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Research Article

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PORTABLE POWER THEFT DETECTOR USING ELECTROMAGNETIC WAVES

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ABSTRACT

Electricity provides the best life that can offer through technology. In third-world countries, electricity is expensive. Thus, many have been attracted to electricity theft through wire tapping's. This alarms the electric company, which legit consumers will pay the overhead. This research developed and tested the functionality of the theft power detector using Arduino to mitigate the problem by the electric company. Using a self-made questionnaire by statistically analyzing using the mean, the results are very acceptable. Simulations were carried out by adding load, which shows abnormal conditions. The results appear to increase power rating, transmitting the signal as the alarm that electricity theft was happening.

Keywords: Power theft detection, Arduino, Theft of electricity, Electromagnetic wave, Portable.

INTRODUCTION

Stealing electricity is a significant problem for electricity distribution companies (Jamil, 2013). Electricity theft is responsible for economic issues for the electric utilities due to revenue loss caused by electricity consumers that are not paying for it (Arango *et al.,* 2016). The most used methods for stealing power are bypassing the phase line, cutting the neutral line, bypassing the entire meter, and distorting the energy meter to avoid the enormous electricity bill (Jaiswal *et al.,* 2020). In the Philippine settings, the most common is bypassing the entire meter which sometimes the main causes of fire due to overload of the line (Budd, 2008). In today's technology-driven society, when appliances and devices rule our lives, the importance of power cannot be overstated (Balta-Ozkan *et al.,* 2013). Nevertheless, there are still areas where power is not available, and their residents do not have access to this (Aries & Newsham, 2008). There are several reasons for this, including insufficient power generation, loss, and geographical terrain (Potts *et al.,* 2010). In Philippine settings, electricity is expensive specially in the Mindanao because of limited renewable energy and relies on carbon and diesel power plants, thus people under poverty tempted to theft electricity (*Plundering Paradise: The Struggle for the Environment in the Philippines - Robin Broad, John Cavanagh - Google Books*, n.d.). The current System monitors and detects power theft using a simple power theft algorithm, notifies the consumer via GSM communications, and cuts off the power supply as needed (Gupta *et al.,* 2020). A separate message is sent back to the microcontroller to remove the illegal supply when illegal actions are detected (*Automatic Power Theft Protection Using Arduino*, n.d.). An SMS is sent automatically to the user via the GSM module. When the prepaid load units purchased equaled the units consumed, a warning message is sent to the user's mobile via the GSM module, and the power supply is cut-off (*DSpace at My University: Presentation on Prepaid Energy Meter Using GSM & Arduino*, n.d.). Since GSM is internet dependent, and when in times of calamity, intermittent GSM connection can cause theft undetected (Bocan & Creţu, 2006). This research implements a wireless direct connection from Arduino using electromagnetic wave.

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The development of the system has two modules, a device one that detects the theft with wireless module and the device two that receives the transmitted signal and give information to the authorities that theft of electricity is happening (Berdaliyev & James, 2016).

