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Implementation of MPPT Algorithm and Investigation of Solar Power in Three Phase Voltage Source Inverter Using an Advanced 150º Conduction Mode

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Abstract— **The solar energy is renewable, non-polluting and easy to install and with low maintenance costs. In this work, the performance of voltage source converter based photovoltaic (PV) system is investigated. This system comprises with PV array, maximum power point tracker (MPPT) and an inverter. Perturb and Observe algorithm is implemented by controlling the voltage and current of the PV array. The MPPT (Perturb and Observe) algorithm is used to check for rapidly changing environmental circumstances. The three voltage source inverter is operated at several modes. From the simulated results it is clear that at 150^0 conduction mode, the inverter generated less harmonics as compared to other mode of operation. For this work MATLAB / SIMULINK software is used.**

Index Terms— **PV system, MPPT algorithm, VSI**

I. INTRODUCTION

THE three-phase voltage source converter is utilized universally as D.C. into A.C. converter. The VSI is used in many power system applications such as A.C. drives, VFD controllers, hybrid electric vehicles, active filters, etc. Today, renewable energy such as wind power systems as well as solar power systems also use VSI. Photovoltaic (PV) energy is one of the most surveyed and widely used renewable energy sources, with various advantages such as abundant availability of sunlight, environmentally friendly operation, and low maintenance costs [1-5]. However, the lower conversion efficiency and non-linear electrical properties of PV cells under changing weather conditions are considered to be the main disadvantages of PV systems. There are various factors that affect solar cell efficiency, such as radiation level, temperature, and connection load. There are usually certain points on the output characteristics of PV cells that can derive maximum available power with the highest efficiency. This special operating point is known as the solar panel's maximum power point (MPP). Therefore, it is very important in PV systems to include maximum power point tracking to guarantee MPP operation. A number of MPPT techniques have been projected to monitor maximum power point under several environmental conditions [1, 2-6]. Maximum Power Point Tracking MPPT is an algorithm which is included in PV system that are used to extract maximum available energy from the PV building block under certain circumstances. The voltage at which the PV module can harvest maximum power is known as maximum power point. The MPPT systems empower a constant DC voltage at the output connection with or without variation in environmental circumstances. The PV array has a strong non-linear current-voltage characteristic that varies with the irradiance and temperature that significantly influences the output power of the array. The maximum power point control for PV system is therefore crucial to the success of a PV system. The several authors [1-2-10] worked on MPPT, their results show that the power which was extracted with MPPT; was more than without MPPT. They studied the comparative analysis between conventional 180^0, 120^0 modes for VSC. Due to switching of power devices in VSI, the harmonics are generated and when these converters are integrated with system networks the power quality of the system is also affected. In order reduce these harmonics, the 150^0 conduction mode is considered for in this work for VSI. The results of 150^0 conduction mode are compared with other conduction modes (120^0 and 180^0). This paper is arranged as follows; Section II PV system designing, section III explanation of methodology, section IV explanation of solar power and voltage source inverter VSI, section V literature review, section VI simulation results and discussion and in final section VII conclusion is discussed.

II. PV SYSTEM

The PV system as shown in Fig.1 consist of a PV array that converts solar power into electrical energy, a DC / DC converters that convert low DC voltages from the PV array into a high DC voltage. MPPT is electronics system that controls the PV module in such a way that maximum power is extracted from the solar energy. At the certain point maximum power can be harvested is called the maximum power point. The maximum power point trackers are in fact an electronic circuits that fulfill the purpose of maximum current consumption of PV cells. By connecting the outputs terminal of the PV array to the inputs terminal of the inverter, the DC-DC inverter duty cycle should be adjusted or controlled to control the PV array voltages and the voltages at which maximum energy is obtained, be retained. Then the obtained results are adjusted with 150^0 conduction mode converter for reduction of harmonics [1-2-3].

processing continues in the same track of perturbation. Or else, the process reveres the disturbance track [1-2]. The flow chart of Perturb and Observe is given fig. 2.

