International Journal of Engineering Research
Volume No.5, Issue No.1, pp : 71-74
ISSN:2319-6890)(online),2347-5013(print)
1 Jan. 2016

Enhanced Power Supply Using Automatic Voltage Regulator Based Three Phase Voltage Selector System

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Abstract: Three phase voltage selector systems do not have voltage regulators incorporated in them and are usually expensive. The 500W AVR-based three phase voltage selector system is a quality, low cost system which automatically regulates the selected phase voltage, while allowing constant power supply to be delivered to the load. The system is designed and developed using components such as auto transformers which does the voltage regulation and high power relays which carry out the function of switching between phases. The system gives an output voltage of 200V to 240V from an input voltage range of 160V to 270V, hence providing uninterrupted power supply to equipment.
Keywords: Selector, Voltage, Uninterrupted, Power, Supply

1 INTRODUCTION

Most electric power supply system consists of network of inductors and associated equipment for energy transfer from the generating stations to the end users. The supply system is divided into two (2) distinct parts namely, transmission and distribution. The distribution system can be further divided into three (3) namely;

- The primary (33kv) distribution
- The secondary (11kv) distribution
- The tertiary (415 L-L, 240 L-N) distribution

The bulk of consumers are however supplied through the tertiary distribution system because the load is much smaller [1] [4]. Due to the crippled electricity management which has led to low quality power, where the available cannot be distributed effectively, either due to overload of transformers or feeder pillars with burnt out fuse holders. The above mentioned cases affect the outputs of the step-down transformer (11/0.415kv) resulting in either over voltage or under voltage that can damage electrical equipment such as radio set, television, mixers, refrigerators, etc. Since these equipment's are designed to operate effectively on 220V-240V ac supply or in cases where there is power outage in any of the phases, this will cause consumers with single phase to experience blackout.

Ordinarily, a consumer feeds from a single phase connection except in the industries where uninterrupted power supply is required for proper operation of equipment, thereby making the availability of the three phases a necessity. The changing from one phase to the other is usually done manually by the consumers in the event of power failure in any of the phases.

This paper presents an AVR – based three phase voltage selector system designed to serve the purpose of automatically selecting the phases with power supply, if there is power outage in the current phase in use, so as to ease the stress of manually changing from one phase to another as well as providing uninterrupted power supply to equipment. The usefulness of this designed system will offer:

- Constant power supply to big hospitals where power outage can cause greatdamage to equipment and medical operations/activities.
- Constant power supply to single phase board operated elevators to ensure smooth operation, as well as to companies and banks to enhance fast system operation.

In order for the electrical gadget to efficiently perform their expected functions, a proper and constant voltage level must be maintained. Hence, the objectives of the design and construction of an AVR – based three phase voltage selector system includes;

- To design and construct an electrical system that will provide appropriate voltages to the load, when different voltages enter the circuit.
- To design and construct an electrical system that will automatically select a particular phase and regulate the voltage supplied at a proper level and cuts off the supply in the event of overload of the system.

The origin of large scale electrical power distribution dates back to August 26, 1895 when water flowing over Niagara Falls were diverted through a pair of high speed turbines that were coupled to two 5000hp generators [2]. The bulk of electricity that was produced was used locally for the manufacture of aluminum and carborundum. The rest were raised to a certain voltage level and were transmitted 20miles by wire and used for lighting and street cars in the great city of Buffalo [2]. In the 1898s, the German invention of machine that rotated glass spheres so that they could be more easily rubbed made it much easier to generate the electric condition [5].

2 MATERIALS AND METHOD

This paper deals with design and construction of an AVR- based three (3) phase voltage selector system. Various block diagrams consisting of electronic components and circuits such as bridge rectifier, resistors, relays etc. and their appropriate selections as relevance for optional functioning of the circuit are shown also.

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2.1 Block Diagram Representation

The block diagram below shows the summary of the major connections between the major stages of the equipment.

