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Design and Construction of an Automatic Three-Phase Change Over Voltage Stabilizer

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Abstract

This paper presents the design and construction of an automatic three-phase change over voltage regulator capable of maintaining constant output voltage of 220Vwith current range of 5-12A. Its output power rating is about 3200W. The input is capable of searching and selecting a live phase from the mains voltage source of readily available power transmission line. The device can also amplify input voltage as low as 50V a.c to a constant 220V a.c. Furthermore, if no power is sensed, from the three live phases, that is if all the phases are in OFF STATE, the device auto-connect to a power generating plant.

Key words: Power Supply; stabilizer; phase Change-over Switch.

1.0 Introduction

Voltage instability in the main supply line is a common phenomenon. While electric gadgets like heaters, fans, bulbs remain unaffected by it, more sensitive device like air conditioners, television, music systems, video players, get easily damage by such fluctuation [1]. Most automatic stabilizer used to correct such breakdown are based on a simple Zener diode sensor. However, the breakdown voltage of such diodes vary with temperature. Therefore the accuracy of control is rather unstable and unreliable [2]. Furthermore, such voltage stabilizers does not automatically detect lives phase from the three-phase main voltage from our local power supply authority and switch over to the available lives line. It is also difficult for any voltage regulating system to trigger input voltage as low as 50V a.c from the main supply to constant output voltage of 220V a.c. The most available ones trigger low input voltage of 100V a.c to a constant output voltage of 220 – 240V a.c. The problems of low voltage supply in our homes, schools, hospitals, multinational companies and our country in general is not new to us. The negative effect of these to our businesses and the national income of our country Nigeria are enormous. The population of Nigeria is increasing at a geometric rate; and so, power consumption in our modern days is also on the increase.

This paper presents the design and construction of an automatic three-phase change over voltage stabilizer capable of supplying a constant output voltage of 220V a.c and current range of 5-12amperes with power rating of 3.2kW with a very low input impendence. More importantly, the input of the stabilizer is connected to the main voltage supply containing three lives phases of our local power supply authority. The device is capable of switching automatically to the next available lives phase without the consumer awareness. The input of the stabilizer is auto-connected to a power generating plant when all the phases are in OFF state. This is done by arrays relays interconnected, operational amplifier (ICS), transistors, capacitors, diodes and resistors which makeup the control circuit and give the final output gain.

2.0 Design Analysis

The three-phase voltage stabilization works variable with three-phase; that is, the system connected to the three-phase supply, automatically select any available phases even when any of the phase or phases are in OFF state. See Fig. 1:

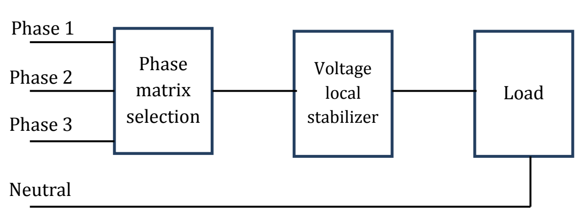

Figure 1: Three – Phase Matrix Change Over

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The phase matrix changeover is also designed to connect to a generating plant when all the phases are in OFF state and automatically return to the main supply as the phases or any of the phase is emerged. See Fig. 2.

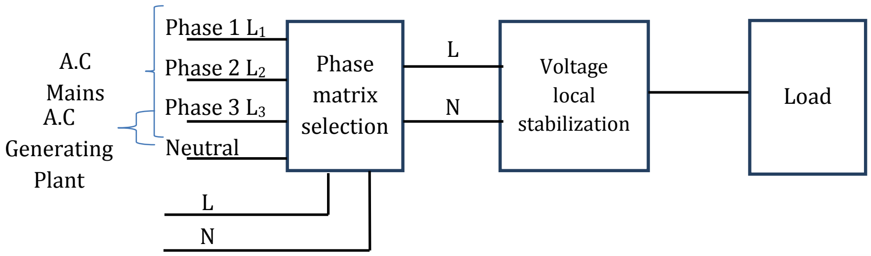

Figure 2: Three – Phase Matrix Change Over with extra phase connecting A.C generator

Considering the switching matrix modules, let phase 1 be ascribed A such that $\dot{A}$ denotes presence of voltage on the first phase, $\overset{*}{A}$ denotes absence of voltage. Also let Phase 2 be ascribed B such that $\dot{B}$ represents the presence of voltage on the second phase, $\overset{*}{B}$ represents absence of voltage, and similarly for phase 3. Then, the following switching matrix modules can be obtained.

