Control of Dynamic Performance Through Feedback Converter SSC In Grid Integrated Wind Energy System

Preeti Rani[1,*], Ved Parkash Arora[1] and Naveen Kumar Sharma[2]

[1]*Electrical Engineering Department, MRSPTU Bathinda, India*
[2]*Electrical Engineering Department, IKGPTU Jalandhar, India*
E-mail: preetisinglaee@gmail.com
[*]*Corresponding Author*

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Abstract

A feedback converter-based Static series compensator (FBC-SSC) is a device that can simultaneously compensate for currents and voltages in a distribution network to enhance the Power Quality (PQ) in Grid integrated Energy System (GIWES). PQ is a term that refers to the conjunction of voltage and current stability. Electronically operated and non-linear gadgets with significant applicability in distribution networks and enterprises have become significant aspects due to PQ constraints such as imbalance voltage and frequency, and transients. Improved hysteresis-based FBC-SSC is suggested in this study for optimizing PQ in GIWES. The novelty in this research is improved hysteresis or hybrid PI and PWM-based hysteresis controlled FBC-SSC. In a wind turbine generation system, improved hysteresis based is used to find the gate trigger pulse for SSC. The suggested controller, when combined with FBC-SSC, improves the WES dynamic performance. Simultaneously, the grid network can compensate for current and voltage irregularities in nearby terminals. All converters in the proposed topology share a standard dc-link capacitor. As a result, power can be transmitted from one distributor to another. The proposed topology is modelled in the

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MATLAB/SIMULINK environment. The effectiveness research is performed using the improved hysteresis controller. Finally, the obtained results are compared to two existing controllers: a Proportional Integral controller and a traditional Pulse Width Modulation (PWM) controller. As a consequence, the performance level can show that the advised technique is effective. When compared to another typical control approach, the suggested system obtains remarkably low THD values of 0.94 percent.

Keywords: Wind, FBC-SSC, control, hybrid, grid.

List of Abbreviations

FBC-SSC	Feedback converter-based Static series compensator
GCWES	Connected Wind Energy System
PQ	Power Quality
DVR	Dynamic Voltage Restorer
PMSG	Permanent Magnet Synchronous Generator
PI	Proportional and Integral
DGR	Distributed Generation Resources
DS	Distribution System
THD	Total Harmonic Distortion
PWM	Pulse Width Modulation
PLL	Phase-Locked Loop
PCC	Point of Common of Coupling

Research Flow Process

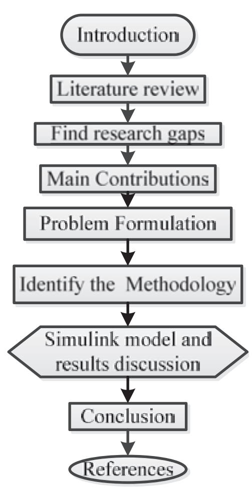

Figure 1 Research flow process carried out in the manuscript.

1 Introduction

Renewable energy sources have received a great deal of attention in recent days as a result of pollution and depletion of carbon fuels resources and increased carbon dioxide emissions. Rapidly used renewable energy sources namely wind energy plays a significant part as a sustainable power source [1]. The kinetic energy of surrounding air traveling over the earth is known as wind energy. This kinetic energy is transformed into mechanical power, which is then converted into electric power [2]. This transformation is primarily based on wind turbines with variable and fixed speeds. Because of the variable wind speed, there is limited use of fixed-speed wind turbines versus variable-speed wind turbines. The Synchronous Permanent Magnet Generator (SPMG) is one of the types of wind turbine generators which are widely used in variable speed and direct drive machines. [3]. The speed control mechanism can be removed from a direct system that operates at poor speeds. Furthermore, the PMSG replaces the field excitation system with a permanent magnet, effectively reducing complexity, failures, expenses, and operating materials [4]. As a result, using PMSG without even a gearbox may be extremely effective and useful for coastal applications that demand less servicing. PMSG is commonly utilized in distribution generation power generating systems, and because grid regulations are being improved worldwide, PMSG wind turbines may be chosen in the long term over conventional wind energy systems that use doubly-fed induction generators [5, 6].

