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A comparative study on MPPT techniques for photovoltaic systems operating under fast changing environments

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***Abstract*—this paper present a new maximum power point tracking for photovoltaic system, variable step perturb and observe, in which to ameliorate the disadvantages of classical perturb and observe, a comparative study between the classical and the variable step is carried out in which many point has been proved, considering the change of temperature and irradiation, the results obtained proved the performance of the variable step including response time and oscillation.**

Keywords—solar energy, maximum power point, boost converter, perturb and observe.

I. Introduction

Solar energy is one of the most important renewable energy sources. As opposed to conventional unrenewable resources such as gasoline, coal, etc..., solar energy is clean, inexhaustible and free. The main applications of photovoltaic (PV) systems are in either stand-alone (water pumping, domestic and street lighting, electric vehicles, military and space applications) [1-2] or grid-connected configurations (hybrid systems, power plants) [3].

Photovoltaic cells convert solar radiation directly into DC electrical energy. The basic material for almost all the photovoltaic cells existing in the market, which is high purified silicon (Si), is obtained from sand or quartz. Basically, three types of technology are used in the production of photovoltaic cells. Mono crystalline; polycrystalline; and amorphous silicon [4].

Photovoltaic cell is a device convert the sun light into electrical energy and are considered to be one of the major ways of producing clean, however this devices does not always maximum efficiency due to the nonlinearity of their output current –voltage characteristic which is affected by the panel temperature and irradiance, Hence, the addition of a high performance maximum-power-point tracking, MPPT, power converter interface is the key to keeping the PV system operating at the optimum power point which then gives maximum efficiency[5-7].

The V-I and V-P characteristic will vary with the change of the irradiation or the temperature, The V–P curve of PV characteristic has a maximum power point (MPP) which is the optimal operation point for efficient use of the PV array. It is necessary to extract the maximum power at any condition in order to minimize power loss from PV array. The boost DC–DC converter with maximum power point tracking (MPPT) keeps the PV array voltage on a maximum operating point.

In this paper, the system contain three parts, the first is PV cell modeling and the environment effects, the second, P&O methods with variable and fixed step detailed, in the last part, simulation result carried out to prove the advantages of variable step the fixed step.

II. PV CELL MODELLING.

The simplest way of representing the solar cell is the single diode model. It consists of a current source in parallel to a diode. The parameters required are short circuit current (Isc), open circuit voltage (Voc) and the diode ideality factor (a). The ideality factor of a diode is a measure of how closely the diode follows the ideal diode equation. Due to the presence of recombination losses, ideality factor other than ideal are produced. The basic model is improved for accuracy by introducing the series resistance (Rs).It does not prove to be efficient under temperature variations. To overcome this drawback, an additional shunt resistance (Rp) is included. This increases the parameters to a considerable level and the computations are increased. Although Rp is added, the model fails under low irradiation conditions. fig (1)

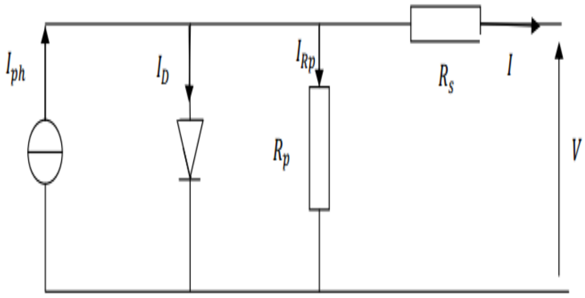


Fig 1: Equivalent Circuit of Single Diode Model.

The characteristic curves of PV cell in simulation environment can be realized using the fundamental equations. A single PV cell is realized as a current source placed in parallel with a diode and the output current equation is given as:

$$I=I_{ph}-I_D-I_{Rp} \qquad (1)$$

The photo voltaic current I_{ph} is a function of the irradiance (G) and is formulated as:

$$I_{ph}= I_{sc}*\frac{G}{1000}*[1+a*(T-T_{Ref})] \qquad (2)$$

The current through the resistor R_p is given as:

$$I_{Rp}= \frac{V+IR_S}{R_P} \qquad (3)$$

The current in the diode is given by:

$$I_D=I_o/[e^{\frac{v+IR_S}{nV_t}} -1] \qquad (4)$$

With The diode saturation current:

$$I_O=I_{ot}*(\frac{T}{Tref})^3*\exp[\frac{qEg}{nk}(\frac{1}{Tref}-\frac{1}{T})] \qquad (5)$$

