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Study of Total Harmonic Distortion (THD) Reduction by Filter in Renewable Energy Inverter

[1]Abdul Hafeez, [2]Dr. S.P. Singh,
[1]*Assistant Professor, Department of Electrical Engineering*,
Rajkiya Engineering College, Ambedkar Nagar, U.P

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Abstract:
This paper is about study of Total Harmonic Distortion (THD) reduction by using filter in inverter output circuit. As the trend of renewable energy is increasing, there is a need of low cost inverter with sufficient good power quality output. First inverter output is found in different mode of operation then LC filter is connected across load and modified response is found and THD is compared for different types of working modes. Low THD is very important for improved power quality. For result, simulation of inverters is created in MATLAB/Simulink Software and THD from their out responses is compared to get the best topology for good power quality.

Keywords:*Total Harmonic Distortion (THD), Inverters, Filters, renewable energy.*

I. INTRODUCTION

The increasing need for electrical energy sources encourages people to use renewable electricity. The most popular renewable energy is photovoltaic. In solar energy photovoltaic cell is used to generate voltage from solar energy. This generated voltage is DC voltage but most of the electrical system is designed as AC voltage system therefore it becomes necessary to convert Dc voltage in to AC voltage. Thus, it requires a tool (inverter) to convert DC voltage into AC voltage.Theoutput voltage of the inverter has a low voltage quality that is due to a very large Total Harmonic Distortion (THD). In order to get a variable ac output, it becomes mandatory to use the controlled switches in inverters. Semiconductor switches used in inverter are nonlinear in nature therefore harmonics in output waveform is introduced.Harmonics in sinusoidal waveform have frequency that is multiples of fundamental frequency. If the frequency of fundamental waveform is f then its second harmonic frequency will be 2f and third harmonic will be 3f and so on. Reduction of harmonics is very important for smooth and efficient running of electrical system because it causes several disadvantages like heating of equipment, increasing of current and undesirable losses. These harmonics cumulatively lead to a distortion called as Total Harmonic Distortion (THD). The THD of a signal is defined as the ratio of the sum of the powers of all individual harmonic components to the fundamental component. THD is used to characterize the quality of power (Power Quality) of electric power systems. Less THD shows that the waveform is more sinusoidal.Reduction of THD in inverters can be achieved by using various filters.

II. RENEWABLE ENERGY INVERTER

Power cut is frequent in India that leads to people towards renewable energy sources because of its self-dependency also it is clean energy and due CO_2 emission in conventional sources this field of energy is growing rapidly. In renewable energy system first energy is stored in batteries that are source of DC energy but electrical system is mainly designed for AC power therefore inverters are needed to convert DC voltage in to AC voltage. Inverters with batteries are used in India from a very long time for storing and utilizing the energy during power cut. The basic work of any inverter is to convert DC power in to AC power either in regular inverter or solar inverter.

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The difference may be only in additional features.Single phase inverters are used in single phase application; there are two types of single phase inverters, half bridge inverters and full bridge inverters Figure 1. shows a basic full bridge inverter with single phase output. This configuration is often called an H bridge due to the arrangement of the power switches and the loads. Half bridge inverter used two semiconductor switches and full bridge inverter used four semiconductor switches the main difference between half bridge and full bridge inverters is the maximum value of inverter output voltage. An inverter can delivered and accept the reactive power and real power

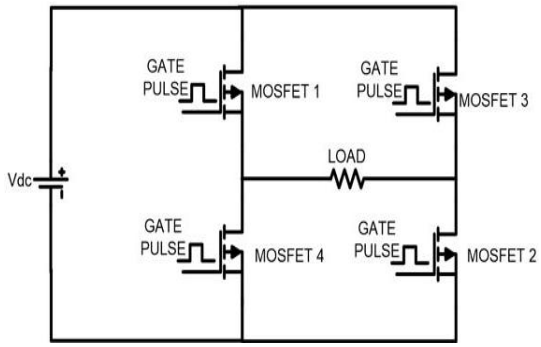

Figure 1. Single Phase Full Bridge Inverter circuit.

