OVERVOLTAGE AND UNDERVOLTAGE LOAD PROTECTION SYSTEM USING ARDUINO UNO

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Abstract -*This project presents the design and implementation of overvoltage and undervoltage load protection system using Arduino Uno. The main purpose of these system is to provide the protection from overvoltage and undervoltage in system. Voltage fluctuations can severely impact electrical equipment, making it critical to develop a system that can detect and respond to unsafe voltage levels in power system. This project is designed to safeguard electrical equipment from harmful voltage fluctuations, the system continuously monitors voltage levels, disconnecting the load when values exceed safe limits. The Arduino processes real-time voltage data and displays it on the LCD, activating a relay to cut off power if needed. By leveraging the capabilities of the Arduino Uno, the system achieves high reliability and flexibility while remaining cost-effective. This low-cost system demonstrates reliable protection for residential and industrial applications, enhancing safety for sensitive devices. The research aims to contribute a viable solution for enhanced load protection in both industrial and residential setting.*

***Key Words*: Overvoltage, Undervoltage, Load Protection, Arduino Uno, LCD Display, Voltage Monitoring**

1. INTRODUCTION

Voltage stability is essential for the safe operation of electrical devices, yet fluctuations such as overvoltage and undervoltage are common due to grid issues, load variations, and environmental factors. Such voltage fluctuations can lead to irreversible damage, reduced performance, and even operational hazards in sensitive equipment. Overvoltage and undervoltage conditions can result in excessive strain on electrical appliances, lead to irreversible damage, inefficiencies, and even operational hazards in sensitive equipment, safety risks like overheating or fires. While industrial-grade voltage protection systems exist, they are often complex and expensive, making them impractical for average household use. To minimize this issues we made a simple, cost-effective overvoltage and undervoltage protection system suitable for domestic use. By leveraging the capabilities of an Arduino Uno microcontroller and LCD display, this project aims to create a system that not only protects household appliances but also provides an easy-to-use interface for monitoring real-time voltage. The primary objective is to detect dangerous voltage levels and automatically disconnect the load to prevent potential damage or hazards.

2. LITERATURE REVIEW

Several studies have explored microcontroller-based solutions for voltage regulation and protection. Research has demonstrated the efficacy of Arduino platforms in monitoring and controlling electrical systems due to their programmability, affordability, and ease of integration with various sensors and display devices.

- **Microcontroller-based voltage monitoring systems:** Research has shown that microcontrollers are effective in monitoring electrical parameters and implementing real-time protection measures. As we know Arduino is easy, reliable and open source microcontroller Arduino-based systems, in particular, offer a reliable solution for detecting voltage variations and protecting connected devices due to their rapid processing capabilities and real-time response. Prior studies have shown that Arduino-based voltage monitoring systems provide reliable, real-time data on voltage levels and have been successfully used in both industrial and residential settings.

- **Arduino as a platform for electrical monitoring:** The Arduino platform has been shown to be highly effective for electrical monitoring due to its ease of programming, affordability, and compatibility with a range of sensors and modules. Research supports its use in voltage regulation projects as it allows for real-time, precise voltage measurement and control and reliable.

- **Affordability and accessibility of arduino:** Due to its low cost and wide availability and open source microcontroller, the Arduino is an ideal choice for most

residential and small-scale applications. Researchers have noted its affordability compared to other platforms, making it a practical option for household voltage protection systems.

- **Application in industrial and residential settings:** Arduino-based systems have been successfully used in both industrial and domestic contexts. Research findings highlight their adaptability, noting that the same platform can be customized for different voltage ranges and operational requirements, ensuring flexibility across different applications.
- **Relay-controlled load protection:** Relay mechanisms are commonly used in voltage protection circuits to control the connection and disconnection of loads. This project leverages a similar setup, enabling the Arduino to activate or deactivate the relay based on voltage readings.
- **User interface with LCD (liquid crystal display) displays:** LCD displays are used in various applications for real-time feedback. In this project, the LCD shows voltage levels and alerts users when voltage conditions exceed safe limits, enhancing the system's usability for household settings.
- **Enhanced safety in household applications:** We have noted that Arduino-based systems with relays and LCDs significantly improve household safety. By disconnecting the load automatically in response to dangerous voltage levels, these systems protect both equipment and occupants, underscoring their practical application in domestic environments.

