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Photovoltaic Maximum Power Point Technique based on Incremental Conductance (InCon) Control Algorithm

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Abstract: Maximum output power status can significantly improve the deployment rate of solar energy system. In order to get the maximum power output, issue of tracking maximum power point (MPP), reduced harmonics around MPP and improve efficiency of the solar power energy system, this paper presents the improved maximum power point tracking (MPPT) control technique algorithm on the basis of traditional Incremental Conductance (InCon) method. Nonlinear engineering model of solar cells is built in the "MATLAB/Simulink", simulation software. Analyze the basic working principle of maximum power point control technology. Design the simulation model of conventional Incremental conductance method and compares the results with modified method. The main circuit of the system consist on DC Boost Converter. The simulation results illustrate that, the modified Incremental conductance (InCon) MPPT algorithm is realistic, fast tracking accuracy, efficient and the stability of output power are superior.

Keywords: Photovoltaic system, MPPT control algorithms, MATLAB/Simulink, DC-DC converter.

I. INTRODUCTION

In the world's energy structure in the 20th century and beyond, the main resources for electrical power generation systems are oil, gas and coal. But since entering the 21st century, the sharp rise in the population and the dramatic increase in living standards have forced us to look for new energy resources because of the limited conventional resources. In the new era of power production, thermal solar photovoltaic power generation is becoming the most sustainable development prospects in renewable resources power generation technology [1], [2].

Solar thermal power energy has the advantages of infinite resource, pollution free, noise free, no running cost, small size, simple structure and high reliability [3].

Depending on the production, photovoltaic cells can be divided into silicon-type, chemical type and organic semiconductor type etc. [4], [5]. the most widely used is silicon photovoltaic cells, silicon photovoltaic cells can be divided into single-crystal silicon and polysilicon [6], [7].

Beside the advantages of solar power generation system, it has some drawbacks. Photovoltaic cells are less efficient, so one of the key research topics of solar power generation in order to maximize the use of solar energy is to improve its conversion efficiency [8]. Therefore, in order to improve the solar cell efficiency and reduce the hormonic in output power, it is important to adopt power adjustment control strategy for photovoltaic power generation systems to keep the system in the continued running state of the maximum output power [9], [10].

For the reason so many control algorithms are developed. Recently most commonly used maximum power point tracking (MPPT) control algorithms are Perturbation and Observation (P&O), Incremental Conductance (InCon), Constant Voltage method etc. [11]. Perturbation and Observation is a simple and practical method, but its drawback is large perturbation range and slow tracking speed [12], [13]. Constant Voltage method is a simplified maximum power tracking control method, which is relatively simple to achieve, but in unstable external environment condition maximum power point (MPP) cannot be tracked in real time.

The Incremental Conductance method is based on the amount of change in the instantaneous conductivity and conductivity of the photovoltaic array by adjusting the output voltage of the PV array to track the maximum power point (MPP) [14], [15]. It is difficult to achieve the exact rated power of the PV output characteristics in practice but MPPT algorithms can improve the overall efficiency of the system [16].

This paper presents an improvement in maximum power point tracking MPPT algorithm for the photovoltaic power generation system based on incremental conductance (InCon) method.

II. PHOTOVOLTAIC CELL DESIGNING AND SIMULATION ANALYSIS

A. Mathematical Equivalent Circuit of PV Cell

According to the principle of electronics, the equivalent of photovoltaic cells can be obtained, as shown in Figure 1.
According the equivalent circuit of photovoltaic cell, total output current of cell is equal to $I = I_{ph} - I_d - I_{sh}$.

$$I = I_{ph} - I_o \left\{ exp\left[\frac{q(V+IR_s)}{AkT}\right] - 1 \right\} - \frac{V+IR_s}{R_{sh}} \quad (1)$$

Here: I_{ph}=photovoltaic cell current; I_o=Reverse saturation current; I_d=Diode current; V=Output voltage; I=Output current; R_{sh}=Parallel resistance to ground; R_s=is a series resistor that shows that the current in the battery is effected by barrier, whose value depends on the depth of PN junction diode; q=electric charge; K=Boltzmann constant.

