IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

PARAMETER ESTIMATION OF SOLAR PV MODEL

[1]AKSHAYA N, [2]AKASH S, [3]BALASUBRAMANIAN S, [4]ALEX STANLEY RAJA T

[1]B.E-Final Year Student, [2]B.E-Final Year Student, [3] B.E-Final Year Student, [4]Assistant Professor

[1]Department of Electrical and Electronics Engineering,

[1]Bannari Amman Institute of Technology, Sathyamangalam, India.

Abstract: The development of solar photovoltaic (PV) technology has made it one of the most important sources of renewable energy in the world, necessitating the use of sophisticated modeling and parameter estimate approaches. With the Single Diode Model and Newton's Raphson method, this work presents a novel method for the precise determination of electrical properties of solar PV modules. The Single Diode Model is well known for accurately describing the electrical behavior of solar PV modules in a straightforward manner. However, getting accurate parameter values is crucial for producing energy efficiently since it makes it possible to monitor the system, find faults, and do preventative maintenance. In this study, we suggest a reliable and effective approach for predicting crucial parameters, such as the ideality factor (n), reverse saturation current (Io), series resistance (Rs), and shunt resistance (Rsh), which have a substantial impact on the performance of solar PV modules. Due to its quick convergence and capacity to generate extremely precise parameter estimates, Newton's Raphson method is chosen as the iterative numerical methodology. Our created computational program uses current-voltage (I-V) curves, temperature, and irradiation parameters from the specific solar PV module under investigation as input data. Extensive simulations and actual experiments on a variety of solar PV modules are used to confirm the effectiveness of the suggested approach. The results show that it is robust in parameter estimation even in the face of data noise, changes in the environment, and ageing of the module. Precise parameter estimate is essential for improving the overall effectiveness, dependability, and longevity of solar PV installations as well as for monitoring system performance in real-time and identifying and resolving any problems. In conclusion, this research makes a substantial contribution to the development of parameter estimate methods for solar PV modelling, providing a useful tool for the renewable energy sector. The proposed methodology, which combines the Single Diode Model and Newton's Raphson method, offers a workable strategy for increasing energy production, making sure solar PV systems are dependable and sustainable, and maximising return on investment. This study has the potential to advance solar energy technology and strengthen its position as a major player in the switch to sustainable and clean energy sources.

KEYWORDS: SOLAR PV MODULE, PARAMETER ESTIMATION, SINGLE-DIODE MODEL, NEWTON'S RAPHSON METHOD, DIODE IDEALITY FACTOR, SHUNTAND SERIES RESISTANCE AND REVERSE SATURATION CURRENT.

I. INTRODUCTION

In order to properly harvest solar energy, solar photovoltaic (PV) module accuracy characterization is essential. The single-diode model serves as a cornerstone in comprehending and modelling the electrical behaviour of these modules in order to do this. A few key variables are used in this model to simplify the complicated relationship between light and materials inside a PV module: photocurrent (Iph), reverse saturation current (I0), ideality factor (n), series resistance (Rs), and parallel (shunt) resistance (Rsh). Engineers and researchers can forecast a PV module's performance under various environmental conditions thanks to these metrics, which capture the complex interplay of physical processes within a PV module. Using the Newton-Raphson approach, accurate values for these parameters are obtained. The single-diode model contains nonlinear equations that this numerical method is recognised for being able to solve iteratively. The process of parameter estimation typically starts with the gathering of experimental data, which includes measuring the current-voltage (IV) characteristics of the module under various irradiance and temperature conditions. The Newton-Raphson method, which iteratively improves initial parameter predictions until a convergence point, is built on these actual observations. The outcome is a collection of estimated parameters that closely match the PV module's real behaviour and offer priceless information about its electrical performance. Additionally, parameter estimate helps with system maintenance and monitoring. Reevaluating the PV module characteristics on a regular basis makes it feasible to quickly identify and deal with problems like degradation or damage. Given the often long operational lifetimes of solar installations, this proactive approach to maintenance can increase the longevity of PV systems and optimise their long-term performance. Furthermore, precise parameter estimate aids in the advancement of research and development within the solar sector. These criteria are used by researchers to evaluate the performance of novel materials, concepts, and technological advancements. It contributes to the overall development of renewable energy technologies by aiding in the continuous improvement of solar cell and module efficiency. It is necessary in practice to estimate the parameters of solar PV modules based on the single-diode model using the Newton-Raphson approach. In addition to supporting the innovation needed to make solar power even more accessible and effective in our search for sustainable energy sources, it serves as the foundation for the design, operation, and continuing maintenance of solar energy systems. In the end, this careful parameter estimation method is essential for maximizing the design and operation of solar energy systems, assuring the effective conversion of solar energy into electrical power.

