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Power Quality Improvement using STATCOM in Grid Connected Solar Wind Hybrid System

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Abstract

Electricity plays an important role in both daily life and industries. Hybrid solar-wind systems extract the energy from renewable sources like solar and wind to produce electricity. Power quality is an important factor in determining the power status. When generating electricity, one of the most crucial factors is the quality of the electricity produced. High-quality electricity ensures efficient performance, stability in supply, and minimal disruption to electrical systems. It impacts both the reliability of power delivery and the longevity of the equipment using it. Factors like voltage consistency, frequency stability, and the reduction of harmonic distortions are all key to maintaining optimal electricity quality. Due to the changing behavior of the power generation in the wind power systems, the problem of high quality may arise. The proposed work presents the simulation and analysis of the solar-wind hybrid system and the power improvement of the synchronous static amplifiers through the control strategy and power transmission. The main objectives of this work to use a STATCOM device that can improve power-system Performance. In some of the unpredictable situations the compensation is provided by additional devices such as distribution generations integrated into the power system. STATCOM is a shunt-connected reactive-power compensation device that is capable of generating and/ or absorbing reactive

power and in which the output can be varied to control the specific parameters of an electric power system. The proposed system integrates both solar and wind energy sources to enhance power generation reliability and efficiency while addressing power quality concerns. The system aims to improve power system performance through the utilization of a STATCOM (Static Synchronous Compensator) device and advanced control strategies. The proposed model is designed using Simulink of MATLAB software.

Introduction

In hybrid power system, the system uses solar panels and a small wind turbine generator to produce electricity. The working of a hybrid solar-wind system is a combination of both the solar and wind energy systems. Solar systems use solar panels to extract the sun's energy to produce electricity.

Wind energy is another form of renewable energy that can be extracted by installing wind turbines and generators. The wind used for ship navigation in countries around the world. The windmill was built in the seventh century AD. The first English-language record is the wind turbine data from 1191 AD pointed out that in 1439 the Netherlands built the first corn grinder. The first electricity in Denmark was generated by wind turbines. In 1890, a wind turbine with a diameter of 23 meters was used [1]. In 1910, Denmark had 5 to 25 kW wind turbines in operation. In the mid-1970s, people had a strong understanding of unconventional energy. At the time, people worried that the environmental impact of fossil energy was similar to the oil from the Organization of the Petroleum Exporting Countries. Explained that technology in wind turbine development in the last 25 years has become a recognized technology in this century [2].

Hybrid Electric System

A hybrid solar-wind system is composed of several key components, including a PV array, wind turbine, battery bank, inverter, controller, and cables. The photovoltaic panels and wind turbines work together to meet the energy demands of the system. When solar and wind energy are abundant, the excess power generated is used to charge the battery bank, particularly during daylight hours when solar power is available. In times of low energy availability, the battery discharges to supplement the energy generated by the PV array and wind turbine, helping to meet load requirements until the battery is depleted. The performance modeling of a hybrid solar-wind system primarily depends on the efficiency of each component. To accurately predict overall system performance, both the solar and wind energy sources should be modeled individually and then integrated to ensure reliable power supply. The hybrid system can be designed to operate in either an off-grid (isolated) mode or a grid-connected mode, facilitated by an electronic power interface. Successful system performance relies heavily on precise prediction of power output from both energy sources.