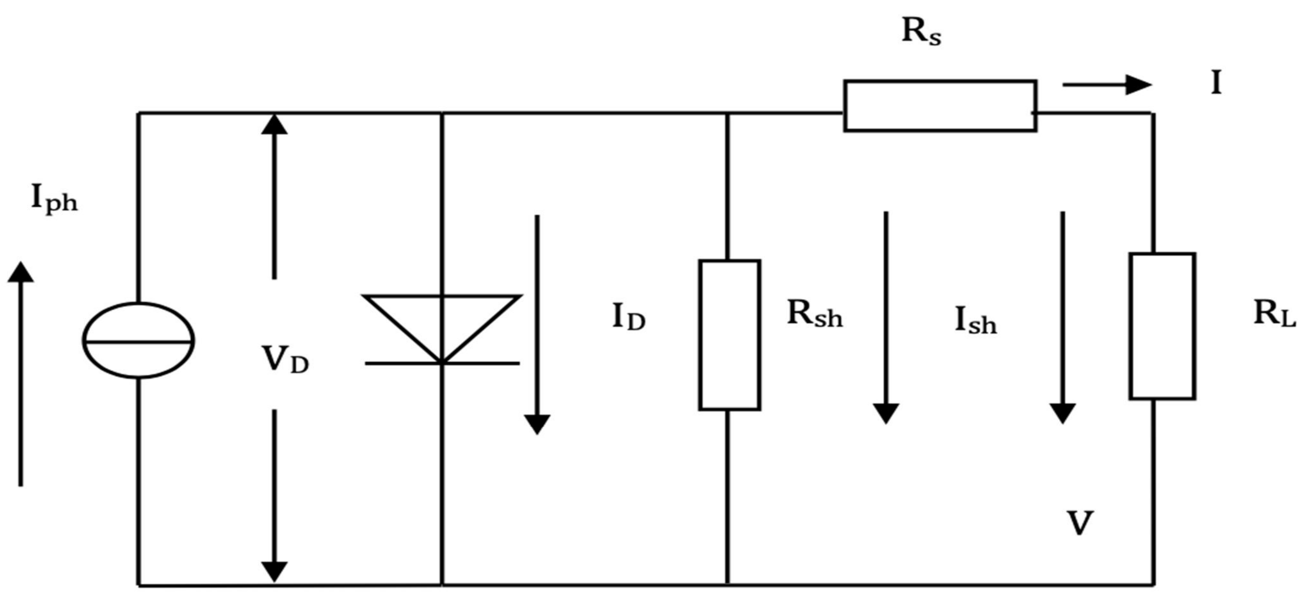

Fig. 1. Equivalent circuit of photovoltaic cell

B. Simulation Model of Photovoltaic Cell

As can be seen from the equation (1), the characteristic equation of photovoltaic cells is a beyond exponential equations and voltage-current are combined which making it difficult to count [17]. In addition, due to the lack of accurate measurement and methods, so that the equation (1) needs to be simplified. Standard manufacturing parameters of photovoltaic cells are; solar irradiance G=1000W/m^2 and temperature T=25 □. Open circuit voltage V_{oc} and short circuit current I_{sh}. Maximum output power of the cell can be derived from the above equation (1), if the maximum voltage of cell is V_m and maximum current I_m. Thus, the simplified engineering model equation (1) can be express as follow [18]:

$$I = I_{sc} - \mu_1 I_{sc}\left[exp\left(\frac{V}{\mu_2 V_{oc}}\right) - 1\right] \quad (2)$$

At the maximum power point, there is;

$$exp\left(\frac{V}{\mu_2 V_{oc}}\right) - 1 \approx \exp\left(\frac{V}{\mu_2 V_{oc}}\right)$$

Hence,

$$\mu_1 = \left(\frac{1-I_m}{I_{sc}}\right) exp\left(\frac{-V_m}{\mu_2 V_{oc}}\right) \quad (3)$$

$$\mu_2 = \left(\frac{V_m}{V_{oc}-1}\right)\left[ln\left(\frac{1-I_m}{I_{sc}}\right)\right]^{-1} \quad (4)$$

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C. Simulation Result of Photovoltaic Cell

According to the nonlinear engineering mathematical model of photovoltaic cell, a photovoltaic cell simulation model is built in MATLAB. Parameters of the photovoltaic cell is given in table 1. Two Parallel and two series cell modules is used during the simulation. Under stable weather condition rated maximum output power is 760W.

Table I: Detailed electrical parameters for Trina solar TSM-185DA01A.08

Parameters	Values
Maximum output power P_m	185.554 W
Current at maximum power point I_{mp}	5.14A
Cells per module (Ncell)	72
Open circuit voltage V_{oc}	44.6V
Voltage at maximum power point V_{mp}	36.1V
Short-circuit current I_{sc}	5.48A
Light-generated current I_L	5.48A
Diode saturation current I_0	2.0381e-10
Shunt resistance R_{sh}	608.2138 Ohms
Series resistance R_s	0.604 Ohms

Output power characteristics curves, under different weather effect of the photovoltaic cell is shown in figure bellow.

