

Design and Simulation of PV System with Incremental Conductance Method for Maximum Power Point Tracking

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Abstract—This paper presents a complete design and simulation of a Photovoltaic System (PVS) with capable of Maximum Power Point Tracking (MPPT). In this paper Incremental Conductance Method (ICM) is adopted for the MPPT technique. The proposed PV System is modelled and simulated in MATLAB/Simulink GUI environment. Finally, dynamic performance of the proposed PV System with ICM is presented to demonstrate its capability of MPPT, which has a better tracking performance.

Keywords—Photovoltaic System (PVS), Incremental Conductance Method (ICM), Maximum Power Point Tracking (MPPT).

I. Introduction

The development of new energy sources are continuously enhanced because of the critical situation of the chemical industrial fuels such as oil, gas and others. Thus, the renewable energy sources, like solar, wind, hydro, biomass etc... have become a more important contributor to the total energy consumed in the world [1]. The market for PV systems is growing worldwide. In fact, nowadays, solar PV provides around 4800 GW. Between 2004 and 2009, grid connected PV capacity reached 21 GW and was increasing at an annual average rate of 60% [2].

With no pollutant emission, Photovoltaic cells convert sunlight directly to electricity. They are basically made up of a PN junction. Fig.1 shows the photocurrent generation principle of PV cells.

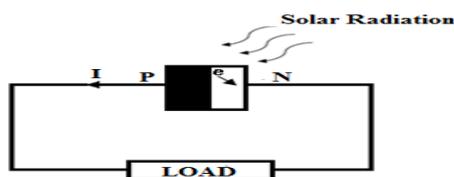


Fig.1. Basic diagram of Photovoltaic current generation

Generally a PV Cell generates a voltage around 0.5 to 0.8 Volts depending upon on material and it's built up technology. This voltage is not enough to use in practice. So, to get benefit from this technology, tens of PV cells (involving 36 to 72 cells) are connected in series to form a PV module. These modules can be interconnected in series and/or parallel to form a PV panel.

With the rapid increment in Solar Power generation in grid connections and also in standalone conditions, it should require a technique to solar power conversion to track the maximum power from the solar radiation. This paper mainly focuses on the design and simulation of PV System with

Incremental Conductance method to achieve the maximum power in MATLAB/Simulink GUI environment.

II. Modelling of PV Array

A. Mathematical Modelling:

Fig.2 shows the well known single diode equivalent circuit model of a photovoltaic cell. Standard simulation tools utilize the approximate diode equivalent circuit shown in Fig.3, which is used to simulate all electronic circuits that contains diodes[3].

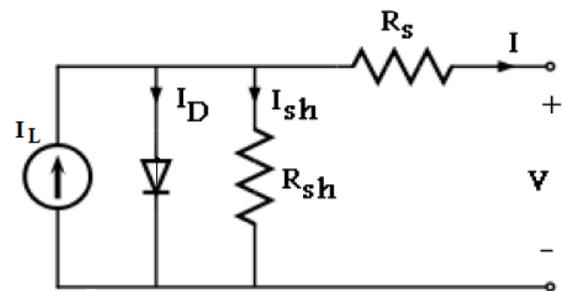


Fig.2. Equivalent circuit of a PV Cell

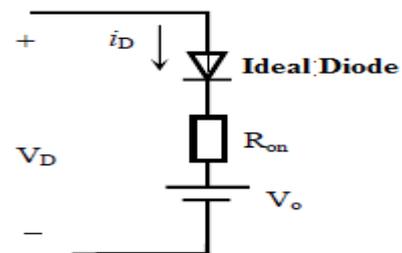


Fig.3. Diode equivalent circuit used in Power System block set / Simulink

The standard I-V characteristics of the solar cell based on Fig.2 and Fig.3 is given by [3]

$$I_D = I_0 \left(e^{\frac{q(V+IR_S)}{KT}} - 1 \right) \quad (1)$$

$$I = I_L - I_0 \left(e^{\frac{q(V+IR_S)}{KT}} - 1 \right) - \frac{V+IR_S}{R_{Sh}} \quad (2)$$

Observations from the above two equations are

I_D = Diode Current (A)

I_0 = Diode saturation current (A)

q = Electron charge (Joules)

I_L = Generated light current (A)

K = Boltzman constant (J/K)

T = Temperature of cell (K)

V = Output voltage of cell (V)

PV array model designed from the simple PV cells. In this way PV array has been assumed to comprise a combination of N_s cells in series and N_p cells in parallel in order to achieve the required output. The Fig.4 gives an idea of designed PV array from a PV cell.

