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Hardware Implementation of Maximum Power Point Tracking System using Cuk and Boost Converters

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***Abstract*— Photovoltaic (PV) systems are used as main source of energy in many applications now a days. Most commonly applied PV systems can be found in remote and rural areas where no public grid is available. The effective usage of the PV modules is extracting the maximum power from it. Many maximum power point tracking techniques are widely applied in photovoltaic (PV) systems to make PV array generate peak power which depends on solar irradiation. Among all the MPPT strategies, the incremental–conductance (INC) algorithm is widely employed due to easy implementation and high tracking accuracy. The main difference of the proposed system to existing MPPT systems includes elimination of the proportional–integral control loop and investigation of the effect of simplifying the control circuit. This paper presents a comparison between Cuk and Boost converters in a novel maximum power point tracking system using incremental–conductance (INC) algorithm. Several aspects of the whole system including converter design, system simulation, controller programming, and experimental setup were dealt in detail in this paper.**

***Index Terms*—Solar Energy, Maximum Power Point Tracking (MPPT), Incremental Conductance, Cuk Converter, Boost Converter.**

I. INTRODUCTION

The Conventional sources of energy are rapidly depleting. Moreover the cost of energy is rising and therefore photovoltaic system is a promising alternative. They are abundant, pollution free, distributed throughout the earth and recyclable. The hindrance factor is its high installation cost and low conversion efficiency. Therefore our aim is to increase the efficiency and power output of the system. It is also required that constant voltage is being supplied to the load irrespective of the variation in solar irradiance and temperature. PV arrays consist of parallel and series combination of PV cells that are used to generate electrical power depending upon the atmospheric conditions (e.g. solar irradiation and temperature). The use of the newest power control mechanisms called the Maximum Power Point Tracking (MPPT) algorithms has led to the increase in the efficiency of operation of the solar modules. A maximum power point tracker (MPPT) is a power electronic DC-DC converter inserted between the PV module and its load to achieve optimum matching. By using an effective MPPT algorithm and a highly efficient DC- DC converter PV system can be made highly efficient.

II. SYSTEM LAYOUT

The overall project layout is shown in the Fig.1. The system consists of a PV panel or panels, DC-DC converter, a MPPT control algorithm and some sort of load. Here 40W solar panel and Resistive load is used.

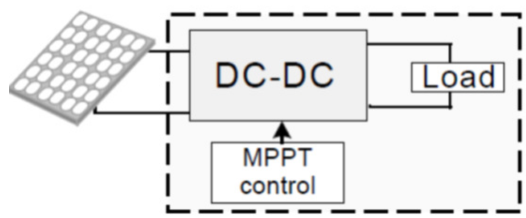

Fig.1. The layout of the overall PV system

III. PHOTOVOLTAIC MODULE

Solar cells consist of a p-n junction fabricated in a thin wafer or layer of semiconductor. In the dark, the I-V output characteristic of a solar cell has an exponential characteristic similar to that of a diode. When exposed to light, photons with energy greater than the band gap energy of the semiconductor are absorbed and create an electron-hole pair. These carriers are swept apart under the influence of the internal electric fields of the p-n junction and create a current proportional to the incident radiation. When the cell is short circuited, this current flows in the external circuit; when open circuited, this current is shunted internally by the intrinsic p-n junction diode. The characteristics of this diode therefore set the open circuit voltage characteristics of the cell.

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A. PV Cell Model

Figure 2 depicts the equivalent circuit of the PV cell empirical model [8]. The circuit consists of a current source I_{ph}, a parallel-connected diode D and a series resistor R_s.

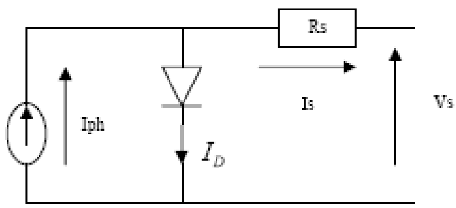

Fig.2 Equivalent circuit of PV cell

The equation describing the I-V curve of the PV cell is derived using Kirchoff's current law as follows:

$$I_s = I_{ph} - I_d \quad (1)$$

The normal diode current is given by

$$I_D=I_0*\{exp((e*(V_s+R_s*I_s))/(m*k*T_j))-1\} \quad (2)$$

Substituting equation (2) into (1) yields:

$$I_s=I_{ph}-I_0*\{exp((V_s+R_s*I_s)/V_t)-1\} \quad (3)$$

Where

I_o is the saturation current, [A]