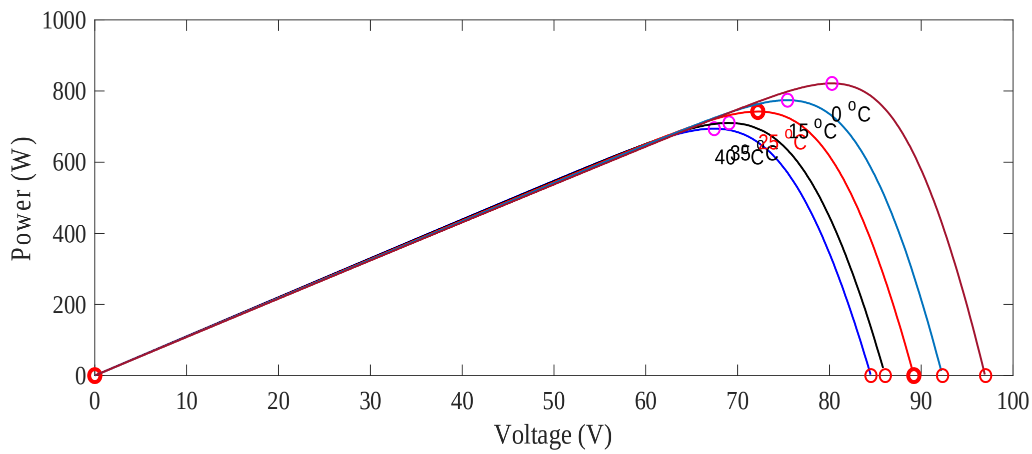

Fig. 2 P-V curve of PV cell at different temperature and stable light intensity (G = 1000W / m^2)

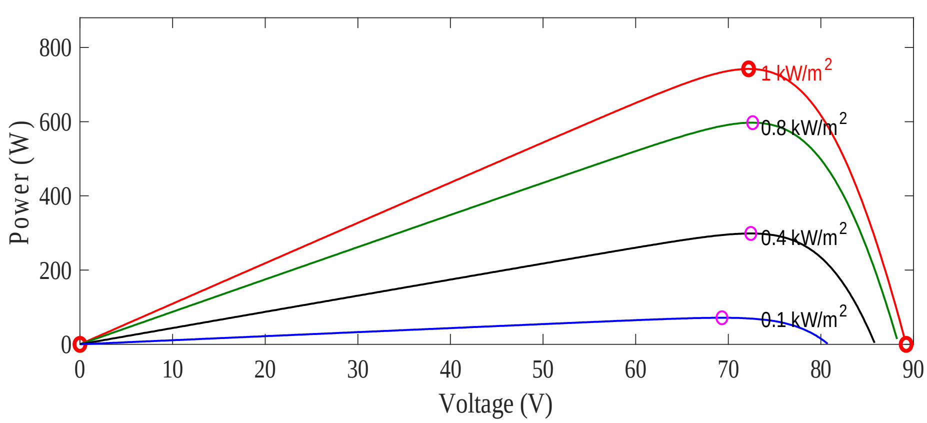

Fig. 3 P-V curve of PV arrays unstable light intensity and constant temperature T=25°C

It can be seen from the above figure 2, when the external environment temperature increases the output power of the cell decreases. It means that PV cell work more efficiently in winters comparatively with summer. In the figure 3, output power rises as light intensity of the sun increases.

III. PRINCIPLE OF MAXIMUM POWER POINT TRACKING (MPPT)

The external temperature and light intensity, create non-linear changes in output voltage and output power of photovoltaic cells. In a certain determination at temperature and light intensity, photovoltaic cell can only reach to the maximum output power if it is operating at maximum output voltage V_m. To get this maximum power from photovoltaic cell we used MPPT control techniques [19], [20]. According to the above simulation results of PV cell, the factor effecting photovoltaic array to operate at maximum output power is the maximum use of solar radiation [21], [22]. At present, there are many control algorithms use for PV system to control MPP such as; Pert and Observe, Incremental Conductance, Fuzzy Logic, Artificial Neural Networks, Constant Voltage, Open Circuit Fractional Voltage etc. [23].

A. Incremental Conductance (InCon) Method

The incremental conductive control technique is widely use in PV system, it is easy to applicable and practical method. In this paper, the simulation model of the conductive increment method is designed, and the following is the algorithm-based analysis of the increment conductance method. The relationship between the output power P of the PV array, its output current I and output voltage V is as given bellow:

$$P = VI \tag{5}$$

$$\frac{dP}{dV} = I + V\frac{dV}{dU} = 0 \tag{6}$$

Maximum power point can achieve according to;

$$I + V\frac{\Delta I}{\Delta V} = 0 \tag{7}$$

$$\Delta I = I_k - I_{k-1} \tag{8}$$

$$\Delta V = V_k - V_{k-1} \tag{9}$$

Control algorithm flow chart of InCon method is given in figure below.

