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# Comprehensive Design and Simulation of a 100 kW Commercial Solar PV System in India

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## Abstract

A 100 kW solar photovoltaic (PV) energy system integrated into commercially feasible buildings is the major goal of this project. The project's focus is on using solar power to generate energy, which is important since both the production and consumption of electricity are on the rise worldwide. A comprehensive engineering evaluation is carried out utilizing PV SYST software to optimize the solar energy system in order to achieve this. Components are selected based on easily available commercial options. On top of it, a model is built in MATLAB Simulink to mimic both DC and AC electrical systems. We compare the PV SYST model's performance with the MATLAB model's output. To determine what variables have the most impact on the LCOE, a comprehensive cost study of the solar power plant is conducted. Therefore, this study not only sheds light on the complex design and development of solar energy systems but also identifies possible avenues for future research to pursue in order to lower the LCOE. Rooftop PV systems that are grid-connected, inverters, and photovoltaic systems (PV Syst) are all relevant terms.

## INTRODUCTION

The Indian economy is experiencing tremendous expansion and is now at a period of unparalleled growth potential. The increased demand for energy consumption is directly proportional to the acceleration of economic development. This correlation between rising energy use and economic activity highlights the critical need for increased access to energy. India is experiencing a period of unparalleled economic prospects as its economy experiences rapid expansion. The increased demand for energy consumption is directly proportional to the acceleration of economic development. This correlation between rising energy use and economic growth emphasizes the critical need for improved energy sources immediately. Consequently, a rooftop PV system may be built to work either with or without grid connection. In a system that is linked to the grid, a power conditioning device transforms the DC energy produced by the solar PV panels into AC electricity. The AC electricity is then sent into the grid, which might be an 11 KV three-phase line or a 220V single-phase line, depending on the particular system design used in different places like business enterprises and residential complexes [9]. During the day, the grid-connected system generates energy and uses it to its full potential, meeting local needs. Contributing to the overall energy supply, any excess energy that exceeds local needs is easily sent into the grid [10]. During the monsoon season and rainy days, when solar energy output is often low, the electricity need may be supplied by pulling power from the grid. A set of rules called "net-metering" controls the installation of solar photovoltaic (PV) systems on rooftops that are linked to the power grid. The utility company receives payment from the system beneficiary according to the net meter reading. The difference between the grid-supplied energy and the extra solar power injected into the grid by the rooftop PV system is accounted for in the net reading. So, to help with efficient energy management and cost-effective use, the net-metering method makes sure that the solar power system and the grid trade electricity fairly and evenly. When it comes to making the most of the energy that rooftop PV power systems provide, net-metering is very crucial. It allows the distribution licensee's network to incorporate excess energy without any problems. Different types of rooftop PV power systems are being shaped by the introduction of solar systems that are based on net metering. Rooftop photovoltaic (PV) power systems may be defined in a variety of ways, and this dynamic approach encourages optimal use of PV electricity while simultaneously contributing to the larger energy grid.

## SYSTEM CONFIGURATION

All the parts and pieces of the proposed solar photovoltaic (PV) power system—from the panels themselves to the inverter, cables, foundation, safety features, energy storage, and distributed control systems—work together to generate electricity. A visual representation of this system architecture is provided by the diagram that follows.

