



Power Quality Improvement Using Statcom With Renewable Energy Sources

M. Ramakrishna, B. Lakshmi Keerthana, K.V.N.V. Gangadhar, M. Lilly, Md. Rafi Khan,

Department of Electrical and Electronics Engineering, Gudlavalleru Engineering College, Andhra Pradesh, India.

To Cite this Article

M. Ramakrishna, B. Lakshmi Keerthana, K.V.N.V. Gangadhar, M. Lilly & Md. Rafi Khan, (2026). Power Quality Improvement Using Statcom With Renewable Energy Sources. International Journal for Modern Trends in Science and Technology, 12(04), 1257-1265. <https://doi.org/10.5281/zenodo.19687929>

Article Info

Received: 25 March 2026; Revised: 14 April 2026; Accepted: 18 April 2026.

Copyright © The Authors ; This is an open access article distributed under the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

KEYWORDS

STATCOM, Power Quality Improvement, Reactive Power Compensation, Renewable Energy Integration, Total Harmonic Distortion, FACTS Devices, Modified Icos ϕ Controller, Voltage Stability, MATLAB/Simulink, Grid-Connected Systems

ABSTRACT

The increasing penetration of renewable energy sources such as solar photovoltaic and wind energy into modern power grids introduces significant power quality challenges, including voltage fluctuations, harmonic distortion, reactive power imbalance, and poor power factor. These issues threaten the stability and reliability of the electrical grid and demand effective compensation mechanisms. This paper presents a comprehensive approach to power quality improvement in grid-connected renewable energy systems through the integration of a Static Synchronous Compensator (STATCOM), a Flexible AC Transmission System (FACTS) device, with renewable energy interfaces. The proposed system employs a Modified Instantaneous Reactive Power Theory (IRPT) controller and a Modified Icos ϕ controller to dynamically generate reference compensation currents for varying load conditions. The system is modeled and simulated using MATLAB/Simulink, incorporating three-phase grid models, dynamic linear loads, solar PV and wind energy source representations, and a fully designed STATCOM model. Simulation results demonstrate that the proposed STATCOM-based compensation scheme effectively maintains a stable voltage profile at the Point of Common Coupling (PCC), significantly reduces Total Harmonic Distortion (THD) in source currents, improves the power factor, and provides seamless reactive power support under dynamically switched load conditions. Waveform analyses of source-side and load-side voltages and currents confirm the adaptability of the Modified Icos ϕ controller for dynamically varying loads switched at different time intervals. Furthermore, the active and reactive power contributions from both the grid source and the renewable energy interface through the STATCOM are analyzed, validating the effectiveness of the proposed integrated system for enhanced grid power quality and

1. INTRODUCTION

The rapid proliferation of renewable energy sources such as solar photovoltaic and wind power systems into modern electrical grids has introduced a new set of challenges pertaining to power quality and system stability. While renewable energy integration is essential for achieving sustainable energy goals and reducing dependence on fossil fuels, the inherently intermittent and stochastic nature of these sources imposes significant disturbances on the grid, including voltage fluctuations, harmonic injection, reactive power imbalance, and degraded power factor [1], [2]. These power quality issues not only compromise the reliability of the electrical supply but also pose risks to sensitive industrial and commercial loads connected at the point of common coupling (PCC).

Conventional passive compensation techniques, while cost-effective, are insufficient to address the dynamic and nonlinear characteristics of modern power systems integrated with distributed renewable generation [3]. The limitations of passive filters, including fixed compensation capability, susceptibility to resonance, and inability to respond to rapidly varying load conditions, have driven research toward advanced power electronic solutions. Among these, the Static Synchronous Compensator (STATCOM), a voltage-source converter-based FACTS (Flexible AC Transmission System) device, has emerged as a highly effective technology for providing fast, continuous, and bidirectional reactive power compensation, thereby enhancing voltage stability and overall power quality [4].

