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A COMPARATIVE STUDY OF POWER CONTROL OF STAND-ALONE PV GENERATION SYSTEM WITH & WITHOUT MPPT

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Abstract - *The need for renewable energy sources is on the rise because of the delicate energy crisis in the world. Solar energy is a fundamental unexploited resource in a tropical country like ours. The main obstacle for the access and reach of solar PV systems is their quite low efficiency and high capital investment cost. Solar panels have a nonlinear voltage-current characteristic, with a distinct maximum power point (MPP), which depends on the environmental factors, such as temperature and irradiation and solar cell material. Therefore maximum power point (MPP) of PV cells changing with solar irradiation & ambient temperature. In order to continuously bring in maximum power from the solar cell panels, they have to operate at their MPP in spite of the usual changes in the environment. This is why the controllers of all solar power electronic converters employ some method for maximum power point tracking (MPPT). Over the past decades many MPPT techniques have been published. The first objective of this paper is to study and analyze them. This paper investigates in detail the concept of Maximum Power Point Tracking (MPPT) algorithm which significantly increases the efficiency of the stand-alone solar photovoltaic system compare with without having MPPT algorithm technique.*

Key Words: Maximum Power Point Tracking (MPPT), Photovoltaic generation, MPPT Algorithm, DC/DC Converter, Boost Converter.

1. Introduction

Global warming and energy policies have become important issues on the all over country. Developed & developing countries are trying to reduce their greenhouse gas emissions. For example, the EU has committed to reduce the emissions of greenhouse gas to at least 20% below 1990 levels and to produce no less than 20% of its energy consumption from renewable sources by 2020 [1]. Renewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and can be naturally replenished. Therefore, for all practical purposes, these resources can be considered to be inexhaustible, unlike dwindling conventional fossil fuels [2].

Solar energy is a clean, a maintenance-free, and an abundant source of energy. The rapid trend of industrialization of countries and increased interest in the use of renewable form of energy such as solar energy, biogas and wind energy. Solar energy can be utilized in two major ways. Firstly, the absorb heat can be used as solar thermal energy, with applications in space heating, water heating. Another alternative is the conversion of incident solar radiation to electrical energy, which is the most usable form of energy. This can be achieved with the help of solar photovoltaic cells or with concentrating solar power plants [3]. Photovoltaic (PV) modules or arrays produce electric power directly from sunlight. Photovoltaic system can be divided into two categories: Stand-alone sometimes it is called as off-grid connection system and grid connection systems. In conventional stand-alone systems PV array feeds load directly with no connection to the utility system and have the advantages of simple system configuration and control scheme. Studies show that a solar panel converts 30-40% of energy incident on it to electrical energy by using MPPT algorithm with compared to system having without MPPT algorithm.

A Maximum Power Point Tracking algorithm is necessary to increase the capacity of the solar panel. Solar energy can be a standalone generating unit or can be a grid connected generating unit depending on the availability of a grid nearby. Thus it can be used to power rural areas where the availability of grids is very low. Another advantage of using solar energy is the portable operation whenever wherever necessary.

In this the algorithms utilized for MPPT are generalized algorithms and are easy to model or use as a code. The algorithms are written in m- files of MATLAB and utilized in simulation. Both the boost converter and the solar cell are modeled using Sim Power Systems blocks.

The proposed model is used to determine the voltage current & power at the MPP and quality of voltage at load terminals for different operating conditions. The model consists of PV module, battery bank, MPPT module, controller, PWM inverter and resistive load. The fluctuation in the output of PV module are controlled and held at maximum power output by MPPT module.

This paper reports modeling & simulation of Stand- Alone Photovoltaic with MPPT features & inverter controlled technique. The results are compared with system of without MPPT controlled technique by using MATLAB/Simulink software. MPPT Algorithm for PV array is proposed here. This Algorithm detects the MPP of the PV the computed maximum power Pmax is used as reference value of control system. On/OFF power controller switch MOSFET is used to control the operation & increases the input power capability of PV module system.

2. WORKING OF SOLAR

The density of power radiated from the sun (referred to as the "solar energy constant") at the outer atmosphere is 1.373Kw/m2. Part of this energy is absorbed and scattered by the earth's atmosphere. The final incident sunlight on earth's surface has a peak density of 1Kw/m2 at noon in the tropics. The technology of photovoltaic (PV) is essentially concerned with the conversion of this energy into usable electrical form. The basic element of a PV system is the solar cells which are made up by different materials. Solar PV cell converts photon energy of sun light into electrical power which is in DC electrical energy form. Solar cells rely on a quantum-mechanical process known as the "Photovoltaic effect" to produce electricity. Photovoltaic cells are made of several types of semiconductors using different manufacturing processes. A typical solar cell consists of a p-n junction formed in a semiconductor material similar to a diode.

