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Determining Maximum Power Point of Solar Array in MATLAB

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Abstract

The MPPT algorithm is based on the calculation of the photovoltaic (PV) output power and the power change by sampling both the PV Array current and voltage Virtual Instrumentation (VI) is widely used in testing, measurement and control application as it is easy to understand and implement. Maximum power point tracking (MPPT) of solar array is demonstrated using a virtual instrument (VI) Find better angle with the help of INC. Voltage and current signals sensed from photo voltaic (PV) array are fed as input to the VI and control signal is obtained as output. The duty cycle of a buck converter which is placed between solar array and the load is controlled using the control signal. Incremental conductance (INC) algorithm is used for tracks maximum power.

Keywords: MPPT, Solar, INC, Photovoltaic, PV systems

Introduction

The non-linear current-voltage and power-voltage characteristics of solar arrays, which change with temperature and radiation. The MPPT approach is important in PV systems for tracking the solar array's maximum power point. A photovoltaic (PV) system's MPPT approach has the task of continually fine-tuning the system such that the solar array always works at maximum power point regardless of the weather or load circumstances.

According to maximum power transfer theorem, the power delivered to the load is maximum when the impedance of source matches the impedance of load. Thus, the impedance seen from the converter side matches the internal impedance of the solar array.

The INC approach is based on the solar module's I-V curve. In order to monitor the maximum power point, the incremental conductance approach takes into account changes in the duty cycle of the converter employed between the solar panel and load. This approach is expensive and complicated since it needs both a current and a voltage sensor. The MPP may be successfully tracked using the INC approach in a variety of meteorological scenarios.

Photovoltaic (PV) systems have witnessed a rapid increment, the yield mainly relies on the working condition. In most cases, it is hard to obtain the optimal yield. Therefore, Maximum Power Point Tracking (MPPT) controllers witness much attention as an important optimization field of PV systems. These controllers employ different algorithms and they vary in their efficiency, performance, modernity, complexity, and tracking speed. MPPT controllers have witnessed a rapid improvement, they can be generally classified as conventional and advanced methods.

Conventional methods are relatively simple but they can't distinguish between the local and global peaks if partial shading occurs, therefore, their efficiency is relatively low. Advanced tracking methods are widely used due to their superior efficiency. Due to the limitation of the singular conventional and advanced methods, hybrid methods find their way to solve these limitations. Selecting the finest MPPT method is still an open issue, this issue can be solved by implementing a survey of the applied methods. This study gives a concise classification and evaluation review of all the applied MPPT methods. This study also provides an accessible reference to undertake mass research works in MPPT in the near future. Recently, a massive number of MPPT algorithms and designs are proposed in the literature. Each approach has its own specifications, limitations, and applications. There is no specific evaluation study that classifies methods since each one can be suitable for an application and not for another. Therefore, there is no unique classification of the MPPT algorithms.

In this study, MPPT methods are classified based on different norms such as tracking technique, sensing implementation, and contemporary. Under each of these classifications, there are several sub-categories based on different factors, working principle or implementation.

Most of the MPPT approaches are using the control variables that sensed from the PV modules output in this implementation, the power stage input VPV and IPV are used as input to the controller for the MPP tracking controller as shown in in this approach, the output power is easily captured directly from the PV arrays. The power converter control parameter α is continuously tuned until the PV array is loaded at its MPP. Firstly, voltage and current at the PV generator output (i.e. MPPT converter input) are sensed, and the power is calculated successively by their multiplication. Then, the MPP is approached in an iterative process.

The control of MPPT using the output parameters of the converters is been applied in many PV systems Unlike MPPT control via the input parameter approach, this implementation employs sensors in the output of the DC-DC converter as measured parameters.