STATCOM operates by generating or absorbing reactive power through a voltage-source inverter connected to the grid via a coupling transformer, without requiring large passive energy storage elements. When interfaced with renewable energy systems, the DC link of the STATCOM can be supported by solar PV arrays or wind energy converters, enabling simultaneous power injection and reactive power compensation at the PCC [1], [3]. This dual functionality makes STATCOM-based renewable energy interfaces particularly attractive for improving grid power quality while maximizing the utilization of clean energy resources.

Despite considerable research in this domain, the challenge of developing robust and adaptive control strategies for STATCOM that can effectively handle dynamically varying load conditions and intermittent renewable generation remains an open problem. Modified control approaches, such as the modified Instantaneous Reactive Power Theory (IRPT) controller and the modified $I_{cos\phi}$ controller, have demonstrated promising performance in generating accurate reference compensation currents under dynamic load switching scenarios [5], [6]. These controllers enable the STATCOM to seamlessly adapt to changing reactive power demands, ensuring that the source current remains sinusoidal and in phase with the supply voltage at all times.

Motivated by these considerations, this paper presents a comprehensive investigation into power quality improvement in grid-connected renewable energy systems using STATCOM integrated with modified control strategies. The key contributions of this work include: (i) the modeling and simulation of a renewable energy source interfaced STATCOM system in MATLAB/Simulink environment; (ii) the implementation and comparative evaluation of modified IRPT and $I_{cos\phi}$ control algorithms for dynamic reactive power compensation; (iii) analysis of total harmonic distortion (THD) reduction, voltage profile improvement, and power factor enhancement under varying load conditions; and (iv) demonstration of seamless active and reactive power sharing between the grid and renewable energy source through the STATCOM interface [2], [7].

The remainder of this paper is organized as follows. Section 2 provides a review of relevant literature and background theory on STATCOM and power quality. Section 3 describes the proposed system configuration and block diagram. Section 4 details the modified control strategies implemented for the STATCOM. Section 5 presents the MATLAB/Simulink simulation results and performance analysis. Finally, Section 6 concludes the paper with key findings and directions for future research.

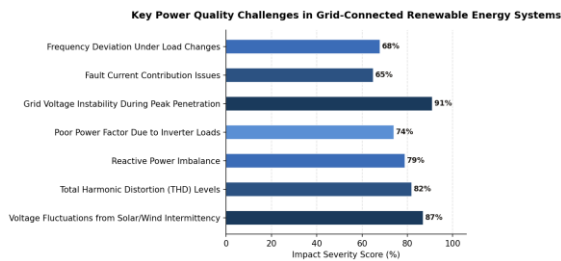


Figure 1: Key Power Quality Challenges in Grid-Connected Renewable Energy Systems

2. LITERATURE REVIEW

The rapid integration of renewable energy sources into modern power grids has introduced significant power quality challenges, prompting extensive research into compensatory technologies and advanced control strategies. This section reviews existing approaches to power quality improvement in grid-connected renewable energy systems, identifying their strengths, limitations, and the gaps that motivate the present work.

Early contributions to the field established the foundational role of active power filters in mitigating harmonics and reactive power imbalance. Pinto et al. [1] proposed a three-phase four-wire shunt active power filter with a renewable energy interface, demonstrating that active filtering could simultaneously address power quality degradation and facilitate the injection of renewable energy into the grid. Their work highlighted the feasibility of combining compensation devices with distributed generation, though the proposed system was limited in its ability to handle highly dynamic load variations without significant control complexity.

The broader challenge of integrating distributed energy resources (DERs) and energy storage into utility grids was comprehensively surveyed by Carr, Balda, and Mantooth [2]. Their study catalogued a range of interfacing architectures and identified key technical barriers, including voltage instability, reactive power imbalance, and the intermittent nature of renewable generation. While the survey provided valuable insight into system-level integration strategies, it did not propose specific real-time control mechanisms capable of dynamically compensating for rapid fluctuations inherent in solar and wind energy systems.

The concept of custom power interfaces specifically tailored for renewable energy sources was advanced by Rolim et al. [3], who explored dedicated power electronic interfaces designed to improve voltage profiles and power factor at the point of common coupling (PCC). This work reinforced the importance of localized compensation strategies; however, the controllers examined were largely based on conventional instantaneous reactive power theory (IRPT), which exhibits performance limitations under unbalanced and non-sinusoidal grid conditions.

