First International Conference on Emerging Trends in Engineering, Management and Scineces"
December 28-30, 2014 (ICETEMS-2014) Peshawar, Pakistan

SINUSOIDAL SYMMETRICAL & ASYMMETRICAL PWM BASED THREE PHASE INVERTER DESIGN

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Abstract

Power Inverters have a high range of applications not only in domestic appliances but also in industries for performing variety of operations regarding switching and conversion of electrical energy. The purpose of this research paper is to analyze a three phase inverter using PWM topology to obtain a smooth and pure sinusoidal wave form of good quality which ensures better operation for sensitive electronic appliances.

A pulse width modulated voltage wave form is generated using an efficient inverter design to minimize the Total Harmonic Distortion (THD). A three phase inverter was evaluated first for symmetric PWM modulation and then for asymmetric modulation. In symmetric PWM modulation the reference is sampled at positive peak of carrier signal and is held constant till next positive peak of carrier signal appears. In asymmetric modulation technique reference signal is sampled at positive as well as negative peak of the carrier signal and held constant between two sampled points. An analysis has been performed to evaluate the effectiveness of the two techniques using simulation models in Matlab/Simulink. The THD analysis as well as Fourier analysis of the designed symmetric and asymmetric inverter is performed using Simulink. The results for different cut-off frequencies have been shown. With optimal modulation index value and number of levels for lower harmonics, it is shown that sinusoidal PWM based inverters not only provide good quality voltage but also reduces voltage stresses on the switches. Furthermore THD is effectively decreased by optimizing cut off frequency of filters.

Keywords

3 Phase inverter, PWM technique, THD, FFT Analysis, Sinusoidal Waveforms.

1. Introduction

The importance of low and medium power in industrial, residential and various renewable systems has enhanced the use of power converters. An efficient power converter should provide energy efficiently in wake of outages, grid uncertainty, weakening of power quality and power security etc. To meet the increasing energy demands, renewable energy resources such as Photo Voltaic (PV), Wind, Bio mass etc. provide a good solution. However for these systems, DC voltage needs to be converted to AC output using an inverter. The output of the inverter can be controlled as a voltage or current source of better quality. Different types of inverters have been designed for different applications both for voltage demand and power applications. Inverters are mainly used in AC motor drives, power supplies, and uninterrupted power sources. To ensure better operation of power electronic appliances, inverters are designed with different operating schemes. Yumurtaci et al. [7] studied current harmonics for different PWM control techniques i.e. Sinusoidal PWM (SPWM), Square Wave PWM, Carrier Based SVPWM and Space Vector PWM (SVPWM) techniques. The results showed that total harmonic distortion is considerably reduced in SVPWM technique that prevents unnecessary switching due to less commutation losses. They found that for same modulation index the output voltage of SVPWM is higher as compared to other Pulse Width Modulation techniques. Similarly, the application of vectorial control is easier in Space Vector PWM technique that has more advantage than other PWM techniques. Bharath et al. [1] carried out their research work on multi-level inverter topologies with improved DC link utilization and harmonic spectrum. Level shifted carrier based PWM technique is used for reducing the Total Harmonic Distortion (THD) having triangular waves as carriers. Experiments indicate that multi-level inverters has high power rating, less switching and conduction losses, and the ability to with stand high switching stresses. Calais et al. [2] examined the behavior of a single phase five level cascaded inverter by using multicarrier PWM techniques. For a symmetrical H-Bridge Multi-Level Inverter the output voltages are greater for high modulation frequencies and its consistency increases by decreasing the number of DC sources. Tolbert and Habetler [6] worked on fixed frequency carrier based PWM method for balancing the switching duty cycle among different levels of the inverters. The research presented a two novel carrier-based multilevel PWM technique to enhance the switch operation in multilevel inverters. For this purpose a 10 kW prototype six-level diode-clamped inverter has been built and controlled with the novel PWM technique that acted as a voltage-source for a motor drive. Dujic et al. [3] carried out their research work on space vector theory regarding PWM waves in order to demonstrate the behavior of multi-phase systems. Experiments suggest that space-vector (SV) PWM provides same switching pattern as carrier-based (CB) PWM with a proper common-mode voltage injection into the modulating signals. Sumithira and Kumar [5] proposed PWM switching technique for getting rid of harmonics occurring in low order of the output waveform. The PWM and SPWM techniques were examined comparably in order to compute satisfactory modulation index value, ANFIS (Adaptive Neuro Fuzzy Inference System) was implemented. Simulation results showed effectiveness of PWM technique as it lowers the harmonic distortions. Shankar et al. [4] carried out research work on a new type of cascaded inverter. The selective harmonic elimination of a new family of multilevel inverters using Genetic Algorithm (GA) has been presented. The new configuration has benefit of a reduced number of switching devices compared to traditional configuration of the same number of levels. The GA technique usually produces more than one possible solution set for each harmonic profile and a given specific modulation index. For multiple outputs, solution that gives lowest THD is selected. Both simulation and experimental results showed that the algorithm can be effectively used for selective harmonic elimination.

