AUTOMATED SYSTEM FOR DETECTING AND REPORTING ELECTRICITY POWER THEFT

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ABSTRACT

Energy meters play a crucial role in the power sector by measuring electricity consumption, which aids in accurate billing by distribution companies (DisCos). However, electricity theft by individuals, businesses, and institutions leads to revenue losses and inefficiencies. To address this issue, this project develops a system that not only detects electricity theft but also reports it to the appropriate authorities. The system consists of two energy meters equipped with Bluetooth technology, with one also featuring GSM technology for reporting. One meter is installed at the consumer's residence, while the other is positioned at the pole, strategically placed on the return path of the current. The consumer's meter records energy usage and transmits the data via Bluetooth to the pole-side meter. Electricity theft typically occurs when energy is illegally tapped from supply lines, bypassing the consumer's meter. In such cases, the consumer's meter does not register the unauthorized consumption, but the pole-side meter detects the discrepancy, as it measures the total current returning through the system. By comparing data from both meters, the system identifies inconsistencies that indicate energy theft. Once detected, the system automatically reports the theft and energy consumption details to the DisCos, ensuring prompt action and reducing losses. Power distribution companies should adopt the dual-meter system to accurately detect and report electricity theft in real time. Pilot implementation and continuous system upgrades are recommended to ensure effectiveness and adaptability.

Keywords: power theft; energy meter; automated theft detection; bypassing; unauthorized tapping; reporting system

1 INTRODUCTION

Electricity distribution companies (DisCos) in Nigeria suffer significant revenue losses, exceeding N30 billion monthly. These losses primarily result from meter bypassing, vandalism, and unpaid electricity bills. In an attempt to recover lost revenue, DisCos often resort to overbilling unmetered customers through estimated billing methods [1] In a developing country like Nigeria, where economic constraints make implementing advanced solutions like smart grids challenging, there is a need for a simpler yet effective approach to detecting and reporting electricity theft. This project focuses on a straightforward method for identifying electricity theft caused by meter bypassing in residential, commercial, and governmental establishments. The system is designed to not only detect unauthorized energy consumption but also report such incidents to the relevant authorities (DisCo). The system consists of two energy meters equipped with Bluetooth communication. One meter is installed at the consumer's location to measure energy usage, while the second is positioned at the electricity supply pole. A GSM

module facilitates real-time reporting of electricity theft to DisCo [1]. To validate the system's effectiveness, four scenarios were analyzed: No electricity usage at the customer's location. Authorized electricity consumption without theft. Complete bypass of the energy meter. Simultaneous electricity usage by the authorized meter and unauthorized consumption through meter bypassing. These scenarios help in accurately detecting discrepancies and ensuring efficient reporting of power theft.

2 LITERATURE REVIEW

Ajay et al. [2] introduced a system that utilizes an online database to store data related to the distribution system, including timestamps. The stored information comprises dispatched power, voltage usage at specific poles, and pole serial numbers. Voltage levels are plotted over time, and the pole number is used to locate instances of power theft. However, for the system to function effectively, consumer loads must be pre-determined. Supriya et al. [3] proposed a system where the Electricity Distribution Company (DisCo) transmits energy using an RF transmitter. On the consumer's end, an RF receiver captures the transmitted energy and confirms its reception by triggering a micro switch. This confirmation is then sent to the head office through an RF transmitter. Shokoya and Raji [4] suggested that implementing a Smart Grid (SG) would serve as a technical solution to reduce electricity theft and enhance power supply in Nigeria. They argued that Smart Grids could facilitate universal electricity access in sub-Saharan Africa. Nilesh et al. [5] designed a system that employs infrared (IR) sensors to detect power theft. The system uses GSM technology to send meter readings to both the customer and DisCo, including the associated costs. When an SMS is received from an authorized server, communication between the customer and DisCo is initiated. Moreover, power supply to the meter can be remotely disconnected upon request from the authorized server without requiring physical intervention. Sheikh and Auqib [6] explored the use of encrypted power signals to prevent theft in distribution systems incorporating distributed generation. Their work focused on addressing non-technical losses (NTL) in power distribution. They incorporated power semiconductor switching systems at the low-voltage end of the distribution transformer, ensuring that the three-phase supply (R, Y, B) and neutral pass through this switching system. A microcontroller generates bit sequences to control the switches, which are synchronized with smart energy meters through RF transmission. As a result, the power line between the transformer and meter carries an encrypted signal that cannot be used to operate appliances, preventing illegal tapping. Jadhav et al. [7] proposed an automated system that alerts the DisCo head office about electricity theft. The system utilizes magnetic sensors to detect magnets placed on meters and piezo elements to sense meter vibrations. It enables centralized monitoring of power consumption in model organizations such as households. By tracking real-time energy usage, the system differentiates between legitimate and unauthorized users, aiding in theft prevention. Depuru et al. [8] designed a smart metering system comprising an external control station, harmonic generator, and filter circuit. Their goal was to identify illegal consumers, optimize energy use, and prevent wastage. The smart meters provide real-time consumption data, while an external control station calculates NTL in the distribution feeder. If significant NTL is detected, a harmonic generator introduces additional harmonic components to damage appliances of unauthorized users.

