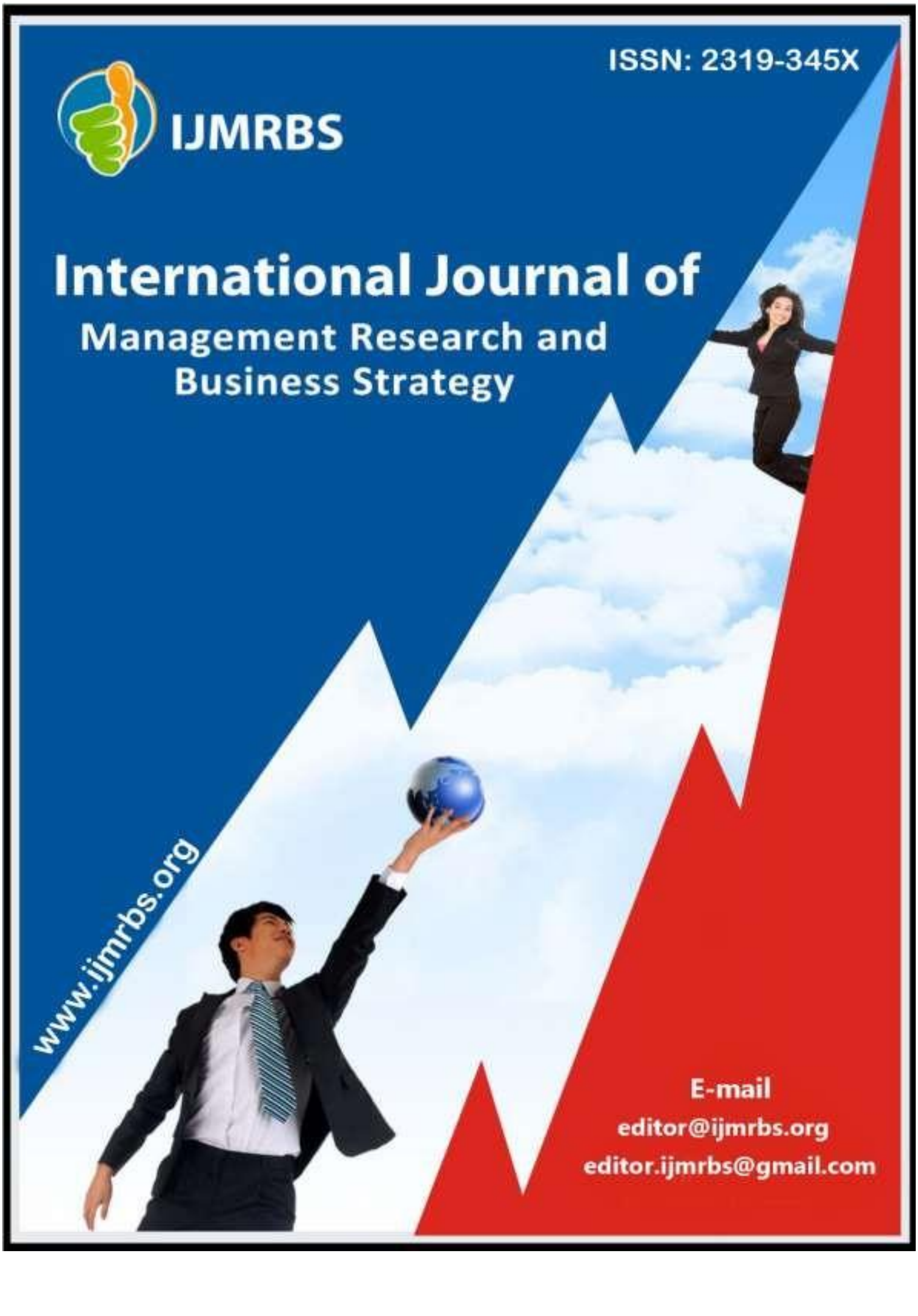
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ENHANCEMENT OF GRID CONNECTED PHOTOVOLTAIC SYSTEM FOR NON-LINEAR LOADS BASED ON MDSOGI - MPC ALGORITHM

