

Development of Overvoltage and under voltage Protection System for A Residential Building Interfaced with a GSM Notification System

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ABSTRACT

Overvoltage and under voltage are undesirable conditions capable of causing damages to electrical appliances. In literature, detection and protection of electrical appliances from these voltage irregularities have been largely explored. Nonetheless, load control during irregularities and fault location remains subjects of considerations. In this work, an overvoltage and undervoltage protection system is designed for a residential building. The voltage limits of 240 V and 200 V are set for overvoltage and undervoltage protection, respectively. The protective system unit is developed utilizing a PIC 16F876A microcontroller. A GSM module, SMS 808, with the capacity to send an SMS and location via longitude and latitude, is interfaced for notification and tracking purposes. With the aid of a variac, five different levels of voltage are fed as input for each condition (normal, overvoltage, undervoltage). At each stage of the tested conditions, the protection system operated as set and notifications were sent as programmed. The results revealed that the device can disconnect the load when there are irregularities as well as notifying the utility company and consumers of the locations.

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INTRODUCTION

Electronic appliances are very sensitive to voltage fluctuations [1, 2]. Voltage irregularities are a big issue in today's companies and households, and they are frequently responsible for the damage of valuable and costly electrical appliances [3-6]. To secure electronic appliances from these voltage irregularities, there is a need for a protection system [1, 6-8]. Voltage

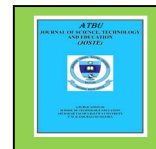
irregularities occur when the voltage is exceedingly high, i.e., overvoltage, or extremely low, i.e., undervoltage [9, 10]. Overvoltage occurs when the magnitude of the supplied voltage in electrical appliance circuits exceeds the design limitations of the appliances [10-12]. This could raise the temperature of the semiconductor components leading to failure of the appliances [13-15]. Undervoltage occurs when the

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magnitude of the supplied voltage falls below the design limits of the equipment. Undervoltage does not normally cause damage to electrical appliances, but it prevents the appliance from operating owing to the current drawn. However, gradual current build-up could result in overheating [2, 6, 9, 16].

Several efforts to implement a protective device for overvoltage and undervoltage have been presented in literature, each with its own unique method. Tung et al. [16] developed an experimental system based on the Arduino Uno microcontroller board for measuring electrical quantities and protecting overvoltage and undervoltage conditions in a single-phase power supply. The proposed method for designing the protective circuit utilize the root mean square (RMS) method to measure electrical quantities. Changchung [17] proposed an adaptive undervoltage tripper with an overvoltage protection function. The proposed system could adapt to the change in supply voltage automatically and provide protection against irregularities. Salihu et al. [18] designed an automatic transfer switch with a generator cut off capable of automatically transferring a load from the main AC supply to the generator when irregularities in voltage magnitude are sensed with respect to the set limit. The control switch was designed without the use of a microcontroller as the voltage sensor does the work of sensing and comparison. These studies, however, failed to incorporate a notification system for the protective device.

When there are irregularities in voltage magnitudes, it is desirable that utility companies are promptly

notified. Khan & Muhtadi [19] developed an Arduino based relay system for overvoltage, undervoltage and overcurrent conditions incorporating a GSM notification system. The set voltage range was within 210-235 V, while the maximum current was set to 10 A. Shrivastava et al. [20] built a GSM Modem SMS-based protection system that monitors input voltage and offers a breakpoint-based low and high voltage tripping mechanism that prevents any load damage and notifies the user if an under-voltage or overvoltage condition arises. Hashir et al. [20] developed a system that monitors and compares input voltage using an Atmega 8051 microcontroller and a GSM module, which notifies the user whenever the voltage crosses the limit. These initiatives have proven to be quite beneficial. A similar SMS control technique was deployed by Otuoze et al. [21] in their design of SMS controlled electronic billboard. These studies and several others include a notification system, however, little or no consideration is given to the location of irregularity. This often complicates the rectification of such condition as utility may spend useful amount of time diagnosing the location.

In this work, a protective circuit with overvoltage and undervoltage tripping mechanisms is developed. The circuit utilizes a PIC 16F876A microcontroller interfacing a GSM module. The protection system in this work is capable of tripping the circuit when there is an irregularity in the input voltage. Furthermore, the user and utility are notified with incidences of irregularities and their locations. Next, Section 2 discusses the

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methodology, Section 3 presents the results and discussion while Section 4 concludes the study.

MATERIALS AND METHODS

The design framework and the strategies employed in the design of the overvoltage and undervoltage protection scheme presented in this work are as detailed in this section.

