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Analysis Solar Photovoltaic System with P&O MPPT Techniques

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ABSTRACT: Over the past years, the energy demand has been steadily growing and so methods of how to cope with this staggering increase are being researched and utilized. One method of injecting more energy to the grid is renewable energy, which has become in recent years an integral part of any country's power generation plan. Thus, it is a necessity to enhance renewable energy resources and maximize their grid utilization, so that these resources can step up and reduce the over dependency of global energy production on depleting energy resources.

This thesis focuses on solar power and effective means to enhance its efficiency through the use of P&O MPPT Technique. An enhanced maximum power point tracking (MPPT) controller has been designed as part of a Photovoltaic (PV) system to generate maximum power to satisfy load demand. The PV system is designed and simulated using MATLAB (consisting of a solar panel array, MPPT controller, boost converter, voltage source convertor, a resistive load and grid). The two different manufacturer's solar panel chosen for the array one is 100-kW PV Array Maximum Power 330 * SunPower SPR-305 (Nser=5, Npar=66) and second Array is 100-kW PV Array Maximum Power 488 * Kyocera-KD205GX-LP (Nser=8, Npar=61) the array is designed to produce 200 kW of power. The P&O MPPT controller is designed and the results are compared to identify different manufacturer's solar PVs analysis and drawbacks. Both manufacturer's solar PV panels was tested under two different scenarios; the first is when the panel array is subjected to constant amount of solar irradiance along with a constant atmospheric temperature and the second scenario has varying solar irradiance and a constant atmospheric temperature. The performance of these two solar PVs are analysed and compared in terms of the output power efficiency, system dynamic response and finally the oscillations behaviour.

KEYWORDS: Photovoltaic, maximum power point tracking (MPPT).

I. INTRODUCTION

The increasing of the world energy demand, due to the modern industrial society and population growth, is motivating many investments in alternative energy solutions, in order to improve energy efficiency and power quality issues. The use of photovoltaic energy is considered to be a primary resource, because there are several countries located in tropical and temperate regions, where the direct solar density may reach up to 1000W/m.

At present, photovoltaic (PV) generation is assuming increased importance as a renewable energy sources application because of distinctive advantages such as simplicity of allocation, high dependability, absence of fuel cost, low maintenance and lack of noise and wear due to the absence of moving parts. The cell conversion ranges vary from 12% of efficiency up to a maximum of 29% for very expensive units. In spite of those facts, there has been a trend in price decreasing for modern power electronics systems and photovoltaic cells, indicating good promises for new installations. However, the disadvantage is that photovoltaic generation is intermittent, depending upon weather conditions. Thus, MPPT makes the PV system providing its maximum power and that energy storage element is necessary to help get stable and reliable power from PV system for both loads and utility grid, and thus improve both steady and dynamic behaviors of the whole generation system.

In the proposed work, Perturb and Observe (PO) MPPT algorithms analyzed and implemented for two different manufacturer's PV array. Thereafter, PV array connected to the utility grid by a boost converter to optimize the PV output and DC/AC voltage source convertor (VSC) to convert the DC output voltage of the solar modules into the AC system. The results of two different manufacturer's solar PV modules with MPPT algorithm responses compared for grid connected PV array. In addition, performance analysis of grid connected PV array with MPP tracking done in terms of grid voltage response, grid current response and grid power response at utility grid using the input parameters,

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and solar radiation obtained from reference data sheet with constant temperature of 250C. The proposed model, the entire components and control systems simulated under MATLAB/Simulink Software.

II. PROBLEM STATEMENT

Due to the previously mentioned reasons, it is highly recommended to keep investing and researching about the enhancement of renewable energy's efficiency. However, in this article the main concentration will only be on photovoltaic systems. The usage of renewable energy is not a recent trend and solar energy is not an exception. However, it was not till 1954 that Bell labs in the United States came up with the first solar photovoltaic device that can actually produce sufficient amount of electricity. The use of solar energy kept increasing until it finally boomed after the 1970s due to the energy crisis that was going on at the time. Solar panels comprise of semi-conducting materials of both P and N-type. This creates an electric field that directs the electrons from the solar rays that hit the surface and thus creating a current.

Unfortunately, a photovoltaic system requires more components that just a solar panel. It requires a robust, steady mounting structure to support the panel at the right angle and through all the changing weather conditions from sandstorms to rain showers. Also, it requires the use of inverters, which are electronic devices that can be used to convert Direct Current (DC) voltage that is generated from the panel to another level of DC voltage or convert the DC voltage to Alternate Current (AC) to be used in the premises or transmitted to the electricity grid.

The final component of the system is an energy storage device or a battery. Batteries are not needed if the system is connected to the grid or direct use of generated power for stand alone. Batteries are only needed if the user requires power during the night and the user stores this energy in the batteries during the day for it to be used during the night. They have a low maintenance cost as they are very durable and are designed to operate for a couple of decades. Finally, they are very quiet as they are a static system with no mechanical movement at all.

