**SMART ENERGY METER**

As a Part of Major Project work submitted in partial fulfillment of the requirement for the award of the degree of

# [BACHELOR](https://www.google.co.in/search?q=BACHELOR&source=univ&tbm=nws&tbo=u&sa=X&ei=nwkoU4L4MYjmrAeB7IHYDw&ved=0CDkQqAI&biw=1366&bih=605) OF TECHNOLOGY

**in**

# ELECTRONICS & COMMUNICATION ENGINEERING

**By**

**VENKATESH.NAYAK(21211A04R2)**

**T. KARTHIK VARMA (21211A04Q5)**

**U. PRUTHVI RAJ (21211A04Q6)**

# Under the esteemed guidance of Mr. MSS BHARGAV M.TECH

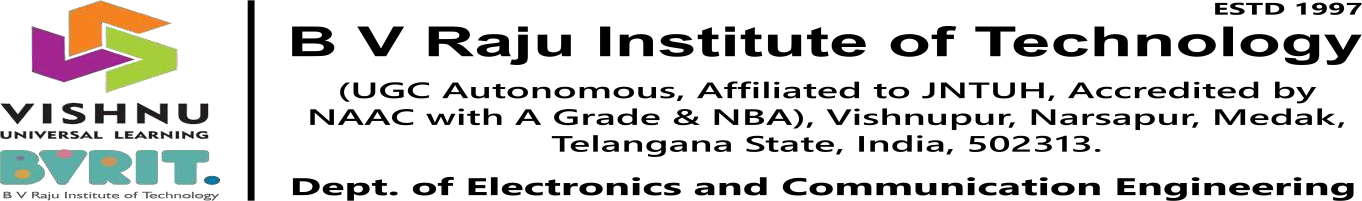
**Assistant Professor**



**B V Raju Institute of Technology**

# (UGC Autonomous, affiliated to JNTUH, Accredited by NAAC with A+ Grade & NBA), Vishnupur, Narsapur, Medak, Telangana State, Indian, 502313.

**2022-2023**



**CERTIFICATE**

This is to certify that the Major Project work Phase II entitled **SMART ENERGY METER** is being submitted by **Mr. Venkatesh. Nayak(21211A04R2), Mr. T. Karthik Varma(21211A-4Q5) and Mr. U. Prithvi Raj(21211A04Q6)** in partial fulfillment of the requirement for the award of the degree of **B.Tech. in Electronics & Communication Engineering** by Jawaharlal Nehru Technological University Hyderabad is a record of bonafide work carried out by him/them under my guidance and supervision from **2022** to **2023 .**The summary and findings presented in this project have been verified and are found to be satisfactory.

## INTERNAL GUIDE HEAD OF THE DEPARTMENT

**Mrs.P.Sravani Dr.B.R Sanjeev Reddy**

## M. Tech, (Ph.D) PhD, MIEEE

**Assistant Professor Professor, Dept. of ECE**

**B.V. Raju Institute of Technology**

**Vishnupur, Narsapur, Medak.(Dt) Pin:502313**

**(Affiliated to JNTU, Hyderabad)**

**Ph: 08458-222000, 222001 Fax: 08458-222002**

**Department of Electronics & Communication Engineering**



**CERTIFICATE**

This is to certify that the Minor Project work entitled

**SMART ENERGY METER USING IOT**  is being Submitted by

**Mr. Venkatesh. Nayak(21211A04R2), Mr. T. Karthik Varma(21211A04Q5),**

**Mr. U. Prithvi Raj(21211A04Q6)** fulfillment of the requirement for the award of

The degree of **B.Tech. in Electronics Communication Engineering**, by

Jawaharlal Nehru Technological University Hyderabad is a record of Bonafide

work carried out by him under my guidance and supervision from

……….. to ………….. .

The results presented in this project have been verified and are found to be

satisfactory.

.

**INTERNAL GUIDE Dr. Sanjeev Reddy**

**B.E, M. Tech, PhD.**

**Professor & HOD, Dept. of ECE**

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We would like to express our profound gratitude to Head of the department **Dr. B.R Sanjeev Reddy, Ph.D,** Dept. of ECE, for his encouragement, inspiration and close monitoring and guidance he gave us during the execution of the project.

We express our sincere thanks to our ES Coordinator **Mr. Anirudh sir , Professor**  **,** Dept. of ECE, for his support and guidance during the execution of the project. Before I close, I would like to thank the almighty for his blessings.

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Regards,

**VENKATESH.NAYAK(21211A04R2)**

**T. Karthik Varma(21211A04Q5)**

**U. Pruthvi Raj(21211A04Q6)**

**DECLARATION**

We hereby declare that the project titled “Smart Energy Meter” submitted to B.V Raju Institute of Technology, affiliated to Jawaharlal Nehru Technological University, Hyderabad for the award of degree of Bachelor of Technology in Electronics and Communication Engineering is a result of original project work done by us under the guidance of Mr. J. Kishore, M-Tech, Assistant Professor Department of ECE It is further declared that the project report on any part therefore has not been previously submitted to any university or institute for the award of degree.

**VENKATESH.NAYAK(21211A04R2)**

**T. Karthik Varma(21211A04Q5)**

**U. Pruthvi Raj(21211A04Q6)**

# ABSTRACT

The growing demand for energy efficiency and the increasing adoption of Internet of Things (IOT)

technologies have paved the way for innovative solutions in the energy sector. This paper

introduces a novel approach to energy consumption management through the development of Smart

Energy Meter (SEM) using IoT. The proposed system aims to address the challenges of traditional

energy meters by offering real-time monitoring, data analysis, and remote control capabilities.

