Study on Prepaid meter test & installation project

A project submitted in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering.

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CERTIFICATION

This is to certify that this project entitled **“Prepaid meter test & installation project”** is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The presentation of the work was held on 31 October 2020.

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The project entitled **“Prepaid meter test & installation project”** submitted by **Md. Najmul Hoque** ID No: **171-33-367**, Session: **Spring 2020** has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** on 31 October 2020.

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DEDICATION

This project dedicated to my parents with love & respect.

DECLARATION

We hereby declare that this project is based on the result found by ourselves. The materials of work found by other researchers are mentioned by reference. This project is submitted to Daffodil International University for partial fulfillment of the requirement of the degree of Bachelor of science in Electrical and Electronics Engineering.

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CONTENTS

CHAPTER-3: FUNCTIONALITY OF ENERGY METERING INTEGRATED CIRCUIT CHIP

CHAPTER-4: PREPAID METER TEST & INSTALLATION OF DESCO PROJECT

CHAPTER-6: CONCLUSION

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANSI	American national standard institute.
AMR	Advanced meter reading.
ASIC	Application specified integrated circuit.
EADM	Electromechanical add-on digital meter.
EEM	Electronic energy meter.
DSP	Digital signal processor.
GPRS	General Packet radio service.
AC	Alternating current.
KVa	Kilo volt ampere
KVar	Kilo volt ampere reactive.
GSM	Global system for mobile.
SMS	Short message service.
IEC	International electro technical commission.
LPRF	low power radio frequency

ABSTRACT

The smart meter system has added features that enabled the utilities to recover the meter energy measurement data remotely (GSM) based to mention a few. The system allows monitoring and transmission of energy consumed in real-time. It calculates the amount of energy consumed through the multiplication of voltage and current signals. A standard electrical measurement such as current, voltage, power and energy consumption will be displayed via liquid crystal display (LCD). The external communication device is required in the actualization of this project, in-conjunction with the control unit based on the existing mobile technology called "GSM". During the collection process of data collected were inadequate due to factors such as bad weather, constant attacks on operators, inability to correct faults, and other factors that rendered the system highly inadequate. However, the rapid growth in population and industrial development has increased the demand for more human operators and longer working hours. The problem of disconnecting and reconnecting supply by utilities due to unpaid bills is considered problematic. However, this cannot be achieved if there is no better way of metering; thus, the need for a smart meter becomes necessary. The smart meter is more reliable and efficient. It is an improved automatic meter reading (AMR) system.

Keywords: Smart meter, Evolution of Electricity meter, LCD, GSM

CHAPTER-1

1.1 Introduction

The present system of energy metering as well as billing in Bangladesh which uses electromechanical and somewhere digital energy meter is error prone and it consumes more time and labor. The conventional electromechanical meters are being replaced by new electronic meters to improve accuracy in meter reading. Still, the Bangladesh power sector faces a serious problem of revenue collection for the actual electric energy supplied owing to energy thefts and network losses.

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 but is also attributed with prepaid recharging ability and information exchange with the utilities pertaining to customer's consumption details.

1.2 Recommendation to improve the usage of prepaid energy meter

Prepaid energy meter is a new concept of Bangladesh. As a result implementation of prepaid meter is facing some challenges which should be overcome. To overcome the challenges of usage of prepaid meter the following steps should be taken.

The awareness program can be arranged through electronic media, leaflet, newspaper, social media, training program etc.

To increase skill and knowledge of organizational officials about prepaid meter so that they can share the knowledge with the consumers and motivate them.

Increase logistic support for the implementation of prepaid meter system like making available vending station at a convenient location; solve meter related problems, the quick response of officials

CHAPTER-2

Literature review of smart energy meter

2.1 Introduction

For many years revenue is collected by the electricity distribution authority of Bangladesh by using the conventional credit metering and billing system. This system has its own limitations. These disquiets for universal service in utilities and to improve efficiency motivated the company and regulators to prescribe technologies and regulatory options aimed at making it easier for consumers to pay for the services. Electricity metering refers to methods of installing and utilizing devices to measure the amount of electricity and the direction of flow of electricity intended for consumption. But prepaid or credit metering requires the consumers to pay before consuming whereas postpaid metering consumers have to pay after using or consuming the electricity. Prepayment mechanism means holding credit by customers and using the service until the credit exists.

2.2 Background

In mid-1980s prepaid electricity billing was first introduced. The primary purpose of this initiative was supplying electricity at an affordable rate to lower income level people. Their motive was to extend the electricity connection in not only the poor urban area but also in the far poor rural areas (Tewari & Shah, 2003). Some studies tried to find out the consumer perception and adaptability on the prepaid metering system (Quayson-Dadzie, 2012). Its aim was to determine the level of consumer adaptability towards prepaid electricity billing in Accra West Region of ECG. It also analyzed the factors considered by the consumers before adopting prepayment process by using a descriptive model of research design. It took a sample size of 391 from the 18000 consumers of a district. The finding of the study approves the existence of some factors considered by consumers and those play a vital role in accepting and using the prepaid billing system. The response of employees and clients to the transition of service from postpaid to prepaid electricity bill payment was studied in the West Kenya region (Miyogo, Nyanamba, & Nyangweso, 2013). Several models have been used in previous researches to determine user acceptance and usage behavior. The Technology Acceptance Model (TAM) was developed in a research (Davis, 1989) which is actually based on the research (Fishbein & Ajzen, 1977). According to this model Behavioral Intentions (BI) can be predicted by two variables named perceived usefulness and perceived ease of use. Here some variables have been considered as exterior which influence perceived usefulness such as design characteristics, user characteristics, task characteristics, nature of the device or implementation process, political influence, organizational structure etc. Other researchers included some other variables as extra such as self-efficacy, prior usage and experience, objective usability, and user characteristics. Another research has found that there is a direct relationship between perceived usefulness and BI (Davis, Bagozzi, & Warshaw, 1989). This study discussed as other studies (Sheppard, Hartwick, & Warshaw, 1988).

2.3 Electronic energy meter (EEM)

In electromechanical meter, energy consumption can be interpreted and documented but existing accumulated information barrier between the consumers and the utility company frustrated and rendered the process ineffective Zivic et al (2016). Due to this effect, EMR technology was developed to solve the problem for both parties BioInitiatives & Zivic et al (2012;2016b). This development eradicates the meter reading challenges associated with collection of energy consumption data.This digital technology is designed to capture and document parameters attributed to the electricity consumption rate, such parameters as power quality, apparent power, reactive power, active power; and other parameters like power factor, frequency, phase voltage, and phase current Chandima & Muzafar Imad Ali Ahmed (2014; 2013). The device has a display unit known as the LCD or light emitter display (LED), together with the radio frequency (RF) purposely for data transfer as shown in Figure 2.5[1]. Although, this picture.

Figure 2.1: The electronic energy meter is only displaying a replica of the EEM. This receiver is a handheld device or radio base network installed in a mobile car for the collection and transfer of energy consumption data, through a wireless means such as ZigBee Zivic et al (2016a).

The picture above was adapted from Visiontek (2019)

2.4 Electronic energy meter (EEM)

ASIC is mostly installed in other devices such as digital camera, washing machines, automobiles, air conditions, and many other appliances. As part of the components, EEM contains voltage and current transformers that operate as the sensors and analogue circuits Thomas et al (2015). The data received or collected from both transformers are referred to as voltage and current measurements Himawan et al (2016). These measurements are mathematically generated within the analogue digital converter (ADC) existing in the ASIC, and therefore convert the digitalized data generated into average values (mean values).