III. METHODOLOGY

A. P&O MPPT Technique

Perturb and Observe (PO) method, also known as perturbation method, is the most commonly used MPPT algorithm in commercial PV products. This is essentially a "trial and error" method. The PV controller increases the reference for the inverter output power by a small amount, and then detects the actual output power. If the output power is indeed increased, it will increase again until the output power starts to decrease, at which the controller decreases the reference to avoid collapse of the PV output due to the non-linear PV characteristic.

Although the PO algorithm is easy to implement, it has a number of problems, including

- PV system cannot always operate at the maximum power point due to the slow trial and error process, and thus solar energy from the PV arrays not fully utilized.
- PV system may always operate in an oscillating mode even with a steady-state sunshine condition, leading to fluctuating inverter output.
- Operation of the PV system may fail to track the maximum power point due to the sudden changes in sunshine.

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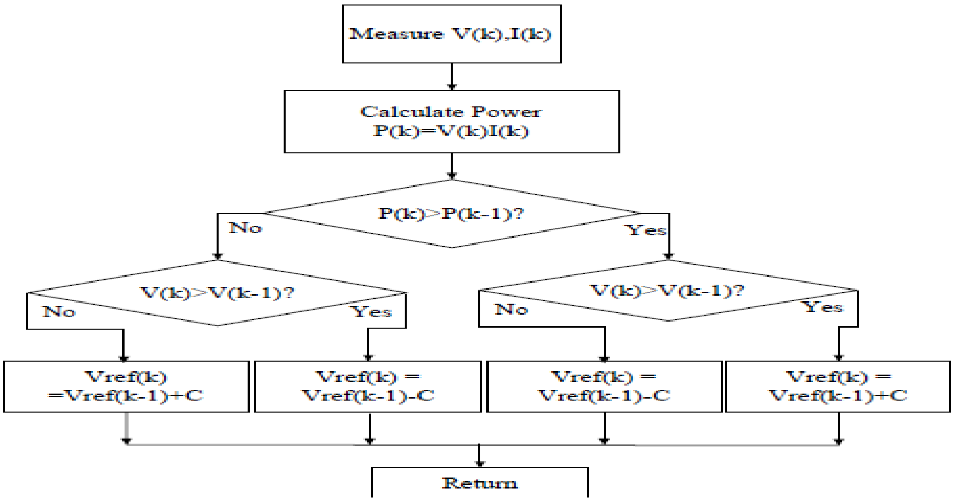

Fig. 1 Perturb & Observe flowchart

Details of implementation:

The block diagram of solar PV system connected with grid with two PV arrays shown in Fig. 2, in which the PV array-1 and PV array-2 each of 100 kW rating but from different manufactures. Perturb and observation MPPT algorithm is used for controlling the maximum power output from solar PV arrays for controlling the boost convertor duty cycle. Both PV arrays output is connected to common DC link capacitors which is the input of voltage source convertor and it is maintain constant by applying closed loop control. Voltage source convertor converts DC voltage in to AC voltage as per the grid voltage, phase angle of voltage etc.

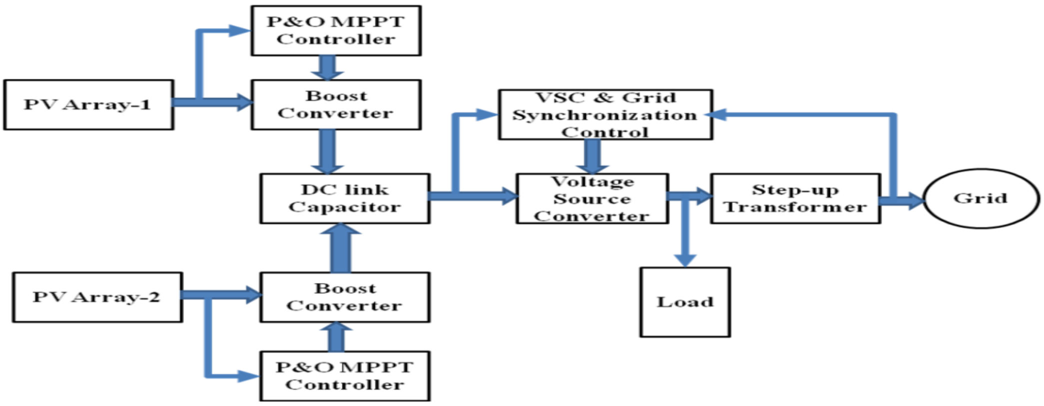

Fig. 2 Block Diagram of proposed work

PV Array-1 Prepared in MATLAB, PV array-1 is 100-kW PV Array Maximum Power 330 * SunPower SPR-305 (Nser=5 and Npar=66) this information is collected from the data sheet of Solar PV module. As per data sheet parameter the PV array is designed in MATLAB 2013b. Fig. 3 shows MATLAB design of PV Array-1 is shown where diode characteristic are as per following.

