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Determination of Energy Consumption for Non-Prepaid Metered Electricity Consumers using GSM Technology

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Abstract:- Mobile communication system advances daily that they can be applied for automatic reporting of faulty equipment over a long distance. The aim of this research work is to assists the Distribution Companies (DISCOs) in Nigeria in keeping an accurate record of hours a transformer in a feeder supplies power to the consumers. This is achieved by ensuring that the operational state of transformers in the distribution network is known at all times, with the developed system automatically reporting any distribution transformer trip to the Distribution System Operator (DSO). The records, in turn, help DISCOs in monthly energy consumption calculation and billing for non-prepaid metered (estimated-billed) electricity consumers, using the correct total number of hours that power is supplied to them in a month. This work comprises a 12V DC power supply unit, voltage sensor unit, controller unit, GSM module, and LCD unit. The controller unit is the ATMEGA328P microcontroller with its instruction set written in C- language. It was observed that the developed system could automatically report a transformer trip to DSO, who then takes a daily record of the total number of hours the transformer is energized in that month and with that value, accurate monthly energy consumption values for non-prepaid metered (estimated-billed) consumers can be calculated and processed.

Keywords:- *ATMEGA328P microcontroller, GSM Module, LCD, Distribution transformer, Voltage sensor, DISCO, DSO.*

I. INTRODUCTION

Electricity is the foundation of a nation's socio-economic development. In reality, the sufficiency of the electrical energy generated for the needs of the people has become an important index of national development [1], [2]. In Nigeria, several challenges are affecting the power sector, challenges include insufficient power generation, inadequate power transmission, and distribution facilities, poor maintenance of power infrastructure, insufficient investment for capital power projects, energy theft, inadequate energy metering, and accurate billing system, etc. [3], [4].

The power sector in Nigeria was privatized in 2013 to ensure its rapid growth and also drive private sector investment as a pathway for sustainable development. Sadly, as of present, there is not much significant difference between the pre and post-privatization in terms of metering all power consumers, quality of service, power reliability, and availability experienced by consumers.

The billing system used by Distribution Companies (DISCOs) in Nigeria for calculating the energy consumed monthly by non-prepaid metered (estimated-billed) electricity customers is a major issue. DISCOs use the total number of hours 11KV or 33KV feeder is ON to calculate the energy consumed by all the customers on that feeder, notwithstanding the number of hours a transformer on that feeder is out of supply and power consumers not supplied by that transformer. Thus, the need to develop a system that automatically reports transformer trip to DSO, thereby ensuring that DSO has daily information about the operational status of the transformer, the time of the trip, and the time it is restored in a particular month for proper billing of non-prepaid metered consumers being fed by the transformer.

II. REVIEW OF RELATED WORKS

Presently in Nigeria, the energy billing and metering system still have the following three modes; spinning disk meters, prepaid meters, and estimation billing systems.

A. Use of Spinning disk meters

Some customers are still on these analog spinning disk meters which are physically read every month by DISCO personnel who record the reading and present it for calculating and processing the bill. The bill is generated and later dispatched to customers for payment. This post-paid mode of billing is obsolete, time-consuming, cost-intensive, and cases of erroneous reading, metering personnel skipping customers or generating reading based on previous readings (estimated bills) and also cases of fraudulent business transactions between customers and DISCO staff so as to reduce energy bills for customers have been observed. This metering and billing system is highly inefficient [5].

B. Use of Prepaid meters

A low percentage of the customers are on pre-paid meters and cases of meter bypass are relatively reduced. The pre-paid metering of consumers' electricity consumption gives better need-based energy management, in which case, with the use of the prepaid metering system, there is a reduced case of lost income, and waste in comparison to the other modes of metering in existence [6], [7]. The DISCOs are trying to check this meter bypass issue by imposing a heavy fine on any customer that is caught and this is done by periodically sending out inspection teams. The prepaid meters used in Nigeria have their energy units purchased at DISCO vending stations. The energy unit in KWh purchased is issued as codes on a paper slip. The code will be used by the customer to recharge the prepaid meter. This mode of recharge requires

establishing several vending stations for easy access by customers and this increases operational costs and also presently the prepaid meter can as well be recharged online.

C. Estimation Billing System

A percentage of customers presently are still on the estimation billing system by DISCOs. Presently in Nigeria, this billing system does not depend on actual energy consumed. The value of the actual amount of electricity consumed by consumers concerned or the size of the buildings/households is not considered. Most consumers on estimated bills see the DISCO bills as being against the law and the illegality arises because of their disenfranchisement in the metering process, consumers being oblivious of the method and procedure applied in the computation of their own bills [8].

