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Power Quality Improvement of Hybrid Power System by Using D-STATCOM

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ABSTRACT

New challenges have emerged for the utility load in terms of power quality, voltage stabilization, and efficient energy utilization as a result of the pervasive usage of distributed energy sources inside the electricity system. Most experts agree that solar and wind power are the most reliable forms of renewable energy. However, due to the unpredictability of wind and solar irradiation, it is difficult to rely on photovoltaic or wind energy systems as a sole source of electricity generation. Consequently, a mix of wind and solar power producing facilities can provide a highly promising and secure supply of electrical power. A combined wind and PV system model is described in this paper. Remote or island communities, where connecting to the grid can be costly, can benefit greatly from this type of technology. However, power distribution system disturbances, such as harmonic production and reactive power adjustment, are induced by the connecting of power electronic devices to DG systems. A 750 kilowatt (KW) hybrid wind-PV generation system simulation model has been given in this work. This system's efficiency in grid-connected mode is evaluated. At varying wind speeds, total harmonics distortion (THD) was calculated to assess the power quality of the wind-SPV hybrid system. Using D-STATCOM, the power quality of this hybrid system was enhanced.

INTRODUCTION

Power quality is a critical aspect of electrical systems, ensuring the reliable and efficient operation of equipment and preventing disruptions. Hybrid power systems, which integrate renewable energy sources, energy storage systems, and conventional generators, face challenges in maintaining power quality due to the variability and intermittency of renewable sources and dynamic load variations. In such systems, power quality issues such as voltage sags/swells, harmonics, unbalance, and flicker can occur, affecting the stability and performance of the system. To address these power quality concerns, the use of Distributed Static Compensator (D-STATCOM) has gained significant attention. D-STATCOM is a shunt-connected power electronic device that operates by injecting or absorbing reactive power as needed to mitigate voltage fluctuations, compensate for reactive power imbalances, and improve power quality. By actively controlling the reactive power flow, D-STATCOM helps stabilize voltage levels, reduce harmonics, and enhance overall power system performance.