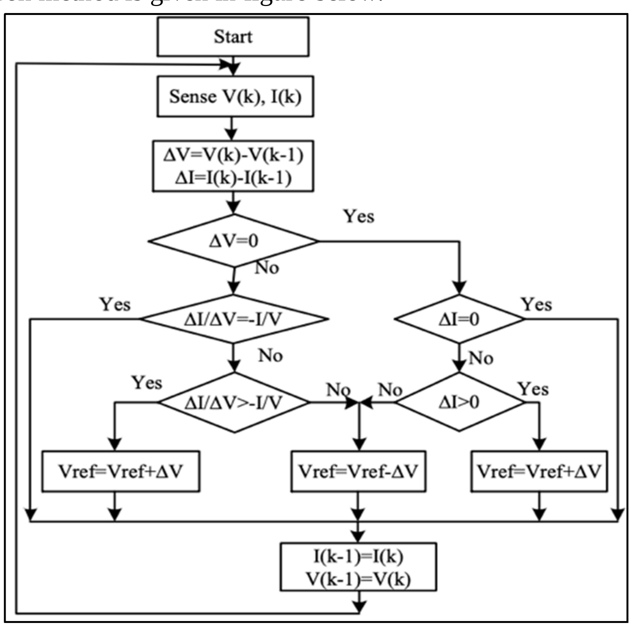

Fig. 4 Flowchart of InCon algorithm

B. Simulation Model and Results of Conventional (InCon) Method

Simulation model and output power characteristics curve of the photovoltaic thermal power generation system is given bellow. Simulation model is built in MATLAB/Simulink software. Simulation model of the photovoltaic system is given in Figure 5. Figure 6 is unstable input light intensity. Figure 7, shows the simulation model of the conventional InCon method. Figure 8, illustrate the output power of the photovoltaic system under stable weather condition, when light intensity is G=1000W/m^2 and temperature

T=25°C. It can be seen in figure 9 when the light intensity of external environment change how it effects the output power of the system. DC-DC Boost converter is used as Main circuit.

