International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 5 Issue 3, March-April 2021 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Analysis and Simulation of Solar PV Connected with Grid Accomplished with Boost Converter and PWM Based Inverter

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ABSTRACT

This paper deals with a solar PV array connected with grid system. This system consists of PV cells with 30 KW system, Boost converter, three phase inverter with suitable control system and three phase load. This paper gives analysis of each components of the system. The output voltage from the solar PV cells are variable according to radiation intensity and temperature so in order to connect with grid the output voltage should be fixed and converted to AC voltage and this job will be done by an inverter. A very effective control system has been developed for the inverter based on pulse width modulation. This paper presents an intensive performance and dynamic behavior of a grid related PV energy conversion system. The PV system is developed and simulated with the help of MATLAB/ Simulink software environment.

KEYWORDS: *Pulse Width Modulation (PWM), Insulated gate bipolar transistor (IGBT), THD (Total harmonic distortion), STATCOM (static synchronous compensator), SVC (static VAR compensator)*

How to cite this paper: Abhishek Verma | Dr. Anup Mishra | Brahma Nand Thakur "Analysis and Simulation of Solar PV Connected with Grid Accomplished with Boost Converter and PWM Based Inverter" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-5 | Issue-3, April 2021, pp.992-995, URL: www.ijtsrd.com/papers/ijtsrd40056.pdf

IJTSRD40056

INTRODUCTION

The world constraint of fossil fuels reserves and additionally the ever growing environmental pollutants have driven powerfully throughout ultimate many years the occasion of renewable strength sources (RES). The necessity of getting obtainable property power systems for substitution bit through bit trendy ones demands the improvement of systems of power provide based on smooth and renewable resources. At present, solar electric photovoltaic (PV) era is ahead redoubled significance as a RES application because of distinctive blessings like simplicity of allocation, high responsibility, absence of gasoline value, low preservation and absence of noise and wear thanks to the absence of moving factors or practical's. Moreover, the alternative energy characterizes a clean, pollutants-loose and inexhaustible power supply. Additionally to those elements are the declining value and expenses of solar PV modules, associate degree increasing efficiency of sun cells, producing generation enhancements and economies of scale [1].

The warming of global surface is increasing 0.6 degree Celsius per century. This warming caused by huge release of carbon dioxide and carbon monoxide. This causes acid rain, depletion of ozone layer and radioactive emission these effects can be minimized by searching some effective solution, this solution also include energy conservation with improved energy efficiency.

Now As per the financial terms electricity generation using renewable sources have higher price as compared to the non-renewable resources. But now a days the major challenge is to generate a good quality power with lesser incremental cost as much as possible and with lesser carbon emission. In that case we use renewable sources to generate power with good quality. So we should adopt the most convenient and cheapest way for generation transmission and distribution. In order to get an optimum power generation hybrid electricity is used so that increase in price may get compensated by the use of renewable assets.

Many government schemes are running for the incentives in installation of renewable sources worldwide that will also be considered in planning of incremental cost of the project as well as payback period from the savings of electricity bills revenue.

PROPOSED MODEL

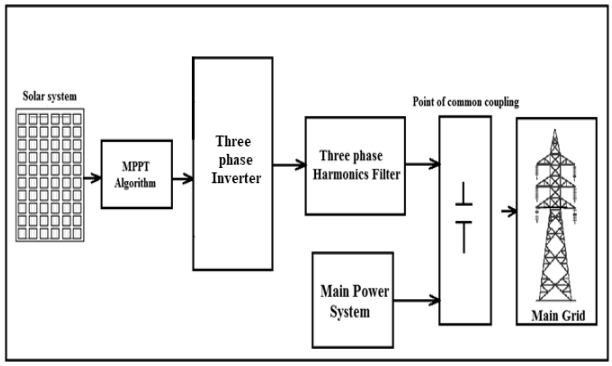

Figure 1 Block diagram of solar PV system connected with grid

Figure 1 shows the solar PV system connected with grid but as we know that solar radiations are not in the same intensity throughout the day due to clouds or shadows or some other disturbances and due to this reason solar energy is unreliable. The PV array output is connected with DC-DC boost converter to rise the output voltage up to a desired level.

