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# 100 KW Photovoltaic Grid Connected System using MPPT and Converter

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**Abstract***:* *In recent times, renewable energy sources have gained immense popularity as an alternative to conventional electrical energy sources. This paper design MATLAB/SIMULINK to simulate a 100kW grid-connected solar PV system. Temperature and solar radiation both affect solar array properties. Due to its nonlinear nature, their power should fluctuate constantly as the weather changes. Under these circumstances, MPPT is utilized to monitor the solar array's maximum power.*

**Keywords:** Photovoltaic (PV), MPPT, Boost Converter, Inverter

## I. INTRODUCTION

[1] presented a MATLAB-based modelling approach to study the effects of partial shading on PV array characteristics. Their work highlighted the importance of accurately simulating the impact of partial shading, which can significantly affect the performance of PV. [2] evaluated different single-diode PV modelling methods. This study is essential because it helps researchers and engineers choose the most suitable model for their specific applications, considering accuracy and computational efficiency. [3] proposed a MATLAB-Simulink-based PV module model designed for conditions of nonuniform irradiance. This model allows for a more realistic representation of real-world scenarios where sunlight conditions are not constant. Such models are vital for assessing the performance and reliability of PV systems in varying environments. [4] presented a MATLAB/Simulink-based modelling approach for photovoltaic cells. Their study delves into the modelling of individual PV cells, a fundamental building block in PV system design. This research contributes to the understanding of cell-level behavior, which is critical for optimizing the performance and efficiency of PV arrays. [5] proposed a comprehensive approach to modeling and simulating photovoltaic arrays. Their work addresses the need for a holistic modelling framework for PV arrays, taking into account various parameters and dynamic factors. This research enhances the understanding of PV array behavior, allowing for more accurate predictions and better system design. In [6] research focuses on addressing the challenges of variable shading, an issue that significantly affects PV system performance. Their method, Sequential ESC, aims to enhance MPPT under such conditions, ensuring optimal energy extraction. [7] explored a popular MPPT algorithm and provided valuable insights into its simulation and practical design. Incremental Conductance is known for its accuracy and fast-tracking capabilities.[8] This study extended the application of Incremental Conductance by integrating it with hardware, emphasizing its potential in real-world PV systems. In [9] focused on the interface between PV arrays and MPPT controllers, offering insights into the hardware components necessary for efficient MPPT.[10] provided valuable information regarding battery charge controller characteristics in PV systems. [11], the scenario and data analysis is performed to carry out the main problems of adopting EVs in India. [12] This work focuses on enhancing the robustness and efficiency of PV systems, particularly when dealing with standalone applications. In[13]efficient power conversion and management strategies in standalone PV systems [14], and the modelling and dynamic interaction of EV with distribution grid systems are studied. [15] deals with the maximum use of PV energy source and reduces the dependability on grid.

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## II. DESIGN AND MODELING OF SYSTEM

Modelling of solar photovoltaic system

A solar cell is represented by an equivalent model of the current source, diode, series resistance, and load. Several P-N junctions are fabricated in a thin semiconductor wafer and being exposed to sunlight, these P- N junctions absorb photons with a higher energy than the band-gap of the semiconductor and produce electron-hole pair. With an external load connected to the PV panel, a direct current (also known as Photocurrent) flows through it to balance out the number of holes and electrons in the semiconductor. An equivalent circuit for a PV solar cell can be presented with a constant current source, a P-N junction diode, a series, and a shunt resistor.

