Maximum Power Point Tracking of PV System by Particle Swarm Optimization Algorithm

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Abstract - *In the recent years, the solar energy has become one of the most important renewable sources of electrical energy, so it is important to operate Photovoltaic (PV) panel at the optimal point to obtain the possible maximum efficiency. This paper presents a best optimization approach in order to maximize the output power of the PV module. The proposed optimization technique is based on an objective function which represents the output power of PV module with some constraints. The Particle Swarm Optimization (PSO) is one of the best techniques that has been performing well on many of the optimization problems. For maximum power point tracking DC-DC boost converter is used in photovoltaic system*

Key Words: Photovoltaic system, Particle swarm optimisation, DC-DC boost converters, Photovoltaic panel, maximum power point tracking.

1. INTRODUCTION

In the last years global warming is rapidly incrementing day by day results in increasing of earth's temperature and energy crisis is the main problem in a country like India. Among available energies, Photovoltaic (PV) system has received a great attention as it appears to be one of the most promising renewable energy sources. Power obtained from PV module has to be maximum in order to meet our requirements. So to maximize the power an optimization technique called Particle swarm optimization (PSO) with some constraints is used. The major problem in PV power generation systems is that the amount of electric power generated by PV module is always changing with weather conditions, i.e., irradiation. To overcome this drawback MPPT techniques are implemented by using DC-DC boost converters.

1.1 Photovoltaic System

Photoelectric effect was first noted by French physicist Edmund Becquerel in 1839. He proposed that certain materials have property of producing small amounts of electric current when exposed to sunlight. A photovoltaic system makes use of one or more solar panels to convert solar energy into electricity.It consists of various components which includes the photovoltaic modules, mechanical and electrical connections, mountings and means of regulating and modifying the electrical output. Because of the low voltage generation in a PV cell, several PV cells are connected in series for high voltage and in parallel for high [6] current to form a PV module for desired output. The PV array has been designed taken into consideration its dependence upon the irradiance, temperature and number of PV cells connected in series and parallel.

Table -1: Design specifications of PV module

Short circuit current (I_{SC})	3.2A
Temperature(T)	273K
Reference temperature(T_{ref})	25K
Charge(q)	1.6*10^(-19)C
Temperature coefficient	0.0017
Number of cells	36
Energy gap	1.1V
Open circuit voltage	21.6V

1.2 Working of PV cell

The basic principle behind the operation of a PV cell is photoelectric effect. In this effect electron gets ejected from the conduction band as a result of the absorption of sunlight of a certain wavelength by the matter (metallic or non-metallic solids, liquids or gases). So, in a photovoltaic cell, when sunlight hits its surface, some portion of the solar energy is absorbed in the semiconductor material. The electron from valence band jumps to the conduction band when absorbed energy is greater than the band gap energy of the semiconductor. By these hole-electrons pairs are created in the illuminated region of the semiconductor. The electrons created in the conduction band are now free to move. These free electrons are enforced to move in a particular direction by the action of electric field present in the PV cells. These electrons flowing comprise current and can be drawn for external use by connecting a metal plate on top and bottom of PV cell. This current and the voltage produces required power.

1.3 Maximum power point tracking

As an electronic system maximum power point tracker (MPPT) functions the photovoltaic (PV) modules in a way that allows the PV cells to produce all the power they are capable of. It is not a mechanical tracking system which moves physically the modules to make them point more directly at the sun. Since MPPT is a fully electronic system, it varies the module's operating point so that the modules will be able to deliver [5] maximum available power. As the outputs of PV system are dependent on the temperature, irradiation, and the load characteristics MPPT alone cannot deliver the output voltage perfectly. For this reason MPPT is required to be implementing in the PV system to maximize the PV array output power. Maximum power point tracker (or MPPT) is a high efficiency DC to DC converter that presents an optimal electrical load to a solar panel or array and produces a voltage suitable for the load. PV cells have a single operating point where the values of the current (I) and Voltage (V) of the cell result in a maximum power output. These values correspond to a particular load Resistance which is equal to V/I as specified by Ohm's Law. A PV cell has an exponential relationship between current and voltage, where as the resistance is equal to the negative of the differential resistance ($V/I = -dV/dI$). Maximum power point trackers utilize some type of control circuit or logic to search for this point and thus to allow the converter circuit to extract the maximum power available from a cell. In the power versus voltage curve of a PV module there exists a single maxima of power, i.e. there exists a peak power corresponding to a particular voltage and current.

