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Maximum Power Point Tracking for a Grid connected PV System using Matlab/Simulink

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ABSTRACT: *Solar photovoltaic systems are gaining popularity as renewable energy sources and may one day be utilised to generate large amounts of electricity. A photovoltaic system turns solar energy into electrical power. Our lives now depend heavily on the usage of energy, thus its supply needs to be reliable and sustainable. Additionally, solar photovoltaic systems are affordable, eco-friendly, and respectable in society. Increasing greenhouse gas emissions due to the usage of traditional energy sources like fossil fuels, which jeopardises our reliable energy supply. A grid-connected PV system is modelled in this research to examine the behaviour of solar output power in Matlab simulation work.*

An AC/DC inverter, a DC/DC boost converter, and a PV cell make up the system. The solar radiation and ambient temperature are taken into account by the simple, precise, and PV cell model. Additionally, it suggests the MPPT method (maximum power point tracking). PV cell maximum power is tracked using an algorithm built into a DC/DC converter. To control the output voltage of the DC/DC converter and link the PV cell to the grid, a DC/AC inverter is then utilised. Based on the results of the simulation, it can be concluded that the model accurately captures the physical properties of a grid-connected PV system.

Key Words: DC-DC Converter, Grid Connected, Inverter, MPPT and PV.

1. INTRODUCTION

Energy is necessary for a variety of purposes, including transportation, industry, agriculture, etc. It may take on a number of different forms, including thermal energy, electrical energy, chemical energy, nuclear energy, and more. Energy utilisation has a significant impact on daily living. The growth of a person or a country is accelerated when there is enough energy available. Our lives now depend heavily on the usage of energy, thus its supply needs to be reliable and sustainable. It should also be affordable, ecologically friendly, and socially acceptable. Our reliable energy supply is threatened by expanding fossil fuel usage and rising greenhouse gas emissions. Therefore, it should be our top goal to produce economical, reliable, secure, and clean energy sources. Solar energy is a reliable and more practical alternative choice. Sunlight is converted into power via a photovoltaic system. A photovoltaic system's primary component is the solar cell. The arrangement of cells can create panels or modules. Our research is focused on photovoltaic cells. Residential loads and remote electrical installations are typical solar energy uses. Additionally, it plays a crucial part in dispersed generating networks. Currently, solar cell efficiencies range from 12 to 20%, which implies that PV panels can only capture a small portion of solar energy (Siemens and North Carolina's Semprius Inc.) recently unveiled a prototype solar panel with a 33.9% efficiency. Therefore, the entire system, including the energy conversion step, must be carefully and effectively built in order to retain this little gathered energy. It requires system integrators to create DC/DC and DC/AC converters that are extremely efficient. Photovoltaic arrays have a nonlinear IV characteristic with a number of factors that need to be tuned using information from actual devices' experimental results. The study of the dynamic analysis of converters may benefit from the usage of the photovoltaic array mathematical model. Solar PV arrays make up photovoltaic systems, which use sunlight to generate electricity. Try to attain MPP from the PV array using an MPPT device, as this will yield the most electricity. We must increase the voltage's magnitude in order to connect it to the grid, which will be accomplished by using a boost converter. The output of the DC-DC converter will then be converted into AC by a DC-AC inverter for grid connection.

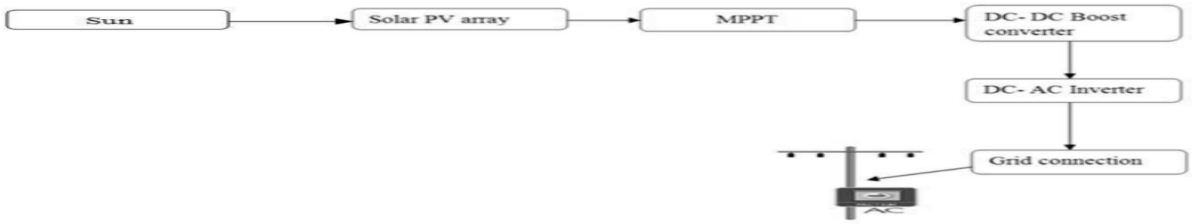


Fig.1 Block diagram of grid connected pv system.

2. LITERATURE REVIEW

A photovoltaic (PV) cell circuit-based simulation model is used to predict how the electrical behaviour of the real cell would change as environmental factors, such as temperature, change. A relationship between the total power output produced by a solar panel and the power needed to position the panel (which is directly proportional to its weight) may be derived, and various strategies to reduce the power need to move the panel can be considered [4]. [5] modifies the curve at three points: open circuit maximum power, short circuit, and the parameters of the nonlinear I-V equation. For power electronics designers that require a straightforward, quick, accurate, and user-friendly modelling method for use in simulations of PV systems, the modelling approach and the suggested circuit model are helpful. The creation of a technique for the mathematical modelling of PV arrays has been examined in this study. The method's goal is to fit the experimentally significant spots on the practical array's I-V curve's I-V equation. Study [6] create a model of a single diode photovoltaic array for analysis and simulation. Finding the parameters of the single diode model equation of an actual photovoltaic array has a closed solution, which is what this work has proposed. Modeling solar arrays is made simple and precise in this paper. The technique is used to derive the array model's parameters using data from the datasheet. With any circuit simulator, the photovoltaic array model can be simulated. A detailed presentation of the model's equations is provided, and experimental data are used to validate the model. This study offers a practical approach for modelling and simulating solar arrays for power electronics designers and researchers. In [7] a contrast between the two most used MPPT controllers, the Perturb and Observe controllers with incremental conductance controllers. The incremental conductance controller is, by far, the best controller for MPPT. A better output value is produced by this controller. These methods differ widely in terms of their ease of use, digital or analogue implementation, sensor requirements, speed of convergence, range of efficacy, implementation hardware, popularity, cost, and other factors. In this paper, the incremental conductance algorithm and the perturb and observe algorithm, two of the most common algorithms, are compared in detail. For comparison in this study, three distinct converters—buck, boost, and cuk—were used. There haven't been many comparisons made between various combinations of efficiency, voltage, current, and power output. Irradiance and temperature variations with constant voltage. Performance evaluation and dynamic modelling of Florida Atlantic University's present grid-tied fixed array 6.84kW solar photovoltaic system (FAU). To increase the systems' stability and dependability, a battery energy storage system is created and implemented. The whole system and its PV module are displayed in their entirety. Using MATLAB Simulink, the corresponding I-V and P-V curves are produced in the following. For the system's modelling and simulation, real data was gathered and used. In order to analyse the system performance that has been tested under two different test conditions: (i) PV power production is higher than the load demand; and (ii) PV generated power is less than required load, a grid-connected PV/Battery system with a Maximum Power Point Tracking (MPPT) controller is modeled [8].