This paper is aimed to minimize the influence of total harmonic distortion by using PWM methodology for both symmetrical and asymmetrical signals. In addition to pulse width modulation, the PWM inverters have an additional circuit for protection and voltage control. The output of a PWM inverter is further purified using a second order filter for different cutoff frequencies.

1.1 Symmetrical & Asymmetrical PWM Signals

Symmetric PWM signal are those signals, whose pulses are symmetrical about the center of each PWM period, while Asymmetric PWM signals are those signals having similar side associated with one termination of each PWM period. As shown in Fig (1).

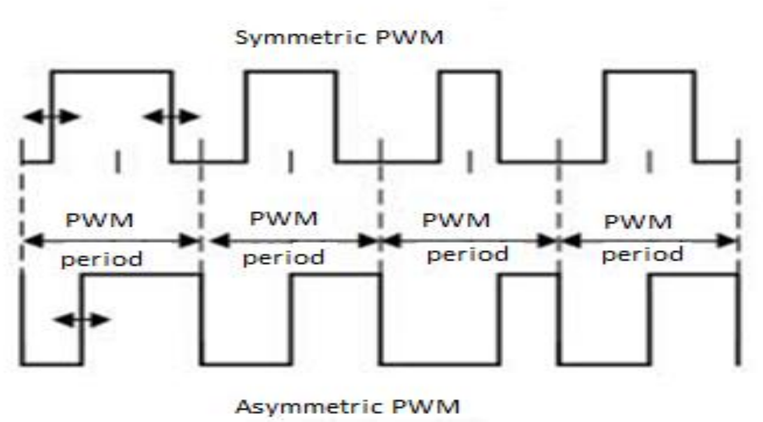

Fig 1: Symmetric & Asymmetric PWM signal

1.2 Pulse Width Modulation Based Inverters

Pulse width modulation is used in inverters to give a steady output voltage. Fig (2) shows pulse width modulation technique. These signals are pulse trains with stable frequency and magnitude while the pulse width is variable. For on-off operation a PWM signal is applied to the gate of a power transistor.

