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ECONOMIC POWER GENERATION THROUGH GRID INTEGRATION OF PHOTOVOLTAIC POWER PLANT

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Abstract

This paper deals with the grid integration of the photo voltage generator to provide active power by the use of renewable sources. The simulation is done in MATLAB to investigate the issues and solution for the grid integration. Photovoltaic cell is operated in maximum power point tracking mode (MPPT), to achieve maximum efficiency throughout the operation. PV generation is implemented to encourage the grid integration to support and provide active power management to the utility grid. To validate the use of MPPT techniques, the results are compared to prove that the MPPT controller increases the efficiency and performance of the PV system. By the use of MPPT controller, the power output of the PV cell can be controlled. PV cell generates DC power which can be converted into AC at desired level of voltage and frequency by the use of converters. The grid synchronization can be achieved by controlling the output of the converter with respect to the grid requirements i.e., the voltage and frequency level.

Keywords: Photovoltaic, Microgrid, Grid integration, MPPT, Renewable energy.

Introduction:

Greenhouse gases emission is increasing day by day. The fossil fuels are used in many industries including power generation sector, as a demand of electricity is increasing at very high rate this causes severe environmental problems. Initiative has taken all around the World, to reduce the emission of greenhouse gases. For example European Union has decided to reduce it below 20% up to 2020. Using renewable sources for the power generation the greenhouse gas emissions can be reduce to a great extent. For the installation of such distributed energy sources, no much space is required they can be installed on the rooftops, in the deserts or at a location where there is no possibility to provide the power supply from the conventional grid. Nowadays PV power generations comes with the grid connecting facility where they can feed power directly to the grid network. In some countries in fact, this is a business to sell power to the main grid and financial benefits are earned. Government has initiated multiple programs to increase and harness renewable sources of energy. Government provides subsidies, discount in billing, and providing high cost equipment at low cost. The main drawback of the renewable sources of energy is that, the efficiency of the sources is very low and availability of the input energy is not fixed during a complete day. So, they must be accommodated with some source of energy storage that can support and provide power during that time so that the continuity of the power is retained. Further as number of conversion stages required from generation to the consumer end, it further decreases the overall efficiency of the system. The efficiency of the system can be increased by employing some power tracking techniques, where the PV cell is operated at maximum power level [1-3]. The overall cost for the electricity generated reduces. The maximum power point tracking techniques, track the operating point of the PV cell at certain level of irradiance and temperature. In literature different techniques are available to track the maximum power point of the photovoltaic cell. The objective of this paper is to study different MPPT algorithms and observe the employability and selection of particular technique.

Need of Renewable Energy Generation:

India is one of the largest and fastest growing countries where demand of energy is very high which is satisfied by the coal, petroleum and other fossil fuels. But still there are many places where there is no electricity yet. About 62% of the population in India lives in rural areas and average supply and power demand gap is about 12%. This is when 412 million Indians do not have any access of electricity. India imports approximately 78% of its oil requirement from the foreign countries which will increase about 90% by 2030 [33]. Indian government is concentrating toward the use of renewable sources of energy, to meet the daily needs of the rural as well as urban areas. For this, Indian government has initiated many programs. At the end of 2017 the total installed capacity from the solar power was about 20GW. Mainly off grid solar power plants have more impact in greenhouse gas reduction. The government has set its target for increasing the capacity solar 100GW by 2022.

PV Generation Principle:

Solar cells are the building blocks of the photovoltaic cell and take the advantage of Photoelectric effect. This is the ability of the semiconducting materials that when they absorb electromagnetic radiation can convert it into electricity. A solar cell is basically a PN junction, which is made of two different semiconducting materials doped with different concentration of impurities [4, 5]. When two layers are joined together at the surface near the junction, creates electric field between the two sides and behave like a potential barrier. The electric field pulls the electrons and holes in the opposite direction so that the current flows only in the one way. If an external electric field is applied across the junction then the force is exerted over the charge carriers and a conducting path across the junction is formed and electricity or current starts flowing [6-10]. When photons of the solar radiation incident over the surface of a solar cell electrons and holes crosses the barrier potential and transfer electrons, if load is connected across the terminals of the solar cell then there will be a continuous power flow in the load. If the Solar radiations continue to incident over it the process continues.

$$I = I_L - I_0 \left\{ e^{\frac{q(V-IR_S)}{AkT}} - 1 \right\} - \frac{(V-IR_S)}{R_{sh}} \quad (1)$$

Where, I, V, Io, q, A, k, T, Rs and Rsh – are the output current, voltage, dark saturation current, electron charge, identity factor, Boltzmann's constant, absolute temperature, series and shunt resistance is of the solar cell respectively.

