

Three Steps AC Voltage Regulator Based on One Step-down Transformer

Hussain Attia

*Electrical, Electronics & Communication Engineering Department
American University of Ras Al Khaimah United Arab Emirates hattia@aurak.ac.ae*

Abstract

Automatic AC voltage regulation is a common domestic and industrial issue especially during loads currents changing. Many solutions are presented in this side based on multi tap transformer, however in this solution the steps of voltage controlling equal to the number of taps of transformer. This paper proposes a new design of one step secondary winding transformer to provide three steps of AC voltage controlling and to cover the case of oscillating between two steps of output voltage that creating problem of surge at the regulator output terminals during controlling jumps between steps by relays contacts. In this work, the designed transformer will be used for increase and decrease the input AC voltage depending upon the continuous monitoring for the instantaneous value of the input voltage. The paper introduces full design and simulation results based on Multisim and PSIM 2-sofwarees.

Keywords: Voltage Regulator (AVR), Voltage Sensing, Transformer, Op-Amps.

Introduction

The AC voltage regulation is an important matter because of the direct relation between the supply voltage level and the connected electrical or electronic equipment. This importance is come from that the designed and manufactured equipment are work by a stable AC supply voltage 220-230Vrms. However, the supply AC voltage suffers from the fluctuation of the supply voltage levels; this fluctuation is a result of the variation in the instantaneous draw currents that followed to the connected loads.

Many researcher works in the field of AC voltage regulation through proposals based on different designs and different methodologies;

The research work of [1] focuses on designing and implementation of an Automatic Voltage Regulator (AVR) that to overcome on the threat to the important electrical and electronic domestic equipment such as like computer, refrigerator, television etc. The work in [1] covers the demerit of the current systems that represented by the problem of oscillating between two steps of output voltage and the problem of creating surge at the output which can damage valuable electronics. This research handled both shortcomings and introduced in the tolerable range of 215-237 volt using several taps. Hysteresis has been introduced while changing from one level to other and thus preventing oscillation. However, in this design need to use multi taps and the control contacts in one time only one tap to the output load while the other become useless, as well as there is a certain short off

time to jump from step to other that may lead to creating surge at the output terminals of the regulator.

The work in [2] proposes the design and implementation of a Programmable Automatic based on a certain microcontroller unit that to cover the problem oscillating between two output voltage, however still in this work did not manipulate the case of off time which happen between each two taps at jumping time as well as still using multi tap transformer.

The study in [3] focuses on Three-phase AC-voltage regulator systems using silicon controlled rectifier (SCR) which broadly applied in industrial field through a novel design of three-phase AC-voltage regulation trigger circuitry of SCR through a certain microcontroller unit. However, the controlling of six thyristors' through controlling conducting angles will lead to have distorted three phase sine waves and consequently the harmonics problems may appear on the connected loads as well as the complexity design.

Description of the 12 commercially available domestic 1kVA Automatic Voltage Stabilizers brands that designed for line and load regulation tests is demonstrated in [4].

Sinusoidal Pulse Width Modulation (SPWM) technique is proposed in [5], [6] to do the AC voltage regulation that to manipulate the voltage fluctuation; the work in [5], used technique on a voltage stabilizer based on a suitable microcontroller through AC/DC/AC stabilizer type. The proposed controlling is made by firstly rectify the input AC voltage to a suitable DC level and through the intelligent micro controller; the output voltage is regulated by PWM technique to produce through a filter a perfect sinusoidal AC voltage. The system is accurate but it characterized by complexity and costly.

The usage of PWM technique for AC voltage regulation is also presented in [6] to regulate the output voltage for standalone wind turbine driven by variable speed wind. The technique is used to regulate the fluctuating voltage of wind turbine. The proposed design and simulation includes utility connection, battery storage system, PWM inverter, and controlling unit that to control the power supplying when wind regulated voltage is dropped from a threshold value due to low wind speed or absence of wind.