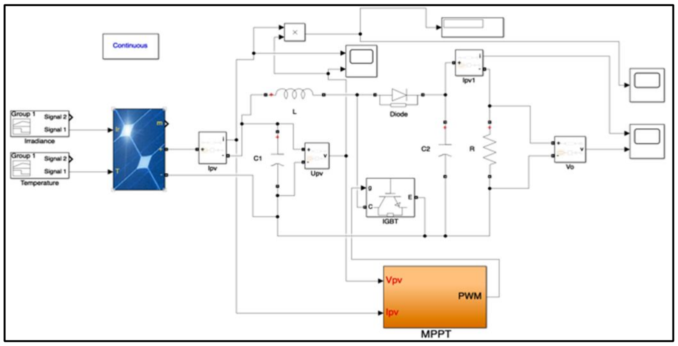

Fig. 5 Simulation model of photovoltaic power system

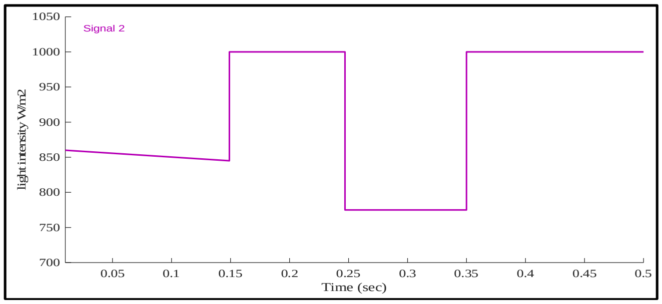

Fig. 6 Unstable input light intensity

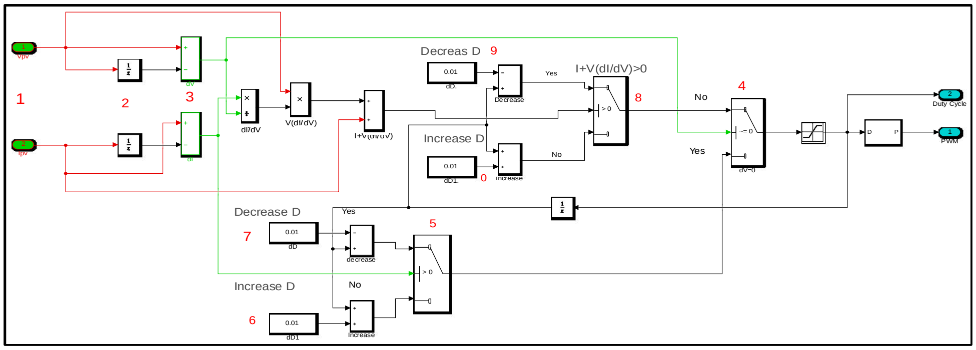

Fig. 7 Simulation model of traditional incremental conductance InCon method

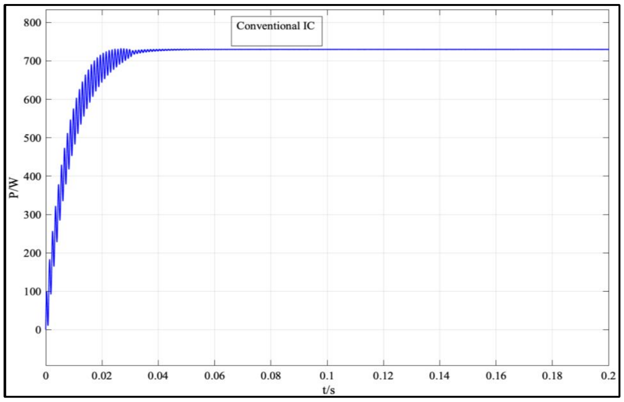

Fig. 8 Output power curve of traditional incremental conductance InCon method under stable weather

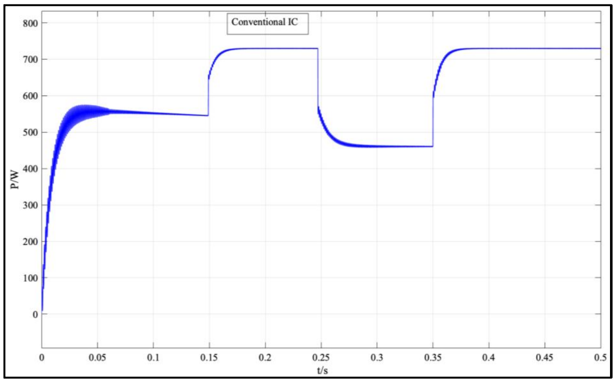

Fig. 9 Output power curve of traditional incremental conductance InCon method when light intensity changes

IV. MODIFIED (INCON) METHOD

In order to be able to meet both tracking speed and tracking accuracy and have good stability, this paper presents a MPPT algorithm to improve conductivity increment method, simulation model is given in figure 10. The algorithm sets a modified current reference value I_{ref}, after various simulation check. Select I_{ref} value as a standard condition for photovoltaic cell 1/3 of the lower peak current I_m. The current reference value I_{ref}, at which point the step symbol before the change is accurately define and give the step length symbol after the mutation, while applying the shifting step. The simulation results show that when the external environment condition changes the system can be fast and accurate to track the maximum power point MPP and the voltage fluctuations are small. Figure 11, is the output characteristics curve when the external environment is stable. The effect of variation in light intensity can be seen in Figure 12.

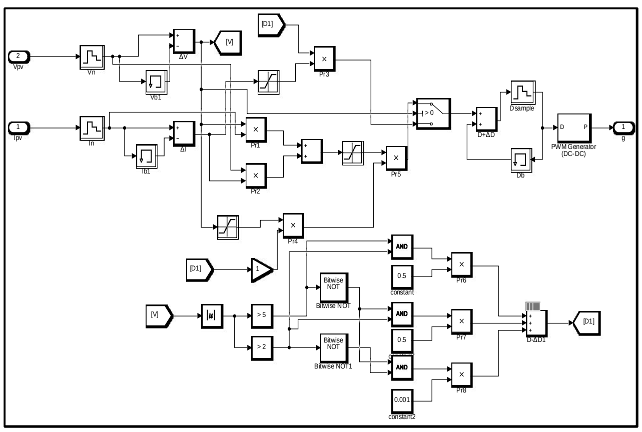

Fig. 10 Simulation model of modified InCon method

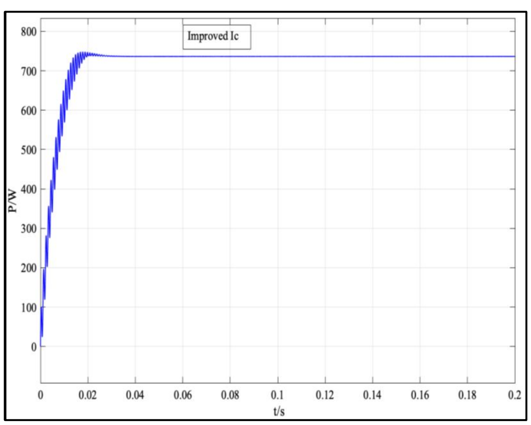

Fig. 11 Output power curve of modified incremental conductance InCon method under stable weather

