Methodology for the Parameter estimation of Diode model for PV cell

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Abstract:
Renewable energy is energy produced from resources that can be renewed naturally through time. Light from the sun is an excellent energy source that can be applied for many different things, including power generation, conversion of solar energy to electricity, and so on. Solar cells, on the other hand, contain a significant degree of non-linearity and have parameters that must be precisely set. This work is a review of parameter estimation and optimization using various approaches, taking into account SDM, DDM, and TDM of PV cells, as well as various objective functions, with the help of literature on Simulink models and single diode model characteristics by software tool. According to the study, because of the nonlinear features of PV cells,The greatest tool for identifying the nonlinear model and its known and unknown parameters is optimization. With this idea, we must first use the analytical method to identify all unknown parameters, and then apply the optimization strategy that is the best and most suitable for all three ways.

Keywords: PV Cell, PV module, SDM, DDM, TDM, Optimization method.

I. Introduction:

Due to escalating energy costs, various energy losses in the electricity grid, the risk of nuclear power generation, and environmental issues, we must shift to another energy source that is in great demand and readily available. As a result, the importance of solar energy is apparent in this notion. Solar energy is a natural resource with numerous benefits, including being clean, long-lasting, readily available, and dependable. As we all know,it is a renewable energy source that can be used in a variety of ways, and we require an interface device or module to convert light energy into electricity. PV cell, under this notion, is a component of a PV system that converts light into electrical energy.It is essentially a semiconductor diode that has been exposed to sunshine. As a result, photovoltaic power generation systems have substantially improved and are now widely used around the world. We need to improve the performance of renewable energy as we focus on rising demand for it, such as solar energy with solar PV cells. We need precise modelling of the generation system for this (PV Cell,PV module, PV System). PV cells are nonlinear in nature, producing varying amounts of power and voltage based on the amount of light and temperature. It is critical to have precise parameter estimate and optimization of PV cells using mathematical models, but it is also critical to increase the quality of the system in power terms generation efficiency. It aids in the device's mathematical modelling quality improvement. The device's precise parameter can be useful in evaluating, optimising, and monitoring the generation system. As a result, we must focus on constructing a precise mathematical model with precise parameter estimation using a variety of mathematical modelling ideas, such as: [6,7,8].

a) PV cell mathematical modelling using the single diode model (SDM)

b) PV cell mathematical modelling using the double or two diode model (DDM)

c) Three diode model (TDM) for mathematical modelling of solar cells [1,3,8,13].

In these models, nonlinear current voltage and Power voltage characteristics of diodes are used for describing how the solar cell generates energy based on the inherent characteristics of the semiconductor photo cell and incoming solar radiation. PV cells with a range of well-known and undiscovered properties All of the well-known metrics open circuit voltage called as (V_{oc}) parameter, short circuit current called as (I_{sc}) parameter, current at maximum or peak power point also called as (I_{mpp}), and voltage at maximum power point (V_{mpp}) are used in electronic circuits (V_{mpp}). The diode ideality factor (n), the current source generated by light denoted as (I_L), the reverse current at saturation point, as well as the previously mentioned unknown characteristics series resistance (R_s), shunt resistance (R_{sh}), and (I_s). When constructing PV cell models for standard testing circumstances, all of these variables are helpful. The parameters that define a solar cell's characteristics can be identified and calculated under a range of climatic circumstances, solar radiation levels, and temperature. [1,2,3,4,5]

II. Modelling of photovoltaic diodes and problem formulation:

We've gone over the fundamentals of diode modelling, as well as analytical and optimization methodologies, now we will consider single diode photovoltaic cell model in terms of basic mathematical equations. [15] [17] [25].

A) Single diode model

Number of circuit models that can use in the modelling of solar cells mathematically.

The ideal model for a photovoltaic cell based on a one diode is as follows: If we examine the optimum model for a solar cell that uses a one diode, the diode is attached in shunt with the source that is current and provided by the light source in this circuitry. The optimum circuit model for a single diode is depicted in the diagram.

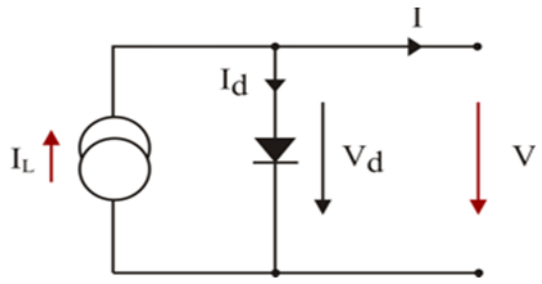

Figure 1 One diode model for PV cell.