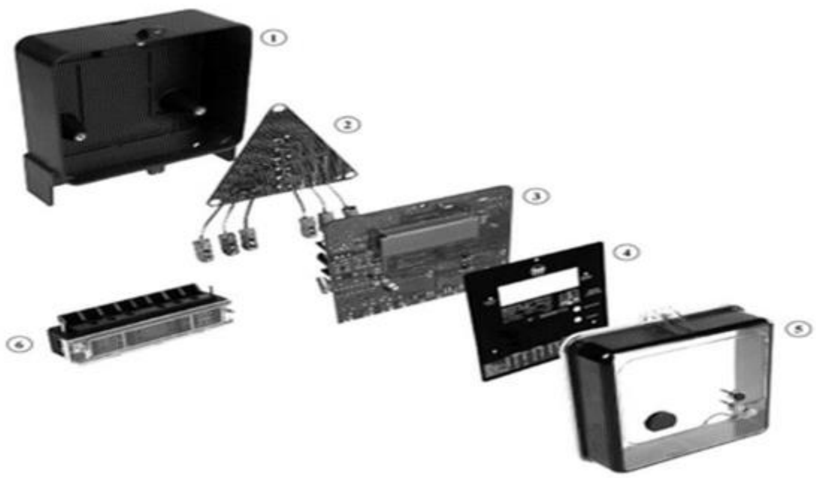


Figure 2.2: The explosive display of electronic energy meter (EEM) components

Average value (mean value) is the measuring unit power Male et al (2014). The resulted output is displayed on LED. These pulses equivalent to the average kilo watt hour (Kwh/unit) (Ali et al (2012). In this case, ASICs generate pulses ranging from 800 pulse/Kwh to 3600 pulse/Kwh. Most of the EEMs installed by the Kerala State Electricity Board (KSEB) have pulses ranging from 3200 pulse/Kwh, which drives the stepper motor that indicates on LED through the rotation of digitals embossed wheels. The most common ASIC company deal in the manufacturing of analogy device where ADE7757 and ADE7755 are largely used in the design and implementation of EEMs. The energy meter can be classified into two phases, which are single and polyphase. The explosive display of the components that constituted the electronic energy meter is presented in the Figure 2.6[2] above.

The explosive picture above was adapted from Toledo (2013)

The explosive display of the components is numerically indicated as follows:

1. Base compartment.
2. Acquisition and measurement board.
3. Computational circuit board.
4. Display board.
5. Main concealment.
6. Terminal connectors and cover.

However, EEMs can also be likened to electromechanical add-on digital meters (EADMs)

2.5 Electromechanical add-on digital meter (EADM)

EADM is designed with the integration of electronic add-on module with electromechanical mechanism inside the meter box (see Figure 2.7[3]). The integration of these two processes generate vital information for both consumers and utility company. The production cost of the device is affordable, and commonly found in India. Further study shows that the electronic addon module was designed particularly to sense the black or red strip existing on the rotation disc, by engaging an infrared (IR) sensor that converts the energy consumption into digital meter readings. The IR sensor IC could be OPB706A and LM324 comparator, designed to count the number of turns made by the rotor subject to the amount of energy consumption rate captured by the meter, and displayed through the digital display unit (Prudhvi et al., 2012).

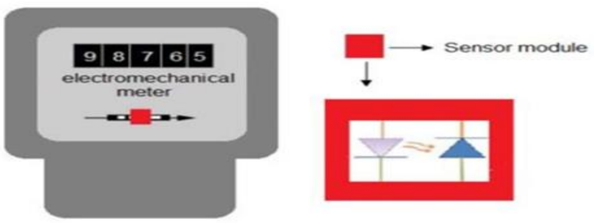


Figure 2.3: Electromechanical add-on module

The above picture was adapted from Prudhvi et al. (2012)

2.6 Types of electronic meters

The electronic meter comes in various forms which are categorized into:

1. Traditional meter,
2. Modular meter, and
3. Pre-pay electricity meter.

2.6.1 Traditional meter

This a type of electronic meter designed with a single module and a seal that gives no room for embedded component upgrade. The seal was added as a protective measure to prevent any form of interfering. For future upgrading, the device undergoes a complete replacement of all the components irrespective of any identified outdated components (see Figure 2.8[4]).

Figure 2.4: Traditional meter

2.6.2 Modular meter

This is a form of energy meter that can be easily upgraded. The design of modular meter aids components upgrades because lifespan of components differs. Among the installed components, only communication technological module and switches are mostly replaced to reduce cost of field operations (Toledo, 2013). The picture of the modular meter displayed in the Figure 2.9 below.

The pictures displayed in Figure 2.4 and Figure 2.5 were adapted from Toledo (2013)

Figure 2.5: Modular meter

2.6.3 Pre-pay electricity meters

Pre-pay electricity meter is developed to relieve the customers from the debt suffered (Jack & Smith, 2016). In addition, the device is perceived as a good veritable tool for low income earners because it assists them in off-setting their outrageous bills and reduces exorbitant use of electricity by consumers Effah Emmanuel & Owusu; Franek et al (2014; 2013). The device is generally adopted by many developing countries in some part of the world such as Africa, Asia, and Latin America. Thus, the process involved entails the purchase of electricity units by consumers from approved vendors or utility company and input the electricity units in the control box of the meter Muzafar Imad Ali Ahmed (2013).

Concisely, if the electricity units inputted is valid then electric current is supplied into the household. Otherwise, no electric current is supplied to the households while the remaining amount of electricity unit is indicated or displayed in Kwh on the control box of the meter. The display process is demonstrated by three different light blinking stages, which varies from ≥1000 units (green light), and blinks yellow light at 500 to 50 units extending to red light, which blinks at ≤20 units.

Furthermore, it is a system that is branded as “pay-as-you-use” Nagarale, Gulhane (2017). Compare to post-paid metering, consumers are tasked to monitor the usage of their electricity unit. In that case, the bills are attributed to monthly or periodical reading of the electricity unit from the meter. The depletion of the electricity unit suggests another payment for energy consumption at the end of use. Effah & Owusu (2014) emphasised that post-paid metering system is used by many African countries to increase revenue. But in some cases, is another means of extorting consumers through skyrocketed bills to be paid. Despite the fact that electricity is never supplied to some regions, however, they are still billed unfairly.

2.7 Classes of pre-payment systems

There are various pre-payment technologies used today that user friendly to the customer. The use of pre-paid meter has aided the customer's ability to stabilise his/her credit generation, credit management, and customer management processes.

2.7.1 Coin meter

Coin meter is found to be used at the end of 19th century in the United Kingdom. Nevertheless, some utility companies around the world still adopt the use of mechanically operated meters (see Figure 2.10). It works by inserting coins in proportion to the amount of energy needed. Furthermore, the coins inserted is collected by the authorised utility agents. Interestingly, similar method is used in some countries as a money collection and saving mechanism.

Figure 2.6: Coin meter

2.7.2 Token meter

Token meter is generally used around the world. It is a type of energy payment meter practically developed from the idea of payphone principle (refer to Figure 2.11[5]). The energy credit is loaded on it as indicated on the meter. It is mostly measured in Kilowatt hours or monetary values. Hence, the energy credit cards could be of two basic forms, which are: 1) Customised energy meter. 2) Non customised energy meter.

The picture displayed in Figure 2.7 was adapted from Muzafar Imad Ali Ahmed (2013)

Figure 2.7: Token meter

2.7.3 Smart card meter

The development of smart card meters was t hrough the feasibility study performed on the token meters. It operates very similar to the token but particularly designed for specific type of meters (refer to Figure 2.12[6] below). Customers are mandated to always carry their smart card

Figure 2.8: Smart card meter

with them to avoid stress whenever there is any need of purchasing energy credit from any pay point location. After loading the energy credit on the smart card, then the card is inserted into the meter in order to load the credit on the smart card meter to discharge power and display customer's energy consumption rate per use in Kwh.

