Simulation and Analysis of MPPT Techniques for PV Systems

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Abstract— The power available at the output of solar arrays keeps changing with solar insolation and ambient temperature. The solar arrays must be operated at maximum power point (MPP) continuously for economic reasons. So, that the different MPPT (maximum power point tracking) Controllers are using for track the maximum power point. Also that these control techniques vary in many aspects as simplicity, sensor required, convergence speed, range of effectiveness, popularity, cost and other aspects. This poster presentation in details comparative study between two MPPT controls techniques are Perturb and Observe (P&O) and Fuzzy Logic Controller (FLC). Two different converter are using for comparative in this study. Few comparisons such as efficiency, voltage, current, and power output for each different combination has been displayed. Multi changes in irradiance, temperature by keeping voltage and current as main sensed parameter been done in the simulation Matlab simulink tools have been used for performance evaluation on energy point. Simulation will consider different solar irradiance and temperature variations.

Keywords: Solar energy, Photovoltaic, Maximum power point tracking, DC-DC Converters

I. INTRODUCTION

The solar cell is converting solar energy into electrical energy, but that output electrical energy has very low efficiency. So that MPPT controllers are using to improve the output electrical energy and efficiency, also a MPPT is used exacting the maximum power from the PV module and transferring that power to the load. A dc/dc converters (step up / step down) serve the purpose of transferring maximum power from the solar PV module to the load. A buck and boost converters are using to purpose of step-down and step-up of voltage with respectively, and comparative this analysis results. P&O and FLC are using both methods to track the maximum power point. By changing the duty cycle the load impedance as seen by the source is varied and matched at the point of the peak power with the source so as to transfer the maximum power.

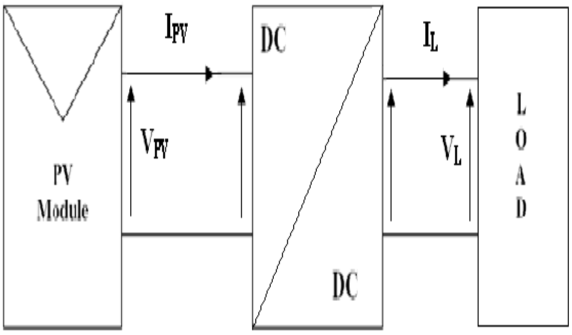

Fig. 1: Block Diagram of Typical MPPT System

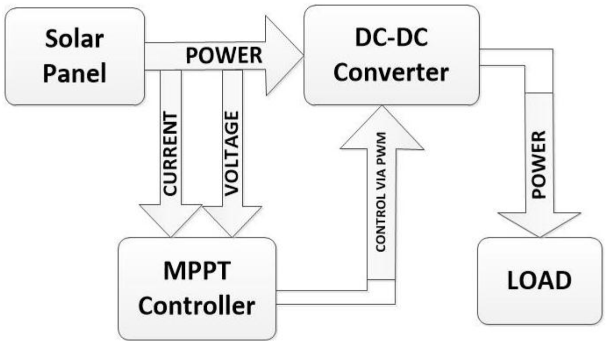

Fig. 2: Block Diagram of DC-DC Converter Incorporating MPPT

II. PV ARRAY

A solar panel cell basically is a p-n semiconductor junction. When exposed to the light, a DC current is generated. The generated current varies linearly with the solar irradiance. The equivalent electrical circuit of an ideal solar cell can be treated as a current source parallel with a diode shown in figure.

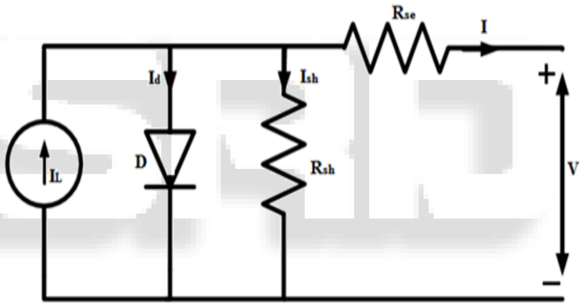

Fig. 3: Equivalent Electrical Circuit of a Solar Cell

The I-V characteristics of the equivalent solar cell circuit can be determined by following equations. The solar cell output current:

$$\mathrm{I} = I_L - I_0\left[\exp\left(\frac{q(V + IR_{se})}{KT}\right) - 1\right] - \frac{(V + IR_{se})}{R_{sh}}$$