1. $\dot{A}\dot{B}\dot{C} = A$
2. $\dot{A}\overset{*}{B}\overset{*}{C} = A$
3. $\dot{A}\dot{B}\overset{*}{C} = A$
4. $\dot{A}\overset{*}{B}\overset{*}{C} = A$
5. $\overset{*}{A}\dot{B}\dot{C} = B$
6. $\overset{*}{A}\dot{B}\overset{*}{C} = B$
7. $\overset{*}{A}\overset{*}{B}\dot{C} = C$
8. $\overset{*}{A}B\overset{*}{C} = X$

From the above modules, we have eight selected modes. However, the matrix module of number one covers that of three and four, and so, we have a total number of six options, that is 3!. Therefore, we need a six control switching system to control the three-phase consecutively. The phase matrix selection or switching system include an array of relays interconnected. See Fig. 3.

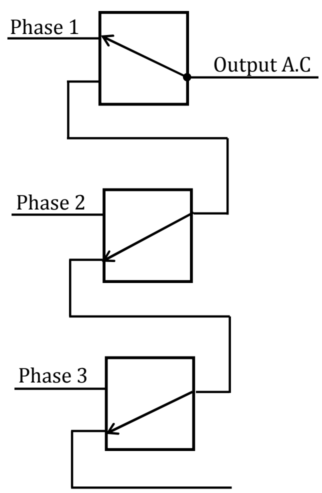

Figure 3: Relays Modules

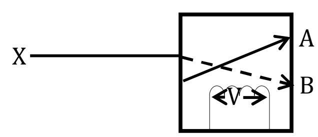

Figure 4: Relays Structure

The relay used (see Fig. 4) is 12V, 10A. Point X is the input source of the relay, XA is when the relay is energized and XB is when it is not activated. The six control switching system is connected to the three phase P_1, P_2 and P_3 as shown below.

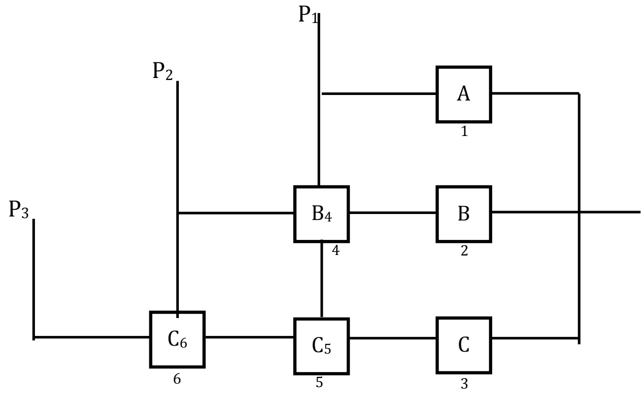

Figure 5: Six Control Relays Interconnectivity

When P_1, P_2 and P_3 are in ON state, A=ON, B_4=ON, B=OFF, C_5=ON and C=OFF. When P_1 is in OFF state, $P_2=P_3$=ON, B_4=OFF, B=ON, C_6=OFF, C_5=ON and C=OFF. When $P_1=P_2$=OFF, P_3=ON, C_6=ON, C_5=OFF and C=ON. If $P_1=P_2=P_3$=OFF, then A=B=C=OFF.

The relay input impedance is 300Ω. If the relays uses 12V (from manufacturer), we can obtain the current through Ohm's law [7] as $V=IR \rightarrow I = {}^{12}/_{300} = 0.04A$. This means that a minimum of 0.04A is required to activate the relay thereby having a drop voltage of 12V.

