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Automated Electricity Power Theft Identification and Reporting System

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Abstract: Energy meters have become an indispensable part of the power sector as they provide a means of knowing how much energy is consumed by a consumer. This information then helps in billing the consumer. Billing is usually done at a specific amount, determined by the distribution company (DisCo). However, sometimes theft of electrical energy is carried out by individuals, businesses, institutions, etc., causing wastage and losses in terms of revenue for the DisCo. It becomes imperative to be able to design a system that can detect this waste or theft. This project solves this problem by designing a system that not only detects theft but also reports it to the appropriate authority. This was achieved by designing two energy meters, each equipped with Bluetooth technology, and equipping one of the meters with GSM technology for reporting. One energy meter is stationed at the home of the consumer, and the other energy meter is stationed at the pole side of the electricity supply. The energy meter at the pole side is installed such that it is in the return path of the current. The meter in the home of the consumer measures the energy consumed by the consumer and sends the information to the energy meter at the pole side through Bluetooth technology. Electricity theft is usually done by illegally tapping energy from the lines that supply power to consumers, thereby bypassing the energy meter. Whenever there is a theft, the energy meter installed at the homes of consumers will not pick up this energy, but the energy meter installed at the pole side will since it is installed at the return path of the current. As the energy meter installed in the home of the authorized consumer sends its information to the energy meter at the pole, if there is theft of energy, the two pieces of information will not be the same. This is how the system knows that a theft of electricity has occurred. A report of theft and energy consumed is then sent out to the DisCo.

Keywords: electricity theft; energy meter; automated theft identification; bypass; illegal tapping; reporting system

1. INTRODUCTION

Distribution companies (DisCos) in Nigeria experience high revenue losses of over N30 billion monthly. This high revenue loss results from customers who are involved in meter bypass, vandalism, and unpaid electricity bills. In a bid to recover some of the accumulated revenue loss, DisCos normally overbill unmetered customers through estimated bills [1]. In a developing country like Nigeria with a not too robust economy, approaches to electricity theft like smart grid will be difficult to implement, hence the need for an easier but effective method to identify and report electricity theft to the DisCo.

This project aims at using a less complex method to identify electricity theft through energy meter bypass in a house, company, government establishment, etc., and report the theft to the authority (DisCo). Two energy meters are designed with capability to communicate via Bluetooth technology. One of the energy meters is mounted at a point where it can measure the electrical energy consumption of the customer while the second energy meter is located at the pole feeding electricity to the consumer. A GSM module is used to report electricity theft to the authority. Four scenarios were considered to arrive at the results:

Scenario 1: Zero electricity usage at customer's location .

Scenario 2: An authorized electricity user is consuming electricity without any theft.

Scenario 3: When the energy meter is completely bypassed.

Scenario 4: There is electricity usage at the energy meter, and electricity is also consumed by the energy meter bypassed.

2. RELATED WORK

In the system proposed by Ajay et al. [2], an online database is used to store all the data related to the distribution system, along with the time and date. The stored data includes power dispatched, voltage consumed at a pole, and the serial number of the electric pole. The voltage value will be plotted against time. The pole number is used to track the location of the theft of power. Consumer loads need to be known beforehand for this system to be effective.

Supriya et al. [3] also proposed a system where the Electricity Distribution Company (DisCo) would transmit the energy via an RF transmitter. At the user end, an RF receiver receives the transmitted power from the DisCo and then provides an acknowledgement about the reception of power by activating a micro switch. The acknowledgement information would be transmitted to the head office via an RF transmitter.

Shokoya and Raji [4] proposed that a Smart Grid (SG) deployment is the technical solution that would help mitigate the lingering electricity theft problem and improve the quantity and quality of power supply in Nigeria. According to their proposal, Smart Grid would assist countries in sub-Saharan Africa to have universal access to electricity.

Infrared (IR) sensors are used to detect power theft in the system proposed by Nilesh et al. [5]. GSM technology is used to transmit the meter reading to the customer and DisCo with the required cost. This happens when SMS is received from authorized server mobile transmission between customer and DisCo. Also, the power supply to the meter can be stopped remotely as per request of authorized server mobile without visiting the residence of electricity power theft.

