IOT based Energy Monitoring for Practical Loads using NodeMCU

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Abstract: - Electrical energy monitoring is increasingly important nowadays for residential and commercial usage. The energy meters are installed in consumer's houses to track their energy usage. There are many chances of human mistakes for every electricity consumer while recording the manual energy meter reading in their houses. Also, the consumer does not have updated information about current electricity usage in each hour, day, and month. To overcome the above problems, the system is developed to remotely monitor from any world location using the NodeMCU and Arduino IDE. The energy monitoring is carried out by using the Node MCU, Arduino IDE, and PZEM-004T sensor. The PZEM-004T module is coupled to the Arduino controller. The sensor module receives a signal from the CT coil which is connected to load. The load parameters such as voltage current power etc., are measured and transferred to the Arduino. A NodeMCU ESP8266 is utilized as a Wi-Fi chip system. By using a Wi-Fi connection and the internet, the acquired data is sent to Thing Speak to save in the cloud to monitor the measured parameters remotely. The power analyzer instrument is also used to measure the real-time parameters consumed by the load which is used to cross verification and compare with the sensor measuring parameters. The passive load resistance, inductance, and 100-watt lamp loads are experimentally connected and tested. The load consumed electrical parameters such as current, voltage, power, power factor, real power, and frequency are monitored in online. Energy monitoring online may reduce the consumer's mistakes by recording the parameters and consumers can know each hour, day, and month's energy consumption up to date according to their usage.

Key-Words: - Arduino, NodeMCU, energy monitoring, PZEM-400T, CT, current, voltage, power analyzer.

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1 Introduction

Present days, the electric power supply is needed for every human's lifestyle. In comparison to prior periods, the amount of power consumption is increasing daily. The electricity energy meters are installed in each consumer's house to measure their energy usage. Many consumers only know the consumed energy at the end of the month or they have to frequently check their energy meter to know the energy consumption. It is difficult to keep track of how much energy is used each day and hour. To track and assess how much energy is consumed in the home and office is developed and implemented by using the intelligent technique in this paper. In recent trends, the IOT (Internet of Things) is extensively used for many applications. The sensors and software, networks are embedded in electronics to simplify the devices to measure and store the electrical parameters. The word "Things" in the Internet of Things states that the communication devices and other electrical apparatus like lights, TVs, and fans for power management in the building, [1], or checking the photovoltaic panels, [2]. There are various paths have implemented to link the Internet of Things, [3].

The IOT application is used to monitor the electrical power and energy measurement systems, [4]. Extensive research studies are available about IOT-based energy monitoring to measure the status of the appliances in homes. The studies, [5], [6], [7], did smart meter design to measure the energy. They designed the GSM (Global System for Mobile Communication) networks to display the measured parameters of the electrical appliances using the PZEM-004T sensor. The Atmega328p microcontroller and Wi-Fi Module were used to monitor the electrical parameters, [8]. They designed the circuit to monitor the power and money transfer system through the Internet.

NodeMCU with the Blynk app was introduced to connect Android mobile phones to quickly measure, record, and compute the electrical bills through the cloud, [9]. The ESP8266 microcontroller and PZEM-400T sensor were used to monitor the power, [10]. Moreover, using the Fiware platform to gather the electrical power and room temperature data to send alerts systems under emergency circumstances, [11]. The remote energy monitoring is also done based on the browser /server (B/S structure), [12]. The system developed not only monitors the energy online also the system helps to save energy. The energy monitoring and controlling in a switchgear industry based on Raspberry Pi, [13]. This energy monitoring system is very useful for the industry day to day energy consumption to conserve energy consumption. IOT-based monitoring the renewable energy is done through Raspberry Pi using the Flask framework, [14]. This system was developed to display the daily usage of renewable energy smartly. The energy monitoring system precisely calculates the power consumed using Arduino and IOT, [15]. This paper explains how to monitor the energy online and remotely control the electrical appliances. The IoT-based energy management system for smart cities is based on the edge computing infrastructure, [16]. This paper presented an emerging deep reinforcement learning (DRL) technique for an energy scheduling scheme for a long-term goal. IOT-based electrical energy was displayed on a smartphone and the data was saved in the cloud system to monitor the energy consumption online, [17].