With

$$I_{ot}=I_{Sc}/[e^{\frac{V_{oc}}{nV_t}} -1] \qquad (6)$$

the output current equation become:

$$I= I_{ph}- I_o/ [e^{\frac{v+IR_S}{nV_t}} -1]- \frac{V+IR_S}{R_P} \qquad (7)$$

Where:

$$V_t=\frac{KT}{q} \qquad (8)$$

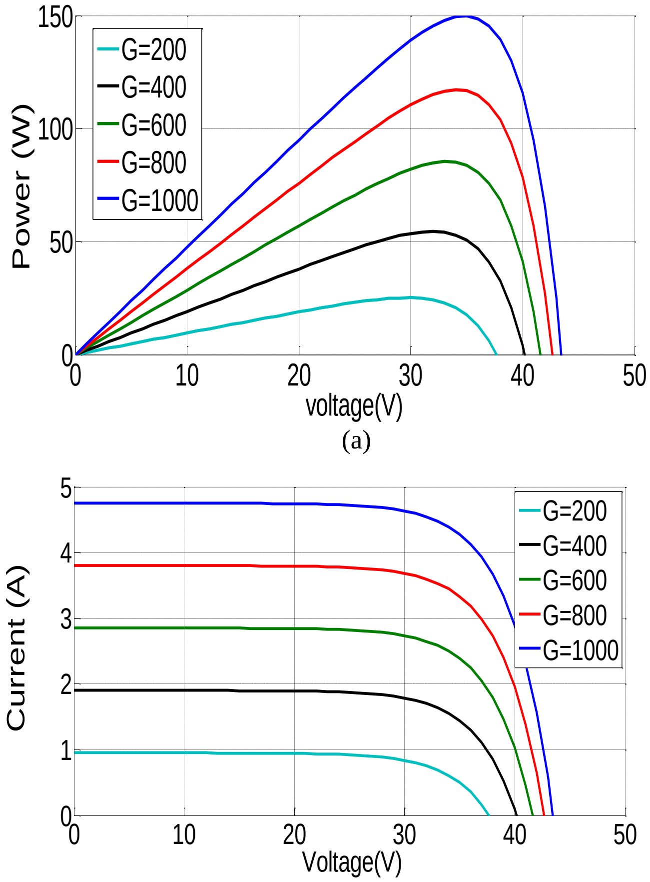
A Single PV Cell is used for simulation for the study. The cells can be connected by increasing the number of cells in series and parallel based on the load requirement. To carry out this simulation, we chose the photovoltaic module BP SX 150 BP Solar. The SX series BP Solar provides a cost effective photovoltaic power for a general purpose direct operating expenses direct current or current loads Alternating on UPS systems equipped. The module consists of 72 solar cells multi crystalline silicon connected in series to produce a maximum power of 150W in 25co and 1000 w/m2. The electrical characteristics of the photovoltaic module are given in Table 1:

Table -1: PV Cell Specifications BP SX 150

Parameter	Value
Maximum power (P_{max})	150W
Voltage at maximum power (V_{mp})	34.5 V
Current at maximum power (I_{mp})	4.35 A
Open circuit voltage (V_{oc})	43.5 V
Short circuit voltage (I_{sc})	4.75 A
Temperature coefficient of I_{sc}(a)	0.065±0.015% /C°

II.1. *Irradiation influence*

Fig. 2 gives the P-V and I-V characteristics of a PV module according to the incident irradiation and at fixed R_s and fixed temperature.



