

Analysis of Solar Photovoltaic System Shading

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Abstract:

Solar photovoltaic (PV) systems provide clean energy but are highly affected by shading. This study analyzes how shading from trees, buildings, dust, or clouds reduces system efficiency and power output. It focuses on the impact of partial shading on I-V and P-V characteristics, where multiple power peaks make maximum power point tracking (MPPT) difficult. Shading can also cause hot spots, leading to potential damage of PV modules. The use of bypass and blocking diodes, along with proper system design and panel placement, helps reduce these effects. This work highlights practical methods to improve the performance and reliability of PV systems under shading conditions.

Index Terms - Solar PV, Shading Effect, Power Loss, MPPT, Bypass Diodes, Renewable

Introduction:

Solar photovoltaic (PV) systems are widely used to generate clean and renewable energy from sunlight. Due to increasing energy demand and environmental concerns, they are commonly used in residential, commercial, and industrial applications. The performance of PV systems mainly depends on the availability of uniform solar irradiance.

Shading is one of the major factors that negatively affects PV system performance. It occurs when obstacles such as trees, buildings, poles, dust, or clouds block sunlight from reaching the panels. Since solar cells are connected in series, even a small amount of shading on a single cell can reduce the output of the entire panel. This creates mismatch losses and limits the overall current flow.

Shading also affects the electrical characteristics of PV systems. Under normal conditions, the I-V and P-V curves show a single peak. However, under partial shading, multiple peaks appear in the P-V curve, making it difficult for Maximum Power Point Tracking (MPPT) to identify the correct operating point. This reduces the overall efficiency of the system.

Another important issue caused by shading is hot spot formation. Shaded cells may operate in reverse bias and generate heat instead of electricity, which can damage the panel and reduce its lifespan. To overcome these problems, bypass diodes and blocking diodes are used to minimize power loss and protect the system.

Proper system design, including optimal panel placement, orientation, and use of advanced technologies like microinverters, helps reduce shading effects and improve the efficiency and reliability of solar PV systems.

System Design:

A. Hardware Components

The hardware components of a solar photovoltaic (PV) shading analysis system include solar PV panels that convert sunlight into electrical energy. Bypass diodes are used to reduce power loss and prevent hot spots during shading conditions. Sensors measure important parameters such as voltage, current, solar irradiance, and temperature for system monitoring. An MPPT controller ensures maximum power extraction from the PV panels, while a DC-DC converter regulates the voltage levels. An inverter converts DC power into AC power for practical use. A battery may be included for energy storage, and the load utilizes the generated electricity.

B. Software Requirements

The software requirements for a solar photovoltaic (PV) shading analysis system include tools for modeling, simulation, control, and performance analysis. Software such as MATLAB/Simulink is commonly used to design and simulate the PV system under different shading conditions. MPPT algorithms like Perturb and Observe and Incremental Conductance are implemented to track the maximum power point efficiently. Monitoring software is required to display real-time parameters such as voltage, current, and power. Additionally, data analysis tools are used to evaluate system performance, compare results under various shading scenarios, and improve overall efficiency.

Working Principle:

When sunlight falls on the solar PV array, the panels convert solar energy into direct current (DC) electrical energy. Under normal conditions, all cells receive uniform sunlight and generate maximum power. However, when shading occurs, some cells receive less sunlight and produce lower current, which reduces the overall output of the system due to series connection.

To minimize this effect, bypass diodes are used. These diodes allow current to bypass the shaded cells, reducing power loss and preventing the formation of hot spots. Sensors are used to continuously monitor important parameters such as voltage, current, temperature, and solar irradiance.

The Maximum Power Point Tracking (MPPT) controller plays a key role by adjusting the operating point of the system to ensure maximum power extraction, even under shading conditions. The DC-DC converter regulates and stabilizes the voltage from the PV array. Finally, the inverter converts the DC power into AC power, which is supplied to the load or fed into the electrical grid.

Circuit Description:

The circuit of the solar photovoltaic (PV) system consists of a PV array, bypass diodes, sensors, MPPT controller, DC-DC converter, inverter, and load. The PV array is formed by connecting multiple solar cells in series and parallel to generate the required voltage and current. When sunlight falls on the panels, DC electrical energy is produced.