An AC line of 220V is needed to derive the relay directly. Hence a resistance drop of R value is approximately selected in series with the relay internal resistance. See Fig. 6;

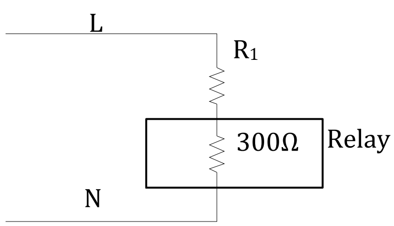

Figure 6: A relay connected to 220V a.c line

The current across the relay is 0.04A and the total voltage drop is 220V. Therefore, the total resistance R_T becomes $\frac{220}{0.04}$=5500Ω. Since $R_T=R_1$ + 300Ω, R_1 becomes 5500 – 300 = 5200Ω. Therefore R_1 = 5kW (approximate).

Furthermore, the relay cannot hold the A.C because of noise factor of 50Hz[2, 5]. Because of ripple rejection the A.C is therefore rectified as shown in Fig. 7.

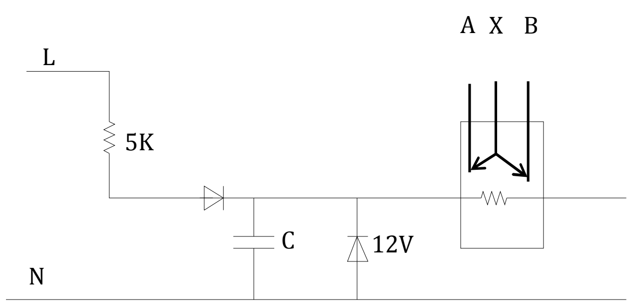

Figure 7: Rectifier Circuit Connected to a 12 V relay

To obtain the value of the capacitor which make up the filtering section, we use A.C input impedance

$$X_c = 5000 = \frac{1}{2\pi fc} \quad (4)$$

where $f = 50Hz$ [4] *and*

$$C = \frac{1}{5000 \, x \, 2\pi \, x \, 50} = 63\mu F \approx 100\mu F \quad (5)$$

The input voltage source of the relay X is looped to point A, when there is a voltage drop across L and N (220V a.c source).

The circuit is designed in a way that line 1 or part A as a priority, super-impose the other two lines (L_2 and L_3) and L_2 over-impose L_3. When phase 1 or line 1 fails, the two lines L_2 and L_3 automatically select an output based on their priority arrangement or choice of programming.

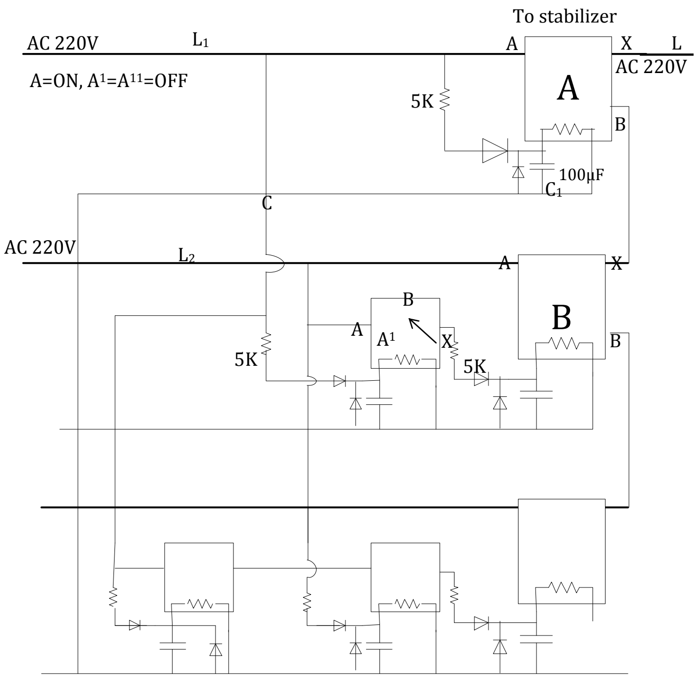

Fig. 8: The Three-Phase Automatic Voltage Change Over.

$\dot{A}\,\dot{B}\,\dot{C} = A = 220V$ a.c

If all the phases have a potential drop of 220V a.c, the input of the device is designed in such a way that port A is a priority to B and C and B is priority to C.

$$\overset{*}{A}\,\dot{B}\,\dot{C} = B = 220V \text{ a.c}$$
$$\overset{*}{A}\overset{*}{B}\,\dot{C} = C = 220V \text{ a.c}$$
$$A\,\overset{*}{B}\,\dot{C} = A = 220V \text{ a.c}$$
$$\overset{*}{A}\,\dot{B}\,\overset{*}{C} = B = 220V \text{ a.c}$$
$$\overset{*}{A}\,\overset{*}{B}\,\overset{*}{C} = x = x\ x\ x$$

Power failure at the three phases auto connect the load to a power generating plant see Fig. 9.