Where:

- I: Solar cell current (A)
- Id: Diode saturation current (A)
- q: Electron charge (1.6×10-19 C)
- K: Boltzmann constant (1.38×10-23 J/K)
- T: Cell temperature in Kelvin (K)
- V: solar cell output voltage (V)
- Rse: Solar cell series resistance (Ω)
- Rsh: Solar cell shunt resistance (Ω)

III. DC-DC CONVERTER

A. *BUCK Converter:*

The buck converter is working as like step-down converter and its dc input voltage (Vi) is greater than output voltage (Vo), Vi>Vo.

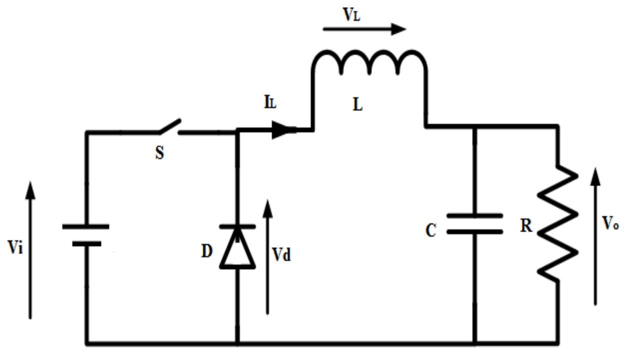

Fig. 4: Ideal Buck Converter Circuit

B. BOOST Converter:

The boost converter is working as like step up converter and its dc input voltage (Vi) is less than output voltage (Vo), Vi<Vo.

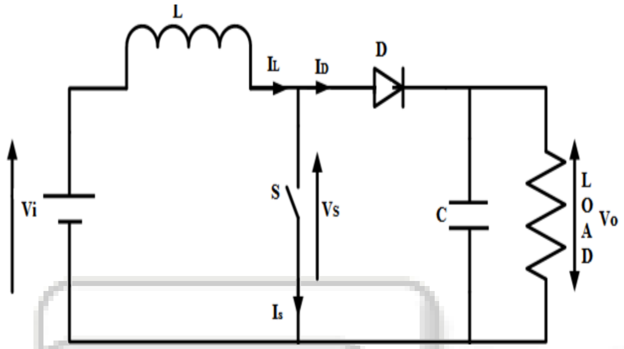

Fig. 5: Equivalent Circuit of a Boost Converter

IV. PROBLEM OVERVIEW

The problem considered by MPPT techniques is to automatically find the voltage VMPP or current IMPP at which a PV array should operate to obtain the maximum power output PMPP under a given temperature and irradiance. It is noted that under partial shading conditions, in some cases it is possible to have multiple local maxima, but overall there is still only one true MPP. Most techniques respond to changes in both irradiance and temperature, but some are specifically more useful if temperature is approximately constant. Most techniques would automatically respond to changes in the array due to aging, though some are open-loop and would require periodic fine tuning. In our context, the array will typically be connected to a power converter that can vary the current coming from the PV array.

V. MPPT CONTROL ALGHORITHM

A. Perturb and Observe (P&O):

In this algorithm a slight perturbation is introduce system. This perturbation causes the power of the solar module changes. If the power increases due to the perturbation then the perturbation is continued in that direction. After the peak power is reached the power at the next instant decreases and hence after that the perturbation reverses. When the steady state is reached the algorithm oscillates around the peak point. In order to keep the power variation small the perturbation size is kept very small. The algorithm is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module. A PI controller then acts moving the operating point of the module to that particular voltage level. It is observed that there some power loss due to this perturbation also the fails to track the power under fast varying atmospheric conditions. But still this algorithm is very popular and simple.

