SHUNT ACTIVE POWER FILTER PERFORMANCE ANALYSIS FOR POWER QUALITY ENHANCEMENT IN GRID-CONNECTED SOLAR PV-SYSTEM

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ABSTRACT

A photovoltaic (PV) system that is directly connected to the electrical grid is known as a grid-connected PV system. This enables the use of solar power during the day and grid power when solar energy is insufficient, allowing for the seamless integration of solar energy into the current power infrastructure. They contribute to a cleaner and more resilient energy future by offering a variety of advantages to the economy and environment. For grid-connected solar PV systems to continue operating reliably and with excellent power quality, a shunt active power filter must be integrated. SAPFs contribute to a steady and effective power supply, enhancing the performance of the grid and the solar PV system, by reducing harmonics, balancing loads, and correcting reactive power. In order to reduce harmonic resonance, this research proposes an active filter with resonant current management. In order to guarantee that the active filter acts as a nearly pure conductance, parallel-connected band-pass filters tuned at harmonic frequencies are used to achieve current control. With fewer mathematical calculations, the suggested method extracts the essential active component of distorted and unbalanced load currents with good accuracy. In addition to enhancing power quality, the system produces clean energy by means of a PV array system that is integrated with its DC-link. The advantages of distributed generation and power quality improvement are combined in the APF-PV. To measure the system performance, Matlab Simulink is used.

Keywords—SAPF, Solar PV, Grid, Power Quality, Harmonics, linear/non-linear load etc.

I. INTRODUCTION

An effective and dependable electrical grid depends on the supply and demand for power being balanced. The role of renewable energy sources (RES) in this balance is growing. Examples of RES include solar, wind, hydro, and biomass. Resilient and sustainable energy systems require the use of renewable energy sources. They improve energy security, diversify the energy mix, and lower greenhouse gas emissions. In order to provide a stable and balanced supply and demand for electricity, the successful integration of renewable energy sources into the grid necessitates a combination of technological, regulatory, and market-based approaches.

Addressing the issues of intermittency, grid stability, and infrastructure is necessary when using renewable energy sources to balance the supply and demand for electricity. Effective integration of renewables requires solutions like energy storage, demand response, grid modernization, hybrid systems, sophisticated forecasts, and supportive legislation.

These tactics can be used to build a more resilient and sustainable energy system that can satisfy the rising demand for clean energy.

In order to synchronize the PV system with the grid, a power controlling technique is used. Typically, a grid connect photovoltaic system consists of two primary power stages. The second stage consists of inverter current control, which regulates the current injected into the grid, and the first is DC link voltage control, which keeps a constant DC link voltage across the inverter input. The widespread use of nonlinear power electronic equipment, which draw extremely distorted currents, is another significant problem with contemporary distribution networks. Depending on the current and grid impedance, these distorted currents create voltage distortion at PCC. Distribution transformers and feeders lose power as a result of these loads. Furthermore, the sensitivity of these loads to PCC voltage dips and rises results in frequent tripping and higher maintenance expenses. Therefore, the integration of renewable energy systems and power quality enhancement is a crucial demand of the modern distribution system.

PV systems can enhance the voltage profile, lower energy losses in the distribution feeder, and lessen the load on the tap changer transformer during peak hours, among other aspects of the power system's performance. There is a lot of ongoing advancement in PV technology. However, the system has certain drawbacks and issues that prevent their widespread usage, including low efficiency, harmonic pollution, feeder overload, expensive investment costs, and limited reliability. The maximum power point tracking (MPPT) controlling mechanism is utilized to increase PV efficiency [1]. With this technique, the generated voltage and current of a photovoltaic panel can be used to control the system power. The tracking system may increase the likelihood of system failure in unforeseen weather conditions. Local loads are disconnected during utility system failures due to fault conditions; PV-based distributed generation (DGs) are energy The PV system is regarded as distributed generation (DG) if it is connected at the distribution level. Because of the PV system's high penetration level in distribution networks, the utility is concerned about potential effects on power quality (PQ), voltage regulation, and stability. On the other hand, harmonic currents are produced by overusing power electronics drives and nonlinear loads at PCC, which lowers the quality of power. The transmission and generation sides become unbalanced as a result, and the load may also lead to harmonics, a voltage profile, and a serious PQ issue in the power system network. At the distribution level, load unbalances and load current harmonics can be readily compensated for by active power filters (APF).

