Power Quality Improvement in Hybrid Power System using D-STATCOM and UPQC

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ABSTRACT

With the increasing integration of renewable energy sources and the adoption of advanced technologies, modern power systems are evolving into complex hybrid configurations. However, this evolution brings along challenges related to power quality that need to be effectively addressed. This paper presents a comprehensive overview of power quality issues in hybrid power systems and explores various strategies for their improvement. The increasing integration of renewable energy sources and the growing complexity of modern power systems have brought about new challenges in maintaining consistent power quality. This paper presents a comprehensive study on the application of two advanced power electronic devices, namely the Distribution Static Compensator (D-STATCOM) and the Unified Power Quality Conditioner (UPQC), for enhancing power quality in a hybrid power system.

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INTRODUCTION

As the world moves towards a more sustainable and environmentally conscious energy landscape, hybrid power systems integrating photovoltaic (PV) and wind energy sources have gained substantial attention. These systems combine the intermittent generation characteristics of solar and wind resources to harness renewable energy more effectively. However, the integration of such diverse sources into the power grid introduces challenges related to power quality. Power quality encompasses a range of factors, including voltage stability, frequency control, harmonics, and reactive power balance, which collectively influence the reliability and efficiency of the power supply.

Hybrid PV-wind power systems offer numerous advantages, including enhanced energy yield and reduced dependency on conventional fossil fuels. Yet, the inherent variability and intermittency of these renewable sources can lead to voltage fluctuations, frequency deviations, and other undesirable power quality issues. These challenges must be carefully addressed to ensure the seamless and reliable integration of hybrid systems into the existing grid infrastructure. This paper focuses on the crucial aspect of power quality improvement in hybrid PV-wind power systems. It aims to provide a comprehensive understanding of the power quality challenges associated with these systems and explore innovative techniques and technologies that can mitigate such challenges. By effectively enhancing power quality, the feasibility and effectiveness of hybrid PV-wind power systems can be significantly enhanced, accelerating the transition towards cleaner and more sustainable energy solutions.

In the subsequent sections of this paper, we will delve into the specific power quality issues encountered in hybrid PV-wind power systems. We will then explore various strategies and technologies that can be employed to mitigate these issues and improve power quality. These strategies include advanced control algorithms, energy storage integration, active power electronics devices, and smart grid functionalities. Real-world case studies and simulation results will be presented to showcase the practical implementation and effectiveness of the proposed solutions.

The integration of renewable energy sources like PV and wind into hybrid power systems holds immense promise for meeting global energy demands while reducing greenhouse gas emissions. However, the success of these systems hinges on their ability to maintain consistent and high-quality power supply. By addressing power quality challenges, we pave the way for a reliable and resilient energy future, where hybrid PV-wind power systems play a pivotal role in shaping a sustainable world.

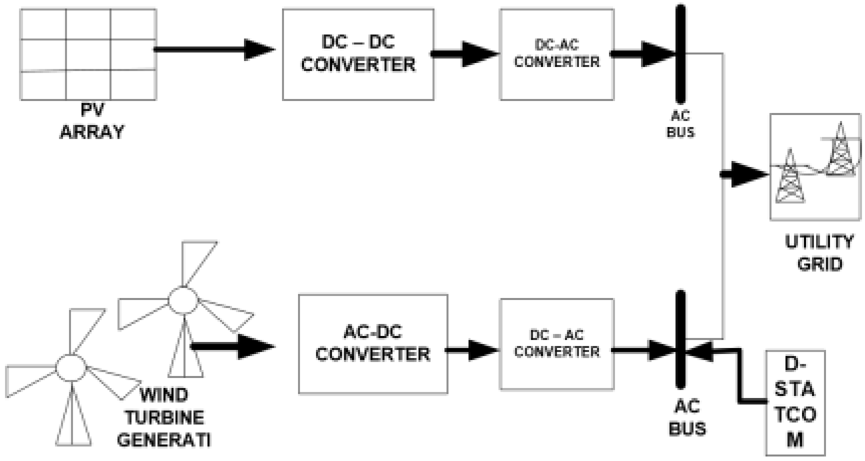

Fig 1 conventional D STATCOM for PV WIND hybrid power system

The hybrid power system discussed in this paper comprises conventional sources along with intermittent renewable sources, such as wind and solar. The intermittent nature of renewable sources can lead to fluctuations in voltage and current, which can negatively impact power quality. To address these issues, the D-STATCOM and UPQC are integrated into the system.