The research studies in [7]-[12] are focus on AC, DC voltage regulation and supplying with/without Sinusoidal Pulse Width Modulation technique for delivering the suitable power to the connected loads.

In [13], the study focuses on the electrical hazards, types of stabilizers, servo voltage stabilizers, how the need for servo stabilizers is rising rapidly. In spite of the content of this study, still the response of the servo voltage stabilizers is slow compared to the fully electronic systems with/without relays.

Comparing to the above research studies, this paper proposes a new electrical / electronic design of a three steps AC voltage

regulator that focuses on avoiding the using of multi-taps transformer as well as removing the case of off time of connection during the jumping between controlling steps. The remaining of this paper is as follows: the details of the new proposed three steps AC voltage regulator is illustrated in section II. The details of simulation work with results are explained and shown the validity of the presented design that is illustrated in section III. The summary of findings and the future work ideas are explained in conclusion in section IV.

Proposed Design

The proposed idea adopts using only one step down transformer in the design of 3-steps AC voltage regulator. The idea focuses on control the delivering of AC voltage to this transformer as well as control the direction of the input voltage, in other word control the phase of input voltage. The primary winding receive the primary voltage which is in can be the same input AC voltage i.e. in the same phase, or receive the primary voltage with out of phase of the input AC voltage. The controlling action has another choice that does not deliver the primary voltage.

Fig. 1 represents the block diagram of the proposed electronic design of single phase AC voltage regulator. The voltage and current specifications of the suitable transformer are depending on the rated current of the designed maximum AC load that will connect to the utility/grid via the voltage regulator. In this study, the transformation rate of the selected step down transformer is 220 V / 20 V, so the secondary winding voltage will vary with respect to this transformationrate and with respect to the instantaneous value of the input AC voltage.

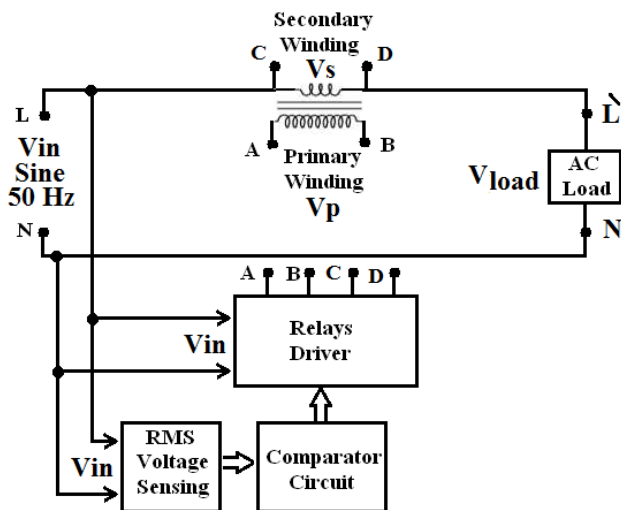


Fig. 1. Block Diagram of the proposed 3-steps AC voltage regulator

The block diagram is started by sensing circuit which designed to sense the currently rms value of the utility voltage, this circuit as shown in Fig. 2 is designed to produce DC voltage level with rate of step down rate of 1/100, i.e. in case the utility rms voltage 220 V, the output voltage of the

sensor is 2.2 V, and if $V_{in} = 250$ V the sensor output voltage is 2.5 V and so on.

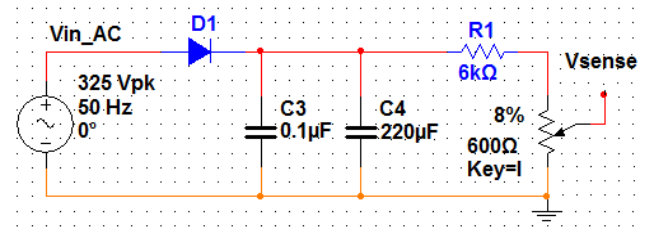


Fig. 2. Sensing Circuit of Input AC RMS Voltage

The second part of block diagram is represented by the comparator circuit which used to compare the value of RMS input voltage after sensing with two voltage limits, namely upper limit level and lower limit level. The upper limit is set at 2.375 DC volt that to compare by first Op-Amp the input voltage with 237.5 V and give indication when the input AC voltage pass over this limit. In the same point of voltage regulation, other Op-Amp is designed to compare the input AC voltage value with the lower limit 2.15 DC volt. Fig. 3 shows the electronic design of the comparator circuit, and the results of Op-Amps comparing are designed to control the state of three relays.

