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Modeling of Photovoltaic Panel by using Proteus

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Abstract

This paper focuses on a Proteus Spice model of the photovoltaic Panel. This model is based on a mathematical equation which is got from the equivalent circuit of the photovoltaic Panel; it includes a photocurrent source, a diode, a series resistor and a shunt resistor. Next, this model is validated by comparing its data with the experimental data. In addition, since Proteus provides in its library different microcontrollers and electronic boards, this model is connected to the Arduino UNO Board through the voltage and current sensors, that in order to acquire and supervise the photovoltaic voltage, current and power. And for experimental validation, a prototype using real components has been developed.

Keywords: PV panel; Spice; Arduino UNO; Proteus; Solar Energy Measurement

1. Introduction

The growing concern about environmental issues and the strong need of low-cost energy sources have engendered a great importance in the use of renewable energy such as the PV solar energy. Currently, PV solar energy has become a perfect promising renewable energy source due to its many benefits namely; low cost maintenance, non-necessity of moving and no pollution. However, the low efficiency of a PV panel and high cost of PV system installation may be a discouraging factor as far as its use [1]. Moreover, the non-linear compartment and heavy dependence of PV modules on the solar irradiation and temperature poses important challenges for researchers in PV solar energy topic [2, 3].

To avoid these limitations, the operation of the PV panel at the MPP is a requirement which can improve the efficiency of the PV system. For this reason MPPT algorithm is used [4]-[9]. And in order to test the performance of such MPPT algorithm, the modeling of PV panel should be done. Therefore several researchers have modeled the PV panel either in Matlab/Simulink or PSIM tools [10]-[12]; however these tools don't provide a microcontroller or an electronic board in which our algorithm can be implemented and tested. Consequently, we can't rely on these tools to validate our algorithm. On the other hand, Proteus is the best simulation software for various designs with electronics and microcontroller. It is mainly popular because of availability of almost all microcontrollers in it. However, it does not contain a PV panel model. Hence, in this paper a PV panel model under Proteus tool is proposed as an alternative, and this model is validated by comparing its data with experimental data. Hence, by using Proteus we can implement our algorithm under a real development board. Therefore, the PV panel is connected to the Arduino UNO Board through the voltage and current sensors, that in order to acquire and supervise

the photovoltaic voltage, current and power. And to validate the functionality and performance of the developed Solar Energy Measurement System, a prototype using real components has been developed.

2. PV Panel model

A PV panel is a component which can convert a solar energy into direct current electricity using semiconducting materials that exhibit the PV effect. The equivalent circuit of the PV panel is shown in Fig. 1[12, 13].

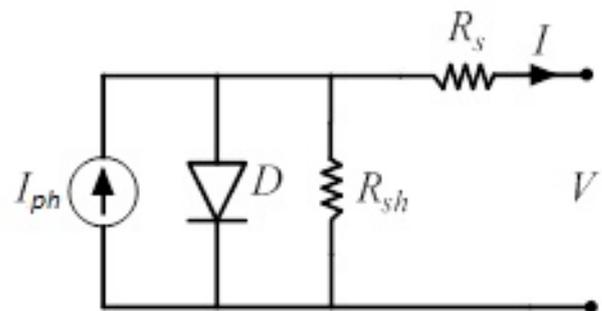


Fig. 1. PV cell equivalent circuit

As presented in fig. 1, the equivalent circuit of the PV panel contains a current source, a diode, a shunt resistor and a series resistor. The current generated by the PV panel can be given as [12, 13]:

$$I = I_{ph} - I_0 \left(\exp \frac{q(V + R_s I)}{aKT N_s} - 1 \right) - \frac{(V + IR_s)}{R_{sh}} \quad (1)$$

In this study the MSX-60 panel is used and table I presents its specification [14]:

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Table 1. Specifications of the PV module Solarex MSX-60 at STC

Characteristics	MSX-60
Maximum power, Pmax	60W
Voltage at Pmax, Vmp	17.1V
Current at Pmax, Imp	3.5A
Short-circuit current, Isc	3.8A
Open-circuit voltage, Vco	21.1V
Temperature coefficient of open-circuit voltage Voc, Kv	-80mV/°C
Temperature coefficient of short-circuit current Isc, Ki	2.4mA/°C

The number of cells	36
Light-generated current Iph	3.8128 A
Diode saturation current I0	2.5245e-10 A
Ideality factor	0.9784
Shunt Resistance Rsh	153.5644Ω
Series Resistance Rs	0.38572Ω

In order to model a PV panel in Proteus tool, its equivalent circuit is done with a controlled current source and a diode with modified Spice code, that in order to design a real model of PV panel. Fig. 2 presents the Proteus model and its Spice code.

