

# AN INTELLIGENT CONTROLLED TRACKING OF POINT OF MAXIMUM POWER IN STANDALONE PV SYSTEM UNDER REALISTIC VARYING IRRADIATIONS

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## Abstract

Owing to the proven footmark for the clean, green energy, compact in size, cost effective and ease of availability of sunlight, applications of photovoltaic (PV) panels are continuously on rise. However, the low conversion efficiency is a major concern for researchers. The conversion efficiency may be improved significantly if PV panels are operating on maximum power point. Solar irradiances received by PV panel are not constant always. The irradiation may be linear and nonlinear, fast, slow and sudden varying in nature. Thus, tracking of maximum power point is a huge challenge. This irregular behaviour of incident irradiances may result in oscillations in output and low conversion efficiency. In order to enhance the performance, a suitably designed controller, operating at maximum power point is needed. This paper highlights maximum power point tracking under varying irradiation conditions (viz. Step Variable Irradiance and Ropp's irradiance profile) using two control techniques namely Perturb and Observe (P&O) and Incremental Conductance (IC). The simulation results obtained for two control techniques are compared for system efficiency, tracking of maximum power point and enhancement of voltage. The comparison of results reveals that there is far better improvement in overall efficiency, output power, output voltage and faster regaining of the maximum power point path with IC technique as compared to P&O technique. Thus, IC control technique excellently tracks maximum power point with reduced probability of deviation and better oscillation damping under varying incident irradiances.

**Keywords:** PV Array; Perturb and Observe (P&O); Incremental Conductance (IC); Maximum power point tracking (MPPT); Irradiances

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## Introduction

Conventional energy resource's extensive exhaustion is the biggest threat to energy security around the world. However, renewable energy's penetration in all fields of concern is rising due to its inexhaustible and green nature (Pushpraj and Singh, 2021). Aiming to total renewable energy goal in coming decades around the world, renewable energy resources are gaining interest in research community. Thus, PV array becomes one of the most promising tools and attaining more attention due to continuing technical developments, different applications such as automatic solar tracking (Kumar and Singh, 2017), large PV Farms as PV inverters, PV Statcom (Kumar *et al.*, 2021; Singh *et al.*, 2023; Kumar *et al.*, 2022). Also, a remarkable drop in the prices of PV panels (Kannan and Vakeesan, 2016; Kajela and Mukhdeep, 2017; Nath and Sen, 2021;). To estimate the economic feasibility of PV array, output power is of great concern. Identifying the standard, I-V characteristics can estimate accurately the power output of the PV array, results in many methods for estimating the profile of PV array which depends on mathematical modelling (Bharatee *et al.*, 2022). Further the optimization is carried out by implementing different intelligent techniques. Many researchers mentioned different techniques for tracking maximum power point (Bollipo *et al.*, 2020). They are further classified as some direct methods and indirect methods, which are then optimized for performance by using intelligent methods (artificial intelligence) such as Fuzzy logic control, PSO etc).

A comparison of traditional MPPT (P&O) and FLC for varying solar irradiances and temperature with the steady state analysis which incorporates enhanced P&O performance through FLC (Remoaldo and Jesus, 2021., Rai and Rahi 2022). The analysis of MPPT (P&O) and IC method by theoretical and digital simulation and concluded that IC has better dynamic performance and improves the output of PV array. (Belkaid *et al.*, 2016; Chen *et al.*, 2018). A comprehensive review of AI-based MPPT techniques on the basis of cost, complexity of system, efficiency, speed of tracking etc. algorithms are categorized and evaluated (Salim *et al.*, 2021). An analysis of seven methods for obtaining parameters using one diode model is discussed. Few methods demonstrate a good determination in I-V characteristics however they fail when incorporated with other PV panels (Duc *et al.*, 2020). A modified P&O MPPT was proposed which is mainly depends on output voltage and current. It includes current as the third parameter. This controller perfectly tracks MPPs with much

less deviation of tracking path. If voltage change w.r.t current is negative, PV array is working at constant irradiation level and tracking method is conventional one, else operating at varying atmospheric conditions with the relative change in duty cycle of converter. Average tracking efficiency of this method is 97.4% (Belkaid *et al.*, 2017). Adaptive P&O MPPT is also discussed. In this primarily a point is searched which is fraction of voltage at open circuit (which depends on photocurrent and saturation current) to irradiance and temperature. If constant irradiation and temperature, then conventional method works, else method shifts to some different point and then applied the traditional P&O. Average and maximum efficiency of this method is 98.85% and 99.8% respectively (Zhang *et al.*, 2013).

Grid tied PV system encounters power quality problems which are readily compensated by many techniques (Badoni *et al.*, 2023). Many optimization algorithms are also incorporated to enhance the performance quality of PV array (Kumar *et al.*, 2022).

A comparison of proposed work with previous studies is presented in Table 1. This has been observed that existing studies mainly consider the incident irradiation patterns comprises of different levels of illumination for fixed time Further, the numeric findings of many parameters are not discussed. The findings are described on the basis of graphical representations. However, proposed work considered multiple testing condition combinations as one incident irradiation pattern which is more realistic realisation of environmental conditions. The findings are supported with numeric values with graphical representation.

The literature review motivates to propose two techniques viz. Perturb and Observe (P&O) and Incremental Conductance (IC) techniques for efficient tracking of maximum power point in PV arrays under varying incident irradiances accompanied with comprehensive performance analysis w.r.t tracking efficiency, ability to regain locus of maximum power point, damping, overall efficiency, output power and voltage. Further, the MATLAB/Simulink results show that incremental conductance technique results in better oscillation damping with accurate tracking as compared to perturb and observe technique under varying incident irradiation conditions.

