

# A Hybrid MPPT Algorithm for Solar PV Array

H. S. Gangadharaiah, Prashant. V. Joshi

**Abstract:** Present days renewable resource is used to generate energy required for most of the applications, like solar energy is used as water heater. Lot of research work is going on to utilize the efficient energy from solar and another important area is power generation. In power generation solar energy is taking vital role. This work is done to get the maximum power from the solar energy by studying different MPPT algorithms and particularly in fractional open-circuit voltage (FOCV) and perturb and observe (P&O) algorithms are used. Both MPPT algorithms are used to get maximum power. FOCV MPPT algorithm is implemented to avoid power interruption at load and P&O is used to maintain the region of MPP. Advantages of both algorithms are achieved.

**Keywords :** FOCV, MPPT algorithm, P&O, Solar PV Power.

## I. INTRODUCTION

The energy sources like fossil fuels are used to supply the energy demand in the world, which generates carbon contents and spoil the environment which leads to Global Warming [1]. Solar system is the best available energy resource for micro grid system; it can also be used as base load point [2].

Using present technology a solar energy can be made efficient renewable energy source. The solar PV array is used to convert light energy into electrical energy. PV array consists of several solar cells in it and these cells produces energy depends on the amount of solar radiation and intrinsic properties of it [3]. Depends on the application requirement the size of the PV array is decided.

There are several MPPT techniques which operate on maximum power point available like: Perturb and Observe algorithm, Incremental Conductance algorithm, Fraction open-circuit voltage (FOCV) algorithm, Constant Voltage algorithm, etc. [4]. In this paper, FOCV and P&O algorithms are studied and implemented hybrid algorithm to get efficient power at the DC-DC boost converter.

Most of the FOCV algorithm is implemented with PI controller based regulator. P&O algorithm is also simple method. This MPPT algorithm is used to compute the PV power output and perturbation changes the PV voltage and current such that power also changes according to the observation of the power [5].

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The second section of the paper talks about the implementation of Solar PV System. At the output of the PV array DC-DC boost converter is implemented with FOCV algorithm and discussed in the third section. Fourth section is all about implementation of P&O algorithm. In fifth section proposed hybrid algorithm and its results are discussed. In the sixth section conclusions are drawn.

## II. SOLAR PV SYSTEM

MATLAB-Simulink is used to implement Solar PV array.. The PV Array model uses series resistance  $R_s$ , current source  $I_L$ , diode  $nI$  &  $I_0$  parameters, shunt resistance  $R_{sh}$  as shown Fig. 1 [6].

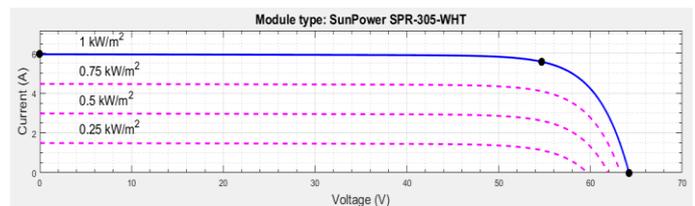
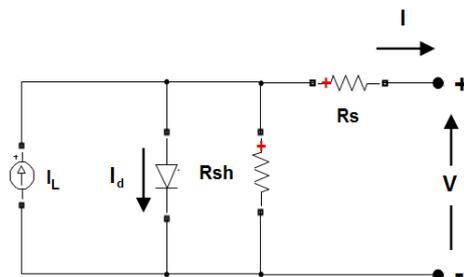


