IoT based energy monitoring and energy theft detection

Cite as: AIP Conference Proceedings **2690**, 020045 (2023); https://doi.org/10.1063/5.0119807
Published Online: 24 March 2023

Vishakha Yadav, Anita Keshav Patil, P. Janardhan Saikumar, et al.

IoT Based Energy Monitoring and Energy Theft Detection

Vishakha Yadav[1,a)], Anita Keshav Patil[2,b)], P.Janardhan Saikumar[3,c)], Santaji Krishna Shinde[4,d)], B.Karunamoorthy[5,e)], S.Hemavathi[6,f)]

[1]*Department of Computer Science and Engineering, BMS Institute of Technology and Management, Yelahanka, Bengaluru -560064, Karnataka, India*
[2]*Department of Electronics and Telecommunication, Dr.Vithalrao Vikhe Patil College of Engineering, MIDC, Vilad Ghat, Ahemdnagar,,– 414111, Maharashtra, India*
[3]*Department of Electronics and Communication Engineering, Audisankara Institute of Technology, Gudur -524101, Andhra Pradesh, India*
[4]*Department of Computer Engineering, Vidya Pratishthan's Kamalnayan Bajaj Institute of Engineering and Technology, Baramati, Pune-413133, Maharashtra, India*
[5]*Department of Electrical & Electronics Engineering, Kumaraguru College of Technology, Coimbatore-641049, Tamil Nadu, India*
[6]*Battery Division, Central Electrochemical Research Institute and Academy of Scientific and Innovative Research, CSIR Madras Complex, Chennai - 600113, Tamil Nadu, India*

[a)] Corresponding author: vishakhay@bmsit.in
[b)]anitamdhoke@gmail.com
[c)]jskumar.ece@audisankara.ac.in
[d)]santaji@rediffmail.com
[e)]karunamoorthy.b.eee@kct.ac.in
[f)]hemavathi@cecri.res.in

Abstract.One of the greatest issues facing the nation today is the energy crisis. The energy crisis can be mitigated to some extent if people keep track of our energy consumption and avoid wasting it. People nowadays confront a variety of issues, including electricity theft. One's own country's economy has a major significant influence on electric power theft and is a type of crime. In this research, an IoT-based power utilizedis proposed andit is measured utilizing current and voltage sensor reading. The proposed IoT technology will readily detect energy theft. This Internet of Things is connected with an Arduino UNO IDE with a Wi-Fi module for IoT connectivity andcustomers will receive information viathe Blynk app. A current sensor is also included in this smart electricity meter, which relays the current information to the microcontroller. Users must connect cell phones to Blynk app so that the electricity theft can be tracked and monitored,which can help you to set up your system. The reading appears on the IoT screen as soon as it activates the system. The reading will be altered following the passage of time. If energy theft occurs, the theft will be detected and displayed on the IoT screen. To prevent theft, the user can use the IoT Blynk app to monitor the tracking of power utilized by the system anywhere and at any time, even after receiving the theft indication signal**.**

Keywords: Energy Theft management, IoT, Tracking, and Monitoring.

INTRODUCTION

The lack of a proper energy management system in most Indian towns has resulted in a slew of electrical concerns, including electricity theft, electrical risks caused by short-circuited electrical cables, and incorrectly connected

ISET International Conference on Applied Science & Engineering (CASE 2021)
AIP Conf. Proc. 2690, 020045-1–020045-11; https://doi.org/10.1063/5.0119807
Published by AIP Publishing. 978-0-7354-4334-1/$30.00

wires. In this time of energy constraint, it's important to be resourceful in electrical energy management and monitoring and that is essential for effective energy control and preventing waste. The proper use of power is extremely vital, as electricity is the lifeblood of the globe. To visualize and analyses energy, consumers' energy consumption statistics must be collected, and energy distribution must be monitored.Furthermore, many people are unaware of how electricity bills are calculated. As a result, to raise consumer awareness about energy consumption, researchers developed an IoT-based real-time monitoring system. In the present circumstances, electricity theft has a significant impact and has caused significant economical complications in developing countries. A loss is incurred as a result of a large amount of revenue. Because there are different methods for committing electrical theft, it is hard to determine in what way a theft occurred, and this problem must be addressed as soon as feasible.