This paper is structured as follows: Firstly, Configuration and mechanism of proposed system is explained which is followed by Simulation implementation and MATLAB modelling. Further, results are presented and finally conclusions are presented

**Table 1. Shows comparison of proposed work with published work**

| References                       | Testing condition                                       | Control Techniques Used | Conclusions/Remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|----------------------------------|---------------------------------------------------------|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ali <i>et al.</i> , (2022)       | Ropp, Sin, One day                                      | P&O                     | Provides a good foundation and motivated for proposed work. Primarily analysed tracking efficiency for grid integrated system. No other parameters are focussed.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Rai <i>et al.</i> , (2022)       | Different Illuminations                                 | P&O, FL                 | Comparison of tracking efficiency for either control technique. No other test conditions are examined. Further no other parameters are analysed.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Remoaldo <i>et al.</i> , (2021)  | Step change                                             | P&O, FL                 | Comparison of tracking efficiency for either control techniques. Analysed for only one test condition.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Abdel-Salam <i>et al.</i> (2020) | Ropp, Step, Ramp                                        | P&O                     | Provides a good foundation and motivated for proposed work. Comparison of tracking efficiency for different P&O methods. No other parameters are discussed.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Shang <i>et al.</i> (2018)       | Step Change, Startup test, ability test                 | P&O, PSO, FP            | Provides a good foundation and motivated for the proposed work. Primarily tracking efficiency is focussed and analysed using controlling techniques. No numerical calculations are provided for improved tracking efficiency. Further no other parameters are discussed.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| Chen <i>et al.</i> (2018)        | Different Illuminations                                 | P&O, IC                 | Comparison of tracking for both control techniques. Analysed for only one testing conditions. Further, no numerical calculations are provided to support the results.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Ali <i>et al.</i> (2018)         | Fast and Step change                                    | P&O                     | Analysed for three phase grid tied inverter system. Primarily focussed on tracking efficiency. No other parameters are discussed.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Proposed Work                    | Step variable irradiance and Ropp's irradiance profile. | P&O, IC                 | Step variable irradiance testing condition is proposed, which covers maximum testing conditions as one incident irradiation pattern which is more realistic realisation of environmental conditions compared to only short phase of irradiations separately (as mainly considered in earlier studies). Further a more comprehensive performance will be analysed based on ability to regain locus of maximum power point, tracking efficiency, damping of oscillations, stability, overall efficiency, output power and output voltage employing P&O and IC controlling techniques that will be supported with numeric values and graphical interpretation from simulation (as compared to earlier studies which presents only one parameter i.e. tracking efficiency. They are primarily supported with graphical interpretation with a few numeric findings). |

## Materials

### Configuration of proposed System PV Array

Photovoltaic cells (also called as solar cells) convert light (photons) directly to electricity (voltage) thus the name. Discovered by Edmund Baquet, a French scientist in 1839, PV cells have remarkable performance with hardly any untouched field. However, increasing conversion efficiency is the need of hour and a new research interest among researchers and designers. As unit solar cell is incapable of producing required amount thus connected in series to form solar modules or panels and then connected in parallel forming solar array. Finally, they are implemented for required application. In this paper 1Soltech LSTH-215-P PV array is taken. We have selected two parallel strings with two modules connected in series per string. Datasheet specification of PV Array is shown in Table 2. Figure 1(a) is displaying I-V and P-V characteristics of selected PV Array for different irradiation values. For 1KW/m<sup>2</sup> of sun's irradiation,

maximum power of 852.6 KW is generated at 58V. Figure 1(b) is depicting PV solar array conversion process. This paper proposes two control techniques namely P&O and IC (explained in following sections) which controls the boost converter duty cycle. A resistive load is used for simplicity.

**Table 2. Shows PV array Specification (1 Soltech 1 STH-215-P)**

| Parameters                           | Values   | Units  |
|--------------------------------------|----------|--------|
| Max. Power                           | 213.15   | W      |
| Open circuit Voltage (Voc)           | 36.3     | V      |
| Voltage at maximum power point (Vmp) | 29       | V      |
| Current at maximum power point (Imp) | 7.35     | A      |
| Cells per Module                     | 60       | -      |
| Temp. Coeff. Of Voc                  | -0.36099 | % / °C |
| Temp. Coeff. Of Isc                  | 0.102    | % / °C |
| Short circuit current (Isc)          | 7.84     | A      |

### Proposed control techniques for tracking maximum power point

Many PV arrays are interconnected in series as well as in parallel to fulfil the requisite of power for particular application. To enhance the efficiency of conversion PV array is expected to operate at point of maximum power. However, in realistic condition of weather, it is hard to make them run at global maximum power point else they take the local maximum power point at operate on it and perhaps results in reduced performance (Zhang *et al.*, 2013). To cope up with this lowered performance, a number of techniques for tracking and control for point of maximum power used so far (Bollipo *et al.*, 2020). They are mainly distinguished as direct and indirect methods which further used as per the application (Saxena *et al.*, 2023). Among all the methods mentioned in literature (P&O, Hill climbing, IC, Constant voltage, current, Fuzzy Logic, Particle swarm etc.) some are classical approaches, some are intelligent approaches, some are used for optimization and could be used in a hybrid way (Uzunoglu *et al.*, 2009; Ibrahim *et al.*, 2015; Khaled *et al.*, 2018; Kamran *et al.*, 2020). The primary concern behind each control techniques is to check for tracking of point of maximum power in PV array so that make them able to operate on this optimal point and thus in turn gaining the excellent performance of it even under varying irradiances (Kesraoui *et al.*, 2016; Belkaid *et al.*, 2017; Shang *et al.*, 2018). Two control techniques viz. Perturb and Observe (P&O) and Incremental conductance (IC) techniques are proposed. The perturb and

observe technique tracks maximum power point power. The fundamental idea behind P&O is to regularly alter the operating point of the power converter and then monitor or sense the resulting effects. The power is checked every time by controller after a small voltage change which in