1.4 Necessity of Maximum Power Point

The efficiency of the solar PV module is low. Since the module efficiency is low it is desirable to operate the module at the peak power point so that the maximum power can be delivered to the load under varying temperature and irradiation conditions. This maximized power helps to improve the use of the solar PV module. In typical PV systems, not all the arrays are exposed to same light irradiance, this partially shaded condition can occur due to existence of trees or clouds. Under partially shaded conditions, the entire array does not receive uniform insulation, the P-V characteristics get more complex, displaying several local maximum power points, but one of them is the global MPP. Finding the global MPP is not a trivial task when the PV array is partially shaded [4], due to the existence of multiple local maximum points. The conventional algorithm would trap in one of these local maxima. Thus, there is a need to develop special maximum power point tracking (MPPT) schemes that can track the global point under these conditions. In this paper, particle swarm optimization (PSO) technique is utilized to search for the global MPP under partially shaded conditions. So the fundamental aim of this part of the paper is to increase the efficiency. There are several methods available, by which we can improve the efficiency by matching the source and load properly. The Maximum Power Point Tracking (MPPT) is one such method, which has a huge importance in the era of Photovoltaic Technology. Now-a-days this technique is vastly used to develop maximum possible power from a varying source under a variable temperature and irradiance conditions. We know, the Maximum Power Transfer Theorem tells that the output power of a circuit is maximum, when the Thevenin's impedance of a circuit i.e. the source impedance matches with the load impedance and complex conjugate to it. So, MPPT problem is one kind of impedance matching problem. Solar cells have a very complex relationship between solar irradiation, temperature and the total resistance that develops a non-linear output efficiency which can be analyzed based on the I-V curve. So the main function of MPPT is to sample the output of the cells and apply the proper load to obtain the maximum power for any given location, time, season and environmental conditions. The MPPT not only enables an increase in the power deliver from the PV module to the load but also enhances the operating lifetime of the PV system. Various types of MPPT methods can be differentiated based on various features including the types of sensors required, convergence speed, cost, range of effectiveness etc.

2. OPTIMIZATION

Optimization forms an important part of our day-to-day life. Many scientific, social, economic and engineering problems have parameters that can be adjusted to produce a more desirable outcome. This thesis investigates the behaviour of best technique known as Particle Swarm Optimisation, a technique that solves problems by simulating swarm. The task of optimization is that of determining the values of a set of parameters so that some measure of optimality is satisfied, subject to certain constraints. It can be used to solve a wide array of different optimization problems.

2.1 PSO Algorithm

The Particle Swarm Optimization (PSO) is a population based optimization method. It is one of the most popular nature-inspired optimization algorithm developed by James Kennedy and Russell Eberhart in 1995[1,2]. Many popular optimization algorithms are deterministic, like the gradient-based algorithms. The PSO, similarly to the algorithms belonging to the Evolutionary Algorithm family, is a stochastic algorithm that does not need gradient informati -on from the function. This allows the PSO to be used on functions where the gradient is either unavailable or computationally expensive to obtain. In this paper constraints considered are temperature, irradiance, velocity, diversity factor etc. There are two types of models in PSO algorithm. One is the G best model and other is the L best model. G best model offers a faster rate of convergence [3] at the expense of robustness. This model maintains only a single "best solution," called the global best particle, across all the particles in the swarm. The L best model tries to prevent premature convergence by maintaining multiple attractors. A subset of particles is defined for each particle from which the local best particle is then selected. The primary objectives of this PSO is as follows:

• To develop a theoretical model for the convergence behaviour of the Particle Swarm Optimization algorithm.