Fig. 2 I-V Characteristics of one module at 25°C

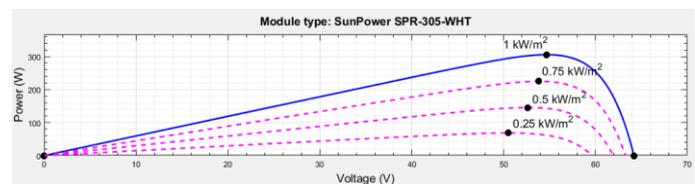


Fig. 3 P-V Characteristics of one module at 25°C

Another two important parameters in Solar PV system are temperature and irradiance. The diode current depends on the irradiance factor and the temperature at each cell or array. The I-V characteristics showed in fig. 2 is a single solar cell characteristic, a SunPower SPR-305-WHT module. The cell operated with the constant temperature at 25°C and different irradiance with different values: 250 W/m<sup>2</sup>, 500 W/m<sup>2</sup>, 750 W/m<sup>2</sup>, and 1000W/m<sup>2</sup>. The current varies with respect to



irradiance values. After 50V current starts decreasing for all different irradiance. The maximum current appears at 1000 W/m<sup>2</sup> and the current value is around 5.5A of current and 55V of voltage. At same irradiance and voltage maximum peak power is considered as shown fig. 3 around 302.5W which is a P-V characteristic. Fig. 4 shows the array of same solar cells which is a SunPower-305-WHT; 10 Series modules and 40 parallel strings. Each string gives around 550V of voltage and 5.5A of current. For 40 parallel strings total current drawn is around 220A of current and fig. 5 shows the P-V characteristics which is around 120kW of power at 550V of voltage and is a maximum peak power.

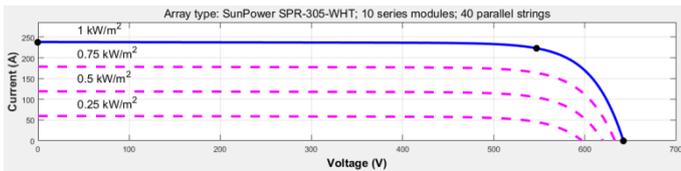


Fig. 4 I-V Characteristics of array at 25° C

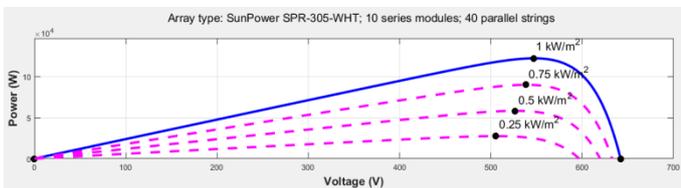


Fig. 5 P-V Characteristics of array at 25° C

The MATLAB-Simulink PV array module is used for this work, below fig. 6 shows the PV array with its input and output parameters. It consists of irradiance as an input parameter and 'm' is a vector parameters consists of PV voltage (V\_PV), PV current (I\_PV), diode current (I\_diode), and irradiance (W/m<sup>2</sup>) and another two terminals gives DC voltage.

Input parameter irradiance varies with time to analyse power variation with respect to the same, fig. 7 shows the plot of irradiance and fig. 8 shows the output parameters plot.

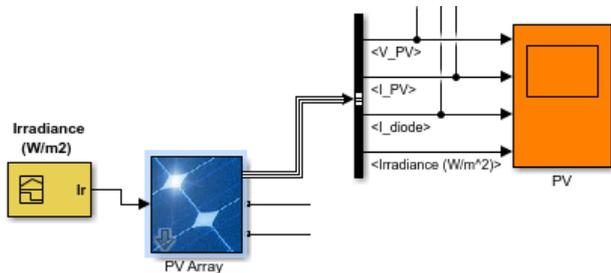


Fig. 6 PV Array with its parameters

Fig. 8 consists of 4 graphs, first graph is V\_PV plot of 500V initially it goes more than 500V and after 0.20 second which is a switching time it remains constant. The second graph is I\_diode after switching ON it becomes 0A. The third graph is I\_PV is of 230A after switching time and varies with irradiance reference plot is shown in fourth graph.

