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Performance Analysis of MPPT and PI Controller Based PV System

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***Abstract*—The reduction in fossil fuel is increasing day by day, this causes the issue closer to global warming and has produced the need to surge for alternative electricity generation. Photovoltaic (PV) devices that use sun energy to provide power are considered as one of the renewable energies available having a superior potential and growing more and more rapidly in comparison to its counterparts of renewable energies, as compared to the conventional electricity sources. Therefore, solar panels have inconsistent voltage-current features, with a definite maximum power point (MPP), which depend upon the environmental conditions, which include temperature and irradiation/insolation. So that it will continuously harvest maximum power from the solar panels, they should perform at their MPP regardless of the inescapable modification in the surroundings. The electricity produced in output through photovoltaic arrays is restored by using the solar radiation intensity and temperature of this solar panel. Therefore, to enhance the performance of the proposed renewable power device, it's necessary to track the maximum power point (MPP) of the input supply. In this, Perturb & Observe method is used for maximum power point tracking algorithm is used to increase power conversion performance.**

Keywords—Solar Photovoltaic, Maximum Power Point (MPPT), Observe and Perturb (P&O), Proportional Integral (PI), renewable energy system (RES)

I. Introduction

At the present time, energy is the most required facility for the individual. The role of renewable energy sources is becoming very essential because of the limited reserves of fossil fuels and worldwide environmental issues for the production of electrical energy and usage. A renewable power system is taken into consideration to provide uninterrupted energy delivery to the system. In detail, the design and analysis of PV electrical converters are properly mentioned. A mathematical model for the PV system, let alone proportional-integral controller and perturbs and observe MPPT method have been designed to access the numerous characteristics of the PV module. The renewable power system is modelled and simulated in MATLAB/SIMULINK. In the proposed work the overall performance analysis of maximum power point tracking (MPPT) algorithms for a PV system were achieved. The simulations done for PV arrays cascaded with boost converter. The outcomes investigated for load power at converter end. Considering that buck converters give much less output voltage in comparison to input voltage, they're no longer suitable for load. Boost converters are properly applicable for load. Similarly, the simulations completed for the developed PV system via a DC converter and results obtained.

II. Renewable Energy Sources (RES)

A. Types of Renewable Energy Sources (RES) :

a. Solar Energy
b. Wind Energy
c. Hydro Energy
d. Bio Energy

B. *Need of RES*

Energy is most essential for the economic, social, and industrial development of a country. It is expected that in the coming years the energy consumption will be many times more than at present. India is a fast-growing country, expanding its industrial growth on one hand, and on the other hand there is a huge shortage of power in the country. Most of the power India was producing came from conventional sources until 2000; then, realizing the adverse effect of power generation from these conventional sources, India started generating power from RES. During the past decade a lot of investments have been made, and at present more than 14% of total installed power in India is generated from RES.

The role of RES has increased considerably in current years due to increasing energy demand with minimum ecological impact. RES are environmentally friendly, clean, safe, and sustainable sources of power RES can complement the present gap of supply and demand and at the same time provide neat and clean energy. India has a huge potential of RES Solar, wind, and bio all have excellent potential to generate power. The share of RES and total installed capacity of the Indian grid of last year is shown in pictorial graph 1.

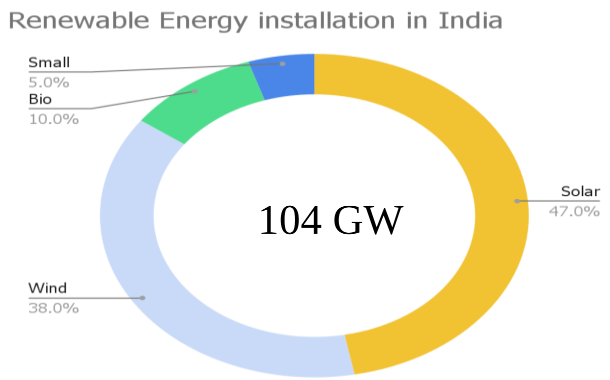

Fig1. Pictorial representation of India's installed capacity (MNRE)

III. SOLAR ENERGY

India has 300 clear days in a year, which is considered quite well for solar power generation. India is receiving on average solar energy of about 5 to 7 kWh/m² in most parts of the country. Following graph shows Indian annual installation of solar panels from 2018 to 2021 in MW. (MNRE)

