IOT-Based Solar Power Monitoring System

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***Abstract*—Modern electrical systems need strong protection to stay safe and avoid damage from problems like low voltage and current leakage. Normal devices such as MCBs and RCCBs give only basic safety and cannot do smart things like real-time monitoring or remote control. Because homes, offices, and industries now use more sensitive electronic equipment, there is a need for an advanced system that can watch electrical values all the time and act quickly when something goes wrong.**

This project builds a Smart IoT-Based Protection System using Arduino Uno, ESP8266 Wi-Fi, voltage sensors, current sensors, relay modules, and cloud monitoring. The Arduino reads voltage and current values, shows them on an LCD, and controls a relay to cut off power if unsafe conditions are found. The ESP8266 connects the system to the internet, so users can check values and faults remotely using the Smart Life mobile app.

***Index Terms*—Arduino Uno, ESP8266 Wi-Fi, Relay, LCD Display, Current Sensor, Voltage Sensor, IoT, ESP32 Microcontroller.**

I. INTRODUCTION

Electricity must be safe and reliable in homes, offices, and industries. As we use more sensitive devices, smart appliances, and automated systems, power networks are becoming more complicated and face more risks. Problems like low voltage, leakage currents, short circuits, and overloads can cause equipment damage, overheating, fires, wasted energy, and even electric shocks. Traditional devices such as MCBs (Miniature Circuit Breakers) and RCCBs (Residual Current Circuit Breakers) give only basic protection. They cannot provide real-time monitoring, remote access, or smart control. One common issue is under-voltage. If the supply voltage stays lower than normal for a long time, machines like motors, pumps, and transformers draw extra current to keep working. This causes overheating, insulation damage, poor efficiency, and eventually

Failure. Another issue is earth leakage, which happens when insulation breaks down or wires are damaged. This can lead to electric shocks and fire hazards. Because of these risks, we need a smart protection system that can watch electrical values all the time and disconnect power when something goes wrong, thanks to the growth of IoT (Internet of Things) and embedded systems, it is now possible to build smart monitoring and protection systems. IoT allows users to check electrical values remotely, get instant fault alerts, and control devices through mobile apps and cloud platforms. This makes systems safer, more reliable, and easier to maintain.

This project introduces a Smart IoT-Based Under Voltage and Earth Leakage Protection System. It uses Arduino Uno, ESP8266 Wi-Fi, sensors, relay modules, and an LCD display. The Arduino acts as the brain, reading voltage and current values from sensors. If unsafe conditions are detected, the relay disconnects the load automatically.

II. LITERATURE SURVEY

identification. With the increasing demand for electrical energy and smart monitoring systems, traditional power monitoring methods are becoming less efficient and difficult to manage. Modern electrical systems require real-time monitoring, remote accessibility, and automatic protection features. IoT-based smart current monitoring systems have become an effective solution for improving energy management and electrical safety.

The literature study mainly focuses on wireless smart current sensor systems using Arduino and ESP32 microcontrollers. Existing systems use current sensors such as HW-666 for measuring current values and IoT technology for transmitting data to mobile applications and cloud platforms. These systems

provide real-time monitoring, automatic fault detection, alarm generation, and remote access capabilities. The measured data can be displayed on a PC, LCD display, or mobile application for continuous monitoring

Researchers have implemented systems using Arduino for data processing and ESP32/ESP8266 modules for Wi-Fi communication. These systems offer advantages such as low-cost implementation, wireless monitoring, automatic power cut-off, and improved electrical safety. However, many existing systems have limitations such as reduced accuracy, limited scalability, fixed voltage assumptions, and delayed real-time response.

From the literature analysis, it is observed that there is a need for a more reliable and intelligent protection system that can provide accurate voltage and current monitoring, automatic under-voltage and earth leakage protection, real-time cloud monitoring, and remote-control capabilities. The proposed project aims to overcome these limitations by integrating Arduino Uno, current and voltage sensors, relay protection, and IoT technology for improved electrical safety and monitoring performance.

