Maximum Power Point Technique (MPPT) for PV System Based on Improved Pert and Observe (P&O) Method with PI Controller

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Abstract - *Photovoltaic power generation system has key rule in electricity production. Although, it is clean renewable energy with unlimited resources but it has some drawbacks in efficiency. In order to maximize the efficiency, PV array must drive at maximum power point. For the reason so, several algorithms are used in PV system to track MPP and reduce the operational losses. The pert and observe P&O algorithm is most commonly used because of its simplicity and low cost. Though it is easy to install, but it has ripple drawback when it reaches to MPP. In this paper improved pert and observe P&O MPPT control technique is introduced by the addition of PI controller to the algorithm. In this method ripple around maximum power point are removed under stable external environment and unstable condition. At the end simulation is performed. Simulation results shows that the improved method MPP tacking effect is improved and the efficiency is also slightly increased.*

***Key Words*: Photovoltaic system, MPPT techniques, MATLAB, Renewable energy, Boost converter**

1. INTRODUCTION

Because of the limited conventional fossil resources for production of electrical energy and growing global population the demand of electricity is increasing accordingly. To meeting the rise in electricity demand, the power production companies are looking for unconventional resources. In the world today, renewable energy is the only replacement, not only to fulfil power requirement, but also can reduced the carbon substances in the air. Solar power generation effect can be considered the highest suitable among the renewable energy resources, because of the cleanest, unlimited amount, and sustainability of solar energy [1].

The basic operation of photovoltaic power system is the direct conversion of sun light into electrical energy by means of semiconductor devices [2]. The productivity of PV array depends on the external environment temperature, solar irradiance, and output voltage of PV unit [3].Because of nonlinear characteristics of PV array, it is important to use power electronics devices along with MPP (maximum power point) control algorithm to maximize the efficiency of photovoltaic array. To achieve maximum power output from a PV array can be done by MPPT (maximum power point technique) controller [4] [5]. A PV array produces lesser power, so the duty of a MPPT in a PV power transformation system is to constantly adjust the system so that it can get full power from the PV array under different weather and load conditions [6]. Numerous MPPT control techniques are established to track the MPP (maximum power point) efficiently. Most of the conventional MPPT techniques has drawback of being slow tracking MPP, the reason so, the efficiency of PV system is reduced. In literature [7] [8] [9] they are largely classified into two kinds, specifically the soft computing and conventional approach. Most often use conventional MPPT are the IC (incremental conductance) [10], P&O (perturbation and observation and hill climbing method [11]. These MPPT control algorithms are commonly used because of their simplicity and strength. Moreover, soft computing MPPT techniques such as fuzzy logic [12], artificial neural network , differential evolution and particle swarm optimization [13] are more flexible and adaptable. These MPPT has improved steady state performance, but these are significantly slow and costly. In the traditional MPPT, P&O is the simple and demonstrates very good. However, this technique suffers from two sober weaknesses. One big problem is the nonstop oscillation that appears across the MPP. Second is slow tracking when whether change rapidly [14]. In addition, Because of the closed loop tracking of sun light, the output of the MPPT controller contains harmonics, which can be minimized by using filter circuit. Due to the small output voltage of PV array, a non-isolated DC-DC converter is used for providing maximum power to the load. A DC to DC converter work as an interface between the load and PV array. The most commonly boost converter is use in PV system as main circuit due to its advantages [15].

2. PHOTOVOLTAIC SYSTEM

Basically, a photovoltaic power generation system is solid state semiconductor device, when it is visible to the sun light it produces electrical energy. Combination of many solar cells in different connection is basically called photovoltaic panel. A photovoltaic module is made by linking several solar cells together in parallel and series. To achieving maximum output current, PV cells are coupled in parallel and for getting maximum output voltage PV cells are connected in series [16].

Photovoltaic power generation system consists on several components such as photovoltaic array, DC-DC converter, MPPT control unit, battery storage and inverter etc. which are shown in figure 1.