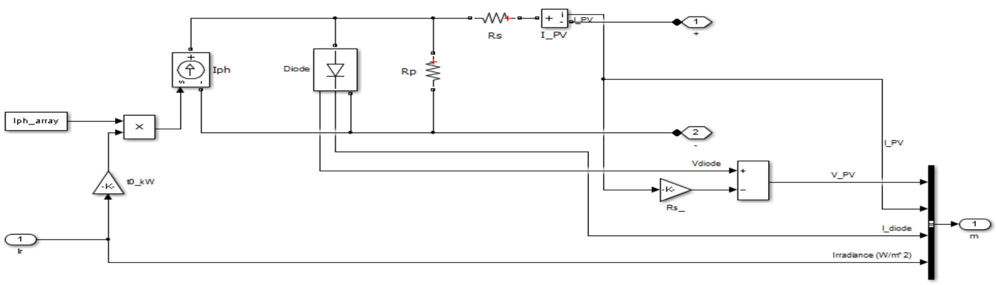

Fig. 3 MATLAB design of PV Array-1

Diode characteristic

Id=Isat*[exp (Vd/VT) -1]

Where:

Id = diode current (A)

Vd = diode voltage (V)

Isat = diode saturation current (A)

VT = temperature voltage = k*T/q*Qd*Ncell*Nser

T = cell temperature (K),

k = Boltzmann constant = 1.3806e-23 J.K^-1

q = electron charge = 1.6022e-19 C

Qd = diode quality factor

Ncell= number of series-connected cells per module

Nser = number of series-connected modules per string

As per same process PV array-2 from another manufacturer is designed.

Boost convertor is used for maintain maximum power point of PV array from perturb and observation algorithm. The programming of perturb and observation algorithm is completed by sensing the PV voltage and current continuously and give the maximum power output continuously. Two series capacitors used as DC link with connected parallel to boost converter. This DC link voltage across capacitor is used as input of voltage source converter. VSC and grid synchronization control block generate the reference gate pulse from sensing grid voltage, grid current and DC link voltage. The reference gate pulse generated is maintaining DC link voltage and synchronization parameters of grid. Fig. 4 shows the complete matlab simulation diagram of 200-kW Grid-Connected PV Array. The two different analysis of with constant solar irradiance with constant temperature and variable solar irradiance with constant temperature are completed.

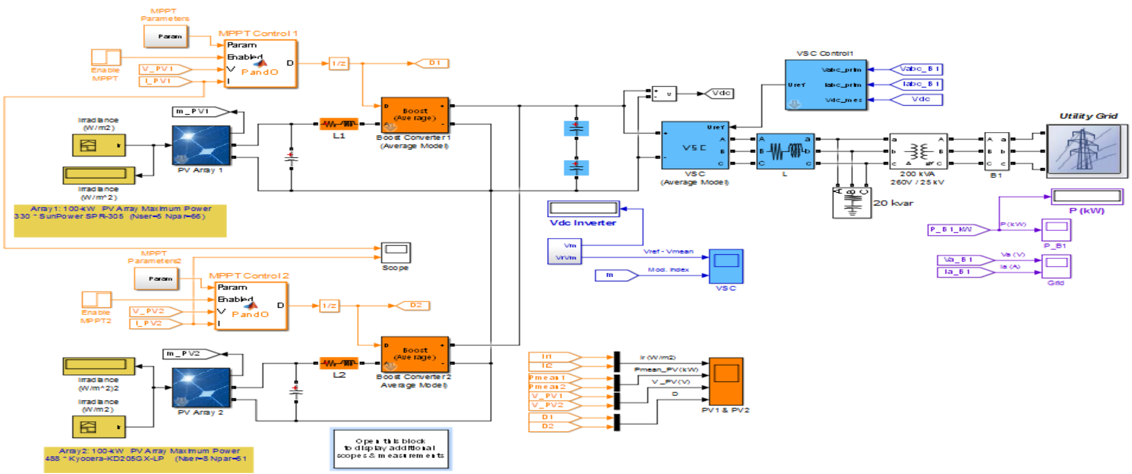

Fig. 4 Implemented Matlab simulation diagram of 200kW Grid connected PV Array

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IV. RESULT AND DISCUSSION

Scenario One: Constant Irradiance and Temperature

This section describes the simulation of the PV MPPT system under constant solar irradiance and module temperature where the irradiance is kept constant at 1000 W per square meter and the temperature at 250C. When both variables are kept constant, the result will be as shown in Fig. 5

