International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 05 | May-2018 www.irjet.net p-ISSN: 2395-0072

Power Quality Improvement for Grid Connected Photovoltaic Systems

Pooja Gupta[1], K.P. Singh[2]

[1,2]Madan Mohan Malaviya University of Technology, Gorakhpur, U.P.-273010.

---***---

Abstract -*In this paper presents complete simulation, modeling and control of three phase grid connected solar Photo Voltaic (PV) module including evaluation of various power quality issues. All the steps involved in complete simulation of three-phase grid connected PV module are presented and discussed in detail. Perturb and Observe (P&O) method has been used for Maximum Power Point Tracking (MPPT). In the proposed model DC bus voltage control, harmonic mitigation and power factor control are discussed as power quality issues. The simulation results are shown in the graphical waveforms and are performed in MATLAB using SIMULINK environment*.

Keywords: PV Array, MPPT, P&O, Irradiation, PWM inverter, STATCOM, THD, Step-up Boost Converter.

1. INTRODUCTION

Due to increased automation, now we all have become heavily dependent on electrical energy. Surely, we all have to look for the alternate sources of energy as the fossil fuels are diminishing with the time and sometimes conventional energy sources are not capable to meet the peak load requirement. Due to limitations of fossil fuels and environmental issues, it is necessary to pay attention towards non-conventional energy sources. Many research efforts have been made and still going on in the field of non-conventional energy sources. Renewable energy source in solar form is the most imperative sustainable energy source as it is the endless source of energy. In this paper solar PV module has been modeled using MATLAB with MPPT controller and VSC Controller with constant and variable irradiation level and reference cited therein [1]-[10]. Several Investigations on MPPT methods and their comparison have been carried out with grid integration also [7]-[18]. In this paper, an attempt has been made to achieve MPPT using P&O algorithm, DC bus voltage control and Unity Power Factor (UPF) at the grid side using Synchronous Reference Frame theory (SRF). Due to the nature of these converters, they inject harmonics to the system and diminish the complete performance. Majorly the power quality is related to the wave shape deformation or distortion. Different issues are involved in power quality such as harmonic analysis, DC link voltage regulation, power factor correction etc. The workability of the proposed model to evaluate and control the power quality issues have been confirmed by the basic models available in Simulink.

1.2 SCHEMATIC REPRESENTATION

Figure 1 shows the basic circuit arrangement for the grid connected solar PV systems. Power electronic based DC-DC boost converter is used to step up and regulate the output DC voltage of PV module. Pulse width modulation (PWM) controller controlled by Synchronous reference frame theory has been used for the switching of IGBT based inverter [17]-[18].

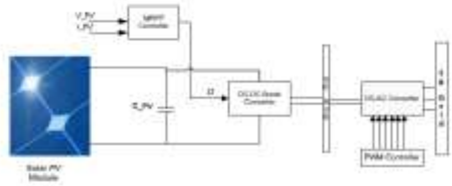


Figure 1. Schematic representation

2. MODELLING OF SOLAR PV CELL AND ARRAY

The electrical equivalent model of solar cell is shown in the Figure2[2]-[3]. Its equations related to the I-V characteristics are expressed in the following [2],[3]:

$$I=I_L-I_0(e^{\frac{q(V-IRs)}{AKT}}-1)-V-IRs/R_{SH} \quad ....1$$

where

I = Solar cell output current ;

V = Solar cell output voltage ;

I0 = Diode saturation current,

q = Charge of an electron (1.602x10-19 C);

A = Diode quality factor,

k = Boltzman constant (1.381x10-23 J/K);

T = Absolute temperature (K)

Rs = Series resistances of the solar cell;

RSH = Shunt resistances of the solar cell

Since in the PV module, some solar cells are connected in series and some are in parallel to match the requirements of the grid. The output I-V characteristics of a PV module are given by:

$$I\approx n_pI_L-n_pI_D(e^{\frac{q(V-IRs)}{n_sAKT}}-1) \quad ....2$$

where np and ns are the number of solar cells in parallel and series respectively [4]-[6].