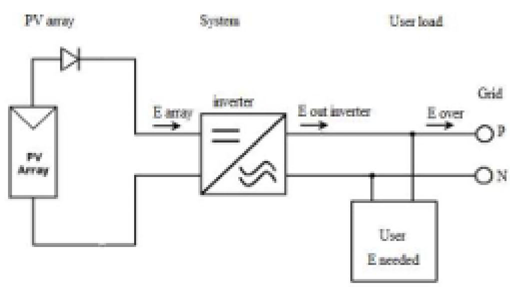


Fig 1 Block diagram of grid connected PV power system

Photovoltaic Modules The load is powered by the energy generated by PV modules, which absorb solar radiation. We feed back into the grid any excess power that isn't required to satisfy the present demand. The panels' electrical output is in the form of direct current (DC). A solar panel's power output is proportional to the intensity of the incoming light and the angle at which it hits the material. The photovoltaic modules used for this project have power ratings between 225 and 250 watts. The sixty cells that make up these modules are linked in sequence. Consumers primarily pick modules in the 225-250W range over higher-capacity choices since there are large, commercially available modules in this range. Device B: Inverting Electricity is converted from direct current (DC) by use of an inverter once it has been generated by the solar panels. The inverter's AC output is then connected to the grid at either 11KV or 440V three-phase systems, depending on the installed system and the power needs [1]. A perfect harmony between the inverter's AC power and the grid's AC voltage and frequency must be maintained. The inverter's design is crucial since it determines how near the photovoltaic (PV) system can run to its Maximum Power Point (MPP). The maximum power production (MPP) occurs when the voltage and current measurements of the solar modules are perfectly matched. C. Framework for Mounting Structures made of hot galvanized iron are recommended because they facilitate the installation of panels and modules. Throughout the mounting process, meticulous attention to panel positioning at proper degrees of tilt is required. Because of its orientation, it will soak up as much sunlight as possible and generate more power in relation to what it gets. Section D. Cable Assembly It is critical to use power and control cables that meet the system's standards when establishing connections. These cables connect the charge controller to the loads, the array to the charge controller, and the panels or modules within the array to one another. The entire load current and fault distribution level of the system must be considered while choosing the appropriate 11KV power cable size. On the other hand, while calculating power cable diameters for 440V systems, voltage loss and full load current are taken into consideration. It is critical to keep the voltage loss below 2.5% while the load is at its greatest. Derating issues must be carefully considered while deciding on the conductor size. Ambient temperature, cable grouping, and installation procedures are some of the factors that need to be considered in order to prevent cables from overheating. After that, to make sure the cable can only handle a certain amount of electricity, we reduce its carrying capacity. Grounding Devices To guarantee the safety of people and equipment, proper grounding practices must be followed. System grounding and equipment grounding are the two main grounding approaches often used with power apparatus. To prevent damage in the event of system grounding, it is recommended to connect individual circuit segments directly [1]. By creating a channel for fault currents, this method reduces risks. Equipment grounding, on the other hand, involves connecting non-current conducting metal components to the Earth. By connecting the metal parts, workplace safety is improved and people are less likely to get electric shocks in case of an accident. Covers for Connectors The capacity to withstand external variables like dust and water is essential for junction boxes used for wiring. When designing a system, it is critical to choose junction boxes with appropriate ratings. It is also important to include fuses with enough ratings to protect the solar arrays from any short circuits. III. Section A: System Design for Modules 1) Maximum Interconnected Modules: 1) Ensure that Nmax stays below the inverter's or module's maximum allowable direct current input voltage (Voc max). The following is how to find your VO2 max: Voc max = Voc + (variation in temperature x temperature coefficient of Voc) Here is the equation (1): Voc max = Voc + ((Tmax - Tstc) x

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temperature coefficient of Voc) The maximum number of modules that may be connected in series is denoted by Nmax, the open circuit voltage of the module is Voc, and the highest temperature that can be measured at the location is Tmax. Secondly, there must be at least one module in series (Nmin) that meets the following requirement: Nmin need to be bigger than or equal to Vmp min, the minimum anticipated maximum power voltage of the module, or the inverter's minimum input voltage. Here is how to determine Vmp min: Equation (2) states that the minimum value of Vmp may be calculated by adding the temperature fluctuation to the temperature coefficient of Vmp, subtracting Tstc from Vmp, and then adding Vmp to the result. Here, Nmin is the smallest number of modules that can be connected in series, Vmp is the highest power voltage, and Tmax is the highest temperature that can be measured at the location. 3) Under Standard Test Conditions (STC), the maximum number of strings in parallel (N) shouldn't be more than the product of the maximum power current and the inverter input current. Tstc stands for the temperature under Standard Test Conditions, and N is the maximum number of threads that may be connected in parallel. Fourthly, here is the formula for finding the highest possible array capacity: N times PTC, where PTC is the CEC-weighted efficiency factor times the maximum power under standard test conditions (Pmp STC), times a set module power derating factor of 0.90, should be less than or equal to the inverter power. Here, PTC denotes Power Test Condition, N is the maximum number of modules that may be connected to the inverter, and CEC is the acronym for California Energy Commission. Pmp STC stands for peak power under typical testing circumstances. Locating the Inverter (B) The solar panels are only one part of a photovoltaic system; there are many others. A common term for all of these parts is "balance of system." Inverters, which convert direct current to alternating current, are necessary components of grid-connected systems and AC loads [1]. Other necessary components include frames for firmly attaching the solar panels and protective relays. Inverters are made by combining alternating current (AC) and direct current (DC), and this section explores that process. This is accomplished by means of a grid-tied inverter, the details of which are detailed in Table 1.