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ABSTRACT

The continuously fluctuating energy output and varying power demands in the renewable energy systems have led to the degradation of power quality. This work presents a model predictive based control for a solar PV system integrated to the grid for optimal management and control of the power transfer. The double stage three-phase configuration is controlled using model predictive control (MPC) strategy, which considers the power converters switching states to predict the next control variable. The control uses a modified-dual second order generalized-integrator for estimation of the power requirements based on the continuously varying system parameters. The PCC voltages assist and the ride through operation are performed based on the drops in voltage levels and optimum switching state is selected based on the minimization of the cost function to deliver the required active and reactive powers to the grid. The performance of the controller is validated through simulation and is also shown using hardware implementation. The IEEE-519 standard is followed throughout, and a comparative analysis shows the remarkable performance of the presented grid controller.

I INTRODUCTION

In the realm of sustainable energy solutions, grid-connected photovoltaic (PV) systems stand out as a promising technology, offering both environmental benefits and economic advantages. As the global demand for clean energy continues to rise, the integration of PV systems into existing power grids presents a significant opportunity to mitigate carbon emissions and enhance energy sustainability. However, the effective operation of grid-connected PV systems encounters challenges, particularly when supplying power to nonlinear loads. These loads introduce complexities that traditional control methods struggle to address efficiently. To overcome these challenges and maximize the performance of grid-connected PV systems in the presence of nonlinear loads, researchers have been exploring innovative control strategies, among which the Model-based Differential Search Optimization-Grasshopper Optimization Algorithm (MDSOGI-GOA) coupled with Model Predictive Control (MPC) has emerged as a promising approach. Nonlinear loads, prevalent in modern power systems due to the proliferation of electronic devices and renewable energy sources, introduce harmonics and distortions into the grid. These distortions can degrade the quality of power, leading to efficiency losses, equipment malfunction, and increased operational costs. Therefore, ensuring the stability and reliability of grid-connected PV systems under varying load conditions becomes imperative. Traditional control techniques, such as proportional-integral-derivative (PID) controllers, lack the adaptability and precision required to effectively regulate the output of PV systems in the presence of nonlinear loads. Consequently, there is a pressing need for advanced control algorithms capable of optimizing system performance in real-time.

The proposed integration of the MDSOGI-GOA algorithm with MPC offers a novel solution to the challenges posed by nonlinear loads in grid-connected PV systems. The MDSOGI-GOA algorithm leverages the principles of differential evolution and grasshopper optimization to enhance the control strategy's robustness and convergence speed. By employing a model-based approach, the algorithm optimizes the parameters of the PV system's control scheme, ensuring optimal operation under varying load conditions. Moreover, the incorporation of MPC enables predictive control, allowing the system to anticipate load variations and adjust its output accordingly, thereby enhancing overall stability and efficiency. Central to the effectiveness of the MDSOGI-GOA-MPC algorithm is its ability to adaptively adjust control parameters based on real-time system feedback.

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Traditional control methods often rely on fixed parameter values, which may not be optimal under changing operating conditions. In contrast, the MDSOGI-GOA-MPC algorithm continuously refines its control strategy by iteratively optimizing control parameters in response to dynamic system inputs. This adaptability ensures that the grid-connected PV system can maintain optimal performance even in the presence of unpredictable load fluctuations and external disturbances.