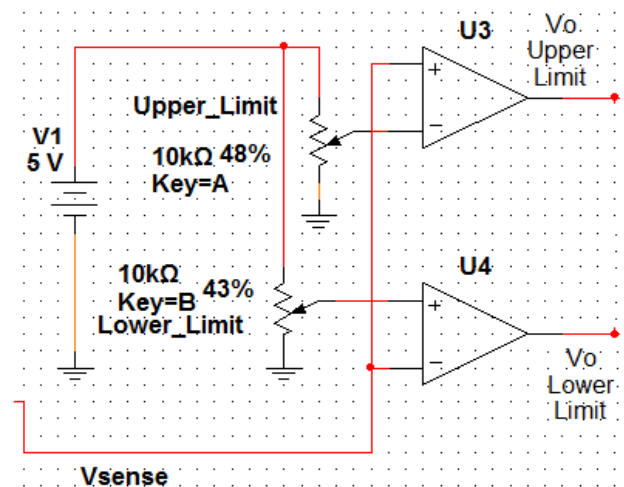


Fig. 3. Comparator Circuit

Relays driver circuit is designed with ability of controlling the direction of the two terminals (L: Life, and N: Neutral) of AC input source by either keeping the same direct of AC input voltage that to increase the load voltage by the step of in phase secondary winding which approximately 20 Vrms or selection the second direction that to decrease the load voltage by the step of out off phase secondary winding. The middle step is keep the load AC voltage without any increment or decrement when the input AC source in a suitable range, and in this case and to avoid any drop voltage on the secondary

winding it's important to remove the mentioned voltage drop by closing the two contacts (CD). Fig. 4 shows the detail design of the relay drivers.

Simulation Results

Simulation results are collected through the 2-software namely; Multisim and PSIM. The first one is used for electronic design that for part represented by RMS voltage sensing circuit and Op-Amps comparator circuit. PSIM is used to do the power part represented by AC input voltage, step down transformer connection, load connection, and collecting the voltage sinusoidal waveforms of the source, secondary winding, and load.

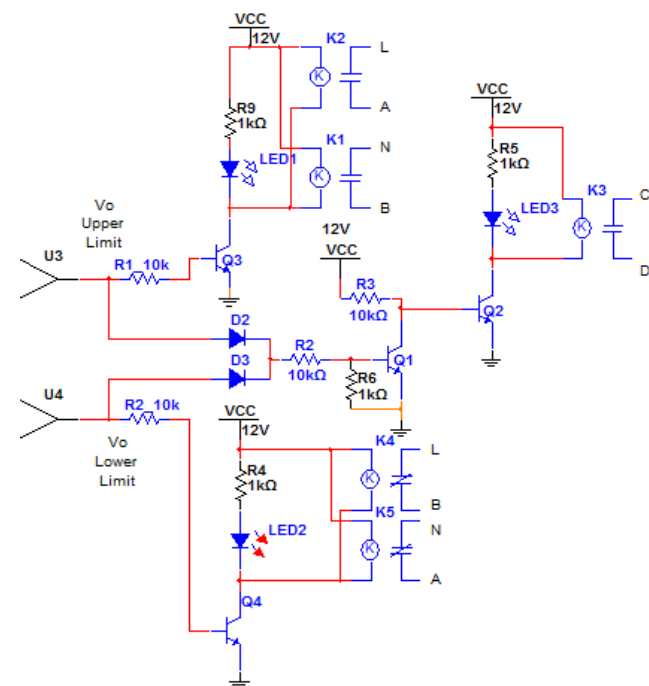


Fig. 4. Relay Drivers Circuit

Fig. 5 shows the detailed records of the outputs voltage of sensing circuit for different input AC levels started by 190 Vrms end with 260 Vrms with 10 Volt step as well as the outputs of the upper limit and the lower limit Op-Amp comparators.

