Design and Optimization of MPPT Routing in Solar Car Cells with the Maximum Power Point Tracking

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ABSTRACT: Photovoltaic systems have no pollution emission and noise production environmentally and no cost of fuel, economically. On the other hand, they require little maintenance and most importantly, they are unending. To trace the maximum power on the basis of actual values of current and PV array voltage, online methods such as P&O and RCC can be employed. In this way, we achieve the optimal performance point of the system. The current study investigated a series connection of two modules in a PV array, that only one of the modules is affected. In this case (the penumbra), in addition to a general maximum, there will be a local maximum point that makes tracing difficult.
Among the existing methods for designing MPPT, P&O and RCC are highly popular. In the simulation section of this paper, two mentioned methods are used with the help of MATLAB software. MSX60 model is used as a proposed solar car and the simulation results of this model are provided at the end of the paper. In the proposed method, a combination of two algorithms P&O and RCC is used to design MPPT. MPPT is designed in two stages; first stage RCC, and the second stage P&O algorithm

KEYWORDS: Photovoltaic, Solar Simulators, RCC control , P&O method.

I. INTRODUCTION

The increase in energy demand, fuel price, global warming, and attention to environmental pollution has led to much more attention to renewable energy sources. Many sources are available as renewable energy, such as solar, wind, earth, heat, hydrogen (fuel cell) and so on. But it seems that among them, the tendency is more towards solar energy [1].
Photovoltaic systems have no pollution emission and noise production environmentally and no cost of fuel, economically. On the other hand, they require little maintenance and most importantly, they are unending. [2].
Photovoltaic systems have two major disadvantages:
- High costs and very low efficiency (about 9 to 16%)
- Continuous change in the amount of power produced by atmospheric conditions (temperature and radiation)
The research has focused on the methods of tracing maximum power in order to extract the maximum amount of one or more connected arrays. For this purpose, many methods have been proposed that have differences in complexity, convergence speed, cost, required sensors, effectiveness range, hardware implementation and etc. which are classified as follows:

- Hill Climbing method
- P&O method
- Incremental Conductance method
- Ripple Correlation Control (RCC) method
- Fractional Open-circuit Voltage method
- Fractional Short-circuit Current method
- Fuzzy Logic Control method
- Neural Network method

Online methods such as P&O and RCC track the maximum power on the basis of actual values of current and PV array voltage. Therefore, the optimal system performance point is achieved. These methods are more expensive due to the use of additional circuits and are usually used in large scale systems [1].

Although the research in this field has led to good results, but these methods need to be developed so that can find the maximum power point in two or more arrays that are connected in series or parallel. Particularly, under radiation and temperature variable conditions which the local maximum will involve MPPT algorithms in those points [2].

Reference [3] presented a new algorithm based on the P&O algorithm. This algorithm has a fast operation and it eliminates the need to use a capacitor with a large value to remove the voltage ripple in the P&O method. Instantaneous value is used instead of the mean voltage and array current which increases the speed of tracking.

Reference [4] presented an improved method named P&O-dp, which makes extra measurements without creating turbulence in the voltage and current. In this way with the three consecutive samples, the effect of turbulence in voltage (current) and the effect of changes in atmospheric conditions are evaluated, so increasing power is applied only when is caused by the MPPT algorithm.

Reference [5] proposed a two-step method for tracking the overall maximum point. In the first phase, the local maximum area can be found, and in the second phase, using the algorithm P&O, the local maximum points are tracked. At first, the nearest local maximum is found, then it searches left side and then right side to find the other local maximums.

Reference [6] proposed an MPPT system with parallel connections, where the modules PV are connected in parallel. Each module will follow specifically its own MPP. If a module placed under the influence of light, its performance is not transmitted to other modules. The problem of this method is high hardware facilities and high cost for implementing it.