Table 1 Inverter Specifications

| Making | | SMA Solar Technology AG SC 500CP XT |
|---|---|---|
| Input Data | Max PV power (kW) | 20.4 kW |
| Maz. Voc (Vdc) | | 800 V |
| MPPT range (Vdc) | | 580-800 V |
| Max. DC input current (Adc) | | 36 |
| Output Data | Max. Output power (Pac) kW | 20 kW |
| Nominal output voltage (Vac) | | 400 V |
| AC output wiring | | 3-wire w/neut |
| Max. Output current (Aac) | | 29 A |
| Maximum efficiency (%) | | 98.5 |
| Transformer (star-delta) | | 125 kVA |

C. Mounting Framework • Lay out all of the necessary tools in a suitable spot before you start the installation. Included in this are necessary replacement components, materials, tools, and reference images [1]. Tools and replacement components are sometimes not readily available in remote areas where solar power installations are completed [7]. These problems may cause expensive holdups, and they're usually caused by things like missing instructions for each part or the inability to find the replacement parts, such as cables, connecting strips, or specialized fasteners. Be very careful to follow the specified installation order. Keep the connections for the appliances, lights, solar cell modules, batteries, and lamps for last. Following the instructions will allow you to complete the joining procedure. D. Laying Out Solar Panels Roofs that are flat or have a little slope may both accommodate solar panels. These modules may be arranged in either a perpendicular or an aligned fashion with respect to the roof surface [6]. If you're in the northern hemisphere, you should orient the panels southward for optimal effects. Follow the installation instructions to a tee. You should wait until the very end to connect any appliances, lights, batteries, or solar cell modules to the controller. Pay close attention to the recommended method of final connection. See [10]. The precise position of our project may be found at these coordinates: 13.38 degrees latitude, 78.29 degrees longitude, 687 meters above sea level, and time zone 5.5. Section E: Wiring Layout and Cable Measurements When connecting electrical components of a PV system, it is crucial to choose a suitable wire or cable to minimize power loss and voltage drop. There are a lot of criteria that must be met when specifying a wire in this situation [11].

F. Estimating the Power Transfer in a 100 kilowatt Power Plant using PV Modules: Table 2: Details of

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PV Modules

| Specification | Module | String | Panel | Array (j inverte |
|---|---|---|---|---|
| P mp (w) | 249.89 | 5476.09 | 16428.27 | 82141. |
| Voc (V) | 37.2 | 855.6 | 855.6 | 855.6 |
| I sc (A) | 8.87 | 8.87 | 26.61 | 133.0 |
| Vmp (V) | 30.10 | 692.3 | 692.3 | 692.3 |
| Imp (A) | 8.30 | 8.30 | 24.9 | 124.0 |
| Po (w) | 329.964 | 7589.17 | 22769.892 | 113849 |

