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Implementation of Carrier based SVPWM for Grid Connected PV System

Rutuja R.Patil[1], Suyog S.Hirve[2]

PG Student [Power System], Dept. of Electrical, Bharati Vidyapeeth Deemed University College of Engineering, Pune, Maharashtra, India [1]

Assistant Professor, Dept. of Electrical, Bharati Vidyapeeth Deemed University College of Engineering, Pune, Maharashtra, India[2]

ABSTRACT: Now-a-days, non conventional energy resources such as photovoltaic systems (PV) are being considered as a future solution for meeting highly increasing power demand. Consequently, this is also minimizing our power dependency over the conventional energy resources such as fossil fuels, coals which ultimately cause the global warming concerns. However, injecting PV power into grid is a challenging task because solid state power electronic switches used for connecting PV at the distribution point of grid results in the harmonic distortion of the system. Thus, to overcome this, an effective control scheme of carrier based space vector modulation is proposed in this paper. This method is much simpler than the conventional method of space vector. The proposed method is realised using Matlab/simulink. Also, the corresponding THD results are presented.

KEYWORDS: Pulse width modulation, Space vector pulse width modulation (SVPWM), Photovoltaic (PV), Renewable energy sources (RES).

I.INTRODUCTION

Energy plays a pivotal role in our daily activities. The degree of development and civilization of a country is measured by the utilization of energy by human beings. Energy demand is increasing day by day due to increase in population, urbanization and industrialization. The world's fossil fuel supply via coal, petroleum and natural gas will thus be depleted in a few hundred years. The rate of energy consumption increasing, supply is depleting in inflation and energy shortage. This is called energy crisis. Hence alternative or renewable sources of energy have to be developed to meet future energy requirement. Due to this reason usage of non conventional energy resources such as hydropower, wind is rapidly increasing. Countries having hydro potential are implementing different turbines technologies for generating electricity and to help utility. Similarly, Wind energy sector is also achieving the progress in wind turbines. In addition to this, the most promising source of renewable power today, is photovoltaic system.
Though renewable energy sources (RES) are promising solution for current power scenario but these sources are intermittent in nature. Thus, a strong research is going on the techniques for improving efficiency and the performance of RES. Here we are considering Photovoltaic system (PV) as a RES. Output of PV is DC and it needs to be converted to AC before injecting to grid. In order to have satisfactory output; it is of prime importance to develop control schemes for the grid coupled inverters which are used for DC to AC conversion. In this paper, Section II explains the block diagram and Simulink model. Carrier based control scheme is mentioned in part III. Simulation results and conclusion are elaborated in Section IV and V respectively.

II.LITERATURE SURVEY

1] This paper describes the interconnection of renewable sources such as solar & wind at the distribution side. Implementation of grid interfacing inverter for improving the power quality at the point of common coupling has also mentioned in this. This paper proposed hysteresis current control method which helps to minimize harmonics in the system. According to this research grid interfacing inverter can be used as shunt active power filter for current unbalance. Also, reactive power requirement by load can also be fulfilled.
2] This paper presented simulation model for photovoltaic array. It has also considered the effect of temperature & solar irradiation on the generation of the output of photovoltaic array. Basic equation expressing output of photovoltaic cell in terms of photo current is used for PV modelling.

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3] This paper elaborated the use of power electronic converters in the integration of renewable energy sources into the grid. Power Electronic converters such as inverters can be used as shunt active power filter. In addition to this it can also helps to minimize the harmonic distortion & can provide control over reactive power flow of the system.
4] This paper has given the overview of grid synchronization techniques required for grid interconnection. Also, suggested the grid converter control strategies.
6] This paper has explained about the control techniques for the voltage source inverters used in grid interconnection. Comparison for various PWM methods on the basis of total harmonic distortion of the system has also mentioned in this. For this thesis we are using space vector PWM as it gives the best result among all PWM methods.
7] This paper have put forward a new concept that space vector PWM method can be treated as modified form of sine triangle PWM method. Here simplified method for implementing conventional space vector pulse width modulation has given which is free from sector checking, look up tables and complex trigonometric calculations.

III.SYSTEM MODEL AND ASSUMPTIONS

A. SYSTEM CONFIGURATION

Different blocks for the system under consideration are mentioned in Fig.1.Here we are using 11KV, 50Hz grid. For injecting output of PV at distribution point we are using 3phase 4 wire transmission network. A voltage source inverter is used for converting DC output of PV system to AC. In addition to this, DC link capacitor is used for having control on 2 sides of the inverter namely; grid side and load side. Control circuit is having logic implemented for carrier based SVPWM. Here, we are analysing the carrier based SVPWM results for both linear as well as non linear load. Lastly, LC filter is also used to minimize harmonics arising due to non linear load switching.

