IoT Based Smart Power Quality Monitoring and Electricity Theft Detection System

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***Abstract*—Electricity theft is a worldwide issue, but it is most prevalent in developing countries like Pakistan. The economic loss is over Rs. 90 billion per year due to electric power theft at commercial, domestic, and industrial levels. For years, the country has faced extraordinary challenges in upgrading its network responsible for the supply of electricity, but results have not been ideal. Power theft, in its various forms, can only be diminished and kept in check by the robust and firm action of power sector organizations. Hence, the objective of this paper is to provide a unique solution for not only line tampering but also meter tampering. This system, when deployed across the electricity distribution network, will help eliminate power theft through smart monitoring of the power distribution infrastructure and consumption data. Our system comprises a network of sensors to transmit real-time power consumption data to the microprocessor, which processes the data to detect power theft. The proposed method involves transmitting power consumption readings to ThingSpeak using IoT. This idea allows the electricity supplier to analyze the energy usage, locate theft and visualize consumer statistics. The physical implementation of this project will succor the electricity supply companies to hunt the culprit accountable for stealing electricity.**

Keywords—power supplier, IoT, Raspberry Pi, ThingSpeak, PZEM-004T, theft detection

I. INTRODUCTION

Electricity theft is a common problem in Pakistan and energy worth billions of Rupees is stolen annually from electricity grids. A huge number of unlawful connections are overloading the grids, which cause not only financial losses to the Electricity Board (EB) but also the main reason for frequent tripping and blackouts. There are two major categories of electricity theft: meter tampering where thieves manipulate the internal structure of the metering system, and line tempering where imposters bypass the electricity meter connection. EB is committed to serving people with consistent and reliable power. To achieve this vision, the utility must also combat the societal menace of power theft and illegal abstraction. In this paper, we aim to provide a solution to EB for Electricity Theft Detection using IoT. In our proposed method, high accuracy energy sensors with a current transformer have been used to measure the current in the transmission line and the current drawn by the load. Raspberry Pi calculates the difference between both the current readings and detects theft when the difference exceeds a specified value in case of line or meter tapping. Raspberry Pi was chosen due to its built-in Wi-Fi chip. The Wi-Fi unit performs the IoT operation by sending an alert message to the EB on ThingSpeak when electricity theft occurs. So, the supplier can do real-time power management and theft detection. The proposed system can easily be integrated with the existing electricity infrastructure, making the joint solution both innovative and cost-effective for grid distributors facing huge line losses through electricity theft.

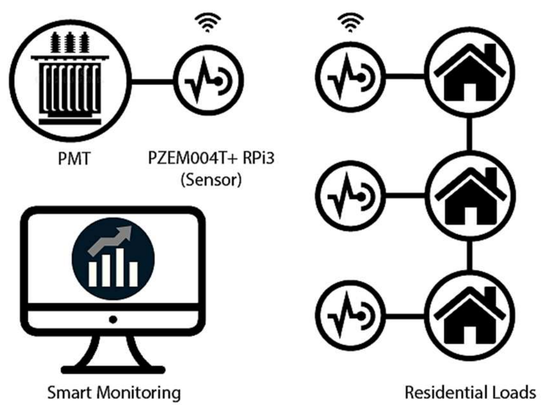

Fig. 1. Real life implementation of the proposed system.

II. Literature Review

Many research efforts have been paid on studying *Power Theft Detection Systems* from both supply and demand-side perspective. In [1], the authors provided a solution to the Electricity Board (EB) for power theft via energy meter tampering, by designing and manufacturing an IoT-based power monitoring and theft detection system. This system provides a reliable way to detect electric theft without any human interface. In [2], the authors proposed an economical and efficient system that detects power theft without involving any manpower. As soon as the theft is detected, an email and a message are sent to the concerned authority, along with the location and image of that particular area. The work presented in [3] proposes a framework for electricity consumers that effectively recognizes the amount of energy consumed and it upgrades the smart home security by sending mobile alert messages to the customer for any illegal alteration that occurred in the power line. In [4], the authors provided a simple way for the power supply company for detecting and specifying the location of the theft in real-time without any human interface. Furthermore, the system will save time and the cost for the utility because the readings of all meters can be taken by a wireless technique. A wireless power monitoring and detecting system is proposed [5] that is used to detect theft automatically and pass the theft information directly to the electricity board via message without any human interference.

