Modeling and Performance Analysis of Approximate Gradient MPPT Method

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Abstract— ***This paper presents a solar cell whose I-V characteristic curve varies with both the irradiance & temperature with change in weather conditions and it becomes essential to extract the maximum power from photo voltaic panel under distinct weather conditions. Photo Voltaic array needs to be utilized up to maximum extent. This is achieved by using various maximum power point tracking (MPPT) algorithms. In this paper a single stage converter i.e, inverter is employed which is single stage is used for both functions, inject the maximum available power and transfer it from the PV array to the electric grid simultaneously by using MPPT methods . The power characteristics comparison of grid photo voltaic system, duty cycle comparison using different MPPT methods and the comparison of performance in eleven stages by variation of irradiation and temperature individually and together is analyzed and presented in this paper. For this comparative analysis, all the MPPT methods are executed in Matlab/Simulation at distinct levels of temperature & irradiation.***

Keywords**:** ***Photovoltaic System, Maximum Power Point Tracking (MPPT), Perturb-and-Observe, Incremental Conductance, Variable step Incremental conductance, Approximate Gradient method.***

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I. INTRODUCTION

Since the output characteristics of photovoltaic (PV) array is nonlinear and influenced largely by environmental factors, the maximum power point tracking (MPPT) [1] of the PV array is essential in the PV generation system [2]. The most widely used MPPT method is perturbation and observation (P&O) method, which adjusts the output voltage with small voltages called perturbation steps to find MPP. In traditional P&O method, the step size is a fixed value that there are oscillations near the MPP. Although a smaller step size can reduce the oscillation, it needs heavy computational time and be easy to fail when atmospheric conditions rapidly changes [3-5].The same is the case with the Incremental Conductance method. Whereas in Variable step Incremental Conductance the step size is automatically tuned accordingly to the inherent PV array characteristics. If the operating point is farther from MPP, it increases the step size which enables a fast tracking ability. On the other hand, if the operating point is close to the MPP, the step size becomes very small that the oscillation becomes well reduced contributing to a higher efficiency and also to adapt step size according to sun irradiation levels using PV output current[6]. This method can increase convergence speed of MPPT for a wide operation range. The approximate gradient method, based on the P&O method and the optimal gradient method, uses a first order difference method to replace the gradient calculation of continuous function. It has many advantages such as simple computation, low cost, fast tracking. Through the research on the principle and process of the approximate gradient method, we intend to improve this method, focusing on optimizing the searching strategy. This method is much easier to apply and it is more efficient in the time changing atmospheric conditions and stationary conditions .It is a more effectual method, which mainly operates in similarity of operating points of input as identical operating system[7].

II. PHOTO VOLTAIC MODEL

A. *Solar cell model*

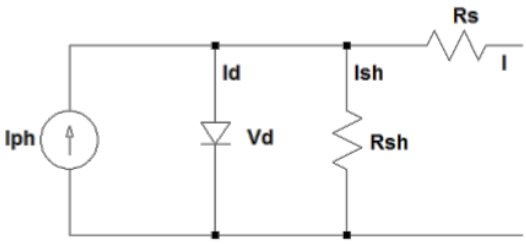


Figure 1: Diode model of photo electric cell

A PV equivalent electrical circuit of solar cell [2] can be represented by a one-diode configuration as shown in Figure1. The mathematical relationship for the voltage and current is given by (1)

$$I = Iph - Io\left[exp\left(\frac{q(V+IRs)}{aKTNs} - 1\right)\right] - \frac{(V+IRs)}{Rsh} \text{ -- (1)}$$

where Iph is Photon current, I0 is reverse saturation diode current, Rsh is shunt resistance, Rs is series resistance, 'a' is ideality factor of diode, V is module output voltage, I is output current of module, k is Boltzmann constant, T is temperature of module, *Ns* is number of series connected cells in module, G is Irradiances, q is electron charge.

B. Single Stage Model

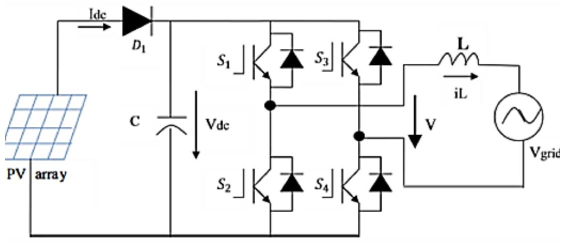


Figure 2: Block diagram of single stage converter design

In two stages, the first stage converter DC/DC enables to track the maximum power and increase the array voltage, the second converter DC/ AC converts the DC power to AC power. On the contrary, the inverter in the single stage is used for both functions, inject the maximum available power and transfer it from the PV array to the electric grid simultaneously. The drawback of two-stage converter design is generally larger in size, heavier in weight and higher in cost than single stage[9] .Figure 2 above shows a block diagram of a single phase single stage grid-connected PV inverter which presents some advantages, such as simple topology and high efficiency. The main components of topology are a PV array, a capacitor (C) as an energy stored element, four power switches (Sl-S4), an inductor (L) as a filter interfacing inverter and mains, and utility grid (V_{grid}).