II. FLOW DIAGRAM OF THE PROPOSED METHODOLOGY OF PARAMETER ESTIMATION

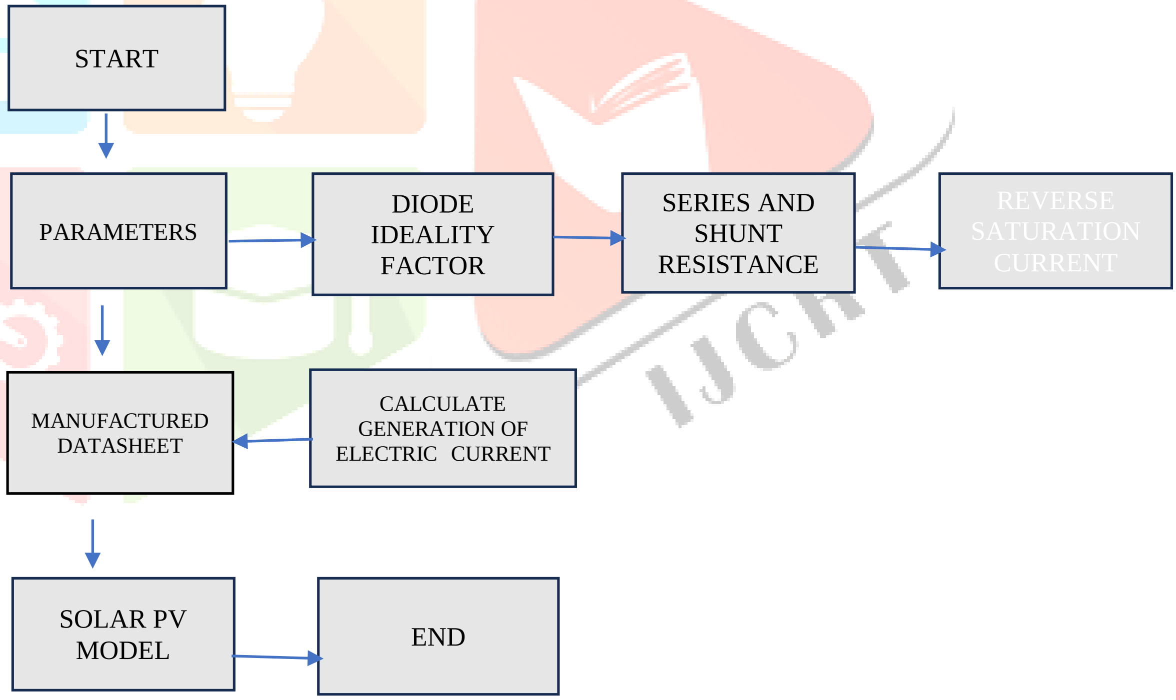


Fig. 1: Flow diagram of the proposed methodology of parameter estimation

III. PROPOSED METHODOLOGY

A crucial step in improving solar energy conversion systems' efficiency and optimising solar photovoltaic (PV) modules' performance is the accurate calculation of their electrical characteristics. The single-diode model is a well-known illustration of the electrical behaviour of a PV module and provides a thorough framework for comprehending its properties under various environmental situations. The Newton-Raphson method, recognised for its precision in resolving challenging nonlinear equations, appears as a strong numerical tool in this setting. The proposed methodology described here intends to use the Newton-Raphson method's strength to improve the estimation of important parameters in the single-diode model, offering a reliable and organised method for characterising PV modules. The first step in this process is to gather real-world data about the current-voltage (IV) properties of the solar PV module under various operating circumstances, such as varied levels of irradiance and temperature. The subsequent parameter estimation procedure is built on top of these measurements. The single-diode model's parameters are iteratively adjusted using the Newton-Raphson approach, which is renowned for its effectiveness in tackling nonlinearities, to reduce the difference between the simulated IV curve and the experimentally acquired data. This suggested methodology has implications for numerous fields related to the solar energy industry. It gives engineers, scientists, and others who build solar energy systems the ability to precisely characterise and model the electrical behaviour of PV modules, improving the accuracy of estimates of energy generation. Additionally, it supports more efficient maintenance procedures and enables early performance issue diagnosis, both of which improve the long-term dependability of solar installations. Additionally, this methodology is crucial for improving current designs and advancing upcoming materials and technologies in the context of solar technology advancement, ushering in a new era of effective and sustainable solar energy utilisation. As a result, the suggested methodology represents a crucial advancement in the effort to fully realise solar energy's promise as a clean energy source.The suggested methodology is an essential step in attaining the goals of integrating renewable energy sources and mitigating climate change. It contributes to the reliable operation of solar power plants, which strengthens grid stability and aids in the switch to renewable energy sources by increasing the accuracy of PV module parameter estimate. Additionally, policymakers, investors, and other stakeholders in the renewable energy sector will find great value in the insights obtained from this methodology as they attempt to make educated decisions about solar energy projects and investments.In conclusion, the suggested methodology embraces the intricacies of actual-world PV module operation in addition to addressing the long-standing problem of accurate parameter estimate. Its importance in the ongoing international endeavour to harvest solar power effectively and responsibly is underscored by its versatility, resilience, and capacity to stimulate breakthroughs in solar technology.

SOLAR PV MODULE:

The core of solar energy systems, solar photovoltaic (PV) modules are in charge of capturing sunlight and transforming it into power. The semiconductor materials used to make these modules, most frequently crystalline silicon, have the extraordinary ability to produce an electric current when exposed to light, a property known as the photovoltaic effect. Solar PV modules have significantly improved in efficiency and design over the years, playing a key role in the global transition to sustainable and renewable energy sources. For solar PV modules to work optimally and to accurately estimate energy generation under a variety of environmental situations, precise characterisation is essential. The single-diode model, which provides an extensive mathematical depiction of a PV module's electrical activity, forms the basis of this characterization. This is described. It is crucial to accurately estimate these factors in order to realize the maximum potential of solar PV modules. Researchers and engineers can iteratively update parameter estimates using the Newton-Raphson method until they are in agreement with the measured current-voltage (IV) characteristics of the module. These crucial parameters may be meticulously and precisely estimated because to this iterative process and the single-diode model's rigorous logic. This parameter estimate procedure is quite important in addition to theoretical modeling. It serves as the basis for planning the energy production, placing PV modules inside arrays to maximize efficiency, and creating dependable and efficient solar energy systems. Additionally, it aids in the early detection of problems such module breakage or degradation, contributing to the performance and durability of solar arrays. For regulators, investors, and stakeholders looking to make educated decisions about solar energy projects and investments, accurate parameter estimation is crucial in the broader context of renewable energy. In conclusion, solar PV modules serve as the fundamental building blocks of solar energy systems. In order to fully utilize solar energy, it is crucial to accurately characterize these modules using the single-diode model and Newton's Raphson approach. This method not only improves our comprehension of PV module behavior but also serves as the foundation for the creation of cost-effective, sustainable solar power solutions that are positioned to be a key component of the global switch to clean, renewable energy sources.