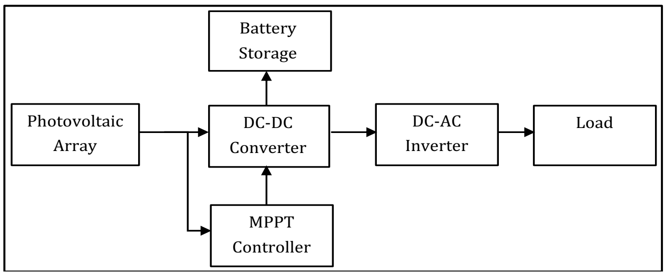

Fig -1: Basic structure diagram of PV system

When PV array generates electricity, the duty of MPPT controller is to calculate the reference voltage and find the MPP (maximum power point). DC-DC converter basically perform work as mediator, which transfer voltage from PV to the load [17]. Battery storage is providing electricity to the output load during at night time or rainy weather when light intensity is entirely low. This only compatible with standard alone PV system. While the inverter circuit is uses to feed AC output voltage [18].

Photovoltaic generation systems are generally categorized on the basis of their functionality and operating systems, element alignments, and the electrical load. Such as standalone and grid connected structures which are proposed to provides power to the load and energy storage systems. The standalone system is proposed to work individually of the utility grid and supply to certain load. On the other hand, grid connected PV system is proposed to work in parallel connection and connected with the electrical grid system. The mostly consist on DC-AC inverter which convert DC output of the PV array [19]. Beside this PV system has one more type called hybrid system, which mostly combined with wind turbine or diesel generator.

2. MODELING AND SIMULATION OF PV SYSTEM

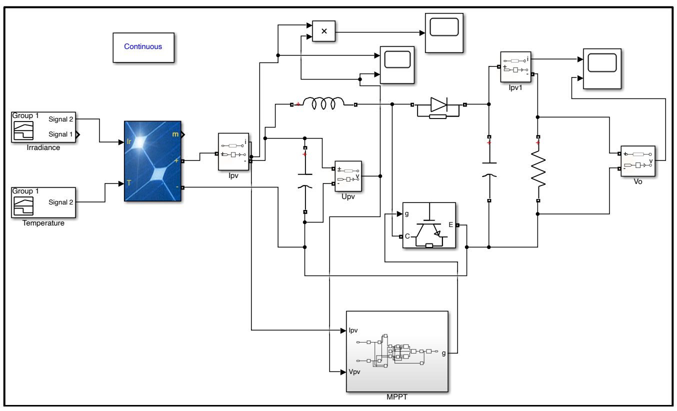

Fig -2: simulation model of PV system

2.1 PV Cell

The voltage of photovoltaic cell is about 0.4V to 0.5V and the working current is about 25mA/cm[2]. For the reason so, these cells are combined together that meet needs of output load. As the sun light strokes on PV cells, it acts like a forward diode on a big surface [20].

Equivalent circuit of Photovoltaic cell is given in figure 3, where; I=output current; V=output voltage, I_{ph}=optical current and I_{sh}=leakage current of the photovoltaic cell.

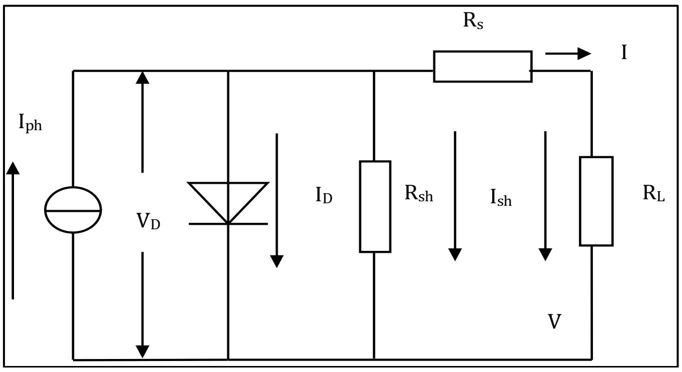

Fig -3: Equivalent circuit for photovoltaic cells

Current producing in cell during light hitting:

$$I=I_{ph} - I_o \left\{\exp\left[\frac{q(V+IR_s)}{AkT}\right] - 1\right\} - \frac{V+IR_s}{R_{sh}} \quad (1)$$

Where; k=Boltzmann's constant, T=temperature, R_{sh}=parallel equivalent resistance and R_s=series equivalent resistance.