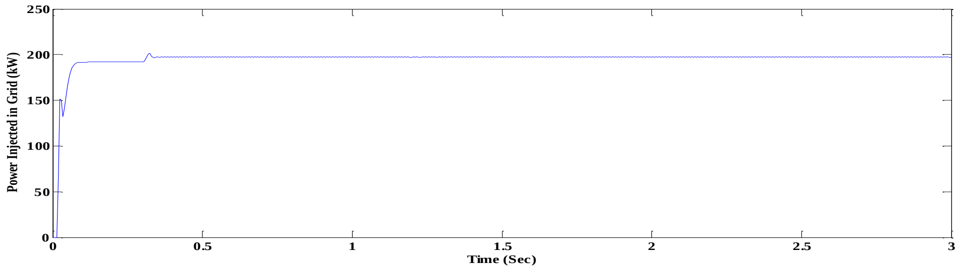

Fig. 5 Output Power under Constant Conditions Using P&O MPPT

Using the P&O algorithm yields a fast response as expected where the rise time is about 0.197 seconds or approximately 0.2 seconds and the settling time is about 0.26 seconds. The output power starts from zero and reaches a maximum value of 197.5 kW at time 4.15 seconds. However, as shown in Fig. 5, the P&O method results in continuous oscillations around the Maximum Power Point. This is clearly presented in Fig. 5 where a segment of the output power was magnified to illustrate these oscillations. The chosen segment is an interval of about 0.3 seconds where it starts at time around 3.4 seconds and ends at about 3.7 seconds. During this interval, the power fluctuates between the values of 197 kW and 197.5 kW with a mean value of about 197.3 kW. The mean for the curve was calculated to be about 197.3 kW. The target output power is 200 kW and hence the system's efficiency when using P&O method at constant irradiance and temperature is 98.65%. Fig. 6 is divided into 5 plots, which are; the duty cycle (DC), the PV output voltage, PV output current system, modulation index of VSC, DC link Voltage, grid voltage, and grid current on the load side. The first graph shows the duty cycle oscillations. The second and third graphs represent the voltage and current produced by the both PV panels. The PV1 and PV2 voltage oscillates heavily around the value of 275 Volts and 230 Volts respectively and similarly the current oscillates around 370 Amperes and 470 Amperes respectively. The last two graphs are the grid or the load side voltage and the current, which are the voltage and current output from the PV panel after passing through the boost converter and VSC. The function of the boost converter is to increase the voltage, decrease the current to reduce the current losses, and reduce both the voltage and current ripples caused by the constant switching. This match with the results where the voltage was amplified to 25 kV, the current reduced to about 5 Amperes, and both curves were smooth and non-oscillating.