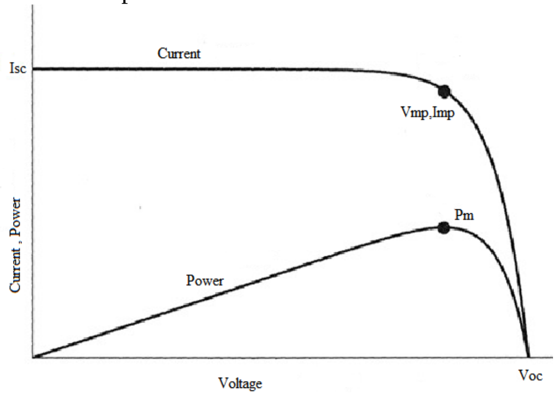

Fig. 6: Characteristic Curve of Solar Photovoltaic MPPT System

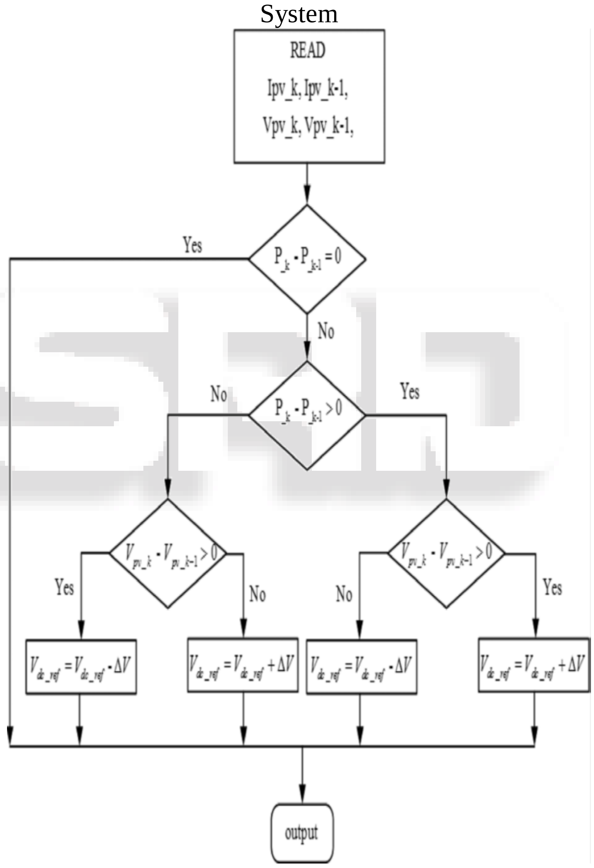

Fig 7: Flow Chart of Perturb and Observe

B. Fuzzy Logic:

The use of fuzzy logic control has become popular over the last decade because it can deal with imprecise inputs, does not need an accurate mathematical model and can handle nonlinearity. Microcontrollers have also helped in the popularization of fuzzy logic control. The fuzzy logic consists of three stages: fuzzification, inference system and defuzzification. Fuzzification comprises the process of transforming numerical crisp inputs into linguistic variables based on the degree of membership to certain sets. Membership functions, like the ones in Figure, are using to associate a grade to each linguistic term. The number of membership functions used depends on the accuracy of the controller, but it usually varies between five and seven.

Shown in table, seven fuzzy levels are using: NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM (Positive Medium) and PB (Positive Big). The values a, b and c are based on the range values of the numerical variable. In some cases, the membership functions are chosen less symmetric or even optimized for the application for better accuracy.

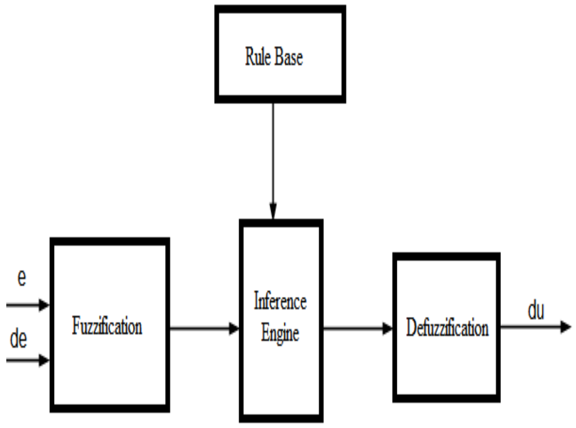

Fig 8: Four Basic Elements in Fuzzy Logic Controller

I_{PV} \\\ V_{PV}	NB	NS	ZO	PS	PB
NB	NB	NS	NS	ZO	ZO
NS	NS	ZO	ZO	ZO	PS
ZO	ZO	ZO	PS	PS	PS
PS	ZO	PS	PS	PS	PB
PB	PS	PS	PB	PB	PB