Because of advancements in microelectronics approaches, a substantial number of microelectronics coupled Distributed Generation Resources (DGR) units have been used near to load center which affects the quality of power [7]. Poor PQ is a severe issue that affects energy system performance. Voltage sag/swell, interruptions, overvoltage, harmonic distortion, unbalances, and power outages, are all common PQ issues in grid-connected Distribution Systems (DS) [8, 9]. The shutdown of wind energy systems due to a drop in voltage magnitude beyond a specified amount namely voltage sag is among the most serious PQ issues associated with GCWES. A voltage sag is a brief event between 2 ms to 1 minute in which the voltage level is reduced. Only two parameters, magnitude and time, are commonly used. The voltage sag lies in between 10% to 90% of operating voltage, with durations ranging from 0.5 cycles to one minute [8, 9]. To resolve these PQ issues, it is necessary to improve PQ and acquire the required load power of DS [10, 11]. The PQ plays a key role in supplying the utilities due to its reliable power supply. To meet users' basic electricity needs, power grids connecting several producing units to demand points are accessible throughout the country [12, 13]. The wind is the cleanest renewable energy source and is widely used to generate electricity. Several PQ issues mitigation techniques have been used to assess the economic impact and to stabilize the voltage profile across grid-connected DGR [14].

Literature Review and Research Gap

Various facts devices are introduced to mitigate PQ issues such as a unified power quality conditioner used in [15] to improve the quality of power. Microsystem technology such as Dynamic Voltage Restorer (DVR) that mitigates PQ issues for wind energy systems is proposed in [16]. Modeling and analysis of DVR to improve the stability and PQ in a small microgrid are presented in [17]. Various PQ issues voltage sag/swell mitigated by DVR presented in [18]. Supercharging capacitor-based DVR protects the sensitive load by mitigating voltage sag introduced in [19]. Back-to-back converter topology is introduced in [1] to control the dynamic performance of grid-connected wind energy conversion systems. A closed-loop DVR with a hysteresis controller is proposed in [20] to mitigate PQ issues. The study of various types of closed-loop integrated DVRs to mitigate PQ issues is represented in [21]. The study on various mechanisms and control schemes integrated into DVR is described in [22]. Hysteresis control-based unified power quality conditioner with multi converters is introduced in [23] to improve PQ in the wind energy system.

As per the literature survey, it has been observed that various studies are conducted to mitigate PQ issues with custom power devices. Moreover, many control strategies are introduced to control the functionality of these devices so that the reliability of the system can be enhanced. Moreover, it is found that the improvement in Total Harmonic Distortion (THD) percentage with the use of hysteresis controller-based custom power devices is not less than 1%. Here hybrid of Proportional and Integral (PI) and PWM-based hysteresis control scheme is used to generate the PWM pulses that drive the feedback converters of the proposed topology such as shunt and series converter. According to the previous method, mitigation topologies has a drawback in terms of optimal size and location of energy storage device. The problem existing in the conventional mitigation technique is rectified by FBC-SSC topology. The WES is also upgraded by the proposed network response. The suggested method is then tested using a genuine PI and PWM-based hysteresis control scheme. As per the outcomes, the suggested model improves the previous one in terms of PQ.

Key Contributions

The key contributions of thimanuscript are to improve the PQ in GCWES. Because of wind variations, the energy of wind systems into an electricity network has the greatest impact on PQ.

- The hybrid of PI and Pulse Width Modulation (PWM)-based hysteresis-controlled FBC-SSC presented in this work improves the PQ.
- FBC-SSC topology, which is one the efficient topology to mitigate above mentioned PQ issues based on shunt and series voltage source converters.
- The impact of multiple power quality factors, such as harmonic distortion and voltage sag/swell has been evaluated and regulated simultaneously.
- The suggested control scheme's existence has been confirmed using a realistic distribution microgrid configuration.

Organization of Research Paper

The following sections constitute this manuscript: Section 2 discusses the problem formulation that has a significant effect on the grid-connected system. Section 3 explains the proposed methodology, which includes improved hysteresis control-based FBC-SSC, Section 4 describes the Simulink model and results in discussion, and Section 5 accomplishes the proposed method of analysis.

2 Problem Formulation

The effectiveness of the proposed system can be affected by several PQ issues like notch transients, voltage dip, interruptions, and THD. This must be eliminated by employing an effective method for developing MHC. So the above-mentioned PQ issues can be reduced by using such proposed schemes.