II. METHODOLOGY

II.1. Introduction of the system under study

Photovoltaic cells have a non-linear I-V characteristic, which depends on the amount of solar radiation and cell temperature. Under ideal conditions, a solar cell can be modeled by a current source which became parallel with a diode. But the losses of the cells can be modeled by R_s series resistance and R_{sh} parallel resistance. So in real terms, the orbital model became a PV cell in Figure 1 [1] and [2].
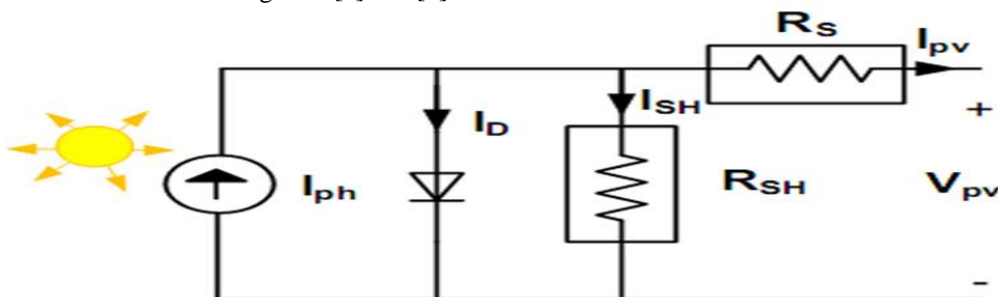

Fig. 1 The circuit model of PV cell

The R_s value is usually very small, and the R_{sh} value is very large. Also the source current of I_{ph} in the dark conditions tends to zero.

According to the equivalent value of a photovoltaic cell and the law of KCL, Equation (1) can be written as follows:

$$(1) \quad I_{pv} = I_{ph} - I_D - I_{sh}$$

Which finally with a good approximation, the following equation is obtained which is called the current equation of solar cell. [3]:

$$(2) \quad I_{pv} = I_{ph} I_\circ \left(e^{\frac{q(I_{pv}+I_{pv}R_S)}{N_S.A.K.T}} - 1 \right)$$

Then, if module PV includes the N_p series cell and infinite resistance R_{sh}, the equations of voltage and power are determined by the following correlations:

$$(3) \quad V_{pv} = \left(\frac{N_S.A.T.K}{q} \right) . In \left(\frac{N_p.I_{pn} - I_{pv} + N_p.I_\circ}{q} \right) - R_s I_{pv}$$

$$(4) \quad P_{pv} = V_{pv} I_{pv}$$

Factors affecting the performance of the modules PV Can be attributed to 4 factors:
1.   Temperature: As shown in Figure 2, temperature rising will reduce the voltage, and current is almost constant.
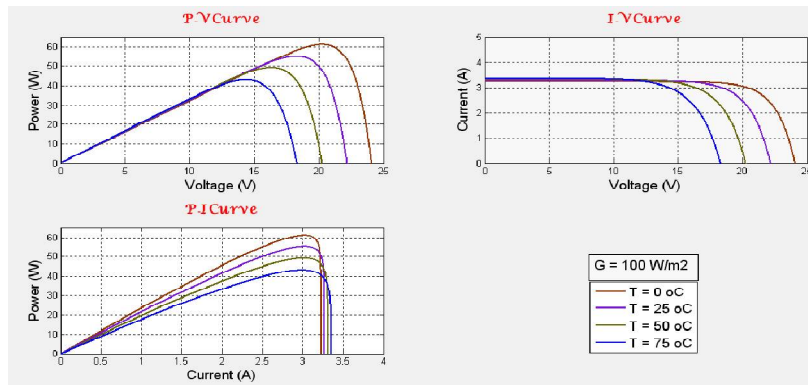

Fig. 2 changes in PV array curves or temperature in the constant radiation intensity