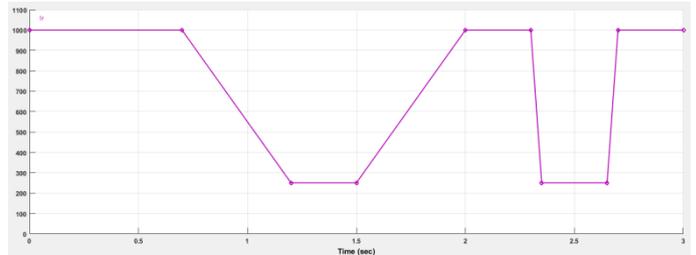


Fig. 7 Variation of Irradiance with time

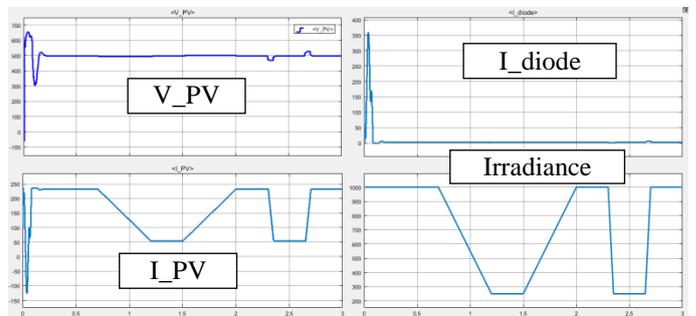


Fig. 8 Output parameters (V\_PV, I\_diode, I\_PV, and Irradiance)

### III. FOCV ALGORITHM

Fractional open-circuit voltage algorithm is based on V\_PV (the maximum voltage at the output of the PV array) which is said as maximum power point voltage and mentioned as V<sub>mpp</sub>. This algorithm works on the base of relation between V<sub>mpp</sub> and V<sub>OC</sub> [7]. The maximum peak power is a constant voltage of open-circuit voltage it is given by Eq. (1)

$$V_{mpp} = k_v \cdot V_{OC} \quad (1)$$

where k<sub>v</sub> is a constant which is between 0.7 and 0.8 depending on the PV cell characteristic measured based on maximum power point voltage and open-circuit voltage.

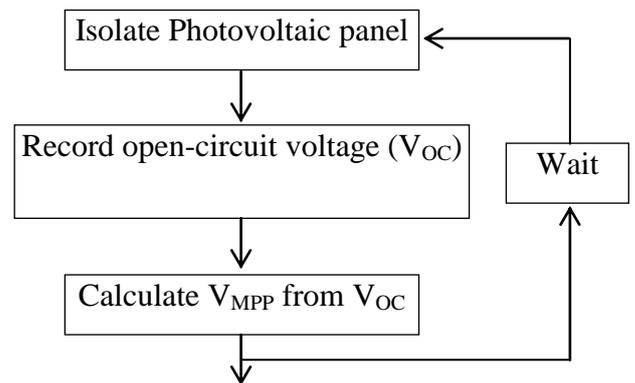


Fig. 9 Flowchart of open-circuit voltage method [7]

The fig. 9 shows the flow chart of the algorithm [8]. The voltage generated by the diode in the cell is approximately 75% of the open-circuit voltage. Once the maximum power point is approximated, closed loop control in the PV array boost converter is used to get the desired output voltage at the PV array [9]. The open-circuit voltage taken from the PV array output, and is measured without connecting it to the load. The maximum power point voltage is approximated by



taking the reference voltage in the algorithm. This algorithm is simple to implement and fig. 10 (a) shows the MATLAB-Simulink implementation.

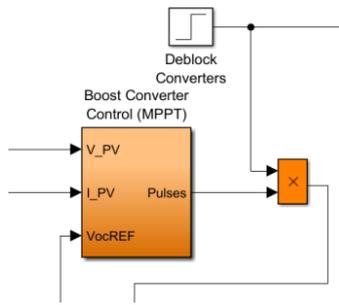


Fig. 10 (a) Boost Converter Control (MPPT)

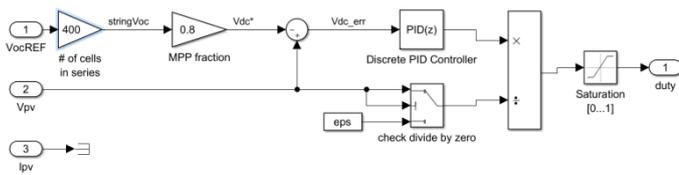


Fig. 10 (b) Internal FOCV Algorithm implementation

Fig. 10 (b) shows the algorithm implementation using MATLAB-Simulink. An open-circuit voltage is taken from the PV array and approximation is done considering the total number of cells in an array. The approximated voltage is then multiplied with constant  $k_v$  term and the difference output is given to PID controller to regulate the voltage.

