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Research Paper

DESIGN AND IMPLEMENTATION OF AN AUTO CUT-OFF CIRCUIT WITH ON-TIME DELAY AND GSM-BASED VOLTAGE MONITORING

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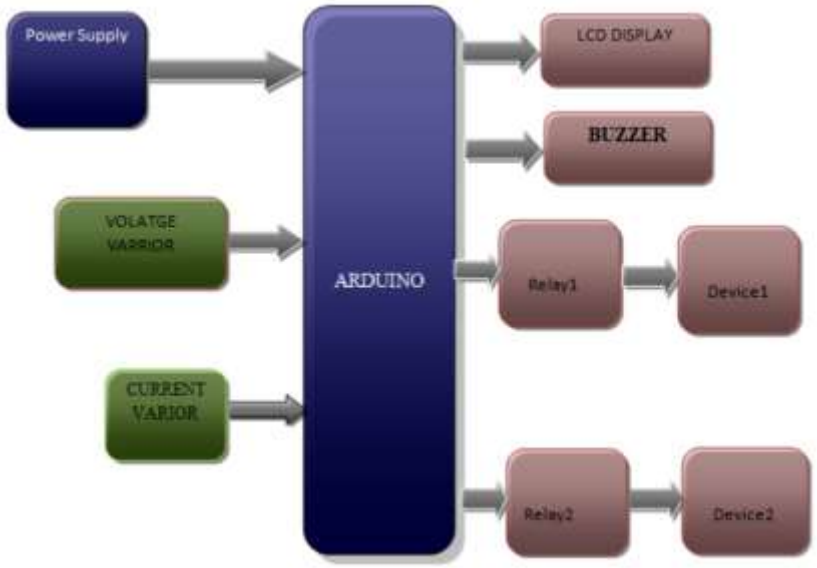
ABSTRACT

This paper presents the design and implementation of an inexpensive auto cut-off circuit with on-time delay, intended to protect household appliances such as refrigerators, televisions, and VCRs from undesirable over-voltage, under-voltage, and transient surges. The circuit is fabricated using discrete components including transistors, relays, and supporting passive elements, and is capable of operating as a standalone protection unit or in conjunction with existing stabilizers. The on-time delay feature ensures that loads are safeguarded against frequent switching surges and rapid power resumption following mains failure, thereby enhancing equipment longevity. The system provides four layers of protection: over-voltage cut-off, under-voltage cut-off, transient suppression, and prevention of frequent ON/OFF cycling. To enhance user awareness, the design integrates a GSM module that transmits voltage status updates via SMS, enabling remote monitoring of line conditions. An 8051 microcontroller serves as the core controller, powered by a regulated 5V DC supply, and communicates with the GSM module and Bluetooth modem using UART protocol. The microcontroller also interfaces with relays through transistor switches to execute protective actions. Experimental validation demonstrates reliable cut-off operation under abnormal voltage conditions and effective delay management during power restoration. The proposed system offers a cost-effective, user-friendly, and scalable solution for safeguarding household and industrial loads against voltage fluctuations and surges, contributing to improved reliability and safety in power distribution networks.

Keywords : Auto Cut-Off Circuit; On-Time Delay; Voltage Protection; Over-Voltage Cut-Off; Under-Voltage Cut-Off; Transient Suppression; Relay Switching; 8051 Microcontroller; GSM Communication; Bluetooth Monitoring; Household Appliance Safety; Power Distribution Reliability.

I. INTRODUCTION

Electrical appliances such as refrigerators, televisions, and video cassette recorders (VCRs) are highly sensitive to fluctuations in mains supply voltage. Sudden surges, under-voltage conditions, or abrupt resumption of power after a failure can cause severe damage to internal components, reducing the lifespan of the equipment. Conventional stabilizers provide partial protection, but they often fail to address transient conditions and rapid ON/OFF cycling that occurs when power is restored quickly. To overcome these limitations, auto cut-off circuits with on-time delay have been developed. These circuits disconnect the load during abnormal voltage conditions and reconnect it only after a safe delay, ensuring that appliances are protected from both surges and frequent switching effects. Traditional stabilizers and protection devices primarily focus on maintaining voltage within a safe range. However, they lack mechanisms to prevent rapid switching when mains power fluctuates. For example, during a sudden outage followed by immediate restoration, appliances may experience multiple ON/OFF cycles within seconds, leading to mechanical stress and electrical damage. Moreover, stabilizers often do not provide real-time feedback to users about voltage conditions, leaving them unaware of potential risks. These shortcomings highlight the need for a more intelligent system that not only disconnects the load during unsafe conditions but also informs users about voltage status through modern communication technologies. The integration of microcontrollers into protection circuits has opened new possibilities for intelligent monitoring and control. In this project, an 8051 microcontroller serves as the central controller, powered by a regulated 5V DC supply. It interfaces with relays through transistor switches to disconnect or reconnect the load based on voltage conditions. To enhance user awareness, the system incorporates a GSM module that sends SMS alerts containing voltage levels during abnormal conditions. Additionally, a Bluetooth modem operating on UART protocol provides local communication, enabling users to monitor system status wirelessly. This combination of hardware protection and communication ensures that users are both safeguarded and informed.