Figure 1 shows a schematic diagram of the cross section through a crystalline solar cell [4]. It consists of a 0.2–0.3mm thick mono-crystalline or polycrystalline silicon wafer having two layers with different electrical properties formed by "doping" it with other impurities (e.g., boron and phosphorus). An electric field is established at the junction between the negatively doped (using phosphorus atoms) and the positively doped (using boron atoms) silicon layers.

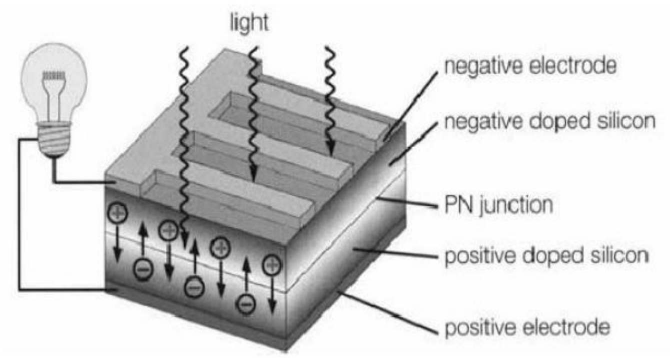


Fig -1: Solar Cell

If light is incident on the solar cell, the energy from the light (photons) generates free charge carriers, which are separated by the electrical field. An electrical voltage is generated at the external contacts, so that current can flow when a load is connected. The photocurrent (I_{ph}), which is internally generated in the solar cell, is proportional to the radiation intensity. Application of solar PV services such as lighting, battery charging, water pumping, Television set, heating, cooling & refrigeration.

3. EQUIVALENT CIRCUIT OF PV CELL

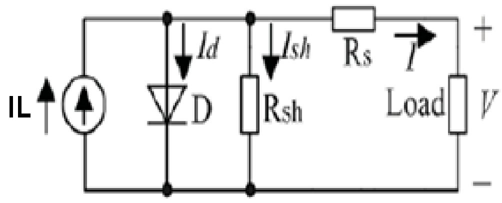


Fig -2: Photovoltaic Cell Equivalent Circuit

The circuit equivalent of a PV cell can be modeled through the circuit shown in Figure 2. This is modeled by the light generated current source (I_L). The intrinsic P-N junction characteristic is introduced as a diode in the circuit equivalent [5].

Where:

I is the cell current (A).
I_{ph} is the photo current (A).
I_o is the diode saturation current.
q is the charge of electron = 1.6x10-19 (coul).
K is the Boltzman constant (j/K).
T is the cell temperature (K).
R_s, R_{sh} are cell series and shunt resistance (ohms).
V is the cell output voltage (V).

Increasing sophistication, accuracy and complexity can be introduced to the model by adding in turn [6]:

- Temperature dependence of the diode saturation current I_0.
- Temperature dependence of the photo current I_{ph}.
- Series resistance R_s, which gives a more accurate shape between the maximum power point and the open circuit voltage. This represents the internal losses due to the current flow.
- Shunt resistance R_{sh}, in parallel with the diode, this corresponds to the leakage current to the ground and it is commonly neglected.
- Either allowing the diode quality factor n to become a variable parameter (instead of being fixed at either 1 or 2) or introducing two parallel diodes with independently set saturation currents.

In view of that, the current to the load can be given as:

[7, 8, 9]

$$I = I_{ph} - I_s\left(\exp\frac{q(V + R_s I)}{NKT} - 1\right) - \frac{(V + R_s I)}{R_{sh}} \quad (1)$$

At different values of Solar illumination and taking constant ambient temperature will influence the output power of PV module, as shown in Figure 3. The MPP will be changed when peripheral condition is changed. For quick and accurate track of MPP under any weather conditions, a precise MPPT algorithm must be applied in PV system.