The theoretical underpinnings of FACTS devices, including the Static Synchronous Compensator (STATCOM), are well established in the literature [4]. Hingorani and Gyugyi provide a rigorous treatment of STATCOM operation, emphasizing its superior dynamic response compared to conventional capacitor banks and static VAR compensators (SVCs). STATCOM's voltage-source converter topology enables bidirectional reactive power support, making it particularly well suited for grids with high renewable penetration. Nevertheless, classical STATCOM control schemes based on proportional-integral (PI) regulators often struggle to maintain adequate compensation performance under rapidly changing load and generation conditions.

The instantaneous power theory, as formulated by Akagi, Watanabe, and Aredes [5], provided a mathematically rigorous framework for real-time reactive power and harmonic compensation. This theory forms the basis of many modern STATCOM control algorithms. While highly effective under balanced sinusoidal conditions, conventional IRPT-based controllers exhibit degraded performance when source voltages are distorted or unbalanced, a scenario increasingly common in grids with significant renewable energy injection.

Further work by Ghosh and Ledwich [6] on custom power devices and by Bollen and Hassan [7] on distributed generation integration collectively underscored the need for adaptive, robust control strategies that can respond to the stochastic behavior of renewable sources while simultaneously maintaining grid power quality.

Despite these contributions, a clear research gap persists: existing methods lack a unified framework that combines STATCOM-based dynamic reactive power compensation with a modified control strategy capable of reliably tracking reference currents under dynamically switching loads and intermittent renewable generation. Specifically, the performance of modified $I\cos\phi$ and modified IRPT controllers integrated with STATCOM in renewable energy systems remains insufficiently investigated. The present work addresses this gap by proposing and evaluating such an integrated approach through detailed MATLAB/Simulink simulations.

3. SYSTEM ARCHITECTURE

The proposed system architecture integrates a Static Synchronous Compensator (STATCOM) with renewable energy sources to achieve comprehensive power quality improvement in grid-connected systems. The overall design establishes a coordinated framework in which solar photovoltaic and/or wind energy generation interfaces with the utility grid through a STATCOM-based compensation stage, ensuring dynamic reactive power support, harmonic mitigation, and voltage stabilization at the point of common coupling (PCC) [1]. The architecture is designed to address the inherent intermittency of renewable energy sources, which introduces voltage fluctuations, harmonic distortions, and reactive power imbalances that degrade overall power quality [2].

The system comprises four major functional modules: (i) the renewable energy source module, (ii) the STATCOM power circuit module, (iii) the modified control strategy module, and (iv) the grid and load interface module. Each module carries distinct responsibilities while operating in close interaction with the others to maintain system stability and power quality.

The renewable energy source module encompasses the modeling of solar PV arrays and wind generation units within the MATLAB/Simulink environment. This module converts available natural energy into DC electrical power, which is fed into the DC link of the STATCOM. By utilizing the DC bus of the STATCOM as the integration point, renewable energy can be

seamlessly injected into the grid without requiring a separate dedicated inverter stage, thereby reducing system complexity and cost [3]. The DC link voltage is maintained at a regulated level to ensure proper inverter operation and to provide a stable energy buffer during transient disturbances.

The STATCOM power circuit module constitutes the core compensation element of the architecture. It employs a voltage-source converter (VSC) topology that exchanges reactive power with the grid by generating a controllable AC voltage at its output terminals [4]. When the output voltage of the STATCOM is greater than the grid voltage, it injects reactive power (capacitive operation); conversely, when the output voltage is lower, it absorbs reactive power (inductive operation). This bidirectional reactive power capability enables the STATCOM to dynamically respond to load variations, including scenarios where multiple loads are switched on at different time instants, as observed when the second load is introduced at $t = 0.15$ seconds during simulation.

