International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 2 Issue 11‖ November 2013 ‖ PP.53-61

Harmonic Analysis of Inverter

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ABSTRACT: This paper deals with harmonic analysis for different types of inverter. To reduce harmonic content filters are designed which in turn improves power factor and efficiency of the system. And also various PWM techniques are used to reduce %THD within IEEE standard. The design and simulation of system is done using MATLAB / SIMULINK and output waveforms and %THD is evaluated.

INDEX TERMS : Types of Inverter, Filter, Harmonics, PWM technique.

I. NOMENCLATURE:

THD – Total Harmonic Distortion
PWM- Pulse Width Modulation
SPWM- Sinusoidal PWM
MI- Modulation Index
VSI- Voltage Source Inverter
MLI- Multi Level Inverter
DCMLI- Diode Clamped MLI
CHB- Cascade H- Bridge Inverter
V_r - reference wave
V_c- carrier wave

II. INTRODUCTION

Increase in the demand of renewable energy sources, inverters plays a vital role in distribution side. But inverter should meet some requirements,

- Output of inverter should be pure sinusoidal for voltage and current.
- %THD of both voltage and current should be within the limit of 5%.

When these converters are interface with system it suffers by harmonics and which will be a great challenge to eliminate it. To reduce harmonic which is present in system filters are used. Most traditionally LC filters are design to bring down %THD. Even different PWM techniques are used in minimization of harmonics. MLI has an attractive advantage such as better utilization of switching device so that switching losses are reduced and efficiency of system is improved. Hence it is widely used in the renewable energy application. This paper focuses on designing of different types of inverters with various PWM techniques and the compares the %THD values.

A. Harmonics and its effects

Harmonics are mainly due to the introduction of non linear loads into the system which draws non sinusoidal voltage and current across network. Some examples of loads which produce harmonics are VAR compensators, inverter, and DC converter. The presence of harmonics results in poor power factor, failure of operation, and poor efficiency, shortens equipment life. And even it leads to overheating of lines, transformers and generators to excessive iron losses. Due to these problems, energy delivered to the end user is an object of concern and power engineer faces the challenge of solving the problem harmonics.

B. Pulse Width Modulation

The basic concept of PWM technique is which compares the carrier wave with reference wave and generates the pulse accordingly.

$$MI = \frac{Vr}{Vc} \qquad (1)$$

Modulation index controls the harmonic content of output voltage waveform.

C. Filter

To avoid effect of harmonics on the operation of sensitive equipments, it is necessary to have harmonic contents within limit and it is achieved by installing filter at load end. Filters are specially designed to remove unwanted frequency component which is present in the signal. Different types of filters are passive, active and hybrid filters. Passive filter are simple in designing and low cost.

Inverter

Inverter which converts DC power input into AC power at desired output voltage and frequency. They are broadly classified into two types based on their operation:

- Voltage Source Inverter

A. Single phase VSI
B. Three phase VSI
C. Current Source Inverter.

Thyristors are used in inverter it requires forced commutation, hence it uses transistor like GTO, MOSFET, BJT, IGBT. In this paper IGBT is used, generally it has the switching frequency of 50 KHz and voltage and current rating of 1200V/500A.

a) Voltage control technique

In industrial, control of voltage is necessary to meet the requirements. Various controlling technique are

1. External control of AC output voltage
2. External control of DC input voltage
3. Internal control of inverter

Among these three techniques, the efficient method of controlling voltage is internal control of Inverter. (PWM). Here, single PWM, SPWM, are discussed and %THD is compared. Advantage of three phase inverter 120 mode is that switching loss is less when compared to three phase inverter 180 mode.

