Journal of Faculty of Engineering & Technology

journal homepage: www.pu.edu.pk/journals/index.php/jfet/index

DESIGN OF AN AC VOLTAGE STABILIZER BY USING INSULATED GATE BIPOLAR TRANSISTORS

O.M. Butt[*1], A.N. Aslam[2], H. Muazzam[3]

[*1] Department of Electrical Engineering, University of the Punjab, Lahore, Pakistan
[2] Department of Electrical Engineering, University of the Punjab, Lahore, Pakistan
[3] Department of Electrical Engineering, University of the Punjab, Lahore, Pakistan

Abstract

Demand of electricity is increasing day by day. With this rising demand some problems are arising in the current system. The major issue is the stability of voltage level in the system. As load is increased or sudden surge is occurred, a dip or overshoot is occurred in the voltage of the system. This has become a serious problem for domestic and especially for industrial user, as the sensitive equipment need a constant level of voltage to work. To make it happen, voltage regulators are required. Previously, techniques that were used for this problem were not efficient as they require much time to stabilize the output and have a distortion in output. So, a novel technique is proposed to counter this problem particularly for heavy industrial loads.

Keywords: Voltage Regulator, Pulse Width Modulation (PWM), Metal Oxide Semi-Conductor Field Effect Transistor (MOSFET), Buck-Boost, Insulated Gate Bipolar Transistors (IGBTs), Push-Pull

1. Introduction

There are many techniques to stabilize a voltage to a constant level. The most common method is by using a relay or a servo motor to change the tapings of transformer [1]. But a new design has substituted this technique which uses an electronic kit for the above purpose. This technique uses switching devices with a push pull topology. Previously MOSFETs were used in the circuit. These were feasible for low loads (under 8 amps) and have a range of 170 volt to 260 volts [2]. If MOSFETs are connected in parallel to increase the capacity of stabilizer for heavy loads, a miss matching was occurred [3].

Therefore, to meet the industrial demands of heavy loads, MOSFETs were replaced by IGBTs (STGE50NC60WD). These IGBTs have capability to bear a load of 50 amps (approx). Pulses of pulse width modulation (PWM) generated by the help of microcontroller (PIC) are

* Corresponding Author: osamabutt26@ymail.com

voltage to make it a constant level of 220 volt [2]. These IGBTs are not only favorable for heavy loads but are also advantageous because of negligible distortion and high switching speed. Beside high switching speed it also results in a pure sine wave at the output side of the stabilizer. The range of the stabilizer is set to 170 volts to 260 volts for prototyping, are not only favorable for heavy loads but are also advantageous because of negligible but it could be further increased just by a little change in the circuit configuration.

2. Background

In the previous work MOSFET IRF840 were used to buck or boost the unregulated voltage to a constant level [2]. A PWM inverter was used by using push-pull topology [4]. To increase the capabilities of the stabilizer, parallel MOSFETs were connected, but due to some properties and fabrication procedure of different producer, a mismatching was occurred. This mismatching results in serious problems of unbalancing, time delay during transition from DC to AC and even effects inverter's technical performance due to the burning of MOSFETs.

3. Design Topology

AC voltage Stabilizer is responsible for two main functions i-e buck or boost of voltage. These two functions are responsible to stabilize the output voltage. In this novel design, there is no mechanical moving part or MOSFETs as used in previous design. That is why this design compensates the voltage more rapidly than the old design. IGBTs (STGE50NC60WD) are used in this design [5]. This technique could bear heavy loads (approx 50 amp) than of MOSFETs. Following features make IGBT favorable for the said problem [6], [7]:

- High current capability
- High frequency operation
- Low CRES/CIES ratio (no cross-conduction susceptibility)
- Very soft ultra fast recovery anti-parallel diode

So, by using IGBTs this proposed design comprises on two parts:

- Control Design
- Buck/Boost Design

3.1. Control Design

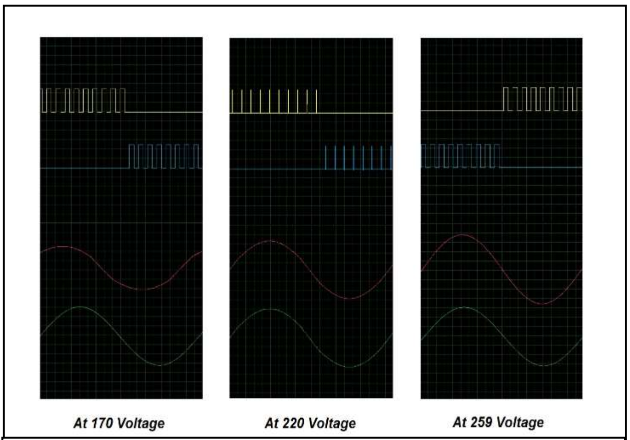
This part of the circuit consists of three major portions.