Related Literature

Electricity is a necessary component of our daily lives. The loss of electricity typically occurs in the generation, transmission, and distribution system. Technical Losses (T.L.) and Non-Technical Losses (N.L.) are the two types of electricity losses (NTL) (Ahmad, 2017). Electricity theft is the most common cause of non-technical losses in the power system (Nagi *et al.,* 2008). Electricity theft is a crime or criminal activity that involves interfering with the electricity meter, bypassing the meter, or hacking the meter. Power theft is most certainly the most severe issue that developed and developing countries throughout the world are dealing with. On the 30th and 31st of July 2012, India had the worst blackout, which occurred on two distinct dates. Over 620 million people in India, or nearly 9% of the world's population, were affected by the blackout (*Smart Meters Take Bite Out of Electricity Theft*, n.d.). Different tactics and strategies were used to combat the power theft anomalies because of the surge in power losses on the power system. A study was carried out to identify power theft, inform users, and turn off the supply as necessary. When power theft is identified, a Short Message Service (SMS) is given to the users through the GSM module, according to the method created in the study. The author also said in the paper that the electrical companies had uncovered specific issues with the technique of monitoring electricity consumption on each meter (Lin *et al.,* 2021a). Their approach, such as the traditional credit metering and billing system, is far more time-consuming. It results in incorrect meter readings, unproductive recollection, inept consumption monitoring, and uses significantly less energy. As a result, the author devises a novel solution to the problem. The development of a theft detection-based GSM prepaid system is a system that is used to solve problems with electricity consumption, avoid bill payments, avoid meter reading errors, and combat power theft (*Conservation, Tourism and Pastoral Livelihoods: Wildlife Conservancies in the Maasai Mara, Kenya - UCL Discovery*, n.d.). There are also different methods to determine and monitor power theft anomalies. Using webpage monitoring systems, algorithms methods, and real-time detection scenarios are also convenient methods to use. Due to technology development, an advanced monitoring system is used to monitor electricity theft (Lin *et al.,* 2021b). IoT (Internet of Things) prevents and monitors electricity theft without human intervention. IoT was selected due to the rapid growth in technology, and IoT utilization has become drastic. Internet of things-based power theft detection was designed to detect unauthorized tapping of conductors through a controller that receives current signals from the current transformer through a bridge rectifier and a conditional operator that compares the current magnitude (Rajasekaran *et al.,* 2020). The authors of this paper focus on a practical and cost-effective solution to the problem of power theft in the distribution system. Calculating the voltage drop and increased current flow: There are many different techniques to determine and monitor power theft irregularities. Algorithms, real-time detection scenarios, and website monitoring systems are excellent options. Because of technical developments, electricity theft is tracked using an effective monitoring system. IoT (Internet of Things) prevents and monitors electricity theft without human intervention. Because of the rapid growth of technology and the rising use of IoT, it was picked. The Internet of Things-based power theft detection system uses a controller that receives current signals from the current transformer through a bridge rectifier and a conditional operator that compares the current magnitude to identify illegal wiretapping. Because of electricity theft, a distribution line has been cut. Electricity theft is a significant challenge in AMI, resulting in millions of dollars in annual revenue losses in industrialized and poor countries. A principal component analysis method was used in the study to solve the problem of power loss and theft activities on the Advanced Monitoring Infrastructure (AMI). The study proposed a quantitative analysis to establish the sensitivity, specificity, and success rate for measuring the theft magnitude determination accuracy. The paper presented an extensive and deep neural network. The method has a wide component and a deep CNN component. The Deep CNN component can reliably identify non-periodicity usage based on two-dimensional electrical consumption data. On the other hand, a Wide component can capture global characteristics of 1-D electricity consumption data. The authors create and test a system that can detect electricity theft by detecting minor differences in real-time data and those of a trained model. Voltage and current sensors make up the energy metering system, while a Support Vector Machine (SVM) model is trained and utilized to classify users as either clean or fraudulent. To identify the current rating of the meter and an isolation device to prevent theft in electrical power networks, the authors employed a network analysis model and constructed four essential components.

Theoretical Framework

According to electromagnetic waves theory, the electric and magnetic fields flow through space as waves at the speed of light. Hertz later established that the electromagnetic field did indeed exist. He also demonstrated that the speed and length of electromagnetic waves might be measured. The incident beam has a wavelength λ_i, a frequency v_i, and a velocity c_0, while the refracted beam has a wavelength s, a frequency v_s., and a velocity c, according to the simple dispersion relation for vacuum. The electric and magnetic qualities of a medium influence the speed of light in that medium, and the speed of light in a vacuum can be described as;

$$c_0 = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$$

ε_0 is equal to the electric permittivity

μ_0 is equal to the magnetic permeability [15].