TYPES OF INVERTER - SIMULATED

The following circuits were simulated. Their specification are provided in Table I, Table II, and Table III

[1] Single phase full bridge VSI with RL load
[2] Three phase VSI – 120˙ and 180˙ Mode with RL load
[3] Single phase – 3 & 5 Level DCMLI with RL Load
[4] Single and three phase – 7 level cascade H bridge MLI with RL Load.
[5]

III . UTPUT WAVEFORM & FFT ANALYSIS FOR DIFFERENT INVERTERS

A**. Single phase full bridge inverter**

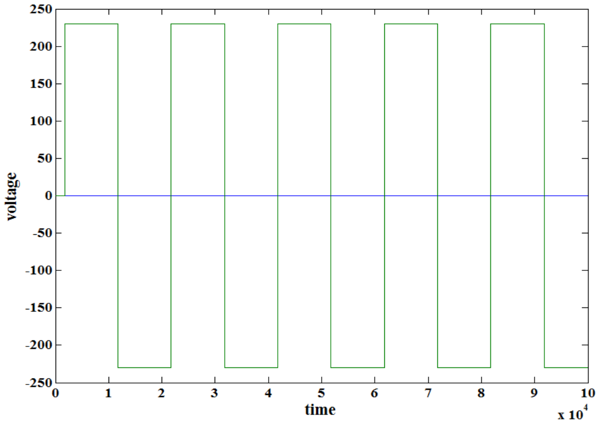

Fig.1 output voltage waveform

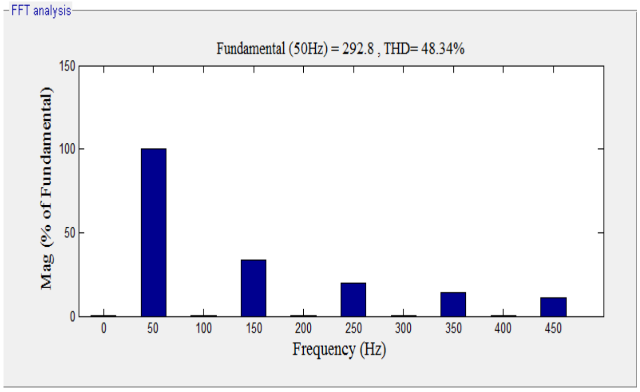

Fig.2 FFT analysis of output voltage

B**. Three phase full bridge inverter ($120^{\cdot}$ Mode)**

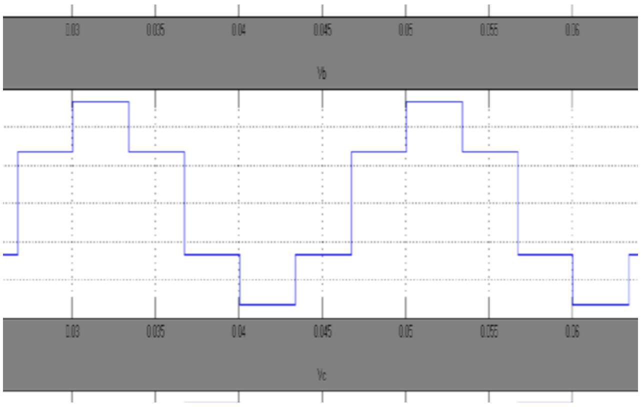

Fig.3 output voltage waveform

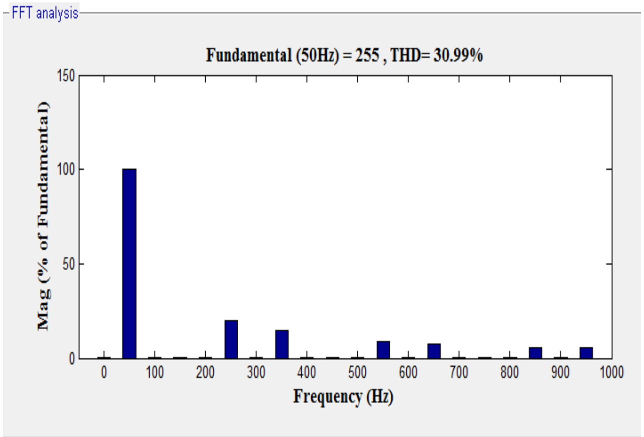

Fig.4 FFT analysis of output voltage

B.1. Three phase inverter (180° Mode)

