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Numerical Simulation and Design of Improved MPPT for Solar Photovoltaic System for Renewable Energy Applications

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Abstract: Two modified MPPTs are proposed in this study. The Perturb and Observe algorithm, as well as the Incremental Conductance method, have been modified. These algorithms were simulated in MATLAB/SIMULINK for both constant and variable step sizes, as well as at two distinct switching frequencies (1kHz and 10kHz). The updated algorithms are compared to the traditional PO and InC algorithms. The most efficient condition for a Maximum Power Point Tracker has been determined by analysing their simulated results in a variety of methods. With 96.26 percent tracking efficiency for non-uniform insolation at 1kHz switching frequency and 97.44 percent at 10kHz, the Modified INC algorithm has been proven to be an improved method.

Keywords*:* MPPT, Step size, Global Maxima, Tracked Power, oscillation, switching frequency, irradiation.

1. INTRODUCTION

The popularity with requirement of sustainable and green energy is increasing throughout the world. There is constantly an inevitable need of making an effective PV system as its popularity is increasing. Only at certain voltage and current conditions, the conversion efficiency of the solar panel is high. This operating point extracts maximum power from the panel so as called Maximum Power Point (MPP). Irradiance and atmospheric temperature are important in making the nonlinear characteristics of Power-Voltage curve of a PV Panel. Under partial shading condition, due to different irradiance lesser voltage and current are produced by the PV panel. As a consequence the total output power of the PV array decreases[1,2,3].

Therefore, Maximum Power Point Tracking (MPPT) Algorithms have been developed and used to make the PV Panel operate at its highest possible voltage and current in order to increase the PV Plant efficiency.

1.1. Tracking of Maximum Power Point

To draw maximum power from a PV Panel, a newly designed feature known as Maximum Power Point tracker can be added to any charge controller. MPPT varies the V-I ratio. As we know the maximum voltage of the PV panel depends on temperature, MPPT detects the amount of variance and V-I ratio is adjusted accordingly [4,5].

1.2. Maximum Power Point Algorithms

In Literature, a various number of MPPT schemes have been developed, such as perturb and Observe (P &O) also known as Hill climbing, Incremental Conductance. Due to its simplicity and ease of implementation P &O is widely used. Step size plays a very important role with irradiance as well in power output of the PV Panel. Switching Frequency has great impact in efficiency of the panel [6,7].

In this paper, four MPPT algorithms have been compared with different step size and switching

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frequency to observe their effectiveness. The first two are traditional methods such as Perturb and Observation method (P &O) and Incremental Conductance Algorithm (InC).

The next two are modified P&O, Modified InC. These two methods are tested for fixed step size & variable step size, switching frequencies of 1 KHz and 10 KHz to verify their effect on output power.

2. DESCRIPTION OF MPPT ALGORITHMS

2.1. Perturb and Observe Algorithm

The most generally utilized algorithm for business purpose is P &O Algorithm. There are few disadvantages of this algorithm but it is easy for implementation. It is also known as Hill Climbing method due to its step by step method. By observing the output power change small increments point by point are done in the operating voltage in this algorithm[8,9]. If the change in power (ΔP) is not negative this means searching the maximum point needs further increment in voltage and power. So, further perturbations in the same direction would reach near to the Maximum power point. If the change in power (ΔP) is negative, it is demonstrated that the operating point has moved away from the Maximum PowerPoint (MPP), in this case the direction of perturbation is reversed to reach the MPP. This means small increment in voltage and respective power needs in reverse direction [10,11]. The working is explained in figure1 with the help of flow chart.

2.2. Incremental Conductance Algorithm

The basic idea behind this algorithm is the derivative of current with respect to voltage becomes zero at MPP.

To overcome the problem associated with perturbation and Observation algorithm. The basic idea behind it is that the derivative of current with respect to the voltage becomes zero at MPP. Hussain et-al indicated that due to dI and dV estimation, differential derivative of power with respect to voltage becomes zero. This results the slope of the curve to become zero. The value dI/dV = -I/V may also occur. Thus, a small change in error value (E) is allowed[12,13].

2.3 Modified Perturb &Observe

The maximum power point voltage is generally about 0.8 times the open circuit voltage at same irradiance and temperature for a PV panel. In modified P &O this characteristic is taken of advantage to lessen the time taken to track the maximum power point voltage.

1) When the PV System started, first the maximum power point voltage is fixed to a particular times of open circuit voltage[14,15]. This fixed times must ensure that the operating point doesn't fall under the constant current part of the V-I curve. Here the fixed times is 0.85.