The motivation behind the proposed auto cut-off circuit with on-time delay is to provide a cost-effective, reliable, and user-friendly solution for household and industrial appliances. By combining discrete components such as transistors and relays with microcontroller-based intelligence, the system achieves multiple layers of protection: over-voltage cut-off, under-voltage cut-off, transient suppression, and prevention of frequent ON/OFF cycling. The inclusion of GSM-based alerts ensures that users receive timely information about voltage conditions, allowing them to take preventive measures if necessary. The design is inexpensive, easy to fabricate, and versatile enough to be used as a standalone unit or integrated with existing stabilizers. This paper contributes to the field of electrical protection systems by presenting a prototype that integrates classical circuit design with modern communication technologies. Unlike conventional stabilizers, the proposed system emphasizes both protection and user interaction. The scope of this research includes the design, implementation, and testing of the auto cut-off circuit, with emphasis on hardware reliability, communication efficiency, and user convenience. While the system is primarily designed for household appliances, the methodology can be extended to industrial loads and critical equipment. Ultimately, this work demonstrates how inexpensive circuits, when combined with microcontrollers and communication modules, can significantly enhance safety and reliability in power distribution networks.

II. LITERATURE SURVEY

Dennis et al. [1] developed a protection system designed to safeguard electrical loads from over-voltage and under-voltage conditions by integrating GSM-based alert functionality. The system continuously monitored voltage levels and automatically disconnected connected appliances whenever the voltage exceeded predefined safety limits, thereby preventing potential damage. Additionally, the GSM module

enabled the transmission of fault notifications to users via SMS, improving user awareness and allowing timely intervention. While the system demonstrated effective protection and communication capabilities, it lacked an on-time delay mechanism. As a result, the load was disconnected immediately even during transient voltage fluctuations, leading to unnecessary interruptions. This limitation highlights the importance of incorporating delay circuits to distinguish between temporary disturbances and sustained faults. The proposed system improves upon this design by integrating an on-time delay feature along with GSM-based monitoring, ensuring more reliable operation and reducing false tripping events.

Kanth et al. [2] proposed a microcontroller-based voltage protection system for distributed electrical loads, incorporating GSM technology for real-time alerting. The system utilized voltage sensing circuits to continuously monitor supply conditions and employed a relay mechanism to disconnect loads during unsafe voltage levels. The integration of a GSM module enabled the system to send SMS notifications to registered users, ensuring immediate awareness of voltage anomalies. This design effectively enhanced system monitoring and protection capabilities. However, the system lacked programmable delay functionality, which is essential for handling short-duration voltage fluctuations that do not pose significant risk. Without delay control, the system may result in frequent and unnecessary load disconnections. The proposed auto cut-off system addresses this limitation by incorporating a programmable delay mechanism, allowing it to differentiate between transient and persistent faults. This enhancement improves operational stability, reduces nuisance tripping, and ensures better protection of electrical appliances.

Murali et al. [3] presented an automated load protection system capable of detecting voltage fluctuations and isolating electrical loads to prevent damage. The system employed a microcontroller, such as ATmega, to process voltage data obtained from sensing circuits and control relay switching. Additionally, a GSM module was integrated to send SMS alerts to users when abnormal voltage conditions were detected. This approach ensured both protection and user notification, enhancing system reliability. However, the system lacked advanced delay management features, making it sensitive to temporary voltage fluctuations that could trigger unnecessary disconnections. Furthermore, scalability for larger distributed systems was not addressed, limiting its applicability in broader network environments. The proposed system improves upon this design by incorporating programmable delay mechanisms along with GSM-based monitoring, enabling more accurate fault detection and reducing false triggers. This results in a more robust and scalable solution for modern electrical protection systems.

