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Investigation of the Effect of Inductive Load on Harmonic Distortion of IGBT based Power System

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Abstract*— Research work carried out to investigate the effect of loads (combination of resistive, capacitive, and inductive) on the IGBT based power system. Total harmonic distortion in the input and output is calculated. Eight different combinations of the load are taken with different values of inductance keeping resistance and capacitance constant. Input and output voltages were recorded for all combinations using Gold wave software having duration of 1 sec with sampling rate of 16,000. A computer algorithm is designed to calculate total harmonic distortion in the input and output of the system. The designed microcontroller and IGBT based power system shows reduction in the distortion at the output.

Index Terms*— Power system, harmonics, Total harmonic distortion.

I. INTRODUCTION

Now a day's power electronics plays a very important role in electrical engineering and demand of power electronics devices are also increase such as inverter, converter and supplies of power in daily life [1].This system also contribute the problem of power quality and electronic devices are very sensitive to disturbances and less tolerant to power quality problems such as voltage drop and harmonic [2]. Area of Power electronics is growing broadly such as transportation, industrial, commercial [3-5] and utility system applications. Most popular power devices such as IGBT (insulated-gate-bipolar-transistor) Metal oxide semiconductor field effect transistors (MOSFET), (Gate-turn-off-Thruster) GTO [6-7]. Power system harmonic are not new fact. It is mainly caused by saturation of loads such as transformers, industrial arc furnaces, cables, Switching mode power supplies and other devices [7].

A harmonic is a sinusoidal component of a complex wave or quantity having a frequency that is an integral multiple of the fundamental frequency [8].

$$f_h = (h) \times (\text{Fundamental frequency})$$

where h is an integer

Harmonic distortions waveform extremely alters the shape of the sinusoid. However, no matter the level of complexity of the fundamental wave, it's just a combination of multiple waveforms called harmonics. The research work is carried out to investigate the effect of impedance i.e. change in the inductance keeping capacitance and resistance constant on the designed IGBT based power system. Signal processing technique is used to evaluate the effect of the impedance and calculation of total harmonic distortion (THD).

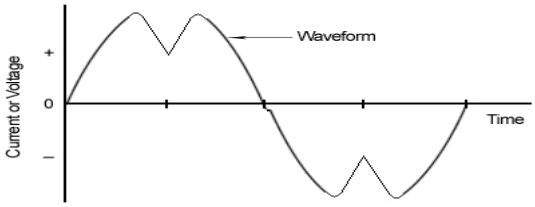

Figure 1: Distorted waveform [9].

II. TOTAL HARMONIC DISTORTION

It is defined as the ratio of the sum of the powers of all harmonic frequencies above the fundamental frequency to the power of the fundamental frequency [10].

$$THD = \frac{\sqrt{\sum n^{\infty} = 2I_{gn}^2}}{I_{g_1}}$$

A. Total harmonic current distortion

It is the ratio of the harmonic current to the non- harmonic current measured for that load point.

$$I_{thd} = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 \ldots\ldots I_n^n}}{I_1} \times 100\%$$

B. Total harmonic voltage distortion

As harmonic current flows through reactance or resistance, a voltage drop is arises. These harmonic voltages cause voltage distortion of the fundamental voltage waveform [11].

$$V_{thd} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 \ldots\ldots V_n^n}}{V_1} \times 100\%$$

C. Effects of harmonic distortion

The effect of current distortion on distribution system can be seriously issue because harmonic does not transfer any power .harmonic current can affect the malfunction of electrical equipment over heating the conductors, motor and transformer insulation failure. Harmonic current can also increase the transformer losses [12].

There are various effect can be described as

- Effect of harmonic on generators, machine, transformers etc

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- Harmful effects of harmonics on ac side.
- Effects of harmonics on power factor, television interferences, TV etc.

III. LOADING EFFECT ON SUPPLY VOLTAGE

Loads are important for analysis and simulation of the dynamic behavior of electric power system [13-14]. Some types of load are designed to trip the voltage sag protect it due to damage [15]. So that both static and dynamic loads have major impact on voltage stability of power system [16-17].Power system load can be performed in two way (1) analysis by similar load and then using predetermined value for each parameter the load [18-19] or (2) selecting a load model and then performing parameter estimation by using appropriate identification technique.