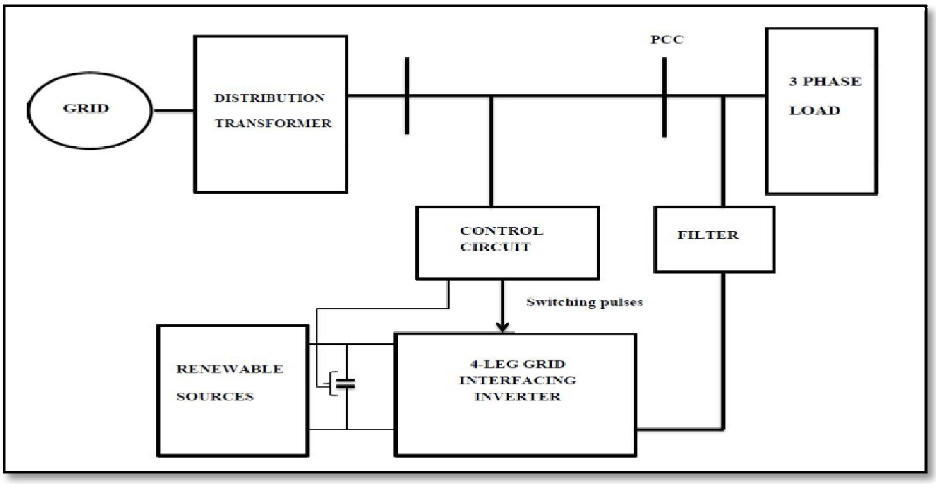

Fig. 1 Block diagram

B.OVERALL MODEL OF THE SYSTEM

By following the above block diagram we have prepared Simulink model as shown in Fig.2.

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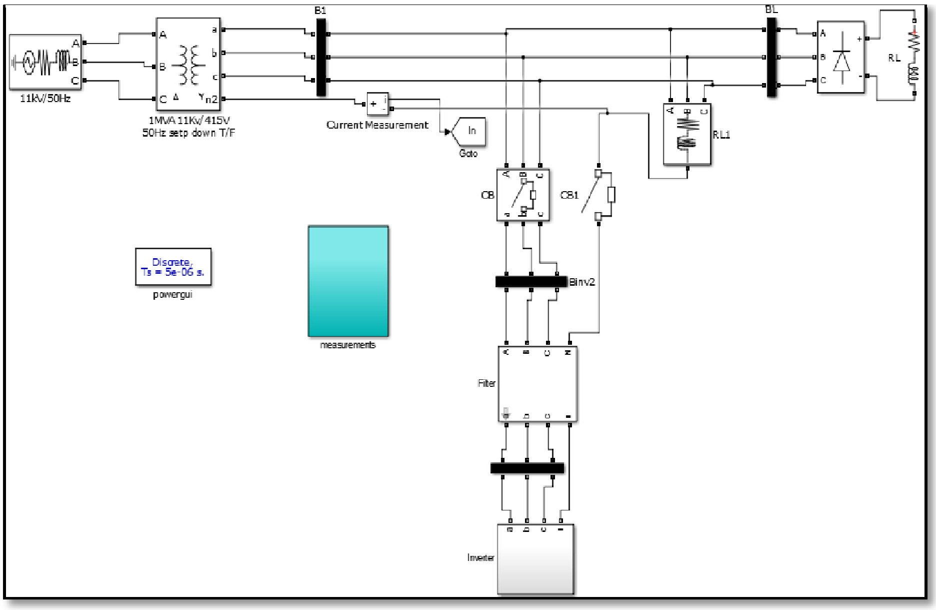

Fig. 2 Simulink Model

Here 1st block from the left side represents the grid of 11KV, 50Hz.Followed by this we have used step down transformer block which step downs the 11KV to 415KV.Inverter block includes the SVPWM method which we have implemented. Measurement block includes all the measurements related to grid, inverter as well as load. RL represents the non linear load and RL1 represents the linear load.

C.SOLAR PHOTOVOLTAIC MODEL

Subsystem of the inverter block is shown in Fig. 3.Here we are using IGBT's for designing two level inverter. For each phase one pair of IGBT is used. Thus, for R-Y-B phases there are in all 6 IGBT's used. Also, one pair is used for the neutral of the system.

