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Function and importance of automatic voltage regulator (AVR) with a constant output voltage

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Abstract

The design, construction and characterization of an automatic voltage regulator (AVR) with special range is presented. The system is designed to give a constant output voltage over a certain input voltage range between 90 V and 260 V from public power supply and a power capacity of up to 3000 W output. The device is made up of two main parts: the autotransformer part and the switching circuit part. The auto transformer provides the required tappings for the contacts of the relays while the switching circuit selects the appropriate contacts of the relays as the voltage varies between the designed ranges to give a constant output voltage of 220 V ± 5% of that voltage. The output voltage as a result will be in the range of 210 V and 235 V to provide for ± 5% voltage variation.

Keywords: Voltage regulator; Switching circuit; Auto transformer; Voltage fluctuations; Input voltage and output voltage

1. Introduction

In the recent time, electric power supply has become more difficult as a result of incessant power outages, low voltage and voltage fluctuations. The electricity consumers are subjected to these problems and in most cases remained without power supply for days, weeks and even months.

Voltage regulators according to Garzon (1995), are unique devices connected to an electrical system to provide protection and control of the circuit by initiating or halting the flow of the voltage.
Every electrical device on the factory floor and in our homes requires power supply. Any equipment that has electronic circuits in it must have a direct circuit supply voltage available, Ekemezie (2003). However, power supply has become unpredictable. The unstable power supply thus creates a wide spectrum of effects ranging from minor domestic inconveniences to serious economic problems.

The need for an automatic voltage regulator (A V R) in the system is one of the ways of preventing such effects as fire out breaks, blast of a blown appliances and damages to our electronic appliances, (Omorondion, 2004; Chukwu, 2003; and Okonkwo, 2006).

In general, voltage regulators are components that maintain a consistent voltage output. They are often responsible for maintaining the required voltage within the range that the electronic component can safely accept. There is the need to replace such voltage regulators the moment they stop working in order to avoid further damage.

The capacitor in an AVR mainly stores electrical energy by electrostatic stress in the dielectric, Theraja (2000). However, Floyd (1995) argued on the need to select the correct type of capacitor in all applications.

It has also been noted by Whitaker (1996), that an AVR requires a steady voltage (DC supply of about 15 V) for its operation. During the process, it is stepped down, then rectified. This is followed by the smoothening of line voltage from the power company unit before regulating it with a voltage drop when the load is added to any ripple that is left over by the filter capacitors.

The transformer according to Rizzoni (1996) is designed to couple two alternating current circuits magnetically rather than through any direct conductive connection and permits a transformation of the voltage and current between one circuit and the other. It therefore transfers electric power from one circuit to another without a frequency change.

2. Objective of the studies

The idea of fabricating / building a device capable of monitoring the output voltage with a reference input voltage with a view to reducing the difference to give a constant desired output has led to the present design of the AVR. When ever there exists a difference between the input and the output voltage either as a result of low voltage for public power supply or fluctuations, the regulator ensures that a constant power supply based on the design is maintained provided the drop is not below the designed reference voltage level.

An AVR is meant to increase or decrease exciter current for a more linear voltage and frequency. It also corrects over voltages and is sometimes referred to as a linear conditioner. It is also meant to perform the activity of managing or maintaining a range of values.

The need to improve on the available design so as to provide a suitable solution to the problem of rampant fluctuating of voltage using relay and autotransformer as switching device between the input voltage ranges of 90 V to 260 V to give a constant output voltage of 220 V has become imperative.

In Nigeria, the power supply is normally in the range of 110 V – 220 V. However, this range can be stepped down from 110 V to 90 V and sometimes more than 220 V, Okonkwo (2005).

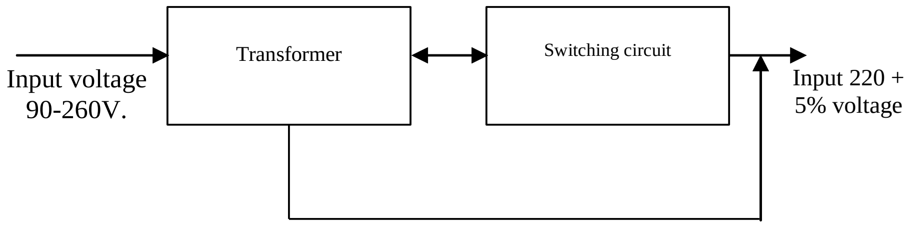

Fig. 1. Block diagram of the Automatic Voltage Regulator (AVR).