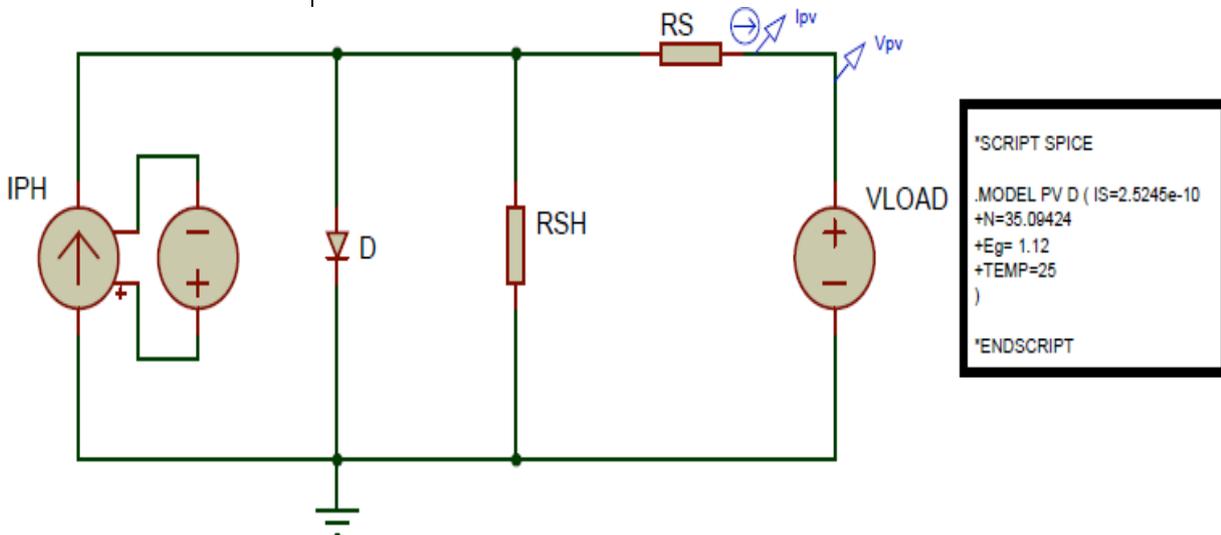


Fig. 2. The PV panel model under Proteus

As shown in Fig. 2, in order to model a PV panel in Proteus tool, the below steps are followed:

1. A "Voltage Controlled Current Source" block controlled by "DC Voltage Source" block is used to model the Current Source. For example to simulate our model under STC, the value of "DC Voltage Source" block is set to 3.8128 V value, which is the photocurrent of MSX-60 panel under STC.
2. As shown in fig.2, a diode with modified spice code is used in this model, because it is required to change the values of the saturation current I_s , the ideality factor, number of cells and bandgap energy in the Spice code according to the specification of MSX-60 panel [14]. Note that N

- is set to 35.09424 which is the multiplication between the ideality factor and number of cells.
3. Two resistors are used to model the shunt resistor and the series resistor with the values mentioned in table I.
4. A "DC Voltage Source" block is connected to the PV panel model as a variable load. Its value is equal to the "Sweep variable" value of the "DC SWEEP ANALYSIS" graph used in order to simulate our model as shown in fig. 3, note that the range of "Sweep variable" variable must be between 0V and the open-circuit voltage.