3. **PV SYSTEM**

3.1 PV Cell

A photovoltaic cell is essentially a semiconductor diode with an exposed p-n junction. Different manufacturing techniques are used to create photovoltaic cells from a variety of semiconductor kinds. At this moment, the only silicon cells available on a commercial scale are those made of mono-crystalline and polycrystalline silicon. A thin film of silicon or a sheet of bulk silicon coupled to electrical terminals makes up silicon photovoltaic cells. The p-n junction is formed by doping one of the sides of the Si layer. On the semiconductor's surface that faces the sun, a thin metallic grid is positioned. A PV cell's physical composition is broadly depicted in Fig.3.1. When light strikes a cell, charge carriers are created. If the cell is shorted, these charge carriers start an electric current. When the incident photon's energy is sufficient to separate the semiconductor's covalent electrons—a phenomena dependent on the semiconductor material and the wavelength of the incident light—charges are produced. Essentially, the PV phenomenon is the absorption of solar light, the creation and transit of free carriers at the p-n junction, and the collecting of these electric charges at the terminals of the PV device. A semiconductor called a photovoltaic (PV) cell uses the photovoltaic effect to collect light energy and transform it into electricity. The photon energy from sunshine is absorbed and transformed into electricity by a semiconductor device known as a PV cell. It is quite challenging to estimate I_{LG}, I_{OS}, R_{sh}, and R_s in the ideal PV Cell model, which is connected to cell temperature and radiation intensity. Applications in engineering are now extremely difficult as a result. Manufacturers of PV arrays offer several experimental technical characteristics such as open-circuit voltage V_{OC}, short-circuit current I_{SC}, the maximum power point current I_m, the maximum power point voltage V_m, and the maximum power point power Pm.

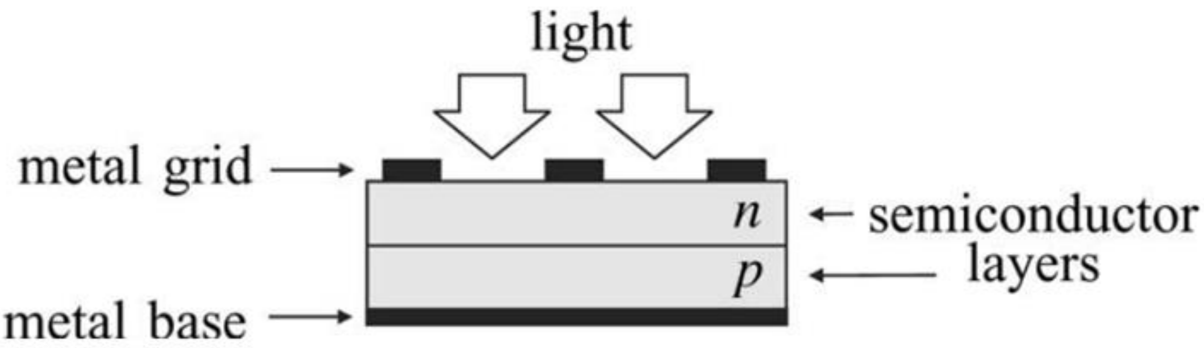


Fig. 2

The amount of light that strikes the semiconductor and its capacity for absorption determine the pace at which electric carriers are produced. The semiconductor band gap, the reflectance of the cell surface (which depends on the shape and treatment of the surface), the intrinsic semiconductor carrier concentration, the electronic mobility, the recombination rate, the temperature, and a number of other factors all play a role in the absorption capacity. Solar radiation is made up of photons of various energy. Low-energy photons are ineffective and produce no voltage or current in a PV cell because their energies are below the band gap of the device. Only the energy corresponding to the band gap is utilised when photons with energies greater than the band gap create electricity; the excess energy is lost as heat in the PV cell's body. Lower band gap semiconductors may benefit from a wider radiation spectrum, but the voltages produced are lower. Si is the only semiconductor material for PV cells whose production is commercially viable on a wide scale, however it is not the sole or even the best. Better conversion efficiency can be attained by other materials, but at greater and commercially unviable costs [1-3].

3.2 PV Modelling

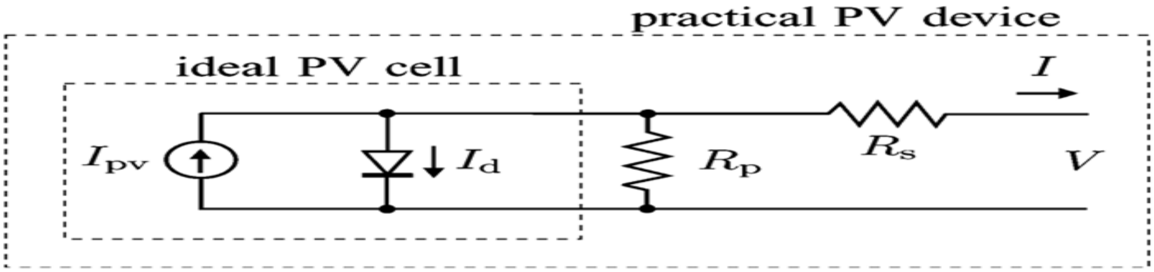


Fig.3 Equivalent circuit of Ideal PV Cell.

