Quadratic Equation Based Solar Panel Modelling Using MOSFET Transistor

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Abstract

- In this presentation, we present a newer dataset generating technique such that a single tool like Matlab can generate the data.
- This generated dataset will be used by ML algorithm to train solar powered drones for effective power management during the search and rescue mission.
- For achieving this, it is essential to remove the non-linearity from the analytical model of the PV module that typically uses 1-diode, 2-diode, or 3-diode.
- The first step is to transform the current source into voltage source.
- Later, the cause of the non-linearity is the presence of the diode in the equivalent PV cell model is replaced with Metal Oxide Semiconductor Field Effect Transistor (MOSFET) based diode.
- The accuracy of the analytical model is verified by using SPICE simulation.

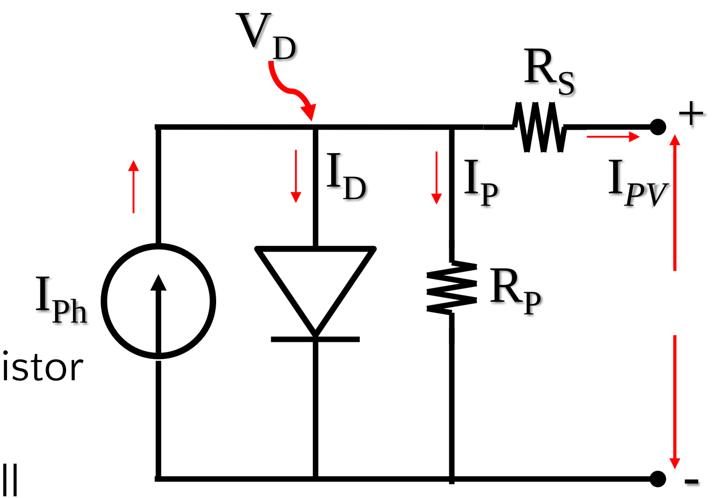
Introduction

- For search and rescue missions, drones are increasingly playing a pivotal role.
- To make drones effective in rapidly evolving situations, it is essential for them to be aerial for a longer time and possess the ability to switch between cross-functional roles in real-time.
- All this can be achieved by powering a drone with a reconfigurable solar panel.
- For the reconfigurable solar panel to be an effective power source for drones for various missions, it is crucial for them to be controlled by intelligent machine learning (ML) algorithms.
- For this purpose, there is a dataset requirement that can train the ML algorithm in different operating conditions.
- Hence, to create a effective dataset that covers all possible operating conditions, multiple tools such as SPICE simulator, and python is used.
- Using of multiple tools for generating a vast dataset will put lot of strain on computing system.
- In this presentation, we are simplifying it by modifying the equivalent solar cell model such that a single tool like Matlab can be able to generate the dataset.

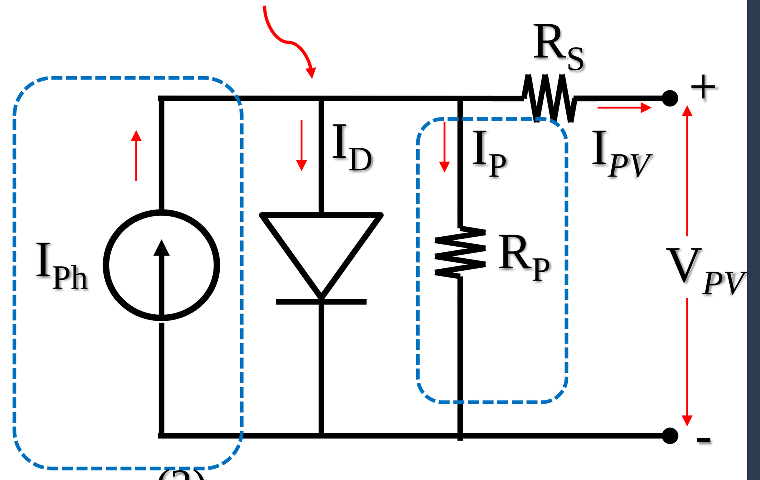
Methodology

Typical Solar Cell Modelling:

Where,
I_{Ph} = Photon Current
I_D = Diode Current
R_P = Shunt Resistance
I_P = Current Across the Shunt Resistor
R_S = Series Resistance
I_{PV} = Current Generated by PV Cell
V_{PV} = Voltage Across a PV Cell



