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Performance Enhancement of Partial Shaded Photovoltaic System With Novel Technique

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Abstract - Partial shading in photovoltaic systems indeed poses significant challenges, potentially leading to mismatch power losses and reduced overall efficiency. Addressing this issue is crucial for maximizing the performance of solar energy systems, especially as they become more prevalent in power production globally. In the context of a 4×4 Total Cross Tied (TCT) PV array with 10W panels, the impact of partial shading on the system's efficiency and power production must be thoroughly analyzed. Techniques that can effectively mitigate mismatch power losses caused by partial shading are essential for optimizing the performance of such arrays. Testing the performance of the PV array under various partial shading conditions is crucial for evaluating its effectiveness. This empirical analysis helps in understanding how different shading scenarios affect the array's output and how mitigation strategies can improve overall efficiency. Efforts to reduce Percentage Power Loss (PLL) while enhancing efficiency are essential for ensuring the economic viability and sustainability of solar energy systems. By developing and implementing effective techniques for managing partial shading, we can improve the reliability and effectiveness of photovoltaic systems, thus accelerating the transition to clean and renewable energy sources.

***Key Words*:** Solar PV, Partial Shading, Reconfiguration, Fill factor, Mismatch loss

1.INTRODUCTION

The widespread adoption of solar photovoltaic (PV) systems has revolutionized the energy sector by offering a sustainable alternative to conventional fossil fuels. With growing concerns over climate change and environmental degradation, solar PV technology has emerged as a key player in the global transition towards clean energy sources. However, despite its numerous benefits, PV systems are susceptible to partial shading, a phenomenon where certain sections of the solar array are obstructed from receiving full sunlight. This shading can occur due to various factors such as neighboring buildings, trees, or even passing clouds, leading to an uneven distribution of sunlight across the array [1],[2] are shown in fig1. Partial shading poses a significant challenge to PV systems as it can result in mismatch power losses, where shaded panels generate less power than unshaded ones, thereby reducing the overall efficiency and output of the system[3].

Addressing the issue of partial shading is crucial for maximizing the performance and reliability of solar PV systems, especially in urban environments where shading is prevalent. Traditional solutions such as bypass diodes and maximum power point tracking (MPPT) algorithms provide partial mitigation but may not fully eliminate the impact of shading-induced losses[4],[5]. As a result, there is a growing interest in advanced reconfiguration techniques that dynamically adjust the electrical connections within the PV array to minimize the effects of shading. These techniques aim to redistribute the electrical current flow in the array, effectively bypassing shaded panels or redistributing power to optimize overall system performance[6].

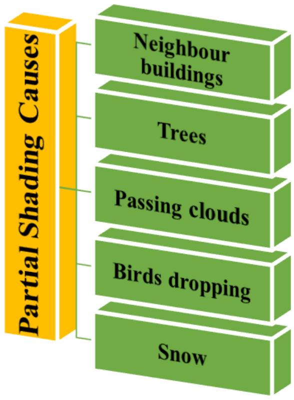

Fig -1: Partial Shading Causes

Recent advancements in reconfiguration techniques have shown promising results in mitigating the detrimental effects of partial shading on PV systems. By intelligently reconfiguring the electrical connections in real-time, these techniques can adapt to changing shading conditions and optimize power production accordingly[7]. Some approaches involve decentralized control strategies that enable individual panels or sub-arrays to autonomously adjust their connections based on local shading conditions, while others rely on centralized algorithms to coordinate reconfiguration at the system level[8],[9]. These innovative solutions offer the potential to significantly improve the efficiency and reliability of solar PV systems, making them more resilient to partial shading and enhancing their overall contribution to the renewable energy mix[10].

In this article, we will delve deeper into the challenges posed by partial shading in solar PV systems, explore the underlying mechanisms of reconfiguration techniques, and examine recent research findings and advancements in this field. By understanding the complexities of partial shading and the potential of reconfiguration strategies to mitigate its effects, we can pave the way for more robust and efficient solar PV installations, accelerating the transition towards a sustainable energy future.

2. DESCRIPTION

our primary objective is to assess the effectiveness of reconfiguration techniques in alleviating the adverse effects of partial shading on a 4×4 solar PV panel array. Initially, we meticulously develop comprehensive mathematical models of both the PV array and its surrounding environment. These models encapsulate various parameters including panel characteristics, shading patterns, solar irradiance fluctuations, and environmental factors such as nearby structures or vegetation. After rigorous validation against existing experimental data, these models serve as the foundation for simulating diverse partial shading scenarios, accurately replicating real-world conditions.