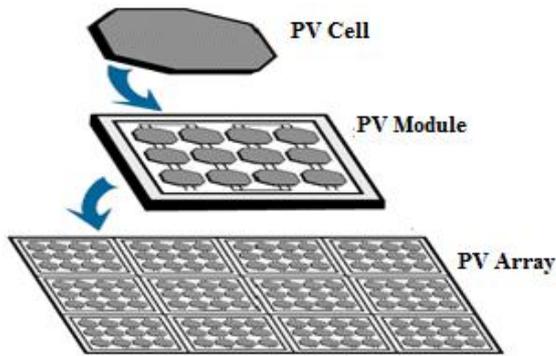
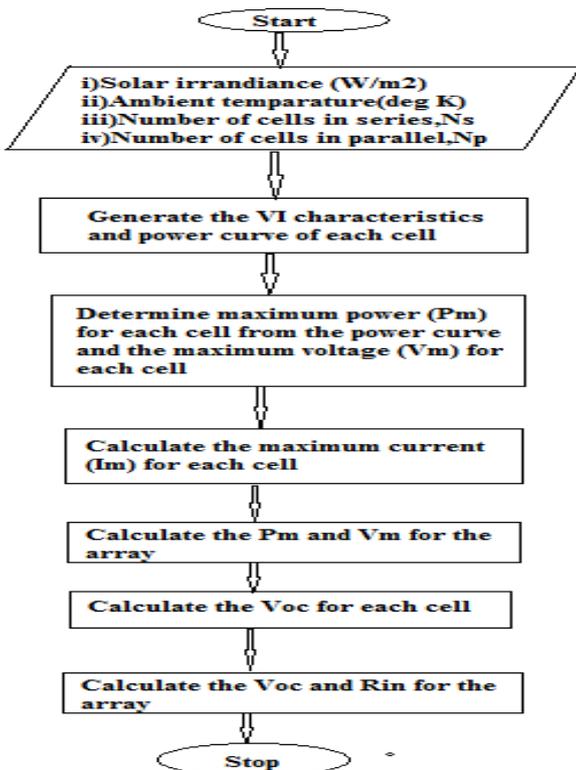


Fig.4.Design of PV array from PV cell

The flow chart for the modelling system is shown in Flow chart .1



Flow chart.1.Calculation of PV array equivalent circuit

B. Characteristics of PV array:

Fig.4 (a) and Fig.4 (b) shows the V-A and P-V characteristics of the PV cell respectively [1]. Lets us compare these shapes with the proposed system simulation shapes in the next section for estimate the accuracy of the system.

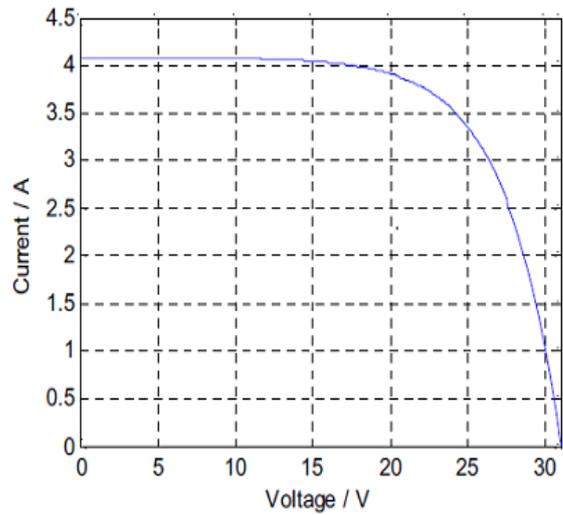


Fig.4 (a).V-A characteristics of PV cell

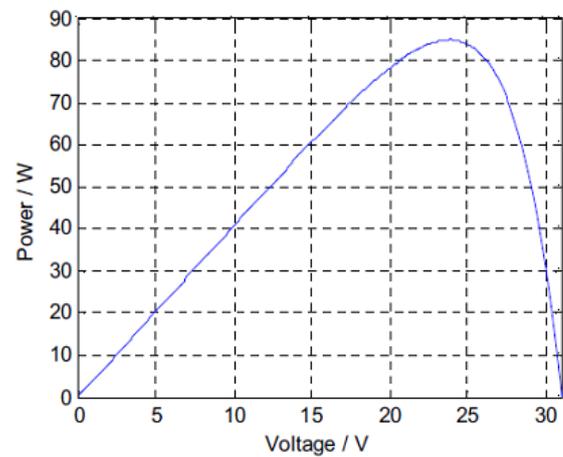


Fig.4 (b). P-V characteristics of PV cell

III. Principle of Operation & Simulation Parameters

A. Principle of Operation:

A boost converter is adopted in the proposed system in order to maintain a constant voltage. For the proposed incremental conductance method to track the maximum power points in the system, the boost converter should adjust its duty ratio (D) continuously to regulate the PV cells output voltage [1].

$$V_{out} = \frac{V_{in}}{1-D} \quad (3)$$

From the Fig.4 (b), slope is zero at the maximum power point.