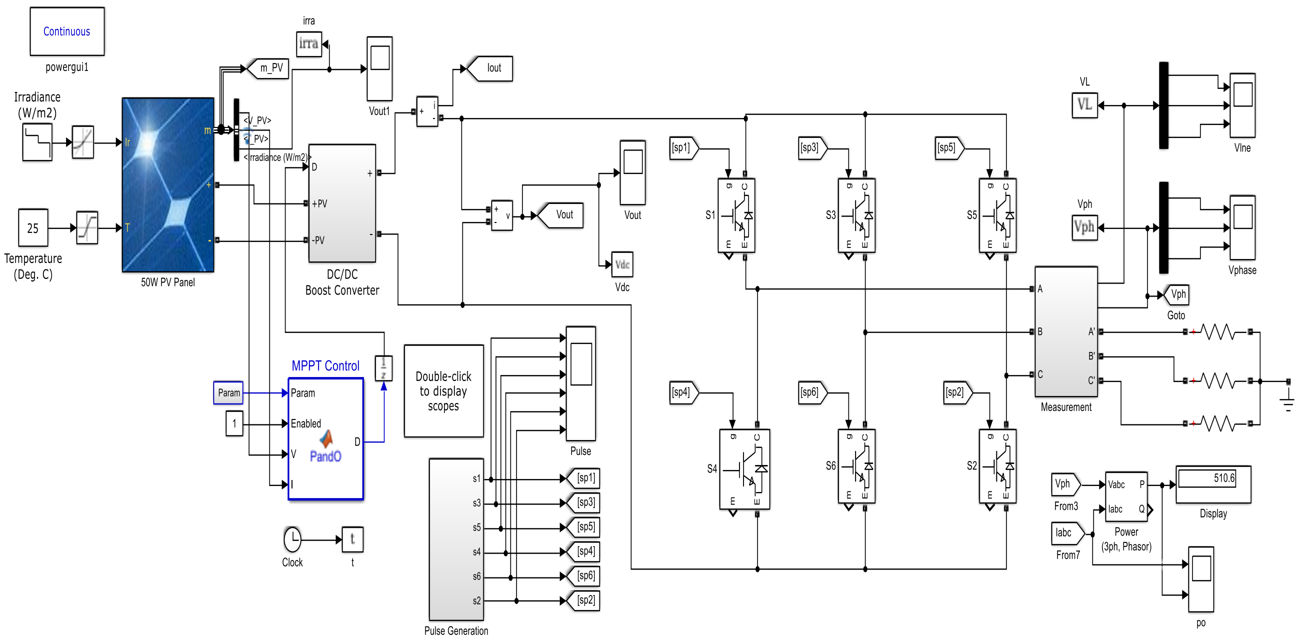


Fig. 1. PV system

III. METHODOLOGY

The following proposed methodology is used for the PV system and results are compared with previous, it is concluded that with the implementation of MPPT more power is observed and with addition of 150^0 mode to inverter, harmonics are reduced.

- Initially the MPPT algorithm for PV system is developed and simulated by connecting PV array with DC to DC converter in MATLAB software
- The developed MPPT is connected with VSC. This complete system as shown in Fig. 01 is developed in same software.
- The performance of VSC based PV system is investigated with several conduction modes
- The harmonics of VSC based PV system at 150°is compared with 180^0, 120^0 conduction modes

IV. PERTURB AND OBSERVE ALGORITHM FOR MPPT

MPPT is actually electronics scheme that controls the PV module in such a way that maximum power is harvested from the solar energy. Power is harvested at maximum points, are known as the maximum power points. Perturb and observer (P & O) algorithm technique is the most widespread because of its simplicity [1]. In this method, the current control is measured and matched with the past values to define the power changes. If the changes in power are greater than zero, then the

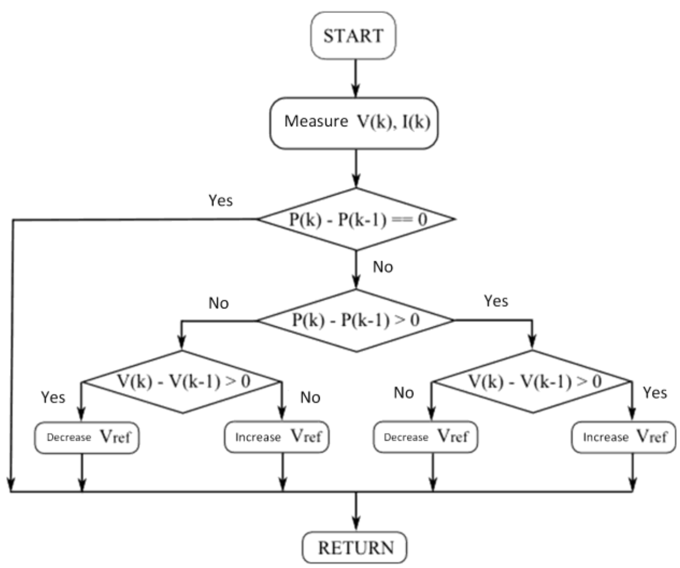


Fig. 2. Flow chart of Perturb and Observe

V. VOLTAGE SOURECE INVERTER (VSI)

The three phase voltage source converters are used as D.C. into A.C. converter. The VSI is used in many power system applications like A.C. drives, VFD controllers, hybrid electrical vehicle, active filters, etc.