## INVESTIGATION OF ENGINEERING FACTORS

Investigating, sizing, and analyzing data concerning complete photovoltaic (PV) systems is made easy using PVsyst 7.4, a PC-designed software package. It includes a wide range of PV systems, including those that are grid-connected, freestanding, pumping, or DC-grid (for public transportation). In addition to conventional tools for solar energy evaluations, the program includes a database of PV system components and a large collection of meteorological data [1]. Scientists, engineers, and draftspeople will find this software bundle useful. In addition, it seems to be highly useful for educational training purposes [10]. Three distinct levels of PV system study are supplied by PVSYST V6.19, and these levels generally correlate to the various phases that a project would go through as it progresses. First, the project design phase aims to use minute-by-minute simulations to put a thorough system design into action. As part of a "project," users may simulate the system several times and compare the results. They need to determine the plane's orientation and choose out the specific system components. Users need to select the number of PV modules to link in series and parallel before they can construct the PV array. Users may get some help with this task from the program. With the correct inverter type, battery pack, and pump arrangement, this design process may be streamlined [1]. 2) Initial design: In the initial project sizing stage, a preliminary cost estimate is provided by monthly system yield assessments utilizing broad system parameters. 3) Measured data analysis: Under the operational phase of a PV system, this functionality lets you import measured data in ASCII format. Then, you can see it in tables and graphs showing real performance. You can compare it with simulated variables and find small differences or anomalies. B. Results of the PV System Using the PVSYST program, the system is designed by carefully choosing modules and inverters that are suitable for the arrangement. The outcomes of these evaluations are predicated on the findings of software simulations. The results of the simulation are then used to provide estimates of power loss. The characteristics of the module are also generated by the simulation. This class includes graphs that display the relationship between current and voltage, as well as between voltage and power. These graphs are generated using a variety of temperature and radiation parameters. The following diagrams are the results of using PVSYST to simulate the design:

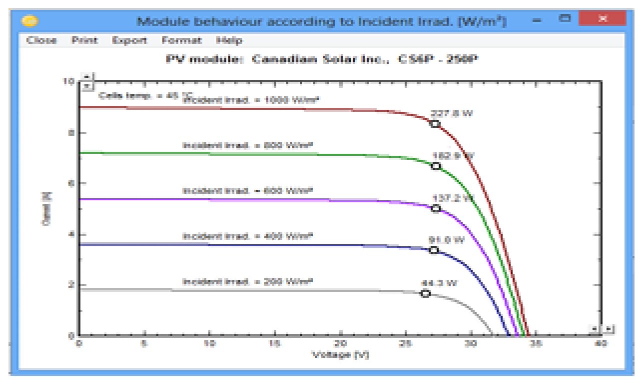


Fig.2 Voltage and current characteristics With reference to the illustrative

Figure 3 shows the complex relationship between voltage and current as a function of irradiance levels maintained at a constant temperature. This detailed analysis reveals the behavior of the solar system by revealing how these basic electrical parameters react to variations in irradiance. The graph helps to visualize this investigation by strategically showing where the ideal operating points are for each irradiance level, allowing for maximum power production. The graph provides a visual representation of the complex dynamics controlling the performance of the photovoltaic system under different irradiance situations by showing the highest power points in relation to their respective irradiance circumstances.

