IOT-POWERED SMART PLUG: A STEP TOWARD SMART ENERGY MANGEMENT

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ABSTRACT_

To control and track single power loads, the Smart Plug system combines Arduino Uno, relays, a current sensor, an LCD display, a Wi-Fi module, and the ThingSpeak IoT platform. The system automatically turns off linked devices to prevent short circuits and equipment damage by measuring real-time power usage, identifying overload scenarios, and so on. A smartphone app lets users remotely operate the smart plug, hence allowing effective energy management. The system also offers total energy consumption statistics, invoicing information, and real-time notifications of device failures or unusual power use. The Smart Plug guarantees improved safety, energy efficiency, and user convenience by using IoT features.

Keywords: Smart Plug, IoT, Power Monitoring, Energy Management, Overload Protection, Remote Control, Real-Time Data, Power Consumption, Billing Information, Energy Efficiency, Fault detection.

1.INTRODUCTION

For both home and business uses, monitoring of energy use and remote management of electrical devices have become very vital. Often causing device damage and higher energy prices, conventional power management systems lack real-time feedback, remote access, and automated protective measures. By including modern technologies like Arduino Uno, current sensors, relays, and Wi-Fi modules, the Smart Plug system overcomes these constraints. Real-time analysis and remote monitoring are provided by a mobile app sending data to the ThingSpeak cloud system. The system can identify overload situations and automatically turn off impacted equipment, hence avoiding electrical risks. An LCD panel also shows energy use and pricing information, so enabling customers to intelligently decide to maximise power use.

Traditional power plugs and monitoring systems lack the capacity to offer real-time energy use insights, remote control features, and automated preventative actions. Often, overload situations and device failures cause electrical risks, equipment damage, and energy waste. Many current smart plugs are either too pricey or lack thorough IoT connection, which would otherwise encourage their use in homes and businesses. A reasonably priced, IoT-enabled Smart Plug system providing real-time monitoring, remote control, overload protection, and thorough energy usage study is therefore required.

2.LITERATURE SURVEY

Research Projects This part shows current research projects in the area of appliance load monitoring. These investigations can be classified as either smart meter or smart plug methods. The site of the sensors used to gather electrical consumption data drives this classification. The smart meter methods install the meter at the building's entrance where it can gauge total electrical use. Conversely, the smart plugs are buried into every socket to gauge each device's power use. According to the number of sensors employed to gather the electrical consumption data, these studies can alternatively be classified as multi-sensor or single-point sensor initiatives. Multi-sensor methods call for sensor installation at power outlets or on every device; single-point approaches call for just one sensor tracking the building. All of these strategies seek to track the electrical use of devices in a facility.

Single-point sensor approaches: Though it does not offer any appliance-specific (i.e., device-level) consumption data, the smart meter may track the total electricity use of any building. Thus, to identify the appliances depending on their electrical consumption, a single sensor linked to the smart meter gathers several electrical load traits. Then, machine learning methods are used to identify several devices. Every one of these methods has its own challenges; for instance, in the case of the smart meter, a technical expert is needed to carry out the smart meter setup following specifications; the outcomes might be wrong; and prior knowledge of appliance power signatures is needed to apply the machine learning techniques as these need a training phase..

Multi-sensor approaches: Artur et al suggested a research of an IoT-based system to identify household appliances, track their use and find anomalies in these devices. These appliances can be identified where they have a particular Electric Load Signature (ELS). The ELS is an electrical feature specific to every appliance comprising: voltage, current, active, reactive and powers. A Home Energy Management (HEM) system able to expose and identify equipment and track their electrical use is the suggested solution. Smart plugs read each appliance's electrical parameters; the data is then communicated to HEM via the internet (Wi-Fi). The ELS so produced is kept in a database. A machine-learning technique is then used to examine the data to find the appliance. The findings show that 10,799 records were gathered and that the system carry out the necessary training and analysis to categorise these information and find the appliances. Among the records produced were 3,600 for the refrigerator, 3,599 for the washing machine, and 3,600 for the television.