$V_t = [(m*k*T_j)/e]$ is the thermal voltage,

m Є [1 2]-ideal factor of the PV cell

$k = 1.38*10^{-23}$[J/ºK]-Boltzmann's constant

$e = 1.6*10^{-19}$[C]-electron charge

The following assumptions can be made for modeling practical solar cell:

$$I_{ph}=I_{sc} \quad (4)$$

$$exp((V_s+R_s*I_s)/V_t)>>1 \quad (5)$$

Putting (4) and (5) into (3):

$$I_s=I_{sc}-I_0*exp((V_s+R_s*I_s)/V_t) \quad (6)$$

Where: I_{sc}-is the short-circuit current, [A]

$$\text{At } I_s=0,\ V_s=V_{oc} \quad (7)$$

Substituting (7) into (6), and after simple mathematical manipulation, the following equation is found:

$$I_s= I_{sc}*[1-exp((V_s-V_{oc}+R_s*I_s)/V_t)] \quad (8)$$

Where, V_{oc}-is the open-circuit voltage, [V]

Equation (8) characterizes the I-V curve of a PV cell. However, the commercial form of PV generator is the PV module. Hence, it is necessary to derive the I-V relation for PV module. This is done in the following section.

B. PV Module Model

The model for PV module is derived from the PV cell's model. Consider a PV module consisting of N_{pm} cells in parallel and N_{sm} cells in series. Thus, all currents in (8) are multiplied by N_{pm} and all voltages are multiplied by N_{sm}, that is:

$$I_{sm} = N_{pm}*I_s$$
$$I_{scm}= N_{pm}* I_{sc}$$
$$V_{sm}=N_{sm}*V_s$$
$$V_{ocm}=N_{sm}*V_{oc}$$
$$R_{sm}= (N_{sm}/ N_{pm})*R_s \quad (9)$$

After simplifications:

$$I_{sm}=I_{scm}*[1-exp(V_{sm}-V_{ocm}+R_{sm}*I_{sm})]/ (N_{sm}*V_t) \quad (10)$$

where, Nsm*Vt - is the curve fitting parameter of the PV module.

IV. MPPT ALGORITHMS

I-V output curve of a PV panel is previously presented. Associated with this curve is a MPP. This is the point where the solar cell is most efficient in converting the solar energy into electrical energy. The MPP is not a fixed point, it actually moves throughout the day depending upon the solar radiation. There are a large number of algorithms that are able to track MPPs. Some of them are simple, such as those based on voltage and current feedback, and some are more complicated. The most commonly employed MPPT Techniques [1] are:

1. Hill Climbing/P&O 2.Incremental Conductance 3.Fractional Open-Circuit Voltage 4.Fractional Short-Circuit Current 5.Fuzzy Logic Control 6. Neural Network

Having a curious look at the recommended methods, hill climbing and P&O are the algorithms that were in the center of consideration because of their simplicity and ease of implementation [6]. Hill climbing is perturbation in the duty ratio of the power converter, and the P&O method is perturbation in the operating voltage of the PV array. However, the P&O algorithm cannot compare the array terminal voltage with the actual MPP voltage, since the change in power is only considered to be a result of the array terminal voltage perturbation. As a result, they are not accurate enough because they perform steady-state oscillations, which consequently waste the energy. By minimizing the perturbation step size, oscillation can be reduced, but a smaller perturbation size slows down the speed of tracking MPPs. Thus, there are some disadvantages with these methods, where they fail under rapidly changing atmospheric conditions. On the other hand, some MPPTs are more rapid and accurate and, thus, more impressive, which need special design and familiarity with specific subjects such as fuzzy logic or neural network methods. MPPT fuzzy logic controllers have good performance under varying atmospheric conditions and exhibit better performance than the P&O control method [3]; however, the main disadvantage of this method is that its effectiveness is highly dependent on the technical knowledge of the engineer in computing the error and coming up with the rule-based table. It is greatly dependent on how a designer arranges the system that requires skill and experience. A similar disadvantage of the neural network

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method comes with its reliance on the characteristics of the PV array that change with time, implying that the neural network has to be periodically trained to guarantee accurate MPPs. The IncCond method is the one which overrides over the aforementioned drawbacks. In this method, the array terminal voltage is always adjusted according to the MPP voltage. It is based on the incremental and instantaneous conductance of the PV module.