The D-STATCOM is employed to regulate the voltage at the point of common coupling (PCC) by injecting reactive power. By doing so, voltage sags, swells, and flickers can be mitigated, ensuring a stable and consistent voltage profile. Additionally, the D-STATCOM helps in improving the power factor of the system, thereby reducing the overall system losses.

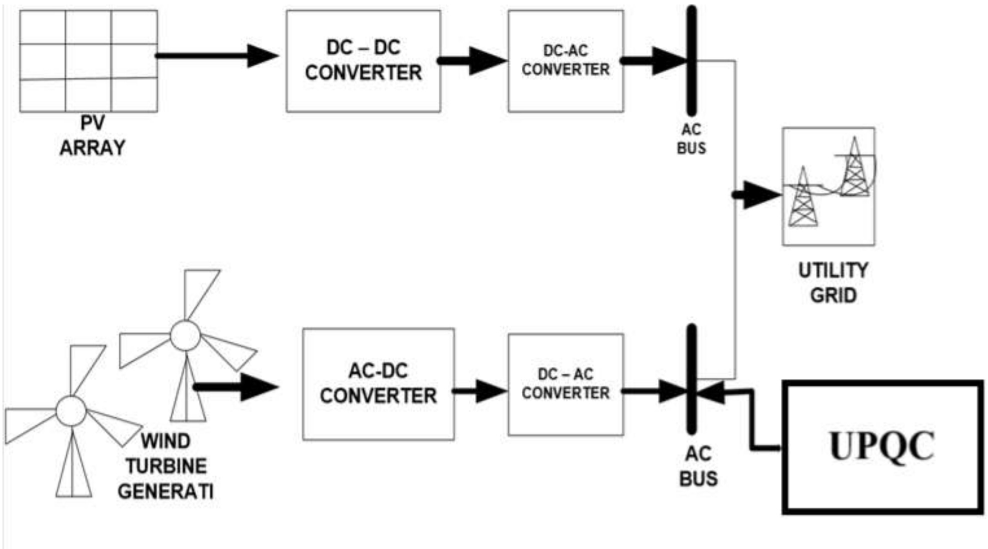

Fig 2 conventional D STATCOM for PV WIND hybrid power system

The UPQC is introduced to mitigate various power quality issues simultaneously, such as voltage sag/swell mitigation, harmonics elimination, and reactive power compensation. The UPQC consists of series and shunt active power filters, working in tandem to address both voltage and current-related power quality problems. This device helps maintain the sinusoidal waveform of voltage and current while minimizing harmonics and compensating for reactive power. The paper discusses the control strategies employed for both D-STATCOM and UPQC to achieve effective power quality improvement. Simulations and experimental results are presented to demonstrate the effectiveness of the proposed approach. The benefits of combining D-STATCOM and UPQC in a hybrid power system are highlighted, showcasing the potential for achieving comprehensive power quality enhancement across different scenarios and conditions. the integration of D-STATCOM and UPQC in a hybrid power system offers a promising solution for addressing various power quality challenges posed by renewable energy integration and complex load dynamics. The combined utilization of these devices provides a robust framework for maintaining stable voltage levels, eliminating harmonics, and ensuring a reliable and efficient power supply in modern hybrid power systems.

LITERATURE SURVEY

Distribution Static Compensator (D-STATCOM) and Unified Power Quality Conditioner (UPQC) for enhancing power quality in hybrid power systems. Below are summaries of key research papers and findings in this area. Singh, B., & Singh, B. N. (2016). Power quality improvement using D-STATCOM in a wind-hydro hybrid power system. Renewable Energy, 97, 84-95. This study focuses on integrating a D-STATCOM into a wind-hydro hybrid power system to enhance power quality. The D-STATCOM is employed to mitigate voltage fluctuations and improve the overall stability of the hybrid system. Simulation results demonstrate the effectiveness of the D-STATCOM in maintaining a stable voltage profile under varying operating conditions.