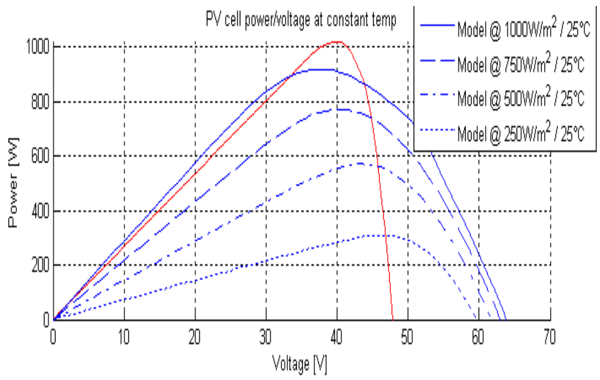


Fig -3: Power-Voltage Characteristics of PV for varying solar irradiation and constant temperature [10]

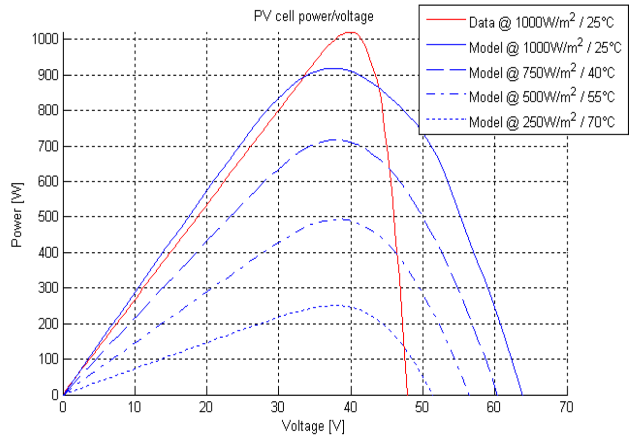


Fig -4: P-V Characteristics of PV Module at Four Different Temperatures and Insolation Values

3.1 Solar Panel

The entire system has been modeled on MATLAB™ R2010a and Simulink™. The block diagram the solar PV panel is shown in Figure 5. The inputs to the solar PV panel are temperature, solar irradiation.

The simulation is carried out for a cell surface temperature of 28° C. The standard Solar cell is used in simulation as available in MATLAB. Then increasing the voltage of solar cell by connecting gain in circuit. The irradiation is taken to be varying, to reflect real life conditions and effectively shows the use of an MPPT algorithm in field runs. The simulation is run for a total of 0.3 seconds, with the irradiation taking up a new value every 0.03 seconds and staying constant i.e. 0.8Kw/m²for the consequent 0.3 seconds.

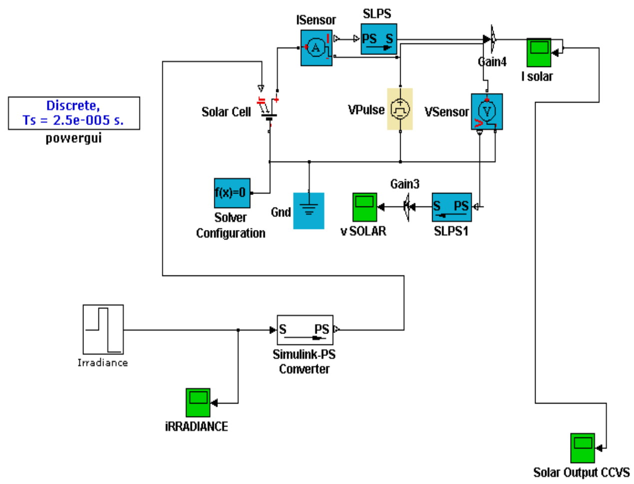


Fig -5: Unmasked Block Diagram of Modeled Solar PV Panel

4. MPPT Interfacing Model

The controlled voltage source and the current source inverter have been used to interface the modeled panel with the rest of the system and the boost converter which are built using the Sim Power Systems module of MATLAB. The block diagram for the model shown in Figure 6 is a simulation for the case where we obtain a varying voltage output. This model is used to highlight the difference between the power obtained on using an MPPT algorithm and the power obtained without using an MPPT algorithm.

