Curtailing Energy Theft by Remote Monitoring Case study: University of Nigeria, Nsukka

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***Abstract*— Nigeria continues to wallow in the doldrums of inadequate generation, supply and distribution of power. Industrialization, a major output of stable and adequate power supply has waned, leading to adverse effects on the economy. A major contributing factor to the ineffectiveness of Nigeria's power network is electricity theft. Many consumers have resorted to electricity theft and tampering of electricity devices leading to unreliability, overloading of power lines and increased billing on the part of legal consumers. It is on the basis of these challenges that remote monitoring on power lines is proposed by designing a power meter that transmits data wirelessly to the base station (Distribution Company). The monitoring system (power meter) is expected to be resident on each transformer, distribution pole as well as the consumer's premises. The readings are then sent to the distribution company office for analysis through the wireless network. This system will increase overall returns to the distribution company and improve transparency in the metering process. We shall adopt the University of Nigeria, Nsukka was used as a case study, making the assumptions that Internet access and a remote cutoff mechanism is available.**

***Index Terms*—Electricity theft, inadequate generation, unreliability, monitoring system**

I. Introduction

Electricity losses abound in the transmission and distribution system of Nigeria's power network. Nigeria's power grid has a total transmission and distribution loss of 40% [1]. This is indeed alarming. The losses are due to either commercial or technical losses. Technical losses occur due to energy dissipated in conductors and equipment used in the transmission and distribution of power. Commercial losses, on the other hand are due to defective meters, in the estimation of unmetered energy supply and electricity theft.

While Losses due to defective meters are defined as the difference between the amount of energy actually delivered through the meters and the amounted registered by the meters; unmetered losses refer to situations where the energy usage is estimated instead of measured with an energy meter.

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Energy theft refers to energy delivered to customers that is not measure by the customer's electricity meter. This paperwill focus on the monitoring of energy theft using the University of Nigeria, Nsukka as a case study.

II. Electricity Theft

Electricity theft can be in the form of fraud (meter tampering), stealing (illegal connections), billing irregularities, and unpaid bills [2]. The emergence of power theft as a serious problem has evolved due to several recent trends. Most countries developed electric power systems that were highly centralized state owned monopolies, where efficiency and profits were not high priority. The privatization of the infrastructure and new modes of power policy requires the new business-like enterprises to operate efficiently and try to optimize profits in an environment of rapid change.

In many countries power theft is an issue of open discussion, even in the most efficient (such as in the USA) and moderately efficient (Malaysia) systems. In South Asian countries, electric power is rarely discussed without reference to power theft, since it is such a prevalent practice. However, in some countries (Thailand, China) the topic is rarely part the analysis of power systems [2].

A. Types of Electricity Theft

Electricity thefts occur in different forms. From available literature and practical daily reports in Nigeria, the common ways include bypassing (illegal tapping of electricity from the feeder), meter tampering (by grounding the neutral wire as it does not measure readings) and physical methods to evade payment of bills. The basic method of stealing electricity is a direct wire-connection to a main power route passing a shop or a house so that electricity can flow to the consumer without crossing the electric meter installed by a government agency which is responsible for providing electrical services to customer. There are different types of theft done all over the world. Huge amount of power theft are done by tapping from line or bypassing the meter, According to a study 80% of the total theft detected all over the world is from residential buildings and 20% from commercial and industrial premises [3].

Theft and pilferage account for a substantial part of the high transmission and distribution losses in Nigeria theft/ pilferage of energy is mainly committed by two categories of consumers, that is, non-consumers and legal consumers.

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Some of the modes for illegal abstraction or consumption of electricity are given below:

1) *Meter tampering*: customers tamper the meter by grounding the neutral wire, this causes the meter to assume an incomplete circuit and it does measure the meter reading.
2) *Meter bypass*: the input terminal and output terminal of the energy meter has been shorted by a wire. This act prevents energy from been registered in the meter.
3) *Illegal terminal taps of overhead lines on the low tension side of the transformer*: primarily, electricity theft affects the power sector as a whole, tapping of the low tension side of the transformer result in overloading which causes tripping and can lead to blackout.
4) *Illegal tapping to bare wires or underground cables*: This is the most used method for theft of power. 80% of total power theft all over the world is done by direct tapping from line. The consumer taps into a direct power line from a point ahead of the energy. This energy source is unmeasured in its consumption and procured with or without switches.
5) *Unpaid bills*: Non-payment of bills by individuals, government institutions and untouchable VIPs results in utility running at a loss and a must continually increase in electricity charges.
6) *Billing irregularities*: This incorporates the inaccurate meter reading taken by bribed servicemen and intentional fixing of the bill by office staffs in exchange of illicit payments from the consumers.

