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PV SYSTEM INCREMENTAL CONDUCTANCE MPPT METHOD APPLIED FLYBACK CONVERTER UNDER VARIABLE TEMPERATURE AND IRRADIANCE

Unal YILMAZ*, Ali KIRCAY*

*Electrical and Electronics Engineering, Harran University, 63000, Sanliurfa, Turkey
e-mails: uyilmaz@harran.edu.tr; kircay@harran.edu.tr

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This paper proposes to Photovoltaic (PV) system with Incremental Conductance (IC) MPPT (Maximum Power Point Tracking) method applied to Flyback converter under variable temperature (25°C-50°C) and irradiance (600W/m2-1000W/m2). The power and voltage of PV panels are nonlinear, they depend on environmental conditions such as temperature and irradiance, changing environment conditions lead to change the power of PV panels, and also change the MPP (Maximum Power Point) of PV panels. There is unique MPP of PV panels at different environment conditions. To operate PV panels at MPP there are many MPPT methods in literature, these methods are differ in same ways like; accuracy, speed, cheapness, easy to implement..etc. In this study IC MPPT method is used because of easy to implement and its good result under variable weather conditions. PV systems are consist of PV panels and DC-DC converters, as a DC-DC converter Flyback converter is used to regulate voltage of PV panel. The maximum power point of PV panel, used in this study, is 75W and the accuracy of MPPT method > 98%, efficiency of system > 94%. The system constructed and analyzed in MATLAB/Simulink and This paper is supported by HÜBAK.

Key words: PV system, MPPT methods, DC-DC converters, Flyback converters

INTRODUCTION

Increasing energy needs with technological advances, reduction of fossil fuels and increasing environmental pollution lead us to use renewable energy sources such as solar energy. Being source of clean energy, produce electrical energy anywhere sunlight exist and low maintenance cost, make solar energy attractive. There are some disadvantages of PV panels, conversion of energy is low (9-16%) and the electrical characteristic of PV panels change under variable weather conditions [1]. The voltage and current of PV panels are nonlinear they depend on temperature and irradiance, to observe effect of weather conditions in this study (25°C-50 °C) temperature and (600W/m2-1000W/m2) irradiance are used. There is one point on the I-V characteristic curve of PV panel named MPP. To operate PV panels at MPP there are many MPPT algorithm in literature such as Perturb&Observe (P&O), Fuzzy logic (FLC), Constant Voltage (CV), Incremantal Conductance (IC) MPPT methods. Using MPPT methods lead to increase the efficiency and decrease the cost of PV systems [2]. In this study IC MPPT method is used because of that it performs precise control under variable weather conditions and easy to implement, [1],[3]. PV systems are consists of PV panels and DC-DC converters such as buck converter, boost converter, buck-boost converter, Flyback converter...etc. MPPT methods applied to DC-DC converters to regulate the duty cycle of PWM which apply to Switch (MOSFET) of converters to regulate voltage and power of PV panels. To be used as a buck converter or boost converter and the transformer used instead of inductance, provide insulation between load and system. In this study Flyback converter is used. The general structure of system is shown in Figure 1. The system constructed and analyzed in Matlab/Simulink.