Nowadays renewable energy like solar system and wind energy systems also used VSI. The common modes of conduction of inverter decides the output voltage and harmonics of systems [9].

The figure of three phase VSI is shown fig. 3.

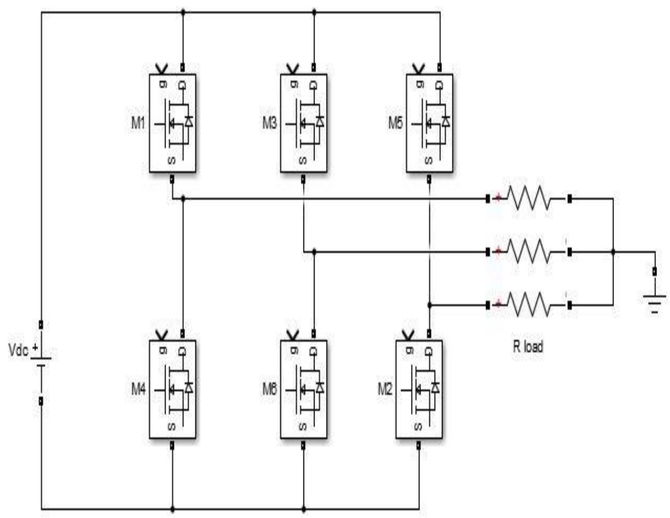


Fig: 3. Three phase voltage Source Inverter

VI. LITERATURE REVIEW

Solar energy is renewable, non-polluting, easy to install, it is almost available throughout the year in tropical region and low maintenance cost [4]. Some of recent research work is given below.

Mustafa et al [1] examined the maximum power is tracked at different condition and observed the efficiency of MPPT at different irradiation levels.

Kumar et al [4] analyzed the advantages of renewable energy over fossil fuels. They mentioned that the solar energy is renewable, non-polluting, low maintenance cost and easy to installation.

Shah et al [7] examined harmonics at the output voltage of voltage source inverter (VSI). They studied the comparative analysis between conventional 180°, 120° conduction mode and 150° conduction mode. Then proved from results that 150° conduction mode is better technique to reduce the THD.

Tahilramani et al [8] designed the cost-effective and modest control track for three-phase voltage source converters. The logics of switching are applied in a drivers circuit and microcontrollers are designed by using opt coupler [8].

Blaabjerg et al [11] studied on fast-growing renewable technology and its popularity.

A. Yafaoui et al [12] using the MPPT algorithm for PV to get maximum solar power.

Parkash et al [13] analyzed that how electricity is generated via solar PV cells and how much it is efficient than other sources of energy.

Dondi, et al [14] modeled the solar PV cells and analyzed the performance of photo cells.

Li Ning et al analyzed different conduction modes of conventional square wave controlled three phase six switch converters. In this work the authors reduce the total harmonic distortion of the converter [15].

VII. RESULTS AND DISCUSSION

The parameters of PV panel as shown in Fig.4 were used to get required results. PV panel consist of solar cell that transforms solar power in electrical power. Solar panels are semiconductor device which are fabricated in a manner to generate electrical energy from solar radiation falling on it [2].

YGE 60 CELL SERIES 2

ELECTRICAL PERFORMANCE

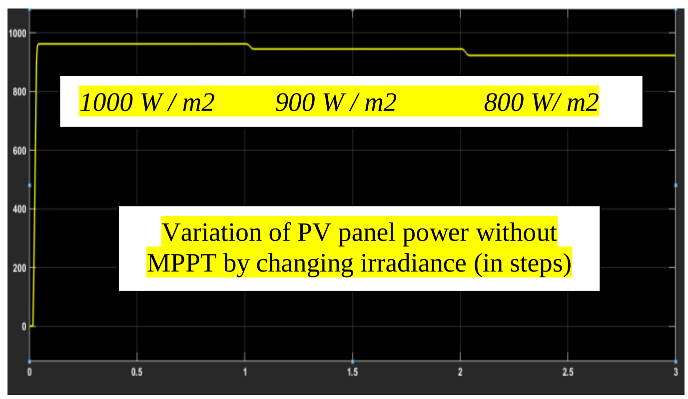
Electrical parameters at Standard Test Conditions (STC)

Module type			YLxxxP-29b (xxx=P_{max})					
Power output	P_{max}	W	275	270	265	260	255	250
Power output tolerances	ΔP_{max}	W	0 / + 5					
Module efficiency	η_m	%	16.8	16.5	16.2	15.9	15.6	15.3
Voltage at P_{max}	V_{mpp}	V	31.0	30.7	30.5	30.3	30.0	29.8
Current at P_{max}	I_{mpp}	A	8.90	8.80	8.70	8.59	8.49	8.39
Open-circuit voltage	V_{oc}	V	37.9	37.9	37.8	37.7	37.7	37.6
Short-circuit current	I_{sc}	A	9.35	9.27	9.18	9.09	9.01	8.92

STC: 1000W/m² irradiance, 25°C module temperature, AM1.5g spectrum according to EN 60904-3.
Average relative efficiency reduction of 3.3% at 200W/m² according to EN 60904-1.