NEWTON'S RAPHSON METHOD:

For solar PV modules using the single-diode model, the Newton-Raphson method, a pillar of numerical analysis, occupies a major role in parameter estimation. The Newton-Raphson approach emerges as a crucial tool in the complex realm of photovoltaics, where the behavior of solar cells is controlled by intricate, nonlinear equations. This iterative numerical approach sets out on a path of improvement, where it systematically converges toward the precise estimation of important electrical parameters. The complex interaction of physical processes within a PV module is encapsulated by these characteristics, which also include the photocurrent (Iph), reverse saturation current (I0), ideality factor (n), series resistance (Rs), and parallel resistance (Rsh). The advantage of the Newton-Raphson approach is that it can handle the single-diode model equations' innate nonlinearity. It uses local linear approximations to update parameter estimates at each iteration, improving their precision over time. Given that solar PV modules operate in dynamic surroundings with variations in temperature and irradiance, this iterative adaptability is of utmost importance. Because of the method's flexibility, the model accurately predicts the behavior of PV modules in practice, allowing for the optimization of system performance and accurate projections of energy yield. The Newton-Raphson approach also enables scientists and engineers to thoroughly decipher the complexity of PV module features. It makes it easier to analyze how each parameter affects module behavior and provides insights that go far beyond parameter estimate. These insights allow for the creation of plans to In terms of precision and versatility in the realm of solar energy, the Newton-Raphson approach stands out. It enables researchers to comprehend PV module behavior profoundly, optimizing solar energy system design and operation. The Newton-Raphson method's accuracy and adaptability are essential for maximizing the performance of solar PV modules and promoting sustainable energy solutions as the world turns more and more to renewable energy sources.

SINGLE DIODE MODEL:

When combined with the iterative accuracy of the Newton-Raphson approach, the single-diode model, a core tenet of photovoltaic science and engineering, acquires an elevated significance in the context of parameter estimation for solar PV modules. This comprehensive model is a useful resource for comprehending and enhancing the performance of PV modules under a variety of environmental situations because it provides a nuanced and thorough description of the electrical characteristics of PV modules. The photovoltaic junction is fundamentally represented by a single diode in this model, which also takes into consideration the intricate interaction of physical processes driving solar energy conversion.A number of significant variables, including the photocurrent (Iph), reverse saturation current (I0), ideality factor (n), series resistance (Rs), and parallel (shunt) resistance (Rsh), are used to describe the electrical behavior of PV modules. . The keystone of the single-diode model, these variables provide a quantitative lens through which the complex relationships between charge carriers, light absorption, and electrical output are understood.The single-diode model is crucial in the field of parameter estimation. It offers a crucial framework for defining the behavior of PV modules, making precise predictions of energy production possible. When used in conjunction with this model, the Newton-Raphson approach sets out on a methodical quest for parameter improvement. It iteratively adjusts parameter estimations to converge with measured current-voltage (IV) characteristics while it navigates the complex terrain of nonlinear equations inherent to the electrical response of the PV module. This iterative convergence produces accurate parameter values that increase the overall modeling accuracy by ensuring that the model's predictions closely match actual observations.Additionally, the single-diode The model enables a thorough understanding of how each parameter affects the performance of PV modules. The effects of Iph on current generation, I0 on reverse leakage, n on ideality factor, Rs on series losses, and Rsh on shunt routes can all be studied in detail. Engineers may now improve module design and operational tactics, minimizing losses brought on by things like shade, soiling, and temperature changes.In the end, the single-diode model, strengthened by the Newton-Raphson method's iterative rigor, acts as a crucial link between theoretical understanding and real-world application in the field of solar energy. It contributes to the global move toward sustainable and renewable energy sources by illuminating the inner workings of PV modules as well as accelerating solar technological breakthroughs. In essence, the single-diode model is a beacon guiding us toward a future where solar power plays a central role in meeting our energy needs while minimizing environmental impact.

