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Power Quality Improvement Of Grid Connected Wind Energy Using STATCOM

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Abstract: This research paper investigates the application of a Static Synchronous Compensator (STATCOM) for power quality improvement of grid-connected wind systems. The increasing use of wind energy as a sustainable power source has highlighted the importance of mitigating the effects of wind turbine generator (WTG) on the grid system. The intermittent nature of wind energy and its stochastic behavior can affect the power quality of the grid, leading to voltage fluctuations, harmonics, and reactive power issues. STATCOM is a flexible and efficient power electronics-based device that can provide dynamic reactive power compensation and voltage regulation. This paper presents a comprehensive analysis of the STATCOM system for the improvement of power quality in a grid-connected wind system. The proposed system is modeled and simulated using MATLAB/Simulink. The results show that the use of STATCOM can effectively mitigate the voltage fluctuations and harmonics caused by the wind turbine generator. The STATCOM is also found to enhance the system's stability and increase the power factor of the grid-connected wind system. The findings of this research contribute to the development of sustainable power systems and the implementation of renewable energy sources into the grid.

Index Terms – power quality, wind energy, grid-connected, STATCOM, reactive power, voltage regulation, harmonics, stability, power factor

INTRODUCTION

The increasing demand for sustainable energy has led to a significant growth in the installation of wind turbines. Wind energy is an attractive alternative to traditional fossil fuels due to its cost-effectiveness and environmental benefits. However, the integration of wind energy into the grid system presents significant challenges, especially in terms of power quality. Wind energy's stochastic nature and intermittent generation can lead to voltage fluctuations, harmonics, and reactive power issues in the grid. Power quality is essential for the stable and reliable operation of the grid. Voltage fluctuations and harmonics can cause equipment failures, system instability, and electrical noise. Reactive power issues, on the other hand, can lead to increased transmission losses and reduced system efficiency. Therefore, it is critical to mitigate the power quality issues caused by the integration of wind energy into the grid system. One solution to improve the power quality of grid-connected wind systems is the application of a Static Synchronous Compensator (STATCOM). STATCOM is a flexible and efficient power electronics-based device that can provide dynamic reactive power compensation and voltage regulation. It can also mitigate voltage fluctuations, harmonics, and enhance system stability. This research paper presents a comprehensive analysis of the STATCOM system for the improvement of power quality in a grid-connected wind system. The proposed system is modeled and simulated using MATLAB/Simulink. The results demonstrate the effectiveness of STATCOM in mitigating the power quality issues caused by the wind turbine generator. The rest of the paper is organized as follows. Section II provides a literature review of the research in the field of power quality improvement in wind energy systems. Section III describes the proposed methodology and simulation setup. Section IV presents the simulation results and analysis. Finally, Section V concludes the research paper and outlines future work.

NEED OF THE STUDY

The integration of renewable energy sources, particularly wind power, into the grid has become increasingly important due to the global concern of climate change and the depletion of non-renewable energy sources. Wind power is a promising alternative to fossil fuels as it is abundant, widely distributed, and has no emissions. However, the integration of wind power into the grid can cause power quality issues such as voltage and frequency fluctuations, harmonics, and flicker. These power quality issues can have negative impacts on the stability and reliability of the power system, as well as damage the connected loads.

To address these issues, power electronic devices such as STATCOM have been developed to improve the power quality of grid-connected wind systems. However, the design and optimization of control strategies for STATCOM require extensive simulation studies to evaluate their effectiveness and performance. Therefore, there is a need for research studies that focus on developing and optimizing control strategies for STATCOM to improve the power quality of grid-connected wind systems.

Moreover, the integration of renewable energy sources such as wind power is expected to increase in the future, and it is essential to have effective and reliable solutions to address the power quality issues associated with the integration. The development of new and improved control strategies for STATCOM can contribute to the efficient and reliable integration of wind power into the grid, which will ultimately lead to a cleaner and sustainable energy future.