Framework of the Design

The various identified units of the designed overvoltage and

undervoltage protective system is as depicted in Figure 1. Every unit plays an important role in the completion of the system. The power supply unit supplies the required voltage utilized by other components. The voltage sensing unit is used to limit the voltage passed through the control unit such that the loads are allowed to operate only in normal conditions. The communication unit is essentially responsible for the SMS notification of the user based on detected condition of voltage outside the normal operating region.

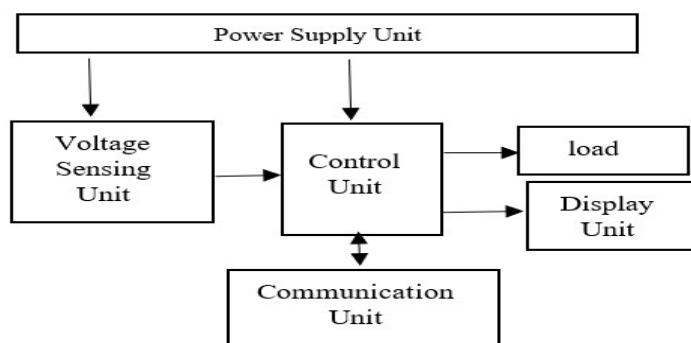


Figure 1: Framework of the Developed Protection System.

The Power Supply Unit

Voltage regulators such as LM2976, LM317, and LM7812 are used to obtain voltages needed by some components, such as the GSM Module, LCD, and relay, in the device respectively. A voltage-sensing unit is used to limit the amount of voltage supplied to the microcontroller. The microcontroller and the LCD are supplied with 5 V, the relay is supplied with 12 V and the GSM module is supplied with 4.3 V. Figure 2 shows the aspect of the power supply unit for this design.

Communication Unit

The GSM modem is used for notification. The modem selected for this

design is an SMS 808, which has a GPS tracking system that enables the GSM to not only send an SMS but also send its location for easy tracking. The GSM SIM 808 gets its power from the buck converter LM2596 and is also connected to the PIC microcontroller using two resistors to divide the voltage from the 5 V of the microcontroller to the 4.3 V needed by the GSM module. The GSM modem constantly waits for a signal from the microcontroller and constantly gives the microcontroller feedback through its Tx and Rx pins. The communication unit is depicted in the circuit of Figure 2.

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The Control Unit

The control unit consists of a PIC 16F876A microcontroller and a relay. The PIC16F876A microcontroller performs the major functions of comparison and control. The PIC16F876A microcontroller is chosen for its easy availability in the market and amenability to various programming languages. It is also used to reduce the complexity of the design and to ensure an easy interface with the liquid crystal display and a GSM module. The microcontroller is the key device of the control unit which controls the notification and activation of the relay to trip through an NPN transistor when the voltage magnitude is not within the set limit. Pins 17 and 18 of the

microcontroller are connected to the R_x and T_x pins of the GSM module, respectively for communication. When the variac is initiated, the microcontroller senses if the input voltage is within range. If it is, the load remains connected and if not, it checks for irregularities. If irregularities are detected, the load is disconnected by the relay. The circuit of Figure 2 shows the control unit and all the units connected to it.

The Display Unit

The Liquid Crystal Oscillator is powered by the LM317 voltage regulator through its V_{cc} pin and has a 5 V connected to its V_{be} pin to adjust the backlight of the text display.

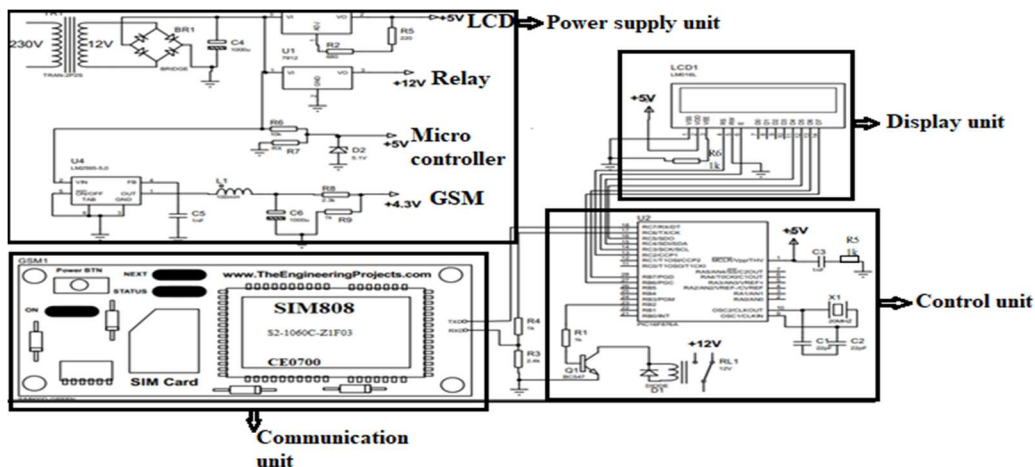


Figure 2: Circuit diagram of the Developed Overvoltage and Undervoltage Protection System.