I. SOLAR PV SYSTEM

To create the necessary power, many solar panels are connected in series and parallel to form a solar photovoltaic array. Photovoltaic (PV) cells are the smallest unit in a solar photovoltaic array. The analogous circuit seen in Fig. 1[2] represents the perfect solar photovoltaic cell. To create a single module, these cells are linked in series of 36 or 72 cells. In a similar vein, an array is created by assembling multiple modules into a single structure. In order to obtain the necessary power, the photovoltaic array assembly is finally connected in parallel. Series resistance (Rs) is somewhat more prevalent in PV modules, while Rsh is optimally thought to be equal to infinity.

The PV cell's open circuit voltage, or VOC, is inversely correlated with temperature and directly related to solar radiation. The I-V and P-V characteristics are used to describe the PV array.

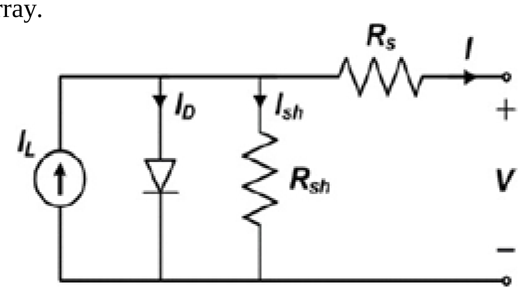

Figure 1: Equivalent circuit of PV cell

Harmonic distortion

Harmonic distortion in a power system is the departure of the voltage and current waveforms from sinusoidal waveforms. The nonlinear devices are the primary source of harmonic distortions. Power electronic converters, which comprise the new generation of loads, do not allow for the desirable draw of entirely sinusoidal current from the distribution network. The network is filled with current harmonics produced by these nonlinear loads, which further disrupt the ideal sinusoidal voltage waveform [3]. Distorted currents flowing through the system's linear, series impedance cause voltage distortion.

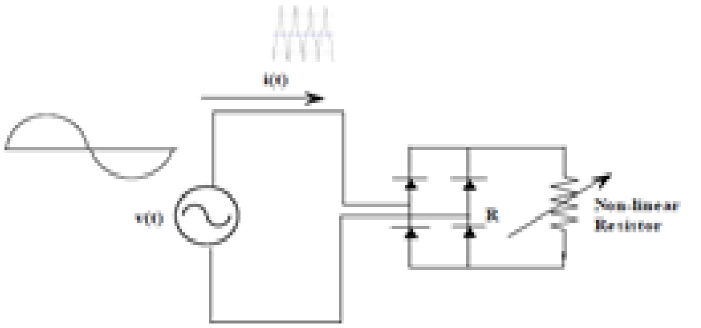

Figure 2: Distorted current produced by a non-linear load

Power electronics are becoming more and more prevalent in a variety of applications, including fuel cells, high voltage DC systems for efficient power transmission, switched mode power supplies, efficient control of lighting and heating, efficient photovoltaic interface, modern home appliances, and variable speed motor drives. Predictions expressed previously have come true thanks to developments in power semiconductor technology, and solid-state techniques are currently used to process significant amounts of electrical power. Power electronic converters, which comprise the new generation of loads, do not allow for the desirable draw of entirely sinusoidal current from the distribution network.