Static load model are very simple method it principle to reflect the voltage and possible frequency dependence of the active and reactive components of the loads. Dynamic load model are of two types: linear dynamic load model and non linear dynamic load. In many cases the uses if static load may be inappropriate due to their failure to accurately reflect the influence of the load on system stability [14] [19-20].

IV. METHODOLOGY

The schematics block diagram of the system as shown in Figure 2. The operation starts by taking the 230 V, 50 Hz AC from the main supply. The blocks consists of voltage measurement circuits, the second block is the stabilization block. Voltages measurements are done at the input and output section of stabilizer. The voltage measurement circuit consists of current transformer. The output of the voltage measurement block is given to the DSPIC controller PIC30F2010. All decisions regarding stabilization of the power are taken by the microcontroller. The controller is connected to the stabilization block which contains IGBT, 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 IRFBE30 MOSFET). Drop in the input voltage caused by the fluctions are stablized by the this block. The output from stabilizer is applied to load. Load consists of series combinations of power resistor, capacitor and inductor.

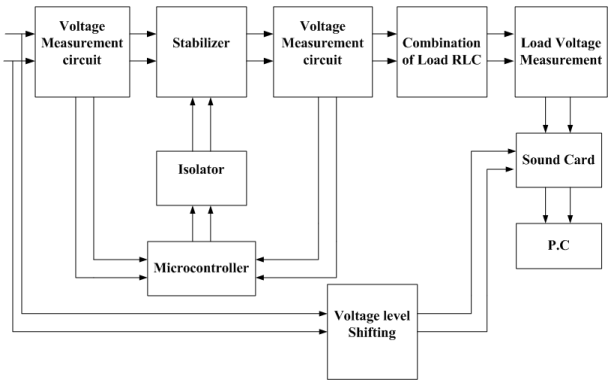

Figure 2: Schematics of the complete block diagram of the system.

Different combinations of impedance are taken shown in Table 1. Eight combinations of the load are taken inductance ranging from approximate value of 250 mH to 1200 mH keeping resistance 36 Ω and capacitance 15 µF. The input and output voltages are recorded in the PC using sound card and voltage level shifting block. This block is required to bring down the voltage level from hundreds of Volts to millivolts, so that it can be applied to sound card. Signals are recorded and processed using Gold wave and digital signal processing software respectively. The sampling rate and duration of measurement are kept at value of 16000 and 1 sec respectively.

Table 1: Different Combination of Load RLC

S NO	R (ohm)	L (mH)	C (µF)
1	36	1232.0	15
2	36	1073.0	15
3	36	873.0	15
4	36	729.5	15
5	36	590.6	15
6	36	470.2	15
7	36	363.0	15
8	36	269.1	15

Total harmonics distortion of the input and output signals are calculated using signal processing technique. The flow diagram of the designed computer algorithm to calculate the THD is shown in Figure 3.

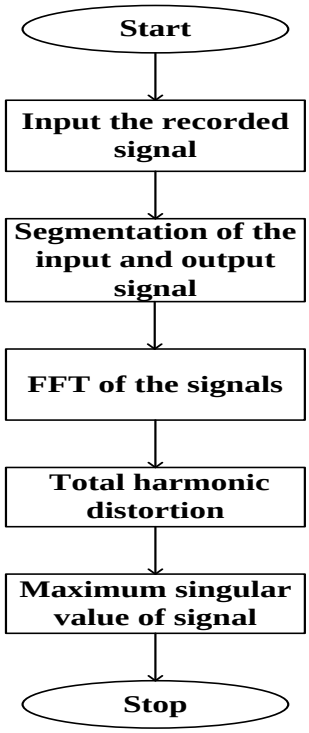

Figure 3: Algorithm flow chart to calculate THD.

V. RESULT AND DISCUSSION

The experiment is carried out to investigate the efficiency of IGBT based stabilization and analysis of harmonic distortion in the input and output caused by various combinations of inductive, capacitive and resistive load. Combinations of load taken in the experiment are shown in