Table_1 tabulates all these data in addition to the three relays state as well as the details of either additional or minimized AC voltage step. The load AC Vrms Voltage is also included in table 1 that to demonstrate the effectiveness of the proposed design.

Fig. 6 shows the sinusoidal waveforms of the AC source voltage, secondary winding voltage, and the load voltage. Fig. 6 clearly illustrate the state of transformer secondary winding that is connected with the load or removed, and in case connected, the state of connection is also illustrated through the shape of the voltage step i.e. the phase of the step voltage (in phase, or out off phase); Fig. 6 (A) Shows the state of increment the input AC voltage by in phase voltage step of the secondary winding. Fig. 6 (B) shows the state of no step

voltage increment in case the level of AC input voltage is acceptable, while Fig. 6. (C) Shows the state of out off phase decrement step by minimizing the input AC voltage by the value of secondary winding voltage.

Fig. 7 summarizes the proposed design effectiveness through illustrate the behavior of the 3-steps AC voltage regulator for the range of input AC voltage started from lower limit voltage level end at higher limit voltage level.

Table_1. Details of Input and Load Voltage Levels and Relays State

Vin rms (V)	Vo Sens (V)	Upper Limit Set (V)	Lower Limit Set (V)	Vo (V) Op Amp Up Lmt	Vo (V) Op Amp Low Lmt	Rly 1	Rly 2	Rly 3	Vi Transformer RMS	Vo Transformer RMS	Vo Load (V)
190	1.9	2.38	2.15	-12.07	11.97	0	1	0	190	17.2	207
200	2.0	2.38	2.15	-12.07	11.97	0	1	0	200	18.1	218
210	2.1	2.38	2.15	-12.07	11.97	0	1	0	210	19.0	229
220	2.2	2.38	2.15	-12.07	-12.07	0	0	1	0	0	220
230	2.3	2.38	2.15	-12.07	-12.07	0	0	1	0	0	230
240	2.4	2.38	2.15	11.97	-12.07	1	0	0	240	21.5	218.5
250	2.5	2.38	2.15	11.97	-12.07	1	0	0	250	22.6	227
260	2.6	2.38	2.15	11.97	-12.07	1	0	0	260	23.5	236.5

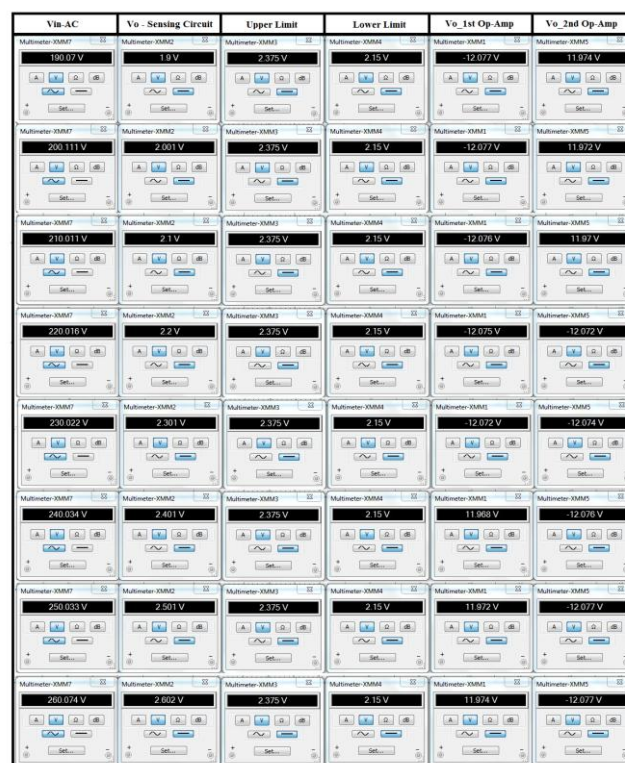


Fig. 5. Output Voltage of Sensing Circuit and Two Op-Amps Comparators for Different Input AC Levels

