International Journal of Science and Engineering Applications
Volume 7–Issue 10,381-385, 2018, ISSN:-2319–7560

Design Calculation of Automatic Voltage Stabilizer Control System

Hnin Hnin Aye
Department of Electrical Power Engineering
Technological University
(Thanlyin), Myanmar

Abstract: Voltage fluctuation always occurs in electrical supply system. Due to voltage fluctuation, life of electrical equipment consumed electricity is shorted really. To solve this problem, automatic voltage stabilizer is needed for domestic and industries. Both single phase and three phases are available. In this journal intend to known that automatic voltage stabilizer plays efficient role in all type of load i.e. resistive, inductive and capacitive loads. This journal present control circuit for automatic voltage stabilizer provides voltage comparator, relays and servo controlled motor that compare instantaneous input and output voltage. Automatic voltage stabilizer consists of two unit; measuring unit and regulating unit. In this stabilizer, toroidal type variable auto transformer is used for regulating unit and electronic control circuit is used for sensing unit. Electromechanical or servo control system is used for measuring unit to sense the supply voltage. This electronic control circuit will operate within the fluctuation range from 120V to 250V.The rating of this automatic voltage stabilizer is 7kVA (single phase) and its frequency range is 50Hz. The output sensitivity is ±1%. If input voltage is lower than 120V or higher than 250V, the system will be automatic shutdown. The main purpose of this research is design calculation of control circuit.

Keywords: voltage stabilizer; LM324; sensing unit; relays; controller design

1. INTRODUCTION

Servo controlled voltage stabilizer is a useful and effective device used to maintain a constant power supply. Voltage fluctuation is a common problem in Myanmar, which can cause damage in electronic devices used in home and in industries. To solve these appliances safe is to use voltage stabilizers. The automatic voltage stabilizers are widely used in industrial application to obtain the stability and good regulation for the sophisticated electrical and electronic equipments such as communication equipments and system, process controller, computer equipment etc[1]. Servo controlled is a closed loop systems for electric motors. The motor used in servo control is usually DC motor used in servo is also possible. The servo system uses a sensor to sense motor position/speed. Servo control has a feedback circuit which changes the drive power going to motor according the control input signals and signal from sensors[2]. There are various type of stabilizers available in market. Based on the change in main voltage, the automatic voltage stabilizers increase or decreases the power supply to rectify the deviation and brings the power supply to normal level. Automatic voltage stabilizer provides a continuous monitoring of output voltage by means of an electronic control circuit that compares the instantaneous output voltage with the set value. Voltage regulation is required for two distinct purposes; under-voltage and over-voltage conditions. Line voltage regulation is the process of maintaining constant output voltage to industrial and domestic users despite a wide variation in input voltage. Under-voltage might result into brownout, distortion or permanent damage while overvoltage in the form of spikes and surges could cause distortion, burn out, melt-down, fire, electro-pulsing and permanent damage. The two distinct reasons of voltage regulation afore mentioned could be caused by abnormal forces of nature, atmosphere conditions, generator power surge, power grid defects, power distribution imbalance etc[5]. With the wide spread use of switched mode power supplies, color television sets today have eliminated the need for a voltage stabilizer. But it is preferable to employ one even for them, to safeguard against momentary voltages over 250V and 120V on the mains.

2. SERVO SYSTEM VOLTAGE STABILIZER

In this journal, automatic voltage stabilizer consists of regulating unit and measuring unit. Fig 1 shown below are the block diagram and circuit diagram of the voltage stabilizer connected to an appliance or load. The stabilizers sizes generally with its rating, which is given in kVA.