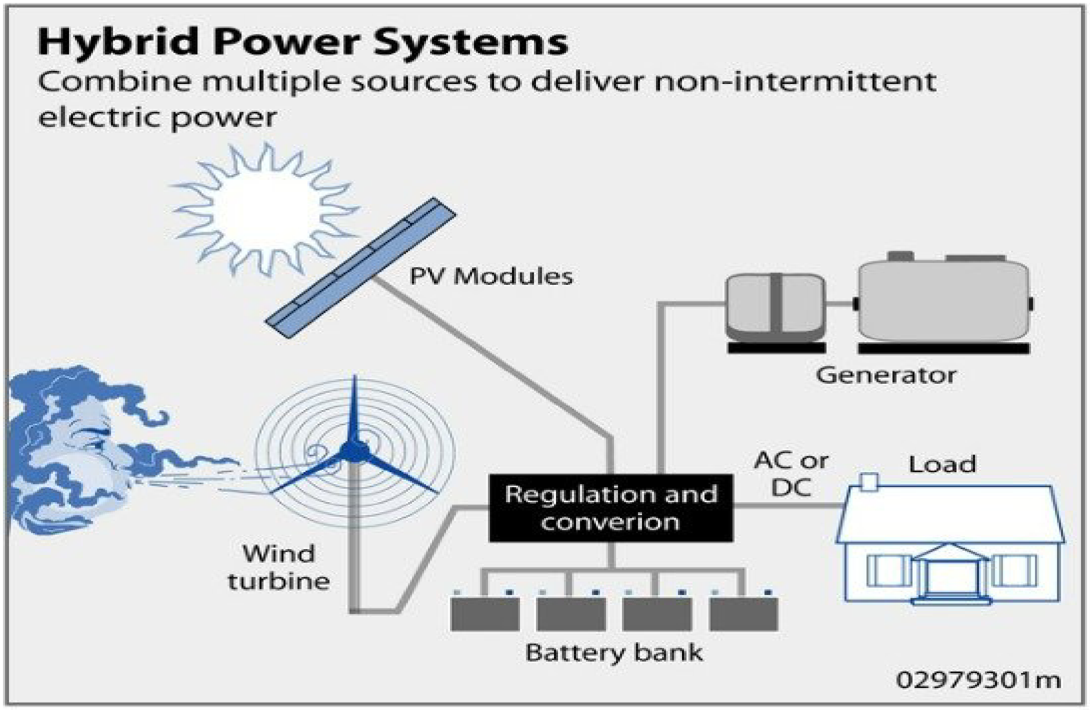

Figure 1: Solar Wind Hybrid Power System[9]

Methodology

The proposed system integrates both solar and wind energy sources to enhance power generation reliability and efficiency while addressing power quality concerns. The system aims to improve power system performance through the utilization of a STATCOM (Static Synchronous Compensator) device and advanced control strategies.

Given the variable nature of wind power generation, maintaining power quality becomes a challenge. To tackle this issue, the article suggests employing simulation and analysis techniques to optimize the filtering, rotation, and power enhancement capabilities of synchronous static amplifiers. These amplifiers, coupled with effective control strategies, can mitigate power fluctuations and improve overall system stability.

The integration of solar and wind energy into the power system involves multiple steps, including power generation, transmission, and distribution. The main objectives of this work are to ensure the continuous supply of electricity to meet customer needs while maximizing the efficiency of power generation.