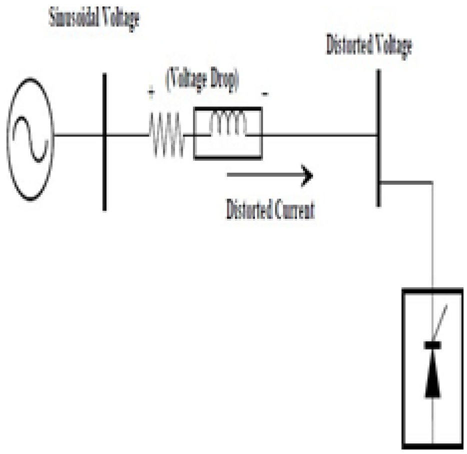

Figure 3: Voltage distortion caused by distorted current atload centers

These power electronic converters have many benefits, but they also have extremely nonlinear characteristics and have trouble extracting reactive power and non-sinusoidal current from the AC mains. The network is filled with current harmonics produced by these nonlinear loads, which further damage the ideal sinusoidal voltage waveform. As seen in Figure 3, distorted currents flowing through the system's linear, series impedance cause voltage distortion. Each harmonic produced by harmonic currents flowing across the system impedance results in a voltage drop, which at the load bus causes voltage harmonics to manifest and causes additional power quality issues. Due to these issues, guidelines and standards like IEEE-519 were put into place to control harmonics on the power system and establish acceptable levels. Therefore, one of the main treatments for the declines in power quality is the avoidance of current waveform distortions caused by harmonics and the correction of reactive power requirements of nonlinear loads.

The utility grid and grid-connected PV system must synchronize under certain conditions, such as matching phase sequence, frequency, and voltage level. Advanced power electronics technology in PV inverters allows them to achieve this synchronization. The electrical characteristics of a photovoltaic unit can be commonly represented by the power-voltage or current-voltage relationship of the cell. These properties are directly affected by variations in the sun irradiation and cell temperature [4]. To translate temperature and radiation variations into generated voltage and current of the PV arrays, an appropriate simulation model is required. In order to examine the PV system's dynamic performance under various weather scenarios.

IV. PROPOSED WORK

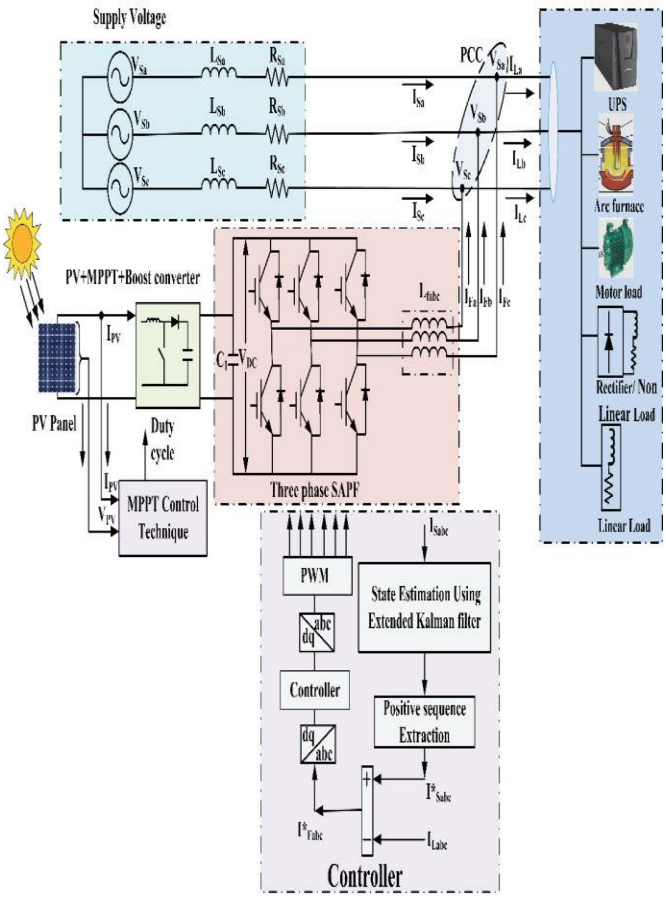

Fig.4. Proposed PV-SAPF system

The utility grid and grid-connected PV system must synchronize under certain conditions, such as matching phase sequence, frequency, and voltage level. Advanced power electronics technology in PV inverters allows them to achieve this synchronization. The electrical characteristics of a photovoltaic unit can be commonly represented by the power-voltage or current-voltage relationship of the cell. These properties are directly affected by variations in the sun irradiation and cell temperature [4]. To translate temperature and radiation variations into generated voltage and current of the PV arrays, an appropriate simulation model is required. In order to examine the PV system's dynamic performance under various weather scenarios.