B. *Implications of Electricity Theft*

Electricity theft has the following implications both to the distribution company as well as the consumer:

1) Increased billing on the part of legal consumers
2) Economic losses to the Utility
3) Overloading of power lines
4) Unreliability of Electricity service
5) Unsafe environment for troubleshooting

III. OBJECTIVES

There are three primary objectives of this paper:

1) To provide concise information of power consumed for each consumer and transformer, to check electricity theft and maximize economic returns using a power meter
2) To remotely monitor supply and consumption of electricity through a wireless network
3) To localize electricity information and hence compare energy supplied to bills issued.

IV. POWER METER DESIGN

The power meter consists of the hardware section, which are: Arduino mega 2560; CC3000 Wi-Fi Shield; Non-Invasive current sensor; 7inch Liquid crystal display (MD070SD); and Voltage sensor (ZMPT101B); will interface with Carriots online database software section using the proposed case study. The current measurement circuit is used to eliminate the negative current readings while the Wi-Fi shield add on board is used to wirelessly connect the module to the internet. A current transducer (clamp on sensor), is used to sense the current by clamping the current sensor on the positive wire while a voltage sensor (ZMPT101B) senses the voltage. The Arduino is programmed to compute energy consumed using the sensed current and voltage and then, wirelessly sends the data to the base station account using a web interface called Carriots [5].

The 7 inch liquid crystal display (MD070SD) adopts 8080 timing sequence with 16-bit parallel bus interface, resolution of 800 × 480, display panel with 16M color and integrated with 8-page video memory and the remaining memory used as extended memory. Table I shows the specification.

Determination of maximum output rms volta, Umax, which is decided by the AD peak voltage in the sample loop as:

As for Bipolar AD, $$U_{\max} = \frac{Peakvoltage}{\sqrt{2}} \quad (1)$$

As for Unipolar AD, $$U_{\max} = \frac{peakvoltage}{2\sqrt{2}} \quad (2)$$

Example: For ±5V AD, the maximum rms voltage of the transformer

$$U_{\max} = 5/\sqrt{2} = 3.53V$$

For 0~3.3V AD, the maximum rms voltage of the transformer

$$V_{\max} = 3.3V/2\sqrt{2} = 1.16V$$

Determination of input current-limiting resistor, R^I:

$$R^I = V/I \quad (3)$$

Where V= rated input voltage
I= rated operating current

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

Figure 1 shows the proposed power meter for the case study.

The current transducer 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. The current clamp reads 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.

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. This current transducer is rated 30A, but similar current transducers rated 1000A can be used for a larger scale. In addition, 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. Figure 2 shows the block diagram of the power meter.

TABLE I
MD070SD MODEL SPECIFICATION

Item	Specification
Display size	7 inches
Display Resolution	800 × 480
Display interface	Parallel 16 Bit
Display Controller	No
Expand	External Flash SD card socket
Board size	18.1 × 10.8 cm

The reference design specifications are specified in Table II and Table III.

TABLE II
MD070SD MODEL SPECIFICATION

Item	Specification
Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage	7-12V
Input Voltage (limits)	6-20V
Digital I/O pins	54 (of which 14 provide PWM output)
Analog input pins	16
DC current per I/O pin	40 mill-ampere
DC current for 3.3V pin	50 mill-Ampere
Flash Memory	256 KB of which 8 KB used by boot loader
SRAM	8 KB
EEPROM	4 KB
Clock speed	16 MHz

