Investigation of Harmonic Distortion for Frequently Changing Input Voltage

Jyoti Lalotra¹, Abhinav Sharma², R. S. Chib³, Parveen Lehana⁴
¹Department of Electrical Engineering, IECs Polytechnic, J&K, India
²Arni University, H.P, India
³SKUAST-J &K, India
⁴Department of Physics & Electronics, University of Jammu, India
Email address: ¹jyotilalotra05@gmail.com, ²abhinavsangotra@gmail.com, ³pklehana@gmail.com

Abstract—This paper presents the concept of improving harmonic distortion in power systems. Investigations were carried out for studying the effect of range dependent voltage switching and random voltage switching (sudden changes) in the input line voltage on the harmonic distortion at the output of the system. The analysis of the results showed that the insulated gate bipolar transistor (IGBT) based power system using the concept of switching resistor is capable of reducing harmonic distortion on the input power lines introduced because of external or internal load conditions. Harmonic distortions in the input and output of the conventional systems are estimated and compared. Reduction in the total harmonic distortion (THD) was also investigated for the proposed IGBT based power system.

Keywords—Harmonic; IGBT; total harmonic distortion; dsPIC microcontroller; signal processing technique; power system.

I. INTRODUCTION

In the last couple of decades harmonics have become a major power quality problem in electric power systems. It is important to identify the harmonic sources in the system to solve and prevent harmonic related problems [1], [2]. Power systems with low harmonic distortion are the key requirement in the modern electronic power systems. Mostly, the power systems are based on switching of transformer tapings for changing the output voltage. The switching of tapings also introduces distortion in the output. In this paper novel approach using a switching resistor is proposed for reducing the distortion. Investigations are carried out to analyze the effect of load on the IGBT based power system developed using the concept of switching resistor. The scope of this research paper is to evaluate the harmonic distortion in modern power systems under different load conditions [3-15]. It has been observed from the literature review that more sophisticated systems are designed using IGBTs and dsPIC controllers. These systems may introduce or improve the amount of harmonic distortion in the output due to fast switching. The objective is to study the harmonic distortions of such systems as a result of varying the loads connected at the output.

The research work is carried out to investigate the effect of varying voltage due to range dependent voltage switching and random voltage switching keeping inductance, capacitance and resistance constant on the designed power system. Signal processing technique is used to calculation of THD.

II. METHODOLOGY

The figure 1 shows the block diagram of the system. It consist of six blocks namely variac, multimeter, power system, series combination of RLC load, load voltage level shifting, sound card with PC and signal processing unit. Input supply is given to variac ranging from 0 to 250 volt which is connected to the system for variation of voltage and also connected to the multi-meter for observing the input voltage. The output from the variac is applied to power system circuit. Power system block contains voltage measurement circuits; microcontroller based stabilization and input voltage level shifting. The voltage measurement circuit which consists of current transformer stabilizes the voltage.

![Block diagram of the experiment](image)

The microcontroller based stabilizer whose, main function to elevate or drop in the input voltage caused by the fluctuations are stabilized which also consists of microcontroller and driver circuits. The controller used in this circuit is DSPIC controller dsPIC30F2010. All decisions regarding stabilization of the power are taken by the microcontroller. The controller is connected to the stabilization block which contains IGBT (CT60), TL3842P current mode PWM controller, TLP250 gate driving circuit of IGBT and other peripheral devices through an isolator circuit consisting of HEF4050B buffer HEX non inverting buffer isolators and IRFB530 MOSFET. The output from power system block is applied to load. Load consists of series combination of power resistor, capacitor and inductor. These three combinations are used in the experiment. The input and output voltage level are observed by the multi-meter.

The figure 2 shows the results obtained for IGBT based power system with varying load conditions. It can be observed from the figure that the harmonic distortion in the output is reduced by using the concept of switching resistor. The results are compared with the conventional system and it is found that there is a significant reduction in the total harmonic distortion (THD) of the output.

The figure 3 shows the total harmonic distortion (THD) for different load conditions. It can be observed from the figure that the THD is reduced by using the concept of switching resistor. The results are compared with the conventional system and it is found that there is a significant reduction in the THD of the output.