2.7.4 Key meter

Key meter is another type of energy meter that uses a similar method of loading digitalised energy credit to initiate energy supply into households (see Figure 2.13). This meter is designed with a chip embedded to store and transfer energy data across energy management institutions.

The pictures displayed in Figure 2.8, Figure 2.9 and Figure 2.10 were adapted from Toledo (2013).

Figure 2.9: Key meter

2.7.5 Keypad meter

Keypad meter is another metering system with a set of buttons used to encrypt credit codes on the meter (see Figure 2.14), and it is perceived to be reliable more than the previously discussed energy meters. In addition, credit purchased by customer is loaded on the meter with the use of this set of buttons (keypad). The machine decodes the codes entered and actively converts them into credit for power supply generation or increment. This process is elevated with energy communication devices like low power radio frequency (LPRF) and general packet radio services (GPRS).

Figure 2.10: Keypad meter

Furthermore, STS and IEC are the open standards that define the code. In the process of purchasing credit, customer is instructed to present his/her allocated meter number to generate an allotted credit codes about the amount of energy to be purchased. Once the IT system receives the payment rate and meter number, then allotted credit codes is generated in sequence with the house meter number or credited to the customer’s account. The net energy credit is converted and measured in Kwh.

CHAPTER-3

Functionality of energy metering integrated circuit chip

3.1 Introduction

The international electrical regulated bodies called ANSI and IEC approved of digital signal processor (DSP) and energy metering IC as requisite devices for the accurate computation of energy parameters measured. These devices are also used in signal conditioning processes such as apparent power, RMS (current and voltage), active power, reactive power, power quality measurement and line frequency.

3.2 Electrical parameter calculation in a sinusoidal single-phase system

Energy meters manufactured by different manufacturers are structurally designed differently with the ability to execute accurately as discovered previous reports Garcia (2017). This quality offers a broad calculation formula for energy and power estimation. In addition, there are some energy chips with the capacity to determine other electrical parameters. This segment concisely elucidates the mathematical techniques and equation used in most energy metering device existing in the market.

3.3 Root mean square (RMS) calculation

RMS is the measured value of an AC signal. Precisely, the rms of an AC signal equals the quantity in value of the required dc to produce an equivalent amount of power in the load. RMS, is expressed mathematically as Equation (3.2) below:

$$F_{RMS} = \sqrt{\frac{1}{T}\int_0^T f^2(t)\,dt} \quad (3.2)$$

Where;

F_{RMS} denotes the RMS value of the function f(t), and

T is the periodic time.

The equation given below represent the RMS value of a time sampling signal.

$$F_{rms} = \sqrt{\frac{1}{N}\sum_{n=1}^{N} f_{\{n\}}^2} \quad (3.3)$$

Where; F_{rms} denotes the RMS value of the sampling signal, N denotes for the number of samples, and n denotes the n^{th} sample point of the signal. To calculate the RMS current of the sampling signal, the following methods were used in most energy measurement chips by considering ADE7953 energy metering IC chip. It uses the following methods to calculate the RMS current.

We can write the instantaneous current as shown in the Equation (3.4) below;

$$I(t) = \sqrt{2}.I^2_{RMS}.\sin(\omega t) \quad (3.4)$$

Hence;

$$I^2(t) = 2I^2_{RMS}.\sin^2(\omega t) \quad (3.5)$$

Where,

I(t) denotes as the instantaneous current,

I_{RMS} refers to the RMS current,

ω denotes the angular frequency, and

t denotes to be the time used.

Therefore, in Equation (3.5), square both sides and substituting the value of 1- $\cos^2(\omega t)$ for $\sin^2(\omega t)$ as explained in a trigonometry formula that states; Recall: $\sin^2(A) + \cos^2(A) = 1$, $\cos(2A) = \cos^2(A) - \sin^2(A)$ (3.6)

The equation above is re-written as Equation (3.7) by making $\sin^2(A)$ the subject of the formula, and it becomes:

$$\sin^2(A) = \cos^2(A) - \cos(2A) \quad (3.7)$$

Since,

$$\cos^2(A) = 1- \sin^2(A) \quad (3.8)$$

$$\sin^2(A) = 1- \sin^2(A) - \cos(2A)$$

$2\sin^2(A) = 1- \cos2(A)$ Therefore,

$$\sin^2(A) = \frac{1 - \cos2(A)}{2} \quad (3.9)$$

∴ from Equation (3.5) above we have:

$$I^2(t) = 2I^2_{RMS}.\sin^2(\omega t)$$

Hence;

$$I^2(t) = 2I^2_{RMS}.\frac{1 - \cos2(\omega t)}{2} \quad (3.10)$$

$$I^2(t) = I^2_{RMS}(1- \cos2(\omega t))$$

$$I^2(t) = I^2_{RMS} - I^2_{RMS}.\cos2(\omega t) \quad (3.11)$$

To obtain the RMS current, the input signal from the current channel linked with ADC is squared as illustrated in Equation (3.11), while the square root of the average value is calculated. The averaging process is done by adding a low pass filter. The signal passes through the low pass filter, and then a high frequency component value is obtained, which is attenuated and the DC term I^2_{RMS} is generated (see Figure 3.5[7]).

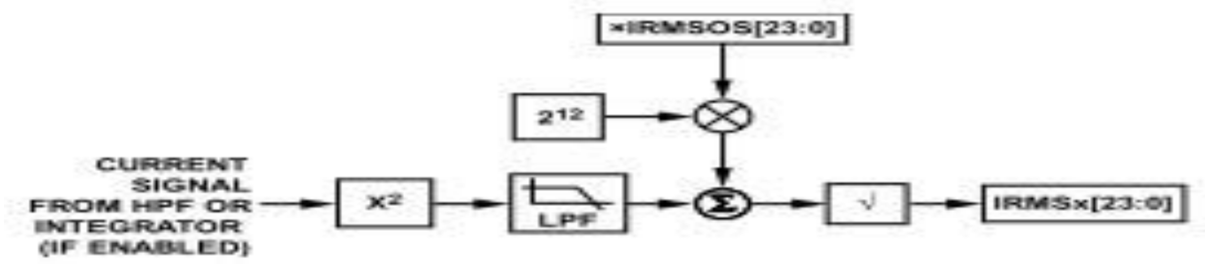


Figure 3.1: Current RMS

3.4 Root mean square (RMS) voltage

The calculation of the RMS voltage is like that of RMS current. However, some energy measurement chips use the mean absolute value calculation to derive the RMS voltage. The mean absolute value is accurate when the signal has only the fundamental component. When the signal has harmonic components, the calculation is somewhat inaccurate. Therefore, the mean absolute value calculation can be described as follow (see Equation 3.12) below;

$V_{MAV} = \frac{1}{T}\int_0^T |\sqrt{2}.V_{RMS.}\sin(\omega t)|dt$ (3.12)

V_{MAV} denotes the mean absolute voltage,

1 _ denotes the periodic time, and T

V_{RMS} denotes the periodic time.

