New MPPT algorithm based on PIC microcontroller

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New MPPT algorithm based on PIC microcontroller

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Abstract

This paper suggests a new MPPT (maximum power point tracker) algorithm and compare it with the two most popular algorithms. A comparison done with the (perturbation and observation) algorithm and the (incremental conductance) algorithm. The accumulation of the Testing results in this research is a difficult task. Hence, this will be obtained by using an interface software build by the designer, drawing on the LabVIEW software for this task. LabVIEW software will help to build a driver in the computer, for the USB of the PIC18f4550, such that the operation of data transfer will be across the USB cable connecting the PIC to the computer. The comparisons show the ability of the proposed algorithm to accumulate more energy as compared with other algorithms.

1. Introduction

Since the manufacturing of the solar energy panels, the researchers worked on enhancements of its performance in many respects especially in the MPPT algorithms. The task of the MPPT algorithm is transferring maximum power from the solar panel to the user by making the maximum point of the power voltage curve (P-V), the operating point of the system. Since, any difference in solar irradiance intensity has led to different P-V curves and that will make MPPT algorithm operates again to find the new maximum power point. The tracking response differs in time, accuracy and quality, depending on the type of the algorithm. The comparison process between algorithms responses is difficult to be done, so LabVIEW software adopted for this task.

As the power supplied by the solar array depends on the insolation, temperature and orientation, then the design of an efficient tracking algorithm of the maximum power point is very important for any solar array system. The purpose of the MPPT is to move the array operating voltage close to the MPP under changing atmospheric conditions [1].

Most of the design guides are based on the constant output while the input can have some pulsation of voltage. The difficulty of the MPPT design is that the input voltage and output voltage are variable [2].

The methods of MPPT vary in complexity, sensors required, convergence speed, cost, range of effectiveness, hardware implementation, popularity, and in other respects [3].

The DC to DC converter which has been used was already designed and implemented by the researchers as seen in Fig.1 [4].

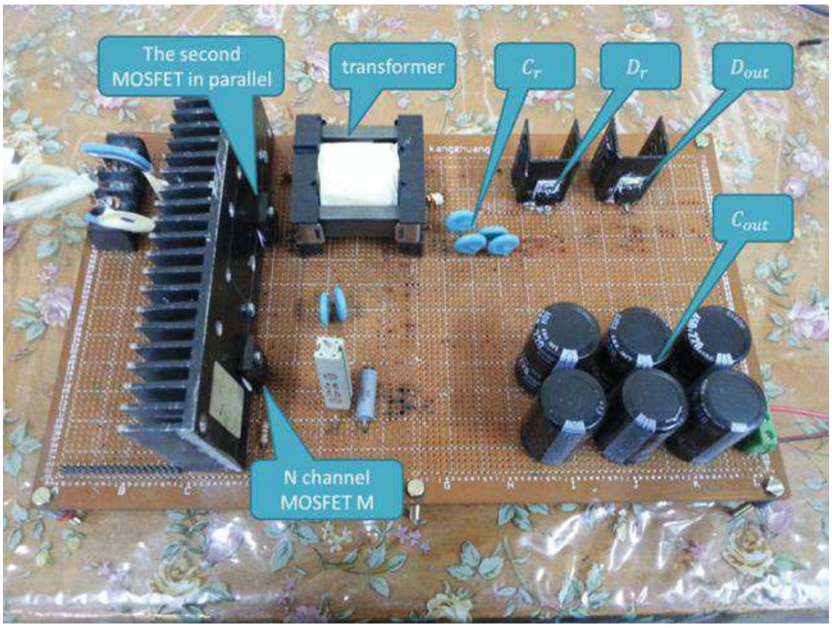


Fig. 1. The DC to DC converter

To reach the optimum converter and MPPT controller design, a need arises for much information about the PV panel used. Table 1 illustrates the parameters of SOLAR ONE 250W PV panel.

Table 1: parameters of the PV panel SOLAR ONE 250W tested by "Sun Simulator"[5]

Operator	Value
Current temperature coefficient (mA/℃)	2.0000
Voltage temperature coefficient (mV/℃)	-2.0000
Model area (cm^2)	100.00
Sensor temperature (℃)	32.5
Irradiance (mW/cm^2)	100.0
Isc (A)	10.3186
Voc (V)	34.7315
P_{MPP} (W)	296.4684
I_{MPP} (A)	10.1569
V_{MPP} (V)	29.1889
F.F. %	82.72
Module efficiency (%)	29.6541
Estimated shunt resistance (Ω)	180.5127
Estimated series resistance (Ω)	0.1401

2. Maximum Power Point Tracker (MPPT)

The MPPT is a strategy followed to harvest the most generated power from certain sources like PV systems and wind turbine [1]. In this research, this mission was entrusted by a microcontroller based DC to DC converter that optimize the match between the solar array (PV panels), and the load. Simply, it is an algorithm fed by the values of the voltage and current of the panel at each instant. It has an ability to utilize these values in changing the input resistance of the load to match the internal resistance of the panel at each instant by changing the pulse width of the DC to DC converter [6]. This process provides the ability to change the load input resistance such that it extract (I_{mpp}) from the panel at its terminal voltage (V_{mpp}) at that instant. This means that the maximum power point of the panel can be instantaneously tracked. This converter cannot be dispensed in any way if solar PV panels used as a source.
Different Methods and topologies are available for applying the MPPT algorithm. The choice depends on many factors according to the ability of each algorithm and its compatibility with the circumstances of the required system. The main topology of these algorithms is shown in Fig. 2.