Table-1: Fuzzy Rules

The inputs of the fuzzy controller are usually an error, E, and the change in the error, ΔE. The error can choose by the designer, but usually it is choosing as ΔP/ΔV because it is zero at the MPP. Then E and ΔE are defined as follows.

$$E = \frac{P(k) - P(k-1)}{V(k) - V(k-1)}$$

$$\Delta E = E(k) - E(k-1)$$

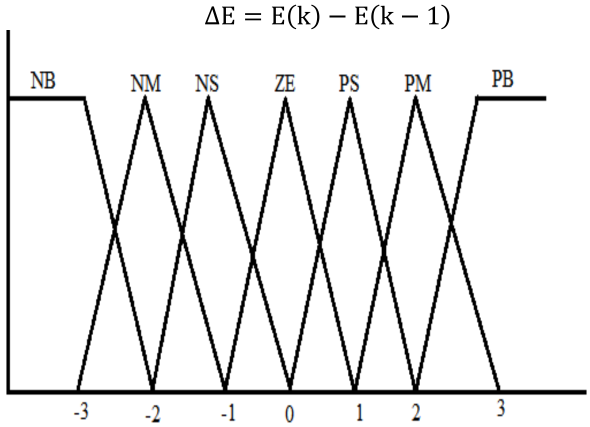

Fig 9: Membership Functions

The advantages of these controllers, besides dealing with imprecise inputs, not needing an accurate mathematical model and handling nonlinearity, are fast convergence and minimal oscillations around the MPP.

VI. MATLAB SIMULINK MODELS

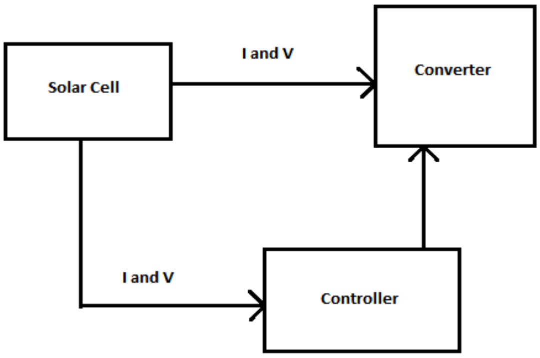

Fig. 10: Basic Block Diagram for MPPT

A. *PV-CELL:*

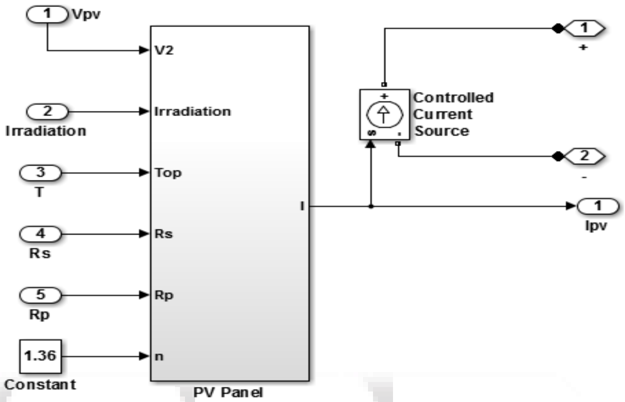

Fig. 11: Simulation Model (Sub-System) For PV Cell [2]