The speed of light in a material to the material "constant" ε_s and the corresponding magnetic permeability μ_0 of a vacuum and μ_s of the material is

$$c = \frac{1}{\sqrt{\mu\ \ \mu_0 \varepsilon\ \ \varepsilon_0}}$$

When created fields pass through magnetic materials that contribute to internal magnetic fields, it can be difficult to tell how much of the field comes from external currents and how much comes from the material itself. Another magnetic field quantity is typically referred to as "magnetic field strength" and is defined by H. The relationship can define it.

$$B = \mu H + M$$

M = magnetization. Normally, the M = 0 for nonmagnetic material if in air, μ_0 = 1.26x10-6H/m

Any closed surface generates zero magnetic flux. This essentially amounts to a claim regarding the magnetic field's sources. Any magnetic flux flowing inward toward the South Pole equals the flux directed outward from the North Pole for a magnetic dipole. In dipole sources, the net flux is always zero. This would result in a non-zero area integral if there were a magnetic monopole source.

$$B = 0$$

B is the magnetic flux density (Web/m2, T)

Any closed surface's electric flux is proportional to the total charge contained within the surface. Gauss's Law's integral form calculates electric field charge objects. When Gauss's Law is applied to the electric field of a point charge, it is consistent with Coulomb's Law. While the area integral of the electric field represents the net charge confined, the electric field's divergence represents the source's density. It has ramifications for charge conversion as well.

$$E = \frac{\rho}{\varepsilon_0}$$

E is equal to the Electric Field (V/m)

$\boldsymbol{\rho}$ is the charge density (c/m^3)

ε_0 is similar to the electric permittivity

Conceptual Framework

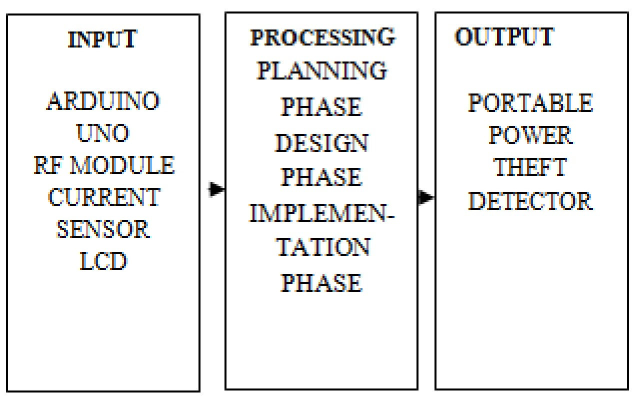

Figure 1. Block diagram of the IPO

Figure 1 depicts the study's input, processing, and output block diagram from the conceptual framework.

Objectives

The general objective of this project study is to detect illegal connections to electrical lines and avoid Non-Technical loss of the System.

Specifically, it aimed to;

- Design a device to detect power theft
- Develop the Device
- Test the performance of the Device

METHODS

Research Design

The researchers utilized an observational strategy, which compares participants to a control group at the end of the study. It enables researchers to see how their participants react when faced with numerous options or situations. The word refers to observing and recording behavior in a non-experimental environment.