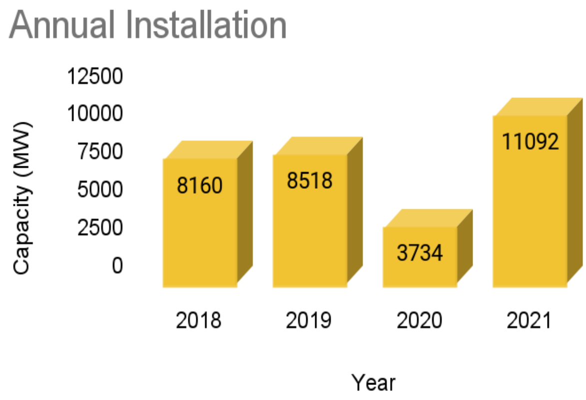

Fig2. Annual Installation of solar panels

A. *Equivalent Circuit of a PV cell*

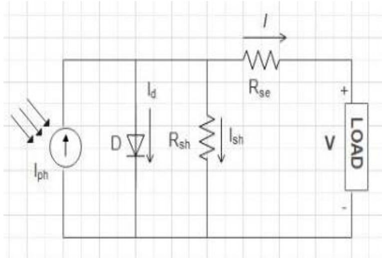

Fig3. Equivalent PV cell with series and parallel resistance

$$I = I_{ph} - I_d - I_{sh} \quad (1)$$

Where photocurrent I_{ph} is,

$$I_{ph} = [I_{sc} + K_i(T_{op} - T_{ref})]I_{rr} \quad (2)$$

I_{ph} = current generated by a PV cell due to incident light
I_d = Diode Current
I_{sh} = Current through shunt resistance R_{sh}
I = Output Current

From theory of semiconductors, the basic equation for I-V characteristics of an ideal PV cell is as follows:

$$I = I_{ph} - I_d\{exp((qV + IR_{se}/AKT) - 1\} - (V + IR_{se})/R_{sh} \quad (3)$$

In this equation I_{ph} is the current generated by PV cell due to incident light, I_d is current leakage through the diode, k is the Boltzmann constant (1.3806503× $10^{-23} J/K$), q is the electron charge(1.60217646 $\times 10^{-19} C$), T is the p-n junction temperature in kelvin, and A is the diode ideality constant.

B. *Specifications*

The specification used for MATLAB Simulation of Solar PV is an essential part to get desired output. In this proposed system instead of sun radiations we have taken irradiance and temperature as input and given it to the solar panel. Solar panel output is connected to a DC-DC boost converter & MPPT.

- **Design of Solar panel-**
  - ***a.*** *Input voltage = Vin = 250-350V*
  - ***b.*** *Output voltage = Vo = 500V*
  - ***c.*** *Rated Power (KW)*

*= no. of Parallel cell * no. of Series cell *Pmp*

*= 47 *10* 213.15*

= 101KW

Specification of solar panel are mentioned in below table those are used in this project -

Table1. Specifications of PV panel

PV Panel Specification	
PV Model	1STH-215-P
Short circuit current (Isc)	7.84 A
Open circuit voltage(Voc)	36.3V
Maximum Voltage (Vmpp)	29V
Maximum current (Impp)	7.35 A
Maximum Power (Pmpp)	213.15 W
Number of cells in series (Ns)	60
Temperature coefficient of Isc	-0.36099%/0C
Temperature coefficient Voc	0.102%/0C
Diode ideality factor (A)	0.98117
Series resistance (Rs)	0.39383
Shunt resistance (Rsh)	313.3991

C. Boost converter (Mathematical implementation)

A boost converter employs an inductor, a switch, and a diode. When the switch is turned ON the inductor is short-circuited and hence stores a large amount of charge, which is then boosted through the diode to the load as the switch is turned off. A capacitor is often connected in parallel to the load to supply a continuous current through it. The switching device used is IGBT. This is called a boost converter (DC to DC).

In the present function, boost Converter is used to compare impedance between input and output by changing the duty cycle of the converter circuit. The main advantage of a boost converter is that the higher voltage obtained from the available voltage depends on the application. The output voltage of the converter depends on the duty cycle, so MPPT is used to calculate the duty cycle to obtain the maximum output voltage because when the output voltage rises the power also increases.