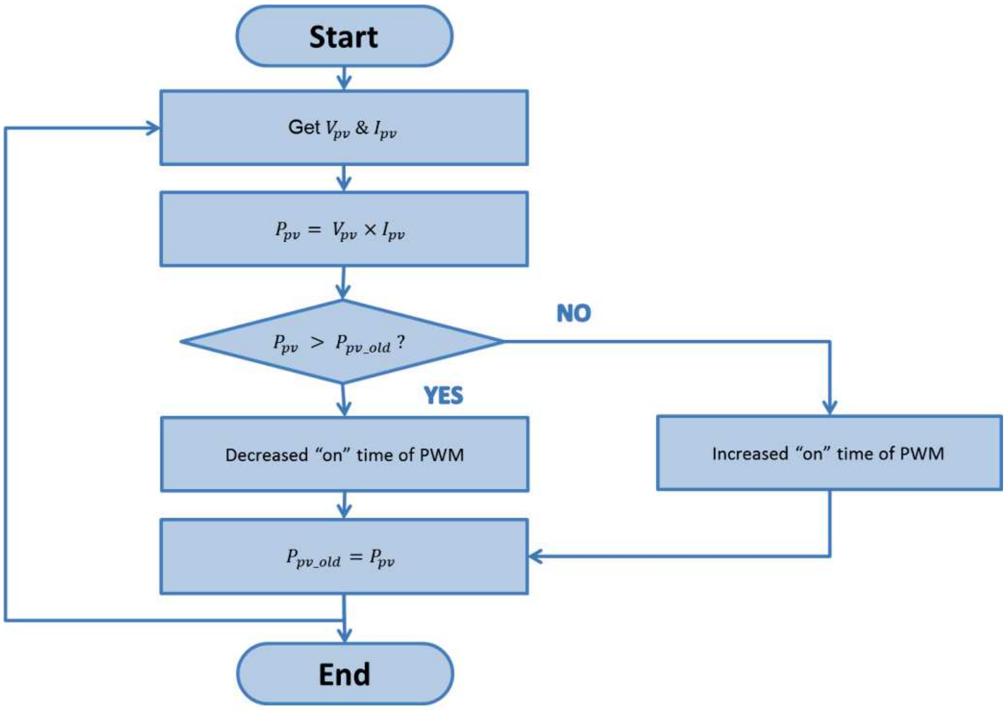


Fig. 2. The Main MPPT Algorithm

There are several types of MPPT algorithms (Constant Voltage Method, Short-Current Pulse Method, Open Voltage Method, Perturb and Observe Method and Incremental Conductance Method) [7]. The popular algorithms are P&O (perturb and observe) and I_C (incremental conductance). Each type has several advantages and disadvantages that make the user prefer one of them due to many requirements and conditions.

2.1. Perturb and Observe method (P&O)

Perturb and Observe method has been widely used because of its simple implementation structure [1]. Perturb and observe operating essentially on the perturbation of the system by increasing or decreasing the "on" time of the PMW at each cycle of MPPT and observing the array terminal voltage and current to detect the maximum point of the PV curve. Its drawback is that, when the maximum point reached, the perturbation persists, and that makes an oscillation around the maximum power point which is leading to decrease the harvesting power from the panel array. There are some types of P&O algorithms have been implemented later [7], but the classical one will be relied on here. At each algorithm cycle, there is a difference between the array terminal voltage and power as compared with the previous one, these are ΔV and ΔP respectively as shown in Fig.3.a. Then the algorithm decides whether the "on" period must be increased or decreased, and it assigns and record the voltage and power values of the cycle to be considered as a reference to the next cycle and so on. This operation repeated until the maximum power point reached as a hill climbing. Hence, the algorithm will continue to oscillate around the MPP in spite of reaching the top of the hill, but the oscillation will be minimized by reducing the perturbation step size [3].

2.2. Incremental Conductance Method

The I_C's algorithm has many topologies, but all that depends on the ΔV and ΔI. The algorithm name came from the term $(\Delta I/\Delta V)$ which is known as the incremental conductance [1]. This value makes the algorithm go in the right direction and achieving the goal at which $\{(\Delta P/\Delta V) = 0\}$ means reaching the maximum power point, as seen in Fig. 4. The I_C algorithm catches the maximum power point exactly and still observing the system by observing the ΔV and ΔI, if they have any changes, then it will repeat the procedure to catch the maximum power point again.
After calculating the ΔV and ΔI through new condition, see Fig. 3.b, if the $\Delta V \neq 0$ this means the algorithm point is somewhere, but not on the maximum power point, so the algorithm looking again at the sign of the new $(\Delta P/\Delta V)$, whether it is positive or negative for pursuing the right direction to reach the MPP again.
Assuming it catching up the maximum power point (MPP) at certain weather condition, if the condition change suddenly the ΔV not change and still equal to zero, but the ΔI has greatly changed, that makes the algorithm to operate again and so on. The increment size determines how fast the MPP is tracked[7]. It's possible to increase the increment size, but at the expense of the accuracy [3].

2.3. The Proposed MPPT Algorithm Method

The proposed system has the same basics of the I_C algorithm, but it possible to control the incremental size depending on the tracking position [8]. If the tracking position is far away from the MPP, the incremental size will adopt its maximum value, and then its size decreased gradually as it moves towards the MPP until it becomes a very small value at the MPP exactly. That makes it faster than the I_C algorithm in order to reach the MPP as seen in Fig. *3.c*. This is will be done by using a lookup table shown in Fig. *3.d*. The table has different values of the increment step $\boldsymbol{\Delta d}$ that make it possible to change the size of the step easily to reduce the time elapsed to reach the MPP as fast as possible. It observes the ratio of the power $\boldsymbol{m}$ w.r.t. the previous one, if the tracking on the left side (positive side) or on the right side (negative side). Then the value of $\boldsymbol{m}$ will be calculated, and from the lookup table the right value of $\boldsymbol{\Delta d}$ can be determined.

