Analysis of Mathematical Modeling of PV Module with MPPT Algorithm

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Introduction

- Generally, Maximum Power Point Tracking (MPPT) techniques are used in PV System to extract maximum possible power which in turn depends on solar irradiance and temperature of PV module.
- Two most widely used MPPT techniques namely incremental conductance (INC), and perturb & observe (P&O) method are analyzed in this paper.
- The PV models compared are simplified single diode model, improved two diode model and simplified two-diode model. The effectiveness of the comparison has been done through MATLAB/Simulink Environment and the results are analyzed.

Model

- Generally, the I-V characteristics for a PV module composed of series connected cells based on single exponential model is expressed as follows:

$$I = I_{pv} - Io\left[\exp\left(\frac{q(V + IR_s)}{N_s KTA}\right) - 1\right] - (V + IR_s)/(R_{sh})$$

(1)

where,

q= Electron charge (1.6×10^{-19} Coulombs)

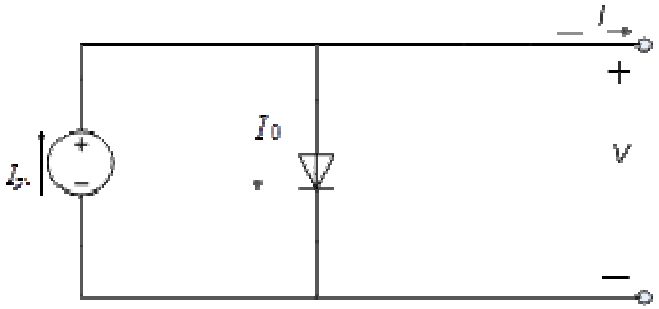
K=Boltzmann constant (1.38×10^{-23} Nm/K)

T=PV Module temperature in Kelvin

A. Ideal Single-Diode Model

Saturation Current can be expressed as follows:

$$I_o = \frac{e^{\left(\frac{|\beta|\Delta T * q}{N_s KTA}\right)} G\left[I_{sc} + \alpha \Delta T\right]}{\left(GI_{sc} / I_{rs} + 1\right)^{\frac{T_o}{T}} - e^{\left(\frac{|\beta|\Delta T * q}{N_s KTA}\right)}}$$



B. Improved Two-Diode Model

Equation (1) describes the output current of the cell:

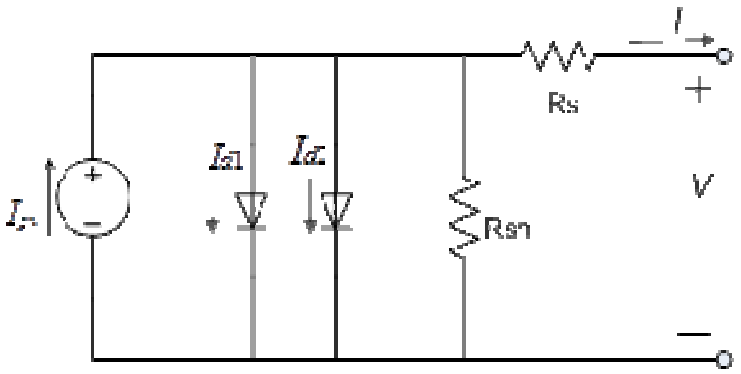
$$I = I_{pv} - I_{d1} - I_{d2} - \left(\frac{V + IR_s}{R_{sh}}\right) \qquad (6)$$

Where

$$I_{d1} = I_{01}\left[\exp\left(\frac{V + IR_s}{a_1 V_{T1}}\right) - 1\right] \qquad (7)$$