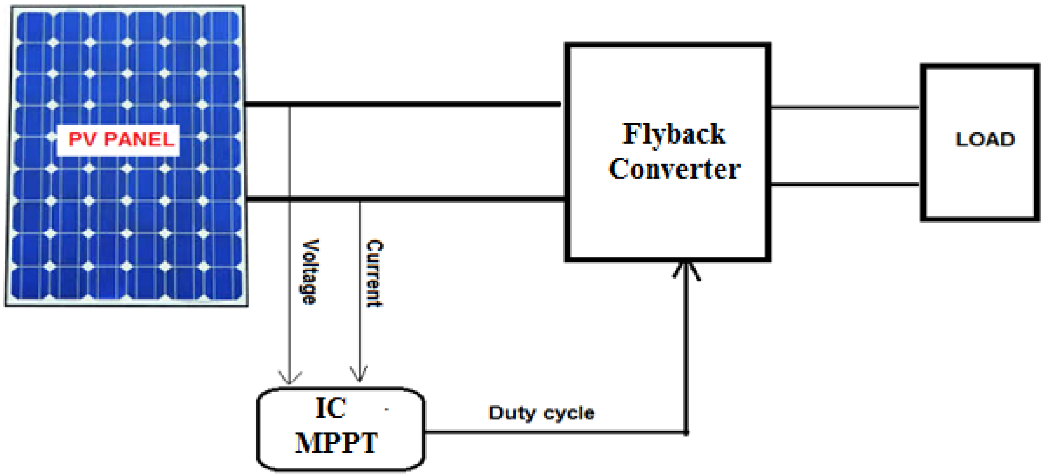


Figure 1. PV system IC MPPT method applied Flyback converter

1.1. Solar Cell and PV Panel

Solar cell is a type of semi-conductor device which convert solar energy to electrical energy. The single diode equivalent circuit of solar cell is shown in Figure 2.

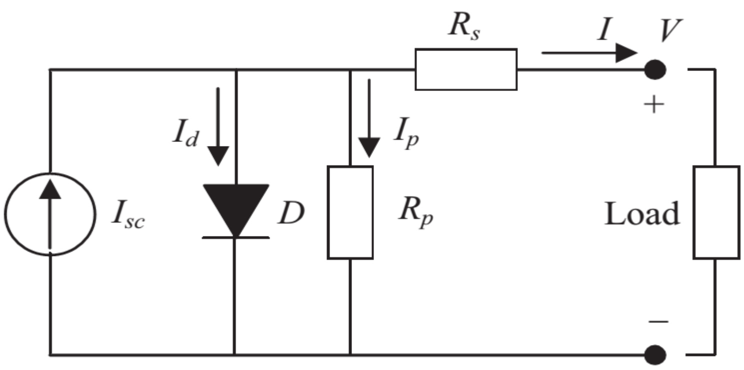


Figure 2. Equivalent circuit of PV panel [4]

Isc means PV panel current without any loss, Id means the leakage current, Rs and Rp means the loss which occur in the solar cell [4].

The mathematical equations for solar cells are following

$$I = I_{sc} - I_0 \cdot (e^{\frac{q.v}{k.T}} - 1) \tag{1}$$

$$V_{OC} = \frac{k \cdot T}{q} \ln(\frac{I_{sc}}{I_0} + 1) \tag{2}$$

$$P = I \times V = VI_{sc} - VI_0(e^{\frac{qV}{kT}} - 1) \qquad (3)$$

For that equations; I= Solar cell current , V= solar cell voltage, P= Power of solar cell power, Isc= short circuit current, Voc = Open circuit voltage, Io= reverse saturation current. q is charge of electron(1.602*10^{-19}), k = Botzmann constant (1.381*e^{-23}), T= absulate temperature [4].
A single solar cell produce very low energy about 1-1.5W, to get desired energy it is need to connect solar cells series or parallel to create PV panels shown in Figure 3.

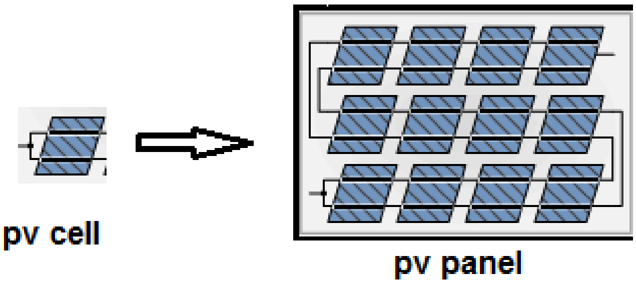
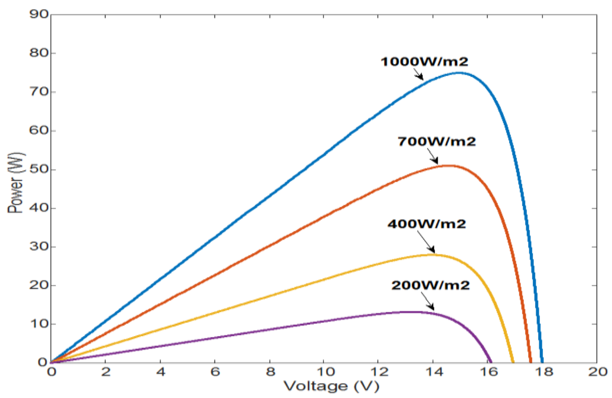
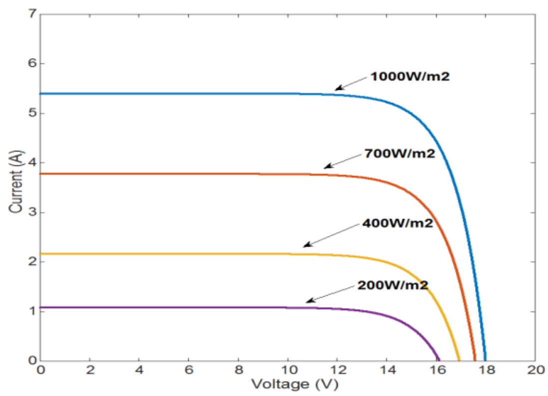