When it comes to power theft, customers used permanent magnets to slow down the rotation of the Current and Voltage Sensor readings in the past [1]. Digital meters were installed to prevent illegal use, yet consumers plundered power bypassing the meter. As a result, by locating the region using smart meters, Power theft can be predicted using the following mode of operation. By collecting load profiles and allowing bi-directional information flow, the automatic metering infrastructure (AMI), which includes smart meters, a communication network, and a data management system, plays a crucial role in power transportation networks [2].Electric power systems today have a huge challenge in terms of both maintaining their infrastructure and assuring service continuity. Furthermore, financial losses caused by electric energy thievery are a major issue for the Electricity Board. Without requiring any human interaction, this device would provide a straightforward approach to identify electrical power theft. In the event of a legal disagreement, it would give a digital record [3]. For optimum use and better energy management, energy management and monitoring play a critical role. As a result, researchers create an IoT framework, which allows consumers to monitor their energy usage in real-time while also allowing the electricity board to track energy theft [4].Most significantly, power theft is one of the critical issues that must be addressed within the distribution system. Because of the power differential between generation and metered consumption, it will be self-addressed. This electric power loss is divided into two categories as follows, technical and non-technical losses. The majority of the ability losses are due to unethical losses and power stealing. The extralegal or unmetered usage of electricity from distribution utilities will be defined as power stealing [5-7].

The distribution utilities suffer monstrous financial losses as a result of the power theft.This research contributes to the reduction and avoidance of the country's existing difficulties [8]. Various researchersare working on power theft detection studies. Some academics have advocated using a prepaid electricity billing meter to keep track of residential electrical appliances [9].-This method uses renewable energy distribution while also decreasing consumer electricity prices. With the inclusion of JADE, an IEEE FIPA compliant multi-agent system platform, the system was created fully in Java [10-11]. This concept uses IoT to automatically measure and bill power usage in home appliances. A billing system based on a microcontroller is proposed for single-phase meters used by distant clients[12].Improved load forecasting and the successful use of smart grid technologies to enhance electric power system operation, energy management, and planning require a greater understanding of customers' real power usage patterns [13]]. Electricity theft can be accomplished in a variety of ways, making it difficult to trace the source of the theft.

Our suggested idea is an automatic detection system for electricity theft when either the meter or the transmission line is bypassed.

- Monitor the energy utilized by the induvial.
- Keep the tracking of energy utilized.
- Indicate energy theft.
- Reduce energy theft.
- Design and implementation of IoT-based low-costenergy theft monitoring system.

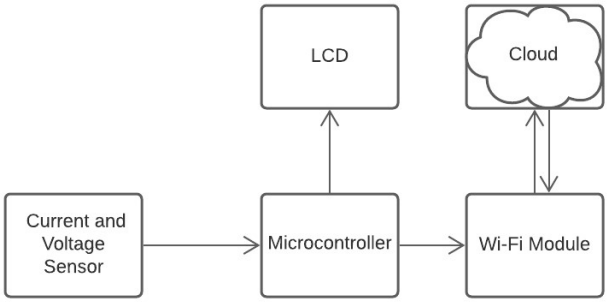

FIGURE 1. Schematic System of Smart Energy Theft Monitoring System Using IoT.

Survey of an Energy Theft Management System

The existing Current and Voltage Sensor reading wireless communication system is designed using ZIGBEE and GPRS. Despite the lack of energy monitoring equipment, this makes it difficult to deploy energy theft detection systems[14]. This research approach is mostly used to protect the entire communication channel and ZIGBEE for serial data transmission. The disadvantage of this technique is that it is impossible to monitor loads in real-time, and the site of theft cannot be determined. Prof.Landi C. Merola P. says that the webserver collects the measurements of power consumption and the data is being loaded into the server only. This study proposes a new model based on supervised machine learning techniques and real-world power usage data [15].Prof.GarrabA Bauallegue A states that AMR solution provides enhanced continuous application, as well as electronics energy measurement, is continuously replacing current technology of electro-mechanical meters. Based on an AI-based identification framework and factual assumptions, the researchers created an energy theft detection system. There are three different types of decision-making modules: The prediction system is a multi-model forecasting system that is the first of these systems. The central concept is to combine different artificial intelligence algorithms into a forecasting framework to estimate how much energy is spent. The following module contains the fundamental dynamic model, which makes use of a Simple Moving Average to filter the framework based on the vitality level that has been provided. The last module is a dynamic model that can be used to detect vitality robbery [16], which is described in more detail below. Specifically, the author offers a system that checks the system at predetermined intervals and notifies the service provider and client on the number of units used by the user. With the assistance of a server [18], the power consumptions are automatically tracked and recorded. According to the author, energy theft is one of the most significant issues that the smart grid is attempting to address through technology. Several studies have found that the country may be vulnerable to a significant amount of energy theft [17]. It is estimated that many businesses have suffered billion-dollar losses as a result of energy theft. Automated Metered Infrastructure (AMI) is being implemented to address this issue. In this instance, a tree-based approach is used to solve the problem. First, the researcher concentrated on tasks linked with improving intraday load forecasting at the framework level by employing bunching to split users with similar burden consumption behaviors from smart meters before completing the load gauging. The AMI data, in contrast to typical cumulative framework burden gauging, provides information on how burden forecasting is done at the framework level as well as at the region level, feeder level, and even customer level, from transitory burden assessment to long haul load projection [18].