Implementation of the Overall Design

The design was implemented by simulating using Proteus software until the code for the design worked satisfactorily before the final programming of the microcontroller and assembly of the components. At each stage of each of the units, tests were carried out to ascertain desired

operating condition is achieved before the overall simulation. The programme code was developed based on the flowchart presented in Figure 3. Figure 4 shows the developed configuration of the protective system for testing the voltage conditions. The variac's input is connected to AC voltage, and the output is connected to the device. The

variatic is used to produce irregularities in supply voltage by raising or reducing the input voltage to produce an overvoltage or an undervoltage. The bulb serves as a load, and the standard operating voltage is set from 200 V to 240 V. All voltage conditions less than

the lower limit of 200 V were simulated for undervoltage while all voltage conditions beyond the upper limit of 240 V were simulated for overvoltage as designed in Figure 3. Notifications were only activated for all conditions of voltage irregularities.

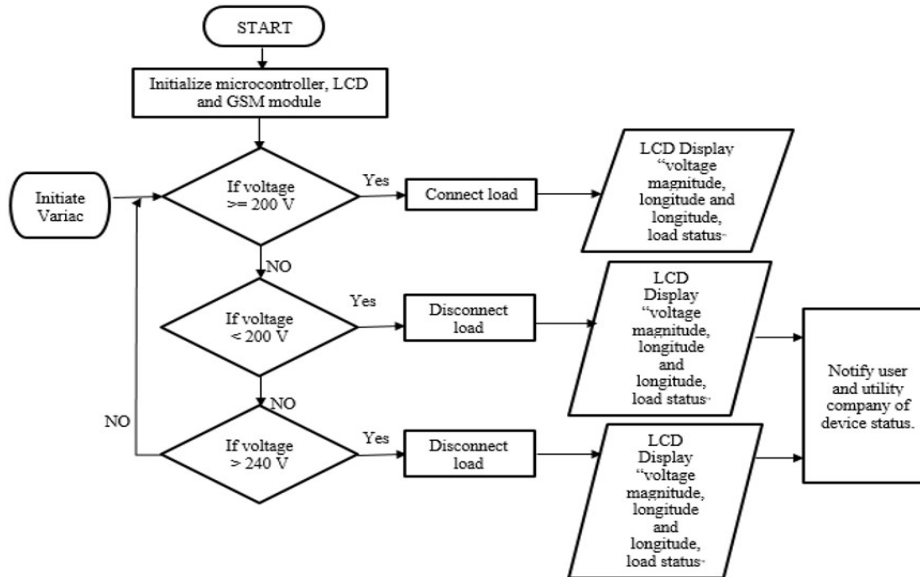


Figure 3: Development of Overvoltage and Undervoltage Protection scheme

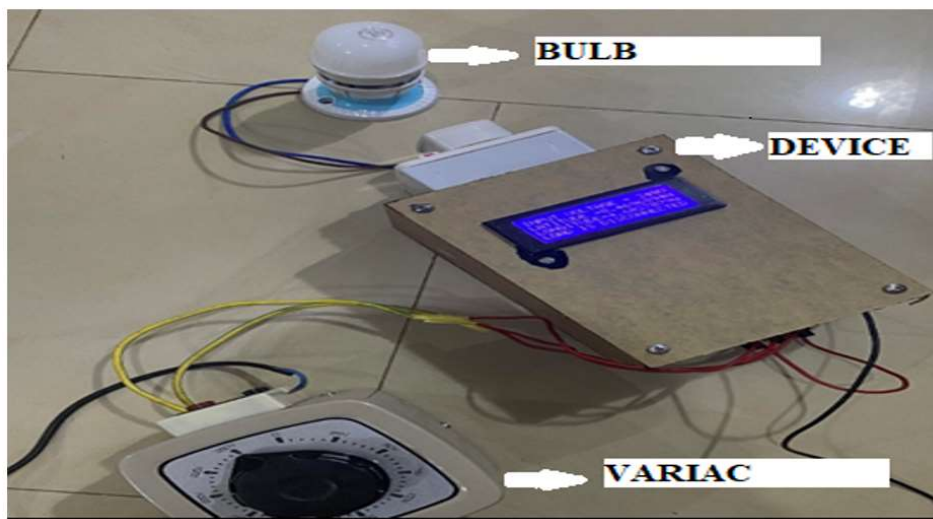


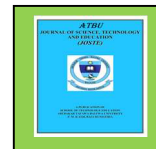
Figure 4: Set-up for the testing of each of the conditions