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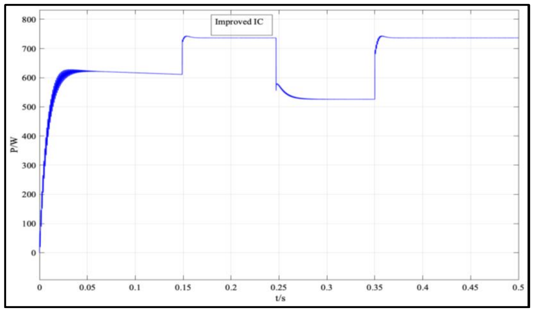


Fig. 12 Output power curve of modified incremental conductance InCon method when light intensity changes

V. SIMULATION RESULTS AND ANALYSIS

Distinct analysis of simulation results for both methods are reviewed earlier. Figure 13, 14 shows the comparative results of both conventional and modified InCon method. PWM signal is generated in algorithm and provided to the gate of IGBT. Principal simulation circuit of the system is given above in figure 5, parameters of the circuit are set as follow; C1=220μF, C2=450μF, L=150μH, R=50V, duty cycle=50% and frequency=20Khz.

Under stable weather condition temperature is setted as T=25°C, light intensity is setted G=1000W / m^2 and the simulation time is set 0.2s.

Under unstable external environment condition, different light intensity signal is delivered through signal builder, its value varies from 780W/m^2 to 1000W/m^2. The output power waveform is given in figure 14. Simulation time is set as 0.4s for variable input signal.

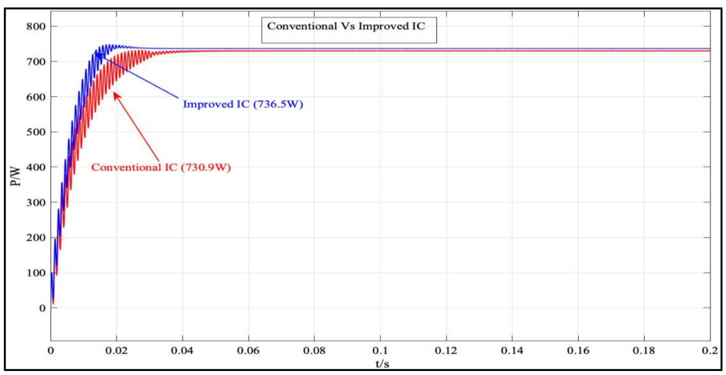


Fig. 13 Comparative output power curve between conventional Incremental Conductance InCon and Modified method under stable weather condition

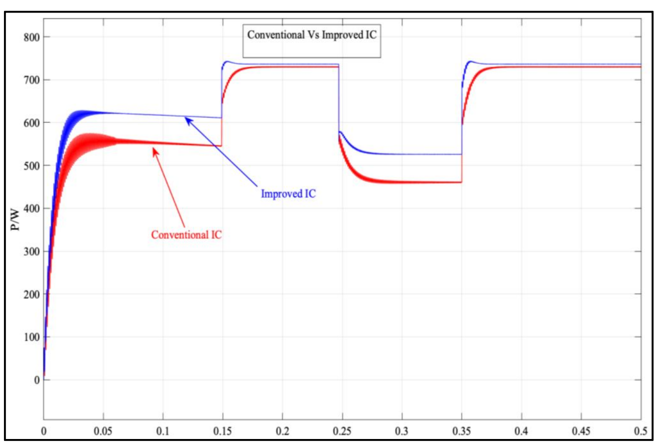


Fig. 14 Comparative output power during unstable weather condition

Table II: Comparison of Traditional Vs Modified Method

MPPT Technique	Improved IC Method	Traditional IC Method
Tracking time during stable weather condition	0.017s	0.03s
Output power	736.5 W	730.9 W
Tracking time when intensity drops to $850W/m^2$	0.05s	0.15s
Output power	620.5 W	555 W
Tracking when intensity increase to $1000W/m^2$ during change in weather condition	0.16s	0.2s
Output power	736.5 W	730.9 W

In the condition, when external environment is stable, it can examine from figure 13, modified method quickly track maximum power point (MPP) value at 0.017s and the conventional method reach to MPP value at 0.03s. During stable weather condition the fluctuation in output power is relatively small as compare to conventional method. When the weather condition is stable; light intensity $G=1000W/m^2$ and temperature T=25°C; output power of the improved method is recorded 736.5W and conventional method is 730.9W. During unstable light intensity condition, it can be seen from figure 14, that the output maximum power of improved method is higher comparatively with conventional method at different level. When change occurs in external environment light intensity, the tracking speed of improved method is fast and fluctuation is lesser compare to conventional method. on the basis of simulation results we can say that the response time of improved method is faster than the conventional method. Fluctuation in output power is reduced in improved method. Overall efficiency of the improved method is slightly increased.