MODELLING OF PV ARRAY

Total 30 array system is connected to achieve 30 KW of power with suitable series and parallel combination. In a single module 30 cells are connected in series to get 22 v open circuit voltage. The mathematical model of PV cell is represented by a current source with a diode connected in parallel as shown in figure 2. The intrinsic series resistance whose value is very small. The equivalent shunt resistance whose value is very high, applying Kirchhoff's law to the node where I_{ph}, diode, R_p and R_s meet. [2]

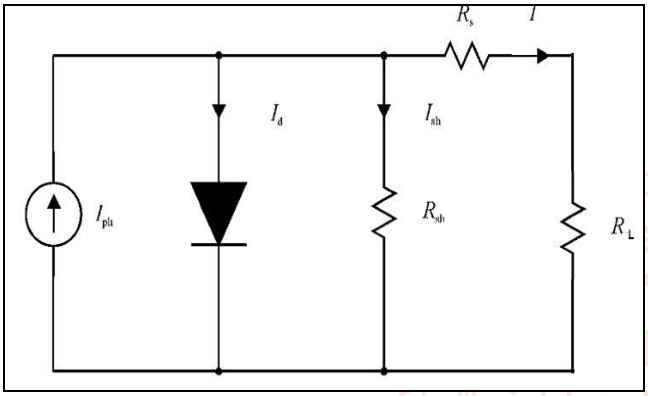

Figure 2 PV Cell Model

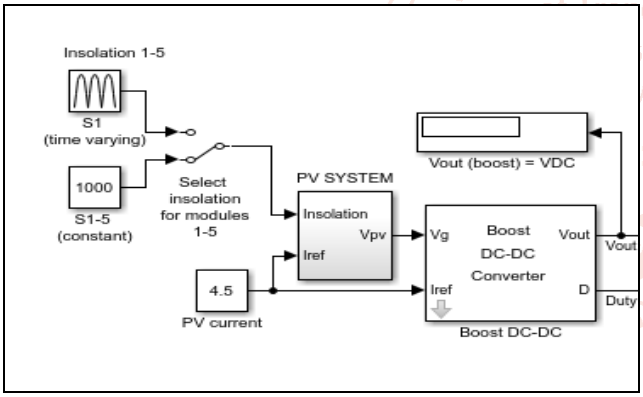

Figure3 Simulink model of PV array

BOOST CONVERTER

The PV system generates DC voltage in all the variable conditions of solar radiations. The generated voltage is low and variable and it must be somewhat high and constant at the input of inverter. So we need a boost converter device to boost the voltage as well it try to maintain constant boosted voltage.