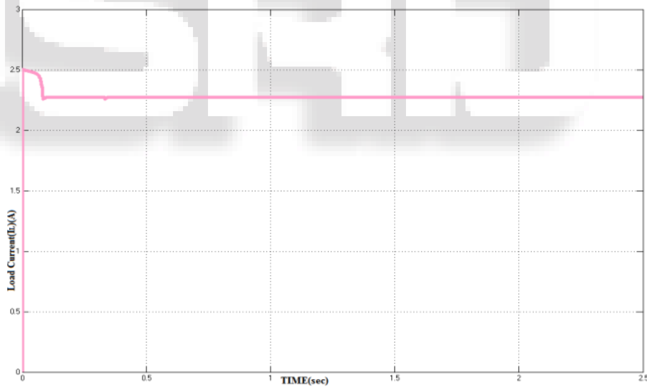

Fig. 12: Waveform of Load Current for PV Cell

B. *P&O Algorithm with Boost Converter:*

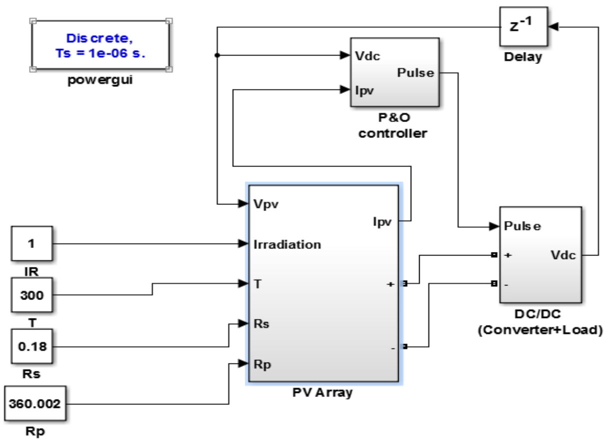

Fig 13: Simulink Model for P&O Algorithm Using Boost Converter

C. P&O Control System:

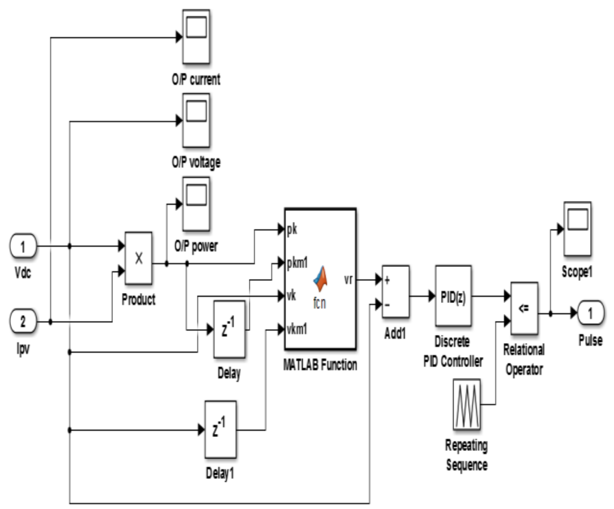

Fig 14: Simulink Model for P&O Algorithm

D. Boost Converter System:

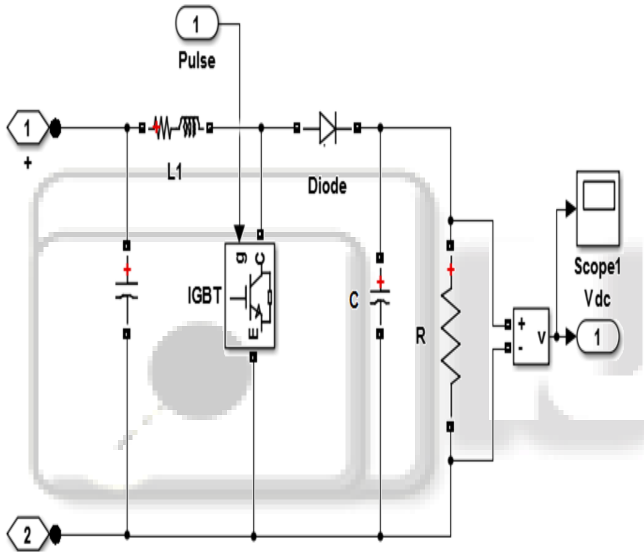

Fig. 15: Simulink model for Boost Converter (P&O)

