International Journal of
Scientific Engineering and Technology Research
www.ijsetr.com

ISSN 2319-8885
Volume.08,
Jan-Dec-2019,
Pages:135-139

Design of AC Automatic Voltage Regulator1000 VA without using Microcontroller

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Abstract: In this paper, 1000VA Automatic Voltage Regulator (AVR) circuit is designed and calculated.The design of 1000 VA automatic voltage regulation is made to solve the problems of fluctuation of current and voltage supplied in the various facilities in our environment. Automatic voltage regulator is an electronic device which takes the over voltage and under voltage and then converts into a constant voltage (220V). This device is very good and active in terms of protecting other electronic devices such as televisions, copiers and refrigerator. When the input voltage is between 170V and 240V, the output voltage can be kept at 220V automatically with the help of automatic voltage regulator circuit. Voltage from AC input is converted into DC voltage by the bridge rectifier. Capacitor is used as filter to produce pure DC voltage. And LED is used because it is used to know whether the electricity is switch on or off.The over and under voltages ranges can be adjusted by using the variable resistors which are used to preset the DC bias voltages for the transistors. The zener diode is the main component which controls the transistor. The transistors are turn on and turn offdepending on the zener voltage Vz. When the bias voltage is greater than the zener diode voltage,the relaysare energized. Thepower transformer is directly connected to the relayin order to get the ac output voltage 220V. Constant output voltage from the auto- transformer is shown on volt meter. AVR is used to prevent electric shock and to regulate the voltage. AVR can be used in homes, many industries and other places which are unstable power supply.

Keywords: Power Supply, Zener, Power Transformer, Variable Resistor, Leds, Transistor.

I. INTRODUCTION

In recent years, the destruction in electrical and electronic equipment caused due to unsteady current has lead many home or family homeless and also an expense. Automatic AC voltage regulator is a wonderful invention of science, which is an electric device designed to regulate a constant voltage in a settable level. The main working of a regulator depends upon the laws of electromechanical physics. The automatic voltage regulator is a protective device that brings out a steady current which varies between 170V-240V. It consists of many active and passive electrical components like adopters, capacitors, diodes and thermostats.

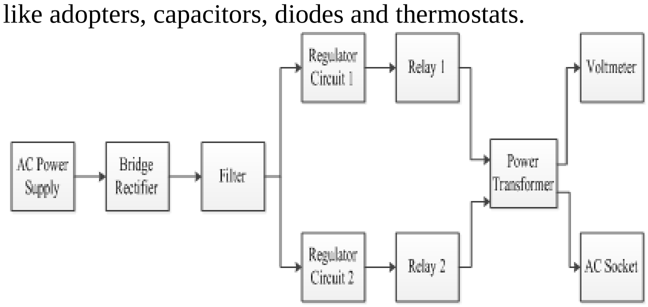

Fig .1: Block diagram of AVR.

There are many functions of an automatic voltage regulator. AVR or automatic voltage regulator can be used with lot of electric appliances for various reasons. AC automatic voltage regulator help in maintaining a desired voltage for the generators within specified limit. Thus AVR is also the important part for our amplifier to work. Automatic voltage regulators have different sizes. There are automatic voltage regulators which are so small that they can be easily placed on a small printed circuit board. They may cover a volume of a small house sometimes [1] and [2]. Thus there is a tremendous variety in the AVR and each has its own specifications. The block diagram of the AVR is shown in Figure 1.

II. SYSTEM MAIN COMPONENTS

The main components of Automatic Voltage Regulator are power supply circuit, variable resistor, zener diode, transistor, relay, auto-Transformer.

A. Power Supply

A power supply circuit consists of ac source, step-down transformer, bridge rectifier, capacitor, resistor and LED and it is shown in Figure.2. AC source can be 170-240 V. A bridge rectifier is a type of full wave rectifier which uses four diodes in a bridge circuit configuration to efficiently convert the alternating current (AC) into Direct Current (DC). The capacitor is used to reduce the ripple factor. The resistor and LED are connected to the circuit to display the power supply circuit is normally operated [6]. The bridge rectifier is made up of four diodes namely D_1, D_2, D_3, D_4, and load resistor R_L. The four diodes are connected in a closed loop (Bridge) configuration to efficiently convert the alternating current (AC) into Direct Current (DC). The input AC signal is applied across two terminal A and B and the output DC signal is obtained across the load resistor RL which is connected between the terminals C and D. The four diodes D_1, D_2, D_3,D_4 are arranged in series with only two diodes allowing electric current during each half cycle. For example, diodes D_1&$D_3$are considered as one pair which allows electric current during the positive half cycle whereas diodes D_2& D_4 are considered as another pair which allows electric current during the negative half cycle of the input AC signal[6].