III. Methodology

The objective of the proposed system is to alert the power supplier of a possible power theft when a difference of greater than 20 mA is measured between the current output from Pad-Mounted Transformer (PMT) and the sum of currents in consumers' energy meters. The system works on the Principle of Conservation of Energy and Kirchhoff's Current Law (KCL). According to KCL, the total current leaving the PMT must be equal to the sum of individual currents entering the consumers' energy meters.

$$I_{PMT} = \sum_{k=1}^{n} I_k \quad (1)$$

where, *n* is the number of consumers' energy meters.

However, in real life, transmission line losses account for the slight difference in current readings. Hence, a slight modification is proposed in (1):

$$I_{PMT} = \sum_{k=1}^{n} I_k + 20\ mA \quad (2)$$

The Raspberry Pi functions as the brain of the system while two PZEM-004T energy meters serve as the heart. The PZEM-004T energy meters, which come with a current transformer, are used to measure current, voltage, frequency,

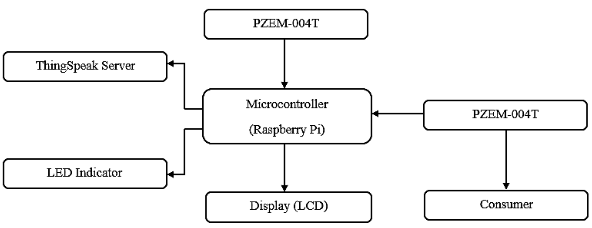

Fig. 2. Block diagram of the system layout.

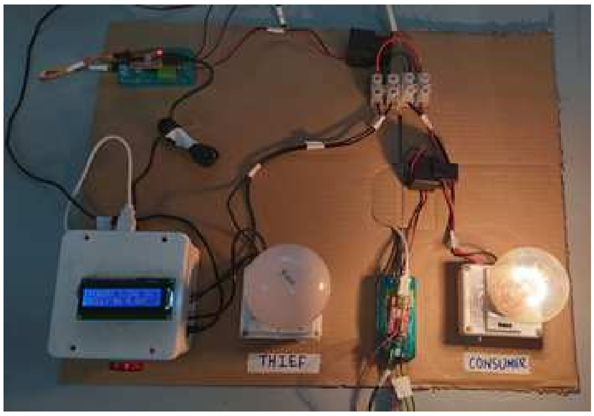

Fig. 3. Hardware prototype of the system under 'normal' conditions

power factor and power consumption at the PMT and the consumer's energy meter.

The Raspberry Pi is programmed to calculate the difference between the current readings every second and compare the difference to a threshold value of 20 mA. If the difference is greater than the specified value, the system issues a visual theft warning through a red LED indicator bulb as well as a prompt on the LCD display.

Consequently, the power supplier is informed of the ongoing power theft through an email. An Anti-Power-Theft team might be dispatched as well to take appropriate actions. The system automatically restores itself to the 'normal' state once the theft have been diagnosed and removed.

A. Software Implementation

Some of the important python libraries used are as follows:

1. Modbus_tk
2. I2C_LCD_driver
3. Smptlib

The Modbus_tk library is used to receive data from the PZEM-004T 100A modules. The Python language is used to program the Raspberry Pi 3.

ThingSpeak server fields are initialized for AC voltage, current, power, energy, frequency, power factor, and the total bill. The values being read from all the sensors are rounded off to an appropriate number of decimal places, as per the specifications in the PZEM-004T datasheet. The bill is calculated using the recent Rs/kWh rates.