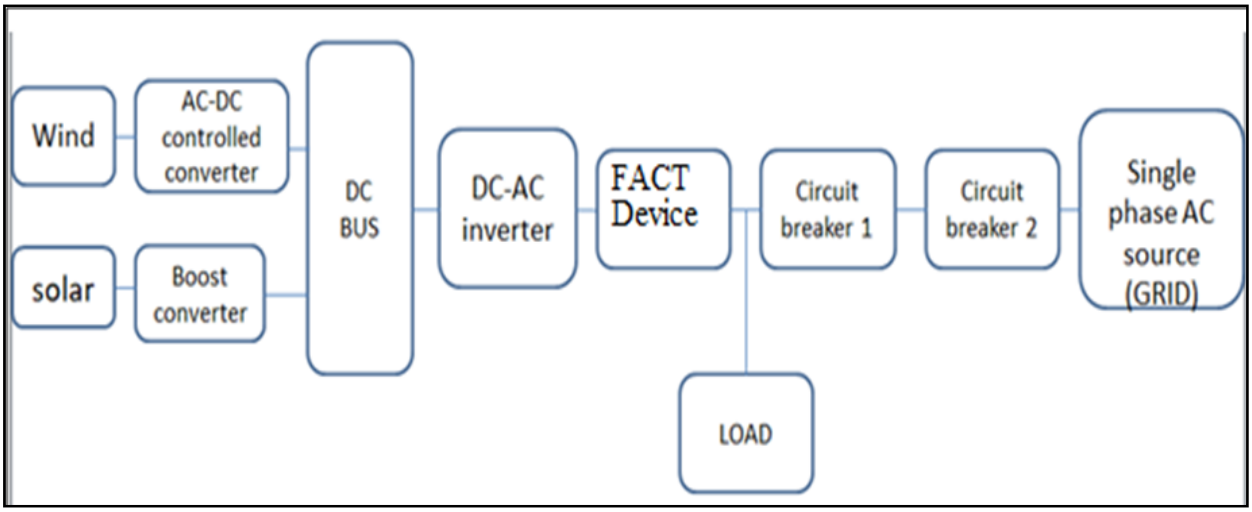

Figure 2: Proposed Flow Diagrams

Simulation Results

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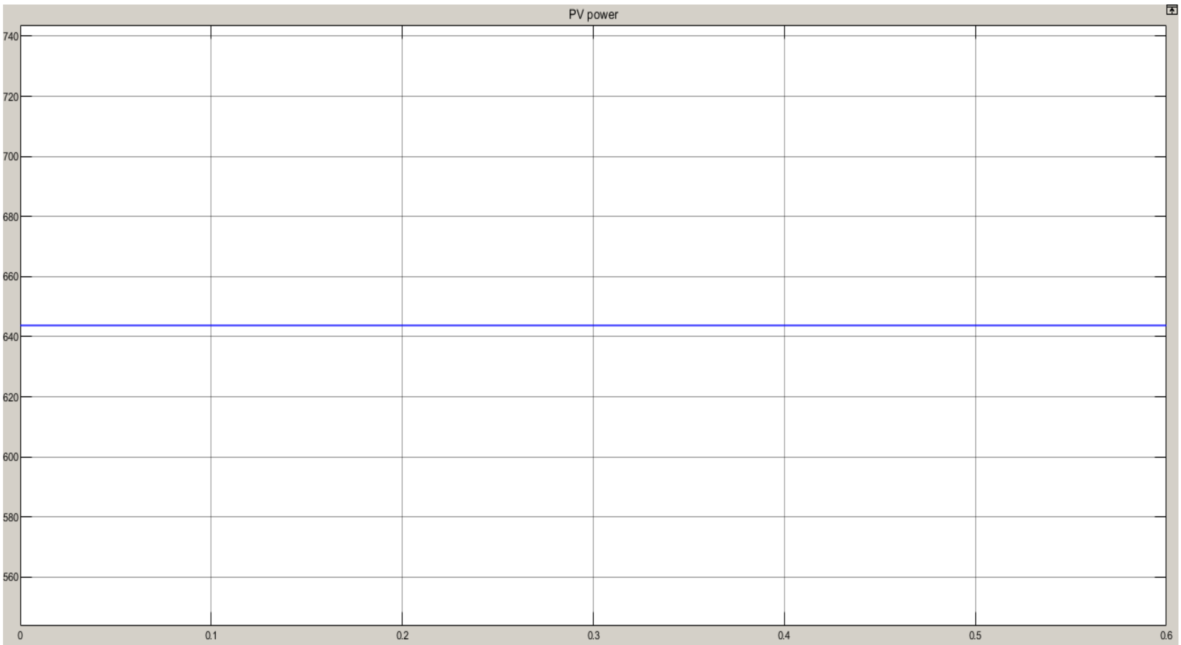