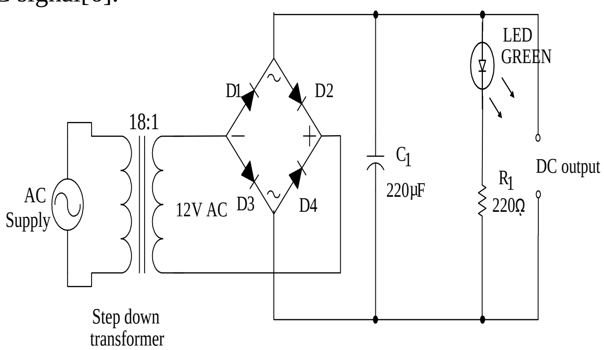

Fig.2: Bridge Rectifier

B. Zener diode

A Zener diode is a type of diode that permits current to flow in the forward direction like a normal diode, but also in the reverse direction if the voltage is larger than the breakdown voltage known as Zener knee voltage or Zener voltage.

Fig.3: Prototype of Zener Diode.

A zener diode is a particular type of diode that, unlike a normal one, allows current to flow not only from its anode to its cathode, but also in the reverse direction, when the zener voltage is reached. A voltage regulator circuit can be designed using a zener diode to maintain a constant DC output voltage across the load in spite of variations in the input voltage or changes in the load current[3]. A zener diode allows current to flow in the forward direction in the same manner as an ideal diode which is shown in Figure.3.

C. Variable Resistor

A variable resistor is a resistor of which the electric resistance value can be adjusted. A variable resistor has 3 terminals and is usually constructed as a resistive track with a terminal at each end and a movable terminal known as the wiper which makes contact with the track. The exact mechanical construction and materials used depends upon the application and environment in which it is going to be used. Variable resistors may often be referred to as potentiometers or rheostats [4].

Fig.4: Variable Resistor Prototype.

D. Relay

Relays are switches that open and close circuits electromechanically or electronically. Relays control one electrical circuit by opening and closing contacts in another circuit. As relay diagrams show, when a relay contact is normally open (NO), there is an open contact when the relay is not energized. When a relay contact is Normally Closed (NC), there is a closed contact when the relay is not energized [5].

Fig.5: 12V DC Relay

E. Autotransformer

An Autotransformer is an electrical transformer with only one winding. In contrast, an ordinary transformer has separate primary and secondary windings which are not electrically connected. The winding has at least three taps where electrical connections are made. In an autotransformer, portions of the same winding act as both the primary and secondary sides of the transformer. The winding has at least three taps where electrical connections are made. Since part of the winding does "double duty", autotransformers have the advantages of often being smaller, lighter and cheaper than typical dual-winding transformer, but the disadvantage of not providing electrical isolation between primary and secondary circuits. Other advantages of autotransformer include lower leakage reactance, lower losses, lower excitation current, and increased VA rating for a given size and mass. It is shown in Figure.6 [5]. Autotransformers are often used to step up or step down voltages in the 110-115-120V range and voltages in the 220-230-240V range- for example, providing 100 or 120V to be used with a 230V supply.

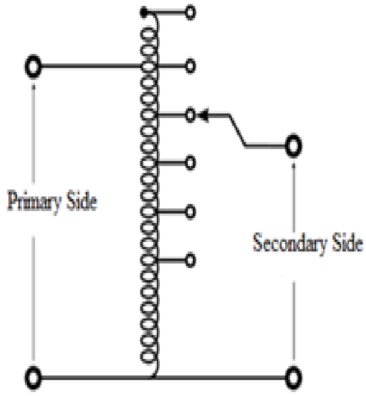

Fig.6: Autotransformer.

F. Transistor

A transistor is a semiconductor device used to amplify or switch electronic signals and electrical power.

Fig .7: NPN Transistor Prototype

The design of a transistor is allows to function as an amplifier or a switch. Transistors are composed of three parts; base, collector and emitter. The base is the gate controller is the larger electrical supply. By sending varying levels of current from the base, the amount of current flow through the gate from the collector may be regulated. The transistor can also be used to turn current on or off in a current as an electrically controlled switch. The NPN transistor is used in the circuit which is shown in Figure.7 [6].