The simulation of the PV panel in ISIS Proteus is presented in Fig. 3

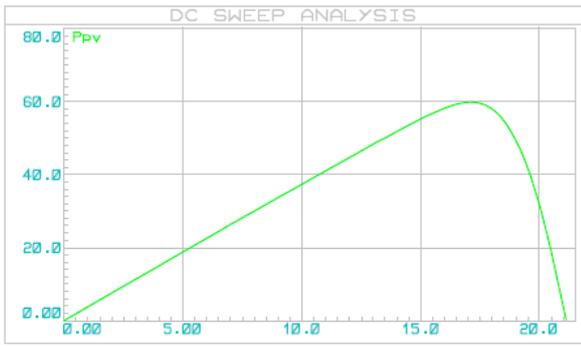


Fig. 3. I-V and P-V characteristics for PV panel by using Proteus

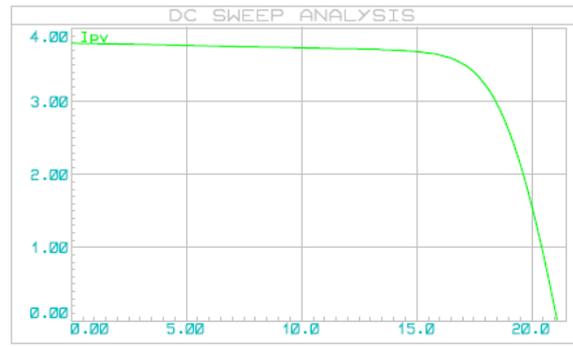


Fig. 4 shows the I-V and P-V characteristics obtained by our model and experimental data at STC. Experimental data are extracted from the datasheet [14]. And as shown in fig. 4, the model accurately is in accordance with the experimental data both in the power and the current characteristics.

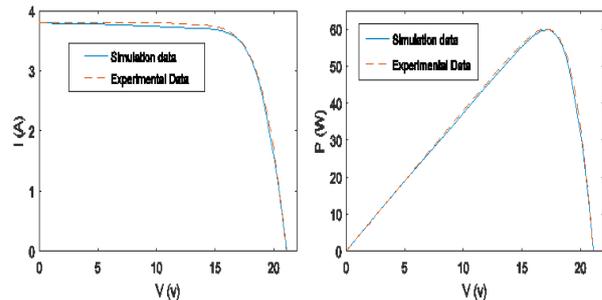


Fig 4. I-V and P-V model curves and experimental data of Solarex MSX-60 module

As presented in fig. 5, the Proteus PV model is put in a sub-circuit in order to make it easy to use.

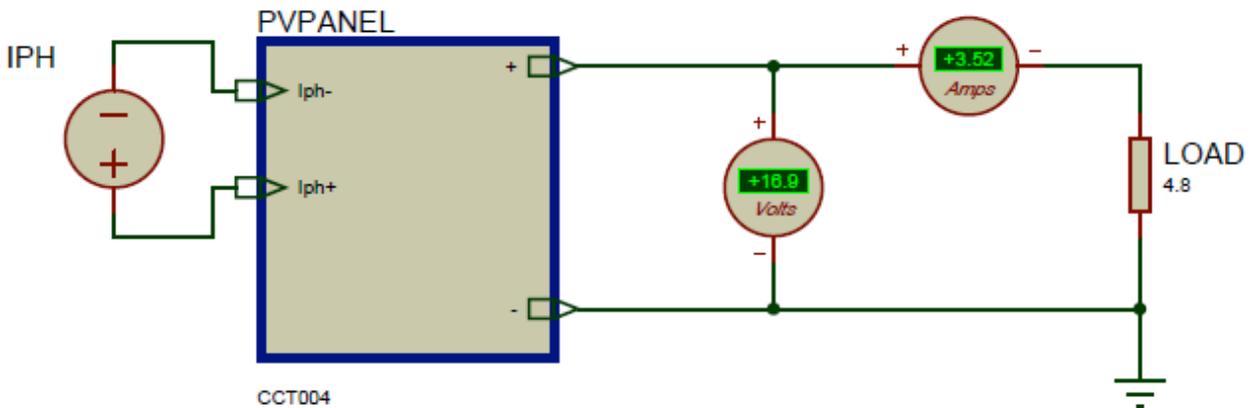


Fig. 5. The sub circuit of the PV panel model under Proteus

Modeling a PV panel in Proteus tool allows controlling our PV system by microcontroller, microprocessor, DSP, and FPGA. Therefore, the performance obtained will be similar to the performance obtained during real experience. One of the aims of this study is to acquire and supervise the current, voltage and power of our PV panel by using Arduino and Proteus.

3. Solar Energy Measurement

3.1. Materials used

In order to supervise the energy of our panel, different components are required apart PV panel such as current sensor, voltage sensor, development board and LCD.