Different MPPT algorithms are programmed to get the maximum power from the PV panel.
Modulation index is defined as the ratio of the fundamental component amplitude of the line-to-neutral inverter output voltage to one-half of the available DC bus voltage.

$$M = 2*V_{LN} / V_{DC} \tag{2}$$

The output voltage of the inverter near the load

$$V_{LN} = V_{DC} *M/2 \tag{3}$$

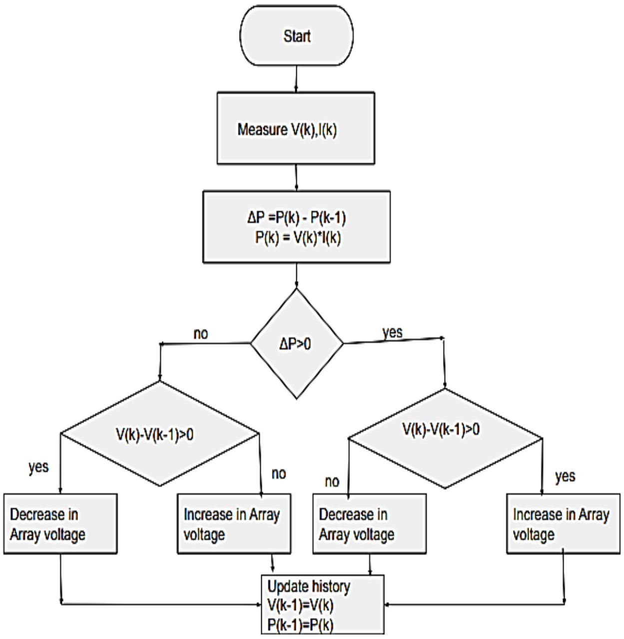
The commutation here is natural commutation, the inverter is pulse width modulated (SPWM) with the help of PI controller.

III. MAXIMUM POWER POINT TRACKING METHODS

A. Perturb & Observe Method

Perturb & Observe (P&O) is the simplest method. In this we use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm.[10]

Figure 3: Flowchart of P & O algorithm



B. Incremental Conductance Method

Incremental conductance method uses two voltage and current sensors to sense the output voltage and current of the PV array. At MPP the slope of the PV curve is 0[10]. Based on that the below equations are written:

$$\left(\frac{dP}{dV}\right)_{MPP} = \frac{d(VI)}{dV} \tag{4}$$

$$0 = I + V\left(\frac{dI}{dVmmp}\right) \tag{5}$$

$$\frac{dI}{dVMMP} = -I/V \tag{6}$$

where, I and V are the PV array current and voltage, respectively.

When the optimum operating point in the P-V plane is to the right of the MPP, (dI/dV)+(I/V)<0 whereas when the optimum operating point is to the left of the MPP, (dI/dV)+(I/V)>0.

As both the voltage and current are sensed simultaneously, the error due to change in irradiance in the PV panel is eliminated. However, the complexity and the cost of implementation of the incremental method increases. As the number of algorithms increases, the complexity associated with them and the cost of implementation also increases, these can be used for a highly complicated system

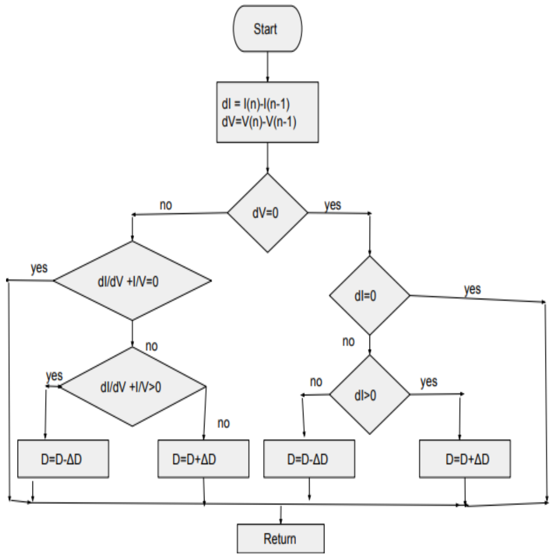


Figure 4: Flowchart of the Incremental Conductance Algorithm

C. Variable Step Incremental conductance method:

The main aim of the method is to track the peak point of P-V curve, so the algorithm should be designed to track the peak point of power curve. Variable step size is introduced in the incremental conductance method to have a better tracking accuracy and speed because in conventional incremental conductance method, the tracking steps remain constant and fixed for the entire algorithm. If tracking steps in the algorithm are small, then the speed of tracking decreases but accuracy increases. If tracking steps are large then speed increases but accuracy decreases. By considering both cases of speed increase and efficiency the VSIC method is developed and it has many advantages over IC method. In IC method the instantaneous conductance (I/V) value of the system and incremental conductance (dI/dV) value are useful to determine the maximum power point on the P-V curve [6].The power to voltage derivative of PV module is used as the parameter for the variable step increment or decrement of VSIC MPPT technique and is given as

$$D(n)= D(n-1) \pm d \qquad (7)$$

$$\text{Where } d = N^*|dP / dV|$$

D(n) is Duty cycle, d is variable step size depends on the change in the power to voltage derivative and N is the adjusted scaling factor and that decides the performance of MPPT.

If change in incremental conductance is zero, then there is no change in the duty cycle. If the power to voltage derivative is more than zero, then duty cycle has to be increased and for less than zero the duty cycle has to be decreased. Then the duty cycle is adjusted by the scaling factor and the decrement and increment in the duty cycle is decided by power to voltage slope. To increase the tracing speed the scaling factor has to be increased. In variable step size IC method the near to MPP there is decrease in step but gradually increases when tracking occurs at far from MPP.