3. COMPARE EXISTING SYSTEM AND PROPOSED SYSTEM

TABLE-1: Comparison between Existing System and Proposed System

Feature	MCB	Overvoltage/Undervoltage Protection System (Arduino)
Protection Type	Overcurrent (overload and short circuit)	Overvoltage and undervoltage
Response Time	Milliseconds	Milliseconds, with minimal processing delay
Manual/Auto Reset	Manual reset	Automatic reset or configurable
Monitoring	None	LCD display with real-time voltage information
Usage Scope	General household and industrial use	Sensitive devices and areas with voltage fluctuation issues
Customization	Limited	High, based on code and settings
Cost	Low	Moderate (due to components like Arduino, relay, LCD)

3.1 Miniature Circuit Breaker (MCB)

Function: MCBs are electromechanical devices that protect electrical circuits from overcurrent due to overloads or short circuits. They trip and cut off the power supply when the current exceeds a pre-set limit.

- Protection Level: MCBs provide basic protection against overloads and short circuits but cannot protect against voltage fluctuations such as overvoltage or undervoltage conditions.
- Response Time: Very fast response to current-related faults, typically in milliseconds.
- Reset Mechanism: MCBs can be manually reset after tripping.
- Usage: They are widely used for home and industrial circuit protection due to their simplicity and reliability.

Limitation:

- Does not detect or protect against voltage fluctuations.
- Limited protection functions focused only on current, not voltage.
- No diagnostic or monitoring features.

3.2 Overvoltage/Undervoltage Load Protection System using Arduino Uno

Function: This system is designed to monitor voltage levels and provide protection by disconnecting the load when voltage exceeds safe levels, either in cases of overvoltage or undervoltage.

Components:

1. Arduino Uno: Serves as the controller to monitor and process voltage levels.
2. Voltage Sensors: Detects overvoltage and undervoltage conditions.
3. Relay Module: Acts as a switch to disconnect or reconnect the load based on voltage levels.
4. LCD Display: Displays real-time voltage readings, alerts, or status of the system.
5. Protection Level: Can protect against both overvoltage and undervoltage, providing a more comprehensive protection system for sensitive devices.

6. Response Time: Quick but can be slightly delayed by sensor and processing time, usually in milliseconds.

7. -Reset Mechanism: Can be programmed to automatically reset when normal voltage levels are restored.

8. Usage: Suitable for areas with frequent voltage fluctuations, providing a tailored solution for sensitive electronic equipment.

Advantages:

- Can detect and react to both overvoltage and undervoltage situations.
- Provides real-time monitoring and displays voltage information.
- Customizable parameters and set-points, allowing for specific protections.

4. SYSTEM COMPONENTS

The load protection system consists of several key components, including an Arduino Uno microcontroller, a voltage sensor, an LCD display, and a relay module. This section details each component and the steps involved in designing, programming, and testing the system.

4.1 Arduino Uno:

The Arduino Uno microcontroller is selected for its accessibility, programmability, and cost-effectiveness. It receives analog voltage data and controls the relay module based on the measured values.

• Functionality:

The Arduino code sets voltage thresholds (e.g., 200V–240V for safe operation) for both overvoltage and undervoltage conditions.

The voltage sensor continuously measures the incoming AC voltage and outputs an analog signal that is read by the Arduino. This analog signal is converted to a voltage value by mapping the sensor's input range. If the voltage exceeds the overvoltage threshold or falls below the undervoltage limit, the Arduino initiates a relay control sequence to disconnect the load. Disconnecting the load to protect it from damage.

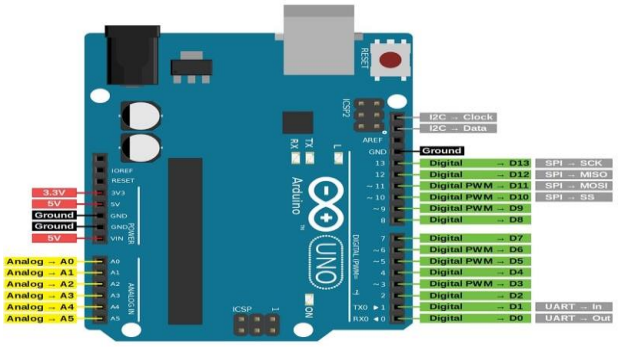

Fig-1: Pin diagram of Arduino Uno

4.2 Relay Module:

Relay modules are commonly used for load protection in voltage regulation systems, allowing a microcontroller to control power to a load based on voltage conditions. A single-channel relay module is used to connect or disconnect the load. The relay is triggered by the Arduino, which controls its state based on voltage conditions.

• Functionality:

The Arduino sends a digital signal to the relay module. When the signal is HIGH, the relay closes, connecting the load to the power supply. When the signal is LOW, the relay opens, disconnecting the load.

This mechanism provides a fast response to voltage fluctuations, ensuring that appliances are disconnected promptly in case of dangerous voltage levels.