III. OVERALL SYSTEM OPERATION

In this section, the operation of the overall circuit is described. The overall circuit diagram of the system is shown in Figure.8.

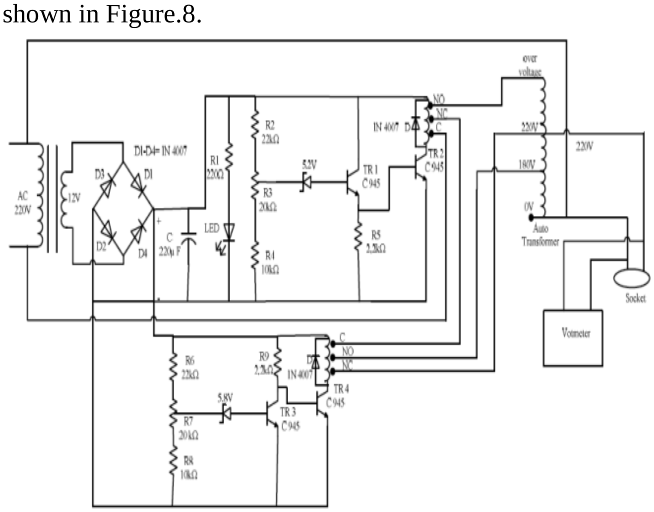

Fig .8: Overall Circuit Diagram of AVR.

In normal voltage, (180V- 220V) current will not flow through the zener diode of over voltage sense circuit, so the relay is off. One cable AC line is connected to common pin of the relay. When the relay is not energized, the common pin is connected to the NC pin. The NC pin is connected to theC pin ofthe relay at low voltage sensor circuit. The voltage is over at the low sense voltage, so the transistor TR3 is on and transistor TR4 is off because the emitter signal is arrived to the TR4 pin base. So, the relay is off. The AC line is connected via common is connected to the 220V of auto-transformer. The output is 220V. At the overvoltage, (240V-250V) the voltage from the transformer secondary coil, over voltage through the zener diode and TR1 is on and TR4 is also on. The relay common pin is connected to the NO pin. NO pin is connected to the overvoltage cable and output of auto-transformer is 220VAC. NC pin of the relay disconnect to the common pin of the second relay. At low voltage (<180V), the voltage from the secondary coil is under at the over sense voltage. So, the transistor TR1 is off and also transistor TR2 is off, relay 1 is off. Common pin of relay 2 is connected to the NC pin of relay 1. The AC line is arrived to the common pin of the relay 2. The incoming voltage is not through zener diode at low voltage sense. TR3 is off and base voltage of TR4 is arrived from the collector of TR3. So, TR4 is on. The common pin is connected to NO pin. The NO pin is connected to the low voltage cable of auto-transformer.

IV. DESIGN CALCULATION

Design consideration at normal, over and under voltage is described in the following equation:

Normal voltage V=220V at V_{z1}= 5.2V

$$\frac{R_3+R_4}{R_2+R_3+R_4}\times V_{dc}=5.2 \quad (1)$$

$$\frac{R_3+10k}{R_3+10k+2.2k}\times 12V=5.2$$

R3= 6.8kΩ

Overvoltage at V=230V, V_{z1}=?

220V at primary → 12V at secondary

$$230V\rightarrow\frac{12\times 230}{220}=12.54V \quad (2)$$

$$V_{peak}=\sqrt{2}\times 12.54V=17.73V \quad (3)$$

$$V_{dc}=17.73-1.4=16.33V \quad 4)$$

To find Vz1, the value of V_{dc} and R_7 are substituted.

$$V_{z1}=\frac{R_3+R_4}{R_2+R_3+R_4}\times V_{dc} \quad (5)$$

$$=\frac{6.8k+10k}{22k+6.8k+10k}\times 16.33V$$

=7.07V

at V =240V, Vz1=?

Substitute in Equation (2),

220V at primary → 12V at secondary

$240V \rightarrow \frac{12\times240}{220} = 13.09V$

Substitute in Equation(3),

$V_{peak} = \sqrt{2} \times 13.09$

$= 18.51V$

Substitute in Equation(4),

$V_{dc} = 18.51 - 1.4$

$= 17.11\ V$

To find Vz1, the value of V_{dc} and R_7 are substituted in Equation (5).

$V_{z1} = \frac{R_3+R_4}{R_2+R_3+R_4} \times V_{dc}$

$= \frac{6.8k+10k}{22k+6.8k+10k} \times 17.11V$

$= 7.4V$

Undervoltage at V = 170V, V_{z1}= ?