The aim of this work is to realize a study and comparison between two methods of MPPT: the Incremental conductance (INC-cond) method and the perturbation & observation method (P & O). For this we devoted a part of the work to the study of the components constituting the global photovoltaic system namely: the photovoltaic module, the DC-DC converter, and the MPPT controller. The second step is reserved to comparison between MPPT methods -both designed in the MATLAB / SIMULINK environment- performed by simulation

Literature and Review

Kriti Jain, Prof. Manju Gupta & Dr. Aashish Kumar Bohre *et al*. [2018] [1] I have initially observed, the overall PV models run with constant irradiations with P and O and INC MPPT technique for the presented system. For constant irradiations the boost converter output voltage including P&O and INC MPPT method are 341 V and 350.2 V respectively. Also, the boost converter output voltage including P&O and INC MPPT method for constant irradiations are 8970 W and 9465 W respectively. It is seen that at constant irradiations the INC MPPT algorithm/ technique/ method gives better results and less oscillation over P&O. Subsequently, the proposed system models run with variable irradiations including P&O and INC MPPT method. In the results analysis it’s found that the output voltage of boost converter including P&O and INC MPPT method for variable irradiations are 274.7 V and 287.8 V respectively. Furthermore, the boost converter output power with P&O and INC MPPT method for variable irradiations are 5825 W and 6393 W respectively. Hence, from the above analysis it can be concluded that the INC method shows a superior performance over P&O method.

LI Sheng-qing, ZHANG Bin, XU Tian-jun and YANG Jun *et al*. [2014] [2] on the basis the study of existing control algorithm of single-stage photovoltaic grid-connected inverter system, this paper proposes a new kind of MPPT algorithm, namely, artificial fish swarm algorithm. Through the establishment of the system simulation model, the operation of the system is simulated and it is compared with the control effect of P&O algorithm. Simulation and experimental results show that single-stage type grid-connected system can be stable and effectively track maximum power point of photovoltaic array tracking under the control of AFSA, it shows a good dynamic characteristic.

Radhia Garraoui, Mouna Ben Hamed and Lassaad Sbita *et al*. [2015] [3] This paper proposes two methods of maximum power point tracking algorithm for photovoltaic systems, based on the first hand on fuzzy logic control and on the other hand on the first order sliding mode control. According to the nonlinear characteristic of photovoltaic array, it’s necessary to find a solution to track the maximum power of the PV system in order to improve its efficiency. The fuzzy logic controller was presented in many works. It provides fast response and good performance against the climatic and load change and uses directly the DC/DC converter duty cycle as a control parameter. Moreover, the sliding mode control approach is recognized as one of the efficient tools to design robust controllers it has been receiving much more attention within the last two decades and many research are dealing with this type of robust controllers. A detailed comparison between the fuzzy logic and slinging mode controllers was presented in this work. Simulation results show that the proposed algorithms can effectively improve the efficiency of a photovoltaic array output.

SAIDI Khadidja, MAAMOUN Mountassar and BOUNEKHLA M'hamed *et al*. [2017] [4] the connection between a photovoltaic generator (GPV) and a continuous type load is still a subject of study. This connection uses an adaptation stage acting as an interface between the GPV and the load. The adaptation stage is usually composed of a DC-DC converter monitored by a controller of the maximum power point MPPT (maximum power point tracking) The aim of this work is to realize a study and comparison between two methods of MPPT: the Incremental conductance (INC-cond) method and the perturbation & observation method (P & O). For this we devoted a part of the work to the study of the components constituting the global photovoltaic system namely: the photovoltaic module, the DC-DC converter, and the MPPT controller. The second step is reserved to comparison between MPPT methods -both designed in the MATLAB / SIMULINK environment- performed by simulation. The comparison results demonstrated good performance of the Incremental Conductance method compared to the Perturbe & Observe method.

Kaipakam Prakash, Pradeep Vejju and B Venugopal Reddy *et al*. [2016] [5] presently, on the planet, demand for electricity is growing on account of expanding populace and industrialization. To take care of the demand, there is a need to produce more power productively. In any case, the traditional sources, for example, fossil powers are draining day by day. So the exploration on the renewable energies particularly on photovoltaic systems/frameworks has achieved extraordinary significance. It is eco agreeable and is commotion less as there are no moving parts. The PV systems are easy to operate and to maintain.

Analysis of PV curve of maximum power point tracking (MPPT)

There are so many conventional and evolutionary MPPT techniques illustrated in the literature that are based on the technique of controlling the duty cycle and the output voltage of the boost converter. The MPPT command, 'Maximum Power Point Tracking', is an essential command for optimal functioning of the photovoltaic system. The principle of this control is based on the automatic variation of the duty cycle α by bringing it to the optimal value so as to maximize the power delivered by the PV panel.

