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Power Quality Improvement in Hybrid Power System using D-STATCOM

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ABSTRACT: The widespread adoption of distributed energy sources in the electricity grid has introduced new challenges for utility load management, particularly in ensuring power quality, stabilizing voltage, and optimizing energy utilization. Wind and solar energy stand out as the most promising renewable options. However, relying solely on either photovoltaic or wind energy systems poses reliability issues due to the unpredictable availability of wind and solar irradiance. Therefore, combining various wind and solar power generation structures presents a highly potential and dependable electricity source. This study introduces a hybrid model integrating wind and photovoltaic systems, particularly advantageous for remote or islanded areas where grid integration is not economically feasible. Nevertheless, integrating power electronic devices into distributed generation systems introduces significant power quality issues, including harmonic generation and reactive power compensation, which disrupt the power distribution system. To address these challenges, the study presents a simulation model of a hybrid wind-PV generation system with a capacity of 750 KW. The system's performance in grid-connected mode is analyzed, with a focus on evaluating the power quality of the wind-solar photovoltaic hybrid system by assessing total harmonic distortion (THD) at different wind speeds. The power quality of this hybrid system has been enhanced through the utilization of DSTATCOM technology.

KEYWORDS: D-STATCOM, Reactive Power Compensation (RPC), Total Harmonics Distortion (THD), Distributed Generation (DG), Solar Photo Voltaic (SPV), Hybrid system

I. INTRODUCTION

Hybrid power systems are gaining traction due to their capability to deliver dependable and efficient electricity to remote and off-grid regions. Nonetheless, these systems often grapple with power quality dilemmas like voltage fluctuations, harmonic distortions, and flickering, posing significant challenges for electrical equipment operation, leading to escalated maintenance expenses and diminished system longevity. An effective remedy to combat these power quality hurdles is the integration of a D-STATCOM (Distribution Static Compensator). Functioning as a power electronic apparatus, the D-STATCOM plays a pivotal role in regulating voltage and current within electrical frameworks. It offers reactive power compensation, voltage stabilization, and harmonic mitigation, thereby bolstering power quality in hybrid power systems. At its core, the D-STATCOM injects a current into the power system that counters the system voltage, facilitating voltage control at the connection juncture and offsetting reactive power. Furthermore, the D-STATCOM adeptly filters out undesirable harmonics and high-frequency disturbances from the power grid. In a hybrid power setting, the D-STATCOM can be seamlessly integrated in parallel with other power sources such as solar panels, wind turbines, and batteries. Through meticulous management of the D-STATCOM's output, the system can operate with heightened stability and efficiency, curtailing power quality issues and elevating overall system performance. In essence, leveraging a D-STATCOM emerges as a viable solution for ameliorating power quality in hybrid power systems. By furnishing reactive power compensation, voltage regulation, and harmonic filtration, the D-STATCOM contributes significantly to ensuring a robust and efficient power supply to remote and off-grid areas.

D-STATCOM MODELLING

In the realm of electrical power systems, addressing reactive power compensation stands out as a paramount concern, particularly given the predominance of AC quantities and the ubiquitous demand for reactive power by various loads.

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Controlling reactive power flow becomes imperative to furnish essential voltage support, especially in Wind Energy Conversion Systems (WECS) to counter voltage fluctuations.During instances of voltage collapse, STATCOMs offer a distinct advantage by efficiently providing capacitive reactive power. These power electronic devices are adept at generating or absorbing reactive power at their output terminals, showcasing versatility in handling real power when coupled with battery storage systems. Unlike Static Var Compensators (SVCs), STATCOMs boast compact designs and do not necessitate extensive inductive and capacitive components to offer reactive power support to transmission lines. Key advantages of STATCOMs include their small installation footprint, high reactive power output even at low voltages, and enhanced damping characteristics from a dynamic stability standpoint.