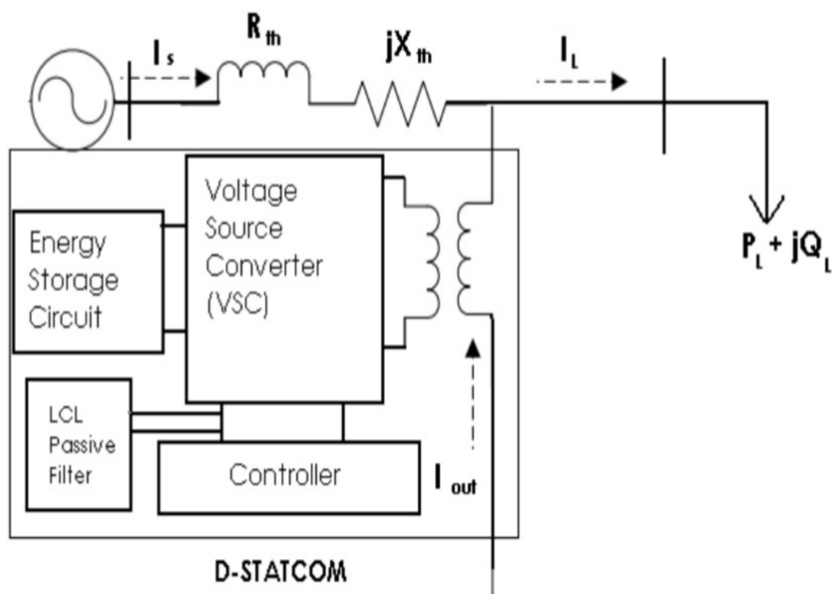

Fig 1 block diagram for D-STATCOM

The objective of this study is to explore the application of D-STATCOM in improving power quality in a hybrid power system. By integrating D-STATCOM into the system, it becomes possible to regulate voltage levels, mitigate voltage fluctuations caused by intermittent renewable sources, and compensate for reactive power imbalances resulting from dynamic load variations. This, in turn, ensures a stable and high-quality power supply to sensitive equipment and minimizes downtime. The study will include the development of a simulation model in MATLAB/Simulink to analyze the impact of D-STATCOM on power quality parameters such as voltage deviation, total harmonic distortion (THD), and power factor. Different control strategies and scenarios will be investigated to assess the effectiveness of D-STATCOM in enhancing power quality and optimizing its performance in a hybrid power system. The findings of this study will contribute to a better understanding of the benefits and challenges associated with using D-STATCOM for power quality improvement in hybrid power systems. The insights gained will assist in the design and implementation of effective power management strategies to ensure reliable and efficient operation of hybrid power systems while meeting stringent power quality requirements.

LITERATURE SURVEY

"Power Quality Improvement of Hybrid Power System Using D-STATCOM in PV-Wind Energy Conversion System" by P. Gowri et al. (2015) This study investigates the use of D-STATCOM in a PV-wind hybrid power system for power quality enhancement. The authors propose a control strategy for D-STATCOM to regulate voltage, compensate for reactive power imbalances, and mitigate harmonics. Simulation results demonstrate improved power quality and stable operation of the hybrid system.

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"Power Quality Improvement of Grid-Connected Hybrid Wind and PV Systems Using D-STATCOM" by M. Esmaeili et al. (2017) The authors analyze the power quality issues in a grid-connected PV-wind hybrid system and propose the utilization of D-STATCOM for power quality enhancement. They develop a control strategy based on a fuzzy logic controller for D-STATCOM to mitigate voltage fluctuations, regulate voltage levels, and compensate for reactive power. The study demonstrates the effectiveness of D-STATCOM in improving power quality parameters.

"Power Quality Improvement of Grid-Connected Hybrid PV/Wind Power System Using D-STATCOM" by T. Subramani et al. (2018) This research focuses on the power quality improvement of a grid-connected PV-wind hybrid power system using D-STATCOM. The authors propose a control algorithm for D-STATCOM to enhance voltage stability, compensate for reactive power, and mitigate harmonics. The simulation results validate the effectiveness of the proposed control strategy in improving power quality.

"Power Quality Improvement in Hybrid PV/Wind Power System Using D-STATCOM" by M. Naveen Kumar et al. (2019) This study presents a comprehensive analysis of power quality issues in a hybrid PV-wind power system and explores the application of D-STATCOM for power quality improvement. The authors propose a control strategy for D-STATCOM to regulate voltage, compensate for reactive power, and mitigate harmonics. Simulation results demonstrate the successful reduction of power quality issues and improved system performance.

"Power Quality Improvement of Hybrid Wind/PV System Using D-STATCOM" by V. J. Ghangrekar et al. (2020) The authors investigate the power quality issues in a hybrid wind-PV system and propose the use of D-STATCOM for power quality enhancement. They develop a control algorithm for D-STATCOM to improve voltage stability, regulate voltage levels, and compensate for reactive power. The study demonstrates the effectiveness of D-STATCOM in improving power quality and system performance.

These selected research articles provide insights into the application of D-STATCOM in PV-wind hybrid power systems for power quality improvement. They discuss various control strategies and simulation results that highlight the effectiveness of D-STATCOM in mitigating power quality issues such as voltage fluctuations, reactive power imbalances, and harmonics. The literature survey serves as a foundation for further research and development in this field, contributing to the advancement of power quality improvement techniques in hybrid renewable energy systems.

PROPOSED SYSTEM SIMULATION

Hybrid power systems, which integrate renewable energy sources, energy storage systems, and conventional generators, are becoming increasingly popular due to their potential to provide reliable and sustainable power supply. However, these systems face challenges in maintaining power quality without the use of mitigation devices like Distributed Static Compensator (D-STATCOM). In this context, this introduction discusses the power quality issues that can arise in hybrid power systems without D-STATCOM and the potential impacts on system performance.

