SIMULATION OF SHUNT ACTIVE POWER FILTER FOR POWER QUALITY ENHANCEMENT IN GRID-CONNECTED SOLAR PV SYSTEM

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Abstract: - The power system's operation can be enriched by using PV systems like improvement in voltage profile, reducing energy losses in the distribution feeder, and reducing the load of the tap changer transformer during peak hours. In PV technology, lots of development is going on. A shunt active shunt filter (SAPF) operated as a harmonic conductance can suppress harmonic resonance in the distribution power system. This project presents an active filter with resonant current control to suppress harmonic resonance. The current control is realized by parallel-connected band-pass filters tuned at harmonic frequencies to ensure that the active filter functions as an approximately pure conductance. The proposed method has good accuracy in extracting fundamental active component of distorted and unbalanced load currents with reduced mathematical computations. Along with power quality improvement, the system also generates clean energy through the PV array system integrated to its DC-link. The APF-PV integrates benefits of power quality improvement and distributed generation. The system performance is carried out using Matlab Simulink.

Keywords: - SAPF, Solar PV, Grid, Power Quality, Harmonics ,etc.

1. INTRODUCTION

Due to increasing power demand many new alternatives of power generation are used effectively. Out of all these photovoltaic generation is effective and can easily be implemented. The power from the PV system has different outputs depending on the condition of temperature and irradiance. To extract maximum power from PV array different MPPT algorithms are available such as, perturb and observe (P&O), incremental conductance (INC) and many more. Out of all these INC have some advantages and commonly implemented in many PV applications. This mppt controller is used to extract maximum power under all the irradiance conditions using boost converter. The output of PV system serves as DC link for the inverter. A power controlling method is employed to synchronize the PV system with grid. Generally, there are 2 main power stages in a grid tie PV system. First is DC link voltage control stage that maintains constant DC link voltage across inverter input and second stage consist of inverter current control that controls the current injected into the grid. Another major issue faced in modern distribution systems is the extensive use of nonlinear power electronic systems, which draw highly distorted currents. These distorted currents cause voltage distortion at PCC depending upon the magnitude of current and grid impedance. These loads also cause losses in feeders and distribution transformers. Moreover, these loads themselves are sensitive to PCC voltage dip/rise, which causes frequent tripping and increased maintenance costs. Hence, the major requirement of the modern distribution system is integrating renewable energy systems and power quality improvement.

The power system's operation can be enriched by using PV systems like improvement in voltage profile, reducing energy losses in the distribution feeder, and reducing the load of the tap changer transformer during peak hours. In PV technology, lots of development is going on. Still, the system has some adverse effects and problems such as low efficiency, harmonic pollution, overloading of the feeders, high investment cost, and low reliability, which impede their prevalent use. For the improvement in the efficiency of PV, the maximum power point tracking (MPPT) controlling method is used[1]. In this method, system power can be controlled using produced voltage and current of a PV panel. There may be a possibility of increasing system failure in unexpected weather conditions due to the tracking system. Whenever utility grid failure during a fault condition, local loads are disconnected at that time PV based distributed generation (DGs) are energies.

If the PV system is connected at the distribution level, it is considered a distributed generation (DG). The utility is anxious due to the PV system's high penetration level in distribution systems as it may cause to affect stability, voltage regulation, and power quality (PQ) issues. However, the excess use of power electronics drives and nonlinear loads at PCC generates harmonic currents, affecting the quality of power. This creates an unbalancing effect on the transmission and generation side and also load can result in harmonics, voltage profile, and a severe PQ problem in the power system network. Active power filters (APF) are easily used to compensate for the load current harmonics and load unbalances at the distribution level.

2. SOLAR PV SYSTEM

The Solar Photovoltaic Array is formed by connecting several solar panels in series and parallel combination to generate the required power. The smallest component of the solar photovoltaic array is called photovoltaic (PV) cell. The ideal solar photovoltaic cell is represented by the equivalent circuit shown in Fig 1[2]. These cells are connected in series of 36 or 72 cells to form one module. Similarly, several modules are assembled into a single structure to form array. Finally, assembly of these photovoltaic arrays are connected in parallel to obtain the required power. In PV module, series resistance(R_s) is comparatively more predominant and R_{sh} is considered equal to infinity ideally. The open circuit voltage(V_{oc}) of the PV cell is directly proportional to solar irradiation and V_{oc} is inversely proportional to the temperature. The PV Array is characterized based on the I-V and P-Vcharacteristic.

