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Maximum Power Point Tracking Technologies for Photovoltaic Efficiency Improvement

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Abstract - *To fulfill the increasing demand of electricity there is substantial growth in the photovoltaic utilization due to the fact that they produce electric power without polluting the environment. To increase the efficiency of PV module characteristic demands some MPPT algorithm to track the maximum voltage and maximum current in IV curve. This technique can be applied by using DC-DC converter. Various MPPT technique have been developed for this purpose. The MPPT and DC-DC converter are implemented using Matlab/Simulink and connected to modeled PV module to validate the simulation obtain result.*

Key Words: **DC-DC Converter, MPPT, PV Module, Perturb and Observe, Modeling and Simulation**.

1. INTRODUCTION

The use of Photovoltaic energy for power generation achieved importance due to increase in efficiency and reduced in cost. Among the other renewable source the electrical energy from Photovoltaic are more useful, as it is abundant, clean, eco-friendly and free distributed over major portion of earth. It is estimated that solar energy incident on the surface of earth is of the order of ten thousand times greater than world energy consumption. The Photovoltaic module itself cannot deliver maximum power output, because it has nonlinear IV curve. Maximum Power Point Technique is used to track Maximum Power Point in IV curve.

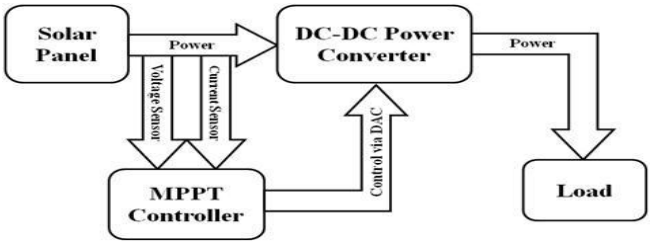

Fig. 1. MPPT based controller in PV system

MPPT algorithm can be applied to DC-DC converter to track the Maximum Power Point in the IV curve; control command is given to DC-DC converter by MPPT algorithm by measuring output voltage and current from Photovoltaic module.

1.1 Photovoltaic module modeling:

Solar cells are made of semiconductor that converts sunlight in to DC voltage process is known as photovoltaic effect. Silicon solar cells produces 0.5 to 0.6 volt depending on Temperature and independent of irradiance.

The equivalent circuit of PV cell is shown in Fig-2

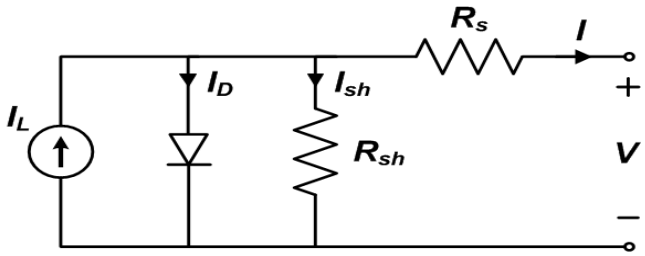

Fig. 2. Equivalent model of Photovoltaic Module

Its mathematical equation

$$I = I_{ph} - I_r \left[e^{q.(V + I.R_s)/\eta.k.T} - 1 \right] - \frac{V + I.R_s}{R_p} \quad (1)$$

where V is the output voltage of PV; I_{ph} Photon generated current; I_r Saturation current; q the electron chagre($1.6 * 10^{-19}$ C); η p-n junction quality factor; k the Boltzmann constant ($1.38 * 10^{-23}$J/k) and T the temperature (K)

1.2 Cell, Module & Array

Photovoltaic cells are connected in series to produce higher voltage and form a PV module. Typically 75 W solar modules includes 36 cells connected in series. A photovoltaic array consist of any number of PV module to get desired maximum current and voltage to meet power requirement by the fixed or varying load.

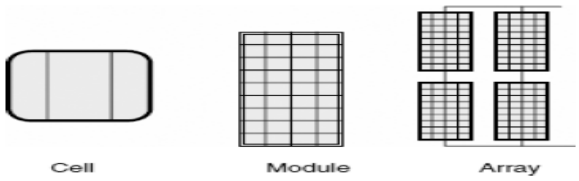

Fig. 3. Cell, Module & Array

The performance of PV module rated under Standard Test Condition (STC) which includes module operating temperature of 25^0C and solar irradiance of 1000W/m^2

TABLE I

THE MAIN PV ELECTRICAL PARAMETER USED IN MATLAB/SIMULINK

	Table 1		
	Parameter	**Symbol**	**Value**
1	Maximum Power	M_P	75W
2	Voltage at Maximum Power	V_{MP}	17V
3	Current at Maximum Power	I_{MP}	4.45A
4	Open circuit Voltage	V_{OC}	21.08V
5	Short circuit current	I_{SC}	4.79A
6	Temperature coefficient I_{SC}	α	$3.18*10^{-3}$ A/^{0}C

Power characteristic analyzed PV Fig.4 Different Irradiance level & Fig 5 Different temperature level.

