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Household electric monitoring IoT system

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ABSTRACT

In dense areas in the Philippines, there are recorded cases of power theft or known to be illegally tapping power lines from another household which results to complaints because of increased electricity bills. To address the power theft problems, this work uses internet of things system for household electric monitoring and control. A transmitter and receiver set up is designed to monitor the energy consumption at both ends. When there is discrepancy with the meter reading, an alert system sends notification that there is an illegal wiretapping. The load is monitored through electric meters and the powers measured are compared. These data are being sent wirelessly through a GSM module. The meter readings for both the transmitter and receiver can be viewed in a mobile phone through a web app developed. A minimum of 3W difference between the transmitter and the receiver will mean a discrepancy and notifies illegal wiretapping. Illegal connections are cutoff when an incident of tapping occurs. Based on the results of the test, the household electricity monitoring system through internet of things (IoT) is found to be 100% reliable in detecting and cutting off illegal connections. Additionally, the system is able to compute the monthly power consumption.

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1. INTRODUCTION

The internet of things (IoT), is a system of interrelated computing devices, mechanical and digital machines, objects, animals, or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction [1]. This allows people to connect daily activities or devices over the internet. This is geared towards using wireless systems wherein the different devices are connected using the internet. Power theft is one of the biggest problems nowadays which causes increased electricity bills and loss of electricity boards. Some of these are done through line tapping, thus electrical power theft detection can possibly be developed [2].

Other countries like the Indian State and Ghana have experienced theft and loss of electricity [3]–[5]. In the Philippines, a lot of cases were reported especially in dense areas [6]. Electricity theft in power lines before the power meter of the provider can be penalized under the Philippine Republic Act 7832 or the Anti-Electricity Pilferage Law. Electricity theft is a crime that is largely undocumented [7], [8]. In the Philippines, some power meters are placed in a relative distance from the service equipment, located inside the household which could be vulnerable to electricity theft.

IoT technology was used in various fields such as smart home, smart building, smart metering, smart environment, commercial applications and others [9]–[11], which in effect could contribute to the conservation of energy [12]. The study of [13] achieved a green networked IoT through a proposed simple, Wi-Fi-enabled and low-cost electricity monitoring system that can track the electricity usage of home

appliances and analyze the electricity usage on a daily and weekly basis. The electricity consumption was monitored in a house with four household members, monitoring the use of appliances. It was observed that during weekends, the overall energy consumption is higher than on weekdays, and the energy consumption at nighttime is greater than in daytime. It shows that IoT is helpful in monitoring electricity consumption and can also monitor other physical parameters through sensors via Wi-Fi module chip and unto the database. Although IoT promises solutions to current problems, there can still be new challenges such as cybersecurity, privacy, and added power consumption of the devices used [14]. The most cost-effective and accessible microcontrollers were found to be Arduino and Node MCU, while it remains a challenge to digitize the signals for accurate measurement of parameters such as voltage and current in electrical lines.

Detecting electricity theft has been a challenge to the law enforcement bodies, while some have developed algorithms based on the consumptions of the customers [15]–[17]. Although these algorithms may have promising outcomes, there still lies hidden theft that is difficult to detect unless a robust system is developed. Real-time systems with data loggers have been attempted to solve such problems [18], yet, an end-to-end verification from the electricity provider to the consumer side is needed. To avoid such thefts, power switches were also developed where the power lines are being cut off [19], however, the jumper lines connected by thieves could not be identified yet.

Emerging technologies such as IoT play a significant role in solving modern problems like electricity theft [20]–[23]. Smart systems for monitoring power were developed using the ubiquity of IoT [24]–[28]. In household electricity monitoring [29], when the current from the meter is not equal to what is being consumed in the household, this could mean a power theft has been attempted. When illegal connection occurs, the household is notified by light a indicator and buzzer. The drawback in this system is that the household is not aware that electricity theft occurs whenever they are out for work or other activities. Hence, electricity theft may persist if the household is not around.

This study aims to develop a system that detects electricity theft in power lines after power meter provided by the provider and automatically cuts the electricity when an attempt an attempt to power line tapping is done. The monitoring of the electricity consumption (including electricity theft) is real time and IoT-based which are monitored through a web application developed. Additionally, a notification is sent via short message system (SMS) when an illegal connection is done. The probe team can check for the power lines for the illegal line tapping.