2.   Solar radiation intensity: radiation intensity rising will increase current and voltage is almost constant
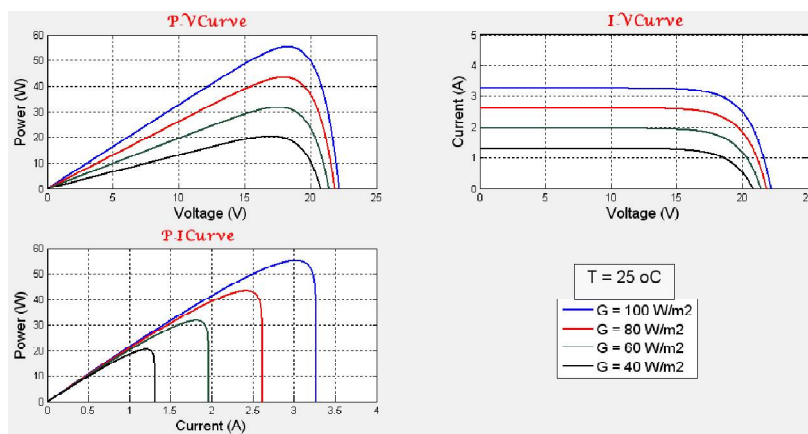

Fig. 3 changes in PV array curves or radiation intensity at a constant temperature

3.   The structure of the array: array performance depends on the type of cells used and the quality of construction by the manufacturer. The values Rsh and Rs can be changed according to the structure.
4.   Shadows: Shadows are either complete or incomplete and are often caused by passing clouds, adjacent buildings and towers, trees, electricity and telecommunications pylons and etc.

II.2. Description of the problem

We describe the studied problem as follows: If in a PV array, two modules are connected together in series and only one of the modules would affected (penumbra terms), in this case, curves I = V, P-I, P-V are affected by the penumbra. Figure 4 shows the Curves IV Array PV Under the terms of the penumbra.
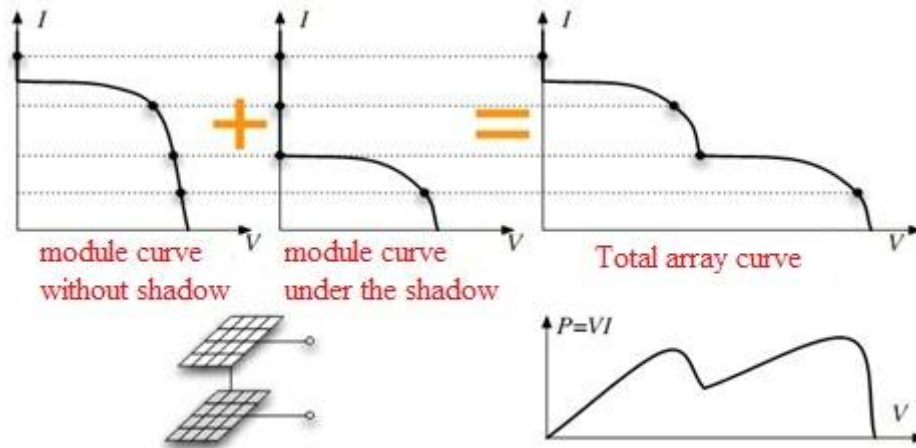

Fig. 4 PV array curve or series connection in the penumbra

It can be seen that the above array in the penumbra in addition to a maximum total has a local maximum point. And since the goal is to track the overall maximum, it makes difficult to trace issue [7]. Therefore, many algorithms have been proposed for this purpose, and in this paper, according to the proposed method, 3 of these algorithms are mentioned briefly.

A) Method P&O / Hill climbing [8-9]

The Hill climbing method would make a change in the rate of D, and P&O makes a change in the PV array voltage. In the case of connecting a PV array to power converter, switching rates of D converter, will change the PV array current, and as a result, PV array voltage would change; P&O and Hill climbing methods are two fundamentally different ways with the same performance. These methods are not successful in the rapidly changing weather conditions.