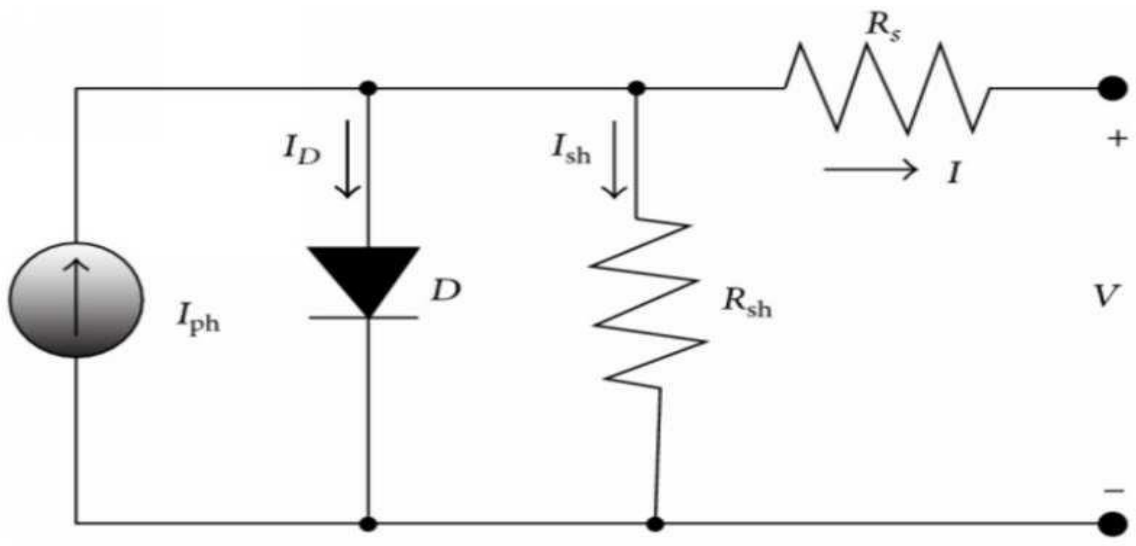


Figure2. eqivalent circuit of single diode model

PARAMETER ESTIMATION PROCEDURE:

The Newton's Raphson Method-based parameter estimate strategy for solar PV modules is a meticulously planned process for obtaining extremely accurate electrical parameter values. The first step in the process is data gathering, which involves taking measurements from the PV module in real-world settings with varying amounts of solar irradiation and temperature. These observations provide the empirical foundation for the subsequent parameter estimation, which is commonly represented by current-voltage (I-V) or power-voltage (P-V) curves. After gathering the necessary information, the process enters the initialization phase, when initial estimates are made for critical electrical parameters such the ideality factor (n), series resistance (R_s), shunt resistance (R_sh), and photocurrent (I_ph). These preliminary estimations frequently come from product specs or previous information, giving the estimation process a place to start. The core of the process is the formulation of equations based on the Single-Diode Model in a mathematical model. In order to account for differences in environmental elements like solar irradiation and temperature, these equations describe the relationship between the PV module's voltage, current, and the aforementioned parameters. The core of this process is the iterative optimization using Newton's Raphson Method. The I-V or P-V curve that the PV module should display under the given conditions is first predicted using the mathematical model and preliminary parameter estimates. The differences, known as residuals, between these forecasts and the actual measured data are then computed. The parameter estimations are then adjusted iteratively using Newton's Raphson Method, minimizing the residuals with each iteration. The parameter estimations are refined iteratively until they reach values that closely match the actual behavior of the PV module. Parameter estimate is only the beginning of the process; a key validation stage is also included. The expected performance of the PV module using the optimized parameter values is compared with additional experimental data that was not included during the parameter estimation procedure to validate the calculated parameters. This validation makes sure that the model's correctness transcends the initial dataset. In the end, this process for parameter estimation gives engineers and scientists the ability to precisely calculate parameter values for PV modules, improving the accuracy of PV system modeling and enabling the optimization of energy production and efficiency in solar PV installations.

DATA PREPARATION OF PARAMETERS:

A crucial step in the parameter estimate process for solar PV modules based on the Single-Diode Model and Newton's Raphson Method is data preparation. Beginning with the painstaking collection of empirical data from the PV module under various working conditions, such as fluctuating levels of solar irradiation and temperature, the process continues with the careful analysis of the results. Typically, the current-voltage (I-V) or power-voltage (P-V) curves in this dataset. After that, a thorough data validation procedure is used to identify anomalies, outliers, or missing values and fix them. Preprocessing procedures are used once the data has been validated. These include interpolation or extrapolation to estimate missing data points, normalization to guarantee uniform scaling across measurements, and robust treatment of outliers to prevent undue influence on parameter estimates. Additionally, depending on manufacturer specifications or prior information, initial parameter guesses for crucial electrical parameters of the PV module, such as the ideality factor (n), series resistance (R_s), shunt resistance (R_sh), and photocurrent (I_ph), are established. The basis for parameter estimation is then laid by formulating the mathematical description of the Single-Diode Model. Then, using the model and the initial parameter hypotheses, the iterative Newton's Raphson Method is used to forecast the anticipated I-V or P-V curve. The residuals—differences between these predictions and the measured data—are calculated. This approach minimizes residuals by adjusting parameter estimates iteratively until the estimates reach values that closely match the actual behavior of the PV module. Lastly, confirm the projected parameters.

MODEL IMPLEMENTATION:

The implementation of the model for parameter estimation of solar PV modules based on the Single-Diode Model using Newton's Raphson Method is a step-by-step process that involves integrating the mathematical model into a computational environment. Firstly, the mathematical equations representing the Single-Diode Model are incorporated into a suitable software platform, such as MATLAB or Python, enabling efficient numerical analysis. These equations encapsulate the relationships between the PV module's voltage, current, and critical electrical parameters (ideality factor, series resistance, shunt resistance, and photocurrent), as well as environmental factors like solar irradiance and temperature. The measured data gathered during the data preparation step, which commonly consists of current-voltage (I-V) or power-voltage (P-V) curves taken under various environmental circumstances, is then entered into the computational environment once the mathematical model has been integrated. The empirical basis for parameter estimate is provided by this data. The iterative optimization method is at the heart of the model implementation. The software forecasts the anticipated I-V or P-V curves that the PV module should display under the specified conditions using the integrated model and the initial parameter assumptions. The actual measured data is then contrasted with these projections. Calculated residuals are the variations between the expected and measured values. The Newton's Raphson Method is applied iteratively to continuously change the parameter estimates while minimizing these residuals throughout each iteration. The parameter estimates are refined iteratively until they reach values that closely resemble the PV module's real behavior. In the end, the model's implementation allows for accurate parameter estimation, improving the PV system model's accuracy and facilitating efficient performance.