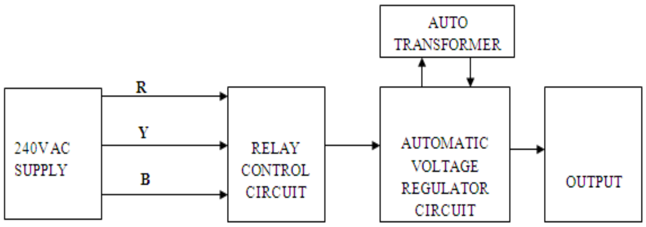

Figure 1: Block Diagram Representation

2.2 RELAY CONTROL CIRCUIT

This circuit consists of the following;

i. Step down transformer (240 – 12V)
ii. Bridge rectifier
iii. Filter capacitor
iv. Relays

The step down transformer converts the 240V AC supply from line 2 (yellow phase) and line 3 (blue phase) to 12V AC, which is then rectified by the bridge rectifier to 12V DC. The filter capacitor reduces the ripples which are contained in the DC output of the rectifier, to produce the required 12V DC supply to activate the 12V 30A relays.

Figure 2 is the 12V 30A relay control circuit. This circuit contains two 12V 30A relays which are used to select the phase that will go to the input of the automatic voltage regulator (AVR).

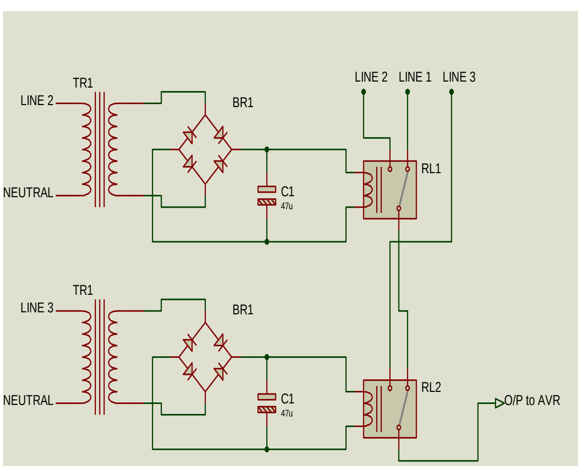

Figure 2: Relay Control Circuit

Line 1 (red phase) is connected to the normally close (NC) terminal of relay (RL_1), while line 2 (yellow phase) is connected to normally open (NO) of relay RL_1. The common of RL1 is connected to the normally close (NC) of relay RL_2. Line 3 (blue phase) is connected to the normally open (NO) of relay RL_2, while the common of relay RL_2 serves as the output of the relay control circuit which is connected to the input of the AVR.

When there is power in the three phases, both relays are activated and line 3 (blue phase) supplies the voltage to the AVR based on priority. If there is power in only line 1 (red phase), none of the relays will be activated and the AVR will be fed by line 1. If there is power in line 2 (yellow phase), only relay RL1 will be activated and the AVR will be fed by line 2. If there is power in line 3 (blue phase), only relay RL2 will be activated and the AVR will be fed by line 3.

2.3 AUTO TRANSFORMER

The auto transformer was designed based on the following specifications;

Power rating = 500Watts

Input voltage = 160V – 270V

Output voltage = 220V ± 5%

Frequency = 50Hz

With a standard supply voltage of 240V

$$I = \frac{P}{V\cos\theta} = \frac{500}{240\ x\ 0.8} = 2.60A \quad (1)$$

At minimum supply voltage of 160V

$$I = \frac{P}{V\cos\theta} = \frac{500}{160\ x\ 0.8} = 3.91A \quad (2)$$

Therefore, the coil was chosen to carry the maximum current of 4A. To calculate for the number of turns per volt of the coil, equation 3 is applied.

$$N = \frac{10^8}{4.44 \times f \times \emptyset \times A} \quad (3)$$

Where

F = frequency of supply voltage

N = number of turns per volts

$\emptyset$ = Flux density

A = cross sectional area of transformer core (square inch)

60,000 lines per square inch was selected for flux density. The cross sectional area of a conventional 500W transformer is calculated using the formula;

$$A = \frac{\sqrt{powerrated}}{5.58} \quad (4)$$

$$A = \frac{\sqrt{500}}{5.58} = 4\ sqinch$$

$$N = \frac{10^8}{4.44 \times 50 \times 60{,}000 \times 4} = 1.88$$

Thus, the number of turns with respect to tap TR1 is;