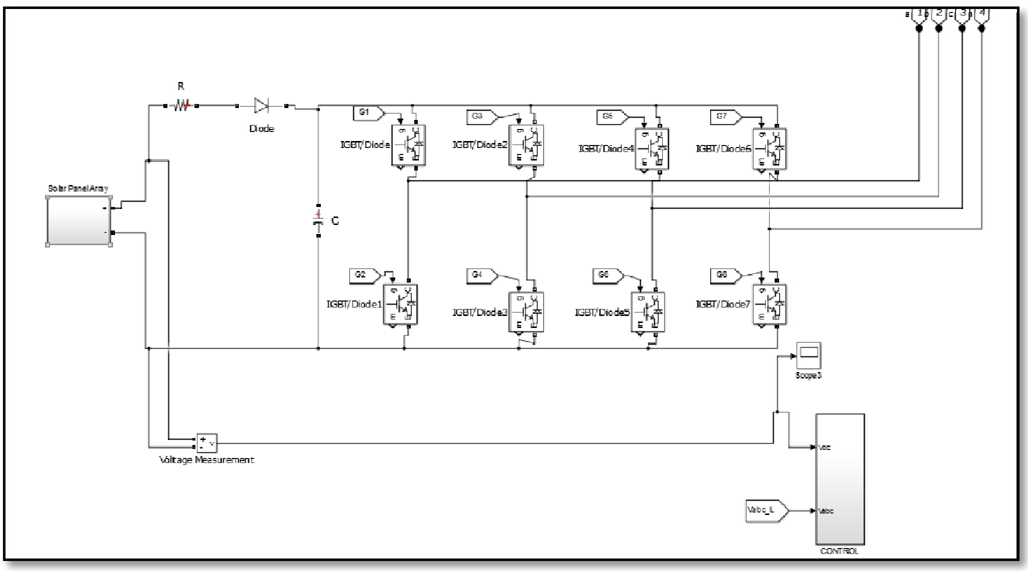

Fig. 3 Subsystem of Inverter Block

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Above model represents the block for solar panel array as well as SVPWM control scheme for the inverter. Solar panel array is designed using PV cell equation (1).

$$V_{cell} = \frac{AkT_{cell}}{q} \ln\left(\frac{I_{photo}+I_{reverse}-I_{cell}}{I_{reverse}}\right) - I_{cell}R_s \quad (1)$$

Where,

q: 1.602 $\times 10^{-19}$ C.
k: Boltzmann constant (1.38 $\times 10^{-23}$ J/^{o}K).
I_{cell}: cell output current, Ampere.
I_{photo}: photocurrent, (5 Ampere).
$I_{reverse}$: reverse saturation current of diode (0.0002 Ampere).
R_s: series resistance of cell (0.001 Ω).
T_{cell}: cell temperature (20 ^{o}C).
V_{cell}: cell voltage, Volt

III.CONTROL SCHEME

A. GRID SYNCHRONIZATION

Output of inverter must be synchronized with the grid. This can be achieved using phase lock loop(PLL).Unit vector templates derived from ϴ extracted by PLL through grid are stated as in (4), (5), and (6).

$$U_a = \sin\theta \quad (4)$$
$$U_b = \sin(\theta - 2\,{}^{\Pi}/_{3}) \quad (5)$$
$$U_c = \sin(\theta + 2\,{}^{\Pi}/_{3}) \quad (6)$$

Instantaneous values of voltages can be derived using above unit vectors. These are given by (7), (8) and (9).

$$V_a^* = V_m \times U_a \quad (7)$$
$$V_b^* = V_m \times U_b \quad (8)$$
$$V_c^* = V_m \times U_C \quad (9)$$

Where, V_m is the output of PI controller. Error between the reference voltage V^*_{dc} and the DC output of PV which are given as inputs for the PI controller generates the active voltage component $V_{m.}$ Here we are considering the balanced 3 phase system and thus maintaining neutral current as zero using 4th leg of inverter and hysteresis current controller.

A. CARRIER BASED SVPWM

In this paper we have proposed a carrier based SVM whose Simulink model is as shown in Fig. 4.

$$V_{offset} = -\left({}^{v_{maximum} + v_{minimum}}/_{2}\right) \quad (10)$$

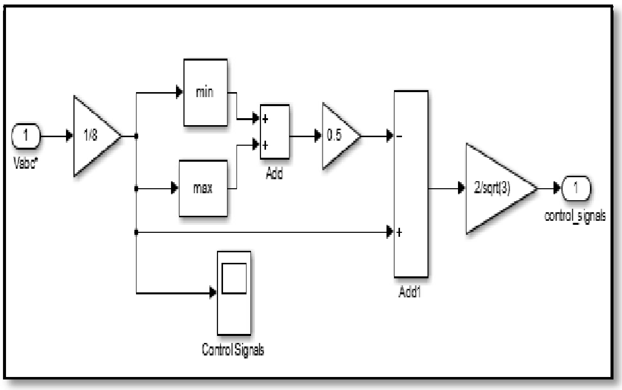

Fig. 4 Carrier based SVPWM

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Modulating signals obtained after grid synchronization are added to offset voltage. The modified signals are compared with the high frequency triangular carrier to produce gating signals for inverter switches.