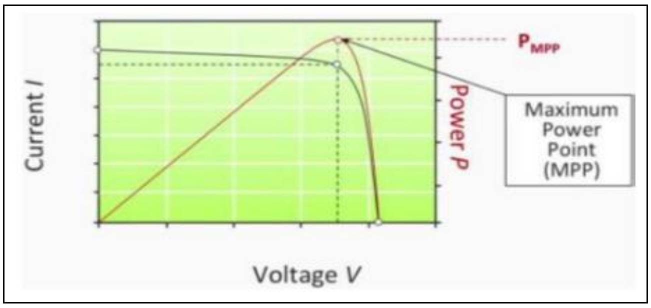

Fig 1: PV curve of maximum power point (MPP)

Incremental Conductance Algorithm 'Inc'

The principle of this algorithm (Figure 2) is based on the knowledge of the value of the conductance and on the increment of the conductance to deduce the position of the operating point relative to the point of maximum power, 'PMP'. If the conductance increment is greater than the opposite of the conductance, the duty cycle is decreased. On the other hand, if the conductance increment is less than the opposite of the conductance, the duty cycle is increased. This process is repeated until reaching the power point.

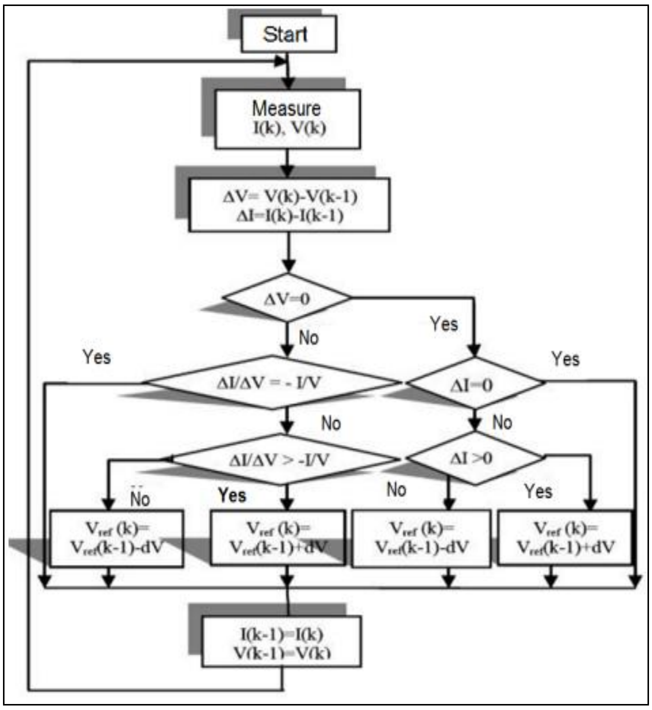

Fig 2: 'INC' algorithm flow chart

Simulation of PV array with INC techniques

The diagram produced under the MATLB / SIMULINK environment consists of a photovoltaic panel, a DC-DC voltage converter, an MPPT controller, and a load of 10 Ω as shown in Figure 2.