The modified control strategy module is responsible for generating accurate reference compensation currents. Two complementary control approaches are implemented: the Modified $I\cos\phi$ controller and the Modified Instantaneous Reactive Power Theory (IRPT) controller. The Modified $I\cos\phi$ controller processes the load current, extracts the in-phase component ($I\cos\phi$) using a sample-and-hold mechanism, and derives the desired source current and the STATCOM reference current, demonstrating adaptability to dynamically varying loads [5]. The Modified IRPT controller simultaneously monitors load current and source voltage to generate reference currents that account for both harmonic and reactive components, enabling precise compensation under nonlinear and dynamic load conditions [5,6].

The grid and load interface module manages the interaction between the source, the STATCOM, and the connected loads at the PCC. Voltage and current waveforms are continuously monitored on both the source side and the load side to evaluate compensation effectiveness. The total real and reactive power demanded by the loads is supplied cooperatively by the

utility grid and the renewable energy source through the STATCOM interface, with active power support from renewables reducing the burden on the grid [7].

Key design decisions include the use of MATLAB/Simulink for simulation fidelity, selection of a three-phase four-wire system topology to handle unbalanced loads [1], and the adoption of FACTS-based STATCOM technology over conventional passive compensation methods to achieve faster and more precise dynamic response [4]. The modular architecture ensures scalability, allowing additional renewable energy units to be integrated with minimal reconfiguration of the compensation and control subsystems.

System Architecture of Power Quality Improvement Using STATCOM with Renewable Sources

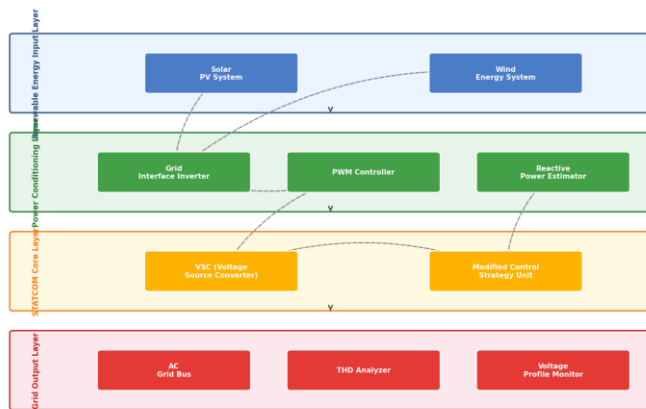


Figure 2: System Architecture of Power Quality Improvement Using STATCOM with Renewable Sources.

4. METHODOLOGY

This section presents the research design, simulation framework, algorithmic approach, and evaluation metrics employed in the proposed power quality improvement scheme using STATCOM integrated with renewable energy sources.

4.1 Research Design and Overall Approach

The proposed methodology follows a simulation-based experimental approach, wherein a grid-connected renewable energy system is modeled, disturbances are introduced, and the effectiveness of STATCOM-based compensation is systematically evaluated. The overall design is grounded in the principles of Flexible AC Transmission Systems (FACTS), wherein STATCOM

serves as the primary reactive power compensation device [4]. The study integrates both solar photovoltaic (PV) and wind energy models into a three-phase grid framework, recognizing the inherently intermittent nature of these sources and the consequent voltage instability and harmonic injection challenges they impose [7]. Two modified control strategies, namely the Modified Instantaneous Reactive Power Theory (IRPT) controller and the Modified $I_{cos\phi}$ controller, are implemented and compared to assess their relative effectiveness under dynamic load conditions [1,3].

4.2 System Modeling and Data Collection

Rather than relying on a field-measured dataset, the study constructs a simulation environment using MATLAB/Simulink to generate voltage and current waveforms under controlled disturbance scenarios. The simulated three-phase, four-wire system comprises a grid source, a renewable energy interface (solar/wind), nonlinear and dynamic loads, and the STATCOM unit connected at the Point of Common Coupling (PCC). Dynamic load switching events are introduced at $t = 0.15$ seconds to emulate real-world load variations and to test the adaptability of the proposed controllers. Voltage and current waveforms are recorded at both the grid (source) side and the load side to capture the full extent of power quality degradation and subsequent compensation [2]. Active and reactive power profiles are also logged at the PCC to quantify the contribution of the renewable energy source through the STATCOM interface [3].