• To extend the PSO algorithm so that it becomes a global optimization technique with guarantee convergence on global optima.

The origins of the PSO are best described as sociologically inspired, since the original algorithm was based on the sociological behaviour associated with bird flocking. The algorithm maintains a population of particles, where each particle represents a potential solution to an optimization problem.PSO consists of a swarm of bird-like particles

• Each particle resides at a position in the search space

• The fitness of each particle represents the quality of its position

• The particles move over the search space with a certain velocity

• The velocity (both direction and speed) of each particle is influenced by its own best position found so far, *p* best the best solution that was found so far by its social neighbors, *l* best, and/or the global best so far *g* best

• "Eventually" the swarm will converge to optimal positions

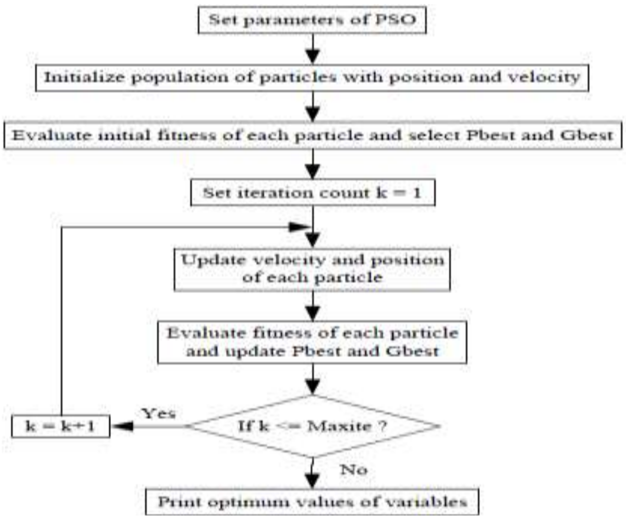

Chart-1: Flow chart of PSO algorithm

3. DC-DC CONVERTERS

The DC-DC converter used to supply a regulated DC output with the given DC input. These converters can be used as switching mode regulators to convert an unregulated dc voltage to a regulated dc output voltage. The regulation is normally achieved by PWM at a fixed frequency and the switching device is generally BJT, MOSFET or IGBT. These are widely used as an interface between the photovoltaic panel and the load in photovoltaic generating systems. The load must be adjusted to match the current and voltage of the solar panel so as to deliver maximum power. DC/DC converters are described as power electronic switching circuits since they convert one form of voltage to other. These are applicable for conversion of different voltage levels. In this paper, the photovoltaic system with DC-DC boost converter [7] and maximum power point controller has been designed and constant voltage is maintained at the output side of the converter. For the specified input variation, a regulated dc output voltage has been obtained resulting in a better efficiency. From the modelling of boost converter, it was also observed that the output voltage of the boost converter increases along with the increase in duty cycle.

3.1 Operation of Boost converter

When the switch S1 is turned on by the pulse of PWM, current flows through the inductor (L) and energy is stored in it. When switch is turned off, energy stored in the inductor in the form of magnetic field provides an induced voltage across the inductor that adds to the input voltage. The input voltage and voltage across the inductor are in series and collectively charge the output capacitor (Cout) to a voltage higher than input voltage [8].The figure (4.1) below shows a step up or PWM boost converter. It consists of a dc input voltage source Vg, boost inductor L, controlled switch S, diode D, filter capacitor C, and the load resistance R. When the switch S is in the on state, the current in the boost inductor increases linearly and the diode D is off at that time. When the switch S is turned off, the energy stored in the inductor is released through the diode to the output RC circuit.