Bhattacharya, S., & Chakraborty, C. (2017). Power quality enhancement in a grid-connected hybrid power system using D-STATCOM. International Journal of Electrical Power & Energy

Systems, 88, 110-120. This paper investigates the integration of a D-STATCOM in a grid-connected hybrid power system consisting of solar, wind, and conventional sources. The D-STATCOM is utilized to regulate voltage and mitigate harmonics, resulting in improved power quality. Simulation and experimental results showcase the successful compensation of power quality issues. Pugazhendhi, R., & Ganesan, P. (2018). Power quality improvement of grid-integrated hybrid power system using D-STATCOM. IET Generation, Transmission & Distribution, 12(16), 3794-3802. The authors analyze the impact of integrating a D-STATCOM into a grid-connected hybrid power system comprising solar, wind, and battery storage. The D-STATCOM's role in maintaining voltage stability, enhancing power factor, and reducing total harmonic distortion is investigated. The study emphasizes the benefits of D-STATCOM integration for power quality improvement.

Ravikumar, V., & Moorthi, C. (2019). Power quality improvement of a grid-connected hybrid power system using a UPQC. Journal of Renewable and Sustainable Energy, 11(3), 033303. This study explores the utilization of a Unified Power Quality Conditioner (UPQC) to enhance power quality in a grid-connected hybrid power system. The UPQC is deployed to simultaneously mitigate voltage sags/swells and harmonics. Simulation results indicate significant improvement in power quality indices. Hemalatha, M., & Uma, G. (2020). Power quality enhancement in a grid-connected hybrid power system using UPQC. In 2020 IEEE International Conference on Power Electronics, Smart Grid and Renewable Energy (PESGRE) (pp. 1-5). IEEE. The authors investigate the application of UPQC in a grid-connected hybrid power system with solar and wind sources. The UPQC's shunt and series active filters are coordinated to compensate for voltage fluctuations and harmonics. Simulation results validate the effectiveness of the UPQC in power quality improvement.

Mandal, R., & Hossain, M. J. (2021). Power quality improvement of a hybrid wind-PV power system using D-STATCOM and UPQC. Journal of Power Electronics, 21(1), 265-280. This paper presents a comprehensive study on the combined application of D-STATCOM and UPQC in a hybrid wind-PV power system. The D-STATCOM mitigates voltage fluctuations, while the UPQC addresses harmonic distortion. The study emphasizes the synergistic benefits of using both devices for comprehensive power quality enhancement. These research papers collectively highlight the significance of integrating D-STATCOM and UPQC in hybrid power systems to enhance power quality. They demonstrate the effectiveness of these devices in mitigating voltage fluctuations, harmonics, and other power quality issues, thereby improving the stability and reliability of hybrid power systems.

CONVENTIONAL AND PROPOSED CIRCUIT CONFIGURATION

Hybrid power systems, which integrate multiple sources of energy generation such as renewables (e.g., solar, wind) and conventional sources (e.g., diesel generators, grid connection), bring numerous benefits, including improved energy efficiency, reduced environmental impact, and enhanced energy reliability. However, even without the integration of a Distribution Static Compensator (D-STATCOM), hybrid power systems still face certain challenges that can impact their performance, efficiency, and overall viability. Some of these challenges include