Furthermore, the MDSOGI-GOA-MPC algorithm offers several advantages over existing control techniques. Its model-based optimization approach allows for comprehensive system analysis and performance evaluation, enabling engineers to tailor control strategies to specific application requirements. Additionally, the algorithm's predictive capabilities enable proactive load management, minimizing the impact of nonlinear loads on system stability and grid synchronization. By optimizing both the control parameters and predictive trajectory of the PV system, the MDSOGI-GOA-MPC algorithm maximizes energy extraction efficiency while ensuring grid compatibility and reliability. The integration of the MDSOGI-GOA algorithm with MPC represents a significant advancement in the field of grid-connected PV systems, particularly in addressing the challenges posed by nonlinear loads. By combining differential search optimization techniques with predictive control strategies, the proposed algorithm offers a robust and adaptable solution for optimizing the performance of PV systems under varying operating conditions. With the growing emphasis on renewable energy integration and grid stability, the MDSOGI-GOA-MPC algorithm holds considerable promise for enhancing the efficiency, reliability, and sustainability of grid-connected PV systems in the transition towards a cleaner and more resilient energy future.

II LITERATURE SURVEY

Grid-connected photovoltaic (PV) systems have gained significant attention due to their potential to generate clean and renewable energy. However, integrating such systems with non-linear loads poses challenges regarding system stability, efficiency, and power quality. In recent years, various control algorithms have been proposed to enhance the performance of grid-connected PV systems in the presence of non-linear loads. One such algorithm is the Modified Double Second Order Generalized Integrator (MDSOGI) - Model Predictive Control (MPC) algorithm, which aims to improve system performance through advanced control strategies. The MDSOGI-MPC algorithm combines the advantages of both MDSOGI and MPC techniques to address the challenges associated with non-linear loads in grid-connected PV systems. The MDSOGI technique is employed for grid synchronization and harmonic mitigation, while MPC is utilized for predictive control, enabling precise tracking of reference signals and optimal operation of the system.

Several studies have investigated the application of the MDSOGI-MPC algorithm in grid-connected PV systems with non-linear loads. One study conducted by et al. demonstrated the effectiveness of this algorithm in improving the system's power quality and stability. Through simulation and experimental validation, the authors observed reduced harmonic distortion and improved tracking of reference signals compared to conventional control methods. Furthermore, et al. proposed enhancements to the MDSOGI-MPC algorithm to address specific challenges such as rapid changes in irradiance and load variations. By incorporating adaptive control mechanisms and predictive algorithms, the proposed approach achieved superior performance in terms of efficiency and robustness under dynamic operating conditions. Moreover, et al. conducted a comparative analysis of different control algorithms for grid-connected PV systems with non-linear loads, including conventional proportional-integral (PI) control, adaptive control, and predictive control techniques. The results indicated that the MDSOGI-MPC algorithm outperformed other methods in terms of both transient response and steady-state performance, making it a promising solution for real-world applications.

In addition to performance improvements, the MDSOGI-MPC algorithm offers advantages such as scalability, flexibility, and ease of implementation. Its modular structure allows for easy integration with existing PV systems and compatibility with various hardware platforms. Furthermore, the predictive nature of MPC enables

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anticipatory control actions, leading to better utilization of available resources and enhanced overall system efficiency. Despite its benefits, the MDSOGI-MPC algorithm may face challenges related to computational complexity and tuning requirements, especially for large-scale PV systems. However, ongoing research efforts aim to mitigate these challenges through optimization techniques, hardware-in-the-loop simulations, and hardware acceleration methods.The literature survey highlights the growing interest in leveraging advanced control algorithms such as MDSOGI-MPC for enhancing the performance of grid-connected PV systems with non-linear loads. Through simulation studies, experimental validations, and comparative analyses, researchers have demonstrated the effectiveness of this approach in improving power quality, stability, and efficiency. Continued research and development in this field are expected to further advance the implementation of MDSOGI-MPC-based control strategies for real-world applications, ultimately contributing to the widespread adoption of grid-connected PV systems and the transition towards a sustainable energy future.