TABLE III
NON-INVASIVE CURRENT SENSOR ELECTRICAL AND WECHANICAL SPECIFICATION

Item	Parameter
Rated Primary current (Amp.) 50/60Hz	30 nom (1-60A maximum)
Turn ratio	Np : Ns= 1: 2000
Current ratio	30A/15mA
DC Resistance at 20°C	250 Ω
Accuracy @ RL ≤ 10Ω	2%
Linearity @ R_L ≤ 10 Ω	0.5%
Phase error at rated current range	≤4°
Operating Temperature Range	-40 ~ 65°C
Storage Temperature Range	-45 ~ 85°C
Dielectric Withstanding Voltage (Hi-pot)	2.5KV/1mA/1min
Insulation Resistance	DC500V/100MΩ min
CUP	PBT
Opening Dimensions	>10mm
Output type	UL 1015 22AWG PVC WIRE (doubling wire)
Approximate weight	60g

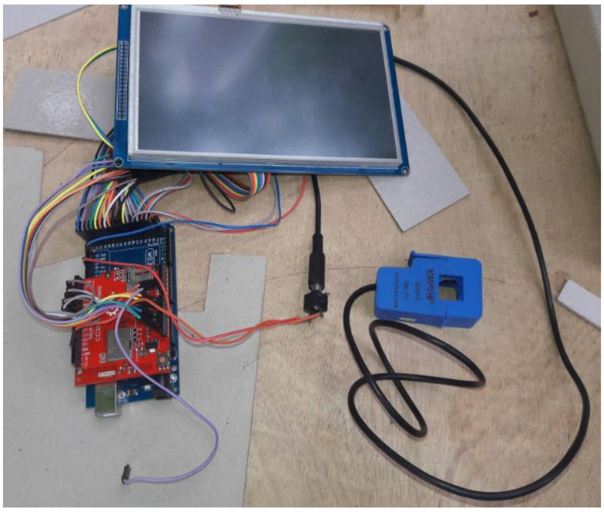

Fig. 1: The power meter

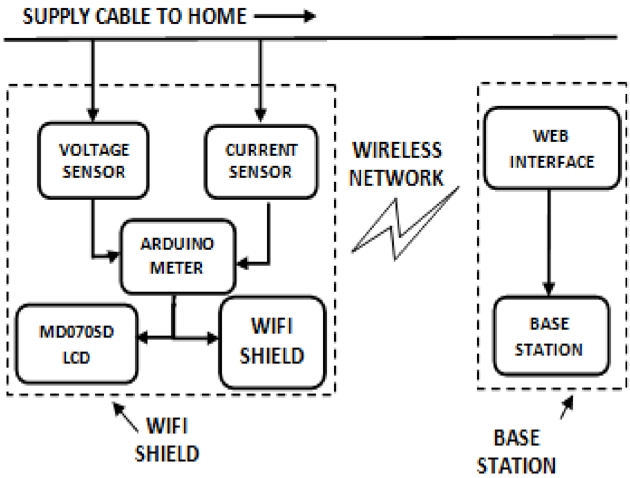

Fig. 2: Block diagram of the power meter

The 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. The power is the computer 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 Wifi shield to a web application interface called Carriots.

V. CARRIOT (ONLINE DATA BASE APPLICATION)

The Carriots serves as an online data base that keeps track of energy consumed for each consumer. Carriots is an application hosting and development platform (Platform as a Service) specially designed for projects related to the Internet of Things (IoT) and Machine to Machine (M2M). It enables data collection from connected objects (the things part), store it, build powerful applications with few lines of code and integration with external Industrial Training (IT) systems (the internet part). Carriots provides a development environment, APIs and hosting for IoT projects development. A snapshot of the online database and data from each meter is shown in appendix.

