

# Over Voltage\Under Voltage System Protection System

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**Abstract:** *The reliability and stability of electrical power systems are highly dependent on the protection mechanisms implemented to safeguard both the equipment and consumers. One of the most common and critical issues in electrical distribution networks is voltage fluctuation, which includes conditions of over-voltage and under-voltage. These fluctuations can lead to severe damage to electrical appliances, reduced efficiency, and even complete system failure. To address this issue, the Over Voltage and Under Voltage Protection System is designed to continuously monitor the supply voltage and automatically disconnect the load whenever the voltage exceeds or falls below the safe operating limits. Once the voltage returns to the normal range, the system restores the connection automatically, ensuring both safety and continuity of operation.*

*This proposed system primarily employs a microcontroller or comparator circuit that senses the voltage level through a potential divider and analog-to-digital conversion process. When an abnormal voltage level is detected, the controller activates a relay mechanism to isolate the connected devices from the main supply. Additionally, visual indicators such as LEDs or LCD displays are used to provide real-time voltage status information to the user. The system can be implemented for single-phase or three-phase power lines depending on the requirement.*

*The main advantage of this system lies in its automatic operation, low cost, and high reliability. It effectively prevents the burning of motors, transformers, and sensitive electronic devices due to irregular voltage levels. Moreover, it reduces maintenance costs and enhances the overall lifespan of electrical equipment. The system can be further improved by integrating Internet of Things (IoT) technology for remote monitoring and control through mobile applications, enabling real-time fault reporting and enhanced user convenience..*

**Keywords:** Over Voltage Protection, Under Voltage Protection, Voltage Monitoring, Power Supply Safety, Microcontroller, Relay Circuit, Comparator, Voltage Sensor, Automatic Disconnection, Electrical Protection System, Voltage Stabilization, Power Quality, Fault Detection, Load Protection, IoT-based Monitoring, Smart Grid, Voltage Control, Power Distribution, Electrical Safety, Automation System

## I. INTRODUCTION

In modern electrical and electronic systems, maintaining a stable voltage supply is essential for ensuring the efficient operation and longevity of connected equipment. Variations in voltage levels, commonly known as over-voltage and under-voltage conditions, are frequent occurrences in both residential and industrial power distribution networks. These abnormalities often arise due to power surges, load fluctuations, switching operations, lightning strikes, or faults in the transmission and distribution lines. Such fluctuations not only disrupt normal operations but also cause permanent damage to sensitive electrical and electronic devices. Therefore, designing a reliable and automatic system that can protect electrical appliances from these voltage irregularities is of significant importance.

An Over Voltage and Under Voltage Protection System serves as a safeguard by continuously monitoring the input supply voltage and disconnecting the load whenever the voltage exceeds or falls below the predefined safe limits. The system functions automatically without human intervention and reconnects the power supply once the voltage returns to



its normal operating range. This ensures uninterrupted power supply and protects valuable equipment from potential damage.

The proposed system generally consists of a voltage sensing unit, a control unit (typically a microcontroller or comparator circuit), a relay driver circuit, and an output load. The voltage sensing unit samples the input voltage through a potential divider circuit and converts it into a measurable signal. The control unit processes this signal and compares it with preset reference values for both upper and lower voltage limits. When the voltage goes beyond these thresholds, the control unit triggers the relay circuit to disconnect the load from the supply, thereby preventing any damage. When the voltage stabilizes within safe limits, the relay automatically reconnects the load.

The significance of implementing such systems has increased with the growing use of sophisticated electronic equipment in daily life. Devices such as computers, televisions, refrigerators, and industrial control systems require stable voltage for reliable performance. A sudden voltage surge or drop can lead to equipment failure, data loss, or even fire hazards. Thus, this system not only improves the reliability of the power distribution network but also enhances electrical safety and reduces maintenance costs.

## **II. LITERATURE SURVEY**

Voltage protection has been a long-standing area of research due to its direct impact on equipment reliability and power quality. Early work concentrated on electromechanical and ferroresonant stabilizers which provided coarse protection against large excursions but suffered from slow response, mechanical wear, and limited precision. As solid-state electronics matured, automatic voltage regulators (AVRs) and tap-changing transformers (OLTC — On-Load Tap Changers) became widely adopted in distribution systems for large-scale voltage regulation; these solutions improved steady-state control but can be costly and complex for residential or small commercial deployment.