The Smart Energy Meter utilizes IoT sensors to gather data related to energy consumption, voltage

levels, current flows, and other relevant parameters. This data is then transmitted to a central cloud

-based platform using wireless communication protocols. The cloud platform processes and analyzes

the data, generating valuable insights for both consumers and utility companies. Users can access this

information through a user-friendly interface, enabling them to monitor their energy usage patterns

and make informed decisions to optimize consumption.

Key words: Energy consumption monitoring, real time data, wireless communication, microcontroller,

Utility management.

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# INTRODUCTION

The growing demand for energy efficiency and the increasing adoption of Internet of Things (IoT) technologies have paved the way for innovative solutions in the energy sector. This paper introduces a novel approach to energy consumption management through the development of a Smart Energy Meter (SEM) using IoT. The proposed system aims to address the challenges of traditional energy meters by offering real-time monitoring, data analysis, and remote control capabilities. The Smart Energy Meter utilizes IoT sensors to gather data related to energy consumption, voltage levels, current flows, and other relevant parameters. This data is then transmitted to a central cloud-based platform using wireless communication protocols. The cloud platform processes and analyses the data, generating valuable insights for both consumers and utility companies. Users can access this information through a user-friendly interface, enabling them to monitor their energy usage patterns and make informed decisions to optimize consumption.

Conventional energy meter which we use in our household to measure energy consumption is an offline device , so it has to be monitored manually. But nowadays there are smart energy meters available in the market whose readings can be monitored from anywhere using internet. Not only energy consumption but we can monitor multiple parameters such as voltage, current, power factor , frequency etc. so today we are building SMART ENERGY METER USING IOT. Here we will use PZEM-004T AC multifunction electric energy metering power monitor module to measure the parameters and will use Node MCU ESP8266 to post the data to an HTML webpage.

# Motivation

# The Smart Energy Meter leverages the power of IoT to revolutionize the way we monitor, manage,

# and optimize energy consumption. Unlike conventional energy meters, which offer limited insights

# and require manual readings, the SEM introduces a new paradigm of real-time data collection,

# analysis, and communication. This real-time aspect provides individuals, households, businesses,

# and utility companies with unprecedented visibility into energy usage patterns, allowing them to

# make informed decisions to conserve energy, reduce costs, and contribute to a more sustainable future.

# The motivation behind the development and implementation of Smart Energy Meters (SEMs) using

# IoT technology stems from several pressing factors and challenges in the contemporary energy

# landscape. These motivations are rooted in the need to address inefficiencies, enhance consumer

# awareness, and contribute to a more sustainable energy future. The key motivations include:

# Energy Efficiency and Conservation

# Lack of Visibility

# Consumer Empowerment

# Remote Monitoring

# Objectives and Outcomes

## Objectives of the project

* Interfacing the sensor to the household appliances.
* Sensor detects the different parameters like power factor, current, voltage etc.
* Redirecting the HTML page in which parameters are present.

## Outcomes of the project

* To develop a reliable system that detects energy consumption at home.
* Monitoring the parameters through mobile phone.

# Scope of the project

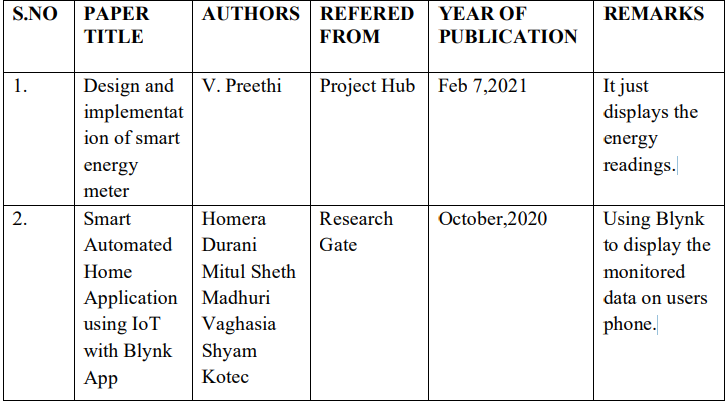
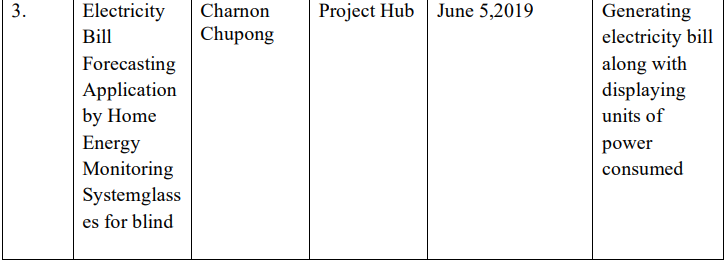
The future scope of Smart Energy Meters using IoT holds immense potential for transforming how we

manage and interact with energy. As technology continues to advance and society becomes more

conscious of sustainability, SEMs are likely to play a central role in creating smarter, more efficient,

and more sustainable energy ecosystem

* + 1. **LITERATURE SURVEY**
* The smart meters can be regarded as costless way of obtaining detailed consumption profiles that can be used in higher level application .The first approach could be a simple energy consumption visualization using In-home displays this measure do not directly the influence the end users consumption. Nevertheless if the user us aware the energy demanded and the economical cost ,some energy saving can be induced.
* The previous model of this project is displaying the voltage ,current power in the LCD display but now we created an HTML page for knowing the parameters through IP address we can know the power consumption and take measures to use less power consumotions



## EXISTING SYSTEM

The earlier models of smart energy meters using IoT share many of the same principles as the more

advanced systems I described earlier. However, they might lack some of the features and capabilities

that have emerged with advancements in technology. Here's an overview of an older model of

smart energy meter using IoT:

Components of an Older Model Smart Energy Meter System:

Basic Smart Meter: The core component is a smart energy meter equipped with measurement

capabilities and communication modules. These meters usually have simpler communication

protocols compared to the latest models.