$= \frac{1}{T}\left[\int_0^{T/2} \sqrt{2}.V_{RMS.} \sin(\omega t)\,dt - \int_{T/2}^{T} \sqrt{2}.V_{RMS.}\sin(\omega t)dt\right]$ (3.13)

When we consider a change in the derivative with respect to $\omega = 2\pi f$; where $f = \frac{1}{T}$,

$\omega = \frac{2\pi}{T}$, $\pi = \frac{\omega T}{2}$, $\pi = \omega(\frac{T}{2})$

$\theta = \omega t$

Find the derivative of θ with respect to t in the equation below

dθ dt

The diagram displayed in the Figure 3.1 was adapted from Devices (2013

$\frac{}{} = \omega(\ ) dt \quad dt$

$\therefore dt = \frac{d\theta}{\omega}$ (3.14)

Furthermore, put $\frac{d\theta}{\omega}$ for dt, θ for ωt, $\frac{\omega}{2\pi}$ for $\frac{1}{T}$ in Equation (3.13) above. Therefore, ω

$$= \frac{\omega}{2\pi}\left[\int_0^{\pi} \sqrt{2}.V_{RMS}.\sin(\theta)\frac{d\theta}{\omega} - \int_{\pi}^{2\pi} \sqrt{2}.V_{RMS}.\sin(\theta)\frac{d\theta}{\omega} \right]$$ (3.15)

$$V_{MAV} = \frac{\omega}{2\pi}.\frac{\sqrt{2}.V_{RMS.}}{\omega}\left[\int_0^{\pi}\sin(\theta)d\theta - \int_{\pi}^{2\pi}\sin(\theta)d\theta\right]$$

Hence, $V_{MAV} = \frac{\sqrt{2}.V_{RMS.}}{2\pi}\left[[-\cos\theta]_0^{\pi} - [-\cos\theta]_{\pi}^{2\pi}\right]$;

$$V_{MAV} = \frac{\sqrt{2}.V_{RMS.}}{2\pi}[-(-1-1) + (1+1)]$$

Finally,

$$V_{MAV} = \frac{\sqrt{2}.VRMS.}{2\pi}$$

$$V_{MAV} = \frac{\sqrt{2}.}{2\pi}.V_{RMS}$$ (3.16)

V_{MAV} is directly proportional to V_{RMS}. Equation (3.16) is applicable when the fundamental components are available. And the equation is then used for the calculation of RMS voltage. The diagram displayed in Figure 0.6[8] illustrates the process involved in attaining the output signal through accurate computation of the RMS voltage.

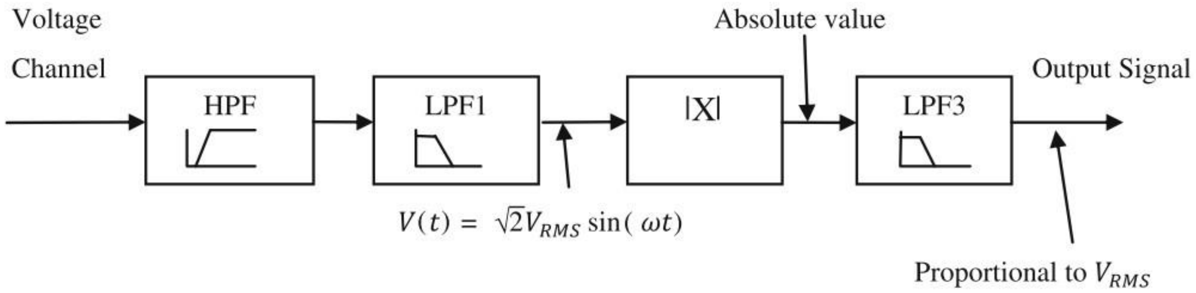


Figure 3.2: RMS voltage

[8] The diagram displayed in Figure 3.2 was adapted from Devices (2013)

3.5 Active power and energy calculations

Active power and energy calculations are being carried out within this section. The definition of the active power for every consumption is quite looked and mathematically solved.

3.6 Active power calculation

The electrical power is defined as the rate at which energy flows from the source to the load for consumption. The product of the instantaneous current and voltage, as written in Equation (3.17) and Equation (3.18) over a waveform, is called an instantaneous power signal. The power signal is equal to the rate at which energy flows within a periodic time (see Figure 0.6 above).

The unit of power is watt or jo ule/seconds. Therefore, mathematically we have:

$V(t) = \sqrt{2}.V_{RMS}.\sin(\omega t)$ (3.17)

$I(t) = \sqrt{2}.I_{RMS}.\sin(\omega t - \emptyset)$ (3.18)

$\emptyset$ denotes the phase angle between the voltage and the current.

V(t) and I(t) denote the instantaneous voltages and current respectively.

Hence, instantaneous power P(t)

$P(t) = V(t).I(t)$ (3.19)

Substituting Equation (3.17) and Equation (3.18) for V(t) and I(t) respectively.

$P(t) = [\sqrt{2}.V_{RMS}.\sin(\omega t)].[\sqrt{2}.I_{RMS}.\sin(\omega t - \emptyset)]$

By opening the bracket, we have

$P(t)=2V_{RMS}.I_{RMS}.\sin(\omega t).\sin(\omega t - \emptyset)$ (3.20)

Recall, the trigonometry products of identities states:

$$\sin(A).\sin(B) = \frac{\cos(A + B) - \cos(A - B)}{2} \quad (3.21)$$

if A=ωt and B = (ωt - ∅), then Equation (3.21) becomes

$$\sin(\omega t).\sin(\omega t - \emptyset) = \frac{\cos(\omega t + (\omega t - \emptyset)) - \cos(\omega t - (\omega t - \emptyset))}{2}$$

Therefore, substitute $\frac{\cos(\omega t + (\omega t - \emptyset)) - \cos(\omega t - (\omega t - \emptyset))}{2}$ for $\sin(\omega t).\sin(\omega t - \emptyset)$ in the Equation (3.20) above.

$P(t) = 2V_{RMS}.I_{RMS}.\sin(\omega t).\sin(\omega t - \emptyset)$

$$P(t) = 2V_{RMS}.I_{RMS}.\frac{\cos(\omega t + (\omega t - \emptyset)) - \cos(\omega t - (\omega t - \emptyset))}{2}$$

$P(t) = V_{RMS}.I_{RMS}.\cos(2\omega t - \emptyset) - V_{RMS}.I_{RMS}.\cos(\emptyset)$ (3.22)

The average power over an integral number of line cycle (n) is given as

$$P = \frac{1}{T}\int_0^{nT} p(t)\,dt \qquad (3.23)$$

Where,

P denotes the average power, and T denotes the line cycle period. For one cycle line, the average power can be obtained as written below:

$$P = \frac{1}{T}\int_0^{T} p(t)\,dt \qquad (3.24)$$

Then, substituting the value of $V_{RMS}.I_{RMS}.\cos(2\omega t - Ø)$- $V_{RMS}.I_{RMS}.\cos(Ø)$ in Equation (3.22) for p(t) in Equation (3.24).

$$P = \frac{1}{T}\int_0^{T} [V_{RMS}.I_{RMS}.\cos(2\omega t - Ø) - V_{RMS}.I_{RMS}.\cos(Ø)]dt \qquad (3.25)$$

If the derivative and the limits are represented in the form of θ, then we have $\frac{1}{T} = \frac{\omega}{2\pi}$ and $\omega t = \theta$, while $dt = \frac{d\theta}{\omega}$. Furthermore, substitute $\frac{\omega}{2\pi}$ for $\frac{1}{T}$, ωt for θ, $\frac{d\theta}{\omega}$ for dt in Equation (3.25) above

$$P = \frac{\omega}{2\pi}\int_0^{2\pi} [V_{RMS}.I_{RMS}.\cos(2\theta - Ø) - V_{RMS}.I_{RMS}.\cos(Ø)]\frac{d\theta}{\omega} \qquad (3.26)$$

$$P = \frac{\omega}{2\pi} \cdot \frac{V_{RMS}.I_{RMS}}{\omega}\int_0^{2\pi} [\cos(2\theta - Ø) - \cos(Ø)]d\theta$$

$$P = \frac{V_{RMS}.I_{RMS}}{2\pi}\int_0^{2\pi} [\cos(2\theta - Ø) - \cos(Ø)]d\theta$$

$$P = \frac{V_{RMS}.I_{RMS}}{2\pi}\left[\int_0^{2\pi}\cos(2\theta - Ø)d\theta - \int_0^{2\pi}\cos(Ø)\,d\theta\right]$$

$$P = V_{RMS}.I_{RMS}\cos(Ø) \qquad (3.27)$$

The active power (P) in the Equation (3.27) is equal to the DC component of the instantaneous power signal P(t). The power signal of the DC instantaneous component helps to extract the active power.