(a)

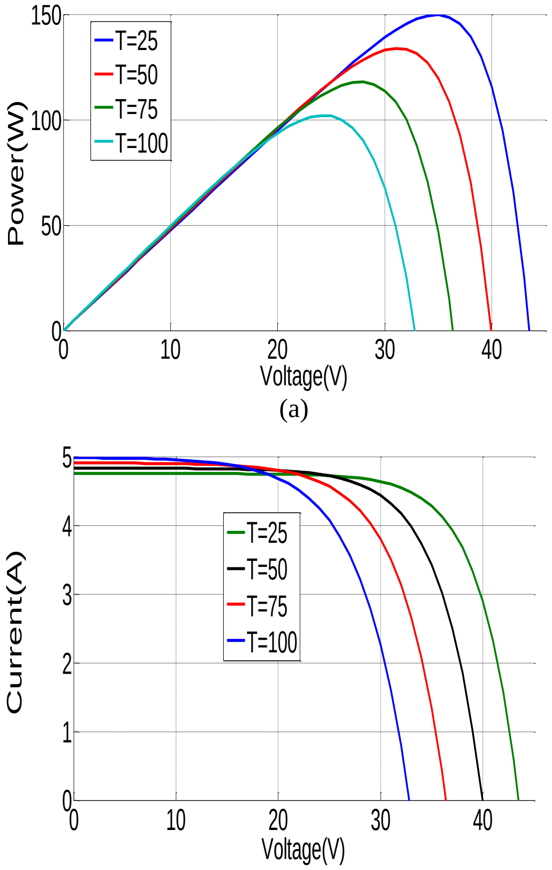
(b)

Fig.2: (a):The P-V and (b) I-V characteristics curve of a PVpanel at different solar radiation and fixed R_s , fixed temperature 25C and fixed R_{sh}.

Fig 2 shows that the value of the short-circuit current is directly proportional to the intensity of the radiation [8-9]. On the other hand, the open circuit voltage does not vary in the same proportions, it remains almost identical even at low illumination. The standard, internationally accepted irradiation for measuring the response of photovoltaic panels is a radiant intensity of 1000 W / m2 and a temperature of 25 ° C. For different irradiation levels we obtain different curves with different maximum powers.

II.2. *Temperature influence.*

Fig. 3 shows the P-V and I-V characteristics for a constant R_s and irradiation and with the various temperature values.



(a)

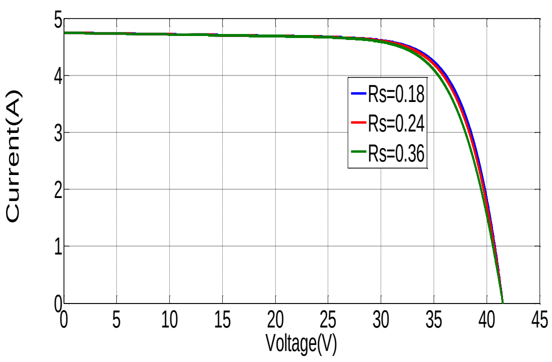
(b)

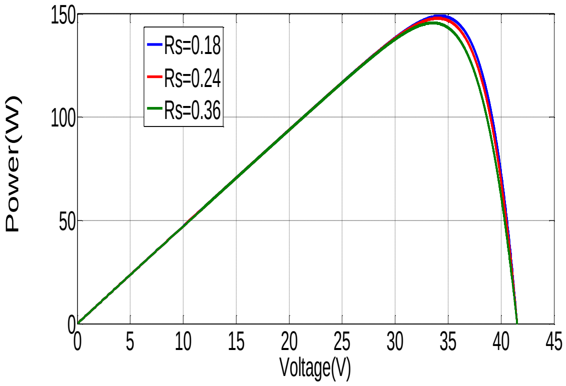
Fig.3: (a):The P-V and (b) I-V characteristics curve of a PV panel at different temperature and fixed solar radiation 1000 w/m^2, fixed R_s=0.18 ohm and fixed R_{sh}.

It is noted that the temperature has a negligible influence on the value of the short-circuit current. On the other hand, the open circuit voltage decreases quite strongly when the temperature increases, therefore the extractable power decreases [8], the increase in temperature also results in a decrease in the maximum available power.

II.3. Influence of series resistance RS.

The effect of the series resistor is very weak and is noticeable only for a large value of parallel resistance.