IoT Connectivity: These older models typically use simpler IoT connectivity options like Zigbee,

which is a wireless communication protocol designed for low-power, short-range connections.

Data Transmission: Energy consumption data collected by the meter is transmitted over the chosen

communication protocol to a local data concentrator or gateway.

Local Data Concentrator: In some cases, the energy consumption data is collected by a local data

concentrator that aggregates data from multiple smart meters within a specific area.

Local Network: The local data concentrator or gateway connects to a local network within the

premises, allowing for communication with other devices and potentially enabling users to access

consumption data locally.

Limited Remote Access: While remote access and cloud-based platforms were less prevalent in older

models, some systems might have provided limited remote access to energy consumption data through

dedicated user interfaces

# Proposed System

The proposed system for smart energy meter is combination of some modern technology

components like microcontroller(mode mcu ESP8266) and sensor to detect energy. Unlike

old version of energy meter. Here we are using IOT(Internet of things) to access the details

and monitor them through internet via HTML Page. Here we have used a single sensor

PZEM-004T to so many parameters through the load that we kept like current, voltage,

power factor, power ,frequency. Instead of using separate sensor for each parameter here

we integrated the this single sensor in this device. From this device we can access the

information through iot via HTML page. This helps us in conserve the energy in our home

by knowing the information of which component is charging more energy.

