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Arduino-based Single Phase AC Voltage Measurement with Under Voltage Protection

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Abstract: This project focuses on the development of an Arduino-based system for measuring single-phase AC voltage and providing under-voltage protection. The system uses a voltage sensor to monitor the AC voltage level and an Arduino microcontroller to process the data. When the voltage falls below a pre-set threshold, indicating under-voltage conditions, the system activates a relay to disconnect the load, preventing potential damage to connected equipment. The user can adjust the threshold voltage according to their requirements, providing flexibility in various applications. The system also includes realtime voltage monitoring, which can be displayed on an LCD screen for easy access. The combination of voltage measurement, under-voltage detection, and protection ensures that sensitive devices are safeguarded from potential electrical issues. This Arduino-based solution offers a cost-effective and reliable method for improving electrical safety and equipment longevity in residential and industrial settings.

Index Terms: Arduino, AC Voltage Measurement, Under Voltage Protection, Relay, LCD Display, Electrical Safety.

I. INTRODUCTION

In modern electrical systems, maintaining stable voltage levels is essential for ensuring the safety and longevity of equipment. A common issue that affects the performance of electrical appliances is the fluctuation of AC voltage, particularly under-voltage conditions, which can cause irreversible damage to sensitive devices. To address this issue, an Arduino- based single-phase AC voltage measurement system with under-voltage protection offers an innovative and cost-effective solution.

This system employs an Arduino microcontroller to process voltage data, where a voltage sensor measures the AC voltage in real-time. The microcontroller continuously monitors the voltage level, and when the voltage falls below a defined threshold, indicating under-voltage conditions, it activates a relay to disconnect the load, thus safeguarding the equipment. The system also provides a user-configurable threshold for voltage levels, making it adaptable to various applications. The integration of an LCD display allows users to view real-time voltage readings, enhancing the usability of the system. This design not only ensures the protection of connected devices but also offers a reliable, scalable, and energy-efficient solution for voltage monitoring and protection in both residential and industrial environments.

II. LITERATURE SURVEY

Several studies have explored the use of Arduino-based systems for voltage measurement and protection. These works provide a foundation for the development of the current system. DD Tung, NM Khoa **[**1**]:** This paper presents an Arduino Uno-based system designed for monitoring both overvoltage and under-voltage conditions in a single-phase power supply. The system utilizes the ZMPT101B voltage sensor and the ACS712 current sensor to collect data, which is processed by the Arduino and visualized through a telemetry viewer. This system efficiently manages power supply conditions by controlling the load based on set thresholds.

MA Sarder, M Rahman, MN Mostakim **[**2**]:** This research focuses on a relay-based voltage protection system using voltage comparators like the LM339 or LM393. The system monitors voltage deviations and disconnects the load when thresholds are crossed, protecting sensitive equipment from over-voltage and under-voltage conditions.

DA Asoh, LN Chia **[**3**]:** This study introduces a monitoring system using Arduino and a voltage divider circuit to track voltage changes. The system trips a protective mechanism when it detects under-voltage or over-voltage, offering real-time updates and SMS alerts via a GSM modem. This solution is particularly useful for regions with unstable power supplies.

MF Kotb, MM El-Saadawi, EH El-Desouky **[**4**]:** The paper discusses a novel over/under-voltage protection relay using Arduino Uno for a Future Renewable Electric Energy Delivery and Management (FREEDM) system. The system ensures protection in medium voltage distribution networks and integrates well with the hardware and simulation models.

MABM Ayub, MR Shaharuddin **[**5**]:** This research integrates IoT technology with over/under voltage protection by using the ZMPT101B sensor and the ESP8266 WiFi module. Users can monitor voltage levels in realtime through the Blynk application, making this system suitable for industrial and residential applications.