Figure 3: PV Power

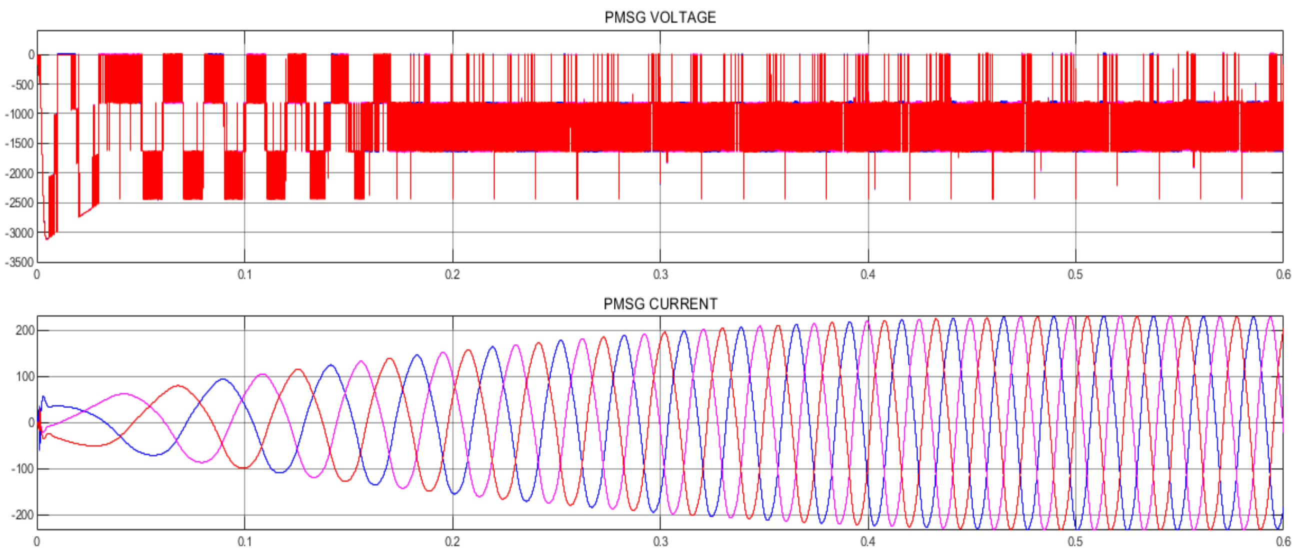

Figure 4: PMSG Current and Voltage

This figure 4 illustrates the current and voltage characteristics of a Permanent Magnet Synchronous Generator (PMSG) within the system

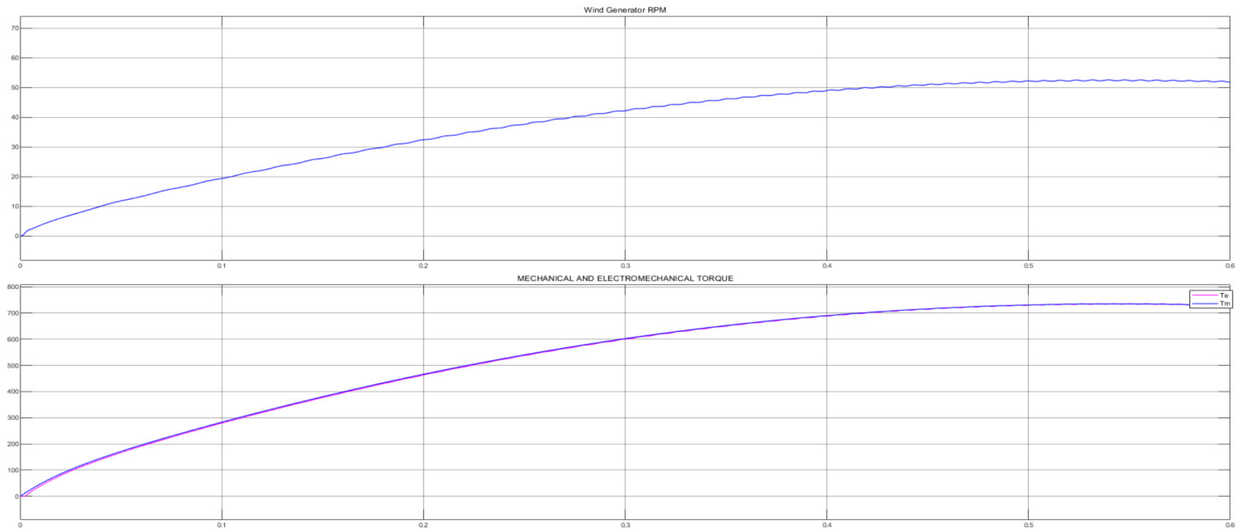

Figure 5: Wind Generation Rpm and Mechanical and Electromechanically Torque

This figure 5 depicts the relationships between wind turbine generation RPM (Revolutions Per Minute), mechanical torque (Tm), and electromechanical torque (Te) within the power generation system.