2.1 Wind Turbine Modelling

The maximum wind power extracted from the wind is expressed as follows [24]:

$$\mathrm{P_{wind}} = 0.5\rho \mathrm{A} \mathrm{v_w^3} \tag{1}$$

Turbine power is expressed as:

$$\mathrm{P_m} = 0.5\rho \mathrm{A} \mathrm{v_w^3} \mathrm{C_p} \tag{2}$$

Wind turbine speed vs wind turbine power characteristics is depicted in Figure 2.

Tip speed ratio of the wind turbine is the ratio of the product of the angular speed of rotor with rotor radius to wind speed given by:

$$\mathrm{TSR} = \lambda = \frac{\omega \mathrm{R}}{\mathrm{V_w}} \tag{3}$$

ρ	Air density (kg/m^3)
A	Swept Area of turbine blade (m^2)
$\mathrm{V_w}$	Wind velocity (m/s)
R	Turbine blade radius(m)
ω	PMSG rotor angular speed (rad/sec)
$\mathrm{C_p}$	Power Coefficient

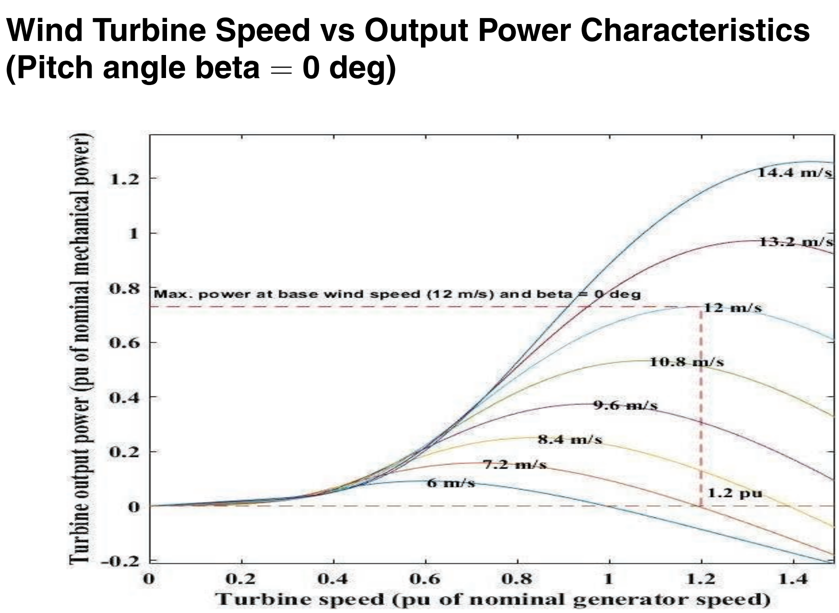

Figure 2 Wind turbine power characteristics.

2.2 PMSG Modelling [19, 25]

The d-q axis ‘park’ concept is shown in Figure 3. The rotor in the PMSG is composed of permanent magnets and is not powered by an auxiliary source of energy to generate magnetic fields. As a result, the rotor voltage equations do not require to be created because the rotor flux varies with time. The following are the voltage equations for the stator.

Stator Voltage Direct and Quadrature Axis Model

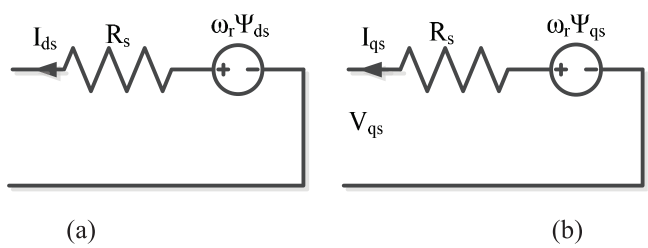

Figure 3 (a) Stator voltage direct axes model, (b) quadrature axis model.

Stator voltage direct and quadrature axis components:

$$V_{ds} = \frac{d\psi_{ds}}{dt} - \omega_e \psi_{qs} - R_s i_{ds} \tag{4}$$

$$V_{ds} = \frac{1}{\omega_b}\frac{d\psi_{ds}}{dt} - \omega_e \psi_{qs} - R_s i_{ds} \tag{5}$$

$$V_{qs} = \frac{1}{\omega_b}\frac{d\psi_{qs}}{dt} - \omega_e \psi_{ds} - R_s i_{qs} \tag{6}$$

With

$$\psi_{ds} = -L_{ds} i_{ds} - \psi_m, \psi_{qs} = L_{qs} i_{qs}$$

In steady-state conditions, the active and reactive power of PMSG is expressed as

$$P_S = V_{ds} i_{ds} + V_{qs} i_{qs} \tag{7}$$

$$Q_S = V_{ds} i_{qs} - V_{qs} i_{ds} \tag{8}$$

R_s Stator resistance
ω_b Base angular speed (rad/sec)
L_s Stator leakage inductance
ψ_m Flux linkage
i_s Stator current

Stator voltage direct axes and quadrature axes are expressed in the above equations and depicted in Figure 3.