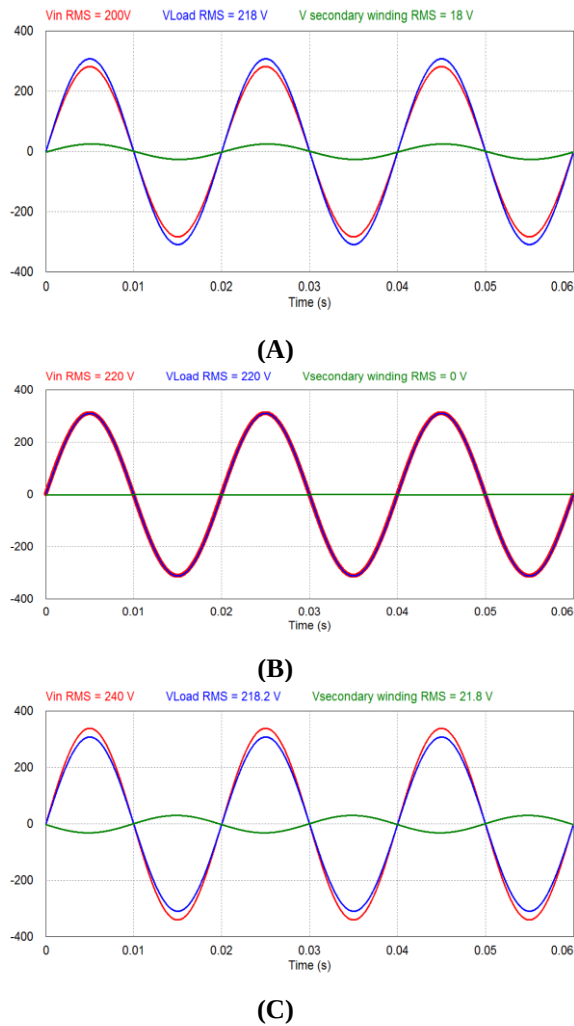


Fig. 6. Sinusoidal Waveforms of AC Supply, Secondary Winding voltage, and the Load voltage. (A): Increment Input Voltage by in Phase Secondary Winding Voltage Step. (B): No Step Voltage Increment to AC Input Voltage. (C): Decrement Input Voltage by Out Off Phase Secondary Winding Voltage Step