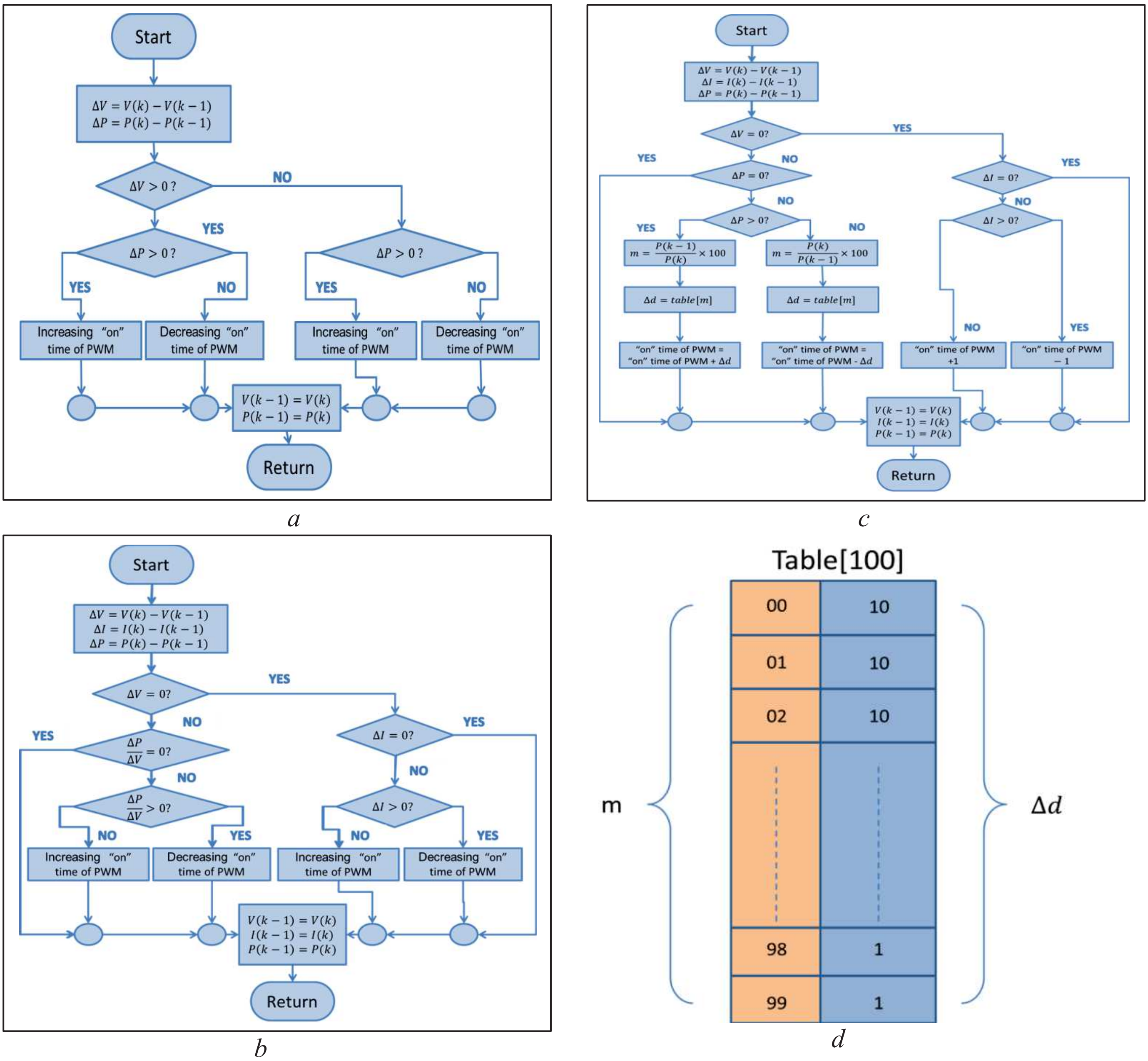


Fig. 3. The types of MPPT algorithms (a) P&O MPPT Algorithm (b) I_C Algorithm (c) Proposed MPPT Algorithm (d) The Lookup Table

