American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-7, Issue-8, pp-16-20
www.ajer.org
Research Paper Open Access

Microcontroller-based under and over voltage protection device

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ABSTRACT : *This work presents the design and simulation of a microcontroller based under and over voltage protection device, which has been achieved using a microcontroller, transistor and other discrete components. A microcontroller PIC16F877A is at the heart of the device which performs the major control of the device. The device is simple and low cost. It can withstand loads up to 2KVA at the required set voltage range for the device, to allow supply to the connected load at the output vary from 200 – 240 Volts. It can be used to protect loads such as refrigerators, radio sets, laptops and VCR/DVD players etc. from undesirable over and under voltage conditions, as well as surges caused due to sudden failure/resumption of mains power supply. This device can be used directly as stand-alone equipment between the mains supply and the load, or it may be inserted between an existing automatic/manual stabilizer and the load.*

Keywords *–Voltage Sensor, Microcontroller, Liquid Crystal Display (LCD), Silicon-Controlled rectifier (SCR),Over-Voltage Protection (OVP)*

Date of Submission: 20-07-2018 Date of acceptance: 04-08-2018

I. INTRODUCTION

The irregularity in voltage is the major issue facing industry and home today and often times, is responsible for damaging valuable electrical equipment [1]. Electrical Power System protection device is required for protection of both user and the system equipment from fault; hence electrical appliances are not allowed to operate without any protective device installed. Power System fault is defined as undesirable condition that occurs in the power system and the undesirable conditions are short circuit, current leakage, ground short, over current, under and over voltage [2].

Technically speaking, an over/under voltage condition is reached when the voltage exceeds/lags the nominal voltage by10% for more than 1 minute. Short duration voltage events can also occur such as transients (both impulsive and oscillatory). Short duration intermittent supply failures can last anywhere from 0.5 cycles up to 1 minute and can be caused by a number of occurrences such as supply system faults, equipment failures, or malfunctions in control equipment. Under-voltage might result into brownout, distortion or permanent damage while overvoltage in the form of spikes and surges could cause distortion, burn-out, meltdown, fire and permanent damages.

II. RELATED WORKS ON OVER AND UNDER VOLTAGE PROTECTION

Most electrical devices can bear voltage up to a certain limits. For example, home fan normal operating voltage is 220V AC. if the voltage input to the fan becomes greater than or less than about 20% of normal operating voltage of the fan, it may burn the fan. This is also applicable to other home appliances therefore, for effective protection of these appliances, a microcontroller based under and over voltage protection device is needed. Early works on the topic involves building of discrete circuits each for under voltage and overvoltage protection.

The early under voltage protection circuit constructed consisted of a single transistor (PNP) and a zenerdiode to sense low voltages. A variable resistor was used to set the threshold voltage at which the supply would be cut off [3]. The moment the input voltage falls below the predetermined reference, the transistor conducts and triggers a relay which cuts off the power supply to the connected load.

The early over voltage protection circuit used the same principle as the under voltage protection circuit explained above with the only difference being that an NPN transistor was used in place of the PNP transistor.

Some other discrete over voltage protection circuit used a thyristor as the major component this method is known as the crowbar method.

In [4], a voltage protection device was constructed which could protect against both under voltage and over voltage. The circuit consisted of a couple of transistor stages integrated together along with an output relay, which was able to perform the function of super safe voltage guard equipment. The circuit was later modified to switch off the load and itself in case of under or over voltage.

In [5], an overvoltage and under voltage protection device was implemented whereby, two OP-Amps (LM741) were used as comparators (each for under voltage and overvoltage) to compare the supply voltage with fixed reference range. Once the supply voltage is outside the prescribed range, above or below, the supply to the connected load is cut off.

The above works provided voltage protection functionality with limitations such as, inability to display the voltage reading on screen (LCD), difficulties in setting preset voltage range using variable resistors, frequent on and off tripping due to voltage fluctuation within the preset voltage range amongst others. To overcome these limitations, this project uses a microcontroller. The microcontroller makes the circuit smart and the voltage range can be easily configured by programming the microcontroller. An LCD is interfaced with the microcontroller to display the status of the load (ON or OFF) and the supply voltage reading.