Equations (1) and (2) have been modelled in MATLAB for 100KW PV array. The P-V and I-V characterstics shown in Figure 3 have been obtained using the simulink-based models.

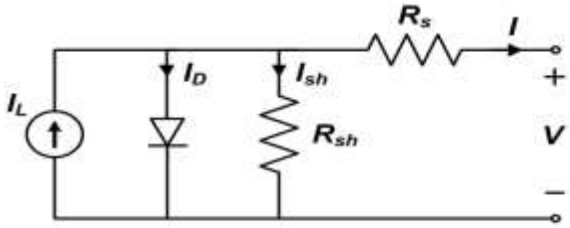


Fig 2. Equivalent circuit of PV array

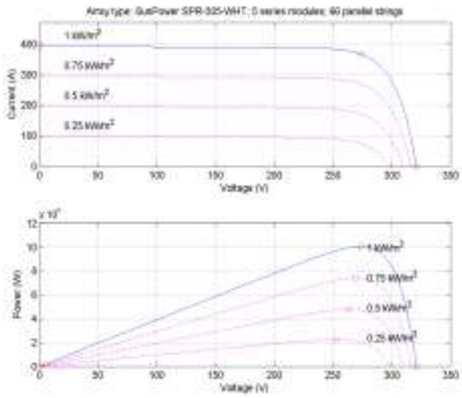


Fig 3. I-V and P-V Characteristics of 100KW solar array

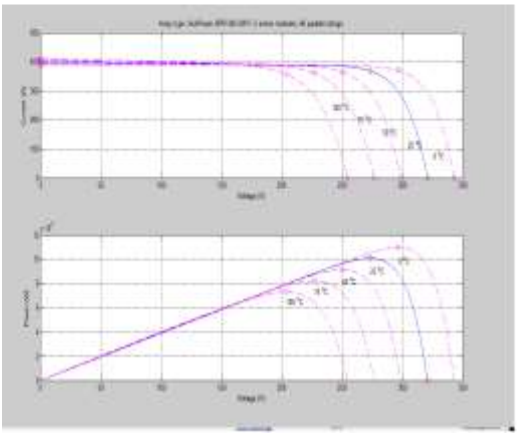


Fig.3.2: I-V and P-V characteristics of the PV module under constant irradiance and different temperature.

4. MAXIMUM POWER POINT TRACKING

To obtain the maximum power from a solar module MPPT is necessary as it varies with radiation level and temperature. There are many methods available and reported in the literature to find the MPP [7]-[10]. Different factors are taken into consideration while applying MPP such as overall efficiency, cost, required sensors etc. In this paper Perturb and Observe algorithm is used to track the maximum power.

4.1: Perturb and observe method

In the Perturb and Observe strategy specifically control is measured utilizing voltage and current Sensor. The control is computed from the voltage and current esteems at nth moment.

By augmenting the estimations of duty cycle by a little proportion the voltage and current esteems will be estimated at N+1th instant. The control an incentive at Nth moment and N+1th moment will be compared. If the adjustment in the power as for the is sure then the procedure is going in the right heading, that is the positive direction. The duty cycle will be increased by a small ratio and the process will be continued for the next cycle.

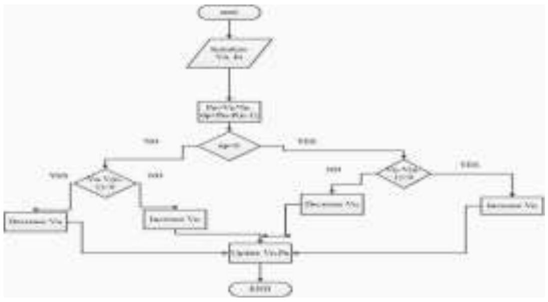


Fig.4.1: Flow chart diagram for perturb and observe method

5. DESIGNING OF DC-DC BOOST CONVERTER

DC-DC boost converter is used to boost and regulate the output voltage of PV module. Following equations are used for designing the boost converter [17]-[18]:

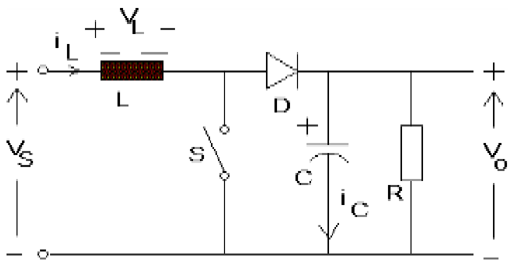


Fig.5: Boost Converter Circuit Diagram

The relation between the output voltages over the input voltage is:

$$Vo/Vs=1/1-D$$

Where, Vs is the source or input voltage to the boost converter, Vo is the output voltage of boost converter, and D is the duty cycle of converter.

5.1. CONTROLLER DESIGN-

The VSC is controlled in the pivoting d-q frame to infuse a controllable three stage AC current into the matrix.To accomplish solidarity control factor activity, current is infused in stage with the network voltage.

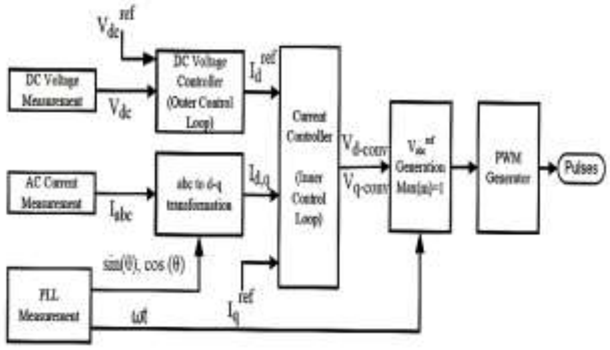


Fig.5.1 Functional control diagram of VSC using vector control

6. SINUSOIDAL PULSE WIDTH MODULATION (SPWM)

The DC-AC inverters generally operate on Pulse Width Modulation (PWM) technique. The PWM is a usually helpful strategy in which width of the door beats are controlled by different systems. PWM inverter is utilized to keep the yield voltage of the inverter at the evaluated voltage independent of the yield stack.

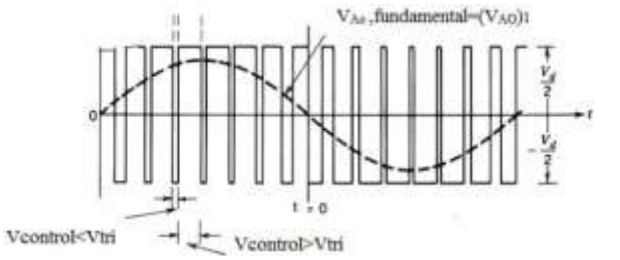


Fig.6 Pulse width modulation waveforms

6.1. Static Synchronous Compensator (STATCOM)

A Static Synchronous Compensator (STATCOM) also known as Static Synchronous Condenser. STATCOM is a regulating device used on alternating current (AC) electricity transmission network. It is based on power electronic voltage source or sink of reactive AC power to an electricity network. STATCOM is a shunt connected compensation device having the ability of injecting or absorbing the reactive power.

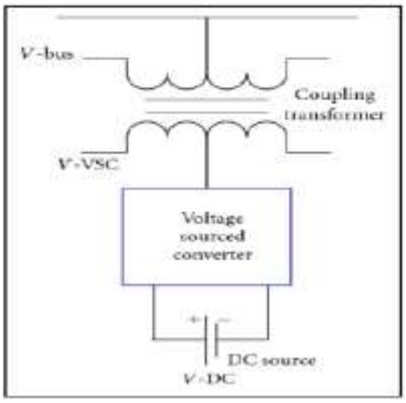


Fig.6.1 Circuit Diagram of STATCOM

7. DEFINITION OF POWER QUALITY

"Power quality is an arrangement of electrical limits that enables a bit of hardware to work in its proposed way without critical loss of execution or future" This definition grasps two things that we request from an electrical gadget: execution and future. Any power-related issue that bargains either property is a power quality concern.