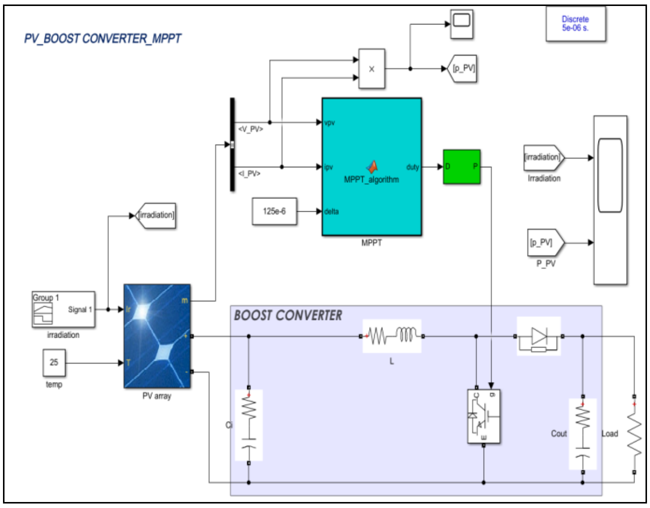

Fig 3: Simulink Model of PV array with MPPT and boost converter

Results

Simulation with Stable Condition: - T = 25 °C and W =800 w/m^2

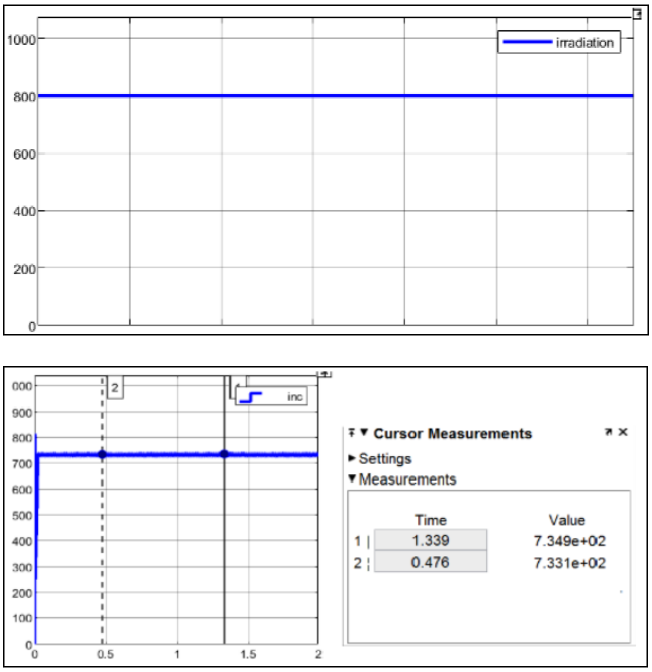

Fig 4: Simulation results of INC MPPT algorithm with stables conditions

Table 1: Analysis of Output Power with the Time

S. No	Time (In Seconds)	Power (In Watts)
1	0.476 Second	733.1 Watt
2	0.485 Second	733.4 Watt
3	0.526 Second	733.6 Watt
4	0.742 Second	733.9 Watt
5	0.926 Second	734.2 Watt
6	1.339 Second	734.9 Watt

Simulation with variable conditions

We started with W= 700 *w / m²* then W=1000 *w / m²* and ended with W=400 *w / m²* According to the Figure 5 which represents the curve of power as a function of voltage, we have:

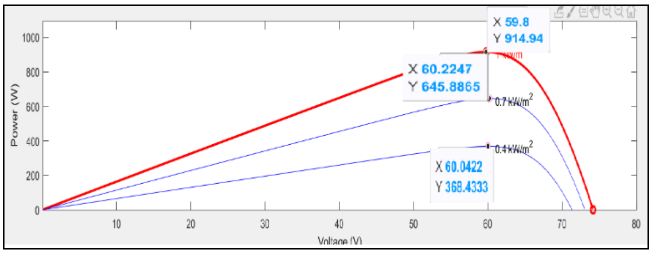

Fig 5: PV curves of panel array

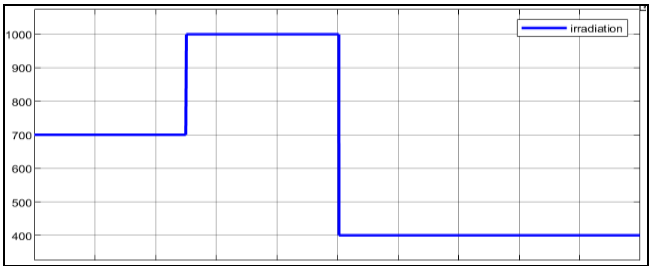

Fig 6: Simulation results INC MPPT algorithm with variables conditions

Table 2: Analysis of Power with the Irradiations

S. No	irradiations (w/ m²)	Power (In Watts)
1	400 w/ m²	368.43 w
2	500 w/ m²	425.45 w
3	550 w/ m²	565.19 w
4	650 w/ m²	598.36 w
5	700 w/ m²	645.86 w
6	1000 w/ m²	914.94 w

INC Methods for Different Level of Temperature & Irradiations

The INC MPPT algorithms are simulated and compared using atmospheric conditions. When atmospheric conditions are constant or change slowly, the INC MPPT method finds the MPP accurately at rapidly changing atmospheric conditions.