Today's most commonly used topology is a three-phase inverter as shown in figure 2.This is an extension of one leg in single bridge inverters control technique for three phase inverter is similar to the control of the single-phase inverter there is only one difference that the reference signals for the different legs have a phase shift of the 120^0 instead of the 180^0 for the single-phase inverter. Due to phase shift in three phase inverters triple odd harmonics (3^{rd} and 9^{th} and 15^{th} etc.) are eliminated from the line-to-line output voltage..

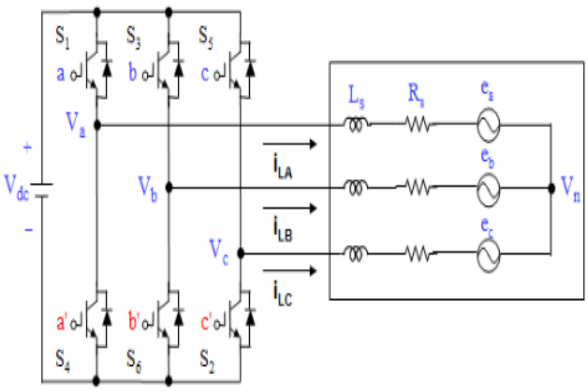

Figure 2. Three Phase Inverter circuit.

III. 180^0 MODE INVERTER

3.1 THREE PHASE INVERTER WITOUT FILTER

A model for three phase 180^0 inverter is derived on simulink without filter as shown in the figure 3 and output response of three phases are shown in figure 4..

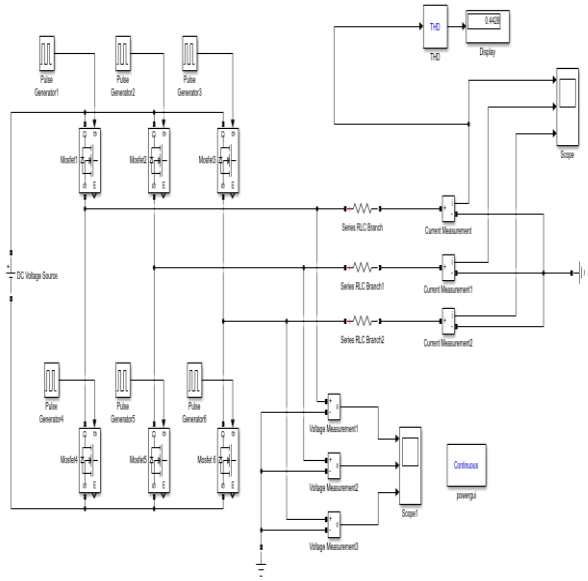

Figure 3. Model ofInverter without filter(180^0 mode).

The DC input is chosen 500V for input panel. Voltage output waveform shape is rectangular that contains very high harmonic components

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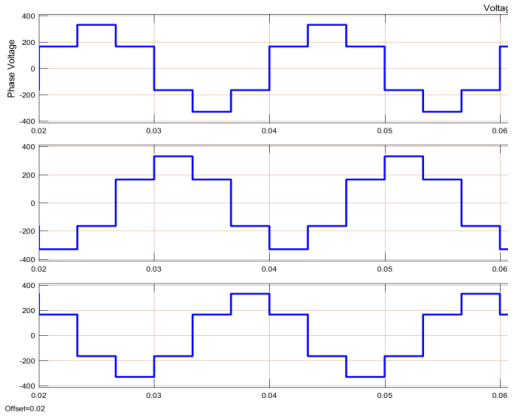

Figure 4. Without filter inverter output voltage(180^0 mode)

3.2 THREE PHASE INVERTER WITH FILTER

LC filter is connected between three phase inverter and load. For different value of L and C shape of output waveform changes. To improve the power quality the values of L and C are modified so as to reduce the THD. Figure 5 shows simulink model of 180^0 inverter with LC filter. Output waveform of three phase inverter with filter working in 1800 mode is shown in figure 6..