A. Incremental conductance method

Incremental Conductance Method uses the PV array's incremental conductance dI/dV to compute the sign of dP/dV. When dI/dV is equal and opposite to the value of I/V (where dP/dV=0) the algorithm knows that the maximum power point is reached and thus it terminates and returns the corresponding value of operating voltage for MPP. This method tracks rapidly changing irradiation conditions more accurately than P&O method. One complexity in this method is that it requires many sensors to operate and hence is economically less effective.

$$P=V*I \quad (11)$$

Differentiating w.r.t voltage yields;

$$dP/dV = d(V*I)/dV \quad (12)$$

$$dP/dV = I*(dV/dV)+ V*(dI/dV) \quad (13)$$

$$dP/dV = I + V*(dI/dV) \quad (14)$$

When the maximum power point is reached the slope dP/dV =0. Thus the condition would be

$$dP/dV =0 \quad (15)$$

$$I + V* (dI/dV) =0 \quad (16)$$

$$dI/dV = -(I/V) \quad (17)$$

B. Direct control method

Conventional MPPT systems have two independent control loops to control the MPPT. The first control loop contains the MPPT algorithm, and the second one is usually a proportional (P) or P–integral (PI) controller. The Incremental Conductance method makes use of instantaneous and Incremental Conductance to generate an error signal, which is zero at the MPP; however, it is not zero at most of the operating points. The main purpose of the second control loop is to make the error from MPPs near to zero. Simplicity of operation, ease of design, inexpensive maintenance, and low cost made PI controllers very popular in most linear systems. However, the MPPT system of standalone PV is a nonlinear control problem due to the nonlinearity nature of PV and unpredictable environmental conditions, and hence, PI controllers do not generally work well. In this project, the Incremental Conductance method with direct control is selected. The PI control loop is eliminated, and the duty cycle is adjusted directly in the algorithm. The control loop is simplified, and the computational time for tuning controller gains is eliminated. To compensate the lack of PI controller in the proposed system, a small marginal error of 0.002 was allowed. The objective of this project is to eliminate the second control loop and to show that sophisticated MPPT methods don't necessarily obtain the best results, but employing them in a simple manner for complicated electronic subjects is considered necessary. The feasibility of the proposed system is investigated with a dc–dc converter configured as the MPPT.

C. Flow Chart

The flowchart of the Incremental Conductance algorithm within the direct control method is shown in Fig. 6.1. According to the MPPT algorithm, the duty cycle (D) is calculated. This is the desired duty cycle that the PV module must operate on the next step. Setting a new duty cycle in the system is repeated according to the sampling time.

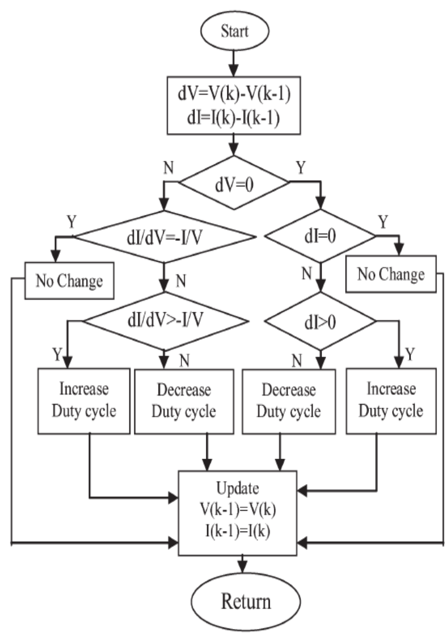

Fig 3 Flowchart of the Incremental Conductance method with direct control

V. CONVERTER SELECTION

A tracker consists of two basic components .switch-mode converter and a control with tracking capability. The switch-mode converter is the core of the entire supply. The converter allows energy at one potential to be drawn, stores as magnetic energy in an inductor, and then releases at a different potential. Switched mode converters are of various topologies. In power trackers, the goal is to provide a fixed input voltage and/or current, such that the array is held at the maximum power point, while allowing the output to match the load voltage. Among the dc-dc converters available, Initially Boost

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converters were found to be efficient and were used. With the newly developing converter topologies Cuk converter provides excellent features like Load current is ripple free. Highest efficiency among non-isolated dc–dc converters can be connected in parallel to measure PV modules with greater power. Hence a comparison between Boost and Cuk converter is being made in this paper to bring out the effective converter for the Maximum Power Point Tracking in Solar.