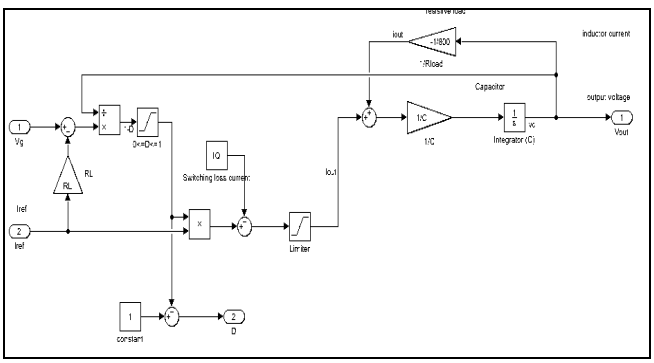

Figure4 Subsystem Of boost converter

Circuit Diagram of boost converter

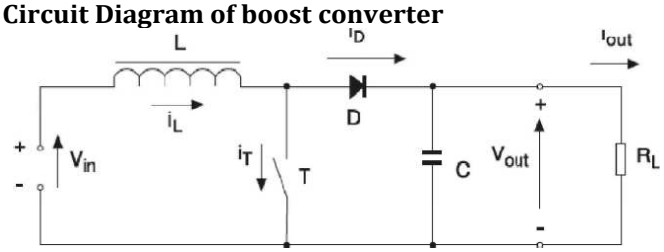

Figure 4 Circuit diagram of boost converter

TheFig.4showsastepuporPWMboostconverter. This consists of adc input voltage source VIN; boost inductor L controlled switch T, diodeD, filter capacitor C and load resistance R_L. When the switch T is in on state, the current in the boost inductor increases linearly and the diode D is off at that time, when the switch T is turned off, the energy stored in the inductor is released through the diode to the output RC circuit. The transfer function for the boost converter is [2]

$$Gs = \frac{Vo}{1\ D} * 1 - \frac{\frac{Ls}{(1-D)^2 * R}}{\frac{LCs^2}{(1-D)^2} + \frac{Ls}{(1-D)^2 *}} \quad \text{.....(1)}$$

PV ARRAY CHARACTERISTIC CURVE

The current to voltage characteristics of solar PV is nonlinear. Therefore it is difficult to determine the maximum power point. The below figure gives I-V and P-V curve for solar irradiation

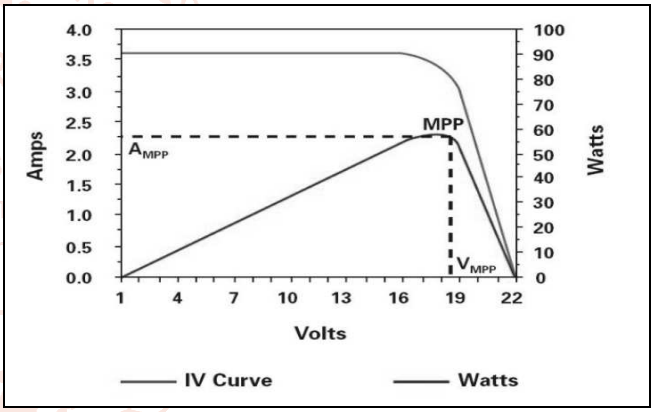

Figure 5 I-V and P-V curve characteristics.

INVERTER CONTROL

Conversion of AC source through Dc sources is achieved by a device known as inverter. Starting from a small switching device to large electricity applications like bulk power transmission inverters are extensively used. Pulse width modulation is a powerful technique for controlling analog circuits with a processors digital output. [3] [4]

The proposed model uses the technique where the variable load is connected to the output of inverter so whenever there is variation in voltage it can be normalized by control methodology process. The voltage at the output of inverter is fed back to the controller where it is compared with the reference bus voltage. The error is then controlled and normalized through PI controller. The proper tuning of proportional and integrator gain is done by initial assumptions.

The PI controller output is in unit tolerance band and to make it alternate proportional to the bus voltage PLL block is used. The pulses generated from PWM generator block is of variable width.

Figure 6 shows the equivalent circuit of voltage source converter PWM VSI used here is a three phase VSI with six

switches. In this figure three phase converters has six semiconductors displayed in three legs a, b and c. Only one switch on the same leg can be conducting at the same time each switch (s1, s2, s3, s4, s5 and s6) in the inverter branch is composed of semiconductor devices connected with anti parallel diode. The semiconductor device is a controllable device and diode is for protection. [5]