With the simulated environment established, we proceed to implement and evaluate different reconfiguration strategies within the PV array. These strategies encompass dynamic panel grouping, bypass diode control, and sophisticated voltage-based optimization algorithms, among others. By applying these techniques within the simulated environment, we aim to observe their respective impacts on mitigating mismatch losses and enhancing overall system efficiency under varying degrees of partial shading. Through extensive simulation iterations, we systematically analyze the performance of each reconfiguration approach across a range of shading conditions, enabling us to quantify their efficacy and identify the most promising strategies.

Following the simulation runs, we conduct in-depth analysis and comparison of the results to discern the relative strengths and limitations of the different reconfiguration techniques. This comparative assessment allows us to determine which approach offers the most significant improvements in power production and mismatch loss reduction. By benchmarking the performance of the proposed reconfiguration strategies against existing mitigation methods commonly employed in solar PV systems, we gain valuable insights into their potential for practical implementation and their suitability for addressing real-world challenges posed by partial shading.

3. RESULT & DISCUSSIONS

The proposed ratio is evaluated against existing configurations, namely Total Cross Tied (TCT) and Sudoku puzzle pattern, under eight distinct shading patterns. These shading patterns include Normal shading, Short and Narrow shading, Uneven Column shading, Uneven Row shading, Short and Wide shading, non-continuous shading, Corner shading, and Center shading. The performance of the proposed array configuration is assessed across these shading scenarios, allowing for a comprehensive analysis of its efficacy in mitigating mismatch losses and optimizing power output. The study is conducted using MATLAB/Simulink® software, providing a robust computational framework for simulating and analyzing the performance of the 4×4 PV array under various shading conditions. Through this comparative analysis, the study aims to provide insights into the effectiveness of the proposed reconfiguration technique in improving the resilience and efficiency of solar PV systems in the face of different shading patterns.

Table -1: Output Power Comparison

Shading Patterns	TCT	Su-Do-Ku	Proposed Ratio
Normal Shading	103	113	115
Short &Narrow Shading	116	123	123
Uneven column Shading	130	130	134
Uneven row Shading	102	131	132
Short & Wide Shading	93	79	99
Non-continuous Shading	116	123	129
Corner Shading	123	117	130
Center Shading	123	124	126

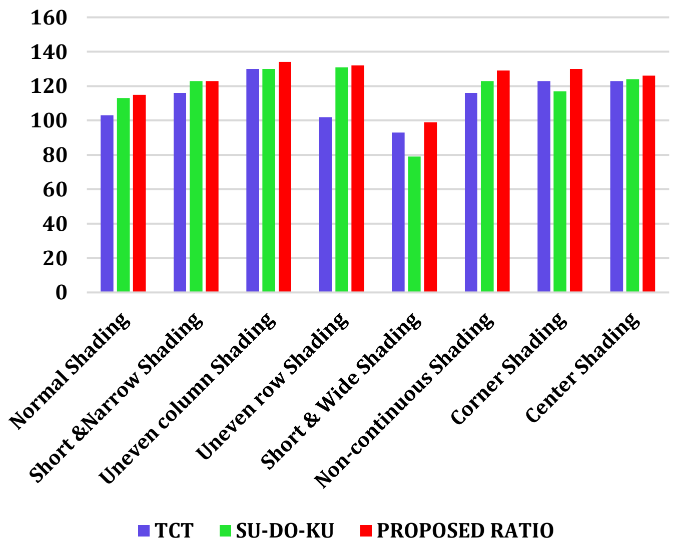

Fig -2: Output Power Comparison

CONCLUSION

This simulation-based methodology provides a systematic framework for evaluating and optimizing reconfiguration techniques to mitigate the impacts of partial shading on solar PV arrays. It enhancing the efficiency, resilience, and performance of solar PV systems in the face of partial shading challenges. The proposed work represents a significant advancement in enhancing the power generation capabilities of PV systems operating under partially shaded conditions. By effectively reducing the mismatch losses that typically arise when certain PV modules are shaded, the proposed technique addresses a key challenge in solar energy production. Through the continuous adaptation of the array layout, the proposed ratio minimizes module mismatch, thereby improving the overall efficiency of the system. Looking ahead, this innovation holds the potential to further enhance power generation in scenarios where partial shading occurs. The proposed technique outperforms TCT and SU-DO-KU configurations in enhancing output power generation under various shading conditions. Its consistent superiority in minimizing mismatch losses highlights its efficacy in optimizing system efficiency. These results signify a significant advancement in solar energy technology, emphasizing the importance of innovative approaches in maximizing PV system performance.

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