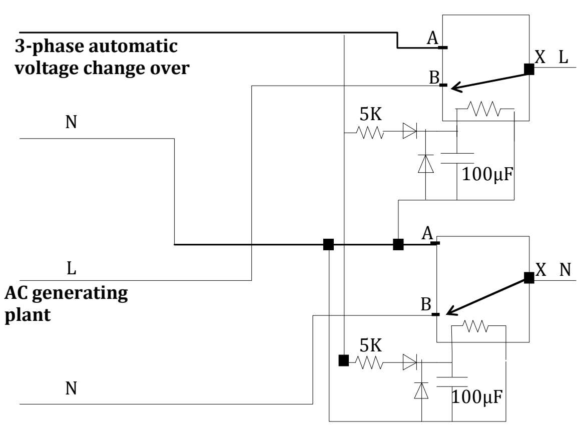

Figure 9: Change over to standby AC plant

The circuit in Fig. 9 shows a three phase change over to a power generating plant.

The final output power in the phase matrix selection is fed into the input of the voltage stabilization

Voltage stabilization helps to maintain a stable voltage output of 220V a.c. Its regulation effect begins from 50V a.c, 50Hzto 260V a.c and maintain a regulated volt of 220V a.c [3]. This composes of a voltage level analyzer using reference voltage comparator, a wined auto-transformer and a switch relay matrix for voltage stabilization. The classical transformer theory is

$E = 4.44 \times 10^{-8} FN\phi_{max}$ [5] - - - - - - (6)

Where E is the peak value of sine wave voltage, f, the frequency in Hertz, N- the number of turns in the winding and ϕ_{max} the peak value of the flux in the core. Thus, basic parameters like voltage, frequency, number of turns and peak magnetic flux are connected by Eqn. (6). The voltage transformation depends on the turn's ratio of the winding. The current carrying capacity of copper must be put into consideration.

From equation (6), we have

$$f = \frac{E \times 10^8}{4.44 \times N \times \emptyset_{max}} \quad (7)$$

and

$$\phi_{max} = \frac{E \times 10^8}{4.44 \times N \times f} \quad (8)$$

The voltage level analyzer (comparator) is using a reference voltage which is an over or under voltage synthesizer. The key features are precision of controlled output due to input signal, accuracy and high reliability [6]. The circuit diagram in Fig. 11 shows a voltage level analyzer using Reference voltage comparator circuit.

