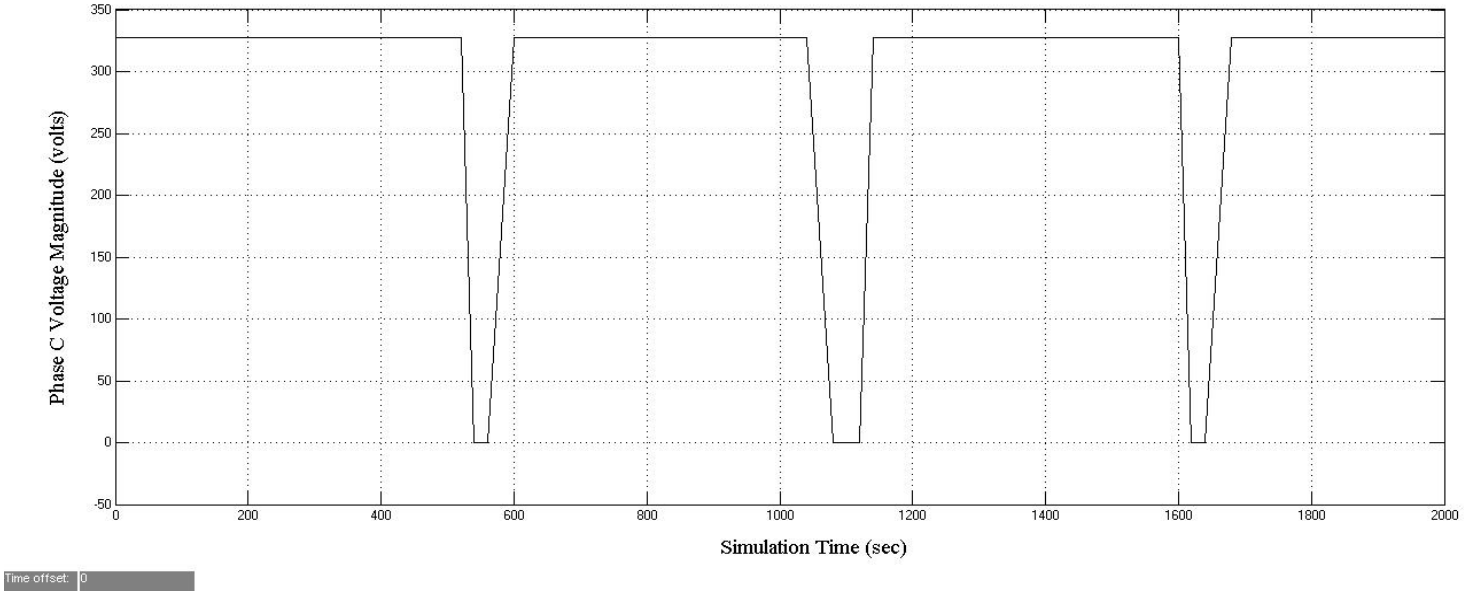

Figure 7. Variation in phase C voltage magnitude based on prepaid card balance

6. Conclusions

This paper presents a model for prepaid meter using mobile communication. This is an effort towards upgrading existing electrical energy meters through their fusion with a prepaid card aiming at collection of bills prior to consumption of energy thus improving the revenue collection for the scheduled supply. Thus the work presented in this paper mainly models the prepaid card proposed to be embedded to the existing meters. The proposed card opens up a contactor once prepaid balance is over. The proposed prepaid meter has been successfully implemented in a software model which has been implemented with the help of Matlab. The proposed prepaid block is modeled in Simulink to monitor the prepaid balance and it duly trips a contactor once the consumer runs out of the balance. The modeling shows that the consumer is never allowed to consume more than what he has paid for and is entitled to request a recharge for continued supply. The power utility recharges the prepaid card through mobile

communication once they get the prepayment from the consumer for recharging prepaid meter. The mobile infrastructure caters to two way communications between the power utility and the prepaid meter enhancing the smart nature of the scheme. The major benefit of proposed prepaid meter is that it doesn't require replacing the already installed energy meter but it will just upgrade the already installed energy meter to prepaid meter with attachment of prepaid card. The authors hope that this proposed prepaid meter will be very useful for the power utilities in developing economies like India which has large population of traditional energy meters as the proposed prepaid meter is achieved by upgrading the existing energy meters which is very economical instead of replacing them fully with another prepaid meters.

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Biographical notes

Amit Jain graduated from KNIT, India in Electrical Engineering. He completed his masters and Ph.D. from Indian Institute of Technology, New Delhi, India. He was working in Alstom on the power SCADA systems. He worked in Korea in 2002 as a Post-doctoral researcher in the Brain Korea 21 project team of Chungbuk National University. He was Post Doctoral Fellow of the Japan Society for the Promotion of Science (JSPS) at Tohoku University, Sendai, Japan. He also worked as a Post Doctoral Researcher at Tohoku University, Sendai, Japan. Currently he is heading, Power Systems Research Center at IIIT, Hyderabad, India. His fields of research interest are IT applications in Power and Energy Systems, power system real time monitoring and control, artificial intelligence applications, smart grid, power system planning and economics, electricity markets, renewable energy, and reliability analysis.

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