The over-billing attitude of DISCOs on non-prepaid customers is the major problem and this leads to payment apathy [9], [10]. In the past years, over 80% of complaints received by the National Electricity Regulatory Commission (NERC) from consumers had been centered on issues of estimated billing, excessive tariffs with the metering methodology, and slow pace in metering all power consumers.

Also, another problem with the out-of-the-meter (estimation) billing system has been that its bill does not tally with the exact amount of energy consumed.

Thus, there is a need to develop a system that monitors and reports transformer trips to DSO notwithstanding that the transformer's service feeder is still energized.

III. METHODOLOGY

The block diagram of the developed system is shown in figure 1. For simplicity, the block diagram is shown for the system that can monitor one distribution transformer. The proposed system consists of a 12V DC power supply unit, voltage sensor unit, controller unit (ATMEGA 328P), GSM module, and LCD unit.

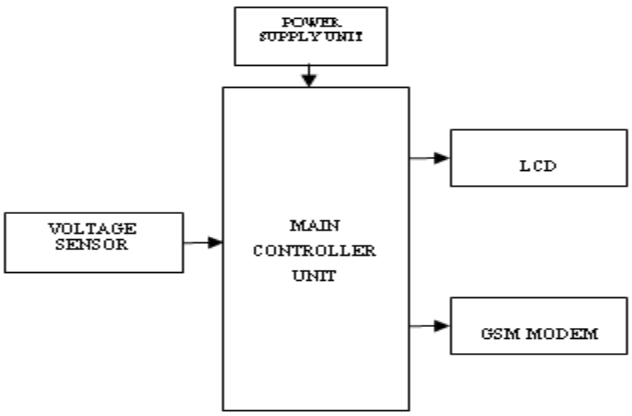

Fig. 1: Block diagram of the developed system

A. POWER SUPPLY UNIT

The power supply unit is an electronic circuit that supplies regulated 5V DC to the other components in the system. This circuit comprises 220/12V transformer, bridge rectifier, resistor, and capacitor that form the filter circuit and also voltage regulator (7805). This power supply unit has a 12VDC rechargeable battery that serves as an alternative supply to the main source. The circuit diagram for the power supply unit is shown in Figure 2.

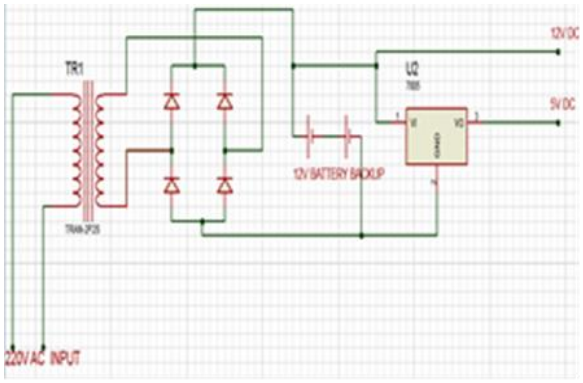

Fig. 2: Power supply circuit diagram

B. VOLTAGE SENSOR

The Voltage sensor always monitors the operational status of the transformer, if it is energized or not. Its input terminals are connected at a low voltage bus in the feeder pillar (before the low voltage fuse connection point) and at the low voltage side of the distribution transformer. This voltage sensor senses the phase voltage value (normal voltage) from the transformer low voltage and sends an analog voltage signal (5V or HIGH digital signal) to the microcontroller. This implies that the transformer is supplying a real voltage to consumers. When it senses a no voltage value, it sends an analog voltage signal (0V or LOW digital signal) to the microcontroller indicating that the transformer is no longer energized (tripped on fault). The voltage sensor unit is shown in figure 3. It comprises a 415/12V transformer, bridge rectifier, paper capacitor, and a potentiometer.

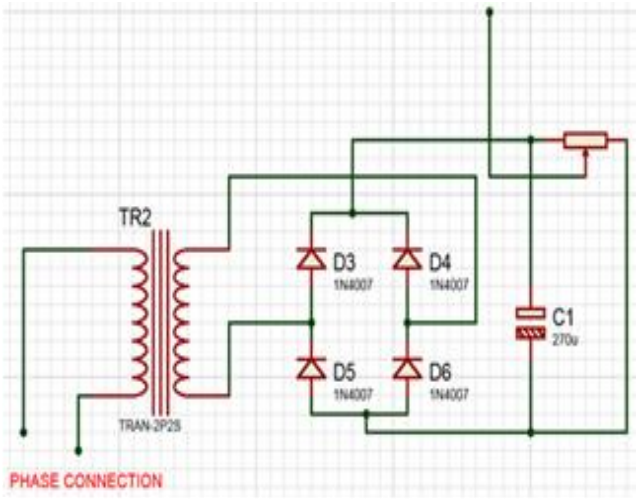

Fig. 3: voltage monitoring circuit diagram

C. MAIN CONTROLLER UNIT

The main controller unit is the ATmega328P microcontroller. It receives and analyzes analog signals from the voltage sensor connected at the transformer's low voltage side through its analog to digital converter (ADC) ports. When