A. Boost Converter

Boost converter steps up the input voltage magnitude to a required output voltage magnitude without the use of a transformer. The main components of a boost converter are an inductor, a diode and a high frequency switch. These in a co-ordinated manner supply power to the load at a voltage greater than the input voltage magnitude. The control strategy lies in the manipulation of the duty cycle of the switch which causes the voltage change.

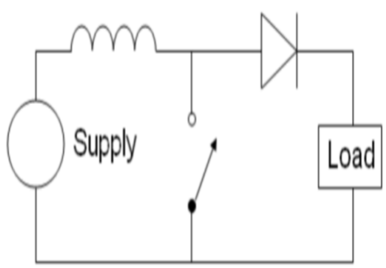

Fig 4 Boost Converter circuit

B. Cuk Converter

The buck, boost and buck-boost converters transfer energy between input and output using the inductor, analysis being based on the voltage balance across the inductor. The Cuk converter uses the capacitor for energy transfer and the analysis is based on the current balance of the capacitor. The circuit of the Cuk converter is shown in Figure 7.3 consists of DC input voltage source V_s, input inductor L_1, controllable switch S, energy transfer capacitor C_1, diode D, filter inductor L_2, filter capacitor C, and load resistance R. An important advantage of this topology is a continuous current at both the input and the output of the converter. Disadvantages of the Cuk converter are a high number of reactive components and high current stresses on the switch, the diode, and the capacitor C_1.

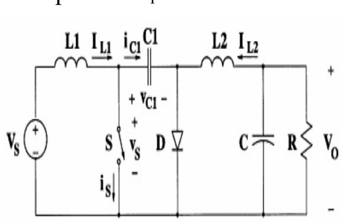

Fig. 5 Cuk converter circuit

VI. SIMULATION RESULTS

The simulation results are obtained for the KC85T Module with the following specifications.

TABLE I
SOLAR PANEL SPECIFICATIONS

PARAMETERS	**RATING**
Maximum Power	40W
Voltage at MPP	17.4V
Current at MPP	2.282A
Open circuit voltage	21.34V
Short circuit current	2.593A

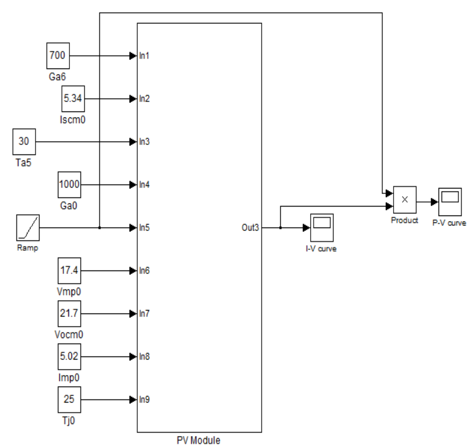

Fig 6Masked structure of PV module

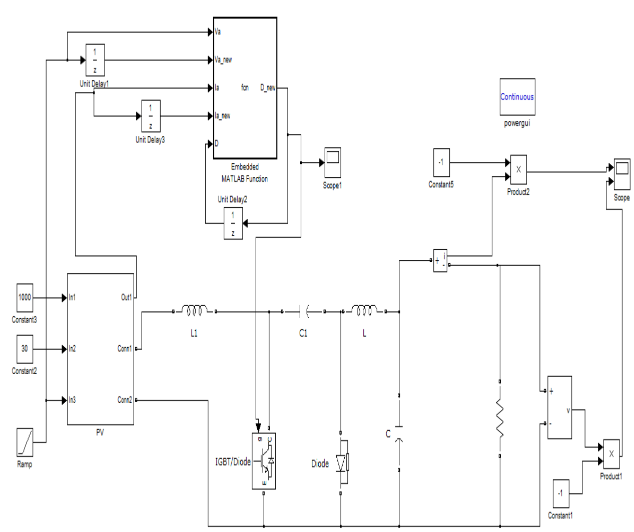

Fig 7 Overall Simulation diagram

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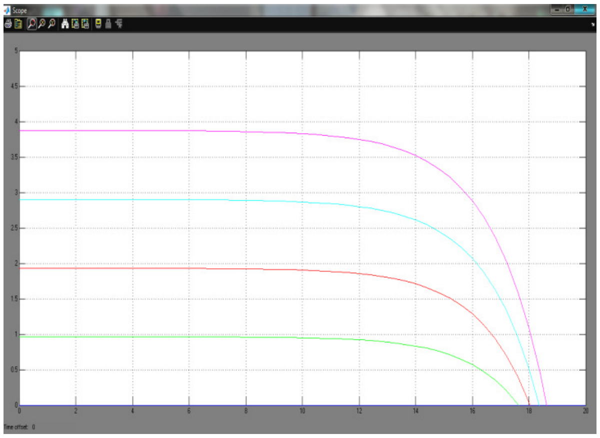
Fig 8 V-I curves for different radiations