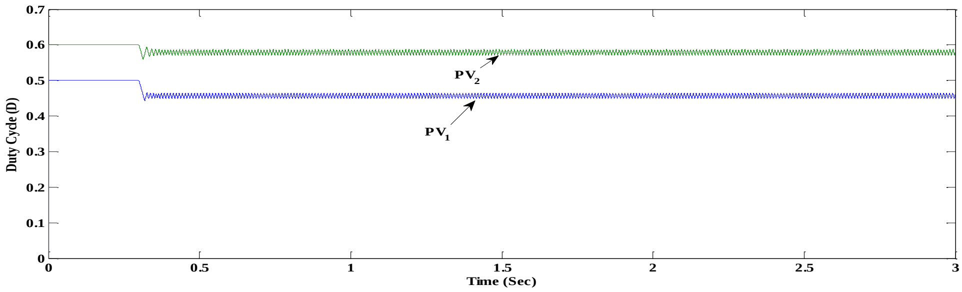

Fig. 6(a) Duty cycle of boost convertor for Both PV Panels

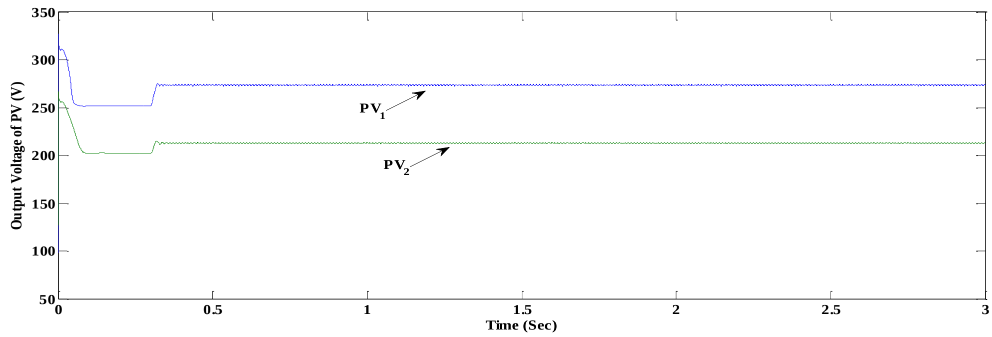

Fig. 6(b) Output voltage of PV panels

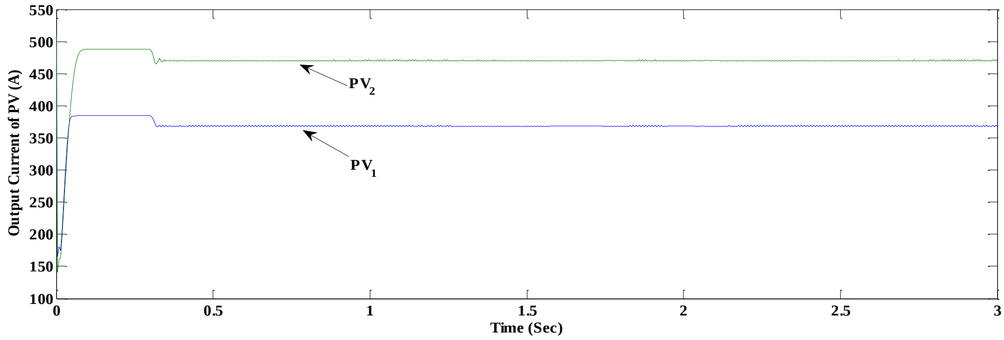

Fig. 6(c) Output current of PV Panels

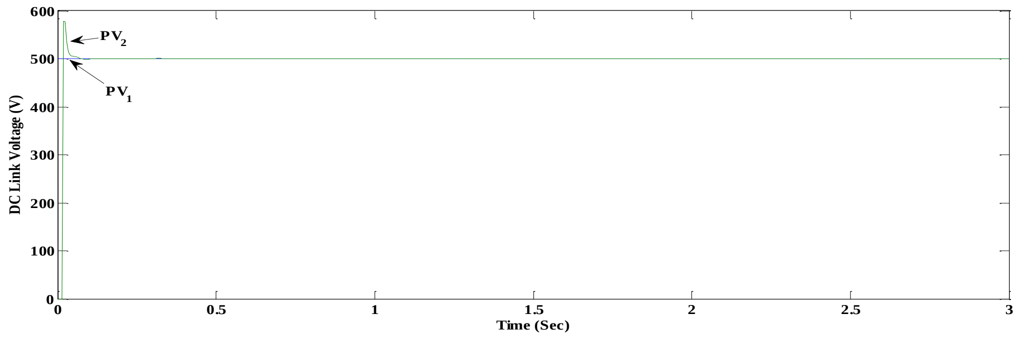

Fig. 6(d) DC link Voltage of PV panel

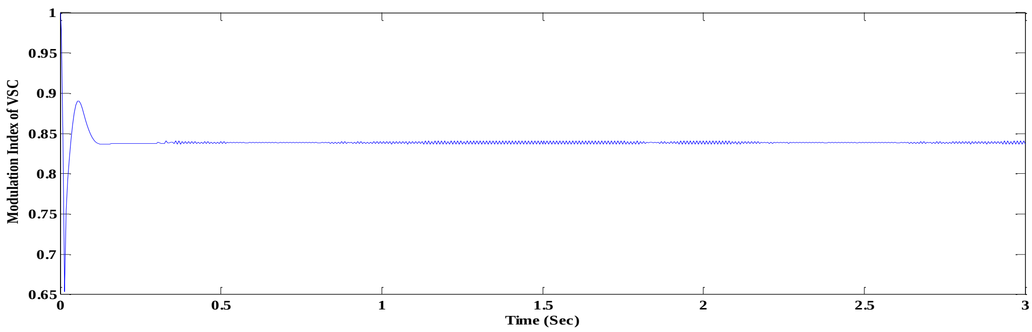

Fig. 6(e) Modulation Index of VSC

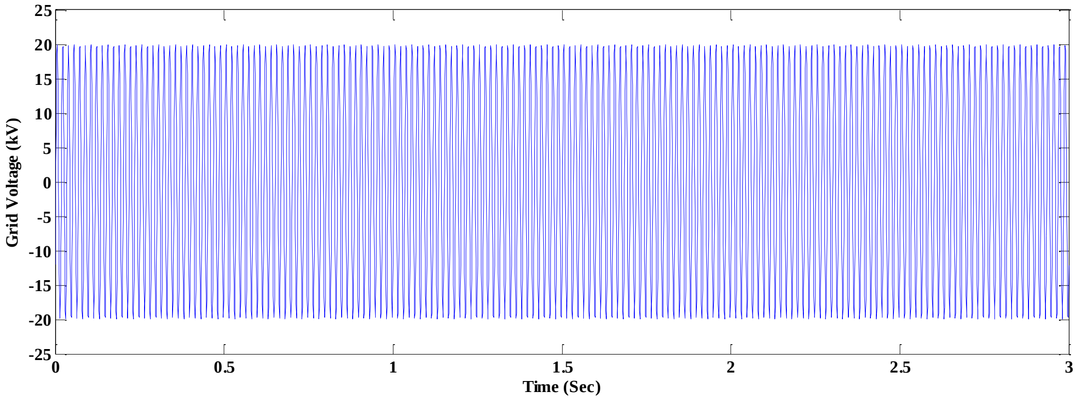

Fig. 6(f) Three phase AC Grid Voltage

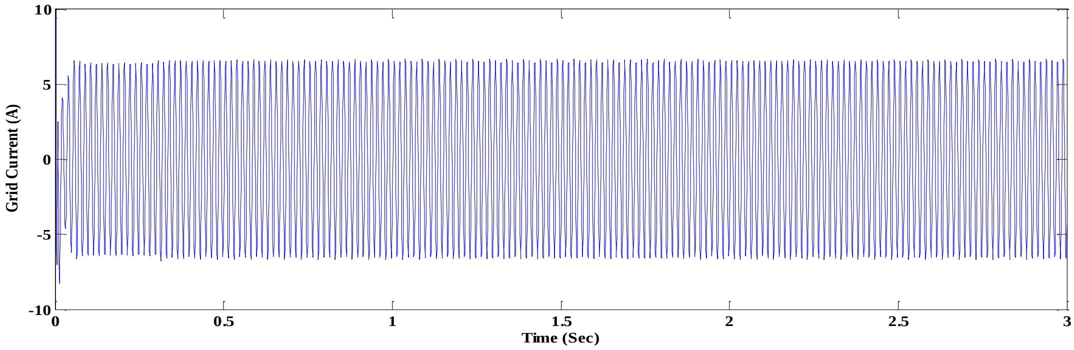

Fig. 6(d) Three phase AC Grid Current

Figure 6: P&O Different waveform Under Constant Conditions: (a) Duty cycle of boost convertor for Both PV Panels (b) Output voltage of PV panels (c) Output current of PV Panels (d) DC link Voltage of PV panels (e) Modulation Index of VSC (f) Three phase AC Grid Voltage (g) Three phase AC Grid Current

Scenario Two: Varying Irradiance and Constant Temperature

There are 5 periods for PV1 and 3 periods PV2 in the second scenario. Each period has the irradiance varied with constant temperature from the previous period as shown in Fig. 7. There are conclusions that can be drawn from this scenario first is regarding the effect of the irradiance individually on the output power, and the second is about the efficiency of the MPPT algorithm used. In this case, it is the P&O used in generating power under varying conditions.