Active Power Filter Role

Because of harmonics, voltage distortion is a significant issue for utilities. Harmonics also contribute to other issues such as reactive power loss in the line, resonance, and equipment heating by lowering system stability. An active filter can help reduce issues brought on by utility-side harmonics. When using this type of filter, harmonic resonance is not an issue. When dealing with nonlinear loads with time-dependent harmonics, the active filter is employed. Certain configurations at the plant utility PCC interface are thought to satisfy IEEE 519 harmonics criteria. There are three types of active filters available: shunt, series, and hybrid, with CSI and VSI inverter topologies. These filters' diameters vary according on the harmonic that needs to be reduced.

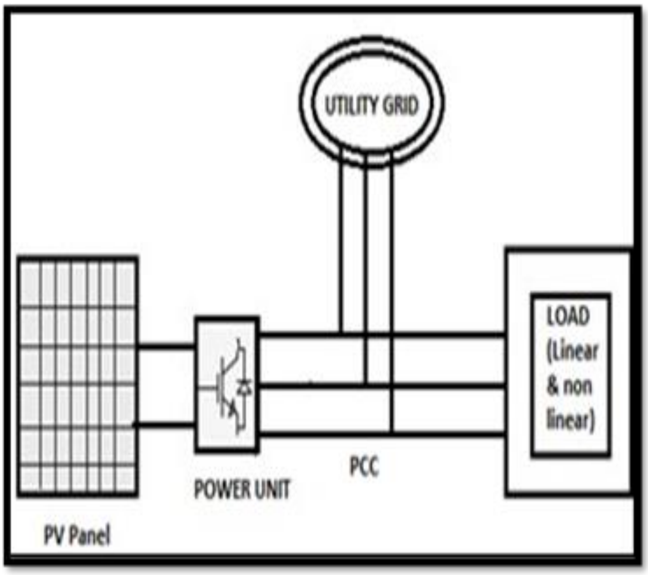

Fig. 5 Grid connected PV system

Shunt Active Filter

- The non-sinusoidal current reference tracking of a shunt active filter is based on the load harmonic current injection theory.
- With the use of an appropriate current controller, a shunt harmonic filter extracts the load's harmonic current. The

switching ripple filter of rating that filters a current is part of the proposed Shunt Active Filter paradigm.

- In order to control and extract the load harmonic current and generate an inverter pulse, synchronous reference frame theory [5] is employed.
- In the distribution power system, harmonic resonance can be suppressed by a shunt active shunt filter (SAPF) when used as a harmonic conductance.
- In order to reduce harmonic resonance, this research proposes an active filter with resonant current management. In order to guarantee that the active filter performs as a nearly pure conductance, parallel-connected band-pass filters tuned at harmonic frequencies are used to achieve current control [6].
- With fewer mathematical calculations, the suggested method extracts the essential active component of distorted and unbalanced load currents with good accuracy.

In addition to enhancing power quality, the system produces clean energy by means of a PV array system that is integrated with its DC-link.