The proposed work is to monitor the energy parameters using the cutting-edge domains of Arduino and the Internet of Things. The circuit is based on the Arduino, ESP8266 controller, PZEM-004T current and voltage sensor. The ESP8266 used only a Wi-Fi chip system and the Arduino was mainly used as controller. The experimental results are carried out by using different practical loads such as resistance, inductance passive loads, and lamp loads of different watts. The measured energy parameters of voltage, current, power, power factor, frequency, and energy are displayed in the LCD. The same parameters are also measured through the digital power analyzer instrument to check and compare between the real-time measured data and sensor-measured data online. The error calculation is also carried out to know the % of errors. The measured electrical parameters are sent to the cloud through the Thing Speak platform for online physical monitoring from anywhere in the world.

2 Problem Formulation

Energy meters are installed on consumer's premises to track their energy usage. It is not easy to see the day, week, or month's energy consumption by the consumer. Moreover, the power meters are fixed at difficult locations in the consumer houses which makes it not easy to regularly monitor their power meter. The problems that might occur with the current system are: The chance of human mistake is very high while recording the manual meter reading, the consumer is not updated about current electricity usage, and the consumer has difficulty knowing the consumed energy in each hour, day, and month.

2.1 Objectives

To design the system for real-time consumption monitoring by graphical form remote monitoring energy usages of the house devices. To detect the electricity theft in the house. To measure more than 5 electrical quantiles such as voltage, current, power, power factor, energy & frequency

3 Block Diagram and Its Description

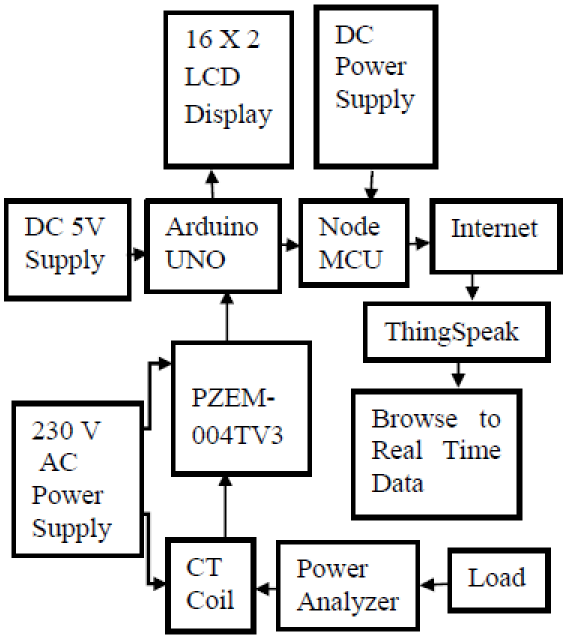

Fig. 1: Block diagram for the project

Figure 1 shows the block diagram of the project. The PZEM-004TV3 module is coupled to the Arduino controller and, through the PZEM, receives a signal from the CT coil that is attached to the lamp load. The PZEM-004TV3 module and CT coil were powered by an external 230 V AC power source. Through a USB wire, a separate DC 5V is provided to the Arduino. According to the programming in the Arduino, the I2C -LCD adapter is used to operate the 16 x 2 display, which displays the voltage, current, and power measurements of the load. A NodeMCU ESP8266 is utilized as a Wi-Fi chip system. By using a WiFi connection and the Internet, the acquired data is sent to Thingspeak to save in the cloud for visualization and analysis purposes. The power analyzer is also used to measure the real-time energy monitor to compare with the sensor measuring parameters.

3.1 Description of Components

In this project, various components are used. The components are discussed below in detail, with their work in this project.

3.1.1 Arduino Uno

Arduino is an open-source prototyping platform with simple hardware and software. It is formed from a circuit board that may be programmed (referred to as a microcontroller). Arduino boards can receive analog or digital input data from a variety of sensors and convert them to an output, such as driving a motor, turning on/off LEDs, connecting to the cloud, and doing a variety of other tasks. There are many types of Arduino depending on the different microcontrollers used, in our project we use Arduino Uno.