Here I_L is source of current source whereas current I which is output or destination current can be written with the help of Kirchhoff's current law Total current I

$$I = I_L - I_d \quad (1)$$

And Id

$$I_d = I_S[\exp(V/nV_T) - 1] \quad (2)$$

Rearranging above equation,

$$I = I_L - I_S[\exp(V/nV_T) - 1] \quad (3)$$

B) Non-ideal circuit model for solar cell with a one diode

In a circuit model which is non-ideal for the PV Solar cell, a single diode model is used, the R_s and the R_{sh}. The connections are shown in Figure 2. The five parameter model is a type of model that incorporates parameters such as and. [1][5][6][7]

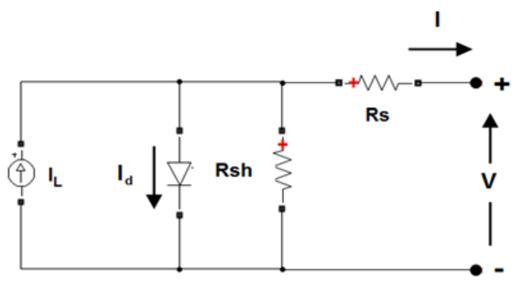

Figure 2 Practical one diode model for solar cell.

In figure 2

A is the diode's ideality factor.

I_d= Diode Current

I_L denotes a current that is generated by light.

Above model have a good series effect and a less shunt resistance. The series resistance and parallel resistance are highly essential in this parameter [1] [2][6][7]. A mathematical equation for a one diode model looks like this:

$$I = I_L - I_d - I_{sh} \qquad (4)$$

Diode current can be obtained as,

$$I_d = I_O(\exp(\frac{V + IR_s}{n_s V_T}) - 1 \qquad (5)$$

$$I = I_L - I_O(\exp(\frac{V + IR_s}{n_s V_T}) - 1) - \frac{V + IR_s}{R_{sh}} \qquad (6)$$

So one diode model has five unknown parameters: [Io, A, Rsh, Rs, IL]. [1] [2] [7] [8] [22][23]

C) PV Cell mathematical modelling using double diode model:

The model using double diode called as single diode modified version model. The only difference is that we add one more parallel diode to the previous diode. We estimated seven parameters using the equivalent model of two diodes as a comparison to the one diode model. Main advantage of this model is that it improves the module's efficiency with respect to a one diode model and estimates more unknown parameters.

The realistic double diode form of solar cells is shown in Figure 3. We can write electrical current with this model.With this model we can write electrical current equation by using Kirchhoff's current law for the load current calculated using below equation:

$$I_L = I_{ph} - I_{d1} - I_{d2} - I_{sh} \qquad (7)$$

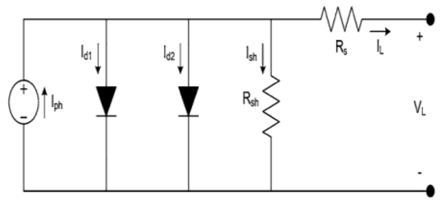

Figure 3: Practical Double diode model for PV cell.

This equation having with notations such as: I_L = Electrical current passing through the load

I_{ph} = Photon Current

I_{d1} = Electrical current of first diode I_{d2} = Electrical current of second diode

I_{sh} =Electrical current of parallel resistor

In this equations I_{d1} and I_{d2} can be calculated as

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$$I_{d1} = I_{sd1}[\exp(\frac{q(V_L + R_s I_L)}{n_1 kT}) - 1] \quad (8)$$

$$I_{d2} = I_{sd2}[\exp(\frac{q(V_L + R_s I_L)}{n_2 kT}) - 1] \quad (9)$$

According to the figure I_{sh} can be calculated $I_{sh} = \frac{(V_L + R_s I_L)}{R_{sh}}$ (10)

By putting equations (8),(9) and (10) into (7) we can rewrite as

$$I_L = I_{ph} - (I_{sd1}[\exp(\frac{q(V_L + R_s I_L)}{n_1 kT}) - 1) - (I_{sd2}[\exp(\frac{q(V_L + R_s I_L)}{n_2 kT}) - 1) - \frac{(V_L + R_s I_L)}{R_{sh}} \quad (11)$$

This the output load current of above Double diode model suppose we write the equation for the load power then simple formula for that is

$$P_L = V_L * I_L \quad (12)$$

And that can be written as

$$P_L = V_L * \{I_{ph} - (I_{sd1}[\exp(\frac{q(V_L + R_s I_L)}{n_1 kT}) - 1) - (I_{sd2}[\exp(\frac{q(V_L + R_s I_L)}{n_2 kT}) - 1) - \frac{(V_L + R_s I_L)}{R_{sh}})\} \quad (13)$$

In this way double diode model discussed above having seven parameters are considered as seven unknown parameters

[n_1, n_2, I_{sd1}, I_{sd1}, R_s, R_{sh}, I_{ph}].