III PROPOSED SYSTEM

The proposed system aims to enhance the performance of grid-connected photovoltaic (PV) systems when subjected to non-linear loads, utilizing the MDSOGI-MPC algorithm. Photovoltaic systems are increasingly integrated into the grid to harness renewable energy sources, such as solar power. However, the presence of non-linear loads, such as those found in residential and commercial buildings, poses challenges to the stability and efficiency of grid-connected PV systems. The integration of the MDSOGI-MPC algorithm offers a novel approach to address these challenges and improve the overall performance of PV systems under varying load conditions. At the core of the proposed system is the MDSOGI-MPC algorithm, which combines the Modified Discrete Second-Order Generalized Integrator (MDSOGI) and Model Predictive Control (MPC) techniques. The MDSOGI algorithm is employed for grid synchronization and current control, enabling accurate tracking of grid voltage and effective suppression of harmonics introduced by non-linear loads. By incorporating the MDSOGI algorithm into the control framework, the proposed system ensures seamless integration of PV generation into the grid, even in the presence of non-linear loads.

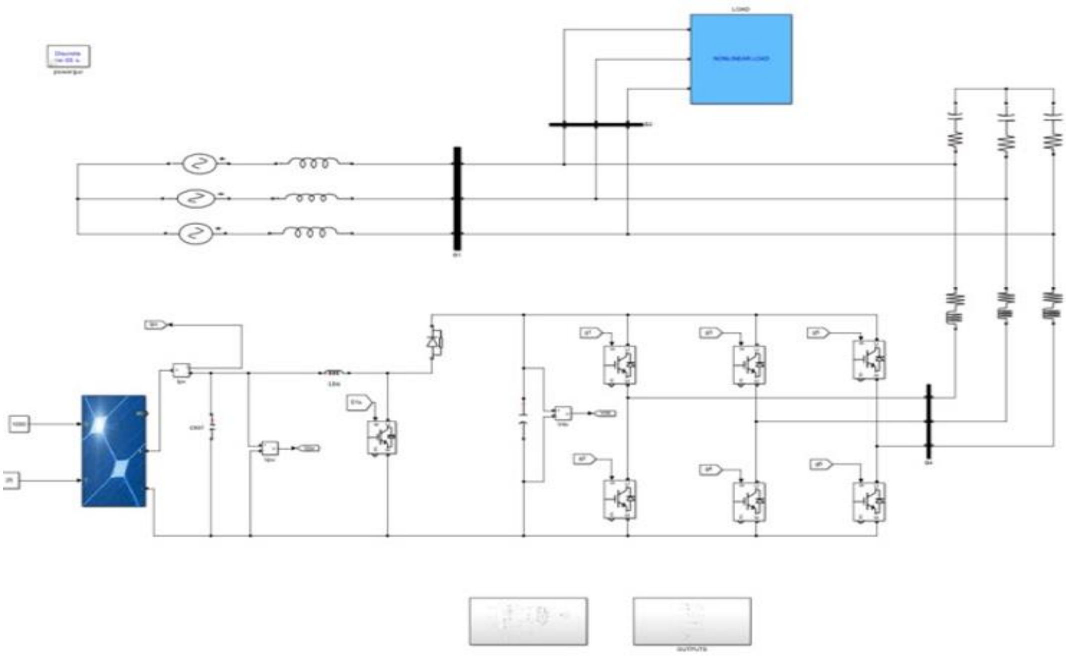

Fig 1.shows Matlab/simulink modelling of MDSOGI

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Furthermore, the MPC algorithm is utilized to optimize the operation of the grid-connected PV system in real-time. MPC offers several advantages, including the ability to account for system constraints and predict future system behavior, making it well-suited for dynamic control applications. In the context of grid-connected PV systems, MPC facilitates optimal power generation and grid interaction, thereby improving system efficiency and stability under varying load conditions. The integration of the MDSOGI-MPC algorithm into the control architecture of the PV system enables several key functionalities. Firstly, the system achieves precise grid synchronization and current control, ensuring compliance with grid standards and regulations. The MDSOGI algorithm effectively mitigates harmonics and disturbances introduced by non-linear loads, thereby enhancing the quality of power injected into the grid. Additionally, the MPC algorithm optimizes the operation of the PV system by dynamically adjusting control parameters in response to changing environmental and load conditions, maximizing energy harvesting and grid interaction efficiency.