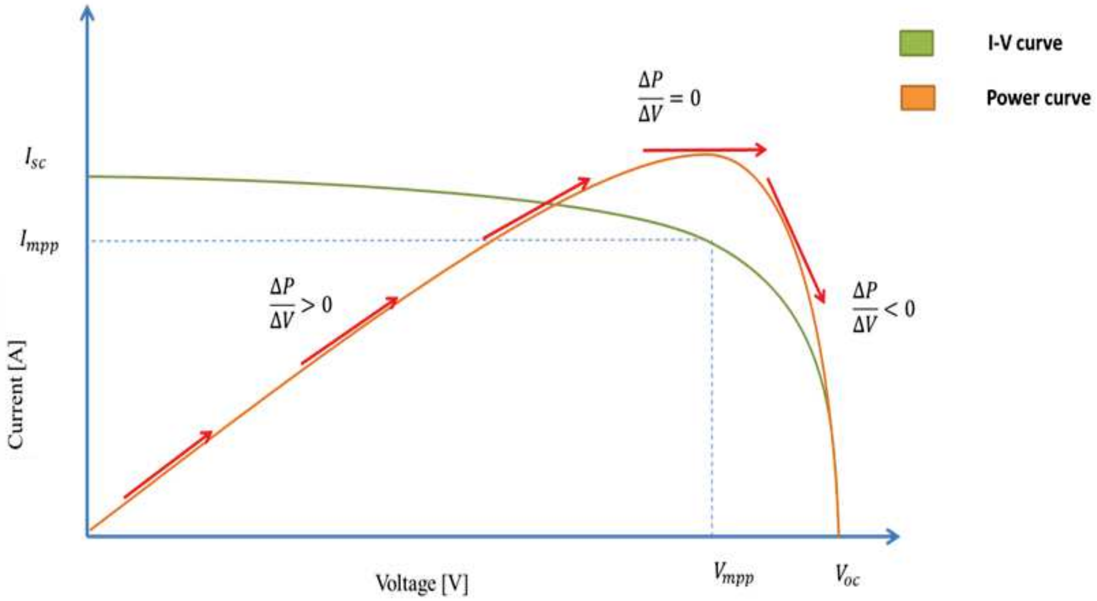


Fig. 4. Operation of I_C Algorithm

3. PIC Microcontroller

The microcontrollers played revolutionary role in the embedded industry after the invention of Intel 8051. The steady and progressive research in this field gave the industry more efficient, high-performance and low-power consumption microcontrollers. The AVR, PIC and ARM are the prime examples. The new age microcontrollers are getting smarter and richer by including latest communication protocols like USB, I2C, SPI, Ethernet, CAN etc. [9]. Novices in electronics usually think that the microcontroller is the same as the microprocessor. That's not true. They differ from each other in many ways. The first and most important difference in favor of the microcontroller is its functionality. In order to use the microprocessor, other components, first of all memory must be added to it. Even though it is considered a powerful computing machine. It is not capable of establishing direct communication with the peripherals [10]. The name PIC initially referred to Peripheral Interface Controller [11]. The PIC microcontroller is very easy to use. It is a single chip that can do all functions you need like ADC (analog to digital converter), timer, comparator, PWM generator and all mathematical functions. In this paper PIC get two values in analog from the sensors in the Fig. 5 and convert it to digital form by ADC function, then multiply it to get the power coming from the PV panel P_{pv} and compare whether this power more than the old one P_{pv_old}. From that condition it can decide to increase or decrease the duty cycle ratio.

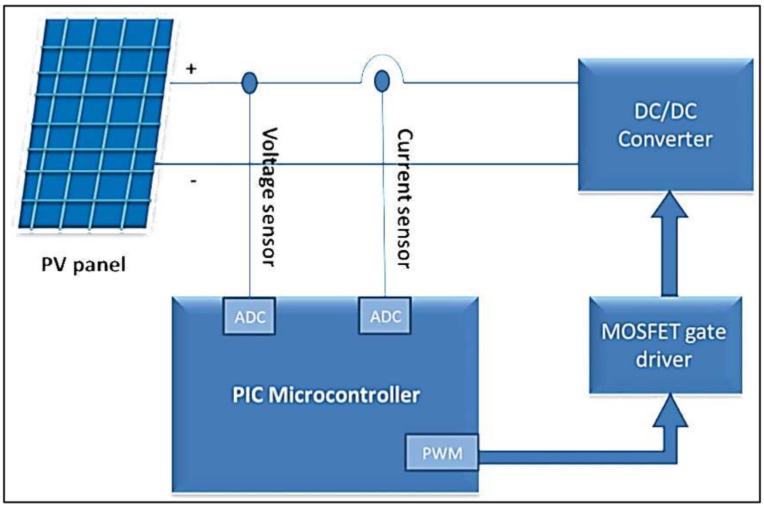


Fig. 5. *Microcontroller block diagram*

The PIC18f4550 has some useful features, first is an analog to digital module (ADC) built-in with it, so no need to convert the analog signals from the sensors to digital form to involve it within the code. The second feature is the built in module for pulse width modulation. The third feature is the existence of the USB connection, which is the reason behind choosing the PIC18f4550. It also contains a full-speed and low-speed compatible USB Serial Interface Engine (SIE) that allows fast communication between any USB host and the PIC microcontroller. Fig. 6 is the 40-Pin PDIP package [12]. Voltage sensor: is no more than a voltage signal used as a measure of the PV panel output voltage(V_{pv}). A voltage divider used for this purpose to send a corresponding signal of the PV panel output voltage to the microcontroller. This is done due to the fact that the maximum voltage can deal with by the microprocessor no more than five volts. Hence, the output voltage (V_{vs}) as shown in Fig. 7.a can be calculated by using the following formula:

$$V_{vs} = V_{pv} \times \frac{R_2}{R_1 + R_2} \dots\dots\dots\dots\dots\dots (1)$$

Current sensor: it is a transducer converting the current flow from the PV panel to its corresponding signal of no more than 5V. This is achieved by using simple sensor of a very small value of resistor, but it is of high power rating in order not to be damaged when it passes the high values of the current and at the same time do not affect the circuit operation as shown in Fig. 7.b Due to its small value, a small voltage appears across it for high current values and that's not enough for current sensing, in that case it will need an amplification unit like an Op-Amp as a noninverting amplifier by ten times to achieve the required value (V_{cs}).