IV.SIMULATION RESULTS

Power obtained from photovoltaic system is injected into the grid at t = 0.3 sec.

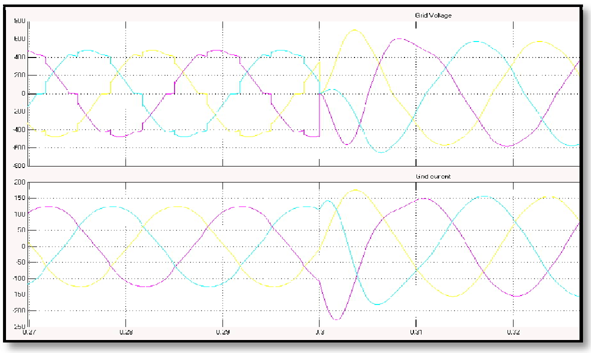

Fig. 5 Grid voltage & current

Waveforms for grid, inverter and load are as shown Fig. 5 above. We can clearly observe that after injection of renewable energy via inverter, we are getting smooth sinusoidal output along with the improvement of voltage profile.

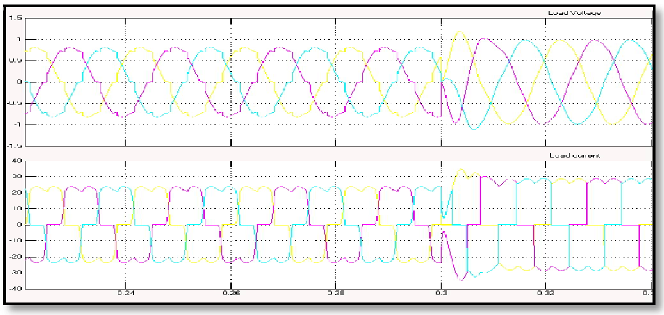

Fig. 6 Load voltage & current

Fig. 6 above shows that before injecting renewable into the system i.e. before 0.3sec there are harmonics in the load voltage. After 0.3sec there is a smooth voltage wave as the total harmonic distortion of the system gets lowered.

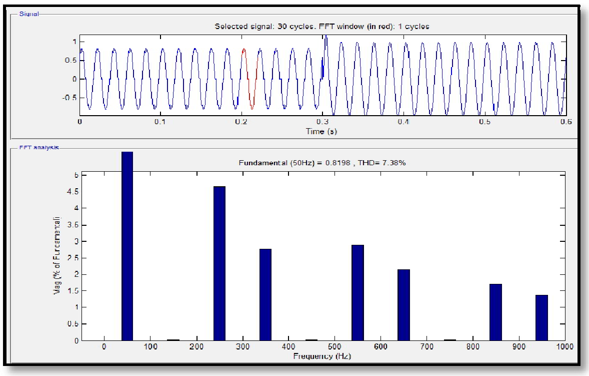

Fig. 7 Before injecting PV power

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To analyse the total harmonic distortion of the system we are performing Fast Fourier analysis. Total harmonic distortion of the system before injecting output of photovoltaic system is higher i.e.7.38% as see in above Fig. 7.

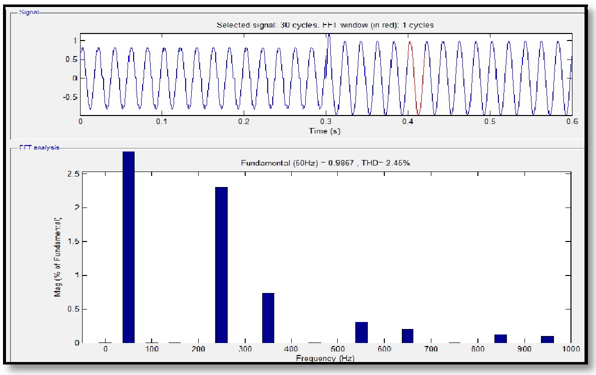

Fig. 8 After injecting PV power

Fig.8 above shows that the total harmonic distortion of the system gets reduced by implementing SVPWM control scheme. Harmonic distortion value gets reduced from 7.38 % to 2.45%.Thus, purpose of using SVPWM method is validated with the results obtained.

V. CONCLUSION

Space vector method used in thus project helps to improve voltage profile of the system. Also, we can also compensate for reactive power. Total harmonic distortion of the voltage can be reduced to the acceptable value as DC utilization is maximum in this method. As compare to sine triangle PWM method, this method is very simple in application. We can easily have its implementation for multilevel inverters also.

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