Ashwin and Krishnamoorthy suggested an IoT-based smart plug load energy management system for an office setting in 2019. The study's primary goals were to enhance energy management and device control. Smart plugs let the project track every workplace appliance's total utilisation. Among the devices employed to evaluate the system were a printer and a coffee vending machine. The web application built allows users to monitor the smart plugs, gather statistics and issue alerts where a pre-determined limit is exceeded. The system also included a scheduling technique allowing for device shutdown at particular time. Furthermore, the technology may spot customer behaviour. A study done to assess the overall energy used before and after system implementation showed a drop in electrical use.

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Ahmed et al. provide a technique meant to track electric power with smart plugs. It aims to examine and grasp the energy used by devices. A Windows phone mobile app lets users control room appliances by on-and-off switch and creation of operating schedules. Apart from the behaviour of linked devices, the application also offers tools to plan the layout of the user's home. Conversely, an interactive web application has been created to display the energy used by various homes on the map, so assisting the power distribution firms in examining and researching consumption patterns. The findings of this study helped to raise knowledge of energy conservation in UAE and to lower use.

Shohin Aheleroffa et al. suggested in 2020 an IoT-enabled system meant to turn any device into a smart appliance and to let sensor and actuator data gathering. Researchers placed an IoT board into the central control board of a conventional refrigerator as a case study to turn it into a smart refrigerator. This board reads the states of various actuators including the heater, the compressor, or the air fan and gathers data including temperature and cooling level. Using Wi-Fi technology, the data gathered is periodically transmitted to the IoT platform to be stored in a database known as Ubidots. This paper also provides recommendations for various IoT platforms that could be used in comparable systems including: AWS IoT, IBM Watson IoT, Microsoft Azure IoT. The IoT platform can provide the findings on the dashboard and enable the analysis and visualisation of the information. A mobile phone linked to the item by Bluetooth technology lets the user additionally operate their refrigerator. This suggested system, let me underline, can be used for all household equipment.

The research described above makes it obvious that some methodologies may be classified as either single-point-based or multi-sensor-based. Based on machine-learning algorithms, the single-point sensors can indicate expected consumption per device as well as general consumption. To get the proper setup in connecting the sensor to the smart meter, they also need technical skills as well as a priori understanding of appliance power signatures. Conversely, while multi-sensor-based methods can offer device-level electrical consumption data, they call for a distinct smart plug for every single device. The research described above makes it evident that many methodologies may be classified into single-point-based or multi-sensor-based. Based on machine-learning algorithms, the single-point sensors can indicate expected consumption per device as well as general consumption. To get the proper setup in connecting the sensor to the smart meter, they do need technical skills as well as a priori understanding of appliance power signatures. Conversely, while multi-sensor-based methods can offer device-level electrical consumption data, they call for a distinct smart plug for every single device.

3.PROPOSED SYSTEM

Designed and created for smart and efficient power management, smart device switching, smart electricity billing, and smart protection over electrical short circuits, the proposed system "SMART PLUG". Proposed approach also allows us to know precise device switching status. The created system is low-cost and operationally adaptable, so it can reduce consumer power costs.

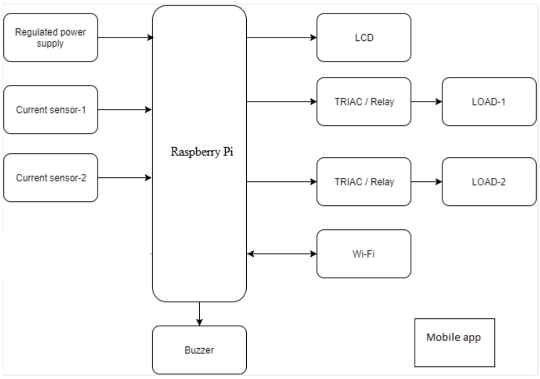

Fig: 3. 1-Block Diagram of Proposed System

By providing real-time energy monitoring, automated overload prevention, IoT-based remote control, and user-friendly mobile app integration, the suggested Smart Plug solution guarantees wiser and safer energy management practices, hence overcoming these limitations.