turn ends when power is not incrementing. This point is maximum power point where power and voltage remain unaltered, along with zero derivative. (Ahmed and Salam 2015; Ahmed *et al.*, 2018). P&O operates by altering the PV array's dc voltage (terminal) and monitoring the effects on the array's output power (Ibrahim *et al.*, 2015). Figure 2(a). shows PV array's block diagram incorporating Boost converter implementing P&O algorithm for controlling duty cycle and thereby tracking the maximum power point. Another approach for monitoring a photovoltaic (PV) solar system's point of maximum power by method of Incremental Conductance (IC). By comparing the incremental conductance with the array conductance, MPP is calculated. When both of these equal values exist, the resultant voltage is referred to as the MPP voltage. The voltage is held at this level by the controller until the amount of radiation changes and the process is repeated. Because of its straightforward design and ability to distinguish between instantaneous increases in power, voltage and w.r.t variation in the external environment, the incremental conductance approach can increase tracking efficiency. Figure 2(b). shows PV array's block diagram incorporating Boost converter implementing IC algorithm.

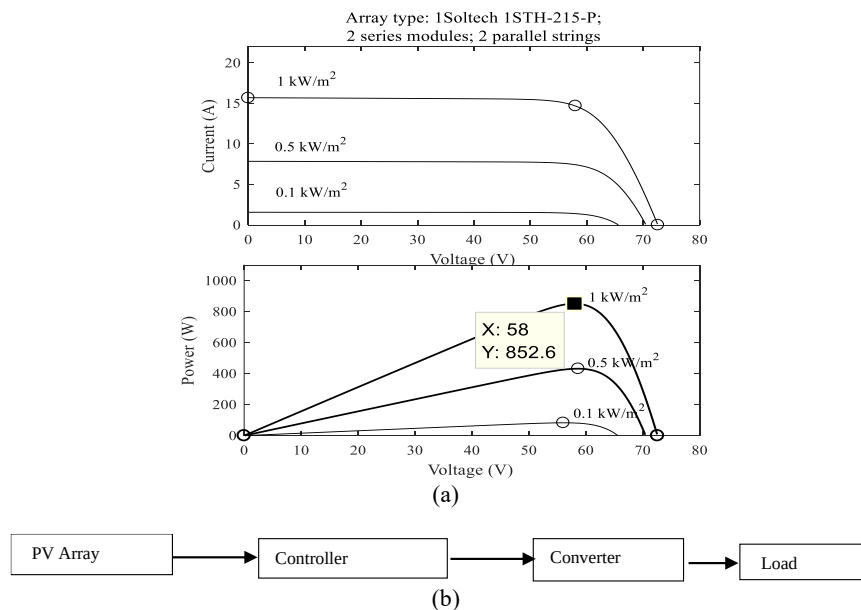
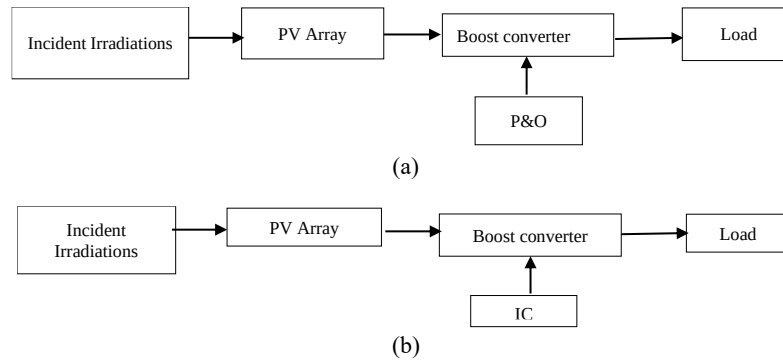
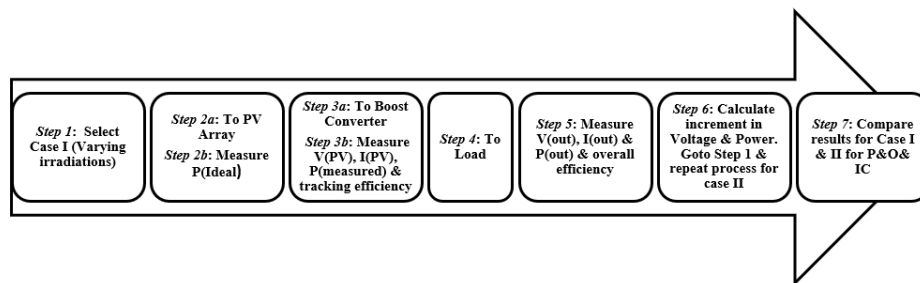


Figure 1. (a). Shows I-V and P-V Characteristics (b). Shows Building Blocks of PV array conversion process



**Figure 2. (a). Shows Block diagram of PV array system incorporating boost converter with P&O (b). Shows Block diagram of PV array system incorporating boost converter with IC**



**Figure 3. Shows Process flow depicting methodology used for obtaining the performance of system**

This work focuses on variable incident irradiances on PV panel. The IC control technique is considered in comparison to P&O control technique. The IC technique is faster and quick over P&O control technique. The dynamic conditions, good damping of oscillations, good tracking of point of maximum power, better accuracy. In P&O technique, perturbation of voltage is carried out and simultaneously notices the change in power whereas IC technique adjusts the operating point by incrementing slope of power-voltage curve. Thus, attain the point of maximum power more quickly. Higher oscillations around the point of maximum power point are more significant in P&O which are not dominant with IC technique. Thus, IC technique is chosen for comparison with P&O.

### Mechanism of proposed system

Step wise step mechanism of proposed system is depicted as in Figure 3.