(a)

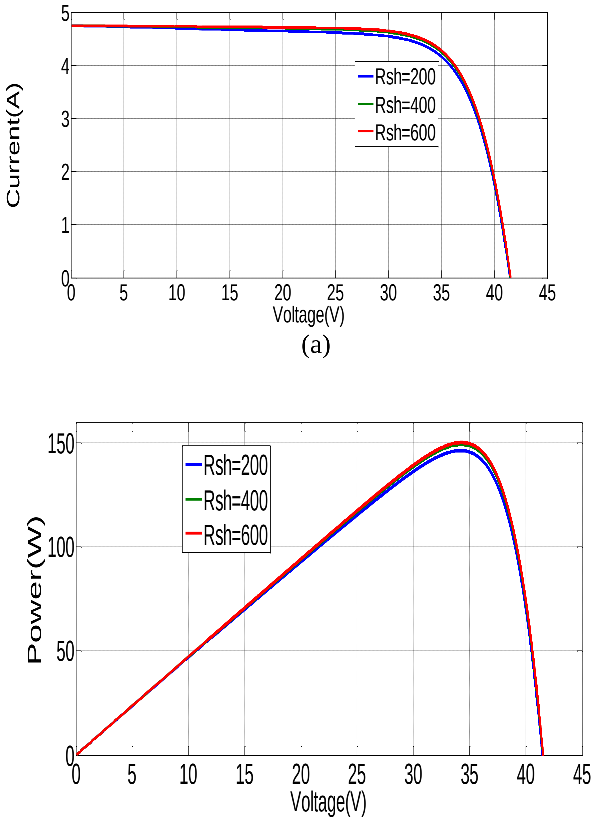
(b)

Fig.4: (a):The I-V and (b) P-V characteristics curve of a PV panel at different R_s and fixed solar radiation 1000 w/m^2 , fixed temperature and fixed R_{sh}.

Fig.4 shows that with increasing series resistance the slope of the curve decreases in the area where the cell operates as a constant voltage generator. [10], we notice that with the increase of the series resistance a decrease of the maximum available power. [11]

II.4. Influence of parallel resistance RSh.

The shunt resistance is usually very high, if it is too low, it will have an impact on the open circuit voltage of the cell; in addition, a cell will no longer give voltage under low illumination.



(a)

(b)

Fig.5: (a):The I-V and (b) P-V characteristics curve of a PV panel at different R_{sh} and fixed solar radiation 1000 w/m^2 ,fixed temperature, fixed R_s.

Fig.5 shows that the influence is an increase in the slope of the panel curve I-V in the area corresponding to an operation as a current source. [11].

III. MAXIMUM POWER POINT TRACKING (MPPT).

Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that “physically moves” the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Additional power harvested from the modules is then made available as increased battery charge current. MPPT can be used in conjunction with a mechanical tracking system, but the two systems are completely different [12].

Photovoltaic solar system consists of PV array, switching converter, MPPT controller and load, which may be a DC load, battery charger or inverter. The input(s)/output(s) of MPPT controller may differ from one method to another. Figure 8 shows the block diagram of a typical MPPT system[13].

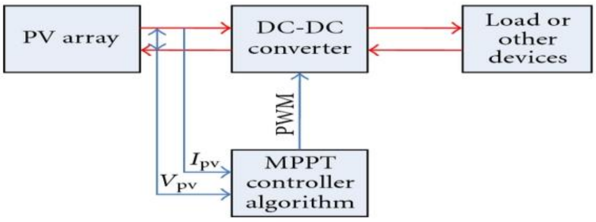


Fig 6: elementary photovoltaic conversion chain.

IV. PERTURB AND OBSERVE (P&O).

Perturb and Observe is the most commonly used method in practice for its simplicity and ease of implementation [8]-[9]. In this method, the output voltage of the solar panel is perturbed periodically, and then the output power is compared to the previous cycle. Next, corrective action is taken to enforce the voltage to move toward the maximum operation output voltage. The comparison can determine the position of the operation point and the direction of perturbation [10]-[11].

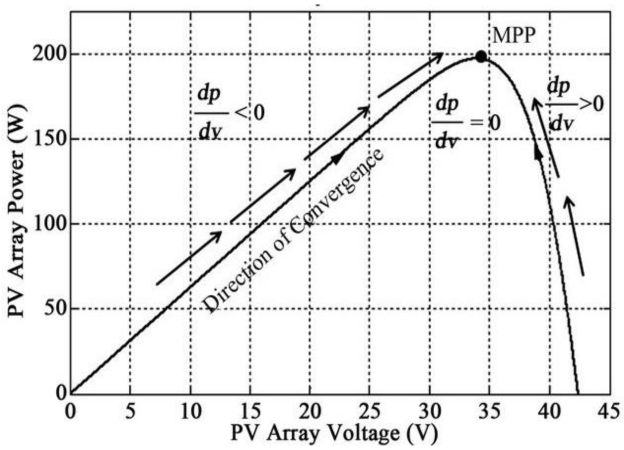


Fig 7: the algorithm of perturb and observe method.

