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Smart Plug for Energy Waste Detection System

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ABSTRACT: In modern electrical systems, unnecessary energy consumption due to standby power and inefficient usage of appliances has become a significant concern. To address this issue, a **Smart Plug with Energy Monitoring and Control using PIC16F877A** is proposed.The system is designed to function as a universal plug adapter that can be connected to any electrical appliance without modifying its wiring. It measures the electrical parameters such as voltage and current using a **Potential Transformer (PT)** and a **Current Transformer (CT)** respectively. These signals are processed through rectifier and filtering circuits to obtain suitable DC levels, which are then fed into the analog-to-digital converter (ADC) of the microcontroller.The **PIC16F877A** processes the input data and calculates the power consumption of the connected load. Based on predefined conditions, the system detects energy wastage, such as when an appliance operates in standby mode for an extended period. Upon detection, the controller automatically switches OFF the appliance using a relay, thereby reducing unnecessary power consumption.Additionally, the system integrates IoT functionality using the **ESP8266 WiFi Module**, enabling remote monitoring and control through the **Blynk** application. Real-time parameters such as voltage, current, and power are displayed locally using an LCD and remotely on a mobile device.This project provides a cost-effective, efficient, and user-friendly solution for energy conservation, making it suitable for residential and industrial applications.

KEYWORDS: Smart Plug, Energy saving

I. INTRODUCTION

In recent years, the rapid increase in the use of electrical and electronic appliances has led to significant energy consumption. A major portion of this energy is wasted due to appliances being left ON unnecessarily or operating in standby mode. This not only increases electricity bills but also contributes to energy inefficiency and environmental concerns. Therefore, there is a growing need for intelligent systems that can monitor and control energy usage effectively.

This project presents a Smart Plug with Energy Monitoring and Control using the PIC16F877A. The system is designed as a universal plug adapter that allows any electrical appliance to be connected without modifying its internal wiring. It continuously monitors electrical parameters such as voltage and current using suitable sensing circuits and calculates the power consumption of the connected load.

Based on the measured data, the system identifies conditions of energy wastage, such as prolonged low power consumption indicating standby mode. When such conditions are detected, the system automatically disconnects the appliance using a relay, thereby conserving energy. In addition to local monitoring through an LCD display, the system incorporates IoT functionality using the ESP8266 WiFi Module, enabling remote monitoring and control via the Blynk application.

II. RESEARCH METHODOLOGY

This introduction sets the stage for a detailed exploration of the 44 concept, focusing on the principles of energy saving, system design, and potential 45 real-world applicationsThis technology offers a dual benefit: reducing energy waste and 46 contributing to renewable energy solutions.

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2.1 Literature Review

Applications such as smart meters, home automation systems, and IoT-based energy monitoring systems demonstrate the importance of integrating sensing, processing, and communication. These systems aim to reduce energy wastage, improve efficiency, and provide user-friendly monitoring interfaces.

2.2 Review of Existing Technologies

Existing technologies for energy monitoring and control include conventional energy meters, smart meters, and IoT-based systems. Conventional energy meters are limited to measuring total energy consumption and do not provide real-time monitoring or control features. Smart meters offer digital readings and sometimes support remote data transmission, but they often lack appliance-level control. IoT-based systems, using modules like the ESP8266 WiFi Module, enable real-time monitoring and remote access through applications such as Blynk. Sensor-based systems using Current Transformers (CT) and Potential Transformers (PT) provide accurate real-time measurements but require integration with controllers for processing. Although these technologies provide useful functionalities, most existing solutions either focus only on monitoring or only on control, and lack a fully integrated, user-friendly system.

2.3 Key Problems Identified

From the analysis of existing technologies, several key problems have been identified. Most systems do not provide automatic detection of energy wastage, particularly during standby conditions. There is limited control over appliances in conventional and basic smart systems. Many existing solutions require complex installation procedures, including modification of appliance wiring, which reduces usability. Additionally, commercial smart plugs are often expensive and not accessible for all users. Traditional systems also lack real-time monitoring and user-friendly interfaces, making it difficult for users to track and manage energy consumption effectively.