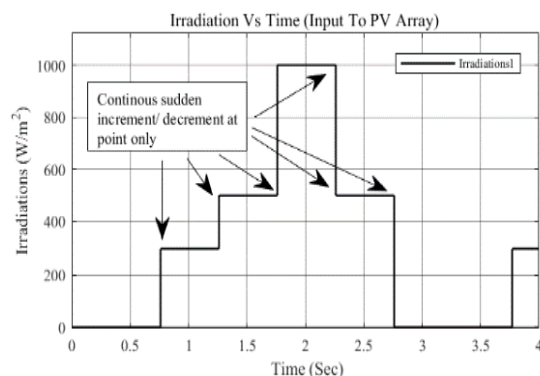
**Step 1:** It starts with selecting the varying incident irradiances, case 1 or 2 as shown in Figure 4 and Figure 5 and described in concerned section 4.

**Step 2a:** At this step, selected case 1 varying irradiances are subjected as input to PV array.

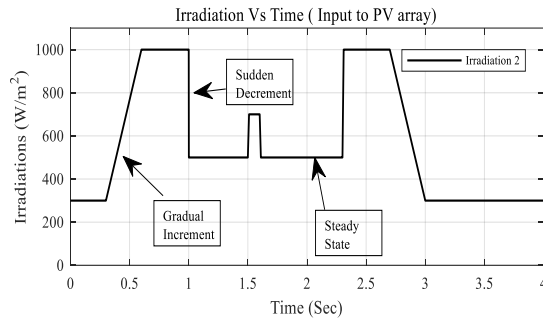
**Step 2b:** At this point, P(ideal) is measured (It is the maximum power in selected PV array for

selected case 1 or 2 of varying irradiances. As mentioned earlier and shown in Figure1(a) maximum power is 852.6 W for 1000W/m<sup>2</sup> of irradiances) as shown in Figure 6, Figure 7, Figure 8 and Figure 10.

**Step 3a:** At this step output of PV array feeds boost converter whose duty cycle is controlled with proposed technique namely P&O or IC.



**Figure 4. Varying Solar Irradiances Showing Sudden variation at points only (Step Variation)**



**Figure 5. Varying Solar Irradiations showing Ropp's Irradiance Profile**

*Step 3b:* At this step,  $V(PV)$ ,  $I(PV)$  and  $P(\text{measured})$  are obtained which are voltage, current and maximum power produced by PV array respectively as shown in Figure 6, Figure 7, Figure 8 and Figure 10. Further tracking efficiency

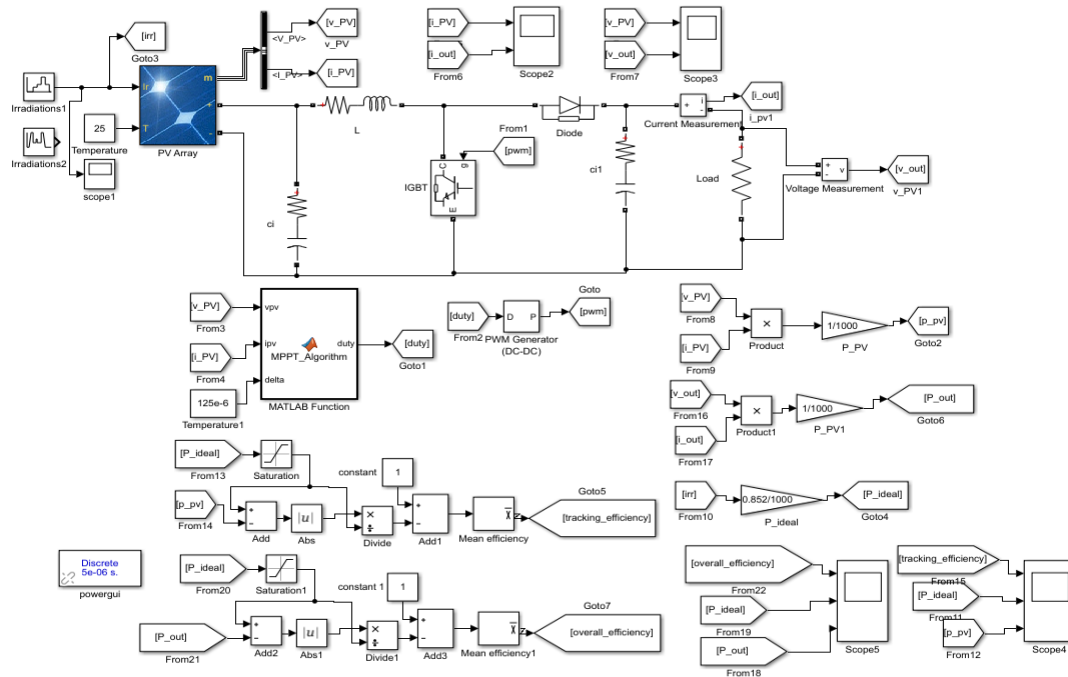
which is tracing of  $P(\text{ideal})$  and  $P(\text{measured})$  as shown in Figure 8 and Figure 10 is deduced

*Step 4:* Finally, a simple resistive load is connected at the output terminal of boost converter.

*Step 5:* At this point  $V(\text{out})$ ,  $I(\text{out})$  and  $P(\text{out})$  are obtained which are voltage, current and power at the load respectively as shown in Figure 6, Figure 7, Figure 8 and Figure 10. Further overall efficiency which is tracing of  $P(\text{ideal})$  and  $P(\text{out})$  of the system as shown in Figure 8 and Figure 10 is deduced.

*Step 6:* At this step, calculation of increment in voltage and power for both technique is done as shown in Table 3, Table 4 and Table 5. Further move to step 1 and repeat the process for case 2.

*Step 7:* At this step all the results for case 1 and case 2 for both the proposed control techniques viz. P&O and IC are compared as shown in Table 3 Table 4 and Table 5.