3.7 Active energy calculation

In the process of computing the active energy, rate of energy flow called power is considerable subject of the formula. The equation formulated is expressed mathematically as:

$$P(t) = \frac{dE}{Dt} \quad (3.28)$$

Where, P denotes the power, and E denotes the energy. The active power within the time domain is equal to:

$$\int dE = \int_0^t P(t)dt$$

$$E = \int_0^t P(t)dt \quad (3.29)$$

T denotes the time period considered. In most energy measurement chips; the discrete accumulation time is used for the active energy calculation.

$$E_D = \sum_{n=0}^{N} p(nt).t \quad (3.30)$$

E_D denotes the obtained discrete time accumulated t denotes sampled period for a discrete time, n denotes the n^{th} sample point, and N is the number of sampled points. When the discrete time sample period tends to zero, the energy calculated will become:

$$\int_0^{t_1} P(t)dt = \lim_{t \to 0} \sum_{n=0}^{N} p(nt).t \quad (3.31)$$

Equation (3.31) illustrates that active energy is measured high, whenever discrete time sample is very small. Thus, to eliminate active energy measurement error, the sample period value should be very small.

3.8 Reactive power and energy calculation

The section examines the how reactive power and energy calculation for every input voltage and current signals can be demonstrated within any particular energy meter.

3.9 Reactive power calculation

Reactive power occurs when the voltage and current waveform signals multiplied phase is shifted by 90^0. The generated waveform is called the instantaneous reactive power signal. Other essential mathematical illustration is formulated to elucidate the attainment of instantaneous current and voltage if an AC source connected to a load is lagging with a power factor. The attained equation is given below as:

$$RP(t) = V(t).I'(t) \tag{3.32}$$

Recall.

Since,

$$I'(t) = \sqrt{2}.\ I_{RMS}\ [\omega t - \emptyset + \frac{\pi}{2}] \tag{3.33}$$

$$V(t) = \sqrt{2}.I_{RMS}.\sin(\omega t - \emptyset + \frac{\pi}{2})] \tag{3.34}$$

Hence, substitute $\sqrt{2}.\ I_{RMS}\ [\omega t - \emptyset + \frac{\pi}{2}]$ for $I'(t)$ and $\sqrt{2}.I_{RMS}.\sin(\omega t - \emptyset + \frac{\pi}{2})]$ for V(t) in Equation (3.32) above.

Then, we have

$$RP(t) = [\sqrt{2}.VRMS.\sin(\omega t)].\ [\sqrt{2}.IRMS.\sin(\omega t - \emptyset + \frac{\pi}{2})];$$

$$RP(t) = [\sqrt{2}.\sqrt{2}.VRMS.IRMS.\sin(\omega t)\sin(\omega t - \emptyset + \frac{\pi}{2})]$$

$$RP(t) = [2.V_{RMS}.I_{RMS}.\sin(\omega t).\sin(\omega t - \emptyset + \frac{\pi}{2})] \tag{3.35}$$

3.10 Reactive energy calculation

The energy is defined in the equation (3.36) below:

$$E_R = \int_0^{t_1} q(t)dt \tag{3.36}$$

Where E_R denotes the reactive energy, q(t) denotes the instantaneous reactive power, and t_1 denotes the considered time period. However, reactive energy measured uses discrete time accumulation for reactive energy calculation. The formula employed in computing the reactive energy is written below:

$$E_R = \lim_{t \to 0} \sum_{n=0}^{N} q(nt).t \tag{3.37}$$

Where t denotes the discrete time sample period, n denotes the n^{th} sample point, and N is the number of sample points. Since the sample period cannot be kept at zero, a system with low reactive energy measurement errors is expected to be produced (by energy chip manufacturer) to keep the value small.

3.11 Apparent power calculation

Apparent power is referred to as the maximum power capable enough to be accessible to a load through the product of V_{RMS} and I_{RMS}. Therefore, apparent power is defined as the product of V_{RMS} and I_{RMS}. This type of power is independent of the phase angle between them.

The apparent power signal is calculated in the AC signal.

$V(t) = \sqrt{2}.\ V_{RMS}.\sin(\omega t)$

$I(t) = \sqrt{2}.\ I_{RMS}.\sin(\omega t + \theta)$

Therefore,

$P(t) = V(t).\ I(t)$ (3.38)

$P(t) = \sqrt{2}.\ V_{RMS}.\sin(\omega t)\ .\ \sqrt{2}.\ I_{RMS}.\sin(\omega t + \theta)$

$P(t) = 2.V_{RMS}.I_{RMS}.\sin(\omega t).\sin(\omega t + \theta)$ (3.39)

Recall from Equation (3.21) that:

$\sin(A)\ .\sin(B) = \frac{\cos(A+B)-\cos(A-B)}{2}$ (3.40)

Therefore, let sin(A) = sin(ωt), cos(A + B)= cos (ωt + (ωt + θ));

sin(B) = sin(ωt + θ), cos(A - B) = cos (ωt - (ωt - θ))

From the above equation (3-40),

$\sin(\omega t)\ .\sin(\omega t + \theta)= \frac{\cos(\omega t + (\omega t + \theta)) - \cos(\omega t - (\omega t - \theta))}{2}$ (3.41)

$\sin(\omega t)\ .\sin(\omega t + \theta)= \frac{\cos(2\omega t + \theta) - \cos(-\theta)}{2}$ Note that, cos(-θ)= cos(θ)

$\sin(\omega t)\ .\sin(\omega t + \theta)= \frac{\cos(2\omega t + \theta) - \cos(\theta)}{2}$ (3.42)

Substitute $\frac{\cos(2\omega t + \theta) - \cos(\theta)}{2}$ from Equation (3.42) for sin(ωt).sin(ωt + θ) in Equation (3.39) and obtain the equation below

$P(t) = 2.VRMS.IRMS.\ \cos(2\omega t + 2\theta) - \cos(\theta)$ (3.43)

Simplification of Equation (3.43) produces Equation (3.44) below:

$P(t) = V_{RMS}.I_{RMS}.[\cos(2\omega t + \theta)-\cos(\theta)\ ]$

$P(t) = V_{RMS}.I_{RMS}\ \cos(2\omega t + \theta)- V_{RMS}.I_{RMS}.\cos(\theta)$ (3.44)

3.12 Apparent energy calculation

Apparent energy calculation is a simplification of important parameters like apparent energy, E_A; instantaneous apparent power, s(t); and time period of consideration, t_1 in the equation below.

$$E_A = \int_0^{t_1} s(t)\,dt \qquad (3.45)$$

3.13 Transients

Transients, one of the orders of degradation caused in a system, is perceived to be triggered by the system itself or other systems involved (Dugan et al., 2004). Transient is classified into two categories, which are AC and DC transient. The AC transient is further fragmented into single and multiple cycles.