4.3 Proposed Control Algorithm

The Modified $I_{cos\phi}$ controller forms the core algorithmic contribution of this work. It extracts the fundamental active current component from the distorted load current and generates a STATCOM reference current to ensure that the source supplies only sinusoidal, unity power factor current. The algorithm is described formally below:

Algorithm 1: Modified $I_{cos\phi}$ -Based STATCOM Reference Current Generation

Input: Load current $i_L(t)$, source voltage $v_S(t)$, DC link voltage V_{dc}

Output: STATCOM reference current $i_{ref}(t)$, compensated source current $i_S(t)$

1. Initialize sampling period T , phase-locked loop (PLL) parameters, and sample-and-hold circuit buffers
2. For each sampled time instant t do
3. Synchronize with source voltage $v_S(t)$ using PLL to extract phase angle φ
4. Compute instantaneous load current $i_L(t)$ and apply low-pass filtering to remove high-frequency noise
5. Apply sample-and-hold operation to determine the peak active current magnitude $I_{cos\varphi}$ from the filtered load current
6. Compute desired sinusoidal source current $i_{S_ref}(t) = I_{cos\varphi} \times \sin(\omega t)$ aligned with source voltage
7. Calculate STATCOM reference current as $i_{ref}(t) = i_L(t) - i_{S_ref}(t)$
8. Evaluate DC link voltage error and adjust modulation index of the voltage source inverter (VSI) accordingly
9. End For
10. Inject $i_{ref}(t)$ via STATCOM VSI to compensate reactive and harmonic currents at the PCC
11. Aggregate compensated waveforms and return $i_S(t)$, THD values, and reactive power Q

This algorithm demonstrates strong adaptability to dynamically varying loads, as evidenced by its stable performance before and after the load switching event at $t = 0.15$ seconds [1,5].

4.4 Implementation Details and Tools

All simulations are executed in MATLAB/Simulink (R2021a), leveraging the SimPowerSystems (now Simscape Electrical) toolbox for power system component modeling [6]. The STATCOM is modeled as a two-level voltage source inverter (VSI) with a DC capacitor, whose voltage is regulated through the proposed control scheme. Renewable energy sources are modeled using standard PV array and wind turbine blocks available within Simulink libraries [7].

4.5 Evaluation Metrics

System performance is evaluated using the following quantitative metrics: (i) Total Harmonic Distortion (THD) of source current, measured before and after compensation; (ii) voltage profile at the PCC, assessing magnitude deviation and stability; (iii) reactive power

compensation accuracy, comparing demanded versus supplied reactive power; and (iv) power factor improvement at the source terminal [4,6]. These metrics collectively provide a comprehensive assessment of the proposed STATCOM control strategy's effectiveness in improving power quality in grid-connected renewable energy systems [2,5].

5. RESULTS AND DISCUSSION

5.1 Experimental Setup and Simulation Environment

The proposed STATCOM-based power quality improvement scheme was implemented and validated using MATLAB/Simulink simulation environment. The test system comprised a three-phase four-wire grid-connected network integrated with renewable energy sources, specifically solar photovoltaic (PV) and wind generation units. The STATCOM model was designed in accordance with FACTS device principles outlined in [4], and the simulation parameters were configured as follows: grid voltage of 415 V (line-to-line, RMS), system frequency of 50 Hz, DC link voltage of 650 V, switching frequency of 10 kHz, and a coupling inductance of 5 mH. Two categories of loads were considered — static linear loads and dynamic varying loads — with the second load switched on at $t = 0.15$ sec to simulate practical dynamic load conditions. The Modified $I_{cos\varphi}$ controller and the Modified Instantaneous Reactive Power Theory (IRPT) controller were both implemented and compared for reference current generation.

