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HIGH ACCURACY TESTING OF MPPT PROTEUS MODEL PERFORMANCE FOR PHOTOVOLTAIC SYSTEM

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Abstract. ***This study examines the performance of the MPPT Proteus model. The high performance of this model was proposed for a photovoltaic system and tested using the most commonly known MPPT techniques. The proposed Proteus model is a simulator of a maximum power point tracking system for a photovoltaic panel connected to the DC-DC converter with digital control. The Proteus software performs simulation and implementation of the photovoltaic panel model based on a one-diode model and a two-diode model with high accuracy. Both photovoltaic panel models were validated by experimental measurements. Simulation results for tracking voltage, tracking current and tracking power show that this model performs satisfactorily. The theoretical evaluation confirms the high performance of the MPPT Proteus model, which offers a high degree of control and planning.***

Key words: I-V Measurements, Implementation, MPPT Proteus model, Microcontroller, Performance, Tracking Power.

1. INTRODUCTION

Maximum power point tracking system can extract and deliver the maximum power in all-weather situations and operate PV panels at the maximum power [1-2]. To test the high performance of MPPT techniques, researchers and professionals often use simulation software and tools, such as Matlab-Simulink, PSIM or Proteus [1], [3]. In literature, several MPPT algorithms have been presented and discussed. With respect to tracking accuracy and speed, component cost and hardware implementation complexity, and various other aspects, each technique has advantages and disadvantages [3-4]. The effectiveness of a particular technique depends on its ability to track instantaneous changes in weather conditions. MPPT techniques are classified as follows:
- Common MPPT,
- Intelligent MPPT,
- Optimized MPPT.

We can mention several optimization-based techniques, including particle swarm optimization, cuckoo search, gray wolf optimization, etc. These techniques tend to search for the actual MPP under dynamic environmental conditions [5], [6]. On the other hand, intelligence-based techniques include artificial neural network, fuzzy logic control, artificial neural network and Gauss-Newton based MPPT, etc. [7]. These methods are intended for dynamic change conditions with higher accuracy. Efficiency and tracking speed are very high. It also suffers from extremely complex control circuit and extensive data processing for prior learning.

For classical MPPT [5], [8], perturb and observe (P&O), variable step size (Adaptive P&O) and incremental conductance (IC), are easily implemented for lower complexity in algorithms [9]. P&O technique is generally the most widely used for its simplicity in hardware and software implementation. However, this technique has problems with oscillations around MPP [9-11]. For the Adaptive P&O, the technique offers good performance, tracking speed is high and MPP oscillations are low [9], [12-14]. The IC offers high performance under changing weather conditions, high accuracy and low oscillations, and high speed to find the MPP, but hardware-wise, the control circuit is complex and expensive [9-10], [15-17]. This study examines and discusses the high performance of the MPPT Proteus model for the photovoltaic panel. Both PV panel models were validated experimentally. The three main classical techniques, P&O, Adaptive P&O and IC were tested and implemented on microcontrollers for measurement and STC conversion.

2. SYSTEM DESCRIPTION

For PV system MPPT techniques, implementation in hardware requires testing and verification of the high performance of the techniques in software under expected and controlled conditions. This work aims to show the good performance of Proteus simulator of MPPT system based on one-diode and two-diode PV panel models.

According to literature, to establish the I-V curve characteristics of PV panel [18-20]. The one-diode

model is commonly used and widely considered [21], due to its simplicity and accuracy. The model consists of a parallel current source, which has high sensitivity to solar irradiation, a diode with opposite shape and two resistors (Figure 1) [22-24]. The IRR, Rs and Rp parameters of the PV models are determined based on the electrical parameters Voc, Isc, Vmp, Imp and A. The aim is to determine the parameters of the model in such a way that the obtained I-V curve corresponds exactly to the experimental curve [25], as shown in Figure 4. Equation of the I-V characteristics is as follows [1], [22-24]:

$$I = I_{RR} - I_0\left[\exp\left(\frac{V+IR_S}{AV_t}\right)-1\right]-\left(\frac{V+IR_S}{R_P}\right) \quad (1)$$

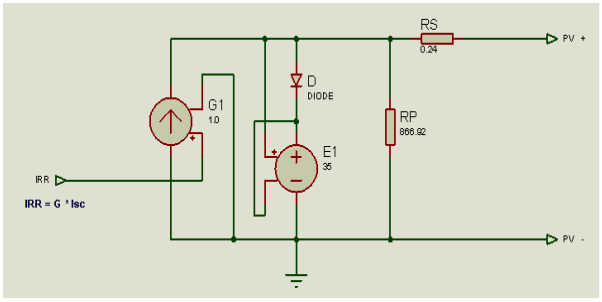


Figure 1. One diode model of a photovoltaic panel.