Proposed Methodology

The research area is to monitor the amount of energy used by enterprises, industries, residences, hospitals, and other organizations, as well as to provide recommendations using IoT. The idea is to use IoT, to measure power usage in a family unit and automatically track and monitor a power utility by the consumer to detect theft. The tracking can be seen throughthe mobile app - Blynk.The Current and Voltage Sensor readingis placed in aninduvialhouse location, and then a Wi-Fi module is located near the Current and Voltage Sensor readingin a solid chamber and connected IoT tracking device. The Current and Voltage Sensor reading connected with IoT later, the

data has been transferred to the server of IoT followed by Mobile App. The data represents the energy reading per unit per hour. As per the standard rule of electricity.

The IoT and Current and Voltage Sensor readings are mounted in the meter box, and the Wi-Fireader interacts with the IoT. The IoT's function is in the hands of the system. Blynk app is being used for tracking and monitoring the individual's full energy theft system. The mapping server uses an IoT server and a mobile app to analyses data from various tracking devices. All of the data is collected and stored in the computer database by the control station (Microcontroller-IoT).The status of the electricity theft and the amount of energy used were also monitored. Using anArduino UNO and anIoT system to track electricity waste as well as energy thefthas been sorted out.

Conventional Method

At present, there is no control over the amount of money spent on power, and the daily usage of an electrical system. As a result, the chunk rates are doubled, resulting in a large charge. The major solution for cost reduction is a force cut-off. The present energy meters are incapable of resolving and estimating chunk rate variations. Only the bi-monthly utilization has been fixed.The client also isn't notified about the use of theft current. There is no any error or any kind of warningmessage or ready supplied regardless of whether the client uses more current units, which is a severe disadvantage. If the client is told about the power usage ahead of time, the user can be reduced, and the cost will be reduced as well.

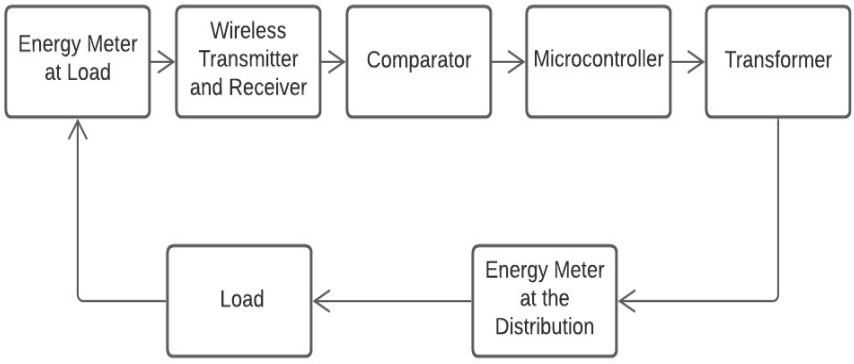

FIGURE 2. Model ConventionalSchematic of a Current and Voltage Sensor Reading Using Microcontroller

PROPOSED METHODOLOGY

The concept of the Internet of Things is being used in the proposed methodology. This proposed system enables users to obtain unit readings without the need for manual intervention.
Following components are being used in the proposed work,

- ✔ Arduino UNO
- ✔ Proteus Software
- ✔ Blynk Mobile App
- ✔ Wi-Fi module
- ✔ Connecting wires
- ✔ Power Supply
- ✔ LCD and Current and Voltage Sensor reading

The data, which includes the unit spent by the customer and is captured at the customer's location, is loaded onto aseparate electrical web server. The authority has access to a database on the server that contains all of the information, such as the consumer number and the number of units utilized. This is accomplished by wiring the Arduino microcontroller to the current and voltage sensors. The authors also propose a method for effective energy management as well as monitoring and tracking energy theft in this paper.