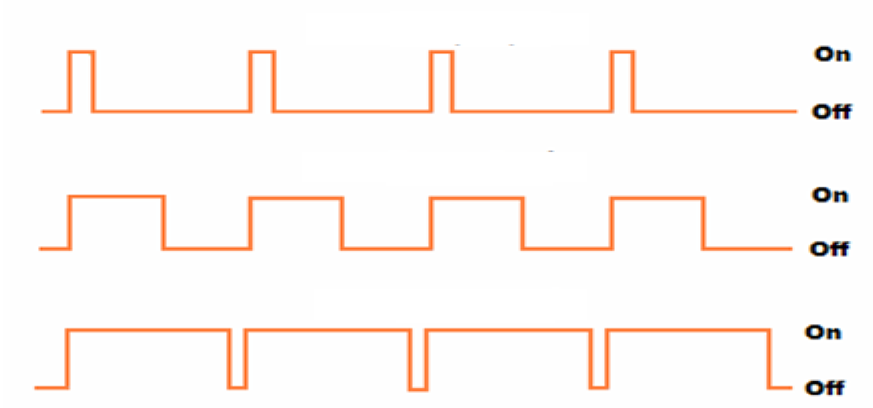

Fig 2: Pulse width modulation for different duty cycles

1.3 Simulation of Symmetrical & Asymmetrical PWM Based 3 Phase Inverter

A three phase sinusoidal PWM based inverter with symmetrical and asymmetrical topology has been designed and simulated using MATLAB/SIMULINK. The three phase PWM based inverter has been modeled using six switches (GTOs), arranged in three legs, two in each leg, and provided with a DC source. GTO's gate pulses were provided from PWM pulse Generator. Sinusoidal (Symmetrical and Asymmetrical) Pulse Width Modulation (SPWM) has been adopted to obtain minimum THD in output. Triangular Carrier signals have been selected with carrier signal amplitude compared with reference signal amplitude. To operate the switches properly modulation index has been varied between 0 and 1. By changing peak amplitude (Vm) of the reference signal, a phase shift of 0^o, 120^o and -120^o has been selected in the reference signal for 3-phase. Fourier Transform Analysis have been performed, THD and harmonic spectrum of the simulated wave forms were obtained and analyzed. THDs for different cut-off frequencies were obtained and compared for symmetrical and asymmetrical sinusoidal signals. The overall block diagram of the proposed system is shown in Fig (3).

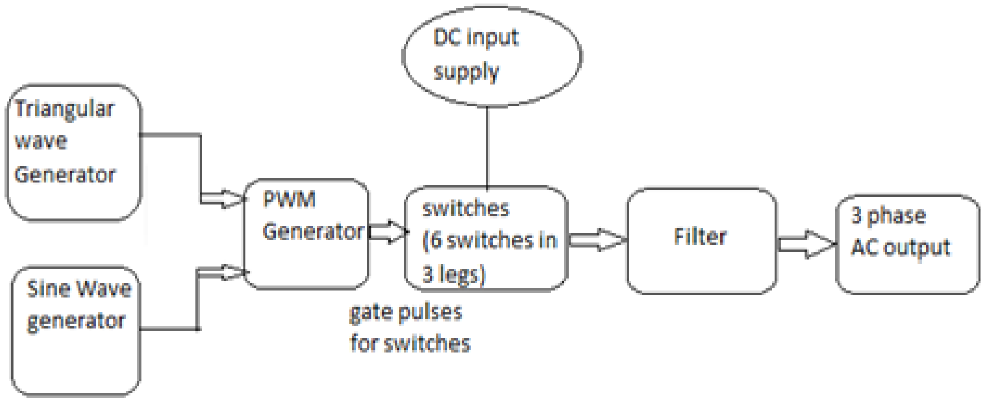

Fig 3: Block diagram of the proposed symmetric/asymmetric 3 phase inverter

The complete simulation model of 3 phase sinusoidal symmetric & asymmetric PWM based inverter is shown in Fig (4).