The figure 4 shows the frequency spectrum for different load conditions. It can be observed from the figure that the frequency spectrum is altered by using the concept of switching resistor. The results are compared with the conventional system and it is found that there is a significant alteration in the frequency spectrum of the output.

The figure 5 shows the harmonic spectrum for different load conditions. It can be observed from the figure that the harmonic spectrum is altered by using the concept of switching resistor. The results are compared with the conventional system and it is found that there is a significant alteration in the harmonic spectrum of the output.

The figure 6 shows the waveform for different load conditions. It can be observed from the figure that the waveform is altered by using the concept of switching resistor. The results are compared with the conventional system and it is found that there is a significant alteration in the waveform of the output.

The figure 7 shows the experimental setup for the proposed IGBT based power system. The setup consists of variac, multimeter, power system, series combination of load RLC, sound card with PC and signal processing unit. The input supply is given to variac ranging from 0 to 250 volt which is connected to the system for variation of voltage and also connected to the multi-meter for observing the input voltage. The output from the variac is applied to power system circuit. Power system block contains voltage measurement circuits; microcontroller based stabilization and input voltage level shifting. The voltage measurement circuit which consists of current transformer stabilizes the voltage.

The microcontroller based stabilizer whose, main function to elevate or drop in the input voltage caused by the fluctuations are stabilized which also consists of microcontroller and driver circuits. The controller used in this circuit is DSPIC controller dsPIC30F2010. All decisions regarding stabilization of the power are taken by the microcontroller. The controller is connected to the stabilization block which contains IGBT (CT60), TL3842P current mode PWM controller, TLP250 gate driving circuit of IGBT and other peripheral devices through an isolator circuit consisting of HEF4050B buffer HEX non inverting buffer isolators and IRFB530 MOSFET. The output from power system block is applied to load. Load consists of series combination of power resistor, capacitor and inductor. These three combinations are used in the experiment. The input and output voltage level are observed by the multi-meter.
output voltages are recorded in the PC using sound card and voltage level shifting block. Thus it cannot be directly applied to the sound card, as circuit is developed to bring down the voltage level from hundreds of volts to millivolts. Signals are recorded and processed using Gold wave and digital signal processing software respectively. Input and output signals of total harmonic distortion are calculated by using the signal processing technique. Note the observation by changing the variac into two parts as under; in the first part of the experiment to investigates the change in harmonic distortion due to range dependent voltage switching. We take the reading of input and output voltage after every 10V intervals by changing the variac that’s ranging is 100 to 250 volts and also take the reading of variable voltage of load with AC input and output. The second part of the experiment to investigates the change in harmonic distortion due to random voltage switching. By suddenly changing the variac the effects are observed on the harmonic distortions and keeping all the conditions same as discussed in first part.

III. RESULTS AND DISCUSSION

To analysis harmonic distortion in the input and output caused by the variation of voltage and keeping the resistance, capacitor and inductance are constant. Input and output values of THD due to varying voltage are noted after duration of every 10V with the help of variac for limited time duration of 1s and sampling rate of 16,000 sa/s as shown in table I. The segments of signals are taken and processed to evaluate the harmonic distortion. Figure 2(a-p) represents the segmented input and output voltage waveforms for varying voltage and combinations of the load with duration of 0.3s. The calculated values of input and output of THD are plotted due to variation of voltage as shown in figure 3. As the value of voltage is increased then the input value of THD rises giving maximum and minimum values of 0.3126 and 0.1428 and output value is 0.2207 and 0.1018 respectively. Difference of input and output value of THD which can be seen in the plot is due to leakage of inductive and capacitive components. From this it is observed that that harmonic distortion in the output is less than the input and output values of AC with loads are shown in table II.

When switched on the system it gives the values of AC input and load. Thus the output of the system is connected to variable rheostat and also connected the multimeter and the output of variable rheostat gives the value of AC output due to variation of voltage we take 10V gap for variation of voltage. Input and output AC voltage due to varying voltage are plotted due to variation of voltage as shown in figure 4.
Fig. 2(a-p). Represents the segmented input and output voltage waveforms for varying voltage.

calculated. Figure 5(a-c) represents the segmented input and output voltage waveforms for sudden change the voltage and combinations of the load with duration of 0.3 s. The calculated value of input and output THD for random voltage switching are shown in table III.