Working of Designed Module

- Current and Voltage Sensor reading Indication and Detection.
- Current and Voltage sensors data storage in the server.
- Indicate the theft.
- Theft Tracking

Proposed Flowchart

Power theft is becoming a serious issue. Several countries have suffered significant losses in the millions of dollars. A smart energy meter may now be used to track and record how much energy is utilized. Energy stealing tactics include hacking into home devices and, more typically, straight snaring on different family units' power sources.

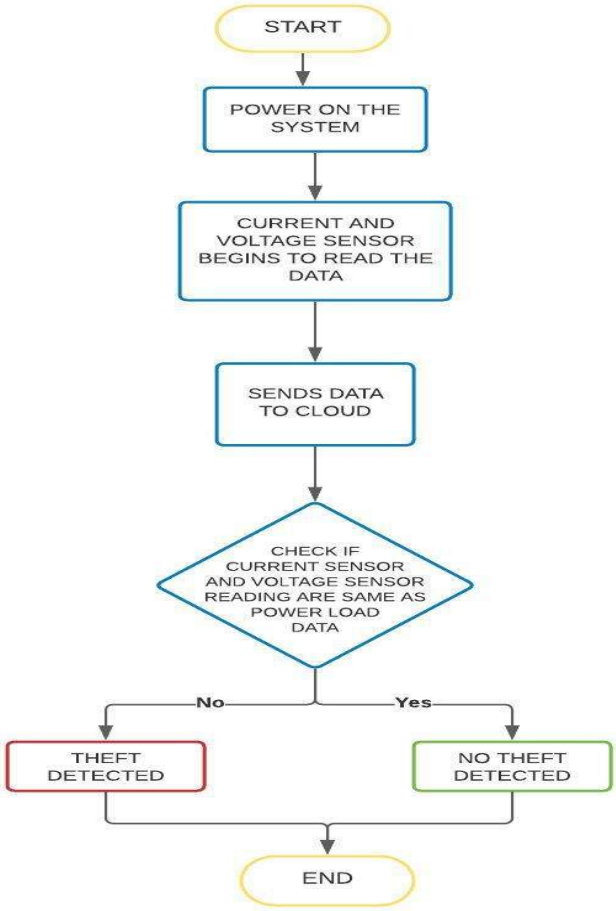

FIGURE 3. Flow Chart of Proposed Methodology

Electricity theft is a social plague that is growing by the day and must be eradicated. This research study proposes an IoT-based solution for detecting and disconnecting power theft utilizing the automatic metering infrastructure (AMI). It is possible to detect any illicit connections. The key benefit is that power theft may be identified by logging into the system (IoT-based Mobile App) using the consumer's phone number, making it simple for officials to take swift action against the customer. If power theft is detected in a specified area, a server automatically indicates the LED indication and specifies the amount of theft power utilized.

HARDWARE

Arduino

The Arduino UNO is an 8-bit AVR microcontroller from the ATmega328P family. It has a 5-volt operating voltage. A0 through A5 are the six analog input pins. Serial pins, external interrupt pins, PWM pins, SPI pins, and an in-built LED pin are among the fourteen input or output pins. Analog pins 4 and 5 are SDA and SCA, respectively, and are utilized for TWI communication via wire library. RESET, VCC, GND, and clock signal pins are found on most microcontrollers.

Power Supply

A controlled power supply unit provides electricity to the circuit. The 230 V AC input from the main supply is converted to 12V AC via a step-down converter. The AC input is converted to DC via a rectifier. The rectifier's output, a pulsed DC voltage, is filtered to eliminate the AC components, resulting in a pure DC value of 5V. The current and voltage transformers are both powered by a 230 V main supply, with the voltage transformer's output being 9 V AC, which is fed into the rectifier unit to generate analog values, and the relay is controlled by a 12 V relay module that receives 12V.

Current and Voltage Sensor Reading

An energy meter is a gadget that measures how much electricity is utilized by users. Kilowatt-hour is used to calibrate them. The most common use of digital energy meters is to measure power usage. The instantaneous power is calculated as the product of instantaneous current and voltage. The energy usage of consumers is calculated by integrating instantaneous power versus time.