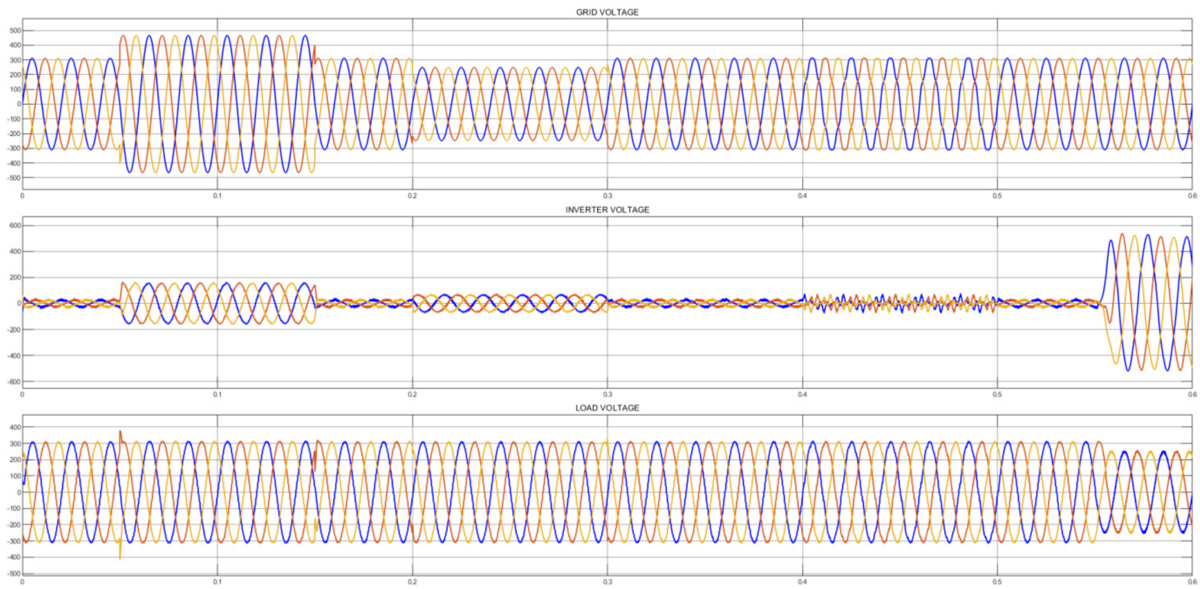

Figure 6: Grid Voltage, Inverter Voltage, Load Voltage

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Analyzing Figure 6 provides insights into the interaction between the grid, inverter, and electrical load in a grid-connected renewable energy system