Table III. Input and output value of THD for random voltage switching.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Random voltage (V)</th>
<th>Input THD</th>
<th>Output THD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>96 to 228</td>
<td>3.0792</td>
<td>2.4137</td>
</tr>
<tr>
<td>2</td>
<td>113 to 226</td>
<td>5.0394</td>
<td>3.2214</td>
</tr>
<tr>
<td>3</td>
<td>243 to 134</td>
<td>2.9577</td>
<td>2.1897</td>
</tr>
</tbody>
</table>

![Graph showing THD input and output](image)

Fig. 6. Experimentally value of input and output THD with the sudden change of variac rheostat.

The calculated experimentally values of input and output of THD are plotted in figure 6 with sudden change of voltage than the input and output value of THD rises giving maximum and minimum values of 5.0394 and 3.0792 and output value is 2.9577 and 2.1897 respectively. Some difference in input and output value of THD can be seen in the plot for certain combinations which arises due to leakage of the inductive or capacitive components and observed that the harmonic distortion in the output is comparatively less than the input.

IV. CONCLUSION

Investigations were carried out to study the effect of switching resistor connected at the output of an IGBT based power system on harmonic distortion in the output. The change in the harmonics distortion due to range dependent voltage switching and random voltage switching was investigated and also investigated the effect of stabilized/unstabilized voltage on the harmonic distortion. It was observed that the harmonic distortion in the output voltage was comparatively less than the input voltage.

REFERENCES


Er. Jyoti Lalotra received her M.Tech. Degree in EEE from Arni University, kathgarh, Himachal Pradesh, India and Bachelor degree in Electrical Engineering from M.B.S.C.E.T, affiliated to University of Jammu (J&K) and also received the Master of Business Administration from Lovely Professional University Jalandhar (Punjab), India. She received her Advance Diploma in industrial Automation & System Design from C-DAC, Mohali, Punjab and also received Advance Certificate in Power Distribution Management from Indira Gandhi National Open University, Regional Centre Jammu, India and presently working as lecturer in Department of Electrical Engineering, IECS polytechnic college, Jammu.

Er. Abhinav Sharma received his M.Tech. Degree in Electrical and Electronics Engineering from Arni University, Kathagarh (H.P), India and B.E. Degree in Electrical Engineering from Mahant Bachittar Singh College of Engineering and Technology, University of Jammu, India. He received his Advance Diploma in industrial Automation & System Design from C-DAC, Mohali, Punjab and also received Advance Certificate in
Power Distribution Management from Indira Gandhi National Open University, Regional Centre Jammu, India.

**Er. Randeep Singh Chib** received his M.Tech. Degree in Electrical Engineering from MMU, Mullana, Ambala, India and B.E degree in Electrical Engineering from Model Institute of Engineering & Technology, University of Jammu, India. He worked as Assistant Professor in Arni University and presently working as JRF in SKUAST-J, Jammu, India.

**Dr. P.K Lehana** (Associate Professor) received his Master degree in Electronics from Kurushetra University in 1992. He worked as lecturer in Guru Nanak Khalsa College, Yamuna nagar, Haryana for next two years. He qualified NET-JRF in Physical science in 1994 and got selected as permanent lecturer in A. B. College, Pathankot, where he worked for one year. He also qualified NET-JRF in Electronic Science and presently working as Associate Professor in Physics and Electronics Department, University of Jammu and received his Ph.D. degree from IIT, Bombay in Speaker Transformation. He also invited for conducting workshops on MATLAB/simulinks in different esteemed institutions/colleges. His research interests include Speech recognition, Speaker transformation, Signal processing, Speech signal processing, Analog and Digital signal processing, Nanowires characterization, Robotics, Image processing, Analog communication, Digital communication, Microwaves and Antennas, Electronics and control systems, Instrumentation, Electronics system designing, etc. and having more than 100 publications in national/international conferences and journals. He has a lot of experience in guiding M.Tech, M.Phil, Ph.D. students and other researchers also.