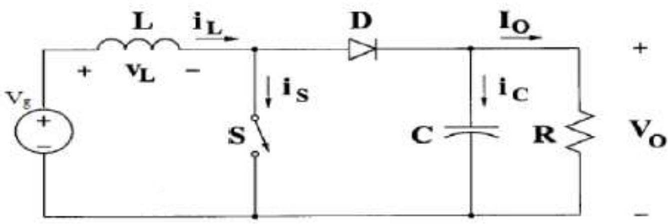

Figure-1: Circuit diagram of Boost converter

3.2 Steady state analysis of boost converter

(a) OFF STATE:

In the OFF state, the circuit becomes as shown in the Figure (2) below [9].

When the switch is off, the sum total of inductor voltage and input voltage appear as the load voltage.

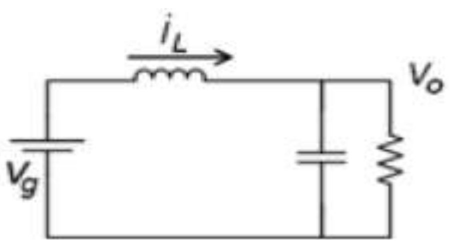

Figure-2: Off state diagram of Boost converter

(b) ON STATE:

In the ON state, the circuit diagram is as shown below in Figure (3)

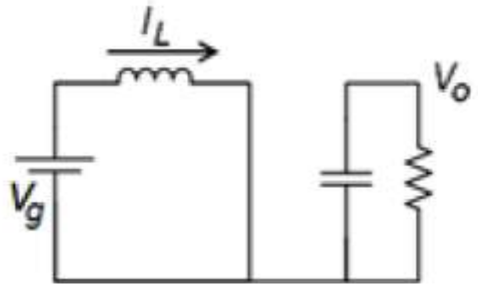

Figure-3: On state diagram of Boost converter

When the switch is ON, the inductor is charged from the input voltage source Vg and the capacitor discharges across the load. The duty cycle, D=25 where T=0.1s