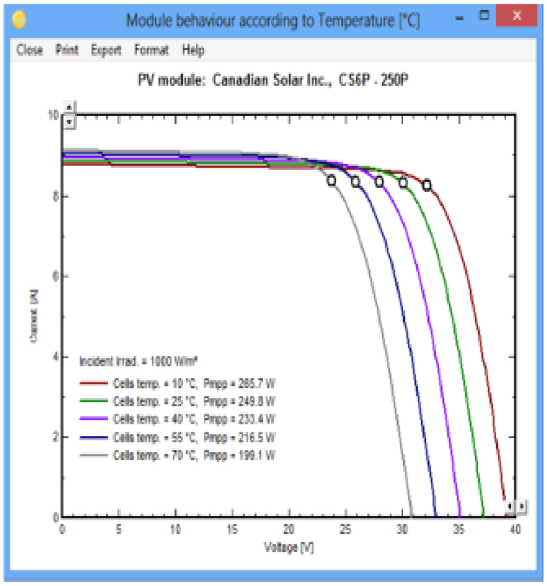


Fig. 3 Voltage and current characteristics

With respect to Figure 3, it is clear that investigating current and voltage properties is doable under conditions of constant irradiance at different temperatures. The effect of temperature changes on these electrical characteristics is the intended focus of this investigation. An important parameter in photovoltaic systems, the maximum power point (MPP) exhibits dynamic behavior as a function of temperature. The figure's graphic depiction follows this trend and shows a sequence of independent MPP values, where each value corresponds to a certain temperature circumstance. The complex connection between temperature and the photovoltaic system's ideal operating point is vividly shown in this illustration.

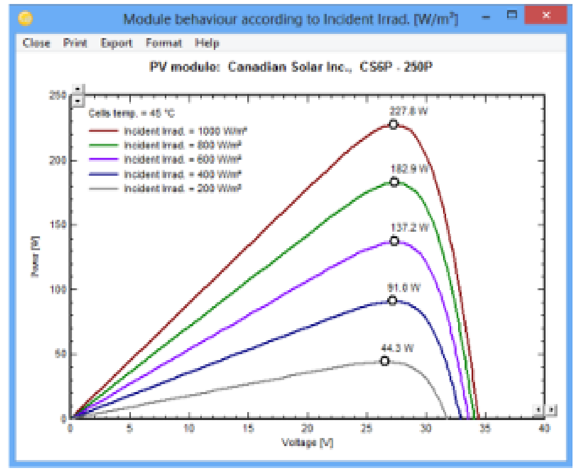


Fig.4 Voltage and power characteristics

A thorough comprehension of the behavior of voltage and power characteristics under circumstances of varying irradiance levels and constant temperature is derived from the data shown in Fig. 4. This analytical effort provides a window into the complex behavior of the main electrical characteristics of the solar system under different irradiation conditions. The noticeable trend in power fluctuation is quite important. Power has a linear relationship with voltage, rising steadily until it reaches a crucial point called the maximum power point (MPP). The power output reaches its maximum at this critical moment, indicating the system is operating at its most efficient under these circumstances. In the context of photovoltaic performance, the careful balance between voltage and power production is shown by the slow drop in power after this peak. We may better understand the fundamental principles governing the system's behavior and get a better understanding of the complex dynamics at work in its reaction to different irradiance circumstances thanks to this detailed observation from the visual depiction.

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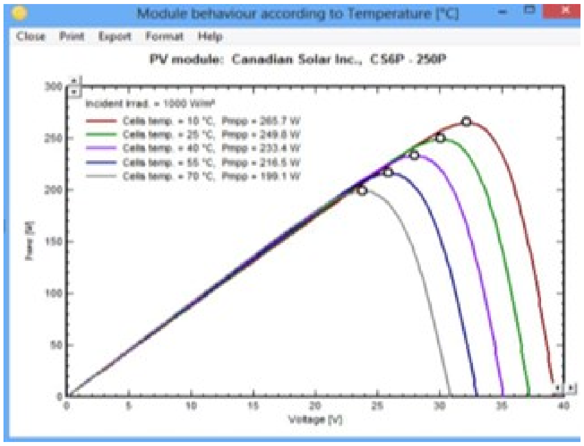
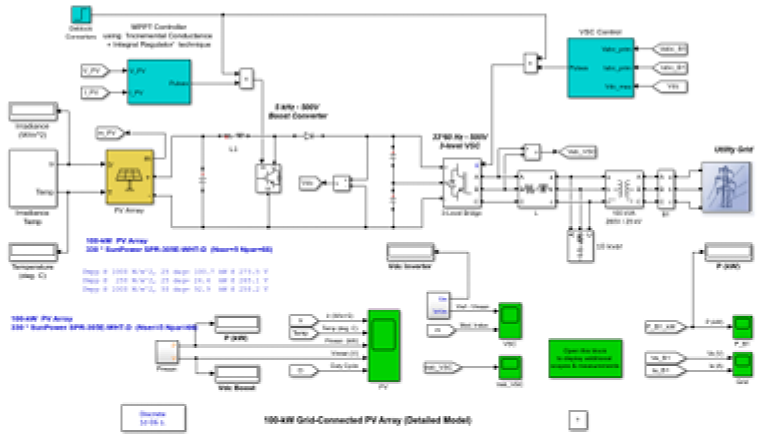