Fig. 3 shows the equivalent circuit of the ideal PV cell. The basic equation from the theory of semiconductors that mathematically describes the I–V characteristic of the ideal PV cell.

$$\begin{aligned} I &= I_{LG} - I_d - I_{RSH} \\ &= I_{LG} - I_{OS}\left\{exp\left[\frac{q}{AkT}(V + IR_S)\right] - 1\right\} - \frac{V + IR_S}{R_{sh}} \qquad (i) \end{aligned}$$

Where

I_{pv}, cell is the current generated by the incident light (it is directly proportional to the Sun irradiation),

I_d is the Shockley diode equation,

I_0,cell is the reverse saturation or leakage current of the diode,

q is the electron charge (1.60217646 × 10−19 C),

k is the Boltzmann constant (1.3806503 × 10−23 J/K),

T (in Kelvin) is the temperature of the p–n junction, and

A is the diode ideality constant.

The basic equation of the elementary PV cell does not represent the I–V characteristic of a practical PV array. Practical arrays are composed of several connected PV cells and the observation of the characteristics at the terminals of the PV array requires the inclusion of additional parameters to the basic equation.

3.3 DC-DC Converter

A DC/DC converter is used to provide the highest amount of power possible from the solar PV cell to the load. An interface between the load and the PV cell is provided by a DC/DC converter. In order to transmit the most power, the duty cycle is adjusted to vary the load impedance and match it with the source at the time of peak power. To link the PV-generated voltage to the grid, we must raise its magnitude. This may be accomplished by using a DC-DC converter; but, for our needs, we have selected a boost converter that will enable us to raise the level of voltage that we have produced.

4 MAXIMUM POWER POINT TRACKING

4.1 Perturb and Observe (P&O) methods.

The P&O technique affects a PV cell's operating voltage, whereas the Hill Climbing approach affects a power converter's duty ratio. Although these techniques are simple to use, they are neither precise or quick enough since the effects of temperature and sun radiation have not been taken into account. A little system perturbation is introduced in this approach. The power of the solar module is altered as a result of this disturbance. If the disturbance results in an increase in power, the perturbation will continue in that direction. As soon as the peak power is attained, the power at the following instant falls, which causes the perturbation to then reverse. After reaching the steady state, the algorithm oscillates around the peak. The magnitude of the perturbation is kept extremely minimal to minimise the power variation. The method was created in a way that it establishes a reference voltage for the module that is equal to its peak voltage. A PI controller then moves the module's operating point to that specific voltage level. It has been noted that some power is lost as a result of this disruption, and the power fails to track when the atmospheric conditions change quickly.

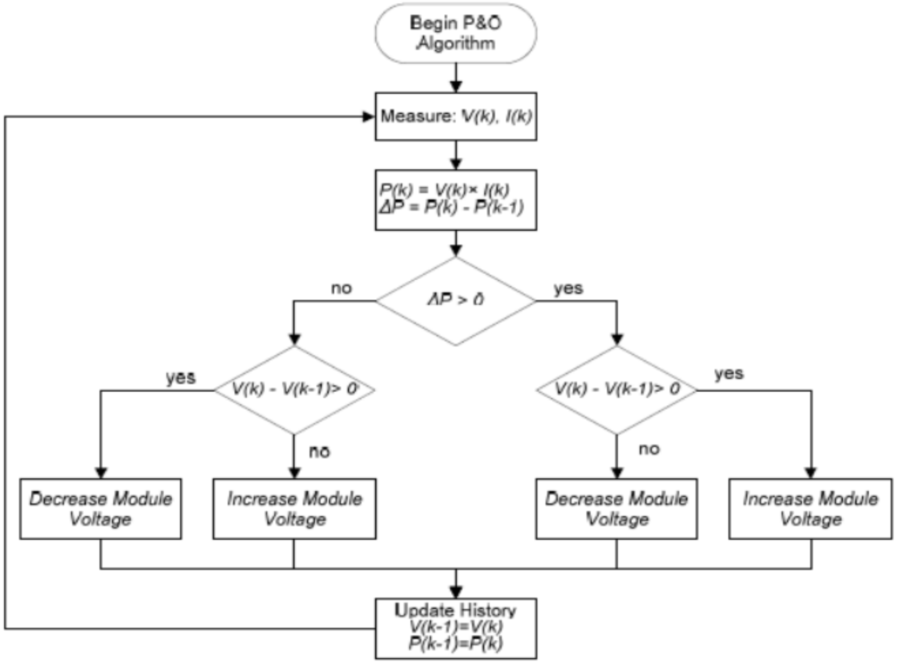


Fig.4: Flowchart of Perturb and Observe Algorithm

The P&O method's flowchart is shown in Fig. 4. The new direction of the perturbation may be identified by comparing the PV cell output power of each control cycle before and after the disturbance. The subsequent cycle will follow the previous voltage perturbation direction if the output power is rising. Otherwise, the direction of the voltage perturbation will shift. By using this technique, the operating point of the PV cell can eventually attain a steady state and approach the maximum power point.

4.2 IMPLEMENTATION OF MPPT WITH BOOST CONVERTER.

The voltage we created with the PV panel has to be increased in magnitude in order to be connected to the grid. A DC-DC converter may be used to do this, but for our needs, we have selected a boost converter that will enable us to create more voltage. The goal of a DC/DC converter is to provide the highest amount of power possible from the solar PV cell to the load. The interface between the load and the PV cell is a DC/DC converter. To transmit the most power possible, the duty cycle must be adjusted in order to vary the load impedance and match it with the source at the time of peak power.

For maximum power point tracking, a PWM boost converter is employed with the following specifications. Figure depicts the DC/DC converter simulation model.

TABLE 1: PARAMETERS OF THE DC/DC CONVERTER

PARAMETER	SYMBOL	VALUE
INDUCTOR	L	0.01 H
CAPACITOR	C1	0.002 F
CAPACITOR	C	0.002 F
RESISTOR	R	100 Ω

5. MODELLING OF GRID CONNECTED SYSTEM

5.1 Solar Panel

Although there are many other types of solar cell materials, silicon is now the most widely used one because of its scalability, momentum, and efficiency in light absorption. This PV array has 50 solar cells total, which produces a maximum power of 170 watts, and is made up of 10 solar cells each subsystem linked in series. Table 2 displays the solar module's specifications for the investigation.

