Design and Simulation of a Photo-Voltaic System to Extract Maximum Power using Perturb and Observation Algorithm

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Abstract - Due to factors like climate change, pollution and depleting resources (coal, Natural gas etc) there is an urgent need to find a source of energy which is renewable as well as abundant, Photovoltaic cell is the solution, which converts the sun radiation into electricity. But there is a problem with this system as sun's radiation changes with time, so we need a system which can adapt.

One method is Perturb and Observation algorithm, this algorithm continuously looks for the maximum power points. The simulation results such as output power, voltage and current is plotted and compared with solar radiation as well as with other systems. For design and simulation Matlab R2017a is used.

Keywords: Photo-voltaic cells, Maximum power point, DC-DC converter,

I. INTRODUCTION

The paper here proposed a PV Solar design using MPPT (Maximum Power Point Tracking) logic and Perturb and Observation Technique to get the maximum power out of the solar panel. The system has an intelligent algorithm to capture the voltage of the solar panel for the maximum power extraction; this system uses DC – DC boost converter this purpose.

Matlab R2017a is used to design the simulation circuit and for the calculation of the efficiency of the system (fig 1). An MPPT, or maximum power point tracker is an electronic DC to DC converter that optimizes the match between the solar array (PV panels), and the battery bank or utility grid. To put it simply, they convert a voltage DC output from solar panels to the voltage needed to charge batteries such that the maximum power from panel can be converted to output power [1].

II. CONVENTIONAL PWM (PULSE WIDTH MODULATION) SOLAR DESIGN

The conventional PWM system relies on the maintaining the voltage to the battery, but there is a loss of the power as it compromises on the current, which reduces the benefit of generation of electricity using solar over conventional fossil fuel [2].
So for the system over 1KW system we use Maximum Power Point Tracking System which produces constant output but at the same time increases the current so that there is no loss of the power.

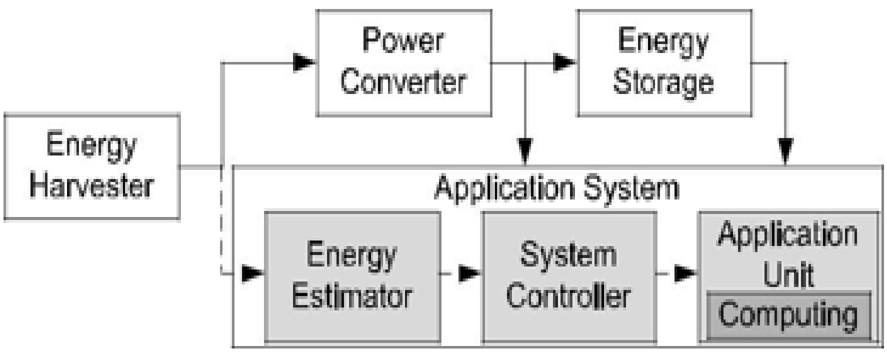

Fig 1:- Building block of the design

The above system has processing system which with the help of Perturb and Observation algorithm controls the input switching frequency of the DC-DC converter to get the maximum power [2].

When the switch is off the power is stored in the inductor and when the switch is turned on the solar panel gets connected to the battery and energy from both panel and inductor stars transferring to the battery and when the voltage starts increasing above the safe zone the switch again turns off.

So the duty cycle depends on the required output and input [3].