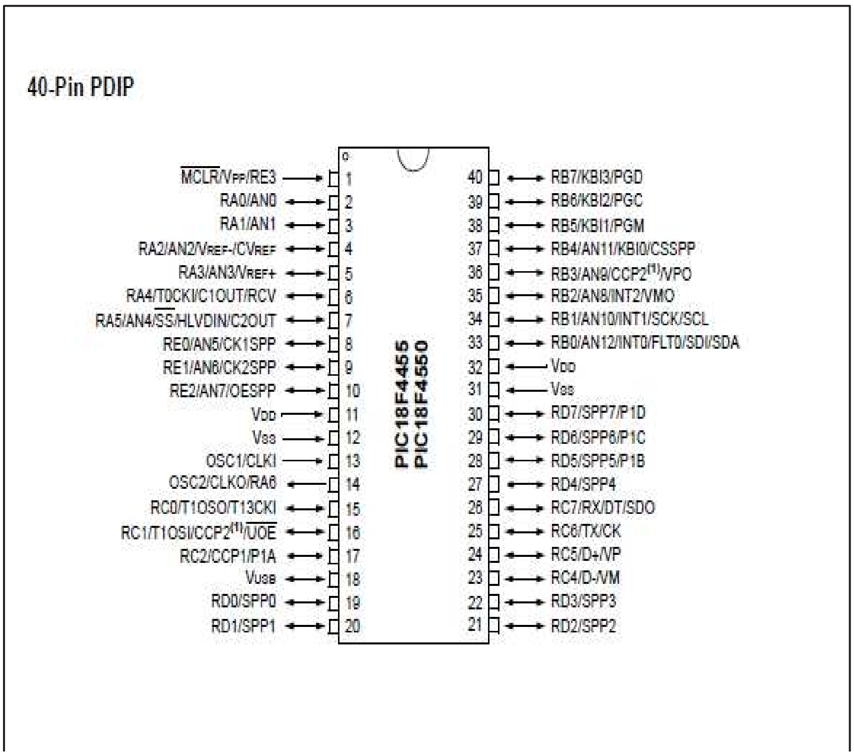


Fig. 6. Pin Diagram of PIC18f4550 Microcontroller [12]

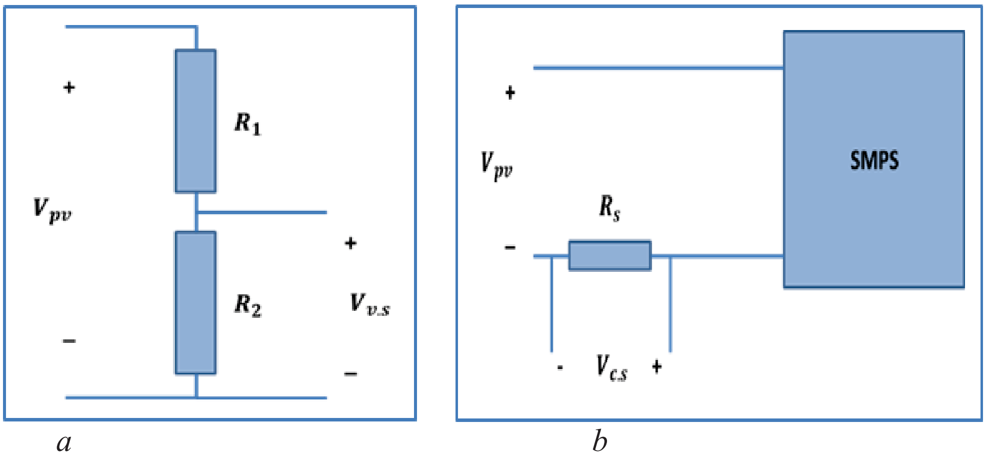


Fig. 7. Analogue sensors (a) simple divider circuit (b) current sensor location to get a true sense

4. Instantaneous Power Meter Program Design

To study and analyse the designed system, a need arises to use the Universal Serial Bus (USB) as an information collector to transfer the data to the computer. The USB was developed by the PC manufacturers to provide a low-cost solution for attaching any peripheral devices and communicate with him, like getting instantaneous information from that device. Since the microcontroller PIC18f4550 has

USB support, and it deals with input/output information through USB connector, so it can be connected to the personal computer (PC). The PC dealings with identified devices like mouse, keyboard, camera, etc. through their USB's connecters because their descriptors are installed on this PC earlier. But when using a new USB device the PC is not able to deal with, in that case a need arises for using a program able to communicate the PIC18f4550 with PC and that's requires to use LabVIEW. NI LabVIEW is a software used for many industrial applications. It is a highly productive development environment for creating custom applications that interact with the real environment data or signals in fields such as science and engineering. It is a tool providing higher quality projects that have been completed in less time with fewer people involved.

Productivity is its special benefit, that is the reason behind the attraction of the engineers and scientists to the product for the later years. Engineers and scientists have a research and work done, they need to show the results of what they did, and they need tools that help them do that. LabVIEW will help because it makes a wide variety of tools available in a single environment, ensuring that the compatibility is as simple as drawing wires between functions. One of these tools used in this research is NI-VISA to communicate with a USB device. LabVIEW is able to install a new USB device and use NI-VISA to communicate with that device, as long as it understands the device communication protocol. VISA is a high-level application used to communicate with instrumentation buses. It has an independent platform, independent bus, and independent environment. In other words, the same application is used regardless of whether a program is created to communicate with a USB device with LabVIEW on a machine running Windows 7 or with a GPIB device with C on a machine running Mac OS X [13].