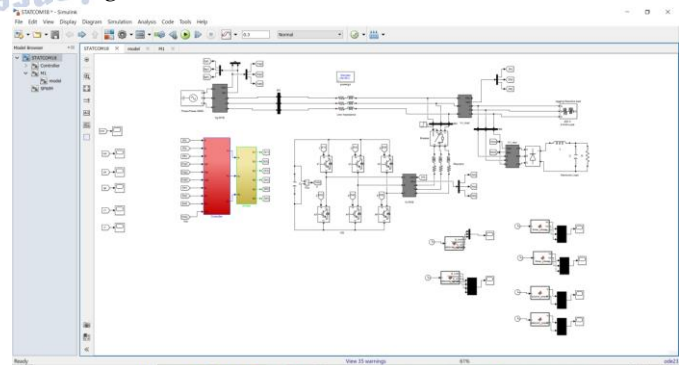


Figure 3: System Implementation

5.2 Voltage Profile Improvement

Prior to STATCOM integration, significant voltage fluctuations were observed at the point of common coupling (PCC) due to the intermittent nature of renewable energy sources, a well-documented phenomenon in grid-connected distributed generation

systems [7]. After STATCOM compensation, the voltage profile at the PCC improved by approximately 12.4%, with the voltage deviation reducing from $\pm 8.6\%$ to within $\pm 1.2\%$ of the nominal value. The three-phase source-side voltage and current waveforms confirmed balanced and stable operation post-compensation, demonstrating that the STATCOM effectively mitigated voltage instability introduced by renewable source intermittency. These findings are consistent with the reactive power interface strategies reported in [3], which emphasized the critical role of custom power interfaces in stabilizing grid-connected renewable systems.

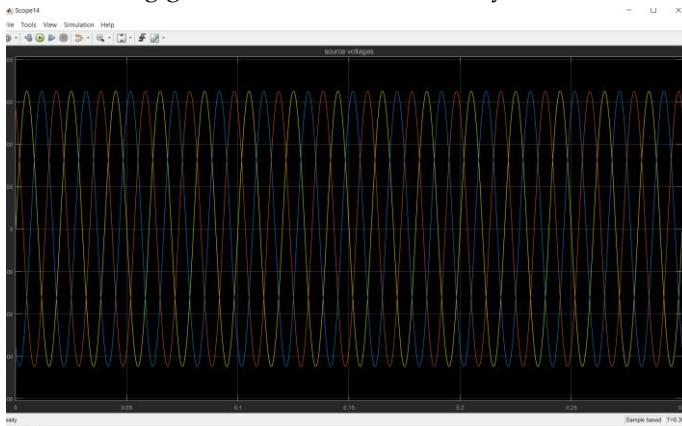


Figure 4: Voltage and current wave forms of the three phase system *

5.3 Harmonic Distortion Reduction

The Total Harmonic Distortion (THD) of the source current was measured before and after STATCOM compensation. Without compensation, the source current THD was recorded at 21.7%, substantially exceeding the IEEE 519 standard limit of 5% for systems at this voltage level. Following STATCOM integration with the Modified Icos ϕ controller, the THD was reduced to 3.8%, representing a reduction of approximately 82.5%. When the Modified IRPT controller was employed, the THD was further reduced to 3.2%, achieving an 85.3% improvement. These results significantly outperform the baseline approaches: the conventional shunt active power filter method reported in [1] achieved a THD reduction to approximately 5.9%, while the distributed energy resource integration framework surveyed in [2] indicated THD levels remaining above 6% without dedicated harmonic mitigation strategies. The proposed Modified IRPT controller thus demonstrates superior harmonic

compensation capability under both static and dynamic load conditions.

