DESIGN OF AN ARDUINO BASED WIRELESS POWER METER

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Abstract— The problems of Nigeria's power sector are numerous. The generation, transmission and distribution sub-sectors are facing their own share of challenges. The issues of non-metering, estimated billing, overbilling and electricity theft have virtually driven the distribution subsector of the Nigerian power sector to a halt. Over the years, electricity consumers have been forced to pay more than they actually consume leading to widespread dissatisfaction. Furthermore, sharp practices such as meter tampering and by-passing of meters have reduced revenue to distribution companies thereby stalling the development of the power sector. In this paper, we attempt to proffer solutions to these lingering challenges affecting the distribution subsector of Nigeria's power sector.

Index Terms— Power meter, current transducer, current meter, Arduino Mega

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1.0 Introduction

It is generally acknowledged that the present epileptic state of the electrical power supply situation in the country is one of the major causes of the economic underdevelopment of the country. There are currently 23 grid-connected generating plants in operation in the Nigerian Electricity Supply Industry (NESI), with a total installed capacity of 10,396.0MW and available capacity of 6,056MW [1] as at December 2013.

In Nigeria, total energy consumption is 1,259TWhr per annum with energy consumption per capita of 8.1MWhr per head [2]. The available generation capacity is far short of what is required. Many of the PHCN's power plants are old and some even have dilapidated generating units due to lack of proper maintenance. A major challenge is the problem of inadequate gas supply to the thermal stations, particularly to those in the western axis of the country. The domestic gas supply infrastructure is very limited and also quite often subject to vandalism [3]. For the Hydro Plants, the problem of improper management of water resources at the dams remains a challenge [4]. Other important challenges for generation are grid-related; one is the instability of the grid that causes tripping of generating units, which in turn results in higher frequency of maintenance due to induced Equivalent Operating Hours (EOH). In transmission, the national transmission grid currently operates at 132KVwith an available capacity of 6870MW [2] which covers a total distance of 4889.2km and 330 kV, with an available capacity of 7805MV which covers a total distance of 6484.05km . Most of the existing switchgear units are over 30 years old and are no longer serviceable due to lack of spare parts. This has resulted in their constant break down which has further aggravated the poor power supply situation [5].

One of the major challenges in the area of Distribution is the issue of very high commercial loses.

Various reasons have been given for this problem. Power theft due to bypassing of meters [6], reluctance of consumers to pay bills based on estimated consumption and sharp practices by meter readers. The issue of overloaded injection and distribution transformers is another challenge in distribution. This is coupled with exposed and unprotected distribution and feeder pillars that lead to easy theft of earth cables and vandalism of these facilities.

The present billing system is minimally able to detect power theft and even when it does that it is at the end of the month. The distribution company is unable to keep track of the changing maximum demand for the domestic consumer while the consumer is faced with problems like receiving due bills for bills paid for and also poor reliability of electricity supply and quality [6].

Prior to the introduction of prepaid meter, various methods were proposed to detect electricity theft which includes: inspection of suspicious load profile, though the method was good certain drawbacks accruing to this method are the requirement of large manpower and huge labour, this failed due to dishonesty of the service workers. A huge amount of money is lost due to theft, in some countries; the government has to provide subsidies to the power sector to maintain a reasonable price of electricity.

The major problem facing the electricity industry in many developing countries is poor revenue generation [6]. This arises from illegal consumption of electricity via mostly meter tampering and bypassing as well as direct connection to the low voltage distribution lines. In order to solve all the problems of the traditional reading, the consumer load should be tracked on a regular basis as this will help ensure accurate billing, keep track of the maximum demand and detect theft.

It is on the basis of these challenges in the power sector that we propose the Arduino-based wireless power meter to bring clarity to the electricity billing system in the country. This device aims to provide a clear picture of a home's power consumption and is essential in commercial as well as in industrial field by enhancing both distribution system and information system. This is expected to provide solutions to the problems of metering, tariffs and billing in Nigeria.

2.0 Power Analysis

Power is a measure of how much work done per given time.
Power factor:
It may be defined as;

i. Cosine of the angle of lead or lag
ii. The ratio $\frac{R}{Z} = \frac{resistance}{impandance}$
iii. The ratio $\frac{true\ power}{apperent\ power} = \frac{watts}{volt-amperes} = \frac{W}{VA}$

- Active power of power is that which is in phase with the applied voltage V given by ($IV\cos\phi$). It is obtained by multiplying KVA by cosϕ. and this gives power in KW.