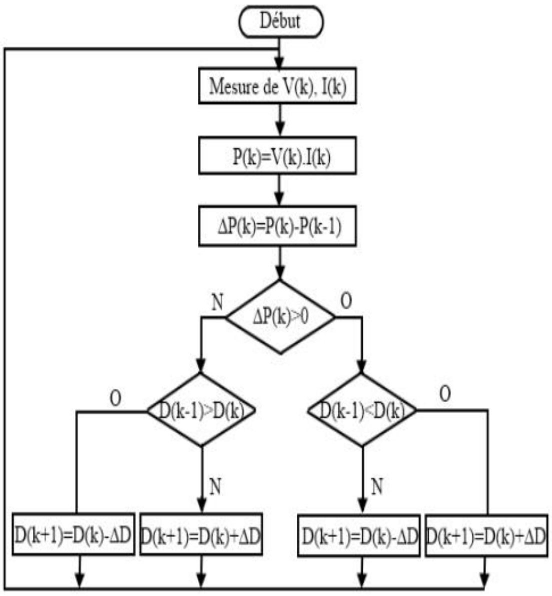


Fig 8: MPPT Algorithm perturbation and observation with fixed step.

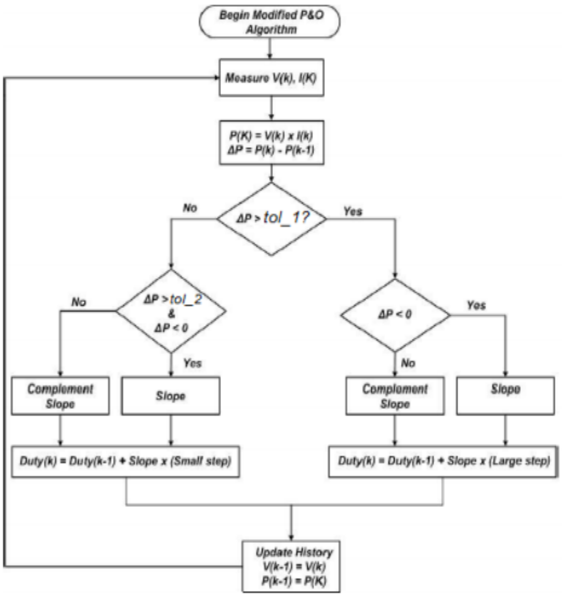


Fig 8: MPPT Algorithm perturbation and observation with variable step.

V. SIMULATION RESULT.

In this paper to verify the simulation result, we will test the proposed MPPT under only climate changing because the effect of RS and R_{Sh} are few, the result is modeled and investigated using Matlab/Simulink.

The MPP point tracking using both P&O MPPTs in case of changing irradiation level from 200 W/m2 to 500 W/m² and from 500 W/m² to 800 W/m² and from 800 W/m² to 1000 W/m² is given in Figs. 9-10. 16, respectively. In this case we evaluate the course of the MPP point (Osc-MPP) for both algorithms the classical fixed step size and the proposed variable step size one.