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In the system proposed by Sheikh and Auqib [6], they explained how encrypting power signals helps in preventing power thefts in distribution system with distribution generation. Their work was aimed at addressing non-technical loss (NTL) during distribution of power. In their proposed system they used power semiconductor switching systems at the low voltage side of the distribution transformer in such a way that the three phases: Red, Yellow and Blue (R, Y, B) and neutral are passed through this semiconductor-based switching system. The switching system is operated through the bit sequence generated by a microcontroller. The same bit sequence is generated at the load circuit inbuilt in smart energy meters through RF transmitter- receiver synchronization. The power line between the distribution transformer and the energy meter is protected as encrypted power signal flows through it which cannot be used for running the home appliances, therefore providing protection against illegal distribution line tapping's in power networks.

Jadhav et al. [7], proposed a system that gives automated information to DisCo head office about electricity theft. For this, magnetic sensor is used to sense magnet which is placed on the meter. The piezo element is used to sense a vibration of a meter. Their system monitored the power consumed by a model organization such as a household consumer from a centrally located point. Monitoring the power means calculating the power consumed exactly by the user at a given time. The power consumed by the user is measured and communicated to the controlling substation whenever needed by the person at the substation. The feedback from the user helps in identifying usages between authorized and unauthorized users which helps in controlling the power theft.

Depuru et al. [8] proposed an architectural design of smart meter, external control station, harmonic generator, and filter circuit. They aimed to detect illegal consumers, conserve and effectively utilize energy. Smart meters were designed to provide data of various parameters related to instantaneous power consumption. NTL in the distribution feeder is computed by external control station from the sending end information of the distribution feeder. If a considerable amount of NTL is detected, harmonic generator is operated at that feeder for introducing additional harmonic component for destroying appliances of the illegal consumers.

3. METHODOLOGY

3.1 Method

This work entails designing and implementing an automated electricity power theft identification and reporting system. To accomplish the work, an energy meter (EM2), which is equipped with Bluetooth technology, is installed at the home of the authorized user. At the pole supplying electricity to the authorized electricity consumer, an energy meter (EM1) is also installed. The EM1 is also equipped with Bluetooth technology, a buzzer, and GSM communication capability. The GSM technology included with EM1 serves the purpose of reporting theft to the DisCo. Figure 1 illustrates a single-line diagram of the layout of the system.

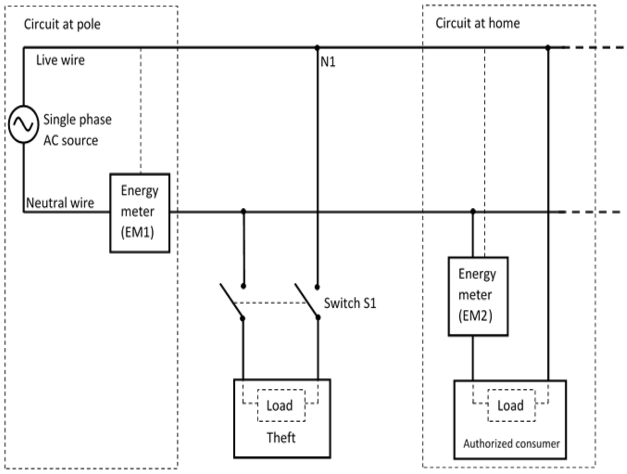

Figure 1: Single line diagram of the layout of the electricity power theft detection and reporting system

When S1 is closed (the electricity theft load is connected), then both the unauthorized and authorized loads will draw their own currents. The combined current for both loads splits at node N1 to supply their loads. This means that the current drawn by the authorized load is different from the current drawn by the unauthorized load. Both currents recombine at the return path where EM1 is installed, so EM1 measures the total energy consumed by both authorized and unauthorized loads while EM2 measures energy consumed by the authorized load only.