3.1 IMPLEMENTATION

1. **Regulated Power supply:** Provides a stable voltage to power the ATMEGA328 and other components.

2. **Current Sensor (ACS712-Module):** Measure the electrical current consumed by the connected loads. These sensors help monitor power usage and detect faults.

3. **ATMEGA328:** The microcontroller that processes data from sensors and controls the smart plug operations. It manages load switching, displays information, and communicates via wi-fi.

4. **Mobile App:** A user interface to remotely control and monitor the smart plug via Wi-Fi. It allows turning loads ON/OFF and viewing power consumption data.

5. **Relay:** Controls the switching of electrical appliances. The microcontroller activates/deactivates loads based on user input or predefined conditions.

6. **LCD Screen:** It is used for Energy Consumption and Billing. The total energy consumed is calculated and displayed on the LCD screen, along with estimated billing information.

7. **Buzzer:** Provides alerts for abnormal condition like over current or faults.

8. **Wi-Fi Module:** A Wi-Fi module is used to enable wireless communication and connectivity. These modules can help in real-time data transfer, cloud integration, and remote monitoring

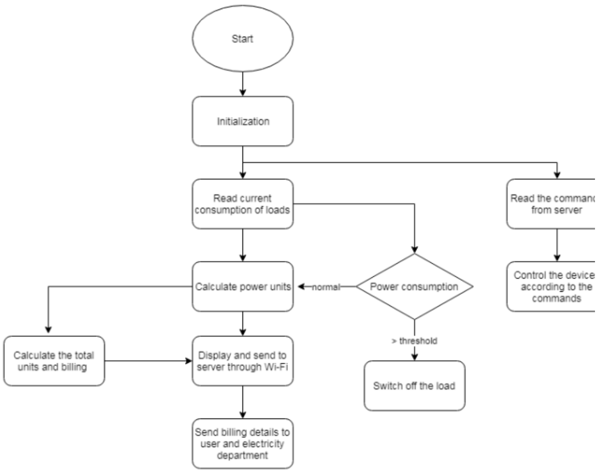

Fig: 2-Flow Chart

Tracking power use, computing energy consumption, and automating load control, the flowchart depicts a smart energy monitoring and control system. The process starts with initialisation; reading the current consumption of linked loads follows. The system then determines power units and checks whether the usage falls within a typical range. The system turns off the load to stop too much use if it beyond a specified limit. Displayed and delivered to a server over Wi-Fi, consumption data shows total units and billing. The billing information is subsequently sent to the power department and the user. The system may also get remote commands from a server to control linked devices accordingly. This guarantees remote-control capabilities, cost tracking, and effective energy management.

3.2 HARDWARE REQUIREMENTS

1. Microcontroller: Arduino Uno (ATMEGA328)

2. Power Supply: Appropriate power source for Arduino and sensors

3.Sensors: Current sensor (ACS712)

4. Communication Module: Wi-Fi Module (ESP 8266)

5. Relay

6. Display: 16x2 LCD

7. Alert System: Buzzer

3.2.1 Arduino Uno Atmega328:

Based on the ATmega328, the Arduino Uno is a microcontroller board. Its features include 14 digital input/output pins (6 of which can be used as PWM outputs), 6 analogue inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It has all required to assist the microcontroller; just link it to a computer using a USB wire or power it with an AC-to-DC converter or battery to begin. Unlike all other boards, the Uno uses no FTDI USB-to-serial driver chip. Rather, it has the Atmega8U2 set up as a USB-to-serial converter. Named to commemorate the approaching launch of Arduino 1.0, "Uno" is Italian for one. Going forward, the standard versions of Arduino will be the Uno and version 1.0. The reference model for the Arduino platform, the Uno is the most recent of a line of USB Arduino boards.