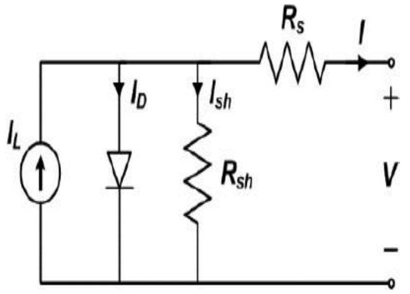

Figure 1: Equivalent circuit of PV cell

Harmonic distortion

In power system, the deviation of voltage and current waveforms from sinusoidal waveforms is known as harmonic distortion. Harmonic distortions are mainly caused by the nonlinear devices. Generally, it is desired to draw purely sinusoidal current from the distribution network, but this is no longer the case with the new generation of loads, consisting of power electronic converters. Current harmonics generated by these nonlinear loads are propagated throughout the network; add further distortion to the ideal sinusoidal voltage waveform[3]. Voltage distortion is the result of distorted currents passing through the linear, series impedance of the system.

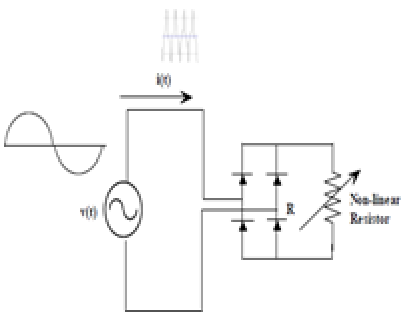

Figure 2: Distorted current produced by a non-linear load

Some applications that are increasingly being dominated by power electronics are variable speed motor drives, switched mode power supplies, efficient control of heating and lighting, efficient interface for photovoltaic, modern domestic appliances, fuel cell and high voltage dc system for efficient transmission of power. Advancements in power semiconductor technology have made earlier predictions true and these days substantial electrical power is being processed through solid- state methods.

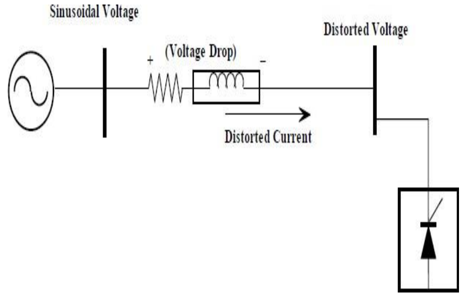

Figure 3: Voltage distortion caused by distorted current atload centers

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In addition to the numerous advantages offered by these power electronic converters, they offer highly nonlinear characteristics and suffer from the problem of drawing non-sinusoidal current and reactive power from the AC mains. Current harmonics generated by these nonlinear loads are propagated throughout the network; add further distortion to the ideal sinusoidal voltage waveform. Voltage distortion is the result of distorted currents passing through the linear, series impedance of the system, as shown in Figure 3. Harmonic currents passing through the system impedance causes a voltage drop for each harmonic, and results in voltage harmonics appearing at the load bus and leads to other power quality problems. These problems led to implementation of standards and guidelines such as IEEE-519, for controlling harmonics on the power system along with the recommended limits. Hence, mitigation of current waveform distortions due to harmonics, and compensation of reactive power requirements of nonlinear loads, is considered among the major remedies for the power quality deteriorations.

3. PROPOSED WORK

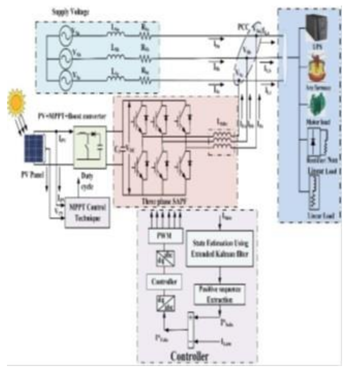

Fig.4. Proposed PV-SAPF system

For the synchronization of utility grid and grid connected PV system, some condition has to satisfy like voltage level, frequency and phase sequence matching. This synchronization is done by PV inverter which having advance power electronicstechnology.