Board: the development board used in this paper is Arduino UNO, in which the ATmega328 microcontroller is integrated. It is a low cost board.

Voltage sensor: it is used to reduce the PV voltage to another voltage between (V_d) [0, 5] which can be supported

by Arduino, because Arduino cannot read voltage more than 5 V, therefore the voltage divider circuit as presented in fig. 6 is used.

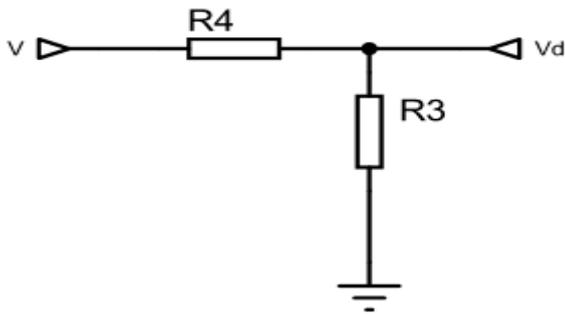


Fig. 6. Voltage divider circuit

The design of resistors R_3 and R_4 is made as follows:

From fig.6,

$$V_d = (R_3 / (R_3 + R_4)) * V \quad (2)$$

Since the range of PV panel voltage (V) is [0, 21.1], therefore the divider's voltage ratio should be lower or equal 0.23, hence, in order to make simple the choice of resistors, a divider's voltage ratio equal to 0.2 is selected. Another requirement is that the resistors should be high in order to minimize the loss of energy (as the voltmeter). Therefore, R_3 is selected with a value equals to 25k Ω and R_4 is selected with a value equals to 100k Ω .

Current sensor: it is used to provide to the Arduino the image of the PV panel current. In this study we design a current sensor as presented in fig. 7. The design of this sensor consists of putting a resistor (R_1) between the panel

and the Load (fig. 8), so the current through this resistor is the PV current, therefore the operational amplifier subtractor circuit is used to compute the voltage across this resistor, and this voltage is provided to the Arduino in order to get the value of PV the panel current. Note that R_1 should be small in order to minimize the loss of energy (as the Ampere Meter).

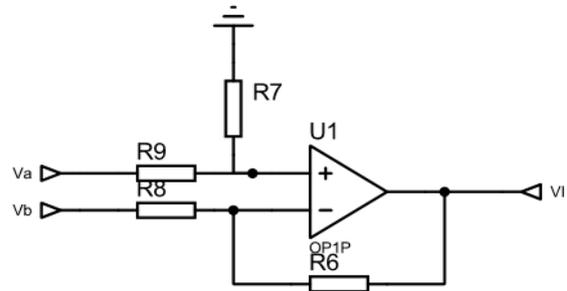


Fig. 7. Operational amplifier subtractor circuit

LCD screen: it is used to display values of PV voltage, current and power.

4. Results and Discussion

As shown in fig. 8, the PV panel is connected to the load and the Arduino board acquires the PV voltage and current from voltage and current sensors in order to use them to compute PV power. And then, the PV power, voltage and current are displayed on the LCD screen. And as presented in fig. 8, the same values displayed on Ampere Meter and Voltmeter are displayed on LCD Screen.