# 3.ANALYSIS AND DESIGN

# Methodology

# The proposed design is combination of various components in which we integrate them to design

# system that detects energy consumed by appliances at home by using sensors this info we can

# access if from internet through HTML page. By using a microcontroller – node MCU ESP 8266

# which is a wi-fi module we connect this node mcu to sensor called PZEM-004T which is a

# multifunctional sensor which detects various parameters through the load. And we created a HTML

# page to monitor the reading

# The methodology for implementing a smart energy meter involves a systematic approach that

# encompasses planning, design, development, testing, deployment, and ongoing monitoring.

# Block Diagram

# 

# 3.3 Flow chart

# 

# 

3.3 Work flow of the proposed system

# 3.4 Schematic Diagram

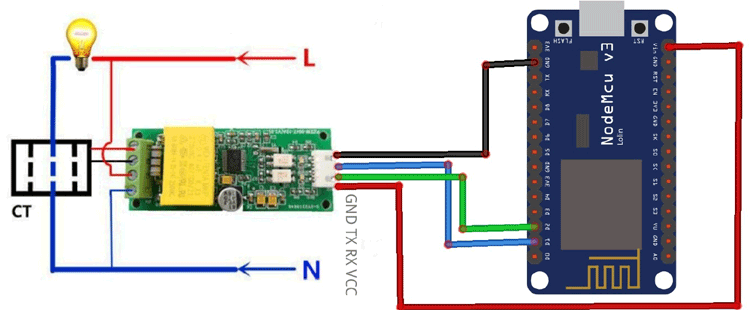


Fig 3.3: Schematic Diagram of proposed system

# HARDWARE REQUIREMENT

# NODEMCU ESP8266

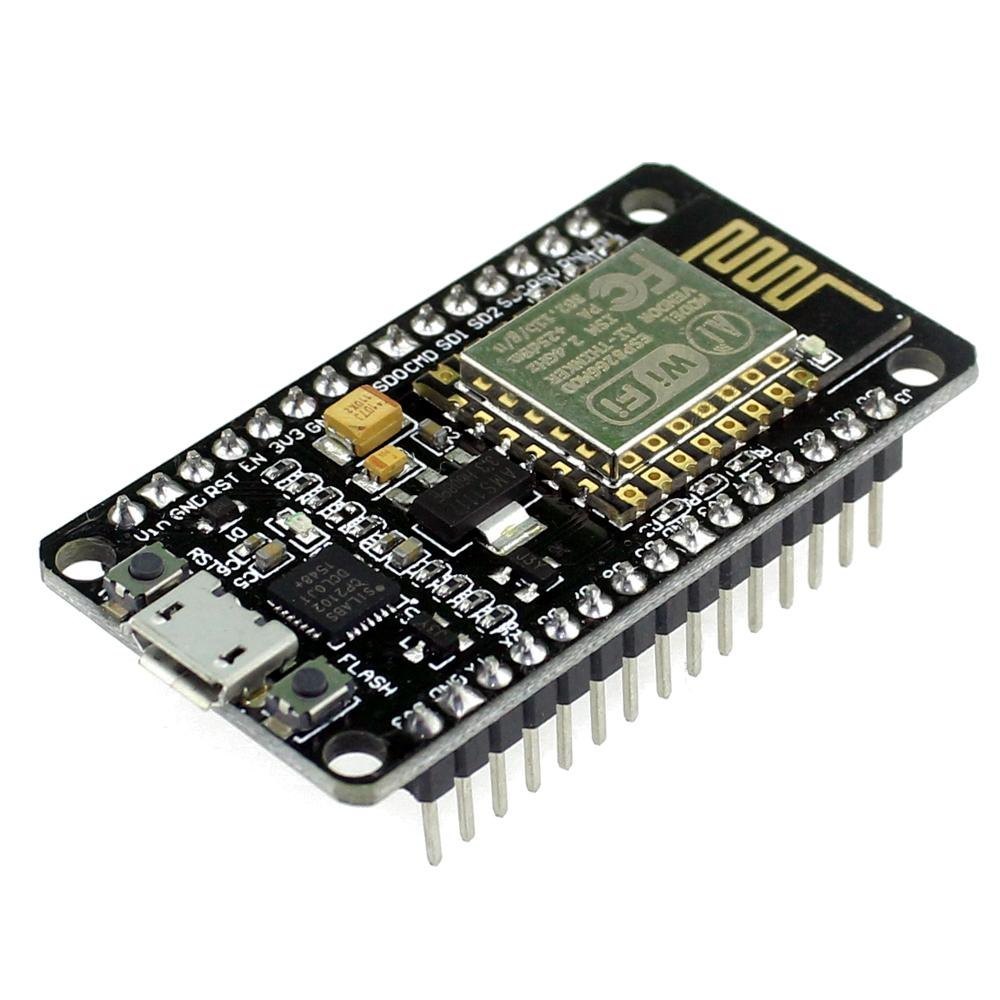


Figure 4.1:NODE MCU ESP8266

The Node MCU ESP8266 is an extensively employed development board in IoT applications,

providing a versatile and cost-effective approach to connect devices to the internet. It features

Wi-Fi and programming capabilities, facilitating speedy prototyping and deployment of IoT

solutions. We use the Arduino IDE to configure the microcontroller and transfer the data via

Wi-Fi to the IoT Hub. The data is then retrieved from the IoT Hub by Node-RED in order

to allow visualization in a dashboard. It has one Analog Input Pin, 16 Digital I/O pins

along with the capability to connect with serial communication protocols like SPI,UART,

and I2C. Node MCU has 128 KB RAM and 4MB of Flash memory to store data and programs.

The ESP8266 is a System on a Chip (SoC), manufactured by the Chinese company Espressif.

It consists of a Tensilica L106 32-bit micro controller unit (MCU) and a Wi-Fi transceiver. It

Has 11 GPIO pins\* (General Purpose Input/Output pins), and an analog input as well. Node

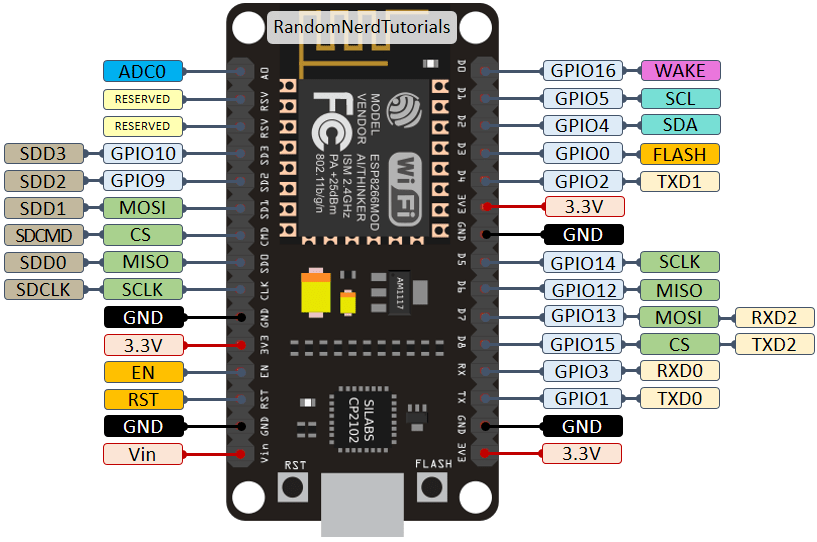
MCU is an open-source LUA based firmware developed for the ESP8266 wi-fi chip. By

exploring functionality with the ESP8266 chip, Node MCU firmware comes with the ESP8266

Development board/kit i.e. Node MCU Development board. Since Node MCU is an open-source

platform, its hardware design is open for edit/modify/build.

* + 1. **Pin Description**



**Specifications**

## Manufacturer : Espressif Systems

## Type : 32-bit microcontroller

## CPU : Tensilica Diamond Standard 106Micro (aka. L106) @ 80 MHz (default)

## or 160 MHz .

## Memory : 32 KiB instruction, 80 KiB user data

## Input : 17 GPIO pins

## Power : 3.3 V DC

## Successor : ESP32

|  |  |  |
| --- | --- | --- |
| **Pin Category** | **Name** | **Description** |
| Power | Micro-USB, 3.3V, GND, Vin | **Micro-USB:** NodeMCU can be powered through the USB port    **3.3V:** Regulated 3.3V can be supplied to this pin to power the board    **GND:** Ground pins    **Vin:**External Power Supply |
| Control Pins | **EN, RST** | The pin and the button resets the microcontroller |
| Analog Pin | A0 | Used to measure analog voltage in the range of 0-3.3V |
| GPIO Pins | GPIO1 to GPIO16 | NodeMCU has 16 general purpose input-output pins on its board |
| SPI Pins | SD1, CMD, SD0, CLK | NodeMCU has four pins available for SPI communication. |
| UART Pins | TXD0, RXD0, TXD2, RXD2 | NodeMCU has two UART interfaces, UART0 (RXD0 & TXD0) and UART1 (RXD1 & TXD1). UART1 is used to upload the firmware/program. |
| I2C Pins |  | NodeMCU has I2C functionality support but due to the internal functionality of these pins, you have to find which pin is I2C. |