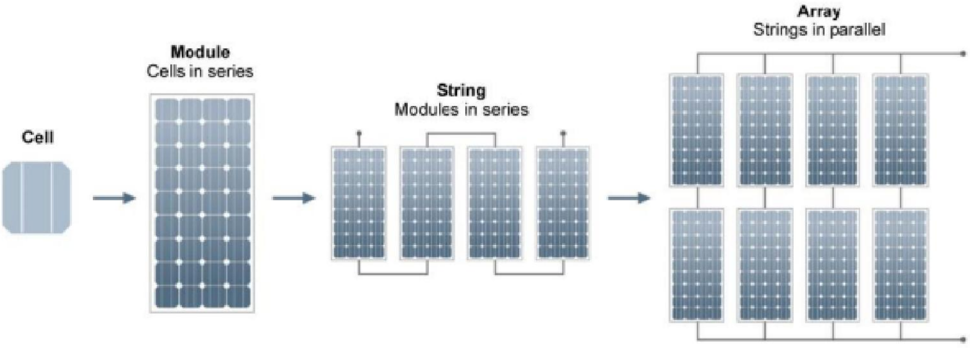

Fig. 1 Electrical configurations of solar cells

$$I = I_{PV} - I_O\left[\exp\left(\frac{V+IR_S}{aV_T}\right)-1\right]-\left(\frac{V+IR_S}{R_P}\right) \tag{1}$$

$$V_{OC} = \eta \cdot V_T \cdot \ln\left(\frac{I_f}{I_0}+1\right);\ V_T = \frac{K \cdot T_{cell}}{q} \tag{2}$$

The open-circuit voltage, generally denoted as $V_{OC}$.

**Boost Converter**

DC-DC converters are versatile electrical circuits that can adjust voltage levels in DC systems. They can step up (boost), step down (buck), or perform both functions (buck-boost) as needed. One of the most critical factors that permits voltage management is the duty ratio, which regulates the converter's on-off time of a switch

Boost Converter: This kind is appropriate for circumstances when you need to step up the voltage, like charging batteries, because it raises the output voltage level relative to the input voltage.

**Maximum Power Point Tracking**

MPPT is an algorithm that forces the point of operation of the panel to be at the MPP. The perturb&Observe algorithm, which is the most used MPPT algorithm, uses a simple feedback arrangement and a few measured parameters (specifically V and I of the PV panel)

## III. RESULT AND DISCUSSION

A 100-kilowatt photovoltaic system is connected to the 25-kilovolt grid through a 3-phase, 3-level VSC and a boost converter. The MPP controller in this setup is based on the P&O algorithm. When the solar array is exposed to 1000 watts per square meter of solar radiation, it can generate up to 100 kilowatts of power. The voltage generated by the solar array increases from 5 kHz to reach the boost converter, which then converts the DC voltage from the PV (initially at 273 volts DC at Pm) to 500 volts DC. Through the P&O approach, the MPPT controller adjusts the switching duty cycle to ensure the extraction of the maximum possible electrical energy from the photovoltaic system. The MPPT system adjusts the duty cycle to meet the required voltage for the 1980 Hz 3-phase, 3-level VSC. This VSC maintains a unity power factor while converting the 500-volt DC input voltage to 260-volt AC output voltage. The VSC control system employs two control loops: an inner loop that regulates the P and Q current components, also known as grid $I_q$ and $I_d$ currents, and an outer control loop that adjusts the DC link voltage within a range of plus or minus 250 volts.

The output of the external DC voltage controller determines the reference current for Id. To maintain a unity power factor, this sets the reference current for Iq to zero. The voltage controller outputs, $V_d$ and $V_{q,}$ are then used to generate three modulated signals. These signals are utilized by the PWM generator with a reference to$_{\text{Uabc.}}$

TABLE -1

| | |
|---|---|
| Parallel strings | 66 |
| Series connected modules per string | 5 |
| Cells per module | 96 |
| $P_m$ (W) | 305.226 |
| $V_{oc}$(V) | 64.2 |
| $I_{sc}$ (A) | 5.96 |
| $V_{mp}$ (V) | 54.7 |
| $I_{mp}$ (A) | 5.58 |

10-kvar bank is utilized to filter out harmonics generated by the VSC. A three-phase connection transformer with a rating of 100 kVA is employed to convert between 260V and 25 KV, facilitating connection to the utility grid. The utility grid operates at a transmission level comparable to 120 KV and a 25 KV distribution feeder.