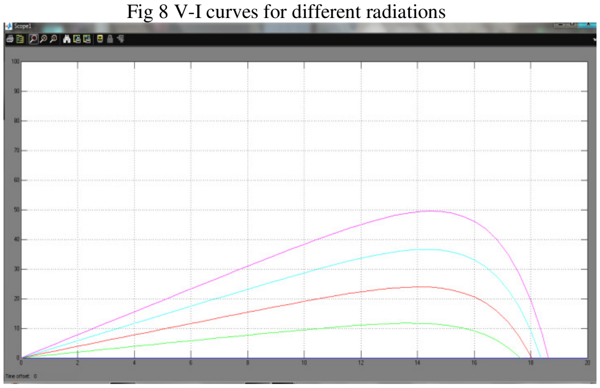
Fig 9.P-V curves for different radiations

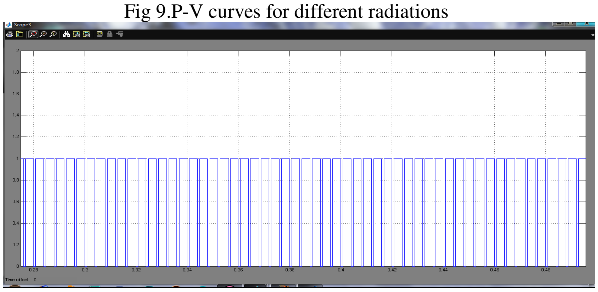
Fig 10 PWM signal generated from Incremental conductance method

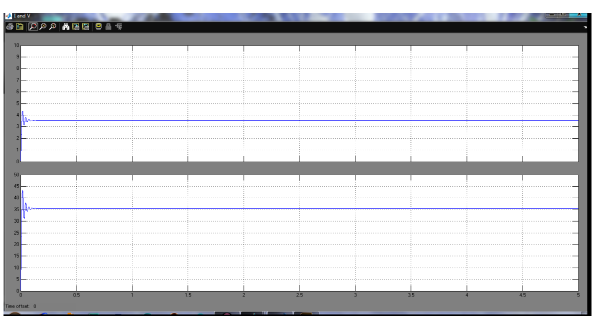
Fig 11: Voltage and current of the Boost converter

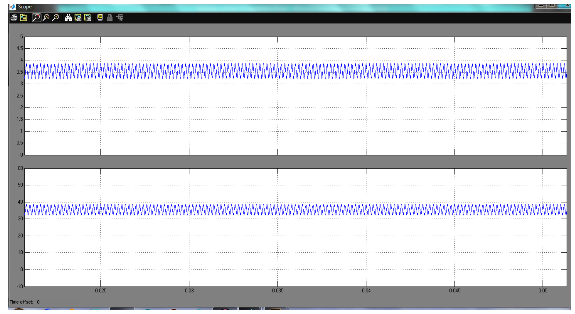
Fig 12 Voltage and current of the Cuk converter

VII. HARDWARE IMPLEMENATION

The hardware implementation diagram is shown in the fig.13. The hardware implementation is done only till MPPT controller. The Solar panel specifications and hardware details are detailed in the table II and III. The Overall hardware circuit is shown in the fig. 14 and fig. 15.The operation of Cuk converter in both buck and boost mode is shown in fig. 16.