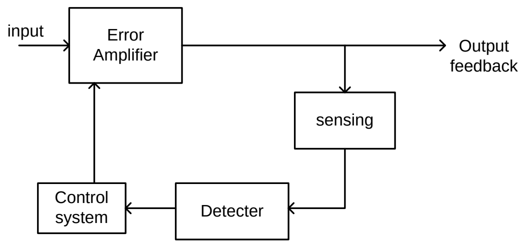

Figure 1. Block diagram of servo controlled voltage stabilizer

The regulating unit consists of toroidal type variable autotransformer. The purpose of the regulating unit is that of acting under the signal from the measuring unit in such a manner as to correct the output voltage of the stabilizer, as near as possible, a constant or predetermined value. Measuring unit includes control circuit. The function of the measuring unit is that of detection a change in the input or output voltage of automatic voltage stabilizer and producing a signal to operate the regulating unit.

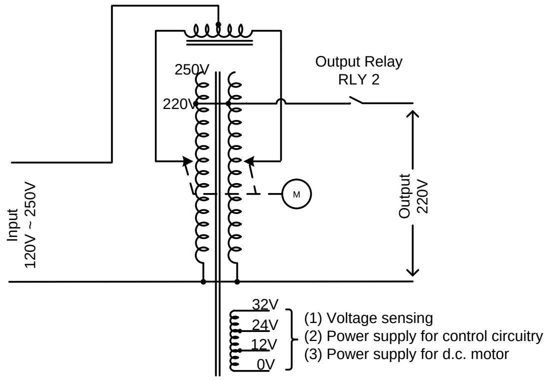

Figure 2. Schematic diagram of automatic voltage stabilizer

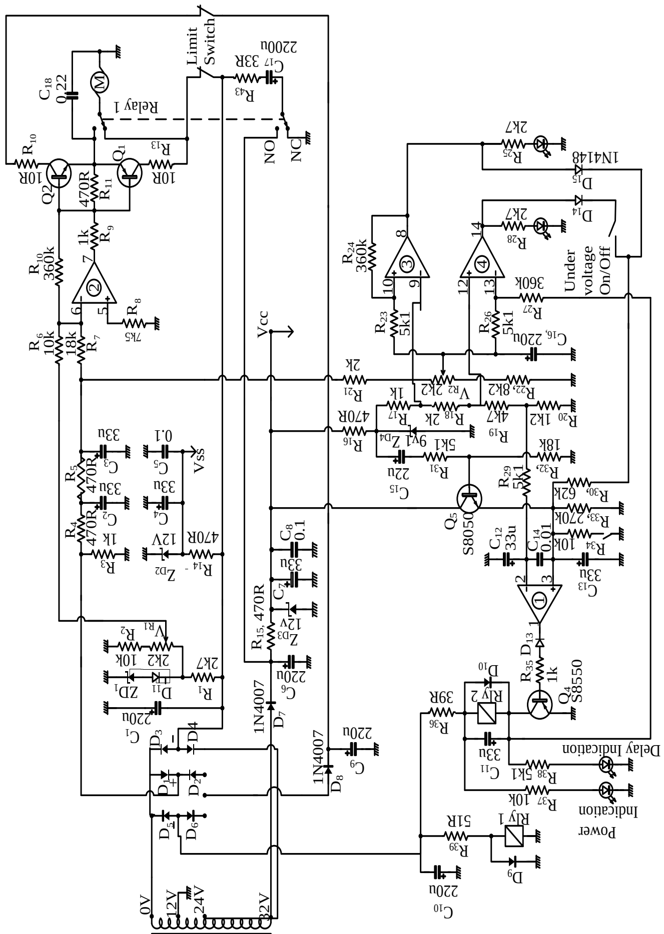

Figure 3 . Overall Circuit Diagram of AVS

Overall circuit diagram of control circuit for AVS is shown in fig:2. Transformer steps down the AC source voltage to 12V. Then, the transformer output is rectified by bridge rectifier. The rectifier output voltage is filtered by capacitor. In this circuit, LM324 is used as comparator and indicator. The non-inverting input ($-V_{in}$) the op-amp is greater than the inverting input ($-V_{in}$) the op-amp is ON-state. At normal condition, positive voltage sensing only. If V_{R1} is adjusted so that when output AC voltage is 220V, the op-amp output is zero. Op-amp (3) is used for over-voltage condition. It is connected as voltage comparator. When transistor Q_2 base receives forward bias and Q_2 goes 'ON' motor runs in the direction to raise voltage. When transistor Q_1 base is forward biased and Q_1 goes 'ON' motor runs in the other direction to lower voltage. After the preset time, op-amp output swings positive and release the relay. The control system is automatically shut down when the voltage fluctuation is lower than 120V and higher than 250V.