- Analog Signal
- PIC Microcontroller
- Pulse Width Modulation

First AC signal ranging 170 volts to 260 volts is scaled and converted into analog signal. This analog is than fed to PIC Microcontroller (PIC16F877A). This microcontroller converts this analog data into digital.

PIC is also favorable in this case as it can tolerate noise created by the analog signal of the input alternating current(ac supply), has built in analog to digital convertor(A/D convertor) and most importantly it has built in PWM (Pulse Width Modulation) module [8].

After the analog signal is digitalized, PIC16F877A produces pulse width modulation (PWM) on pin 16 & 17 [9]. This PWM is generated according to the input analog data and responsible to either buck or boost the input voltage. Magnitude of this voltage is dependent on the width of the pulses as depicted in figure 1. This PWM has approximately a frequency of 4.00 Khz.



Yellow, Blue = Pulse Width Modulation Train

Red = Input Ac Voltage

Green = Output

Pulses that are produced from the microcontroller according to the input, are then fed to a current booster circuit, where these pulses are amplified enough to drive the IGBTs [10].

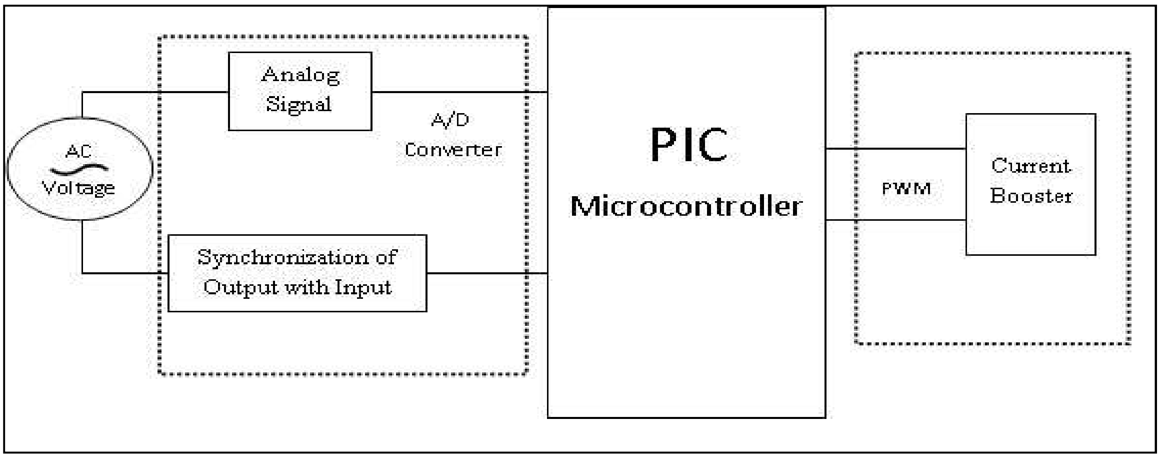


Figure 2: Control Section of Stabilizer

3.2. Buck/Boost Design

In the previous work, pulses from PIC were fed to MOSFETs (IRF840). But to increase the capabilities of stabilizer, IGBTs are introduced. Pulses are feed on the gate of the IGBTs [10] which are switched alternatively to produce an AC voltage which should be compensated from main voltages in order to stabilize the output. AC compensating voltages are generated by using push-pull topology. These IGBTs switches the rectified sine wave coming through the bridge rectifier to produce unfiltered sinusoidal wave as shown in figure 3 [11].