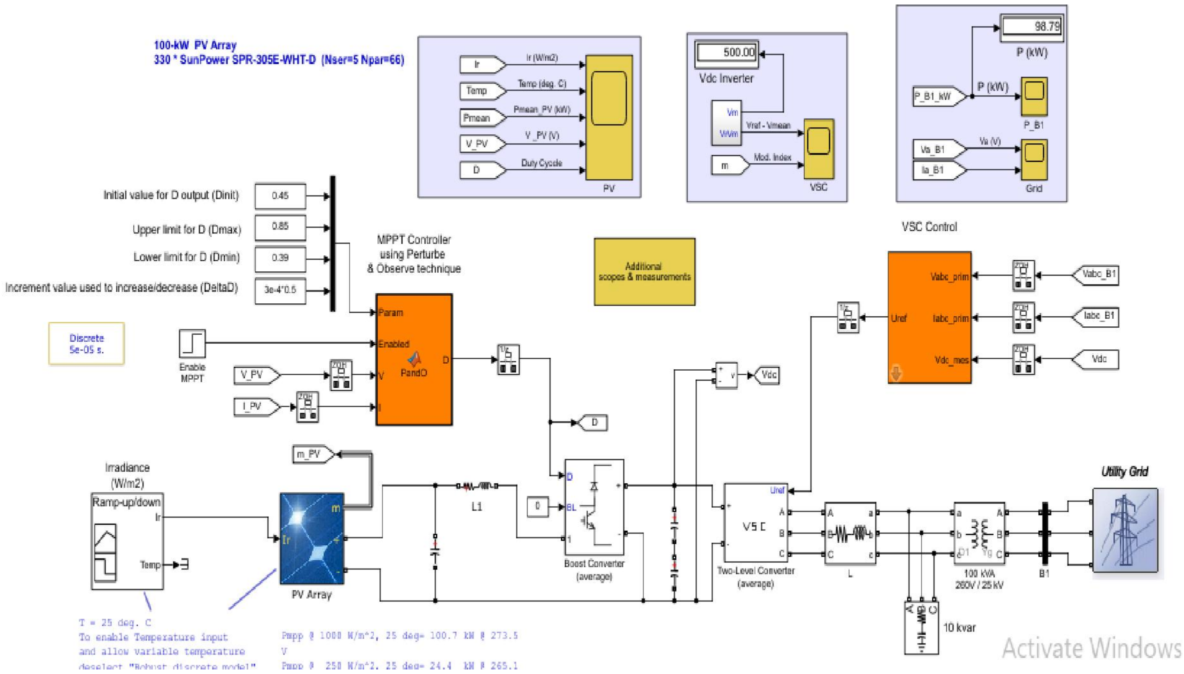

Fig. 2 Simulation model of 100 Kw PV system with grid-connected using a converter.

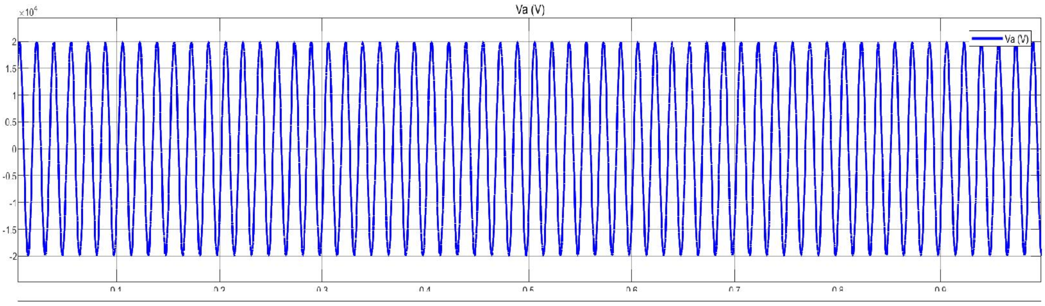

Fig.3 Grid Voltage Waveform

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The PV array consists of 330 SunPower modules, which collectively generate 100 KW of power. These modules are arranged in 66 strings, with each string comprising five series-connected modules that are connected in parallel. This configuration results in a total power output of 100.7 KW. Each individual module, according to the manufacturer's specifications, contains 96 series-connected cells and exhibits the following characteristics Voc of 64.2 volts, Isc of 5.96 amperes, and at maximum power, Imp of 5.58 amperes and Vmp of 54.7 volts