USB is a message based on communication bus. A PC and a USB device communicate by sending commands and data over the bus as text or binary data. Each USB device has its own command set, can be provided by the designer in case of using PIC18f4550, a descriptor file edited by the designer. The read and write functions of NI-VISA can be used to send commands to an instrument (new USB device) and read the response from this instrument. Each USB device has a definition, so-called descriptor file. Descriptor file is a program carries all of vendor name and product name of the USB device so it cannot resemble another USB device. While the PC must have a driver for this USB device and still waiting until that USB connector have the same names of the vendor and product to interact with it. So the descriptor file in the PIC18f4550 programmed and prepare the driver through the program LabVIEW as mentioned above to receive the information from the PIC through the sensors. Finally, the Instantaneous Power Meter achieved by using the information from the sensors to get the value of the input power at each instant. This is done by multiplying the input voltage and the input current together. Then, it displays the result on the PC screen as illustrated in the Fig. 8. The USB connector needs more than hardware particles and specific code software, its need another software installed on the PC as a driver for a new USB device and that achieved by LabVIEW as mentioned earlier.

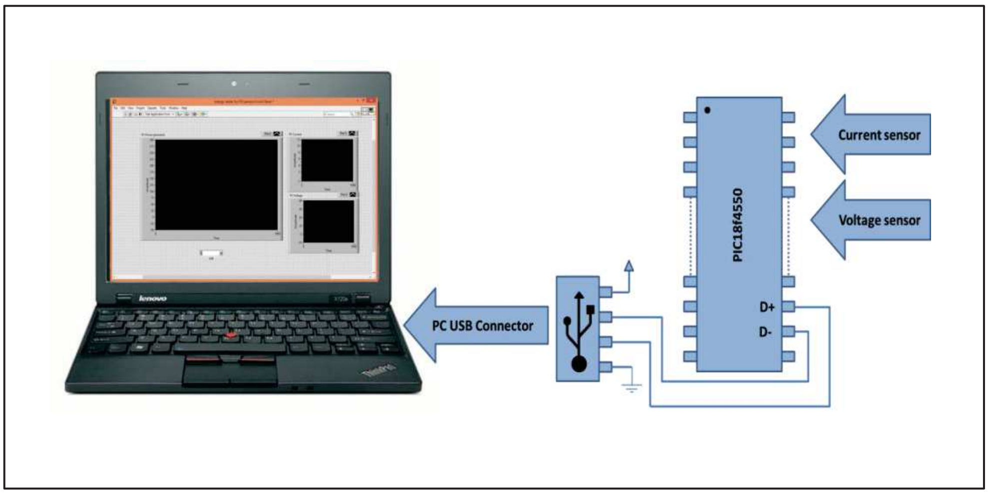
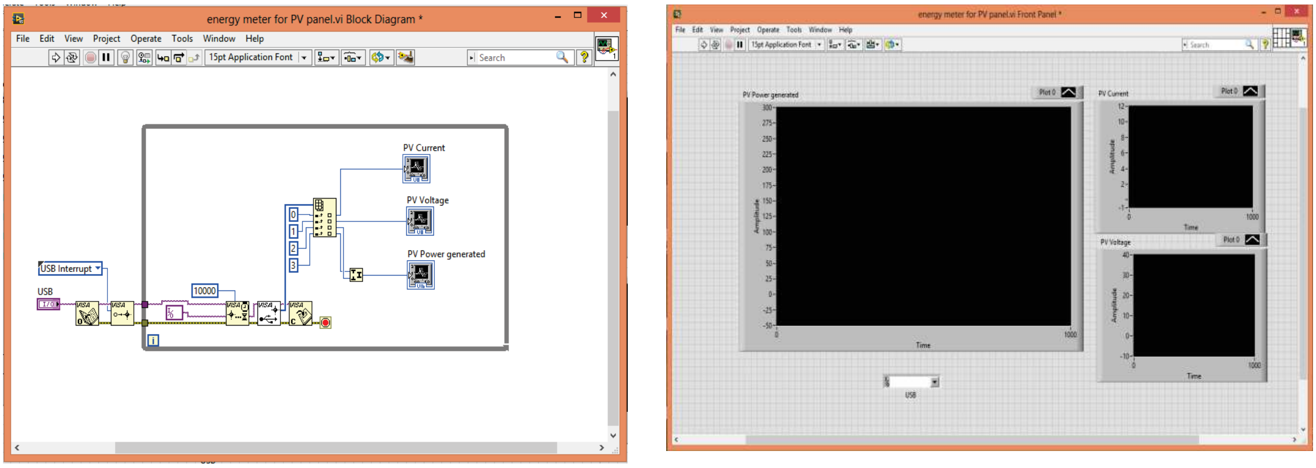


Fig. 8. Instantaneous Power Meter Structure

Fig. 9 illustrates the block diagram of all the functions that needed to deal with the USB device and can display the information come from it. And shows the display units on the front panel window.



a *b*

Fig. 9. LabVIEW program windows (a) Front Panel Window of the LabVIEW (b) Block Diagram Window of the LabVIEW

5. Experimental results

Since, the converter is already implemented [4], and then a comparison between different MPPT algorithms used in this converter is possible now. In this section a test and analysis of three different MPPT algorithms can be done. The comparison between them considers three aspects:

1. The value of the harvest energy.
2. The speed of reaching the maximum power point for certain weather condition.
3. The tracking response to a quick change in weather conditions.

Hence, the advantages and disadvantages of each algorithm achieved. This leads to the ability of utilizing the most suitable algorithm for a certain circumstance. The MPPT algorithms differ in the above three features. This means that there is a certain algorithm to be chosen for a specified case to obtain maximum energy. Tests have been done as follows below, by using an Instantaneous Power Meter program (LabVIEW driver and USB match the PIC and PC).