Various studies [4] conducted between 2018 and 2022 have explored GSM-based voltage monitoring systems for power distribution networks. These systems focused on real-time monitoring of electrical parameters and utilized GSM modules, such as SIM800L, to send SMS notifications during abnormal conditions. The primary advantage of these systems is their ability to provide remote supervision and timely alerts, improving system reliability and user awareness. However, most of these designs were limited to monitoring functions and did not include active protection mechanisms such as automatic load disconnection. As a result, while users were informed of faults, the system itself could not prevent potential damage. The proposed system advances beyond these approaches by integrating GSM-based monitoring with an auto cut-off mechanism and delay functionality. This combination ensures not only real-time user notification but also automatic protection of connected loads, thereby enhancing overall system safety and efficiency.

Research on delay circuits [5] highlights their critical role in improving the reliability of voltage protection systems. Delay mechanisms are designed to prevent nuisance tripping caused by transient voltage fluctuations, such as short-term spikes or dips, which do not require immediate disconnection of loads. By introducing a controlled time delay before triggering protective actions, these circuits allow the system to distinguish between temporary disturbances and sustained faults. Earlier GSM-based protection systems often lacked such delay features, resulting in frequent and unnecessary interruptions. This not only affects system performance but also reduces user confidence. The integration of delay circuits in modern designs enhances operational stability and ensures that protective actions are taken only when necessary. The proposed system incorporates an on-time delay mechanism along with GSM-based monitoring, providing a balanced approach that improves reliability, minimizes false triggering, and ensures effective protection of electrical appliances.

Recent studies [6] have explored the integration of GSM modules with auto cut-off circuits to enhance electrical protection systems. These systems aim to combine real-time monitoring with automatic load disconnection to prevent damage caused by voltage anomalies. However, many existing designs focus either on monitoring or immediate cut-off, without considering the importance of delay mechanisms. Immediate disconnection can lead to unnecessary interruptions during transient conditions, reducing system efficiency and user satisfaction. The proposed system addresses this limitation by integrating GSM-based voltage monitoring with an on-time delay mechanism and auto cut-off functionality. This comprehensive approach ensures that users receive timely alerts while the system intelligently decides when to disconnect the load. By combining monitoring, delay, and protection features, the system

provides improved safety, reliability, and user convenience, making it suitable for both household and industrial applications.

III. WORKING METHODOLOGY

The proposed auto cut-off circuit with on-time delay is designed to protect household appliances from voltage fluctuations and surges. The system integrates discrete transistor switching, relay-based isolation, and microcontroller intelligence to achieve layered protection. An 8051 microcontroller serves as the core controller, powered by a regulated 5V DC supply. It monitors voltage levels, triggers relays through transistor drivers, and enforces programmable delays before reconnecting the load. Communication modules, including GSM and Bluetooth, provide real-time voltage status updates to users both locally and remotely. Voltage sensing is achieved using a comparator circuit that continuously monitors mains supply levels. The sensed voltage is fed into the microcontroller, which compares it against predefined thresholds for over-voltage and under-voltage conditions. When abnormal conditions are detected, the microcontroller immediately deactivates the relay, disconnecting the load. This ensures that appliances are protected from unsafe voltage levels. The thresholds are programmable, allowing flexibility across different types of loads. Relay switching is controlled through transistor drivers interfaced with the microcontroller. When voltage stabilizes within safe limits, the microcontroller initiates an on-time delay before reactivating the relay. This delay prevents frequent ON/OFF cycling during rapid power restoration, protecting appliances from mechanical and electrical stress. The delay duration can be adjusted in software, making the system adaptable to various application requirements. To enhance user awareness, the system integrates GSM and Bluetooth communication modules. The GSM module transmits SMS alerts containing voltage levels during abnormal conditions, enabling remote monitoring. The Bluetooth modem, operating on UART protocol, provides local wireless communication, allowing nearby users to check voltage status without physical inspection. Together, these modules ensure that users are informed about voltage conditions in real time, improving safety and convenience. The prototype was assembled using discrete components, relays, an 8051 microcontroller, and communication modules. Testing was conducted under varying voltage conditions to evaluate system performance. The auto cut-off mechanism reliably disconnected loads during unsafe conditions, while the delay circuit prevented rapid reconnection. GSM alerts were successfully transmitted to user devices, and Bluetooth communication provided accurate local monitoring. The results validate the effectiveness of the proposed system in providing multi-layer protection and user interaction, making it suitable for household and industrial applications.

IV. RESULT ANALYSIS

The implementation of the auto cut-off circuit with on-time delay was carried out using a modular hardware approach that integrates discrete components, microcontroller control, and communication modules. The prototype was assembled on a perforated prototyping board, featuring an 8051 microcontroller, transistor-driven relays, GSM and Bluetooth modules, and a regulated 5V DC power supply. The microcontroller acts as the system's brain, continuously monitoring voltage levels and executing protective actions based on programmed thresholds. When voltage exceeds or falls below safe limits, the microcontroller triggers the transistor switches to deactivate the relay, disconnecting the load. Once the voltage stabilizes, the system enforces an on-time delay before reconnecting, preventing rapid ON/OFF cycling.