Fig. 4. Parameters of PV panel

Waveform of PV panel power without & with MPPT at different irradiance is shown in fig 5.



(a)
(b)

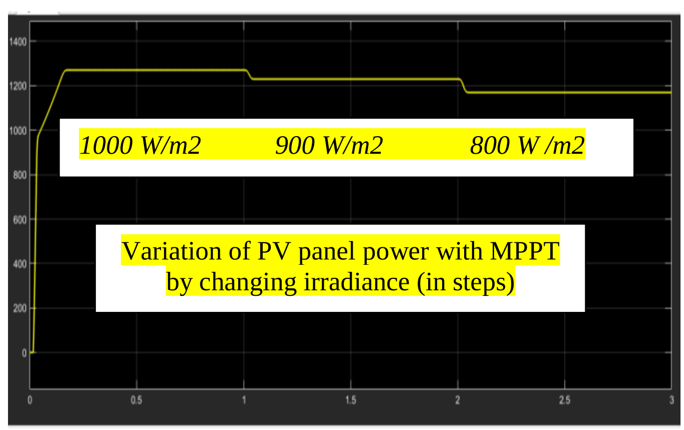


Fig. 5. Waveform of PV panel at different radiation (a) without MPPT (b) with MPPT

The results of PV panel power without & with MPPT at different irradiance is shown Table 1.

Irradiance (W/m2)	Power (w) Without MPPT	Power (w) With MPPT
1000	962	1270.5
900	944	1230
800	922	1169.6

Table. 1. The PV panel power without & with MPPT at different irradiance

Results of PV module is taken at different temperature P–V and I–V curves of PV Building block is given in fig. 6.

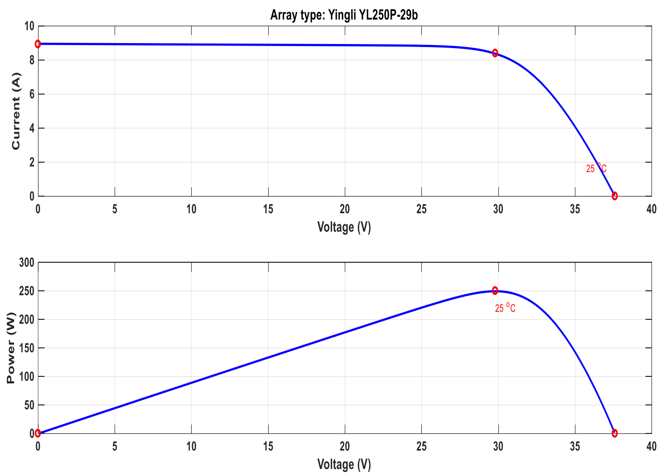


Fig .6. P–V & I–V curves of PV Component

I–V and P–V curves of PV panel under certain temperatures are shown in Fig.7.

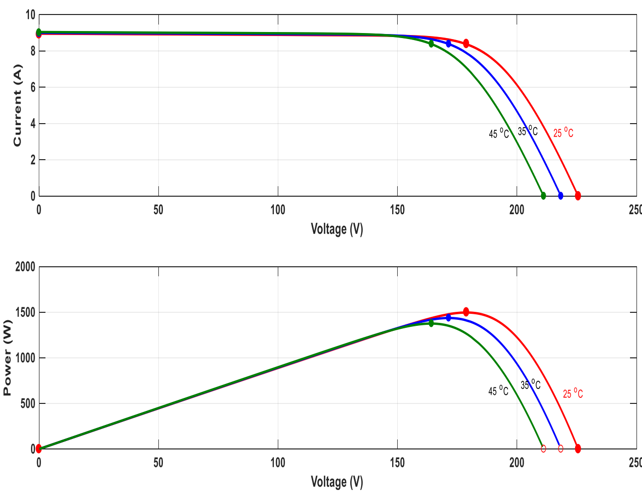


Fig. 7. I–V & P–V curves of PV Array under various temperatures

I–V and P–V curve of PV Arrays under varying solar irradiances is shown in fig. 8.