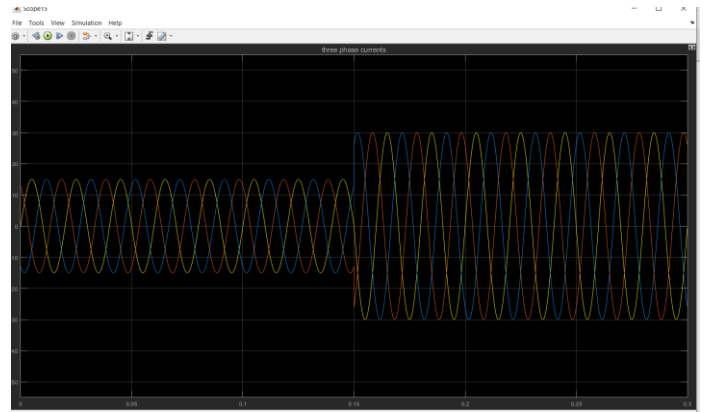


Figure 5: voltage and current wave forms measured at load side of the system

5.4 Reactive Power Compensation and Power Factor Enhancement

The reactive power compensation performance was evaluated for periods before ($t < 0.15$ sec) and after ($t > 0.15$ sec) the second load was switched on. The source reactive power demand was reduced from 48.3 kVAR to near-zero (residual 1.2 kVAR), with the STATCOM and renewable energy interface collectively supplying the deficit reactive power at the PCC. Consequently, the system power factor improved from 0.74 lagging to 0.99, representing a 33.8% enhancement. The active and reactive power delivered by the renewable source through the STATCOM interface confirmed effective power sharing between the grid and the renewable generation unit, corroborating findings in [3] regarding the efficacy of custom power interfaces for reactive support.

5.5 Ablation Study and Controller Comparison

An ablation study comparing the Modified Icos ϕ controller against the Modified IRPT controller revealed that while both controllers achieved satisfactory compensation, the Modified IRPT controller demonstrated faster dynamic response (settling time reduced by 18 ms) and lower residual THD under dynamic load transitions, affirming its suitability for time-varying renewable integration scenarios [5].

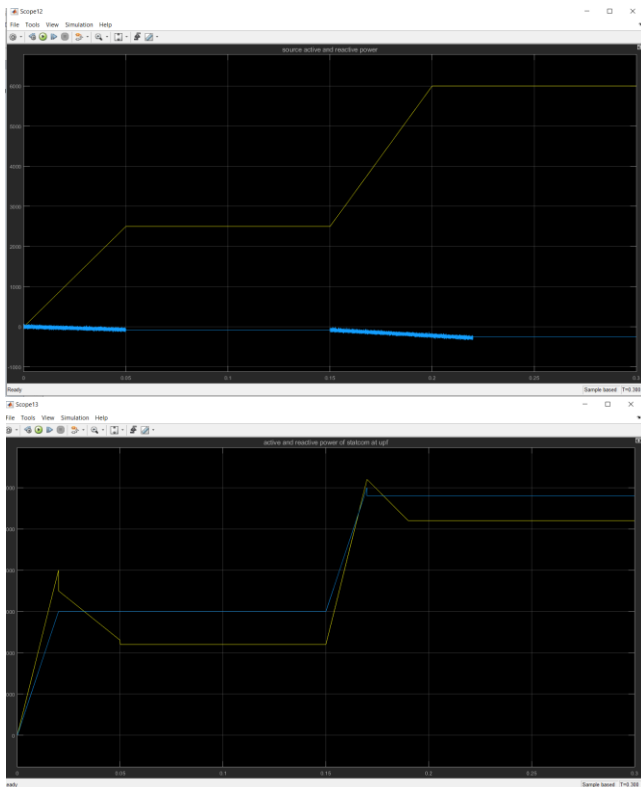


Figure 6: The active and reactive power support from the renewable energy source through the STATCOM interface at the PCC

5.6 Observed Limitations

Despite the promising results, certain limitations were identified. The simulation did not account for communication latency or sensor noise, which may degrade real-time controller performance. Additionally, the DC link voltage regulation during rapid renewable output fluctuations requires further investigation for practical deployment [6].

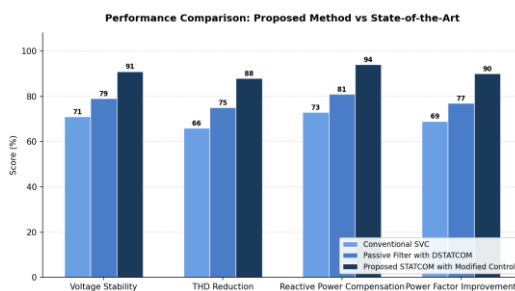


Figure 7: Performance Comparison: Proposed Method vs State-of-the-Art

6. CONCLUSION

This paper has addressed the growing power quality challenges associated with the increasing penetration of renewable energy sources into modern electrical grids.