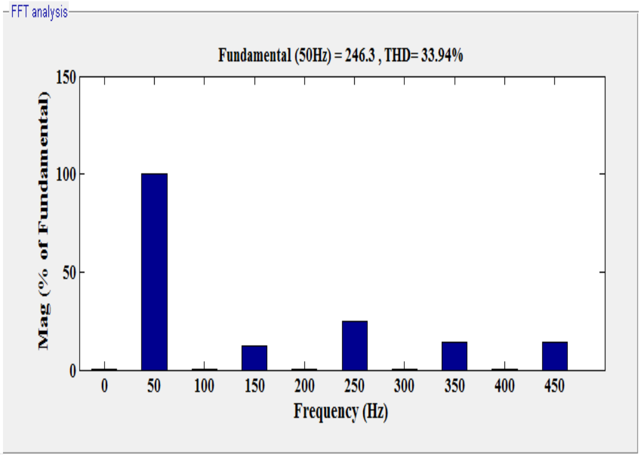

Fig.6 FFT analysis of output voltage

C. Single phase full bridge inverter with filter

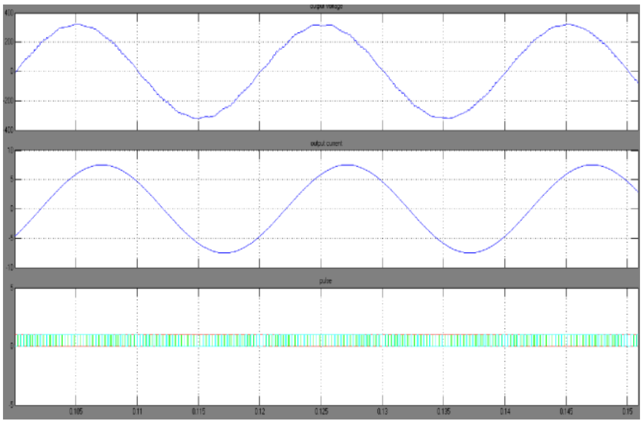

Fig.7 output voltage and current waveform

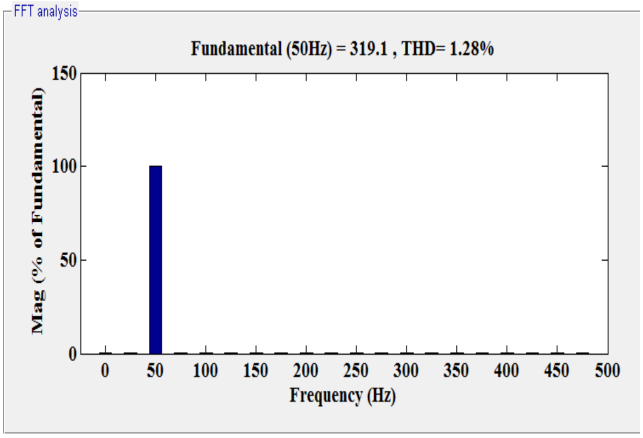

Fig.8 FFT analysis of output voltage

D.Three phase full bridge inverter with filter

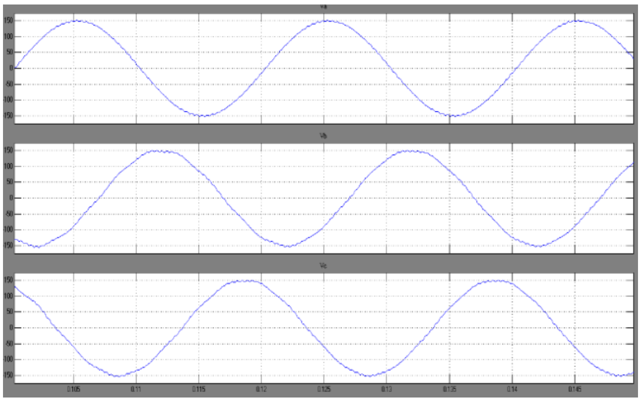

Fig.9 output voltage waveform

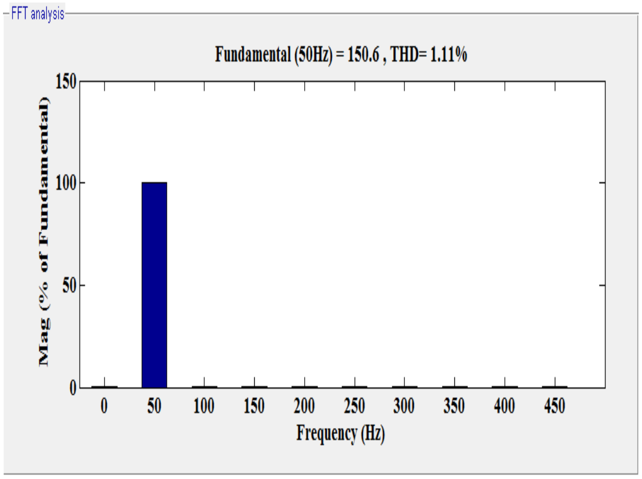

Fig.10 FFT analysis of output voltage

E. Single phase 5 – level DCMLI

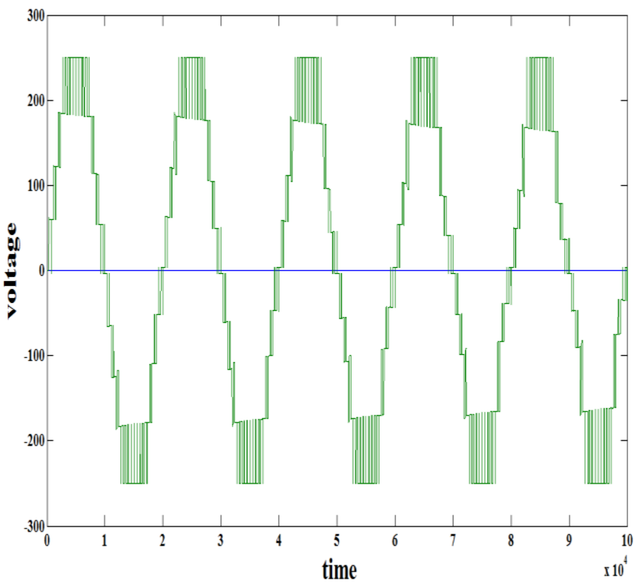

Fig.13 output voltage waveform

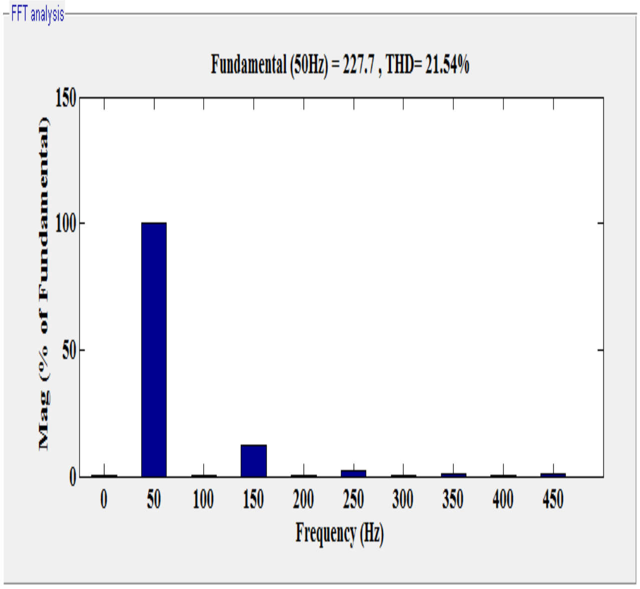

Fig.14 FFT analysis of output voltage

F. Three phase 5 – level DCMLI

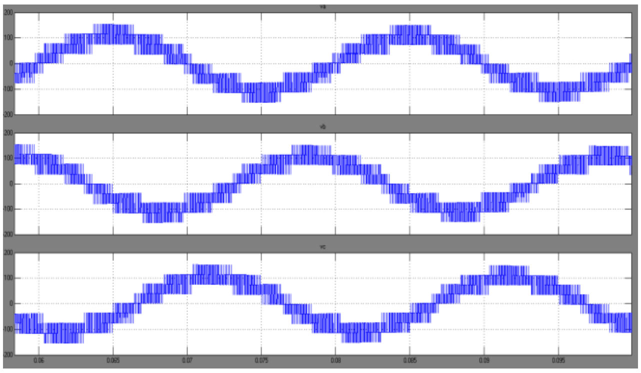

Fig.15 output voltage waveform

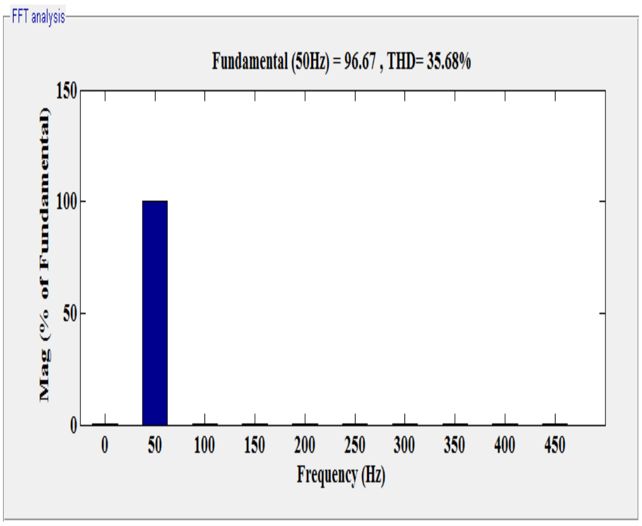