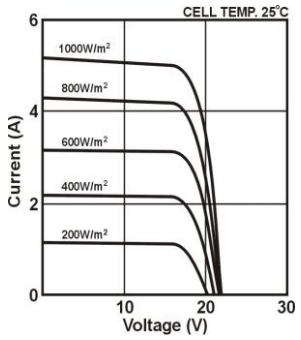

Fig. 4. IV Curve at different irradiance

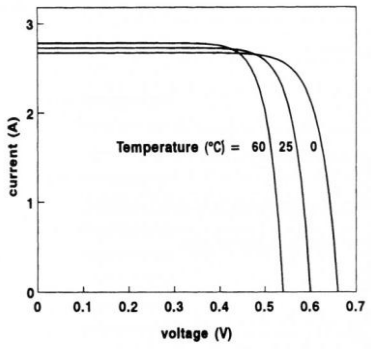

Fig. 5. IV Curve at different temperature

2. DC-DC converter

In a PV system DC-DC converter are widely used to interface load with PV module. These converters must be selected carefully to boost the module output for MPPT operation. To increase the conversion the conversion of PV module proper selection of DC-DC converter is required. Since the system required step up DC-DC converter in which PV module is followed by Boost Converter. For the given input voltage output can be varied upto desired level by varying D (t_{ON} & t_{OFF})

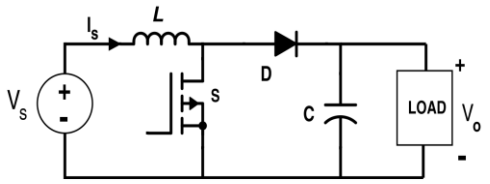

Fig. 6. DC-DC Boost Converter

Value of component can be calculated as

$$L = \frac{1.25 * D(1-D)^2 * R_{Load}}{2 * f_{sw}} \quad (2)$$

$$C_o = \frac{D}{R(\Delta V_o / V_0) * f_{sw}} \quad (3)$$

$$V_{in} = V_{Mpp} \quad (4)$$

$$V_o = \frac{V_{in}}{1-D} \quad (5)$$

3. MPPT Technique:

We know that Solar PV Module deliver variation in parameter in case of change in operating temperature and irradiance. Parameter in which variation is observed are Maximum Power, Maximum Voltage, Open Circuit Voltage, Maximum Power Current & Short Circuit Current. MPPT algorithm proposed applied to DC-DC converter to extract maximum available power to solar PV module output under variation in operating temperature & irradiance.

MPPT technique is more efficient under following operating conditions-

- Cold and cloudy weather
- When battery is in deep discharge state

Some efficient power extraction algorithms are follows-

- Hill climbing/Perturb and observe MPPT
- Fractional V_{OC} and I_{SC} based MPPT
- Incremental Conductance MPPT
- Scan based MPPT

Which have been examined and applied in field application giving high tracking efficiency.

4. Proposed PV control algorithms:

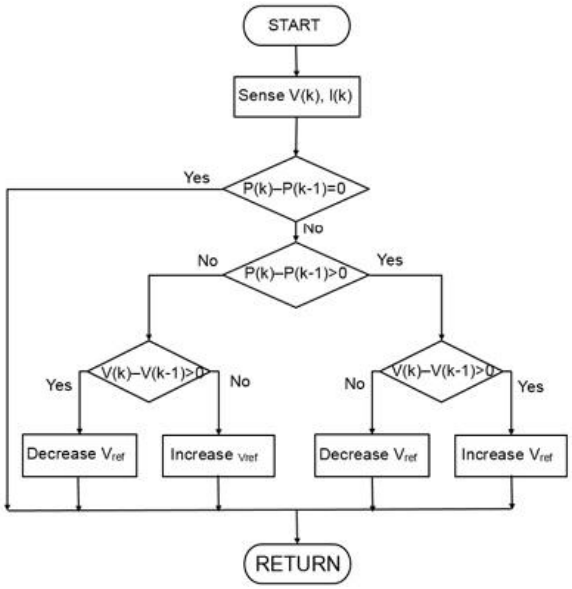

Fig. 7. P&O MPPT Algorithm

Algorithm proposed in this section, it insures optimal operation of system under various condition.

Fig 7 shows the proposed PV power control MPPT algorithm. Objective of MPPT algorithm is to automatically find the maximum operating voltage and maximum operating current on which PV module can operate at maximum power point under given Irradiance and temperature condition.