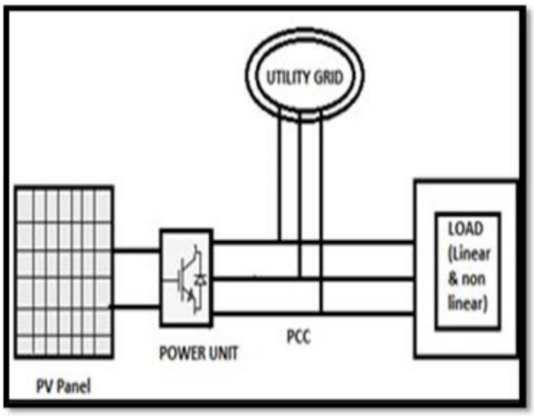

Fig. 4 Grid connected PV system

The power-voltage relationship or current-voltage relationship of the cell can generally be representing the Electrical characteristics of a PV unit. The changes of solar irradiance on the cell and the cell temperature are directly varies these characteristics[4]. A proper simulation model is needed to convert the changes of temperature and radiation on generated voltage and current of the PV arrays. So that at the different weather conditions, the dynamic performance of PV system can be analyze.

Active Power Filter Role

Voltage distortion is a major problem on utility side due to cause of Harmonics. Other problems like line loss reactive power, resonance, heating of equipment's are also due to harmonics which reduce the stability of system. An active filter is solution to mitigate problems encountered due to harmonics on utility side. Harmonic resonance is not a concern with this kind of filter. The active filter is used for nonlinear load having time dependent harmonics. There are some topologies are considered to meet IEEE 519 harmonics standards at plant utility PCC interface. Shunt active filter, series active filter, hybrid active filter with CSI and VSI inverter topologies are available. The sizes of these filters are depending upon the harmonic which have to mitigate.

Shunt Active Filter

- Shunt active filter is based on load harmonic current injection principle and is characterized by non- sinusoidal current reference tracking.
- Extraction of load harmonic current is carried out by shunt harmonic filter with the help of suitable current controller. Proposed model of Shunt Active filter comprises switching ripple filter of rating which filters a current.
- Synchronous reference frame theory[5] is used for controlling and extraction of load harmonic current and generating pulse for inverter.
- A shunt active shunt filter (SAPF) operated as a harmonic conductance can suppress harmonic resonance in the distribution power system.
- This project presents an active filter with resonant current control to suppress harmonic resonance. The current control is realized by parallel-connected band- pass filters tuned at harmonic frequencies to ensure that the active filter functions as an approximately pure conductance [6].
- The proposed method has good accuracy in extracting fundamental active component of distorted and unbalanced load currents with reduced mathematical computations.

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4. SIMULATION AND RESULT DISCUSSION

Matlab Simulation of Grid Connected Solar PV system

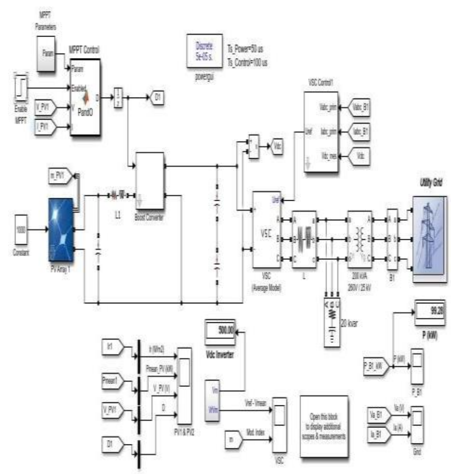

Fig 6- Matlab Simulation of Grid Connected Solar PV system

To model a PV array, it is unrealistic to simulate every solar cell in the array. Moreover, PV manufacturers usually only provide end users with complete and environmentally protected modules rather than solar cells in bulk. In addition, in real working conditions, solar cells packaged in the same module usually have almost the same irradiance conditions. For these reasons, we can simply assume that all the solar cells in each PV module have identical characteristics and working conditions. Thus, a PV module can be viewed as a basic unit consisting of identical solar cells