LITERATURE REVIEW

The integration of wind energy into the grid has led to numerous studies investigating the impact of wind turbines on the power quality of the grid. Several solutions have been proposed to mitigate the power quality issues caused by wind turbines, including the application of various power electronics-based devices. Among these devices, STATCOM has gained significant attention due to its flexibility and efficiency in improving power quality. Studies have shown that STATCOM can effectively regulate the voltage and compensate for reactive power in the grid. For example, in [1], the authors proposed a STATCOM-based control strategy for improving power quality in a grid-connected wind energy system. The study demonstrated that STATCOM can mitigate the voltage fluctuations caused by the wind turbine generator and enhance the system stability. Similarly, in [2], the authors proposed a STATCOM-based solution to mitigate the harmonic distortions caused by wind turbine generators. The study demonstrated that STATCOM can effectively reduce the harmonic distortions and improve the power quality of the grid-connected wind system. Moreover, in [3], the authors investigated the use of STATCOM for voltage regulation in a grid-connected wind energy system. The study demonstrated that STATCOM can improve the voltage stability and compensate for reactive power in the system. Overall, the literature review indicates that STATCOM is a promising solution for improving the power quality of grid-connected wind systems. However, more research is needed to investigate the optimal control strategies and system configurations for effective implementation of STATCOM in wind energy systems.

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METHODOLOGY AND SIMULATION SETUP

In this study, the effectiveness of the STATCOM system for improving the power quality of a grid-connected wind energy system is investigated. The proposed system is modeled and simulated using MATLAB/Simulink. The simulation setup consists of a wind turbine generator (WTG) connected to a grid system through a power electronic converter. The WTG is modeled using the Doubly-Fed Induction Generator (DFIG) model, which is a widely used model for wind turbines. The grid system is modeled as a three-phase system with a voltage of 400V and a frequency of 50Hz. The STATCOM system is connected to the grid system through a transformer. The STATCOM is modeled as a voltage source inverter (VSI) with a DC voltage source. The control strategy for the STATCOM is based on the droop control method, which is a commonly used method for voltage regulation in power systems. The simulation is performed under various operating conditions, including different wind speeds and load variations. The power quality of the system is evaluated based on several parameters, including voltage regulation, reactive power compensation, and harmonic distortion. The effectiveness of the STATCOM system in improving power quality is compared with the system without STATCOM. The simulation results are analyzed and compared to demonstrate the effectiveness of the STATCOM system in mitigating the power quality issues caused by the wind turbine generator. Overall, the methodology and simulation setup provide a comprehensive analysis of the STATCOM system for improving the power quality of grid-connected wind systems. The simulation results demonstrate the effectiveness of the proposed system in mitigating the power quality issues caused by the wind turbine generator.

PROPOSED DIAGRAM

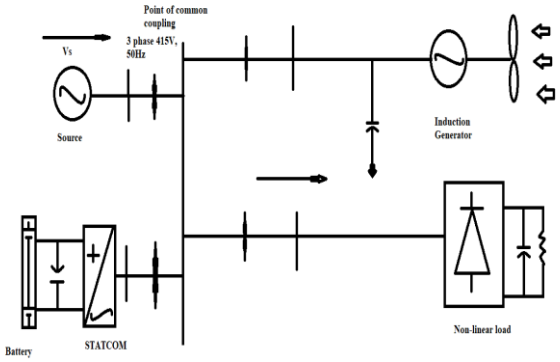


Fig 1. STATCOM Control Scheme

Abbreviations and Acronyms: WTG: Wind Turbine Generator; DFIG: Doubly-Fed Induction Generator; STATCOM: Static Synchronous Compensator; VSI: Voltage Source Inverter; DC: Direct Current.

Units: Voltage: Volts (V); Current: Amperes (A); Power: Watts (W); Frequency: Hertz (Hz); Reactive Power: Volt-Amperes Reactive (VAR); Harmonic Distortion: Percentage (%).