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- Reactive power is that which is in quadrature with VI i.e. IV-COSϕ it is known as wattles power,known as KVA and obtained by multiplying KVA by sinϕ, written as KVAR the fig 1 below shows KVA triangle where KVA which is lagging has taken a negative angle. The following relationship can be deduced below
- $KVA = \sqrt{(KW)^2 + QkVAR^2}$; $KW = kVA\cos\phi$ and $kVAR = kVA\sin\phi$ CITATION THE59 \l 1033 | [7]}

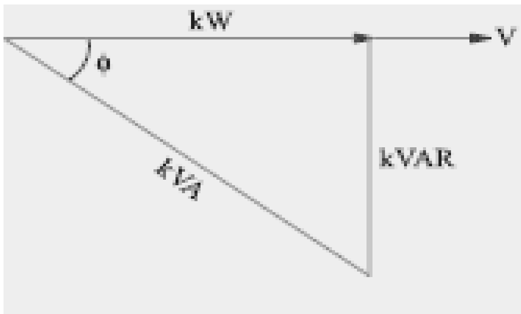

Figure 1 Graphical representation of power calculations [7]

2.1ACTIVE REACTIVE AND APPARENT POWER

Suppose we have an R-L circuit which draws a current *I* when an alternating voltage of r.m.s. value V is applied to it. Suppose that current lags behind the applied voltage by ϕ. The three powers drawn by the circuit are as under:

i. **Apparent power (*S*)**

It is given by the product of r.m.s. values of applied voltage and circuit current.
Therefore, $S = VI = (IZ).I = I^2Z$ volt-amperes (*VA*)

ii. **Active power (P or W)**

It is the power which is actually dissipated in the circuit resistance.
$P = I^2R = VIcos\phi$

iii. **Reactive power (Q)**

It is the power developed in the inductive reactance of the circuit.
$Q = I^2X_L = I^2Zsin\phi = VIsin\phi$volt-amperes-reactive (VAR)
Figure 2 below shows the three power

$S^2 = P^2 + Q^2 \; or \; S = \sqrt{P^2 + Q^2}$

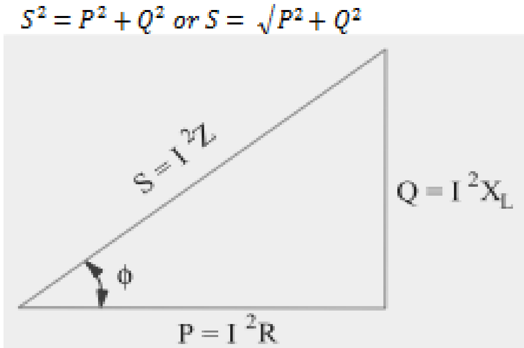

Fig. 2: Graphical representation of Reactive power [7]

2.2 Voltage Sensor

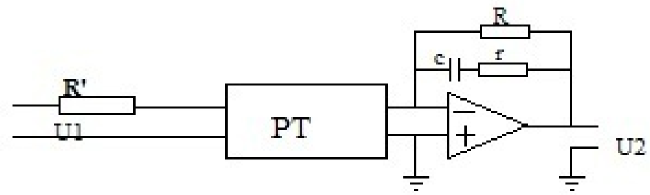

Figure 3: The schematic of ZMPT107 [8]

ZMPT101B/ZMPT107 usually works at rated current:1~2mA.

2.3 Determination of Input Current-Limiting Resistor R'

Current-limiting resistor R′=V/I
V=Rated input voltage
I = Rated operating current （when Coil resistance is compared with current-limiting resistor R′, it can be ignored.）
For this design, the rated input voltage V=220V;
I=1.1mA;
R′ =$\frac{V}{I}$
Where R′ =200kΩ

2.4 Determination of the Sampling Resistor R

$$\frac{Voutputmax}{1} = \frac{Voutputmax}{Vinputmax} \cdot R$$

For this design, Voutputmax=5v, Vinputmax 230V, R′ =200k Ω
Therefore R = (5/230) * 200kΩ = 4.34k Ω