3.1.2 PZEM-004TV3 Module

The PZEM-004T board measures 3.1 by 7.4 cm. The module's CT coil has a 33mm diameter. The SD3004 chip from SDIC Microelectronics Co., Ld. is the module's primary component [9]. The board has an Atmel 24C02C erasable PROM EEPROM with a 4.5V to 5.5V voltage range. Two PC817 opt couplers are used to galvanic ally separate the serial interface. Electronic modules like the PZEM-004T are used to measure things like voltage, energy, power, frequency, current, and power factors. The PZEM-004T module is ideal for use as a project or experiment to measure the power on an electrical power network, such as a household or building, because it includes all of these capabilities and functionalities. The PZEM-004TV3 module is used with a measuring range of 100A. The range to measure the voltage is 80-260V. The range to measure the current is 0-10A and 0-100A. The range to measure the active power is 0-2.3kV and 0-23kV. The range to measure the power factor is 0-1. The range to measure the frequency is 45HZ-65HZThe range to measure the voltage is 80-260V. The range to measure the current is 0-10A and 0-100A. The range to measure the active power is 0-2.3kV and 0-23kV. The range to measure the power factor is 0-1. The range to measure the frequency is 45HZ-65HZ.

3.1.3 CT Coil

A sort of "instrument transformer," the Current Transformer (C.T.), is made to produce an alternating current proportional to the current monitored in its primary winding in its secondary winding. The genuine electrical current flowing in an AC transmission line can be safely monitored using a standard ammeter using current transformers, which reduce high voltage currents to manageable levels. A basic current transformer operates on a somewhat different principle than a standard voltage transformer. CTs can be used to monitor current or to turn the main current into the decreased secondary current for meters, relays, control devices, and other devices. The high voltage primary is isolated by CTs that convert current. The current transformer, employed with an air core, a current transformer contains a main winding, a core, and a secondary winding. Over a certain range, a current transformer is designed to maintain an exact ratio between the currents in its primary and secondary circuits.

3.1.4 I2C LCD Module

A conventional LCD is simpler to attach than an I2C LCD. Rather than 12, only connect 4 pins. Start by attaching the GND pin to the ground and the VIN pin to the Arduino's 5V output. I2C pins are unique to each Arduino board and must be linked properly. On Arduino boards with the R3 configuration, the AREF pin is close to the headers for the SDA (data line) and SCL (clock line) pins. There are two more names for them: A5 (SCL) and A4 (SDA).
An I2C LCD has four pins which interface it to the outside world**:**
GND: The ground pin, GND should be linked to the Arduino's ground.
VCC: The module and the LCD are both powered by VCC. Connect it to the Arduino's 5V output or a different power source.
SDA: SDA stands for Serial Data. This line is used to send and receive data.
SCL: SCL stands for Serial Clock. The Bus Master provides this signal as a time signal.

3.1.5 Load

The circuit is connected with the 100 W Lamp load and passive loads 2kW (resistance and inductance).

3.1.6 NodeMCU

The NodeMCU (Node MicroController Unit) is an open-source hardware and software development. The ESP8266 NodeMCU is powered using a MicroB USB port on the device's PCB. The board contains an integrated LDO (Linear and Low-Dropout) voltage regulator to maintain a constant voltage of 3.3V and 600 mA. The ESP8266's operating voltage range is 3V to 3.6V. The operational current for RF transmissions is 80 mA. On one of the board's sides, the regulator's output is also divided up and designated with the number 3V3. This pin can be used to power external components.

4 Circuit Diagram

The circuit diagram consists of the following main components represented in Figure 2.