Project Design

Device 1

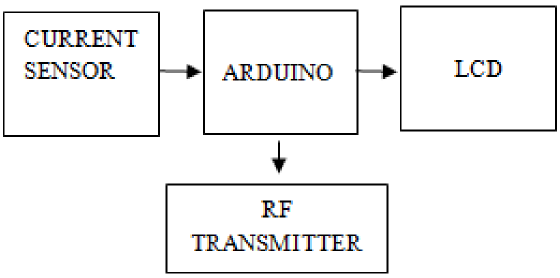

Figure 2. Block Diagram of device 1

Device 2

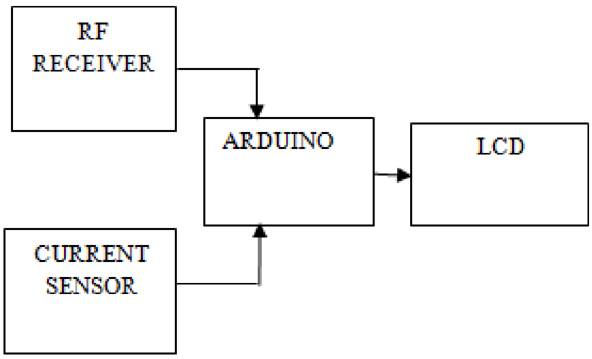

Figure 3. Block Diagram of device 2

The researchers' study is depicted in the block diagram. The first circuit includes an Arduino, a current sensor, an LCD, and a radio frequency transmitter. The second circuit has an Arduino, LCD, R.F. receiver, current sensor, and consumer load. The System is activated when the first circuit is clamped in the distribution lines and the second circuit is clamped in the consumer's electric meter. The Arduino in the first circuit will detect electricity theft using a current sensor, calculate the amount spent, and broadcast the data using an R.F. transmitter. R.F. modules, which employ an electromagnetic wave to transmit data, are used in this System. The receiver receives data in the second circuit. The Arduino configures the amount of electricity utilized by the customer and the amount of electricity consumed by the theft. It then appears on the LCD. In a typical circumstance, the second circuit transmits current consumption data to the first circuit, which compares in its measure line currents. And if the two sets of data are identical, there is no evidence of theft on the LCDs.

Project Development

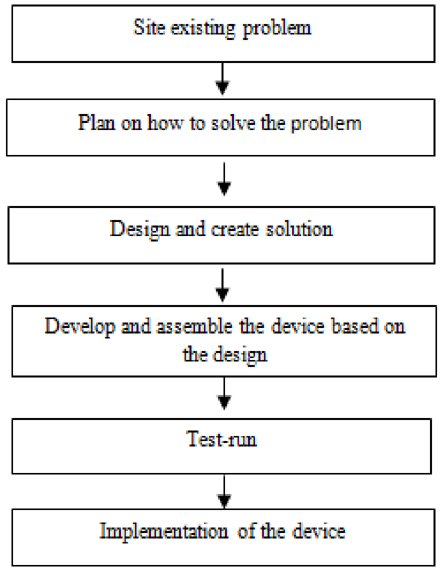

Figure 4. Project Development

From the beginning of the process to the end, the evolution of the project depicts the process and how the actual Device will evolve. During this step, the researcher must identify a problem that needs to be addressed within the community. The researcher will design and create an appropriate solution depending on the issue that has been identified after determining the problem. The researcher will then collect all required materials and begin developing and building the Device. After being constructed, the Device will be evaluated for functionality before being used in the designated region.

Project Implementation

To do this, the researchers devise a rudimentary distribution system that would be used to test the Device's effectiveness. This simple distribution system aims to keep the researchers secure while they do their research. The simple distribution system comprises circuit breakers, a switch, a load, and an electric meter. There were two parts to the test. The initial step is to install the Device in the distribution line under normal operating conditions, where the process data is recorded. The load is then bypassed to the electric meter in the second section. When an electricity theft occurs, the Device is connected to the distribution line, and data is recorded. The two data sets collected after the two tests must be compared to ensure that the Device can detect power theft.

Project Setting

Figure 5. Location Map

The project's implementation site is depicted in Figure 5. P-Paradise, Penaranda Street, Brgy. Taft, Surigao City, will be the location of the research.

Participants of the Study

Participants	f(n=10)	% of Involvement
Residents	7	70
SURNECO	3	30
Total	10	100

Table 1. Participants of the Study

Purposive sampling was used in this investigation. Purposive sampling was used to ask residents and some members of SURNECO about their knowledge and opinions on electricity theft. The three SURNECO members were also chosen to consult on the project because they are more knowledgeable and trustworthy in this area. As a result, the researchers enlisted the support of ten people to complete their tasks.

Instruments

- Simulation
- Tabulation

To evaluate the Device, the researcher employed simulation. A basic distribution system was built, and the Device was tested for reading current in normal conditions and detecting power theft in abnormal situations. The researcher used data tabulation to evaluate the Device's ability to see current on various loads, including resistive, inductive, and capacitive loads.

Research Ethics

In the proposed endeavor, the researchers pick objectivity and intellectual property ethics. Avoiding bias in experimental design, data processing, data interpretation, peer review, personal decisions, grant writing, expert testimony, and other elements of research is what objectivity is all about. It reveals any personal or financial changes that could impact the analysis. Patents, copyright, and different types of intellectual property are all examples of intellectual property that should be respected. To avoid plagiarism, always provide credit where credit is due to the author.