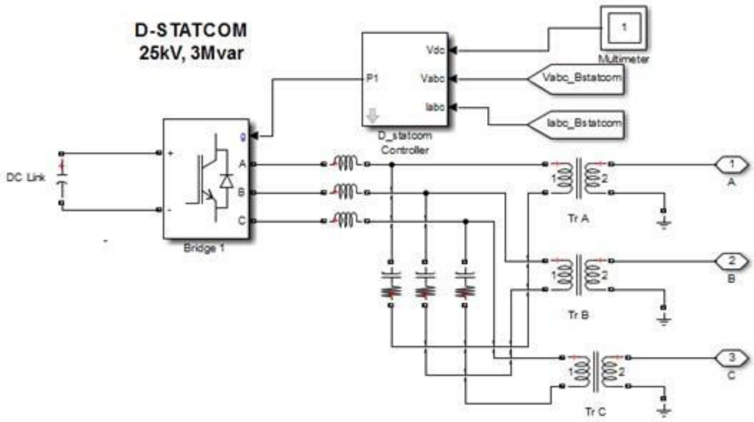

FIG 1: Model of D-STATCOM

In this study, the integration of a D-STATCOM has been employed to bolster the power quality of a hybrid micro-grid. Positioned at the point of common coupling (PCC), the D-STATCOM serves to mitigate both voltage and current-related power quality issues. Operating in current control mode, the D-STATCOM ensures balanced and pure sinusoidal source currents by injecting harmonic and reactive components of the load current. Moreover, when operating in voltage control mode, it regulates the PCC voltage relative to a reference value, thus safeguarding critical loads against significant voltage disturbances.

II. PROPOSED SYSTEM

Within the domain of electrical power systems, addressing reactive power compensation emerges as a pivotal concern, given the prevalence of AC quantities and the widespread demand for reactive power across various loads. Effectively managing reactive power flow becomes essential to furnish crucial voltage support, particularly in the context of Wind Energy Conversion Systems (WECS) aimed at mitigating voltage fluctuations.During episodes of voltage collapse, STATCOMs offer a distinctive advantage by efficiently providing capacitive reactive power. These sophisticated power electronic devices excel in generating or absorbing reactive power at their output terminals, demonstrating remarkable versatility when paired with battery storage systems. Unlike traditional Static Var Compensators (SVCs), STATCOMs feature compact designs and do not necessitate extensive inductive and capacitive components for offering reactive power support to transmission lines.

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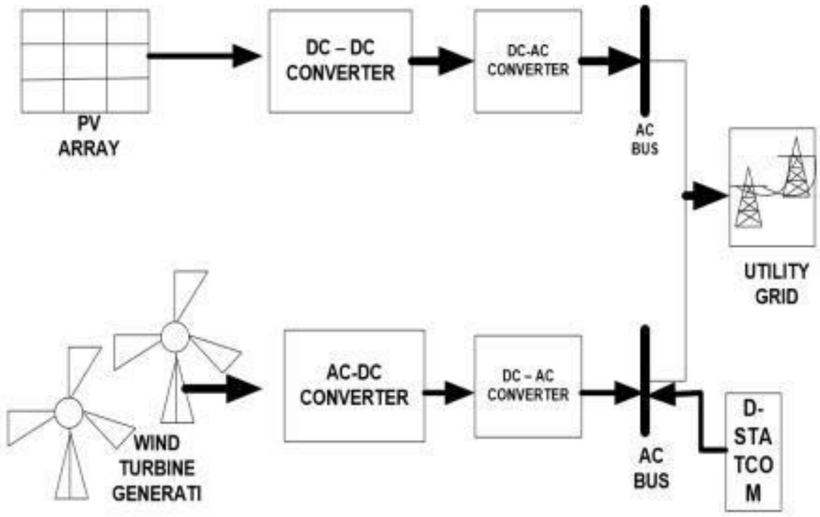
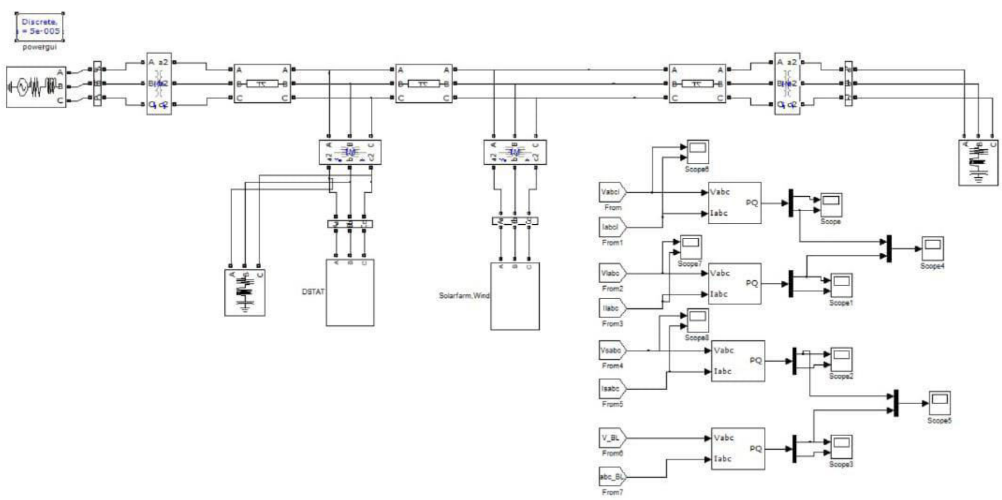