III. MAXIMUM POWER POINT TRACKING SYSTEM

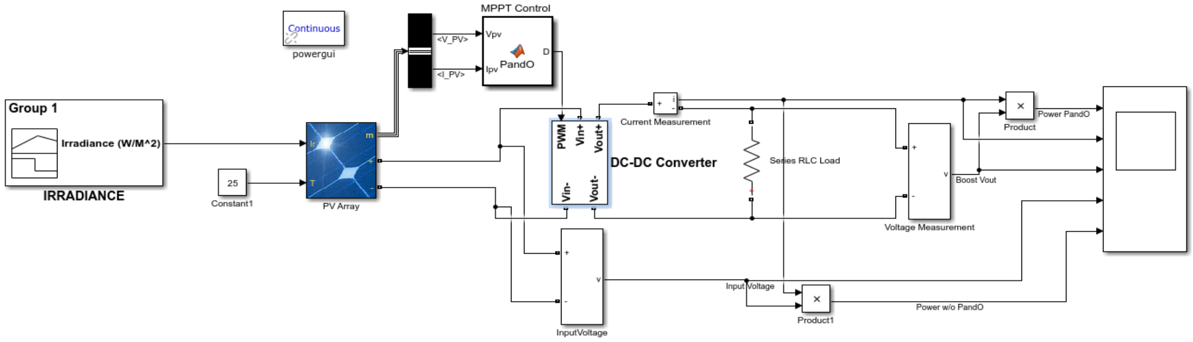

Fig. 2 Simulation Model for the proposed system

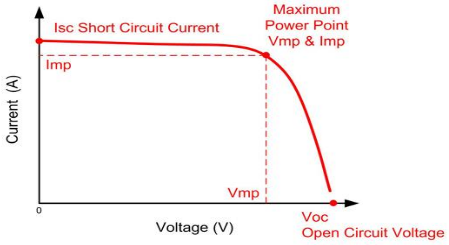

Fig. 3 voltage to current relation for the DC-DC converter

For Boost converter

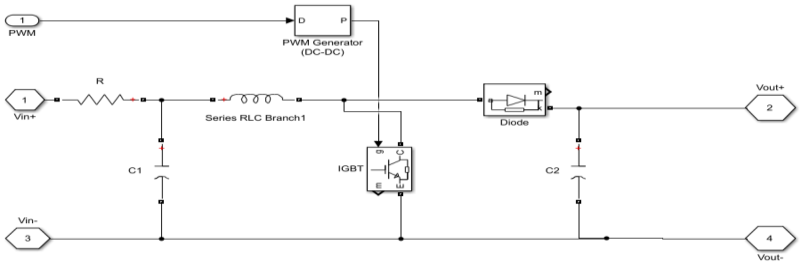

Fig. 4 Simulation model for the DC-DC boost converter

$$\frac{Vo}{Vi} = \frac{1}{1-D}$$

R= 0.1ohm
Inductor Resistance = 0.3 ohm
Capacitor Resistance = 1Mohm

Capacitor Capacitance = 1000uF

As we can see in the figure 4, the maximum power is extracted at a specific voltage (Vm) and specific current (Im), the value of voltage doesn't change much with the change of voltage , but the real difference comes in the current , which drastically increases or decreases with respect to the radiation.[2]

IV. PERTURB AND OBSERVATION METHOD

The Perturb and Observe method (P&O), sometimes called Hill climbing method [5], P&O measures the PV's terminal voltage and output current, from which the actual Power is calculated and the duty cycle of the DC-DC converter is varied to achieve the Maximum Power Point (fig.6).