Table 3: INC V/S Temperature with MPPT

Irradiations G (w/m2)	Temperature °c	Power in watts using (INC)
350	30	332
550	30	425
856	35	712
1155	40	1036
965	45	865
750	50	689
895	50	725
1025	48	895

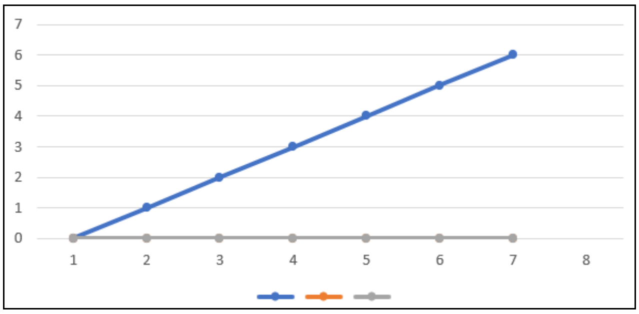

Fig 7: MPPT Power at different level of Temperature & Irradiations

Simulation and Results

The simulation and results of incremental conductance (INC) MPPT techniques for PV system with constant irradiations and variable irradiations are presented in this system simulation is divided into two sections:

INC MPPT techniques for PV system with constant irradiations

In the first case simulation of the PV system under irradiation = 1000 W/m2 and T = 25 °C and for second case simulation of system when solar irradiation, changes from 400 to 1000W/m2 at constant temperature T = 25 °C.

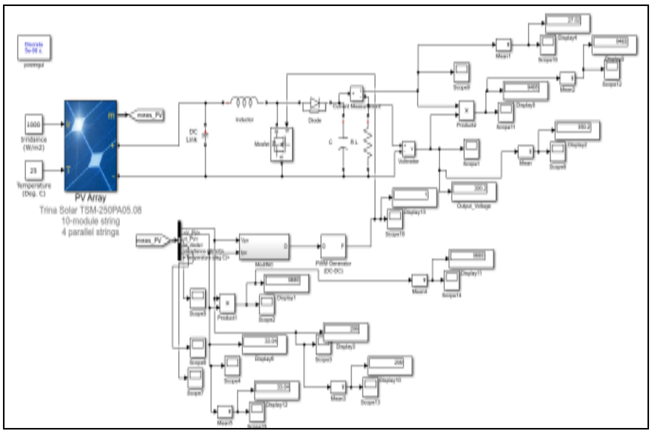

Fig 8: Simulation modeling of system with INC MPPT method for constant irradiation

The INC MPPT methods for PV system are presented including constant irradiations which is 1000 W/m2. The PV system was constructed using a 249.86 W array connected in centralized mode. The array composed with 4 parallel strings each containing 10 modules in series to obtain a suitable terminal voltage. The simulation modeling of system with INC MPPT method for constant irradiation is illustrated in Figure 7. PV array parameters is given in Table 3. The array voltage stabilized at approximately from 299 V for INC. The analysis of simulation results are illustrated in the Table 4 and Figures 8 to 12, also the Output Parameters with INC MPPT Method for Constant Irradiation is presented in Table below.

Table 4: PV array parameters

Max. Power	250 Watt	Current at Maximum Power	8.06
Isc	8.55 A	Voltage at Maximum Power	31
Voc	37.6 Volt	Series Connected String	10
Cell/Module	60	Parallel String	4

Table 5: Output Parameters with INC MPPT Method for Constant Irradiation

S. No.	Parameter	Output at Constant Irradiation 1000 (W/m2) (INC Method)
1	Panel Voltage	299
2	Panel Current	33.04
3	Temperature	25
4	PV Maximum Power/MPPT	9880
5	Boost Converter Output Voltage	350.2
6	Boost Converter Output Current	27.02
7	Boost Converter Output Power	9465