The current readings from all the consumers are added and equated with that received from the main line or PMT. The individual readings from the consumers are then continuously sent over the ThingSpeak server and visualized using IoT, while being saved in an online database.

The power and bill values are also displayed on an on-site LCD, using a serial communication protocol I2C (or IIC), where data is sent bit-by-bit to the LCD via the I2C_LCD_driver library. In case of any discrepancy greater than 20 mA, the power supplier is notified via an email using Smptlib library.

B. Hardware Implementation

Hardware components used for the prototype are described as under:

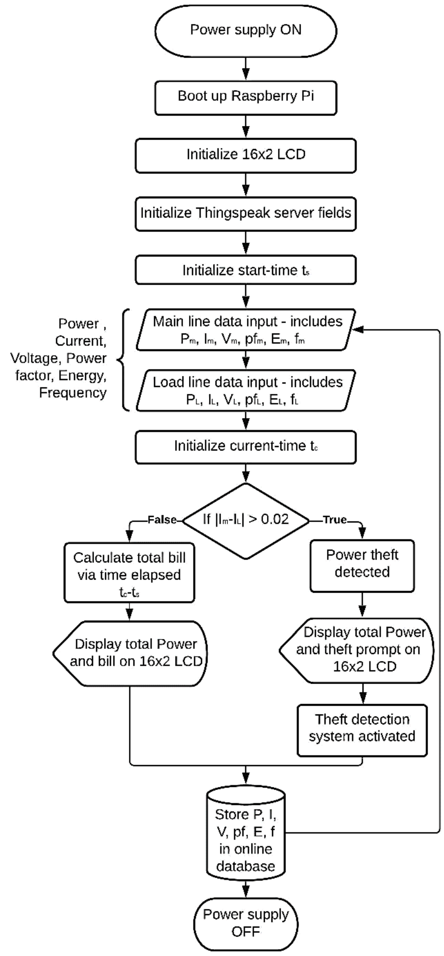

Fig. 4. System flow diagram showing the working and operation.

a) Raspberry Pi 3

Raspberry Pi 3, a single-board microcomputer, functions as the CPU or brain of the system which is programmed using Python to carry out the tasks as displayed in Fig. 4. It has four USB ports out of which two are used to connect the two PZEM-004T sensors. The Raspberry Pi is programmed to carry out the tasks as shown in Fig. 4.

b) PZEM-004T

PZEM-004T-100A is an AC communication module primarily used here for accurately measuring essential line parameters such as AC voltage, current, active power, frequency, power factor, and active energy. The 100 A version of this module comes with an external transformer and has a measuring range of 0-100 A.

c) FT232RL USB to TTL Module

The communication protocol used between energy sensors and Raspberry Pi is Modbus RTU, with an FT232 USB to UART module as an interface or layer. The FT232RL USB to TTL module is used to connect the TTL serial communicating PZEM-004T sensors to the Raspberry Pi via a USB mini port.

d) 16×2 LCD Screen

A 16x2 LCD can display 16 characters per line and has two such lines. This screen is used to display the meter readings under 'normal' conditions and a theft alert when a theft has been detected.

e) LCD I2C Interface Adapter

By default, the 16x2-character LCD display is driven by 4 parallel data lines along with a couple of chip select and chip enable pins. As this would occupy several pins on the Raspberry Pi, this interface adapter minimizes the required number of data pins to only two pins which can also be shared with other I2C devices.

f) Red LED Indicator Bulb

The red LED indicator bulb is directly connected to the Raspberry Pi through PZEM-004T and is used to give visual alert in the case of power theft.

IV. Results

In this paper, the experimental setup for smart metering and theft detection is performed and tested using automation and IoT. Two sets of energy sensors monitor the essential power quality values of the main line and individual consumer lines. With the python coding, the current values coming from the sensors of the individual consumer lines to Raspberry Pi 3 are added, which are then equated to the main line current reading from the sensor at PMT.