III. SYSTEM OVERVIEW

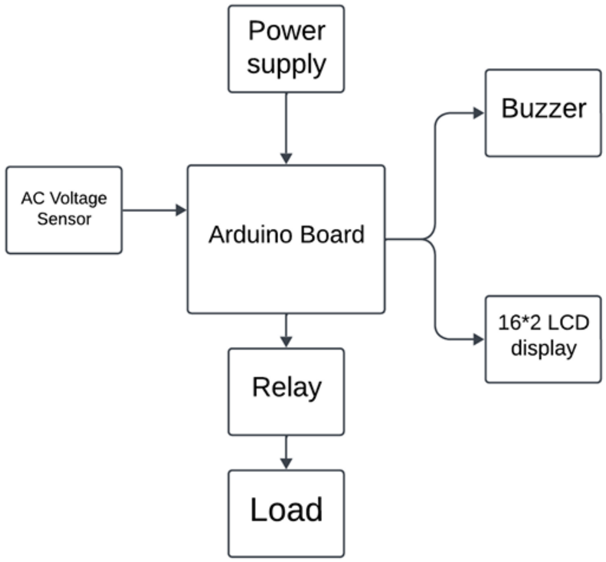

Fig. 1. BLOCK DIAGRAM

The proposed system consists of several key components working in tandem to provide accurate voltage measurements and under-voltage protection:

1) AC Voltage Sensor: The ZMPT101B is used to measure the AC mains voltage. This sensor provides a proportional output signal, which is then processed by the Arduino.
2) Solid State Relay (SSR)**:** The SSR-40DA is used to control high-voltage AC loads with a low-voltage DC signal from the Arduino. It ensures smooth and reliable switching without mechanical wear.
3) Arduino Board**:** The central controller of the system, responsible for processing sensor data, comparing it against the threshold, and triggering the relay if under-voltage conditions are detected.
4) LCD Display**:** The 16x2 I2C LCD display provides realtime voltage readings to the user, making the system intuitive to operate.
5) Buzzer**:** The buzzer provides an audible alarm when under-voltage conditions are detected, alerting the user to the issue.
6) Reset: The reset functionality is built into the system to allow operators to reset the Arduino and sensor readings after a fault has been addressed or after the system has been disconnected. This could be a manual reset through a button or automatically triggered after a certain condition is met, ensuring that the system is back in a safe and functional state after any faults have been cleared.

IV. METHODOLOGY

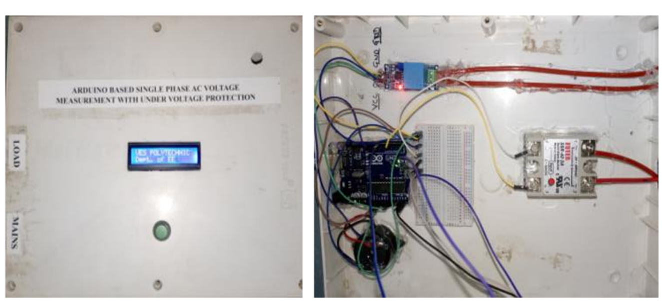

Fig. 2. KIT PHOTO

1) AC Voltage Sensor (ZMPT101B)

The ZMPT101B voltage sensor is designed to measure AC voltage and convert it into a corresponding analog signal, which can be read by the Arduino. The sensor includes a transformer and a voltage divider to step down the high AC voltage, ensuring the output is safe for processing by the microcontroller. The output of the sensor is typically between 0-5V, which corresponds to the RMS value of the input AC voltage.

2) Solid State Relay (SSR-40DA)

The SSR-40DA is an electronic relay that controls high- voltage AC loads using a low-voltage DC input. It eliminates the mechanical parts typically found in traditional relays, providing higher reliability and durability. The SSR is used in this system to disconnect the load from the AC power supply when under-voltage conditions are detected by the Arduino.

3) Arduino Uno

The Arduino Uno microcontroller is the core of this system. It is responsible for receiving input from the AC voltage sensor, comparing the voltage with the pre-set threshold, and controlling the relay. The Arduino Uno offers a simple programming interface, making it an ideal platform for prototyping and development in embedded systems.

4) LCD Display (16x2 I2C)

The 16x2 I2C LCD display is used to provide real-time voltage readings to the user. The I2C interface simplifies wiring by using only two data lines (SDA and SCL), reducing the complexity of the system. This display is essential for providing live feedback to the user about the system's status.

5) Buzzer

The buzzer is an essential component that provides an audible indication when under-voltage conditions are detected. It alerts the user to the fact that the system has activated the protection mechanism.