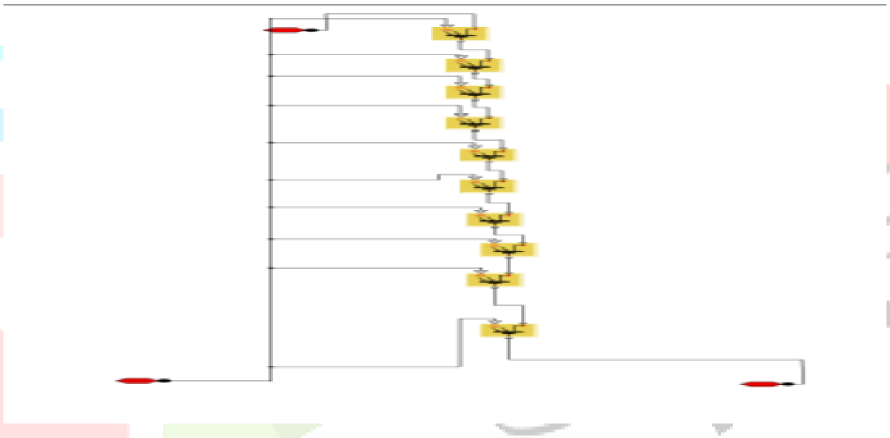


Fig. 5: 10 solar cell in series

TABLE 2: SPECIFICATION OF SOLAR MODULE

Cell type	**Polycrystalline silicon**
No.of cells	50 in series
Maximum Power rating(Pmax)	170W
Open circuit voltage(Voc)	30.6 V
Short circuit current	7.38 A
Maximum power voltage	24.6V
Maximum power current	6.93A

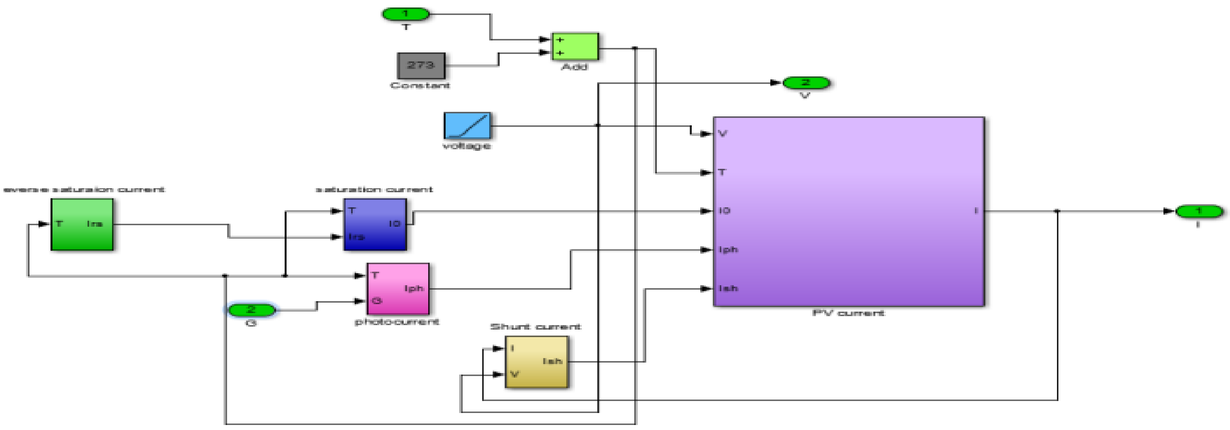
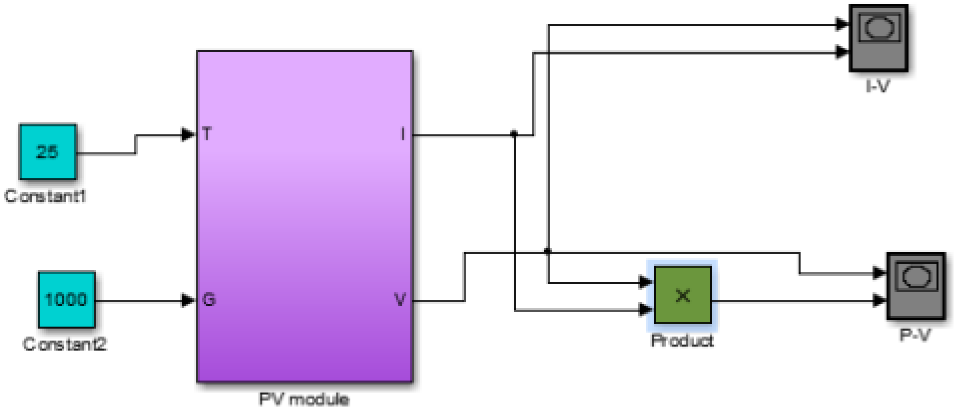