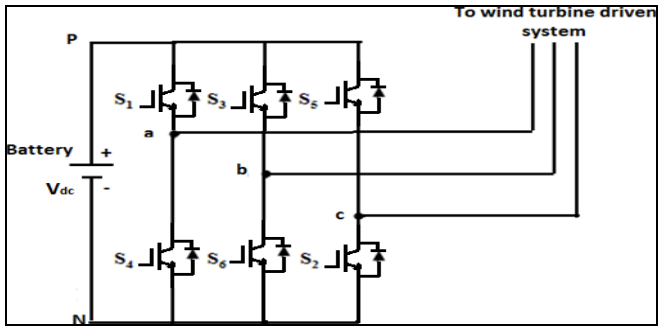

Figure 6 Six switch composition of converter

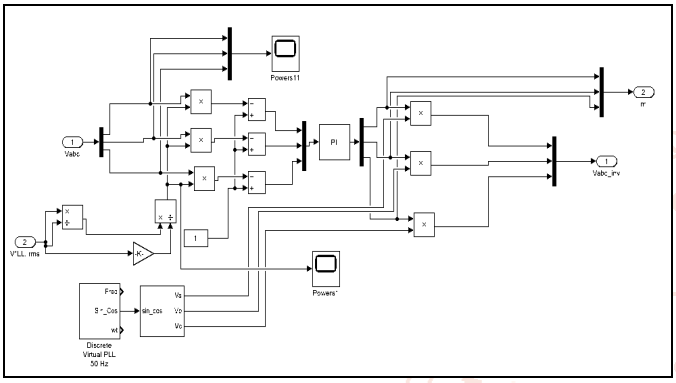

Figure 7 Simulink model of controller

This control system of inverter consists of three main subsystems. The first subsystem is voltage measurement block. This block measured three phase voltage of load side as it varies as voltage magnitude varies. This voltage is then converted to phase voltage, line voltage and rms value of phase voltage. The next subsystem is controller. The VLL gives the reference line voltage which has to be maintained across the grid. This VLL is then multiplied with the rms value of phase voltage and the obtained value is compared with the unit value. The produced signal is given to the PI controller. The values of gain in PI controller is set to normalize the voltage value, the signal generated from PI controller is a DC signal. So in order to make a perfect sinusoidal signal a PLL block is added to match the bus sinusoidal voltage and frequency. The output of this controller then passes through the PWM generator. This PWM generator compares the sinusoidal signal with the triangular wave and then generates the firing pulses by PWM modulation technique.

PROPOSED MODEL

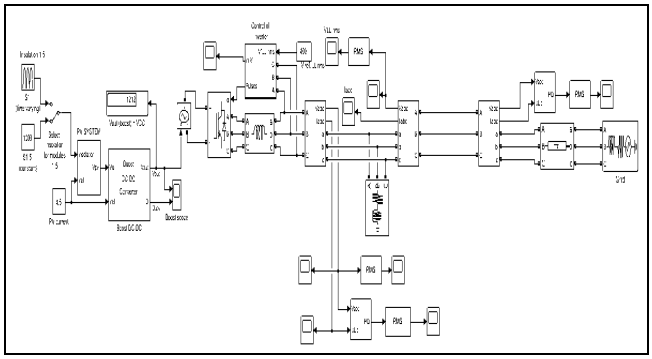

Figure 8 Proposed model

This proposed model describes the PV array of 30 KW which is further connected to DC-DC boost converter to boost the output voltage from array and this DC voltage is converted to AC voltage with the help of inverter and for the constant voltage magnitude and frequency a control system has been developed so that a constant voltage and frequency will be available to the load side or grid.

Various measurement system has been placed at various stages to measure all the parameters for the research and analysis at various stages of the system.