3 METHODOLOGY

This work involves the design and implementation of an automated system for detecting and reporting electricity theft. To achieve this, an energy meter (EM2) is installed at the residence of an authorized user. This meter is integrated with Bluetooth communication, following the IEEE 802.15.1 standard for short-range wireless data exchange. The design of the metering system aligns with the IEC 62053 series standards, which specify requirements for electricity metering equipment. Figure 1 below presents a single-line diagram depicting the system layout. These standards ensure interoperability, accuracy, and reliability in the measurement and transmission of energy consumption data.

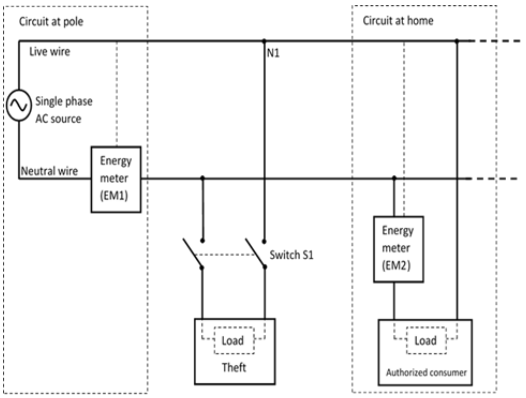

Figure 1. Simplified schematic representation of the electricity theft detection and reporting system.

When switch S1 is closed (indicating that an unauthorized load is connected), both the authorized and unauthorized loads draw their respective currents. At node N1, these currents combine before being distributed to their respective loads. As a result, the current drawn by the authorized load differs from that of the unauthorized load. The two currents merge again in the return path where EM1 is installed, meaning EM1 records the total energy consumed by both loads, while EM2 measures only the energy used by the authorized load. EM2 is integrated with an HC05 Bluetooth module operating in master mode, allowing it to transmit the authorized user's energy consumption data to EM1. EM1, equipped with an HC06 Bluetooth slave module, receives this data from EM2. Since EM1 also functions as an energy meter, it compares its own recorded energy consumption with the data received from EM2. If both readings match (indicating that switch S1 is open), no electricity theft is detected. However, if the readings differ, it signifies that switch S1 is closed, indicating unauthorized electricity consumption. Figure 2 illustrates the block diagram of energy meter EM2.

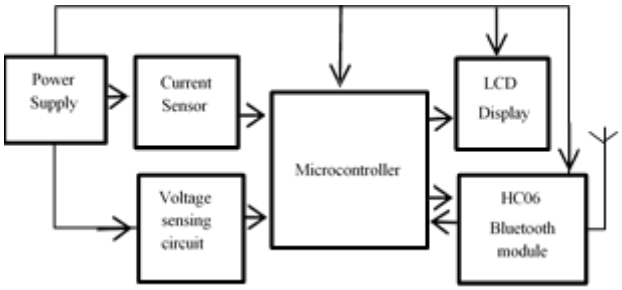

Figure 2. Schematic representation of the energy meter (EM2)

When EM1 identifies unauthorized electricity usage (indicated by a discrepancy in energy readings), it sends an SMS notification to the relevant authority, providing a summary of the theft and the amount of energy consumed. If the theft persists, the system will continue to send reports every 60 seconds. Figure 3 presents the block diagram of the energy meter (EM1).