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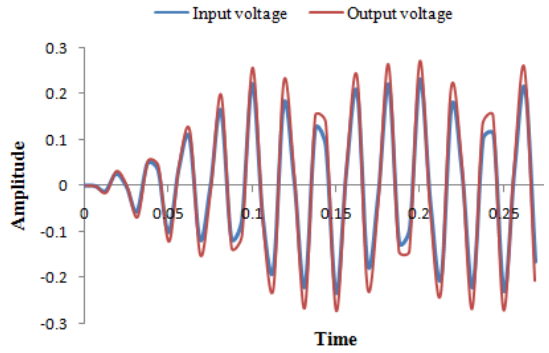
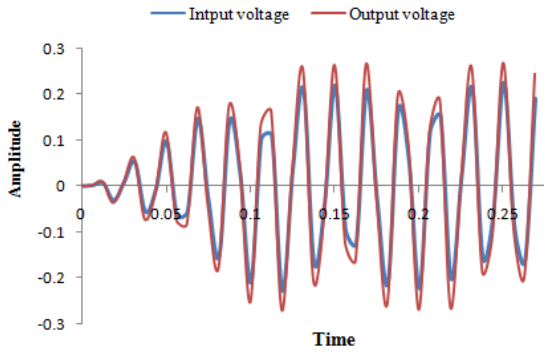
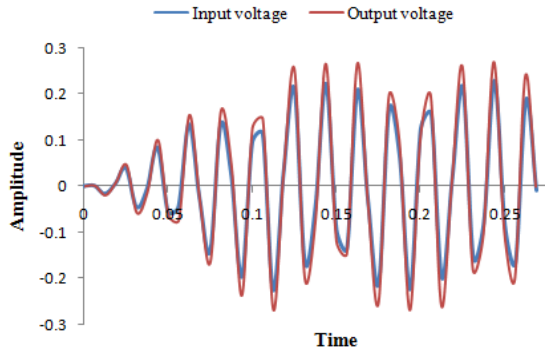
Table 1. Input and output voltages for various combinations were recorded for limited time duration of 1 sec with sampling rate of 16,000. The signals were processed using signal processing technique to evaluate the harmonic distortion. Segment of the signals are taken and harmonic distortion in them are calculated. Figure 4(a) to Figure 4(h) represents the segmented input and output voltage waveforms for eight different combinations of the load with duration of 0.25 sec.