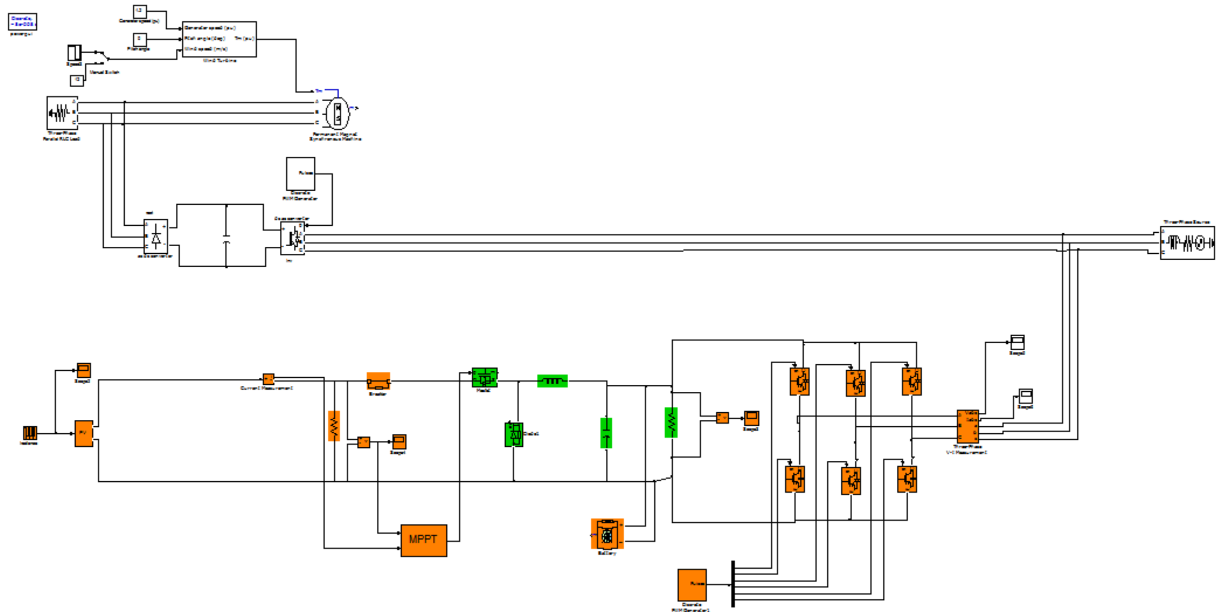

Fig 2 Proposed circuit configuration without STATCOM

Power quality issues in hybrid power systems without D-STATCOM:

Voltage fluctuations: The integration of renewable energy sources such as solar and wind can lead to voltage fluctuations due to their intermittent nature. Without D-STATCOM, the system may experience voltage variations, resulting in potential voltage sags and swells. These fluctuations can adversely affect sensitive equipment and disrupt the operation of critical loads.