3.14 Interruption / under voltage / over voltage

These are the very common types of disturbances. It occurs during power interruption as the voltage level of a bus goes down to zero (Sengupta, 2011). The interruption maybe for short, medium, or long period of a time. The fall and rise of voltage levels of a particular bus give rise to either over-voltages or under-voltages (Dugan et al., 2004). Nevertheless, under-voltages and over-voltages are permitted for certain percentage limits. If these limits are exceeded, therefore they are disturbance. Disturbance increases the amount of reactive power drawn or delivered by the system Sengupta (2011).

CHAPTER-4

Prepaid meter test & installation of DESCO project.

4.1 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.

4.2 Prepaid card and communication module

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.

4.3 Working Scheme

The scheme for working of the proposed idea has been explained with the help of a block diagram in Fig.4. 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.

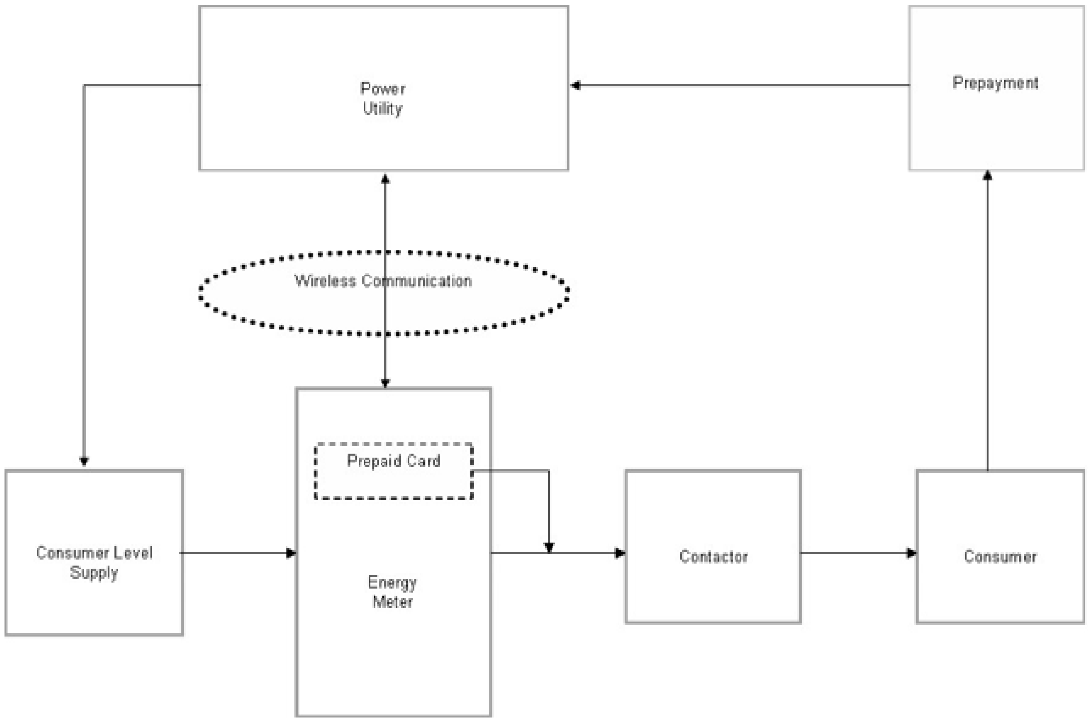


Figure 4.1: Prepaid meter working schema

4.4 Meter test

Here is a three phase pre-paid meter. Meter test module was installed. Then the power supply is given. Eight ports in three phase pre-paid meters. Three Phase pre-paid meter identify the phase L1, L2, L3 show the meter LCD display. 1, 3, 5 and 7 acted as inputs in any three Phase prepaid meter. 1,3, and 5 are phases and port 7 is neutral ports. 2, 4, 6 and 8 act as outputs. Pages 2, 4 and 6 of the output, and port 8 act as the neutral of the output. Test module the meter is mounted on the test module with the help of eight pins. The meter given in the picture is three phase prepaid meter.

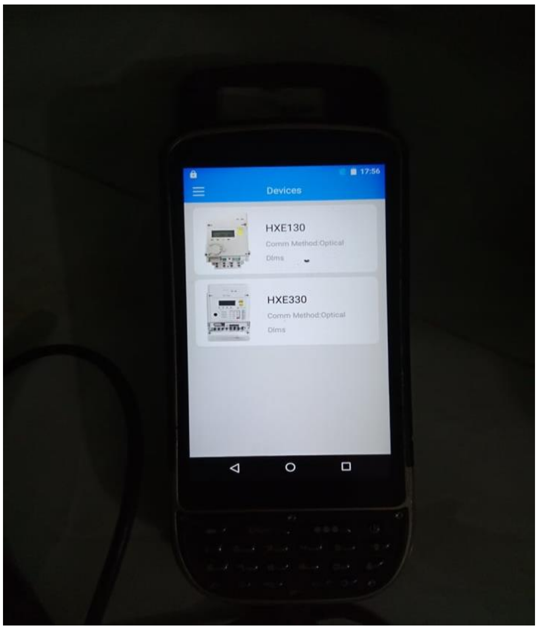
Figure 4.2: Meter test board

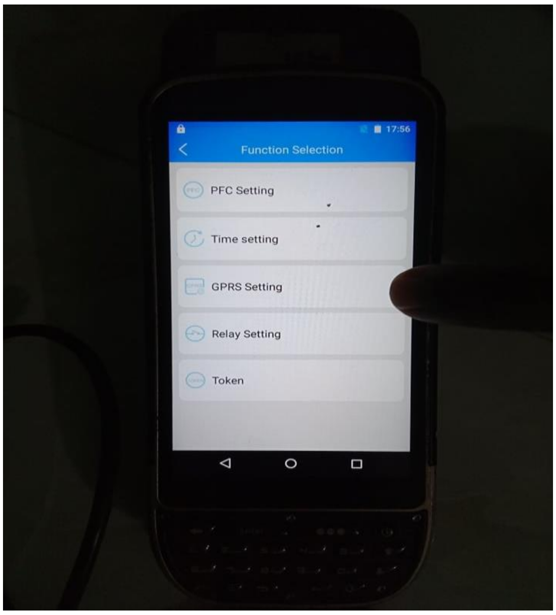
4.5 IP Setting

This picture three phase four wire system prepaid meter installed device. The meter is equipped with a sensor, a cable is used to connect the meter to the device. There are two functions: an HXE130 for single phase and HXE330 for three Phase.