Figure 4.1.1:ESP8266 Pinout

## Node mcu ESP8266 pins used in the proposed system:

## GND : Ground.

## VCC : power supply of 3.3v.

## D1 : Digital pin 1 to connect to energy sensor module.

## D2 : Digital pin 2 to connect to energy sensor module.

# PZEM-004T MODULE

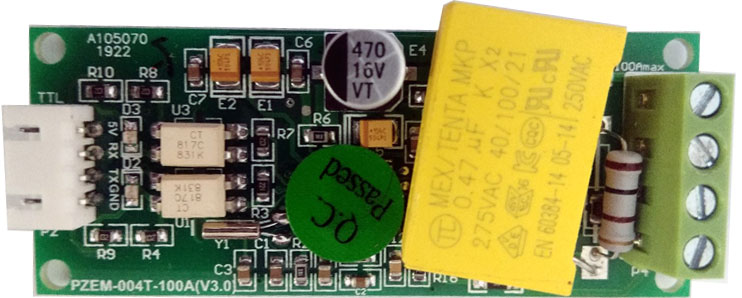


Figure 4.2 PZEM-004T

The PZEM-004T module is a common power monitoring module used to measure various electrical parameters in real-time. It's often used in projects related to smart energy monitoring and management. Here's an overview of the PZEM-004T module and how it fits into a smart energy meter system:

PZEM-004T Module Features:

The PZEM-004T module is designed to measure several electrical parameters of an AC circuit:

Voltage (V): Measures the instantaneous voltage of the AC supply.

Current (I): Measures the instantaneous current flowing through the circuit.

Active Power (P): Calculates the real power being consumed.

Apparent Power (S): Calculates the total power, including reactive power.

Power Factor (PF): Represents the efficiency of power usage.

Frequency (Hz): Measures the frequency of the AC supply.

Integration into a Smart Energy Meter System:

The PZEM-004T module can be integrated into a smart energy meter system to provide real-time measurement and monitoring of electrical parameters. Here's how it fits into the overall system:

Hardware Integration:

The PZEM-004T module is connected to the electrical circuit that you want to monitor, typically in series with the load.

The module requires both voltage and current connections, usually obtained through voltage divider circuits and current transformers.

The module has communication pins that allow data retrieval, often using serial communication protocols like TTL UART or Modbus.

Data Collection and Processing:

The PZEM-004T module continuously measures voltage, current, and other parameters.

These measurements are sent to a microcontroller (such as Arduino, ESP8266, or ESP32) for data processing.

Firmware and Software:

The microcontroller's firmware processes the received data, calculates power, power factor, and frequency.

Communication protocols (e.g., Modbus RTU) may be used to retrieve data from the module.

The firmware can store the data locally and transmit it to a central server or cloud platform for analysis and storage.

User Interface:

Data collected from the PZEM-004T module can be displayed on a local display (if available) or accessed remotely via a mobile app or web portal.

The user interface provides real-time energy consumption, power quality, and usage patterns.

Energy Analytics:

The collected data can be analyzed to identify energy consumption patterns, load profiles, and trends.

Insights can be generated to help users make informed decisions about energy usage optimization.

Remote Control and Alerts:

In advanced setups, users can receive alerts when power usage exceeds predefined thresholds.

Some systems allow remote control of appliances or loads based on real-time data.

# Pins used in the proposed System:

* **VCC :** 5V DC Input supply for the Module
* **GND :** Ground electrical Reference
* **TX :** Transmits data serially
* **RX :** Receive data serially.

# Specifications of PZEM-004T Module

**VCC:** 5V DC Input supply for the Module

**GND:** Ground electrical Reference

**TX:** UART Transmission pin for Data

**RX:** UART Receiver pin for Data

# TECHNICAL FEATURES

* Voltage Measuring Range: 80-260 VAC
* Current Measuring Range: 0-100 Amp
* Active Power Measuring Range: 0-23KW
* Power Factor Measuring Range: 0-1
* Frequency Measuring Range: 45-65 Hz
* Module Working Voltage: 5V DC
* Output Interface: TTL

**4.4. CT COIL**



Figure 4.4 CT coil

A CT coil, short for Current Transformer coil, is a crucial component in smart energy meters and various power monitoring applications. It's used to measure current flowing through a conductor without the need to physically interrupt the circuit.

Functionality of CT Coil:

A CT coil is typically a ring-shaped device made of a ferromagnetic core around which a primary conductor (the wire carrying the current to be measured) is passed. The primary conductor's current induces a current in the secondary winding of the CT coil, which is then used for measurement. The induced current is proportional to the primary current but at a much lower level, making it safer to measure.

Integration with Node MCU for Smart Energy Meter:

To build a smart energy meter using a Node MCU (an ESP8266-based development board), you can follow these steps:

CT Coil Connection: Pass the wire carrying the current you want to measure through the CT coil's central hole. Connect the secondary terminals of the CT coil to an analog input pin (e.g., A0) on the Node MCU.

**Other hardware materials requirement**

**Breadboard :** For interfacing node MCU onto it for better connectivity.

**Jumper wires** : For connecting the node MCU and the sensor.

**Laptop cable** : For connecting node MCU and laptop.

**Bulb**  : For load.

# SOFTWARE REQUIREMENTS

# NODEMCU ESP8266 operating system

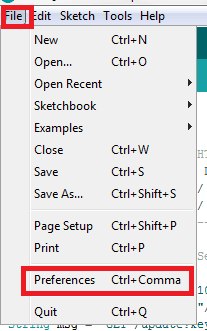
# Node MCU is an open-source Lua based firmware and development board specially targeted for IoT based Applications. It includes firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module.

# Installing node MCU ESP8266 operating system

# The most common way to program the NodeMCU is by using the Arduino IDE (Integrated Development Environment). You can download it from the official Arduino website: <https://www.arduino.cc/en/Main/Software>.