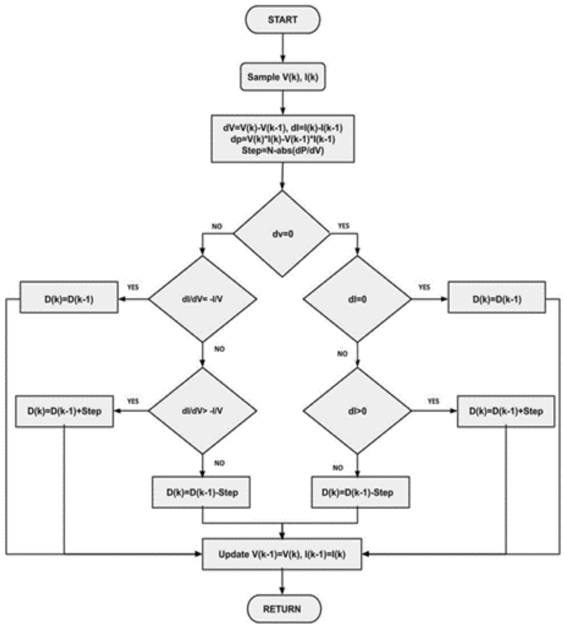


Figure 5: Flowchart of Variable Step Incremental Conductance Algorithm

D. Approximate Gradient Method:

In gradient method the step size is decided based on the distance of the operating point from the MPPT. First the MPPT to be reached is calculated by taking 75% of open circuit voltage(V_M) and the corresponding current I_0 to that, read as P_0 and $V_0 = V_M$. The operating point is compared with the MPPT point and based on that the step is decided. If the distance from the MPPT is more, then large steps are taken, as it reaches MPPT the step size becomes small. The iteration continues till the point $\Delta P/ \Delta V=0$ is reached. But when $\Delta P=0$, ΔV tends to zero and this might cause the "Divide by zero" error .This error is overcome by taking the judgment are $|\Delta P| \leq \varepsilon$ instead of $\Delta P/ \Delta V=0$, where ε is a very small value [7].

$\Delta P/\Delta V=0$, where ε is a very small value [7]. For small disturbance, changing the perturbation step to V' when $\Delta V=0$ is desirable. But for the big disturbance, power changes greatly that V' is not reliable enough to approach the MPP rapidly. By adjusting the voltage to V_M and then using the initial step for a new round of tracking, we evade the calculation of the step caused by uncontrollable big disturbance. The critical condition for small and big disturbance is selected as $|\Delta P| \leq 10\%P_0$. The constraint conditions taken are $V' = 0.15V$ and $\varepsilon = 0.1W$.

IV SIMULATION AND ANALYSIS

In this simulation model of MPPT system using the MPPT algorithms, 3500W PV array is connected to the utility grid using the single stage model via a single phase H bridge inverter with IGBT/Diode switches

MPPT is implemented in the inverter by using Matlab code and PWM generator using the single stage model via a single phase H bridge inverter with IGBT/Diode switches MPPT is implemented in the inverter by using Matlab code and PWM generator

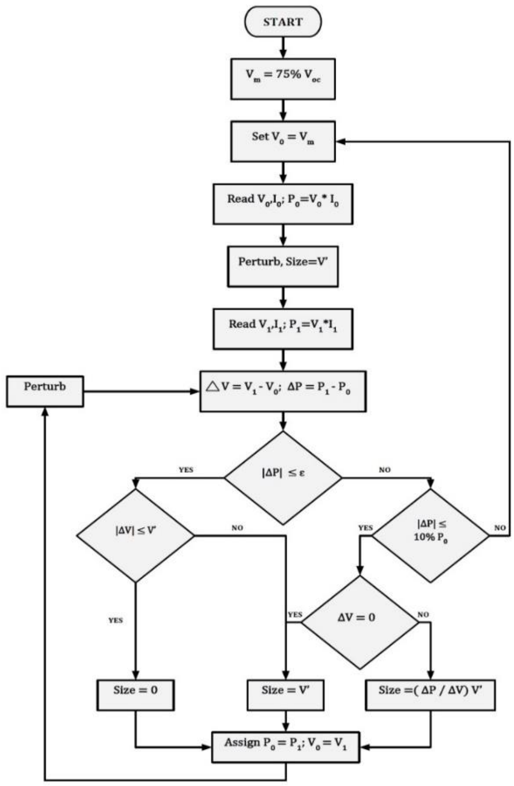


Figure 6: Flowchart of Approximate gradient method

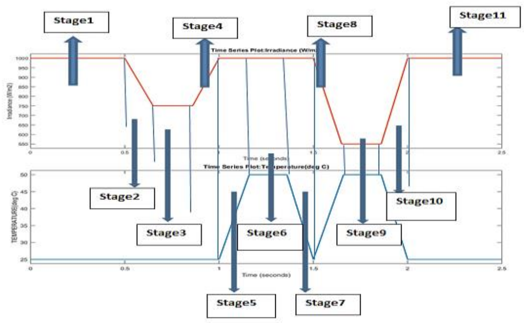


Figure 7: Varying Irradiance and Temperature

Using the parameters mentioned in Table 1, the MATLAB/Simulink is implemented using the above mentioned algorithms and the results are compared and the efficiency of these algorithms is analyzed by varying the temperature and irradiance as shown in Figure 7.

In this simulation model of MPPT system using the MPPT algorithms, 3500W PV array is connected to the utility grid using the single stage model via a single phas H bridge inverter with IGBT/Diode switches MPPT is implemented in the inverter by using Matlab code and PWM generator.

Table 1: Parameters taken during simulation

S.no	Parameter	Value taken for Simulation
1.	Irradiance	1000W/m^2
2.	Temperature	25^{0}Celsius
3.	Switching Frequency	5000HZ
4.	Temperature coefficient of (Voc)	-0.35 %/deg.C
5.	Temperature Coefficient of (Isc)	0.06%/deg.C
6.	No. of parallel strings of an array	1
7.	No. of series connected modules for each string	14
8.	Open circuit voltage (V_{OC})	37.6 volts
9.	Short-Circuit Current (I_{SC})	8.55 amps
10.	Maximum power of Module	249.86 W
11.	Light-generated current I_L (A)	8.5795 amps

V RESULTS AND DISCUSSIONS

The Simulink model was first operated at a constant irradiance of 1000W/m^2 and a temperature of 25^0 Celsius using all the four algorithms and the power obtained at the PV panel and the grid were recorded. The maximum power that could be extracted from the panel would be 3498W.