Bypass diodes are connected across individual cells or modules to protect the system during shading conditions. When a cell is shaded, the diode provides an alternate path for current flow, reducing power loss and preventing hot spot formation.

Sensors are included in the circuit to measure important parameters such as voltage, current, temperature, and solar irradiance. These signals are sent to the MPPT controller, which continuously adjusts the operating point to extract maximum power from the PV system.

The DC-DC converter regulates and stabilizes the output voltage from the PV array, ensuring efficient power transfer. The regulated DC power is then fed to an inverter, which converts it into AC power suitable for household loads or grid supply.

Finally, the load utilizes the generated electrical energy. The overall circuit is designed to maintain efficient operation and reduce the negative effects of shading on system performance.

Advantages:

The analysis of shading in solar photovoltaic (PV) systems offers several advantages by helping to understand how shading affects power generation and system efficiency. It assists in reducing power losses and preventing hot spot formation, which can damage solar panels. Proper shading analysis also improves system design, enhances the

performance of Maximum Power Point Tracking (MPPT), and increases the overall reliability and lifespan of the PV system.

Applications:

Shading analysis in solar PV systems is used to improve the design and efficiency of solar power plants and rooftop installations. It helps identify obstacles and reduce shading effects for better energy generation. It is also useful in smart grids and agricultural applications like solar water pumping. Additionally, it supports research and development to enhance PV system performance.

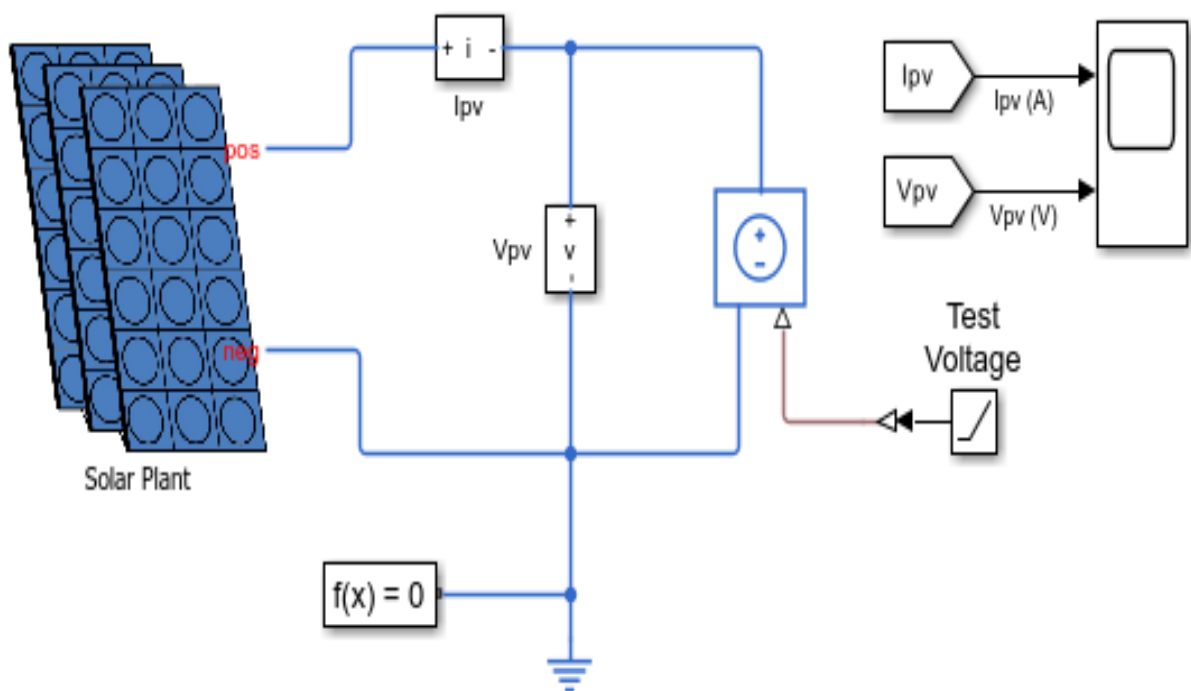
Limitations:

Solar PV systems under shading have several limitations, including high initial cost and dependence on environmental conditions like weather. Partial shading creates multiple peaks in the power curve, making MPPT complex and reducing efficiency. Proper design and regular maintenance are required to minimize shading effects. Additionally, energy storage is needed for continuous supply, and efficiency may decrease over time.