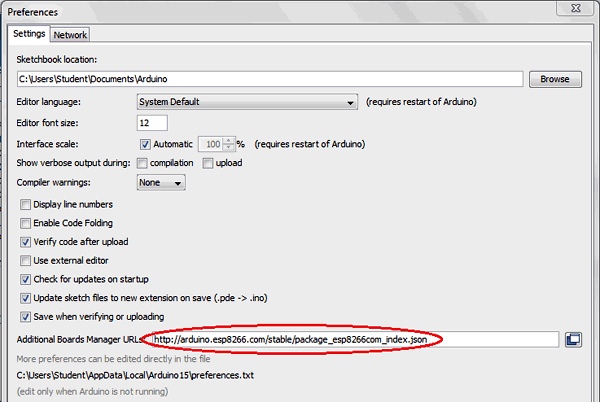
To **upload code into Node MCU using Arduino IDE**, follow the steps below:

1. Open Arduino IDE, then go to ***File–>Preferences–>Settings***.



2.

Type ***https://arduino.esp8266.com/stable/package\_esp8266com\_index.json***in the **‘Additional Board Manager URL**’ field and click ‘Ok’.



3. Now go to ***Tools > Board > Boards Manager.*** In the Boards Manager window, Type ***ESP*8266** in the search box, select the latest version of the board, and click on install.



4. After installation is complete, go to ***Tools ->Board -> and select Node MCU 1.0(ESP-12E Module).***Now you can program Node MCU with Arduino IDE.

**5.2. Code elaboration**

After the above setup for programming Node MCU using Arduino IDE, upload the complete code into ESP8266 Node MCU. The stepwise explanation of the complete code is given below.

First, include all the required library files in the code. Here ESP8266 board library is used for NodeMCU and **PZEM004Tv30.h** is used for the Energy monitoring module.

#include<ESP8266WiFi.h>

#include<WiFiClient.h>

#include<ESP8266WebServer.h>

#include <PZEM004Tv30.h>

Then an object is created in the class PZEM004Tv30 which can be used throughout the program scope. The Software serial pins are also defined, which are D1 and D2 in my case.

PZEM004Tv30 pzem(D1,D2); //RX/TX

Then create the ESP8266WebServer class object with the name server and default port number 80.

ESP8266WebServer server (80);

Now, declare the network credentials, i.e. SSID and password. It is required to connect our NodeMCU to the internet.

const char\* ssid = "admin";

const char\* password = "12345678";

Then, to connect NodeMCU to the internet, call **WiFi.begin**and pass network SSID and password as its arguments. Check for the successful network connection using WiFi.status() and after a successful connection, print a message in Serial Monitor with IP address.

Serial.begin(115200);

WiFi.begin(ssid, password);

while (WiFi.status() != WL\_CONNECTED)

{

delay(500);

Serial.print(".");

}

Serial.print(WiFi.localIP());

In the next step, an HTML page is created as shown below, which has an HTML table to show the product details and billing information in the cart. The HTML page is stored in a string variable so that it can be sent back on client request using the server.send() function.

server.on("/", []()

{

page = "<html><head><title>Smart Energy Meter using IoT</title></head><style type=\"text/css\">";

page += "table{border-collapse: collapse;}th {background-color: green ;color: white;}table,td {border: 4px solid black;font-size: x-large;";

page += "text-align:center;border-style: groove;border-color: rgb(255,0,0);}</style><body><center>";

page += "<h1>Smart Energy Meter using IoT</h1><br><br><table style=\"width: 1200px;height: 450px;\"><tr>";

page += "<th>Parameters</th><th>Value</th><th>Units</th></tr><tr><td>Voltage</td><td>"+String(voltage)+"</td><td>Volts</td></tr>";

page += "<tr><td>Current</td><td>"+String(current)+"</td><td>Amperes</td></tr><tr><td>Power Factor</td><td>"+String(pf)+"</td><td>XXXX</td>";

page += "<tr><td>Power</td><td>"+String(power)+"</td><td>Watts</td></tr><tr>";

page += "</tr><tr><td>Frequency</td><td>"+String(frequency,1)+"</td><td>Hz</td></tr>";

page += "<meta http-equiv=\"refresh\" content=\"3\">";

server.send(200, "text/html", page);

});

server.begin();

Inside **loop()**, different parameters are read using dedicated functions like voltage(), current(), etc. and then assigned to separate variables that will be appended with the HTML webpage.

voltage = pzem.voltage();

current = pzem.current();

power = pzem.power();

frequency = pzem.frequency();

pf = pzem.pf();

In the end, to handle the client request, we have to call server.handleClient(). It will handle new requests and check them.

server.handleClient();

1. **Implementation**

* ASSEMBLE HARDWARE

Collect the all required materials like NODEMCU ESP8266,PZEM-004T module, CT(current transformer) coil, connecting accessories.

And connect all the components as shown in the circuit diagram.

* SOFTWARE

First we create a HTML page for the output and integrate this HTML in code in Arduino IDE. Here we have to install a library for PZEM-004T.

After complete connections and hardware setup ,just upload the code into NODEMCU and the IP address printed in the serial monitor.

Here we have have attached AC bulb to monitor the energy consumed the by the bulb along with the parameters like voltage ,current ,power factor etc.

Here we don’t have to worry about the calculations the voltage ,current ,power etc as a library provided for PZEM-004T module(pzem004tv30.h) has all the functions related to it ,we just have to call them to display the related info.

So this is how we can build the IOT based smart energy meter using NODEMCU ESP8266

1. **Working**

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After completing and connecting all hardware and software setup the working will be as follows

**Hardware Integration**:

The PZEM-004T module, equipped with a current transformer (CT) and voltage divider circuit, is connected to the Node MCU development board.

The CT is placed around the electrical wire carrying the current to be measured.

The PZEM-004T module communicates with the Node MCU via serial communication.