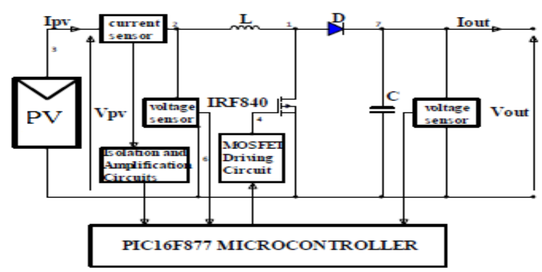

Fig.13 Hardware Block diagram of MPPT Controller

TABLE II
HARDWARE DETAILS

1	Solar Panel	40 W
2	PIC Controller	PIC 16F877A
3	DC-DC Converter	
	Input Inductor	5 mH
	Capacitor (PV side)	47 µf
	Filter Inductor	5 mH
	MOSFET	IRF540
	Diode	IN4001
	Capacitor (filter side)	1 µF
4	Resistive load	10 Ω

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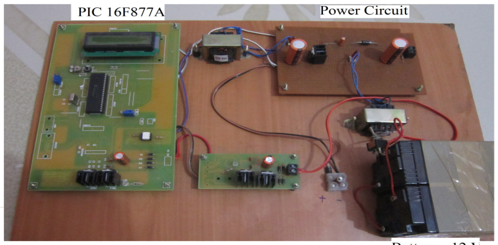

Fig.14 Controller and Power circuit of CUK converter

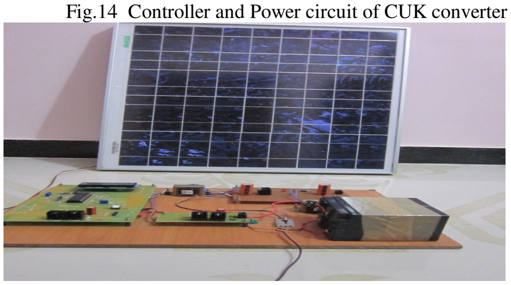
Fig.15 Overall Hardware PV panel connection

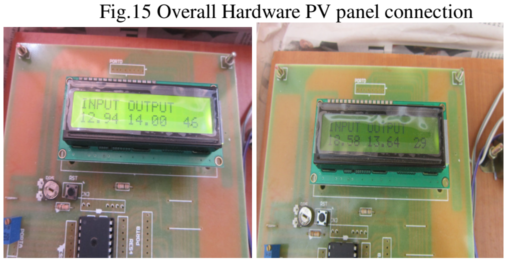

Fig.16 Output of the Cuk converter obtained in both buck and boost mode

VIII. CONCLUSION

This paper has presented a comparison of Buck, Boost, Buck-Boost and Cuk Converters used in a solar Maximum power point tracking. The P-V and I-V curves were obtained from the simulation of the PV array designed in MATLAB environment explains in detail its dependence on the irradiation levels and temperatures. Among the converters used Boost and Cuk converter provide best results for the MPPT controller. Cuk converter is still more advantageous than Boost converter as they have fewer ripples in the load current.

REFERENCES

[1] T. Esram and P. L. Chapman, "Comparison of photovoltaic array maximum power point tracking techniques," *IEEE Trans. Energy Convers.*,vol. 22, no. 2, pp. 439–449, Jun. 2007.

[2] E. Roman, R. Alonso, P. Ibanez, S. Elorduizapatarietxe, and D.Goitia,"Intelligent PV module for grid-connected PV systems," *IEEE Trans. Ind.Electron.*, vol. 53, no. 4, pp. 1066–1073, Jun. 2006.

[3] F. Salem, M. S. Adel Moteleb, and H. T. Dorrah, "An enhanced fuzzy- PI controller applied to the MPPT problem," *J. Sci. Eng.*, vol. 8, no. 2, pp. 147–153, 2005.

[4] F. Liu, S. Duan, F. Liu, B. Liu, and Y. Kang, "A variable step size INCMPPT method for PV systems," *IEEE Trans. Ind. Electron.*, vol. 55, no. 7,pp. 2622–2628, Jul. 2008

[5] F. M. González-Longatt, "Model of photovoltaic module in Matlab," in *2do congresoiberoamericano de estudiantes de ingenierıacute;aeléc- trica, electronicaycomputación, ii cibelec*, 2005, pp. 1–5.

[6] N. Femia, D. Granozio, G. Petrone, G. Spagnuolo, and M. Vitelli, "Predictive & adaptive MPPT perturb and observe method," *IEEE Trans. Aerosp. Electron. Syst.*, vol. 43, no. 3, pp. 934–950, Jul. 2007

[7] MASTERS, G. M. : Renewable and Efficient Electric Power Systems, John Wiley & Sons, New Jersey, 2004.

[8] Gomathi B," Analysation of PV Module Performance by Modelling the Solar Radiation", International Journal of *Innovative Research in Science Engineering and Technology*, Vol 5, Issue 12, December,2016.

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