- Design of the Converter (Boost Converter)

1. Inductance = L = $\frac{V_{in}(V_o - V_{in})}{\Delta I \times F_s \times V_o}$ = 1.25mH (4)
2. Capacitor = C = $\frac{I_o(V_o - V_{in})}{F_s \times V_o \times \Delta V}$ = 4μF (5)

Where,

$\Delta V = 0.01 \times V_o = 5V$ (6)

$\Delta I = 0.05 \times I_o \times \frac{Vo}{Vin} = 20A$ (7)

Output current = $I_o = \frac{P}{V_o} = 200A$ (8)

$F_s = 5$ KHz.

IV. MPPT & PI CONTROLLER

Maximum power point tracking (MPPT) is used to track high power from the system. This plays an important role in renewable energy sources due to its transient nature. However, there are some limitations, such as efficiency which depend on other portable parameters. Solar photovoltaics (PVS) is considered a promising source. The performance of a solar photovoltaic system depends on various parameters such as solar irradiance, cell temperature, dust, spectral density, etc. This flexible efficiency problem can be controlled with the help of various control strategies. The point of maximum power (MPP) is the area where most of the energy can be released from the solar cell. This point can easily be traced to the curve of a solar cell element. To get the most out of solar energy, we must always work somewhere in the power-voltage (P-V) curve where the efficiency of the solar photovoltaic system is at its highest. To obtain maximum power from the solar cell, it should always operate at a point on the power-voltage (P-V) curve where the efficiency of the solar photovoltaic system is at its maximum.

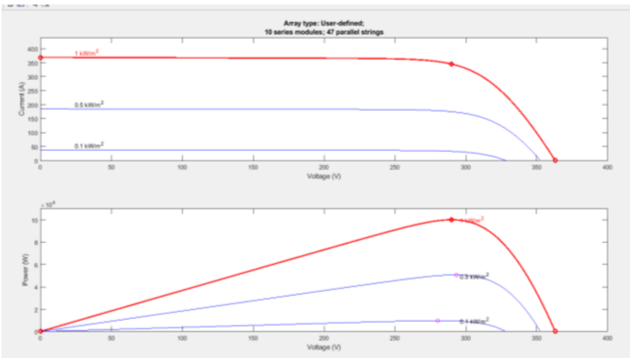

Fig4. I-V & P-V curves for PV panel

The most common applied conventional MPPT methods are-

1. Perturb and observe (P&O)
2. Incremental conductance (INC)
3. Parasitic capacitance (PC)
4. Constant voltage
5. Constant current

