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CONSTANT POWER GENERATION USING MODIFIED MPPT P&O TO OVERCOME OVER VOLTAGE ON SOLAR POWER PLANTS

P. Mukambika, T. Shilpa, C. Shareef Vali, C. Manimalik, Dr. M. RAMASEKHARA REDDY

[1,2,3,4]UG students, Dept of EEE, JNTUA College of Engineering

[5]Assistant Professor, Dept of EEE, JNTUA College of Engineering

ABSTRACT

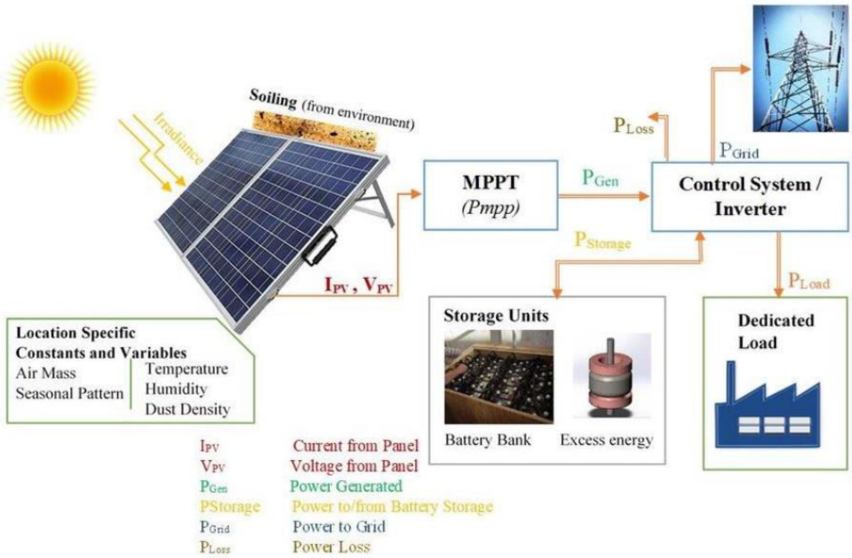
The increasing reliance on solar energy as a renewable power source necessitates efficient energy management strategies to address the intermittent nature of photovoltaic (PV) generation. Maximum Power Point Tracking (MPPT) techniques, such as the Perturb and Observe (P&O) method, optimize the efficiency of solar panels by ensuring they operate at their most effective voltage. However, traditional MPPT control often results in excessive voltage generation, leading to overvoltage conditions that can damage solar panels and connected loads. To overcome this issue, a Modified MPPT-P&O approach is proposed, integrating a Constant Power Generation (CPG) mode to regulate voltage levels and maintain system stability. This method allows the system to transition between MPPT and CPG modes, ensuring that power output remains within safe operational limits. The approach is implemented using PSIM software, a powerful simulation tool for power electronics applications, enabling precise modeling and validation of the proposed control strategy. By adopting this enhanced MPPT method, solar power plants can achieve stable and reliable power generation, mitigating the risks associated with overvoltage and ensuring sustainable energy utilization. This study contributes to improving the performance and longevity of solar energy systems, making them more viable for large-scale deployment.

Keywords: MPPT, P&O method, constant power generation, solar PV, overvoltage mitigation, PSIM simulation, renewable energy.

INTRODUCTION

Solar energy has emerged as one of the most promising renewable energy sources due to its availability and sustainability. However, despite its numerous advantages, solar power generation is inherently intermittent, making it unreliable as a standalone energy source. This variability in power output is largely influenced by changes in solar irradiance and temperature, which directly affect the efficiency of photovoltaic (PV) systems. To address these challenges, Maximum Power Point Tracking (MPPT) techniques have been widely implemented to optimize the power output of PV panels. Among various MPPT techniques, the Perturb and Observe (P&O) method is one of the most commonly used due to its simplicity and effectiveness in locating the maximum power point (MPP) of a PV system.

The primary function of MPPT is to ensure that PV modules operate at their most efficient voltage level to extract the highest possible power. This is achieved by continuously adjusting the operating point of the PV system to track fluctuations in irradiance and temperature. However, while MPPT enhances power extraction, it also leads to an increase in output voltage, sometimes exceeding the reference value. This overvoltage phenomenon poses a significant challenge as it can lead to damage in the PV system components, reduce their lifespan, and affect the stability of the connected loads.