2. METHOD

2.1. System setup

The system is composed of two modules, the transmitter and receiver. The transmitter side is located in the pole, right after the meter whereas the receiver side is located in the service equipment inside the household. Both the transmitter and receiver side use an electricity sensor to measure the electricity being consumed as shown in Figure 1.

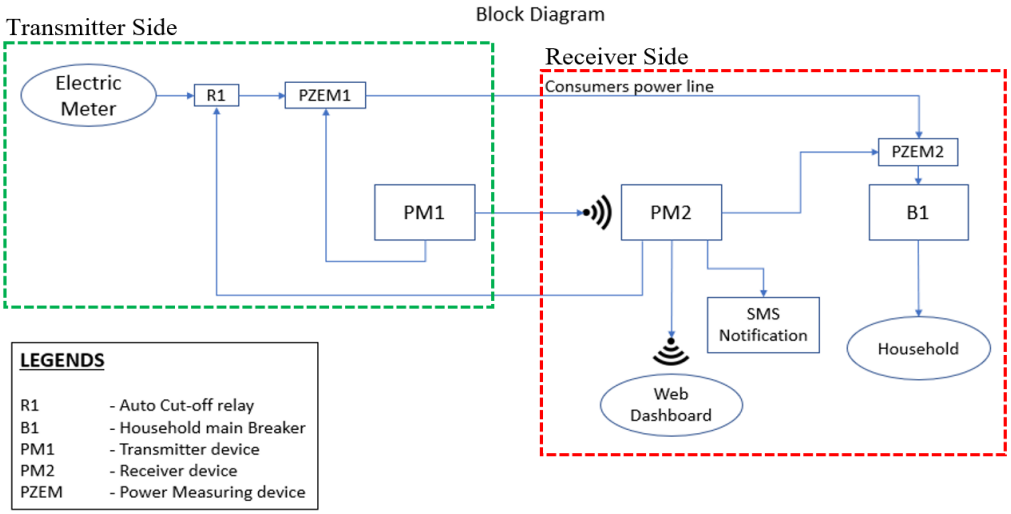

Figure 1. Block diagram of household electric monitoring system through IoT. This shows the transmitter and receiver side setup

In actual application, the system setup can be viewed in Figure 2. The power meter can be mounted with permission to the service pole with a sealed meter box. The wireless transmission can be up to 30 meters. The power thieves are defined as those who connect jumper lines between the household and the power service poles. When the difference in the measured power from both power meters is below 3 watts, an alarm is triggered, and a notification is sent via SMS and through the IoT web app developed.

The transmitter and receiver module setup are presented in Figures 3 and 4 respectively. The transmitter module consists of NRF2401, as the wireless module, Arduino Nano microcontroller, PZEM-004T as the energy monitoring unit, and an LED indicator. The receiver module consists of NRF2401, PZEM-004T, GSM module SIM800L, and ESP32 as a microcontroller unit.

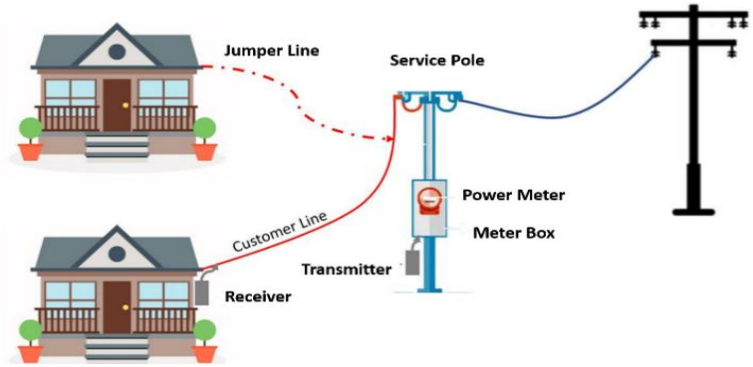

Figure 2. The project set up where the transmitter and receiver in the customer power line

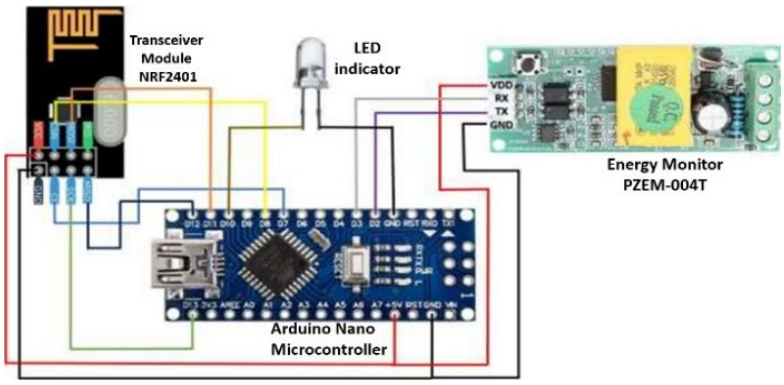

Figure 3. Transmitter module wiring diagram composed of the NRF2421 transciever, an LED indicator, Arduino Nano microcontroller, and PZEM-004T energy monitor