Simulation model of the photovoltaic array, output power characteristic curves and parameters table are given as follow. One parallel and two series connected array module is used in the simulation.

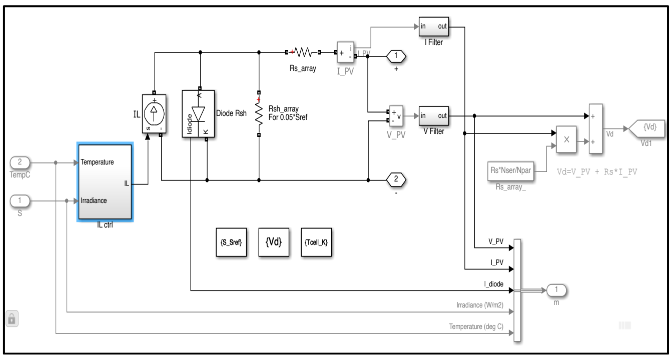

Fig -4: simulation model of PV cell

Table -1: Detailed electrical parameters for Trina solar TSM-185DA01A.08

Parameters	Values
Maximum output power (P_m)	185.554 W
Current at MPP (I_{mp})	5.14A
Cells per module (Ncell)	72
Open circuit voltage (V_{oc})	44.65V
Voltage at MPP (V_{mp})	36.1V
Short-circuit current (I_{sc})	5.48A

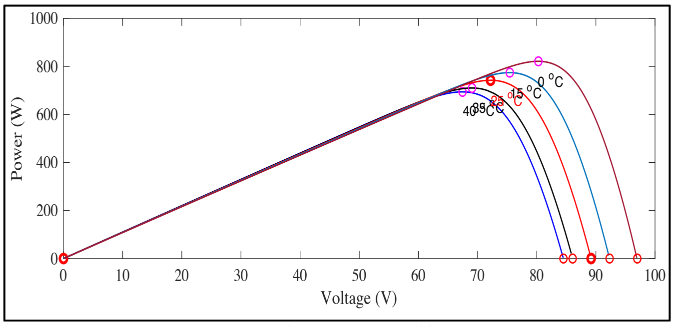

Fig -5: P-V curve of array at different temperature (irradiance G = 1000W / m²)

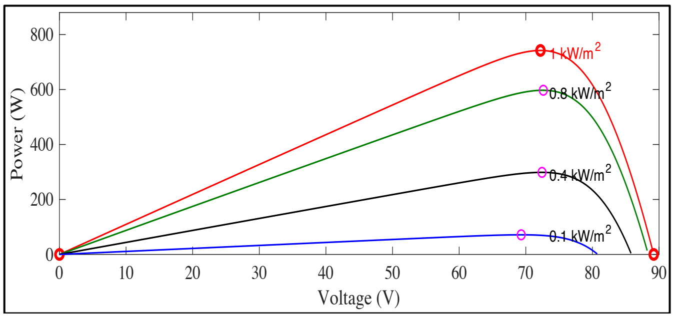

Fig -6: P-V curve of array when irradiance change and (temperature T=25°C)

2.2 DC-DC Boost Converter

According to working operation if S is a switching module MOSFET, D is duty cycle which means comparative conduction time and if ($T = t_{on} + t_{off}$). the D is given by Equation (2):

$$D = \frac{T_{on}}{T_{on} + T_{off}} = \frac{T_{on}}{T} \quad (2)$$

When the switch S is on source release energy to inductor, during that time inductor stores some energy by producing magnetic field [18] [21]. When switch is in off condition that time current drain to the load. But if the impedance is higher the current will be small. Simulink model of the boost circuit is given in figure 7. Boost converter is used as main circuit of the system. The parameters of boost circuit are set as follow; V= 90V, L= 0.00015 H, C= 0.0009F, D=50%, R=50ohms and F=20khz.