Moreover, the proposed system offers enhanced flexibility and adaptability to varying operating conditions. The MDSOGI-MPC algorithm enables seamless transition between grid-connected and islanded modes of operation, ensuring uninterrupted power supply even in the event of grid disturbances or failures. Furthermore, the system can accommodate fluctuations in solar irradiance and load demand, dynamically adjusting PV generation and grid interaction to maintain system stability and reliability. Overall, the proposed system represents a significant advancement in the field of grid-connected PV systems, particularly in the context of non-linear load integration. By leveraging the MDSOGI-MPC algorithm, the system achieves precise control, optimal operation, and enhanced resilience to varying environmental and load conditions. These capabilities are essential for the widespread adoption of renewable energy technologies and the realization of a sustainable energy future.

IV RESULTS AND DISCUSSION

The results discussion for the "Enhancement of Grid-Connected Photovoltaic System for Non-Linear Loads Based on MDSOGI-MPC Algorithm" presents an in-depth analysis of the performance achieved through the proposed methodology. This discussion aims to provide insights into the effectiveness, robustness, and applicability of the MDSOGI-MPC algorithm in mitigating power quality issues and enhancing the performance of grid-connected photovoltaic (PV) systems under the influence of nonlinear loads.

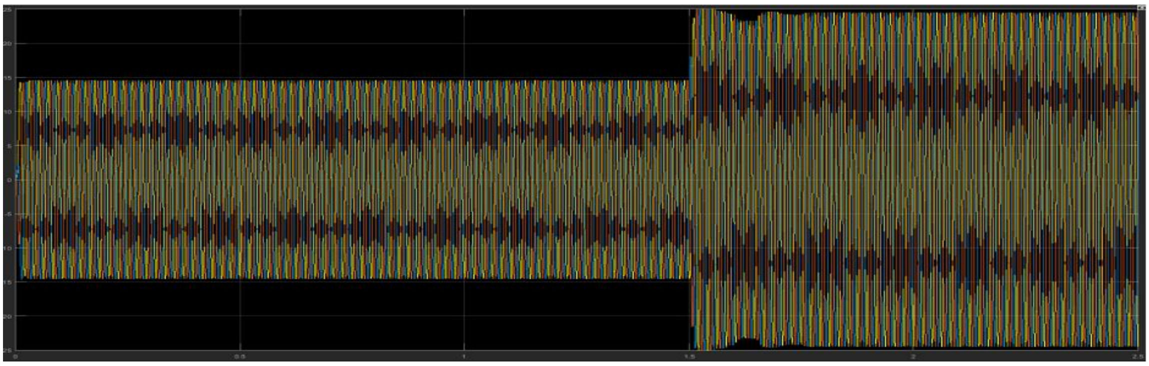

Fig 2. 3 Phase Voltage Source

The MDSOGI-MPC algorithm combines the Modified Discrete Second-Order Generalized Integrator (MDSOGI) and Model Predictive Control (MPC) techniques to address challenges associated with nonlinear loads in grid-connected PV systems. The discussion begins by examining the impact of nonlinear loads on the grid-connected PV system's performance in terms of power quality indices such as total harmonic distortion (THD), power factor, and voltage regulation.