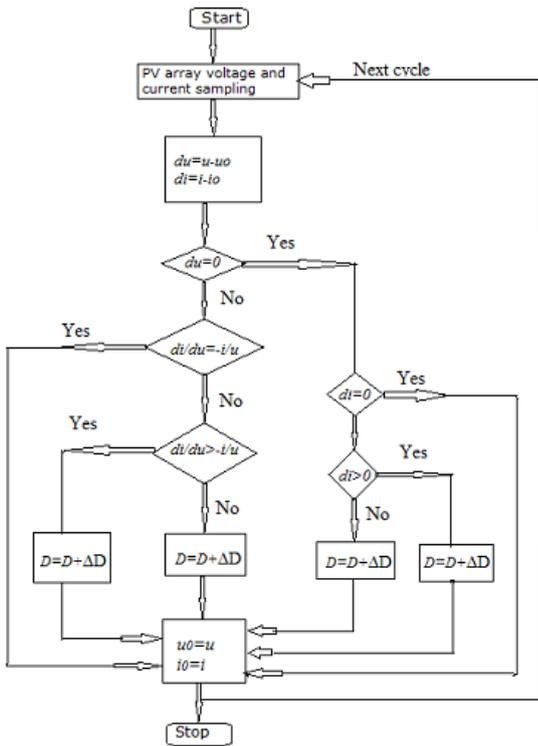
$$P_{max} = V \cdot I \quad (4)$$

$$\frac{dP}{dU} = I + V \cdot \frac{dI}{dU} \quad (5)$$

According to [1] and also from Fig.4 (b), the above equation becomes zero, and hence

$$\frac{dI}{dU} = -\frac{I}{U} \quad (6)$$

The total steps involved in the proposed Incremental conductance method given by the Flow chart.2 and its Simulink program is given in Fig.5



Flow chart .2. Incremental Conductance method

```

1 function y = MPPT( u, i, u0, i0, D)
2     m=0;
3     du=u-u0; di=i-i0;
4     if du==0
5         if di==0, m=D;
6         else
7             if di>0, m=D-0.01;
8             else
9                 m=D+0.01;
10            end
11        end
12    elseif di/du==-(i/u)
13    else
14        if di/du>-(i/u), m=D-0.01;
15        else
16            m=D+0.01;
17        end
18    end
19    y = m;
20 end
    
```

Fig.5. Window Simulink Programme of proposed Incremental Conductance Method

In the Simulink programme, i.e., in Fig.5, u and i represents the sampling voltage and sampling current values respectively, u0 and i0 represents the previous sampling values of voltage and current respectively. D stands for initial duty ratio of the boost converter.

B.MATLAB based designed parameters:

In this paper according to the load requirement, development of the PV array as follows,

$$\text{Total number of modules, } T = \frac{P_g}{P_m} \quad (6)$$

$$\text{Number of series modules, } N_s = \frac{1.1V_g}{V_m} \quad (7)$$

$$\text{Number of parallel modules, } N_p = \frac{T}{N_s} \quad (8)$$

In view of [1], the parameter equation of the PV array is given by

$$I = N_p \left\{ I_1 - I_0 \left[\exp \left(\frac{V}{N_s N_p} + \frac{I R_s}{N_p} \right) - 1 \right] - \frac{V}{N_s N_p} + \frac{I R_s}{N_p} \right\} \quad (9)$$

The simulation parameters of the proposed PV system in this paper is given in Appendix section

MATLAB based PV array is shown in Fig.6

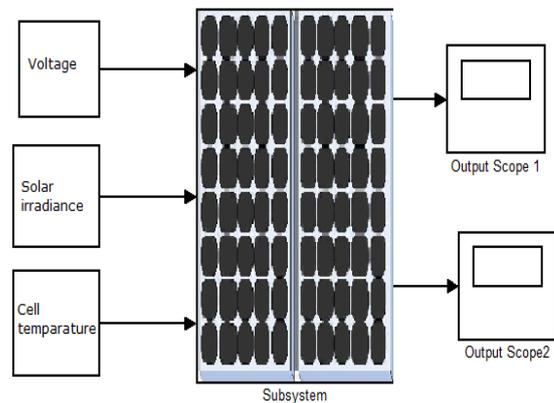


Fig.6. Masked MATLAB based diagram of PV array

MATLAB based proposed PV system with Incremental Conductance method is shown in Fig.7