B) Ripple Correlation Control (RCC) method [8] and [10]

When PV array is connected to the power converter, the switching act creates a ripple in the voltage and the PV array current which in return created a ripple in power. The RCC would use of ripple to run MPPT. Recently, some research has been done in the field of tracking the array maximum power using this ripple as inner turmoil. RCC method makes the connection between the time derivative of the current with the time derivative of current and array voltage which is variable with time, until the slope of power can be equal to zero, so that MPP achieved.

C) S-P&O and S-RCC two-step methods

This is a two-step method of tracking the maximum power, which for two modules connected in series, it will determine the overall maximum points. The first phase of the method would measure the radiation and the temperature of the array, and it finds the final P-I curve. Then, a search algorithm would run to estimate the location of MPP with two indices of current and power in the MPP point. When climate changes go beyond a certain level, the search would repeat. The second phase is the actual characteristic curve method, which began the search for MPP from the estimated point of the first phase or from the performance of its former performance point, where the P&O and RCC methods used. This case depends on changes in the performance conditions.

Among the existing methods for designing MPPT, two approaches P&O and RCC are better. In the simulations section and in this paper, two methods are done with the help of MATLAB software. The model MSX60 is used as a proposed solar car, and the simulation results of the model are provided at the end of the article. In the proposed method, a

combination of two algorithms P&O and RCC are used to design MPPT. MPPT designing will be done in two stages. In the first stage, the RCC is used, and in the second stage the P&O algorithm is modeled.

III. DESIGN AND SIMULATION OF SOLAR CAR

III.1. BP MSX60 model

MSX60 is an example of the PV modules with the power of 60 watts, which is selected for modeling. This module has 36 poly-crystal series connected cells. The main specifications of this model are shown in the table 1.

Table 1. Key specifications of MSX60 panel

Parameter	Specifications	Value
Pmax	Maximum power output	60W
Vmp	Voltage for maximum power	17.1 V
Imp	Current for maximum power	3.5 A
ISC	Short-circuit Current	3.8A
VOC	Open-circuit Voltage	21.1V
KV	Thermal coefficient for open circuit voltage	- (80 ± 10) mV / ° C
KI	Thermal coefficient for short circuit voltage	(0.065± 0.15 65)% / ° C
KP	Thermal coefficient for power	- (0.5 ± 0.05)% / ° C
NOCT	Rate of cell with environment	47 ± 2 ° C

In curve of Figure 5, MSX60 model has been shown for different levels of radiation. As shown in this figure, it can be said that the constant curve of power is tangent to each one of shown VI curves.
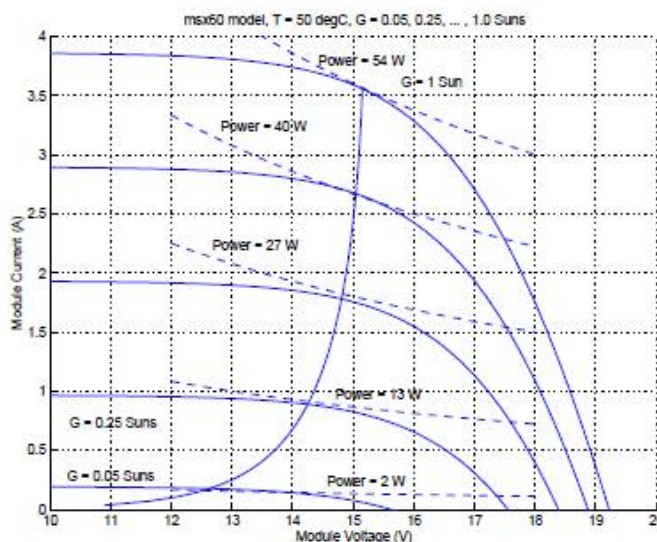

Fig. 5 Curve for MATLAB model for different levels of radiation (G = 50; 250; 500; 750; 1000 Wm2) in nominal operation of panel with temperature 50 C.

As expected, the results for the model MSX60 in MATLAB are corresponding to the characteristic VI curve which presented in the proper context.

III.2.1. Introduction MPPT controller

An MPPT system designed with a converter DC-DC and a microcontroller based on the control device.