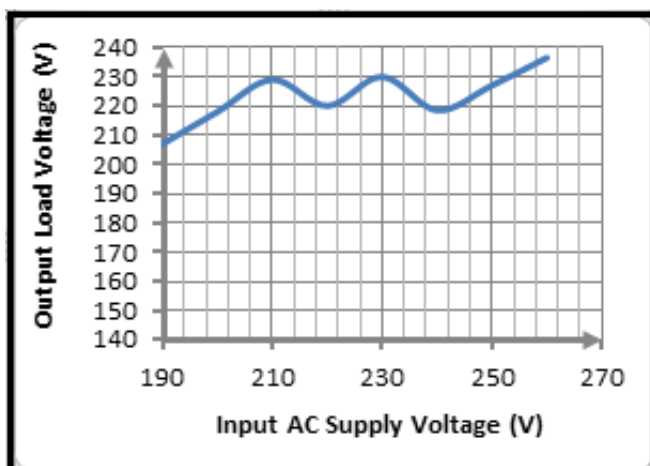


Fig. 7. Behavior of Proposed 3-Steps AC Voltage Regulator

Conclusion

The details of electronic circuits design and simulation results are done in this study for automatic AC voltage regulation, the proposed design is based on discrete components. The new proposed idea of AC voltage regulation adopts using one secondary winding coil to regulate the fluctuation of input AC voltage the 3-steps voltage control. the selected step is approximately 20 Vrms , in other word, the three steps are increment, No change, or decrement of input AC voltage that to deliver the connected load by less fluctuated AC supply voltage. The additional merits of the proposed work are; using only one secondary winding of step down transformer that means the controlling is save because deal with low voltage controlling. the second merit is avoiding the power spike during the controlling jump of relay contacts that because the value of voltage step ($\approx 20\text{ V}$) is less than 10% of the rated voltage of input AC supply ($\approx 220\text{ V}$).

References

- [1] Mohammad Shah Alamgir and SumitDev, "Design and Implementation of an Automatic Voltage Regulator with a Great Precision and Proper Hysteresis", International Journal of Advanced Science and Technology Vol.75, (2015), pp.21-32
- [2] Mohammad MurshadulHoque, "Design, implementation and performance study of programmable automatic voltage regulator", Journal of Electrical Systems 10-4 (2014): 472-483
- [3] Guoshun Zhou, TuYa, Shukun Zhao, "A Three-phase AC-Voltage Regulator System", TELKOMNIKA Indonesian Journal of Electrical Engineering, Vol.12, No.5, May 2014, pp. 3501 ~ 3508
- [4] AkinloluAdediranPonnle, "Performance of Domestic AC Voltage Stabilizers in Meeting Low Voltage Problems in Nigeria: A Case Study of 12 Different Brands", International Journal of Engineering and Technology Volume 5 No. 6, June, 2015
- [5] K. N. Tarchanidis, J. N. Lygouras and P. Botsaris, "Voltage Stabilizer Based on SPWM technique Using Microcontroller", Journal of Engineering Science and Technology Review 6 (1) (2013) 38-43
- [6] Arshad Nawaz, Muhammad NaeemArbab, "Voltage Regulation of Variable Speed Wind Turbine using MATLAB/Simulink", International Journal of Engineering and Advanced Technology (IJEAT), Volume-2, Issue-5, June 2013, 357-360
- [7] H. A. Attia, Y. I. Al-Mashhadany and B. N. Getu, "Design and Simulation of a High Performance Standalone Photovoltaic System", ICREGA'14 - Renewable Energy: Generation and Applications, Springer Proceedings in Energy, Springer International Publishing Switzerland 2014
- [8] Hussain A. Attia, BezaNegashGetu, HasanGhadban, Ahmed K. Abu Mustafa, "Portable Solar Charger with Controlled Charging Current for Mobile Phone Devices", Int. J. of Thermal & Environmental Engineering, Vol. 7, No. 1 (2014) 17-24

- [9] BezaNegashGetu and Hussain A. Attia, “ Remote Controlling of Light intensity Using Phone Devices”, Research Journal of Applied Science, Engineering and Technology, Vol. 10, No. 10, 2015, pp. 1206-1215
- [10] Hussain A. Attia, BezaNegashGetu, Nasser Hamad, “ Experimental Validation of DTMF Decoder Electronic Circuit to be Used for remote Controlling of an Agricultural Pump System”, International Conference on Electrical and Bio-medical Engineering, Clean Energy and Green Computing, 2015, Dubai, UAE
- [11] Hussain A. Attia, BezaNegashGetu, “Design and Simulation of Remotely Power Controller”, International Journal of Applied Engineering Research, Vol. 10, No. 12, 2015, pp. 32609-32626
- [12] Yousif I Al-Mashhadany, Hussain A. Attia, “Novel Design and Implementation of Portable Charger through Low Power PV Energy”, Advanced Materials Research, Vol. 925, 2014, pp. 495-499
- [13] SudhaVenkatesh, KrishnaveniMuthiah, “Power Fluctuations – usage of servo voltage stabilizers in industries”, INTERNATIONAL JOURNAL OF APPLIED ENGINEERING RESEARCH, DINDIGUL, Vol. 2, No 1, 2011