With the advent of low-cost microcontrollers and ADCs, several studies shifted focus to compact, electronic over-voltage/under-voltage protectors that monitor line voltage and operate relays or electronic switching elements to disconnect loads during excursions. These systems typically use potential dividers and comparator thresholds or digital sampling with software-set limits. Researchers have demonstrated such designs that prioritize low cost, ease of installation, and automatic reconnection strategies with programmable hysteresis to avoid relay chattering. Comparators provide extremely fast trip action but lack advanced diagnostics; microcontroller-based designs add logging, adjustable setpoints, and user interfaces.

Advanced control strategies have been proposed to improve robustness and reduce nuisance trips. Fuzzy logic and adaptive thresholding have been applied to distinguish transient spikes from sustained faults, allowing the system to ignore short disturbances while still protecting against sustained over/under-voltage. Model-predictive and DSP-based approaches have been used in research prototypes for high-precision industrial applications, enabling faster detection and coordinated multi-phase protection. Studies comparing algorithms report trade-offs between detection speed, false-trip rate, and implementation complexity. Several papers address three-phase systems where asymmetrical conditions (phase-to-phase or single-phase sag) complicate protection logic. Approaches using symmetrical component analysis or phase-sequence-aware sampling provide better discrimination of harmful conditions while preserving continuity of service. In the distribution network context, integration with grid-side monitoring systems and communication protocols has been explored; combining local protection with centralized SCADA/AMI data helps in coordinated responses and in distinguishing utility-level disturbances from local faults.

Comparative evaluations in the literature highlight several gaps: many low-cost solutions lack standard compliance testing, long-term reliability data, and comprehensive handling of complex grid disturbances (e.g., voltage swells combined with harmonics). There is also limited published work on cost-effective solutions for three-phase commercial systems that require fast response without significant capital investment. Finally, while IoT-enhanced protectors offer richer functionality, standardized communication interfaces and secure architectures remain open research areas.

## **III. PROBLEM STATEMENT**

In today's electrical distribution systems, voltage instability has become a significant challenge due to increasing power demand, aging infrastructure, and fluctuating loads. Over-voltage and under-voltage conditions frequently occur as a



result of power surges, lightning strikes, transmission faults, or sudden load changes. These irregularities cause serious damage to sensitive electrical and electronic devices such as motors, transformers, computers, and home appliances. Traditional protection methods, like manual circuit breakers or stabilizers, are often slow, inefficient, and require human intervention, making them unsuitable for modern automatic systems.

The main problem addressed in this project is the lack of a reliable, automatic, and cost-effective protection mechanism that can continuously monitor the supply voltage and respond instantly to abnormal conditions. Without an automated protection system, voltage fluctuations can lead to equipment burnout, energy losses, reduced lifespan of devices, and high maintenance costs. Therefore, there is a critical need for an intelligent system capable of detecting abnormal voltage levels, disconnecting the load during unsafe conditions, and reconnecting it once stability is restored.

This research aims to design and implement a microcontroller-based over-voltage and under-voltage protection system that ensures safety, minimizes equipment damage, and enhances the overall reliability of electrical power networks.

#### **IV. AIM AND OBJECTIVES**

**Aim:** The main aim of the Over Voltage and Under Voltage Protection System is to design and develop an automatic, reliable, and cost-effective system that can continuously monitor the input voltage and protect electrical and electronic equipment from damage caused by abnormal voltage conditions. The system ensures safety, enhances equipment lifespan, and maintains stable operation by automatically disconnecting the load during over-voltage or under-voltage conditions and reconnecting it when the supply returns to the normal range.

##### **Objectives:**

- To design a microcontroller or comparator-based system capable of detecting voltage fluctuations accurately and efficiently.
- To develop an automatic protection mechanism that disconnects the load when the supply voltage exceeds or falls below the preset limits.
- To ensure quick response time for fault detection and protection to minimize damage to electrical devices.
- To provide a visual or digital indication (LED or LCD display) for monitoring voltage status and system operation.