The algorithms are compared based on the maximum power they could extract from the PV panel. As seen in the below Table 2, efficiency is maximum in Approximate Gradient method.

The above MPPT algorithms are executed in the Simulink model shown in Figure 8 with different irradiation and temperature shown in Figure 7 and the Power characteristics of the curves at the output i.e the grid are compared.

The comparison was further divided in eleven stages with varying irradiation and temperature as shown in Figure 7 and the results are analyzed.

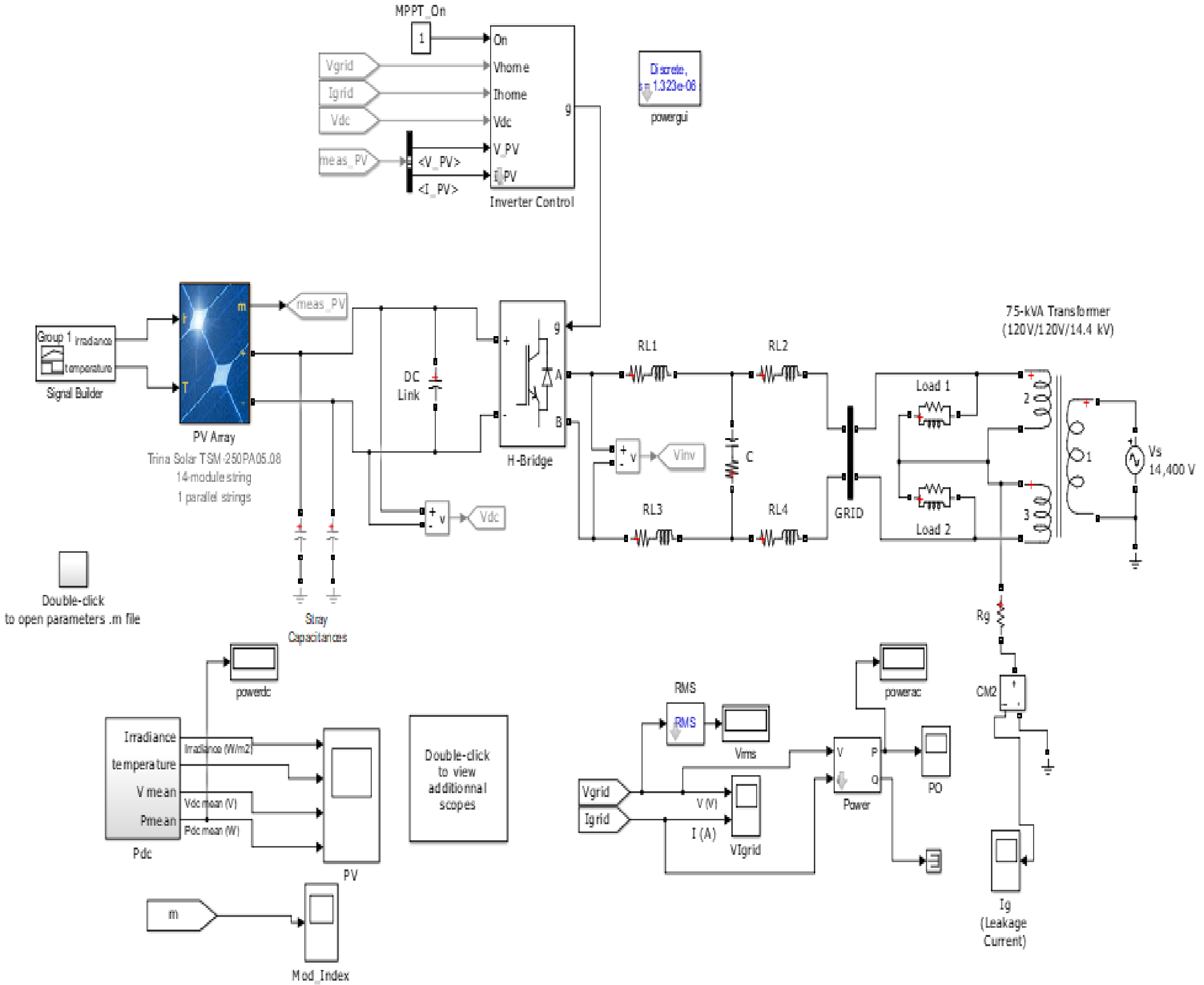


Figure 8: Simulink Model of the MPPT system using various algorithms

Table 2: Tracking efficiency of algorithms run at constant irradiation and temperature

ALGORITHM	OUTPUT AT THE PV PANEL	OUTPUT AT THE GRID	TRACKING EFFICIENCY
P&O	Power: 3479 Watts Voltage : 425 Volts Current : 8.186 amps	Power: 3449 Watts Voltage : 239 Volts Current : 14.44 amps	99.45%
InC	Power: 3479 Watts Voltage : 425 Volts Current : 8.187amps	Power: 3447 Watts Voltage : 239 Volts Current : 14.41 amps	99.45%
VSIC	Power: 3480 Watts Voltage : 425 Volts Current : 8.193amps	Power: 3448Watts Voltage : 239 Volts Current : 14.41 amps	99.48%
Approximate Gradient	Power: 3482 Watts Voltage : 426.2 Volts Current : 8.171 amps	Power: 3455 Watts Voltage : 239 Volts Current : 14.42 amps	99.54%

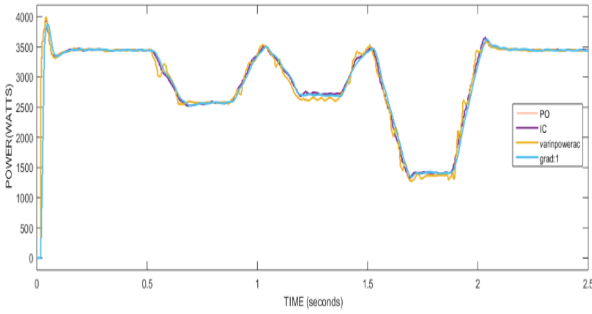


Figure 9: Power characteristics comparison of grid Photo Voltaic system showing various MPPT algorithms vs. time