Fig. 5 Features of power and voltage

Looking at the supplied visual aid, Figure 5, we can learn a lot about the power and voltage characteristics under conditions of constant irradiance and a range of temperature variations. An interesting story about the photovoltaic system's behavior at different temperatures is revealed by this analytical effort. It is worth mentioning the noticeable pattern that power shows in respect to voltage. The power output shows an attractive linear increase when the voltage parameter passes through incremental adjustments. This pattern continues until a crucial moment, the maximum power point (MPP), when the power output reaches its peak. Now is the time when the solar system is functioning at its peak efficiency, displaying the ideal setup for the current temperature conditions. The association between voltage and power production in solar technology is subtle, but it becomes much more apparent after this peak when the power output begins a slow decline. This complex discovery, shown in the picture, deepens our understanding of the basic principles guiding the photovoltaic system's performance and enhances our understanding of how it reacts to different temperature conditions.

## ROOFTOP SOLAR PS SIMULATION USING SIMULINK

MATLAB, a popular numerical computing environment and programming language, was developed by MathWorks Inc., an innovative firm. Originating from the word "matrix laboratory," MATLAB is well-known for its many numerical processing capabilities, adaptability, and dependability. In this article, we will explore the main features that make MATLAB so useful in many different scientific, technical, and industrial domains: Reliability: MATLAB's reliability is much appreciated. A solid and well-supported platform, it has undergone refinement over decades. The reliability of MATLAB's output makes it an indispensable resource for academics, researchers, and students of all stripes. One thing that makes MATLAB stand out is how versatile it is. It finds use in many different fields, including as biology, mathematics, physics, engineering, economics, and finance. The many libraries and toolboxes that it comes with make it very adaptable to different types of applications. In MATLAB, users have the option to personalize their workspace according to their requirements. Numerical Computation: MATLAB's primary function is to facilitate numerical calculations. Its ability to accurately handle a broad variety of mathematical issues is guaranteed by its powerful collection of built-in mathematical functions. The tools provided by MATLAB are extensive and can handle both basic arithmetic and complicated numerical analysis. The Mathematical Functions Library in MATLAB is large and comprehensive. Users are spared the trouble of having to write intricate mathematical procedures from beginning since these features are already part of the program. A wide variety of mathematical and statistical routines, as well as those for processing signals and images, are included in this collection. These features may be used by engineers and researchers to simplify their work and find efficient solutions to complex challenges. Strengths in Problem-addressing: MATLAB is capable of addressing a wide variety of problems. Complex arithmetic, optimization, nonlinear systems, linear systems, differential equations, and many other specialized computations are handled very well by it. Because of these features, it has become a popular tool for solving practical issues in many different industries. The modular architecture of MATLAB makes it possible to include specific toolboxes. Specialized functionality and tools are made available in these toolboxes. An example of a toolbox might be one that caters to control systems, images, machine learning, and so on. Its versatility and problem-solving capability are further enhanced by its extensibility.



The 100 kilowatt solar photovoltaic power plant model in Simulink is shown in Figure 6.

## Conclusion

Reviewing a 100 kilowatt (KW) rooftop solar power system requires real-time data collecting, software-based design using PVSYST, theoretical calculations for component selection, and simulation with MATLAB. An all-encompassing strategy allows for a full evaluation of the system's performance, which in turn leads to the identification of design or operational improvements that improve energy production and efficiency. The ability to feed back surplus energy is a crucial feature that guarantees proper functioning of the system and maximizes energy consumption. The MATLAB Simulink model provides a more comprehensive examination of the system's behavior in different conditions, while the PVSYST application handles system design, performance forecasts, and energy yield assessment.

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