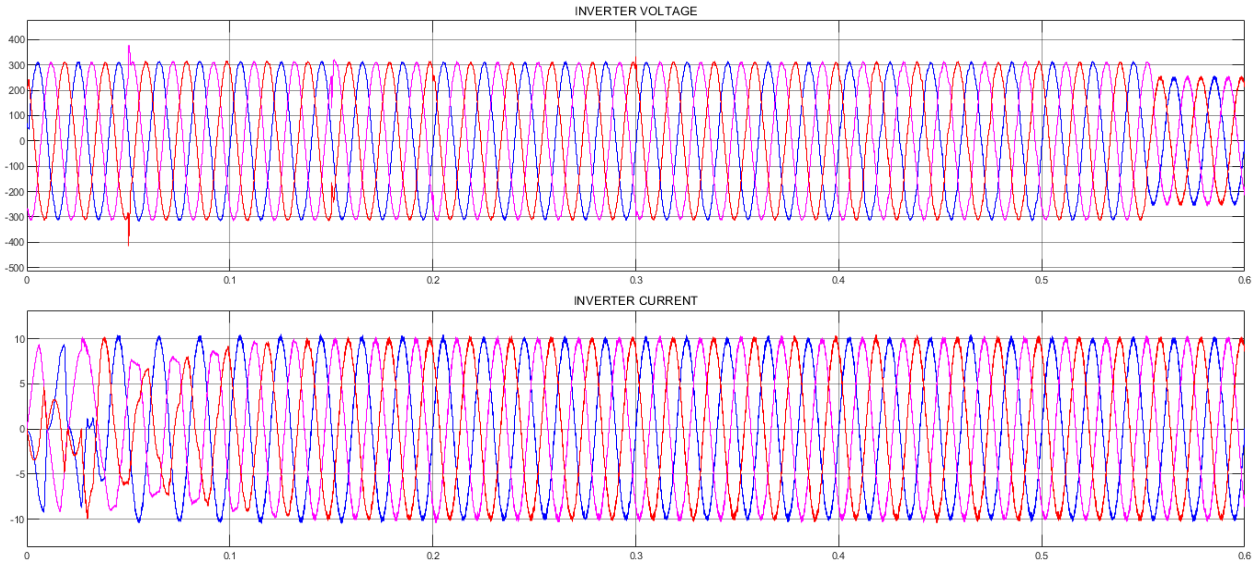

Figure 7:Inverter Voltage and Inverter Current

Figure 7 typically illustrates the current characteristics in a grid-connected power system with an inverter and electrical load. Analyzing these currents provides insights into the dynamics of power flow within the system, including how the inverter manages energy conversion and synchronization with the grid, and how load demands impact overall system operation and efficiency.

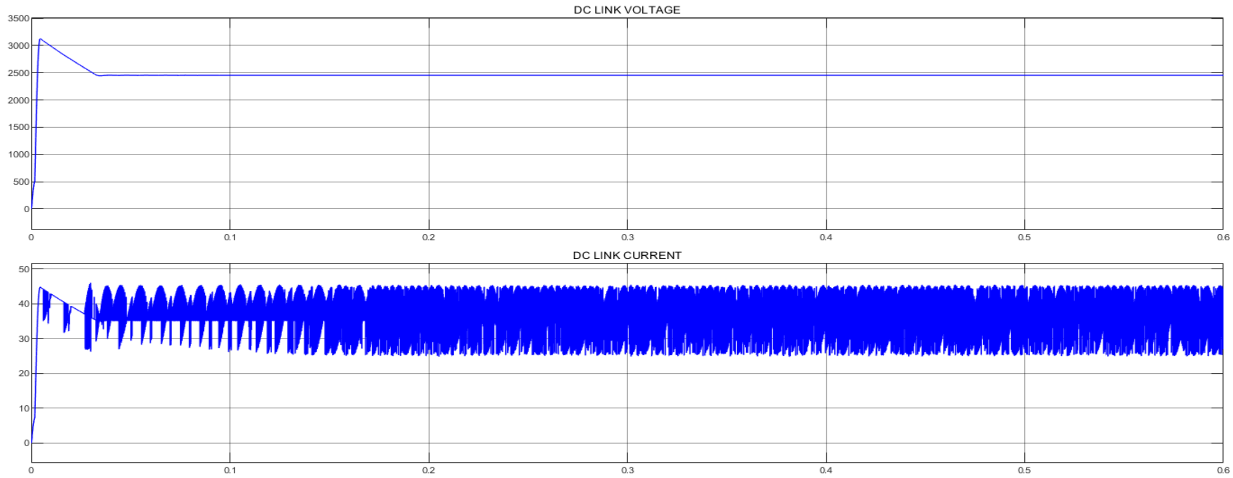

Figure 8:Dc Link Voltage and Dc Link Current

Figure 8 typically illustrates the relationship between DC link voltage and DC link current.