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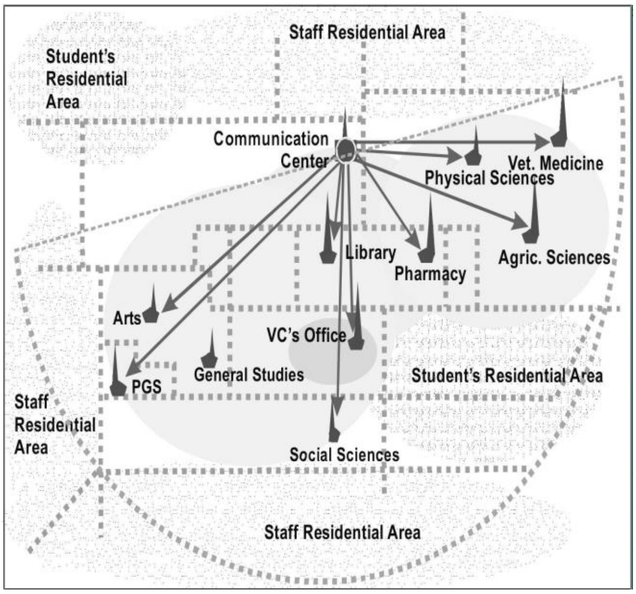
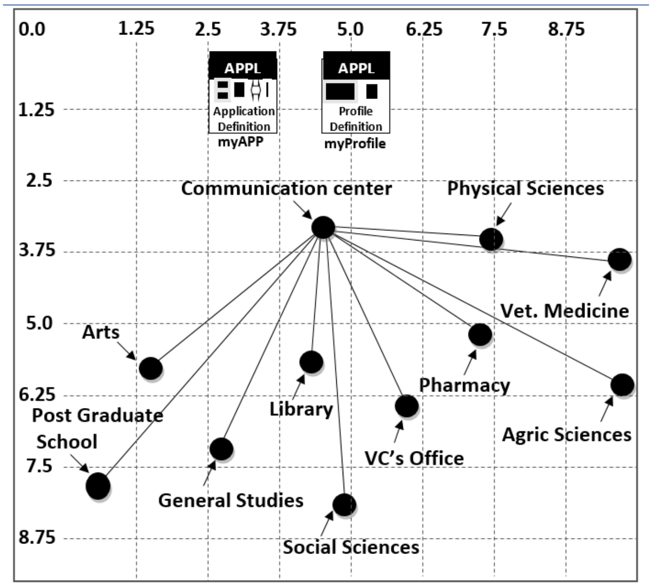
VI. WIRELESSLY MONITORING POWER CONSUMPTION

The use of radio waves to achieve a wireless connectivity solution would definitely be cheaper to implement. The adopted topology is a star topology. This topology has the advantage of speedy setup and easy extension. As for the kind of applications that the network will accommodate, it is expected that, initially, the network will be exclusively used for distribution of Internet access campus-wide [6].

The Computer Communication Center (CCC) was chosen to host the central server system as the centre of communications for the study as shown in figure 3. This was primarily because of its position roughly equidistant from all points in the academic/administration centers.



a. Radio network for the University



b.Simulated system

Fig. 3: The radio network for the University and a simulated system using OPNET

The network required to connect the power meters is shown figure 4 with a bandwidth requirement of about 20kbps per node since traffic on the links consists of only clear text. The subnet at communication center consists of server for which has database capabilities for saving power consumption details sent from the power meters.

VII. PRINCIPLE OF OPERATION

The principle of operation is simple and is explained in the following steps and illustrated in figure 5:

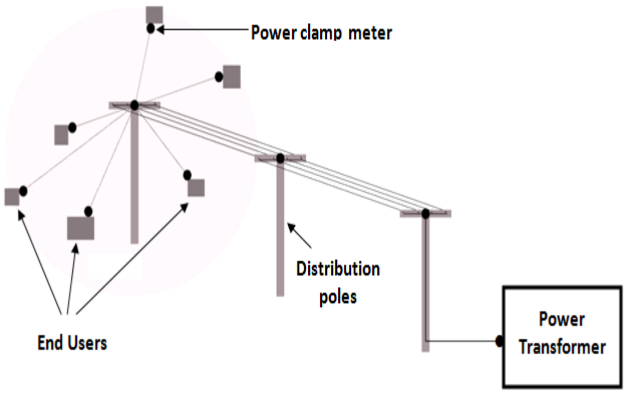


Fig. 5: Power meters monitoring consumption

1) Power meters are placed on the transformer supplying current to the location, each transmission tower attached to the corresponding transformer and the end users on each tower.
2) The amount of power consumed at the various end users is measured via the power meter installed at each user's location. The total amount of power consumed is cross checked by the amount of power supplied from each transmission tower.
3) The total amount of power consumed via all the transmission towers is then summed up and checked with the power supplied from the transformer.
4) All these readings are wirelessly transmitted from each power meter to the base station (figure 4), where the analysis is carried out (allocation was made for leakage current).
5) Preventive measures are then carried out remotely by identifying power losses either from the end user or transmission tower and remotely switching it off.
6) In the instance when it is not possible to isolate the erring user remotely, the transformer supplying power to that area is switched off.