Figure 3. Solar cell to PV panels

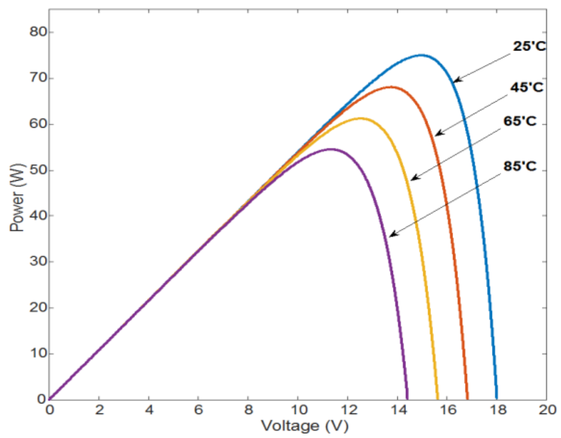
The most important step for MPPT algorithm is determining the I-V and P-V characteristics of PV panels. The electrical characteristic of PV panel used in this study is shown in Figure 4.



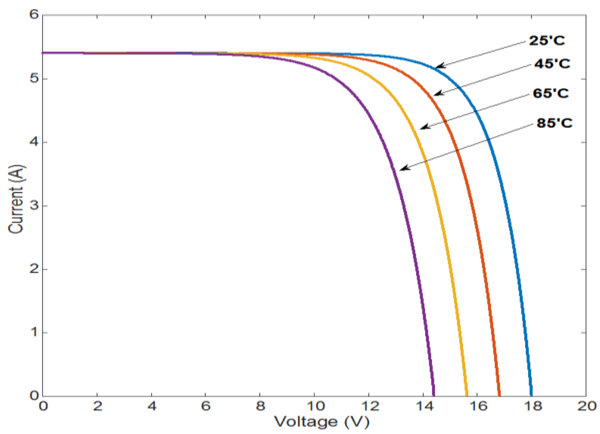
(a)



(b)



(c)



(d)

Figure 4. (a) P-V characteristic (variable irradiance) (b) I-V characteristic (variable irradiance), (c) P-V characteristic (variable temperature) , (d) I-V characteristic (variable temperature)

1.2. IC MPPT Algorithm

To operate PV panels at maximum power point, reduce cost, and increase efficiency. Many MPPT methods are developed so far, Incremental conductance MPPT method is one of them. This method use the derivative of conductance to reach maximum power point[5],[6],[7]. The power-voltage (P-V) characteristic of PV panel is shown Figure 5.

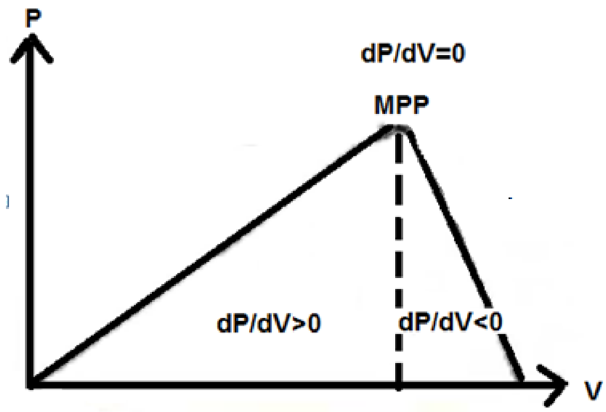


Figure 5. P-V characteristic of PV

Derivative of conductance is (Masood, Siddque, Asif and Zia-ul-Haq, 2014, pp. 354-358);

$$\frac{dP}{dV} = \frac{d(I \cdot V)}{dV} = I + V.\frac{dI}{dV} \quad (4)$$

If the derivative of instantaneous conductance is at the left side of P-V characteristic the (dP/dV>0)

$$\frac{dP}{dV} > 0 \Rightarrow \frac{dI}{dV} > \frac{-I}{V} \text{ , increase voltage } V + \Delta V \text{ and } \Delta V = +\delta \quad (5)$$