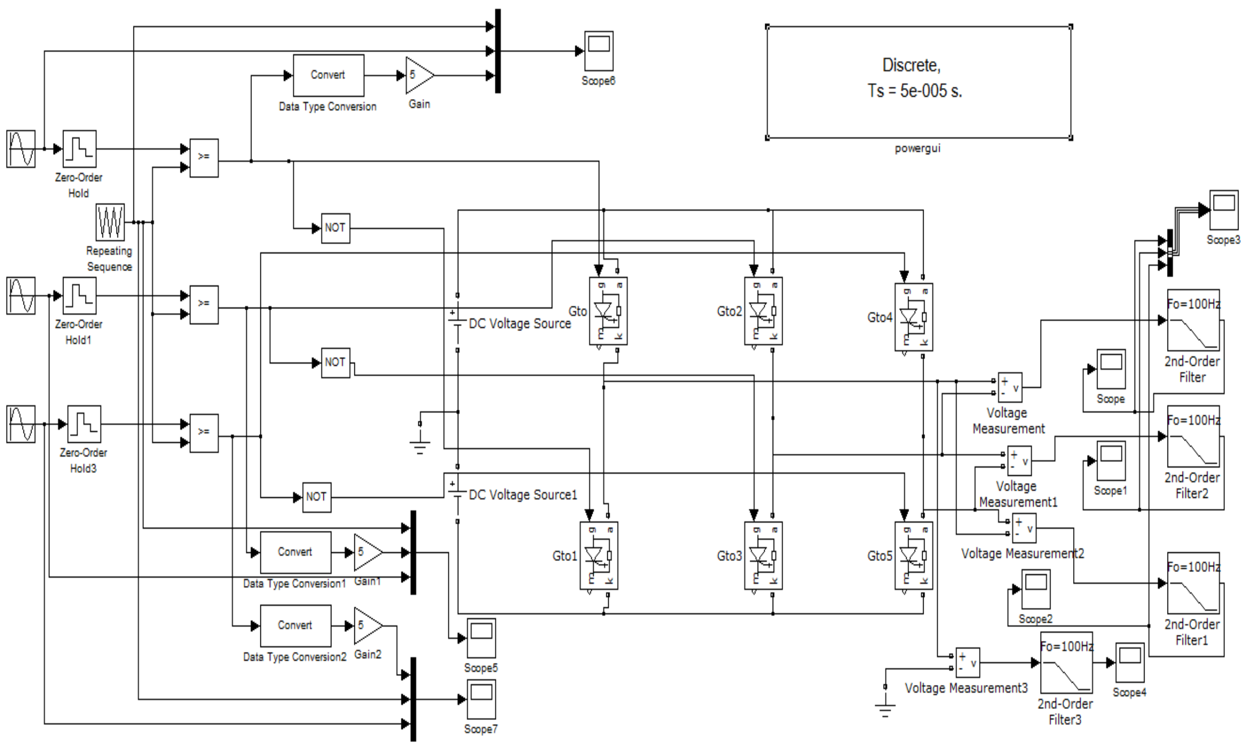

Fig 4: Simulation model of sinusoidal symmetrical & asymmetrical PWM based 3 phase inverter

Gate pulses generated by comparing carrier signal (triangular) and reference signal (sinusoidal) are shown in Fig (5). Individual output AC waveforms obtained from each leg after passing through 2nd Order filter are shown in Fig (6), (7) and (8) respectively.