3. DESIGN CONSIDERATION

Power supply system is an essential part of each electronic system from simplest to the most complex. Input voltage supply is 220V AC supply. Automatic voltage stabilizer control system is based on mainly control circuit.

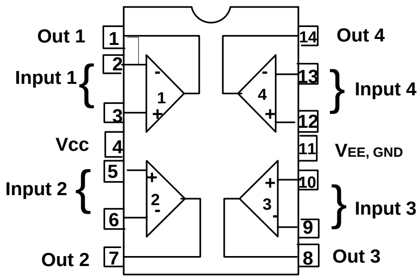

Figure 4. Diagram of Pin Function of LM324

In figure 3 , LM324 is a 14 pin IC consisting of four independent operational amplifiers (op-amp) compensated in a single package. Op-amp are high gain electronic voltage amplifier with differential input and usually, a single-ended output. The output voltage is many times higher than the voltage difference between input terminals of an op-amp.

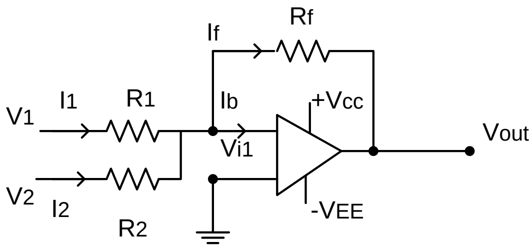

Figure 5. Summing amplifier of op-amp

Applying Kirchhoff's Current Law (KCL),

$$I_1+I_2=I_f + I_b$$

$$I_1+I_2 \approx I_f$$

$$\frac{V_1-V_2}{R_1}+\frac{V_2-V_{i1}}{R_2}=\frac{V_{i1}-V_0}{R_f}$$

The open loop gain, $A=\frac{V_0}{V_{id}}=\frac{V_0}{V_{i2}-V_{i1}}$

$$\therefore V_0=-R_f\left[\frac{V_1}{R_1}+\frac{V_2}{R_2}\right]$$

4. RESULTS AND DISCUSSION

In this section the results obtained from the design calculation of stabilizer controller. There are three conditions by the unstable input supply.

4.1 Normal Condition

The parameter of Op-amp 2,

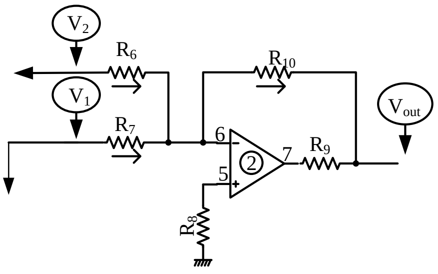

Figure 6. Circuit Diagram of Op-amp 2 of LM324N

Op-amp (2) is connected as a summing amplifier.
Applying KCL,
At pin 6 and virtual ground concept.

$$\frac{V_{out}}{R_{10}} = -\left(\frac{V_1}{R_7} + \frac{V_2}{R_6}\right)$$

V_1 is positive and represents the sample of output a.c voltage.
V_2 is fixed negative voltage: it acts as reference voltage.
Assume, V_1=9.87V, V_2=-5.48V
Apply the KCL,

$$\frac{V_1}{R_7} + \frac{V_2}{R_6} = 0 \quad (\because \text{ In normal condition, } V_{out} = 0)$$