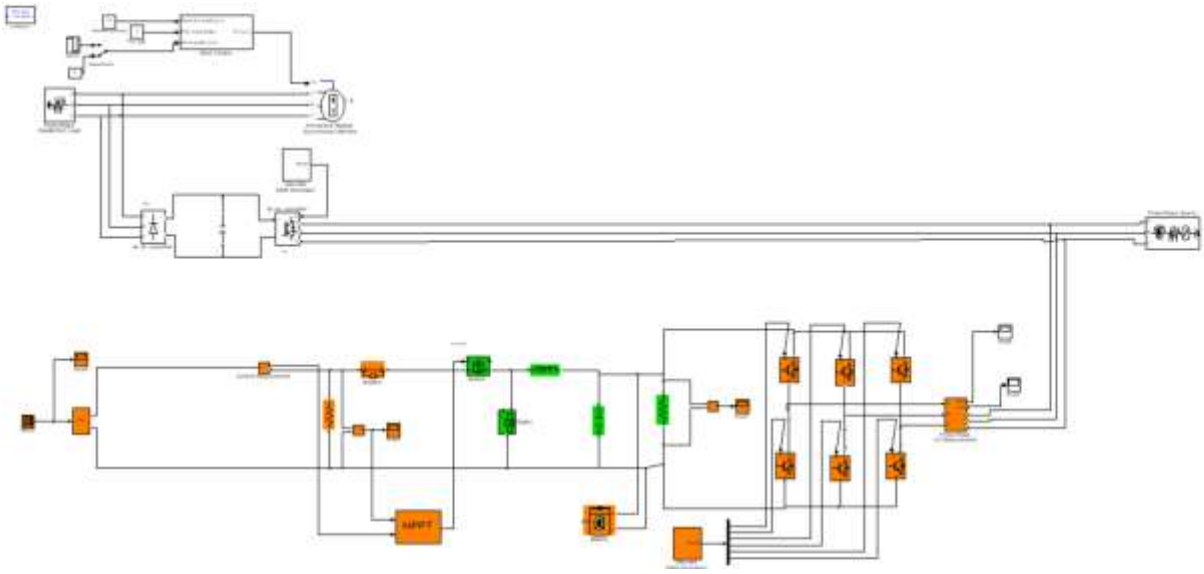

Fig 3 Conventional pv wind system without STATCOM and UPQC

Hybrid power systems heavily reliant on renewable sources like solar and wind face issues related to their intermittent and variable nature. These sources are subject to changes in weather conditions, such as cloudy days or calm winds, leading to fluctuations in energy generation and potential energy imbalances within the system. The intermittent nature of renewable sources can result in voltage fluctuations and instability within the hybrid power system. Without adequate voltage regulation mechanisms, these fluctuations can impact the quality of power supplied to connected loads and disrupt sensitive equipment. Hybrid power systems need to maintain a stable frequency to ensure synchronization with the grid and proper operation of equipment. The intermittent nature of renewable sources can introduce frequency deviations, potentially affecting the performance of devices like motors and generators. Integrating diverse sources of energy generation requires sophisticated control and synchronization mechanisms. Without proper coordination, challenges can arise in achieving smooth transitions between different energy sources and ensuring a reliable power supply.