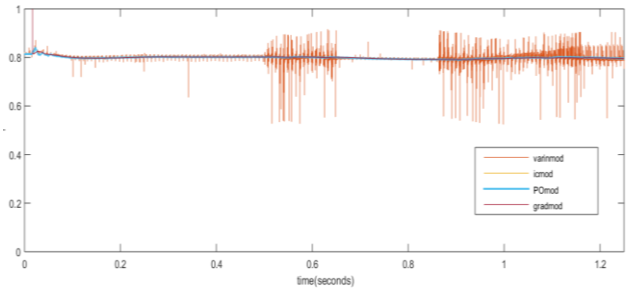


Figure 10: Comparison of Duty Cycle of a grid Photo Voltaic system showing various MPPT algorithms vs time.

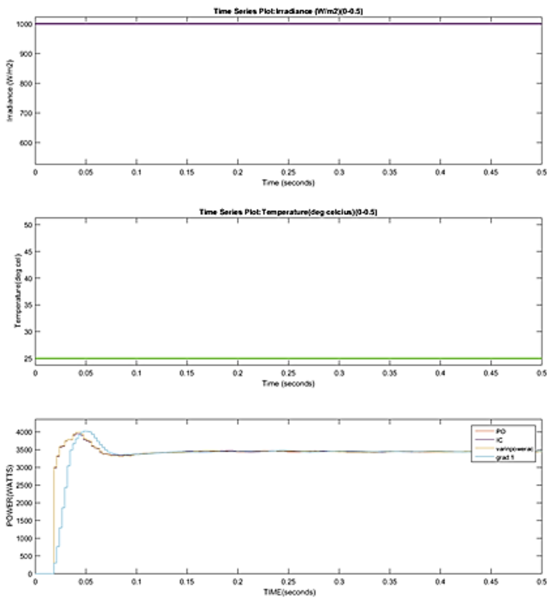


Figure 11: variation of Irradiance, Temperature and Power with time in stage 1

Stage 1: From (0 to 0.5) the irradiation is maintained constant at 1000 W/m^2 and the temperature is 25^0 Celsius. The variation of power starts from 0 and reaches the maximum point due to variation of temperature and irradiance.

Gradient has more power compared to other methods as shown even in Table 2.

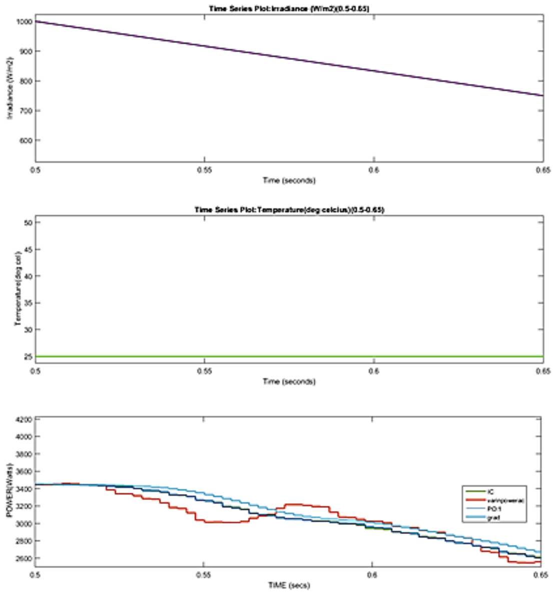


Figure 12: variation of Irradiance, Temperature and Power with time in stage 2

Stage 2: From (0.5 to 0.65) the irradiation is decreases from 1000 W/m^2 to 750 W/m^2 and the temperature is 25^0 Celsius. The variation of power decreases due to variation of irradiance.

When the radiance is dropping and temperature is constant, Gradient has more power compared to other methods and variable step incremental conductance has very less power

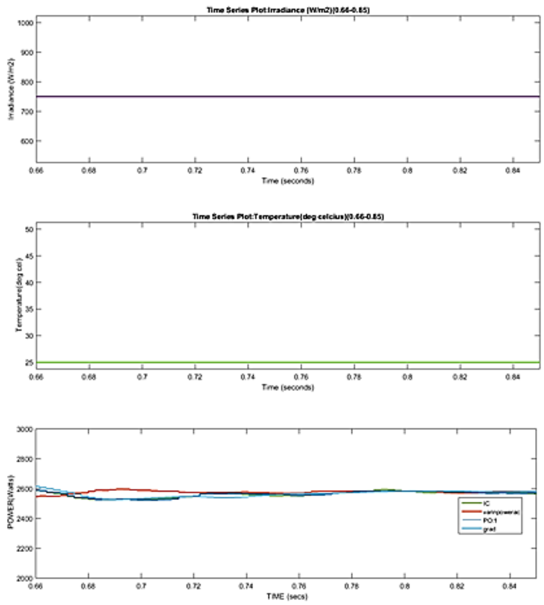
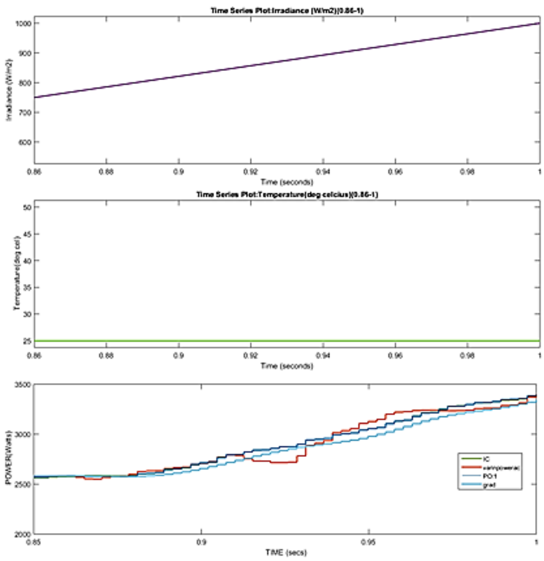