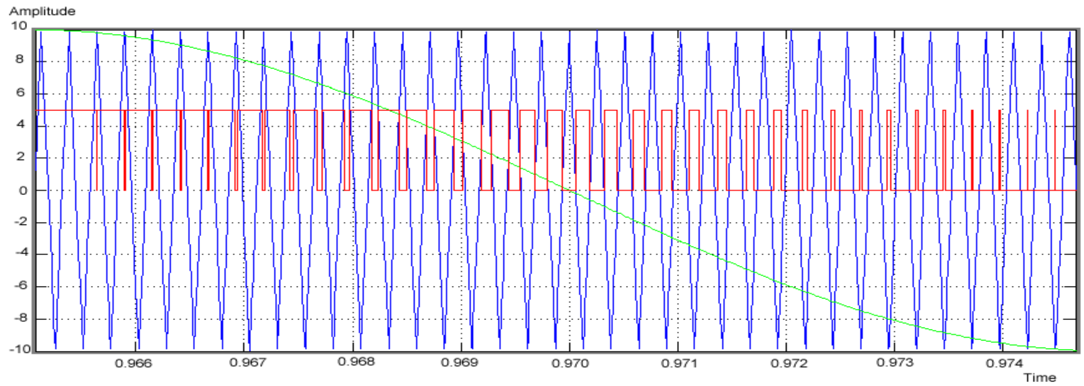

Fig 5: Gate pulses for switches operation

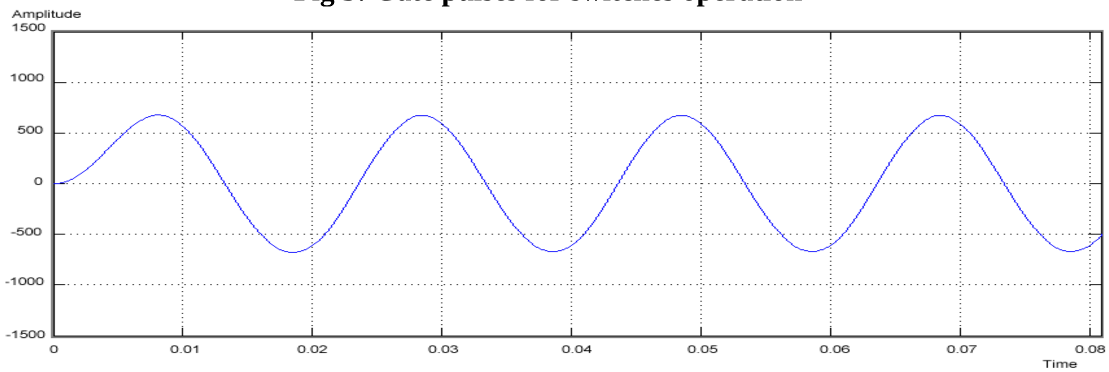

Fig 6: Output AC wave form from 1st leg

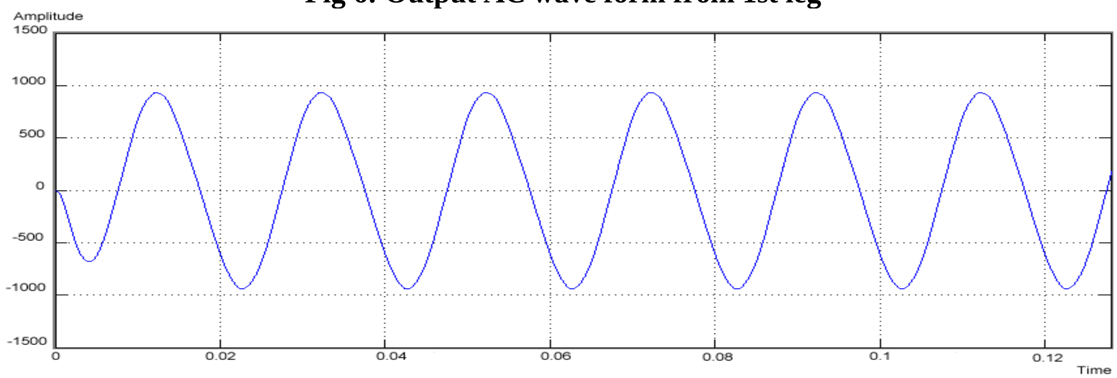

Fig 7: Output AC wave form from 2nd leg

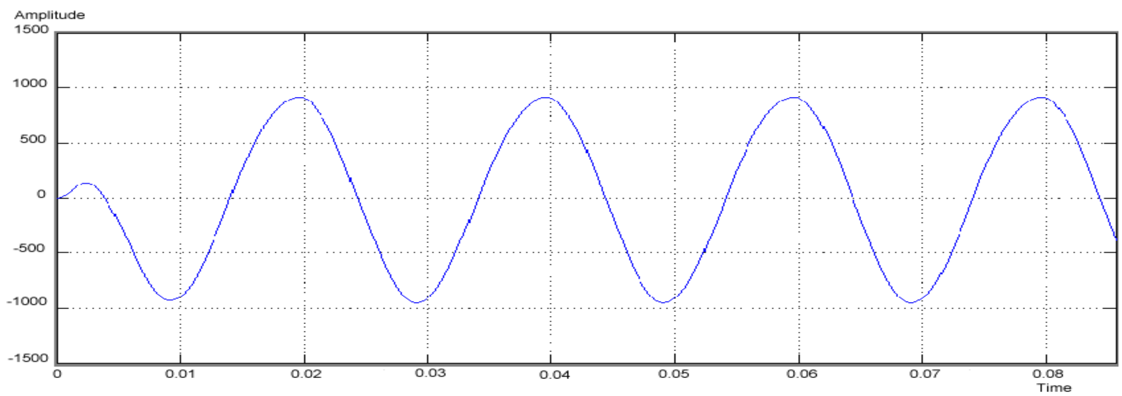

Fig 8: Output AC wave form from 3rd leg

The 3 phase output AC waveform obtained from all the six switches is shown in Fig (9).