#### IV. P&O ALGORITHM

P&O algorithm finds PV array voltage and current. It calculates power. Then the voltage is decreased or increased depending on the tracing of maximum power for PV array voltage. If the power and voltage are greater than zero then increases the reference voltage ( $V_{ref}$ ). If the power is greater and voltage is less than zero then voltage decreases. The algorithm follows the same technique till it gets maximum power by observing step by step and makes the changes by increasing or decreasing voltage.

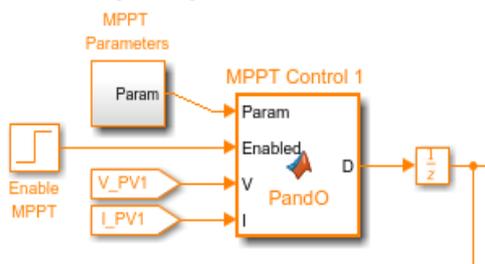


Fig. 11 MATLAB Simulink model for P&O MPPT

Fig. 11 shows the MATLAB Simulink model inline with PV array as shown in fig. 6. Fig. 12 shows the flowchart for P&O algorithm [5].

#### V. COMPARISON OF DIFFERENT PID CONTROLLER BASED REGULATOR

The discrete PID controller is utilized to direct the voltage. The PID controller is a MATLAB-Simulink block, its increases are tunable either by manual process or automation.

The PID Controller square yield is a weighted total of the i/p signal, the basic of the i/p signal, and the subsidiary of the i/p signal. The loads are the relative, essential, and subordinate addition parameters. All the diverse controller types are executed and watched the yield control in the wake of reversing the PV cluster's DC voltage.

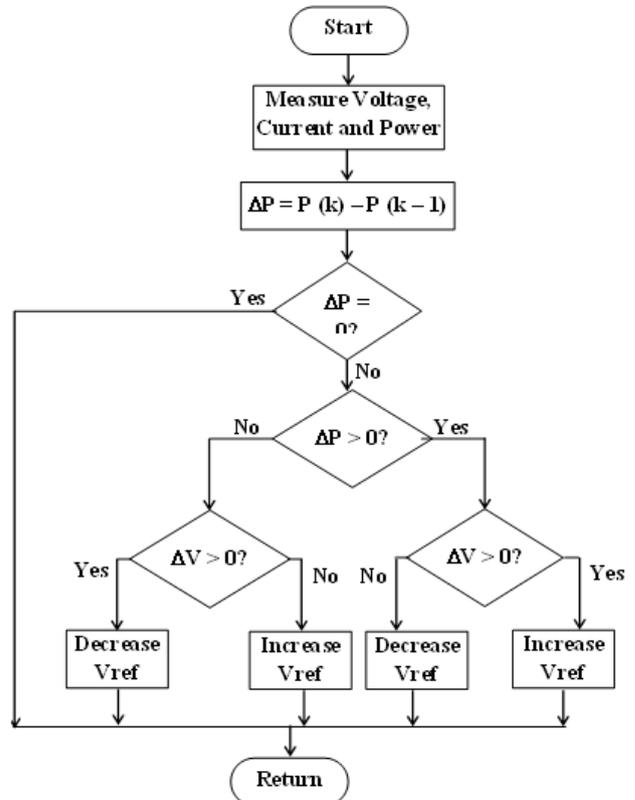


Fig. 11 Flow chart for Perturb and Observe Algorithm

Table 1. Comparison output power for different controller

Controller	AC Voltage (V)	Input Power (kW)	Output Power (kW)
PID	340	120	118
PI	340	120	117.7
PD	338.5	120	62.45

#### VI. SIMULATION RESULTS

The FOCV algorithm is implemented and only the part of the algorithm which is a regulator is concentrated to get maximum power at the output of the solar system. The regulator plays an important role to get the maximum power. To get the maximum power different PID controller based regulator is implemented in MATLAB-Simulink and simulated results are discussed with different PID controllers.