Tap TR 1 – TR 2 = 13 X 1.88 = 24.44 turns

Tap TR 1 – TR 3 = 160 X 1.88 = 300.8 turns

Tap TR 1 – TR 4 = 200 X 1.88 = 376 turns

Tap TR 1 – TR 5 = 240 X 1.88 = 451.2 turns

Tap TR 1 – TR 6 = 270 X 1.88 = 507.6 turns

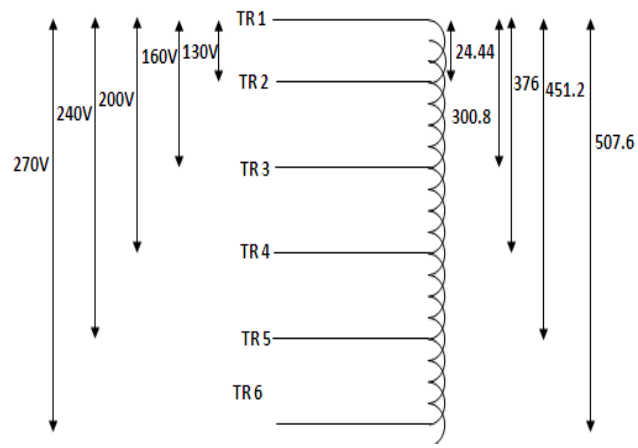

Figure 3: Auto Transformer Winding with Taps

2.4 Automatic Voltage Regulator Circuit

The automatic voltage regulator circuit primarily does the function of voltage selection between 160V to 270V AC. It consists of four (4) relays of 12V/7Amps each. The first three (3) relays are used to control the input voltage, while the fourth (4th) relay is used to control the delay of the output. Each of these relays is controlled by an NPN transistor. When each transistor receives a positive signal from the ICs at their respective bases, the collector collects the signal and sends it to the negative terminals of the four relays. The emitter of each of the four transistors is connected to the ground.

Each of these relays is connected to the transistor through a 33Ω resistor to ensure that the right current is flowing to each of the relays and also the 6V zener diode and the 470Ω resistor, prevents damage to the IC components by ensuring that the voltage flowing into the ICs is not more than 6V.

TR No 1 of the auto transformer is connected to the ground of the circuit, while TR No 2 of the transformer supplies 13V to the AVR section which is rectified and filtered to supply the positive voltage to the relays as well as for the ICs through the 6V zener diode. The three (3) 5KΩ variable resistors are used to vary the voltage of the relays as of when to switch in case of low, medium and high voltage.
When an input voltage of less than 160V is taken from any of the phases, none of the relays will be activated, thereby producing no output. This is a case of under-voltage condition.
If the voltage from the phases is within the range of 160V to 270V, all the relays will be activated and relay three (RL 3) will receive the voltage from the TR No 5 terminal of the auto transformer which is around 240V and sends it to the output through relay four (RL 4).

If an over voltage condition is met, i.e. a voltage above 270V is encounteredthen the relays will also be activated thereby producingno output.

2.5 OPERATION OF THE SYSTEM

The operation of the system can be summarized in the flowchart shown in figure 4.

