151. Comparative Power Quality Analysis of Voltage Source Inverter Topologies

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Abstract

Due to increase in power demand day by day it is beneficiary to connect renewable energy sources like solar, wind, fuel cell, geo thermal energy, etc which are unlimited unlike conventional energy sources, pollution free and environmental friendly, to the grid. Utilization of alternative energy and interconnection with the grid is not easy hence power electronics converter are used for this purpose. The power inverter is a key component in most alternative energy systems. In this paper, an experimental and simulation study is done to investigate the performance of voltage source inverter topologies. In ac the quality of sinusoidal waveform is more important than the quantity. In order to achieve that, inverter with less harmonics is needed. For this purpose, the power quality analysis of square wave inverter and phase shift inverter is carried out through Matlab simulation and results are validated with experimental results. The performance of these inverters are evaluated in terms of Total Harmonic Distortion, power factor and true power. The simulation results are in good agreement with experimental results. It is concluded from simulation and experimental results that the total harmonics distortion in voltage and current waveforms of phase shift inverter are 17.7% and 20 % is less than the square wave inverter but with scarifying in active power and power factor.

Keywords: *Power Quality Analysis, Voltage Source Inverter, Square Wave Inverter, Phase Shift Inverter.*

1. Introduction

Since environmental pollution are increasing day by day there is need of natural resources like photovoltaic and wind energy for power generation application [1-3], which are environmental friendly and free from pollution and are abundant in nature [4, 5]. Since the output of solar and wind are dc and almost all home appliances works on ac power, therefore there is dire need to convert dc power into ac [6]. The device which converts dc power into conventional ac is known as inverter.

The inverter has been widely used in many fields, such as the motor control, the UPS, and the solar inverter systems etc. The inverters are power electronics converters which enables for converting dc to ac power by using the power electronics devices like the IGBT and MOSFET [7]. Traditionally, many inverter systems will be implemented by the analogue components. As the development of the digital processors, more and more low-cost and high-performance microcontrollers have gotten into the market. At the same time, more and more inverter systems tend to use the microcontrollers to implement the digital controller, which cannot only simplify the system structure but also improve the output performance of the inverters [8].

As the pure sine wave inverters are superior in quality and performance, very low harmonic distortion, reliable for many sensitive electronics load and won't make any noise and heating in inductive load [9, 10] but in-spite of all these advantages, drawbacks of pure sine wave inverter is, it is very much expensive, high switching losses, requires significant control circuitry and output power is also low as compared to Square Wave Inverter [11]. Therefore this paper focus on inverters which are less expansive, high output power, low switching losses that are Square Wave and Phase Shift Inverter [12].

Square Wave inverters are simplest and cheapest from all other kinds of inverter. Square wave can be obtained from simple full bridge inverter with appropriate switching of switches when the input is dc. Output seen from square wave inverter is either maximum or minimum or zero voltage/current depending on switches on and off state [13].

The output waveform of phase shift inverter is analogous to square wave with some exception that output waveform of phase shift inverter becomes zero for a while before swapping to positive and negative half cycles. Phase shift inverter have fairly improved characteristics than Square Wave inverter even though still economical [14].

Both Square wave inverter and phase shift inverters are perfect for Equipment that runs on Non-Sinusoidal Current [15]. Both inverter use dc power in more efficient way to overcome this job. Output of these two inverters is usually sufficient to run many small and medium electronic devices with some distinct exceptions [16].

Every power electronics converters have some power quality issues. From the literature review it is found that the main issue of power quality related to these inverters is harmonics [17].

2. Simulation Model

The simulation model of single phase inverter is shown in Fig. 1 In this model three phase ac supply is converted into single phase dc and then filtered out by using capacitor, then this dc is fed as an input to inverter. IGBTs are used in inverter circuit. By giving suitable pulses to IGBTs the output seen from inverter is square wave and phase shift. Fast Fourier Transform (FFT) tool of MATLAB software is used to analyse the total harmonics distortion of inverters.