If the derivative of instantaneous conductance is at the right side of P-V characteristic the (dP/dV<0)

$$\frac{dP}{dV} < 0 \Rightarrow \frac{dI}{dV} < \frac{-I}{V} \text{, decrease voltage } V + \Delta V \text{ and } \Delta V = -\delta \quad (6)$$

If the derivative of instantaneous conductance is zero ("0")

$$\frac{dP}{dV} = 0 \Rightarrow \frac{dI}{dV} + \frac{I}{V} = 0 \text{, } V + \Delta V \text{ and } \Delta V = 0 \quad (7)$$

The flowchart of IC MPPT method is shown in Figure 6.

1.3. Flyback Converter

PV system consists of PV panels and DC-DC converters. Flyback converter is a type of buck-boost converter but using transformer instead of inductance, the transformer provide insolation between load and source and also by the turn ratio of transformer load voltage can be regulated [8],[9]. The Flyback converter constructed in Matlab/Simulink is shown in Figure 7.

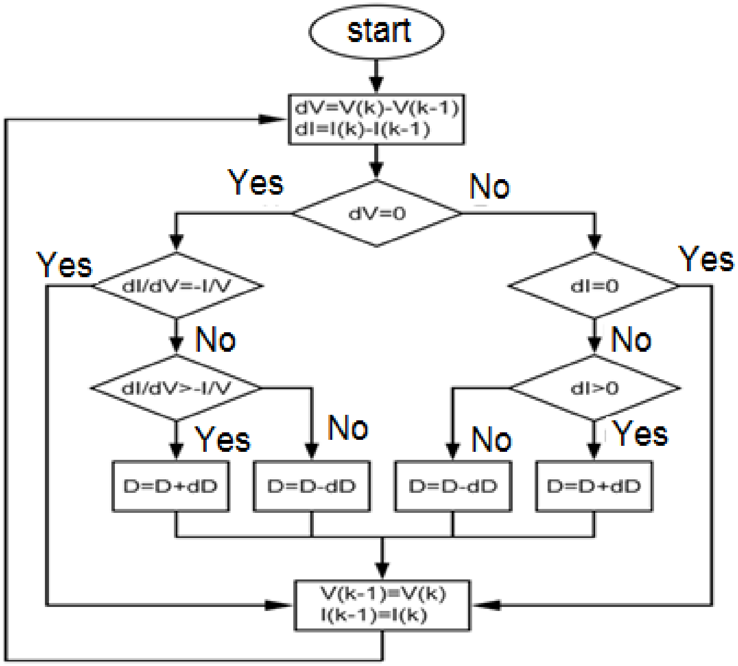


Figure 6. Flowchart of IC MPPT method

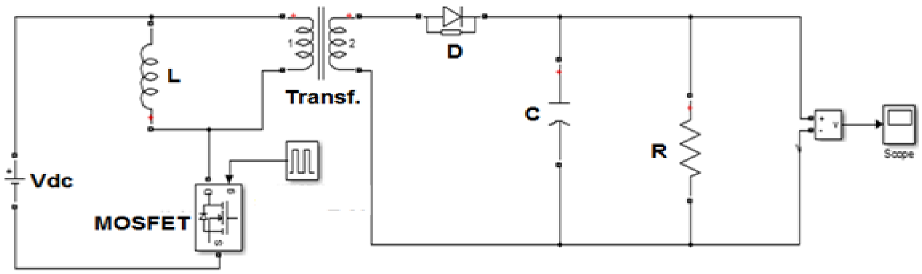


Figure 7. Flyback converter

The total current change of inductance is zero, so the duty cycle is; [8].

$$\frac{D}{1-D} = \frac{(V_{dc} - V_{DS}) \cdot n}{V_O + V_d} \qquad (8)$$

Vdc=input voltage, Vd= diode voltage, n=turn ratio Vds=switching voltage, Vo=output voltage

RESULTS AND FINDINGS

The simulation results are given in this section, this study operated four different states, the temperature and irradiance of simulation are shown in Figure 8 and Figure 9.