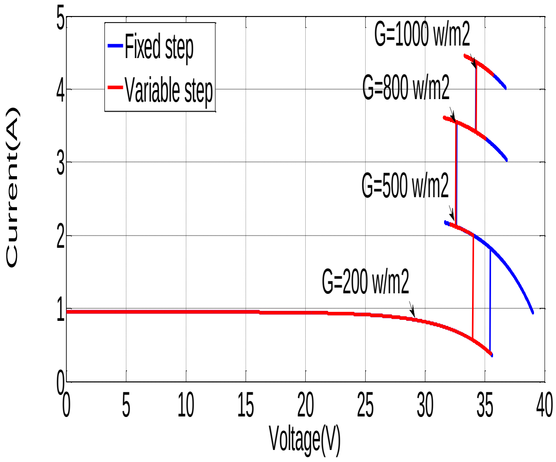


Fig 9 : I-V characteristics

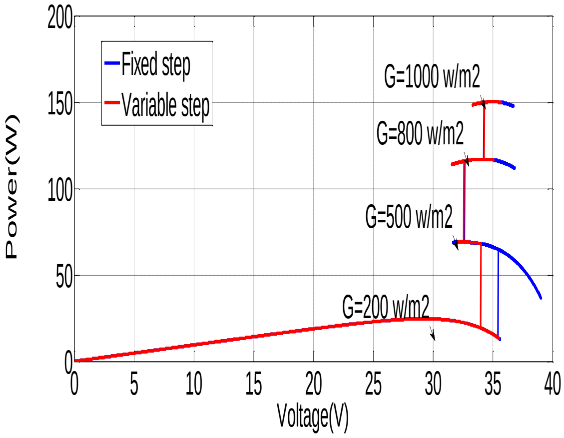


Fig 10 : I-V characteristics.

As can be seen from Figs 9-10, the Proposed MPPT with variable step showed less oscillation than the fixed step in both curve.

Fig 11 shows the output power for different irradiation starting with 200 to 1000 w/m^2,

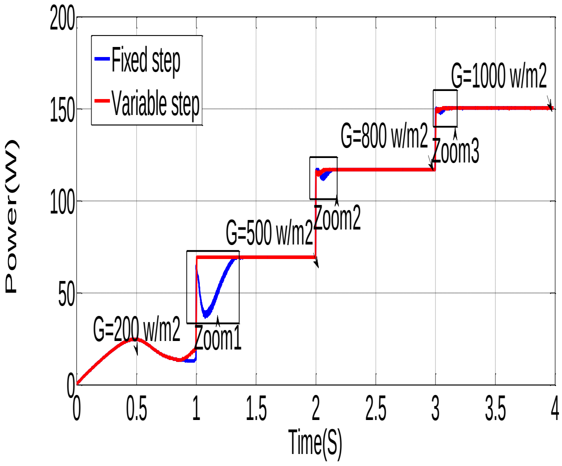


Fig 11 : Output Power with variable irradiation.

We can see clearly that the variable step minimized the oscillation and response time of fixed step, figs 12-13-14 show zooms for every changing.

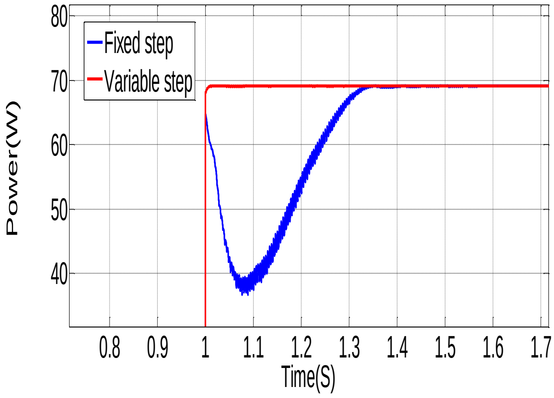


Fig 12 :Output power with variable irradiation: Zoom in Point 500.

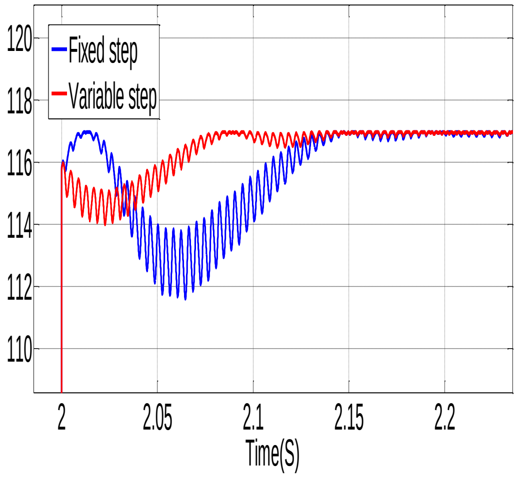


Fig 13 :Output power with variable irradiation: Zoom in Point 800.