The two-diode model of the PV panel was analyzed based on Equation (2) that describes the analogy of the two-diode PV panel circuit (Figure 2).

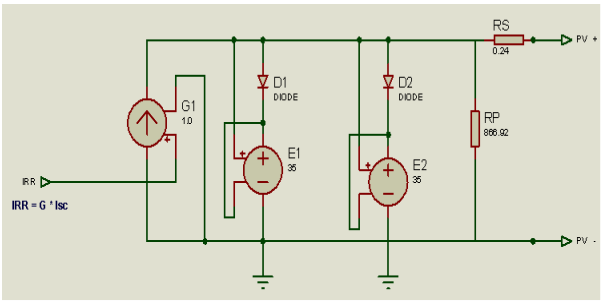
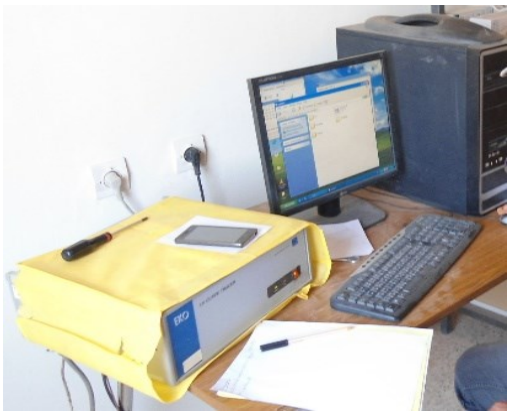


Figure 2. Two diode model of PV panel.

The circuit consists of a photo current source IRR, two diodes, a parallel resistance Rp, and a series resistance Rs. For the two-diode model, the I-V characteristic equation is given as follows [1], [24], [26]:

$$I = I_{RR} - I_{01}\left(\exp\frac{q(V+IR_S)}{AlVt1}-1\right)-I_{02}\left(\exp\frac{q(V+IR_S)}{A2Vt2}-1\right)-\left(\frac{V+IR_S}{R_P}\right) \quad (2)$$

To experimentally validate the PV panel models, a real PHOTOWATT PWX-500 PV panel was tested. The I-V and P-V curves of the PWX-50 PV panel were measured using the MP-160 I-V curve tracer, as shown in Figure 3.





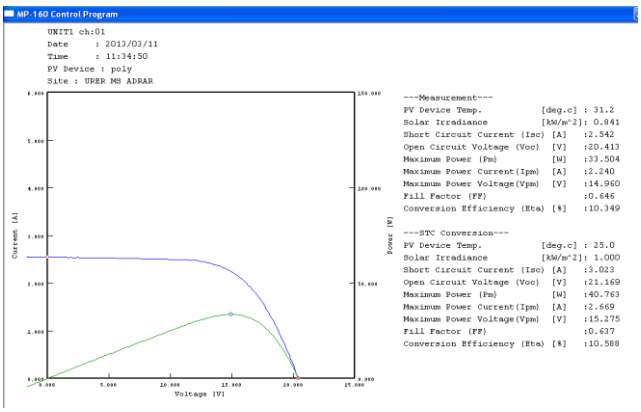
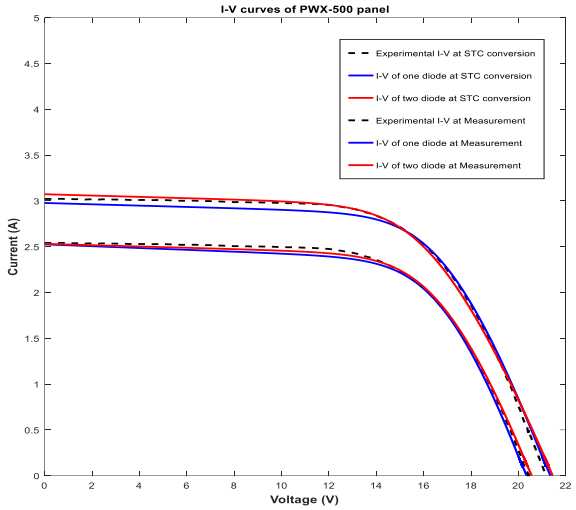


Figure 3. Experimental measurement information.