State 1: 25^{o}C and 600W/m2

State 2: 25°C and 1000W/m2

State 3: 50°C and 600W/m2

State 4: 50°C and 1000W/m2

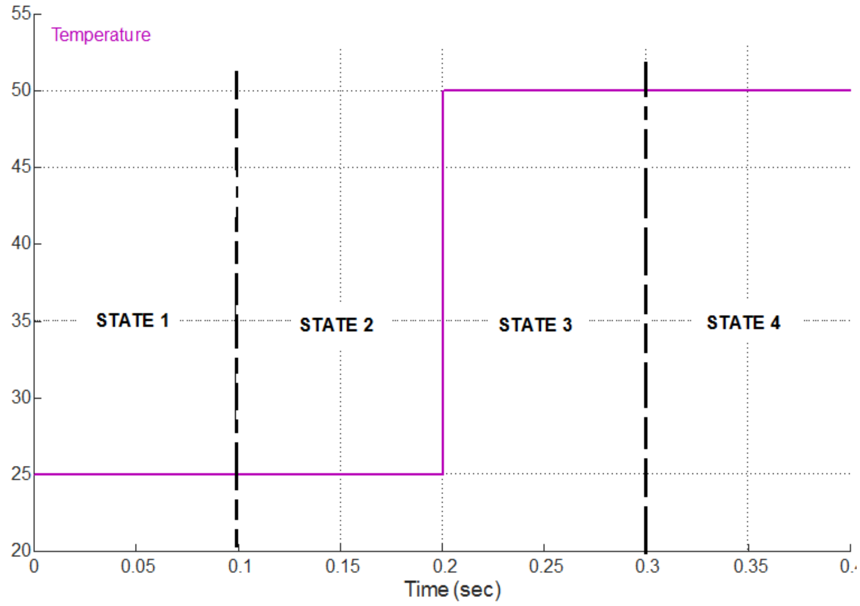


Figure 8. Temperature of System

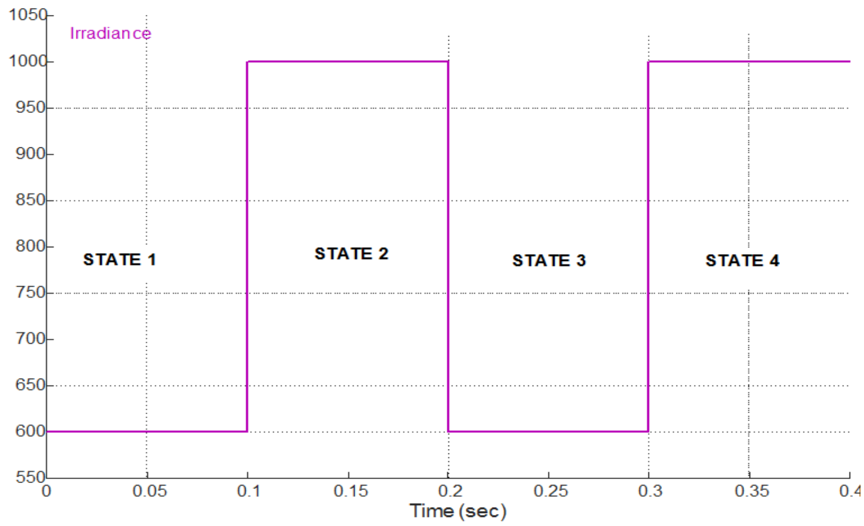


Figure 9. Irradiance of System

At four different states the varying of P-V characteristic and MPP of PV panel shown in the Figure 10