D)Mathematical modelling of PV Cell using triple diode model:

The triple diode model for the PV cell is depicted in Figure 4. In comparison to the one diode and two diode models, the multi-diode model contributes more parameters which are unknown, resulting in improved efficiency and accuracy for the output parameters. This model was utilised to improve the estimation and optimization

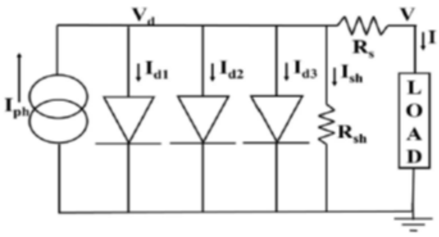

Figure 4: Practical triple diode model for PV cell.

The current owing to diffusion as well as recombination into the emitter and bulk part of the P-N junctions is represented by three currents in the three diodes, such as, in the circuit diagram. The third diode current in this circuit reflects the influence of grain boundaries and leakage current. The relevance of the semiconductor material resistance at the neutral regions of solar cells is represented by the series resistance RS. The leakage current at the solar cell's surface is represented by the parallel resistance Rsh. We may put down the equation for the three diode model using the reference to the above figure.

The realistic three-diode model of solar cells is shown in Figure 4. We may write the electrical current equation using this approach.With this model we can write electrical current equation by using Kirchhoff's current law for the load current obtained through the following equation:

Three diode equations:

$$I_L = I_{ph} - I_{d1} - I_{d2} - I_{d3} - I_{sh} \quad (14)$$

In above equation diode current equation can be written as on the basis of schoktky diode equation $I_{d1} = (I_{sd1}[\exp(\frac{q(V_L + R_s I_L)}{n_1 kT}) - 1)$ (15)

$$I_{d2} = (I_{sd2}[\exp(\frac{q(V_L + R_s I_L)}{n_2 kT}) - 1) \quad (16)$$

$$I_{d3} = (I_{sd3}[\exp(\frac{q(V_L + R_s I_L)}{n_3 kT}) - 1) \quad (17)$$

Putting equations (15),(16),(17) into the (14) we can rewrite as

$$I_L = I_{ph} - (I_{sd1}[\exp(\frac{q(V_L + R_s I_L)}{n_1 kT}) - 1) - (I_{sd2}[\exp(\frac{q(V_L + R_s I_L)}{n_2 kT}) - 1) - (I_{sd3}[\exp(\frac{q(V_L + R_s I_L)}{n_3 kT}) - 1) - \frac{(V_L + R_s I_L)}{R_{sh}} \quad (18)$$

III. Optimization Techniques.

As is well known, a parameterized model is utilized to estimate the output of a solar cell. Examples of such models are the one diode, double diode, s well as triple diode models for photovoltaic cell that we looked at in great detail above. The parameters can found from the sheet called as data sheet, and measurements can be taken of the current and voltage also power voltage characteristics. Estimated Parameter yields superior outcomes when measured against the production data sheets of the PV module or PV cell. Two main techniques, Data-Sheet and measurement-based, can be used to calculate the parameters of the PV model in order to improve the process. In some earlier methods, for instance, it is possible to acquire the parameter estimation for a single diode model..[13,15,17,23]. Some of the parameters estimate the starting values of the parameters and then use the collected data to minimise the cost functions. Estimation of parameters using various methods. To obtain the features, which will be used to measure the parameter. All of the parameter features are broken down into known and unknown parameters. And these PV module properties for various irradiance and temperature conditions. Our model is varied from an open circuit to a short circuit situation to acquire the features and output parameter.The following are the several types of parameter estimation:

Five Estimation and optimization of parameters using a single diode mathematical model

Estimation and optimization of seven parameters using a double diode mathematical model.

Estimation and optimization of nine parameters using a mathematical model based on three diodes.Parameter estimate comes in a variety of forms.