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the microcontroller receives a no voltage (0V or LOW digital signal) analog signal from the voltage sensor, it sends two signals simultaneously; the first signal to the LCD that displays "BLACK-OUT" on the LCD, signifying that there is no voltage supply from the transformer and the second signal, to the GSM module for onward SMS to the Distribution System Operator (DSO) indicating that the transformer is tripped (OFF). When the microcontroller receives a normal voltage (5V) analog signal from the voltage sensor, it sends two signals simultaneously; the first signal to the LCD that displays "TX ACTIVE" on the LCD, signifying that the transformer is energized for there is real voltage supply from it and the second signal to the GSM module for SMS to be sent once to the DSO indicating that the transformer is restored and is energized.

Fig. 4: The Pin-out of ATmega328P Microcontroller

D. GSM MODULE

The GSM module receives two signals from the main controller unit, the first signal signifies that the particular transformer is OFF (not supplying voltage) and the module sends a pre-programmed SMS to Distribution System Operator (DSO) indicating that the transformer is OFF. The second signal signifies that the transformer is restored and is now energized.

E. LCD

LCD displays the status of the transformer it is monitoring. It is a type of fault diagnostic display, confirming to the power provider's maintenance team, who are on a routine maintenance check or who are invited by the system's delivered SMS on the transformer status, the transformer that has issues. This helps the maintenance team to be specifically directed to the faulty section, thus reducing the downtime spent in restoring the lost transformer phase. The LCD displays "BLACK-OUT" when the transformer trips (off) and displays "TX ACTIVE" when it is restored.

F. OPERATING PRINCIPLE OF MICROCONTROLLER-BASED CAPACITOR SWITCHING SYSTEM

The system provides an automated mode of reporting to the agent of the DISCOs which is the Distribution System Operator (DSO) using GSM's SMS, about no voltage supply from a transformer connected to a feeder as a result of the transformer trip on fault despite the fact that the transformer's service feeder is still active or energized. This system assists the Distribution Companies (DISCOs) in Nigeria in keeping an accurate record of the total number of hours a transformer in a feeder supplies power to its consumers and this, in turn, helps the DISCOs in monthly energy consumption calculation and billing for non-prepaid (estimated-billed) consumers using the correct total number of hours that power is supplied to consumers in a month. The voltage sensor unit continuously monitors the low voltage side of the transformer. When the trips on fault, the voltage sensor unit sends a no voltage (0V) analog signal to the microcontroller, who analyses the analog signal and sends two signals simultaneously; the first signal to the LCD that displays "BLACK-OUT" on the LCD, signifying that the transformer is not active (off) and the second signal, to the GSM module for onward SMS to the Distribution System Operator indicating that the transformer is OFF.

Immediately the DSO receives a no voltage SMS, he takes record of the time at which the trip occurred in the Logbook and informs the maintenance team of the particular transformer that tripped for faster restoration processes.

The maintenance team writes and obtains a permit for the outage on that feeder that has the faulty transformer and whenever they finish with servicing the transformer and officially surrender the permit, the DSO will energize that feeder to restore the power supply to that transformer.

The DSO also takes a record of the time at which the transformer was restored in the Logbook. These two records of time, when the transformer tripped and when it is restored will assist the Energy billing staff of the DISCOs in determining the correct total number of hours in a month, that particular transformer readily supplied voltage to its consumers. This in turn helps in calculating the accurate energy consumed by non-prepaid (estimated-billed) consumers being connected to that transformer.