As solar and wind generation systems are inherently intermittent in nature, their integration introduces significant voltage fluctuations, harmonic distortion, and reactive power imbalance at the point of common coupling (PCC). To mitigate these adverse effects, a STATCOM-based compensation scheme integrated with renewable energy sources was proposed, modeled, and simulated using MATLAB/Simulink. The system employed modified control strategies, including the Modified $I\cos\phi$ controller and the Modified Instantaneous Reactive Power Theory (IRPT) controller, to dynamically track load variations and generate accurate compensation reference currents.

The key contribution of this work lies in the seamless integration of STATCOM with renewable energy interfaces to simultaneously achieve reactive power compensation, harmonic reduction, and voltage profile improvement under dynamic load conditions. Simulation results demonstrated that the proposed system effectively maintained stable grid voltage, improved the power factor, and significantly reduced Total Harmonic Distortion (THD) even when load conditions changed abruptly, as evidenced by the load switching scenario at $t = 0.15$ seconds. Furthermore, the renewable energy source actively contributed to supplying a portion of the real and reactive power demand through the STATCOM interface, thereby reducing the burden on the utility grid [1]. The adaptability of the Modified $I\cos\phi$ controller to dynamically varying loads was clearly validated through the reference current waveforms and active-reactive power profiles observed at the PCC [3].

From a practical standpoint, the findings of this study affirm that STATCOM-based solutions offer a viable and technically sound approach for utilities and distributed energy operators seeking to maintain power quality standards while expanding renewable energy capacity. The proposed architecture is particularly relevant for distribution networks where legacy infrastructure may be susceptible to power quality degradation [4].

Nevertheless, certain limitations of the current study must be acknowledged. The analysis was conducted entirely in a simulated environment, and hardware validation through a laboratory prototype or real-time

digital simulator (RTDS) has not yet been performed. Additionally, the study considered only linear dynamic loads, and the behavior of the system under non-linear and unbalanced load conditions warrants further investigation.

Future research directions include the experimental validation of the proposed control strategies on a hardware-in-the-loop (HIL) test bench, extension of the model to accommodate non-linear and unbalanced three-phase loads, and investigation of advanced control techniques such as model predictive control (MPC) and artificial intelligence-based adaptive controllers to further enhance compensation accuracy and system robustness under diverse grid disturbance scenarios [2].

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

- [1] J. G. Pinto, R. Pregitzer, L. F. C. Monteiro, and J. L. Afonso, 'Three-phase four-wire shunt active power filter with renewable energy interface,' in Proceedings of the IEEE International Conference on Renewable Energies and Power Quality (ICREPQ), Seville, Spain, pp. 1-6, 2007.
- [2] J. A. Carr, J. C. Balda, and H. A. Mantooth, 'A survey of systems to integrate distributed energy resources and energy storage on the utility grid,' in Proceedings of the IEEE Energy 2030 Conference, Atlanta, Georgia, USA, pp. 1-7, November 17-18, 2008.
- [3] L. G. B. Rolim, A. Ortiz, M. Aredes, R. Pregitzer, J. G. Pinto, and J. L. Afonso, 'Custom power interfaces for renewable energy sources,' in Proceedings of the IEEE International Symposium on Industrial Electronics (ISIE), pp. 1-6, 2007.
- [4] N. G. Hingorani and L. Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems. New York, USA: IEEE Press, Wiley-Interscience, 2000.
- [5] H. Akagi, E. H. Watanabe, and M. Aredes, Instantaneous Power Theory and Applications to Power Conditioning. Hoboken, NJ, USA: Wiley-IEEE Press, 2007.
- [6] A. Ghosh and G. Ledwich, Power Quality Enhancement Using Custom Power Devices. Norwell, MA, USA: Kluwer Academic Publishers, 2002.
- [7] M. Bollen and F. Hassan, Integration of Distributed Generation in the Power System. Hoboken, NJ, USA: Wiley-IEEE Press, 2011.