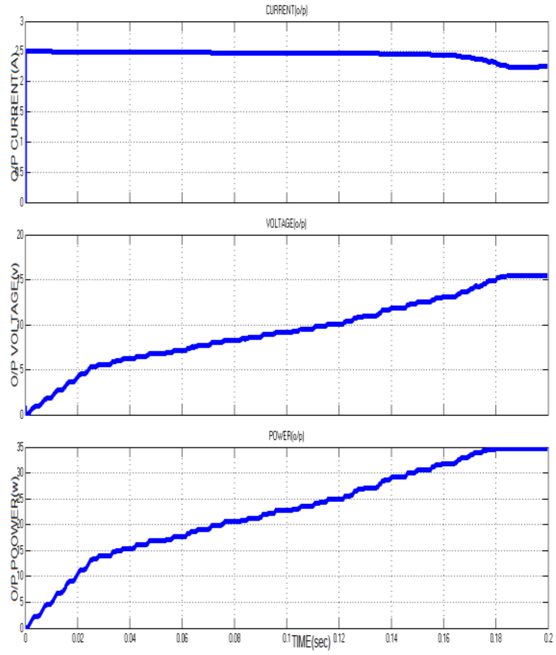

Fig. 16: Output current/voltage/power with P&O Controller

E. FLC with Boost Converter:

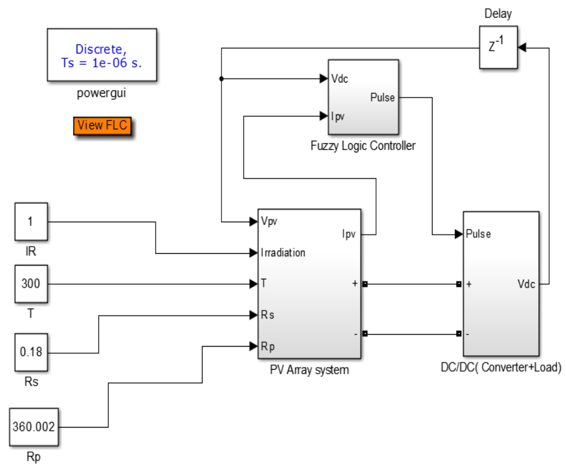

Fig. 17: Simulink model FLC using boost converter

F. FL Control System:

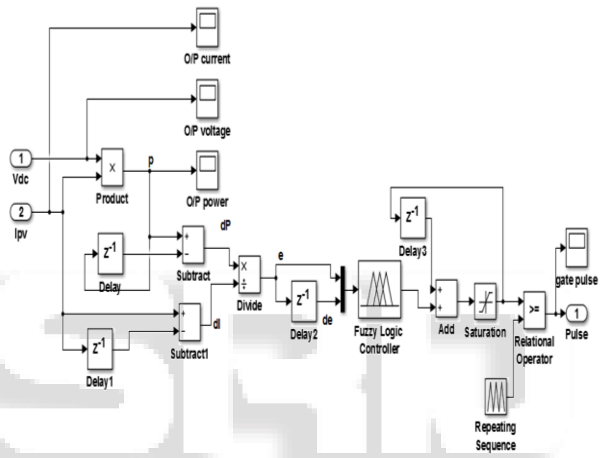

Fig 18: Simulink model for FLC

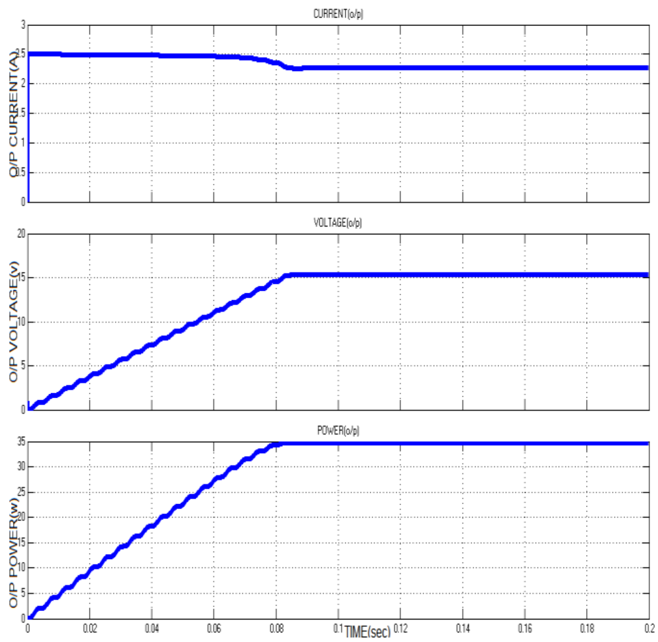

Fig. 19: Output current/voltage/power with FL Controller

VII. RESULTS AND SIMULATION

All simulation and result for every converter have been recorded to make sure the comparison of the circuit can be determined accurately. The input, output, voltage, current and power is the main comparison to take into consideration. The complexity and simplicity of the circuit have been determined based on the literature. Convergence speed, hardware required and range of effectiveness.