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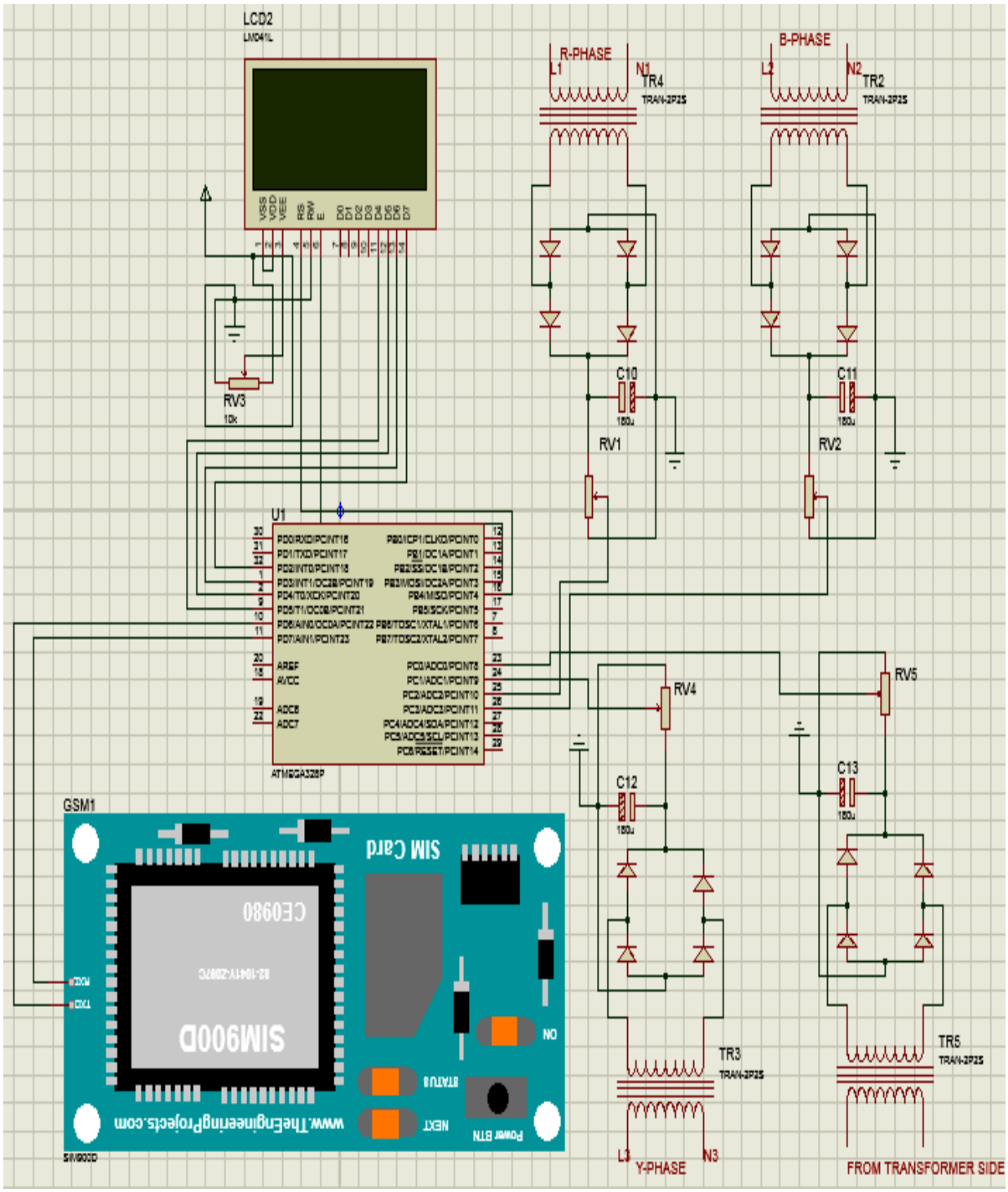