V. SIMULATION AND RESULT DISCUSSION

Matlab Simulation of Grid Connected Solar PV system

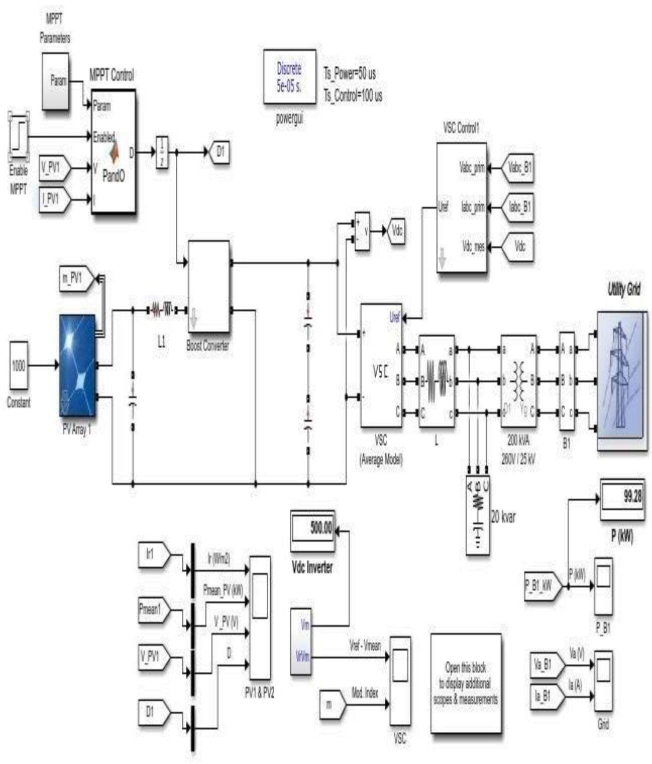

Fig 6- Matlab Simulation of Grid Connected Solar PV system

It is impractical to attempt to replicate each and every solar cell in a PV array while modelling one. Furthermore, rather than selling solar cells in bulk, PV producers typically only deliver finished, environmentally safe modules to end users. Additionally, solar cells packaged in the same module typically have almost identical irradiance characteristics under real-world working settings. Because of these factors, we may safely assume that every solar cell in every PV module has the same properties and operational parameters. As a result, a PV module can be thought of as a fundamental component made up of identical solar cells.

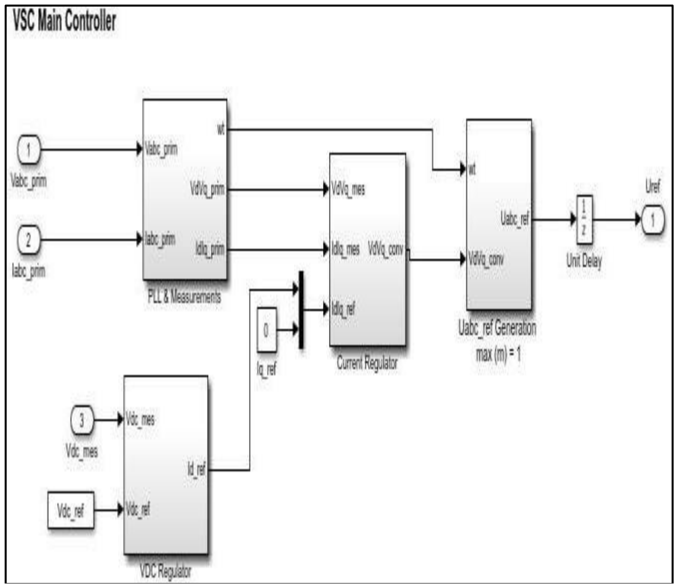

Fig 7- Matlab Subsystem of VSC Controller

A circuit simulation program can mimic the suggested numerical model (shown in Fig. 6), and MATLAB/Simulink can simulate it accurately due to its simplicity. Since the Sim Power Systems toolbox in MATLAB/Simulink can provide an open and flexible interface to model numerical, electrical, and control systems, this thesis uses it as its simulation environment.