The tracer offers a high degree of accuracy in calculating the current and voltage value of the I-V curve with an error of 0.5% against full scale [21], [27]. Both PV models were tested and confirmed through experimental measurement information.

Figure 4 shows the simulation results of the I-V and P-V curves for the one-diode and two-diode models. The curves correspond precisely to the key points, the maximum power point, the open circuit point, and the short circuit point. The three curves are also quite close at other points. It is clear that the two-diode model is very accurate and efficient compared to the one-diode model, which is close to the parameters in the datasheet (Figure 3). Studied MPPT Proteus model consists of a PV panel, DC-DC converter, and microcontroller for MPP techniques that allow the PV system to operate at the maximum power [28]. Knowing the output values of the PV panel, the tracking system follows the maximum

power. Therefore, two voltage and current sensors are required.



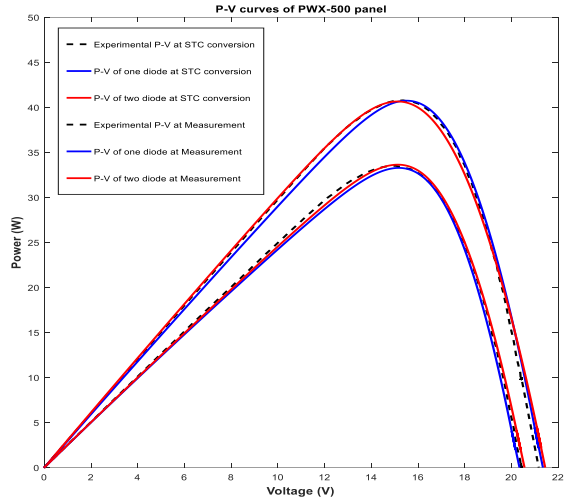


Figure 4. Experimental and simulation measurement.

3. RESULTS AND DISCUSSION

In this case, Proteus software offers a good substitute. Proteus is a virtual electronic modeling and application system for circuit simulation. Proteus software provides many electronic and microcontroller models in its library[3], [29]. In this studied MPPT Proteus model, the DC-DC converter is used to achieve the maximum output power of a PV module and the microcontroller is used to control and optimize the correlation between the PV panel and the load. The control depends on the duty cycle to achieve the MPP. The algorithm helps to track the current and voltage values that are measured by the current and voltage sensors and gives the trigger signal to the DC-DC converter [30]. The code of MPPT algorithms is first developed in the program in C language and then its hexadecimal codes are downloaded to the microcontroller board. In this MPPT Proteus model, the PIC16F876A is used for simple implementation, which is more efficient, accurate and convenient, without the need for complicated mathematical operations [31], [32].

The various MPPT techniques most commonly used and tested (P&O, adaptive P&O and IC) imply high performance of this model. These techniques use simple feedback available to small measured parameters. The P&O method is a widely used approach in MPPT research due to its simplicity and requires only PV array voltage and current measurements [33]. In this approach, the module voltage is periodically perturbed and the corresponding power output is compared to that of the previous perturbation cycle [34]. The tracking is slow for small steps, but the oscillations are small around MPP. Fast tracking is achieved by using a larger step size to obtain larger oscillations. Thus, the P&O method with fixed step sizes suffers from an inherent trade-off problem in tracking oscillations [15], [35], [36].

However, to minimize the steady-state oscillations around the MPP, a modified P&O technique has been used, called adaptive P&O [28]. The appropriate mechanism intelligently varies the size of the disturbance to minimize the steady-state oscillations [30], [31]. As the operating point moves away from the MPP, the disturbance becomes larger. This maximizes the tracking speed. As the operating point approaches the MPP, the size of the disturbance is dynamically reduced until it becomes zero. Therefore, the tracking speed is high and the oscillations around the maximum power point are low [37]. For the incremental conductance technique, it was observed that in the operating limits, the output power increases with the voltage across the PV module (the slope of the power curve is positive). On the contrary, at the operating points after MPP, there is a decrease in output power with an increase in the PV module terminal voltage (the slope of the power curve is negative). When the operating point is exactly at MPP, the slope of the expected curve is zero [29], [38].