**Data Collection**:

The PZEM-004T module continuously measures electrical parameters, including voltage, current, power, energy, and frequency.

The Node MCU sends commands to the PZEM-004T module to retrieve these data points.

**Node MCU Programming**:

The Node MCU is programmed using the Arduino IDE and relevant libraries.

It establishes serial communication with the PZEM-004T module, requesting and receiving data.

Code is written to process the received data, extracting individual parameter values.

**Real-time Monitoring**:

The Node MCU provides real-time monitoring of energy consumption and related parameters.

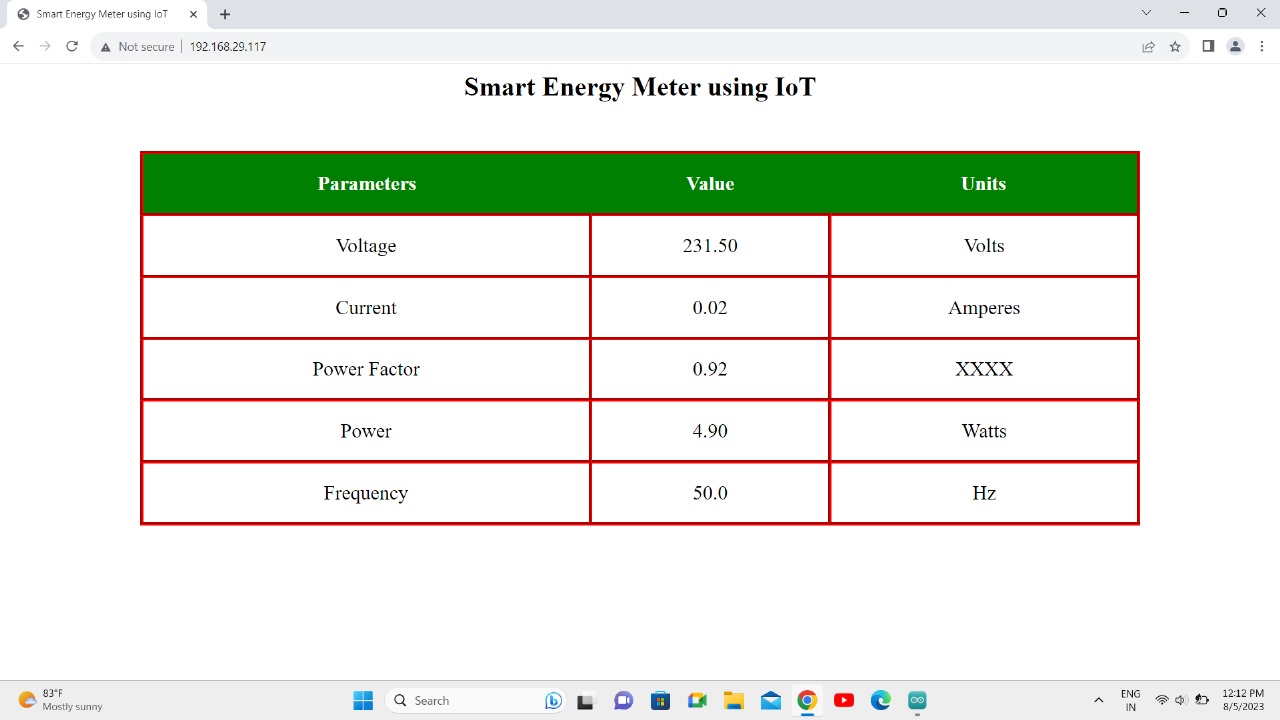
It calculates and updates these values periodically, giving users a live overview of their energy usage.

Display and Data Presentation:

The data is displayed on HTML webpage.

Users can access and interpret their energy consumption data conveniently.

* 1. **TESTING RESULTS**

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In the above result in the HTML web page the all parameters have been detected and shown in the result. That means the PZEM-004T has successfully detected the current, voltage, power, frequency, power factor. And now we can access and monitor the energy through the IP address which will further redirect to the HTML page .

1. **Advantages and applications**

SMART ENERGY METER

**Advantages**

**Real-Time Monitoring**: Smart energy meters provide up-to-date information about energy consumption, enabling users to track usage patterns and make informed decisions to reduce energy waste.

**Accurate Billing**: Traditional energy meters may lead to estimations and inaccuracies in billing. Smart meters provide accurate readings, ensuring that consumers are billed for the exact amount of energy used.

**Remote Access**: Users can access their energy consumption data remotely through mobile apps or web interfaces, allowing them to monitor usage even when they are not at the location.

**Immediate Alerts**: Smart meters can send alerts and notifications to users when unusual energy consumption levels are detected, helping to identify potential faults or energy wastage.

**Load Management**: Utility companies can remotely control certain appliances during peak demand periods to balance the energy load on the grid. This helps prevent blackouts and reduce overall energy costs.

**Renewable Energy Integration**: Smart meters facilitate the integration of renewable energy sources like solar panels. Users can monitor energy generation and optimize consumption patterns accordingly.

**Energy Conservation**: By visualizing energy consumption data, users are encouraged to adopt energy-saving behaviors, leading to reduced consumption and lower bills.

**Data Analytics**: Smart meters generate a wealth of data that can be analyzed to identify trends, optimize energy consumption, and plan for energy-efficient infrastructure improvements.

**Applications**

**Residential Sector**: Smart energy meters are widely used in homes to monitor and manage household energy consumption. They help individuals and families understand their energy habits and make adjustments for efficiency.

**Commercial Buildings**: Smart meters are installed in offices, retail stores, and other commercial spaces to monitor energy usage, identify peak demand periods, and optimize operational costs.