S

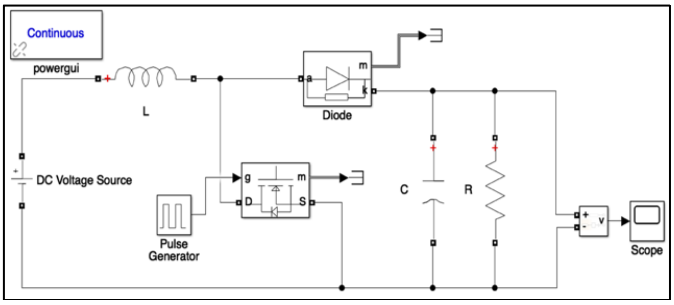

Fig -7: MATLAB Simulink model of Boost converter

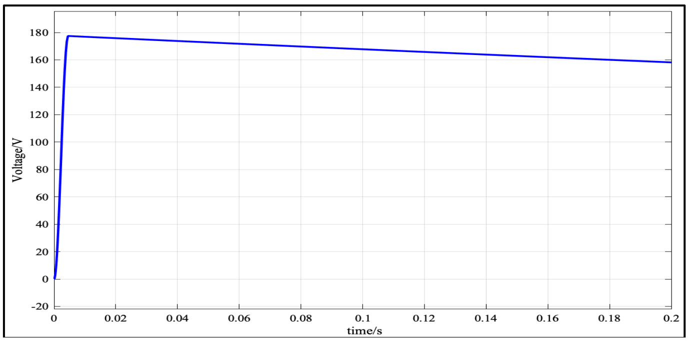

Fig -8: Boost circuit output voltage curve

3. MPPT CONTROLLER BASED ON PERT AND OBSERVE (P&O)

3.2 Conventional Pert and Observe P&O

P&O algorithm is used most commonly as MPPT controller in PV system because of its simplicity and applicability. it works based on the perturbation and observation of the solar irradiance direction [22]. If the photovoltaic array power rise, the point of the operation towards MPP will go rig thus the voltage works in the same direction. when the power from PV cell reduces, the working point of the field differs from the MPP, and the direction perturbation voltage has become overturned [23] [24]. Change in the power is define from the following formula [25]:

$$\Delta P = P(k) - P(k-1) \quad (3)$$

A disadvantage of traditional P&O MPPT method is the steady state oscillation in output power during tracking new MPP when weather changes and the response of the system also very slow. P&O algorithm is given in figure 9.

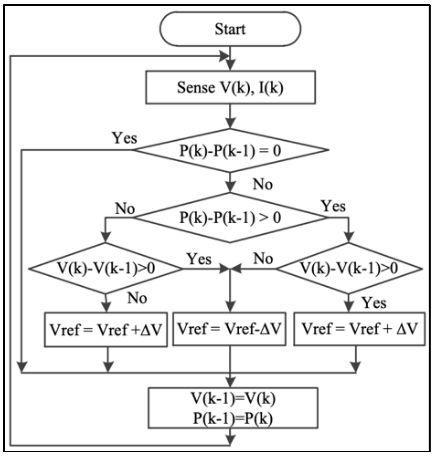

Fig -9: P&O algorithm

Simulation model of the photovoltaic system with boost converter circuit, conventional P&O simulation circuit and the result of output power characteristic curve is given below. Parameters of the circuits are explained in above detail. simulation time is set 0.2s – 0.5s.