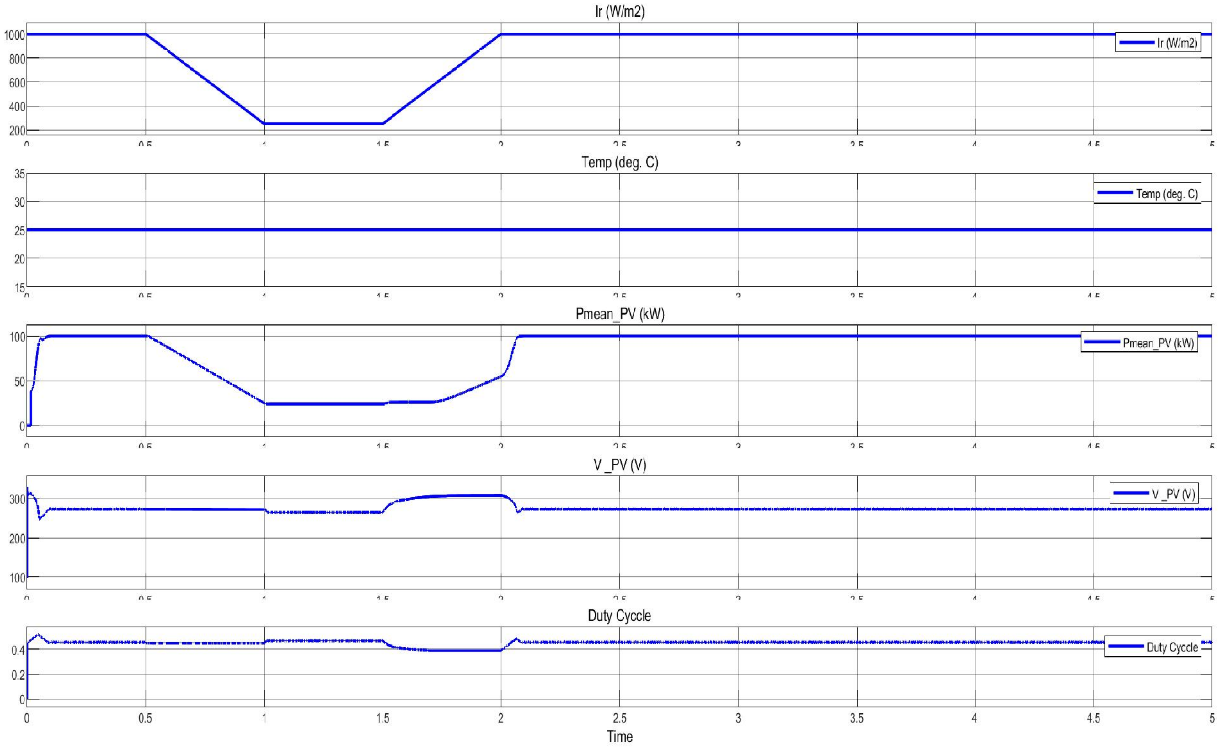

Fig. 4 PV Panel waveform (a)Irradiation (b) Temperature (c) Power (d) Panel voltage (e) Duty Cycle