Data Collection Procedure

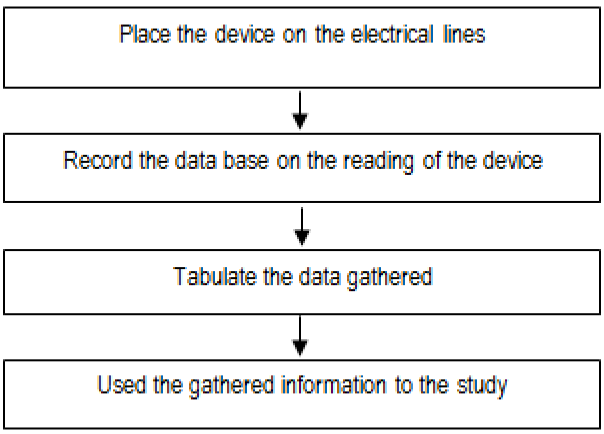

Figure 6.Block Diagram

The data collection gathers information from the produced devices' output. The researchers will first test the Device on the electrical lines in a normal situation based on the consumption power of the consumers. Then they will try their Device in a condition where an unlawful connection is present and compare the two data sets.

Statistical Tools

- Mean

As a statistical tool, the researcher employed the mean. The Device's functioning is assessed using this tool. The researcher used the data acquired from the 10 study participants who evaluated the Device to calculate the overall mean and come up with a very satisfactory evaluation.

Financial Analysis

Product costing is a financial analysis tool used on a commercialized project. The product costing tool will provide project transparency and calculate all project costs, including labor costs. The following formula can be used:

$$\text{product cost} = \frac{(\text{total DM}) + (\text{total DL}) + (\text{total overhead})}{No. of\ units}$$

Direct materials	Amount
Arduino	₱ 1000
RF Modules	₱ 100
LCD	₱ 390
Connecting Wires	₱ 200
Arduino Acrylic Case	₱ 90
Current Sensor	₱ 1000
Resistor	₱ 24
Capacitor	₱ 40
Battery 9V	₱ 120
Potentiometer	₱ 40
PCB	₱ 80
Device casing	₱ 150
Antenna	₱ 100
Total	₱ 3334
Direct Labor Cost	₱ 1000
Manufacturing overhead	
Others	₱ 1500

$$\text{Product Cost} = \frac{(\text{total DM}) + (\text{total DL}) + (\text{total overhead})}{No. of\ units}$$

$$product\ cost = \frac{(3334) + (1000) + (1500)}{1}$$

$$\text{Product Cost} = ₱\,5834$$

So the product cost in commercial is 5834 pesos.

RESULTS AND DISCUSSIONS

Design of the Power Theft Detector

Figure 7. Hardware Design of the System

The figure shows the hardware design of the System for the project study.

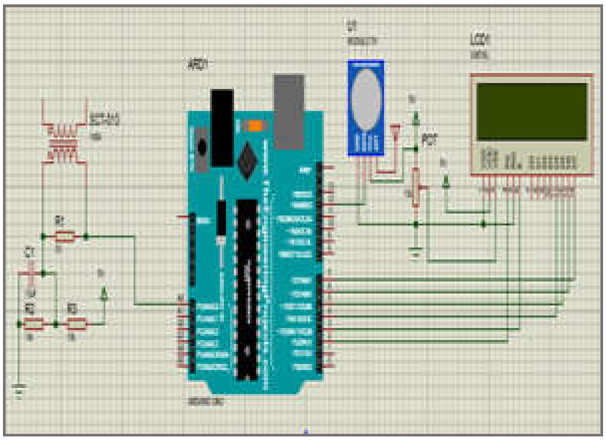

Figure 8. Schematic Diagram of Device 1

The schematic diagram of device 1 with all of its components is shown in the illustration. The SCT- 013 current sensors are shown on the left. A load resistor provides a few ohms of resistance. It prevents inrush current from affecting the Device to which the power unit is connected. The current sensor is then attached to the microcontroller's analog pin A0. The R.F. module transmitter's data pin is connected to the microcontroller's digital pin side. The 16 by 4 LCD displays and prints data on the screen.