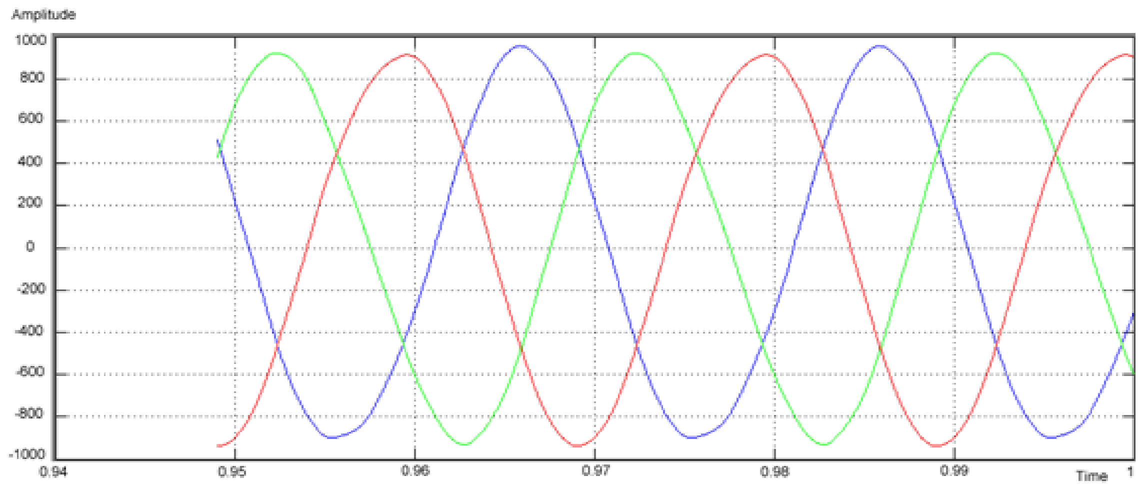

Fig 9: Three phase output AC wave form

1.4 Tatal Hormonic Distortion (THD)

Filters are used to reduce THD. By varying the cut-off frequency f_o of a filter the THD can be controlled i.e. as cut-off frequency decreases THD also decreases. The cutoff frequency is characteristic of filtering devices, such as RC circuits. At this point, the amount of attenuation due to the filter begins increase rapidly. The magnitude of low frequency signals is relatively unaffected before the cutoff frequency. After the cutoff frequency, however, we see much more attenuation

Total Harmonic Distortion (THD) for different cut-off frequencies has been evaluated. Evaluation of THD has been performed for symmetrical and asymmetrical PWM signals. As cut-off frequency decreases THD (%) also decreases. The behavior of symmetrical & asymmetrical PWM signals for cut-off frequencies i.e. 200 Hz, 100Hz and 50Hz are shown in Fig (10), Fig (11) and Fig (12).