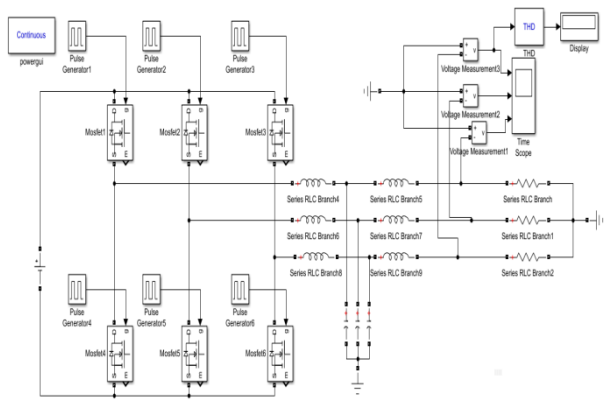

Figure 5. Model ofInverter with filter(180^0 mode).

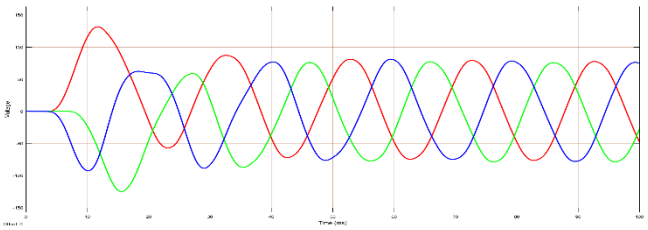

Figure 6. With filter inverter output voltage(180^0 mode)

IV. 120^0 MODE INVERTER

4.1 THREE PHASE INVERTER WITOUT FILTER

A simulation model for three phase 120^0 inverter is derived on simulink without filter as shown in the figure 7 and output response of three phases are shown in figure 8.

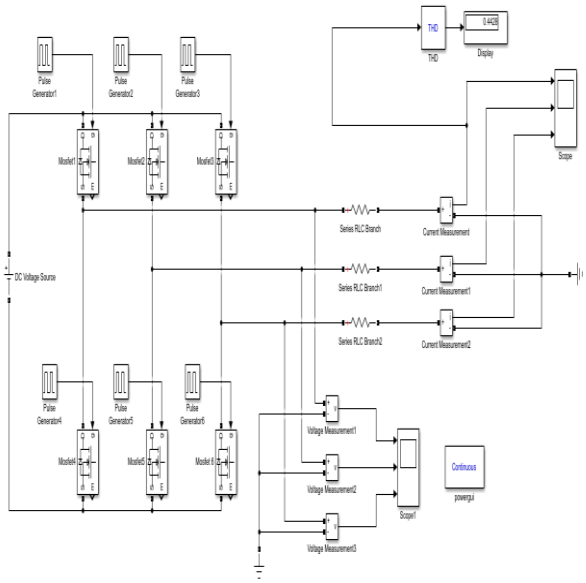

Figure 7. Model ofInverter without filter(120^0 mode).

The DC input is chosen 500V for input panel. Voltage output waveform shape is rectangular that contains very high harmonic components

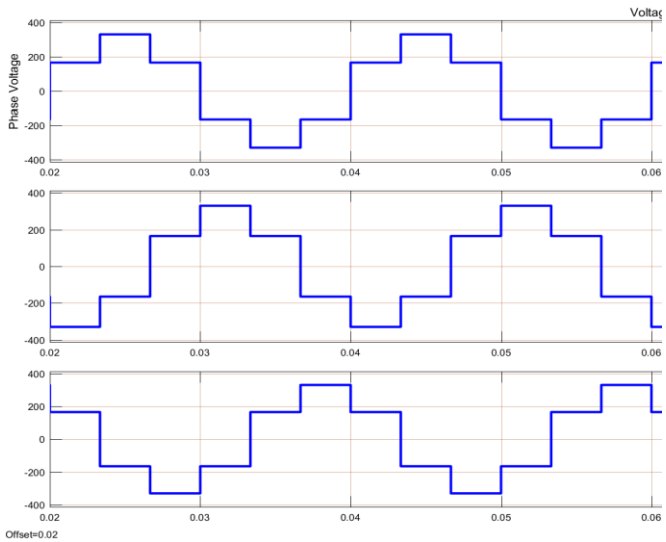

Figure 8. Without filter inverter output voltage(120^0 mode)