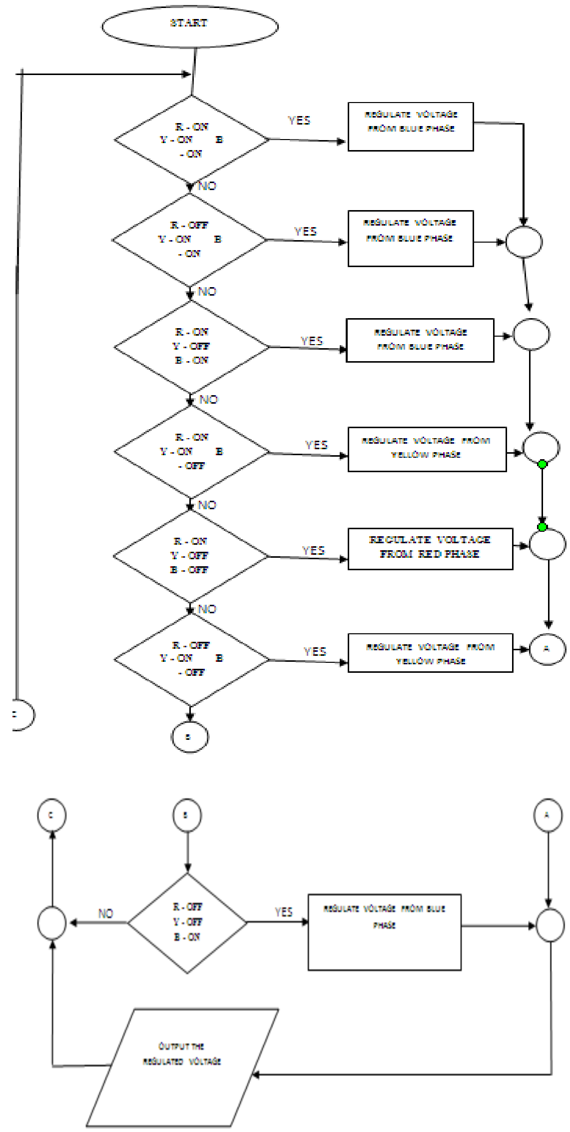

Figure 4: System operation Flowchart

3 RESULTS AND DISCUSSION

The aim of this test was to determine the functionality of the design and how the overall performance of the design was achieved. The circuit was tested and it performed the required function of which it was designed for.

First, the components were assembled on the bread board to carry out temporary test of the circuit to check whether the components were actually working before they were finally transferred to the printed circuit board (PCB) and then soldered.

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After the soldering of the components, the circuit was powered and tested using a digital multi meter and a variac which provides ac supply that can be varied between 0volts to 300volts.

The relay trip points for the auto-cut and sensor circuits were set by adjusting their respective variable resistors using the variac to set the desire input voltage. The digital multi meter was used to determine the voltage level at certain points in the circuit.

3.1 Testing of the Control Circuit

Using a multi meter, a test was carried out between the input terminals of the relay to ensure that it is 12V, needed to energize the relay to function. Then, a continuity test was carried out between the output of the phases that goes to the AVR and each phase.

3.2 Testing of the AVR

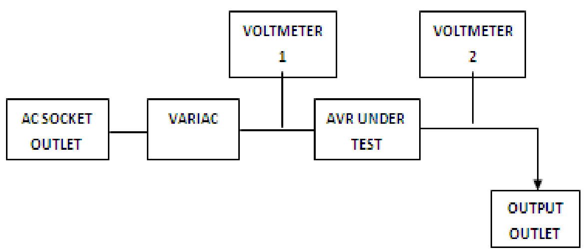

Figure 6: Block Diagram of Testing Equipment

The input of the variac device was connected to the supply from the ac main (220V), the output of the variac device was fed into the automatic voltage regulator (AVR) and severalreadings were obtained using the digital multi meter for different voltage levels.

3.2.1 Test Procedures

The following steps were strictly adhered to, in the testing of the automatic voltage regulator:

1. A 15A plug of the input power cable of the automatic voltage regulator was connected to the AC socket.
2. The output of the variac was connected to the input of the AVR.
3. Voltmeter 1 was connected to the input of the AVR to measure different input voltage applied to the AVR.
4. Voltmeter 2 was connected to the output of the AVR to measure the corresponding output voltage as the input voltage is varied.
5. The variac was used to vary the voltage fed to the AVR, which were confirmed by the readings of the voltmeter.
6. For each varied input voltage, the corresponding output voltage was read by voltmeter 2.

Table 1: Values of Input Voltages fed from Variac to the Designed AVR and the Corresponding Output Voltages.

Input Voltage (V)	Output Voltage
150	No output
160	200
170	206
180	225
190	236
200	239
210	235
220	240
230	239
240	229
250	238
260	227
270	237
280	No output

3.3 DISCUSSION

From the results obtained during the testing of the AVR system, it was observed that the output of the system is within the range of 200V to 240V as expected as shown in table 1. Also, from table 1, voltages below 160V and above 270V did not produce any output, and this is also expected. The AVR-based three phase voltage selector system is therefore, performing its required function as observed from the tests carried out.

4 CONCLUSION AND RECOMMENDATION

The switching process involved in this work is the use of high quality relays which carry out the function of switching between phases when there is a voltage drop in a particular phase and the auto-cut circuit in the AVR section, renders protection from both over voltage and under voltage surge, thereby ensuring safety to appliances.

For modification on this work, it is recommended that a comparator circuit in the phase selector circuit be incorporated into this existing work to compare the voltage level sensor output with a fixed reference voltage.

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