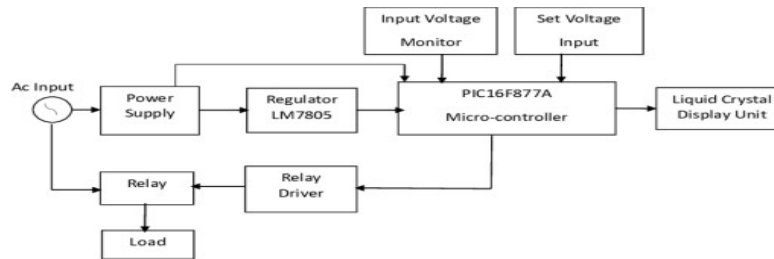
#### **V. SYSTEM ARCHITECTURE**

The system architecture of the Over Voltage and Under Voltage Protection System is designed to provide continuous monitoring and automatic protection of electrical loads from abnormal voltage conditions. The architecture consists of several key components, including a power supply unit, voltage sensing circuit, microcontroller unit (MCU) or comparator circuit, relay driver circuit, load section, and indication/display unit. All these components are interconnected to ensure efficient communication and automatic operation.

The power supply unit converts the AC mains voltage into a regulated DC voltage required to operate the control circuitry. The voltage sensing circuit uses a potential divider and rectifier to scale down the input AC voltage to a measurable DC level suitable for the microcontroller or comparator. The microcontroller unit acts as the brain of the system; it continuously reads the voltage levels, compares them with predefined upper and lower thresholds, and makes logical decisions accordingly. If the sensed voltage exceeds the upper limit (over-voltage) or drops below the lower limit (under-voltage), the controller sends a signal to the relay driver circuit to disconnect the load. Once the voltage returns to the normal range, the microcontroller reactivates the relay to reconnect the load automatically. The indicator or display unit (LEDs or LCD) provides real-time status information such as "Normal," "Over Voltage," or "Under Voltage."

This architecture ensures fast response, reliability, and automation without human intervention. It can be easily implemented for single-phase or three-phase systems and upgraded with IoT modules for remote monitoring and control. Thus, the architecture effectively safeguards electrical devices, minimizes energy loss, and enhances power system stability and safety.





## VI. COMPONENTS

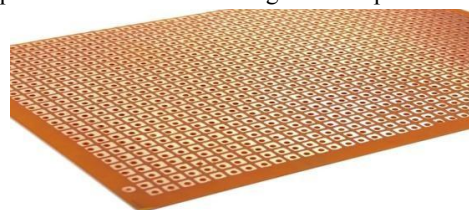
### • Power Supply

The power supply unit in an over-voltage and under-voltage protection system is responsible for providing a stable and regulated DC voltage to all the circuit components such as the microcontroller, sensors, and relays. It typically consists of a step-down transformer, rectifier, filter, and voltage regulator circuit. The transformer converts high AC mains voltage to a lower AC level, which is then rectified into DC using diodes. The filter smooths the ripples, and the regulator maintains a constant output voltage. This ensures that the system operates accurately and reliably, regardless of input voltage variations or external disturbances.



### • Zero PCB

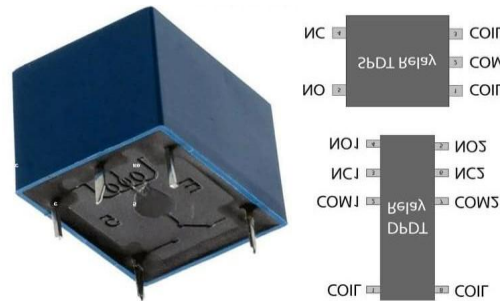
A Zero PCB (Printed Circuit Board) is a type of prototyping board used to build and test electronic circuits without designing a custom PCB layout. It contains pre-drilled holes arranged in a grid pattern with copper pads for soldering components and connecting wires. Zero PCBs allow easy modification, quick assembly, and debugging of circuits during development. In an over-voltage and under-voltage protection system, a Zero PCB is ideal for connecting components like resistors, relays, microcontrollers, and sensors in an experimental setup. It provides a strong and reusable platform for testing circuit performance before making the final printed circuit design.