2.5 Current Transducer

The current transducer clamp sensor is an electrical device having two jaws which open to allow clamping around an electrical conductor. This allows properties of the electric current in the conductor to be measured, without having to make physical contact with it, or to disconnect it for insertion through the probe.
Current clamps are used to read the magnitude of a sinusoidal current (as invariably used in alternating current (AC) power distribution systems), but in conjunction with more advanced instrumentation the phase and waveform are available. A very high alternating currents (1000A and more) are easily read with an appropriate meter; direct currents, and very low AC currents (milliamps) are more difficult to measure [9].
The device is essentially a short extension cord with the two conductors separated, so that the clamp can be placed around only one conductor. The figure 4, shows a pictorial operation of the current transducer [10].
The current transformer consists of only one or very few turns as its primary winding. This primary winding can be of either a single flat turn, a coil of heavy duty wire wrapped around the core or just a conductor or bus bar placed through a central hole as shown. The primary winding is in series with the current carrying conductor.

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Fig. 4: A current transducer clamped on a wire for reading [10]

The secondary winding may have a large number of coil turns wound on a laminated core of low-loss magnetic material which has a large cross-sectional area so that the magnetic flux density is low using much smaller cross-sectional area wire, depending upon how much the current must be stepped down. The reading produced by a conductor carrying a very low current can be increased by winding the conductor around the clamp several times; the meter reading divided by the number of turns is the current, with some loss of accuracy due to inductive effects. Clamp meters are used by electricians, sometimes with the clamp incorporated into a general purpose multimeter. It is simple to measure very high currents (hundreds of amperes) with the appropriate current transformer. Accurate measurement of low currents (a few milliamps) with a current transformer clamp is more difficult. Less-expensive clamp meters use a rectifier circuit which actually reads mean current, but is calibrated to display the RMS current corresponding to the measured mean, giving a correct RMS reading only if the current is a sine wave. For other waveforms readings will be incorrect; when these simpler meters are used with non-sinusoidal loads such as the ballasts used with fluorescent lamps or high-intensity discharge lamps or most modern computer and electronic equipment, readings can be quite inaccurate.

The current transducer is rated 30A/1V. It accepts a maximum input current of 30A and gives a maximum output voltage of 1V [9]. This 1V peak-to-peak oscillates between the negative and positive axis with one half-cycle on the positive y-axis and the other on the negative y-axis. We were able to restrict the oscillation of the waveform to the positive y-axis to enable compatibility with Arduino. The circuit used to achieve this is shown below:

3.0 Data Transmission

CARRIOTS

Carriots is an application hosting and development specially designed for projects related to the internet of things (IOT) and machine to machine (M2M). It enables data collection from connected objects, stores it, builds powerful applications with few lines of code and allows for integration with external it systems [11]. Carriots provides a development environment, APIs and hosting for IOT projects development. [8]

Listeners can be programmed to send and SMS containing data or an email to a required email address. This will allow for easier power management by the electricity consumer. The Carriots interface has one listener for SMS and another for email by a given user [11]:
New listeners can also be programmed as required by the distribution company. The rules tab allows you to create rules to manage the listeners. The listeners are then triggered to act once the conditions given by the rules are met.

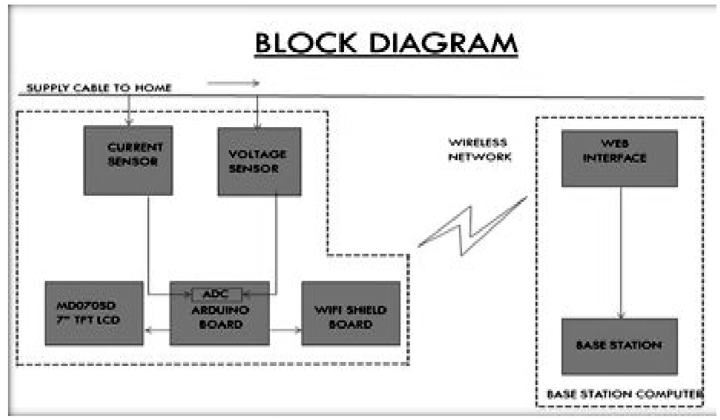

Fig. 5: Block diagram of the arduino based wireless power meter

Current will be measured from a current carrying wire using a non-invasive current transducer, into the main power panel. A supply cable from the main power panel is sent to the house. A voltage sensor, ZMPT107 senses the voltage on the line, the sensed current and voltage are transferred to the Arduino micro controller (Arduino Mega) which converts the signals to digital for further operations. The power is the computed in the Arduino Mega the calculated values are sent to the display on the resident's house and wirelessly sent to the base station using a Wifi shield (cc3000). The data will be transmitted over a wireless connection from the power meter, through the Wifishield to a web application interface called Carriots. The Carriots serves as an online data base that keeps track of energy consumed for each consumer.