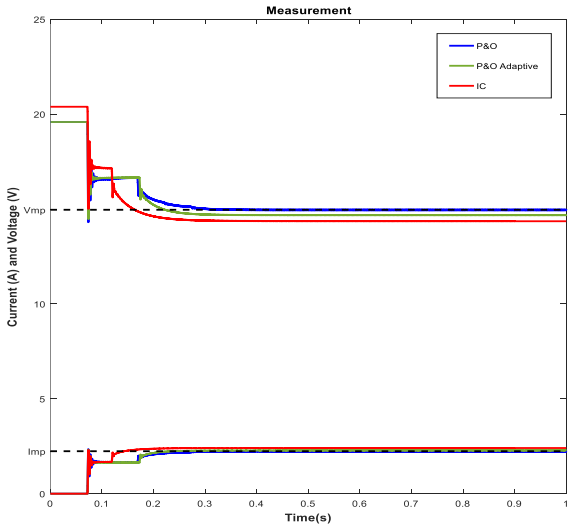
3.1 Measurement

This section discusses the theoretical results of the electrical parameters (voltage, current and power) tracking. The simulation test was performed using experimental measurements (Figure 3) [39]: maximum power (Pmp =33.504w), maximum power voltage (Vmp= 14.960V) and maximum power current (Imp=2.24A).

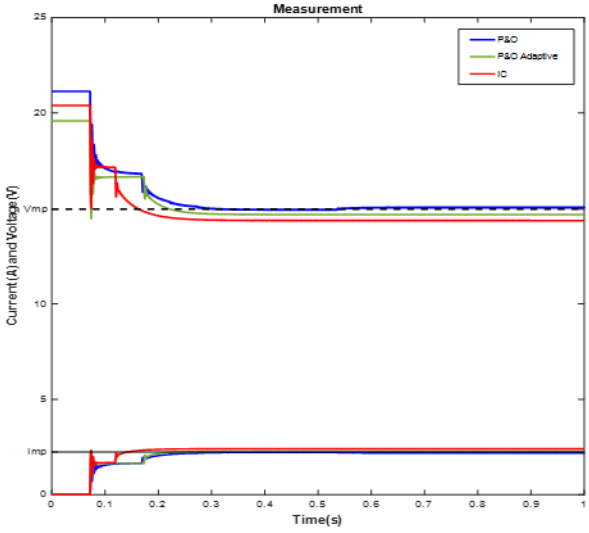
A. Tracking voltage and tracking current

Figure 5 shows tracking voltage Vpv and tracking current Ipv using different techniques for one-diode and two-diode models under measurement conditions. Conventional P&O technique has the slowest dynamic

response with few oscillations. In a one-diode and two-diode model where typical maximum supply voltage is Vmp = 14.96 V and the typical maximum current is Imp= 2.24 A, tracking voltage values reach 14.9 V and 15.0 V respectively and tracking current values reach 2.22 A and 2.19 A respectively.



a. One diode model



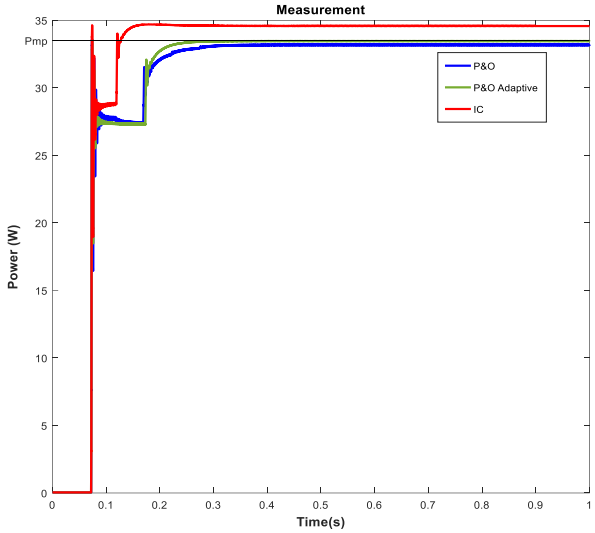
b. One diode model

Figure 5. Tracking voltage Vpv and tracking current Ipv.