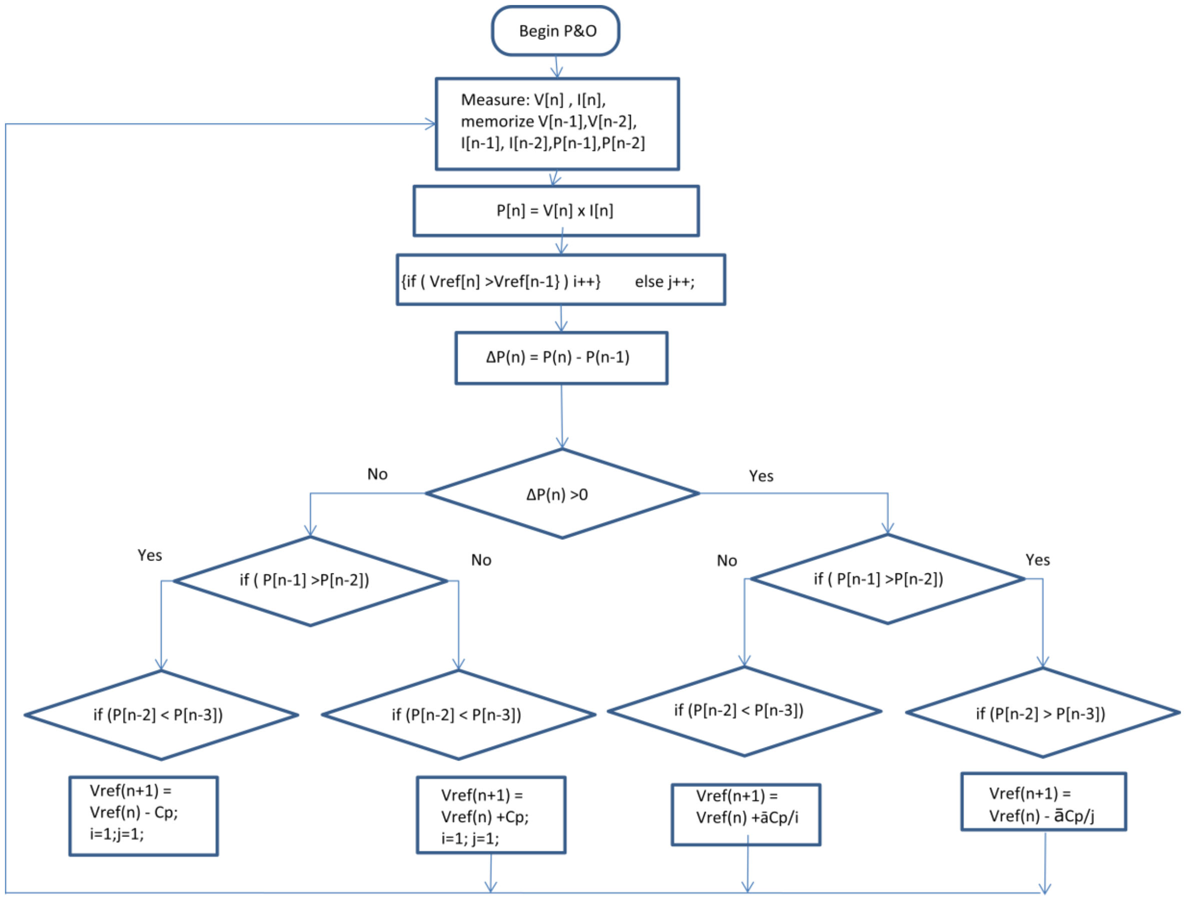

Fig.6 Perturb and Observation Algorithm

V. OPERATION

The operation starts by operating the DC-DC converter with the initial set duty cycle, and then increases or decreases the duty cycle with a certain step size (user defined), and the Power is observed/calculated at each step. If at a certain time period the observed Power gets less than its previous value that means that the duty cycle should get one step in the opposite direction to get to the MPP again [6].

VI. RESULTS

The simulation results are plotted below, where fig.7 is the radiation, whose value is randomly varied to test the circuit in case of sudden changes in the environment, the current (fig.9) and voltage value (Fig.8) is also plotted in the following section, here we can analyse that MPPT system is performing better than the PWM system and also we have plotted the MPPT result with respect to the real radiation (Table 1). [8] The system was able to achieve MPPT in 65 msec