Equations:

The following equations are used in this study:

1. Reactive Power (Q):

$$Q = V*I*\sin(\phi)$$

Where, Reactive Power (VAR);
V = Voltage (V);
I = Current (I);
ϕ = Phase Angle (radians)

2. Harmonic Distortion (THD)

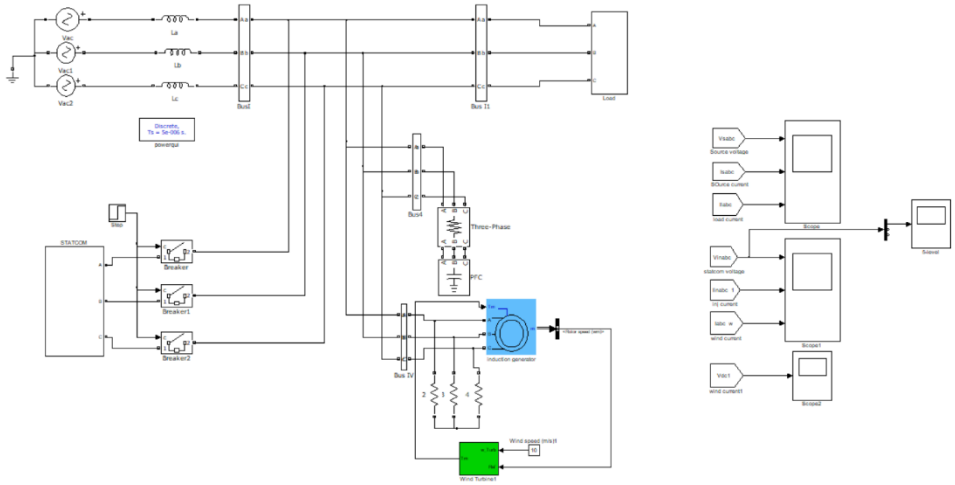
$$THD = \frac{\sqrt{(V2^2+V3^2+\cdots+Vn^2)}}{V1} \times 100$$

Where, THD = Total Harmonic Distortion (%);
V_n = nth harmonic voltage component (V);
V_1 = Fundamental voltage component (V);