7.1 POWER QUALITY DISTURBANCES CLASSIFICATION

The effects of power disturbances vary from one piece of equipment to another and with the age of the equipment. Equipment that is old and has been subjected to harmful disturbances over a prolonged period is more susceptible to failure than new equipment. With the purpose of classify different types of power quality disturbances, the characteristics of each type must be known. In general, power quality disturbances are classified into two types: steady state and non-steady state.

These disturbances are mainly caused by:

- External factors to the power system: for example, lightning strikes cause impulsive transients of large magnitude.
- Switching actions in the system: a typical example is capacitor switching, which causes oscillatory transients.
- Faults which can be caused, for example, by lightning (on overhead lines) or insulation failure (in cables). Voltage dips and interruptions are disturbances related to faults.

SIGNAL ANALYSIS

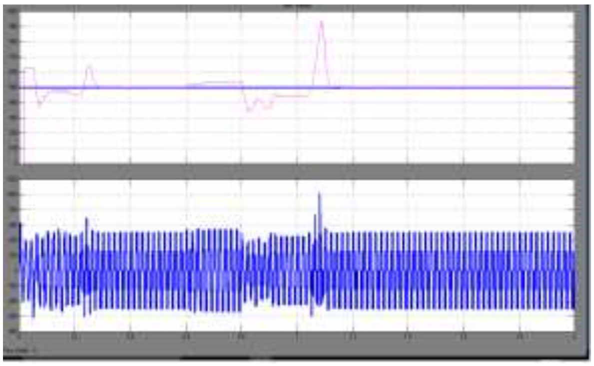
This is the step for monitoring power quality disturbances. It involves signal processing techniques in order to analyze the detected disturbance signals. The main objective of the analysis procedure is to justify the disturbance signals features.

Fast Fourier Transform (FFT)

FFT is a basic method used widely in signal processing. FFT is applied to extensive data that has been selected based on various measurements. The FFT spectrum is normally used for detecting dominant harmonics, inter-harmonics and their related magnitudes.

STEADY STATE ANALYSIS

The investigated system comprises of a 96 kW PV array which is associated with a boost converter, and after that the boost converter is associated with the grid by means of a three-phase inverter. The PV panel utilized in this thesis is SUNPOWER: SPV 305 KW. In this study, the 96 kW array consists of 66 parallel string each comprise 5 series connected panel.First, the simulation is obtained while applying the P&O algorithm and set the irradiances to 1KW/m2 and the temperature to 25oC.



Vref and mean voltage of PV array without statcom

FFT Analysis Total Harmonic Distortion THD without STATCOM

The total harmonic distortion (THD) level is around 9.70.Percentage for liner compose stack like the inductive sort of load. The going with figure exhibits the present waveform for 5 cycles. It gives the data about the key portion appear in the yield waveform. The essential fragment is occurring 2.04e+04 amps out of the aggregate load current.