2) The modified P& O proposed in this paper adds a voltage readjustment block to the traditional P &O. If the difference between current output and former output voltage is in the scope, then no correction to the voltage control reference is needed. Here the scope is [-0.3, 0.3]. b) If that difference is more than 0.3 times, then adjustment of 1/1.3times of present output voltage of the PV module is provided to the control block. c) If within one P&O step, that difference is lower than 0.3 times of the former output voltage, then the voltage needs to be adjusted by -0.3times by adjusting the voltage control reference to 1.3 times compared to previous output voltage of the PV panel. d) A fast decrease in control voltage may arise due to a rapid decrease in irradiance. To overcome this one extra judgment step is added. If the output power decreases continuously, then the voltage control reference is adjusted same as several steps before[16,17].

2.4 Modified Incremental Conductance

The adopted algorithm is on the basis of typical INC algorithm, in which gradual variations in PV voltage and current are checked to study its impact.

This algorithm can deal with dynamic conditions quicker than P&O. INC also oscillated at the MPP as steady state are reliant on step-

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size(Offset). Higher step size causes higher oscillations. Lower step size could result in lowering the tracking process by lowering the duty cycle. Using a settled step size shows a compensation problem between steady state oscillation and faster response. Thus, variable step size is incorporated to boost performance of the MPPT[18,19].

3. SIMULATION MODELS &RESULTS WITH DISCUSSION

To increase the effectiveness of solar system, electronic accessory to be chosen wisely. Temperature along with irradiation plays an important role in PV Plant output and electronic accessory output as well. Effect of temperature and irradiation, each MPPT algorithm are shown with mathematical model.

All the models have been simulated at 1kHz & 10kHz for fixed and variable irradiation. Their results have been compared for better analysis.

3.1. Simulink Model of Solar PV System

The subsystem represents the PV panel with two inputs as irradiation and temperature. It gives output as voltage and current of the PV panel. These outputs are given as input to a product block which produces a output as Power. One Scope represents IV characteristics, where as other shows PV Characteristics.

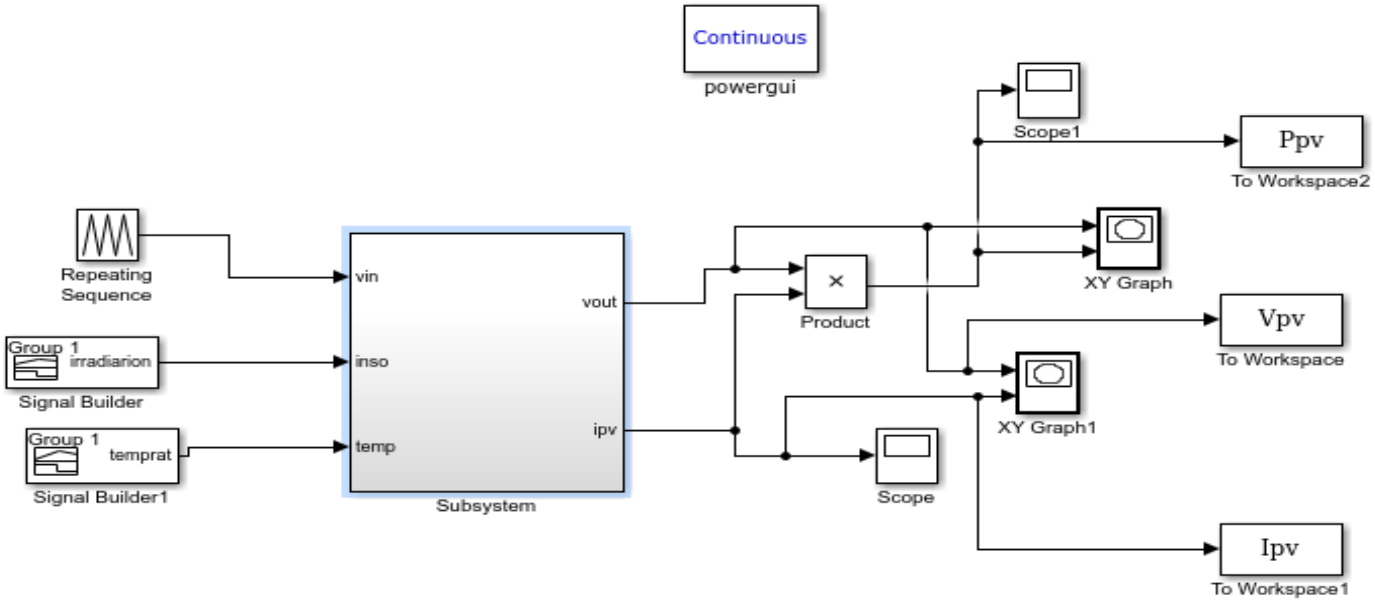

Fig.1 Simulink model of PV system

3.2 Simulation of P&O Algorithm for Maximum Power

The following is the Simulink model for Perturb and observe algorithm based PV system. The Simulink model for the rest of the MPPT models is merely same other than algorithm and switching frequency with irradiation.