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GSM SMS Text Command

The GSM module is programmed by a set of commands to send notification when voltage irregularity is detected. When there is an overvoltage or undervoltage, the GSM modem notifies the user and utility companies of the location of the irregularities for quick rectification to avoid increased technical and economic losses. The device status also conveys

SMS. Regardless of whether there are voltage irregularities, the text commands are also set to remotely connect and disconnect the load and get information from the device at any time. The SIM modem receives the text (query) and is transferred to the microcontroller, which decodes the message using a set of commands. The command codes employed in this study are as contained in Table 1.

Table 1: SMS Commands and the Set Output

COMMAND	OUTPUT
*2022#info?	Information from Node at Latitude = 8.4694080 N, Longitude = 4.6023817 W, Input Voltage = 229 V; Lower limit = 200 V; Upper limit = 240 V; relay is connected
*2022#connect	Connects the load.
*2022#disconnect	Disconnects the load.

RESULTS AND DISCUSSION

Testing of the device was done for the three different conditions considered (normal, overvoltage & undervoltage) with five different voltage magnitudes for each of the operating conditions. The set values and the results are as illustrated in Tables 2, 3 and 4. In the normal condition i.e., when there are no irregularities, the voltage is within the typical set limit of 200 V to 240 V, hence, the loads are not disconnected as the relay remains closed. Since there is absence of irregularities, neither the user nor the utility company received any SMS notifications (Table 1) i.e., no SMS is sent when there are no irregularities. The first three tests in Table 2 shows a different location from the last two, carried out at Awolowo Road, Tanke, Ilorin, Kwara State and IBEDC office, Osogbo regional branch, Osun State respectively. For Tables 2, 3, and 4, the set voltage magnitude is the

input value set from the variac while sensed voltage is the detected voltage level by the circuitry. The locations are indicated by the shown Longitudes ($^{\circ}$ W) and Latitudes ($^{\circ}$ N). The SMS output gives the notification sent to the operator who is either the user or the utility or both.

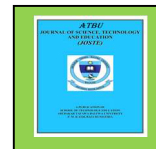
When an overvoltage (Table 3) or undervoltage (Table 4) conditions were simulated, the non-inverting terminal (pin 23) of the microcontroller becomes high. Pin 23 of the microcontroller, linked to the transistor's base, feeds the transistor with a low current of 1 mA at its base, which is the current necessary to activate it. The transistor switches on the relay, causing the circuit to trip. Overvoltage is detected when magnitude of the input voltage is above the set upper limit of 240 V, while undervoltage is detected when the input voltage is below the set lower limit of 200 V. The device displays and sends an SMS output indicating the voltage operating

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condition, location of irregularity and the voltage magnitude. Tables 3 and 4 show the results of the tests carried out for overvoltage and undervoltage conditions, respectively. The first three

results in each of these tables shows a different location with the last two, carried out at Awolowo Road, Tanke, Ilorin, Kwara State and MFM Road, Tanke, Ilorin, Kwara State.

Table 2: Results for Normal Voltage Operating Conditions

S/No.	Set Voltage Magnitude (V)	LCD Display	SMS Output
1.	202	Sensed Voltage = 202.0 V Latitude = 8.4694080 °N Longitude = 4.6023645 °W Load Status: Connected	NIL
2.	207	Sensed Voltage = 206.8 V Latitude = 8.4694080 °N Longitude = 4.6023645 °W Load Status: Connected	NIL
3.	217	Sensed Voltage = 216.9 V Latitude = 8.4694080 °N Longitude = 4.6023645 °W Load Status: Connected	NIL
4.	220	Sensed Voltage = 219.6 V Latitude = 7.7782664 °N Longitude = 4.5485620 °W Load Status: Connected	NIL
5.	230	Sensed Voltage = 230.0 V Latitude = 7.7782664 °N Longitude = 4.5485620 °W Load Status: Connected	NIL