In P&O MPPT algorithm it starts from calculating of PV output power and its change in power by sampling both PV module current & voltage. The MPPT technique in this method periodically tracking increment or decrement in solar PV module voltage. If such perturbation generated in same direction and if its result in decrease in PV module power then perturbation is generated in opposite direction. The duty cycle is varied until the MPPT obtained, however the system oscillates around the MPPT point reducing perturbation step size reduces the oscillation but slow down its tracking.

5. Matlab Modeling & Simulation:

The proposed PV System is modulated In Mathwork 2014a of the MATLAB and Simulink Product Families. Proposed model is simulated at 20KHz operating frequency and corresponding parameter value using Simscape power system toolbox.

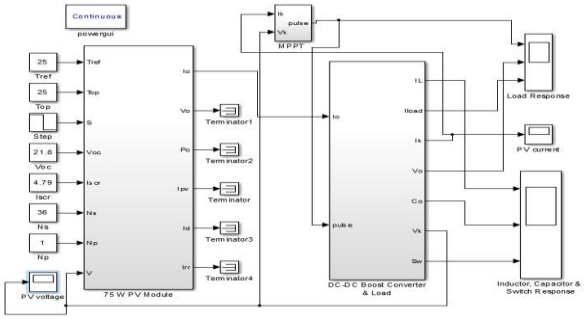

Fig. 8. Simulation block diagram of complete PV System

5. Result & Discussion:

The modeling and simulation of MPPT controller done using Perturb and Observe technique test were perform under varying irradiance condition in two steps(1000w/m^2 & 600w/m^2) at fixed temperature condition(25°c).

Results obtains are follows-

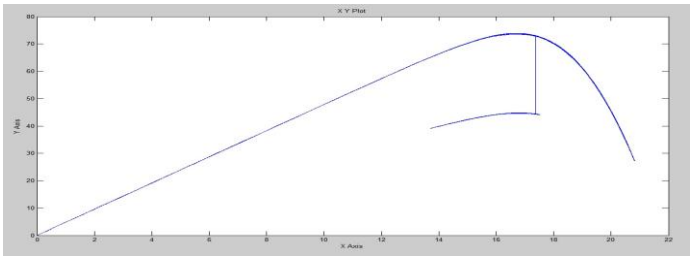

Fig. 9. PV MPPT Curve

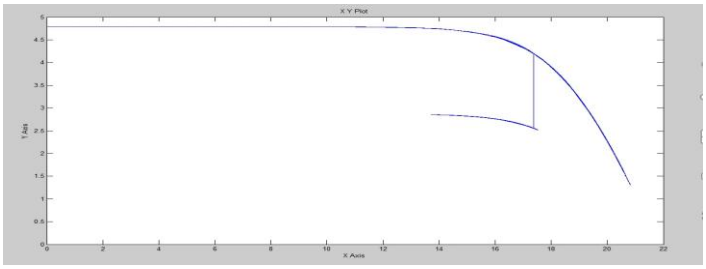

Fig. 10. IV MPPT Curve

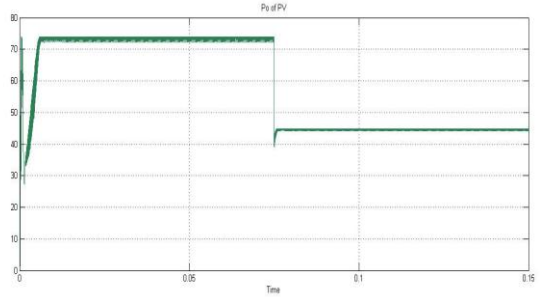

Fig. 11. Output Power of PV at two step irradiance

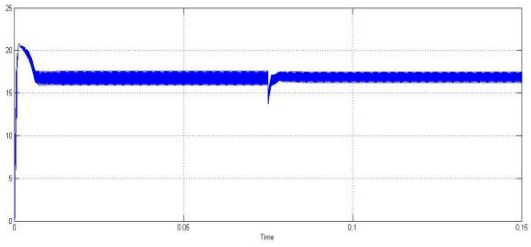

Fig. 12. Output Voltage of PV at two step irradiance

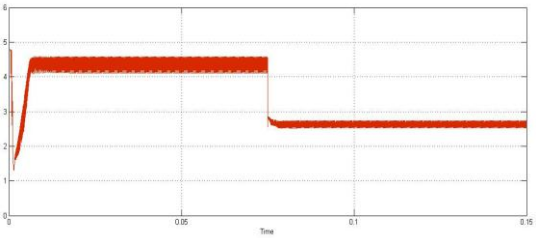

Fig. 13. Output Current of PV at two step irradiance

6. Conclusion:

In this paper the perturb and observe MPPT method was applied to DC-DC boost converter which shows an excellent result. This potentially leads to less cost for such PV system . Simulation results validated the proposed and MPPT algorithm for two step change in irradiance.

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