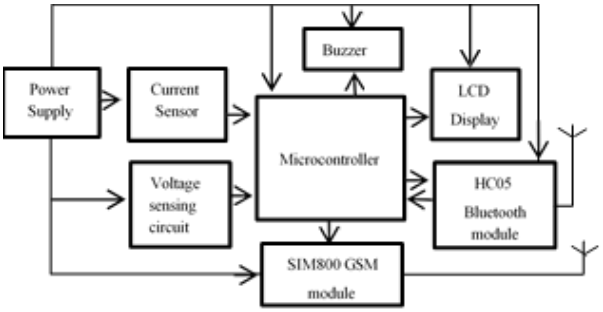

Figure 3. Block diagram of energy meter (EM1)

3.1 Algorithm for Electricity Theft Detection and Reporting

The algorithm flow chart representation is shown in figure 4. The automated system for detecting and reporting electricity theft follows the algorithm below to identify unauthorized power consumption and notify the relevant authorities: Measure the AC voltage and AC current at both EM1 and EM2. Calculate the power consumption by multiplying the voltage, current, and power factor at both EM1 and EM2. Determine the total energy consumed in watt-seconds or kilowatt-hours by multiplying the power consumption with time. Transmit the energy consumption data from EM2 and EM1 to the microcontroller via Bluetooth. The microcontroller compares the energy readings from EM2 and EM1. If both values match, no action is taken. If the readings differ, a report is generated and sent to the relevant authorities, indicating electricity theft. A buzzer is activated whenever the system detects power theft.

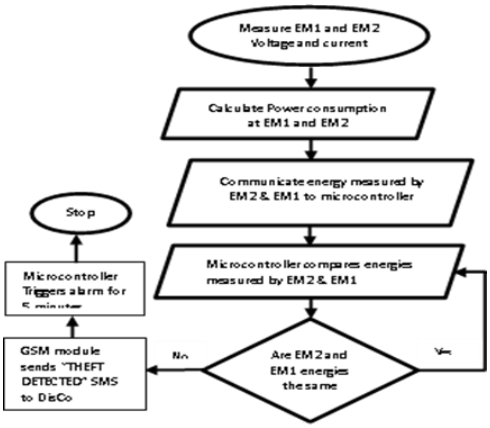

Figure 4. Flow chart of the system

3.2 Simulation Overview of the System

Before the circuit was built and implemented, a simulation was conducted. The simulation for this project was performed using Proteus 8 Professional circuit design suite. This software was chosen due to its extensive library, which includes all the components required for the design. In addition to Proteus, VSPE was utilized to simulate Bluetooth wireless communication between the two energy meters. Figure 5 below illustrates the simulation environment.

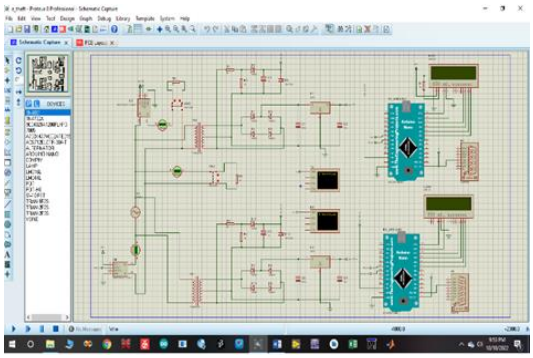

Figure 5. Simulation Environment

4 RESULTS AND DISCUSSION

4.1 Simulation Results

The simulation produced satisfactory results, demonstrating a high level of accuracy in transmitting parameters from EM2 to EM1. The following figures present the simulation outcomes for the four scenarios that were analyzed.