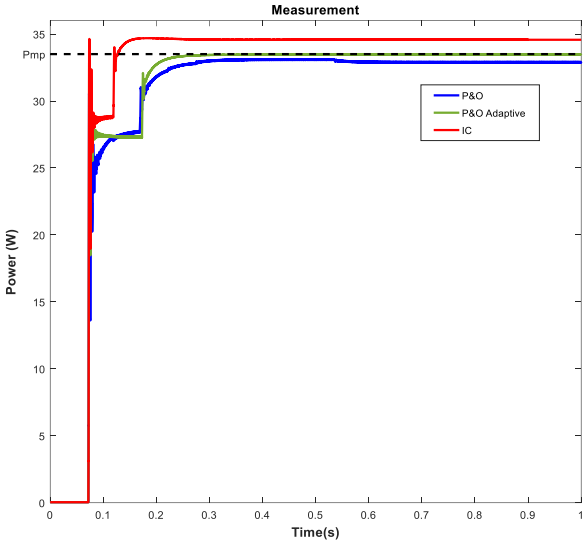
On the other hand, adaptive P&O improves on conventional P&O by automatically adjusting step size. For both designs, tracking speed is always slow, with small oscillations around tracking current and MPP tracking voltage. The tracking voltage value reached 14.70 V, and the tracking current value reached 2.28 A for both models. Regarding the Incremental Conductance algorithm (Figure 5), it is clear that this technique has a fast dynamic response and high tracking speed of voltage and current.

B. Tracking power

Figure 6 illustrates Ppv tracking power of photovoltaic panel using different techniques for one-diode and two-diode model under measurement conditions. Efficiency of tracker is associated with accuracy of tracking MPP in minimum time. Conventional P&O, adaptive P&O and IC show high performance of MPPT Proteus model. It is clear that Proteus MPPT model has good dynamic response and high maximum power tracking speed, despite some oscillation around MPP due to testing techniques used in MPP research. As conclusion, proteus model of studied MPPT system offers good performance.



a. One diode model



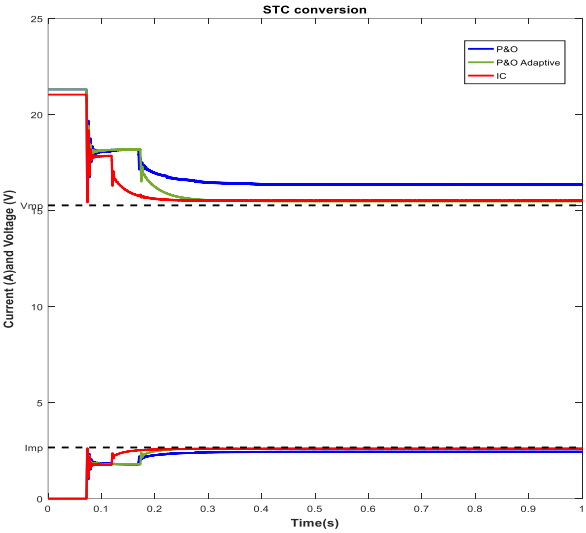
b. Two diode model

Figure 6. Tracking power Ppv.