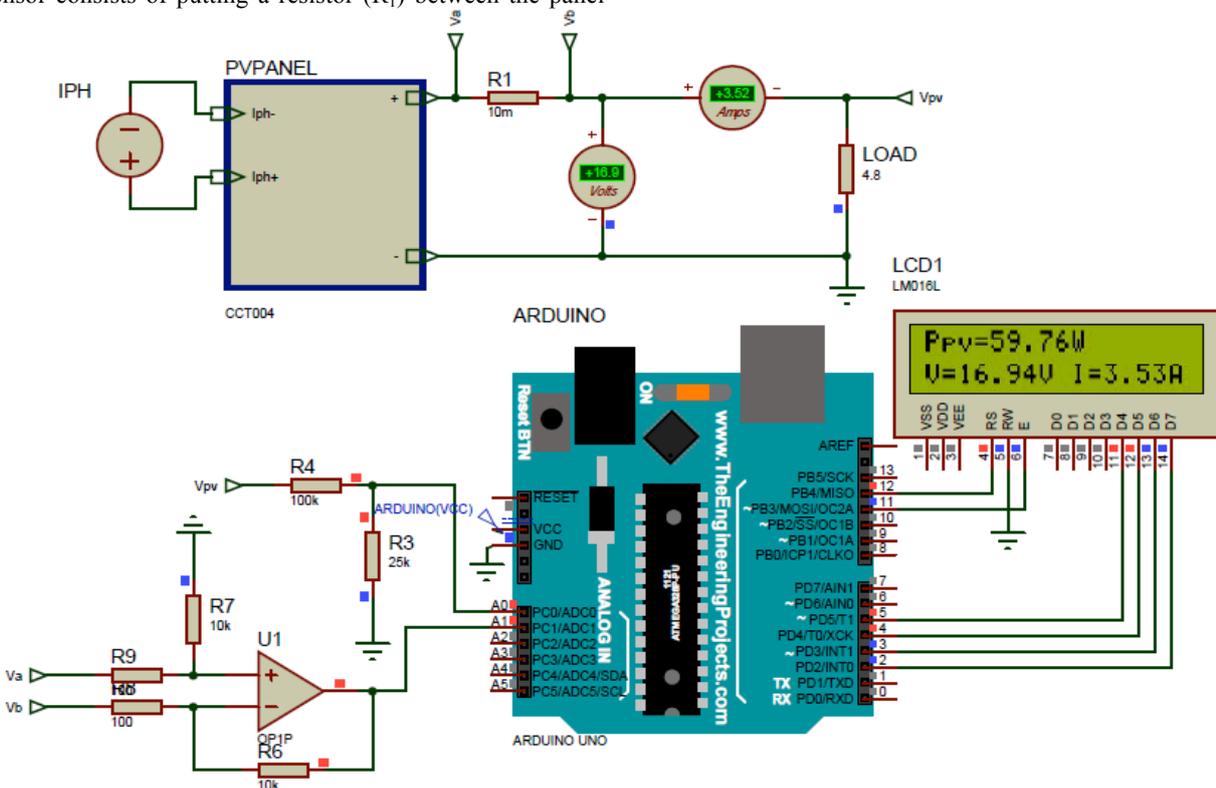


Fig. 8. Solar Energy Measurement Using Arduino and Proteus

To validate the functionality and performance of the developed Solar Energy Measurement System, a prototype by using real components has been developed as shown in fig. 9, and the experiment is performed using the artificial insolation with the help of lamps. Note that the same Arduino code used in Proteus is used in the experiment, and this is the benefit of using Proteus in simulation instead of PSIM and

Matlab/Simulink, because by using PSIM and Matlab we must again write the code of our algorithm once we start the experiment. Another benefit is that if our system is tested by using Proteus and it gives good performance, it will probably give the same result in the experiment, because we use the same components and Arduino code in simulation and experiment.