Solar power plant block diagram

To mitigate this issue, a Modified MPPT-P&O method incorporating Constant Power Generation (CPG) mode is proposed. This approach ensures that when the PV output power exceeds a predefined reference level, the system transitions from MPPT mode to CPG mode, thereby stabilizing the power output and preventing voltage surges. The integration of CPG mode into the MPPT framework effectively limits excessive voltage levels, ensuring that the PV system operates within safe parameters while maintaining optimal power efficiency.

The implementation of this advanced control strategy is carried out using PSIM software, a specialized simulation tool for power electronics and motor drive applications. PSIM provides an effective platform for modeling and simulating PV systems, allowing researchers and engineers to analyze circuit behavior and validate control strategies before real-world deployment. The software employs nodal analysis and the trapezoidal rule integration for its simulation algorithm, offering high accuracy in power electronics simulations. Additionally, PSIM includes various modules that extend its capabilities into control theory, renewable energy systems, and electric motor applications.

In a conventional MPPT system using the P&O method, the controller perturbs the operating voltage and observes the corresponding change in power output. If an increase in voltage results in higher power, the controller continues to perturb in the same direction; otherwise, it reverses the perturbation direction. This iterative process ensures that the system operates at the MPP. However, when the available power significantly exceeds the reference level, the excessive voltage generated can pose risks to system stability. By incorporating CPG mode, the controller actively limits the output power, maintaining a constant voltage and preventing damage to PV modules and loads. This dual-mode operation enhances the reliability and safety of solar power plants, particularly in large-scale grid-connected applications.

The instability in solar power generation is a well-documented challenge, as PV panels rely on fluctuating solar irradiance and exhibit relatively low energy conversion efficiency. Without proper regulation, the system experiences fluctuations in power output, which can lead to inefficiencies and potential failures in the electrical grid. The integration of MPPT with CPG mode provides an intelligent control mechanism that dynamically adjusts power generation according to the system's requirements. This is particularly beneficial for grid-connected solar power plants, where maintaining voltage stability is crucial for seamless integration with the power distribution network.

Another key advantage of the proposed Modified MPPT-P&O method is its adaptability to varying environmental conditions. Unlike conventional MPPT techniques that solely focus on maximizing power extraction, this method prioritizes both efficiency and system protection. By continuously monitoring the power output and switching between MPPT and CPG modes as needed, the system ensures that energy harvesting is optimized without exceeding safety limits. This capability is especially valuable in regions experiencing high solar irradiance, where overvoltage issues are more prevalent.

The use of PSIM software in this study provides a robust simulation environment to evaluate the effectiveness of the proposed control strategy. PSIM's advanced modeling capabilities enable detailed analysis of PV system behavior under different operating conditions. The software's schematic capture interface allows for precise circuit design, while its waveform viewer facilitates real-time analysis of voltage, current, and power parameters. By leveraging PSIM's powerful simulation tools, researchers can develop and refine MPPT algorithms with greater accuracy and efficiency.

Furthermore, the implementation of CPG mode does not compromise the overall energy yield of the PV system. Instead, it ensures that power generation remains within optimal operating limits, preventing energy losses due to excessive voltage fluctuations. This balance between power optimization and system protection enhances the long-term performance and reliability of solar installations, making them more viable for widespread adoption.

The integration of MPPT with CPG mode represents a significant advancement in PV system control, addressing the longstanding challenge of overvoltage while maximizing energy extraction. The Modified MPPT-P&O method offers a practical and effective solution for improving the stability and efficiency of solar power plants, particularly in high-irradiance conditions. By utilizing PSIM software for simulation and validation, this study demonstrates the feasibility and benefits of the proposed approach, paving the way for its real-world implementation in renewable energy systems.

As the demand for sustainable energy solutions continues to grow, advancements in PV control strategies such as the Modified MPPT-P&O method play a crucial role in ensuring the reliability and efficiency of solar power generation. By addressing the challenges associated with power fluctuations and overvoltage, this approach contributes to the development of more resilient and adaptable renewable energy infrastructures. Moving forward, further research and development efforts can focus on optimizing this method for different PV configurations, enhancing its applicability across various solar energy systems. The successful implementation of this technique will ultimately support the global transition towards clean and sustainable energy solutions, reinforcing the role of solar power as a key component of the future energy landscape.

LITERATURE SURVEY

Numerous studies have explored the application of MPPT techniques to enhance the efficiency of solar power generation. Research highlights that conventional MPPT methods, including the perturb and observe (P&O) method, provide optimal power extraction but often lead to overvoltage scenarios that can damage the PV system. Several improvements have been proposed in literature to overcome these issues, such as adaptive MPPT algorithms that modify tracking parameters dynamically to prevent excessive voltage fluctuations. Studies have demonstrated that integrating a constant power generation (CPG) approach into MPPT can significantly stabilize solar power output and prevent overvoltage conditions.