RESULTS

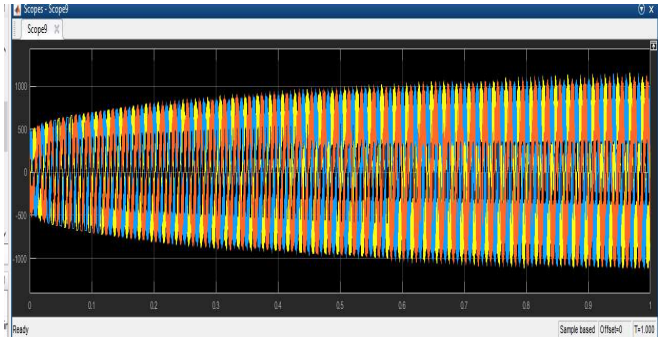

Figure 8 Three phase voltage at output

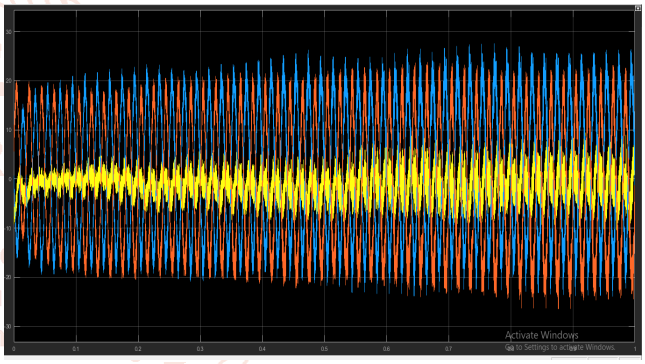

Figure 9 Three phase current at output

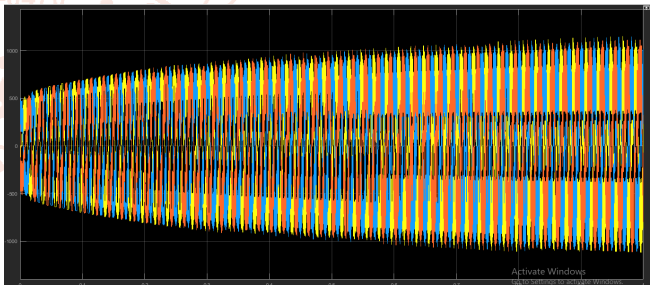

Figure 10 Inverter line to line voltage

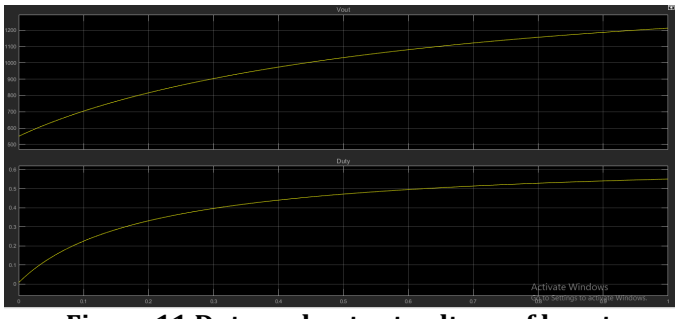

Figure 11 Duty and output voltage of boost converter

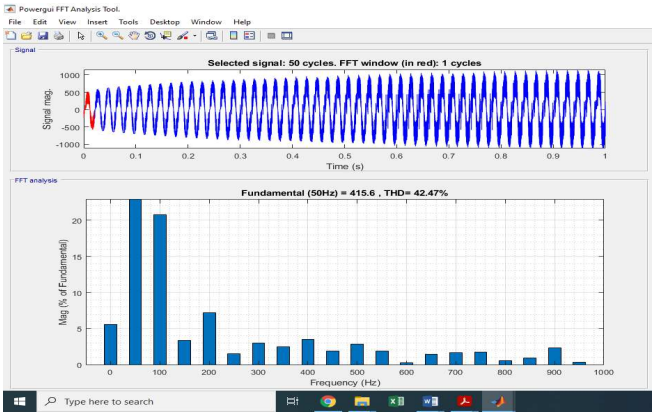

Figure 12 FFT analysis

S.NO	PARAMETERS	
	Name of block	Specification
1	PV Array	Parallel strings = 3 Series connected modules per string = 10 Short circuit current = 5.45 Open circuit voltage = 22.5
2	Grid	Phase to phase voltage = 400 Frequency = 50
3	Boost converter	Capacitance = 20 microfarad Initial capacitor voltage = 550

CONCLUSION

This paper presents a solar PV system connected with grid in which PWM based inverter is used to produce three phase electricity generation. The whole model is simulated in MATLAB Simulink. Parameters taken has been described in the above table and the results are as shown in the above figures almost sinusoidal some more filtration has to be done accordingly to get the smooth output. In future we can work out on the total harmonic distortion that may be reduced from the 42% by using different FACTS devices like SVC and STATCOM.

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