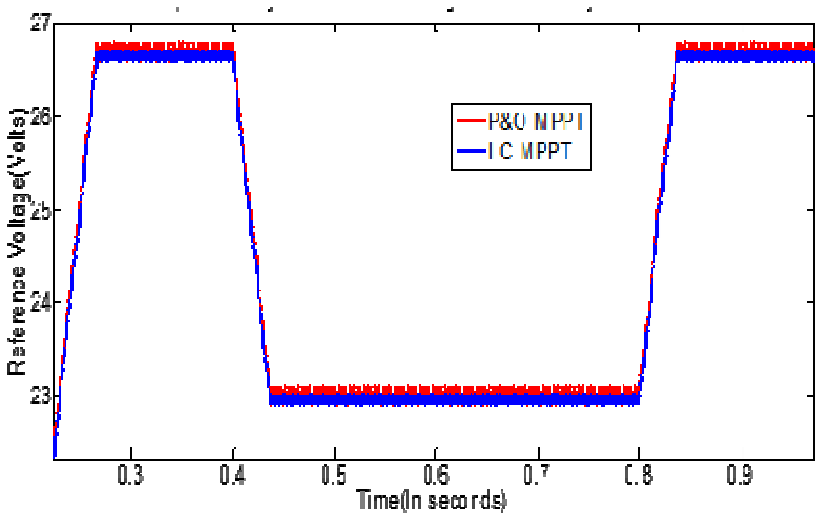
and

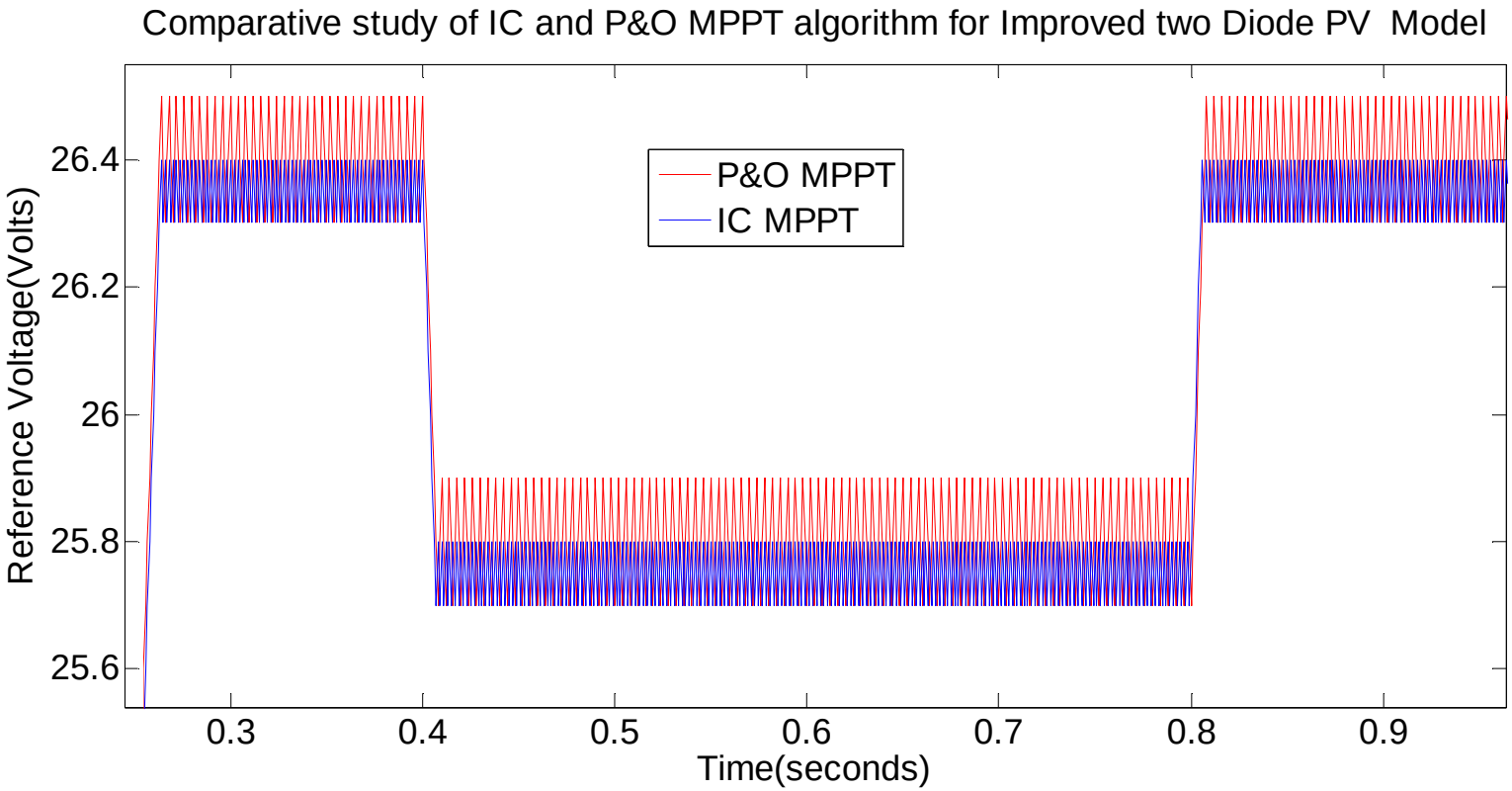
$$I_{d2} = I_{02}\left[\exp\left(\frac{V + IR_s}{a_2 V_{T2}}\right) - 1\right]$$