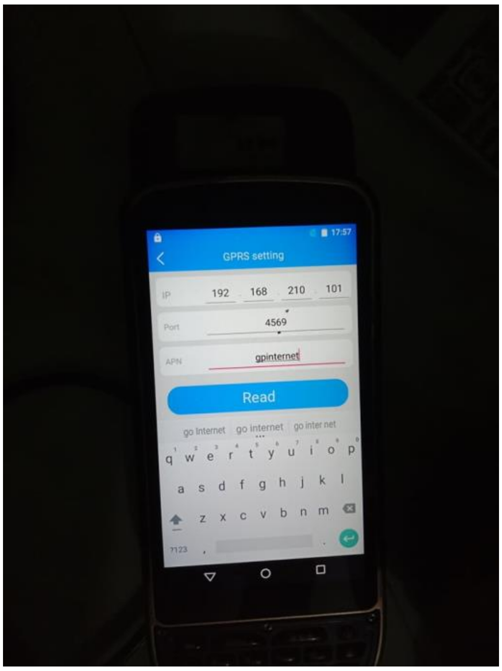
Explained how to IP Setting for three Phase;

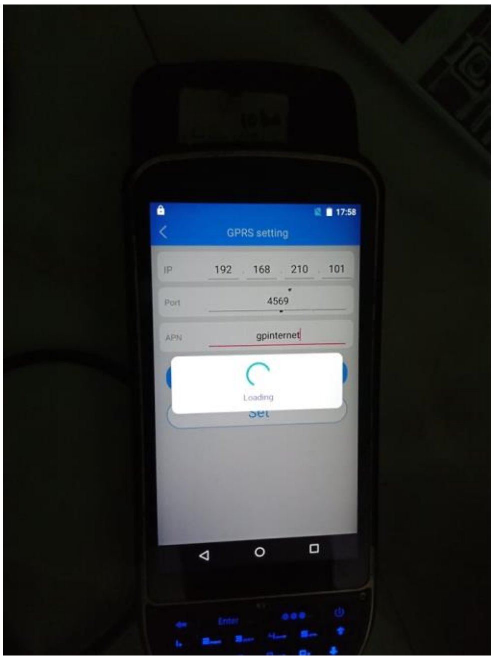
Select HXE330 then GPRS setting then Ip then port number then pin number. When the meter is loaded under GP Internet, the success will be written.





a **b**



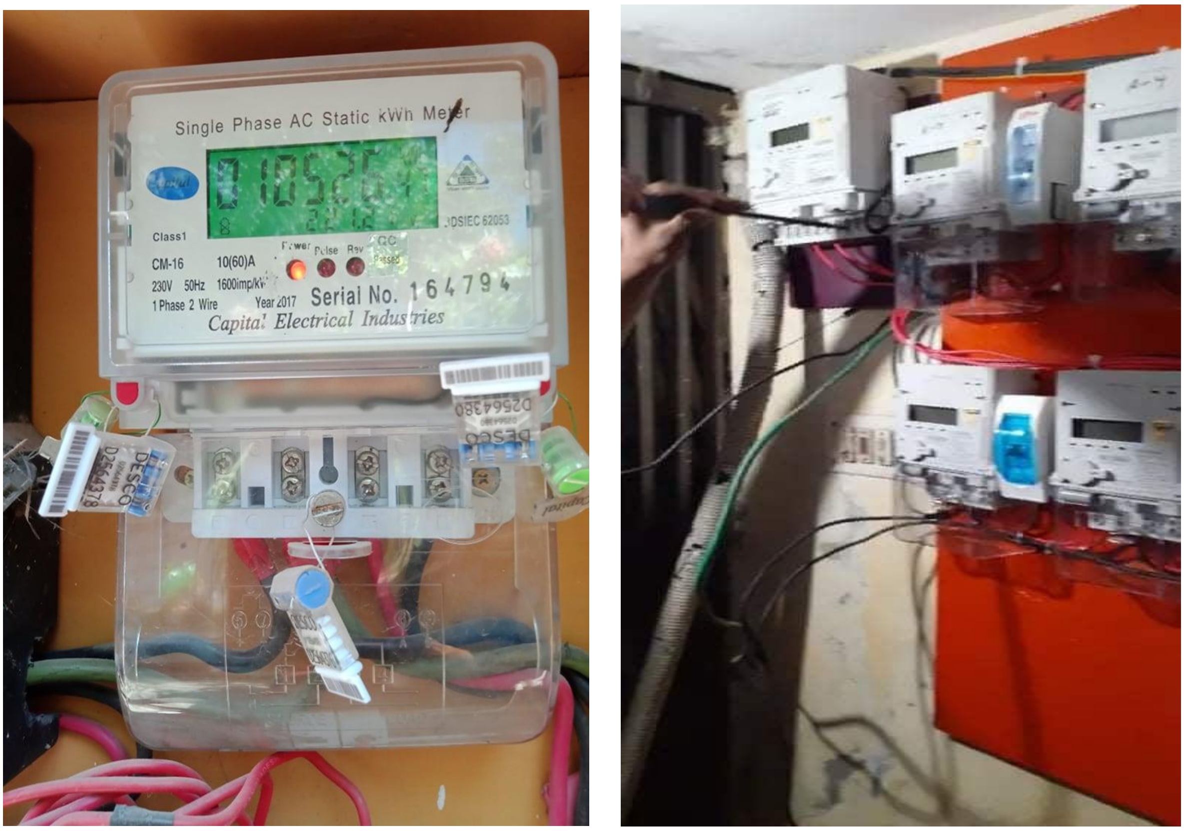


c d

Figure 4.3: IP setting device

4.6 Placed new meter against of old meter

The picture shows a house wiring of old meters and after placed new meter. First you have to check the meters. Then instead of the old meter, the meters should be installed by looking at the following c.m.o. Every c.m.o different meter. The work must be done with care.



i **ii**

Figure 4.4: Old meter and replaced new meter

4.7 Check terminal cover

After installing the meter, the terminal cover should be set up well. If the terminal cover is not installed properly, the meter will not get relay connection. This is a sensor system. If the prepaid meter customer tries to open the terminal cover somehow, the output load will be disconnected. The meter LCD display show signal, when the consumer uses an invalid load from the meter.

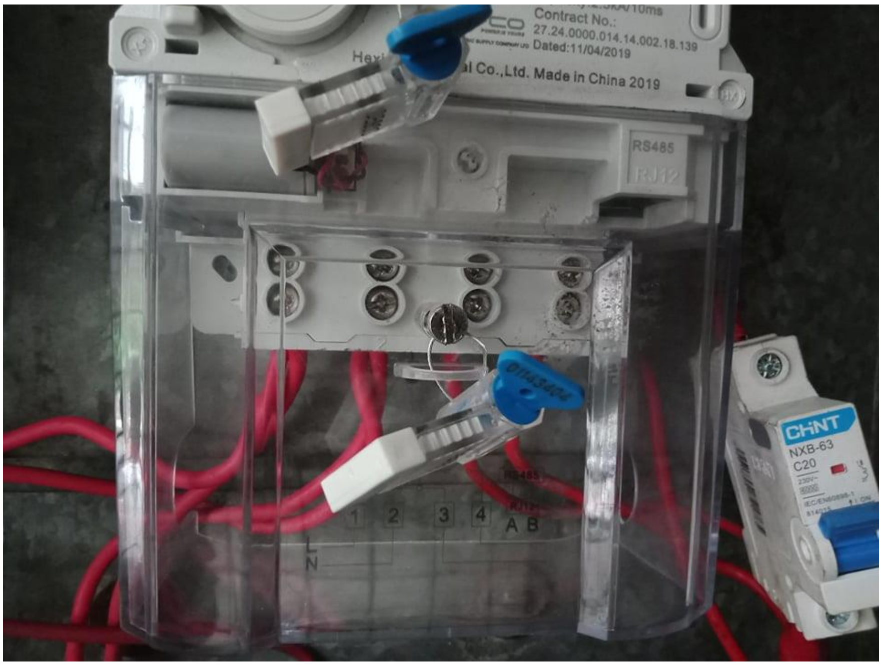


Figure 4.5: Show terminal cover

4.8 Punched test card

When the technician completes the installation of the meter, then if you want to load from the meter, first you have to punched a test card. If there is a problem with the meter, the LCD display guides it through some code. If the meter is successfully installed, free text will appear on the LCD display without any problem.

Figure 4.6: Show prepaid meter before punched test card.

4.9 Rely or don’t rely

If the meter is not installed properly, when the test card is punched in the meter, the meter relay will not be worn. The reason for not reading the meter relay is IC-03 show on the display. And if the meter is installed properly the meter rely is good of show LCD display.