EM2 is equipped with a HC05 Bluetooth module that is configured in master mode. This enables EM2 to send the energy consumed by the authorized user to EM1. EM1 is equipped with a HC06 Bluetooth slave module. This enables EM1 to receive energy readings from EM2. EM1, which is also an energy meter, compares its own energy readings with the energy reading sent from EM2. If both readings match (switch S1 is open), then it means that no electricity theft has been detected. But if the reading gotten from EM2 does not match the readings from EM1, then it means the switch S1 is closed, which in turn means there is theft of electrical energy. Figure 2 shows the block diagram of energy meters (EM2).

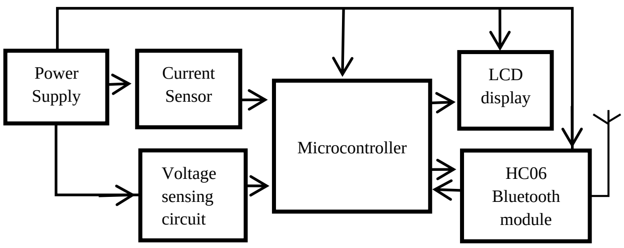

Figure 2: Block diagram of energy meter (EM2)

Whenever EM1 detects theft of electrical energy (i.e., a difference in energy readings), it sends an SMS to the appropriate authority with a summary or report of the theft and energy consumed. If the theft is not removed, then the report will continue to be sent to the authority every 60 seconds. The block diagram of the energy meter (EM1) is shown in figure 3.

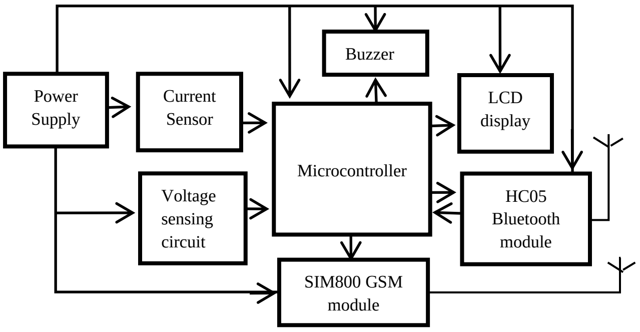

Figure 3: Block diagram of energy meter (EM1)

3.2 Algorithm for Electricity Power Theft Detection and Reporting

The automated electricity power theft identification and reporting system follows the algorithm below to identify electricity power theft and then report identified theft to concerned authorities.

- Measure AC voltage and AC current at bothEM1 and EM2.
- Calculate wattage consumption by multiplying voltage, current, and power factor at both EM1 and EM2.
- Establish energy consumed in watt-sec or kilowatt-hours by multiplying wattage power consumed with time.
- Communicate the energy consumed and measured by EM2 and EM1 to the microcontroller via Bluetooth.
- The microcontroller compares the energy from EM2 to the energy measured at EM1.
- If both energies are the same, then nothing is done.
- If both energies are not the same, then a report is sent to the appropriate authorities informing them of electricity theft.
- The buzzer will sound when electricity theft is detected by the system.

The flowchart representation of the algorithm is shown in Figure 4.

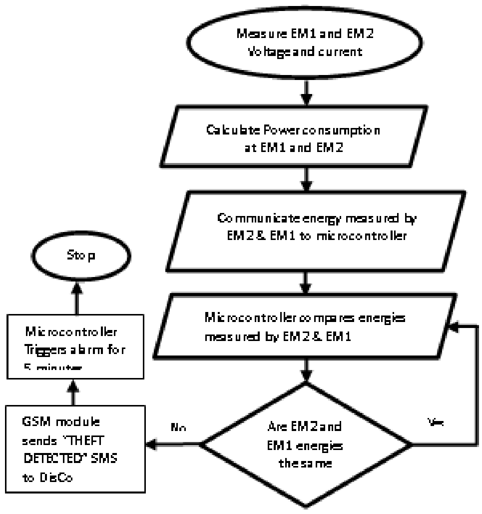

Figure 4. Flow chart of the system

3.3 Simulation Overview of The System

Before the circuit was constructed and implemented, simulations were done. The simulation in this project was carried out using the Proteus 8 professional circuit design suite. This design software was preferred because it possessed libraries of all components used to achieve this design. VSPE was also employed to simulate Bluetooth wireless communication between the two energy meters. Figure 5 below shows the simulation environment.