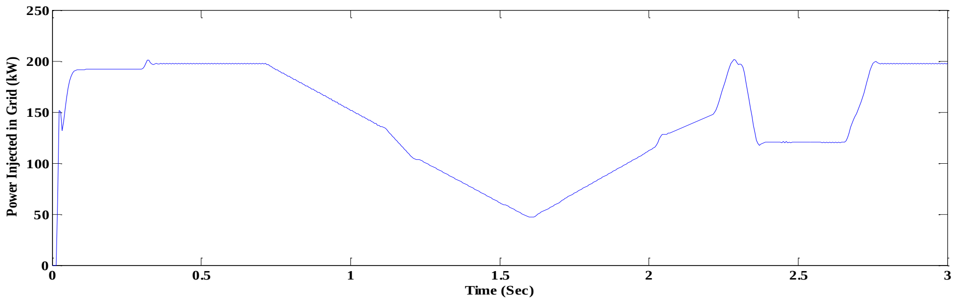

Fig. 7 Output Power under Varying Conditions Using P&O MPPT

In Fig. 7 shows power of PV1 and PV2, period A has an irradiance of 1000 W per square meter and module temperature of 250C and has the output power curve increasing from zero to 197.5 kW of power. It drops down to about 54.5 kW in period B when the irradiance is dropped to 250 W per square meter and the temperature is kept constant. In part C, the irradiance is increased again to 1000 W per square meter and thus the power output is close to that in part A which 197.5 kW. Part C is done in preparation for part D, where the irradiance is dropped to 250 W per square meter and again increased to 1000 W per square meter. Part E the irradiance is kept constant to 1000 W per meter square.

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As expected, the irradiance has a substantial effect on the output power where a 75% decrease in the irradiance causes about an 84% drop in the output power as shown in part B.
Even though the drop in power output in the two cases where the irradiance decreases, it is how efficient the actual output of the P&O is compared to the theoretical values when the variations occurred.