- Arduino UNO
- PZEM-004TV3 module
- CT coil
- 16*2 LCD
- I2C LCD adapter
- Node MCU
- Load, AC 230V supply
- DC Power supply

The project circuit consists of an Arduino Uno board, AC 230 V supply mains, Current transformer load, and PZEM-004t module. The PZEM -004T module is made by Peacefair Electronics and its operation is based on the current transformer measurement (CT). The PZEM 004T module is responsible for all parameters parameter measurements such as voltage, current, power consumption, energy consumption, frequency, and power factor. The PZEM module is connected to the Arduino Uno board through the UART (Universal Asynchronous Receiver and Transmitter) serial communication port Tx and Rx on one side of the module and the static load line is connected on the other side of the module. The supply line and neutral are directly connected to the PZEM-004T module to deliver the voltage measurement. The 100A/ 100mA current transformer (CT) is looped through the load neutral to provide the current measurement.

The PZEM-004T module internally measures and computes the voltage, current, power consumption, energy consumption, frequency, and power factor. The output data is sent to the Arduino Uno board. The Arduino will send this output to LCD to display the measured parameters. Here the different types of loads are used to measure the parameters. The loads such as 100 Watts lamp load, static resistive load bank, and static inductive load bank are used with different load levels. The loads are connected from the supply mains through the CT and Digital Power Analyzer to monitor and compare the real-time measured parameters with PZEM-measured parameters.

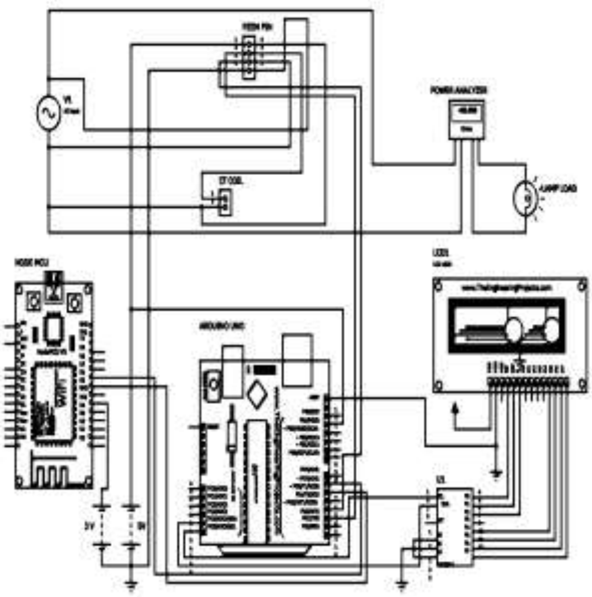

Fig. 2: Circuit diagram

The Node MCU is connected to the Arduino Uno board through the UART (Universal Asynchronous Receiver and Transmitter) serial communication port TX and RX on pins 5 and 6 respectively. The NodeMCU will transmit the measured data via an internet connection. On a desktop or laptop computer, a browser can be used to access real-time data.

When the load circuit is switched on, the load current starts to flow in the load circuit and is sensed by the current transformer. The sensed current is read by the power side circuit of PZEM-004T. The PZEM-004T module sends a command to Arduino to display the load circuit current. Similarly, voltage is read by PZEM-004T and commands the Arduino to display. Based on the current and voltage across the load, the frequency, power, energy, and power factor are displayed on the LCD. The PZEM-004T operates with a 5V DC power supply. The measured parameter data is sent to the cloud through the Node MCU with the Thing Speak platform.

4.1 Hardware Connection Description

Figure 3 shows the Hardware connection

- The Vin pin of the LCD-I2C is connected to the pin 5V of the Arduino.
- The GND pin of the LCD-I2C is connected to the GND of the Arduino.
- The SDA pin of the LCD-I2C is connected to the pin A4 of the Arduino.