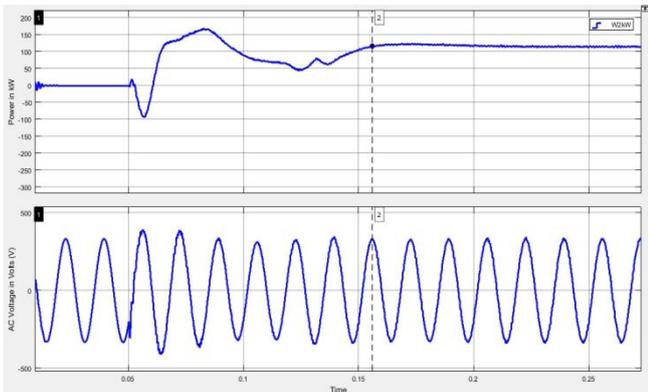


Fig. 11 (a) Output power and AC Voltage for PID Controller

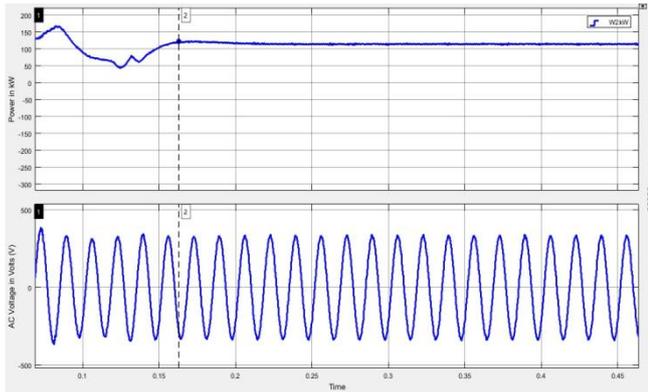


Fig. 11 (b) Output power and AC Voltage for PI Controller

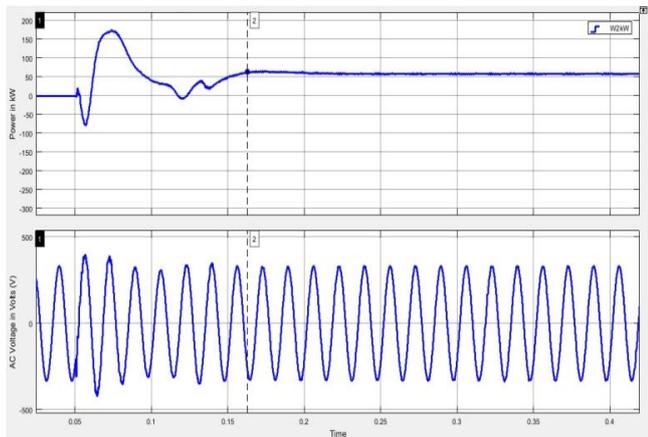


Fig. 11 (c) Output power and AC Voltage for PD Controller

Fig. 11 shows the output power and AC voltage at the output of the inverter with different PID controller. Fig. 11 (a) shows the output power and AC voltage for PID controller, fig. 11 (b) for PI controller and fig. 11 (c) for PD controller. The settling time achieved (simulation) for this FOCV algorithm is around 160ms. During this settling time power fluctuations are observed. After settling time, the output power becomes constant and varies with respect to the current as current depends on the irradiance of the solar cells.

The three phase AC voltage and current appears as shown in fig. 12 for different PID controller. Fig. 12 (a) is showing the three phase AC voltage and Current for PID controller, fig. 12 (b) for PI controller, and fig. 12 (c) for PD controller. The entire FOCV algorithm is implemented with PI controller regulator.