Research has also emphasized the importance of power electronic interfaces in solar energy conversion systems. The two-stage conversion process, comprising an initial DC-DC conversion followed by an inverter stage, is widely adopted but contributes to energy losses. Alternative single-stage conversion techniques have been explored, aiming to reduce energy loss while maintaining efficiency. Several studies have proposed hybrid MPPT algorithms that combine P&O with machine learning techniques to optimize power generation further. These approaches improve response time and adaptability under varying environmental conditions.

Another critical area of research is the role of simulation tools like PSIM in designing and validating MPPT and CPG strategies. Simulation-based studies highlight how PSIM can be used to model different operational modes and analyze the effectiveness of various control algorithms. PSIM-based modeling helps optimize control strategies before implementation, reducing experimental costs and time.

Comparative analyses in the literature have demonstrated that traditional MPPT techniques may lead to abrupt voltage variations, adversely affecting system stability. Advanced control methods, including fuzzy logic and artificial neural networks, have been proposed to enhance MPPT performance. These techniques allow for more intelligent decision-making based on real-time data inputs. Furthermore, researchers have investigated the impact of shading and partial irradiance conditions on MPPT efficiency. Studies indicate that conventional P&O methods may fail under partial shading conditions, necessitating more sophisticated tracking mechanisms.

The literature review highlights that while MPPT is essential for maximizing solar power generation, it must be coupled with voltage regulation techniques to ensure system reliability. Implementing constant power generation (CPG) alongside MPPT provides an effective solution to overvoltage issues, thereby enhancing the overall efficiency of solar power plants.

METHODOLOGY

The implementation of the Modified MPPT-P&O method for constant power generation involves a systematic approach that integrates efficient power tracking with overvoltage prevention. The methodology follows a structured workflow, starting from the modeling of the

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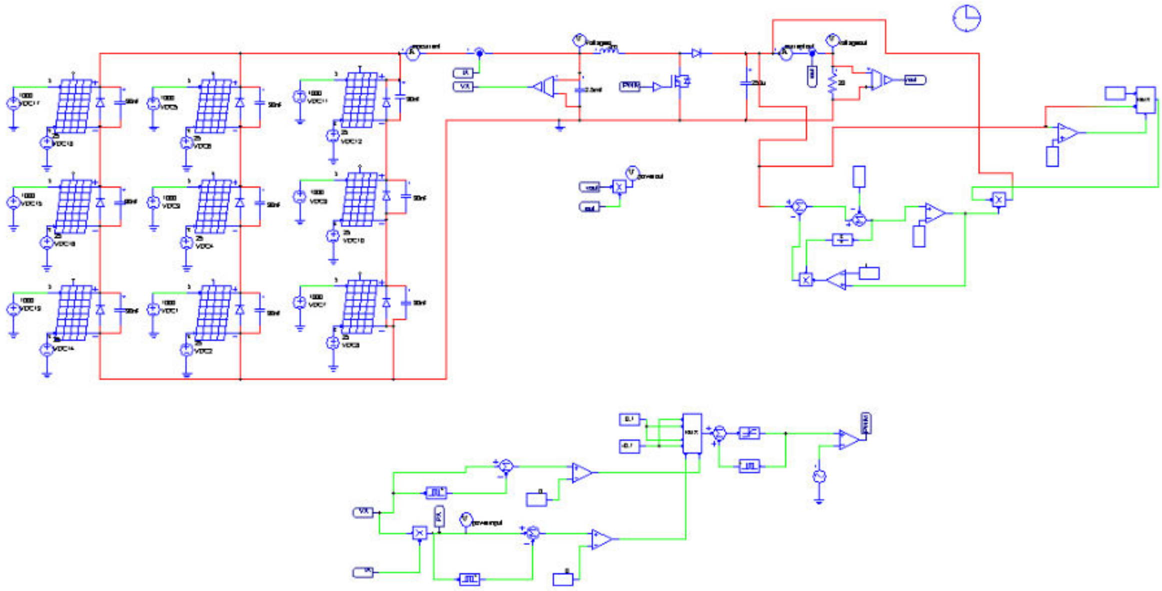
solar PV system, incorporation of the control algorithm, and simulation using PSIM software. The key steps in this methodology are as follows. Initially, the solar photovoltaic system is modeled with appropriate parameters, including solar irradiance, temperature, and load conditions. The PV module characteristics are derived based on the I-V and P-V curves, which determine the operating range of the system. The voltage, current, and power variations are analyzed under different environmental conditions to ensure accurate modeling.