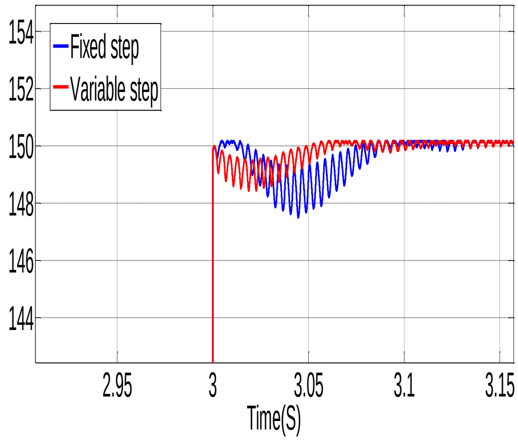


Fig 14 :Output power with variable irradiation: Zoom in Point 1000.

From Figures 12 to 14, it is clear that the proposed variable step size PO MPPT performs better than the standard fixed step size PO MPPT in case of changing irradiation.

Fig 15 shows output power for variable temperature 25,50 and 75C.

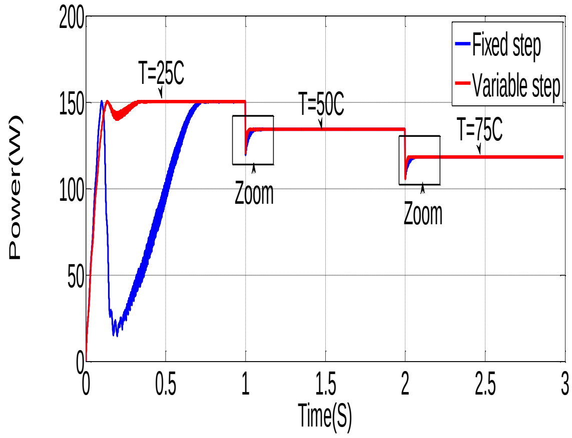


Fig 15 :Output power with variable temperature.

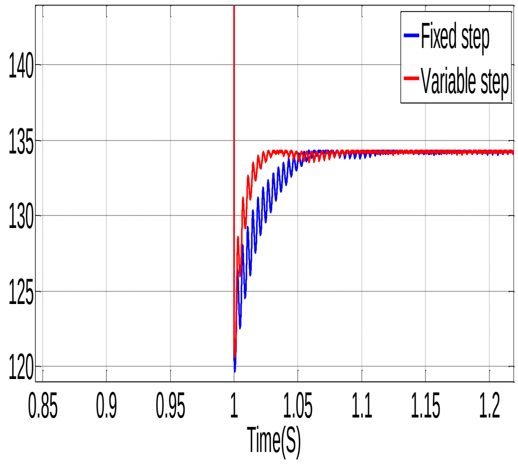


Fig 16 :Output power with variable temperature: Zoom in Point 50C.

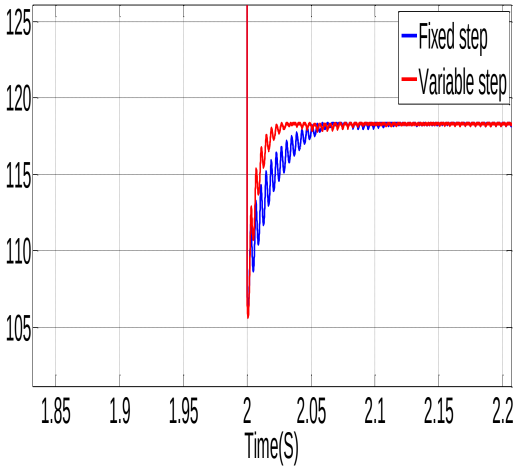


Fig 17 :Output power with variable temperature: Zoom in Point 75C.

The change of temperature effects the proposed MPPT but variable step showed less oscillation and response time then the fixed step.
This result confirms the robust of the proposed system under any change.

VI. Conclusion

This paper has proposed a variable step size P&O for trucking maximum power point of PV system, the whole system consist PV generate, DC-DC boost with resistive charge and MPPT P&O, the comparative study between both methods fixed and variable step prove the advantage of the variable step than the fixed, the proposed control minimized the oscillation and response time under any climate change even temperature or irradiation, this advantages necessary to minimize the loss of power in each change.

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