**Figure 6. Shows simulation of PV array incorporating P&O for varying incident irradiances**

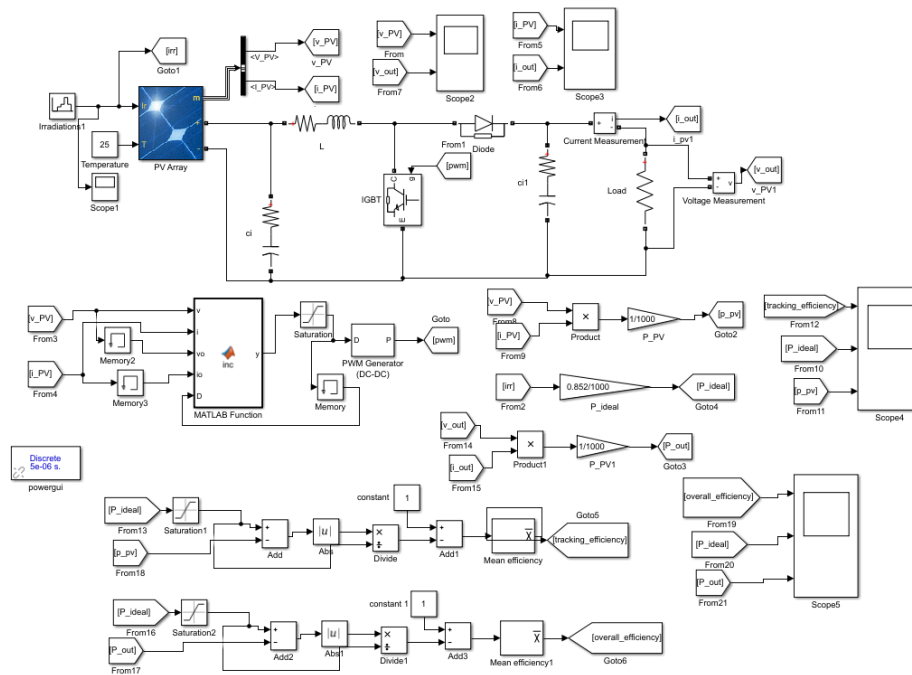


Figure 7. Shows simulation of PV array incorporating IC for varying incident irradiances

## Methods

### Simulation implementation and MATLAB modelling:

The proposed system is modelled with two controlling techniques namely P&O and IC in MATLAB and Simulink environment R2017b. Also, two testing scenario showing different variation of incident solar radiations w.r.t in PV array are also simulated. A short span of time is taken for showing the ability of proposed controlling techniques for accurate, efficient and fast tracking of point of maximum power in PV arrays. Both techniques are then tested for each scenario one by one and results are deduced thereafter.

### Incident solar irradiances

PV arrays encounter variable incident irradiances throughout the day. These PV arrays are specified with parameters for standard conditions in their datasheets. However, before implementing for any application, they are tested for some irradiation tests which represent the realistic scenario of incident solar irradiation at the input of PV array. These tests give useful information regarding the tracking of point of maximum power and thereby optimizes the performance of PV array.

Two tests are conducted one is incorporating step variation at one point only whereas another

shows the gradual and sudden increment and decrement variations (Shang *et al.*, 2018; Abdel-Salam *et al.*, 2020; Ali *et al.*, 2022). A wide range of tests highlighted in the literature are incorporated in aforesaid two test scenarios thereby authors trying to test the tracking algorithms for maximum spower point for all the maximum possible realistic condition of change in irradiance level (Abdel-Salam *et al.*, 2020; Ilyas *et al.*, 2021). One is Startup test, which evaluates at the starting condition (Shang *et al.*, 2018). Since there is low power generation at the night, every morning PV system need to be started. Another is step test it occurs when clouds or birds passes very rapidly over the PV system. (Kumar *et al.*, 2023) Another is gradual increment, which is tested as ramp input. All the tests stated earlier are incorporated in two cases and are explained as follows:

### Case 1: Step Variable Irradiance

As shown in Figure 4, irradiation variation is changing continuously at one point only (step variation) (Shang *et al.*, 2018). It starts with a step change of 300 W/m<sup>2</sup> at 0.76 sec then another step changes to 500 W/m<sup>2</sup> at 1.26 sec then third sudden step change is given at 1.76 sec to enhance it up to 1000 W/m<sup>2</sup> afterwards a steady state of 1 sec is provided then sudden decrement occurs step wisely at 2.26 sec and 2.76 sec respectively.

### Case 2: Ropp's irradiance profile

Figure 5 depicts a different pattern which resembles Ropp's irradiance profile (Abdel-Salam *et al.*, 2020). This test too determines whether the tracking algorithm is able to cope with sudden and gradual increment and decrement in incident radiations. This irradiation profile starts with a gradual (linear) increment at initial points then sudden step decrements are provided which is followed by steady state condition then sudden step increment and lastly sudden decrement are given and finally steady state condition is achieved. A wide range of variation is incorporated in both the irradiation scenario so as to create a realistic solar variation thereby checking the capability of tracking algorithm.

### Simulation setup

The simulation of PV array under varying solar irradiation patterns (case 1 and case 2), is carried out in MATLAB and Simulink environment. PV array (Table 2.), incident solar irradiation patterns (case 1 and case 2), Boost converter assembly with following specification:  $R = 0.1\Omega$  and  $L = 2\text{mH}$ ,  $R = 0.01\Omega$  and  $C = 100\mu\text{F}$ .

### Perturb and Observe(P&O)

In this, improved P&O algorithm is designed and written in Simulink and MATLAB

environment. Firstly, PV array is set to fed with variable incident irradiances as in case 1 then it is linked to boost converter assembly. Its duty cycle is controlled with P&O algorithm. Finally, performance of PV array is obtained. Secondly the same PV array - boost converter assembly is fed with variable incident irradiation as in case 2 and same technique for boost converter's duty cycle controlling are employed. Finally, performance is again obtained.