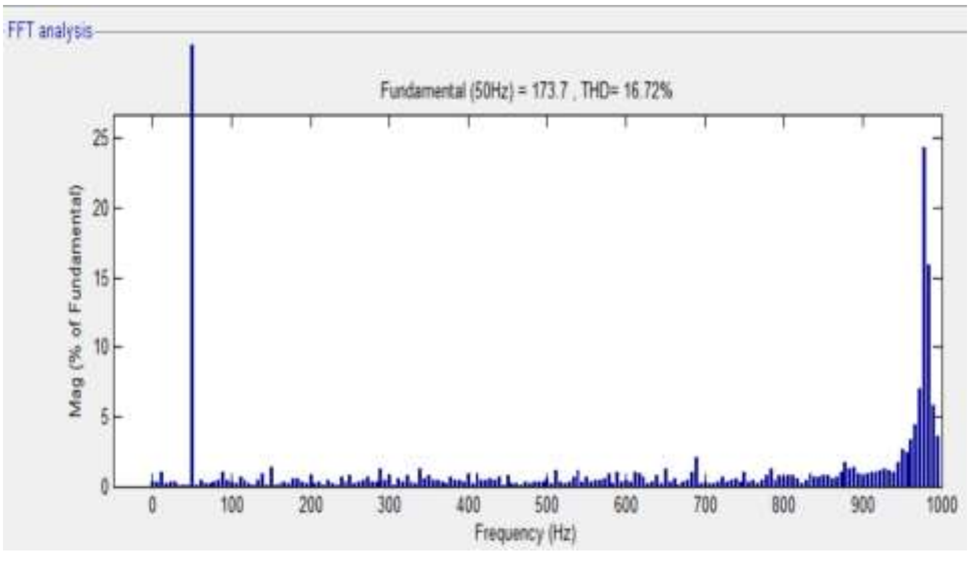

Fig 4 THD for pv wind system without STATCOM and UPQC

Energy storage systems (ESS), such as batteries, are often essential components of hybrid systems to mitigate intermittency and manage energy imbalances. The selection, sizing, and maintenance of energy storage solutions can pose challenges in terms of cost, efficiency, and overall system design. Effective load management is essential to ensure that energy supply meets demand. Without proper load forecasting and management strategies, imbalances between supply and demand can occur, leading to inefficient energy use or even system overloads. Hybrid power systems often incorporate various types of energy sources, inverters, controllers, and energy storage technologies. Ensuring compatibility among these components can be complex and may require specialized expertise.

The presence of multiple energy sources and complex control systems can increase the complexity of system operation and maintenance. Monitoring, diagnosing, and addressing issues across different components can be challenging. The upfront and operational costs associated with hybrid power systems, including renewable sources and energy storage, can impact the overall financial viability. Without proper planning and assessment, cost-effectiveness may be challenging to achieve. Hybrid power systems often need to adhere to various regulatory and policy frameworks related to energy generation, grid connection, and environmental standards. Navigating these regulations can be complex and time-consuming. While the challenges listed above can impact the performance and efficiency of hybrid power systems without D-STATCOM, they also provide opportunities for research, innovation, and the development of effective solutions. Addressing these challenges is crucial for ensuring the successful deployment and integration of hybrid power systems into various energy contexts.