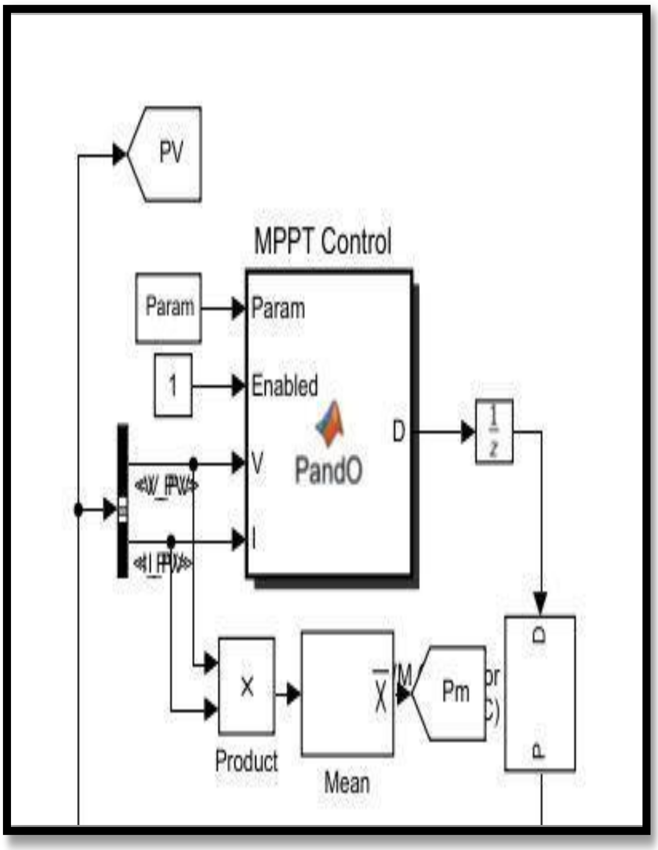

Fig 8- MPPT Control using P&O Algorithm

Simulation Results

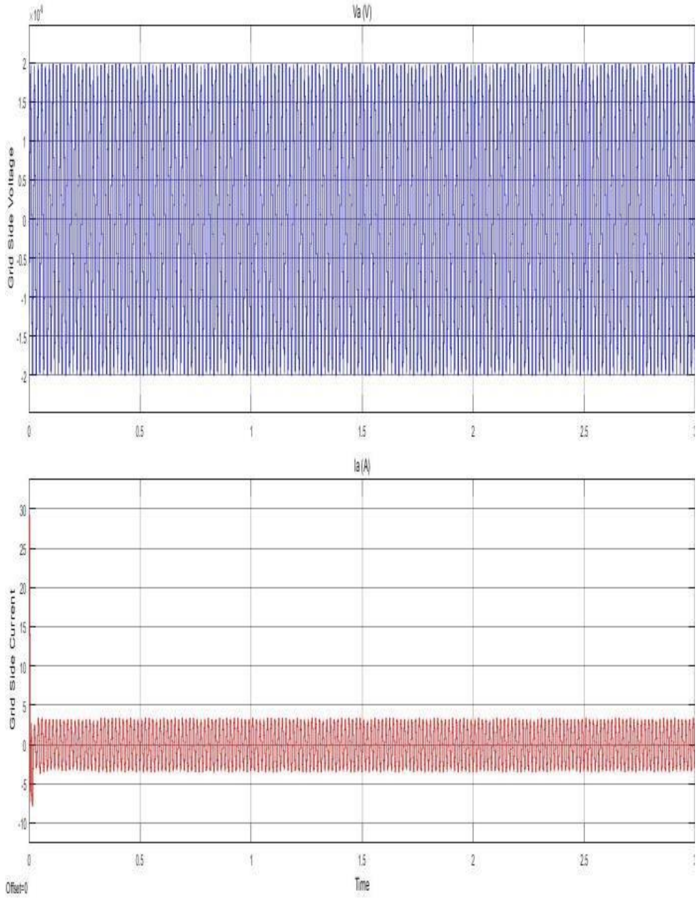

Fig 9- Grid Side Output Voltage and Current

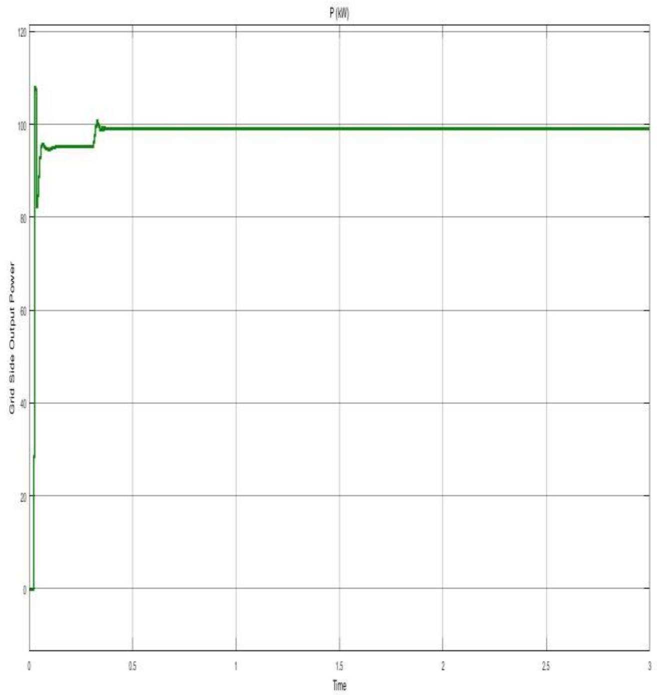

Fig 10-Grid Side Output Power

Fig 11- Grid Side Voltage and Current with Zoom Scale

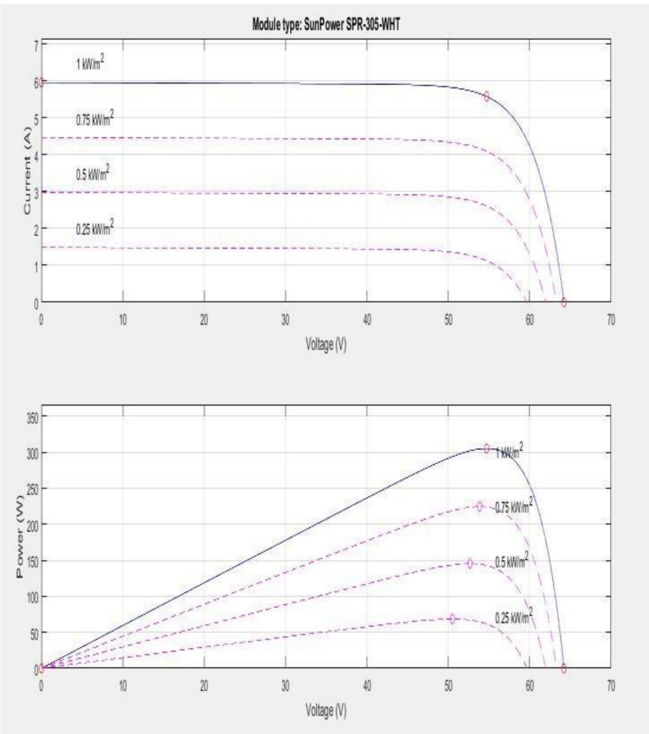

Fig 12- Solar I-V and P-V Characteristics for one Module ofPV

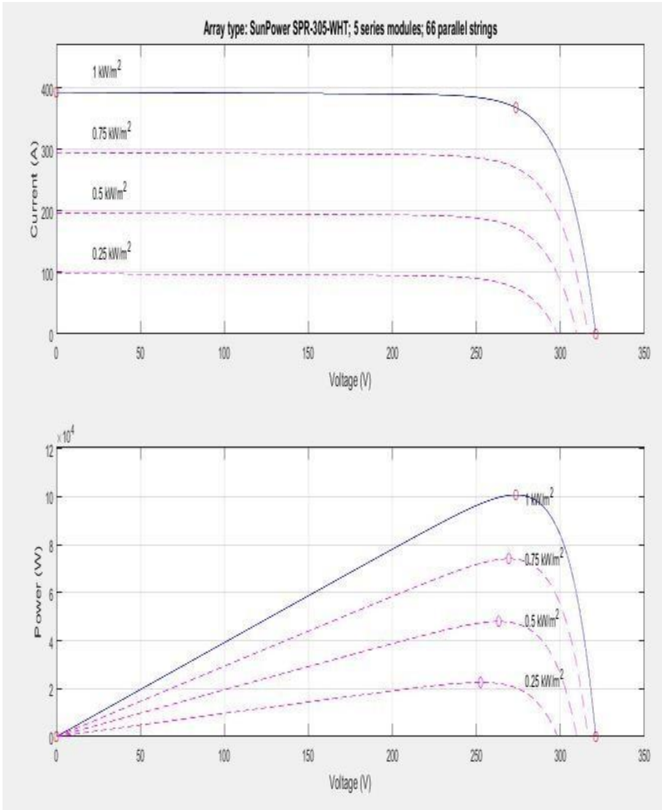

Fig 13- Solar I-V and P-V Characteristics for PV Array

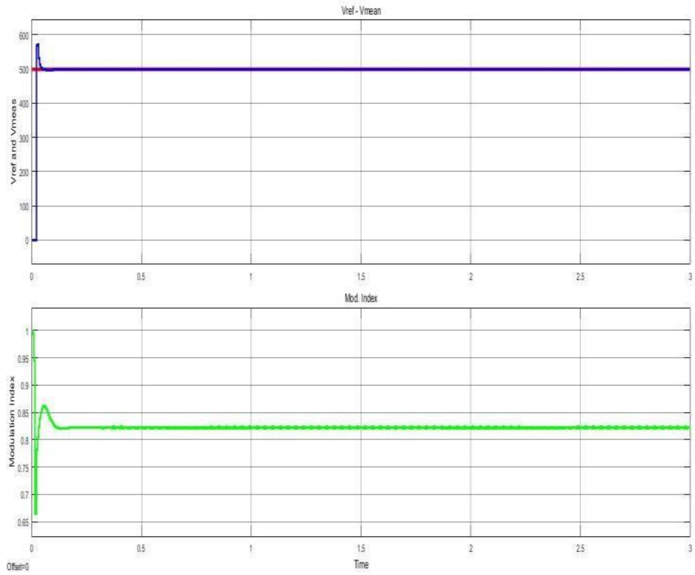

Fig 14-VSC Controlling Parameters