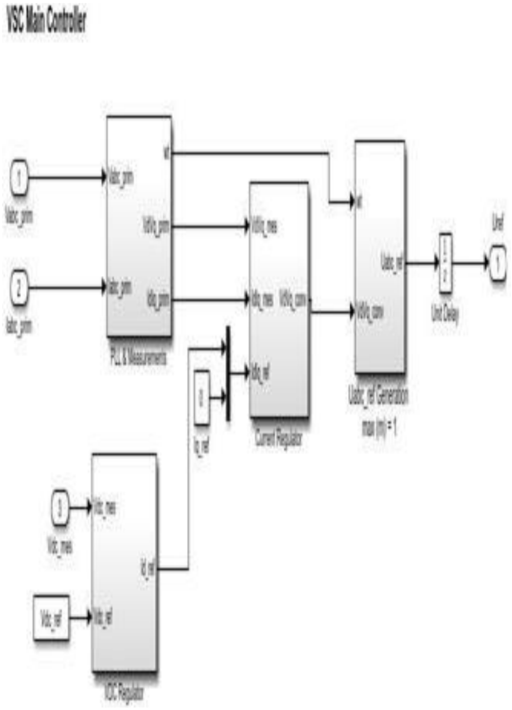

Fig 7- Matlab Subsystem of VSC Controller

The proposed numerical model (shown in Fig. 6) can be simulated in any circuit simulation package, and it is even simple enough to be accurately simulated in MATLAB/Simulink. This thesis adopts MATLAB/Simulink as the simulation environment, since it has Sim Power Systems tool box which can offer an open and flexible interface to model numerical, electrical and control systems.