4.10 Many reason for don’t rely

The meter may not read the relay for the following reasons,

1. If not well connected.

2. If there is a problem with the meter, if the IP setting is not correct.

3. If the terminal cover is not fitted properly.

4. Module cover open.

4. If you do not punch the test card before punching the consumer card.

5. Magnetic error.

4.11 For not rely gate clear event

If there is no relay in the meter then the card is re-activated by inserting the card in a punch machine with the help of meter card online code. If the meter is Single phase meter covered by three phase meter and if the three phase meter is already online then the card can be operated without a punch machine.

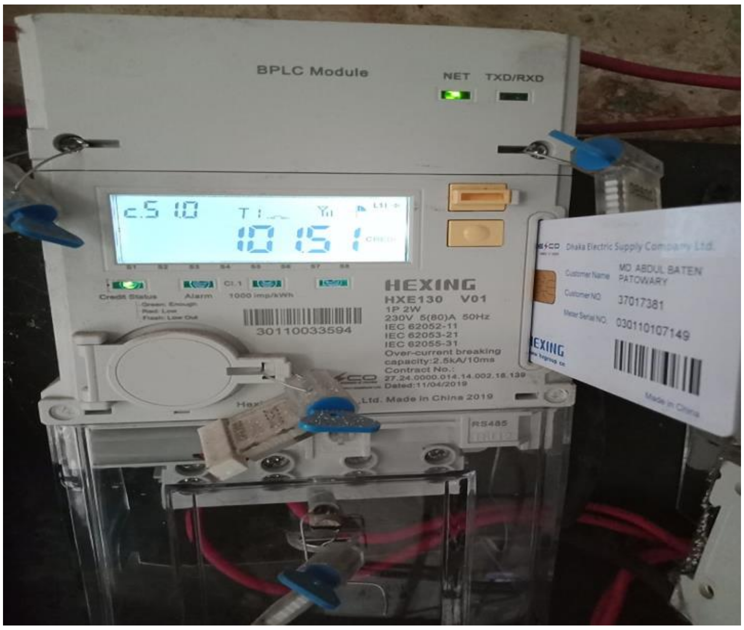
4.12 Again punched test card

If there is a problem with the card or if there is a problem due to any other reason, the meter displays the signal through some code on the LCD display.

4.13 Punched consumer card

If you are successful in using the test card in the meter, the consumer card can be inserted in the meter, you must keep in mind that if the card number is correct with the meter number, then the card will be successfully taken in the meter. IC-01 can be seen on the meter display when you enter another meter. This means that the meter card cannot be identified

a



b

Figure 4.7: Shows consumer card and punched consumer card.

4.14 GSM-Based recharge system

The power utility sets the amount in the prepaid card to a measure that the consumer recharges the card to, called Recharged Amount (R_A). 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 recharged amount to obtain a balance.

4.15 Load connected

Only when the meter relay is completed will it be possible to run the load from the output to the housing. Once the load is connected, the meter will automatically deduct money on unit basis, the program is run on each meter. The meter can be loaded with Tk. 200 to Tk. 8 lakhs. When there is a balance of Tk. Emergency balance continues to load up to Tk. Three phase meter continues to load up to Tk. 500 in emergency balance. The meter does not automatically provide any load when the emergency balance is exhausted, each customer can see how much money is in the balance on the LCD display in his meter.

Figure 4.8: LCD display show load connected symbol.

CHAPTER-6

Conclusion

It plays a vital role for economic development for a country. It ensures better service for the consumer through sincerity, dedication and new technology adoption. Now a day prepaid energy meter is a smart system for introducing new technology in the power distribution sector using prepaid meter will end almost all confusions and problems of traditional billing system like an extra bill, bill missing, overbilling, under billing etc. This system will help not only the consumer but also the Government of the country by reducing system loss and improving revenue collection and lead the country to prosperity. The authority is well aware of the importance of prepaid metering system. If the consumers increase the use of prepaid meter, this will develop the economic condition of Bangladesh.

REFERENCE

[1] Tewari, Devi Datt, & Shah, Tushaar. An assessment of South African prepaid electricity experiment, lessons learned, and their policy implications for developing countries. Energy Policy, 31(9), 911-927. 2003.

[2] Quayson-Dadzie, John. “Customer Perception and Acceptability on the Use of Prepaid Metering System in Accra West Region of Electricity Company of Ghana” unpublished.

[3] Miyogo, CarolyneNyanchama, Nyanamba, Steve Ondieki,

[4] Davis, Fred D. “Perceived usefulness, perceived ease of use, and user acceptance of information technology.” MIS quarterly, Vol. 13, No. 3. (Sep., 1989), pp. 319-340.

[5] Fishbein, Martin, &Ajzen, Icek. “Belief, attitude, intention, and behavior: An introduction to theory and research.” 1977.

[6] Davis, Fred D, Bagozzi, Richard P, &Warshaw, Paul R. “User acceptance of computer technology: a comparison of two theoretical models.”Management Science; Aug 1989; vol35,no. 8; 982

[7] Sheppard, Blair H, Hartwick, Jon, & Warshaw, Paul R. “The theory of reasoned action: A meta-analysis of past research with recommendations for modifications and future research.” Journal of consumer research, 15(3), 1989 325-343.

[8] Ali, A., Saad, N.H., Razali, N.A. & Vitee, N. 2012. Implementation of Automatic Meter Reading (AMR) using radio frequency (RF) module. PEC on 2012 - 2012 IEEE International Conference on Power and Energy, (December): 876–879.

[9] Chandima, D.P. 2014. Applied sciences and technology Smart Metering Design and. Sri Lanka: Springer Berlin Heidelberg.

[10] Dugan, R.C. McGranaghan, M.F. Santoso, S. & Beaty, H.W. 2004. Distributed Generation and Power Quality. Electrical Power Systems Quality: 373–435.

[11] Effah Emmanuel & Owusu, K.B. 2014. Evolution and Efficiencies of Energy Metering Technologies in Ghana. Global journal of researches in engineering: for electrical and electronics engineering, 14(4–5): 1–9.

[12] Garcia, F.D. Marafao, F.P. Souza, W.A. De & Silva, L.C.P. Da. 2017. Power Metering: History and Future Trends. IEEE Green Technologies Conference: 26–33

[13] Muzafar Imad Ali Ahmed. 2013. Single phase intelligent GSM based pre-paid energy meter by Muzafar Imad Ali Ahmed. University of Khartoum.

[14] Nagarale, Gulhane, P. 2017. Prepaid Energy Meter Using Microcontroller and Smart. International Journal of Electronics, Communication & Soft Computing Science and Engineering, 119–123: 119–120.

[15] Prudhvi, P. Bhalodi, D. Manohar, M., Padidela, V. & Adapa, S. 2012. A smart energy meter architecture in Indian context. 2012 11th International Conference on Environment and Electrical Engineering: 217–222.

[16] Sengupta, S.C. M.M.S. 2011. Electric Power Quality.

[17] Sharma, K. & Mohan Saini, L. 2015. Performance analysis of smart metering for smart grid: An overview. Renewable and Sustainable Energy Reviews, 49: 720–735.

[18] Toledo, F. 2013. Smart Metering Handbook. United States of America.

[19] Vadda, P. & Seelam, S.M. 2013. Smart Metering for Smart Electricity Consumption:2-71.

[20] Zivic, N.S. Ur-Rehman, O. & Ruland, C. 2016a. Evolution of smart metering systems. 2015 23rd Telecommunications Forum, TELFOR 2015: 635–638.