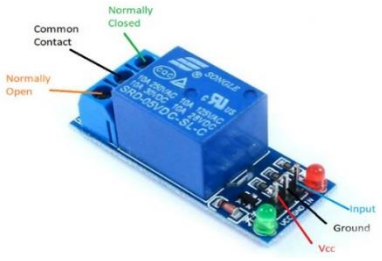

Fig-2: Pin diagram of Relay Module

4.3 16x2 LCD Display:

An LCD display enhances the usability of the system by providing real-time voltage readings and alerts for the user .A 16x2 LCD module is used to display voltage readings and alert messages. It connects to the Arduino either through direct wiring or via an I2C adapter to reduce wiring complexity.

• Functionality:

The LCD displays the current voltage level and the system's operational status. This provides the user with instant feedback, allowing them to visually monitor voltage conditions.

Messages like “Voltage Stable,” “Overvoltage Detected,” or “Undervoltage Detected” alert users to the system’s state, enabling them to take any additional precautions if necessary.

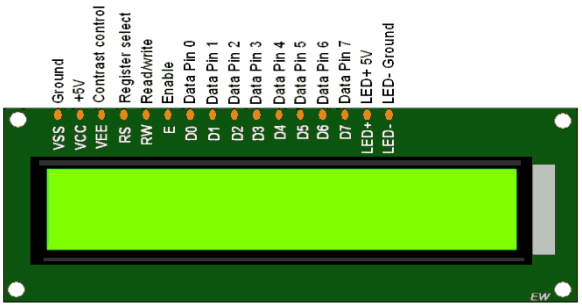

Fig-3: Pin diagram of 16x2 LCD Display

4.4 Voltage sensor (ZMPT101B):

The ZMPT101B AC voltage sensor module measures AC voltage and is used in a variety of applications. The ZMPT101B uses a voltage transformer to measure AC voltage accurately. It has an analog output that can be adjusted.

• Functionality:

The ZMPT101B voltage sensor monitors AC voltage levels and sends an analog signal to the Arduino, which interprets these readings.

Based on preset voltage thresholds, the Arduino either allows normal operation or triggers a relay to disconnect the load if unsafe voltage levels are detected, protecting appliances. The real-time voltage levels are also displayed on an LCD for easy monitoring by the user.

Fig-4: Pin diagram of voltage sensor (ZMPT101B)

5. CIRCUIT DIAGRAM OF SYSTEM

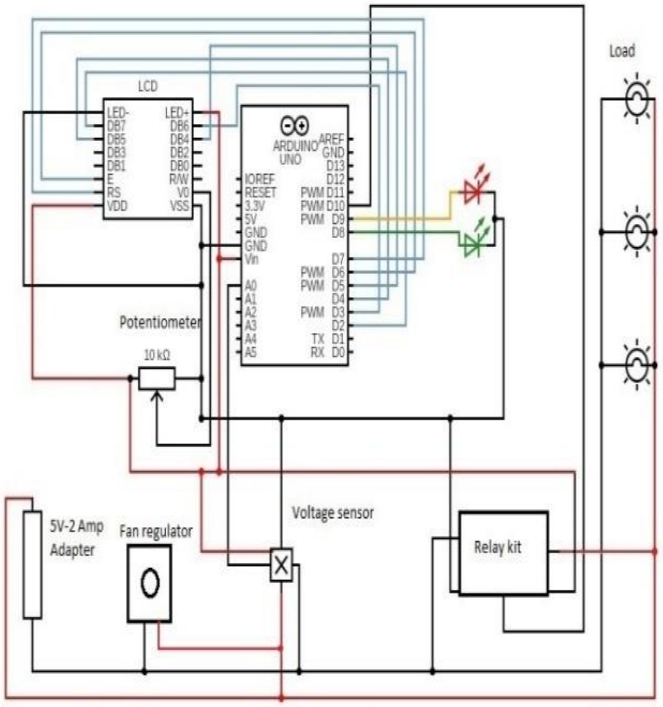

Fig-5: Circuit diagram of project

6. METHODOLOGY

6.1 Implementation:

- The 5V adapter provides power to the entire circuit, specifically the Arduino Uno. The adapter is connected to the Arduino's Vin and GND pins to supply 5V DC, which is also distributed to other components as needed.
- The Arduino Uno acts as the control unit in this system, receiving input from the voltage sensor (ZMPT101B), processing it, and controlling the relay module and LEDs. It uses analog and digital pins to interface with the various components.
- The ZMPT101B sensor is a specialized module for measuring AC voltage. It provides an analog signal output proportional to the AC voltage it measures. Connect the output of the ZMPT101B to one of the Arduino’s analog input pins (e.g., A0). The ZMPT101B has power and ground pins, which are connected to the Arduino’s 5V and GND respectively.
- The 16x2 LCD Display shows real-time voltage readings and status messages (such as “Safe Voltage,” “Overvoltage,” and “Undervoltage”). VSS and VDD pins of the LCD connected to GND and +5V from the Arduino. RS and E pins on the LCD are connected to digital pins (D12 and D11, respectively) on the

Arduino for controlling the data flow. D4-D7 on the LCD are connected to the Arduino's digital pins (e.g., D5-D8).