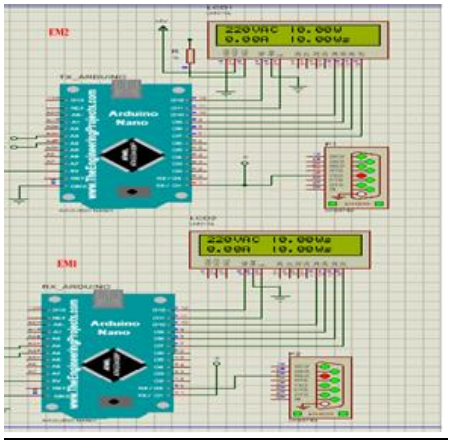

Figure 6. Scenario 1- Zero electricity usage at customer's location

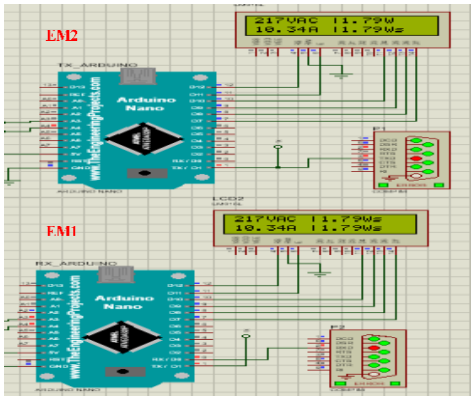

Figure 7. Scenario 2- Authorized electricity user consuming electricity energy without any theft

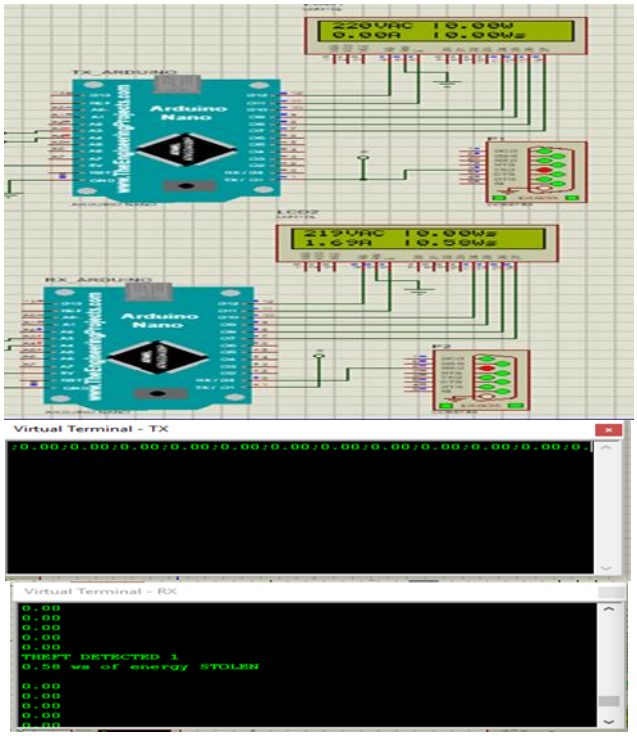

Figure 8. Scenario 3- Energy meter completely by-passed

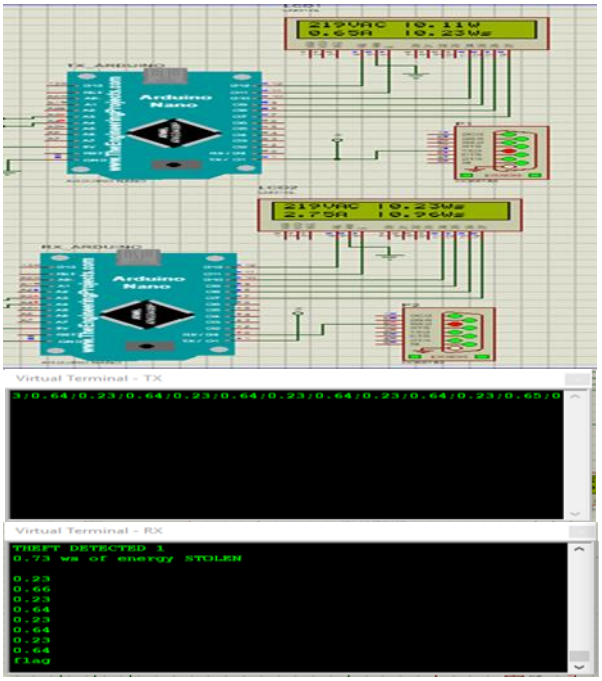

Figure 9. Scenario 4- Electricity usage at the energy meter and electricity also consumed by energy meter by-pass

4.2 Summary of Simulation Results

Table 1 presents a summary of the simulation results for Energy Meter 1 (EM1) and Energy Meter 2 (EM2). The data for scenarios 1 and 2 were recorded after 1 second, whereas the results for scenarios 3 and 4 were obtained after 2 seconds.