FIG 2: Block diagram of hybrid power system

Prominent advantages of STATCOMs encompass their compact installation footprint, high reactive power output even at lower voltages, and heightened damping characteristics from a dynamic stability perspective. In this investigation, the incorporation of a D-STATCOM has been harnessed to enhance the power quality of a hybrid micro-grid. Positioned strategically at the point of common coupling (PCC), the D-STATCOM serves to alleviate both voltage and current-related power quality challenges. Operating in current control mode, the D-STATCOM ensures the production of balanced and sinusoidal source currents by injecting harmonic and reactive components of the load current. Furthermore, when operating in voltage control mode, it maintains the PCC voltage in accordance with a reference value, thereby shielding critical loads against substantial voltage disruptions. It is worth noting that the response speed of a STATCOM exceeds that of an SVC, while also exhibiting lower harmonic emissions. However, STATCOMs typically entail higher losses and may incur greater costs compared to SVCs, hence the prevalence of the latter technology. Conducting a power quality site survey proves instrumental in identifying and addressing various power quality issues, ranging from harmonics to voltage sags and interruptions. Implementation of strategies such as designing electrical systems to prevent harmonic-related damages, employing power conditioning equipment, and collaborating with utilities to mitigate harmonic influences on the grid, proves essential in maintaining optimal power quality standards.

III. RESULTS AND ANALYSIS



PROPOSED CONFIGURATION SIMULINK WITH D-STATCOM

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The assessment of power quality encompasses various parameters such as voltage sag, current harmonics, and power factor. In this study, we utilize the calculation of total harmonic distortion (THD) to gauge the quality of power supplied by the Wind-PV system. THD in the current waveform is determined using the following equation

$THD=\sqrt{\sum I_h^2}/I_1$

Where, I_h represents the harmonic current of the h^{th} order, and I_1denotes the fundamental component of the current. The THD analysis is conducted utilizing the FFT (Fast Fourier Transform) Analysis Toolbox available in MATLAB. The efficacy of the proposed system configuration is evaluated by assessing the THD in the current supplied to the grid. To facilitate a comparative analysis, THD calculations are performed at a wind speed both with and without the inclusion of a D-STATCOM.