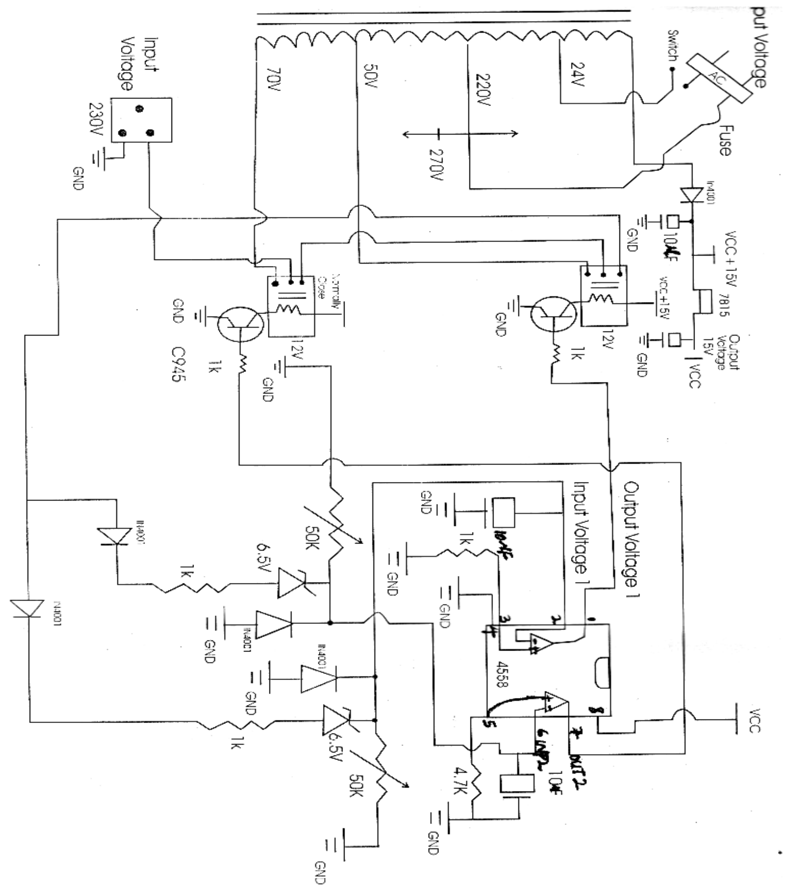

Fig. 2. The complete circuit design of AVR.

3. Circuit design and analysis

The block diagram of the system is shown in fig. 1 with the transformer and switching circuit. The complete circuit design of the automatic voltage regulator is shown in fig.2. The circuit analysis of fig. 2 shows that the input source is the alternating current (ac). When switching ON the transformer senses a signal, it then triggers ON when the voltage supply is below or above 220V. It in turn sends a signal to the switching circuit which contains the main sensor part waiting for a response either to continue function or not. The integrated circuit (IC 4558) used as window comparator in the circuit serves to compare two voltage between 90V and 260 V. As it receives the signal from the transformer, it compares whether the supplied voltage is low or high. The output (pot 7) is sent to the relay number 2 through the same process to still obtain an output of 220V.

Ports 4 and 5 are grounded while port 8 is connected to the Vcc input. Port 2 is connected to a capacitor for filtration and then to diode and zener diode for constant voltage. The variable resistor is used for the variation of the voltage. The first diode serves as a full rectifier which converts the AC to DC.

The rectifier rectifies the AC output from the transformer. The +15V output from the transformer was connected to the rectifier input. The DC load voltage V_{DC} from the rectifier according to Garzon (1995) shows that

$$V_{DC} = 2Vp / 3.142 \quad (1)$$

where V_p is the peak secondary voltage. He also shows that

$$V_p = 1.44 \text{ x } V \quad (2)$$

hence $V_p = 15.0 / 0.707 = 21.22$ V
However, if this value is substituted in eqtn (1) for V_p, then V_{DC} gives 13.51V. This value was gotten after rectification and this was still up to the value of 15.0 V required to power the IC 4558.