The simulation begins with the use of standard test settings, where the temperature is 25 degrees Celsius, and the solar irradiance is set to 1000 watts per square meter (W/m²). Between t=0.05 seconds and t=0 seconds, the pulses sent to both the VSC and the Boost converters are halted. During this period, the PV voltage equals the open-circuit voltage, calculated as the product of the number of $N_{ser}$ and the $V_{oc,}$ resulting in a value of 321 volts. capacitor is charged 500 volts, and the three-level bridge in the system functions as a diode rectifier. At t=0.05 seconds, the VSC and Boost converters are re-activated. The regulation voltage for the DC link is set at $V_{dc}$=500 volts. The D for the boost converter is fixed at 0.5, as indicated on the PV scope. By t=0.25 seconds, the system has reached a steady state. The PV voltage (V_PV) is calculated as (1-D) times Vdc, resulting in (1-0.5)*500 = 250 volts, as observed in the $V_m$trace on the PV scope. The solar array's initial $P_0$ is 96 kilowatts, while the Pmax under 1000 W/m² irradiation conditions is 100.7 kilowatts. The voltage and current in phase A at the 25-KV bus are in phase according to the grid's scope. The MPPT system is activated at t=0.4 seconds.

To $P_{max}$, the MPPT controller initially adjusts the solar voltage by modifying the duty cycle. When the duty cycle D is set to 0.454, it results in achieving Pmax at 100.4 KW. The specifications of the solar module, calculated as the product of the number of Nser and the Vmp, indicate that the mean voltage of the PV array at t=0.6 seconds will be approximately 274 volts. Meanwhile, the solar irradiance undergoes a gradual decrease from 1000 W/m² to 250 W/m² between t=0.6 and t=1.1 seconds. Throughout this period, the MPPT system continuously tracks and maintains the Pm By t=1.2 seconds, when the irradiance has fallen to 250 W/m², the duty cycle is adjusted to D=0.461, resulting in a PV Vm=268 volts and an associated power output of Pm=24.3 kilowatts. It's worth noting the MPPT's effective tracking of the maximum power during this rapid change in illumination conditions.

To investigate the effect of temperature increase, the solar irradiance is maintained at 1000 W/m² between t=1.2 and t=2.5 seconds, after which the temperature is raised to 50 degrees Celsius. It should be noted that as the temperature increases from 25 $^{0}$C to 50 $^{0}$C , the output power of the PV array decreases from 100.7 KW to 93 KW.