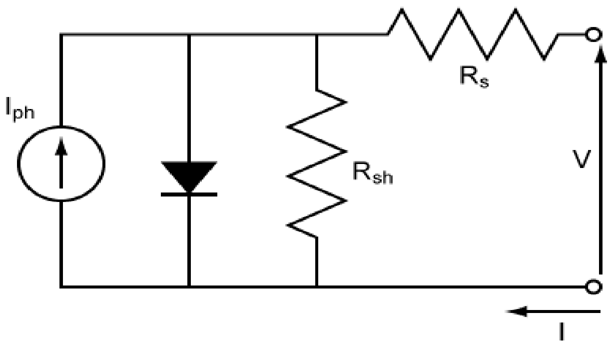

Figure 1. Equivalent circuit of the photovoltaic cell

Figure 1 shows the equivalent circuit of the photovoltaic cell. Sometimes the effect of shunt resistance is not considered in the equivalent circuit or shunt resistance is taken as infinite. A PV array is made of multiple solar cells, depending upon the requirement of voltage and current.

$$V_{OC} \approx \frac{AkT}{q} \ln\left(\frac{I_L}{I_O} + 1\right) \quad \text{and} \quad I_{SC} \approx I_L \quad (2)$$

Equation (2) shows the voltage when open terminals and short circuit current of a PV cell. On the V-I graph, where the product of current with voltage is maximum that point is known as MPPT point. It is a unique point corresponding to the solar radiation and temperature of the surrounding [11-15].

Effect of Temperature and Solar Irradiance:

For the operation of PV cell depends upon the two important factors i.e., solar radiation and temperature. The variation in the temperature and solar radiation causes the output power to be changed correspondingly. However, the MPPT techniques continuously track the MPPT point where, at certain level of solar irradiance with respect to the operating point of V-I curve to fetches the maximum power point [16, 19-25]. The effect of temperature and solar radiation is depicted in figure 2.

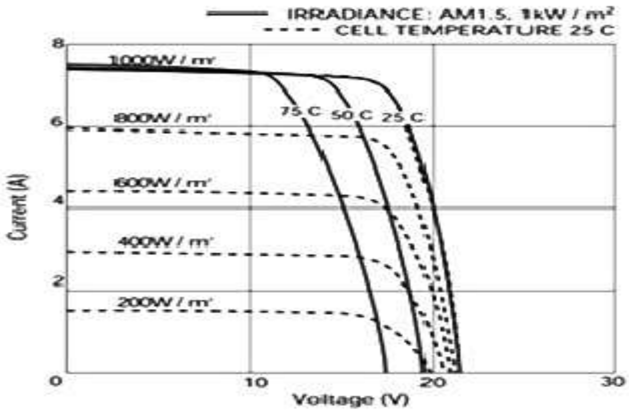

Figure 2. V-I Characteristics of PV cell at different Irradiance Level (Source; www.researchgate.net)