Table 1. Simulation Results

Energy Meter	Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 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

The simulation results obtained in this study were evaluated against findings from existing literature to assess their validity and alignment with typical energy usage patterns in low-voltage residential

settings. The simulated voltage levels for both Energy Meter 1 (EM1) and Energy Meter 2 (EM2) remained within the range of 217–220 V across all four scenarios. This aligns with the standard voltage range of 210–230 V reported in studies on Nigerian and Sub-Saharan distribution networks [9]. The observed current values ranged from 0.00 to 10.34 mA, which are notably lower than the 500–2500 mA range typically associated with residential appliances such as fans, TVs, and lighting [10]. This suggests that the simulation focused on ultra-low power devices, such as sensors or metering systems, rather than conventional household loads. Energy consumption in the simulations varied between 0.00 Ws and 1.79 Ws, consistent with literature findings on energy usage for lightweight electronic and IoT systems [11]. The power calculation for Scenario 2 (1.79 W) further corroborates the internal consistency of the voltage and current parameters recorded. Additionally, the simulation demonstrated energy transfer between EM2 and EM1 in Scenarios 2 and 4, indicating a potential peer-to-peer or distributed energy sharing configuration. This is conceptually supported by studies on cooperative energy metering in smart grid environments [12]. Overall, the simulation results align well with established benchmarks for voltage and energy use in low-power metering systems and reflect emerging trends in distributed energy management.

4.3 Implementation Results

The developed system was tested under conditions identical to those used in the simulation to enable a comparison of results. Table 2 presents the outcomes after implementation. The data for scenarios 1 and 2 were recorded after 1 second, while the results for scenarios 3 and 4 were obtained 2 seconds after a bypass attempt.

Table 2. Implementation Results

Energy Meter	Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 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

At the implementation stage, the system generated and sent an SMS report to the distribution Company once theft was detected, as depicted in Figure 10.

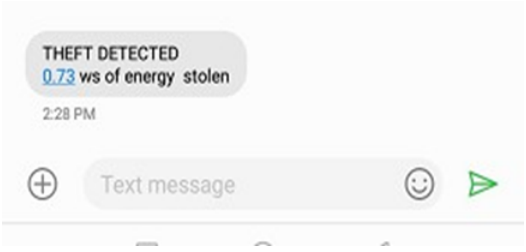

Figure 10. SMS notification sent to the Distribution Company upon detection of theft

4.4 Comparison of Simulation and Implementation Results

The results from the simulation and implementation are compared using bar charts, as shown in Figures 11 to 15.

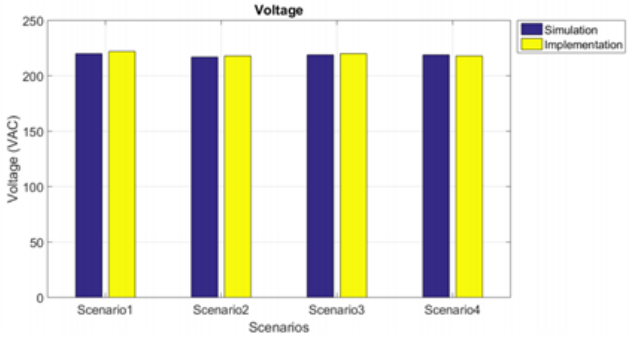

Figure 11. Bar chart comparing the voltage results from simulation and implementation