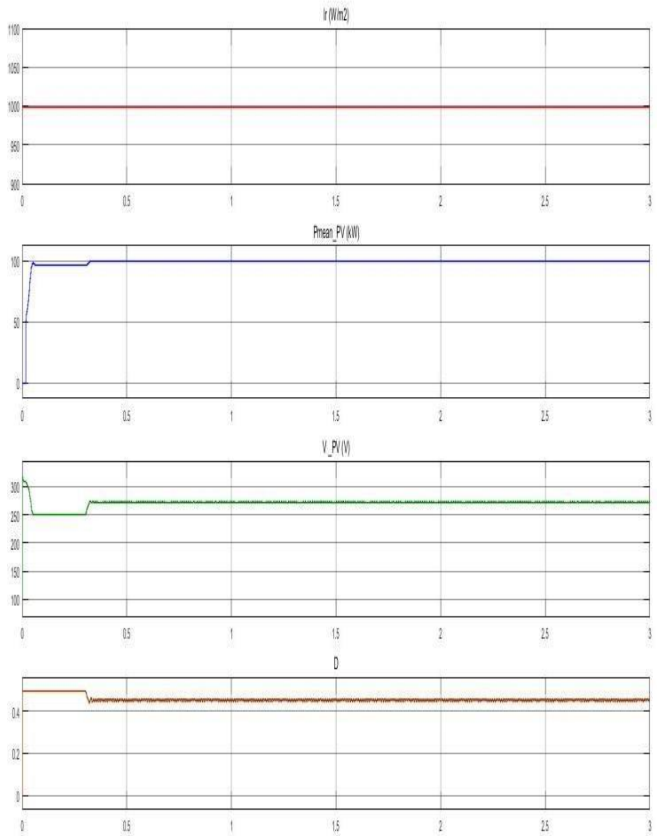

Fig 15- Solar PV output Parameters

CONCLUSION

The graph illustrates how the P-V and I-V properties of a photovoltaic system vary with temperature and irradiance. As a result, the PV generation is extremely sensitive to changes in both temperature and radiation. As a result, this fluctuation will immediately affect the output values of every component that is connected. We can retain power by regulating the voltage or controlling the current to reach the maximum power point. MPPT controls the duty cycle in the suggested system in order to maintain voltage and produce the highest possible power. MATLAB-SIMULINK is used to implement the Boost Converter Simulation with Perturb and Observe MPPT technique. It is evident from the Simulink results that the MPPT method described here can concurrently improve the PV system's steady state and dynamic performance. Through simulation, it is shown that, in spite of variations, the system successfully completed the MPPT. The technology can swiftly track the maximum power point even in the event of an abrupt change in the external environment.

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