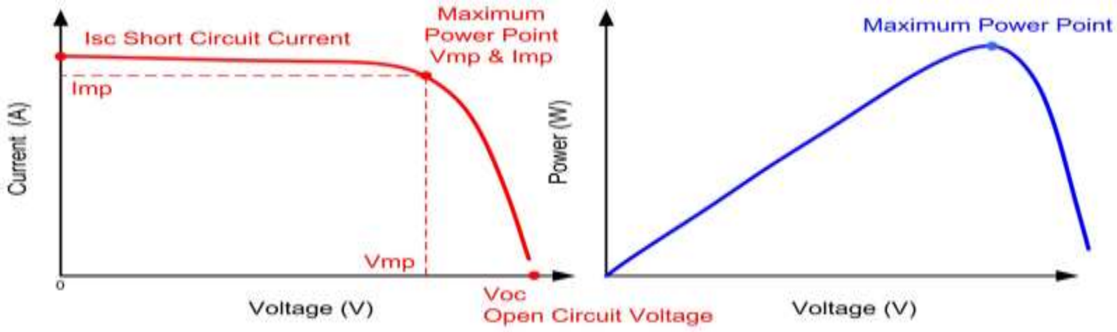

Figure 3. Maximum Power Point at V-I Curve

Photovoltaic modules are prepared by connecting solar cells in different combination to have the required value of voltage at the output terminals of the module. Finally the solar cells are encapsulated to protect them from weather and other problems that make them robust and corrosion free [17]. PV modules are encapsulated in a layer of ethyl phenyl acetate airtight envelope so as to protect them during transportation and handling. The top cover of the PV module is an anti-reflective tempered glass used to absorb more solar irradiance concentrated over it. At the lower surface of module polyvinyl chloride is fixed to avoid the moisture and chemical attack from the underneath and finally it is framed in an aluminum frame to provide extra protection from the shocks and transportation effects.

Maximum Power Point Tracking Techniques:

There are different approaches to achieve the maximum power point of a PV module such as Hill Climbing technique, perturb and observe technique, incremental conductance method, Fuzzy Logic Control based MPPT technique, neural network based MPPT technique and current sleep technique etc. The Hill Climbing technique is one of the most popular techniques. Tracking MPPT of a PV module by Hill Climbing technique gives good performance when solar irradiance is constant [26] [27]. In the incremental conduction technique, the slope of the curve between voltage and power is tracked to reach the (maximum power) MP point. At MP point, the slope of the characteristic curve is zero and at the either side it is positive or negative so, by comparing the incremental slope the MP point is tracked. The time taken for the technique to reach the maximum power point depends upon the size and steps of the increment. But this technique can easily lose the track if the irradiance of the solar energy changes at a very high rate [28]. Fuzzy Logic technique also gaining popularity from the last decade as it can handle most of the uncertainties and nonlinearity in the input. By the coordination of fuzzy logic and the microcontroller higher degree of accuracy can be achieved. Fuzzy Logic technique does not require an accurate mathematical model of the system to implement it. Neural network based MPPT control techniques, emulate the human brain capabilities. It is a combination of multiple layers of neurons, which take input and produces a required output for tracking the MPPT of the PV array. The main drawback of the union based technique is the fact that they must be trained corresponding to the required input and output parameters and conditions [29-32].

Grid Integration of PV System:

When distribution generating units have to be connected with the grid they must have to follow the grid standard. An electric grid is a huge network of the electric power. If the generated power of the distributed generation unit is higher than the local load connected to it then extra power can be delivered to the utility grid at the voltage and frequency of the grid. The grid integration offers number of advantages such as load balancing, frequency management, active power support, reactive power support, increased efficiency, full utilization of the transmission and distribution network, low cost of electricity to the consumer, high quality of power, power security and reliability [33-35].

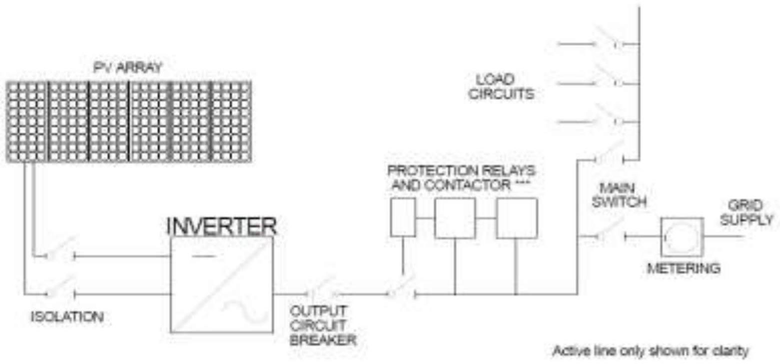

Figure 4. Grid Connected PV Array (source: http://www.brijfootcare.in/grid-connected-pv-systems)

The grid connection of PV system is accomplished through an inverter which converts DC output power from PV array into AC power at grid frequency and voltage. For synchronization, the inverter control is done by controlling the gate signal with respect to the grid requirements. Figure 4 shows the grid connected PV array.