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4.2 THREE PHASE INVERTER WITH FILTER

Model of three phase inverter working in 120^0 mode is modified by adding LC filter at load side to get better output response as shown in figure 9. Output response of this system is sinusoidal as shown in figure 10.

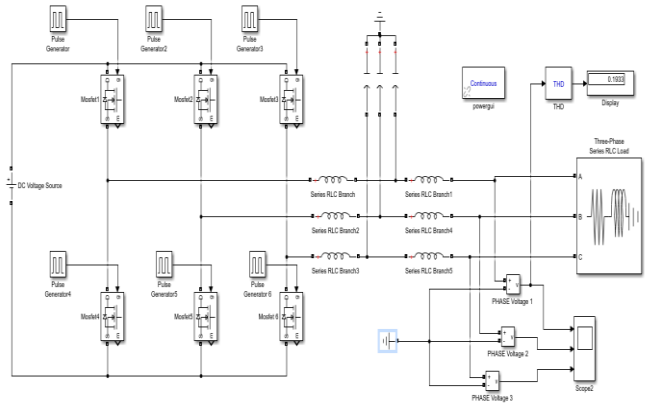

Figure 9. Model ofInverter with filter(120^0 mode).

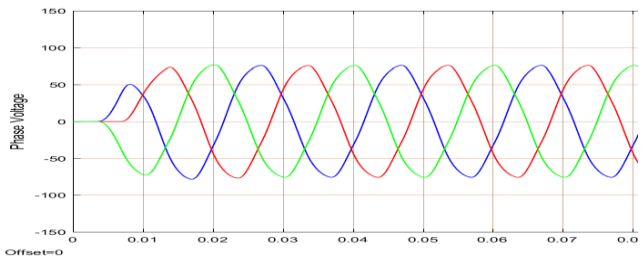

Figure 10. With filter inverter output voltage(120^0 mode)

V. RESULT AND ANALYSIS

Output voltage of 1800 mode inverter without filter is changing in steps that contain higher number of harmonics. Its THD is found to be 31.17 %. It is a high distortion for reducing it a LC filter is connected on load side after that THD becomes 14.72 %. Another method of operation in three phase inverter is 1200. Its output waveform is shown in figure 8 and figure 10.THD is case of without inverter is 46.65 % that reduces to 19.33% with filter at load side

TABLE I Variation of THD for different inverter mode with and without filter

INVERTER MODE	THD (%)	
Mode I	Without filter	44.28
	With filter	14.72
Mode II	Without filter	46.65 %
	With filter	19.33

Variation of total harmonic distortion for an inverter with and without filter for both 120^0 and 180^0 conduction is shown in Table 1. It is concluded from the table that, after connection of a filter the power quality of a waveform gets improved and THD reduced from 46.65 % to as low as 14.72 %.

VI. CONCLUSION

In this paper, simulation models for different systems were drawn in MATLAB/simulink and their output responses are found. Using LC filter for harmonic reduction is important for less cost application such as renewal energy for domestic purpose. When filter is not connected then response waveform is changing in step that shows high harmonic contamination in output voltage. After LC filter application waveform of output voltage gets modified in 180^0 as well as 120^0 cases and becomes sinusoidal that contains lesser harmonic.From the output phase voltages response of 180^0 it is found that Total Harmonics Distortion (THD) in case of simple circuit was 44.28 % and after filter it becomes very less 14.72 %. In 120^0 mode operation without filter THD was 46.65 % that becomes 19.33% after LC filters across load. It is found that in case of filter power quality is sufficiently improved and also found that 180^0 inverter with filter is better than 120^0 inverter with filter with lesser THD.

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