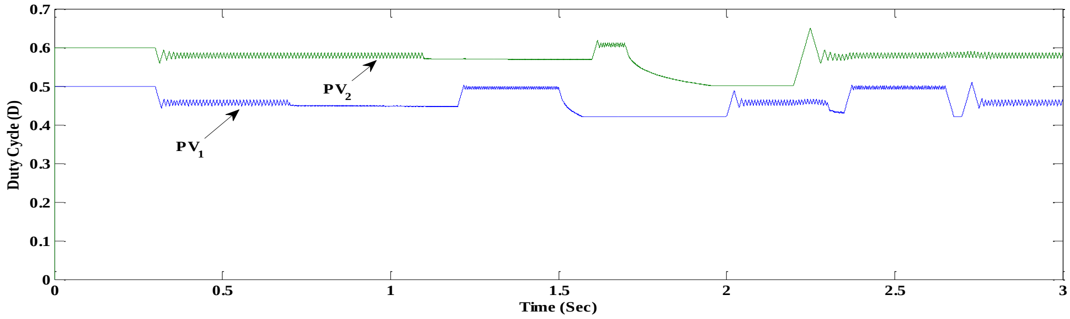

Fig. 8(a) Duty cycle of boost convertor for Both PV Panels

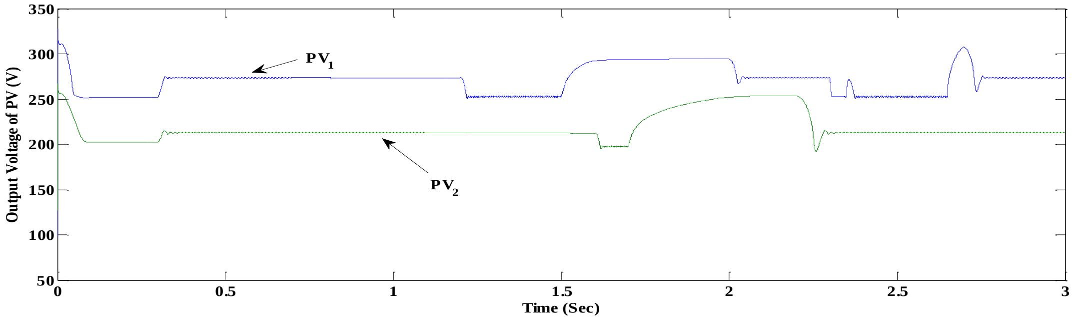

Figure 8(b): Output voltage of PV panels

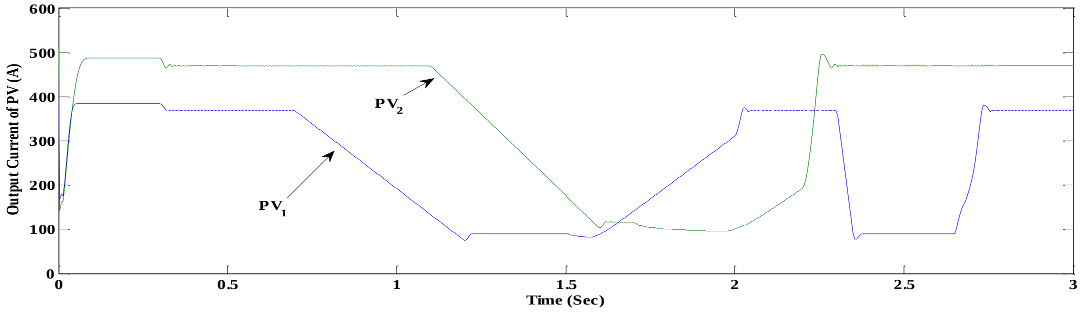

Figure 8(c): Output current of PV Panels

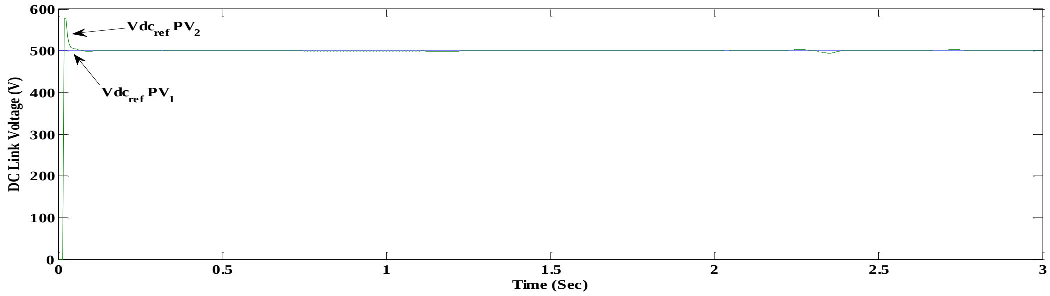

Figure 8(d): DC link Voltage of VSC

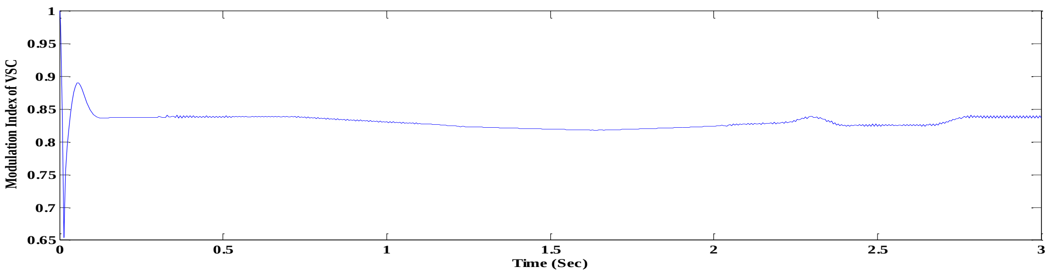

Figure 8(e): Modulation Index of VSC

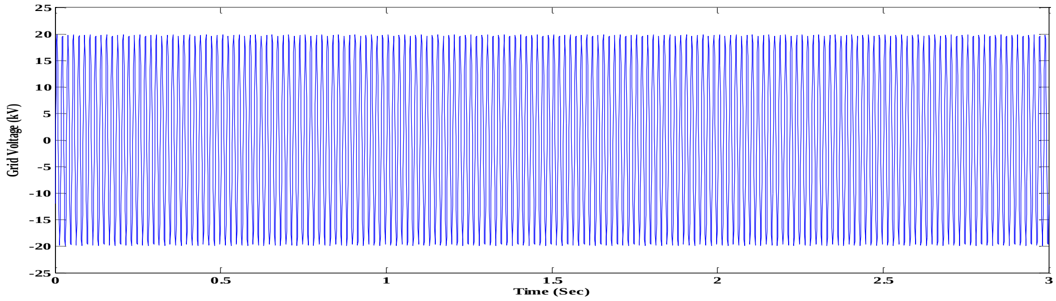

Figure 8(f): Three phase AC Grid Voltage

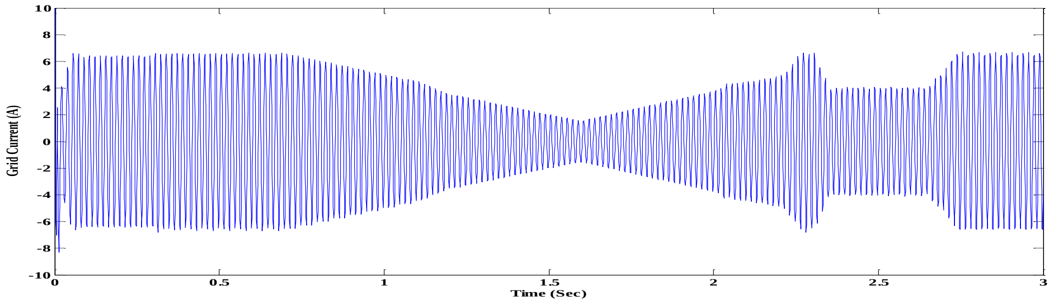

Figure 8(g): Three phase AC Grid Current

Fig. 8: P&O Different waveform Under Varying Conditions: (a) Duty cycle of boost convertor for Both PV Panels (b) Output voltage of PV panels (c) Output current of PV Panels (d) DC link Voltage of VSC (e) Modulation Index of VSC (f) Three phase AC Grid Voltage (g) Three phase AC Grid Current

The last part of this scenario is Figure 8 shows the duty cycle values, PV output voltage and current, DC link voltage, Modulation Index of VSC and the grid output voltage and current. Similar to the first scenario, the PV output voltage and current oscillate heavily until they pass through the boost converter, which allows for a boost in voltage, a drop in current, and removing the oscillations from both curves. Moreover, an observation in the PV voltage and current curves is that while a decrease in irradiance affects both these variables as shown in period B and Q, the PV current is affected more. The current drops from an average of 420 Amperes to an average of 100 Amperes, while the voltage only drops from an average of 505 Volts to about 450 Volts.

The output voltage starts at 580 Volts in period A, drops to about 450 Volts in period B, goes back up to 580 Volts in period C and finally reduces a bit more to 550 Volts in period D and again reach to 580 Volts in period E. Likewise, the output current starts at 840 Amperes, drops to 336 Amperes, back to 840 Amperes, and finally reduces to about 5 Amperes after the VSC and step up transformer.

V. CONCLUSION

In the proposed work the performance analysis of maximum power point tracking (MPPT) algorithms for a grid connected PV system have been done. The MPPT techniques considered in the proposed work is Perturb & Observe (PO) controller. The simulations carried out for PV array cascaded with boost converter. The results investigated for load power at converter end. Since boost converter provides more output voltage as compared to input voltage. Boost converters are well suited for grid connectivity. Further the simulations carried out for developed PV system with 25kV AC utility grid through a three-phase DC/AC voltage source converter and results obtained for grid power.The peak

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power obtained at converter end for P&O algorithms is 197.5 kW. The rise time, settling time and efficiency of PV array-2 is slightly better than PV array-1.

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