Table 1. Parameters Selected

PV Parameter	Selected Values
P_{mp}	315.2
V_{mp}	58.70
I_{mp}	5.78
V_{oc}	62.17
Isc	6.02
R_s	0.04
R_{sh}	999.41

Table 1 shows the various parameters selected for the modeling of the PV module. Figure 5 shows the MPPT and boost converter used for the MPPT tracking and voltage stabilization at the point of common coupling where DC power is extracted by the inverter and supplied to the local load as well as grid in case if extra power available [36].

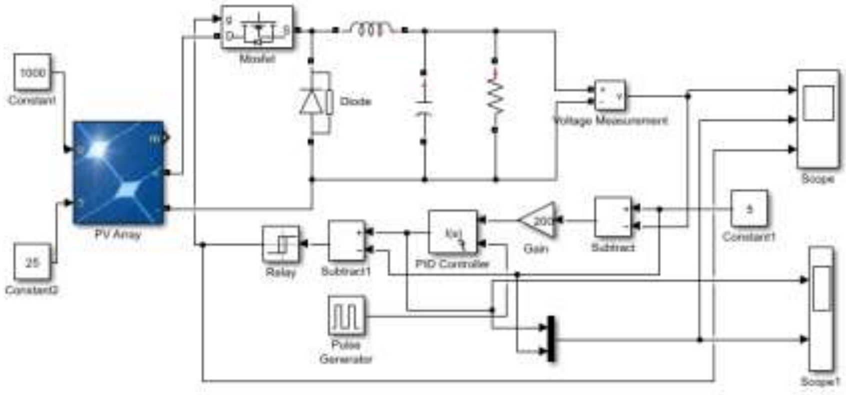

Figure 5. MPPT and boost converter for the MPPT Tracking

Results:

The results corresponding to the different radiation level irradiance level of the Solar Energy are shown in the figure and it is observed that boost converter and MPPT Controller are capable to track the maximum power point of the PV module in very efficient and quick manner.

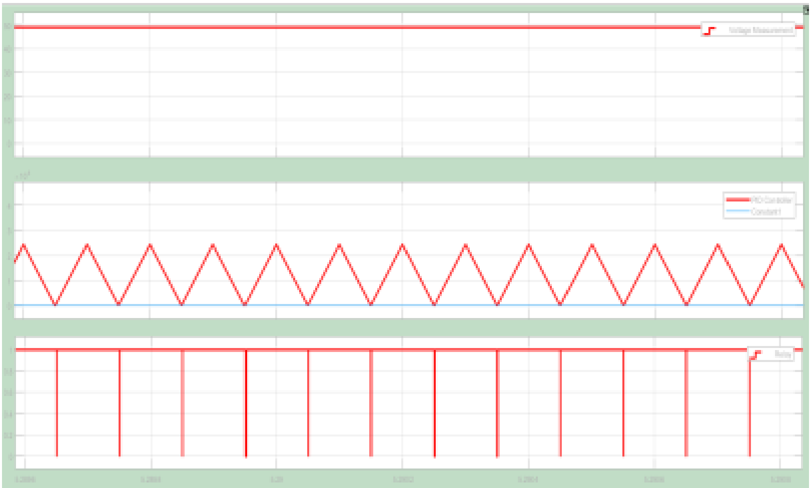

Figure 6. Output of the MPPT Controller

The grid voltage and frequency are maintained by the inverter where the controlling of the inverter is done in stand-alone as well as in grid connected mode. In grid mode, voltage and frequency for reference are provided by the grid while in standalone condition the inverter has to supplied reference values so that the voltage and frequency remains within the tolerable limits.

Conclusion:

PV cell generate electricity without any kind of emission. The generation completely depends on the solar radiation. One time investment for the installation of PV module can serve up to 25 years hence the cost of electricity is almost negligible. If generated power is higher than the local load then this extra power can be sold to the utility or the other consumers to earn the profit. MPPT techniques increase the efficiency of the PV module in great manner. The grid connection of the PV module offers flexibility in the grid operation by providing ancillary services to the utility grid. The future work can be done to harness power from solar, wind, tidal and small hydro etc. to feed a common load.

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