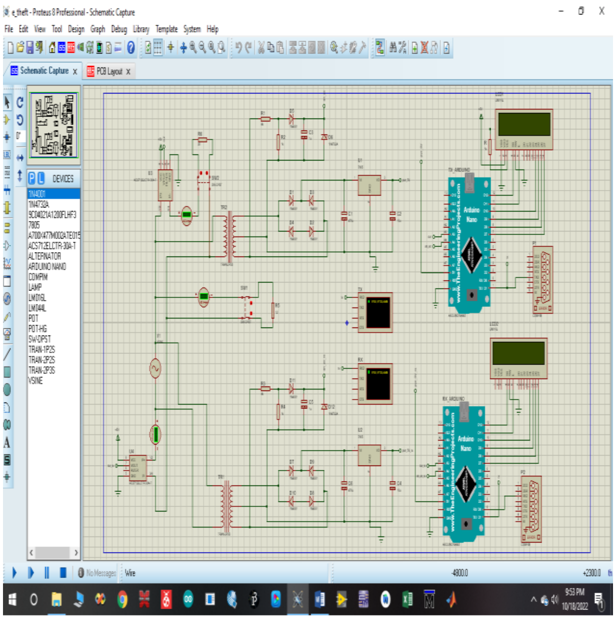

Figure 5: Simulation Environment

4. RESULTS

4.1 Simulation Results

Satisfactory results were obtained during the simulation with high accuracy in transmitting parameters from EM2 to EM1. Figures 6–9 below show the simulation results of the four scenarios that were considered.

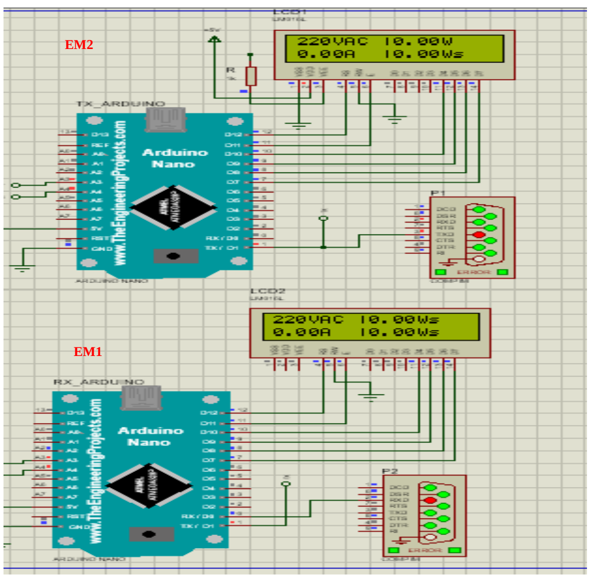

Figure 6: Scenario 1- Zero electricity usage at customer's location

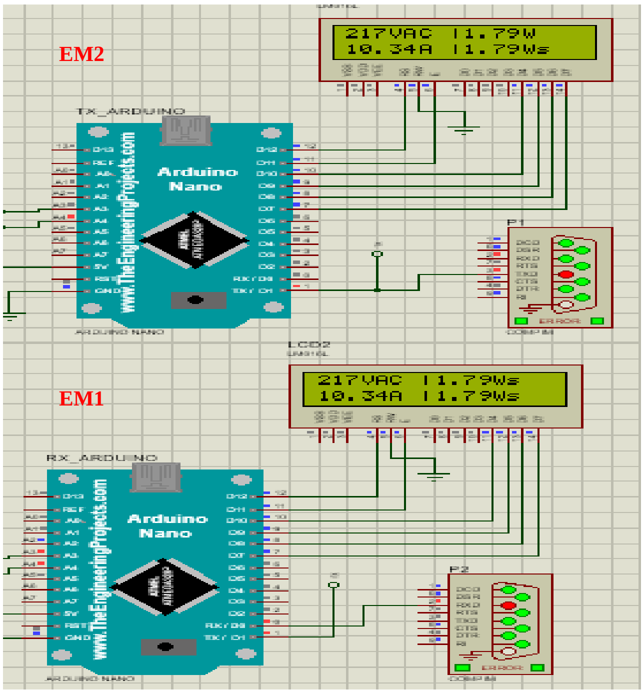

Figure 7: Scenario 2- Authorized electricity user consuming electricity energy without any theft