**Industrial Facilities**: Large industrial complexes benefit from smart meters to monitor energy consumption across different sections, helping them identify energy-intensive processes and improve overall efficiency.

**Renewable Energy Systems**: Smart meters play a crucial role in monitoring the generation and consumption of energy from renewable sources such as solar panels, wind turbines, and microgrids.

**Utility Companies**: Utility companies benefit from smart meters by receiving accurate consumption data without the need for manual readings. This streamlines billing processes and helps them manage energy distribution more effectively.

**Smart Cities**: In the context of smart city initiatives, energy meters contribute to a comprehensive energy management system, enabling efficient energy distribution, load balancing, and demand response programs.

**Electric Vehicle Charging**: Smart meters can be integrated into electric vehicle (EV) charging infrastructure, allowing users to monitor and manage their EV charging patterns.

**Energy Auditing**: Smart energy meters are valuable tools for energy auditors who assess energy usage in buildings and recommend energy-saving measures.

Overall, the advantages and applications of smart energy meters contribute to energy efficiency, cost savings, and sustainable energy management across various sectors.

1. **Conclusion and future scope**

**Conclusion**:

The implementation of a smart energy meter using a Node MCU and a PZEM-004T module marks a significant step towards efficient energy management and sustainability. This system provides real-time, accurate data on energy consumption, enabling users to make informed decisions about their energy usage. The integration of modern technology with energy monitoring addresses many limitations of traditional meters, enhancing user awareness, reducing wastage, and promoting environmentally conscious practices.

**Future Scope:**

Advanced Data Analytics: The collected data can be further analyzed using advanced algorithms and machine learning techniques. This could provide deeper insights into consumption patterns, forecast peak demands, and suggest customized energy-saving strategies.

Integration with Smart Grids: Smart energy meters can play a pivotal role in the development of smart grids. Integration with bi-directional communication systems can enable dynamic load management, demand response, and real-time adjustments based on grid conditions.

Smart Home Integration: Integrating smart energy meters with other smart home devices can offer enhanced energy management. For example, syncing with smart thermostats and appliances could lead to automatic energy optimization.

User Engagement and Gamification: Developing interactive interfaces, mobile apps, or web portals can engage users further by turning energy conservation into an interactive game, offering rewards for reduced consumption.

Peer Comparison and Social Impact: Incorporating features that allow users to compare their energy consumption with that of their peers can encourage healthy competition and create a social influence for energy conservation.

Renewable Energy Feedback: Integrating with renewable energy sources could provide not only consumption data but also offer feedback on the impact of energy generation and the potential for selling excess energy back to the grid.

Predictive Maintenance: Implementing predictive maintenance algorithms could help identify potential faults or issues in the energy distribution system before they escalate, reducing downtime and improving efficiency.

Blockchain Integration: Utilizing blockchain technology could enhance data security and transparency, especially in scenarios involving energy trading or peer-to-peer energy transactions.

Policy and Regulatory Impact: The data collected by smart energy meters could inform policymakers about energy consumption trends, aiding in the development of targeted energy-saving policies and regulations.

IoT Integration: Expanding the system to be part of the Internet of Things (IoT) ecosystem could lead to more comprehensive energy management, where interconnected devices communicate to optimize energy use.

In conclusion, the smart energy meter using a NodeMCU and a PZEM-004T module is a stepping stone towards a smarter and more sustainable energy future. The system's continuous evolution holds the promise of enhanced user engagement, greater energy efficiency, and a significant positive impact on both individual consumers and the larger energy ecosystem.

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1. Code

#include<ESP8266WiFi.h>  
#include<WiFiClient.h>  
#include<ESP8266WebServer.h>  
#include <PZEM004Tv30.h>  
PZEM004Tv30 pzem(D1,D2);  //RX/TX  
const char\* ssid = "admin";//Replace with your network SSID  
const char\* password = "12345678";//Replace with your network password

ESP8266WebServer server(80);  
float voltage,current,pf,frequency,power;  
String page = "";  
void setup()   
{  
Serial.begin(115200);  
WiFi.begin(ssid, password);  
while (WiFi.status() != WL\_CONNECTED)  
  {  
  delay(500);  
  Serial.print(".");  
  }  
  Serial.println(WiFi.localIP());  
  server.on("/", []()  
  {  
    page = "<html><head><title>Smart Energy Meter using IoT</title></head><style type=\"text/css\">";  
    page += "table{border-collapse: collapse;}th {background-color:  green ;color: white;}table,td {border: 4px solid black;font-size: x-large;";  
    page += "text-align:center;border-style: groove;border-color: rgb(255,0,0);}</style><body><center>";  
    page += "<h1>Smart Energy Meter using IoT</h1><br><br><table style=\"width: 1200px;height: 450px;\"><tr>";  
    page += "<th>Parameters</th><th>Value</th><th>Units</th></tr><tr><td>Voltage</td><td>"+String(voltage)+"</td><td>Volts</td></tr>";  
    page += "<tr><td>Current</td><td>"+String(current)+"</td><td>Amperes</td></tr><tr><td>Power Factor</td><td>"+String(pf)+"</td><td>XXXX</td>";  
    page += "<tr><td>Power</td><td>"+String(power)+"</td><td>Watts</td></tr><tr>";  
    page += "</tr><tr><td>Frequency</td><td>"+String(frequency,1)+"</td><td>Hz</td></tr>";  
    page += "<meta http-equiv=\"refresh\" content=\"3\">";  
    server.send(200, "text/html", page);  
  });  
  server.begin();  
}  
void loop()   
{  
voltage = pzem.voltage();  
current = pzem.current();  
power = pzem.power();  
frequency = pzem.frequency();  
pf = pzem.pf();  
server.handleClient();  
}