Over and under Voltage Protection designs include a silicon-controlled rectifier (SCR) across the output that would be quickly turned on if an overvoltage condition is detected [6]. The SCR essentially puts a short circuit across the output to prevent the output voltage from going to a high value and staying there. The SCR circuit is sometimes called a “crowbar” circuit since it acts like taking a large piece of metal, such as a crowbar, and placing it across the power supply output terminals to protect the device under test (DUT) from excessive voltage. Turning on an SCR across the output of a power supply as a response to an overvoltage condition originated as a result of older linear power supply designs. Linear regulators use a series pass transistor. If the series pass transistor fails shorted, all of the unregulated rail voltage inside the power supply appears across the output terminals. This voltage is higher than the maximum rated voltage of the power supply and can easily damage a DUT [7]. When the Over and under Voltage Protection is activated, a signal is sent to turn off the series pass transistor. However, if that transistor failed or is shorted, the turn-off signal will be of no use. In this situation, the only way to protect the DUT is to trigger an SCR across the output to essentially short the output. Of course, the SCR circuit is designed to have a large enough capacity to handle the rail voltage and then the current that will flow when it is tripped. If a series pass transistor fails shorted, the AC input line fuse will sometimes blow when the SCR shorts which will completely disable the power supply protecting the DUT. Switching regulators have multiple power transistors that can fail. However, unlike the linear regulator design, when a switching transistor fails, it does not create a path between the rail voltage and the output terminals [7]. So it is unlikely that a failed switching transistor will cause an OVP. And when an OVP activates for another reason in a switching regulator, all of the switching transistors are set to turn off, preventing any power from flowing to the output. As a result, there is no need for an SCR across the output for added protection against an overvoltage.

III. FORMULATION OF BLOCK DIAGRAM

The block diagram for the smart under and over voltage protection device is shown figure 1. The input supply from the public utility where the device will be energized is supplied directly to the relay contacts in the device which connects the load to the supply when the supply is within 200V – 240V range. The voltage regulators are used to regulate the supply for microcontroller and relay operations. The PIC16F877A microcontroller performs the major functions of decision and control. The input voltage monitor is connected to the microcontroller; this provides a sample of the input supply voltage for comparison with the programmed set values in the microcontroller. The PIC16F877A microcontroller was used in the design in order to reduce the complexity of the design and to ensure an easy interface with a liquid crystal display. The voltage sensor interfaces with the microcontroller to monitor the supply voltage; the value of this voltage varies as the input mains voltage changes. The LCD displays the value of supply voltage at any given time as well as the status of the device. A relay is used to turn on and turn off mains power to the load. The relay gets control signal from microcontroller through a relay driver. The relay driver is a transistor that controls and supplies current through the coil of the relay that connects the mains supply to the load.

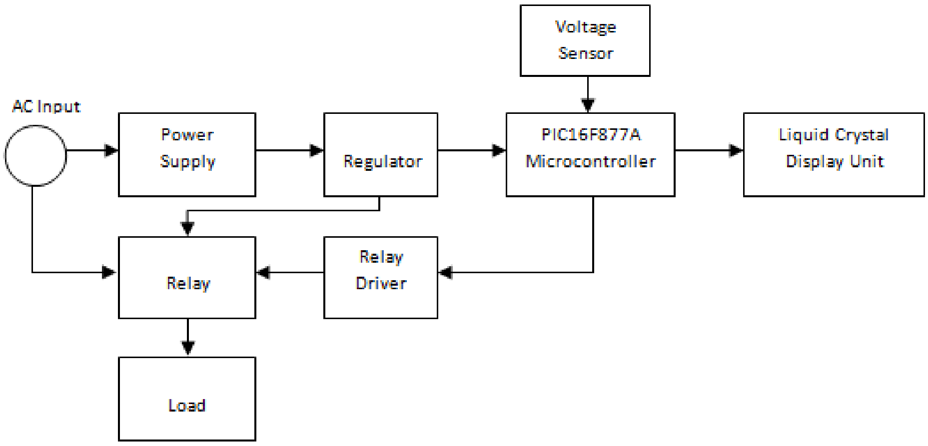

Figure 1: Block Diagram of the Under and Over Voltage Protection Scheme

The complete schematic diagram of the designed circuit is as shown in the figure 2. The input mains supply is stepped down by the transformer TR_1 to 15Vac at input mains voltage of 220Vac. TR_1 with diodes D_1 to D_4 (Bridge Rectifier) provide full wave rectification, which is smoothened by the capacitor C_1. The unregulated dc output is fed to the positive fixed voltage regulators U_1(LM7805) and U_2 (LM7812), which give regulated output voltages of 5V and 12V respectively.