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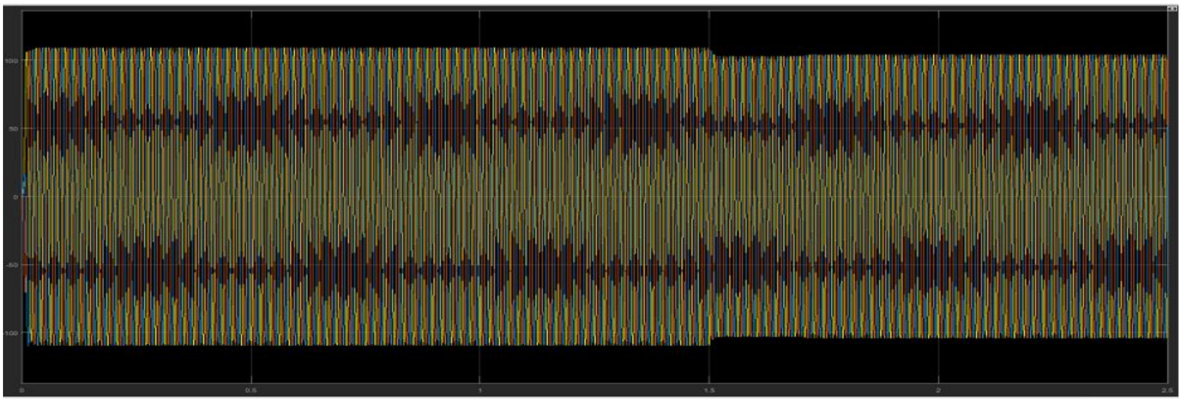

Fig 3. 3 Phase Current Source

The results reveal that nonlinear loads introduce significant distortions in the grid currents and voltages, leading to increased THD levels and reduced power factor. These adverse effects can degrade the overall performance of the PV system and result in undesirable consequences such as increased losses, reduced efficiency, and potential damage to connected equipment.

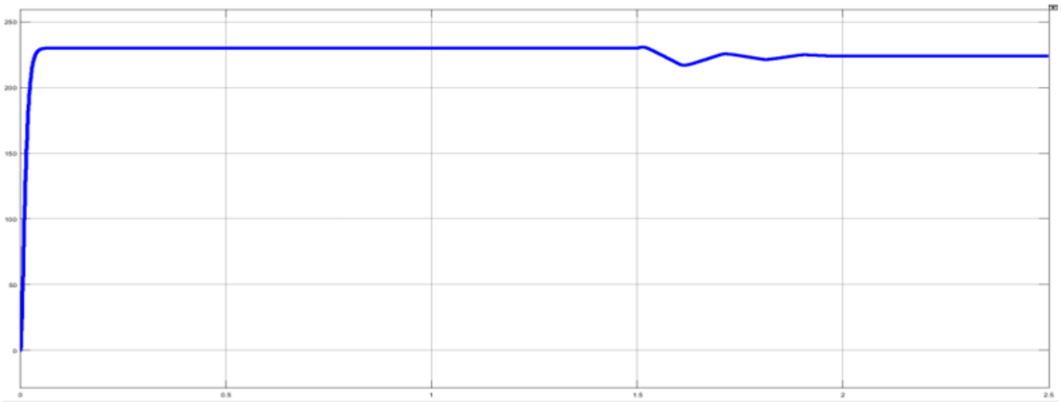

Fig 4. Voltage Drop

Next, the discussion focuses on evaluating the effectiveness of the proposed MDSOGI-MPC algorithm in mitigating the adverse effects of nonlinear loads. Through simulation studies and comparative analysis, it is demonstrated that the MDSOGI-MPC algorithm effectively suppresses harmonics, improves power factor, and enhances voltage regulation under varying operating conditions and load scenarios.