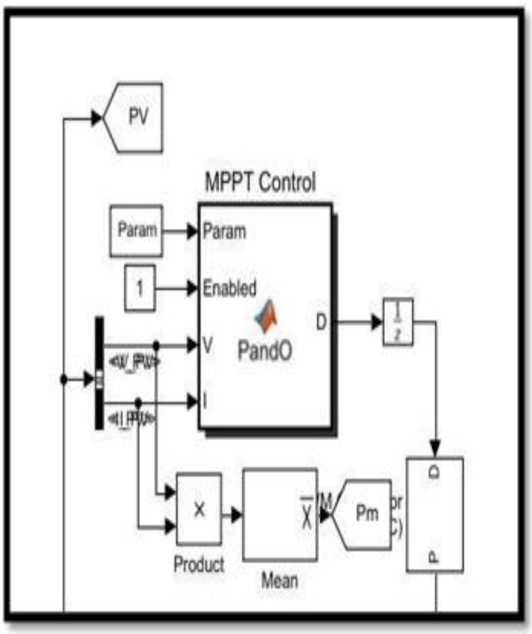

Fig 8- MPPT Control using P&O Algorithm

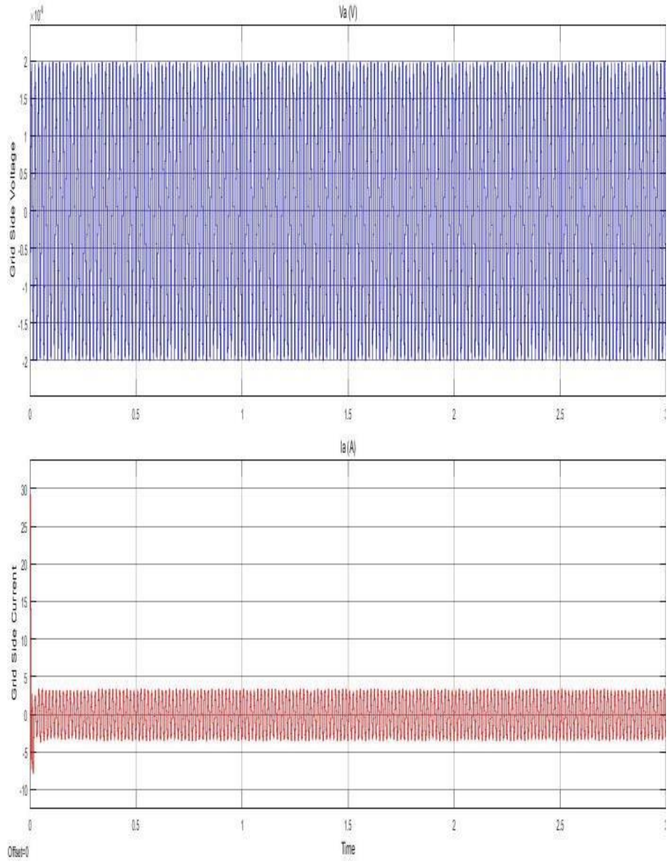

Fig 9- Grid Side Output Voltage and Current

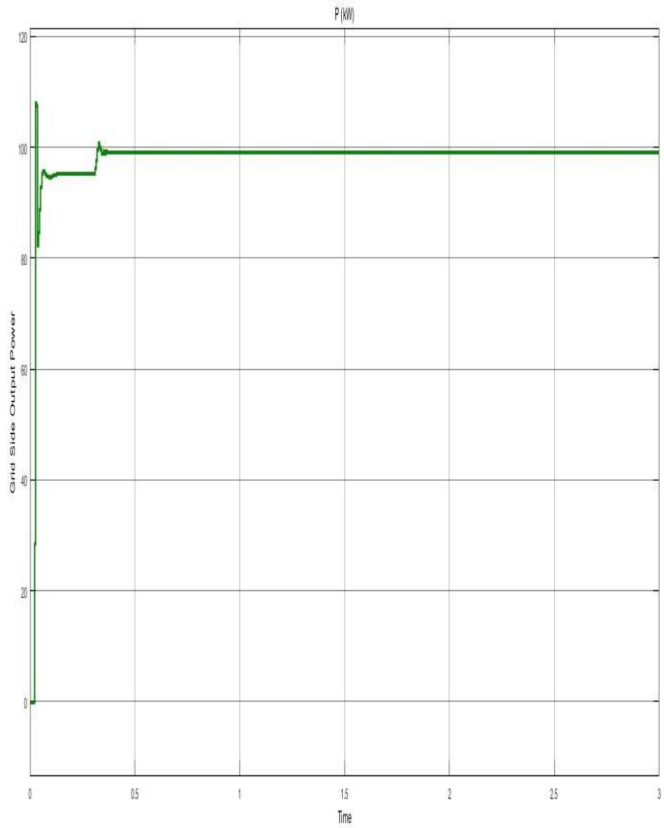

Fig 10-Grid Side Output Power

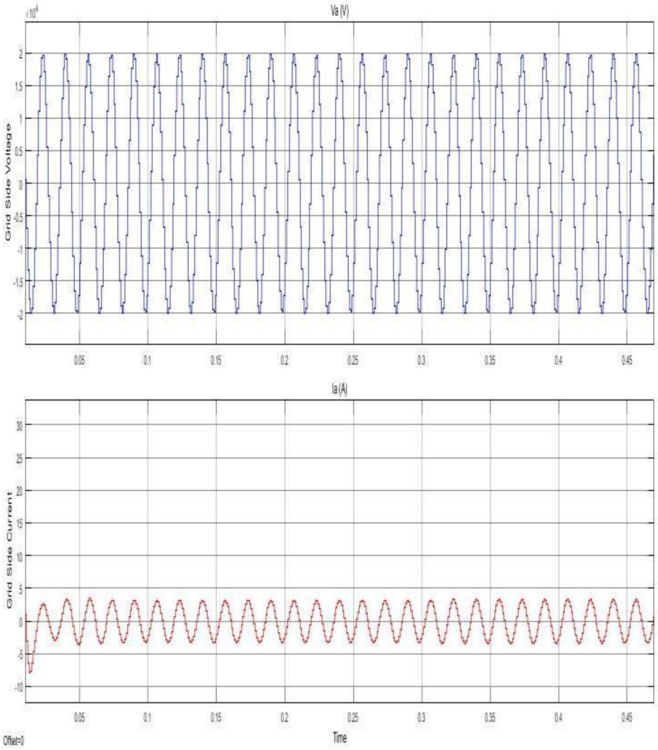

Fig 11- Grid Side Voltage and Current with Zoom Scale

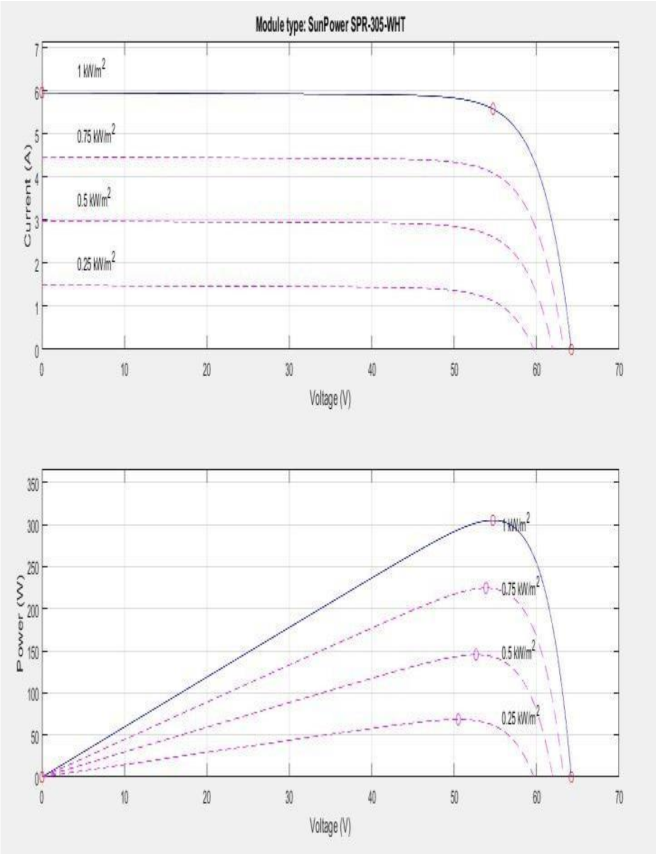

Fig 12- Solar I-V and P-V Characteristics for one Module ofPV

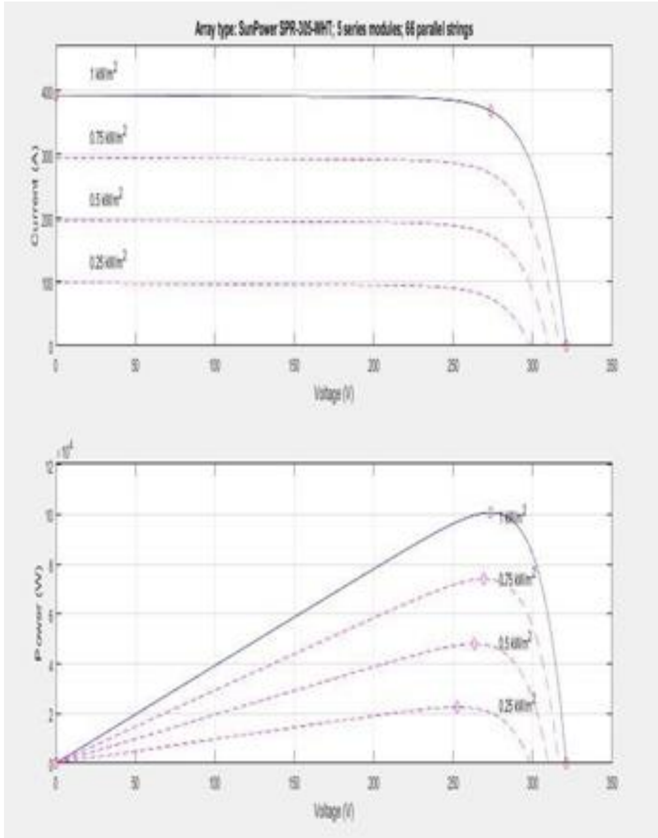

Fig 13- Solar I-V and P-V Characteristics for PV Array

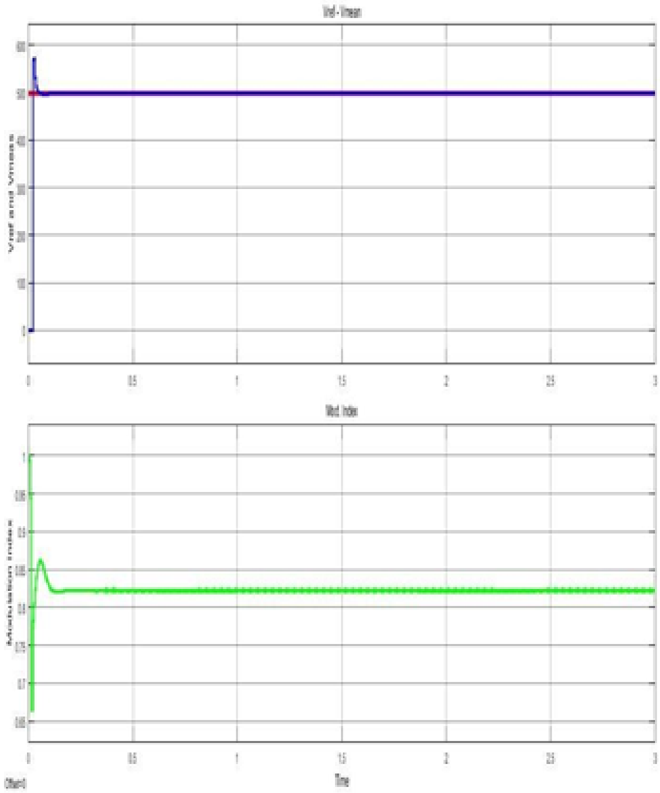

