

Proceeding Paper

# Modeling and Analysis of STATCOM for Renewable Energy Farm to Improve Power Quality and Reactive Power Compensation <sup>†</sup>

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**Abstract:** Power Quality (PQ) improvement in grid-integrated photovoltaic (PV) and wind energy hybrid systems for effective power transfer is presented in this paper. Due to interlinked hybrid renewable energy resources and nonlinear loads, various issues arise which affect the power quality, i.e., voltage sag, harmonic distortion increases, and also reactive power demand. In order to mitigate these issues, flexible alternating current transmission system (FACTS) devices are utilized. In this paper, hysteresis band current controller (HBCC)-based static synchronous compensator (STATCOM) is modeled to reduce PQ problems. HBCC is a robust and simple technique to improve voltage profile, reduce total harmonic distortion (THD) and fulfill the reactive power demand. Two case scenarios of the hybrid system, i.e., (I) grid integrated hybrid system without HBCC (II) grid integrated hybrid system with HBCC, are tested. Results demonstrate that under scenario II, load bus voltage is regulated at 1.0 p.u., THD of system voltage and current is reduced 0.25% and 0.35%, respectively, and reactive power demand of 30 kVAR is fulfilled. The HBCC was designed for reducing THD of the system with the limits specified by standards IEEE 519-1992 STATCOM using hysteresis band current controller to improve power quality in the distribution system which is simulated using MATLAB/SIMULINK. After that, the performance of the system is better in terms of power quality.

**Keywords:** renewable energy resources; reactive power; voltage sag; total harmonic distortion; STATCOM; HBCC



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## 1. Introduction

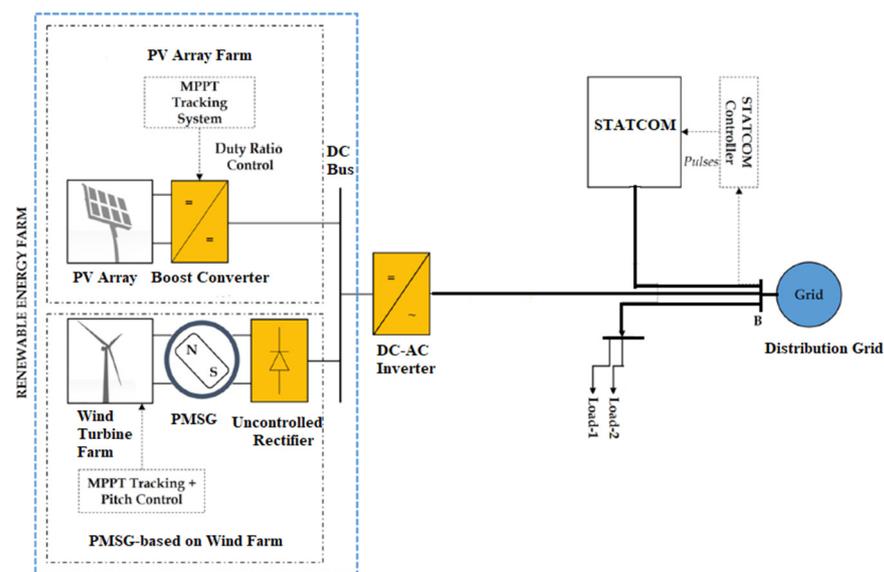
The increasing power demand causes a utility burden due to urbanization, industrialization, and rising living standards. Traditional power sources are inadequate to meet global power demand, posing electricity stability and security challenges, while massive amounts of pollutants pose major environmental concerns [1,2]. Renewable and distributed energy resources (DER) have arisen by way of replacing traditional energy resources during the last couple of decades, and utility engineers consider them a viable solution for meeting load demand while effectively addressing power problems [3,4]. The latest development in the renewable energy system is Hybrid Renewable Energy Systems (HRES) based Distributed Generation (DG), which has proved to achieve high performance and dependability [5]. There were numerous proposals for successfully utilizing various renewable energy resources to generate electricity [6]. Wind and solar energy sources are being used effectively in various hybrid systems, amongst all developed renewable energy resources. Solar PV-Wind hybrid systems have recently received much interest from utility companies worldwide [7,8]. Power quality has become a significant concern, with more renewable energy generated and more nonlinear demands added to the system. This

problem arises mainly due to the usage of nonlinear power electronic devices, which alter the sinusoidal pattern of the supply by introducing frequency distortions into the grid.

Furthermore, several investigations have shown that connecting REC with the power grid adds a certain quantity of harmonics into the PCC. This research uses the STATCOM converter as an active power filter to adjust voltage, reactive power, and power quality when connected to a grid wind farm or solar farm. The following is a breakdown of the paper's structure: In Section 2, the system model is presented. The brief introduction of the HBCC converter used as a reactive power compensator and an active filter is shown in Section 3. Section 4 contains the simulation findings. In Section 5, there is the conclusion of the whole discussion.