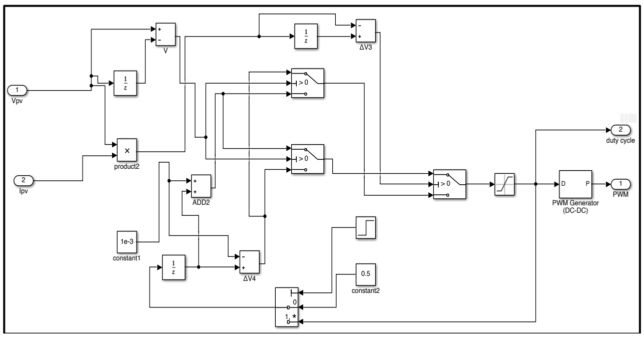

Fig -10: Simulation model of conventional P&O

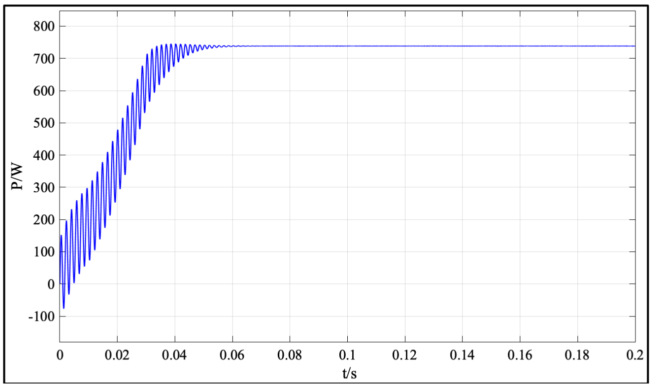

Fig -11: Output power curve

Above figure 11, is output power curve of photovoltaic system based on the conventional P&O control MPPT technique. In this case temperature is constant at 25 °C and light intensity is stable at 1000W/m².

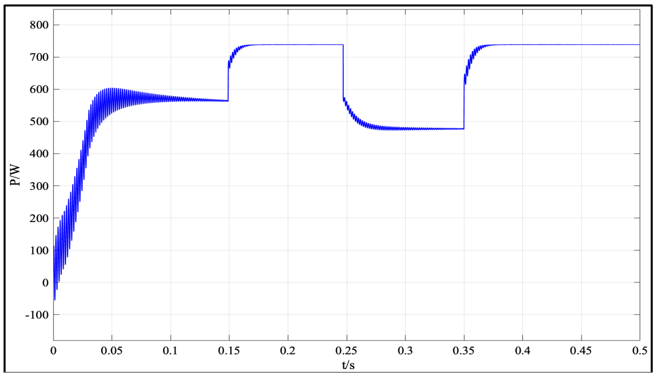

Fig -12: Output power curve when temperature is 25 °C and light intensity change.

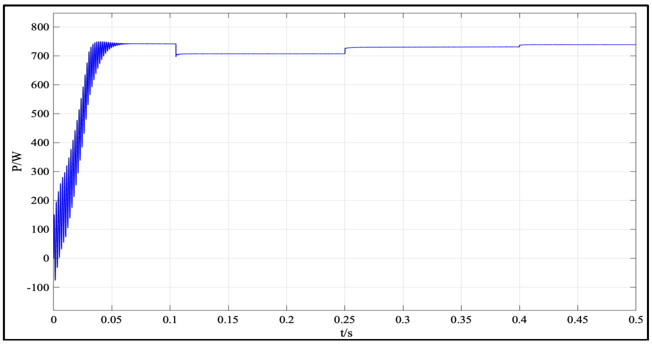

Fig -13: Output power curve when light intensity is stable 1000W/m² and temperature vary

3.3 Modified Pert and Observe P&O

The improved method is designed to prevent ripples when trying to identify the maximum power point of a traditional algorithm and to identify the point more quickly after a major power change. In this method, represents power change is:

$$\Delta P = P_{new} - P_{old} \quad (4)$$

The improved method has unique feature, which sets the array corresponding reference voltage to the module peak voltage. The PI controller then transfers the array operating point to that specific voltage level [26]. When the external environment changes and reference voltage of cell and converter is boosted or reduced according with this power change, it can be seen from the simulation results that fluctuation is reduced and next MPP is tracked sooner. During stable weather condition when no power change no iteration is executed and ripple across MPP are abolished. Simulation model of the improved technique with PI controller is shown in figure 14 below. Simulation results are given as follow.

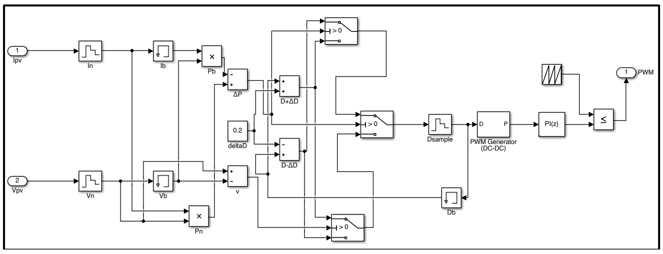

Fig -14: Simulation model of improved P&O

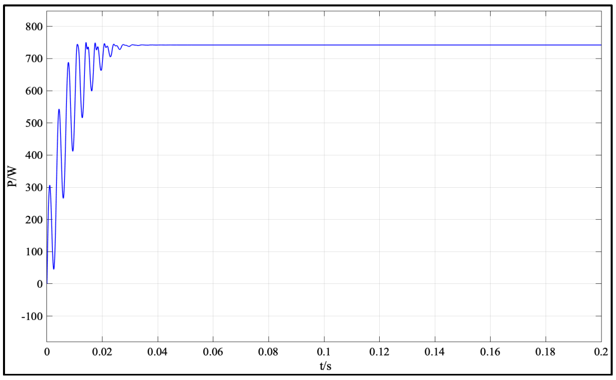

Fig -15: Output power curve (weather stable)