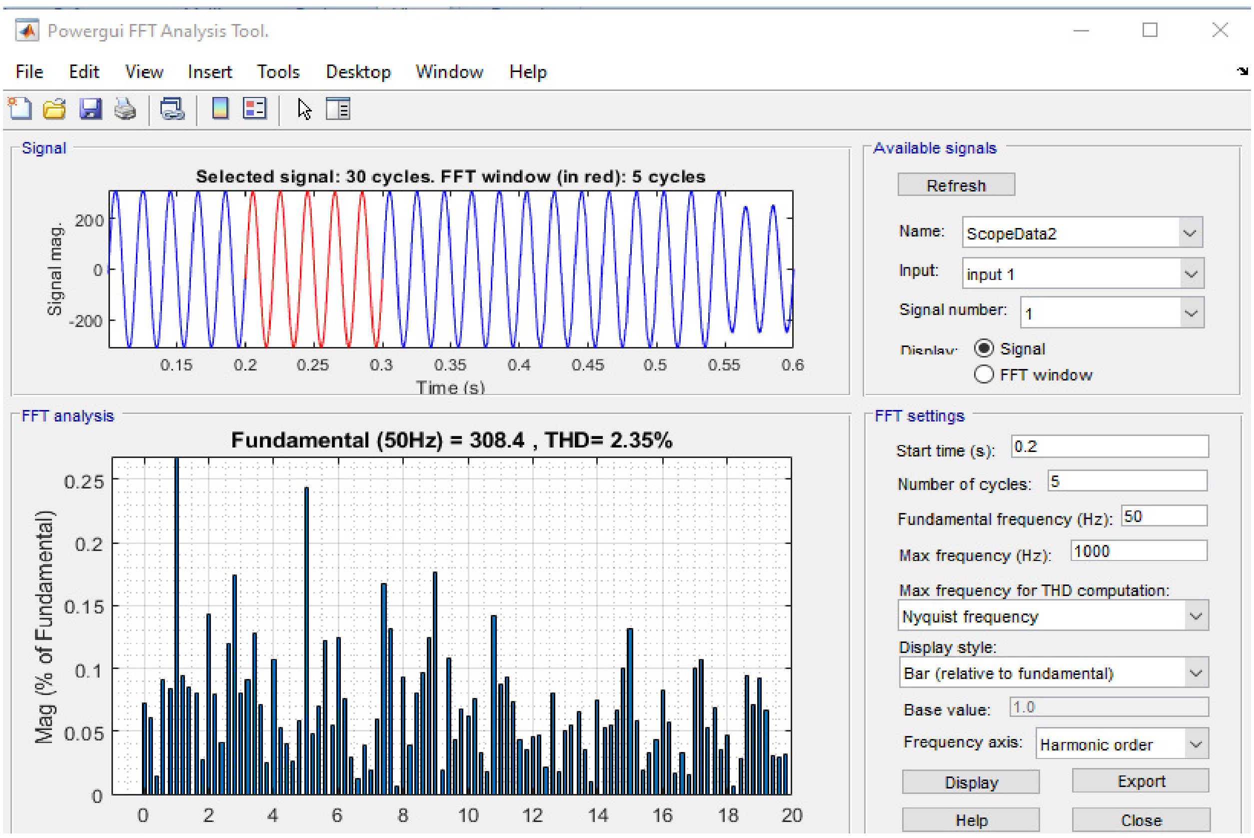

Figure 9: THD with STATCOM

Table 9 presents the Total Harmonic Distortion (THD) performance of a Simulink model, comparing the system's harmonic distortion with and without a STATCOM (Static Synchronous Compensator). The THD value without the STATCOM is 2.59%, indicating a higher level of harmonic distortion in the system's voltage or current waveforms. In contrast, the presence of a STATCOM reduces the THD to 2.35%, demonstrating its effectiveness in improving power quality by mitigating harmonic distortions.

Conclusion

In this study, the proposed methodology focuses on enhancing power quality and system stability in renewable energy integration, particularly addressing the variability of wind power generation. Through simulation and analysis techniques, the research optimizes the filtering, rotation, and power enhancement capabilities of synchronous static amplifiers, complemented by the strategic deployment of a STATCOM device. Integrated within the MATLAB/Simulink environment, the STATCOM is configured with a PI controller to manage reactive power compensation effectively. Initial conditions such as wind speed profiles and solar irradiance are considered to simulate various operational scenarios, enabling the assessment of key metrics like voltage stability and power quality. This approach aims to improve overall power system performance while ensuring reliable electricity supply to meet customer needs.

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