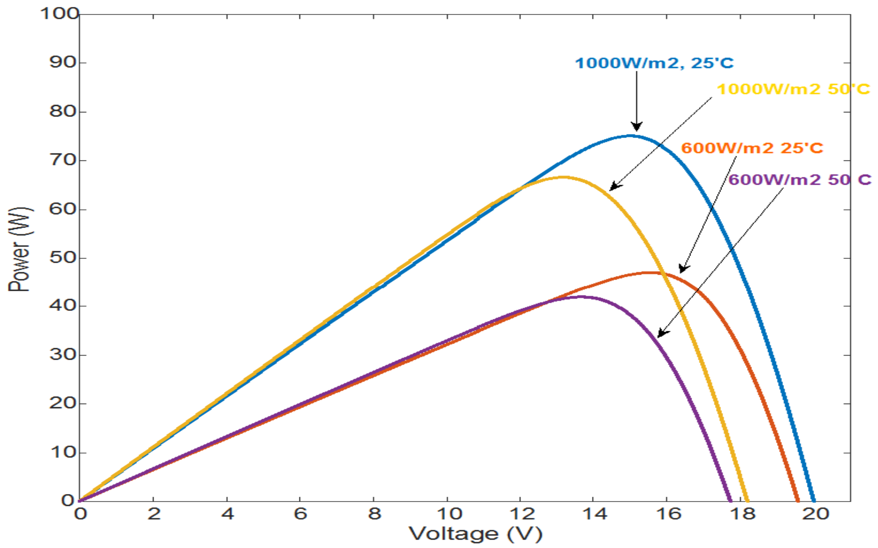


Figure 10. P-V characteristic of PV panel

At four different states, The react of PV voltage and load voltage of the flyback converter is shown in Figure 11, increasing irradiance lead to increase the PV voltage and increasing temperature lead to decrease the voltage

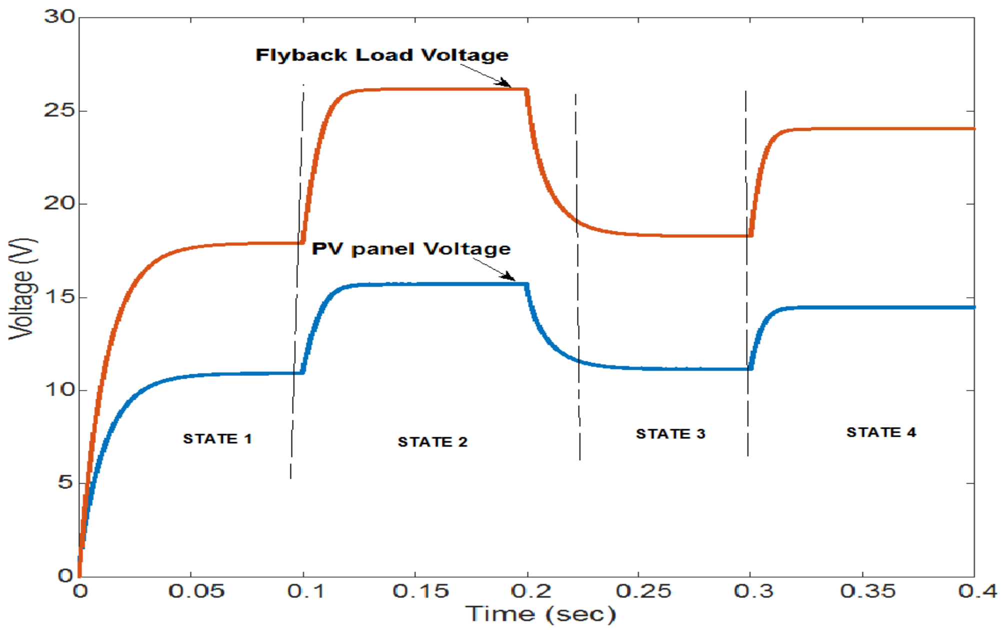


Figure 11. PV voltage and load voltage of system

At four different states, the PV power and load power of the system, increasing irradiance lead to increase the PV power and increasing temperature lead to decrease the power of PV shown in Figure 12.