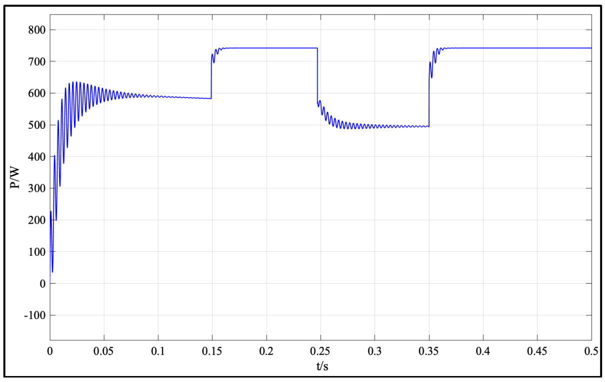

Fig -16: Output power curve when temperature is 25 °C and light intensity change.

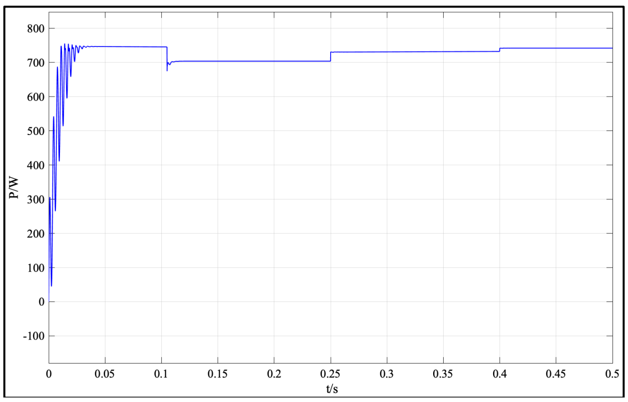

Fig -17: output power curve when light intensity remains= 1000W/m^2 and temperature vary

4. COMPARATIVE ANALYSIS OF MPPT CONTROL TECHNIQUE SIMULATION RESULTS

Through the experimental analysis it can be evaluated that the response time of the improved pert and observe P&O MPPT technique is faster than the conventional method. For better understanding comparison table is given.

Table -2: Comparison of MPPT results between traditional P&O MPPT and improved P&O MPPT

MPPT Technique	Improved P&O Method	Traditional P&O Method
Tracking Time when the Environment is Stable	0.012s	0.025s
Output Power	743 W	738.5 W
Tracking when Light Intensity Drops	0.022s	0.05s
Output Power	620.5 W	605 W
Tracking when Light Intensity Increases	0.016s	0.018s
Output Power	743 W	738.5 W

It can be seen from the simulation result during stable weather condition the improved method track MPP in 0.012s. A small fluctuation can be seen around MPP but it maintains stable power output 743W at 0.03s. On the other hand, conventional method finds MPP in 0.025s and its output fluctuate for long time, after 0.07s it gives stable output power 738.5W. Moreover, during unstable condition the improved method track new MPP extremely fast as compare to conventional method. In this condition it takes 0.001s-0.006s to give stable output. Maximum power output of the PV array is 760W, when temperature is 25 °C and light intensity is 1000W/m^2. So, the efficiency of improved method is about 97.7% and conventional method is 97.17%. The response time of improved method to finding MPP is doubled than the conventional method.

5. CONCLUSIONS

In this paper, to start with the introduction of Photovoltaic system. According to the working principle different types of PV system are analyzed. Simulation model of DC Boost circuit and PV array are studied. The model of conventional and improved method is simulated in MATLAB/Simulink. The results show that when the solar irradiance increase the output power of PV array increase. Later on, after comparison, results shown the advantages of improved method over conventional method.

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