5.1. The value of the harvest energy

The result obtained from the Instantaneous Power Meter program, I_C and the new MPPT were equal in harvesting the power as much as possible, but the P&O algorithm appears unstable all the period causing a decrease in the energy which harvested from the PV panel. Note the Fig. 10 below.

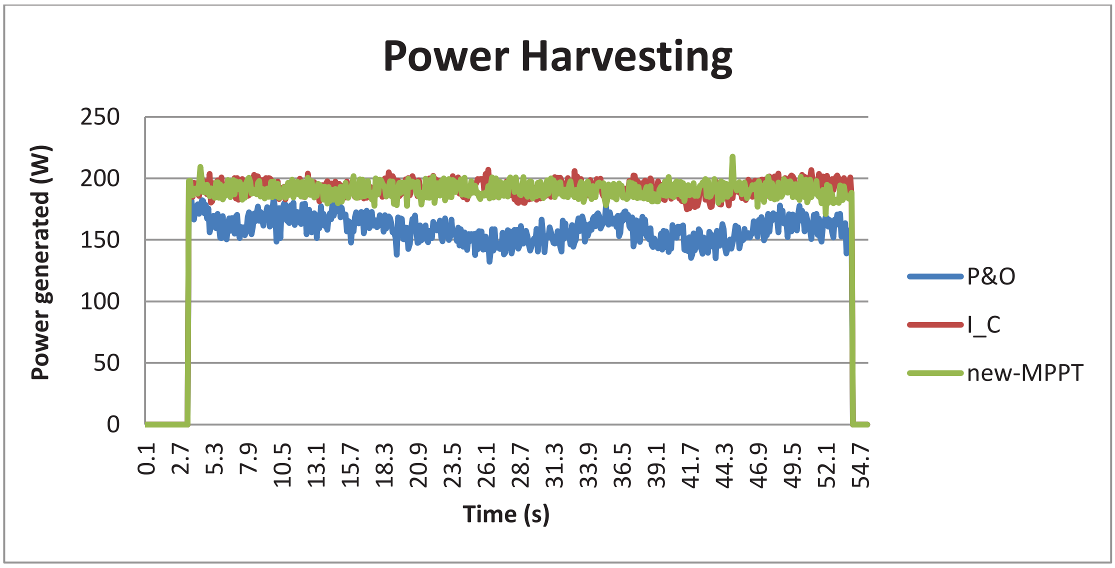


Fig. 10. Power Harvesting Compression

5.2. The speed of reaching the maximum power point for certain weather condition

Speed of reaching the MPP or speed of detecting the MPP does not mean speed of the algorithm execution because the latter itself is another problem. As it must be, the speed of the algorithm is limited to be (not so fast and not slow); it must be compatible with the response of the power circuit (the time constant of the circuit). Fig. 11 represents the results of the energy meter program, showing the time elapsed to reach the MPP for each algorithm.

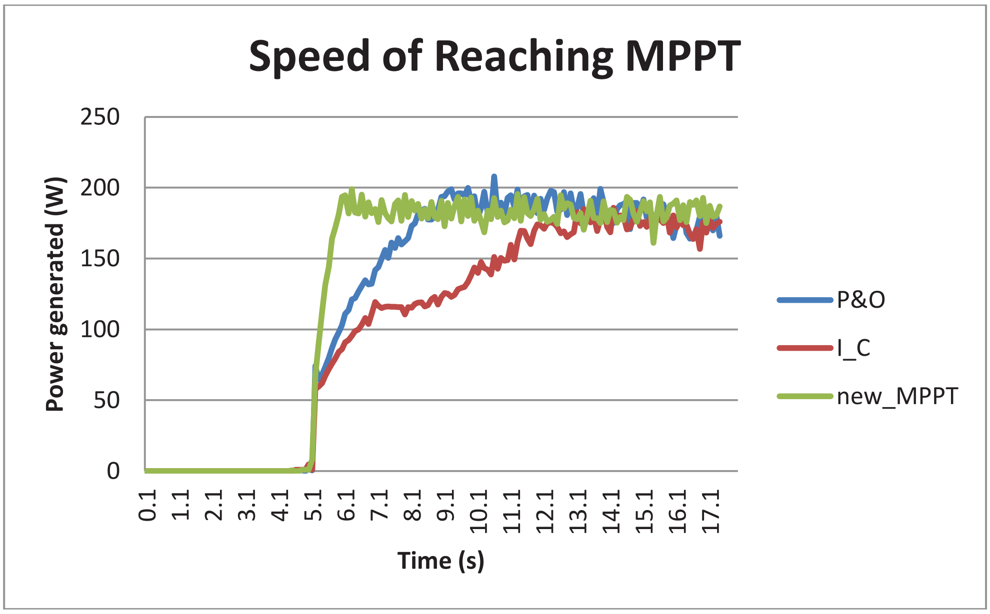
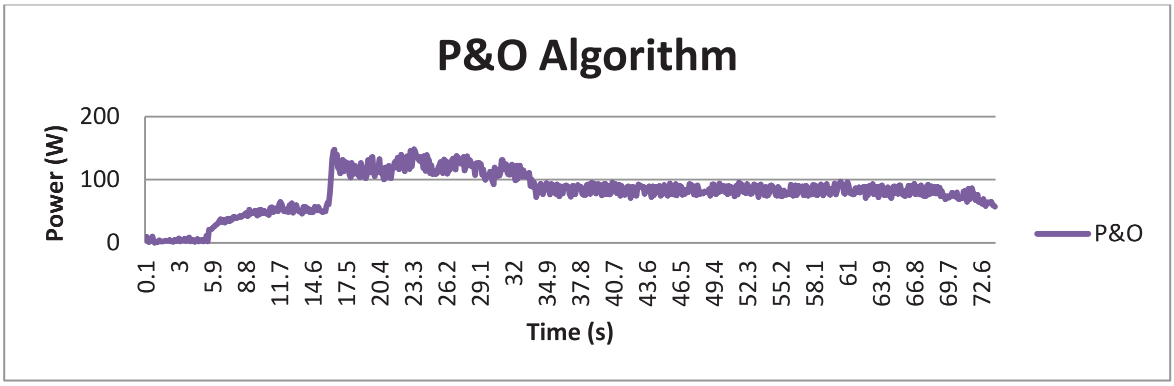