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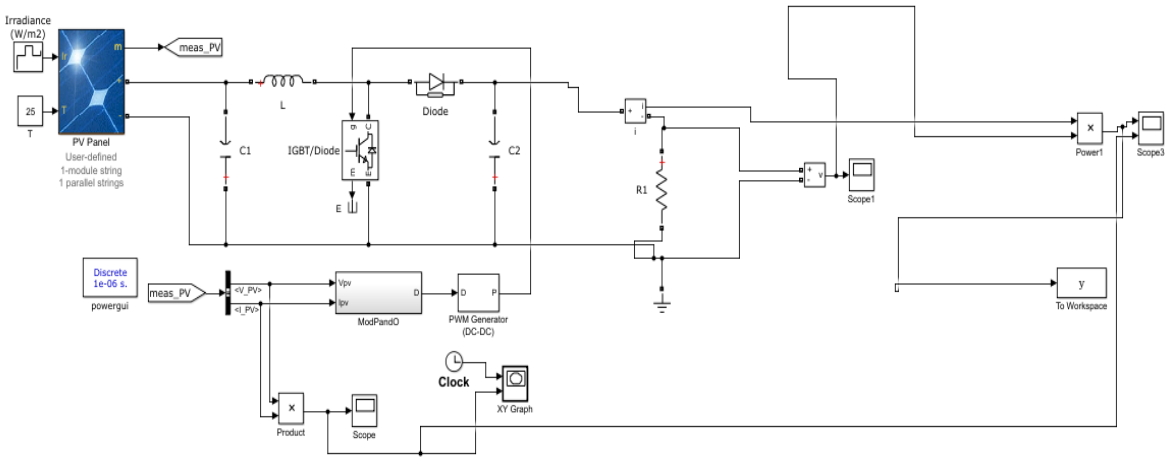

Fig.2 Simulation model for P&O algorithm based PV system

3.3 Analysis of Simulation Results

3.3.1 Comparison Table

Below Table.1 shows the maximum Tracked values for each MPPT algorithm which reveals that Modified INC at 10 KHz switching Frequency gives maximum among all i.e. 58.464W. This tracked value is 97.44% closer to the peak value. Power output at fixed radiation are not considered while comparing powers as it is not practically feasible to have same irradiation throughout the day.

Table 1. Power output comparison for each MPPT Algorithm

Slno	Name of MPPT Algorithm	MaximumTracked Power in Watts	Power tracked(%)
	P &O	288.19	96.06
	INC	294.92	98.30
	Modified P&O(1kHz,Fixed Irr)	58.543	97.57
	ModifiedP&O(1kHz,VariableIrr)	57.498	95.83
	Modified P&O(10kHz,Fixed Irr)	58.43	97.383
	Modified P&O(10kHz,VariableIrr)	47.146	78.57
	Mod INC(1kHz,Fixed Irr)	58.434	97.383
	Mod INC(1kHz,Variable Irr)	57.76	96.26
	Mod INC(10kHz,Fixed Irr)	58.787	98.645
	Mod INC(10kHz,Variable Irr)	58.464	97.44

Variable irradiation is caused due to change in irradiation (Sun's position and other environmental factors) throughout the day which is a practical condition. Lower switching frequency has advantages like lower switching loss, lower heat generation etc. Here for same switching frequency and variable irradiation both the algorithm shows almost equal outputs.

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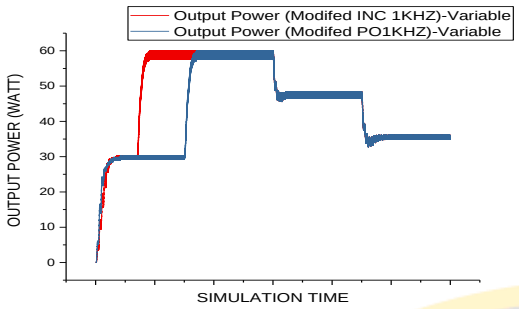

Fig.3 Comparison graph for modified PO and Inc at 1kHz switching Frequency&variable irradiation

3.3.2 Comparison of Output power for PO &INC

The below figure shows the power output curves for traditional P&O and INC which reveals that INC performs better as compared to P&O.