Substitute in Equation (2),

220V at primary → 12V at secondary

$170V \rightarrow \frac{12\times170}{220} = 9.27V$

Substitute in Equation (3),

$V_{peak} = \sqrt{2} \times 9.27 = 13.11V$

Substitute in Equation(4),

$V_{dc} = 13.11 - 1.4 = 11.71V$

Substitute in Equation (5),

$V_{z1} = \frac{R_3+R_4}{R_2+R_3+R_4} \times V_{dc}$

$= \frac{6.8k+10k}{22k+6.8k+10k} \times 11.71V$

$= 5.07V$

V= 160V, V_{z1}=?

Substitute in Equation(2),

220V at primary → 12V at secondary

$160V \rightarrow \frac{12\times160}{220} = 8.72V$

$V_{z1} = \frac{R_3+R_4}{R_2+R_3+R_4} \times V_{dc}$

Substitute in Equation (3),

Vpeak= 12.34V

Substitute in Equation (4),

Vdc=10.94V

Vz1=4.73V

Normal V=220V, at V_{z2}= 6.5V, R_7=?

$6.5 = \frac{R_7+10k}{10k+22k+R_7} \times 12$

$0.5416 = \frac{R_7+10k}{32k+R_7}$

$R_7 = 15.9k\Omega$

Overvoltage, V= 230V, V_{z2}=?

Substitute in Equation (2),

220V at primary → 12V at secondary

$230V \rightarrow \frac{12\times230}{220} = 12.54V$

Substitute in Equation (3),

$V_{peak} = 17.73V$

In Equation (4),

$V_{dc} = 16.33V$

$$V_{z2} = \frac{R_7+R_8}{R_6+R_7+R_8} \times V_{dc} \quad (6)$$

$= 9.5V$

V= 240V, V_{z2}= ?

Substitute in Equation (2),

220V at primary → 12V at secondary

$240V \rightarrow \frac{12\times240}{220} = 13.09V$

Substitute in Equation (3),

$V_{peak} = 18.51V$

Substitute inEquation(4),

$V_{dc} = 17.11V$

Substitute in Equation (6),

$V_{z2} = \frac{16.9k+10k}{10k+22k+15.9k} \times 17.11V$

= 9.25V

Under voltage V=170, V_{z2}=?

Substitute in Equation (2),

220V at primary → 12V at secondary

$170V \rightarrow \frac{12\times170}{220} = 9.27V$

Substitute in Equation (3),

V_{peak}= 13.11V

Substitute in Equation (4),

V_{dc} =11.71V

Substitute in Equation (6),

$V_{z2} = \frac{15.9k+10k}{10k+22k+15.9k} \times 11.71V$

= 6.3V

V=160V, V_{z2}=?

Substitute in Equation (2),

220V at primary → 12V at secondary

$160V \rightarrow \frac{12\times160}{220} = 8.72V$

Substitute in Equation (3),

V_{peak}= 12.34V

Substitute in Equation (4),

V_{dc} =10.94V

Substitute in Equation (6),

$V_{z2} = \frac{15.9k+10k}{10k+22k+15.9} \times 10.94V$

= 5.91V

V=150V, V_{z2}=?

Substitute in Equation(2),

220V at primary → 12V at secondary

$150V \rightarrow \frac{12\times150}{220} = 8.18V$

Substitute in Equation (3),

V_{peak}= 11.56V

Substitute in Equation (4),

V_{dc} =10.16V

Substitute in Equation (6),

$V_{z2} = \frac{15.9k+10k}{10k+22k+15.9k} \times 10.16V$

= 5.49V.

V. CONCLUSION

This paper has been successfully presented a design of automatic voltage regulator (1000VA). The automatic voltage regulator system is designed using AC power supply, filter, and regulator circuit, relay and power transformer. This design ensures to regulate 170-240 V AC variation of input to the tolerable range of 220V AC output by adding many taps at a secondary side of auto transformer and relay. THE user can make a new automatic voltage regulator which can regulate input voltage range of 80-350V AC to a stable 220V AC output voltage. Here Output Voltage Regulation is very good. This design makes fast voltage correction speed. This design can produce a stable and steady current and can prevent the life span of electronic, any electrical and electric devices that makes the use of it. This system can be improved with microcontroller, i.e. PIC and Arduino microcontroller can also be used as an adjustable voltage source by adjusting a variable resistor in the voltage sensing circuitry. Microcontroller is also intended to introduce a compact Automatic Voltage Regulator.

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