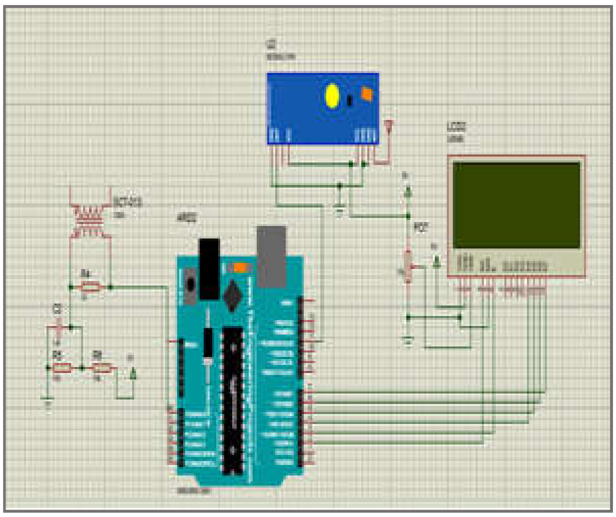

Figure 9. Schematic Diagram of Device 2

Device 2 has the same design as Device 1. The sole difference is that it employed an R.F. receiver module to receive data from the other Device and a 20 by 4 LCD to display more variables on the screen.

Simulation of the Develop System

Figure 10. The figure shows a simple distribution system

A primary distribution system is shown in Figure 10. The researchers used this basic distribution system to test the Device's affectivity in detecting a power theft in unusual circumstances.

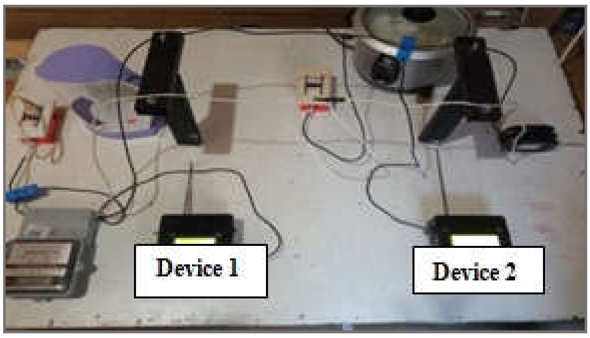

Figure 11. The figure shows the Device was being tested

Two devices are connected on the primary distribution line depicted in Figure 3.2. Device 1 is used to monitor current use on the consumer's end. The distribution line is connected to Device 2, which is a current consumer meter that detects power theft. As depicted in the diagrams, the two devices were subjected to the test in normal situations. The researchers assigned a load to a water heater with a 60-hertz frequency and 900 watts of power.

Figure 12. Shows the Device 1

Device 1 reads the current consumption on the consumer's side, as shown in the diagram. When the heater is turned on, the Device measures the current.

Figure 13. Shows The Device 2

The current reading from Device one was communicated to Device two and displayed on the LCD, as shown in the diagram. Because the researchers tested the Device under normal conditions, there is no current power theft. The Device reports that there is no theft

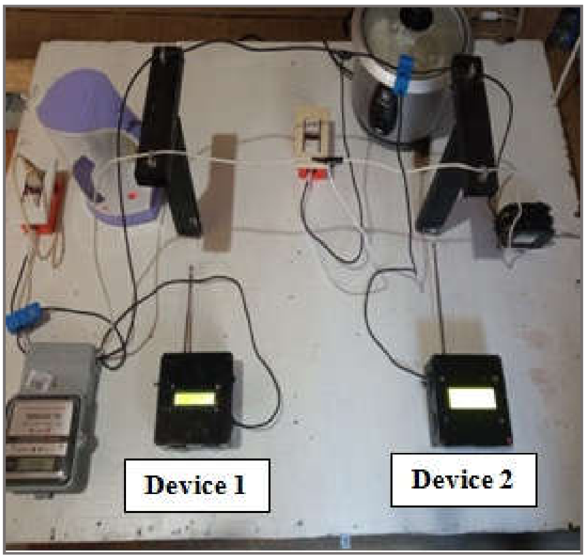

Figure 14. The figure shows the Device tested under abnormal conditions

The researcher in this illustration tries the Device's functionality in unusual circumstances, such as when electricity is being stolen. A rice cooker is being used as a power thief at this time. A water heater is classified as a load on the consumer side.