ESP8266 WIFI Module

The ESP8266 is a low-cost Wi-Fi module for Arduino UNO microcontrollers. The ESP8266 is equipped with a 32-bit low-power CPU, ROM, and RAM. It's a self-contained Wi-Fi network that can run software programs on its own or with the assistance of a microcontroller (MCU). The AT Command firmware is included in the module and may be used with any MCU that has a COM port.

SOFTWARE IMPLEMENTATION

IoT Webpage Blynk

It's a web-based Internet of Things (IoT) service that connects hardware and software solutions for remotely monitoring, controlling, and automating operations using Arduino.Data may be collected from Current and Voltage Sensor readings and broadcast over the internet, as well as device control, by providing the relevant command lines in the Arduino UNO microcontroller.

Proteus Software

Proteus is a robust software tool that guides users through the whole development process. Intelligent principle layout, hybrid circuit simulation and precise analysis, single-chip software debugging, single-chip and peripheral circuit co-simulation, and PCB automated layout and wiring are only a few of the benefits. This module has a lot of storage. With a high level of on-chip integration, the front-end module requires less extra circuitry and has a reduced PCB footprint. There appears to be an unending amount of data, all of which is possible thanks to amazing local support.

RESULTS AND DISCUSSION

Using this strategy, consumers will be informed of the number of units they consume daily. The following outcomes were accomplished as a result of putting the proposed IoT-based tracking and monitoring strategy into action. As shown below, the Proteus software simulation displays real-time tracking and monitoring data, which is received once every second by the software. Proteus is a software tool that is used to simulate planned work before it is implemented in hardware. To check that the hardware and software are functioning properly, this program is utilized. The findings of Proteus' simulation are displayed in parts A and B. Sections C, D, and E demonstrate the output of the Blynk program.

Software Simulation of No Theft Current and Voltage Sensor Reading

Figure 4 shows that software simulation of no theft has been detected in the energy utilized by using Proteus Simulation. In this simulation, three different loads have been connected with the help of microcontroller IDE. The LCD shows that the current reading at station reading is 2.52 and the current at load is also 2.52. Since both the current at station and load isthe same, there is no theft in the current reading. Since theft is being detected by measuring current and voltage sensor reading and comparing with load data and there is no deviation in the load power.

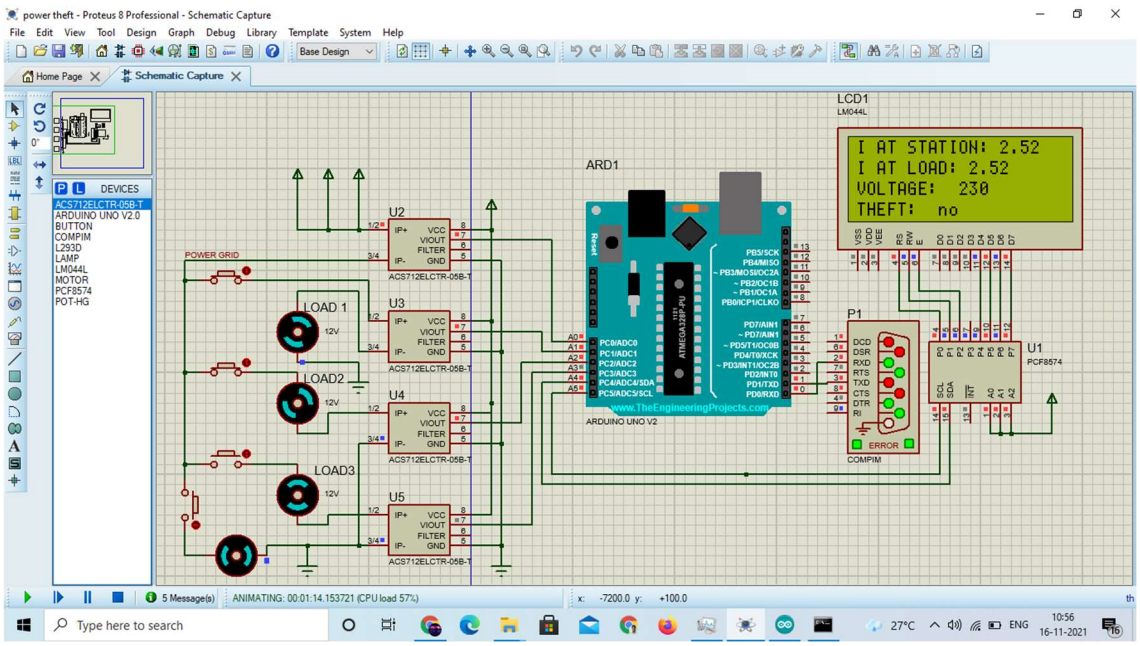

FIGURE 4. Proteus Simulation of No Theft Detection

Software Simulation of Theft Current and Voltage Sensor Reading

Figure 5 shows that software simulation oftheft has been detected in the energy utilized by using Proteus Simulation. In this simulation, three different loads have been connected with the help of microcontroller IDE.