Proposed Solar Cell Modelling



Using Kirchhoff's Current Law

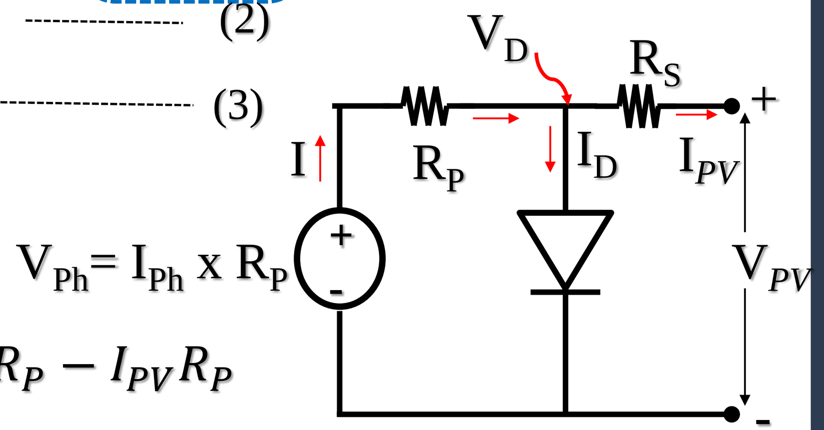
$$I = I_D + I_{PV} \quad (1)$$

$$V_D = V_{Ph} - IR_P$$

$$V_D = I_{Ph}R_P - (I_D + I_{PV})R_P \quad (2)$$

$$V_D = V_{PV} + R_S I_{PV} \quad (3)$$

Equating (2) and (3) gives



$$V_{PV} + R_S I_{PV} = I_{Ph}R_P - I_D R_P - I_{PV}R_P$$

$$I_{PV}(R_S + R_P) = I_{Ph}R_P - I_D R_P - V_{PV}$$

$$I_{PV} = \frac{1}{(R_S + R_P)}(I_{Ph}R_P - I_D R_P - V_{PV}) \quad (4)$$

Presence of I_D is cause of non-linearity in the IPV mathematical modelling.

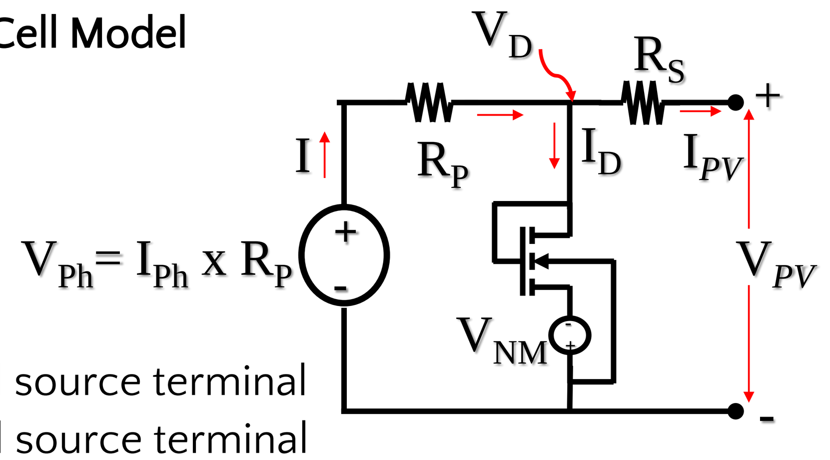
$$I_D = I_S(e^{\frac{V_D}{nV_t}} - 1) \quad (5)$$

Hence, the diode can be replaced with NMOS based diode by shorting the gate and drain terminal.