The microcontroller monitors the input voltage through a potentiometer pot1, which sets the input voltage range at which the relay will be energised and activates the liquid-crystal display LCD which displays the input mains voltage level and other information as the case may be. The microcontroller sends signal to the relay driver Q_1 and thus energises the relay RL_1, thereby connecting the mains supply to the load.

To protect the load from switching surges as well as from mains voltage fluctuation around the limits of under or over voltage pre-set points, an "on-time" delay is programmed in the microcontroller. When the mains supply goes out of pre-set (over or under voltage)limits, the relay/load is turned off immediately and it is turned “on" only when AC mains voltage settles within the pre-set limits for a period equal to the on-time delay period.

IV. IMPLEMENTATION AND SIMULATION

The circuit was implemented in Proteus 8 professional software environment. The designed circuit was then simulated with different values of supply voltage. When the supply voltage was within the specified range (200 volts to 240 volts), the relay was closed and the connected load (lamp) got energised, the supply voltage was displayed on the LCD with the information "NORMAL VOLTAGE" also displayed. An LED indicating normal voltage is also powered on as shown in figure 2.

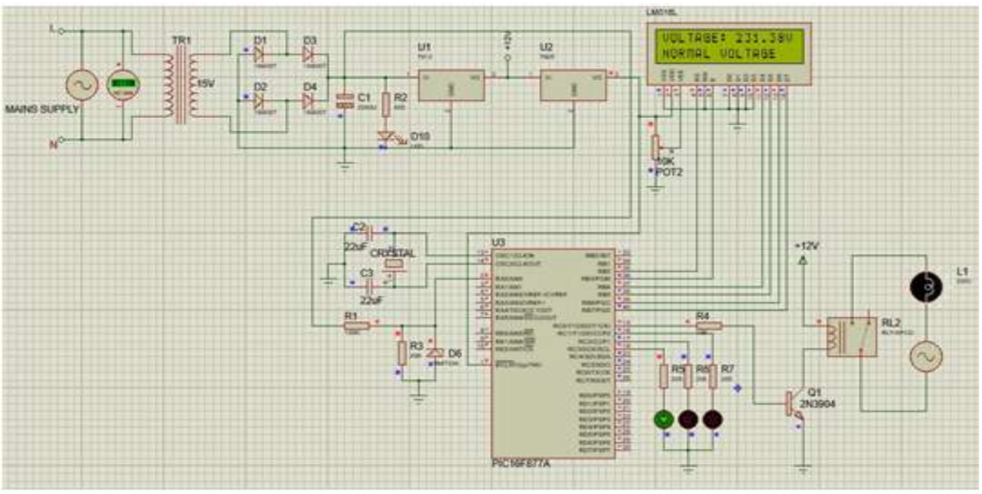

Figure 2: Simulation Result with 232V Supply Voltage (Within Range)

When the supply voltage was increased above the specified range (higher than 240 volts), the relay tripped to the normally open position and the power supply to the connected lamp load was cut-off. More so, the new supply voltage reading and the information "OVER VOLTAGE" were displayed on the LCD. An LED indicating high voltage is also powered on as shown in figure 3.

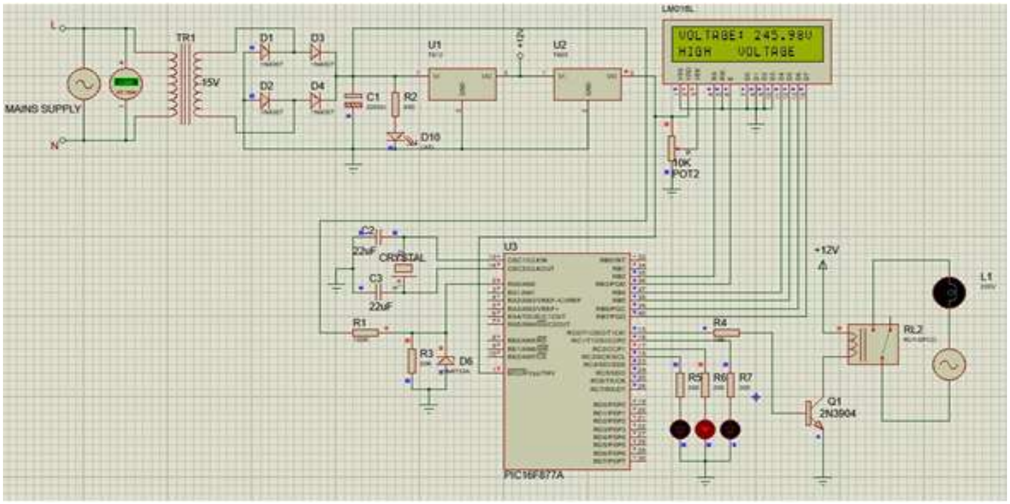

Figure 3: Simulation Result with 246V Supply Voltage (Above Range)

When the supply voltage was decreased below 200 volts, the relay also tripped to the normally open, and the power supply to the connected lamp load was cut off. The new supply voltage reading and the information "UNDER VOLTAGE" were displayed on the LCD. An LED indicating low voltage is also powered on as shown in figure 4.