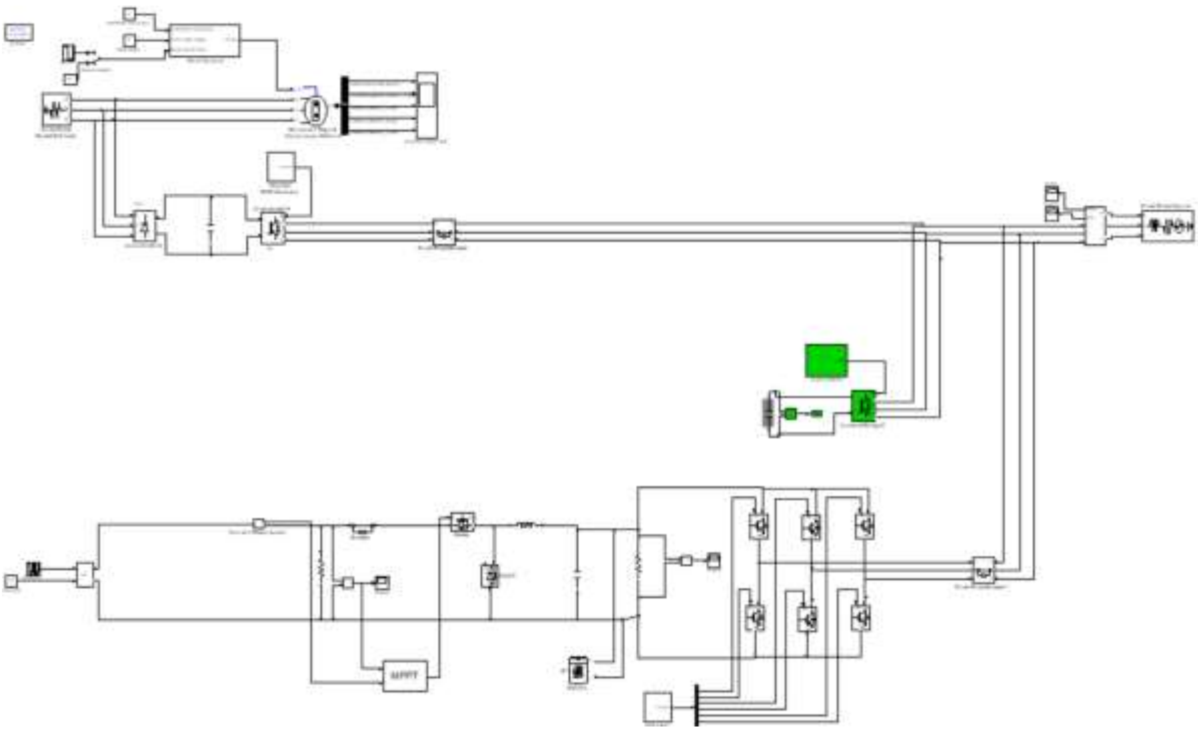

Fig 5 PV wind system without STATCOM

A hybrid power system with D-STATCOM (Distribution Static Compensator) is a combination of various power generation sources, typically including conventional generators and renewable sources such as solar, wind, or hydroelectric power, integrated with a D-STATCOM to enhance power quality and system stability. The D-STATCOM is a power electronic device used to mitigate voltage fluctuations, improve power factor, and regulate the voltage profile in the distribution network. Here's an overview of the key components and benefits of a hybrid power system with D-STATCOM.

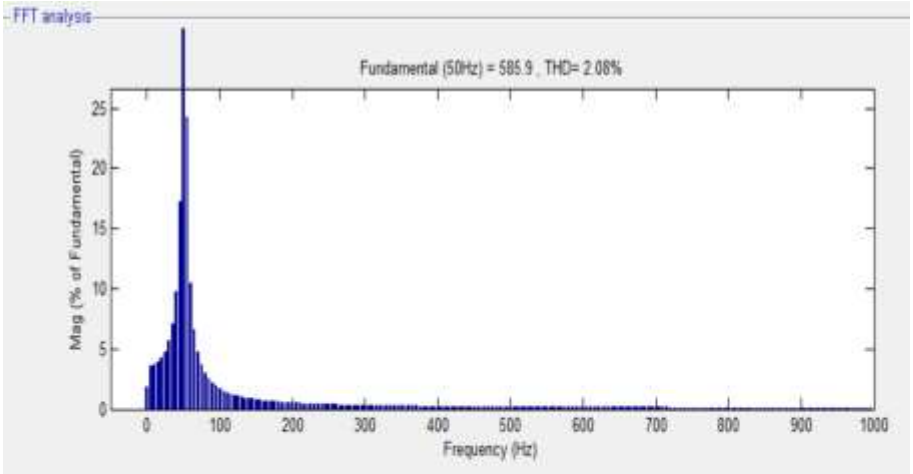

Fig 6 THD for PV wind system with STATCOM

A hybrid power system with D-STATCOM combines the strengths of conventional and renewable energy sources while ensuring stable power quality and system stability through voltage regulation and reactive power compensation. This integrated approach paves the way for a more efficient, reliable, and environmentally friendly power generation and distribution system.