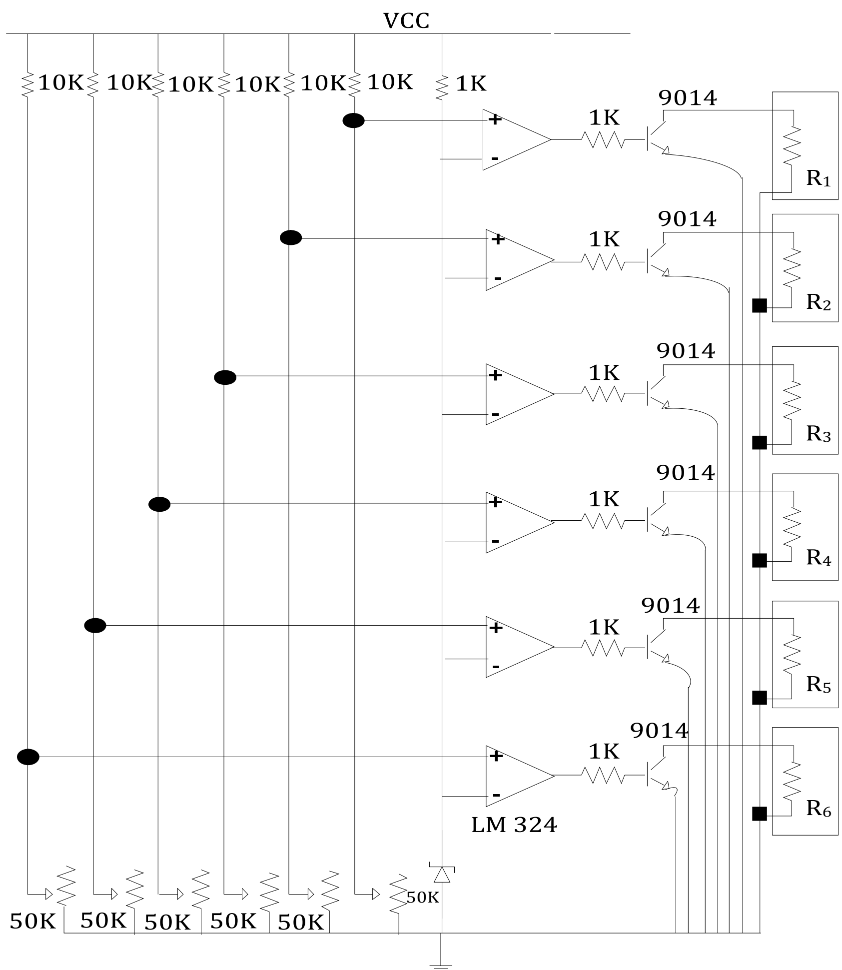

Figure 10: Voltage Level Analyzer using Reference-Voltage Comparator Circuit

Now the circuit in Fig.11 shows a simple voltage analyzer comparator.

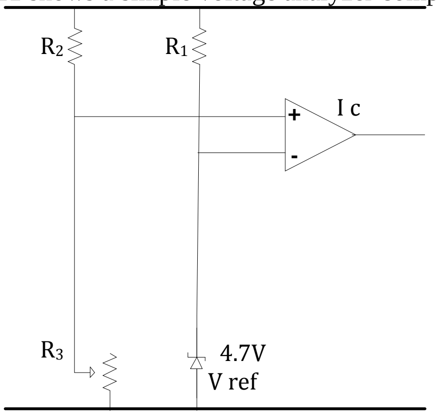

Figure 11: Voltage analyzer comparator.

Choosing Zener diode of 4.7V, 0.0153A provides a fixed voltage level for this design circuit, yielding

Maximum Voltage = 20V

Voltage across R_C = 20 – 4.7 = 15.3V

$R_C = \frac{15.3}{0.0153} = 1000\Omega = 1k\Omega$

R_2 and R_3 are chosen for a variable voltage change from 50V a.c – 260V a.c

Hence R_1=10k and R_2=50k variable. The 1C is LM324 (comparator 1C) see Fig. 12.

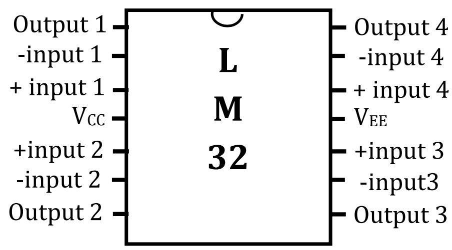

Figure 12: IC LM324 configuration (comparator).

The switch relays drive the transistor C9014 to amplify the output signal of the comparator which in turn is used to activate switch relay matrix.

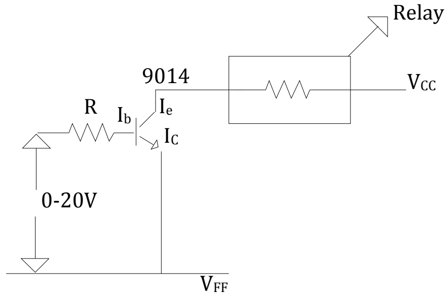

Figure 13: Switch relay matrix circuitry

The current of the op-amp output through R to the base of the transistor to ground V_{EE} is 0.02A see Fig. 13.