Fig. 6. SIMULINK MODEL OF PV SYSTEM



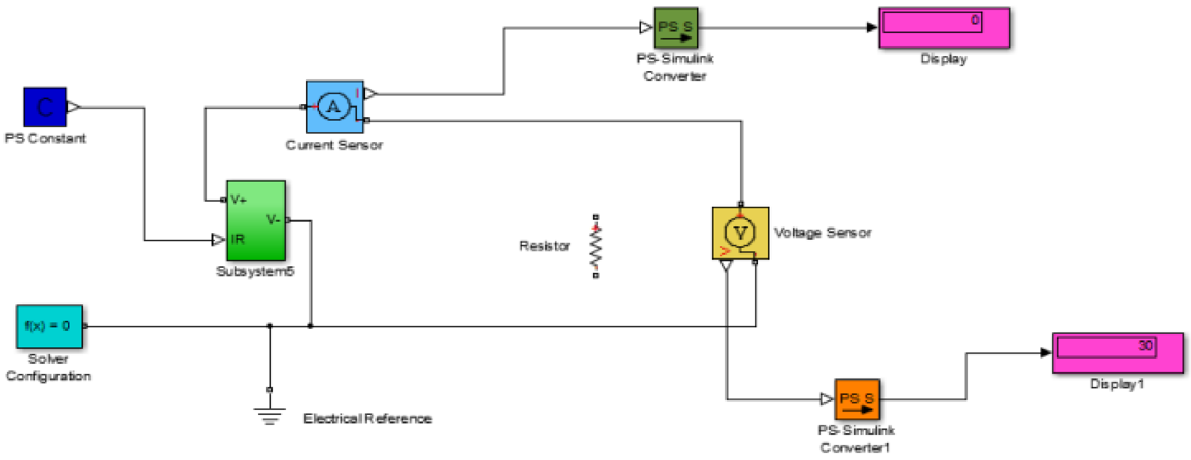


Fig. 7: Simulink model to observe open circuit voltage

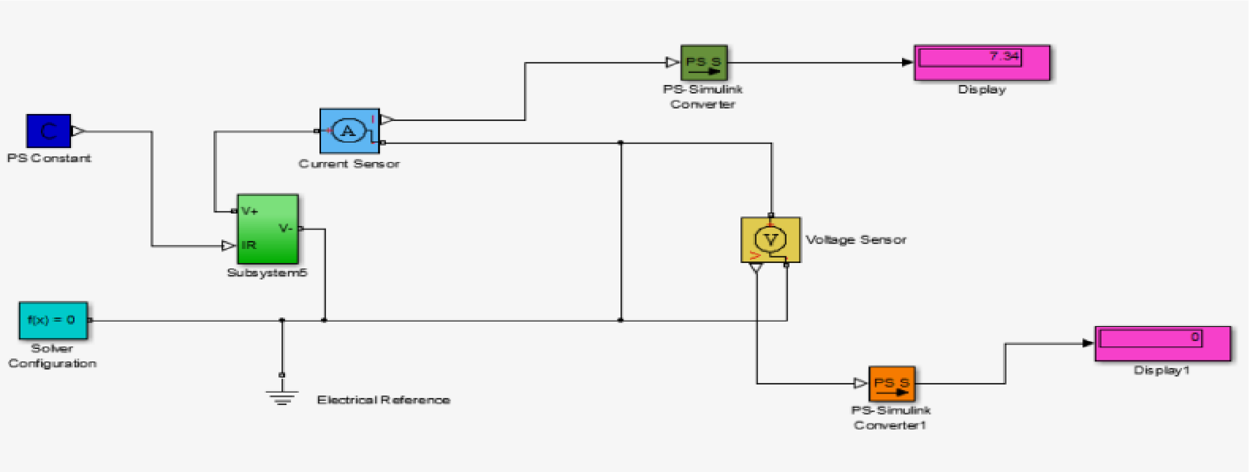


Fig.8: Simulink model to observe short circuit current

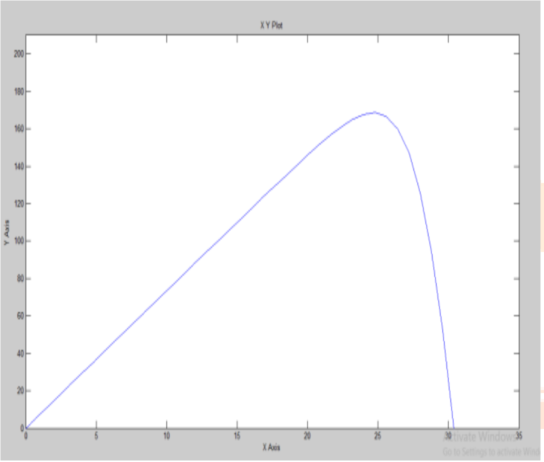


Fig.9: Characteristics of power vs voltage

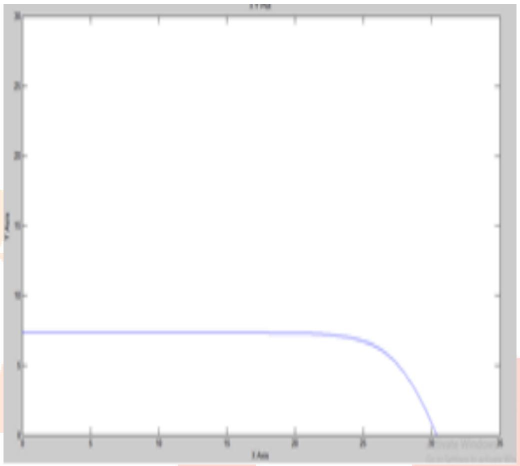


Fig.10: Characteristics of current vs voltage

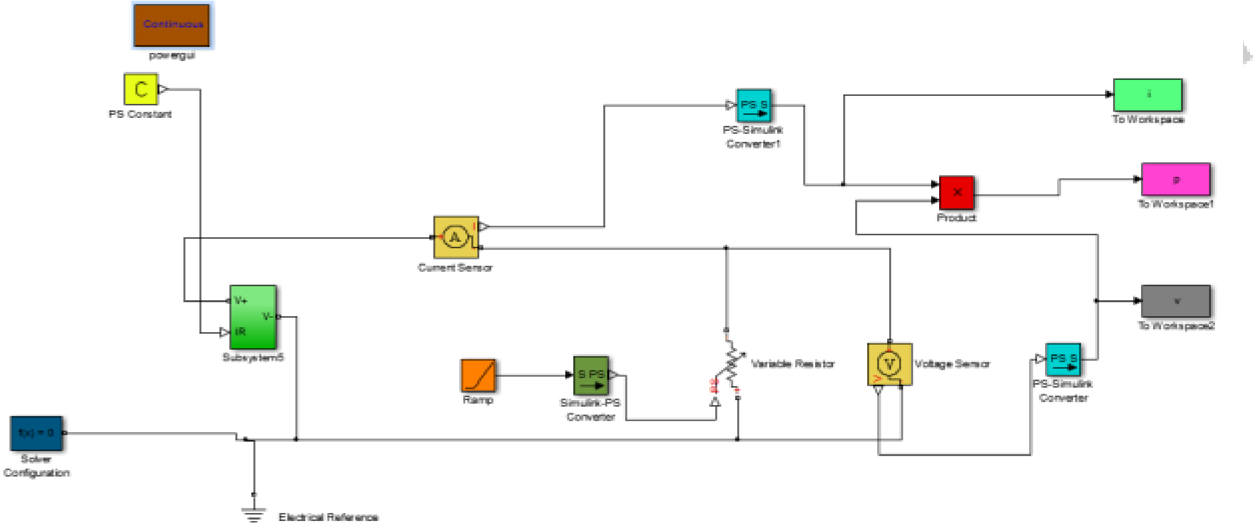


Fig.11: Simulink model for effect of SOLAR IRRADIATION, TEMPERATURE AND SERIES RESISTANCE