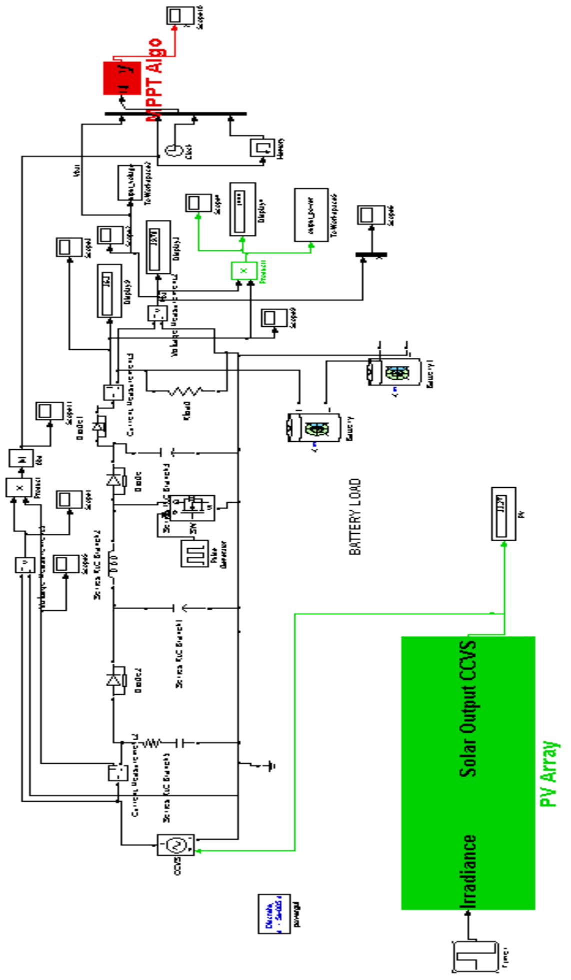


Fig -6: Block Diagram of SIMULINK™ Model of MPPT System

To compare the power output in both the cases stated above, the model is equipped with a automatic switch as shown. There is two model used for comparing the output from solar PV cell. One without MPPT, no tracking system. In this case output from cell is obtained naturally correspondingly 1100 W. In second system with MPPT algorithm where it tracks the maximum power from solar system which have capacity of nearly 2500 W. Hence we obtain the desired power, voltage and current outputs through the respective scopes. Here our main theme is to change the impedance of circuit by switching on/off MOSFET to get maximum power from the same solar at same solar irradiance and same voltage. In this system the load is reflective type on solar PV cell. Only constant voltage signal is providing through the controlled voltage source to circuit, because current is function of power of MPPT algorithm.

4.1 Model of PV Module without MPPT

To confirm the concept, the stand-alone PV system with the MPPT was studied by simulation using the configuration of Figure 7. The PV module used is as same in with MPPT system. The battery bank has a voltage of 48 V and capacity of 925 Ah. To supply ac loads, a boost dc–dc converter is utilized in order to increase the battery bank voltage to the required dc bus voltage, which is necessary for generating the ac output voltage from an inverter. The simulation results of the dynamic performance, which validates the efficient MPPT of PV generation system

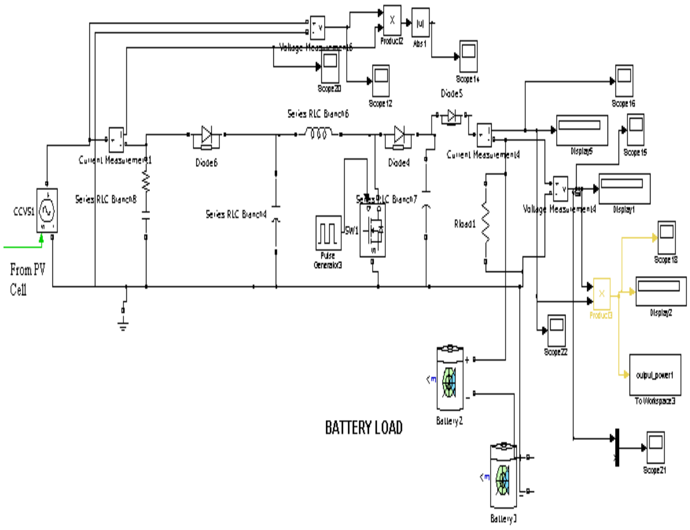
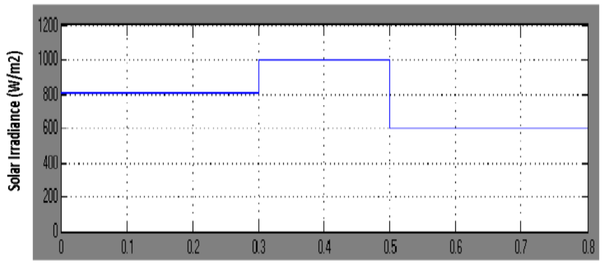