2.4 Design and Component Selection

The proposed system is designed as a compact smart plug adapter that integrates sensing, processing, control, and communication functionalities. The PIC16F877A is selected as the main controller due to its built-in ADC, low cost, and ease of interfacing. Current measurement is performed using a Current Transformer (CT), which provides safe and non-invasive sensing through electromagnetic induction. Voltage measurement is achieved using a Potential Transformer (PT), which steps down the high AC voltage to a safe level. The measured signals are processed through rectifier and filter circuits to convert them into stable DC voltages suitable for ADC input. A relay module is used to control the appliance by switching it ON or OFF based on the controller's decision. For communication, the ESP8266 WiFi Module is used to enable IoT functionality, allowing remote monitoring and control via the Blynk. An LCD display is used for local monitoring of parameters such as voltage, current, and power.

2.5 Theoretical framework

The proposed system is based on fundamental electrical and embedded system principles. The relationship between voltage, current, and resistance is defined by Ohm's law, while electrical power is calculated using the formula $P = V \times I$. The Current Transformer (CT) operates on the principle of electromagnetic induction, producing a current proportional to the primary current flowing through the conductor. The Potential Transformer (PT) steps down the high voltage to a lower, measurable value while maintaining proportionality.

2.6 PIC16F877A

The PIC16F877A is an 8-bit microcontroller used as the main controller of the system. It processes input signals from sensors, performs calculations such as power computation, and controls output devices like relays and displays. It has built-in features such as Analog-to-Digital Converter (ADC), timers, and communication interfaces, making it suitable for embedded applications.

2.7 Current Transformer

A Current Transformer is a device used to measure alternating current (AC) without direct electrical connection. It works on the principle of electromagnetic induction, where the current flowing through a conductor generates a magnetic field that induces a proportional current in the transformer. It provides isolation and safe measurement of high currents.

2.8 Potential Transformer

A Potential Transformer is used to step down high AC voltage to a lower, measurable level. It ensures safe voltage measurement by maintaining a proportional relationship between the input and output voltage while providing electrical isolation from the high-voltage line.

2.9 Relay

A relay is an electrically operated switch used to control high-voltage appliances using a low-voltage signal from the microcontroller. It allows the system to turn appliances ON or OFF safely without direct electrical connection.

2.10 ESP8266 Wifi Module

The ESP8266 is a low-cost WiFi module used to provide internet connectivity to the system. It enables communication between the microcontroller and cloud platforms, allowing remote monitoring and control of the system.

III. OUTPUT TOOLS AND POWER ELECTRONIC COMPONENTS

To evaluate the efficiency, performance, and economic feasibility of the system, various output tools and econometric models are applied.

3.1 Mobile Application

Blynk is an IoT platform that allows users to monitor and control hardware devices remotely using a smartphone. It provides a user-friendly interface to display sensor data and control outputs such as relays..

3.2 LCD

A Liquid Crystal Display (LCD) is used to show real-time information such as voltage, current, power, and system status. It provides a simple and effective way for users to monitor system performance locally.

3.3 AC-DC Power Supply Module

An AC-DC power supply converts high-voltage AC (230V) into low-voltage DC (5V or 3.3V) required for the operation of electronic components like the microcontroller and sensors. It ensures safe and stable power for the control circuit.

3.4 Resistors

Resistors are passive components used to limit current, divide voltage, and set operating conditions in circuits. They are used in signal conditioning and protection of components.

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3.5 Capacitors

Capacitors are used to store electrical energy temporarily. In this project, they are mainly used for filtering and smoothing the rectified signals to produce a stable DC output.

3.6 Diodes

Diodes are semiconductor devices that allow current to flow in only one direction. They are used in rectifier circuits to convert AC signals into DC.

IV. RESULTS AND DISCUSSION

The proposed smart plug system was successfully implemented using the **PIC16F877A**. The system was able to measure voltage and current accurately using the Potential Transformer (PT) and Current Transformer (CT), and the obtained analog signals were successfully converted into digital values using the built-in ADC of the microcontroller. Based on these values, the power consumption of the connected appliance was calculated effectively.

The relay control mechanism functioned as expected, allowing the system to automatically switch OFF the appliance when energy wastage was detected, such as during standby conditions. The LCD display provided real-time monitoring of voltage, current, and power, which helped in verifying system performance locally.