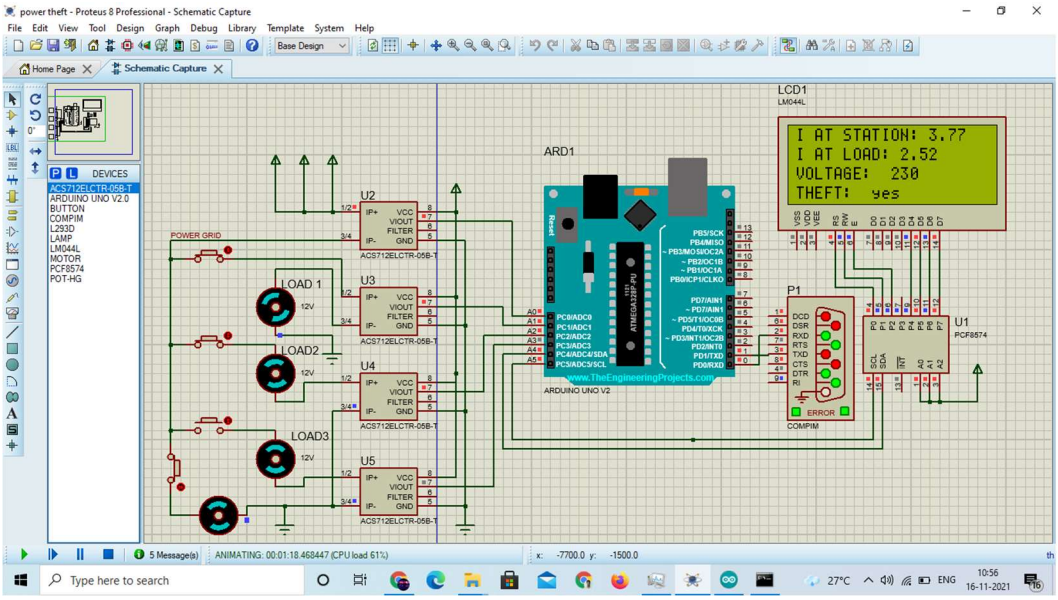

FIGURE 5. Proteus Simulation of Theft Detection

The theft has been detected in the energy utilized by using Proteus Simulation. Each load power varies according to the load current and sensor reading varies.The LCD shows that the current reading at station reading is 3.77 and the current at load is 2.52. The simulation result of figure 5 shows that both the current at station and load are different and henceforth there is a theft in the current reading. Since theft is being detected by measuring current and voltage sensor reading and comparing with load data and there is a deviation in the load power.

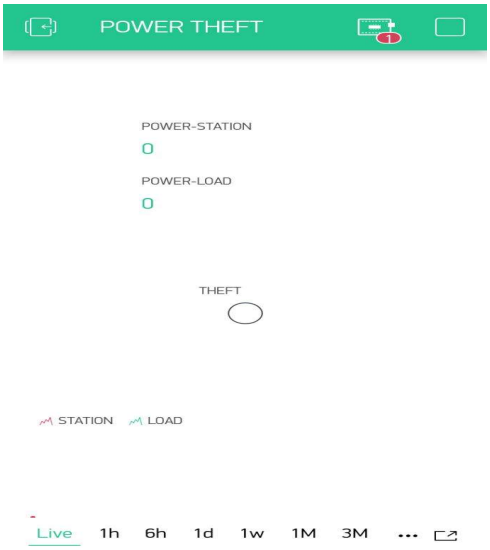

FIGURE 6. IoT Mobile App Homepage for Energy Theft Monitoring and Tracking

Software IoT – Blynk webpage for Energy Reading Consumption

Figure 6shows that software programmed IoT mobile app homepage for energy theft monitoring and tracking system. This mobile application connects the programming knowledge of IoT and the Blynk platform. The home page consists of the current and voltage sensor reading and power at each load station for each load concerning the time.

Further, figure 6indicates the live tracking of power consumed and an indication of power theft LED present on the homepage.