- SCL pin of the LCD-I2C is connected to the A5 of the Arduino
- PZEM module Rx is connected to the pin 3 TX of the Arduino.
- PZEM module Tx is connected to the pin 2 RX of the Arduino.
- PZEM module GND connected to the GND of the Arduino.
- PZEM module 5V is connected to the pin 5V of the Arduino.
- PZEM module input pin 1 and 2 is connected to supply main Phase and Neutral
- PZEM module input pin 3 and 4 is connected to the CT coil terminal Phase and Neutral
- Neutral of the supply line is looped through the CT to the input terminal (Neutral) of the Digital Power analyzer.
- The phase of the supply line is directly connected to the input terminal (Phase) of the terminal of the Digital power analyzer.
- The Load is connected across the output of the Digital power analyzer.
- The Arduino is connected to the laptop through a USB wire.
- Node MCU GND connected to the GND of the Arduino.
- Node MCU 3.3V is connected to the pin 3.3V of the Arduino.
- Node MCU RX is connected to the pin 6 of the Arduino.
- Node MCU TX is connected to pin 5 of the Arduino

Fig. 3: Hardware connection

5 Result and Discussion

Figure 4 shows the 100-watt lamp load setup. The voltage, current, frequency, power, energy, and power factor parameters are measured by connecting the different practical loads. All the loads were tested instantly and no specific time was fixed to measure the parameters. The PZEM sensor measures the voltage and current when the load is connected. The Arduino receives a signal, and the LCDs measure parameters. The measured electrical parameters are sent to the cloud server using the Thing-speak platform. The parameters are accessed by the laptop and mobile device through the web browser. The load current, power, energy, and power factor are observed to vary according to the load patterns.

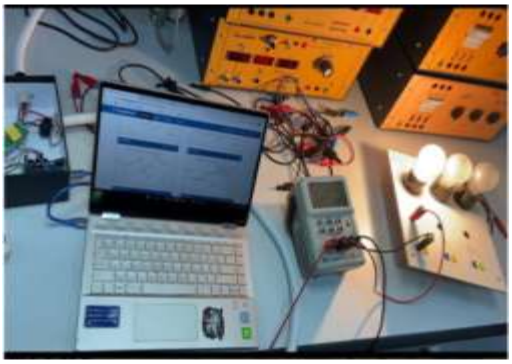

Fig. 4: 100 Watts Lamp Load experimental setup

Depending on the time and load power, the energy varies. According to the input level, the supply voltage and frequency are both kept constant. The sample reading of the 100Watts lamp load measured parameters of the power analyzer, LCD, and Thingspeak output is shown in Figure 5, Figure 6a and Figure 6b The real-time measured data by the power analyzer is cross-checked with the PZEM sensor measured data. The error values of the voltage and current are calculated by using the error calculation formula (1).

$$Error = \frac{\text{Meter reading} - \text{PZEM Sensor Reading}}{\text{Meter reading}} \text{ X } 100$$

(1), [17].

Fig. 5: Power analyzer and LCD readings for the 100–watt Lamp load

The calculated % error for the voltage and current values are tabulated in Table 1. A smaller percentage of errors is observed as compared with the real-time measured by using a digital power analyzer meter against sensor-measured data.

Table 1. 100 Watts Lamp Error calculation

	V	I	P	E	% Error V	% Error I
Meter	254	0.44	116	0.00006	-0.27	0
PZEM Sensor	255	0.44	112.6	0.5		