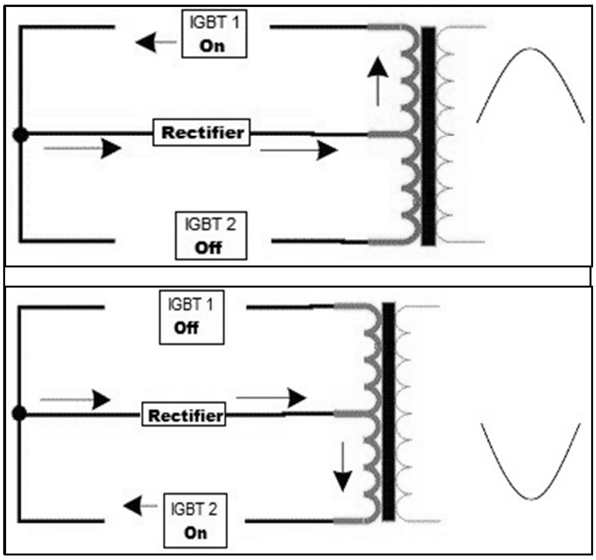


Figure 3: Push-Pull topology

Compensating voltages are generated on the secondary side of the transformer which is to be serially added in the main input voltage in order to stabilize the output. In the boost mode an in phase to the input voltage is generated of the magnitude to be added while in buck mode out phase voltage is generated to regulate the actual voltages.

A capacitor produces a link between the compensating voltages and original voltages which are to be stabilized. Another capacitor is attached at the primary side if the transformer. This is to smooth the output wave by removing the ripples as shown in figure 5.

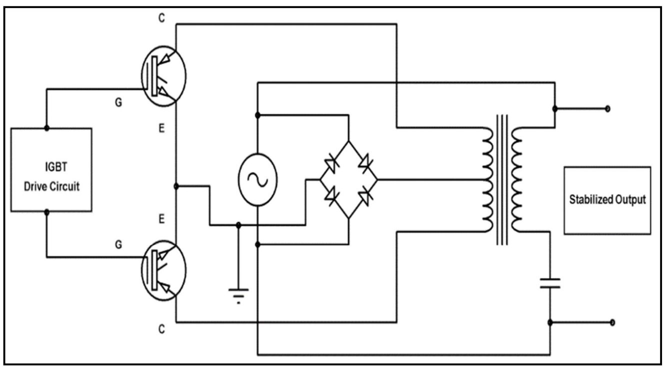


Figure 4: Buck/Boost Section of Stabilizer

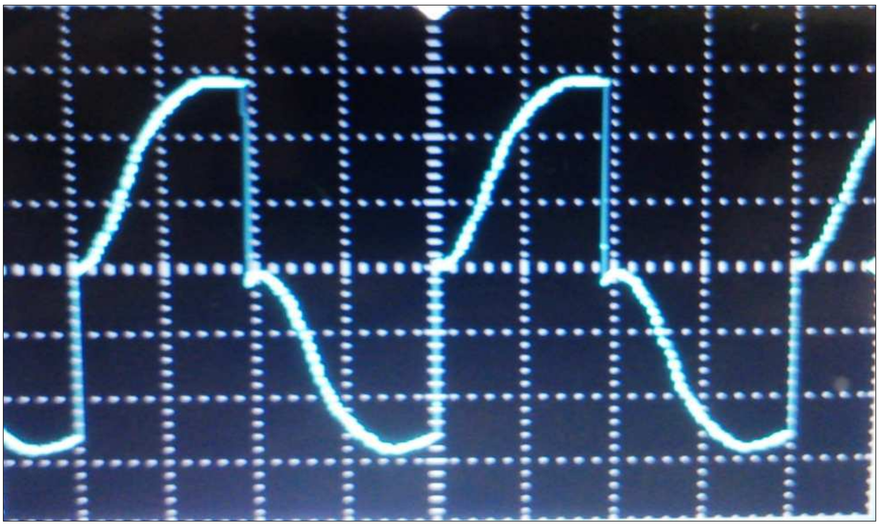


Figure 5: Unsynchronized output wave form

To synchronize this output waveform, pin 30 of PIC16F877A is used. This pin is attached with the input analog signal by a variable resistor. This variable resistor is used to synchronize the output waveform with input (as shown in figure 6).