### • Relay Module

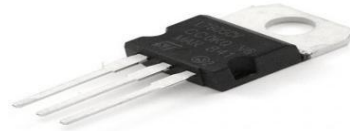
A relay module is an electromechanical switching device used to control high-voltage or high-current loads using low-voltage signals from a microcontroller or control circuit. It operates through an electromagnetic coil that activates an internal switch to connect or disconnect the load. In an over-voltage and under-voltage protection system, the relay module plays a vital role in isolating the load from the supply when abnormal voltage conditions are detected. Once the voltage returns to normal, the relay automatically reconnects the load. It provides electrical isolation, safety, and automation, making it an essential component in power protection circuits.





### • Transistor

A transistor is a semiconductor device used for switching and amplification in electronic circuits. It consists of three terminals — the base, collector, and emitter. When a small current flows through the base, it controls a larger current between the collector and emitter. In an over-voltage and under-voltage protection system, the transistor is often used in the relay driver circuit to control the relay operation. It acts as an electronic switch, allowing the microcontroller to activate or deactivate the relay based on voltage conditions. Transistors provide fast switching, low power consumption, and reliable performance in electronic protection systems.



### • Capacitor

A capacitor is an electronic component that stores electrical energy in the form of an electric field between two conductive plates separated by an insulating material called a dielectric. It is widely used for filtering, timing, and energy storage applications. In an over-voltage and under-voltage protection system, capacitors are primarily used in the power supply section to smooth out voltage fluctuations by filtering ripples from the rectified DC output. Capacitors also help in protecting the circuit from sudden voltage spikes and maintaining consistent performance.

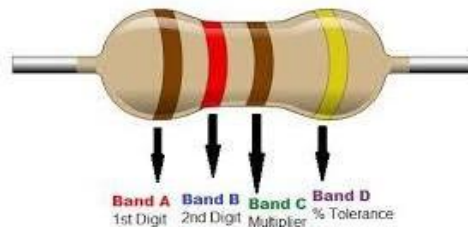


### • Resistor

A resistor is a passive electronic component that opposes the flow of electric current, thereby controlling the voltage and current in a circuit. It is used to limit current, divide voltage, and protect components from excessive power. In an over-voltage and under-voltage protection system, resistors play a crucial role in the voltage sensing circuit by forming a potential divider network that scales down the input AC voltage to a safe level for the microcontroller or comparator. They also help in biasing transistors, setting reference voltages, and ensuring stable operation. Resistors are essential for accurate voltage detection and circuit safety.







## VII. WORKING

The Over Voltage and Under Voltage Protection System operates on the principle of continuous voltage monitoring and automatic disconnection of the load when the supply voltage deviates beyond safe limits. The system ensures that electrical appliances receive voltage within the permissible range, thereby preventing damage and enhancing their lifespan.

The operation begins with the voltage sensing circuit, which samples the input AC supply using a potential divider network. This circuit reduces the input voltage to a low, measurable level suitable for the microcontroller or comparator. The sensed voltage is then converted into a digital value through an Analog- to-Digital Converter (ADC) in the case of a microcontroller-based design. The microcontroller continuously compares the sensed voltage with two preset reference values — the upper threshold (for over-voltage) and the lower threshold (for under-voltage). When the supply voltage remains within the normal range, the microcontroller keeps the relay energized, allowing the load to receive power. However, if the voltage rises above the upper limit, the system detects an over-voltage condition. Similarly, if the voltage falls below the lower limit, an under-voltage condition is identified. In both cases, the microcontroller immediately sends a control signal to the relay driver circuit, which deactivates the relay and disconnects the load from the supply. This quick action protects the connected appliances from potential damage caused by voltage fluctuations.

Once the voltage returns to its normal operating range, the microcontroller senses this correction and automatically re-energizes the relay, reconnecting the load to the power supply. The indicator or display unit provides real-time feedback: for example, a green LED or LCD message indicates “Normal Voltage,” while red or yellow LEDs display “Over Voltage” or “Under Voltage.”