Methodology - continue

Proposed MOSFET based Solar Cell Model

Where,
I_M = Current across the NMOS
K_N = Process Transconductance
W= Width of NMOS
L= Length of NMOS
V_{GS} = Voltage between gate and source terminal
V_{DS} = Voltage between gate and source terminal
V_{tn} = Threshold voltage of NMOS transistor
λ = Channel Length Modulation



$$I_{PV} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

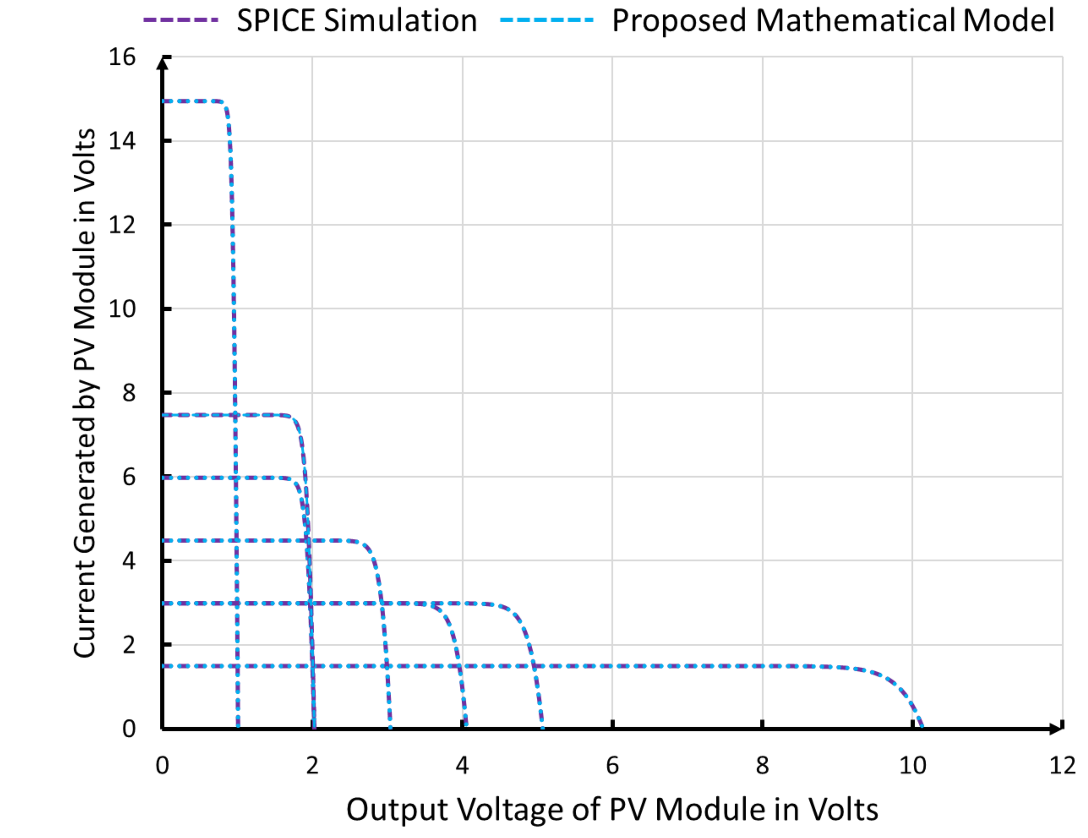
$$a = \frac{K_n {R_s}^2 (W/L)}{2}$$

$$b = R_P + R_S + K_n R_S \left(\frac{W}{L}\right)(V_{PV} - V_{tn})$$

$$c = \frac{K_n}{2}\left(\frac{W}{L}\right){V_{PV}}^2 - \frac{K_n}{2}\left(\frac{W}{L}\right)V_{PV}V_{tn} + V_{PV} + \frac{K_n}{2}\left(\frac{W}{L}\right){V_{tn}}^2 - I_{ph}R_P$$

Results

Type of PV Cells (AMO Sunlight (135.3mW/cm2) GaAs/Ge Single Junction Solar Cells.
J_{SC} = 30.5 mA/cm², V_{OC}= 1.025V, Area of PV Cell = 7 cm x 7 cm.



Conclusion

- The use of MOSFET to replace diode in the equivalent solar cells was able to simplify the modelling technique.
- The MOSFET based diode resulted in transforming the non-linear equation for computing output current, I_{PV}, into quadratic equation.
- Parameter extraction from solar cells and modules is very challenging task.
- The proposed technique will simplify the process.
- Same is the case with multi-junction solar cells and modules. The proposed technique will make the modeling for them much easier.
- The large-scale solar farm are getting much more popular over the years. Due to simplicity of the proposed technique this will make the solar farm simulation less resource intensive.
- Couple of other solar panel modelling technique where MOSFET transistors were used. In future, we will compare the performance of proposed technique with other published work.

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