Conclusion:

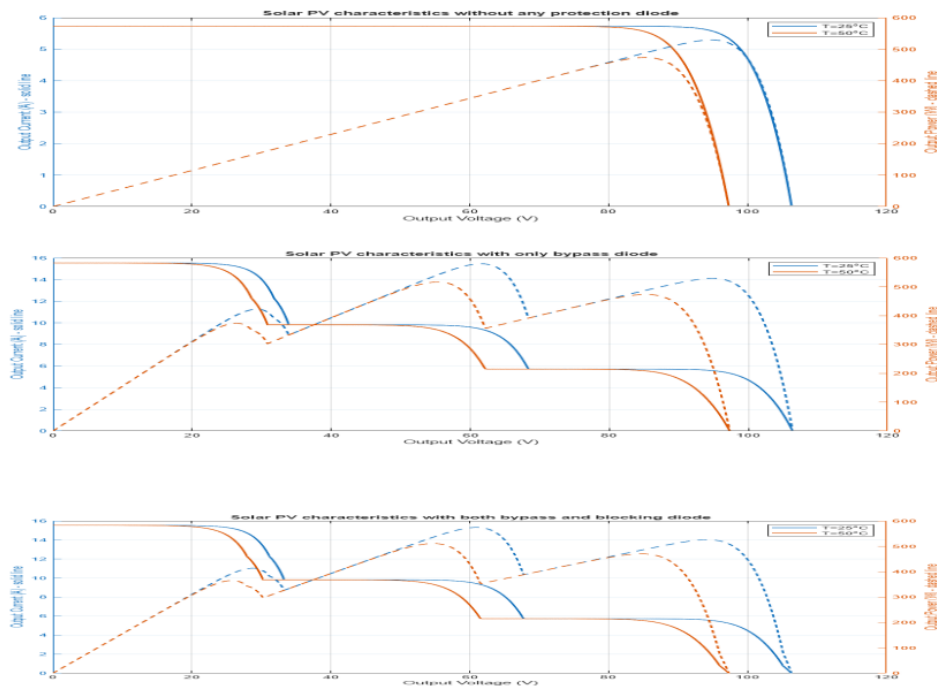
Shading significantly affects the performance of solar PV systems by reducing power output and causing issues like mismatch losses and hot spots. Proper analysis of shading is important to understand its impact on system efficiency. The use of bypass diodes, MPPT techniques, and good system design helps minimize these effects. Overall, reducing shading improves efficiency, reliability, and lifespan of PV systems.

Circuit diagram:



Results:

The simulation results of the solar PV system clearly show the impact of shading on performance under no shading, uniform shading, and partial shading conditions. It was observed that shading reduces output voltage, current, and overall power. Partial shading causes multiple peaks in the P–V curve, making power tracking difficult. The study confirms that shading significantly affects both power output and the electrical characteristics of the PV system.



The performance of the solar PV system was analyzed under no shading, uniform shading, and partial shading conditions. Under no shading, the system operates at maximum efficiency with smooth I–V and P–V curves and a single peak, allowing easy MPPT tracking.

In uniform shading, all panels receive reduced sunlight equally, resulting in a decrease in power output, but the system remains stable with a single peak in the P–V curve.

Under partial shading, the system experiences significant power loss due to mismatch in current generation. The I–V curve becomes irregular, and the P–V curve shows multiple peaks, making it difficult for MPPT to track the global maximum power point. Shading may also cause hot spots if protection diodes are not used.

Overall, the results show that shading reduces efficiency, with partial shading having the most severe impact on system performance.

Conclusion:

Shading significantly reduces the performance of solar PV systems, especially under partial shading conditions. It causes power loss, mismatch issues, and difficulty in MPPT tracking. The use of bypass diodes and proper system design helps reduce these effects. Overall, minimizing shading improves efficiency, reliability, and lifespan of PV systems.

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