Results

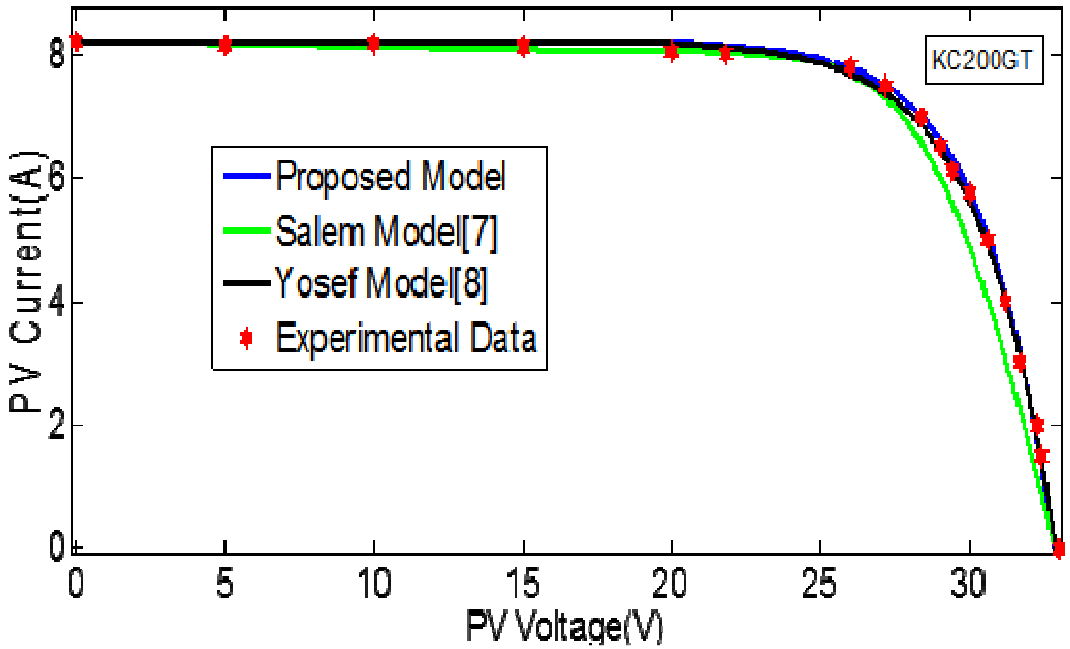
- To compare the performance of the two MPPT Algorithm (IC and P&O) with the common fixed step size (0.1), the simulation is configured under standard test conditions (STC) to compare the performances. The irradiation was suddenly changed from 1000 to 200 W/m^{2}at 0.4s and changed back to 1000W/m^{2}at 0.8s.

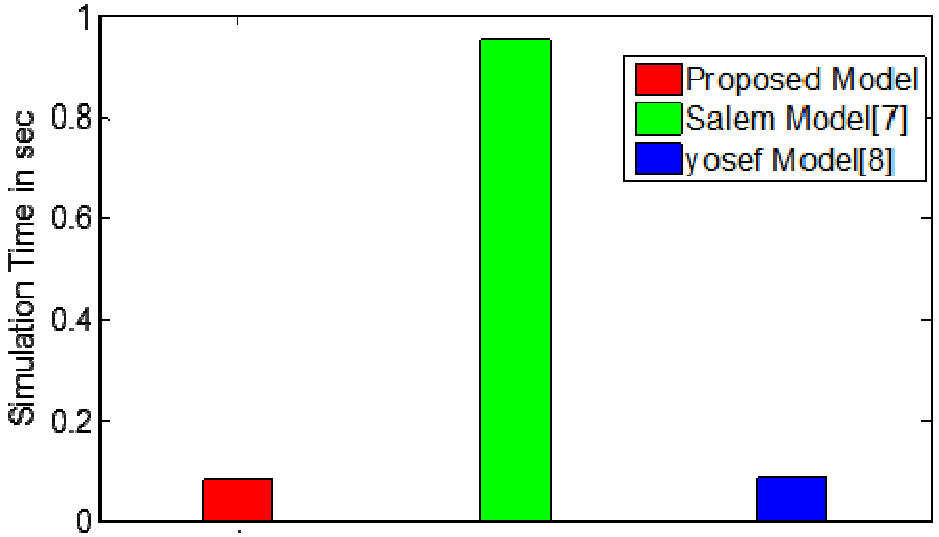



Comparative study of IC and P&O MPPT algorithm for Improved two Diode PV Model
P&O MPPT
IC MPPT
Reference Voltage(Volts)
26.4
26.2
26
25.8
25.6
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Time(seconds)

Discussion

- For ideal single diode model the model is significantly improved and is almost approximated to the actual PV module but, this approach deteriorates accuracy at low irradiance, especially in the vicinity of V_{oc}.
- The simplified two-diode model takes advantage of the simplicity of single diode model and enhances the accuracy by deriving a mathematical representation, capable of extracting accurate estimates of the model parameters, directly related to manufacturer datasheets. The characteristics curves closely coincide with the experimental data sheet of PV module.
- As a result, simplified two-diode model takes lesser simulation time as compared to improved two-diode model and it was clearly shown in Figures


KC200GT
Proposed Model
Salem Model[7]
Yosef Model[8]
Experimental Data
PV Current(A)
PV Voltage(V)
0
2
4
6
8
0
5
10
15
20
25
30


Proposed Model
Salem Model[7]
yosef Model[8]
Simulation Time in sec
0
0.2
0.4
0.6
0.8
1

Conclusions

- The paper presents the mathematical modeling of PV module with the effective comparison of two popular MPPT Techniques.
- Thus it can be concluded from the study that, Incremental Conductance MPPT algorithm is better one as it produces **less Voltage ripple**.
- Though P&O MPPT is much easier and easy to implement but IC MPPT algorithm gives better results.
- Among the PV array models, simplified two-diode model and Ideal Single Diode Model (ISDM) are simple and easy to simulate.
- In ISDM PV Model there is no need for any numerical solver as current is function of only the Voltage term. Therefore the simulation time for ISDM Model with MPPT algorithm is lower as compared to Improved two Diode Model. Thus it is concluded that Incremental Conductance MPPT algorithm with Ideal Single Diode PV model is fast and gives desired output with less ripple voltage.