$5.48R_7 = 9.87R_6$

If R_6=10kΩ , R_7=18kΩ

∴ The standard of R_6=10kΩ and R_7=18kΩ

And then, $I_6 = \frac{V_2}{R_6} = -\frac{5.42}{10k} = -0.55$ mA

$$I_7 = \frac{V_1}{R_7} = \frac{9.87}{18k} = 0.55 \text{ mA}$$

If AC output voltage is 1% change,

V_1=0.99×9.87=9.77V

$$\frac{V_{out}}{R_{10}} = -\left(\frac{V_1}{R_7} + \frac{V_2}{R_6}\right)$$

$$V_{out} = \left(-\frac{9.77}{18k} + \frac{5.48}{10k}\right) R_{10}$$

$V_{out} = 5.22\times10^{-6}\ R_{10}$

Assume motor pick-up voltage =2V

R_{10}=382kΩ

∴ The standard value of R_{10}=382kΩ

In this research, R_8=7.5kΩ and R_9=1kΩ are chosen. When V_1 falls below normal, inverting input becomes negative and op-amp output swings positive and drives the motor in the direction to increase output voltage. If V_1 increase above normal, the process is reverse order.

time delay is calculated by the equation, $V_c = V.e^{-\frac{t}{\tau}}$

R=9.642kΩ, C=33µF, V=12V, V_c=1.23V

$$-\frac{t}{\tau} = \ln\left(\frac{1.23}{13}\right)$$

∴ t = 0.7sec

4.2 Over-Voltage Condition

The parameter of Op-amp 3,

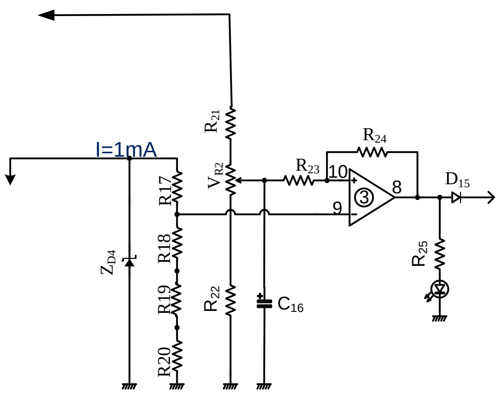

Figure 7. Circuit Diagram of Op-amp 3 of LM324N

From normal condition, node voltage V=9.87V
Assume, the non-inverting input (pin 9) = 8.08V (fixed voltage)
Assume, I=0.8mA
Non-inverting input (pin10) is fed from voltage sensing supply through voltage divider R_{21}, VR_2, R_{22}
Apply by KVL,
$IR_{21}+IV_{R2}+IR_{22}$=9.87V
$R_{21}+V_{R2}+R_{22}$= 12.34kΩ
By Ohm's Law,
V=IR

$$R_{21} = \frac{9.87\text{-}8.3}{0.8m} = 1.96\text{k}\Omega$$

$$V_{R_2} = \frac{8.3\text{-}6.5}{0.8m} = 2.2\text{k}\Omega$$

$R_{21}+V_{R2}+R_{22}$= 12.34kΩ
R_{22}=8.2Ω
∴ The standard value of R_{21}=2kΩ, V_{R2}=2.2kΩ and R_{22}=8.2kΩ
V_{R2} is adjusted so that at normal condition there is about +7.35 at pin 10.
At normal condition, op-amp output is negative because 8.08>7.35V
When output voltage increase to 242V,
Pin 10 voltage = 8.085V
Since 8.085V > 8.08V, op-amp output goes positive and drives the relay.
Assume I=1mA through voltage divider R_{17}, R_{18}, R_{19}, R_{20}.
R_{17} = 1.02 kΩ
Apply by KVL,
$IR_{18}+IR_{19}+IR_{20}$=8.08V

$$R_{18} + R_{19} + R_{20} = \frac{8.08}{1m} = 8.08 \text{ k}\Omega$$

$$R_{18} = \frac{8.3\text{-}6.5}{1m} = 1.8 \text{ k}\Omega$$

By Ohm's Law,

$$R_{20} = \frac{1.23}{1m} = 1.2\ k\Omega$$

$R_{18} + R_{19} + R_{20}$=8.08kΩ

R_{19}=5.08kΩ

∴ The standard value of R_{17}=1kΩ, R_{18}=2kΩ, R_{19}=4.7kΩ and R_{20}=1.2kΩ.