EXECUTION OF NEWTON'S RAPHSON METHOD:

A crucial procedure that achieves precision in parameter estimations is the implementation and application of Newton's Raphson Method for parameter estimation of solar PV modules based on the Single-Diode Model. Initial guesses are made for important electrical parameters such the ideality factor (n), series resistance (R_s), shunt resistance (R_sh), and photocurrent (I_ph) during the parameter initialization phase of the process. These educated assumptions, which are frequently based on manufacturer standards or general knowledge, serve as the basis for the estimation process. The Single-Diode Model's mathematical representation, which captures the connections between the voltage, current, and the aforementioned characteristics of the PV module, is then integrated into a computer environment. The success of numerical analysis depends on this stage. To calculate expected I-V or P-V curves under particular environmental variables, such as varying amounts of solar irradiation and temperature, model equations are defined within the software platform. Iterative optimization is at the heart of how the Newton's Raphson Method is implemented. The software starts the iterative process after integrating and initializing the model. Using the preliminary parameter hypotheses, it predicts the anticipated I-V or P-V curve and contrasts its predictions with the actual measured data gathered during the data preparation stage. Calculated residuals are the differences between the expected and measured values. To reduce these residuals, the approach then iteratively adjusts the parameter estimations. The parameter values are improved with each cycle, getting them closer to the PV module's actual functionality. The parameter estimations are refined iteratively until they converge, signifying that they are very near to the PV module's actual performance. In order to decide when the operation should stop, convergence criteria, such as a predetermined tolerance level, are often set. The final estimated parameter values give a very precise description of how the PV module will behave electrically under various operating circumstances. In conclusion, Newton's Raphson Method implementation and execution for parameter estimation in solar PV modules provide a systematic approach to fine-tune parameter values, resulting in accurate modeling and simulation capabilities for planning and improving solar PV systems. The electrical characteristics of the PV module are correctly captured thanks to this iterative process, which also improves the efficiency and performance predictability of solar energy installations.

MATHEMATICAL MODEL DEVELOPMENT:

A fundamental numerical method for approximating equation solutions iteratively, particularly for equations having nonlinear interactions, is Newton's Raphson algorithm. Due to its capacity to quickly converge towards extremely precise parameter values, this method is of utmost significance in the context of solar PV parameter estimates based on the Single-Diode Model. The key feature of the approach is its iterative process, which uses the tangent line to the equation's curve to improve an initial guess for the parameter values. The ideality factor, series resistance, shunt resistance, and photocurrent are only a few of the parameters that are initially estimated. The equation is then evaluated using these estimates, the slope (derivative) of the equation at that location is determined, and the estimate is modified in light of this information. Until the estimate closely resembles the actual equation's root or surpasses a predetermined tolerance limit, this iterative process is continued. Newton's Raphson algorithm is an excellent tool for improving the accuracy of PV module modeling and simulation, ultimately leading to better solar PV system design and performance prediction. It is effective in quickly converging to exact parameter values.

ADVANTAGES:

High Accuracy: The Newton's Raphson Method is renowned for its ability to quickly converge to extremely precise solutions. This accuracy is essential for accurately predicting the values of important electrical characteristics including the ideality factor, series resistance, shunt resistance, and photocurrent. As a result, the output of the model closely

resembles empirical data. The Single-Diode Model and Newton's Raphson Method can be used to analyze a variety of PV module types and combinations. It is a useful tool for solar energy research and system design because of its adaptability, which enables parameter estimation across diverse technologies and manufacturers. Efficiency: When compared to manual or trial-and-error procedures, the Newton's Raphson Method's iterative structure makes parameter determination relatively speedy. The design of PV systems can be optimized and problems in existing installations can be resolved more easily because to its efficiency. Reduced Reliance on Manufacturer Information Newton's Raphson Method lessens the reliance on manufacturer-provided data, even though initial parameter assumptions may be based on manufacturer standards. When working with older or customized PV modules, where precise specifications might not be accessible, this is especially helpful. Robustness: By minimizing the impact of outliers or noise in the measured data, the iterative optimization process increases robustness. By gradually adjusting parameter values, it improves the resilience of parameter estimation and makes sure that the results are accurate even when there are data uncertainties. Model Validation: Ongoing model validation is possible thanks to the iterative structure of the process. The parameter estimations will continue to be correct as the PV module matures or runs under changing conditions since engineers and researchers may regularly compare the model's predictions with fresh data. Engineers may design solar PV systems that maximize energy production and efficiency by using accurate parameter estimates. As a result, the system's performance is boosted, its return on investment is increased, and its lifetime operating expenses are decreased. Research and Development: The accurate parameter estimates made possible by Newton's Raphson Method are crucial to these endeavors. These estimations can be used by researchers to investigate cutting-edge technologies, enhance PV module designs, and evaluate the performance effects of various combinations and materials. For parameter estimation in solar PV modules based on the single-diode model, Newton's Raphson Method offers a number of benefits, including high precision and efficiency as well as applicability across different PV technologies. Due to these benefits, it is a crucial instrument in the design, improvement, and study of solar energy systems.