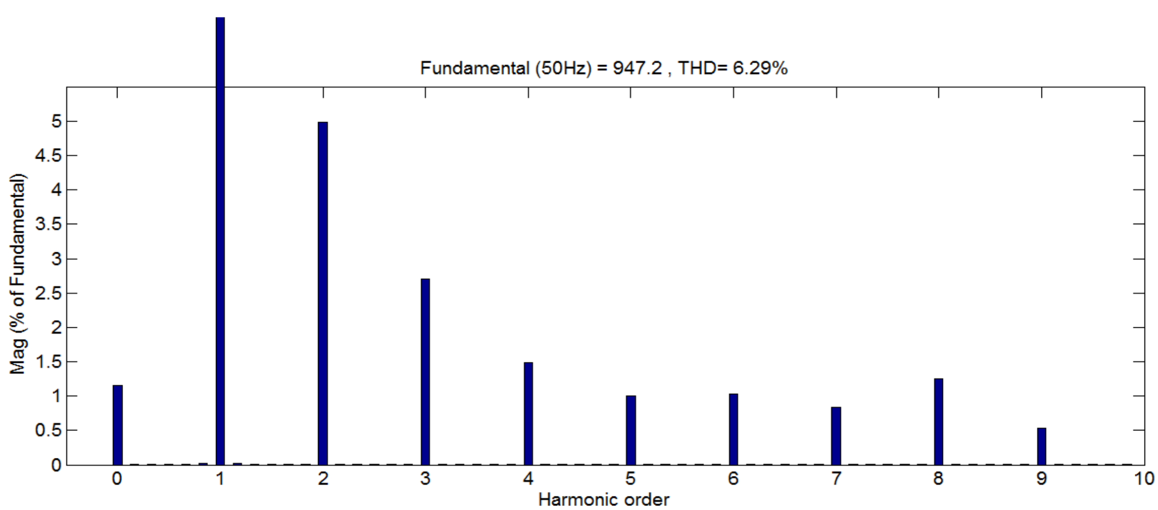

Fig 10(a): THD (%) FFT analysis for Symmetric PWM signal (cut-off, f=200Hz

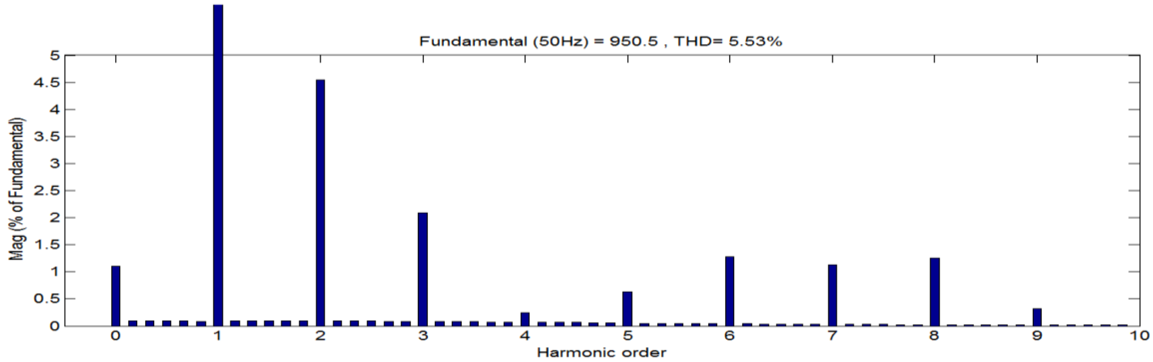

Fig 10(b): THD (%) FFT analysis for Asymmetric PWM signal (cut-off, f=200 Hz)

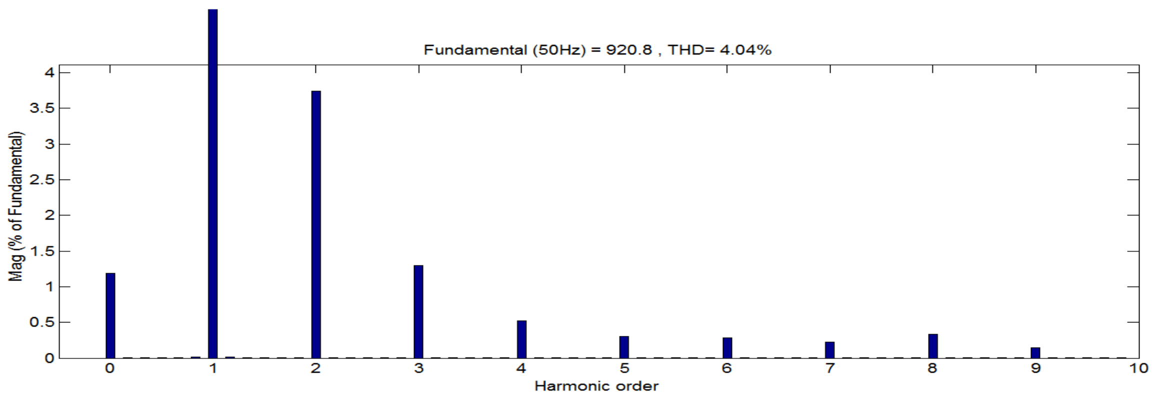

Fig 11(a): THD (%) FFT analysis for Symmetric PWM signal (cut-of, f=100 Hz)

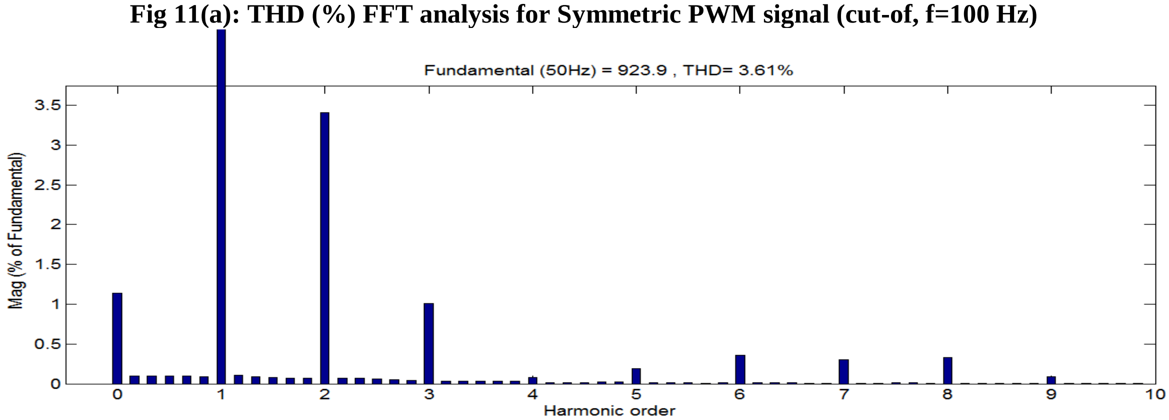

Fig 11(b): THD (%) FFT analysis for Asymmetric PWM signal (cut-off, f=100 Hz)