VI. CONCLUSION

This paper introduces basic principle of control methods for maximum power point tracking (MPPT) in solar power generation system, and finally implements incremental conductance method. Design the mathematical engineering model of photovoltaic cell, built its simulation model in MATLAB/Simulink platform and gets simulation results. Design simulation model of conventional incremental conductance method and modified InCon method in MATLAB. At the end compare the result of both methods.

REFERENCES

[1] Y. W. A. Z. H. H. I. S. M. A. B. K. Kifayat Ullah, "Maximum Power Point Technique (MPPT) for PV System Based on Improved Pert and Observe (P&O) Method with PI Controller," International Research Journal of Engineering and Technology (IRJET), vol. 6, no. 12, pp. 813-819, 2019.

[2] S. H. Shehadeh, H. H. Aly and M. El-Hawary, "Investigation of photovoltaic coverage ratio for maximum overall thermal energy of photovoltaic thermal system," Renewable Energy, vol. 134, pp. 757-768, 2019.

[3] A. Salari and A. Hakkaki-Fard, "A numerical study of dust deposition effects on photovoltaic modules and photovoltaic-thermal systems," Renewable Energy, vol. 135, pp. 437-449, 2019

[4] S. Agarwal and Y. K. Prajapati, "Analysis of metamaterial-based absorber for thermo-photovoltaic cell applications," IET Optoelectronics, vol. 11, no. 5, pp. 208-212, 2017.

[5] G. Cibira, "Relations among photovoltaic cell electrical parameters," Applied Surface Science, vol. 461, pp. 102-107, 2018.

[6] A. Benami, "Effect of CZTS Parameters on Photovoltaic Solar Cell from Numerical Simulation," Journal of Energy and Power Engineering, vol. 13, no. 1, 2019.

[7] I. Tolić, M. Primorac and K. Miličević, "Measurement Uncertainty Propagation through Basic Photovoltaic Cell Models," Energies, vol. 12, no. 6, p. 1029, 2019.

[8] T. Nahak and Y. Pal, "Comparison between conventional, and advance maximum power point tracking techniques for photovoltaic power system," in IEEE 7th Power India International Conference (PIICON), 2016.

[9] R. Li and Z. Tan, "Study on Maximum Power Point Tracking Based on Parabolic Approximation Method for Photovoltaic Power Generation System," in 37th Chinese Control Conference (CCC), 2018.

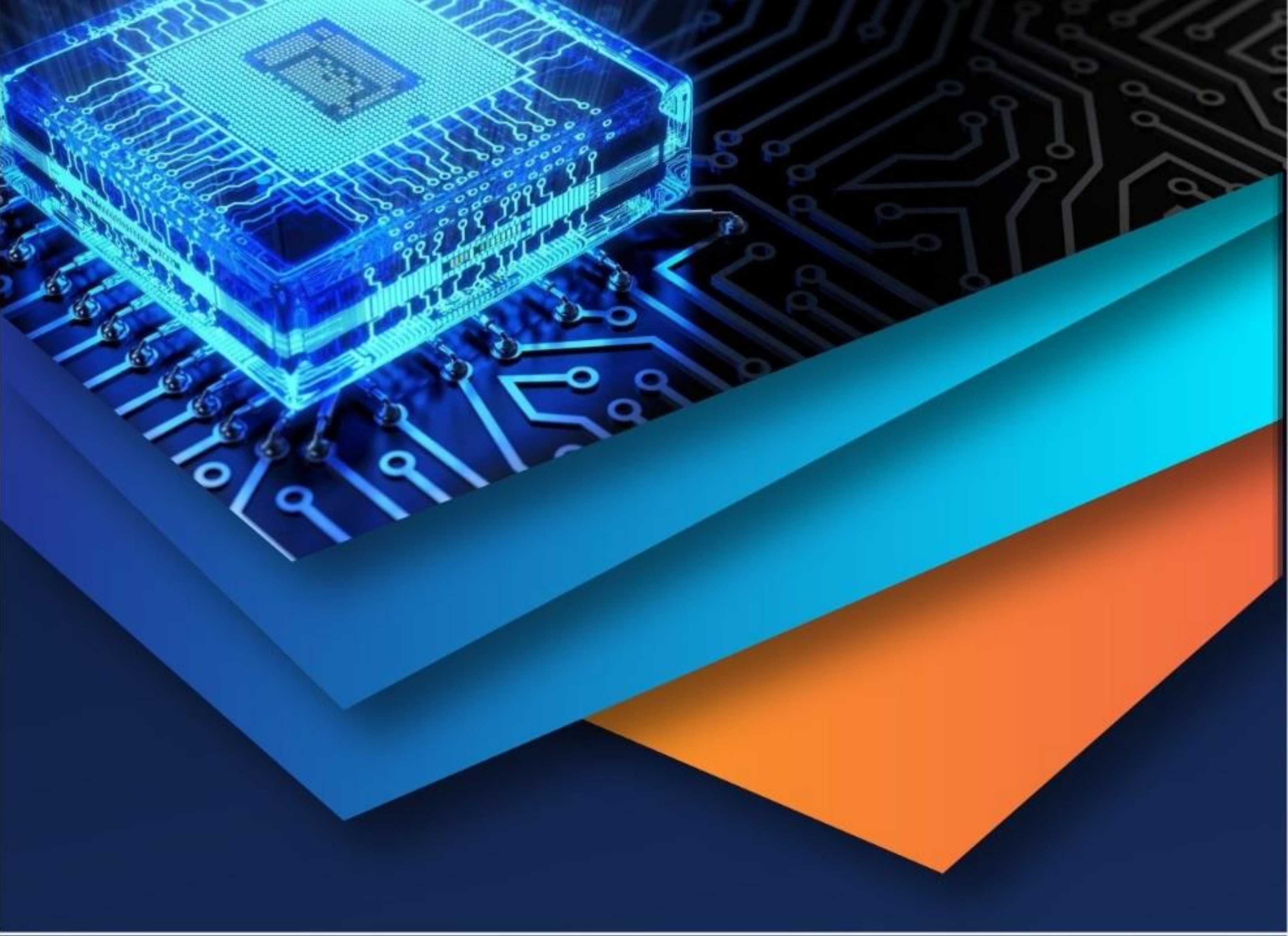
[10] F. a. p. g. m. p. p. t. t. f. p. system, "Fast and precise global maximum power point tracking techniques for photovoltaic system," IET Renewable Power Generation, vol. 13, no. 14, pp. 2569-2579, 2019.