The software architecture for an independent MPPT system can be very simple. One suitable way for control MPPT as well as low-power processor is using a single processor. This requires that MPPT test in the architecture that is able to adapt to tasks related to control the inverter in the development stage.
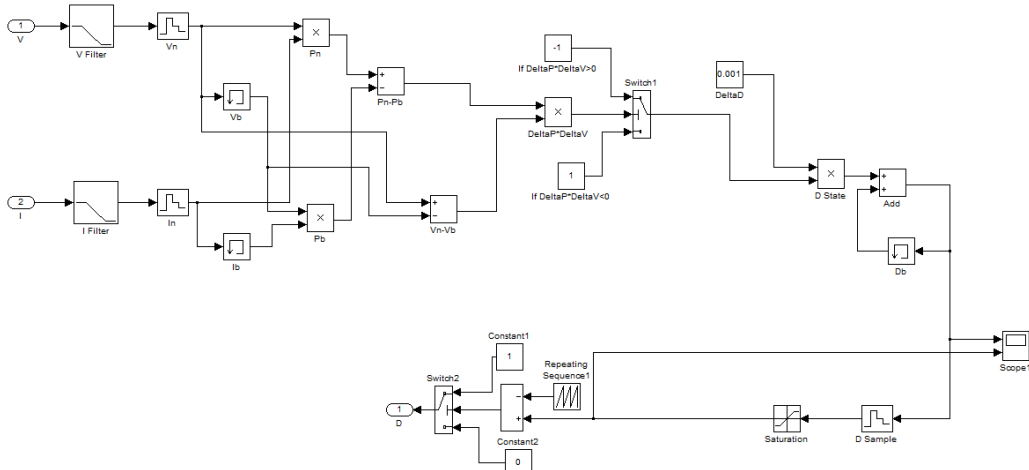

Fig. 6 Simulation MPPT model in MATLAB

The model shows a simulation of an MPPT in MATLAB. Voltage and current are inputs of this subsystem. At first, a low pass filter applied over two inputs and then a sampling is done. Next, a delay applied over the sampled signals. The power obtained from current and sampled voltage as well as delay current and voltage are calculated. After applying changes and comparing them with each other, the output of MPPT was applied to the circuit.

As it has been shown in figure 7 (PV design), the MPPT is used as a controller. Subsystem 1 with taking two fixed values which considered 25 and 400, and a voltage that is obtained as feedback, it generates the current as the output.
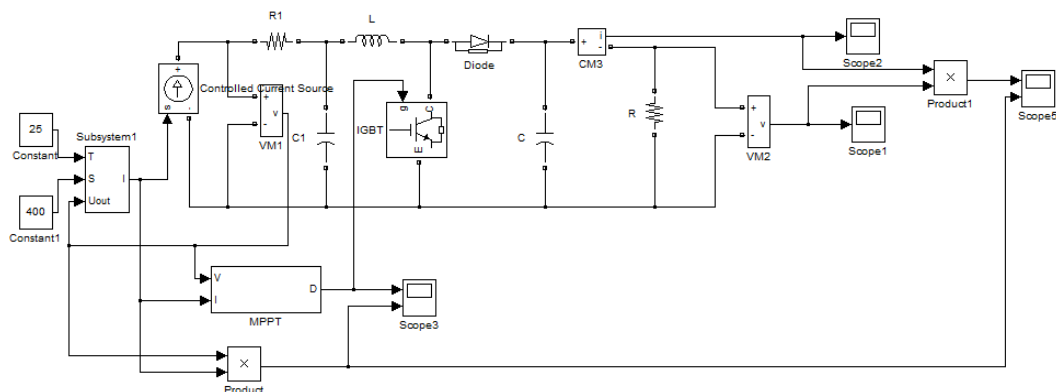