Overall constant power generation using modified MPPT in perturb and observe method

The MPPT-P&O algorithm is implemented to track the maximum power point (MPP) efficiently. In the conventional P&O method, small perturbations are introduced in the operating voltage, and the resulting power variations are monitored. If an increase in power is observed, the perturbation continues in the same direction; otherwise, it reverses direction. While this method ensures MPP tracking, it often results in overvoltage scenarios, particularly under high irradiance conditions.

To overcome this limitation, the proposed modification introduces a Constant Power Generation (CPG) mode in conjunction with the P&O method. The transition between MPPT and CPG modes is controlled by a predefined power reference level. When the power output reaches or exceeds the reference level, the CPG mode is activated, adjusting the duty cycle of the converter to maintain a constant power output, thereby preventing excessive voltage generation. This hybrid approach balances power extraction efficiency with system stability.

A DC-DC boost converter is integrated into the system to regulate the voltage and ensure a stable power output. The converter's duty cycle is dynamically adjusted based on the control signals from the modified MPPT algorithm. The control mechanism is designed to prioritize MPP tracking while keeping the output voltage within safe limits. The converter efficiency is optimized to minimize power losses and enhance overall system performance.

Simulation of the proposed methodology is conducted using PSIM software, which is widely used for power electronics and renewable energy applications. The PV model, boost converter, and control algorithm are implemented within the PSIM environment, allowing real-time analysis of system behavior. Various scenarios, including changes in irradiance, temperature

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fluctuations, and varying load conditions, are simulated to validate the effectiveness of the proposed approach.

Panel Ratings:

Parameters	PV Module	PV Array
Maximum power (Pmax)	300 W	2700 W
Voltage at Pmax	33.5V	106.5V
Cuurent at Pmax	8.45A	25.4A
Open circuit voltage	44.71V	134.13V
Short circuit current	9A	27A

To evaluate performance, key parameters such as voltage regulation, power stability, and conversion efficiency are analyzed. The results are compared with conventional MPPT methods to demonstrate the advantages of the proposed hybrid MPPT-CPG approach. The reduction in overvoltage occurrences and the improvement in power stability are key metrics that establish the effectiveness of the methodology.
The final step involves refining the control strategy based on simulation results and optimizing parameters to enhance system resilience. Fine-tuning the power reference levels, modifying perturbation step sizes, and adjusting the converter duty cycle contribute to achieving a robust and reliable power generation system. This systematic approach ensures that the solar PV system operates efficiently without encountering overvoltage risks, thereby enhancing the longevity and reliability of solar power plants.

PROPOSED SYSTEM

The proposed system integrates a Modified MPPT-P&O algorithm with a Constant Power Generation (CPG) mode to regulate power output and mitigate overvoltage conditions in solar power plants. The working principle of the system is based on dynamically switching between MPPT and CPG modes depending on power levels, ensuring stable and efficient operation.
The system begins with a solar PV module generating power based on available irradiance. The output characteristics of the PV module, including voltage and current, are continuously monitored. Under normal operating conditions, the MPPT algorithm functions to extract the maximum power by adjusting the operating voltage. The Perturb and Observe (P&O) method is employed, where voltage perturbations are introduced, and power variations are analyzed. If an increase in power is detected, the perturbation continues in the same direction; otherwise, the direction is reversed.
As the PV system operates under varying environmental conditions, there are instances where the generated power exceeds the predefined reference level. When this occurs, the system transitions from MPPT mode to Constant Power Generation (CPG) mode. The CPG mode is designed to maintain power output at a set threshold, preventing excessive voltage rise. This is