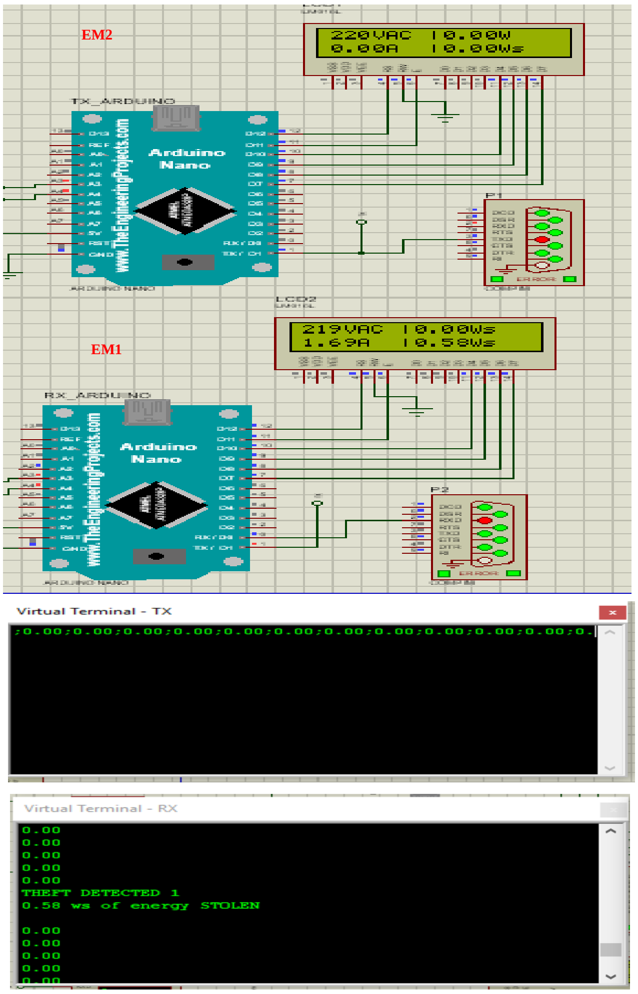

Figure 8: Scenario 3- Energy meter completely by-passed

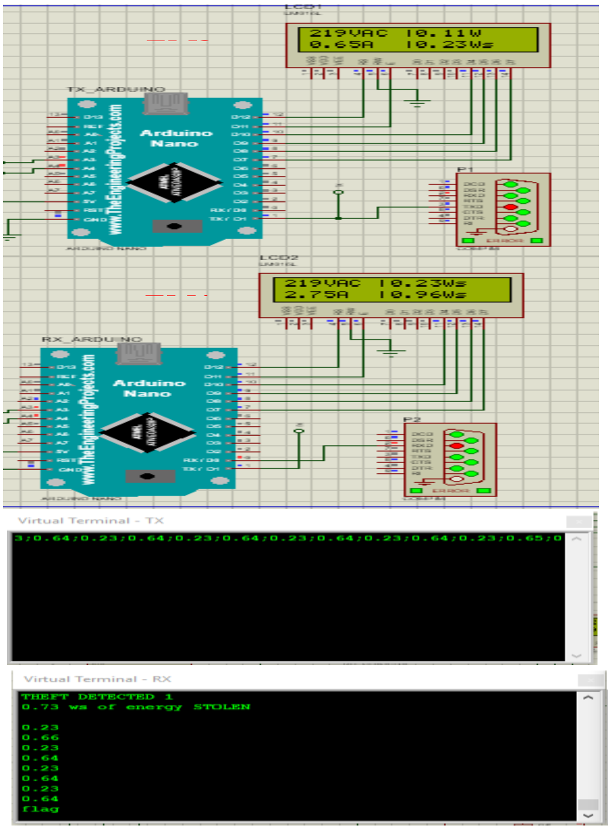

Figure 9: Scenario 4- Electricity usage at the energy meter and electricity also consumed by energy meter by-pass

4.2 Summary of Simulation Results

The summary of the simulation results for Energy Meter 1 (EM1) and Energy Meter 2 (EM2) is presented in Table 1. The results obtained in scenarios 1 and 2 are after 1 second, while the results in scenarios 3 and 4 are after 2 seconds.