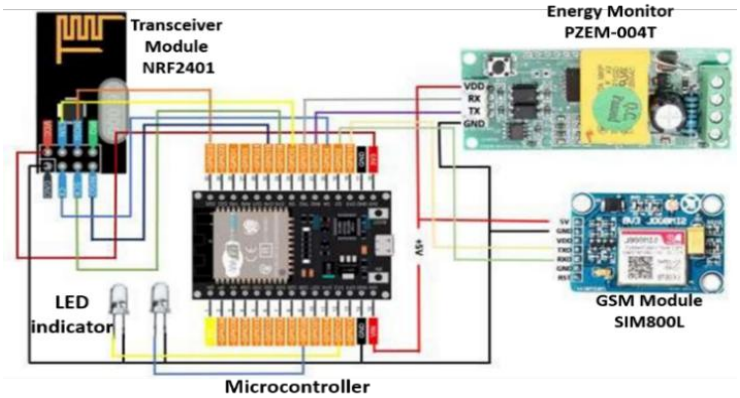

Figure 4. Receiver module wiring diagram composed of a GSM module SIM800L, micrcocontroller, LEDs, energy monitor PZEM-004T, and NRF2401 transciever

2.2. Test and evaluation

The system is tested based on its functionality. Different electrical loads are tested while tapping into the household power lines. These loads vary based on its rated power such as soldering iron, electric fan, and LED lamp. The real time monitoring of the power consumption can be viewed from a dedicated IoT web application. For redundancy and validity of the power measurements, a digital clamp meter and PZEM-004T module were compared.

3. RESULTS AND DISCUSSION

3.1. Evaluation platform

The evaluation platform was developed to conduct the live simulation setup. The components are presented in Figure 5. Figure 5(a) shows the live simulation setup with its identified components: lamps, switches, transmitter and receiver indicators. Figure 5(b) shows the corner view of the setup. Figure 5(c) presents the interconnection of components inside the developed simulation box, such as the wireless modules, relays, power supplies, and the sample electrical loads.

(a) (b) (c)

Figure 5. The evaluation platform prototype: (a) live simulation setup composed of the switches and lamps as electrical loads, (b) corner view of the setup, and (c) components and connections inside the platform

3.2. Test and evaluation results

The prototype developed was able to measure and record the actual electricity from the transmitter and receiver side. The web application developed successfully tracked the real time consumption on both sides as seen in Figure 6. The energy consumption was monitored on a daily basis. In this example, the terminal power and household power measured are both 34.6 watts.

When an electricity theft occurs, a discrepancy in measurement of power consumption between transmitter (terminal power) and receiver side (house power) are detected. A sample of this was displayed in the web app as shown in Figure 7. Notice the significant difference between terminal and house power measured 18.9 watts, which means that an electricity theft occurred. An SMS notification is sent to the mobile phone number as shown in Figure 8.

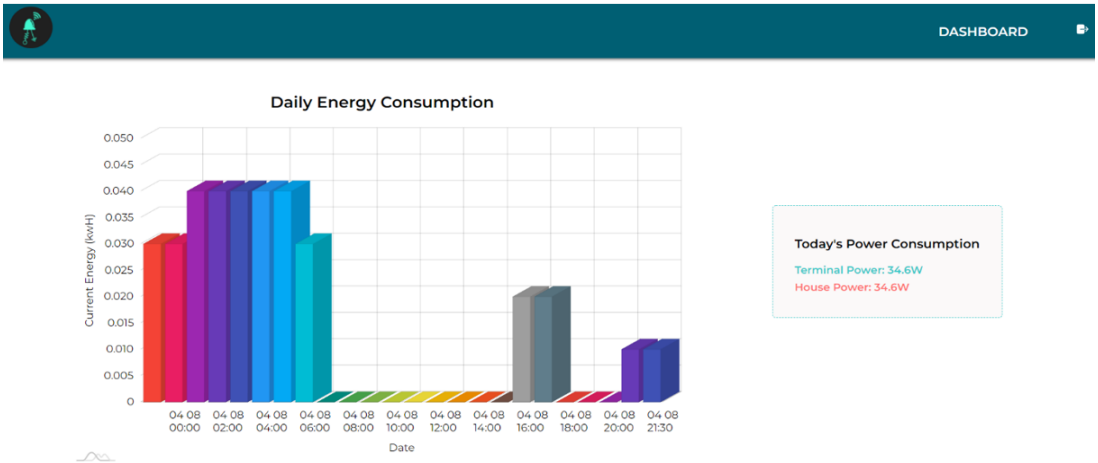

Figure 6. IoT-based display of real-time consumption of electricity without illegal wire tapping