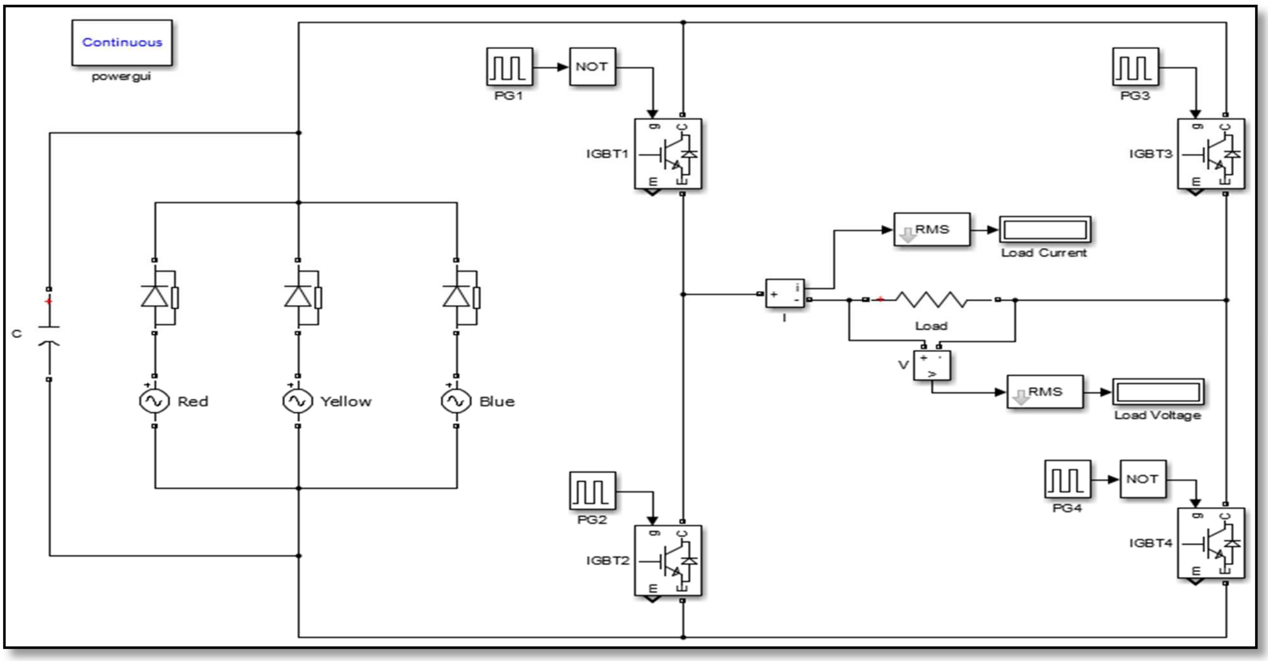

Fig. 1. Simulation Model of single phase inverter.

3. Harmonic analysis of Simulation Model of an inverter

In this work, the harmonics of single phase square wave (S.W.I) and phase shift inverters (P.S.I) are analysed. The output voltage waveform of square wave inverter is shown in Fig. 2 (a) while its harmonic spectrum is illustrated in Fig. 2 (b).

FFT analysis of inverters are done to see the magnitude of harmonics present in the output of inverters. The output voltage waveforms of both inverters have no dc component and very less magnitude of even harmonics.

(a) (b)

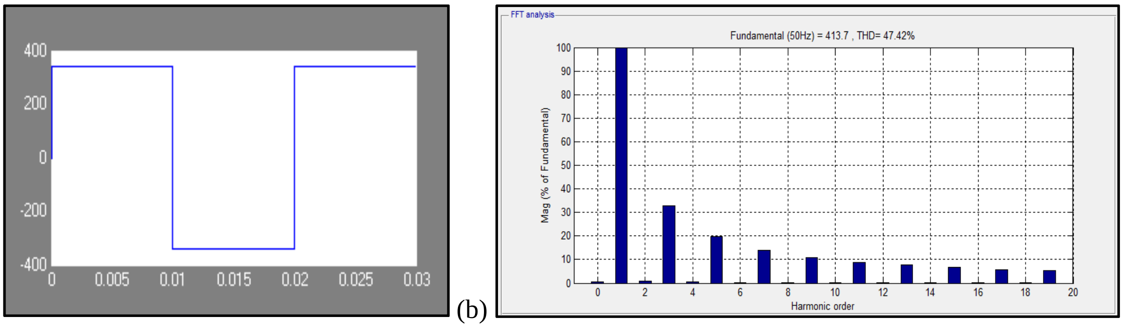

Fig. 2. (a) Voltage waveform of S.W.I (b) %THD of Square Wave Inverter.

4. Experimental setup

In order to validate the simulation results of inverters, an experimental setup as shown in Fig. 3 has been established. Power quality analyser (Fluke 43B) is used at different points to take readings of THD, active power, power factor and to see the waveforms. The recorded results of power quality analyser are further analysed in Fluke view software. In experimental setup input is 3phase ac supply which is converted into single phase dc by using diodes and which is fed to inverter. Here resistive and inductive loads are connected to see behaviour of inverters at different loads.

Fig. 3. Experimental Setup.

5. Waveforms and THD Graphs from Experimental Setup

Waveforms and THDs are very important to see the behaviour of inverter. The waveform as shown in Fig. 4 (a) gives the magnitude of voltage of square wave inverter (S.W.I) at resistive load. From PQ analyser it can be seen that the output THD harmonics or square wave inverter is 46.7% shown in Fig. 4 (b).