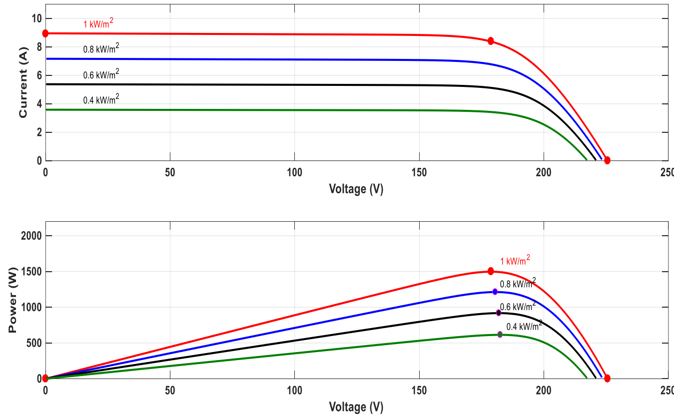


Fig. 8. I–V and P–V curves of PV Array varying solar irradiances

Line voltages waveforms of inverter at 150^0 mode is shown in Fig.9.

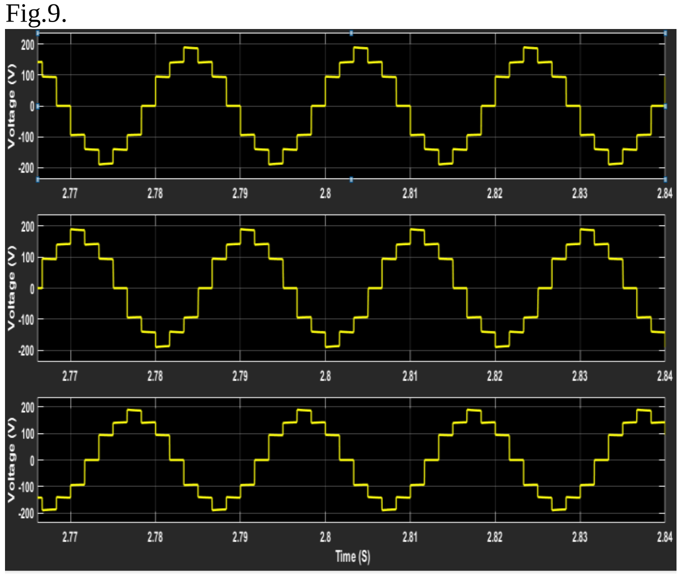


Fig. 9. Line voltages waveforms of inverter at 150^0 mode

Harmonics spectrum of line voltages at 150^0 mode are given in figure. 10. It indicates that when inverter operated at this mode of operation, the 16.7 % THD is generated in output voltages.

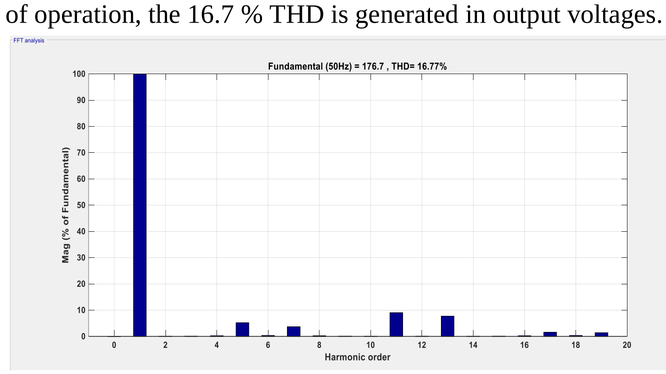


Fig. 10. The Harmonics spectrum of line voltages at 150^0 mode

Phase voltages waveforms of inverter at 150^0 mode is shown in Fig 11 while Harmonics spectrums of phase voltage at 150^0 mode is shown in Fig.12.