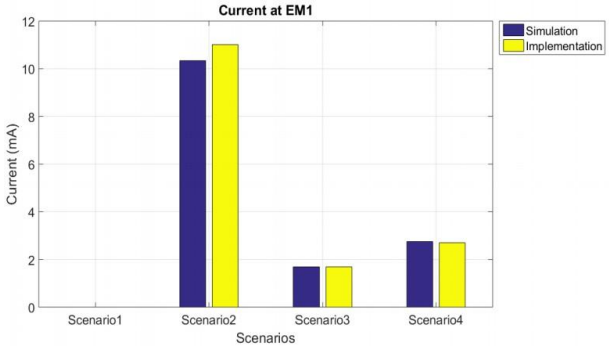

Figure 12. Bar chart comparing the current measurement results at EM1 from simulation and implementation.

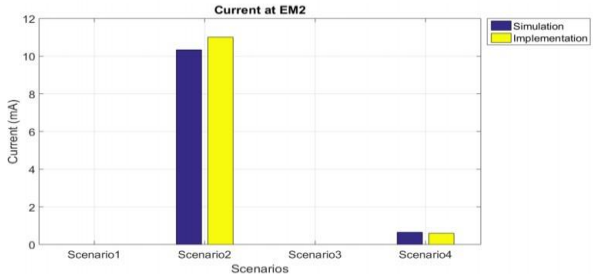

Figure 13. Bar chart comparing the current measurement results at EM2 from simulation and implementation

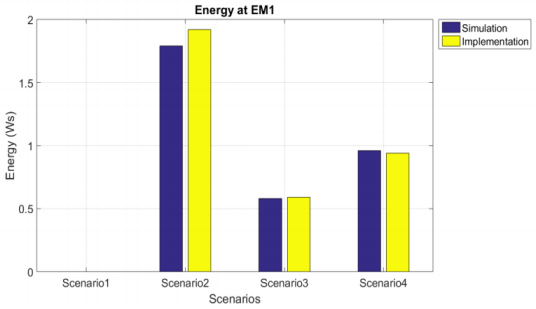

Figure14. Bar chart comparing the energy measurement results at EM1 from simulation and implementation

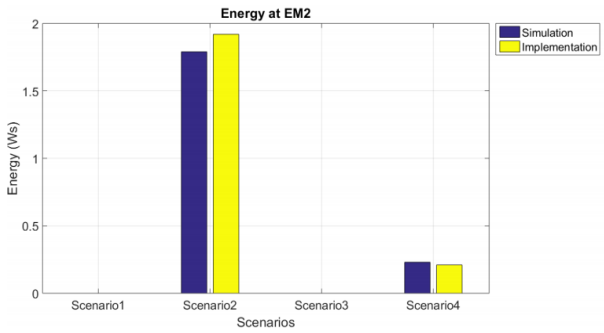

Figure 15. Bar chart comparing the energy measurement results at EM2 from simulation and implementation

4.5 Validation of Results

During the project implementation, an AC voltmeter and an AC ammeter were designed to measure wattage and energy consumption. After successfully designing these meters, a multimeter and a variac (variable AC power supply) were used to test, verify, and validate the results. Figure 16 illustrates the validation phase of this design.

Figure 16. Validation of Results

The multimeter was employed to verify the AC current, while the Variac was used to confirm the AC voltage. Table 5 presents the data collected during the validation stage, and Figure 17 provides its graphical representation.

Table 5. Results of 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

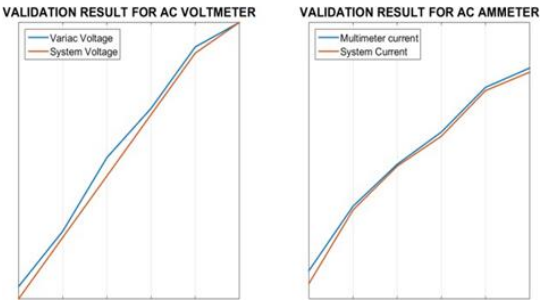

Figure 17. Graphical representation of the validation results

5 CONCLUSIONS

The developed system simplifies the identification of electricity theft, with the theft location determined using the Mobile Station International Subscriber Directory Number in the GSM module. In conclusion, the system has successfully met its objectives.

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