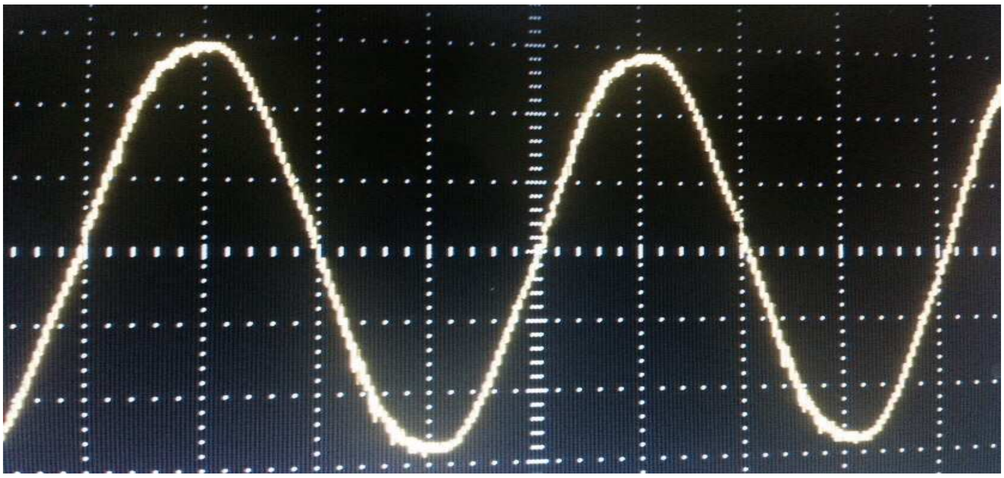


Figure 6: Synchronized output wave form

4. Conclusions

This advanced and novel technique is very much effective and reliable for heavy loads but uneconomical for domestic purposes. This design has negligible distortion with less response time, and produces a fine sinusoidal wave as output. Due to fast switching time, it can stabilize the output voltage in no time with a precision of 98% (approx). Last but not the least, this stabilizer need insignificant maintenance as no wear and tear occurs due to no involvement mechanical movement.

In future, this design may be modified another new design can be bring in for the three phase systems.

References

[1] S. Venkatesh, K. Muthiah, “Power Fluctuations – usage of servo voltage stabilizers in industries” International Journal Of Applied Engineering Research, DINDIGUL ISSN 09764259, Volume 2, No 1, pp 283 – 289, 2011

[2] O.M.Butt, S.M.H.Gillani, M. Ahmed, A.N. Aslam, H.T.Mustafa, “Alternating Current Voltage Stabilizer by Using Pulse Width Modulation” International Journal of Scientific & Engineering Research ISSN 2229-5518, Volume 5, Issue 12, pp 928 -931, December-2014

[3] Q. Kabashi, M. Limani, Nebi Caka, Milaim Zabeli, “The impact of mismatch threshold voltage MOSFETs in parallel connection of Push-Pull Power Inverter”, in of Proceedings of 2010 International Conference on Circuits, Systems, Signals at Malta, pp 328 – 332, 2010

[4] O. X. Avelar, O. de la Mora etal, “Implementing a Push-pull Voltage Inverter (DC-AC Converters)”, POWER ELECTRONICS (ESI 012A) Institution Tecnológico y de Estudios Superiores de Occidente (ITESO) Departamento de Electrónica, Sistemas e Informática (DESI), November 2009.

[5] “STGE50NC60WD N-channel 50A - 600V – ISOTOP Ultra fast switching Power MESH™ IGBT”, STMicroelectronics, July 2007.

[6] A.D. Rajapakse, A.M. Gole, etal,”Approximate Loss Formulae for Estimation of IGBT Switching Losses through EMTP-type Simulations”, Presented at the International Conference on Power Systems Transients (IPST’05) in Montreal, Canada , June 19-23, 2005

[7] D. Graovac, M. Purschel,” IGBT Power Losses Calculation Using the Data-Sheet Parameters”, Published by Infineon Technologies AG, Edition 2009-01-29, V 1.1, January 2009

[8] M.A. Mazidi, R.D. Mckinlay, D. Causey “PIC Microcontroller and Embedded Systems using assembly and C”, Pearson Education International.

[9] M. Verle, “PIC Microcontrollers”, 1st ed, Mikro Elektronika.

[10] M.H. Rashid, “Power Electronics Circuit Devices and Application”, 3rd ed, Pearson Education International, Upper Saddle River, New Jersey 07458.

[11] M. Šoja, S. Lubura, “Design of Transformer and Power stage of Push-Pull Inverter”, published in Electronics, Vol. 13, No. 1, pp 23 – 29, June 2009.