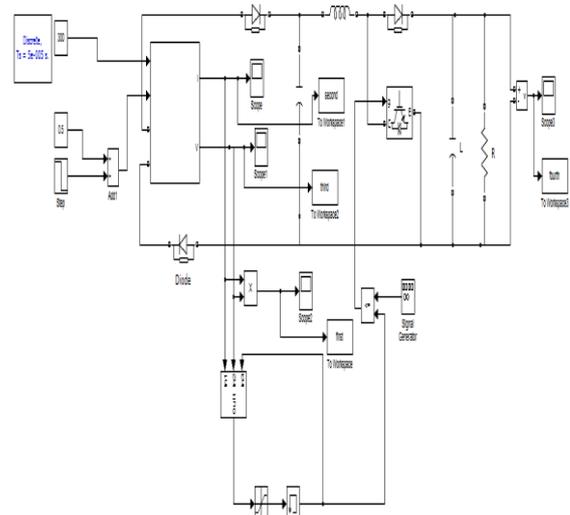


Fig.7. Complete MATLAB based diagram of PV System with Incremental Conductance Method

IV. Simulation Results & Conclusion

i. Simulation Results

In the simulation process, the input temperature is set at the value of 300°C at the starting of simulation and the light intensity is at $1\text{kW}/\text{m}^2$. To observe the simulation results more accuracy, light intensity changes from its previous value to $0.82\text{kW}/\text{m}^2$ after the 0.3 seconds.

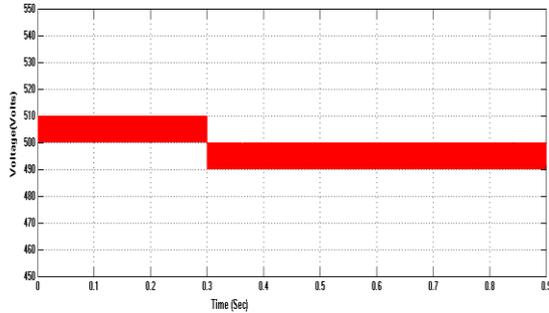


Fig.8.Simulation graph between Voltage and Time of proposed PV system

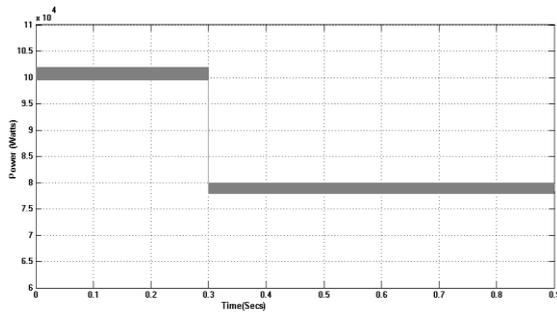


Fig.8.Simulation graph between Power and Time of proposed PV system

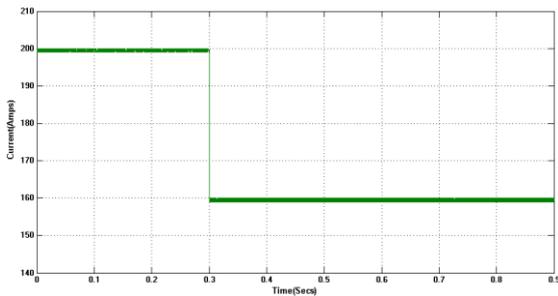


Fig.8.Simulation graph between Current and Time of proposed PV system

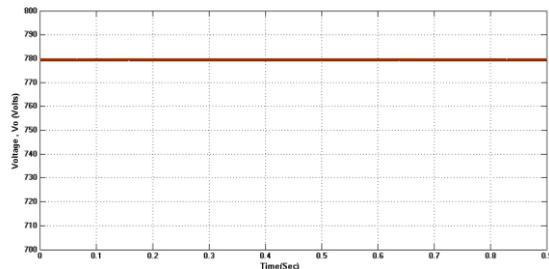


Fig.8.Simulation graph between rated output voltage (V_o) and time of proposed PV system

ii. Conclusion

In this paper design and simulation of PV system with Incremental Conductance method was carried out by MATLAB/Simulink 2009a version programming in GUI environment with ode3 solver. The proposed system reaches maximum power point tracking technique successfully irrespective of fluctuations. When the external input changes suddenly, the proposed system reacts dynamically to track the maximum power point very quickly.

Appendix

In this paper the following parameters are used to simulate the proposed system

Parameter	Rating
Total modules(T)	1177.9=1178
Series modules(N_s)	21.9=22
Parallel modules (N_p)	53.6=54
voltage V_{oc}	683V
R_s	0.0053 Ω
R_{sh}	2750 Ω
P_g	100kW
I_o	70.09 μA

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