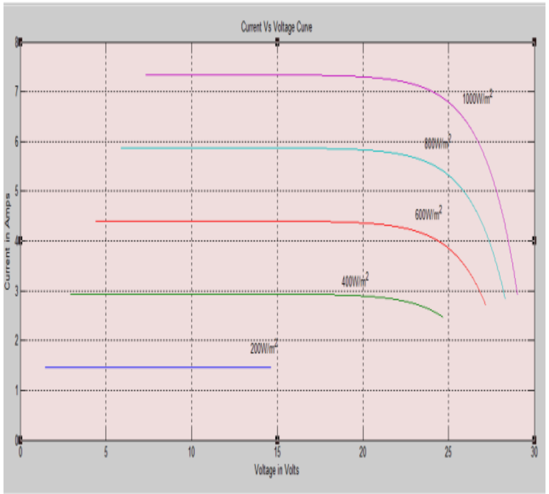


Fig.12: Impact of solar irradiation on current vs voltage.

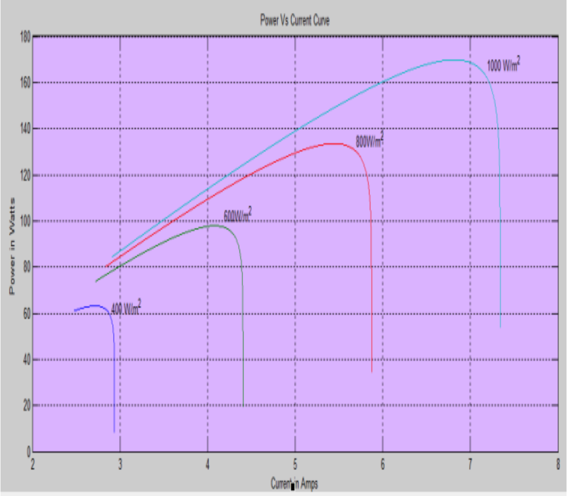


Fig.13: Impact of solar irradiation on Power vs current.

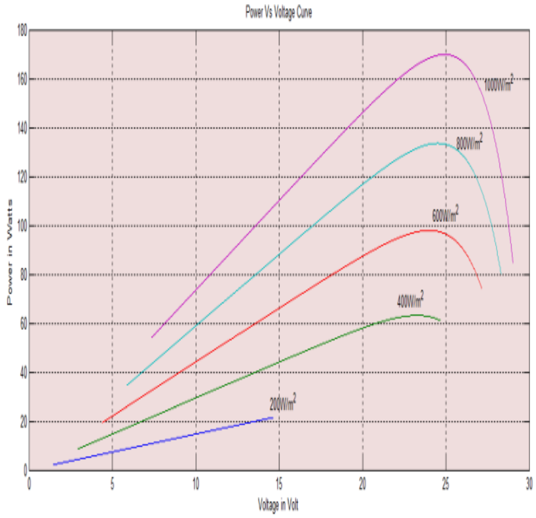


Fig.14: Impact of solar irradiation on Power vs current fig:- impact of solar irradiation on power vs voltage