## 2. System Model

In this section, both PMSG-based wind turbine (1.5 MW) and solar PV array (831 KW) are combined at dc bus link (400 V), which is connected with utility grid via Grid-side converter. The STATCOM and three-phase load are connected across the ac bus bar. The model consists of a three-phase voltage source with the rating of 400 V connected to a three-phase load of 1 kW and 1 kVAR. An extra inductive load of 30 kVAR is added after 0.4 s. The STATCOM is switched on after 0.4 s. The ac side voltage and frequency are maintained at 400 V (L-L) and 50 Hz, respectively. All the bus-bar measurements are carried out per unit (p.u.). The detailed simulation model of the proposed system is shown in Figure 1.



**Figure 1.** Configuration of hybrid renewable energy farm connected to the grid using STATCOM.

## 3. Methodology

### *Hysteresis Current Control Technique*

The hysteresis band current controller approach is essentially a robust feedback current control technique. The actual current through the STATCOM branch follows the reference current constantly inside the defined hysteresis band. The reference current is generated by controllers by measuring the ac terminal voltage and the dc voltage across the capacitor upon the inverter's dc link. The reactive component of the load current starts to increase as the reactive power of the load changes. The size of the q-axis component ( $I_q$ ) of the reference current  $I_{ref}$  is determined by measuring the rise in reactive current. The capacitor's dc voltage is measured and compared to a reference value. The magnitude of the d-axis component ( $I_d$ ) of the reference current  $I_{ref}$  is derived by passing the error signal via a PI controller. The hysteresis band current controller regulates the current flow by the STATCOM branch towards the reference currents and creates gate signals accordingly.

#### 4. Results and Discussion

This model consists of a three-phase voltage source with the rating of 400 V connected to a three-phase load of 1 kW and 1 kVAR. An extra nonlinear (inductive load) of 30 kVAR is added after 0.4 s. The STATCOM is turned on after 0.4 s.

##### 4.1. Load Source Current

The three-phase source current of the load depicts that when a highly reactive load of about 30 kVar is connected at 0.5 s, the current increases tremendously as the voltage leads the current. The load is inductive; it consumes both active and reactive power.

##### 4.2. Reactive Power by Load and STATCOM

Table 1 depicts the active and reactive power flow via the load and the STATCOM. The source supplies only the active power. The STATCOM supplies only reactive power. To adjust for the losses in the STATCOM branch, it uses a very small amount of reactive power. When the nonlinear load of 30 kVAR is switched on, the voltage drops to 0.771 p.u. The STATCOM is turned on for 0.4 s. Still, after a few short cycles, the STATCOM action raises the system voltage to 0.99 and 1.002 p.u. as shown in Table 1, when the STATCOM is turned on, the source is released since the STATCOM provides the load's reactive power. As a result of the preceding observation, STATCOM appears to be sending reactive power to the load while maintaining the system voltage at the rated value at 1.0 p.u.

**Table 1.** Parameters evaluation with and without HBCC.

Controller	Voltage Sag	Q Demand by Load
Without Hysteresis Band Current Controller	0.771 p.u. voltage downs	30 kVAR
With Hysteresis Band Current Controller	Voltage at PCC 1.0 p.u.	Q supplied by STATCOM 29 kVAR

##### 4.3. FFT Analysis

The three-phase grid side VSC causes harmonics in waveforms of voltage and current of the hybrid system under investigation (DC–AC inverter). Harmonics seen using the FFT Analysis Tool available in the MATLAB/Simulink system are still within IEEE Standard 519–1992 limitations. The total harmonic distortion due to both nonlinear load and both RECs is 31.83%. The THD seen in grid side voltage and the current was reduced to 0.25% and 0.35%, respectively, in the presence of STATCOM. A comparison Table 2 with and without HBCC-based STATCOM was presented in terms of THD in voltage and current with constant switching frequency.

**Table 2.** THD analysis using FFT.

Controller	Voltage (%THD)	Current (%THD)
Without Hysteresis Band Current Controller	24.03	31.83
With Hysteresis Band Current Controller	0.25	0.35

#### 5. Conclusions

A STATCOM-based control technique named hysteresis band current control is presented in this work. A STATCOM is interlinked at PCC of renewable energy farm on the distribution side. HBCC-based STATCOM is a more robust technique for improving power quality and reactive power compensation, as presented in the above Tables. A MATLAB-based simulation is investigated to analyze the performance of STATCOM. STATCOM generates the reactive current opposite to disrupting signal throughout the grid's current using the HBCC technique. Total harmonic distortion gets reduced due to STATCOM

operating as an active power filter. Moreover, STATCOM possesses the ability to regulate the voltage at load bus and offer a better solution for the reliability of these systems. Hence, STATCOM can be a multifunctional device for reactive power compensation and a filter to reduce THD.

**Conflicts of Interest:** The authors declare no conflict of interest.

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