Fig.16 FFT analysis of output voltage

G. Single phase 7 – level Cascade H-Bridge Inverter

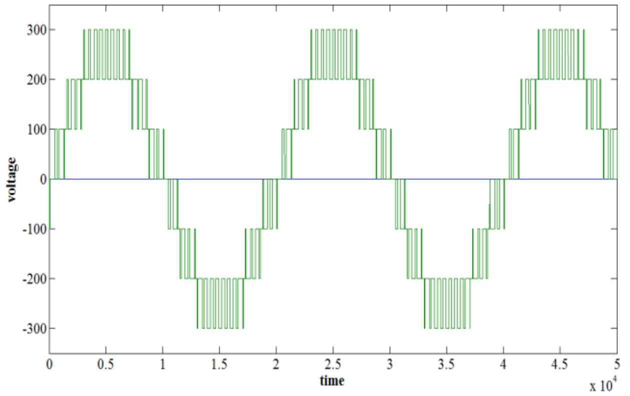

Fig.17 output voltage waveform

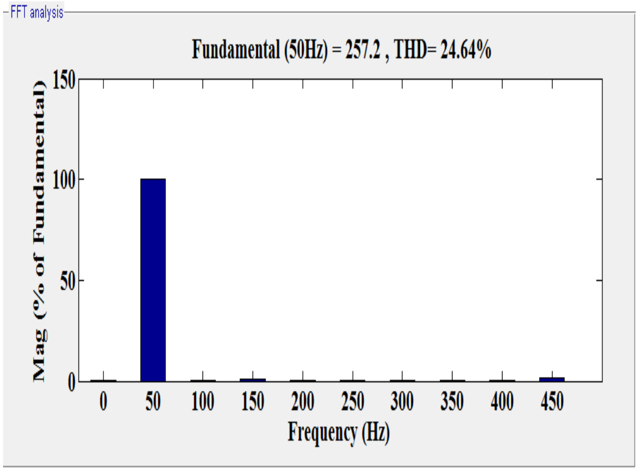

Fig.18 FFT analysis of output voltage

H. Three phase 7 – level Cascade H-Bridge Inverter

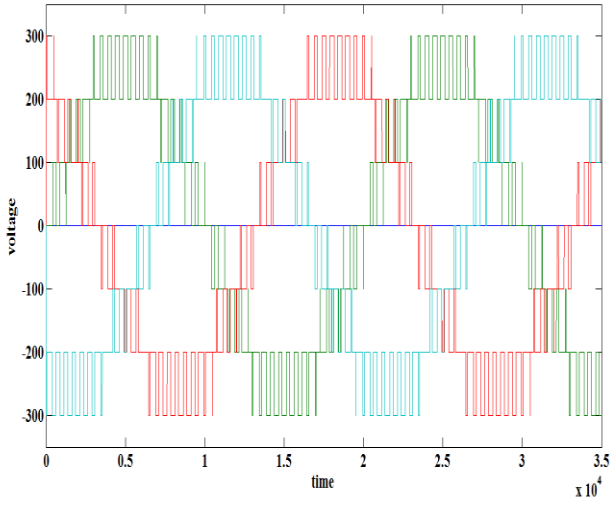

Fig.19 output voltage

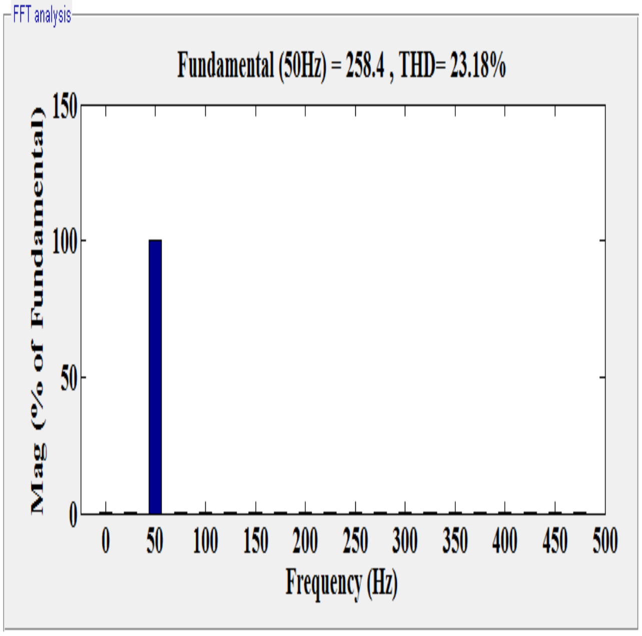

Fig.20 FFT analysis of output voltage

TABLE I
ANALYSIS OF %THD FOR DIFFERENT INVERTER
(WITHOUT FILTER)

S.No	Parameter	Types of Inverter		
		1ϕ	3ϕ	
			120 Mode	180 Mode
1.	Input voltage	230	400	400
2.	Output voltage	230	400	400
3.	Power	1KW	1KW	1KW
4.	Power factor	0.8	0.8	0.8
5.	%THD	48.34%	30.99%	33.94%

TABLE II
ANALYSIS OF %THD FOR DIFFERENT INVERTER
(WITH FILTER)

S.No	Parameter	Types of Inverter	