Table 3: Results for Overvoltage Voltage Operating Conditions

S/No.	Set Voltage Magnitude (V)	LCD Display	SMS Output
1.	248	Sensed Voltage = 248 V Latitude = 8.4694080 °N Longitude = 4.6023645 °W Load Status: Disconnected	OVERVOLTAGE detected at Latitude = 8.4694080N, Longitude = 4.6023817W, Input voltage = 248 V; Lower limit = 200 V; Upper limit = 240 V; Relay is disconnected
2.	255	Input Voltage = 254.6 V Latitude = 8.4694080 °N Longitude = 4.6023645 °W	OVERVOLTAGE detected at Latitude = 8.4694080N, Longitude = 4.6023817W, Input voltage = 254.6 V;

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		Load Disconnected	Status: Lower limit = 200 V; Upper limit = 240 V; Relay is disconnected
3.	259	Input Voltage = 259 V Latitude = 8.4694080 °N Longitude = 4.6023645 °W	OVERVOLTAGE detected at Latitude = 8.4694080N, Longitude = 4.6023817W, Input voltage = 259 V;
		Load Disconnected	Status: Lower limit = 200 V; Upper limit = 240 V; Relay is disconnected
4.	267	Input Voltage = 266.0 V Latitude = 8.4798164 °N Longitude = 4.6200695 °W	OVERVOLTAGE detected at Latitude = 8.4798164N, Longitude = 4.6200695W, Input voltage = 266.0 V;
		Load Disconnected	Status: Lower limit = 200 V; Upper limit = 240 V; Relay is disconnected
5.	273	Input voltage = 272.7 V Latitude = 8.4798164 °N Longitude = 4.6200695 °W	OVERVOLTAGE detected at Latitude = 8.4798164N, Longitude = 4.6200695W, Input voltage = 272.7 V;
		Load Disconnected	Status: Lower limit = 200 V; Upper limit = 240 V; relay is disconnected

Table 4: Results for Under Voltage Operating Conditions

S/No.	Set Voltage Magnitude (V)	LCD Display	SMS Output
1.	147	Sensed Voltage = 147 V Latitude = 8.4694080 °N Longitude = 4.6023645 °W	UNDERVOLTAGE detected at Latitude = 8.4694080N, Longitude = 4.6023817W, Input voltage = 147 V;
		Load Disconnected	Status: Lower limit = 200 V; Upper limit = 240 V; Relay is disconnected
2.	157	Input voltage = 157 V Latitude = 8.4694080 °N Longitude = 4.6023645 °W	UNDERVOLTAGE detected at Latitude = 8.4694080N, Longitude = 4.6023817W, Input voltage = 157 V;
		Load Disconnected	Status: Lower limit = 200 V; Upper limit = 240 V; Relay is disconnected
3.	162	Input voltage = 162 V Latitude = 8.4694080 °N	UNDERVOLTAGE detected at Latitude = 8.4694080N,

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		Longitude = 4.6023645 °W Load Status: Disconnected	Longitude = 4.6023817W, Input voltage = 162 V; Lower limit = 200 V; Upper limit = 240 V; Relay is disconnected
4.	178	Sensed Voltage = 178 V Latitude = 8.4798164 °N Longitude = 4.6200695 °W Load Status: Disconnected	UNDERVOLTAGE detected at Latitude = 8.4798164N, Longitude = 4.6200695W, Input voltage = 178 V; Lower limit = 200 V; Upper limit = 240 V; Relay is disconnected
5.	189	Sensed Voltage = 189 V Latitude = 8.4798164 °N Longitude = 4.6200695 °W Load Status: Disconnected	UNDERVOLTAGE detected at Latitude = 8.4798164N, Longitude = 4.6200695W, Input voltage = 189 V; Lower limit = 200 V; Upper limit = 240 V; Relay is disconnected

CONCLUSION

Overvoltage and undervoltage conditions have necessitated increase in research in search for the best possible way to prevent these occurrences. This study has led to the development of a smart protection system that can safeguard domestic electrical equipment against overvoltage and undervoltage conditions. A PIC 16F876A microcontroller serves as the main hub of the protection system. With the incorporation of a GSM notification system, faults are easily located. The GSM module, SMS 808, has the capacity to send an SMS and location via longitude and latitude. The irregularities in voltage magnitudes were simulated using a variac. Detection of irregularities tripped the load with notifications sent via SMS as desired. The device designed in this study can be used for load protections for all residential and buildings. For future designs, a mobile application or

other web-based designs can be incorporated to enhance the monitoring of overvoltage and undervoltage conditions.

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