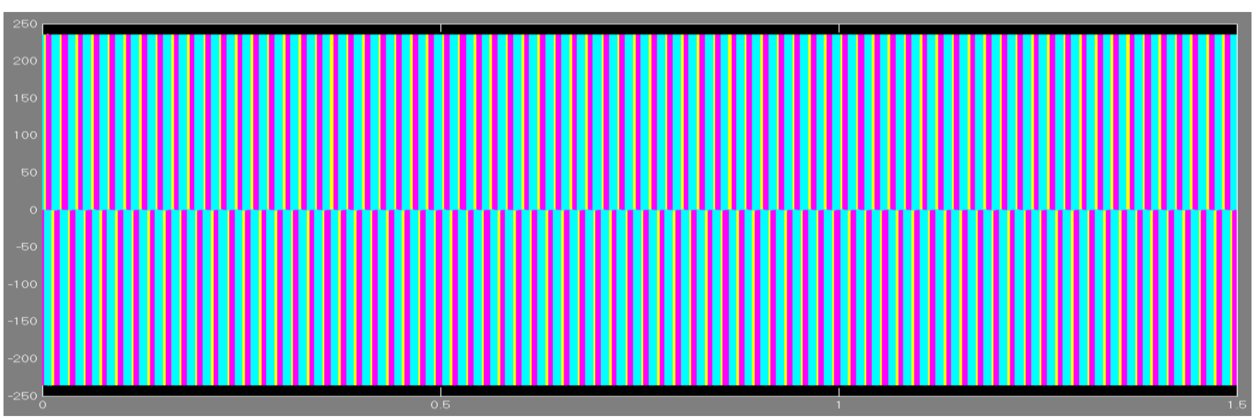

Fig 3 PCC VOLTAGE WITHOUT STATCOM

Harmonics: Hybrid power systems often incorporate various power electronic devices, such as inverters and converters, to interface renewable energy sources and energy storage systems. These devices can introduce harmonics into the system, causing waveform distortion and increasing total harmonic distortion (THD). High THD levels can impact the performance of equipment, leading to increased losses, overheating, and reduced power quality.

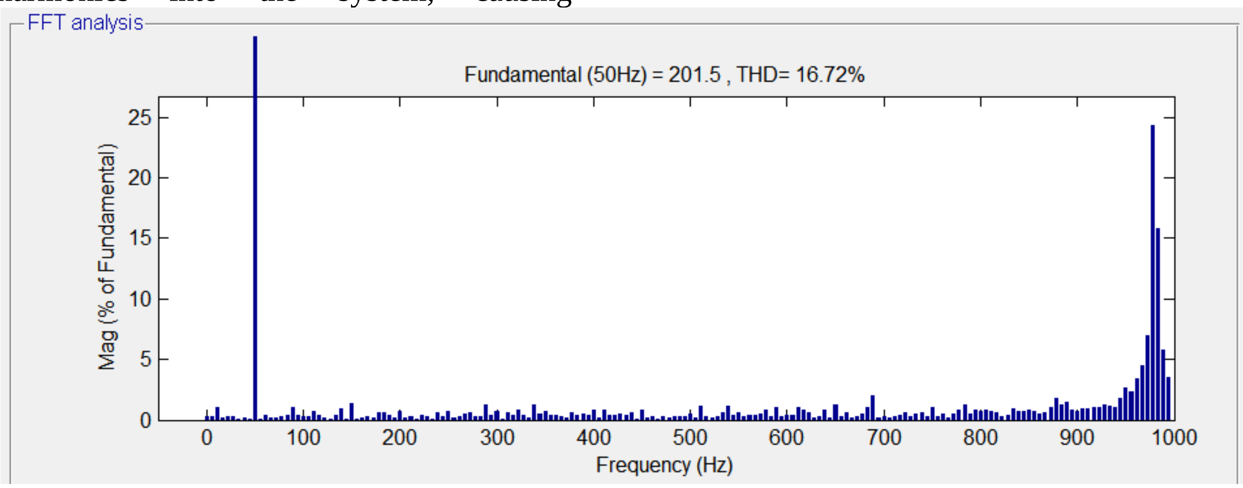

Fig 4 THD WITHOUT STATCOM

Unbalance: In three-phase hybrid power systems, unbalanced voltage or current distribution among the phases can occur due to uneven loads or system asymmetries. Without D-STATCOM, unbalance issues may arise, leading to inefficient operation of three-phase loads, motor overheating, and increased stress on system components.