THD level with straight loads without statcom

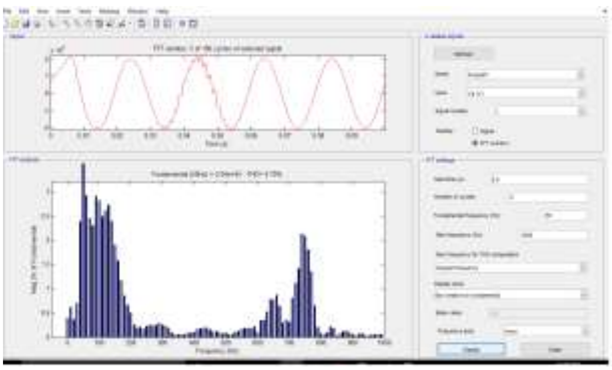


Fig -1: THD level without STATCOM

FFT Analysis Total Harmonic Distortion (THD) Level with STATCOM

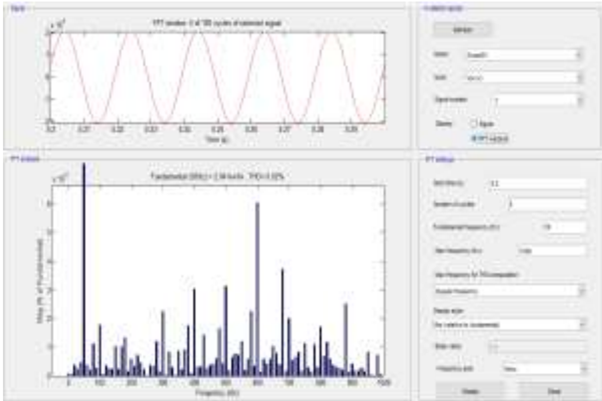


Fig -1: THD level with STATCOM

The following figure shows the total harmonic distortion (THD point present in the yield current of the system, in the wake of applying the responsive power pay want to the inverter circuit. The THD level is getting 0.02 rates. The THD level without applying the STATCOM plans is about the 9.70 rates. The THD level decreases fundamentally by applying the STATCOM plot.

3. CONCLUSION

The renewable energy sources such as solar energy play an important role in electric power generation, it is clean and unlimited. A P&O was designed to maximize the energy received from solar cells by tracking the maximum power point with the help of DC-DC converter, and then the system is connected to the grid with a DC-AC inverter. The advantage of the P&O control is that it does not strictly need any mathematical model of the plant. It is based on plant operator experience, and it is very easy to apply. Hence, many complex systems can be controlled without knowing the exact mathematical model of the plant. In addition, P&O algorithm simplifies dealing with nonlinearities in systems. The proposed algorithm is by implementing a maximum power point tracker controlled by P&O controller and using Boost DC-to-DC converter to keep the PV output power at the maximum point all the time. The comparison shows that the P&O controller was faster response in tracking the maximum power point under variable and constant irradiance and gives minimum oscillations around the final operating point compared to the other algorithms.

REFERENCES

1. A. Timbus, Grid Monitoring and Advanced Control of Distributed Power Generation Systems, 2007.

2. M. Rashid, Power Electronics Handbook- Devices, Circuits and Application, Academic Press, 2011.

3. S. Kalogirous, Solar Energy Engineering: Processes and Systems. Academic Press, 2009

4. A. Goetzberger, Photovoltaic Solar Energy Generation. Springer, 2005.

5. Governor Schwarzenegger Advances State's Renewable Energy Development, California Governor's Executive Order S-14-08, November 2008.

6. Renewable 2013: Global Status Report, REN21, 2013.

7. Solar Photovoltaic's: Status, Costs, and Trends, EPRI, Palo Alto, 1015804, 2009.

8. R. A. Messenger and J. Ventre, Photovoltaic Systems Engineering, CRC Press, 2010.

9. U.S. Department of Energy, 2010 Solar Technologies Market Report, First Solar. [Online]. http://www.firstsolar.com/Projects/Topaz-Solar-Farm.

10.http://en.wikipedia.org/wiki/Electricity_sector_in_India, Accessed on Apr. 2015.

11. Hamad, M.S, Fahmy, A.M andabdel-geliel,M, M, "Power quality improvement of three phase grid connected PV system with MPPT controller," in Arab academy for science, technology and maritime transport(AASTMT).,pp. 1839-1842., 2013.

12. Prabha K,Malathi T,Muruganandam M, "Power quality improvement in three phase grid connected nonlinear loads", vol.4, no.3, pp. 1269-1276, 2015.

13. Rama krishan, Yang raj sood, Uday Kumar, "Simulation and design for analysis of photovoltaic system based on mat lab," pp.647-651, 2011.

14. N. C. Sahoo, I. Elamvazuthi, Nursyarizal Mohd Nor, P. Sebastian and B. P. Lim,'' PV Panel Modelling using Simscape,"pp.10-14,2011

15. N. Femia, G. petrone, V. Spagnuolo, M. Vitelli, 'Optimization of Perturb and Observe maximum Power Point Tracking Method', IEEE Trans. on Power Electron., Vol. 20, No. 4, July 2005.