Renewable energy sources currently account for 33% of global electrical energy output, with this percentage predicted to rise in the future [1]. Solar photovoltaics (PVs) have been the most significant contributor among these renewable resources so far [2]. Electrical equivalent circuit models depend on current versus voltage graph of solar cells and PN junction diode has been created to learn about the physical behaviour of PV cells.

Some factors in these models must be defined in order to comprehend the behaviour of PV cells under various operating conditions. Furthermore, the PV cell manufacture method can be improved [2]. Many methods for estimating these model parameters have been offered. They are, nevertheless, divided into four groups in this work. The first group includes analytical approaches, which are mathematically based approaches. The second type of approach is iterative, which manipulates data using numerical techniques [6].

Analytical-metaheuristic, numerical-metaheuristic, and metaheuristic-metaheuristic are three examples. These are the most commonly used stochastic optimization approaches that produce more accurate outcomes in less time [7][10]. A good parameter estimate strategy is one that gives accurate results in less computing time for many datasets among all of these approaches. Because the current versus voltage curve of a PN-junction or solar cell is non-linear, as seen in Fig.1, estimating photovoltaic cell parameters is a non-linear challenge. Short circuit, open circuit, and maximum power point are the three points marked. The datasheet provided by the manufacturer contains information on these points. (Voc, 0) (0, Isc) (Vmp, Imp) Figure 1 shows a PV cell's current vs. voltage graph. in the maximum power point. The maximum voltage of monocrystalline and polycrystalline solar cells is about the same, while monocrystalline has a higher current than polycrystalline. Amorphous solar cells, too, have the highest maximum voltage and current. Conversion efficiency for mono and polycrystalline solar cell technologies increases when irradiance lowers, but conversion efficiency for amorphous solar cells declines as irradiance decreases.

A) Numerical approaches for parameter estimation

By considering datasheet information, technique useful is called analytical, whereas numerical techniques are better for experimental information. These provide a rough solution to an issue. These approaches are quick and use precise algorithms to produce results since they are iterative. Some numerical methodologies that have been utilised in the literature have been reviewed, and the complete forms of the acronyms used in the table are shown below:

B).Metaheuristic approaches for parameter estimation

Many complex engineering issues can be solved using this strategy [22-25]. If a good technique and appropriate initial states are adopted to solve the issue and goal function, accurate parameters of PV cells can be estimated[21-23]. They have the benefit of having excellent global optimal solutions. They are capable of solving non-linear functions without the use of derivatives. As a result, metaheuristic methodologies for evaluating PV cell parameters are becoming increasingly common.They have the benefit of having excellent global optimal solutions. They are capable of solving non-linear functions without the use of derivatives. As a result, metaheuristic methodologies for evaluating PV cell parameters are becoming increasingly common. A review of some metaheuristic approaches that have been employed in the literature has been conducted. Hybrid approaches for parameter estimation The fourth technique is a combination of the previous three. This can be a combination of analytical and metaheuristic techniques, numerical and metaheuristic techniques, or combination of metaheuristic methods. Two ways are combined to produce outcomes that are superior to those produced by employing a one approach to solve an issue. Two ways are combined to eliminate flaws in each other. In the literature, there are a few hybrid techniques that have been used.

C)Analytical approaches for parameter estimation

These approaches are particularly used for estimating one diode model parameters, but only at less irradiance. Because researchers are concentrating on partial shade circumstances these days, analytical methodologies are failing to generate reliable results, indicating that additional models with more components are required. As a result, other models are emerging, such as triple or more diode models, although their computations are quite difficult. In this case, a solar simulator that can deliver fast, precise, and realistic results is required. It also raises the cost of computing on computers. As a result, soft computing algorithms for estimating photovoltaic parameters become more relevant in this scenario. Due of the gradual convergence of soft computing techniques, researchers are currently focusing on hybrid approaches. Following a rigorous examination of analytical methodologies for estimating,

• Some analytical methods result in complicated transcendence equations.

• Some methods rely on ideal conditions to deliver outcomes that aren't accurate or practical.

• Some procedures necessitate the use of beginning values.

• Some approaches don't always lead to the best results.

Because metaheuristic optimization algorithms can give real-time solutions, they can be applied.

• They are straightforward and easy to implement.

• They do not necessitate differentiating data.

• They tend to gravitate toward global solutions.

• They are quick and powerful in terms of calculation.

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• They provide precise findings. The methods listed below could be used to combine two or more procedures in order to estimate solar cell properties.

• Numerical methods are used to find parameters. It creates a search space that is required for metaheuristic methods, and it remove parameters from search space. Some parameters can be calculated analytically, while others can be discovered via metaheuristic algorithms.