Table 1. Table of Simulation Results

Energy Meter	Para-meter	Scen-ario 1	Scen-ario 2	Scen-ario 3	Scen-ario 4
Energy Meter EM1	Voltage (VAC)	220	217	219	219
	Current (mA)	0.00	10.34	1.69	2.75
	Energy (Ws)	0.00	1.79	0.58	0.96
	Energy from EM2 (Ws)	0.00	1.79	0.00	0.23
Energy Meter EM2	Voltage (VAC)	220	217	219	219
	Current (mA)	0.00	10.34	0.00	0.65
	Watt (W)	0.00	1.79	0.00	0.11
	Energy (Ws)	0.00	1.79	0.00	0.23

4.3 Implementation Results

The designed system was subjected to similar conditions as the simulation so that the results could be compared. Table 2 below shows the results after implementation. The results obtained in scenarios 1 and 2 are after 1 second, while the results in scenarios 3 and 4 are after 2 seconds of bypass attempt.

Table 2. Table of Implementation Results

Energy Meter	Para-meter	Scen-ario 1	Scen-ario 2	Scen-ario 3	Scen-ario 4
Energy Meter EM1	Voltage (VAC)	222	218	220	218
	Current (mA)	0.00	11.01	1.69	2.70
	Energy (Ws)	0.00	1.92	0.59	0.94
	Energy from EM2 (Ws)	0.00	1.92	0.00	0.21
Energy Meter EM2	Voltage (VAC)	222	218	219	218
	Current (mA)	0.00	11.01	0.00	0.60
	Watt (W)	0.00	1.92	0.00	0.10
	Energy (Ws)	0.00	1.92	0.00	0.21

The system at the implementation stage generated and transmitted an SMS report to the distribution company after a theft was detected, as shown in figure 10.

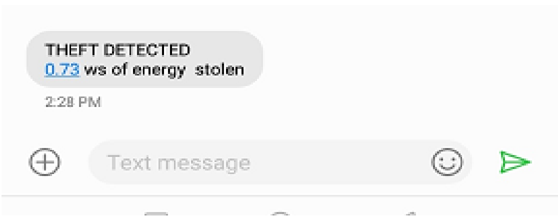

Figure 10: SMS sent to Distribution Company when theft is detected

4.4 Comparison between Simulation and Implementation Results

The simulation and implementation results are compared using bar chart representation, as shown in figures 11 to 15.

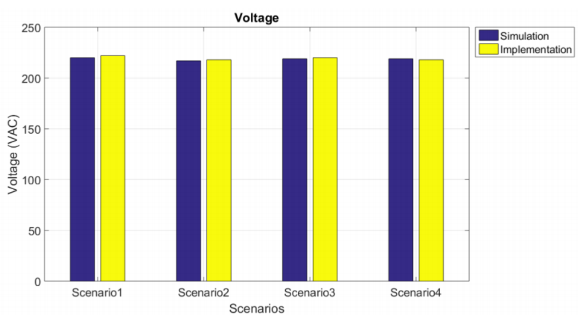

Figure 11: Bar chart representation of simulation and implementation voltage

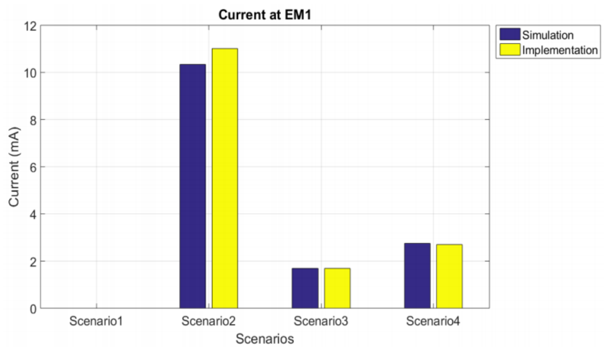

Figure 12: Bar chart representation of simulation and implementation of current measurement results at EM1