### Incremental Conductance (IC)

Now the PV array is fed with input irradiation as in case 1 and in turn connected with boost converter. The converter duty cycle is controlled with IC algorithm (designed in Simulink/MATLAB environment). The PV array-boost converter assembly is set to variable incident irradiances as in case 2 and again results are obtained and finally comparison is obtained on the ground of tracking of maximum power point.

## Results and Discussion

Results are obtained from simulation for case 1 and case 2 for two proposed techniques (P&O and IC). For first controlling technique (P&O), Figure 8 shows simulation results for case 1 and Figure 9

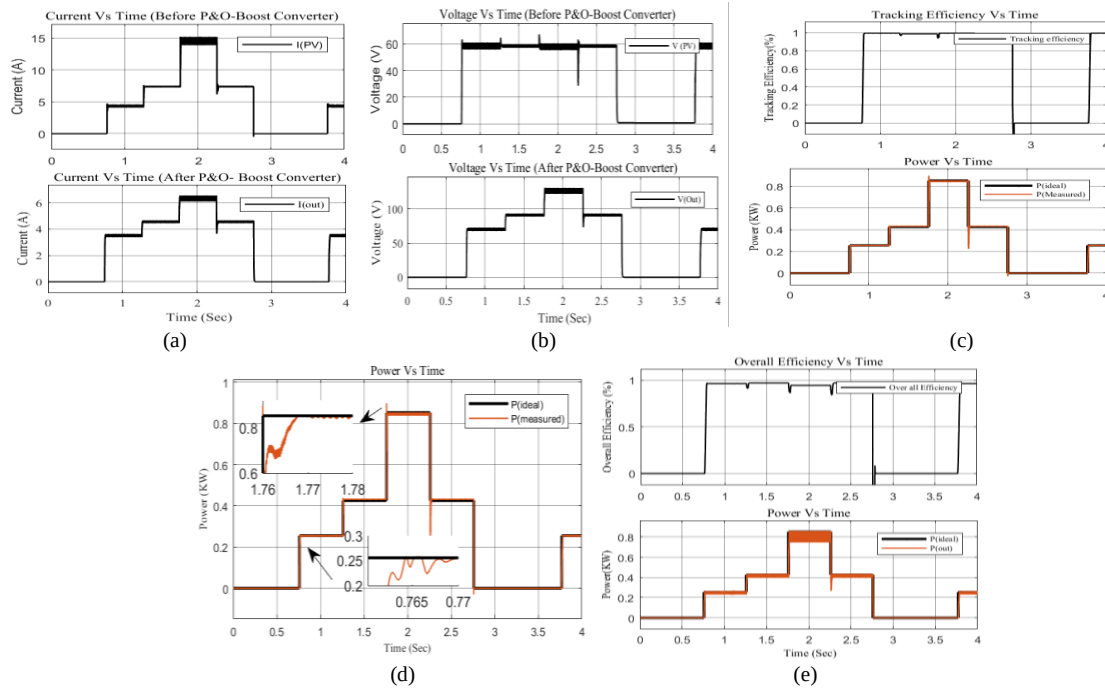


Figure 8. (Case 1) results showing simulation before and after implementation of P&O-Boost Converter (a) Current Variation (b) Voltage Variation (c) Tracking Efficiency and Power Variation (d) Enlarged view of Power variation (e) Overall Efficiency and Power variation

shows simulation results for case 2. For second controlling technique (IC), Figure 10 shows simulation results for case 1 and Figure 11 shows simulation results for case 2.

Case 1: Step Variable Irradiance (Implementing P&O Control Technique)

Case 2: Ropp's irradiance profile (Implementing P&O Control Technique)

view of Power variation (e) Overall Efficiency and Power variation

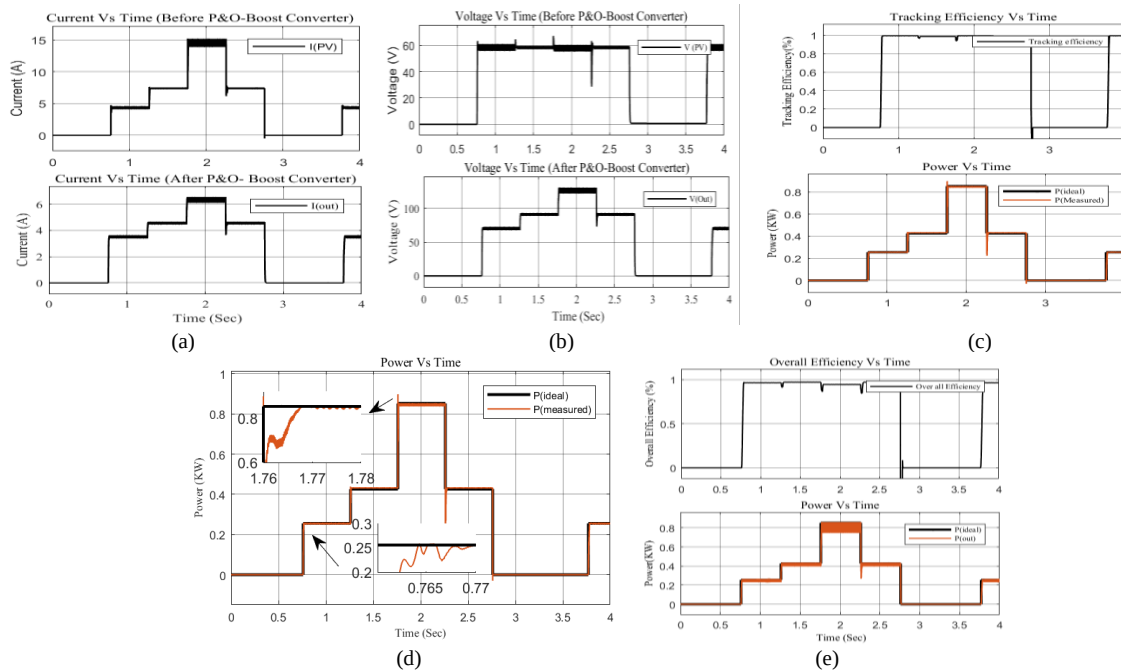
Figure 8(a) and Figure 9(a) show variations in current whereas Figure 8(b) and Figure 9(b) show voltage variations before and after implementation of P&O-Boost converter. Figure 8(c) and Figure 9(c) show variations in P (ideal) and P (measured) and thus deduced the tracking efficiency. Further enlarged view of variations in P (ideal) and P (measured) is presented in Figure 8(d) and 9(d). This shows fast and accuracy in maximum power point tracking with variations in incident

irradiation. Lastly, Figure 8(e) and Figure 9(e) show the variations in P (ideal) and P (out) and thus overall system efficiency is evaluated