Software IoT Webpage for Energy Reading Consumption – No Theft Detection

Figure 7 shows that software simulation of theft has been detected in the energy utilized by using Proteus Simulation and the same is shown in the tracking app and is indicated by the red signal.

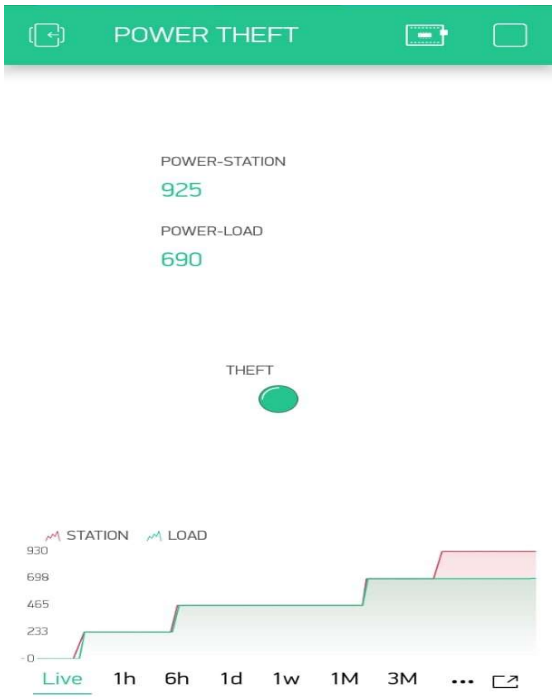

FIGURE 7. IoT Mobile App – Power Usage with Energy Theft Tracking

The simulation result shows that the live tracking is being monitored for each hour and followed by months. A load power utilized is indicated by 690 and it is indicated by a green signal. The power utilized by the station is indicated by a red signal and it is measured as 925. In this figure 7, the sensor data and load power data are not the same and hence it is being measured as theft current. The power data is calculated concerning current and voltage readings.

Software IoT Webpage for Energy Reading Consumption – No Theft Detection

Figure 8 shows that software simulation of theft has not been detected in the energy utilized by using Proteus Simulation and the same is shown in the tracking app.

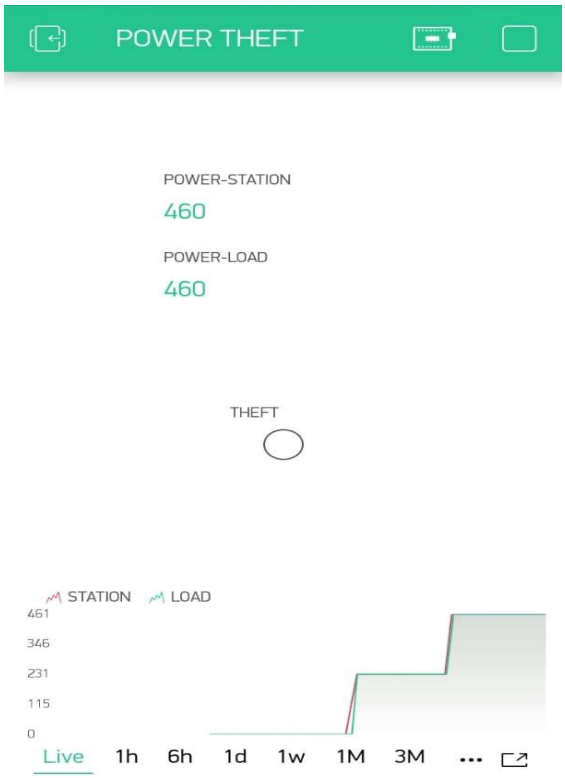

FIGURE 8. IoT Mobile App – Power Usage without Energy Theft Tracking

In this figure 8, the simulation result has tracking of two different loads and it's been indicated by two different signals namely red and green. In this figure 8,the load power utilized is indicated as 460 and it is indicated by the green signal. The power utilized by the station is indicated by a red signal and it is measured as 460.Since the sensor data and load power data are the same and hence it is being measured as no theft power.

CONCLUSION

This research proposes an IoT platform for real-time power theft detection and proper current and voltage sensor adherence. To determine the theft of a current reading, an IoT-based energy theft monitoring, and tracking technology is being used. The communication infrastructure for the theft identification and alerting system is implemented using an IoT-based design. A Web-based Human application was created for easy monitoring of load power usage at each power station as well as power used by loads. A picture system is being implemented by validating the simulations results of Proteus and several test scenarios are considered to validate the proposed system.A mobile application may track power usage and indicates and send an SMSto the user when a theft is being detected. Further,the advanced IoT technology may automatically shut the main power if theft is detected.