In the AVR, the required minimum cut off voltage is set to be 90 V and the maximum cut off voltage is set at 260V. The voltage was however, kept constant using a 7815 voltage regulator for the positive and negative supply. The capacitor across the output improves the transient response and keeps the impedance low at high frequencies. The 7815 voltage regulator keeps a maximum regulator of 15 V when the transformer input voltage rises to a high input value of about 300 V. The input voltage supplied to IC 4558 can also be determined and the sum of low input and high input supplies taken.

For the low input supply voltage,

$$220 \text{ V} = 8.5 \text{ V} \quad (3)$$

$$\text{and} \quad 90 \text{ V} = V_1 \quad (4)$$

By solving eqtns (3) and (4), the value of V_1 obtained becomes 3.50 V.
Also for the high input supply voltage,

$$220 \text{ V} = 8.5 \text{ V} \quad (5)$$

$$\text{and} \quad 260 \text{ V} = V_2 \quad (6)$$

Again by solving eqtns (5) and (6), the value of V_2 obtained becomes 10.05 V.

$$\text{Thus } V_{DC} = V_1 + V_2 \quad (7)$$

The value again for V_{DC} is 13.55 V which equals the calculated rectifier voltage value. The required power in the circuit is a steady DC supply. The 10μF capacitor serves to smoothen out the waveform from the rectifier. The capacitor placed across the pulsating output holds the voltage steady by charging and discharging with a ramp waveform.

A 10μF capacitor also serves to give a fairly constant DC supply to the regulator. As a result, it charges up as the input voltage rises and then discharges as the input voltage falls. The 7815 voltage regulator keeps a maximum regulator voltage of 15 V when the transformer input voltage rises to a high input of about 300V.

The IEEE News (2004) outlined that the voltage requirement increases due to large power requirement. As a result, the switching speed in lower power supplies are as high as several megahertz (MHz) and decreases to several kilohertz (KHz) for high power traction.

4. Testing and results

Tests were carried out on the systems output to confirm that the desired result was obtained. For the power supply unit, the test was carried out to confirm the out voltage power supply transformer from the voltage regulator 7815. This enables the variation of the input voltage to find the input / output relationship when there is fluctuation in the supply voltage. The continuity test was carried out on both the resistors and diodes in the system. The capacitor was also tested for the leakage using the digital multimeter which also measures the input and the output voltages. The difference between this and the existing voltages is that while the existing ones have a range of between 120 V-250 V, the present system has a range between 90 V-260V. This is so because when the voltage of the existing one falls below 100 V, most of the system would usually trip off or give an output voltage less than 220 V, hence the systems under operation cannot work. However in this one, when the input voltage falls below 120 V, the output still remains at 220 V and the system still functions effectively. The results obtained during the test were comparable to Chukwu (2003), Okonkwo (2005) and Okonkwo (2006). The results are shown in Table 1.

Table 1
Input and output voltage test results

Input voltage (v)	*90*	*100*	*110*	*200*	*220*	*240*	*260*
Output voltage (v)	210	215	220	220	225	230	230

The last test was carried out on the relay to check whether it makes or breaks at the required time and also whether the available voltage was enough to trigger the AVR ON. The test results of input and output voltages show that as the input voltage increases, the output voltage also increases. It is also noted that despite the voltage input of between 90 V – 260 V, the output voltage remains constant at 220 ± 5%. Thus, the AVR is always in good condition if it is of the same output voltage and frequency as the appliances that are connected to it.

Conclusions

The automatic voltage regulator (AVR) special voltage range of 90 V – 260 V has been presented. The system was found to be highly functional and different from the existing ones as it ranges from 90 V-260 V compared with the existing ones which have ranges from 120 V – 250 V. This AVR is such that when the voltage falls below 100 V, it gives an output above 200 V hence the system still functions effectively. The system has been seen as a readily alternative substitute to the existing automatic voltage regulators.

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