Fig. 7 Design PV with MPPT

In figures 8 and 9, voltage and the current circuits curve are shown in terms of time. It is acknowledged that the power consumption value is equal to current multiplied by voltage, and the results of applying MPPT are shown in figure 10. As it stands, using MPPT leads into power consumption improvement and stability.
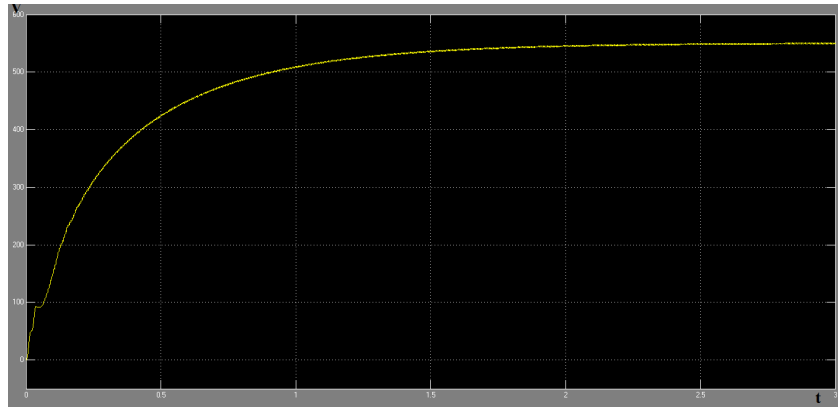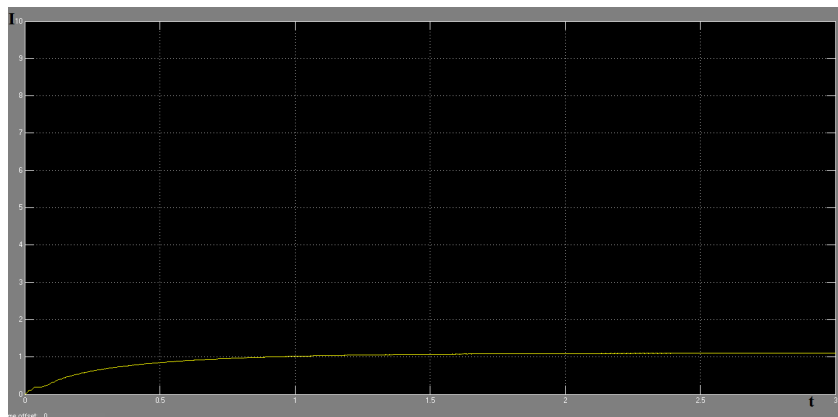
Fig. 8 circuit voltage diagram
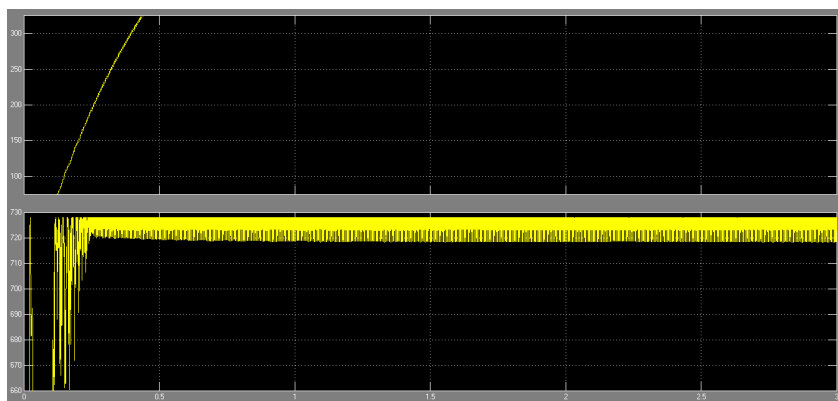

Fig. 9 circuit current diagram

Fig. 10 circuit output using MPPT (above), circuit output without using MPPT (below)