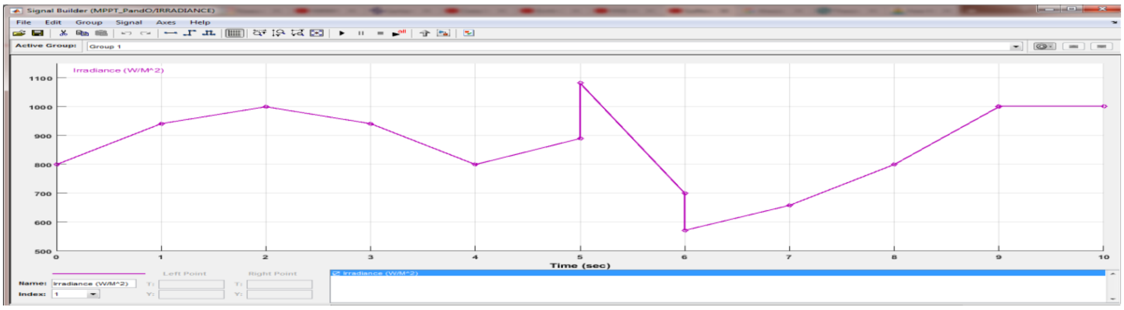

Fig.7 The input Radiation for Boost converter design

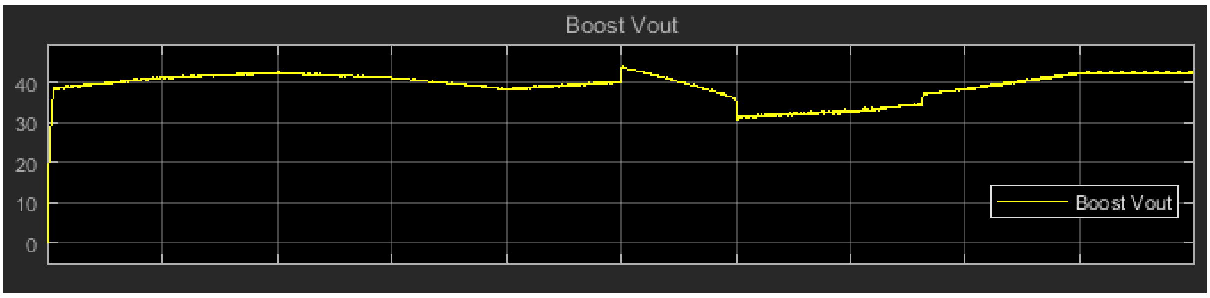

Fig.8 Boost Voltage from the solar panel

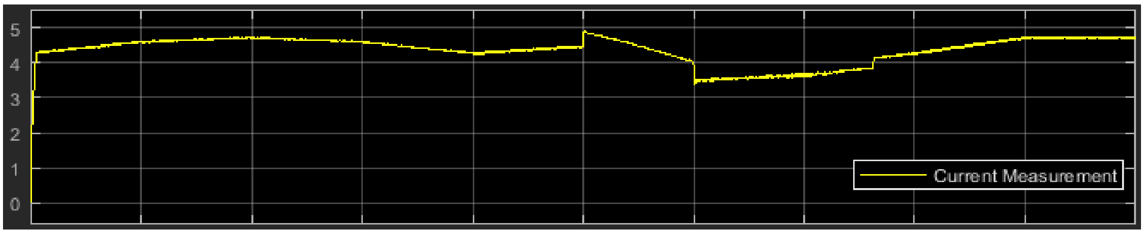

Fig.9 Output current in proportion to the input radiation power

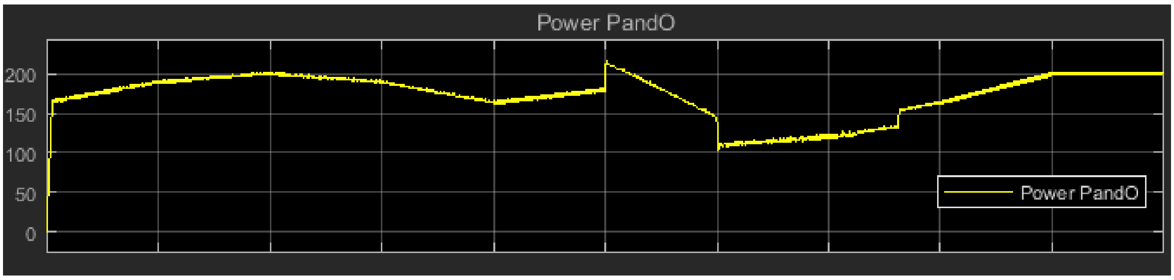

Fig.10 Output power WITH MPPT

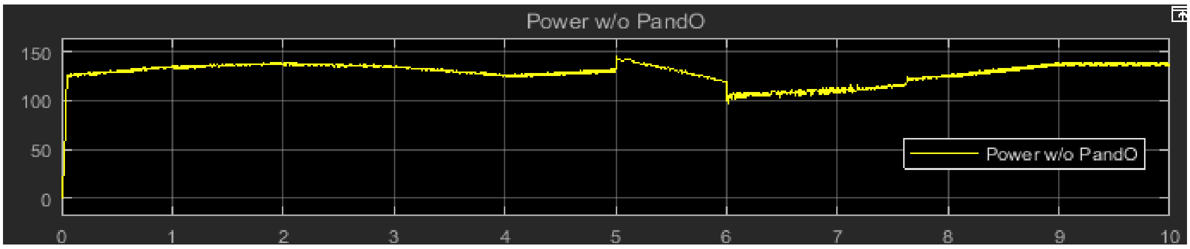

Fig.11 Output Power WITHOUT MPPT

To analyse the performance of the structures we have simulated the PWM as well as MPPT circuits and compared the results in the following table.

SR No.	Input Radiation (W/m^2)	Solar Panel (W)	Power without MPPT	Power with exixting MPPT (Watts)(1)	Efficiency (%)	Improved MPPT power	Efficiency (%)
1	800	170	120	152	89	155	91.3
2	925	192	134	171	89	174	90.8
3	1000	210	150	192	91	191	91.0
4	925	192	138	172	89	175	91.2
5	800	170	121	153	90	156	92.0
6	1185	245	180	221	90	224	91.3
7	700	145	110	133	92	133	91.8
8	660	137.5	101	120	88	126	91.6
9	800	170	118	152	89	155	91.4
10	1000	210	148	188	90	190	90.6

Table 1: Performance of exixting MPPT v/s improved MPPT(8)

To analyse the performance of the structures we have simulated the existing MPPT circuits and compared the results in the above table.Here in the above table we can see that with improved algorithm the system is more efficient than exixting MPPT and the efficiency of regular MPPT is 89.6%.
Here the total power that is converted for the usefull purpose is calculated , We can see that the average efficiency of the system is 91.3%.

Now the system is designed so as to connect it to a battery, so we need a constant output voltage of around 14V. In this paper we have also discussed the above model with the help of buck converter.
Following are the results of MPPT system with Buck converter.