A. *Comparison of Output Voltage:*

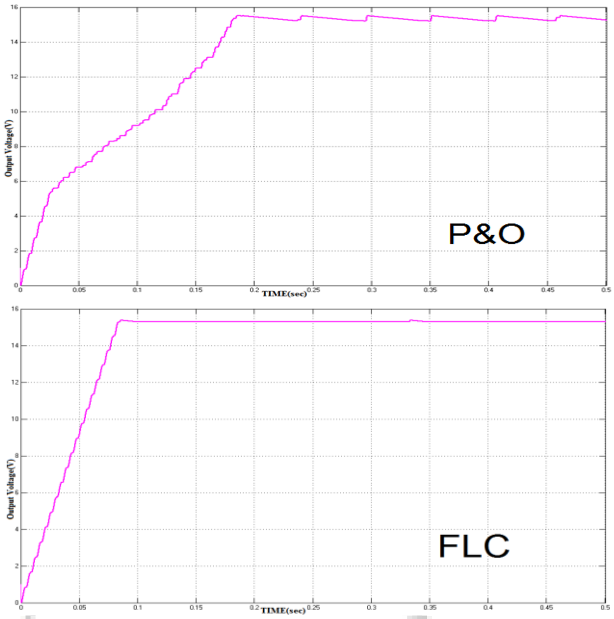

Fig. 20: Comparison of Output Voltage for P&O and FL Controllers

B. *Comparison of Output Power:*

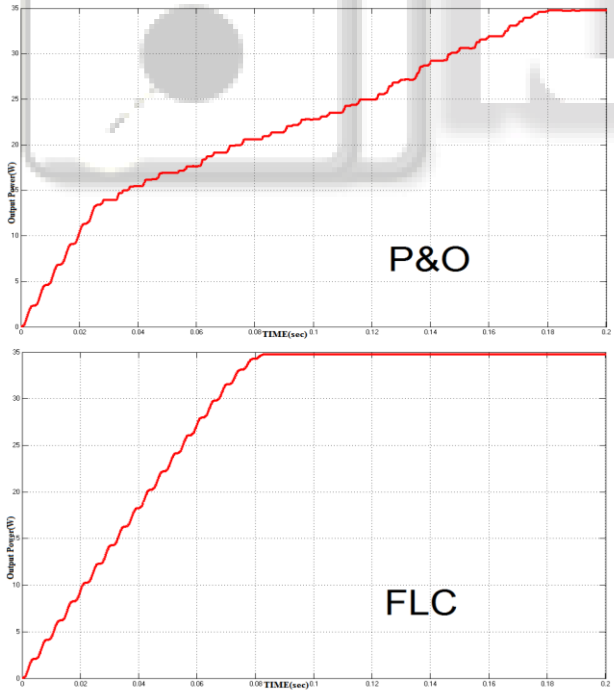

Fig. 21: Comparison of Output Power for P&O and FL Controllers

Output	**P&O**	**FLC**
Current	2.476 (A)	2.272 (A)
Voltage	9.197 (V)	15.34 (V)
Power	22.77 (W)	34.75 (W)

Table 2: Comparison between P&O and FLC at 0.1 second

VIII. APPLICATIONS

– Space and Orbital Stations
– Solar Vehicles
– Residential Use
– Street Lighting

IX. CONCLUSION

Using MPPT Technique (P&O and FLC) and get more output of the PV Array in solar system in MATLAB\SIMULINK.FLC is better than P&O controller with boost converter for PV system in MATLAB\SIMULINK.

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