Hence $R = \frac{V}{I} = \frac{20}{0.02} = 1000\Omega = 1k\Omega$

The switch relay input impedance is 1000Ω, the Transistor (9014) hfe(transistors gain) is 200 [1]. But the input transistor ratio is 25.Hence,

$I_b = \frac{0.02}{25} = 0.0008A$

$I_C = 200 \times 0.0008 = 0.16A$

Voltage drop across relay = 0.16 x 100 = 16V

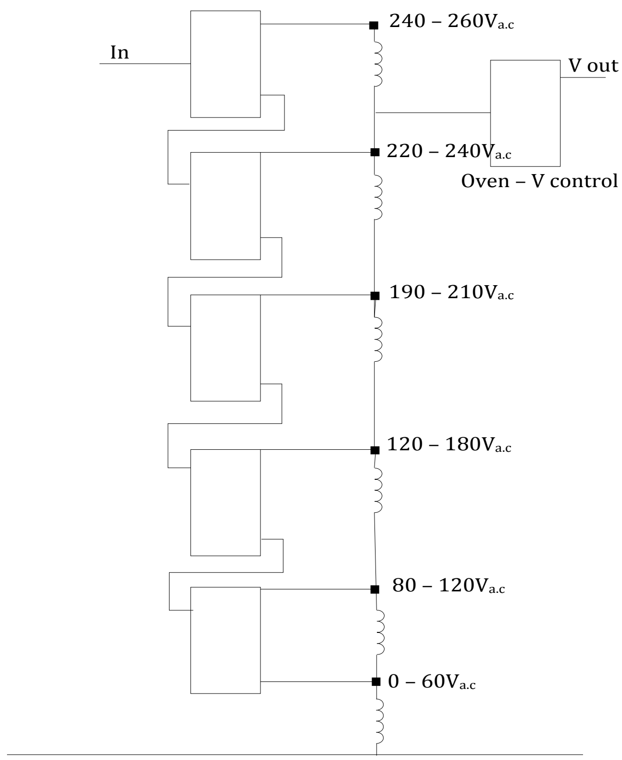

Figure 14: Switch Relay Matrix for Voltage Stabilization

The IC in the main circuit is the comparator. It controls the relays to select the required voltage.

The output power from the comparator (2 ICs) cannot drive the relay directly because the output power of the comparator is low; moreover, the comparator works effectively when it is loading high input impedance due to temperature compensation [4]. The comparator output is now coupled to power the relay via a buffer (transistor – a common emitter configuration) [8]. Each of the relays is set at a preset voltage level to identify the voltage output from the main supply. A relay set at 50V a.c can only respond to 50V a.c and below [9].

3.0 Result and Discussion

After the design and construction of this automatic three phase main input voltage stabilizer, the following readings were obtained from each phase connected to power generating plant and varying the input voltage by the use of the plant choke and consequently monitoring the output voltage.

The values obtained from Tables 1, 2 and 3 simply show that at variable input voltages, the output of the device (stabilizer is nearly constant, as shown in Figs. 16, 17 and 18; strictly, it is constant (220Va.c).

Table 1: Input/ Output Voltage for Phase 1

Phase 1 (Volt)	Output Voltage (Volt)
50	218.5
60	219
80	220
100	220
120	220
160	220
180	220
200	220
220	220
240	221
260	221

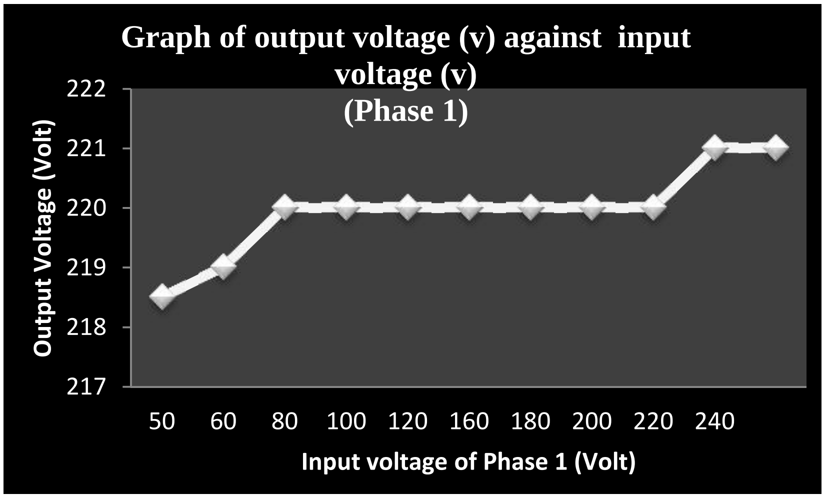

Figure 15: Graph of output voltage (v) against input voltage (v) of phase 1 (Phase 1)