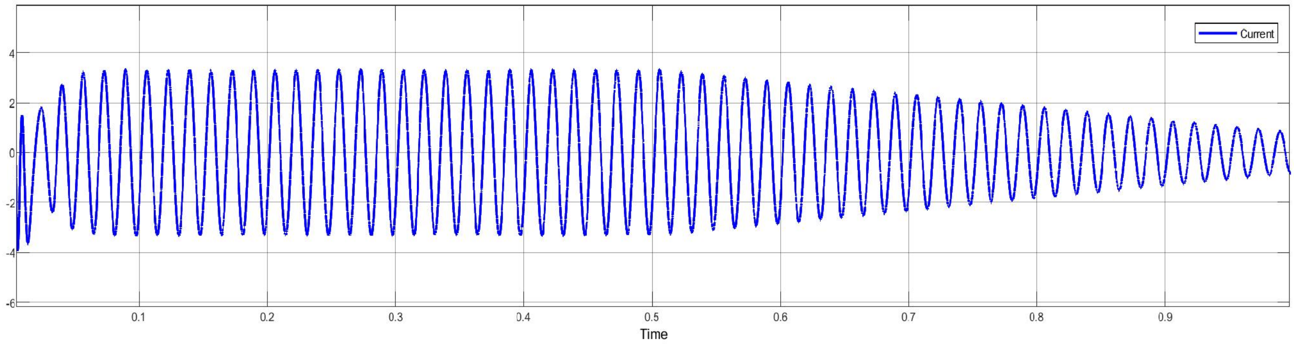

Fig.5 Grid Current Waveform

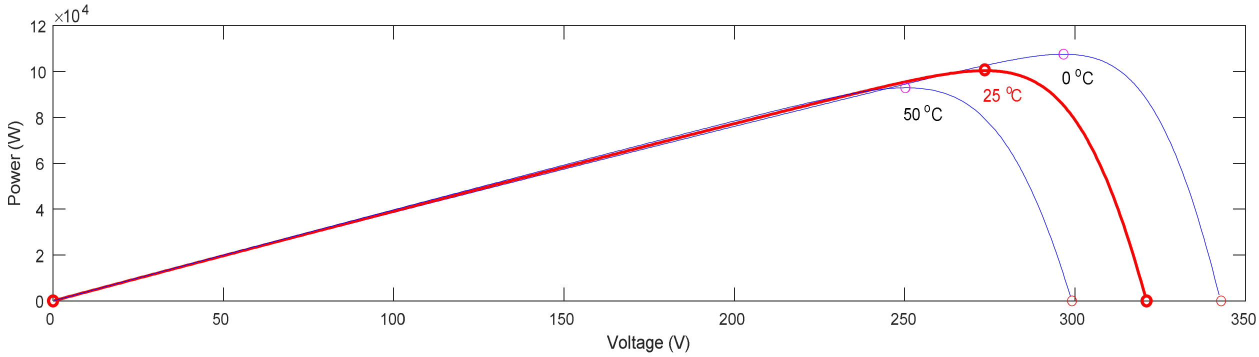

Fig. 6 P-V Array at 1000 w/m2 irradiation and different temperatures

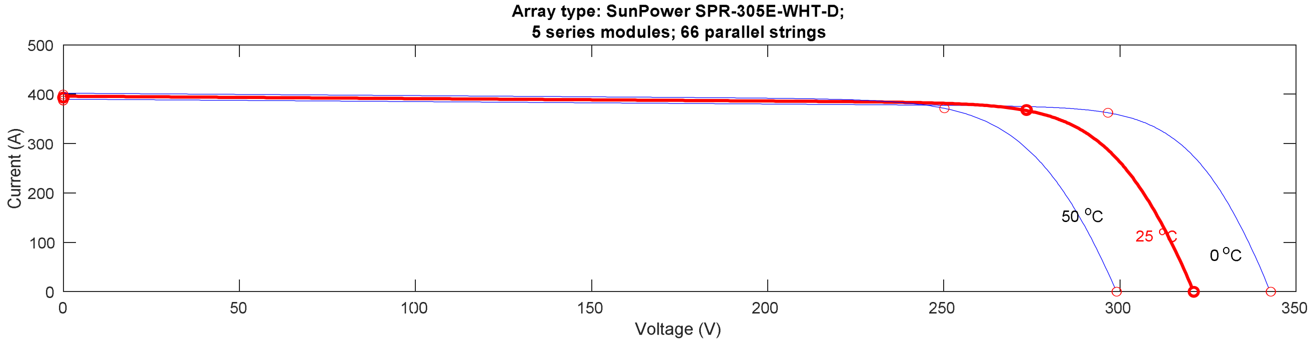

Fig. 7 V-I at 1000 w/m2 irradiation and different temperatures

## IV. CONCLUSION

We conducted a modeling and simulation study of a Photovoltaic (PV) system employing the Perturb and Observe MPPT Algorithm within a Grid Connected Photovoltaic System framework. The simulation was carried out using MATLAB/SIMULINK. We provided a concise overview of the MPPT Algorithm and executed a simulation employing the Perturb and Observe algorithm. This algorithm is employed to continuously track and extract the maximum power that can be supplied to the grid from the PV system.

We also presented the various waveforms generated during the simulation, which serve as evidence of the successful MPPT results. In comparison to a more detailed model, this simplified model offers a significant advantage in terms of speed and efficiency. Additionally, we examined the performance of two Perturb and Observe MPPT controllers under varying irradiance conditions. Notably, it becomes evident that this type of MPPT controller is most effective when irradiance levels remain relatively constant. In the project, our aim was to design an efficient and cost-effective solar PV power generation system, and we accomplished this objective using MATLAB software.

Future endeavors in this field can explore different Maximum Power Point Tracking (MPPT) methods and modified algorithms to enhance efficiency, particularly in rapidly changing environmental conditions. There's potential for designing a more compact and cost-effective model for solar PV systems, with reduced operating and maintenance expenses to make it more appealing to users. Furthermore, future work could involve designing inverters using Switched-Mode Power Supply (SMPS) circuits, building upon the insights gained from this project's implementation.

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