VIII. CONCLUSION

Electricity theft has eaten deep into the economic, infrastructural development in Nigeria. It is imperative to reduce power theft or at least keep it within reasonable bounds. This can be achieved using this remote monitoring system as it is simple to use and setup as long as there is an existing wireless network.

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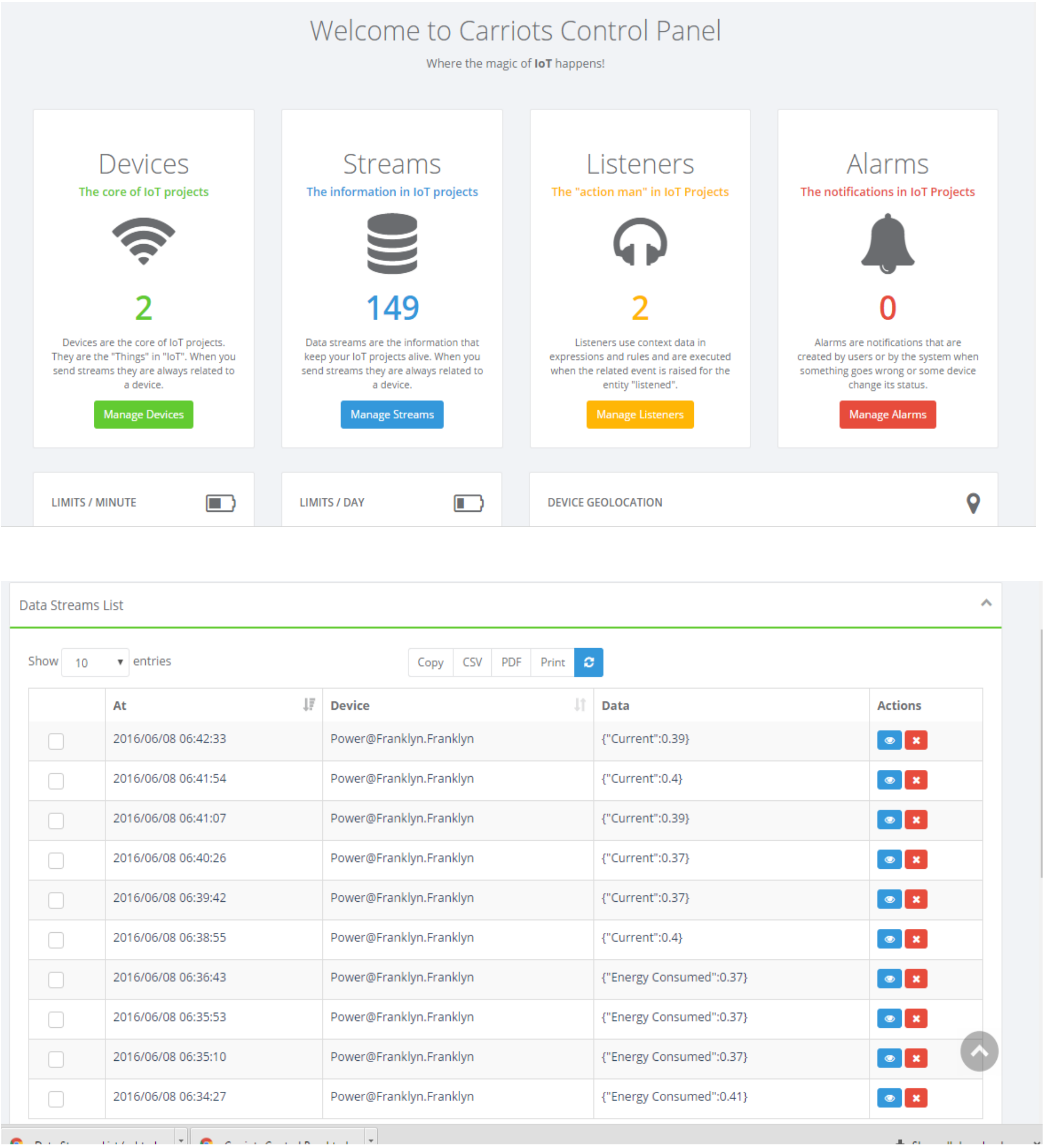
APPENDIX



Snapshot of the Carriots Online database

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