Figure 13: variation of Irradiance, Temperature and Power with time in stage 3

Stage 3: From (0.66 to 0.85) the irradiation is maintained constant 750 W/m^2 and the temperature is 25^0 Celsius. All methods have approximately same



power

Figure 14: variation of Irradiance, Temperature and Power with time in stage 4

Stage 4: From (0.86 to 1) the irradiation is increases from 750 W/m^2 to 1000 W/m^2 and the temperature is 25^{0}Celsius. The variation of power is increases due to variation of irradiance.

When the irradiation is increasing and temperature is constant P & O method and IC method have more power when compared to all methods

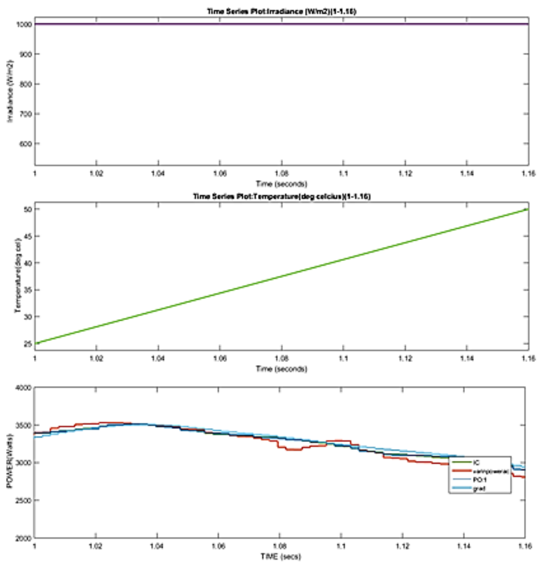


Figure 15: variation of Irradiance, Temperature and Power with time in stage 5

Stage 5: From (1 to 1.16) the temperature is increases from 25^{0}Celsius to 50^{0}Celsius and the irradiance is 1000 W/m^2. The variation of power is decreases due to variation of temperature.

When the irradiation is constant and the temperature starts increasing there is a fall in power, Gradient method has more power compared to other methods , followed by VSIC , P&O and InC.

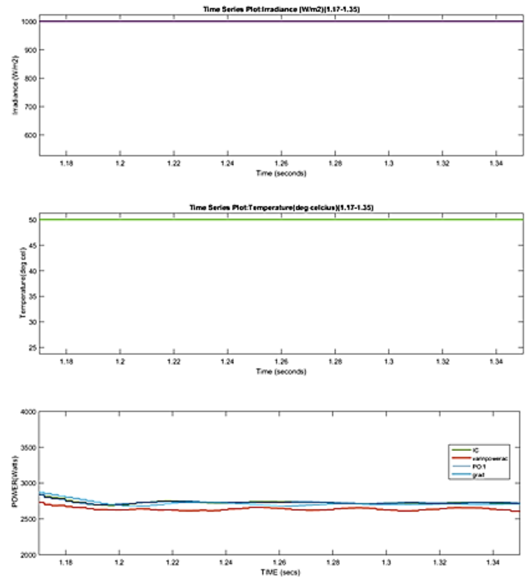


Figure 16: variation of Irradiance, Temperature and Power with time in stage 6

Stage 6: From (1.17 to 1.35) the temperature is maintained constant 50^{0}Celsius and the irradiance is 1000 W/m^2. The variation of power is also constant due to variation of irradiance and temperatures are constant.

When the temperature is increased, the power decreases and Variable step Incremental conductance method has less power when compared to all other methods

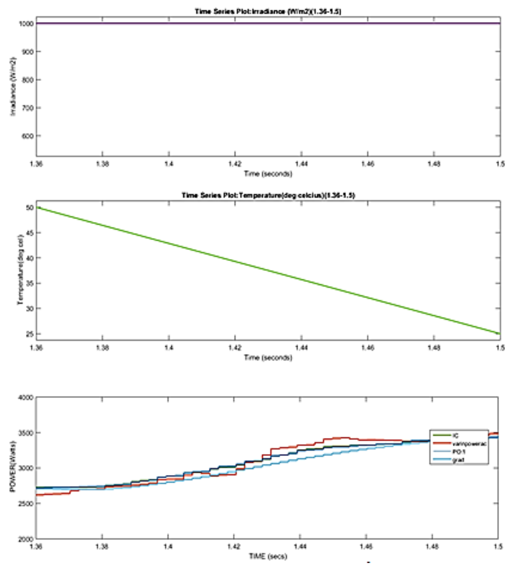


Figure 17: variation of Irradiance, Temperature and Power with time in stage 7

Stage 7: From (1.36 to 1.5) the temperature is decreasing from 50^0Celsius to 25^oCelsius and the irradiance is 1000 W/m^2. The variation of power is increasing due to variation of temperature.
Variable step incremental conductance method has more power compared to all other methods