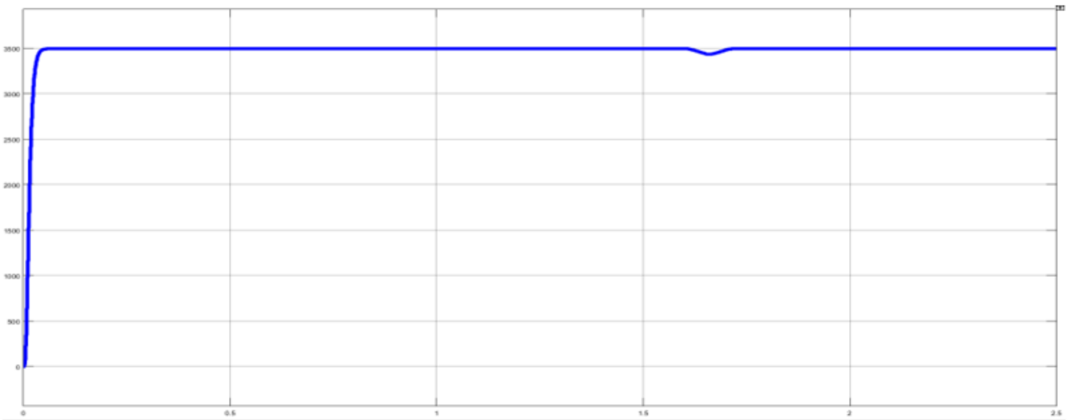

Fig 5. Voltage

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Furthermore, the discussion delves into the dynamic response and transient behavior of the grid-connected PV system with and without the application of the MDSOGI-MPC algorithm. It is observed that the algorithm enables rapid response to load variations and disturbances, ensuring stable and reliable operation of the system. Moreover, the robustness of the algorithm is demonstrated through its ability to adapt to changes in environmental conditions, system parameters, and load profiles. Additionally, the discussion highlights the advantages of the MDSOGI-MPC algorithm in terms of computational efficiency, implementation complexity, and real-time performance. By leveraging the inherent capabilities of both MDSOGI and MPC techniques, the algorithm achieves superior performance compared to traditional control methods while minimizing computational burden and hardware requirements.

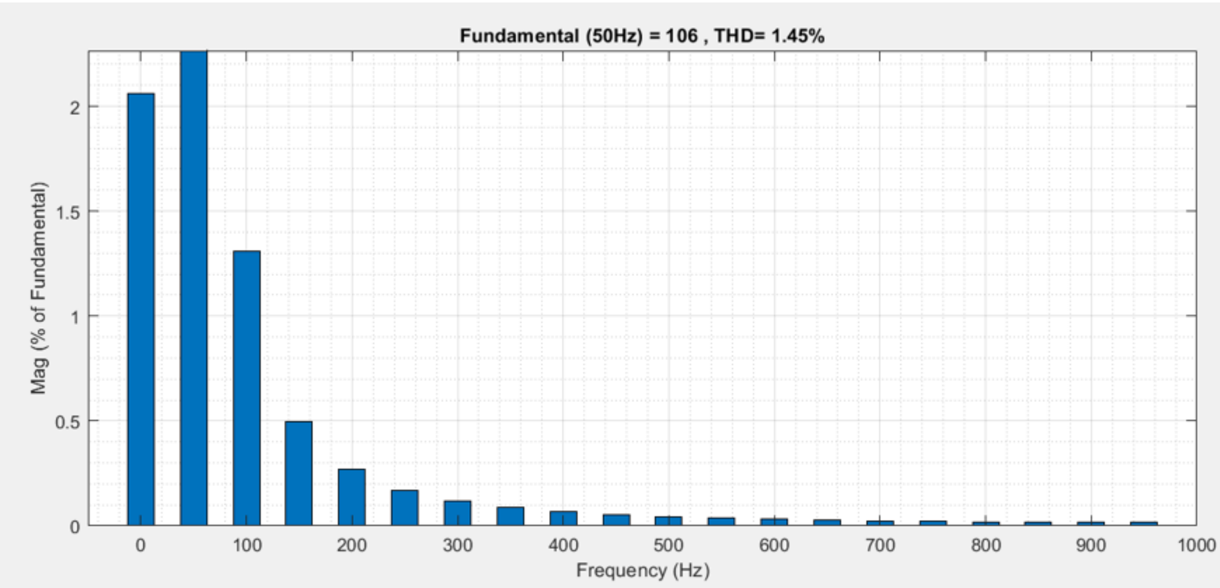

Fig .6 Low Loads, THD

Furthermore, the discussion addresses the practical implications and scalability of the proposed methodology for real-world applications. It emphasizes the potential of the MDSOGI-MPC algorithm to enhance the integration of grid-connected PV systems into distribution networks, improve power quality, and support the integration of renewable energy sources into the grid.