A. P & O method

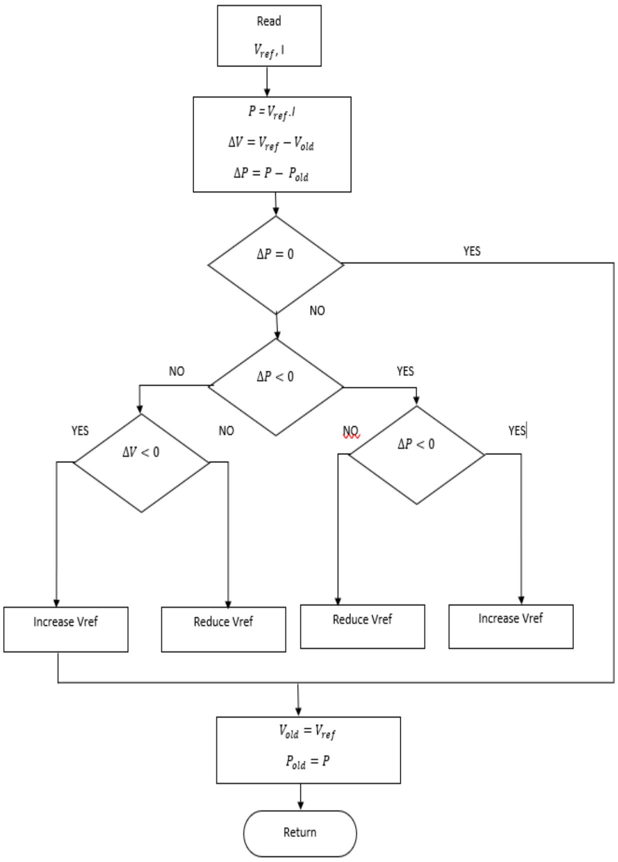

Fig5. P&O algorithm

The simplest and most commonly used method of tracking a large area of power is perturb and observe (P&O). This algorithm can be easily implemented by making small changes in the control parameter, which can be the voltage, current and the rate of duty of the power converter. This algorithm is based on the fact that after making a change in the voltage of the array, if the power increases, then the next interruption should be on the same side (i.e., the voltage increases), but if the power drops, then the next interruption should look back. But this algorithm does not provide a high precision power point because in a stable state there are oscillations around a large power area. To avoid this oscillation disturbance, the step size should be reduced, but this will also reduce the speed. In this variation, a distraction approach has been proposed to achieve improvement in terms of speed and accuracy. This process also does not work under dynamic atmospheric conditions. This route is also known as "the hill climb." A flow chart showing this method is shown in Fig5.

B. PI Controller

The developed PI controller is used to reach MPPT by monitoring the voltage and current of the PV array and adjusting the duty cycle of the DC/DC converter. The design task of MPPT is formulated as an optimization problem which is solved by the P&O algorithm to search for optimal parameters of the PI controller.

V. PROPOSED SYSTEM

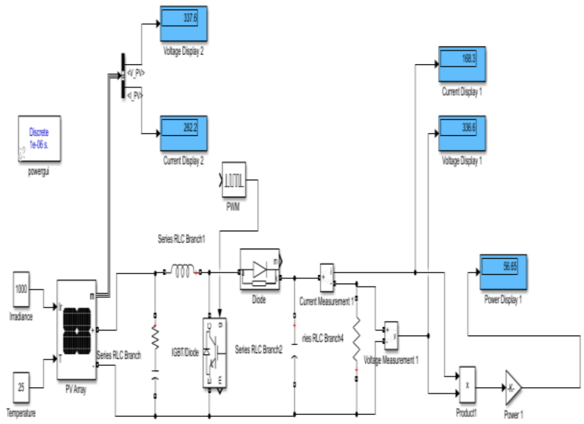

Fig6. Present solar system with boost converter

This is the existing system (Fig6.).This electric current passed through boost converter & the power output of this system is 56.65KW.

Fig.7 Shows block of proposed system of solar panel. In this MPPT and PI controller is connected. The PWM generated from the MPPT & PI controller is given to the converter.