REFERENCES

1. R. M. Sahu, AkshayGodse, Pramod Shinde,Reshma Shinde, "Garbage And Street Light Monitoring System Using Internet Of Things" International Journal Of Innovative Research In Electrical, Electronics, Instrumentation And Control Engineering, Issn (Online) 2321 2004, **4,4**, April (2016)
2. Kanchan Mahajan, J. S. Chitode, "Waste Bin Monitoring System Using Integrated Technologies", International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization) **3,7,**July (2014)

3. C. Landi, P. Merola, “ARM-based energy controlling system based on A new Garrab A Bauallegue A AMR method in Smart Networks for energy saving based on Smart Meter and partial Power Line Communication”, in Region 10 Conference (TENCON) IEEE, 3386– 3389 (2018)
4. W. Li, T. Logenthiran , V.-T. Phan, and W. L. Woo, “Intelligent multi-agent system for power grid communication,” in Region 10 Conference (TENCON), IEEE, 3386– 3389 (2016)
5. Weixian Li et.al. “Housing development building management system (HDBMS) for optimized electricity bills,” Transactions on Environment and Electrical Engineering, **2, 2,** 64–71 (2017)
6. Naziya Sulthana, N. Rashmi, N. Y. Prakyathi, S. Bhavana, K. B. Shiva Kumar, “Smart Energy Meter and Monitoring System Using Iot”, International Journal of Engineering Research & Technology (Ijert) Ncetesft , **8, 14,** (2020)
7. C. Yang, J. Yao, W. Lou, and S. Xie, “On-demand response management performance optimization for microgrids under imperfect communication constraints,” IEEE Internet of Things Journal(2017)
8. F. L. Quilumba, W.-J. Lee, H. Huang, D. Y. Wang, and R. L. Szabados, “Using smart meter data to improve the accuracy of intraday load forecasting considering customer behavior similarities,” IEEE Transactions on Smart Grid, **6, 2,** 911– 918 (2015)
9. W. Li, T. Logenthiran, V. Phan and W. L. Woo, "A Novel Smart Energy Theft System (SETS) for IoT-Based Smart Home," in IEEE Internet of Things Journal, **6, 3,** 5531-5539, June (2019)
10. R. and K. V., "IoT Based Smart Energy Theft Detection and Monitoring System for Smart Home," 2020 International Conference on System, Computation, Automation, and Networking (ICSCAN), **1-6** (2020)
11. S. K. Kadala, A. K. Rajagiri, A. Ajitha, and A. K. Thalluri, "Development of an IoT-based solution for Smart Distribution Systems," 2021 International Conference on Sustainable Energy and Future Electric Transportation (SEFET), **1-6** (2021)
12. W. Li, T. Logenthiran, V. Phan and W. L. Woo, "A Novel Smart Energy Theft System (SETS) for IoT-Based Smart Home," in IEEE Internet of Things Journal, **6, 3**, 5531-5539, June (2019)
13. R. Punmiya and S. Choe, "Energy Theft Detection Using Gradient Boosting Theft Detector With Feature Engineering-Based Preprocessing," in IEEE Transactions on Smart Grid, **10, 2**, 2326-2329, March (2019)
14. C. Bhuvaneshwari, A. Manjunathan, “Advanced gesture recognition system using long-term recurrent convolution network”, Materials Today Proceedings, **21**, 731-733 (2020)
15. C Bhuvaneshwari, A Manjunathan, “Reimbursement of sensor nodes and path optimization”, Materials Today: Proceedings, **45,** 1547-1551 (2021)
16. K Balachander, G Suresh Kumaar, M Mathankumar, A Manjunathan, S Chinnapparaj, “Optimization in design of hybrid electric power network using HOMER”, Materials Today: Proceedings, **45**, 1563 - 1567 (2021)
17. M.D. Udayakumar, G. Anushree, J. Sathyaraj, A. Manjunathan, “The impact of advanced technological developments on solar PV value chain” , Materials Today: Proceedings, **45**, 2053–2058 (2021)
18. T.V. Kumar, M. Mathankumar, A. Manjunathan, J. Sathyaraj,“Time based costing of energy storage system with optimal scheduling and dispatch under demand” Materials Today: Proceedings, **45**, 1738–1741 (2021)