		1ϕ	3ϕ
1.	Input voltage	230	326
2.	Output voltage	230	230
3.	Power	1KW	1KW
4.	Power factor	0.8	0.8
5.	Switching frequency	2KHz	2KHz
6.	Modulation Index	1	1
7.	%THD	1.28%	1.11%

TABLE III
ANALYSIS OF %THD FOR MLI

S.NO	***Parameter***	**Types of inverter**			
		DCMLI (5 level)		***CHB (7 level)***	
		1ϕ	**3ϕ**	**1ϕ**	**3ϕ**
1.	Input voltage	326	326	300	300
2.	Output voltage	230	230	300	300
3.	Power	1KW	1KW	1KW	1KW
4.	Power factor	0.8	0.8	0.8	0.8
5.	Switching frequency	2KHz	2KHz	2KHz	2KHz
6.	Modulation Index	1	1	1	1
7.	%THD	21.54%	35.68%	24.64%	23.18%

III. INFERENCE

In single and three phase inverter without filter they draw more harmonics. By using filter circuit the harmonic content are suppressed. Different types of filter are used to reduce harmonics in the system but LC filters are traditionally used to reduce harmonics but design of LC filter for each odd harmonics which results in circuit complexity. Hence, MLI is used to reduce the harmonic content. And with suitable design of filter the harmonic content can be reduced. When the level of MLI is increased harmonics are reduced.

IV. CONCLUSION

In this paper, the different types of inverter were designed by using MATLAB / SIMULINK and %THD was compared. In this model various PWM techniques along with LC filter were designed to bring down harmonics within its limit. As a result of study MLI has greater advantage even without using filter design the harmonics are suppressed to some extent. MLI can be used in high power application which has balanced voltage. And it plays a vital role in renewable energy sources.

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