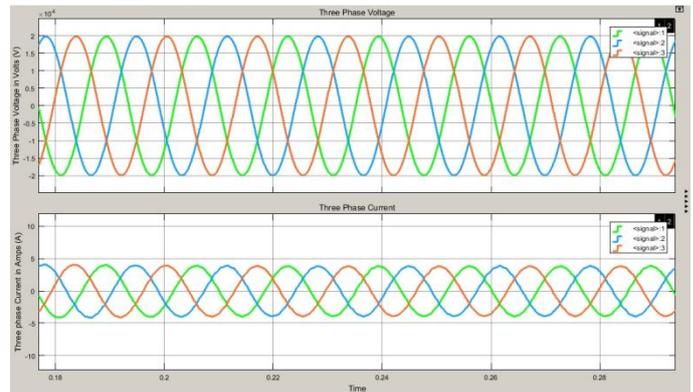


Fig. 12 (a) Three phase Voltage and Current for PID

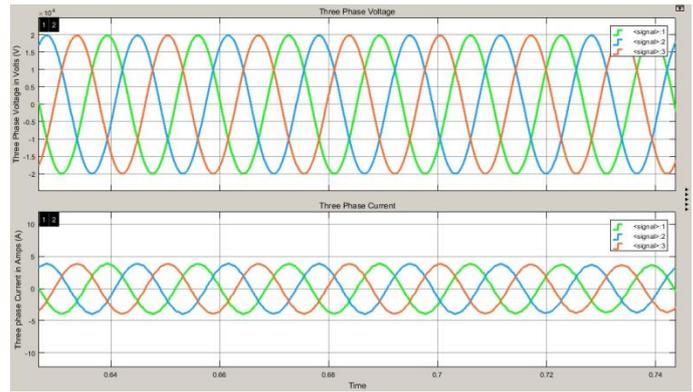


Fig. 12 (b) Three phase Voltage and Current for PI

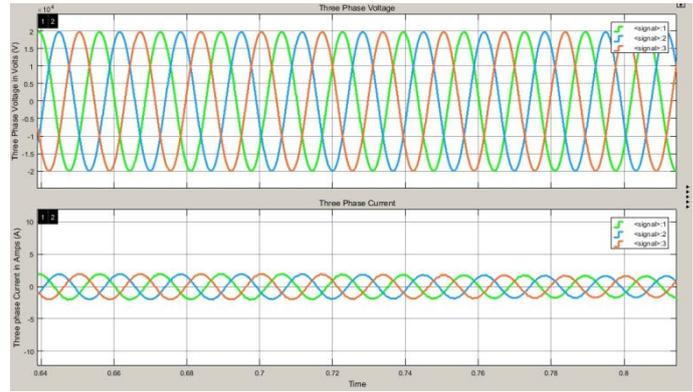


Fig. 12 (c) Three phase Voltage and Current for PD

Three phase voltage and current is measured at the output of the three-phase transformer which is used to step up the voltage and given to the power-grid. The transformer parameter is as follows: three-phase 200kVA/230V/20kV. The out of the DC-DC boost converter is given to the inverter with gate controller and output of the inverter given to the three-phase transformer. The output power is measured at the output of the three-phase transformer and shown in fig. 12. The current in PD controller decreases due to the derivative term.

## VII. CONCLUSIONS

The Solar PV array is implemented using FOCV algorithm to generate the power of 120kW. The complete power grid is implemented in MATLAB-Simulink to get the maximum power by using different PID controller based regulator in FOCV



type MPPT algorithm. The maximum power observed with different PID controller in FOCV algorithm. By comparing all the three different controllers, PID is the best controller which gives better output power compared with PI controller. Around 300W of power is improved by using PID controller which gives 98.33% of efficiency compared with PI controller which gives 98.08% efficiency whereas PD controller which gives 52% of efficiency and is not at all a feasible controller to be used in this algorithm.



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