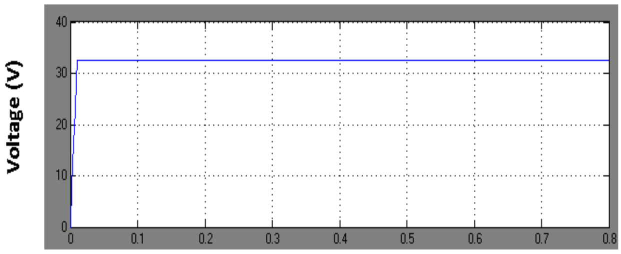
Fig -7: SIMULINK™ Model of without MPPT System

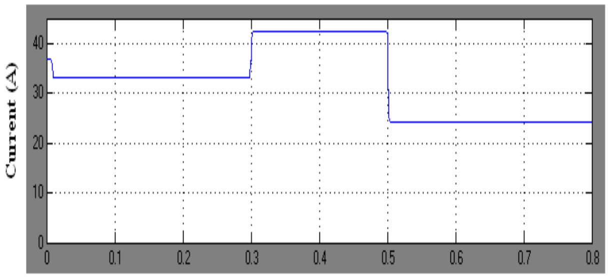
5. SIMULATION RESULT

The results are found as shown in Figure 8 in which applying solar irradiation 800, 1000 & 600 W/m² at different time intervals the current of PV cell also changes in proportion of solar irradiation. Hence current is directly proportional to solar irradiation. The simulation is run for a total of 0.8 seconds.