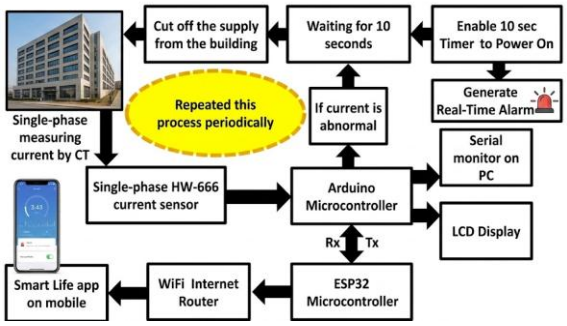
III. OBJECTIVE

- To design and develop a Smart IoT-Based Under Voltage and Earth Leakage Protection System.
- To continuously monitor voltage and current parameters in a 230V AC electrical system.
- To detect under-voltage and earth leakage faults in real time.
- To automatically disconnect the load during abnormal operating conditions using a relay module.
- To provide remote monitoring and control using ESP8266 Wi-Fi module and Smart Life mobile application.
- To display voltage, current, and power values on an LCD display for local monitoring.
- To improve electrical safety, reduce equipment damage, and minimize electrical hazards.
- To develop a low-cost and reliable smart protection system for residential and industrial applications.

IV. METHODOLOGY

The block diagram of the Smart IoT-Based Under Voltage and Earth Leakage Protection System shows the complete flow of operation and interconnection between different hardware components. The system mainly consists of a power supply unit, Arduino Uno, voltage sensor, ACS712 current sensor, ESP8266 Wi-Fi module, relay module, LCD display, and electrical load

Block Diagram



Block Diagram (Combined Report Explanation)

1. Power Supply (24V DC SMPS)

The power supply unit converts the 230V AC supply into regulated DC voltage required for electronic components. It provides stable power to the Arduino Uno, ESP8266 Wi-Fi module, sensors, relay module, and LCD display. Proper voltage regulation ensures safe and reliable operation of the system.

2. Voltage Sensor

The voltage sensor continuously measures the supply voltage of the electrical system. It sends analog voltage data to the Arduino Uno for monitoring and processing. If the voltage falls below the predefined safe limit, the system detects an under-voltage condition and activates the protection mechanism.

3. ACS712 Current Sensor

The ACS712 current sensor is used to measure load current and detect leakage current conditions. It continuously monitors current flow in the circuit and sends real-time current data to the Arduino. This helps in identifying abnormal current leakage or overload conditions.

4. Arduino Uno

Arduino Uno acts as the main controller of the system. It receives sensor signals, processes voltage and current values, and executes protection logic. The

Arduino continuously compares measured values with predefined safety limits. It also controls the relay module and communicates with the ESP8266 Wi-Fi module for IoT monitoring.
The electrical power is calculated using:
P=V×IP = V \times IP=V×I

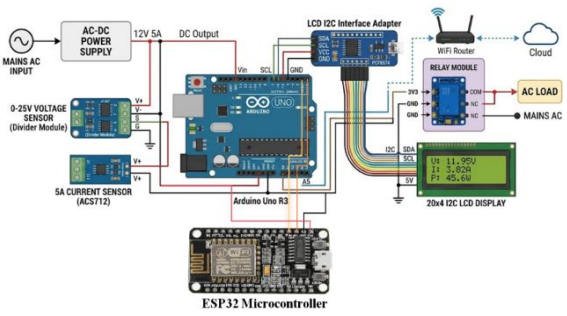
5. ESP8266 Wi-Fi Module
The ESP8266 module provides IoT connectivity through Wi-Fi communication. It sends real-time electrical parameters such as voltage, current, and power to the Smart Life mobile application or cloud platform. This allows remote monitoring and instant fault notifications from anywhere using a smartphone or internet connection.

6. Relay Module
The relay module acts as an automatic switching and protection device. During normal operation, the relay keeps the load connected to the power supply. If under-voltage or earth leakage is detected, the Arduino sends a signal to the relay to disconnect the load immediately. This protects electrical equipment from damage and improves system safety.

7. LCD Display
The LCD display is used for local monitoring of electrical parameters. It displays real-time voltage, current, power values, and fault status. This helps users easily observe system conditions without using a mobile application.

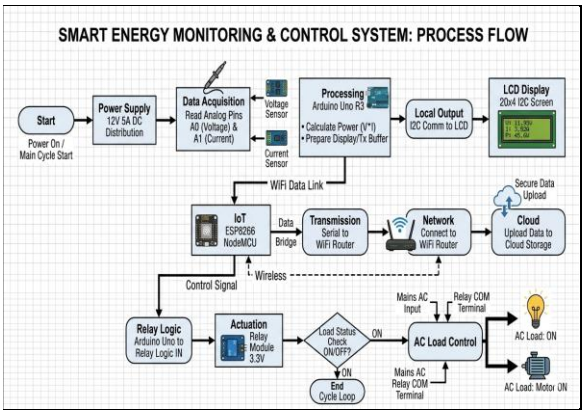
8. Electrical Load
The electrical load represents appliances or devices connected to the protection system. The load operates normally when voltage and current conditions are safe. During fault conditions, the relay disconnects the load to prevent electrical damage and hazards.