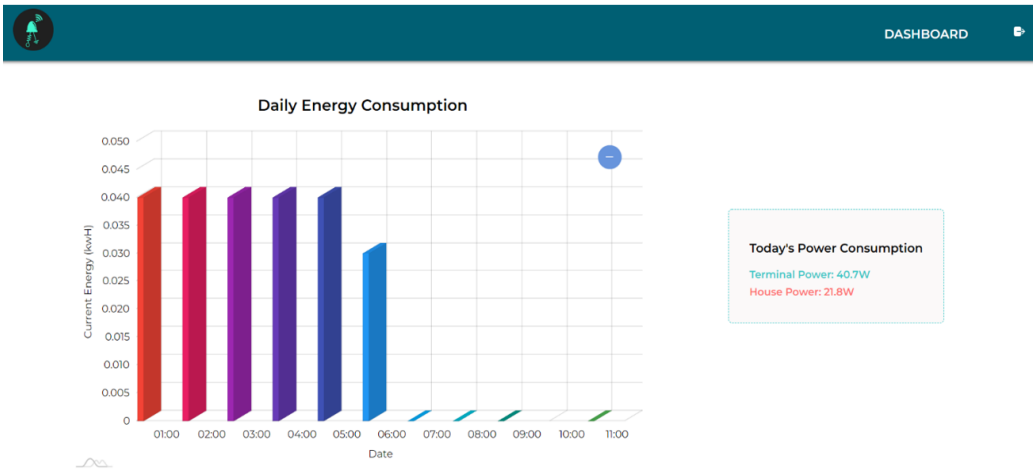

Figure 7. IoT Based display of real-time consumption of electricity with electricity theft detected

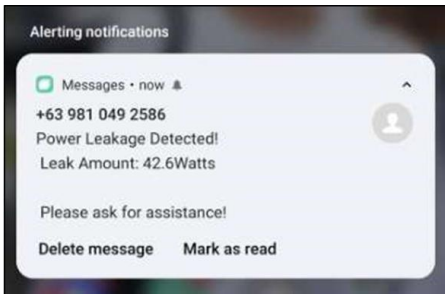

Figure 8. SMS notification when a power leakage is detected

Ten trials have been conducted for the power leakage test with different loads. Table 1 shows the loads tested when connected illegally to the household power lines. The % error for both a calibrated digital clamp meter and the PZEM-004T were shown to verify the integrity of the power readings. The detection and cutting-off of electricity to illegal connection had been tested and found to be 100% functional based on the tests conducted. The maximum distance between the transmitter and receiver side were tested, with and without obstruction. The result showed that the distance can reach up to 24 meters with obstruction and beyond 30 meters without obstruction.

Table 1. Test and evaluation using electrical loads

Variable	Rated power (Watts)	Digital clamp meter	% Error	PZEM-004T	% Error
Soldering iron	40	37.4	-6.5	37.8	-5.5
Electric fan	43	44	2.33	42.6	-0.93
Two 7W LED Light Bulb	14	13.2	-5.71	14.2	1.43
Cellphone with charger	33	33.2	0.61	34.1	3.33
Laptop with charger	30	30.6	2	33	10
Electric fan and cellphone with charger	70	71.4	2	70.4	0.57
Minicomputer and monitor	11	11.2	1.82	11	0

4. CONCLUSION

In this study, the developed setup for household monitoring systems through IoT was able to detect electricity theft in the power line between the power meters of the household and the power service. This was accomplished by comparing the transmitted measurements of electricity sensors between transmitter and receiver side via an IoT setup. These power measurements are recorded and monitored through a developed web application. An SMS notification is sent to the owner when electricity theft has occurred. This work is found to be 100% reliable in detecting and cutting off illegal connections.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

- The data that support the findings of this study are available from the corresponding author, Mark Joseph B. Enojas, upon reasonable request.

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