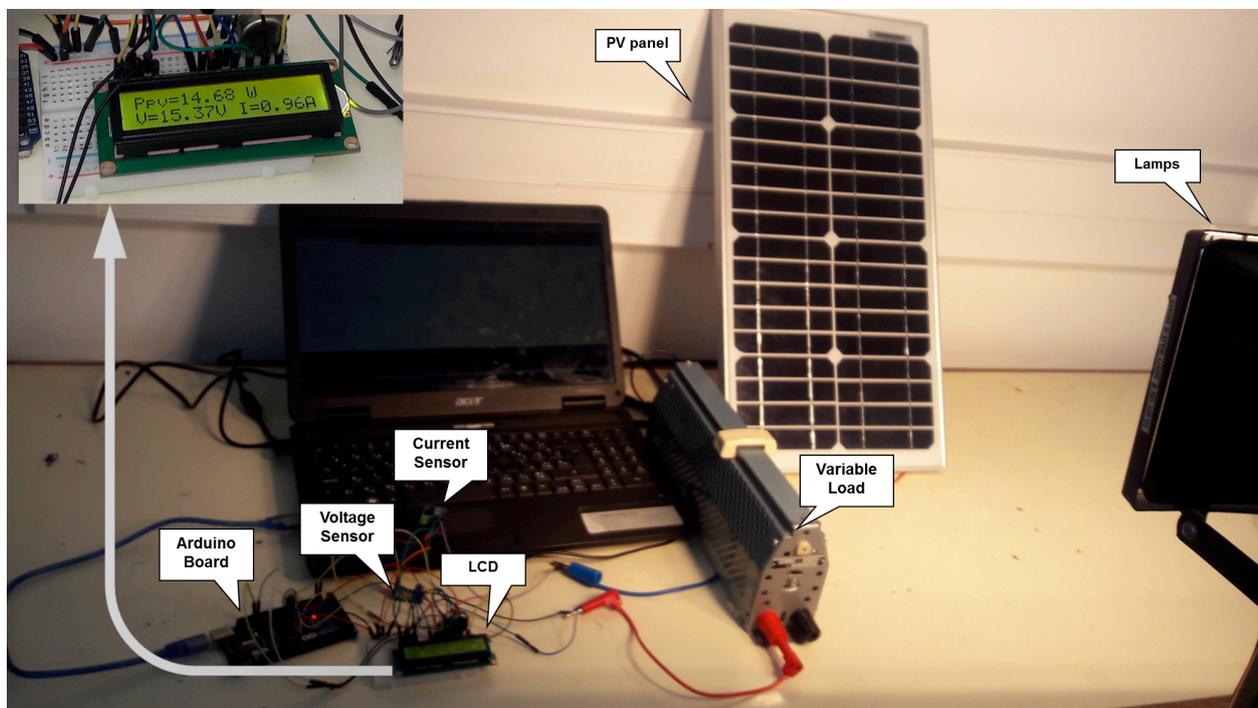


Fig. 9. Experimental setup of the developed Solar Energy Measurement System

5. Conclusion

In this paper, a Proteus Spice model of the photovoltaic Panel is made, and it is validated by comparing its data with experimental data, hence the model is in accordance with experimental data. As a result, a Solar Energy Measurement System is done by using electronic board provided by Proteus (Arduino UNO), in which our algorithm is implemented and tested. And to validate the functionality and performance of our system, a prototype by using real components has been developed, and the same Arduino code used in Proteus is used in the experiment. That can decrease the time spent in debugging runtime errors during the experiment, and this is the benefit of using Proteus in

simulation instead of PSIM and Matlab/Simulink, because by using PSIM and Matlab we must again write the code of our algorithm once we start the experiment. Another benefit is that if our system is tested by using Proteus and it gives good performance, it will probably give the same result in the experiment, because we use the same components and Arduino code in simulation and experiment

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Nomenclatures

- a : diode's ideality factor;
- I : panel output current;
- I_0 : diode saturation current;
- I_{ph} : panel photocurrent;
- K : constant of Boltzmann;
- N_s : number of cells connected in series;
- q : electron charge;
- R_s : series resistance;
- R_{sh} : shunt resistance;
- T : junction temperature;
- V : panel output voltage;
- V_d : output of voltage divider circuit.

Abbreviations

- STC: standard test condition.
- PV : Photovoltaic;
- MPP : maximum power point;
- MPPT : maximum power point tracking;
- LCD: Liquid Crystal Display.

APPENDIX

Data of this paper:

- PV Panel in Proteus:

<https://github.com/motahhir/PV-Panel-in-Proteus>

- Data for: Photovoltaic system with quantitative comparative between an improved MPPT and existing INC and P&O methods under fast varying of solar irradiation:

<https://github.com/motahhir/Data-for-Photovoltaic-system-with-quantitative-comparative-between-an-improved-MPPT-and-existing-IN>

More Data:

- MATLAB/Simulink Model of Photovoltaic Cell, Panel and Array:

<https://github.com/motahhir/MATLAB-Simulink-Model-of-Photovoltaic-Cell-Panel-and-Array->

- MPPT in PSIM Software:

<https://github.com/motahhir/MPPT-in-PSIM-Software>

- PV panel under shading and implementation of DMPPT:

<https://github.com/motahhir/PV-panel-under-shading-and-implementation-of-DMPPT>

- Data for: MIL and SIL and PIL tests for MPPT algorithm Paper:

<https://github.com/motahhir/Data-for-MIL-and-SIL-and-PIL-tests-for-MPPT-algorithm-Paper>

- Data for: Development of a low-cost PV system using an improved INC algorithm and a PV panel Proteus model:

<https://github.com/motahhir/MPPT-in-Proteus>