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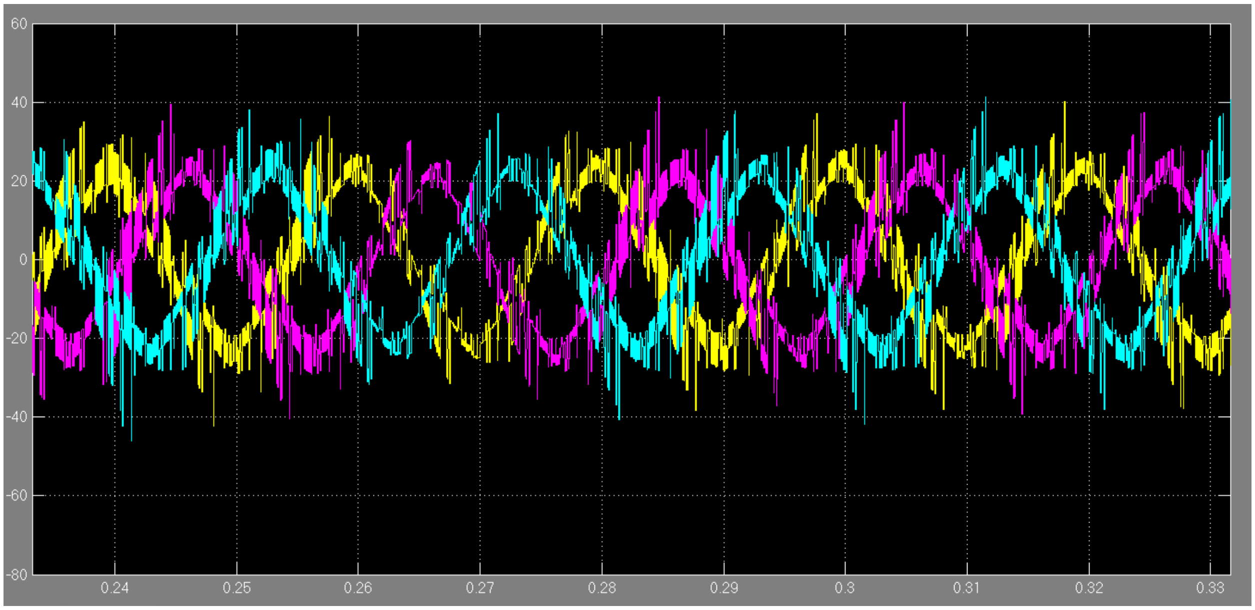

Fig 5 PCC CURRENT WITHOUT STATCOM/UPQC

Flicker: Flicker refers to the perceived variation in light intensity, often caused by rapid voltage fluctuations. In hybrid power systems without D-STATCOM, fluctuations in renewable energy generation or sudden load changes can result in flickering lights, which can be a source of discomfort and annoyance. Moreover, flicker can impact sensitive equipment and affect their performance and lifespan.

The integration of renewable energy sources, such as photovoltaic (PV) and wind, into hybrid power systems offers numerous advantages in terms of sustainability and reduced dependence on fossil fuels. However, the intermittent nature of these renewable sources can pose challenges to power quality in the system. To address this, the implementation of Distributed Static Compensator (D-STATCOM) in a PV-wind hybrid power system can significantly enhance power quality and system performance. This introduction provides an overview of the power quality issues in PV-wind hybrid systems and highlights the role of D-STATCOM in improving power quality.

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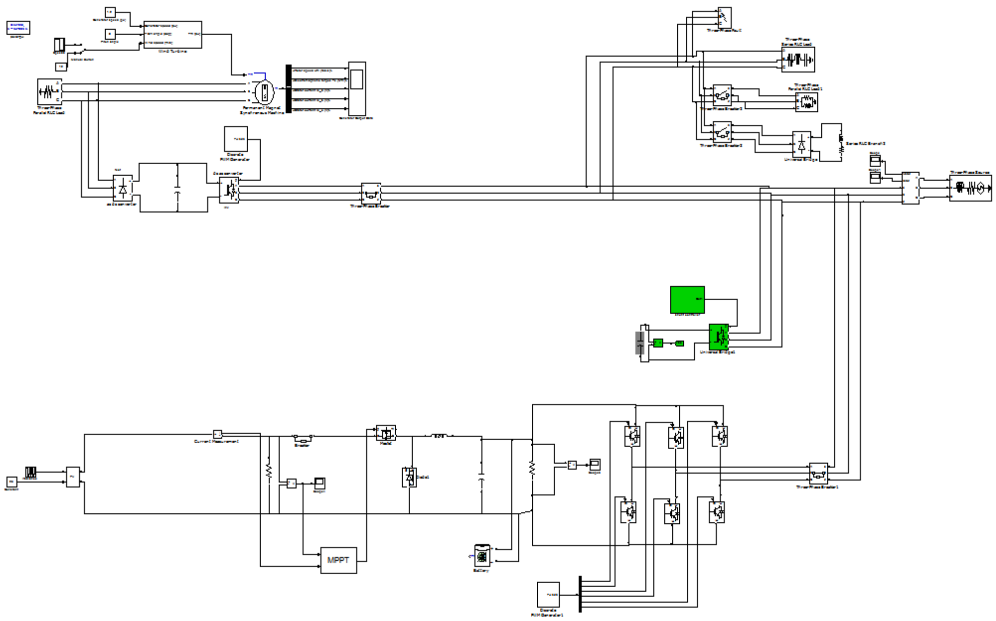