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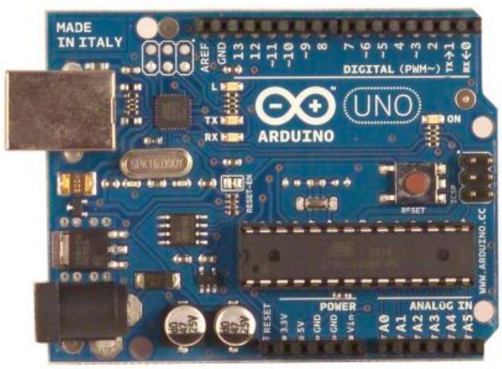

Fig: 2-Arduino Uno ATmega328

3.2.2 Current Sensor

Fig: 3 ACS712 Current Sensor Module

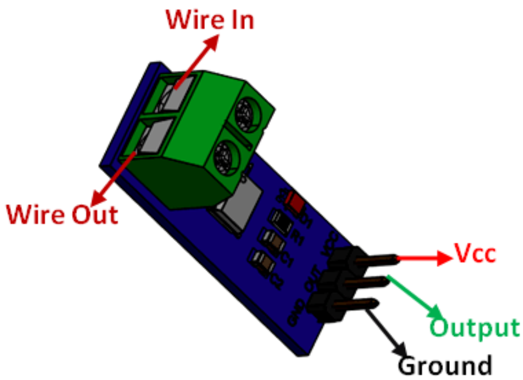

Fig: 4 ACS712 Current Sensor Pinout

3.2.3 LCD (Liquid Crystal Display):

LCD 16×2 Pin Configuration and Its Working:

These days, we constantly utilise the gadgets made up of LCDs such CD players, DVD players, smart watches, computers, etc. These are often employed in the screen sectors to offset CRT consumption. Compared to LCDs, Cathode Ray Tubes consume significant power; CRTs are also larger and heavier. These devices are slimmer as well energy use is quite reduced. The working concept of the LCD 16×2 is that it blocks the light instead of dispersing it. An overview of LCD 16X2, pin configuration and its operation is covered in this paper.

Fig:5 - 16X2 LCD

3.2.4 WIFI MODULE(ESP8266)

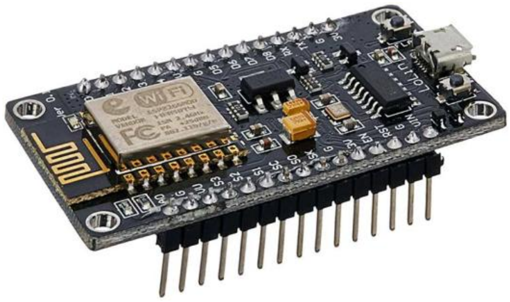

Fig:6 NodeMCU ESP8266

Brief About NodeMCU ESP8266

The NodeMCU ESP8266 development board features the ESP-12E module with Tensilica Xtensa 32-bit LX106 RISC microprocessor built inside ESP8266 chip. Operating from 80MHz to 160 MHz changeable clock speed, this microcontroller runs RTOS. NodeMCU features 128 KB RAM and 4MB of Flash memory to keep programs and data. Its great processing power with in-built Wi-Fi / Bluetooth and Deep Sleep Operating capabilities makes it perfect for IoT applications. Micro USB jack and VIN pin (External Supply Pin) can power NodeMCU. It offers I2C, SPI, and UART interface

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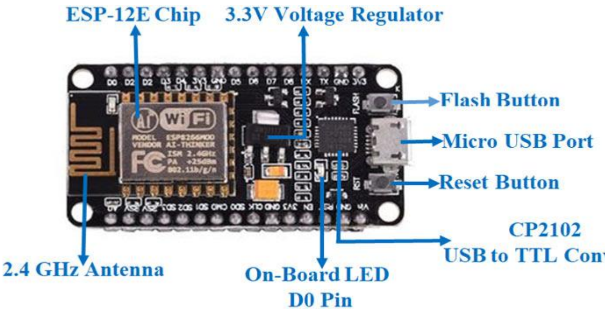

Fig: 7 Labeled Components of NodeMCU ESP8266

4.RESULTS AND DISCUSSION

The Smart Plug system successfully achieved its objectives of real-time power monitoring, overload detection, and remote device control. The key outcomes include:

1. **Accurate Power Monitoring:** Real-time energy consumption data was accurately displayed on the LCD screen and ThingSpeak platform.