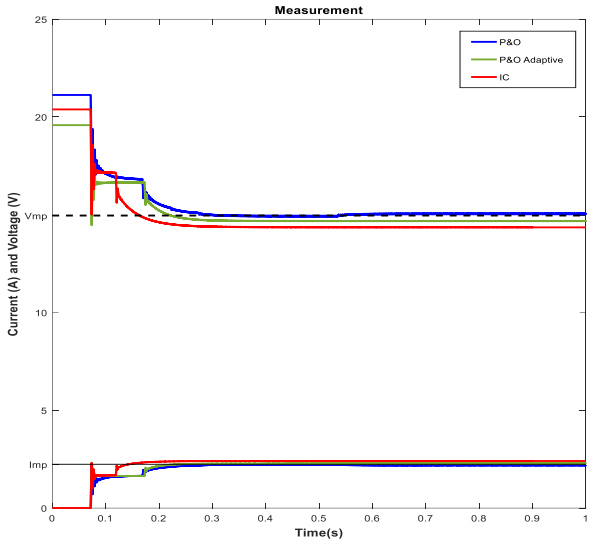
3.2 Test for STC conversion

Figure 7 and Figure 8 illustrate Ppv tracking power, tracking voltage and tracking current of the PV panel using different techniques for the one-diode and two-diode models under measurement conditions. Tracker efficiency is associated with MPP tracking accuracy in minimum time. Conventional P&O, adaptive P&O and IC appear the high performance of

MPPT Proteus model. It is clear that the MPPT Proteus model has a good dynamic response and high maximum power tracking speed. Thus, Proteus model of studied MPPT system offers good performance.

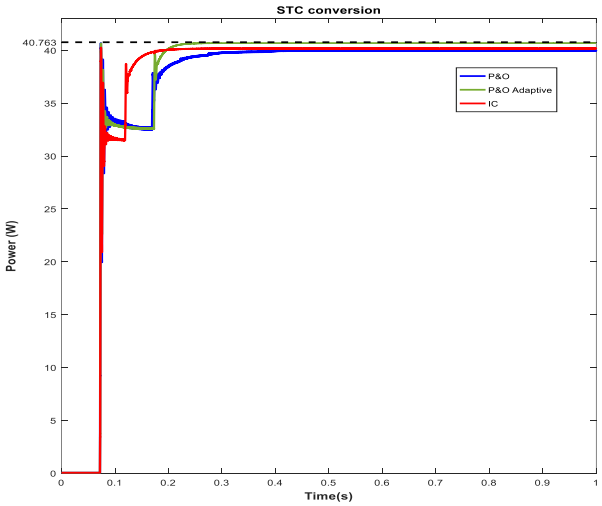


a. One diode model

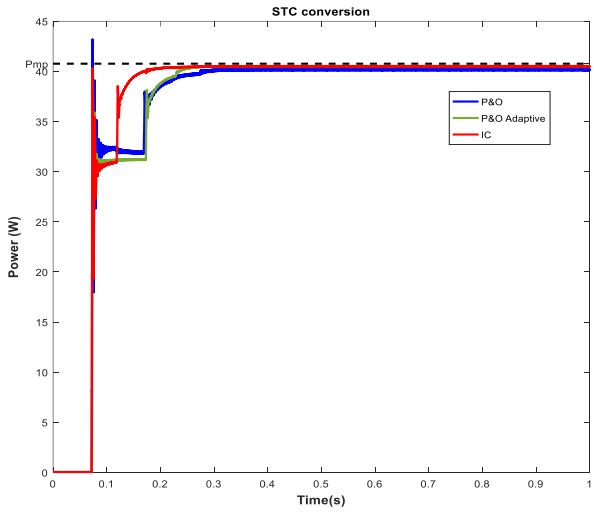


b. Two diode model

Figure 7. Tracking voltage Vpv and tracking current Ipv.



a. One diode model



b. Two diode model

Figure 8. Tracking power Ppv.

4. CONCLUSION

The study aimed to test and discuss high performance of MPPT Proteus model for photovoltaic panel. Implementation and simulation of a PV panel model based on a high-accuracy two-diode model using Proteus simulation software were presented. Information from experimental measurements and theoretical operations that were performed using conventional MPPT techniques confirm the high performance of the MPPT Proteus model. The MPPT Proteus model provides a high degree of control and planning of MPPT photovoltaic systems. The proposed Proteus model can help researchers and professionals to design and develop MPPT for solar PV systems.

Table 1. Error measurements.

MPPT Techniques	P&O %		Adaptive P&O %		Incremental Conductance %	
PV Panel model	One diode	Two diodes	One diode	Two diodes	One diode	Two diodes
At STC Conversion Pmp	- 2.03	- 1.63	- 0.37	- 0.27	- 1.51	- 0.49
At measurement Pmp	- 1.27	- 1.95	- 0.035	- 0.035	+ 3.58	+ 2.00

5. ACKNOWLEDGMENTS

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