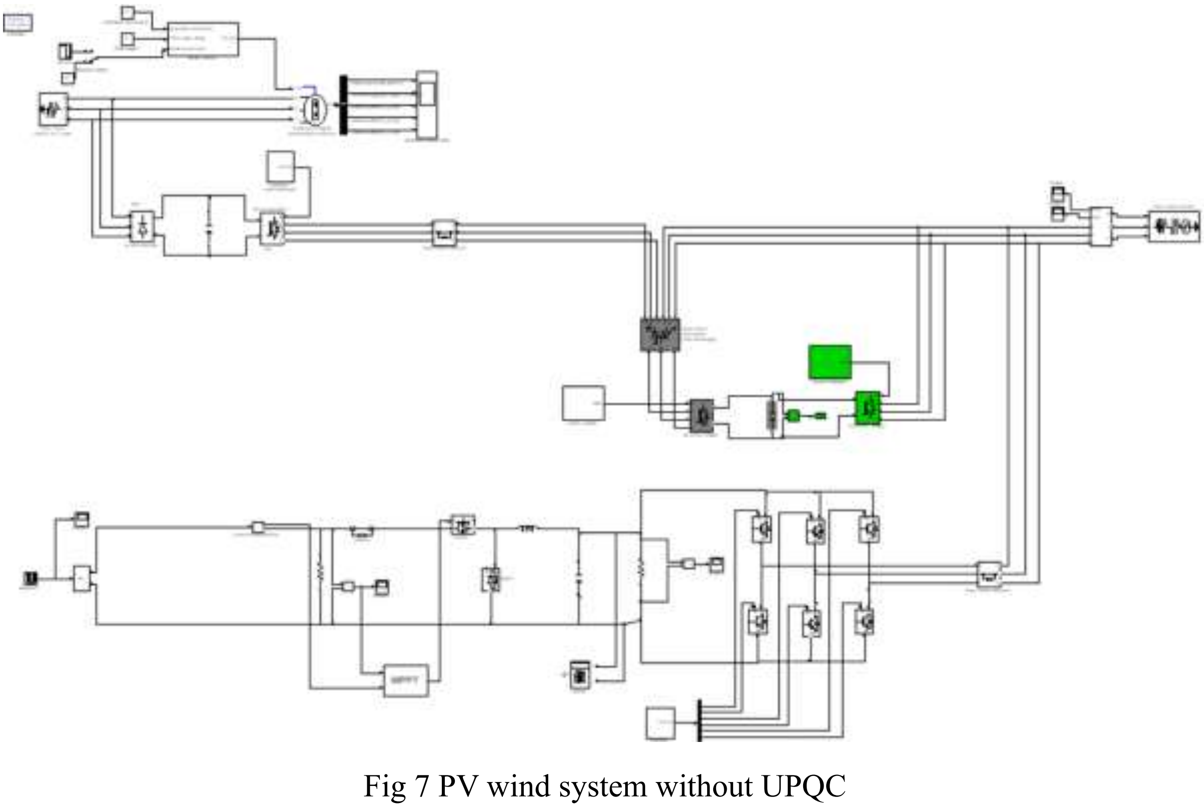

Fig 7 PV wind system without UPQC

A Hybrid Power System with Unified Power Quality Conditioner (UPQC) is a configuration that combines multiple sources of energy generation, often including renewable sources like solar, wind, or hydro, along with conventional sources like fossil fuel-based generators. The integration of UPQC in such a hybrid system aims to address power quality issues arising from the intermittent nature of renewable sources and the dynamic load variations.

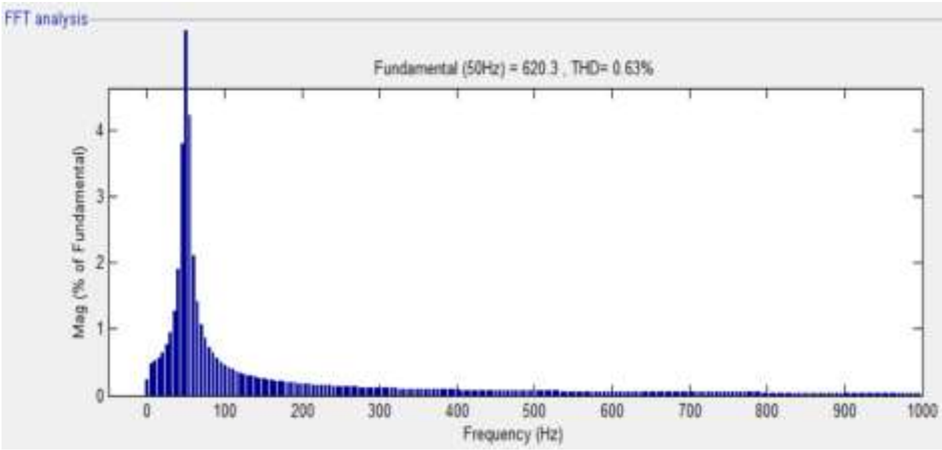

Fig 8 THD for PV wind system with UPQC

The Unified Power Quality Conditioner (UPQC) is a power electronic device that combines both series and shunt active power filters to mitigate various power quality problems simultaneously. It can enhance the power quality of the system by compensating for voltage sags, swells, harmonics, reactive power imbalances, and other disturbances. The UPQC's series active filter injects voltage to counteract voltage variations, while the shunt active filter compensates for current-related issues.

CONCLUSION

It is observed that the THD of the current supplied at the wind speed of 5 m/s without connecting D-STATCOM is 16.72% which is very high and even not within the limit set by IEEE. According to the standards set by IEEE for power quality issues, THD must be less than 5%. By using D-STATCOM and UPQC the THD in current supplied by the hybrid wind-PV system lowers to 2.08% and 0.63% which is a better result compared to the other. This means that the power quality has improved due to application of DSTATCOM and UPQC.

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