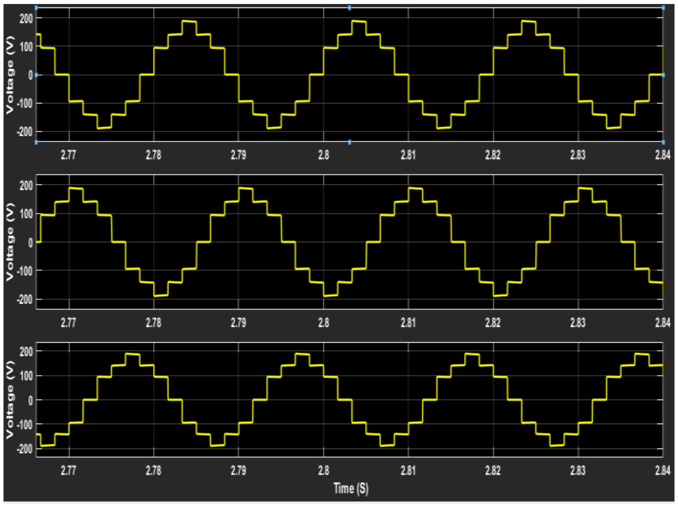


Fig. 11. Phase voltages waveforms of inverter at 150^0 mode

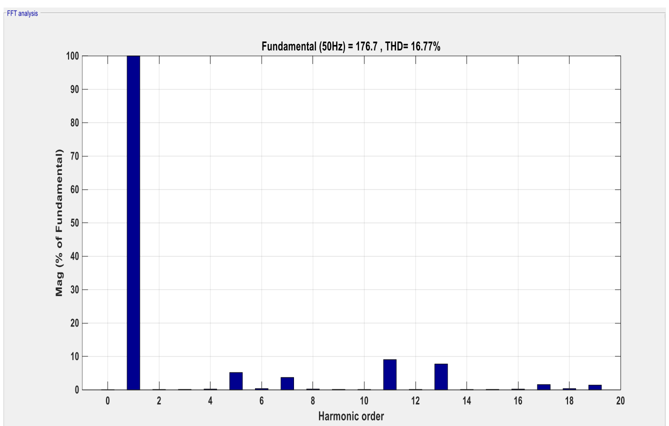


Fig. 12. The Harmonic spectrum of phase voltages at 150^0 mode

The three phase VSI is also simulated at 180^0 mode of operation. The waveforms of Line and phase voltages are shown in Fig. 13 and Fig 14 respectively.

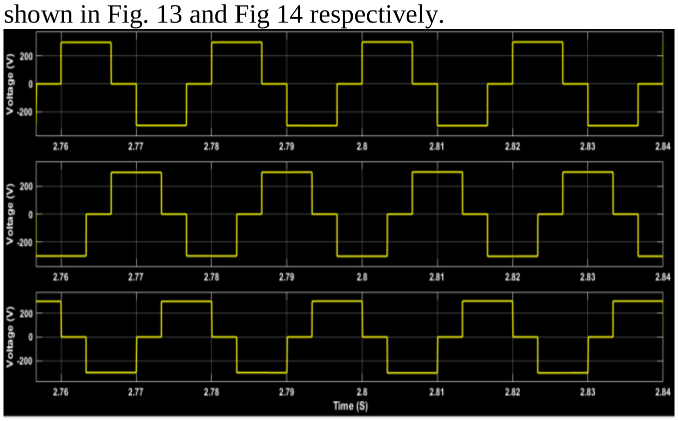


Fig. 13. Line voltages waveforms of inverter at 180^0 mode.

Phase voltages waveforms of inverter at 180^0 mode

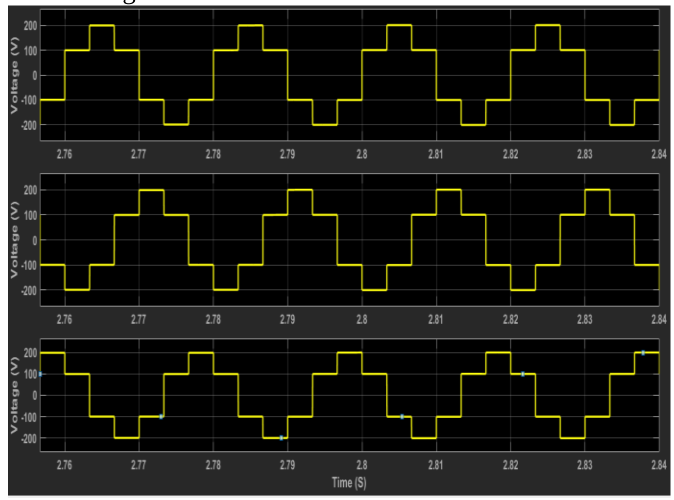


Fig.14. Phase voltages waveforms of inverter at 180^0 mode

The Harmonic spectrum of Line and phase voltages at 180^0 mode are shown in Fig. 15 and Fig. 16 respectively.