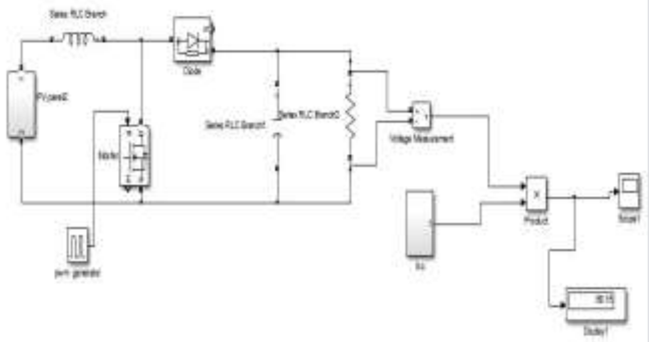

Fig-4: Output power of boost converter in simulink

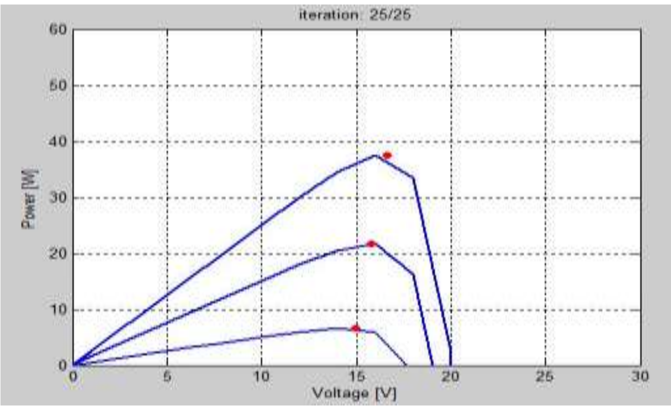

Fig-5: PV curves for maximum power

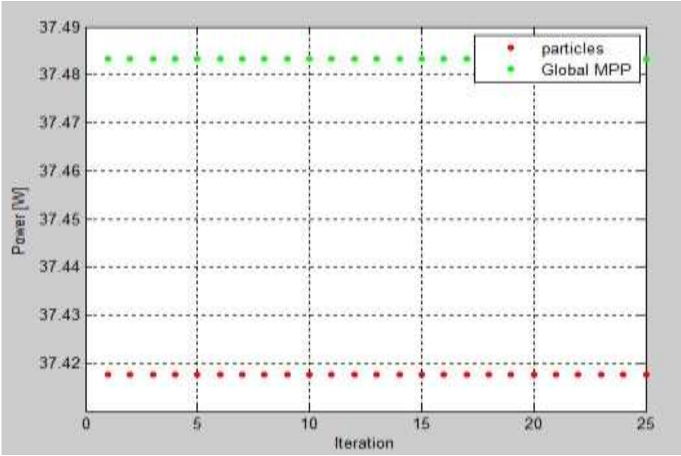

Fig-6: Global and optimized power

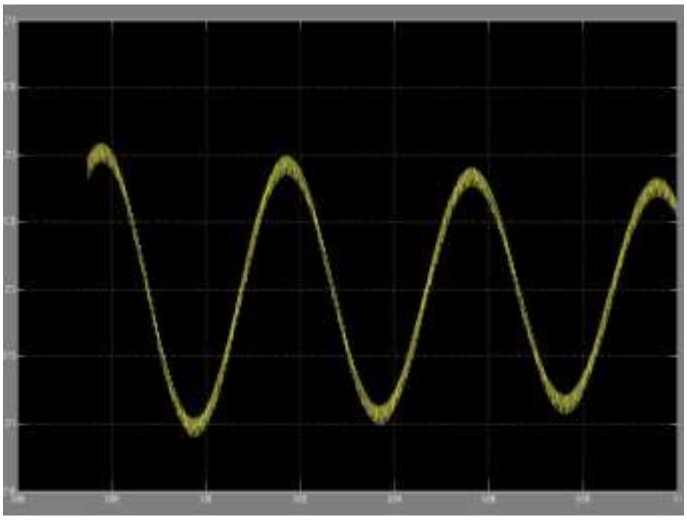

Fig-7: Output voltage in simulation

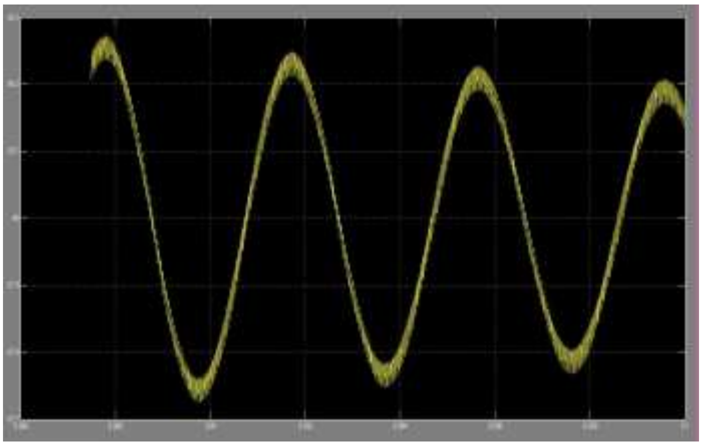

Fig-8: Output power in Boost converter

3. CONCLUSIONS

In this paper an approach to achieve maximum power point tracking of the power obtained from PV panel by using a particle swarm optimization algorithm technique with some constraints is discussed. This Particle Swarm Optimization is one of the best algorithms in the point of guarantee convergence. It converges to a local maxima or minima depending up on the objective function we implement. In this paper, the concepts of particle swarm optimization have been discussed on finding the maximum power point. Further, its algorithm has been developed.

In this paper by using a DC-DC boost converter one can observe, the boosted voltage as well as required output power. In this paper PV panel is the voltage source to boost converter and its pulses are given by pulse generator which reduces complexity and improves efficiency of the circuit as there is increase in green house effect today this paper gives best power output followed by PSO to track maximum power from solar panel without pollution and green house emission.

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