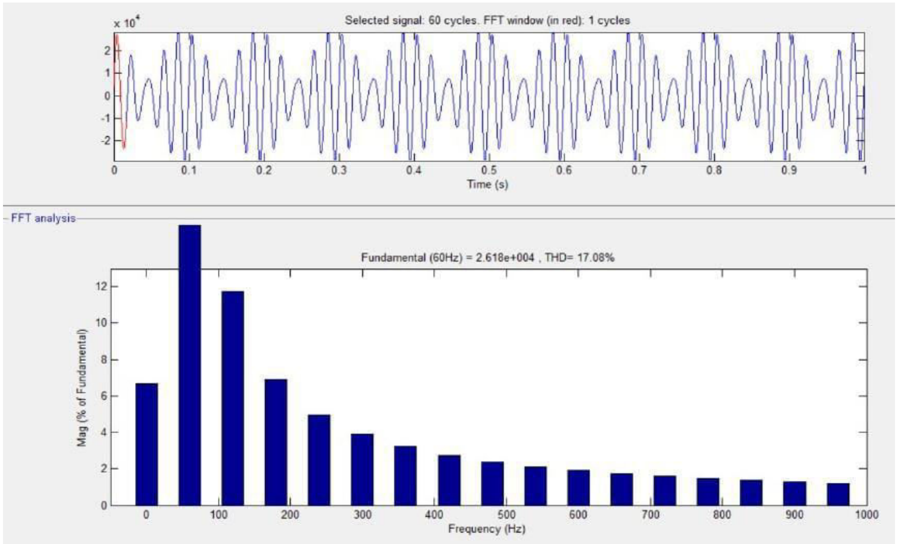

FIG 3: THD of the current supplied by the hybrid Wind PV system at wind speed without D-STATCOM

The analysis reveals that the THD of the current supplied without the connection of D-STATCOM at the specified wind speed is recorded at 17.08%, indicating a notably high level of distortion. It is imperative for THD to remain below 5%. Hence, to address this discrepancy, compensation techniques are employed, with the integration of D-STATCOM serving as a pivotal solution to mitigate total harmonic distortion effectively.

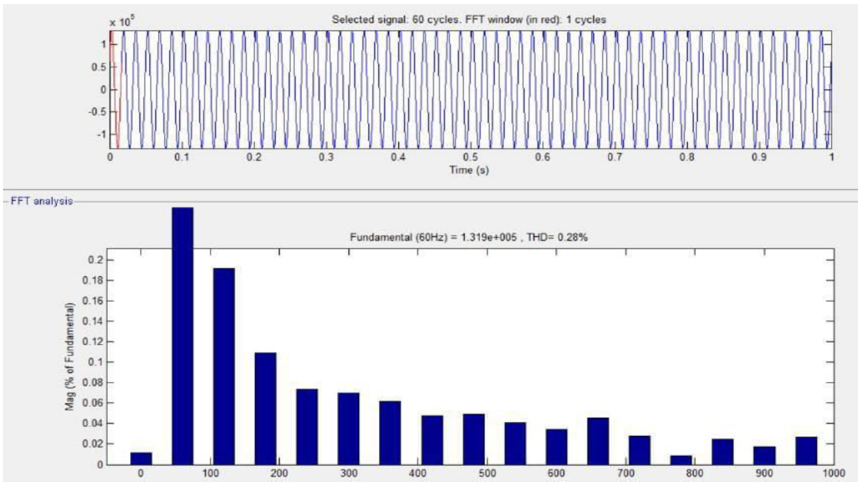

FIG 4: THD in current supplied by the hybrid Wind-PV system at wind speed with D-STATCOM

Figures Fig-3 and Fig-4 depict the comparison of total harmonic distortion in each scenario, both with and without the utilization of D-STATCOM. Through the incorporation of D-STATCOM, there is a notable decrease in THD in the current supplied by the hybrid wind-PV system, achieving a remarkable reduction to 0.28%. This signifies a substantial enhancement in power quality attributed to the implementation of D-STATCOM. Consequently, the quality of power supplied by the proposed wind-PV hybrid system is markedly improved.

IV. CONCLUSION

This study successfully accomplishes the objective of enhancing the power quality of the proposed hybrid PV-wind system. The enhanced THD achieved in the presence of D-STATCOM, as depicted in Figure 4 through FFT analysis, corroborates this improvement. A simulation model incorporating the D-STATCOM within the hybrid power system is employed to validate these findings. The results unequivocally demonstrate a reduction in total harmonic distortion (THD), indicating the effective operation of the proposed wind-PV hybrid generation model.

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