Table 2: Input/ Output Voltage for Phase 2 (Phase 1)

Phase 2 (Volt)	Output Voltage (Volt)
50	219
70	220
90	220
110	220
130	220
150	220
170	220
190	220
210	220
230	220
250	220

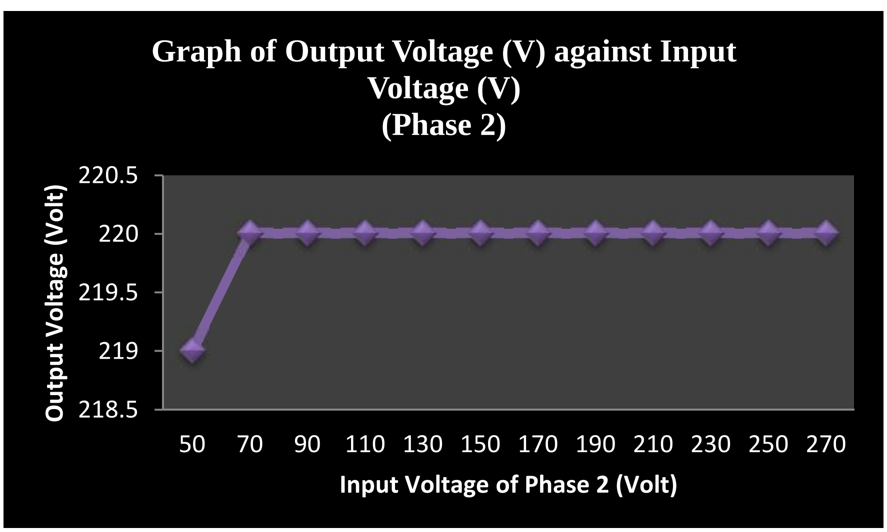

Figure 16: Graph of output voltage (v) against input voltage (v) of phase 2 (Phase 1)

Table 3: Input/ Output Voltage for Phase 3 (Phase 1)

Phase 3 (Volt)	Output Voltage (Volt)
50	220
55	220
75	220
95	220
115	220
125	220
145	220
165	220
185	220
205	220
230	220

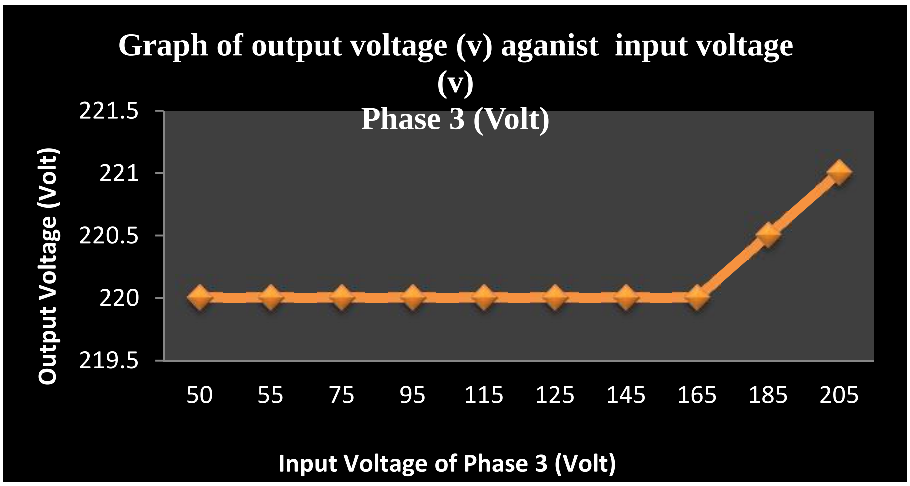

Figure 17: Graph of output voltage (v) against input voltage (v) of phase 3 (Phase 1)

4.0 Conclusion

Automatic three-phase change over voltage stabilizer has been designed and analyzed. It is capable of maintaining constant output voltage of 220V a.c with current range of 5 – 12Ampers. Its output power rating is about 3200W. The input is capable of searching and selecting a lives phase from the main voltage source of reality available power transmission line and if no live is detected; it is capable of switching to a power generating plant.

5.0 References

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