A. Outcome 1

When both sets of readings are similar, the system remains in 'normal' condition displaying the main line readings, and the total electricity bill in Pakistani Rupees on the ThingSpeak server and on-site LCD screen.

B. Outcome 2

If the current values of the PMT and the consumers differ by more 20 mA, this will indicate that an extra load is connected in between the two points. The theft alert system will turn on, informing the remote supplier through an email, while indicating theft via a red light, and a 'Theft Detected' prompt on the LCD screen.

V. Discussion

This paper presents a novel approach for smart power monitoring and theft detection using a distinctive combination

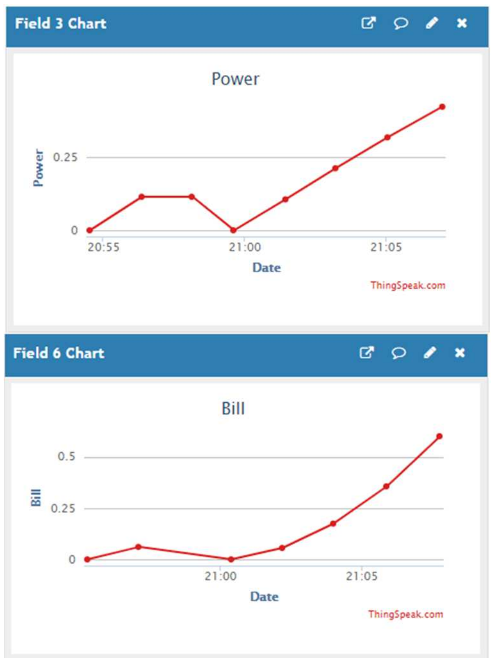

Fig. 5. Smart power monitoring through ThingSpeak

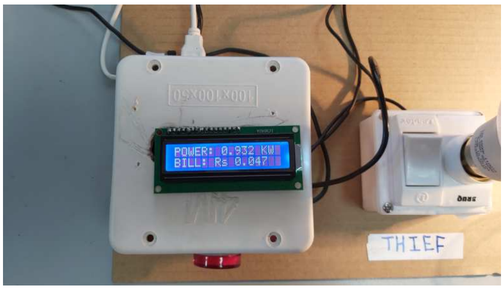

Fig. 6. Power consumption and the bill displayed on the LCD screen

of conventional hardware. An electricity meter to display power consumption and a smart meter to detect power theft are integrated with an automation system which is the backbone of smart grids. The system gives an insight to the power distribution companies about areas where illegal power theft is more prevalent, aiding them to curb the issue. While being a highly useful product for the suppliers, it can be used at consumers' end for power usage and quality monitoring as a very important addition to smart homes.

VI. CONCLUSION

In this paper, an efficient approach to power theft detection using Raspberry Pi is presented. The proposed system detects power theft and automatically sends an alert email to the power supply company, requesting it to dispatch a team to analyse the fault. The system offers remote monitoring of the essential electricity parameters on the ThingSpeak server using IoT. ThingSpeak not only displays the real-time values but also maintains a data log which gives supplier an insight into the trends of energy consumption. Additionally, the LCD screen of the meter displays total power consumption and the bill, and in case of theft, a message prompt on the screen. The use of PZEM-004T 100A energy sensor, which has a measurement accuracy of $\pm$0.5%, means the current, voltage, and power sensors have been replaced with a single module, providing excellent efficiency in terms of operation and cost. Hence, the system provides a cost-effective solution for detection of line tampering and meter tampering, which can further be integrated into smart grids to widen its scope.

VII. FUTURE WORK

The idea presented in this paper is currently a proof of concept and a lab prototype which has been tested under a controlled environment. However, it is planned to implement this system on a smart home model for further testing and improvements. Also, the system might be advanced to detect the exact point of theft, for example, by identifying the particular PMT and hence the specific street where theft is taking place. Later on, the system is expected to be brought into a finished commercial product which will not only help the supply company but also the potential consumers.

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