Fig 6 PROPOSED CIRCUIT CONFIGURATION WITH STATCOM

Power quality issues in PV-wind hybrid systems:

Voltage fluctuations: PV and wind generation are subject to variability due to environmental conditions. This can lead to voltage fluctuations in the hybrid power system, affecting the stability and quality of the supplied power. Rapid changes in PV and wind power output can cause voltage sags and swells, potentially impacting sensitive equipment.

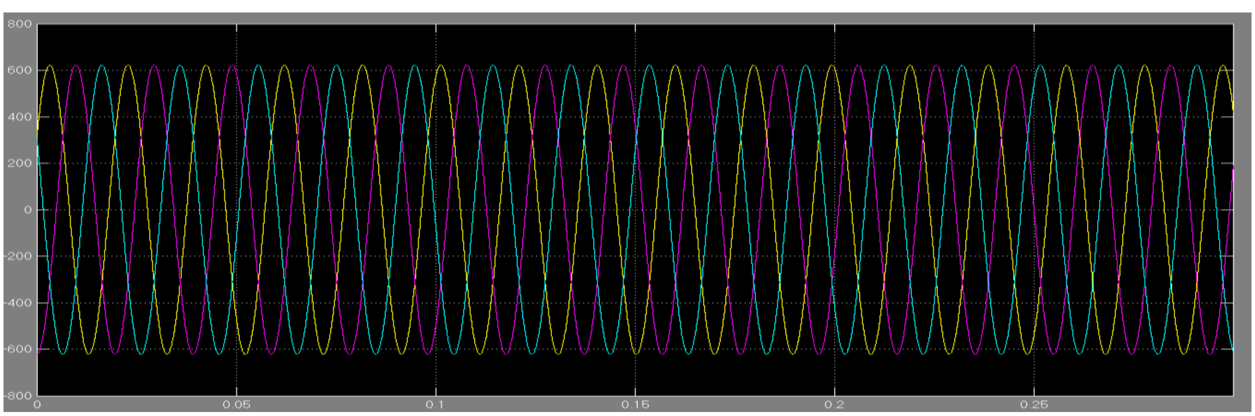

Fig 7 STATCOM PCC voltage

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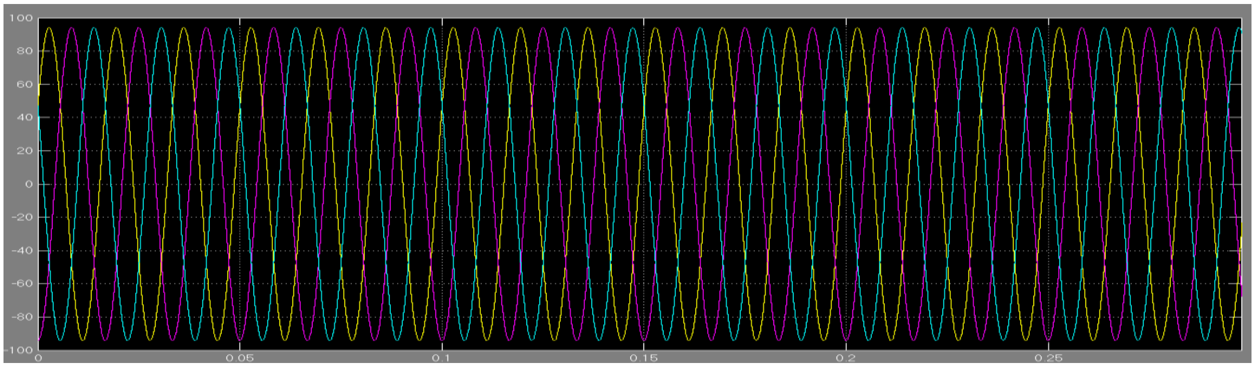