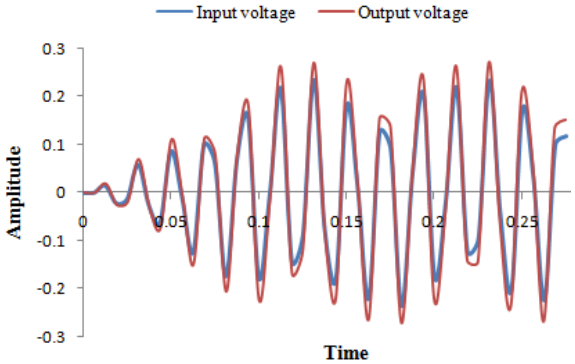
(a): Z = 178.20 ϕ =78



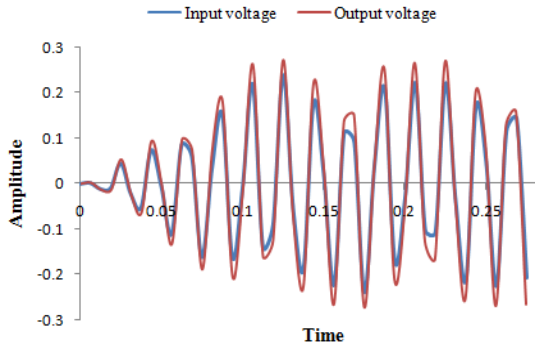
(b): Z =129.70 ϕ = 73



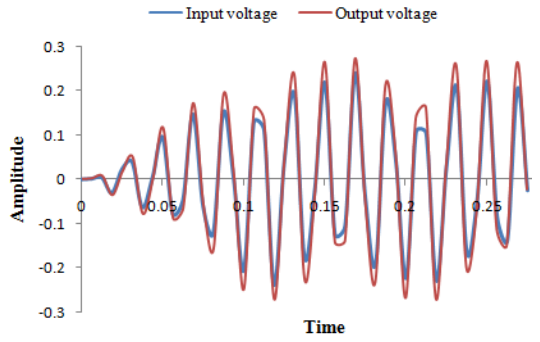
(c): Z =71.52 ϕ =59



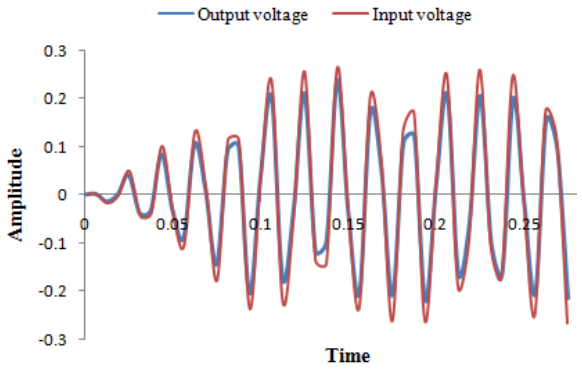
(d): Z =39.70 ϕ =25



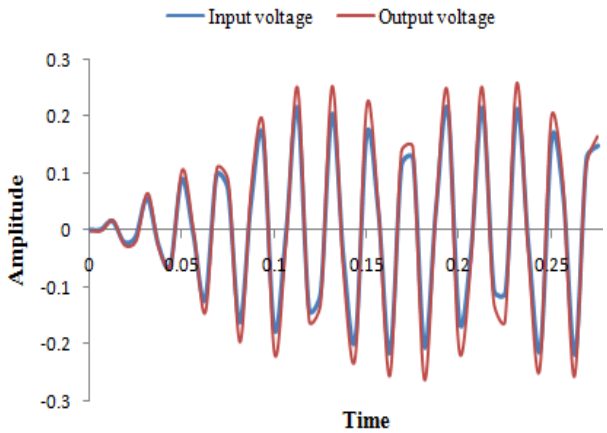
(e): Z =44.91 ϕ =-36



(f): Z =74.01 ϕ =-60



(g): Z =104.71 ϕ =-69



(h): Z =132.79 ϕ =-74

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Figure 4: Input and output voltage signals (a to h) with eight varying values of inductance and constant values of resistance and capacitance. Signal recorded at 16,000 sampling rate.

Impedance of the load is calculated according to the following formula given below:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

where $X_L = 2\pi fL$ and $X_C = \frac{1}{2\pi fC}$

The calculated value of impedance, input, and output total harmonic distortion for eight different load values are given in Tables 2.

Table 2: Input and output value of THD

S NO	Impedance Z	Input THD	Output THD
1	178.20	0.2548	0.1875
2	129.70	0.2798	0.1996
3	71.52	0.2963	0.2117
4	39.70	0.2191	0.1580
5	44.91	0.2862	0.2072
6	74.01	0.1688	0.1222
7	104.71	0.2853	0.2048
8	132.79	0.2445	0.1815

The calculated experimentally values of input and output of THD are plotted in Figure 5 with different impedance values.

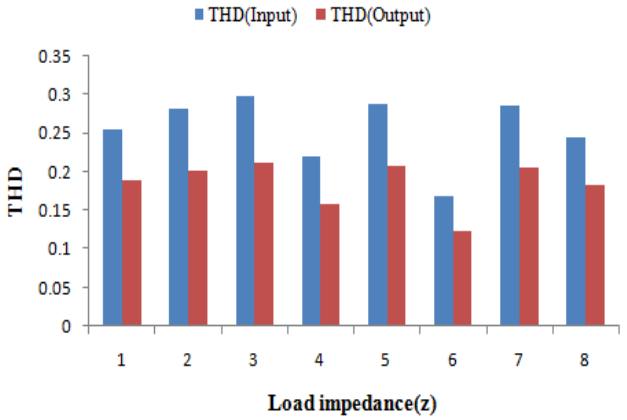

Figure 5: Experimentally values of input and output of THD with different impedance values.

As the values of the impedance is decreased i.e. variation in the value of inductance from Henry (H) to mH, the input and output value of total harmonic distortion (THD) rises giving maximum and minimum values of 0.2548 and 0.2445 and output value is 0.1875 and0.1815 respectively. There is also some difference in input and output value of THD is seen in the plot for certain combinations which may arise due to leakage of the inductive or capacitive components. Form the calculated values of THD in input and output it is observed that the harmonic distortion in the output is comparatively less than the input.

VI. CONCLUSION

In this research work carried out effect of loads (combination of resistive, capacitive, and inductive) on the IGBT based power system causing harmonic distortion is investigated. Eight different combinations of the load are taken with different values of inductance keeping resistance and capacitance constant. Input and output voltages were recorded for all combinations using Gold wave software with sampling rate of 16,000. A computer algorithm is designed to calculate total harmonic distortion in the input and output of the system. The designed microcontroller and IGBT based power system reduced the distortion in the output. The maximum value of THD in the input is 0.2963 and corresponding output THD is 0.2117.

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