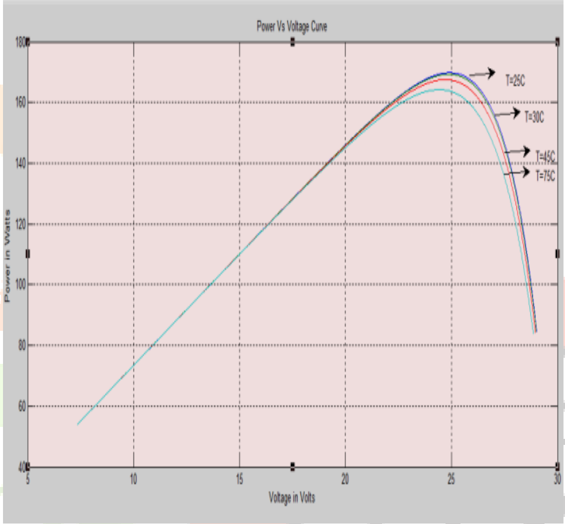


Fig.15: Impact of temperature on power vs voltage

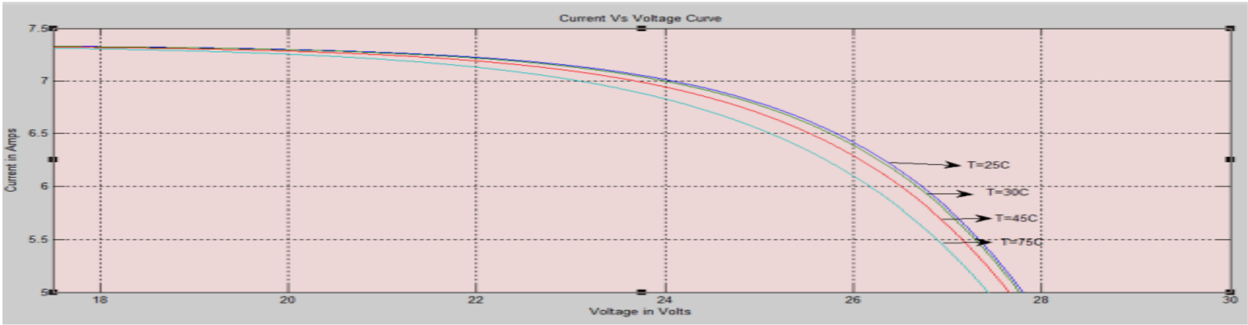


Fig. 16: Impact of temperature on current vs voltage

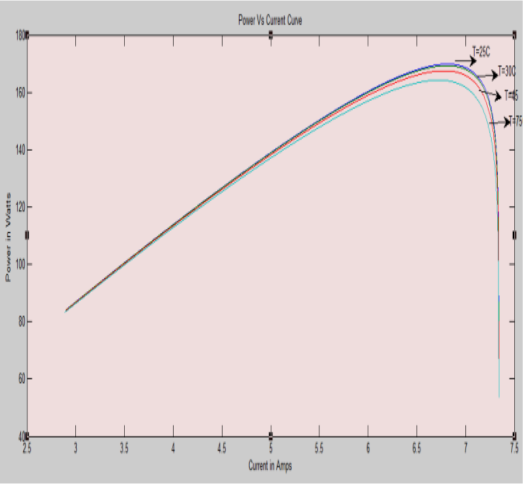


Fig. 17: Impact of temperature on power vs current

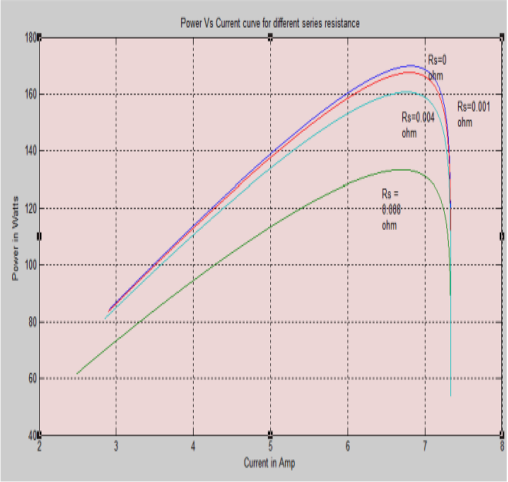


Fig.18: Impact of series resistance on power vs current

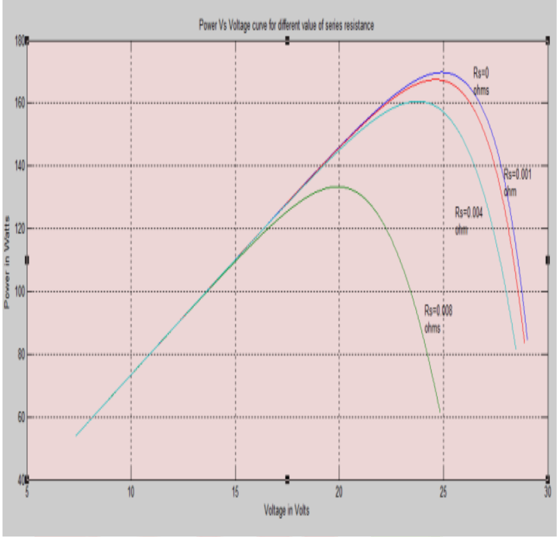


Fig.19: Impact of series resistance on power vs voltage

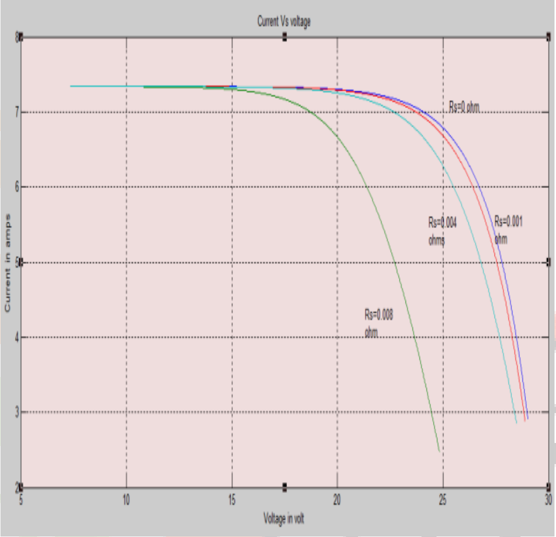


Fig. 20: Impact of series resistance on voltage vs current

6. SIMULATIONS AND RESULTS

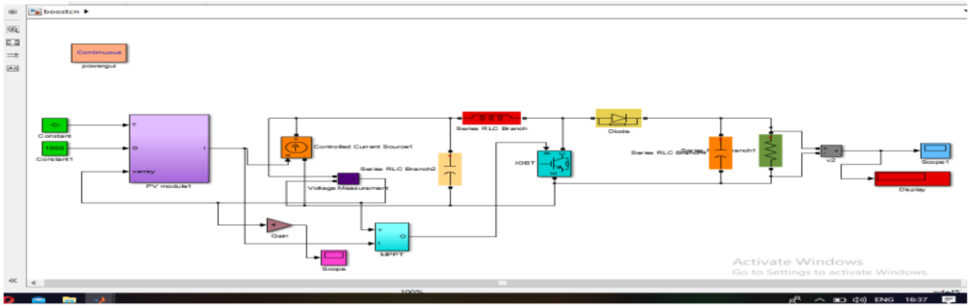


Fig.21: Simulink model for DC-DC Converter

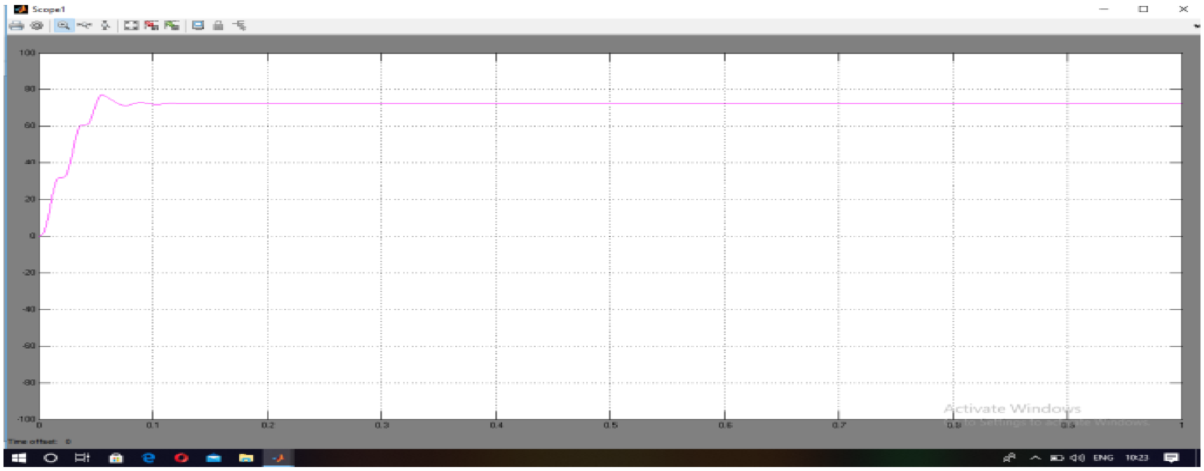


Fig.22: Voltage waveform of DC-DC Converter

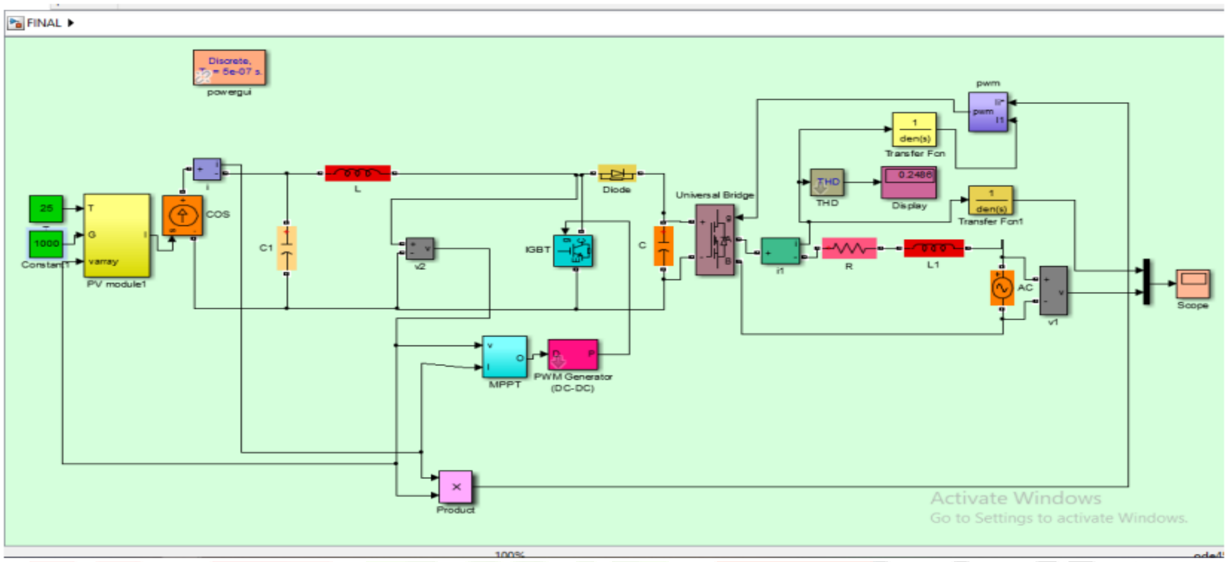
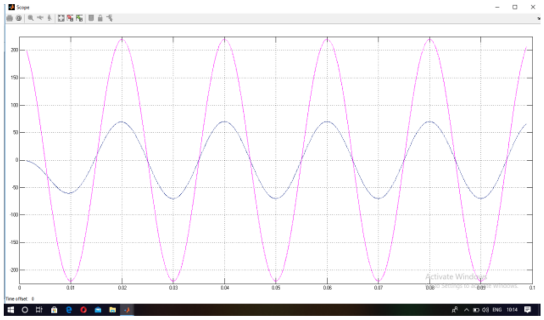


Fig.23: Simulink model of PV Grid-Connected System



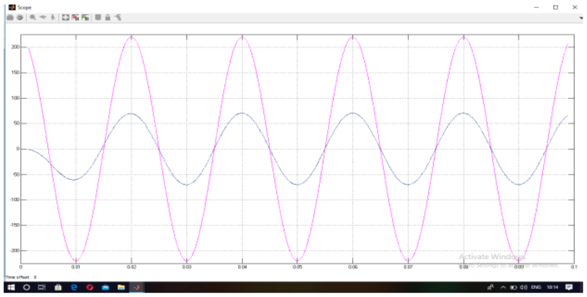


Fig.24: Wavefrom of PV Current with Grid Voltage when Temperature 25℃, Solar Radiation 1000 W/m^2

Fig. 25: Wavefrom of PV Current with Grid Voltage when Temperature 75℃, Solar Radiation 900 W/m^2

When comparing the PV current waveform with the grid voltage graph, we can see that the generated PV current is ahead of the grid voltage by for a very little period of time (0.03s). For this time period, change the grid voltage waveform's equation to Sin (wt) instead (wt). When the time approaches 0.03s, the PV currents generated are 100% in phase with the grid voltage, yielding precise and effective outcomes.

CONCLUSION

The output voltage of the DC/DC converter is controlled and synchronised with the grid using a DC/AC inverter. By matching the phase of the grid voltage to the generated solar current, simulation results show that the suggested model may successfully realise the actual physical properties of a grid-connected PV system. The system is made up of a photovoltaic (PV) cell, a DC/DC boost converter, and a DC/AC inverter. The internal workings of a solar cell are described with a schematic and an approximate PV cell. The PV cell model is straightforward, accurate, and takes into account both ambient temperature and solar radiation. The model is capable of carrying out the essential duty in a variety of temperature and light conditions. Additionally, it uses an algorithm to examine several kinds of maximum power point tracking (MPPT) methodologies. A DC/DC converter is used in conjunction with an algorithm to track the maximum power of a PV cell. With the help of a modified P&O MPPT algorithm based on a Boost DC/DC converter, the maximum power of the PV cell is monitored. The PV cell was connected to the grid and the output voltage of the DC/DC converter was controlled by a DC/AC inverter. Simulink simulates the entire photovoltaic grid-connected system. Special circumstances like a quick temperature shift and solar radiation have been investigated and simulated.

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