Figure 15. Shows the Device 1

Device 1 reads the current consumption on the consumer side under abnormal conditions, as shown in the diagram.

Figure 16. Shows the Device 2

The current reading from Device one was communicated to Device two and displayed on the LCD, as shown in the diagram. The Device detected power theft and displayed it on the LCD because it was tested under unusual circumstances.

Test the Performance of the System

Figure 17. The System is Tested Using more Loads

The System is tested with two additional loads in the figure to see how it performs in this situation. Load number one, a flat iron, and load number two, a water heater, accounted for most of the consumer side load usage. The System is tested with two additional loads in the figure to see how it performs in this situation. Load number one, a flat iron, and load number two, a water heater, accounted for most of the consumer side load usage.

Figure 18. Reading of the Actual Device

The Device that reads the total current consumption of both loads connected on the consumer side is shown in the diagram. The Device that reads the total current consumption of both loads connected on the consumer side is shown in the diagram.

	POWER(KW)	VOLTAGE	CURRENT
LOAD 1	1000	230	4.34 A
LOAD 2	900	230	3.91A
TOTAL	1900	460	8.25 A
DEVICE READING			7.87 A

Table 2. Tabulation of Data Under normal conditions

The table below depicts the load configuration used in the study to evaluate the System's performance. The calculation of both loads is shown here compared to the produced Device's reading.

Figure 19. The System tested under the abnormal condition with more loads

The System is tested in an atypical situation where more loads are stacked on the distribution line, as shown in the diagram. Load 1 is a flat iron, and load 2 is a water heater. Therefore, the load consumption on the consumer side is applied. Load 3 (the rice cooker) and load 4 (the electric fan) operate as inductive loads on the theft side.

Figure 20. Reading of the Actual Device

The picture depicts the accurate reading of the Device, which detects power theft by detecting the current in abnormal conditions on both the source and consumer sides of the distribution system. The picture depicts the accurate reading of the Device, which detects power theft by detecting the current in abnormal conditions on both the source and consumer sides of the distribution system.

CONSUMER'S LOAD	POWER (KW)	VOLTAGE	CURRENT
LOAD 1	1000	230	4.34 A
LOAD 2	900	230	3.91 A
TOTAL	1900	460	8.25 A
DEVICE READING SOUCRE LOAD			7.87 A
LOAD 3	400	230	1.74 A
LOAD 4	20	230	0.08 A
TOTAL	420	460	1.82 A
DEVICE READING			1.39 A

Table 3. Tabulation of Data Under Abnormal Condition

The configuration of all the devices used to test the System's performance under abnormal conditions is shown in the table. It compares the actual readings of two devices to the total current on both the consumer side and the source line of the distribution system.

FUNCTIONALITY	MEAN	DESCRIPTION
1.) Reads current on both sides of the distribution line	4	Very Acceptable
2.) Detects and calculate the consumption of current from the source load to the consumer's load	4	Very Acceptable
3.) Transmit data wirelessly	3.6	Very Acceptable
4.) The Device read an actual reading based on the configuration of the load used	3	Acceptable
Overall Mean	3.6	Very Acceptable

Table 3. The functionality of the Device

Table 4 shows the data of the Device functionality as evaluated by ten evaluators. The first item got a mean of 4 which means it has very high acceptability. The Device was able to read the current consumption for both sides of the consumer and the distribution system source. The second item also got a mean of 4, which falls to the descriptive rating of very acceptable. The next item got the mean of 3.6, and the Device has a very acceptable rating for transmitting data wirelessly. Then the last item got an acceptable descriptive rating with a mean of 3. The overall mean is 3.6 is equivalent to the descriptive rating of very satisfactory. With this, it implies that the Device is functioning well.

CONCLUSIONS

The researcher used Proteus software to create the schematic diagram for the Device. The design includes an Arduino Uno microcontroller, SCT-013 current sensors, a Radio Frequency module, and LCDs. The created Device was successful because it could read current readings on both the consumer and distribution lines under normal and abnormal conditions. It may also detect power theft when an unlawful connection is made. The Device's performance in detecting and reading current with diverse loads attached to the distribution line is excellent. It can also read current on several loads, including inductive and resistive loads.

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