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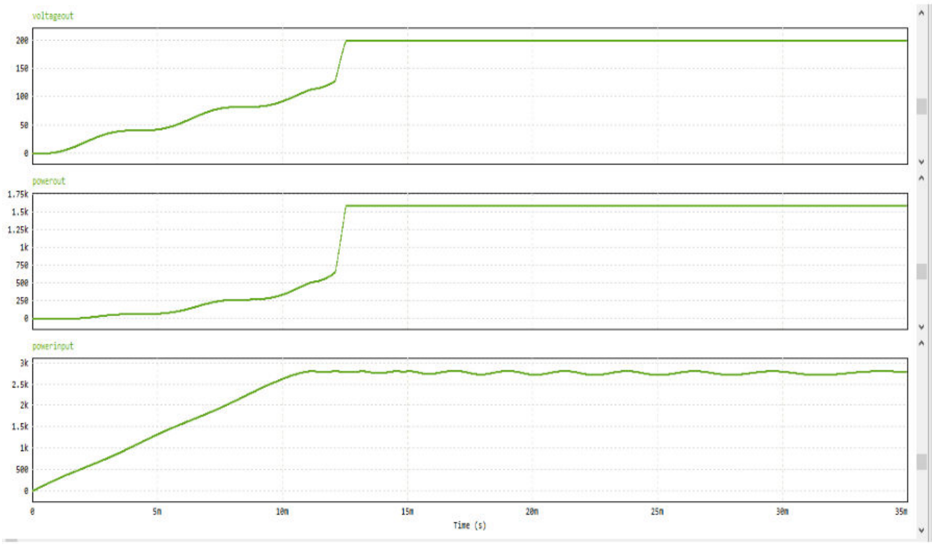
achieved by dynamically adjusting the duty cycle of the boost converter, limiting the power fed to the load or grid.

A DC-DC boost converter plays a critical role in regulating the voltage levels. The converter receives input from the PV module and adjusts its duty cycle based on control signals from the MPPT-CPG algorithm. During MPPT mode, the converter ensures optimal power extraction by continuously varying the voltage. In CPG mode, the converter limits voltage rise by controlling the switching frequency and duty cycle, ensuring that the power does not exceed safe operational limits.

The control strategy employs feedback loops to maintain stability. Voltage and current sensors continuously measure system parameters, feeding data into the control unit. The decision-making process involves real-time comparison of power output with the reference value. If power remains below the threshold, MPPT mode continues; if it reaches or surpasses the threshold, the system smoothly transitions into CPG mode. This adaptive control mechanism ensures seamless operation, preventing power surges and overvoltage conditions.



25 OHM CPG output

PSIM software is utilized to model and validate the system's performance. The simulation includes varying solar irradiance levels, temperature fluctuations, and different load conditions to assess the response of the MPPT-CPG algorithm. The analysis focuses on power stability, voltage regulation, and system efficiency. The simulation results confirm that the proposed approach effectively mitigates overvoltage while maintaining high power extraction efficiency.

One of the significant advantages of this system is its ability to enhance the reliability of solar power plants. By preventing excessive voltage buildup, the risk of damage to solar panels, inverters, and connected loads is minimized. This leads to improved system longevity and reduced maintenance costs. Additionally, the smooth transition between MPPT and CPG modes ensures uninterrupted power supply, making the system suitable for grid-connected and standalone solar applications.

The proposed system is scalable and can be adapted for different PV installations, ranging from small-scale residential setups to large solar farms. By fine-tuning control parameters, the system can accommodate varying power demands while maintaining operational stability.

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Furthermore, the incorporation of PSIM-based simulations provides a platform for further enhancements, enabling researchers and engineers to refine the methodology for broader applications.

variable loads

Load value	Voltage	Current	Power
20	200	10	2000
15	200	13.3	2680
25	200	8	1600

In conclusion, the proposed Modified MPPT-P&O with CPG mode offers a practical and effective solution for addressing overvoltage issues in solar power plants. The integration of a boost converter, dynamic duty cycle adjustment, and adaptive control mechanisms ensures efficient power management. Through rigorous simulation and analysis, the system has demonstrated superior performance compared to conventional MPPT methods, establishing its potential for widespread implementation in the renewable energy sector.

CONCLUSION

The integration of a Modified MPPT-P&O method with Constant Power Generation (CPG) mode significantly enhances the stability and efficiency of solar power plants. Conventional MPPT techniques, particularly the P&O method, are effective in extracting maximum power from photovoltaic (PV) modules. However, they often result in overvoltage conditions that can lead to component degradation and operational inefficiencies. The proposed system effectively mitigates these risks by transitioning between MPPT and CPG modes, ensuring power output remains within safe limits.

Using PSIM software for simulation and validation, the results demonstrate that the proposed control strategy successfully regulates voltage levels, minimizes fluctuations, and enhances the overall reliability of solar energy systems. This approach contributes to increasing the lifespan of PV panels, protecting electrical loads, and improving grid integration by reducing instability. Furthermore, the CPG mode prevents excessive energy generation, making it ideal for large-scale solar farms where power regulation is critical.

Future research can explore hardware implementation to validate simulation results under real-world conditions. Additionally, integrating machine learning or adaptive control algorithms could further optimize MPPT efficiency and responsiveness. By implementing such advancements, the transition to sustainable energy can be made more reliable, fostering widespread adoption of solar technology in modern power systems.

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