D).Techniques for Simulink-based Optimization

Estimating the PV system's performance is quite important. This necessitates the use of dependable, effective, and predictive instruments. These instruments must be sensitive to all of the solar cells' physical properties. The higher performance of the tools is required to optimise the PV system performance and increase the cost effectiveness of the system. When a researcher creates a mathematical model based on better performance, the behaviour should be defined by accurate modelling and simulation. As a result, simulation tools are required for the construction of the mathematical model, which will aid in the control of actual PV systems.

Among all, Sim electronics-based, Simscape-based and Simulink-based environment are there which can be used for the estimation and optimisation of the parameters of the Solar cells. And this simulation having the basic reference models such as Single diode, double diode and triple diode model. Simulations results compared with practical modelling results and the PV model manufacturer’s data sheets along with different optimization methods. According to the simulation results it is confirmed that output power generated of the PV cell affected by the temperature and the irradiance which are very important factors of the environment. [8,9,16,17].

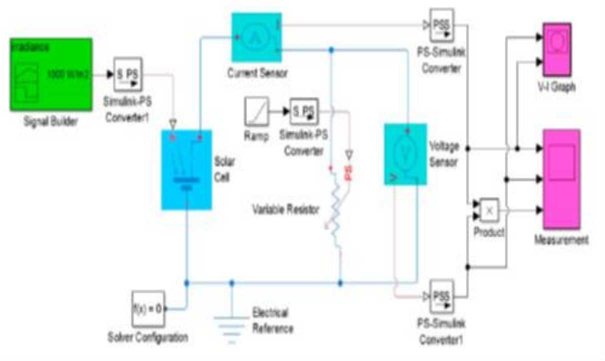

Figure 5: Simulation Model for a single Cell

On this foundation, MATLAB Simulink provides the ability to describe a wide range of devices, components, and complex systems in a variety of ways. Sim electronics-based, Simscape-based, and Simulink-based environments are among them, and they may all be used to estimate and optimise the parameters of solar cells. This simulation also includes basic reference models like single diode, double diode, and triple diode. The results of the simulations were compared to the results of actual modelling and the data sheets provided by the PV model maker, as well as other optimization strategies. According to the simulation results, the output power provided by the PV cell is affected by temperature and irradiance, both of which are critical environmental parameters. [8,9,16,17].

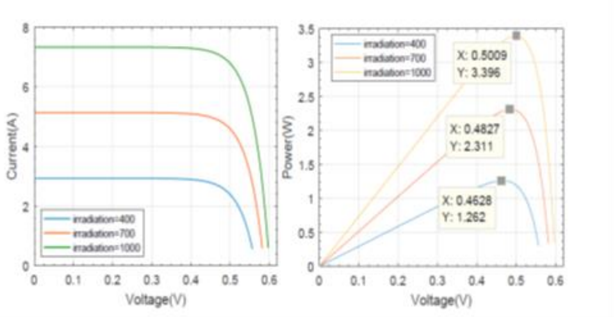

Figure 6: I-V and P-V characteristics of Single cell PV model using Sim Electronics Simulation Model

IV. Objectives and Methodology

Any Solar PV module can be built using the Single, Double, or Triple Diode types. The main objective of this modelling is to make it possible for the solar PV model to predict the I-V characteristics of the PV module. To minimise the discrepancy between expected and real I-V characteristics, we must modify the solar PV model's parameters.This can be accomplished by employing an optimization method. So, first and foremost, we must assess the research objectives.To begin, we must choose a PV model for the PV cell or Module (That is different diode model)

Estimate the parameters using the formulas provided by the model (for different diode model which has unknown parameters and graphical representation.

Compare and contrast this optimization method with another metaheuristic optimization method.We will require data sheets for the comparative analysis. As a result, collecting standard datasheets are also a goal of our research.Last but not least, the best application for the job.

V.CONCLUSION:

The multiple approaches for estimate and optimization of the PV cell characteristics using different modelling principles were reintroduced in this report. There are various analytical and non-analytical methods for optimization. Simulink mathematical formulae were also discussed, which can be utilised to depict the basic properties of the PV cell. With several references focusing on the base literature for the estimate and optimization of PV cell parameters. With all of the parameters concepts and a review of the literature, we can conclude that parameter estimation and optimization is a difficult way to find the unknown and known parameters of the PV cell and module using various analytical and non-analytical methods, but it can be done with the help of various references.

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