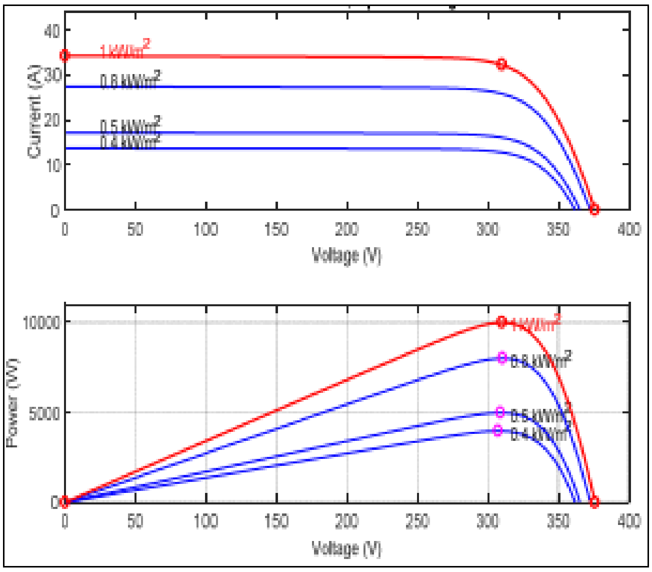

Fig 9: PV array V-I and P-V characteristic for varying irradiation

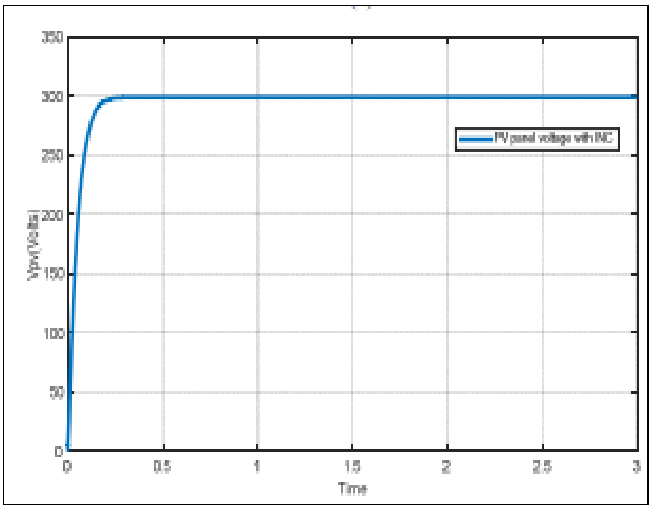

Fig 10: PV array voltage for constant irradiation with INC Method

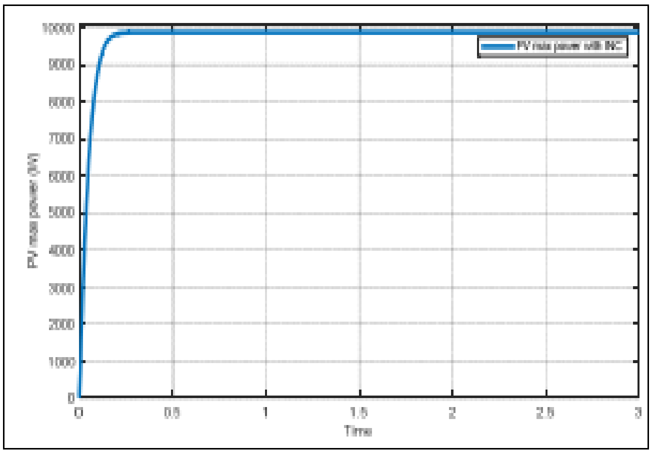

Fig 11: PV array maximum power for constant irradiation with INC Method

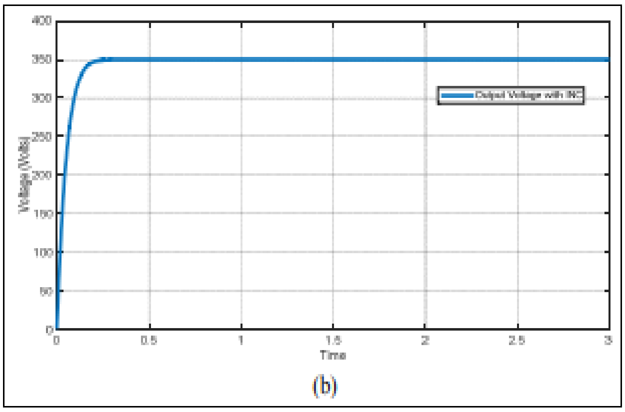

Fig 12: Boost converter output voltage for constant irradiation with INC Method

Conclusion

The converter provides in optimal conditions a voltage at its output greater than that provided by the PV generator. The MPPT command adapts the PV generator to the load: transfer of the maximum power supplied by the PV generator. Our study focused on the analysis, implementation MPPT methods with the INC. To this end, the GPV, the DC-DC Buck converter controlled by the MPPT commands were simulated on Mat lab environment by Simulink software. The simulation result showed that the In-kind method has a better performance succeeded in minimizing the oscillations around the MPP point but the disadvantage is that the MPP tracking time is slower, the INC can be improved by adjusting the incrementing step so as to have a rapid response.

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