- The V0 pin of the LCD is connected to the middle terminal of a 10k Ohm potentiometer. The other two terminals of the potentiometer are connected to 5V and GND, allowing the user to adjust the display contrast. This potentiometer is used to adjust the contrast of the LCD.
- The relay module is used to control the connection to the load (bulbs). It acts as a switch, which the Arduino controls based on the voltage level. The signal input of the relay is connected to one of the Arduino's digital output pin. The power and ground pins of the relay is connected to the Arduino's 5V and GND. The bulbs is connected to the normally open (NO) terminals of the relay, allowing them to be turned on or off depending on the voltage conditions.
- The load in this setup consists of three bulbs connected in parallel. Each bulb is mounted in a holder.
- Two LEDs provide a visual indication of the system status. Green LED indicates that the voltage is within a safe range. Red LED lights up when an overvoltage or undervoltage condition is detected. The green LED is connected to one digital output pin (e.g., D6) on the Arduino with a current-limiting resistor (typically 220 ohms) to ground. The red LED is connected to another digital output pin (e.g., D5) with a similar current-limiting resistor to ground.
- The fan regulator in the diagram may help stabilize the AC voltage feeding into the voltage sensor, especially in regions with frequent fluctuation.

6.2 Working Process:

1. Voltage Monitoring:

   The ZMPT101B voltage sensor continuously monitors AC voltage levels in real-time. It converts the measured voltage into an analog signal, which is then read by the Arduino. The Arduino processes this signal and converts it into a readable voltage value, which is then displayed on the LCD.

2. Voltage Comparison:

   The Arduino compares the measured voltage against preset safe thresholds for overvoltage and undervoltage conditions. These thresholds define the safe operational range, protecting the connected load from extreme voltage fluctuations.

3. Relay Control:

   Overvoltage or Undervoltage Conditions: If the voltage is above the overvoltage limit or below the undervoltage limit, the Arduino outputs a LOW signal to the relay. This LOW signal causes the relay to disconnect the load (e.g., bulbs), preventing potential damage. Normal Voltage Range: When the voltage is within the safe limits, the Arduino keeps the relay HIGH, ensuring the load remains connected.

4. LED Indicators: Green LED:

   Lights up when the voltage is within the safe range, indicating normal operation. Red LED: Lights up when the system detects an overvoltage or undervoltage condition, signaling a fault in the voltage levels.

7. RESULTS AND DISCUSSION

The system was tested under various simulated voltage conditions to evaluate its effectiveness in detecting unsafe voltage levels and responding appropriately. Table 2 illustrates the system's response to different voltage conditions, highlighting its reliability and response time.

TABLE-2**:** System Response to Voltage Conditions

Voltage Condition	Relay Response	Response Time (ms)	LCD Display Output
Normal Voltage	Load Connected	-	"Voltage Stable"
Overvoltage	Load Disconnected	< 500	"Overvoltage Detected"
Undervoltage	Load Disconnected	< 500	"Undervoltage Detected"

The system consistently demonstrated prompt disconnection of the load during overvoltage and undervoltage conditions. This ensures that household appliances remain protected, confirming the system's efficacy and reliability.

- **Analysis**

The system's performance was evaluated based on accuracy, response time, and user interface functionality. The Arduino-based design proved to be a cost-effective solution with rapid response times, disconnecting the load within 500 ms of detecting unsafe voltage levels. Additionally, the LCD display improved usability by providing clear, real-time information on the system's status, making it suitable for domestic use.

8. CONCLUSION

In conclusion, the successful implementation of an overvoltage and undervoltage load protection system which provide safety to electrical equipment from potential damage caused by voltage fluctuations in the power supply. This project has indicate the effectiveness of a circuit designed to detect and respond to both overvoltage and undervoltage conditions. By utilizing a voltage sensor and a relay module, the system accurately monitors the input voltage and disconnects the load whenever it exceeds predefined thresholds. The project's outcomes highlight the importance of reliable power protection, especially in regions inclined to power supply irregularities. Overall, this project serves as a solid foundation for developing robust and intelligent power protection systems, contributing to the overall reliability and efficiency of electrical infrastructure.

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