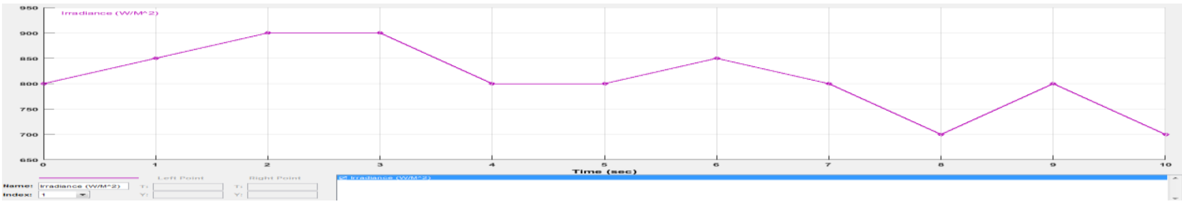

Fig.12 The input Radiation for buck converter design

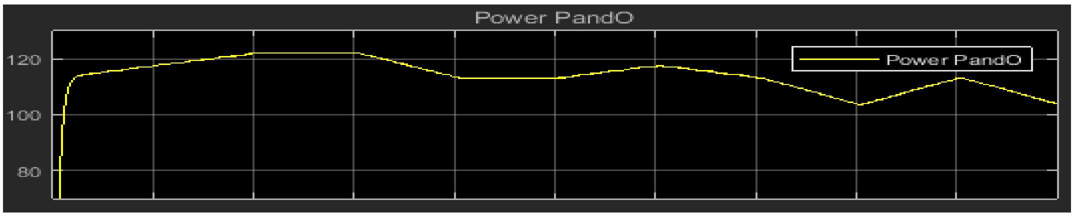

Fig.13 Output power from buck converter

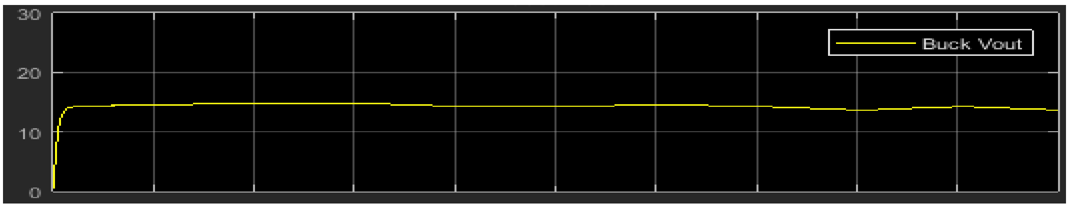

Fig.14 Output voltage from buck converter

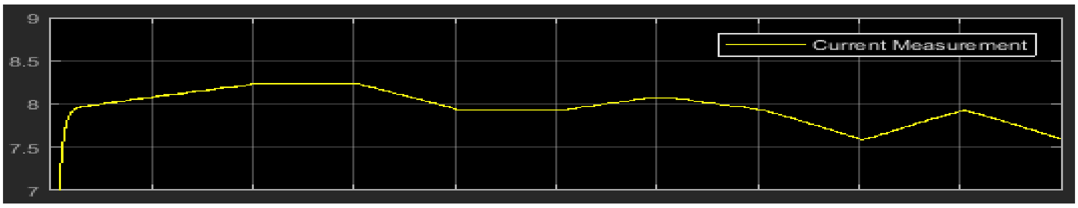

Fig.15 Output current from buck converter

SR No.	Input Radiation W/m^2	Input Power (W)	DC- DC output Current (A)	DC-DC Output Voltage(V)
1	800	160	10.1	14.5
2	850	170	10.5	14.8
3	900	180	11	14.8
4	900	180	11.1	14.8
5	800	160	9.8	14.4
6	800	160	9.8	14.4
7	850	170	10.8	14.5
8	800	160	10.1	14.4
9	700	140	8.9	14.3
10	800	160	10	14.4
11	700	140	8.9	14.3

Table 2: Buck converter output with respect to solar radiation

VII. CONCLUSION

The overall efficiency is around 91.3%, which is 1.7% more than the efficiency of conventional MPPT (89.6%) and the system was in synchronization with the radiation. We can also see in the buck converter that the output voltage was approximately fixed even when there was change in the solar radiation. The overall efficiency of system has increased and the MPPT is able to follow the radiation pattern with the help of improved perturb and observation algorithm.

VIII. FUTURE SCOPE

The system efficiency can be increased further with more simulation data and more parameters are taken into consideration, Time to time the DC-DC converter designs are evolving and we can use these designs to enhance the performance of the design. In future the system grid connectivity can be designed. The system is designed for the charging of Lead Acid battery, but system can also be designed for charging lithium –ion batteries.

IX. REFERENCES

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