CASE 1: System with MPPT







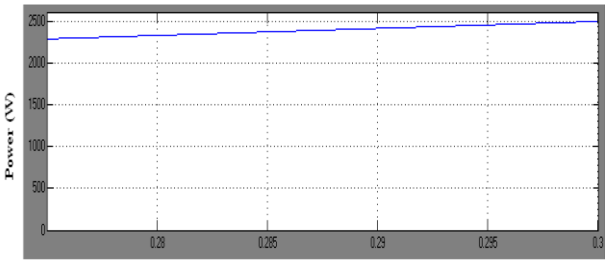


Fig -8: PV Output Power Waveforms at 1 Kw/m² Irradiance with MPPT

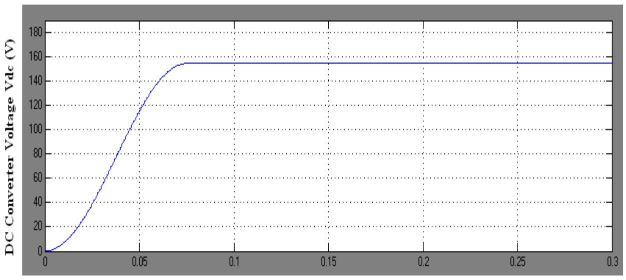


Fig -9: Boost Converter Voltages with MPPT

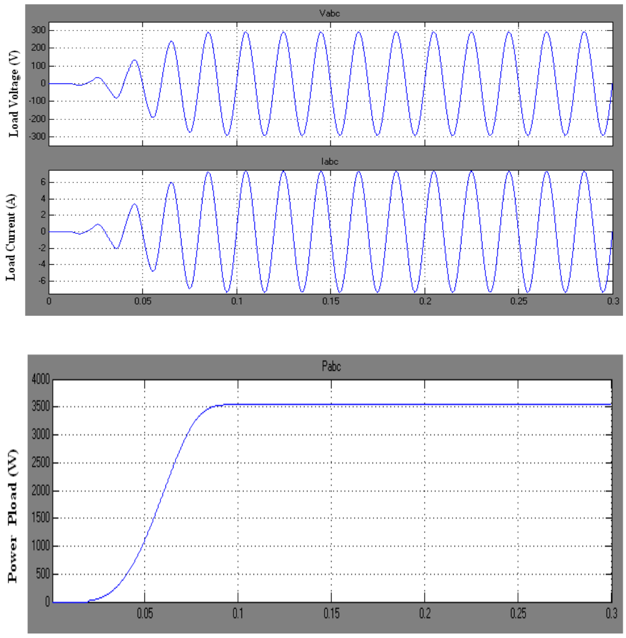


Fig -10: Load Voltages, Current & Power Waveforms with MPPT

CASE 2: System without MPPT

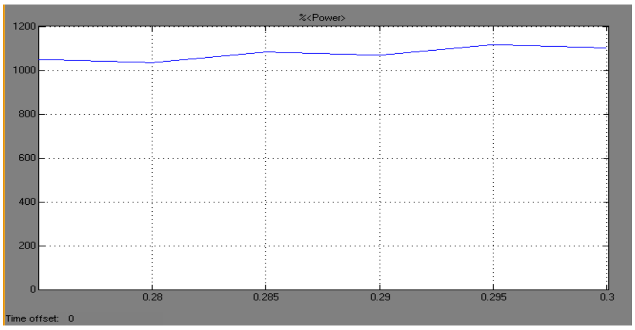


Fig -11: PV Output Power Waveforms at 1 Kw/m² Irradiance without MPPT

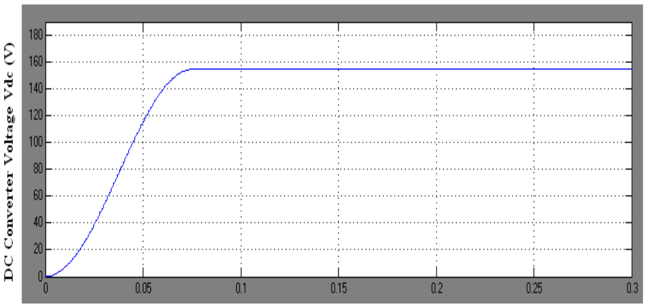


Fig -12: Boost Converter Voltages without MPPT

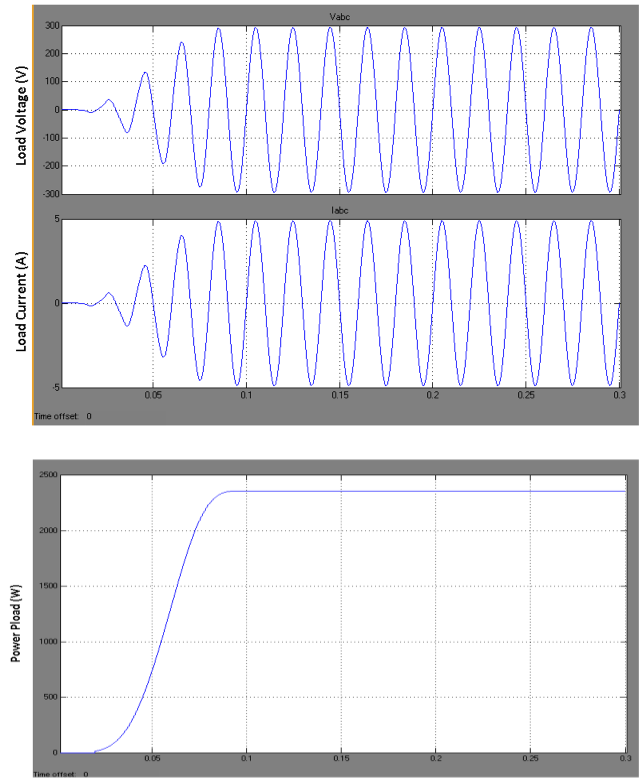


Fig –13: Load Voltages, Current & Power Waveforms without MPPT

6. CONCLUSION

This model is based on the essential circuit equations of a solar PV cell taking into consideration of the effects of physical and environmental parameters such as the solar radiation and cell temperature. The simulation was first run with the switch on without MPPT mode, bypassing the MPPT algorithm block in the circuit. It was seen that when we do not use an MPPT algorithm, the power obtained at the load (AC) side was around 2359 Watts (Figure 13) for a solar irradiation value of 1Kilowatts per sq. mtr. Here MPPT algorithm was developed in which it on/off MOSFET switch for varying impedance of system, therefore it achieve maximum power from solar cell.

The simulation was then run with the switch on with MPPT mode. This included the MPPT block in the circuit and the controller was fed the P_{ref} as calculated by the algorithm. Under the same irradiation conditions, the PV panel continued to generate around 3539 Watts power (Figure 10). In this case, however, the power obtained at the load side was found to be around 3539 watts. The loss of power from the available watts generated by the PV panel can be explained by switching losses in the high frequency PWM switching circuit and the inductive and capacitive losses in the Boost Converter circuit.

Therefore, it was seen that using the MPPT technique increased the output power of the photovoltaic system by approximately 150% from an earlier output power of around 2359 watts to an obtained output power of around 3539 watts.

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