6) Reset

The reset function is integrated into the system to enable operators to restart the Arduino and refresh sensor readings once a fault is resolved or the system has been disconnected. This reset may be initiated manually via a button or automatically under certain conditions, ensuring the system is restored to a safe and operational state after addressing any issues.

7) Code Logic

The proposed under-voltage protection system is implemented using an Arduino microcontroller, a ZMPT101B voltage sensor, an LCD, a relay, and a buzzer. The system continuously monitors the AC voltage and triggers protection mechanisms when the voltage falls below a predefined threshold. The key steps in the code logic are as follows:

Initialization:

The system initializes the hardware components by setting up the pin modes for the relay, buzzer, and reset pin. The Liquid Crystal Display (LCD) is also initialized to display relevant information.

The voltageSensor object is created to interface with the ZMPT101B voltage sensor. The sensitivity of the sensor is set using a predefined constant, SENSITIVITY.

A calibration factor is applied to adjust the voltage readings to accurate values based on empirical testing.

Display Initial Messages:

Upon startup, the LCD displays a welcome message and group member names for a brief period. After that, the system enters a waiting period for 10 seconds, during which the LCD displays a "Ready to Monitor" message.

Voltage Monitoring:

After the waiting period, the system starts reading the AC voltage from the ZMPT101B voltage sensor.

The sensor's analog output is converted into a digital voltage value, and a calibration factor is applied to ensure the reading corresponds to the actual AC voltage.

The system continuously monitors the voltage and displays the current value on the Serial Monitor for debugging purposes and on the LCD for user reference.

Protection Mechanism:
If the voltage drops below a threshold of 210V, the system triggers the protection mechanism:
The relay is turned off to disconnect the AC power supply.
The buzzer is activated to alert the user of the under-voltage condition.
The LCD displays "Under Voltage ON" along with the current voltage reading.
If the voltage exceeds 210V, the protection mechanism is deactivated:
The relay is turned on to restore the AC power supply.
The buzzer is turned off to stop the alert.
The LCD displays "Under Voltage OFF" along with the current voltage reading.
Reset Mechanism:
The system includes a reset feature, where if the reset pin (RESET_PIN) is pressed (active low), the system will reset itself by turning off the relay and the buzzer. This is achieved using an assembly command (asm volatile(" jmp 0");), which restarts the program from the beginning.
Stabilization and Delay:
A 1-second delay is introduced between voltage readings to ensure stable sensor outputs and reduce fluctuations in the displayed values.
The system operates continuously in this manner, monitoring the AC voltage, applying the protection logic, and updating the display until the reset pin is triggered or the system is powered down.

V. RESULTS AND DISCUSSION

The under-voltage protection system successfully operated as intended, demonstrating reliable performance in detecting and responding to voltage fluctuations. Upon initialization, the system correctly set up all hardware components, including the relay, buzzer, and LCD, and displayed relevant information on startup. The voltage monitoring function worked effectively, continuously reading the AC voltage through the ZMPT101B sensor and displaying the results on both the Serial Monitor and LCD. The protection mechanism was triggered when the voltage fell below the predefined threshold of 210V, deactivating the relay and activating the buzzer, while the LCD displayed an under-voltage alert. When the voltage exceeded the threshold, the system deactivated the protection mechanism by restoring the power and silencing the buzzer. The reset feature also worked as intended, allowing the user to restart the system if needed. However, while the system performed well overall, there are areas for improvement, such as enabling threshold customization, adding over-voltage protection, optimizing power consumption, and enhancing user interaction with more visual feedback. Nonetheless, the system showed great promise in protecting devices from under-voltage conditions, with potential for further development and refinement.

VI. CONCLUSION

The Arduino-based single-phase AC voltage measurement and under-voltage protection system offers a cost-effective and reliable solution for monitoring and safeguarding electrical equipment. The integration of real-time voltage monitoring, user-adjustable thresholds, and automatic protection ensures that sensitive devices are protected from the harmful effects of under-voltage conditions. This system can be used in both residential and industrial settings, offering enhanced electrical safety and operational stability. Future developments may include wireless monitoring, integration with IoT platforms, and additional safety features.

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