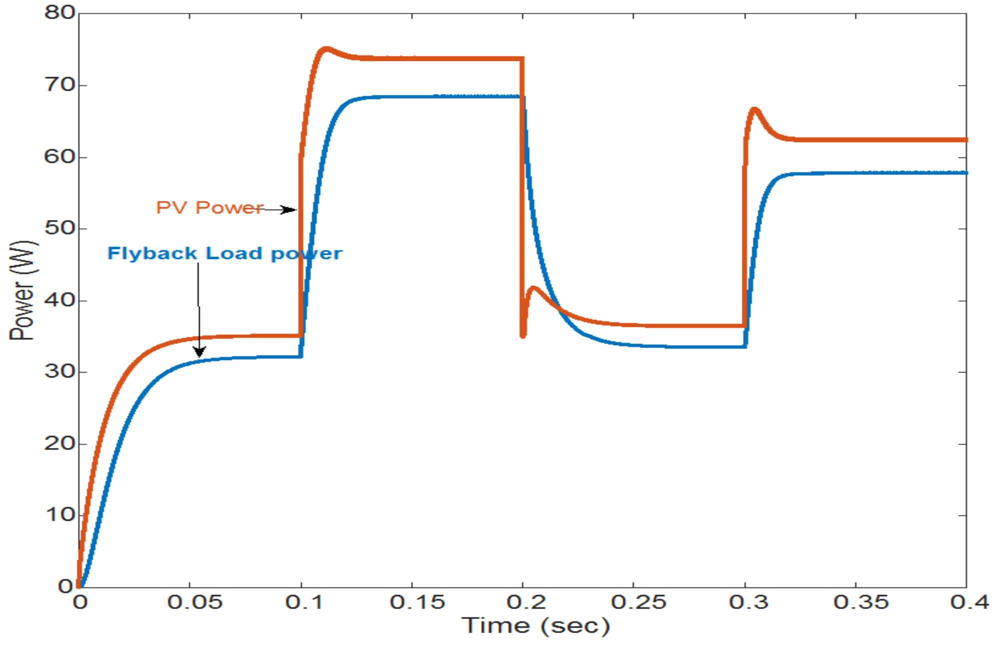


Figure 11. PV power and load power of system

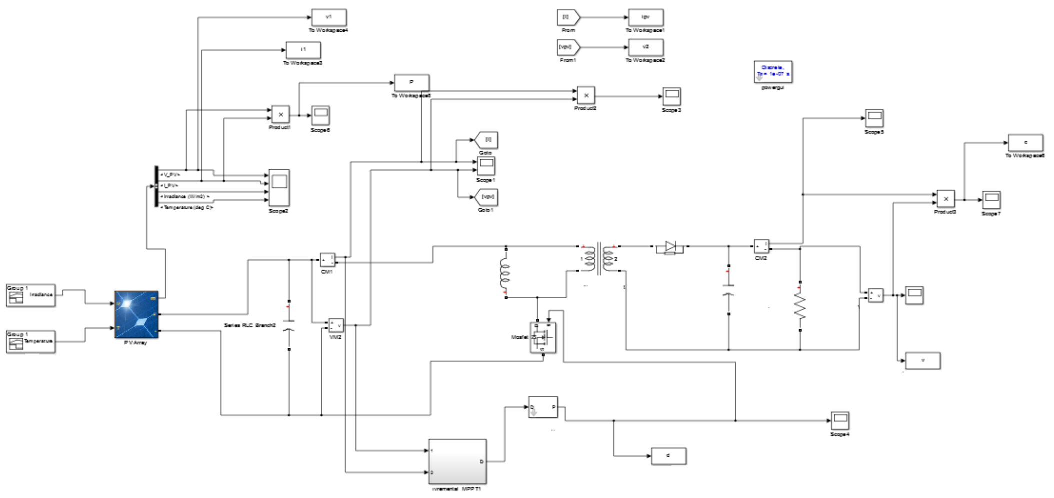


Figure 12. The system constructed in Matlab/Simulink

The efficiency of system and accuracy of MPPT method shown in Table 1

Table 1. The results of system

States	PV power	Maximum Power	Load Power	Efficiency
State 1	73.78 W	75 W	70.01 W	94.9%
State 2	66.24 W	68.7 W	62.1 W	93.75%
State 3	41.2W	43.1W	37.3W	90.53%
State 4	35.01W	38.6 W	31.7W	90.54%

CONCLUSION

This paper proposed to IC MPPT method applied Flyback converter under variable temperature (25^{o}C-50^{o}C) and irradiance (600W/m2-1000W/m2), for four states the efficiency of system change from 90.54% (state 4) to 94.9% (state 1) and accuracy of MPPT method change from 90.69 (state 4) to 98.37% (state 1). Using another MPPT method will give different accuracy, also can change response time and cost of system, because of that many parameters should be considered when selecting MPPT method. As the transformers losses occur in the flyback converter the efficiency of system can be low, so that using another converter such as boost and buck converter, the efficieny will be increase. The advantage of transformer is providing insolation between load and source and make it easier to adjust output voltage with the turn ratio

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