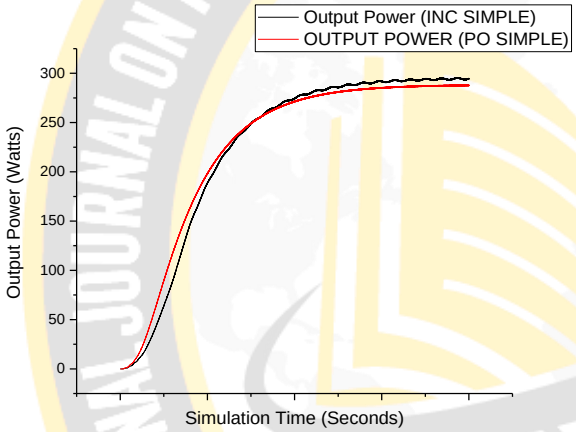

Fig.4 Comparison graph forpower output of PO &INC

3.3.3 Comparison of Output power for PO &INC

Switching Frequency has been changed to 10kHz as higher switching frequency has few advantages like small inductor and capacitor, better dynamic performance etc. Figure3.25 shows that modified PO at 10kHz switching Frequency with variable irradiation tracks more power than INC although the difference is very less.

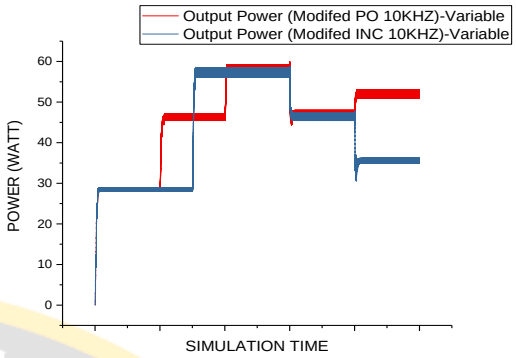

Fig.5 Comparison graph forpower output of PO &INC

3.3.4 Comparison of Output power for Mod PO &INC

Fixed irradiation at 1 kHz: Comparison of Fixed irradiation is not practically feasible. It is done only to see the effect of irradiation change on the output power. INC works more effectively than P&O.

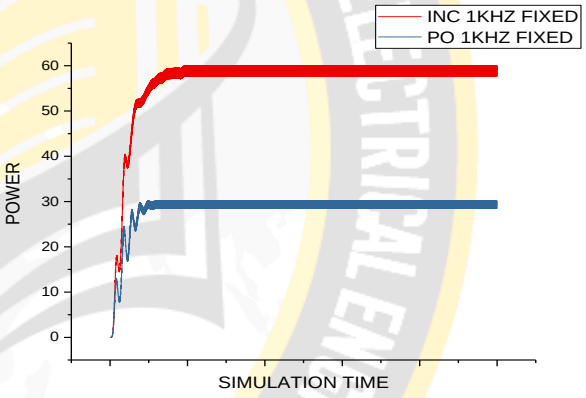

Fig.6 Comparison graph forpower output of PO &INC

3.3.5 Comparison of Output power for Mod PO &INC for Fixed irradiation at 10kHz

At 10 kHz switching frequency INC performs better although the power difference between both the algorithms is very less.

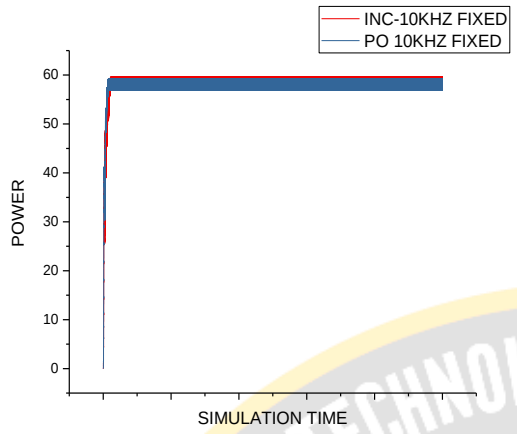

Fig.7 Comparison graph for power output of PO &INC,10kHz& Fixed irradiation

4. CONCLUSION

Analysing all the cases reveals that modified INC stands efficient amongst all methods.So, Modified INC algorithm based MPPT performed better for our given conditions and parameters. The Modified INC is proved to be improved algorithm with 96.26% tracking efficiency for non-uniform insolation at 1 kHz switching frequency and 97.44% at 10 kHz respectively.

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