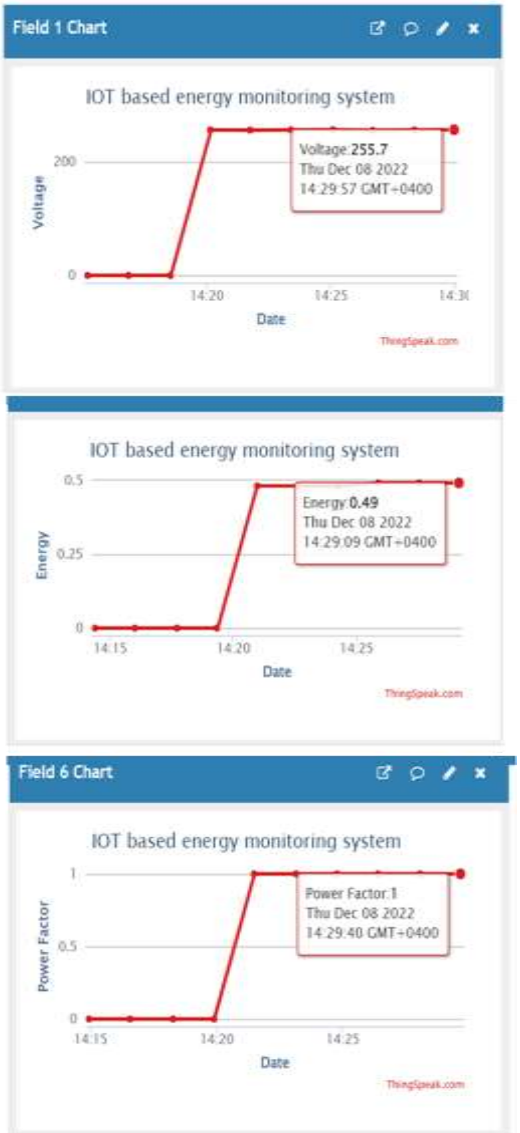

Fig. 6a: Thingspeak output

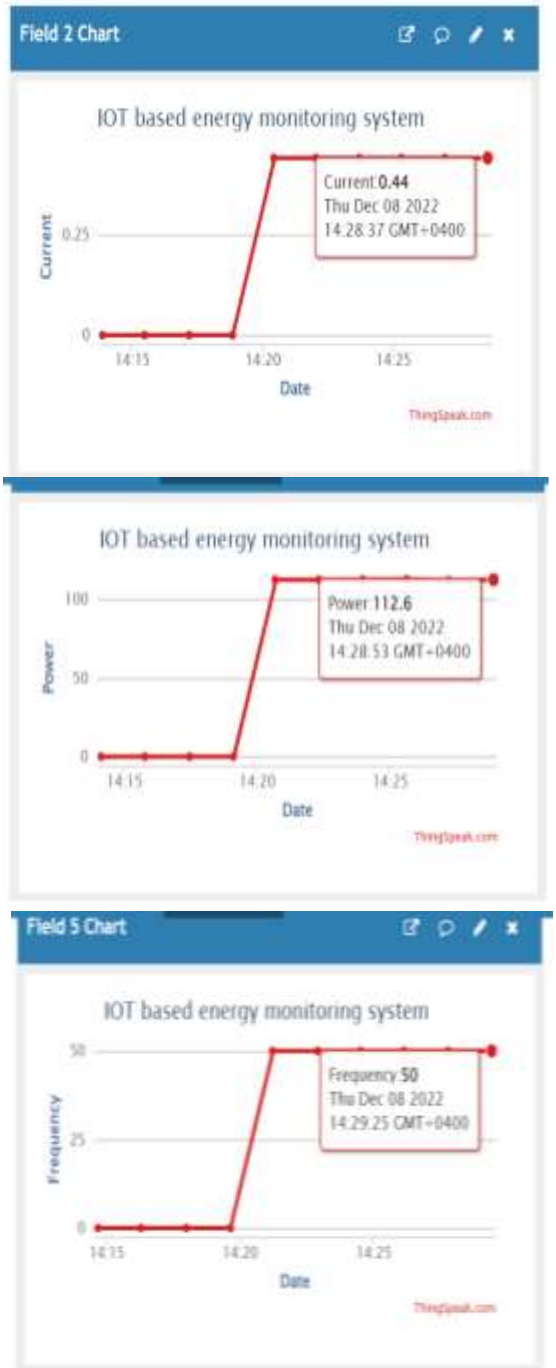

Fig. 6b: Thingspeak output

6 Conclusion

The proposed "IOT Based Energy Monitoring for Practical Loads Using NodeMcu " project was successfully created and tested. The experimental results of the energy monitoring system with different load parameters are measured and data is transmitted to the server through the Thing-speak platform. Through the online browser, the real-time measured data is viewed by laptop graphically. This method is a straightforward, low-cost circuit that allows for the simultaneous measurement of many electrical characteristics and significantly eliminates the need for additional meters. It reduces the costs associated with installing various meters. The error calculation was also made and compared with the real-time measured parameters by using the power analyzer.

In the future, the system can be more compact and user-friendly and it would allow users to monitor their homes for theft prevention as a smart house.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflict of Interest

The authors have no conflicts of interest to declare.