Furthermore, integration with the **ESP8266 WiFi Module** enabled remote monitoring and control through the **Blynk** platform. Users were able to view live data and control the appliance from a mobile device, demonstrating the effectiveness of IoT integration.

4.1 BLOCK DIAGRAM

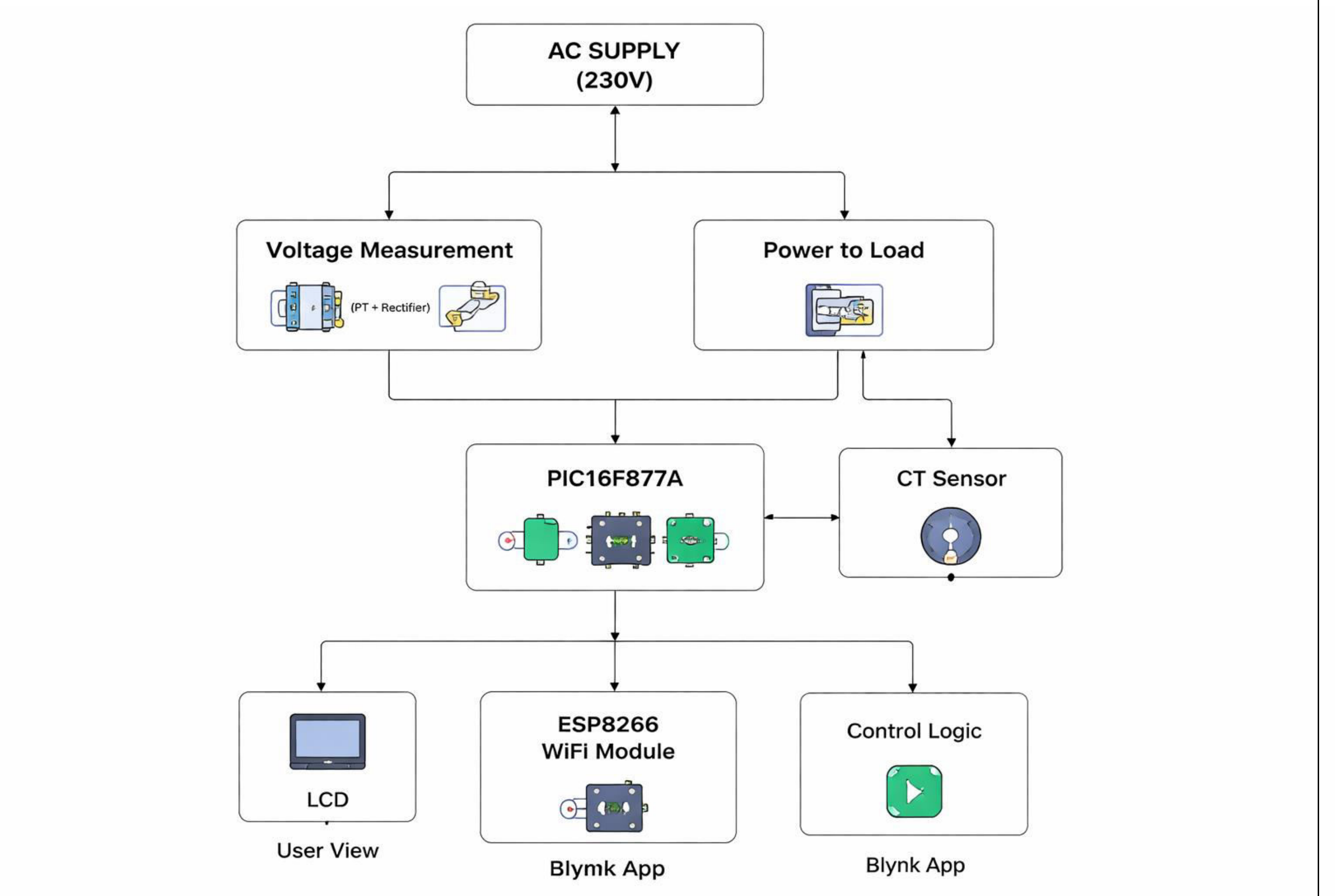

Figure 1 the block diagram represents how the input power is measured using sensors, processed by the **PIC16F877A**, and used to control the appliance through a relay, along with monitoring via display and IoT modules.

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