Case 1: Step Variable Irradiance (Implementing IC control technique)

Case 2: Ropp's irradiance profile (Implementing IC control technique)

Figure 10(a) and Figure 11(a) show variations in current whereas Figure 10(b) and Figure 11(b) show voltage variations before and after implementation of P&O-Boost converter. Figure 10(c) and Figure 11(c) show variations in P (ideal) and P (measured) and thus deduced the tracking efficiency. Further enlarged view of variations in P (ideal) and P (measured) is presented in Figure 10(d) and Figure 11(d). This shows fast and accuracy in maximum power point tracking with variations in incident irradiation. Lastly, Figure 10(e) and Figure 11(e) show the variations in P (ideal) and P (out) and thus overall system efficiency is evaluated.



**Figure 9.** (Case 2) results showing simulation before and after implementation of P&O-Boost Converter (a) Current Variation (b) Voltage Variation (c) Tracking Efficiency and Power Variation (d) Enlarged view of Power variation (e) Overall Efficiency and Power variation

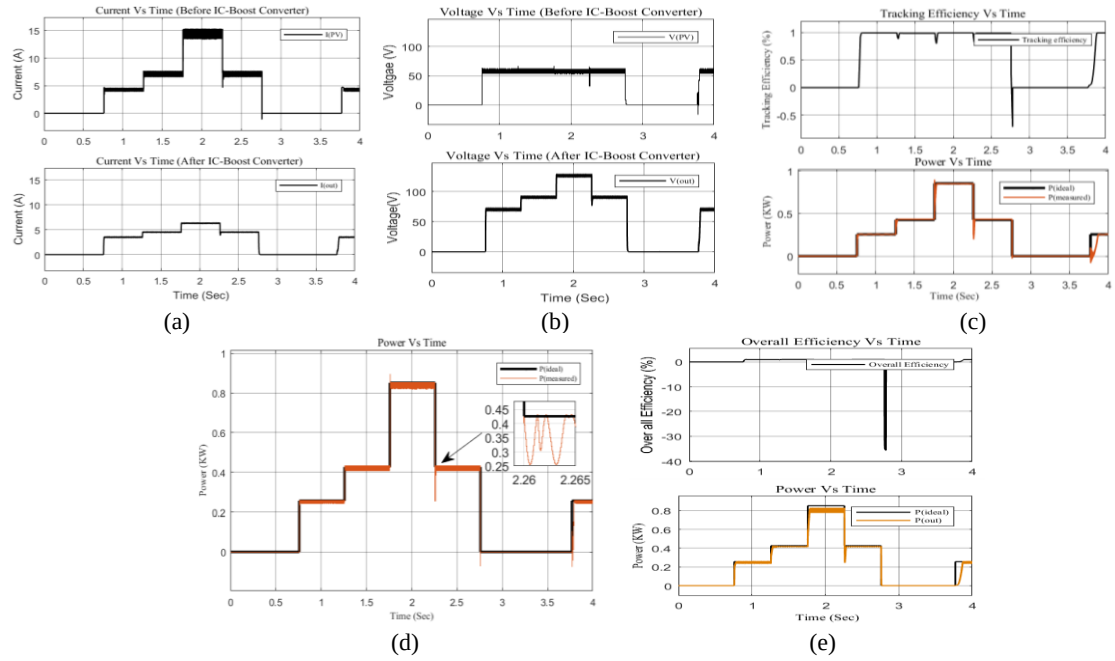


Figure 10. (Case 1) Simulation results showing before and after implementation of IC-Boost Converter (a) Current Variation (b) Voltage Variation (c) Tracking Efficiency and Power Variation (d) Enlarged view of Power variation (e) Overall Efficiency and Power variation