In this circuit, R_{23}=5.1kΩ, and R_{24}=360kΩ is used for prevent short circuit.

Assume, I=5mA for LED lamp

$$R_{25} = \frac{12}{5m} = 2.4k\Omega$$

∴ The standard value of R_{25}= 2.7kΩ

4.3 Under-Voltage Condition

The parameter of Op-amp 4,

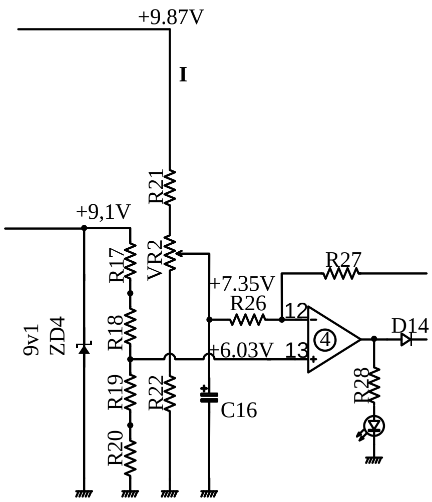

Figure 8. Circuit Diagram of Op-amp 4 of LM324N

Under-voltage condition circuit is almost same as over-voltage condition except that op-amp inputs are interchanged.

Reference voltage at non-inverting input is 6.03V

Assume, fixed voltage V=6.03V and I=1mA

$$R_{17} = \frac{9.1\text{-}8.08}{1m} = 1.02\ k\Omega$$

$R_{17}+R_{18}$= 3.07kΩ

R_{18}=2.07kΩ

Apply by KVL,

$IR_{18}+IR_{19}+IR_{20}$ = 8.08V

$R_{18}+R_{19}+R_{20}$=8.08kΩ

$R_{19}+R_{20}$=6.03kΩ

Assume time delay voltage=1.23V

By Ohm's Law,

V= IR

$$R_{20} = \frac{1.23}{1m} = 1.23\ k\Omega$$

∴ $R_{18}+R_{19}+R_{20}$ = 8.08kΩ

R_{19} = 4.78kΩ

∴ The standard value of R_{17}=1kΩ, R_{18}=2kΩ, R_{19}=4.7kΩ and R_{20} = 1.2kΩ.

In this circuit, R_{26}=5.1kΩ and R_{27}=360kΩ is used for prevent short circuit.

Assume, I=5mA for LED lamp

$$R_{28} = \frac{12}{5m} = 2.4\ k\Omega$$

∴ The standard value of R_{25}=2.7kΩ

If a.c output voltage falls below 180V, pin 13 voltage falls below +6.03 V and op-amp output goes positive.

When output voltage decreases to 180.4V,

$$\text{pin 12 voltage} = \frac{7.35}{220} \times 180.4 = 6.02V$$

Since 6.02 < 6.03, op-amp output goes positive and drives the relay.

A variable resistor V_{R2} is used so that the user can adjust the voltages settings at the desired position. In this case, over-voltage setting ≈ 240V and under-voltage setting ≈180V.

time delay is calculated by the equation, $V_c = V.e^{-\frac{t}{t}}$

R=9.642kΩ, C=33μF, V=12V, V_c=1.23V

$$-\frac{t}{\tau} = \ln\left(\frac{1.23}{13}\right)$$

∴ t = 0.7sec

Table 1. Summary of Detailed Data for Normal Condition

Condition	Symbol	Units	Design Values
Normal Voltage	R_6	kΩ	10
	R_7	kΩ	18
	R_8	kΩ	7.5
	R_9	kΩ	1
	R_{10}	kΩ	382