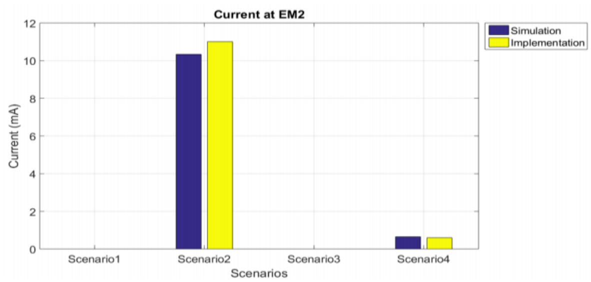

Figure 13: Bar chart representation of simulation and implementation current measurement results at EM2

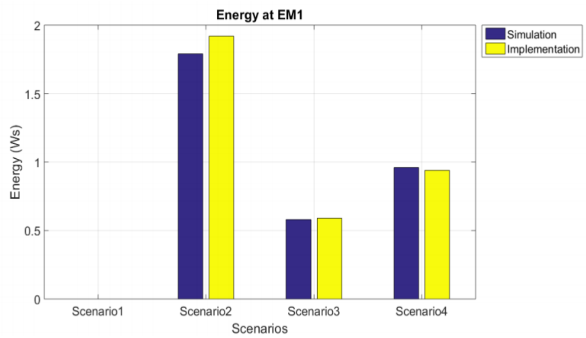

Figure 14: Bar chart representation of simulation and implementation energy measurement results at EM1

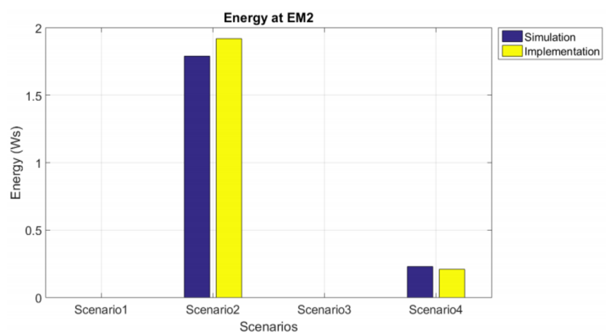

Figure 15: Bar chart representation of simulation and implementation energy measurement results at EM2

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4.5 Validation of Results

An AC voltmeter and AC ammeter were designed during the project implementation as they are needed to calculate wattage and energy consumption. After the successful design of these meters, a multimeter and a variac (variable AC power supply) were used to test, verify, and validate the results. Figure 16 shows the validation stage of this design.

Figure 16: Result Validation stage

The multimeter was used to validate the AC current, while the Variac was used to validate the AC voltage. Table 5 below shows the data obtained during the validation stage, and Figure 17 shows its graphical representation.

Table 5. Result Validation

S/N	Variac AC voltage (V)	System AC voltage (V)	Multimeter AC current (mA)	System AC current (mA)
1	177	175	13.61	13.33
2	186	185	15.01	14.93
3	198	195	15.92	15.88
4	206	205	16.62	16.53
5	216	215	17.59	17.52
6	220	220	18.01	17.92

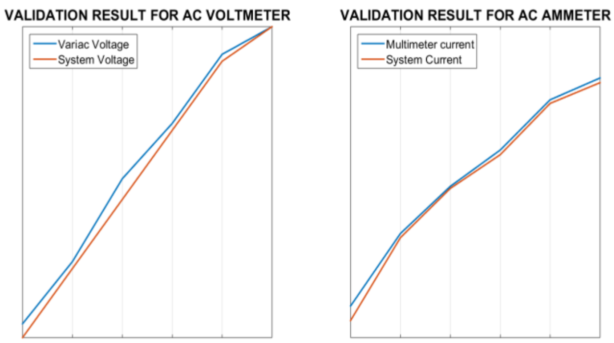

Figure 17: Graph of validation results

5. CONCLUSION

The designed system eases the process of electricity theft identification, and the location of theft is identified using the Mobile Station International Subscriber Directory Number in the GSM module.

6. ACKNOWLEDGEMENT

I wish to thank my project supervisor, Engr. Simon W. Pallam, of the Modibbo Adama University, Yola, for his guidance and support.

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