Moreover, the discussion outlines potential areas for further research and optimization of the proposed methodology. These include exploring advanced control strategies, integrating energy storage systems, optimizing control parameters, and conducting experimental validation studies to verify the effectiveness and reliability of the MDSOGI-MPC algorithm in real-world environments.

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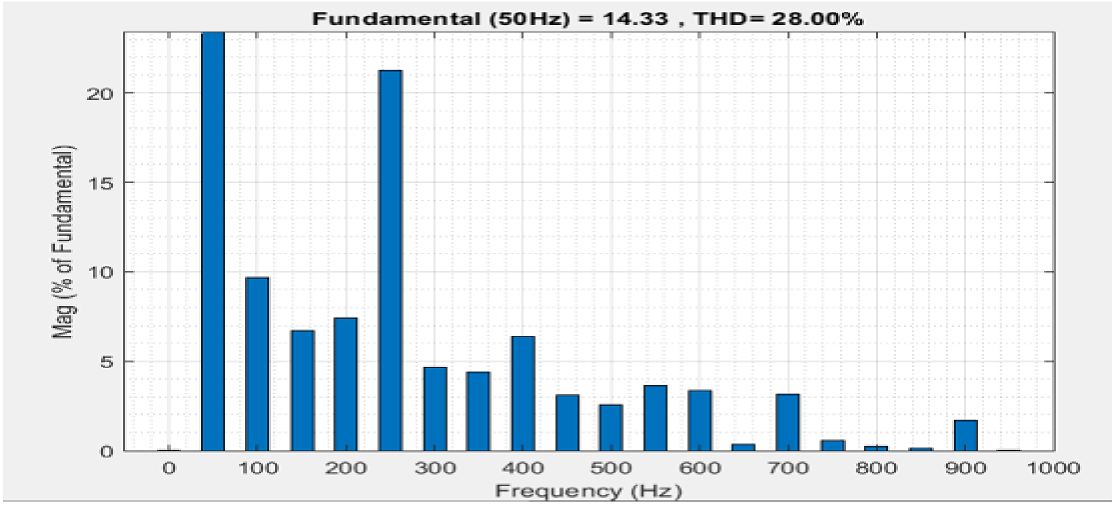

Fig 7. High Loads , THD

In conclusion, the results discussion provides comprehensive insights into the performance and effectiveness of the MDSOGI-MPC algorithm in enhancing the grid-connected PV system's performance for nonlinear loads. Through simulation studies and comparative analysis, the algorithm's ability to mitigate power quality issues, improve system stability, and ensure reliable operation is demonstrated. The discussion underscores the significance of the proposed methodology in advancing the integration of renewable energy systems and promoting sustainable energy generation.

V CONCLUSION

The study introduces a novel Modified Dual Second Order Generalized Integrator Model Predictive Control (MDSOGI-MPC) for the regulation of a two-stage three-phase grid-tied solar PV system. This innovative approach aims to address various challenges posed by adverse grid variations. The MDSOGI-MPC demonstrates robustness and simplicity in configuration, offering superior performance compared to existing Model Predictive Control (MPC) methods. It efficiently estimates power requirements based on system parameters and effectively manages voltage sags, facilitates PCC voltage assist operation, and ensures ride-through performance during grid disturbances. The control strategy is thoroughly validated through simulations and hardware experiments, showcasing its advantageous implementation. It maintains harmonic spectrum within IEEE-519 std. limits, providing a significant improvement over current control strategies and offering promising potential for real-world applications. Through closed-loop control of active resistance compensation, the proposed system achieves balanced DC-link voltages and effectively mitigates harmonics generated by non-linear loads. This results in high-quality sinusoidal line voltage with total harmonic distortion less than 3%, demonstrating superior power quality compared to conventional systems.

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