Fig 14-VSC Controlling Parameters

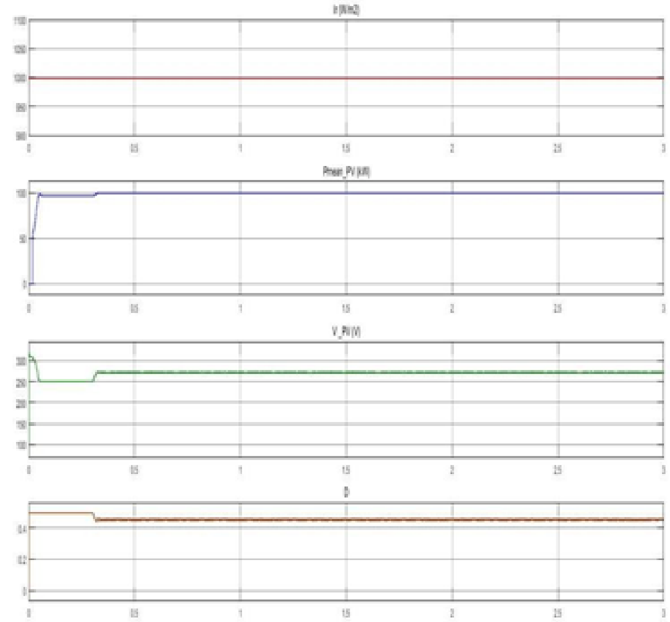

Fig 15- Solar PV output Parameters

5. CONCLUSION

As shown in the graph the P-V and I-V characteristics of PV system changes as per the change in temperature as well as irradiation. So, the PV Generation is very sensitive to any change in the value of temperature as well as irradiation. So accordingly, the output values of all the components connected will be directly affected to this variation. To achieve maximumpower point, we can control the current or regulate the voltage to maintain the power. In the proposed system, MPPT regulates the duty cycle to maintain voltage and achieve maximum power. Boost Converter Simulation with Perturb and Observe MPPT method is implemented in MATLAB-SIMULINK. From the Simulink results it is cleared that the MPPT method simulated here is capable of improving the dynamic and steady state performance of the PV system simultaneously. Through simulation it is observed that the system completed the MPPT successfully irrespective of fluctuations. With the sudden change in external environment the system can track the maximum power point quickly

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