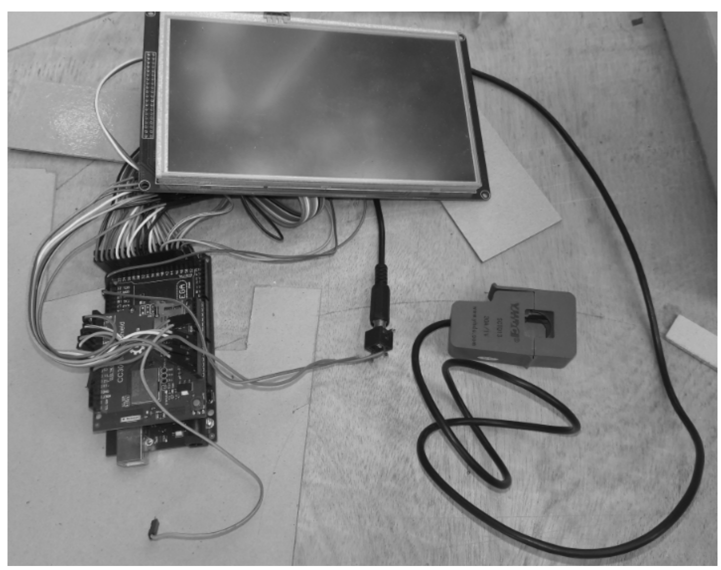

Fig. 6: The meter before packaging

4.0 Challenges Faced

- **Insufficient power supply:** The epileptic power supply state of Nigeria, is really still alarming. During this work, we experienced challenges trying to move from one place to another to power up our devices. This leads to a delay in the speed and results gotten.
- **Unavailability of some components in the local market:** During the implementation of the design, some components like the LCD was not found in the local market. After, a thorough search online, we gave in to make purchases from shops outsides the country, this brought about delay in delivery and other emotional stress of uncertainty if the components will arrive.
- **Delay in arrival of components:** Some components like that Arduino kit, the voltage sensor arrived a month later than it ought to. This led to a considerable delay in the implementation of the work.
- **Expensive components:** Purchasing some components would have been cost effective, but because of some trust issues we had in some local sites, we had to get them from expensive shops. Also, we had to get some components even at the high costs because they were unavoidable.
- **Difficulty in obtaining required information from sources:** visits to different offices in the quest for valid data and statistics were vain in some cases when we could not get them. For example, the officials in EEDC could not give us vital information because they do not have any. It was observed that some data was seen as trivial like the power consumed at different areas that it was distributed was never accounted for.

- **Difficulty in transmission of data because of unstable internet services:** The wireless infrastructure we have in the University of Nigeria which is Lionet is usually not stable. This caused a lot of havoc during the data transfer to the base station. This posed a big challenge because the data needs to be updated at the stated time.

5.0 Recommendations

- **Placing the meters per pole and per transformer:** to keep an accurate data on the total power distributed and energy consumed, the electricity company is to advance the meter and install them on each pole and each transformer. This will help keep track of the power going into the transformer and the power distributed and the total revenue generated from the payment of the bills.
- **Making the meter rechargeable at comfort:** We recommend addition of a rechargeable unit to the meter. The ability for each customer to recharge his meter from his comfort zone gives the meter an edge over others.
- **Implementation should be done on a stable internet connectivity zone:** We also recommend that the implementation of this meter should be in a place where we are sure that the internet connectivity is stable. This is to avoid delay and issues during data transmission to the base station.
- **Inclusion of an anti-tamper circuit to the meter to combat illegal connections:** An anti-tamper circuit with an alert to the base station is important on the per pole and per transformer installation. This is necessary because the current transducer is non- invasive and will be physically clamped on the wire. This will help signal the electricity officials when an illegal connector tampers with the current transducer device.

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