[11] L. A. Shravan and D. Ebenezer, "Maximum Power Point Tracking (MPPT) for a Solar Photovoltaic System: A Review," Applied Mechanics and Materials, vol. 787, pp. 227-232, 2015.

[12] S. Zaineb and S. Lassad, "P&O controller for the maximum power point tracking in photovoltaic system," in International Conference on Green Energy Conversion Systems (GECS), 2017.

[13] Chou, Yang and Chen, "Maximum Power Point Tracking of Photovoltaic System Based on Reinforcement Learning," vol. 19, no. 22, p. 5054, 2019.

[14] M. A. Awan and T. Mahmood, "A Novel Ten Check Maximum Power Point Tracking Algorithm for a Standalone Solar Photovoltaic System," Electronics, vol. 7, no. 11, p. 327, 2018.
[15] T. Wang, "Design of Stand-Alone Photovoltaic System Based on Maximum Power Point Tracking," in IEEE 4th International Conference on Computer and Communications (ICCC), 2018.
[16] F. Belhachat and C. Larbes, "A review of global maximum power point tracking techniques of photovoltaic system under partial shading conditions," Renewable and Sustainable Energy Reviews, vol. 92, pp. 513-553, 2018.
[17] O. Abdel-Rahim, H. Funato and J. Haruna, "Novel Predictive Maximum Power Point Tracking Techniques for Photovoltaic Applications," Journal of Power Electronics, vol. 16, no. 1, pp. 227-286, 2016.
[18] E. Koutroulis and F. Blaabjerg, "Overview of Maximum Power Point Tracking Techniques for Photovoltaic Energy Production Systems," Electric Power Components and Systems, vol. 43, no. 12, pp. 1329-1351, 2015.
[19] C.-C. Tong and C.-J. Chao, "An adaptive maximum power point tracking controller design for serial-connected photovoltaic modules," in IEEE 43rd Photovoltaic Specialists Conference (PVSC), 2016.
[20] S. Agarwal and M. Jamil, "A comparison of photovoltaic maximum power point techniques," in Annual IEEE India Conference (INDICON), 2015.
[21] F. Khosrojerdi and N. H. Golkhandan, "Microcontroller-based maximum power point tracking methods in photovoltaic systems," in 9th Annual Power Electronics, Drives Systems and Technologies Conference (PEDSTC), 2018.
[22] S. Wei, J. Lei, E. Tan and D. Wang, "Study on maximum power point tracking control techniques in PV system," JOURNAL OF ELECTRONIC MEASUREMENT AND INSTRUMENT, vol. 25, no. 6, pp. 490-494, 2011. .
[23] Koutroulis and F. Blaabjerg, "Overview of Maximum Power Point Tracking Techniques for Photovoltaic Energy Production Systems," Electric Power Components and Systems, vol. 43, no. 12, pp. 1329-1351, 2015.



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