This system’s working is fully automatic, requiring no manual reset or supervision. It provides high reliability, rapid response, and consistent protection even during sudden voltage changes. The design can also be integrated with IoT modules to allow remote monitoring, voltage logging, and fault reporting via smartphones or computers.

## VIII. RESULTS

The Over Voltage and Under Voltage Protection System was successfully designed, implemented, and tested to verify its performance and reliability. The results demonstrate that the system effectively detects abnormal voltage conditions and provides immediate protection to connected electrical loads. During testing, the system was subjected to varying input voltage levels ranging from 150V to 260V AC to simulate both over- voltage and under-voltage conditions.

Under normal operating conditions (approximately 200V–240V AC), the system allowed continuous power flow to the load without interruption. When the input voltage exceeded the upper threshold limit (above 240V AC), the microcontroller detected the over-voltage condition and instantly deactivated the relay, disconnecting the load from the supply within milliseconds. Similarly, when the voltage dropped below the lower limit (below 190V AC), the system identified the under-voltage state and disconnected the load automatically.

Once the supply voltage returned to the normal range, the system automatically reconnected the load without requiring manual intervention. The LED indicators and LCD display clearly showed the voltage status — green for normal, red for over-voltage, and yellow for under-voltage — allowing users to easily monitor system behavior. The results confirm that the designed protection system provides high accuracy, fast response, and consistent performance under different



voltage conditions. The circuit remained stable and reliable throughout extended testing periods. The prototype achieved the desired objectives by ensuring equipment safety, reducing the risk of damage, and maintaining operational continuity.

## **IX. ADVANTAGES & APPLICATIONS**

### **• Advantages**

1. Automatic Operation: The system automatically disconnects and reconnects the load based on voltage conditions without human intervention, ensuring continuous safety and reliability.
2. Fast Response: It detects abnormal voltage levels and operates the relay within milliseconds, preventing equipment damage caused by sudden surges or drops.
3. Cost-Effective: The design uses simple, low-cost components such as microcontrollers, relays, and sensors, making it affordable for both residential and industrial applications.
4. High Reliability and Accuracy: Continuous voltage monitoring ensures precise operation and consistent protection from over-voltage and under-voltage conditions.

### **• Applications**

1. Residential Buildings: Protects household appliances such as refrigerators, air conditioners, televisions, and washing machines from voltage fluctuations.
2. Industrial Automation: Ensures stable voltage for machinery, motors, and control circuits used in factories and manufacturing units.
3. Commercial Establishments: Used in offices, shops, and hospitals where continuous and stable power is essential for equipment operation.
4. Telecommunication Systems: Safeguards communication and networking equipment from power surges or voltage drops.

## **X. FUTURE SCOPE**

The Over Voltage and Under Voltage Protection System holds significant potential for future development and technological enhancement. With the growing demand for automation, smart energy management, and reliable power systems, this project can be upgraded to meet modern industrial and domestic needs more effectively.

In the future, the system can be integrated with Internet of Things (IoT) and cloud-based platforms to enable remote voltage monitoring, control, and data logging through mobile or web applications. This would allow users to track voltage trends, receive real-time alerts, and even control connected appliances from anywhere. The collected data could also be used for predictive maintenance and fault analysis, improving system reliability and efficiency. Another major improvement lies in the use of Artificial Intelligence (AI) and Machine Learning (ML) algorithms to predict voltage fluctuations and automatically adjust protection thresholds. Such intelligent systems could differentiate between short-term transients and sustained voltage faults, minimizing false trips and enhancing system accuracy.

Additionally, future designs can incorporate wireless communication protocols such as Wi-Fi, GSM, or LoRa to expand system coverage in industrial zones and rural power networks. Compact PCB designs and energy-efficient components can make the system more portable, scalable, and suitable for renewable energy applications like solar and wind systems.

## **XI. CONCLUSION**

The Over Voltage and Under Voltage Protection System provides an automatic, reliable, and low-cost solution for protecting electrical equipment from voltage fluctuations. It ensures system safety by disconnecting loads during abnormal conditions and reconnecting them when normal voltage is restored, thereby enhancing equipment lifespan, efficiency, and overall power reliability.



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