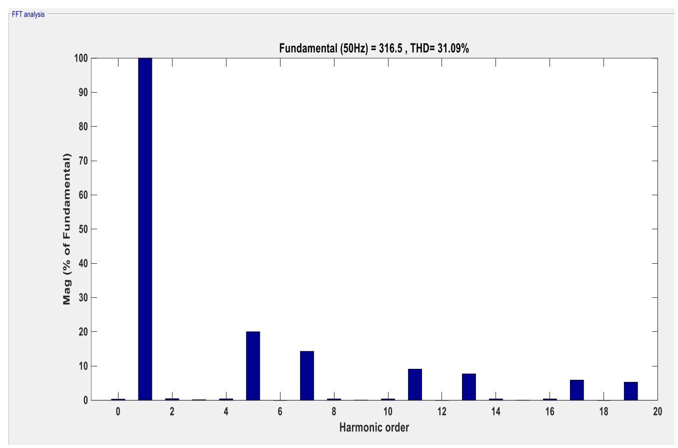


Fig. 15. Harmonic spectrum of Line voltages at 180^0 mode

Harmonics spectrum of phase voltages at 180^0 mode

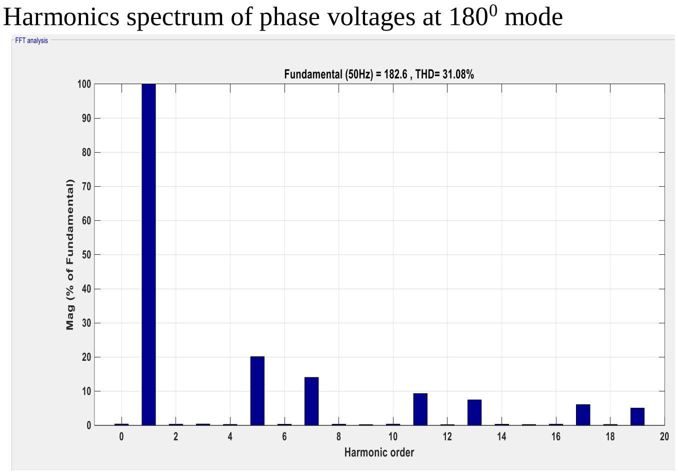


Fig. 16. Harmonic spectrums of phase voltage at 180^0 mode

Line voltages waveforms of inverter at 120^0 mode

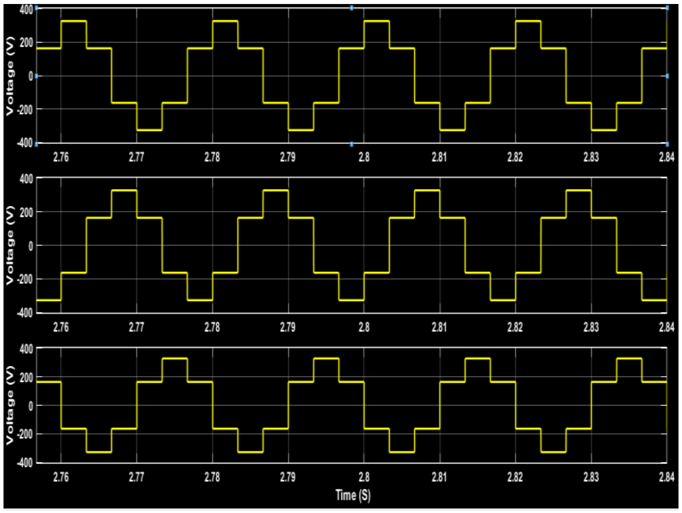


Fig.17. Line voltages waveforms of inverter at 120^0 mode

Harmonic spectrum of Line voltages at 120^0 mode

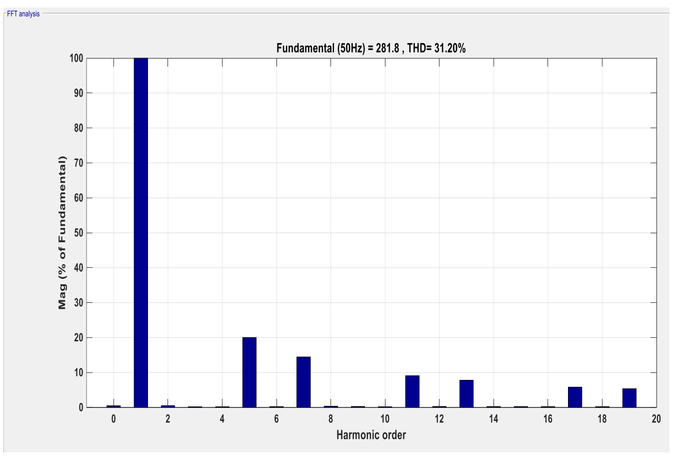


Fig. 18. Harmonic spectrum of Line voltages at 120^0 mode

Phase voltages waveforms of inverter at 120^0 mode

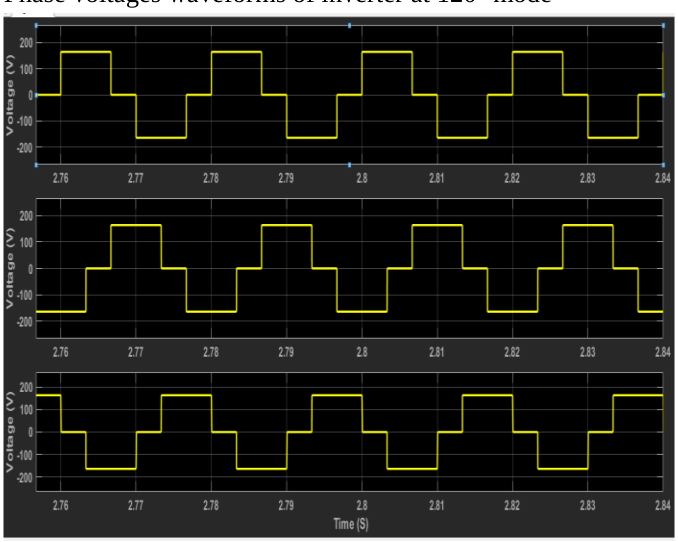


Fig. 19. Phase voltages waveforms of inverter at 120^0 mode

Harmonic spectrum of phase voltages at 120^0 mode

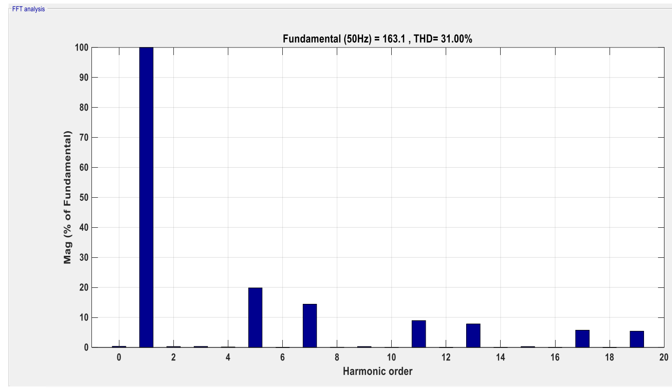


Fig. 20. Harmonic spectrum of phase voltages at 120^0 mode

Graph of Output power of three phase inverter at different modes is shown in fig. 21.

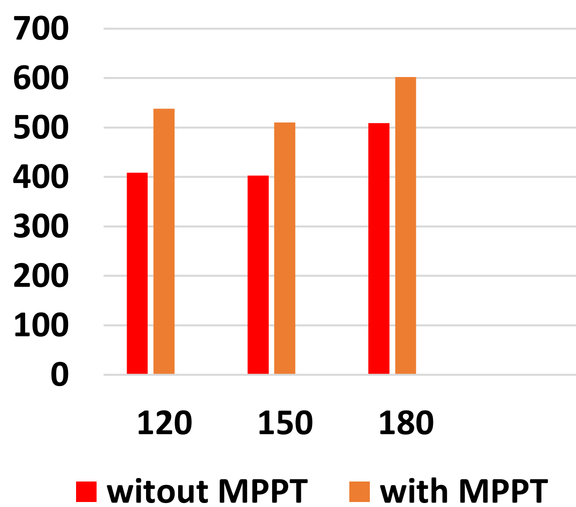


Fig.21. Graph of Output power of three phase inverter at different modes

Table & Graph of Comparison of THD in phases of voltages in three phase inverter at different modes

Operating modes of inverter	Total Harmonic Distortion (THD) in phase voltages
150	16.76