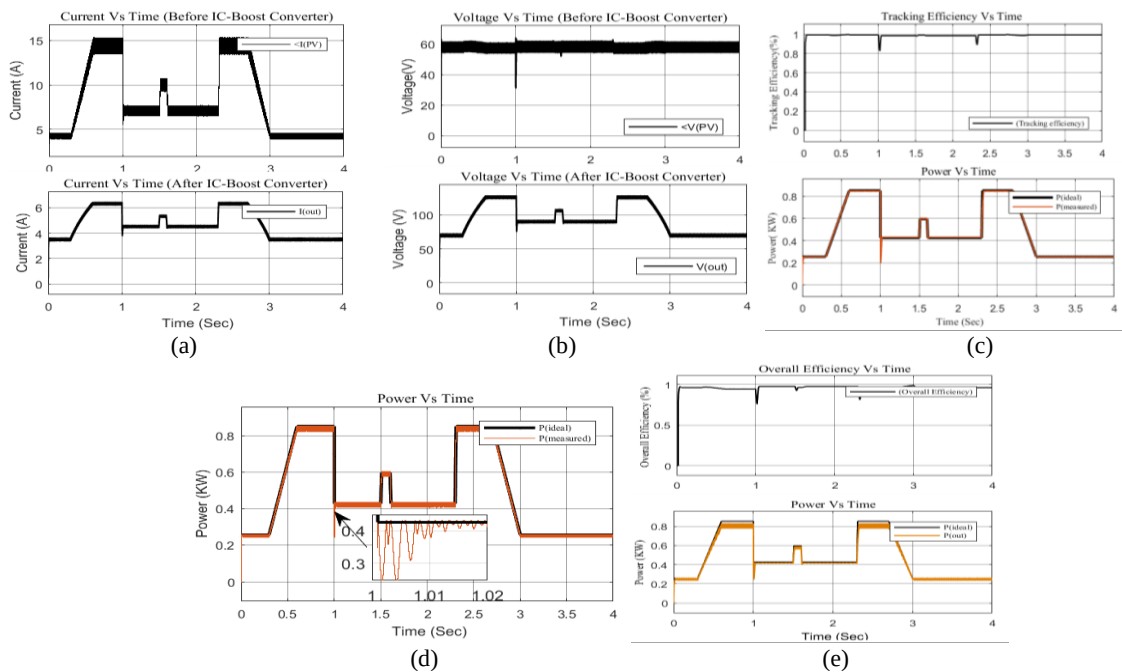


Figure 11. (Case 2) Simulation results showing before and after implementation of IC-Boost Converter (a) Current Variation (b) Voltage Variation (c) Tracking Efficiency and Power Variation (d) Enlarged view of Power variation (e) Overall Efficiency and Power variation

**Table 3. Shows comparison summary for two incident irradiation cases**

| Parameter                 | Case 1  |        | Case 2   |        |
|---------------------------|---------|--------|----------|--------|
|                           | P&O     | IC     | P&O      | IC     |
| (%) Increment in Voltage  | 95.441% | 91.27% | 105.614% | 97.09% |
| (%) Increment in Power    | 0.96%   | 0.23%  | 0.93%    | 0.11%  |
| Overall System Efficiency | 97.27%  | 97.73% | 97.66%   | 98.98% |
| Tracking Efficiency       | 99.53%  | 99.55% | 99.79%   | 99.85% |

**Table 4. Shows Performance comparison of PV array using proposed schemes (Case 1: Step Variable Irradiation)**

| Control Technique | Controller-Boost Converter Voltage |               | (%) Increment in Voltage<br>$\left[ \frac{V(PV) - V(PV1)}{V(PV)} \right] \times 100$ | Controller-Boost Converter Power |               | (%) Increment in Power<br>$\left[ \frac{P(Ideal) - P(out)}{P(Ideal)} \right] \times 100$ | Efficiency     |          |
|-------------------|------------------------------------|---------------|--------------------------------------------------------------------------------------|----------------------------------|---------------|------------------------------------------------------------------------------------------|----------------|----------|
|                   | Before V (PV)                      | After V (PV1) |                                                                                      | Before P (Ideal)                 | After P (out) |                                                                                          | Overall System | Tracking |
| P&O               | 67.13V                             | 131.2 V       | 95.441%                                                                              | 0.852 KW                         | 0.860KW       | 0.96%                                                                                    | 97.27%         | 99.53%   |
| IC                | 67.39 V                            | 128.9 V       | 91.27%                                                                               | 0.852 KW                         | 0.854KW       | 0.23%                                                                                    | 97.73%         | 99.55%   |

**Table 5. Shows Performance comparison of PV array using proposed schemes (Case 2: Ropp's Irradiance Profile)**

| Control Technique | Controller-Boost Converter Voltage |               | (%) Increment in Voltage<br>$\left[ \frac{V(PV) - V(PV1)}{V(PV)} \right] \times 100$ | Controller-Boost Converter Power |               | (%) Increment in Power<br>$\left[ \frac{P(Ideal) - P(out)}{P(Ideal)} \right] \times 100$ | Efficiency     |          |
|-------------------|------------------------------------|---------------|--------------------------------------------------------------------------------------|----------------------------------|---------------|------------------------------------------------------------------------------------------|----------------|----------|
|                   | Before V (PV)                      | After V (PV1) |                                                                                      | Before P (Ideal)                 | After P (out) |                                                                                          | Overall System | Tracking |
| P&O               | 63.76V                             | 131.1 V       | 105.614%                                                                             | 0.852 KW                         | 0.860 KW      | 0.93%                                                                                    | 97.66%         | 99.79%   |
| IC                | 65.4 V                             | 128.9 V       | 97.09%                                                                               | 0.852 KW                         | 0.853 KW      | 0.11%                                                                                    | 98.98%         | 99.85%   |

As depicted in Figure 8, Figure 9, Figure 10 and Figure 11 tracking of point of maximum power is achieved excellently thereby decreasing the possibility of losing the direction of tracking is achieved. Output power oscillations are reduced considerably.

As deduced from Tables 3-5, Tracking Efficiency of 99.53%, 99.79% for P&O and 99.55 % and 99.85 for IC for case 1 and Case 2 is achieved respectively. Voltage enhancement of 95.441%, 105.614% for P&O and 91.27% and 97.09% for IC are achieved for case 1 and Case 2 respectively. There is about 0.96% and 0.93% increment in power for P&O and 0.23% and 0.11% for IC control techniques for case 1 and Case 2 respectively.

## Conclusions

The PV array conversion efficiency is adversely affected by varying irradiation conditions. Further tracking of locus for point of maximum power is again important. In order to run PV panels on point of maximum power, two techniques namely P&O technique and IC control technique are proposed and compared for two realistic changing irradiances in this work. The simulation results reveal that in comparison with P&O technique, IC control technique results in minimal oscillations and excellent tracking of the maximum power point for different varying irradiation scenario. Further, lesser

probability of deviation from its maximum power point path along with fast regaining of locus of maximum power point is achieved. Also, enhanced overall system efficiency with significant increment in voltage and power are achieved. Thus, IC control technique proves to be far superior than P&O control technique.

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