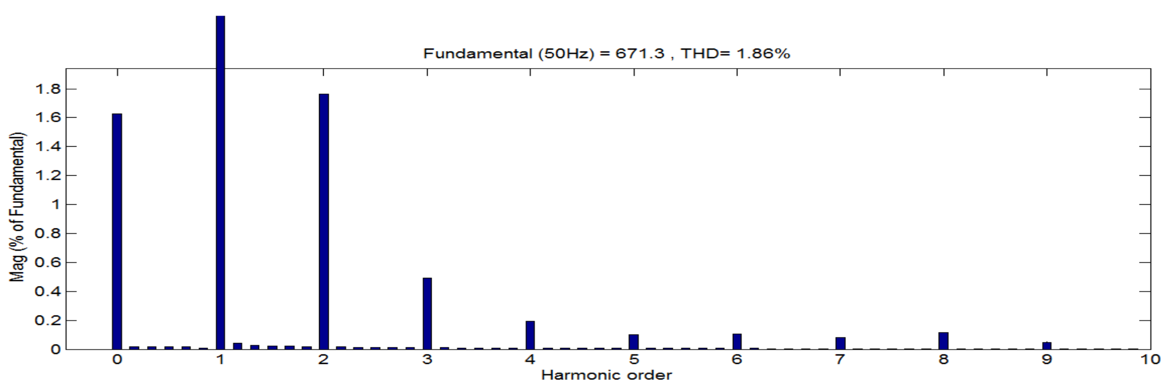

Fig 12(a): THD (%) FFT analysis for Symmetric PWM signal (cut-off, f=50 Hz)

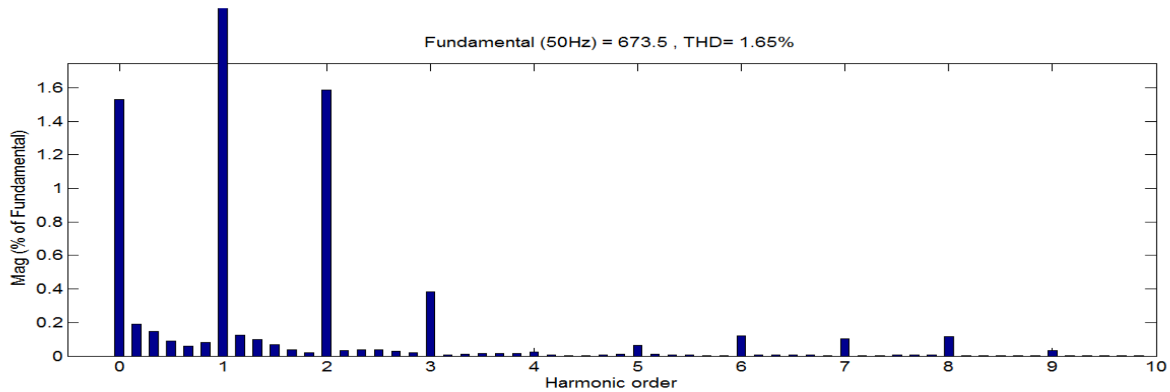

Fig 12(b): THD (%) FFT analysis for Asymmetric PWM signal (cut-off, f=50 Hz)

2. Conclusion

In this research paper we have evaluated that, In Sinusoidal PWM Based inverters the voltage quality can be enhanced and voltage stresses can be reduced upon switching components, further more Total Harmonic Distortion (THD) can be decreased considerably using PWM based inverters, lowering the Cut-off frequency of low pass filters resulting in an output wave form closely approaching to a sinusoidal waveform. Solving certain issues of voltage balancing and generation of accurate gate pulses for switching, Sinusoidal PWM Based inverter has achieved a remarkable place in industrial application as well as in renewable power sources. The THD analysis using MATLAB/ Simulink program has been performed for different cut-off frequencies. As cut-off frequency decreases THD (%) also decreases.

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