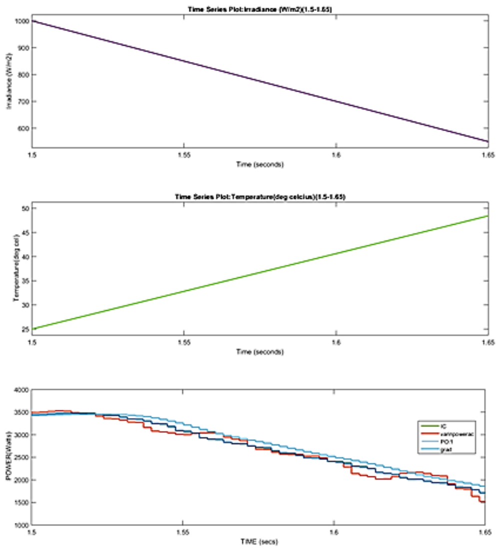


Figure 18: variation of Irradiance, Temperature and Power with time in stage 8

Stage 8: From (1.5 to 1.65) the irradiation is decreases from 1000 W/m^2 to 500 W/m^2 and the temperature is increases from 25^0Celsius to 50^0Celsius. The variation of power is decreases due to effect of variation of both irradiance and temperature.
When the irradiation is decreasing and the temperature is increasing, Gradient method has more power compared to all other methods

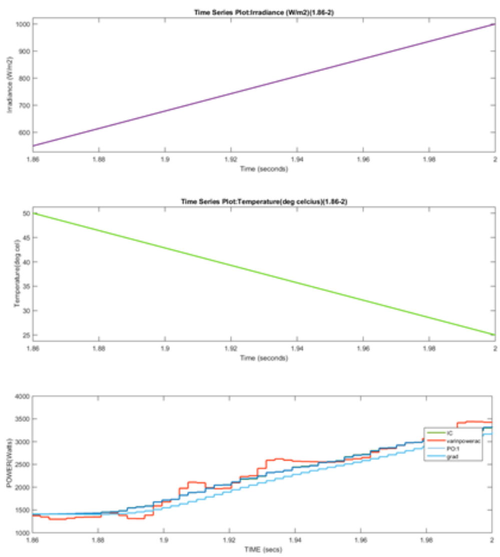


Figure 19: variation of Irradiance, Temperature and Power with time in stage 9

Stage 9: From (1.66 to 1.85) the irradiation is maintained constant 500 W/m^2 and the temperature is also maintained constant at 50^0Celsius. The variation of power is constant due to effect of both irradiance and temperature maintained constant.
Gradient method has more power compare to all methods and variable step incremental conductance method has less power

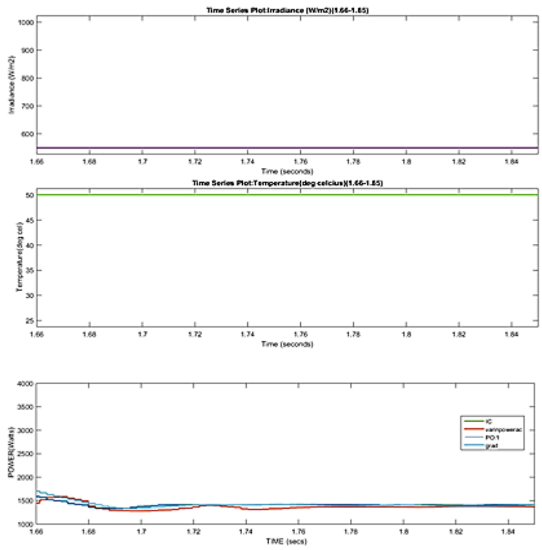


Figure 20: variation of Irradiance, Temperature and Power with time in stage 10

Stage 10: From (1.86 to 2) the irradiation is increases from 500 W/m^2 to 1000 W/m^2 and the temperature is decreasing from 50^0Celsius to 25^oCelsius. The variation of power is increases due to the effect of variation of irradiance and temperature.

When the irradiation is increasing and temperature is decreasing, Gradient method has less power and VSIC has more power .PO and InC methods have same power.

Stage 11: From (2 to 2.5) the irradiation is 1000 W/m^2 and the temperature is 25^0Celsius. The variation of power is constant due to the effect of both irradiance and temperatures are maintained constant.

Table 3: Power characteristics comparison of a grid Photo Voltaic system working various MPPT algorithms with input as Irradiance & Temperature.

Stages	Irradiance (W/m^2)	Temper-ature (Deg C)	Perturb & Observe (Method1)	Incremental Conductance (Method 2)	Variable step Incremental conductance (Method 3)	Approximate gradient (Method 4)
1	Constant 1000 W/m^2	Constant 25^oC	Less power compared to method 4	Same as method 1	Same as method 1	More Power
2	Decreases	Constant 25^oC	Less Power than method 4 but more than method 2&3	Less Power than method 4&1 but more than method 3	Less Power	More Power
3	Constant $750W/m^2$	Constant 25^oC	Less power than method 4	Same as method 1	Same as method 1	More Power
4	Increases	Constant 25^oC	More Power	Same as method 1	Less power	More Power compared to method 3 and less compared to methods 1&2
5	Constant 1000 W/m^2	Increase	Less Power	Same as method 1	Less than method 4 but more than methods 1 & 2	More Power
6	Constant 1000 W/m^2	Constant 50^oC	More than method 3	Same as method 1	Less power	More Power
7	Constant 1000 W/m^2	Decrease	Less Power	More than method 1 but less than methods 3 &4	More Power	Less power compared to method 1,2 & 3
8	Decreases	Increase	Less than method 4 and more than method 2	More than method 3 but less than methods 1 &4	Less Power	More power
9	Constant $500W/m^2$	Constant 50^oC	More than method 3	Same as method 1	Less power	More Power
10	Increase	Decrease	More power	Same as method 1	Less power	More Power compared to method 3 and less power compared to method 1&2
11	Constant 1000 W/m^2	Constant 25^oC	Less power	More than method 1 but less than methods 3 &4	Less than method 4 but more than methods 1 & 2	More power

Table 4: Power at the output of the PV panel with constant irradiation and temperature (in Watts)

Irradiance (W/m^2) and Temperature (^0C)	P &O (Method 1)		InC (Method 2)		VSIC (Method 3)		Appr Gradient (Method 4)	
	Power at the output of the PV panel(W)	Power at the grid(W)	Power at the output of the PV panel(W)	Power at the grid(W)	Power at the output of the PV panel(W)	Power at the grid(W)	Power at the output of the PV panel(W)	Power at the grid(W)
1000 and 25	3479	3447	3479	3447	3480	3448	3482	3455
1000 and 50	2758	2721	2750	2430	2820	2791	2754	2711
750 and 25	2614	2580	2614	2320	2615	2581	2619	2583
750 and 50	2043	2014	2037	1788	2089	2063	2045	2001
500 and 25	1738	1693	1738	1516	1739	1716	1740	1719
500 and 50	1290	1260	1291	1139	1324	1311	1292	1258

VI.CONCLUSION

The comparison of various maximum power point tracking techniques for grid connected Photo Voltaic system with varying input as Irradiance & Temperature is shown in Table 3.