Fig. 5: Circuit Diagram of an Automated GSM-Based Reporting System

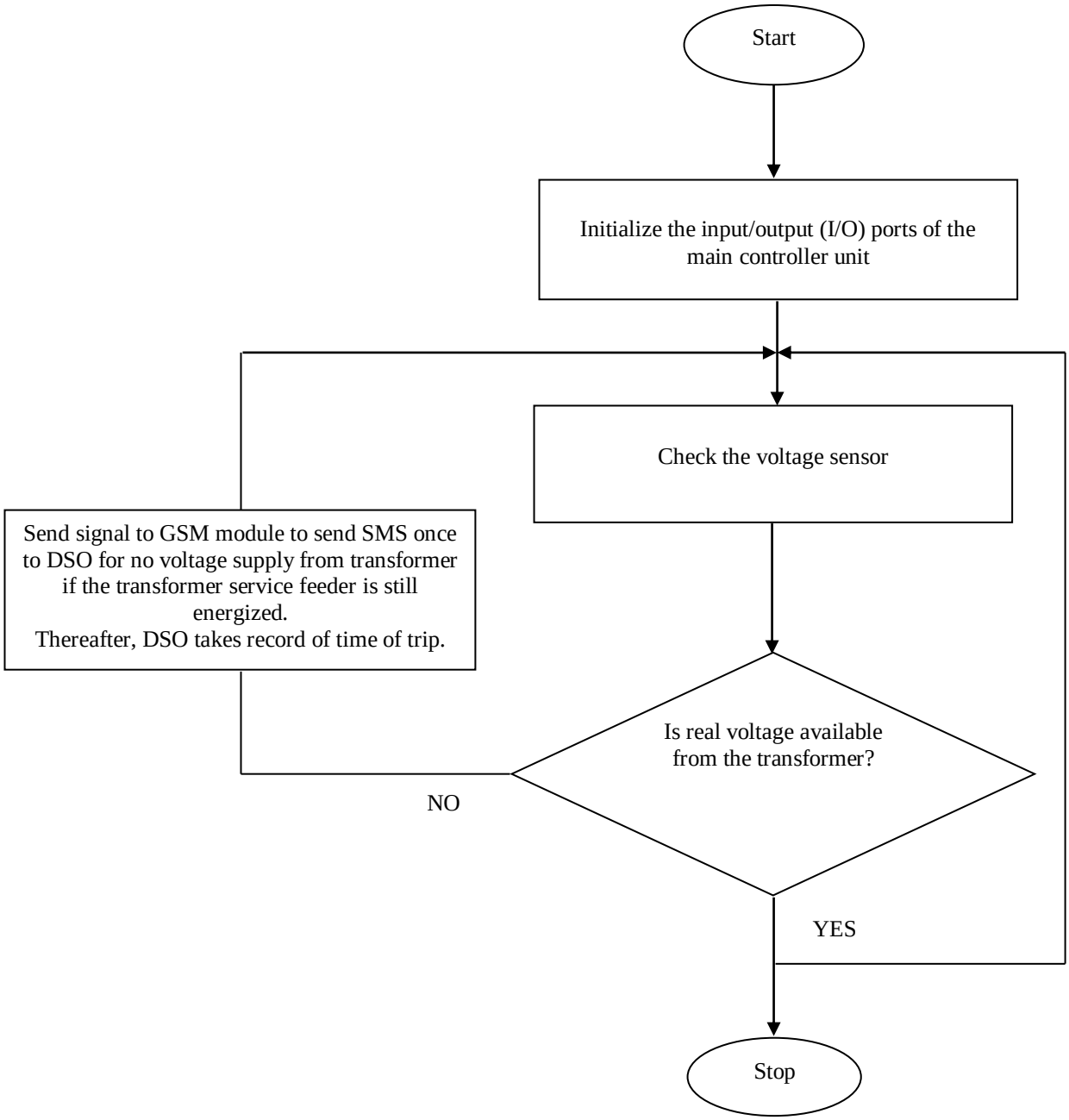

Fig. 6: Flowchart diagram of an Automated GSM-Based Reporting System

IV. RESULT

The developed system was able to automatically report a transformer trip to DSO, who then takes a record of the total number of hours the transformer is energized in that month. With this true/actual number of hours that the transformer is on-stream or energized, accurate monthly energy consumption values for non-prepaid metered (estimated-billed) customers can be calculated, processed, and distributed to this group of electricity consumers.

V. CONCLUSION

This research work involves the development of a GSM-based automated reporting system that ensures prompt reporting of both the transformer trip and subsequent restoration of power supply from that same transformer after servicing of the transformer by the maintenance team. This system assists the DSO to keep a proper record of the time when the transformer tripped and also a record of the time when it was restored, thus helping in getting the justified and true number of hours the transformer itself supplied power to its consumers in a month. This accurate number of hours is used in calculating the amount of energy consumed by non-prepaid metered customers in a month thereby solving the problem of exploitative bills issued to non-prepaid power consumers.

The system was built around the ATMEGA328P microcontroller as the main controller unit, together with the voltage sensor, GSM module, and LCD unit.

VI. RECOMMENDATION

It is recommended that Distribution Companies (DISCOs) should adopt this method of automatic reporting of no voltage supply from Distribution transformers as this will assist in the following ways:

- Taking record of the actual number of hours a particular transformer is delivering power (energized) to electricity consumers in a month.
- Determining the correct amount of energy consumed by electricity consumers in a month once the true number of hours the service transformer delivered power is recorded.
- The power regulators in Nigeria (NERC) solve the issue of constant complaints of exploitative bills given to non-prepaid metered customers by the DISCOs.

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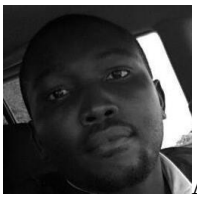

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