Table 2. Summary of Detailed Data for Over-voltage Condition

Condition	Symbol	Units	Design Values
Over- Voltage	R_{17}	kΩ	1
	R_{18}	kΩ	2
	R_{19}	kΩ	4.7
	R_{20}	kΩ	1.2
	R_{21}	kΩ	2
	R_{22}	kΩ	8.2
	R_{23}	kΩ	5.1
	R_{24}	kΩ	360
	5. R_{25}	kΩ	2.7
	VR_2	kΩ	2.2

Table 3. Summary Design Detailed for Under-voltage Condition

Condition	Symbol	Units	Design Values
Under- Voltage	R_{17}	kΩ	1
	R_{18}	kΩ	2
	R_{19}	kΩ	4.7
	R_{20}	kΩ	1.2
	R_{25}	kΩ	2.7
	R_{26}	kΩ	5.1
	R_{27}	kΩ	360
	R_{28}	kΩ	2.7

If the supply voltage is lower than 120V and more than 250V, the supply of the motor will be cut out. After that the relay will cut out the supply. So, automatic voltage stabilizer will not produce the power supply without being 220 stable voltage. If the input voltage of the stabilizer is lower than output voltage, the sensing circuit is unbalanced that and the op-amp output is positive. The motor rotates clockwise direction as to increase the stabilizer output voltage to 220V. If the input voltage of the stabilizer is higher than output voltage, the sensing circuit is unbalanced that and the op-amp output is positive. The motor rotates anti-clockwise direction as to decrease the stabilizer output voltage to 220V.

6. CONCLUSION

1. In this circuit when the input voltage is lower than 220V, the relay starts energized and the motor rotates the clockwise direction.
2. The input voltage is higher than 220V, the motor rotates the anticlockwise direction.
3. The control circuit components are available in local market. So, the circuit component can be replaced easily when they are damaged. This automatic voltage stabilizer is very suitable and economical for all electrical equipments.
4. This automatic voltage stabilizer is very convenience and economic for domestics and industries. So, automatic voltage stabilizer having with these conditions will offer the stable output voltage or stable output voltage for all electrical equipments and will improve productivities and reduce downtime.

Considering all the above on design of control system. Automatic voltage control system works between the voltage range of 120V and 250V efficiently. The control circuit is to drive the motor and adjust the stable output voltage. The output voltage accuracy is ± 1% and efficiency is above the 98 %.

7. ACKNOWLEDGMENTS

The author is deeply grateful to her dissertation superior and co-supervisor. The author also thanks to all teachers at Technological University (Thanlyin) and all who provided her with necessary assistance for this paper. The author wishes to express her guidance to all persons who helped directly or indirectly towards the successful completion of paper. Finally, the author wishes to express her special thanks to her parents for their support and encouragement to attain her destination without any trouble.

8. REFERENCES

[1] G NAVEEN KUMAR. “DESIGN OF A LOW COST SERVO CONTROLLED VOLTAGE STABILIZER.” International Journal of Research in Engineering & Technology (IMPACT: IJRET) Vol.4, Issue 3, Mar 2016, 43-46.

[2] Servo controlled voltage stabilizer introduction, amjadeeeseminars blogspot, 1st December 2012.

[3] P. Eswaran, “Design of fuzzy logic controller for customized servo voltage stabilizer” , 2nd International Conference on Electronic and Communication Systems, 26-27 February 2015, pages 103-106.

[4] Instruction manual for servo-controlled stabilizer, Servel Electronics Private Limited.

[5] McGranaGhan M. F., Mueller D. R. and Samotyi m. J. (1993), “Voltage Sag in Industrial Systems,” IEEE Transactions on Industry Applications, Vol.29, pp.397-403.

[6] M. Htay and K. San Win, “Design and Construction of an Automatic Voltage Regulator for Diesel Engine Type Stand-alone Synchrous Generator,” PP.652-658

[7] Instruction manual for servo voltage stabilizer with isolation transformer, Suvik electronic PVT.LTD.

[8] A text book of power electronic P.S. Bhimra.