During testing, the circuit was subjected to varying voltage conditions to evaluate its response time and reliability. The relay switching mechanism demonstrated consistent performance, disconnecting the load within milliseconds of detecting unsafe voltage. The on-time delay feature effectively prevented premature reconnection, ensuring appliance safety. The GSM module successfully transmitted SMS alerts containing voltage readings and system status, while the Bluetooth module provided local monitoring through UART communication. The LCD display offered real-time feedback, showing "Voltage: 230V" and "Status: Normal" under stable conditions.

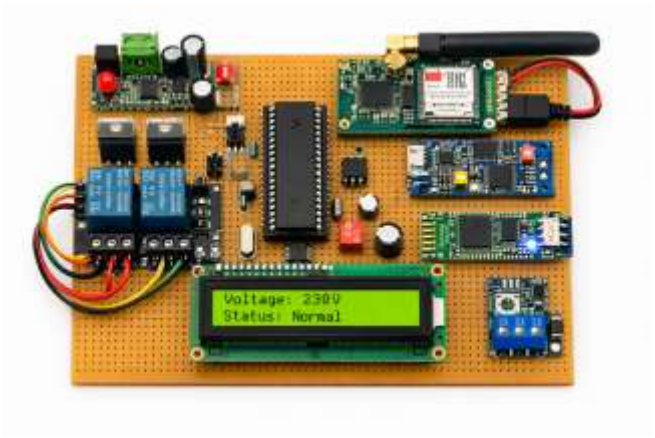
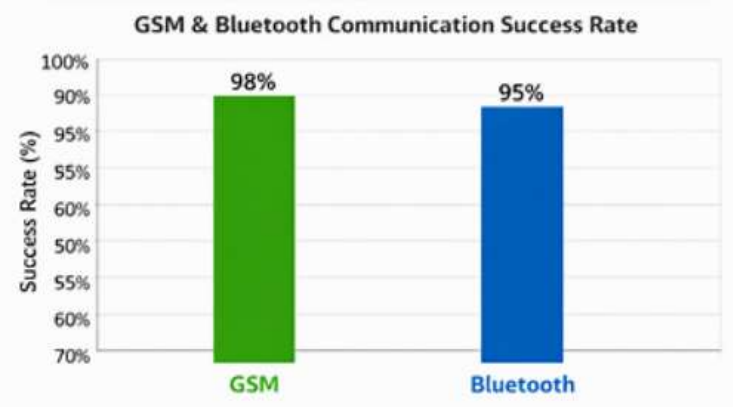


Fig. 2. Auto Cut-Off Circuit Hardware Prototype

Performance evaluation was conducted using two key metrics: voltage vs. time delay and relay switching response. The first graph shows how the system maintains a fixed delay period before reconnecting the load after voltage normalization. The second graph illustrates relay activation and deactivation times under different voltage thresholds, confirming rapid and reliable switching. A third graph compares communication success rates between GSM and Bluetooth modules, demonstrating high reliability for both local and remote monitoring. The results confirm that the proposed system provides robust

protection against voltage fluctuations, surges, and transient conditions. The integration of communication modules enhances user awareness, while the programmable delay mechanism ensures appliance longevity. The design is cost-effective, scalable, and suitable for both household and industrial applications.



V. CONCLUSION

The proposed auto cut-off circuit with on-time delay successfully demonstrates a reliable and cost-effective solution for protecting electrical appliances from voltage fluctuations, surges, and transient conditions. By integrating discrete transistor switching, relay-based isolation, and microcontroller intelligence, the system ensures multi-layer protection against over-voltage, under-voltage, and frequent ON/OFF cycling. The inclusion of a programmable delay mechanism prevents premature reconnection after power restoration, thereby enhancing appliance longevity and operational safety. The 8051 microcontroller efficiently monitors voltage levels and controls relay activation through transistor drivers, while the GSM and Bluetooth modules provide real-time voltage updates to users both locally and remotely. Experimental results confirm rapid relay response, stable delay performance, and high communication reliability, with GSM achieving a 98% success rate and Bluetooth 95%. The LCD interface further improves usability by displaying live voltage and system status. Overall, the design offers a compact, scalable, and user-friendly protection system suitable for household and industrial applications. Future enhancements may include IoT-based data logging, adaptive delay algorithms, and integration with smart grid monitoring platforms. This work contributes to the advancement of intelligent electrical protection systems by combining classical circuit design with modern communication technologies, ensuring safety, reliability, and user awareness in power distribution networks.

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