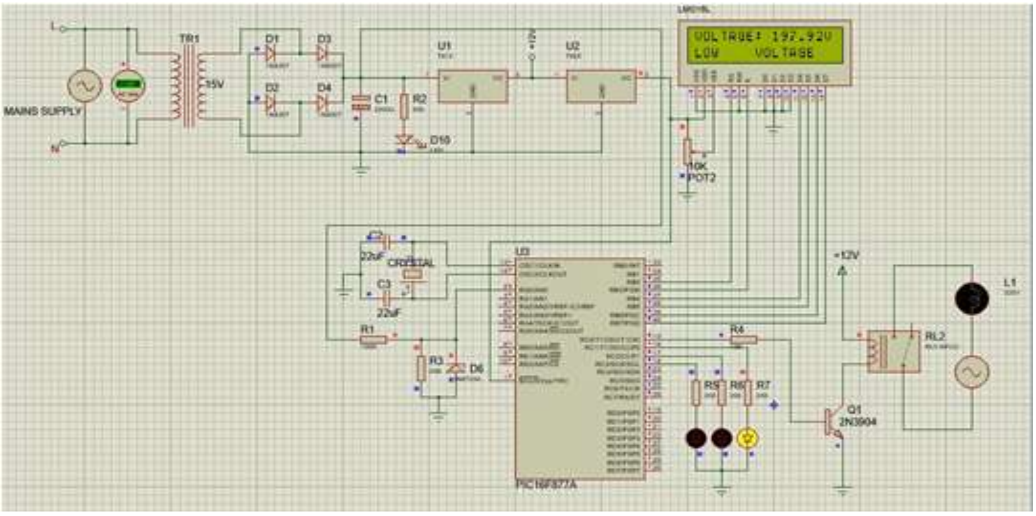

Figure 4: Simulation Result with 198V Supply Voltage (Below Range)

V. CONCLUSION

In this paper, a simple approach to addressing the problem of under and over voltage condition is employed with the aid of a microcontroller. This system can be modified to a higher capacity to provide protection for industrial equipment against under and over voltages. This system would provide more reliable protection for home and office appliances. The simplicity of the design means there is significant reduction in the cost of the device. A key advantage is the scalability of the system which allows any number of appliances to be included without any major changes in the implementation.

REFERENCES

[1]. A. Ponnle and Omojoyegbe M. O,"Development of a Low Cost Microcontroller Based Under and Over VoltageProtection Device", International Journal of Scientific Engineering and Technology, Sept.,2014,Vol. No.3 Issue No.9, pp. 1225-1229.

[2]. R. Bayindir et al. “Fault Detection and Load Protection Using Sensors”, IEEETransactions on Energy Conversion, 2008, Vol. 23, Issue 3, pp. 734–741.

[3]. Charles, P. and Fredrik, J., "Encyclopedia of Electronic Components", Vol.2, Maker Media, Inc., 1005 Gravenstein Highway North, Sebastopol,CA 95472, 2015.

[4]. M. Clive, et al, "Electrical Engineering: Know It All", Newness Press, 30 Corporate Drive, Suite 400, Burlington, MA 01803, USA, 2008.

[5]. B. Robert, and N. Louis “Electronics Devices and Circuit Theory", 7th edition, Prentice Hall, Upper Saddle River, New Jersey, 2004.

[6]. F. P. Charles, "Encyclopedia of Electronic Components", Vol.1, O’Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472, 2013.

[7]. How electronics switches work for noobs: Relays and transistors. Online at https://www.instructables.com/id/How-Electronic-Switches-Work-For-Noobs-Relays-and/[Assessed May, 2017].

Kpochi Paul Kpochi "Microcontroller-based under and over voltage protection device..” American Journal of Engineering Research (AJER), vol. 7, no. 08, 2018, pp. 16-20