III.2.2. P&O and RCC algorithms

Because of its simple feedback structure and less measured parameters, P&O method has been used widely. P&O method needs an external circuit to repeat the array voltage transformation, so then it will be able to measure changes in output.
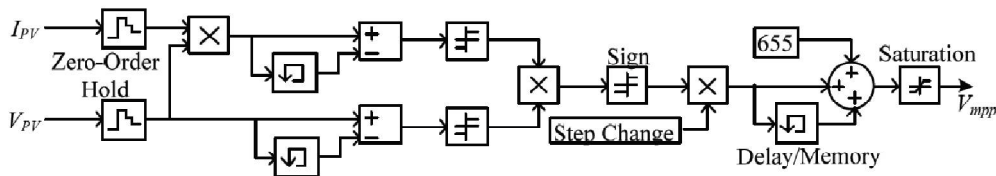
Fig. 11 P&O algorithm

As shown in the P&O algorithm in figure 11, current and voltage are considered as the circuit inputs. After sampling both of signal inputs, the power can be produced as output.

The RCC is a high-performance real-time optimization method that can be used to get the maximum photovoltaic power. The RCC method makes a connection between the time derivative of the power and the time derivative of current and array voltage which are variable with time, until the slope of power equals to zero, so that MPP could be achieved. Figure 12 shows an RCC algorithm.
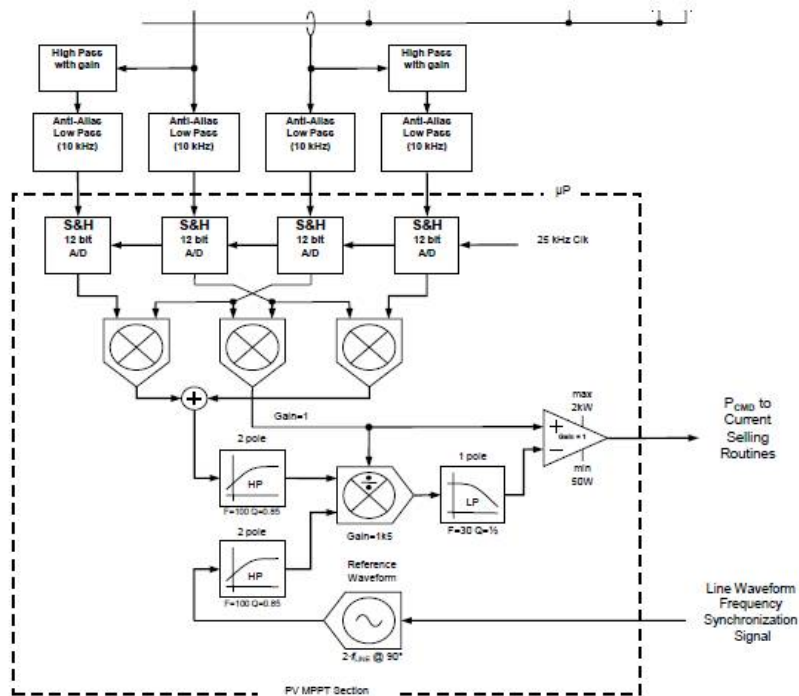

Fig. 12 RCC algorithm

III.3. Simulation proposed MPPT

This article was employed a two-step MPPT control algorithm for improving the power. The first step is to model RCC control algorithm and it was used the P&O model in the second step of controller design.