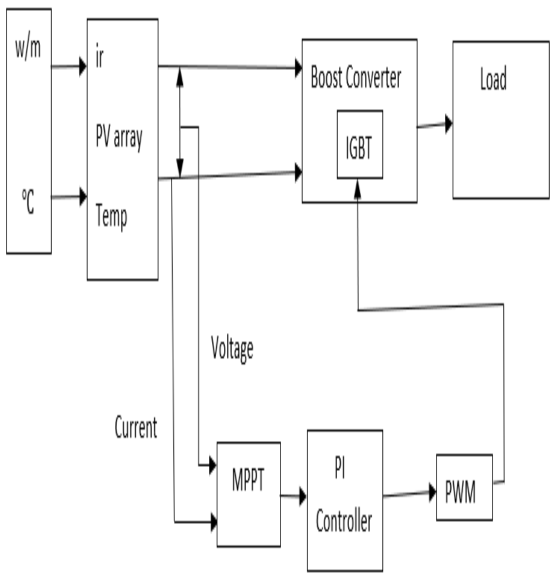

Fig7. Block diagram of proposed system

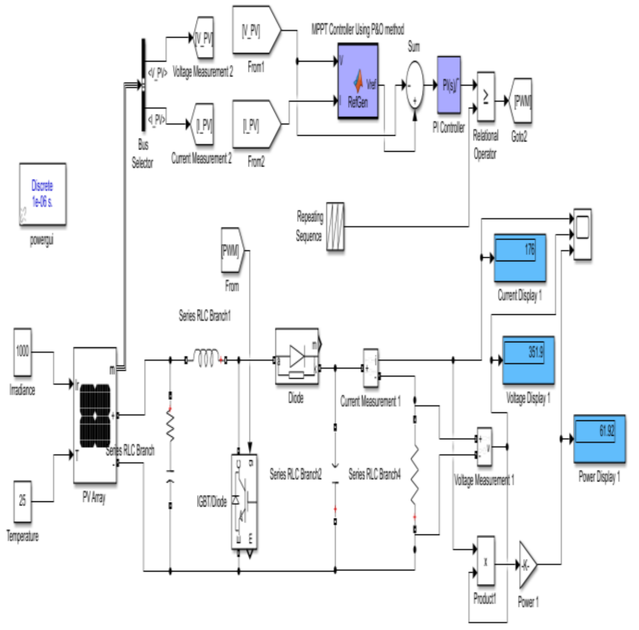

Fig8. Proposed Solar system with MPPT & PI controller

In the proposed work (Fig8.) the performance analysis of maximum power point tracking (MPPT) algorithms for PV systems has been done. The MPPT techniques considered in the proposed work are Perturb & Observe (PO) and PI controller. The output of the proposed system is 61.92 KW.

VI. Result and Discussion

The simulation study was made to illustrate the response of the proposed method to rapid temperature & solar irradiance. For this purpose, initially irradiation is 100 W/m², and is switched, at 0.5 s and 1000W/m² at 0.5 s respectively. At 100W/m² the output for the existing system is 2.7KW and for the proposed system is 3.38KW. The switching pulse is provided to IGBT switches by using the PI controller to maintain the constant voltage across the load. As it is discussed in simulation results that the output power of 56.65 KW and 61.92 KW are extracted through the boost converter respectively at 2 Ω resistive load. Hence, it has been found that the PV connected MPPT and PI controller is more efficient than the only PV connected Boost converter in the form of output voltage and output power.

The proposed system improves the system power quality and gives the continuous power supply to the load demands. Also, PV solar systems have been recognized as a feasible opportunity for energy supply in rural areas and it is also cost effective to the remote areas. Efficiency, Power, Voltage is more in Solar PV System with MPPT & PI controller as compared to Solar PV System (refer Table2).

Results and key findings have been tabulated -

Table2. Result

Parameters	**Solar PV**	**Solar PV + MPPT + PI**
Temperature	25	25
Irradiance	1000	1000
Current	168.3 A	176 A
Voltage	336.6 V	351.9 V
Power	56.65 KW	61.92 KW

The output waveforms (Current,Voltage,and Power) at 1000W/m² for a solar panel with MPPT & PI controller are shown below. After reaching the maximum point, solar output is constant-

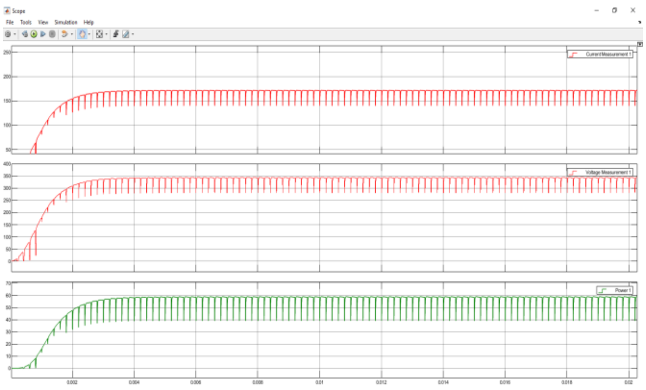

Fig9. Output Current, Voltage, Power at MPP

VII. Conclusion

In this paper, Performance analysis of maximum power point tracking (MPPT) algorithm for PV systems has been done. This system is designed and modeled in MATLAB and SIMULINK. The MPPT techniques considered in proposed work are Perturb & Observe method, PI controller. Perturb and observe method is used to achieve improvement in terms of speed and accuracy.The simulation study was made to illustrate the response of the proposed method to rapid temperature & solar irradiance. For this purpose, initially irradiation is $100W/m^2$ and is switched, at 0.5 s and $1000W/m^2$ at 0.5 s respectively. At $100W/m^2$ the output for the existing system is 2.7KW and for the proposed system is 3.38KW**.** The proposed system improves the system power quality and gives the continuous power supply to the load demands. Also, PV solar systems have been recognized as a feasible opportunity for energy supply in rural areas and it is also cost effective to the remote areas.

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