180	31.08
120	31

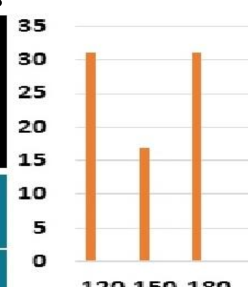


Fig.22. Table & Graph of Comparison of THD in phase voltage of three-phase inverters at different modes

Table and graph of comparison of THD in line voltage of three phase inverter at different modes.

Operating modes of inverter	Total Harmonic Distortion (THD) in line voltages
150	16.77
180	31.09
120	31.20

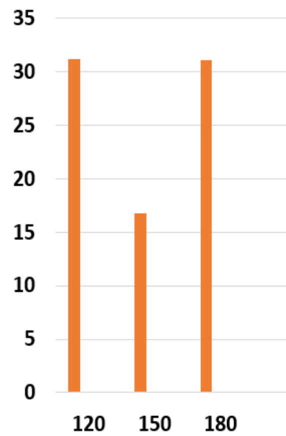


Fig. 23. Table and graph of comparison of THD in lines voltages of three phase inverters at various modes.

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VIII. CONCLUSION

The simulation model of three phase bridge inverter at 150^0 mode is developed and integrated with PV system by using MATLAB software. In this work, a perturb and observation algorithm for MPPT is implemented. From the tabulated results, it is concluded that PV system has more power with MPPT. The harmonics at the output of voltage source inverter is also compared at different conduction modes. From the result it is proved that 150^0 conduction mode has less THD as compared to other operating conduction modes. The power circuit for 150° conduction mode inverter is same as other conventional conduction modes.

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