Fig 8 STATCOM PCC CURRENT

Harmonics and interharmonics: Power electronic converters used in PV and wind systems can introduce harmonics and interharmonics into the system. These harmonic distortions can result in increased Total Harmonic Distortion (THD), causing voltage and current waveform distortions. High THD levels can lead to inefficient operation of equipment, increased losses, and interference with communication systems.

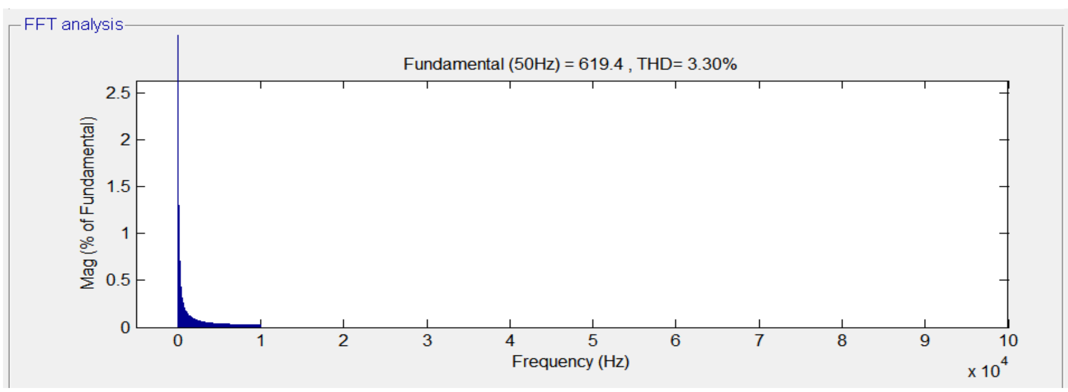

Fig 9 With STATCOM THD at PCC

Reactive power imbalance: The intermittent nature of PV and wind generation can cause reactive power imbalances in the system. Reactive power imbalances affect voltage stability and can lead to voltage fluctuations and reduced system efficiency.

Role of D-STATCOM in power quality improvement: D-STATCOM is a voltage-source inverter-based device capable of injecting or absorbing reactive power to regulate and stabilize system voltage. In a PV-wind hybrid power system, D-STATCOM can effectively address power quality issues through the following mechanisms:

Voltage regulation: D-STATCOM monitors system voltage and injects or absorbs reactive power as needed to regulate voltage levels within acceptable limits. This helps mitigate voltage fluctuations, voltage sags, and swells caused by intermittent PV and wind generation.

Harmonic compensation: D-STATCOM can actively filter out harmonics and interharmonics generated by power electronic converters in PV and wind systems. By injecting equal and opposite reactive power, D-STATCOM cancels out the harmonic components, reducing THD and improving power quality.

Reactive power control: D-STATCOM can provide reactive power support to balance the system and compensate for reactive power imbalances. By injecting or absorbing reactive power, it helps stabilize system voltage, reduce losses, and improve overall power system efficiency.

Fast response and dynamic control: D-STATCOM offers rapid response and precise control over reactive power injection. It can quickly detect and respond to changes in system conditions, ensuring efficient power quality improvement in real-time.

CONCLUSION

In this work, the objective of the power quality improvement of proposed hybrid PV-wind system has been achieved. The improved THD in presence of D-STATCOM is found by the FFT analysis, is shown. A simulation model of hybrid power system with the D-STATCOM is used. The result shows that the total harmonic distortion (THD) is within the limit of 5% set by IEEE. This indicates the satisfactory operation of the proposed wind-PV hybrid generation model.

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