In the first level of control, the VPV array voltage and the PPV power are given as inputs to RCC unit. After that, the RCC unit calculates the working cycle of the system and sends the maximum available power for loading at steady state. In the second stage, a new working cycle is calculated, and then it routed from RCC unit to P&O unit, where the dynamics of the whole photovoltaic power conversion system are improved. Figure 13 shows the proposed simulation according to the above description.
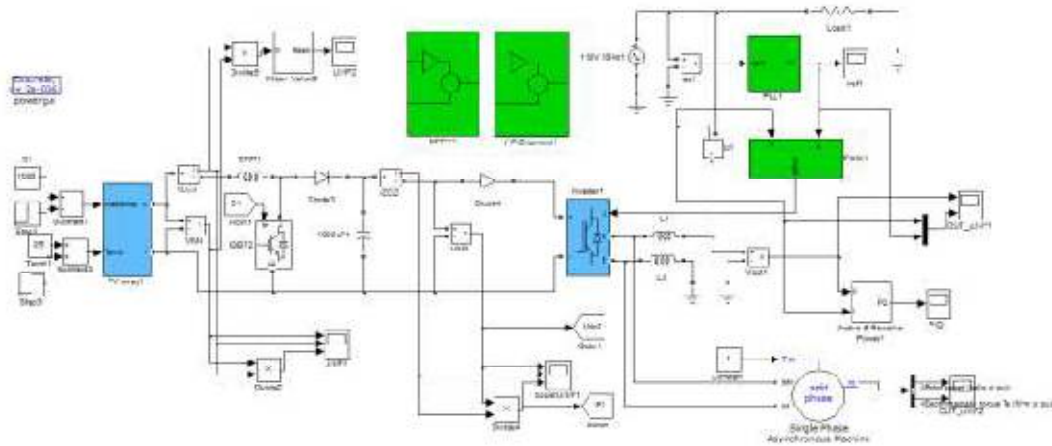
Fig. 13 Simulation proposed MPPT

Figure 14 (A) shows a comparison between the input voltage and the increased voltage. As it can be seen, when the input voltage is 41 volts and the current is 1.637 Amp, the power value can be equal to 67.09 watts. According to the given input, the output voltage should be in a way that the settlement power and the voltage increase less. In this figure, the waveform of voltage, current and power input to the boost converter (increasing DC-DC converter) are shown. It can be seen from the diagram that the current initially rises, and begins with its maximum value.

Since this converter works based on switching, in order eliminate ripple in the output voltage, a capacitor used, and also by using a diode, the output current became one-way, so the reactive loads could be fed without problem.

Figure 14 (B) shows the wave incremental outputs. When you see the voltage waveform, voltage is 3 times more than the input value. This additive voltage is achieved in less time than 0.2 Sec.
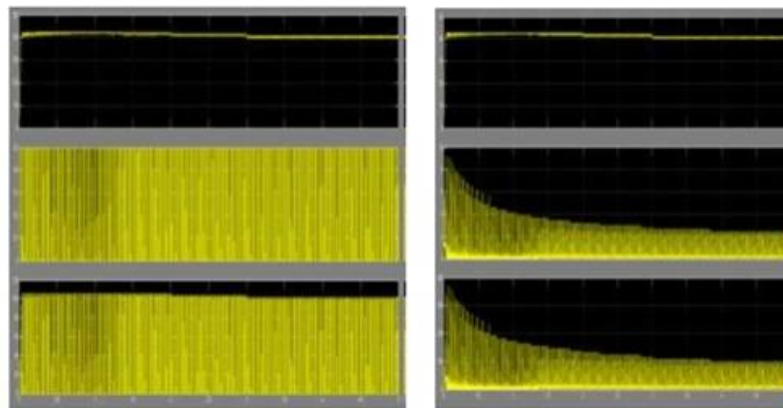
Fig. 14 (A) (waveform of voltage - current, and power input to the boost converter)(B) increased output wave

IV. CONCLUSION

To improve the efficiency of photovoltaic systems, MPPT algorithm is used to create the maximum power available for solar arrays. Important issues that should be considered in the MPPT algorithm include system complexity, uncertainty and dynamic performance. This research provided an adaptive control architecture, which can reduce the complexity of the control system, and effectively address the ambiguities and turmoil in photovoltaic systems. In this study a control two-step MPPT algorithm is used to improve the consuming power; the first phase includes an RCC control model algorithm, and P&O model is used in the second phase of controller design. Using MSX60 as proposed

solar car, and according to the simulation results of these two methods using MATLAB software (Figure 14), it can be concluded that the output voltage is three times more than the input amount, and this additive voltage is achieved in less time than 0.2 Sec.

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