LIMITATIONS:

Sensitivity to Convergence: The effectiveness of Newton's Raphson Method significantly depends on accurate initial parameter estimations. Convergence may be sluggish or the procedure may completely fail to converge in situations where initial estimates are greatly off from the real values. Accurate first estimates might be difficult to get, particularly for complicated or unusual PV module designs. Data Quality and Noise: The approach depends on the accuracy of the incoming data. Unreliable parameter estimates might result from noisy or imprecise measurements. Even if preprocessing and data validation are crucial, measurement errors may still have an influence. Model Complexity: Despite being thorough, the Single-Diode Model nevertheless simplifies the intricate physical processes taking place inside a PV module. Parameter estimations may not accurately reflect real-world behavior if the model assumptions are violated due to temperature gradients, uneven shading, or non-ideal behavior. Local Minima: If the parameter space is complex or non-convex, the iterative nature of the approach may cause local minima to be reached rather than the global minimum. As a result, parameter estimates may not be accurate or have any real physical significance. Computing Power: The Newton's Raphson Method for parameter estimation can be computationally demanding, especially when working with big datasets or when maximizing numerous parameters at once. It might take a lot of time and computing power to accomplish. Limited Range of Parameters: The main goal of the method is to estimate the vital electrical properties of the PV module. While these characteristics are crucial for simulating electrical behavior, they do not account for all the variables that affect how well PV modules function, such as spectrum changes, soiling effects, or degradation mechanisms. Validation Data: Having additional validation data that wasn't used during the estimation phase is crucial for ensuring the accuracy of parameter estimates. Such data might not always be accessible and can be difficult to obtain. Variability in the environment: The Single-Diode Model presumes that variables in the environment, like as temperature and irradiance, are constant throughout the module. The model does not fully take into account the geographical and temporal fluctuations that PV modules can actually encounter in these circumstances. Interpretability of Parameters: Although the approach yields parameter estimations, deciphering their physical significance, particularly for non-specialists, can be challenging. Expertise in the area is necessary to comprehend how parameter values affect PV module performance. In conclusion, Newton's Raphson Method has some drawbacks while being a useful tool for parameter estimation in solar PV modules. These drawbacks highlight how crucial it is to use this approach carefully, validate the model, and take into account the intricacies of the real world.

IV. RESULTS AND DISCUSSION

With the help of MATLAB/SIMULINK, the proposed methodology of parameter estimation of solar pv module is emulated. The parameters estimation is done based on a single-diode model using Newton Raphson's method. The main goal is to estimate the parameters using diode ideality factor, series and shunt resistance, and reverse saturation current for the accurate measurement of electric current generated in different environmental conditions. Matlab/Simulink simulation atmosphere, Which enables you to assess the system's efficiency, validate control algorithm.. The digram for the parameter estimation is given.

INPUT:

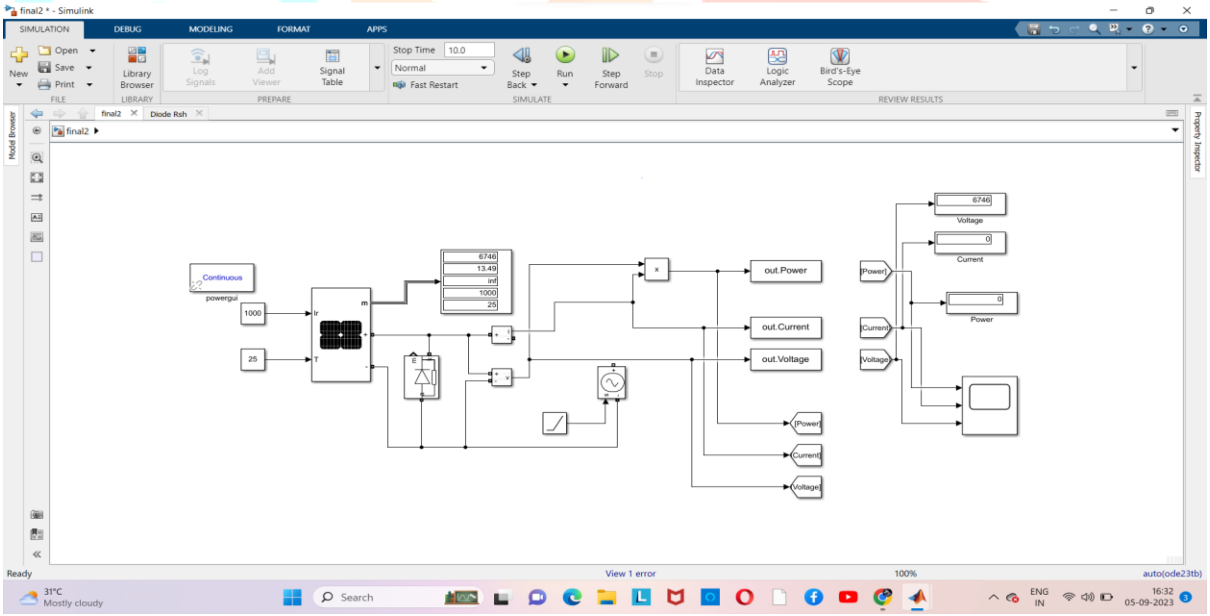


Fig. 3: Circuit model of PARAMETER ESTIMATION OF SOLAR PV MODEL

MATLAB CODE:

```
% Load your experimental data into MATLAB
% Example data: Voltage (V) and Current (I)
V = [0.7, 0.8, 0.9, 1.0, 1.1, 1.2]; % Replace with your voltage data
I = [0.1, 0.3, 0.5, 0.7, 0.9, 1.1]; % Replace with your current data

% Initial guess for the parameters
n_guess = 1.2;  % Diode ideality factor (n)
Rsh_guess = 1000; % Shunt resistance (Rsh) in ohms
Rs_guess = 0.1;   % Series resistance (Rs) in ohms
Io_guess = 1e-9;  % Reverse saturation current (Io) in amperes
```

```
% Define a function that calculates the residual (difference between model and data)
model = @(params, V) params(4) * (exp(params(1) * (V + params(3))) - 1) - (V + params(3)) / params(2);
residual = @(params) model(params, V) - I;

% Use Newton's Raphson method to estimate the parameters
params_guess = [n_guess, Rsh_guess, Rs_guess, Io_guess];
options = optimset('Display', 'iter', 'TolFun', 1e-6, 'TolX', 1e-6);
params_estimate = fsolve(residual, params_guess, options);

% Extract the estimated parameters
n_estimated = params_estimate(1);
Rsh_estimated = params_estimate(2);
Rs_estimated = params_estimate(3);
Io_estimated = params_estimate(4);

% Display the estimated parameters
fprintf('Estimated Parameters:\n');
fprintf('Diode Ideality Factor (n): %.4f\n', n_estimated);
fprintf('Shunt Resistance (Rsh): %.4f ohms\n', Rsh_estimated);
fprintf('Series Resistance (Rs): %.4f ohms\n', Rs_estimated);
fprintf('Reverse Saturation Current (Io): %.4e A\n', Io_estimated);

% Plot the experimental data and fitted model
V_model = linspace(min(V), max(V), 100); % Voltage range for the model
I_model = params_estimate(4) * (exp(params_estimate(1) * (V_model + params_estimate(3))) - 1) -
(V_model + params_estimate(3)) / params_estimate(2);

figure;
plot(V, I, 'bo', 'MarkerSize', 8); % Experimental data points
hold on;
plot(V_model, I_model, 'r-', 'LineWidth', 2); % Fitted model
xlabel('Voltage (V)');
ylabel('Current (I)');
legend('Experimental Data', 'Fitted Model');
title('Single-Diode Model Fitting');
grid on;
```

OUTPUT:

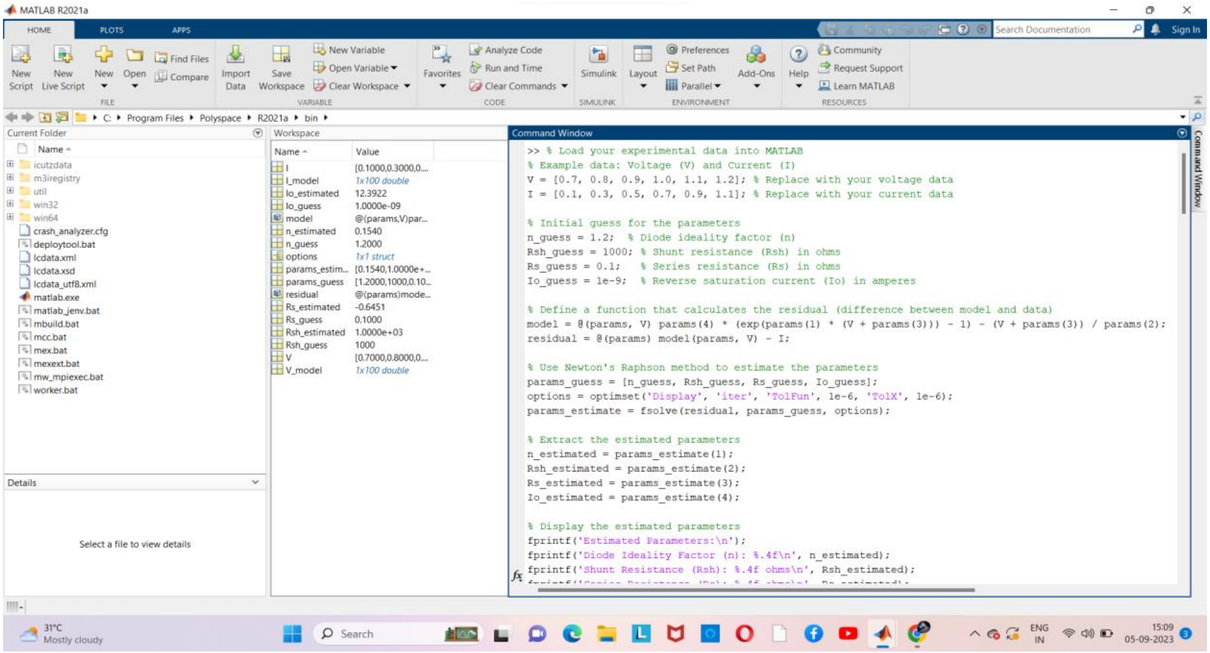
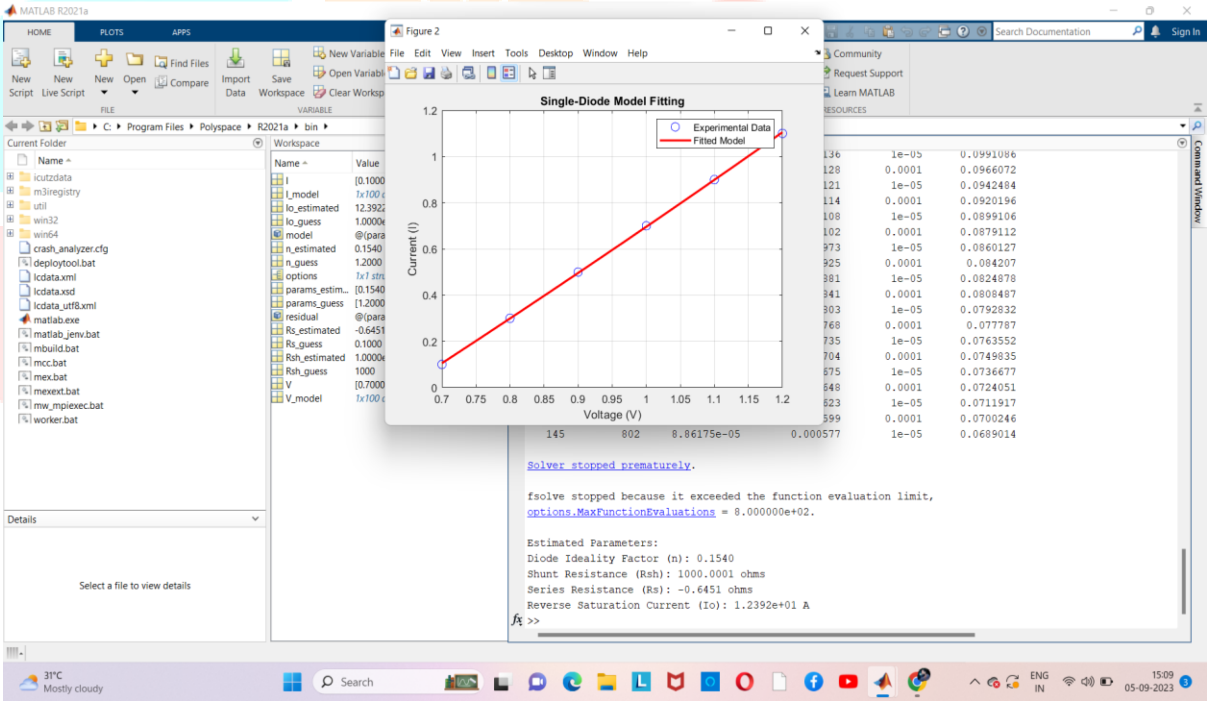