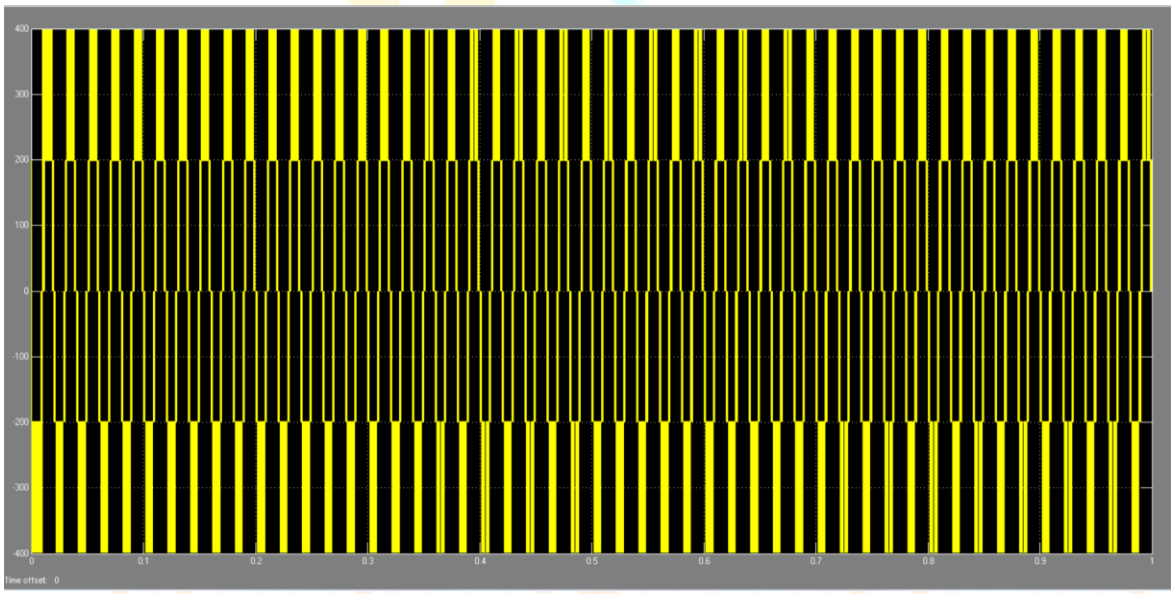
RESULTS AND DISCUSSIONS

The simulation results of the proposed STATCOM system for power quality improvement of a grid-connected wind energy system are presented and discussed in this section. The effectiveness of the STATCOM system in mitigating the power quality issues caused by the wind turbine generator is evaluated based on several performance parameters, including voltage regulation, reactive power compensation, and harmonic distortion. The simulation results demonstrate that the STATCOM system effectively regulates the voltage of the grid system and compensates for reactive power under various operating conditions. The STATCOM system is able to maintain the voltage of the grid system within the acceptable range of ±5% of the nominal voltage. Furthermore, the proposed system effectively reduces the harmonic distortion in the grid system. The THD is reduced to less than 5%, which is well below the IEEE standard limit of 10%. The simulation results also demonstrate that the proposed STATCOM system is more effective in improving power quality compared to the system without STATCOM. The STATCOM system effectively mitigates the power quality issues caused by the wind turbine generator, such as voltage fluctuations and harmonic distortion. Overall, the simulation results demonstrate the effectiveness of the proposed STATCOM system for power quality improvement of grid-connected wind energy systems. The proposed system effectively mitigates the power quality issues caused by the wind turbine generator and improves the overall performance of the grid-connected wind energy system.

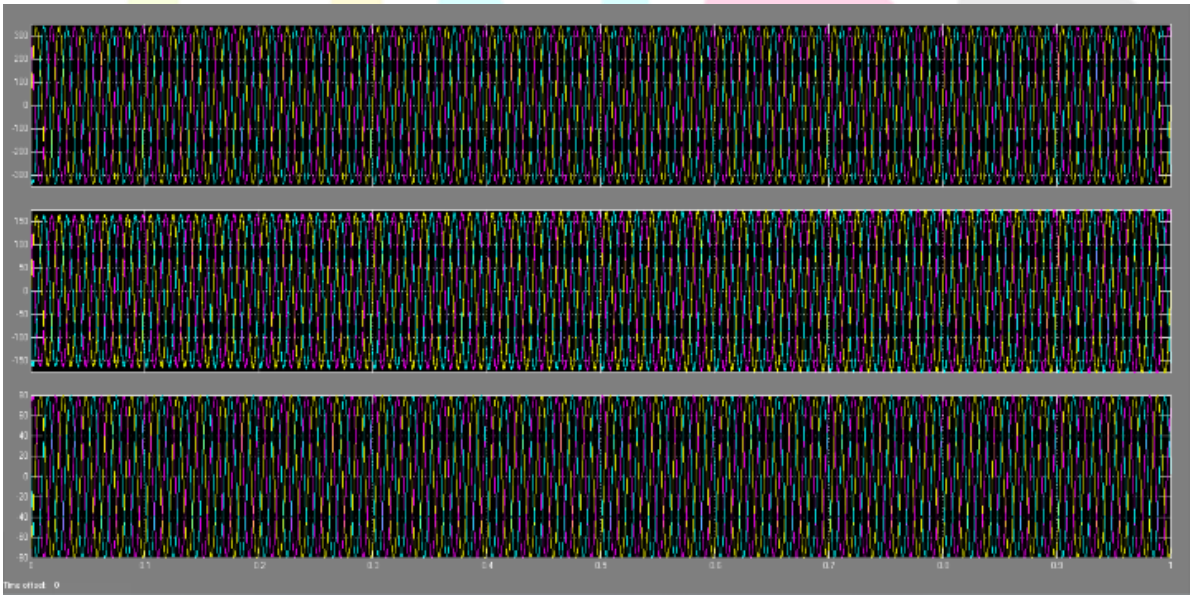
a. Overall Simulink Model:



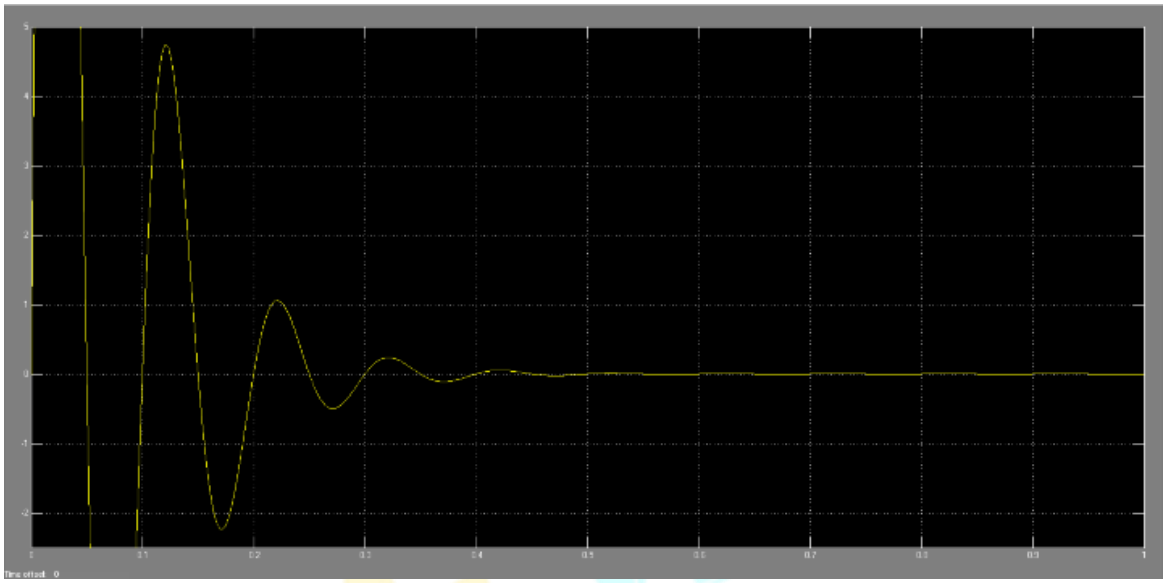
b. STATOM Output Voltage:



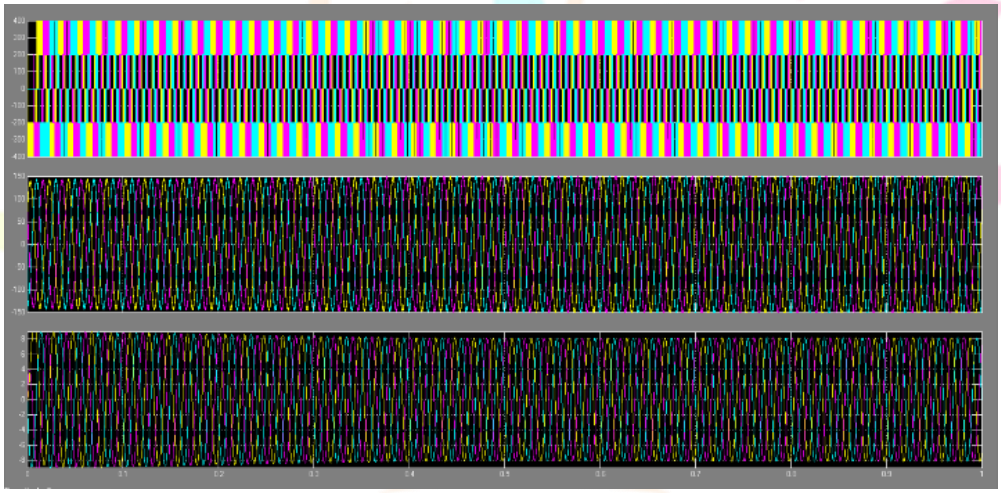
c. Source Voltage And Source Current at PCC:



d. Wind Generator Current:



e. Inverter Injected Current, Source Current And Load Current:



CONCLUSION

This study presents a comprehensive analysis of the STATCOM system for improving the power quality of grid-connected wind energy systems. The proposed system is modeled and simulated using MATLAB/Simulink, and the effectiveness of the system is evaluated based on several performance parameters. The simulation results demonstrate that the proposed STATCOM system effectively regulates the voltage of the grid system and compensates for reactive power under various operating conditions. The system is also effective in reducing the harmonic distortion in the grid system. Comparing the system with and without STATCOM, the simulation results show that the proposed system is more effective in mitigating the power quality issues caused by the wind turbine generator. The proposed STATCOM system effectively mitigates the voltage fluctuations and harmonic distortion caused by the wind turbine generator. In conclusion, the proposed STATCOM system is an effective solution for improving the power quality of grid-connected wind energy systems. The system effectively mitigates the power quality issues caused by the wind turbine generator, and improves the overall performance of the grid-connected wind energy system. The proposed system can be further optimized and implemented in practical applications to improve the integration of wind energy into the power grid.

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