V. CIRCUIT DIAGRAM



ESP32 Microcontroller

VI. FLOW CHART



VII. SOFTWARE SPECIFICATION

Arduino IDE is an open-source software platform used to program both Arduino Uno and Node MCU ESP8266 for embedded and IoT applications. It provides a simple and user-friendly interface for writing, editing, compiling, and uploading code. The IDE supports programming languages such as C and C++. It contains a built-in compiler that converts source code into machine code understandable by microcontrollers.
Users can upload programs directly to Arduino Uno and Node MCU boards using a USB cable. For ESP8266 programming, developers must install the ESP8266 board package in Arduino IDE. The software provides various built-in and external libraries for sensors, LCD displays, relays, Wi-Fi modules, and communication devices. It also includes a Serial Monitor for debugging and monitoring real-time data transmission.
Node MCU ESP8266 uses its built-in Wi-Fi capability to connect with cloud platforms such as smart life for remote monitoring and control. Arduino Uno is mainly used for reading sensor data and controlling hardware components. Together, these platforms help develop smart automation, wireless monitoring, and IoT-based systems relays, and cloud platforms like smart life. The software is simple, open-source, and widely used for IoT development. It helps create smart automation and wireless monitoring systems.

Program Description:
Arduino Code
#include <Wire.h>

```
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27,20,4);
const int currentPin = A1;
float voltage,current,power;

void setup () {
Serial.begin(9600);
lcd.init();
lcd.backlight();
pinMode (relayPin, OUTPUT);
digitalWrite(relayPin, HIGH);}

void loop () {
int vRaw = analogRead(voltagePin);
voltage = (vRaw * 5.0 / 1023.0) * 5;
int cRaw = analogRead(currentPin);
float sensorVoltage = cRaw * (5.0 / 1023.0);
current = (sensorVoltage - 2.5) / 0.185;

if (current < 0)
current = 0;
power = voltage * current;

lcd.setCursor(0,0);
lcd.print("Voltage:");
lcd.print(voltage);

lcd.setCursor(0,1);
lcd.print("Current:");
lcd.print(current);

lcd.setCursor(0,2);
lcd.print("Power:");
lcd.print(power);

if (power > 500) {
digitalWrite(relayPin, LOW);}
else {digitalWrite(relayPin, HIGH);}

Serial.print(voltage);
Serial.print(",");
Serial.print(current);
Serial.print(",");
Serial.println(power);
delay (1000);}
```

ESP32 / IoT Code

```
#define BLYNK_TEMPLATE_ID "YourTemplateID"
#define BLYNK_DEVICE_NAME "EnergyMonitor"
#define BLYNK_AUTH_TOKEN "YourAuthToken"
#include <WiFi.h>
#include <BlynkSimpleEsp32.h>
char ssid[] = "WiFi_Name";
char pass [] = "WiFi_Password";
String data;

void setup () {
Serial.begin(9600);
Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);}

void loop () {
Blynk.run();
if (Serial.available()) {
data = Serial.readStringUntil('\n');

int a = data.indexOf(',');
int b = data.indexOf(',', a+1);

float voltage = data.substring(0, a). toFloat ();
float current = data.substring(a+1, b). toFloat ();
float power = data.substring(b+1). toFloat();

Blynk.virtualWrite(V0, voltage);
Blynk.virtualWrite(V1, current);
Blynk.virtualWrite(V2, power);}
```

VIII. RESULT

The developed solar-powered IoT monitoring system successfully monitored solar voltage, battery voltage in real time. The Arduino Uno accurately processed sensor data, while the ESP32 Dev Kit transmitted the information to the cloud through Wi-Fi. The relay module effectively controlled AC loads remotely based on user commands. The system demonstrated efficient renewable energy utilization, reliable monitoring, and remote automation capabilities

IX. CONCLUSION

This project presents an efficient and smart solution for monitoring and controlling electrical loads using solar energy and IoT technology. By integrating sensors, micro-controllers, WiFi communication, and

cloud platforms, the system provides real-time monitoring and remote-control features. It reduces dependence on conventional power sources and supports sustainable energy management. The project can be further enhanced by adding more sensors, AI-based automation, and improved energy storage systems.

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