From the Table 3 & Table 4 considering the output at the grid and the output at the PV panel, it clearly indicates that stages 1,3,11 where the temperature is constant(25^{0}C) and irradiation keeps changing , the Gradient method delivers more power at the output and extracts maximum power from the panel compared to other algorithms. Variable step incremental conductance method delivers approximately same power as P&O and InC. From the Table 3 & Table 4 results it is clearly indicates that in stages 6 and 9 where the temperature increases and is more than 25^{0}C, the gradient method delivers more power compared to all other methods followed by P&O,InC and VSIC. Variable step incremental method delivers the least power to the grid though it extracts maximum power at the PV panel due to the oscillations.

From Table 3,in stage 2, where the irradiation is decreasing and the temperature is constant, we see Gradient method delivers maximum power compared to other methods followed by P&O ,InC and VSIC. In stage 8, where the irradiation decreases and temperature increases that i.e, both the parameters vary, we see Gradient method gives maximum power followed by P&O, InC and VSIC. In stage 5, when the irradiation is constant and temperature increases, Gradient method maintains and delivers high power followed by VSIC ,P&O and InC.
In stage 4, where the irradiation is increasing and temperature is constant, we see P&O and InC deliver the maximum power, followed by Gradient and VSIC.In stage 10 where the irradiation increases and temperature decreases, P&O and InC deliver the maximum power followed by Gradient and VSIC. In stage 7, where the irradiation is constant and the temperature decreases, the VSIC delivers power compare to other methods.

From the above analysis it can be stated that Approximate Gradient delivers maximum power compared to other methods when the irradiation decreases with constant temperature and temperature increases with constant irradiation. Variable step incremental conductance method extracts maximum power from the PV panel when the temperature increases compared to other methods but at the output of the grid Gradient method delivers more power.

While there is increase and decrease in irradiation and temperature Approximate Gradient delivers appreciable power with a smooth curve and less variations compared to other methods.

From the Figure 9 results it clearly indicates that variable step incremental conductance method has more oscillation when compared to Approximate Gradient, P& O and IC based techniques. Nearly a fixed duty cycle (without oscillation) is present in Approximate Gradient method.

Approximate Gradient method algorithm is better to obtain more power and having more complexity when compared to the IC method and P&O method (SIMPLE in Implementation) under various irradiation and temperature conditions.

Considering for the best performance oscillations should be minimum and power obtained is maximum, looking into the analysis it can be said as Approximate Gradient method is best among the four methods.

REFERENCES:

[1] Barchowsky A, Parvin J P, Reed G F, et al. A comparative study of MPPT methods for distributed photovoltaic generation[C]. *IEEE PES Innovative Smart Grid Technologics(ISGT)*, 2012:1-7.

[2] Parida B, Iniyan S, Goic R. A review of solar photovoltaic technologies[J]. Renewable and Sustainable Energy Reviews, 2011, 15(3):1625-1636.

[3] Stjepanović A, Softić F, Bundalo Z, et al. Solar tracking system and modeling of PV module[C]. Proceedings of the 33rd International Convention MIPRO,2010,105-109.

[4] Koutroulis E, Blaabjerg F. Methodology for the optimal design of transformerless grid- connected PV inverters[J]. *Power Electronics IET*,2012,5(8):1491-1499.

[5] Bifareti S, Iacovone V, Cina L, et al. Golbal MPPT method for partially shaded photovoltaic modules[C]. *IEEE Energy Conversion Congress and Exposition(ECCE)*,2012:4768-4775

[6] Rakesh Ranjan Sahoo, Dr. Madhu Singh. Analysis of Variable step incremental conducatance method MPPT technique for PV system, *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 11, Issue 2 Ver. III (Mar. – Apr. 2016), PP 41-48* www.iosrjournals.org

[7] Chen Zhou, Xi Ziqiang, Lu bin. Improved Approximate Gradient Method in MPPT Control of Photovoltaic Generation System, *International Conference on Intelligent Systems Research and Mechatronics Engineering (ISRME 2015)*

[8] Raghuram Munasala, T Padmavathi. Analysis of Maximum Power Point Tracking techniques for Photo Voltaic System.

[9] Faicel EL AAMRI, Hattab MAKER, Azeddine MOUHSEN, Mohamed HARMOUCHI, A new MPPT using Gradient Method for Grid-Connected PV Inverter[C],2014,*IEEE*.

[10] Arjav Harjai, Abhishek Bhardwaj, Mrutyunjaya Sandhibigraha, STUDY OF MAXIMUM POWER POINT TRACKING (MPPT) TECHNIQUES IN A SOLAR PHOTOVOLTAIC ARRAY.

[11] Ahmed M. Atallah, Almoataz Y. Abdelaziz, and Raihan S. Jumaah, "Implementation of Perturb and Observe MPPT of PV System with Direct Control Method using Buck and Buck-Boost Converter" Emerging Trends in Elec., Electronics & Inst. Eng.: An inter. Journal (EEIEJ), Vol. I, No. I, February 2014.

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