Fig. 4 Simulation output voltage waveforms of PARAMETER ESTIMATION



V. CONCLUTION

As a result, Newton's Raphson Method's parameter estimation of solar PV modules based on the Single-Diode Model is a potent and accurate method that is essential to improving the quality of PV system modeling and design. The ideality factor, series resistance, shunt resistance, and photocurrent are critical electrical parameters that must be estimated with extreme accuracy by engineers, researchers, and solar energy practitioners in order to characterize the behavior of PV modules. Parameter estimation fine-tunes starting hypotheses using the iterative optimization process of Newton's Raphson Method, producing parameter values that closely match real-world performance data. This precision makes it possible to create trustworthy PV system models, which in turn leads to improved system design, more accurate performance prediction, and effective energy production in solar systems. However, it's important to recognize the drawbacks and difficulties of this approach, including its sensitivity to educated assumptions, the quality of the data, and the inherent simplifications of the Single-Diode Model. To ensure the robustness of the parameter estimation process, these aspects call for thorough data preparation, model validation, and consideration of real-world complexities. In order to successfully harvest solar energy, parameter estimate using Newton's Raphson

Method is a useful tool. It enables scientists and engineers to fully utilize solar PV modules, fostering the expansion and sustainability of renewable energy systems across the globe. Accurate PV module parameter assessment is still crucial as solar technology develops if we are to maximize energy output, cut costs, and lessen environmental effect.

VI. ACKNOWLEDGEMENT

This is a great pleasure and immense satisfaction to express my deepest sense of gratitude and thanks to everyone who has directly or indirectly helped me in completing our paper work successfully. I express my gratitude towards guide Mr. T. ALEX STANLEY RAJA who guided and encouraged me in completing the work in scheduled time.

VII. REFERENCES

[1] Alhassan A. Teyabeen, Najeya B.Elhatmi, Akram A.Essnid, Ali E.Jwaid, “Parameter estimation of solar PV module based on single diode model”, “11th International Renewable Energy Congress [IREC2020]”.

[2] Clifford W. Hansen, “ Parameter Estimation for Single Diode Models of Photovoltaic Modules”, “SAND2015-2065 Unlimited Release Printed March 2015”

[3] "Parameter Estimation of Single-Diode Photovoltaic Models Using Machine Learning Techniques" (2021.

[4]” Parameter Estimation of a Single-Diode Photovoltaic Cell Model Using the Dragonfly Algorithm" (2018)..

[5] Clifford W. Hansen“ Parameter Estimation for Single Diode Models of Photovoltaic Modules”.

[6]"Solar Cell Device Physics" by Stephen Fonash,

[7] "Solar Photovoltaic System Applications: A Guidebook for Off-Grid Electrification" by Hemchandra Shertukde.

[8]” An Effective method for Estimating Solar Cell” published in 2021