Fig. 11. Periods reaching to MPP Compression

5.3. The tracking response to a quick change in weather conditions

This test is the most complex one because it requires special experimental conditions which are not available in the lab. This is simulated practically by changing the tilt angle manually (the same angle, irradiance intensity and temperature for the same Panel) and getting the result through the energy meter program for each algorithm. The results of the P&O algorithm in Fig. 12 show the algorithm response due to the weather condition changing and show the response for I_C and new_MPPT algorithms respectively.



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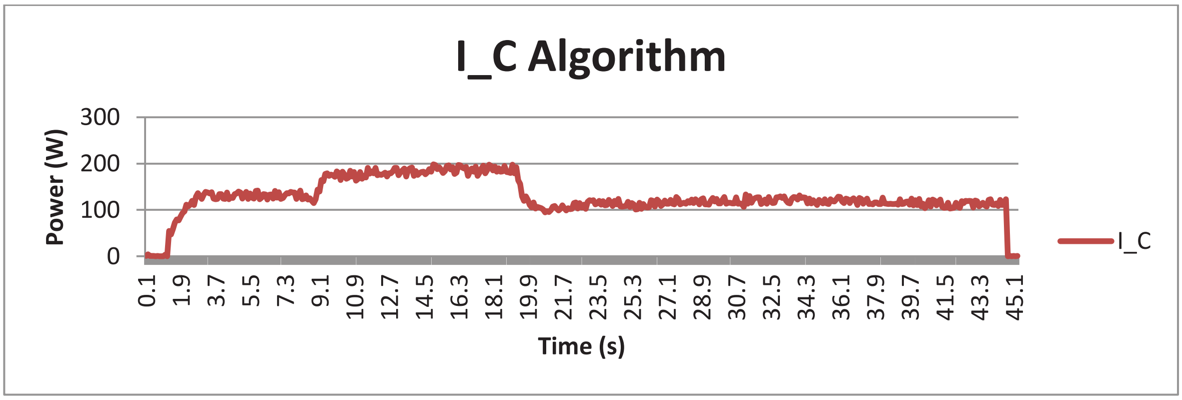

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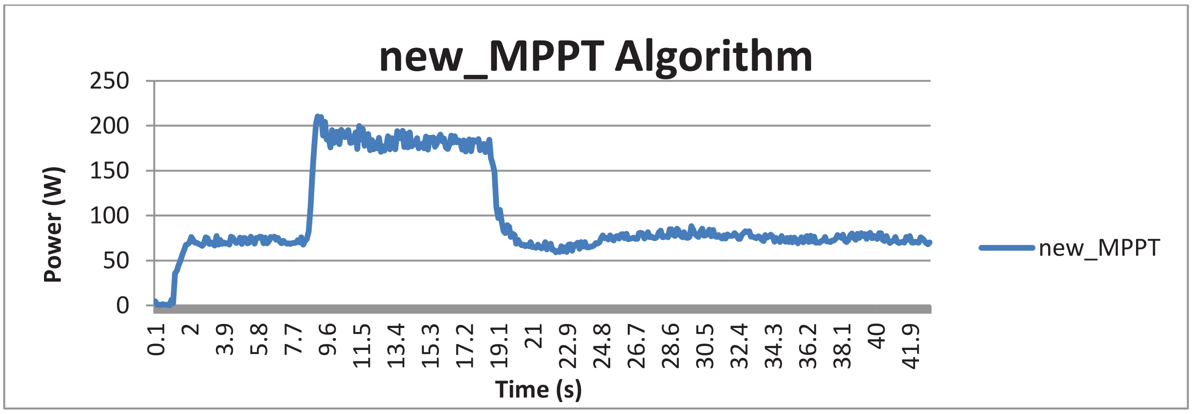

c

Fig. 12. The tracking response to a quick change in weather conditions (a) P&O Response (b) I_C Response (c) Proposed Algorithm Response

6. Conclusion

The prototype of the proposed converter shows that it is robust and reliable. Also, the application of the (new_MPPT) increases the extracted energy from the panel due to its ability in what is known as a (hill climbing) to reach the MPP in the shortest time as compared with other algorithms. Hence, the new algorithm is the preferable one, since the weather changes are a quick events in nature. Table 2 shows the comparison between the three studied algorithms from different points of view:

Table 2: Comparisons of Algorithms Features

Features	P&O	I_C	New_MPPT
Complexity	Simple	Complex	More complex
Program coded	Easy to implement	Difficult	Difficult
Processor Memory	Little space	More space	More space than previous
Power harvesting in Steady state	Lowest as compared to the others	Better	Better
Hill clamping speed	Fast	Slow	Faster
Fast changes in Weather	Fail	Successful to some extent	Successful
Stability	Vibrant (oscillatory)	Stable to some extent	More stable
Total Extracted Energy	Good	Better	Best

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