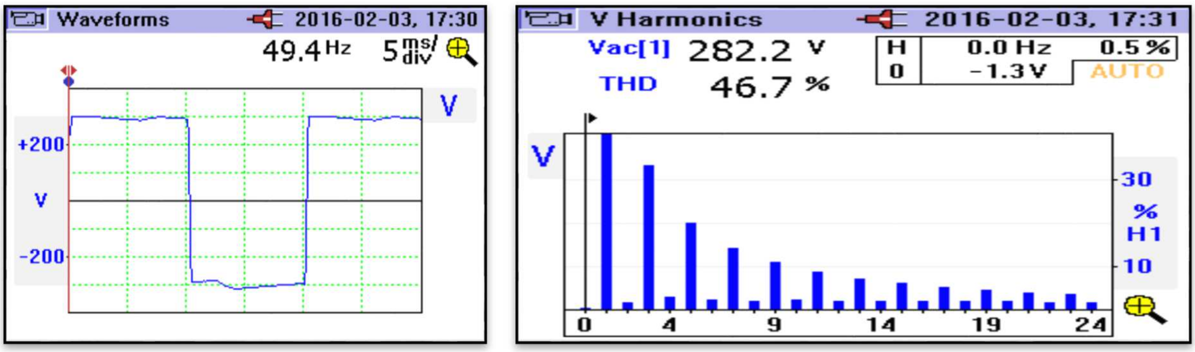

Fig. 4. (a) Voltage waveform of S.W.I (b) %THD of Square Wave Inverter.

6. Result Discussion

6.1. Inverter parameters from experimental Model

Table 1 shows inverter parameters from experimental model at resistive and inductive loads. Various parameters such as THDs of Voltage and current, power factor and active power is taken from PQ analyser. It can be seen from measured values that the square wave inverter has high % THD in voltage and current at both R and at RL loads. On the other hand, phase shift inverter has lower value of THD in voltage and current but with sacrificing in active power and power factor values.

Table 1. Inverter Parameters from experimental Setup

	At Resistive Load				At Inductive Load			
	% THD (Voltage)	**% THD (Current)**	**Active Power**	**Power Factor**	**% THD (Voltage)**	**% THD (Current)**	**Active Power**	**Power Factor**
Square Wave Inverter	46.7%	48.0%	192W	0.989	48.0%	41.8%	464W	0.960
Phase Shift Inverter at 60^0	30.4%	31.4%	145W	0.979	31.4%	29.0%	361W	0.949
Phase Shift Inverter at 120^0	29.7%	28.0%	107W	0.972	30.5%	28.2%	280W	0.937

6.2. THD Comparison of Simulation Model and Practical Setup at R Load

To validate the results, THD values of square wave inverter and phase shift inverter at resistive and at inductive load taken from simulation model are compared with results obtained from experimental model. Table 2 showing comparative THDs of voltage and current at resistive and at inductive load through simulation and through practically.

Table 2. Comparative %THD of simulation model with experimental results at R and RL load

	At Resistive Load			At Inductive Load		
	Square Wave Inverter	**Phase Shift Inverter at 60^0**	**Phase Shift Inverter at 120^0**	**Square Wave Inverter**	**Phase Shift Inverter at 60^0**	**Phase Shift Inverter at 120^0**
THD (V) Hardware	46.7%	30.4%	29.7%	48.0%	31.4%	30.5%
THD (V) Simulation	47.42%	31.09%	28.79%	47.42%	35.34 %	33.14%
THD (I) Hardware	48.0%	31.4%	28.0%	41.8%	29.0%	28.2%
THD (I) Simulation	47.42%	31.09%	28.79%	41.68%	29.63%	28.61%

7. Conclusion

In this research work, simulation models of square wave and phase shift inverters have developed in MATLAB software. Also the experimental setup of proposed inverter topologies had done. The harmonics of simulation and experimental models are analysed.

It is clear from results, that more pure, safe and suitable electrical energy source is Phase Shift Inverter but with sacrificing in Power and P.F and also expensive then Square Wave Inverter. On the other hand Square wave Inverter have more output with greater P.F but %THD is greater and are mostly used at domestic level due to low cost.

8. Future Work

In this research work comparison of inverter parameters through simulation and through practically are done. This research work can be extended to minimize the harmonics of these inverters. Filters can be design to make its output sinusoidal for the use in most sensitive devices and equipments like medical devices etc. Results obtained in this research are very useful for the designer to design inverter for different purpose like for renewable energy grid connection or for standalone applications etc.

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