2. **Overload Protection:** Devices were automatically disconnected during overload conditions, preventing potential hazards.

3. **Remote Accessibility:** Users were able to control and monitor devices via the mobile app.

4. **Energy Billing Display:** Accurate billing information based on power usage was displayed on the LCD.

5. **Cloud Integration:** Historical data was logged on the ThingSpeak platform for future analysis.

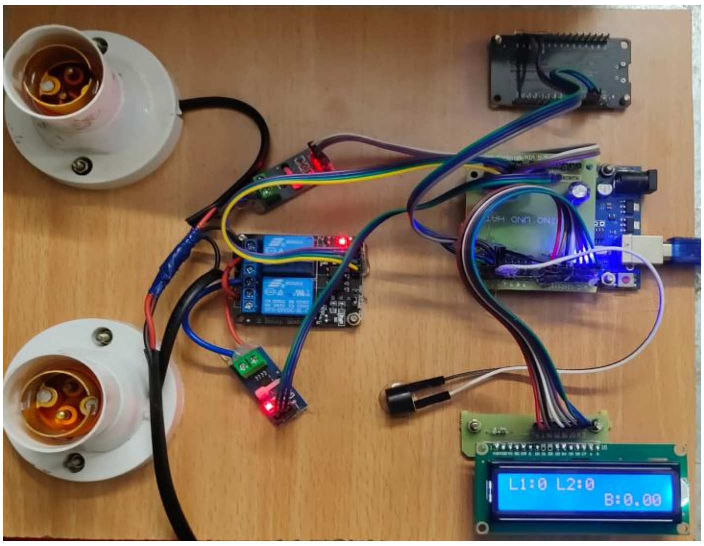

Fig: 8- Project Kit

Fig: 9- Output

Fig: 10-Readings on LCD

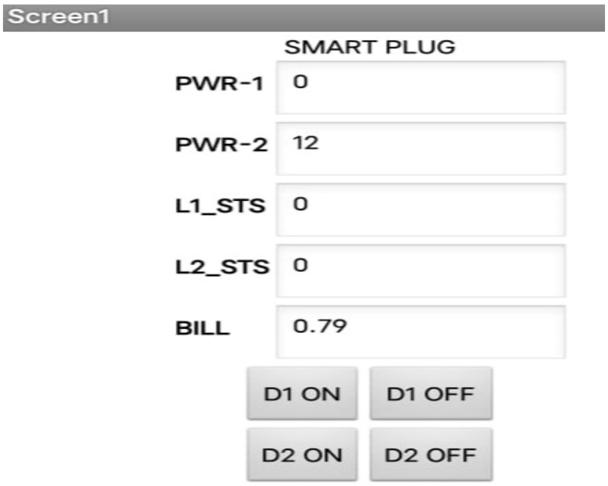

Fig: 11- Remote Access on App

5.CONCLUSION AND FUTURE SCOPE

Real-time energy monitoring, overload prevention, and remote device control are combined with IoT technology by the Smart Plug system. It lowers running expenses, improves energy use, and increases safety. The system is scalable for larger deployment in both residential and industrial environments, affordable, and user-friendly. All things considered, the Smart Plug is a strong tool for current energy management requirements. Designed and developed, a smart plug system aims at putting into use an intelligent building. The built system efficiently manages and tracks the use of electrical appliances in an ageing home. A website therefore allows one to see the real-time monitoring of the electrical appliances. The technology can be expanded to track the entire smart building. We want to identify the areas of daily peak hours of power use levels and provide a solution by which we may reduce the consumption, protection and improve better use of existing constrained resources during peak hours.

Future Scope:

Future efforts on artificial intelligence-driven energy management may help to improve the features of the IoT-powered smart plug. The smart plug can forecast user behaviour and maximise power utilisation depending on past data by use of machine learning techniques. Combining grid connection with renewable energy sources, such Solar power, can help to increase efficiency even more by letting the plug smartly switch between power sources. Including blockchain-based security as well helps to improve data protection by means of safe transactions and control of the smart plug's access denial.

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