2.3 THD Measurement [26]

THD is defined as the ratio of the RMS of the voltages/power harmonics to voltage/power fundamental harmonics, as stated by the equation

In voltage

$$\mathrm{THD_V} = \frac{\sqrt{\mathrm{V}^2 + \mathrm{V}^{3+} + \mathrm{V}^4 + \mathrm{V}^5 \ldots \mathrm{V}^n}}{\mathrm{V_{RMS}}} \tag{9}$$

In power

$$\mathrm{THD_P} = \frac{\sqrt{\mathrm{P}^2 + \mathrm{P}^{3+} + \mathrm{P}^4 + \mathrm{P}^5 \ldots \mathrm{P}^n}}{\mathrm{P_{RMS}}} \tag{10}$$

3 Proposed Methodology

To maintain stability in the injection of active power, FB-HC of multi converters of FBC-SSC for GCWES is proposed in this work. It enhances the PQ by introducing the PWM signal from grid network voltage at each switching period. Implementation of non-linear loads in industries and DS has been increased, which leads to distortion in the supply waveforms [27]. PQ issues are also caused by a variety of power system failures including interruptions, voltage sag/swell, interruptions, and THD. Flexible AC Transmission System (FACTS) has recently become a well-known word in energy systems for improved stability via signal conditioning devices. The FACTS devices have been given greater adaptability for increasing the use of old systems and changing system performance [28].

The method for power generation with wind turbine-based PMSG, pitch control, is depicted in Figure 4. Because of its benefits, the PMSG is preferred as a generation engine above all the other engines due to its cost-effectiveness and flexibility. The pitch angle control scheme manages the wind turbine blade angle for controlling the speed of rotation in such a manner that each airflow is maintained constant. The FBC-SSC controller can help you prevent PQ problems.

Grid Connected Wind Energy System With FBC-SSC

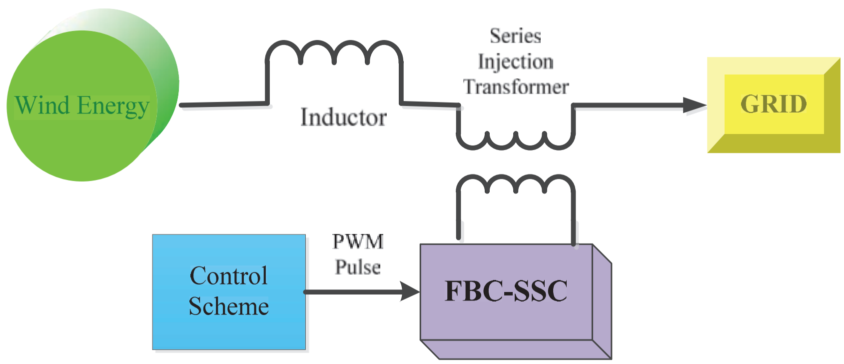

Figure 4 Schematic diagram of GCWES with FBC-SSC.

3.1 FBC-SSC

It is also known as the storage less DVR. A FBC-SSC device is present here to limit the interruption in grid-connected sensitive loads, and it is coupled to the WES distribution network. In this device key element is the voltage storage component namely the battery to supply to the converter and the output of the converter injected into the network in series which is controlled by the FBC-SSC control scheme. Battery size and storage capacity are the main limitations of this device. To overcome these limitations this paper introduces a modified FBC-SSC and it is also known as FBC-SSC. Modified FBC-SSC consists of voltage converters, out of these one converter namely a rectifier connected in parallel through an AC link, and another converter namely an inverter linked in series to GCWES. This feedback link with two converters has been used to compensate for the PQ issues depicted in Figure 5.

The main aim of the designed FBC-SSC are:

- To protect the grid integrated load L_1, the grid voltage V_{g1} is regulated from various 3-phase faults in the distribution network.
- To protect the load L_2, the load voltage V_{l2} is regulated from various 3-phase faults in the distribution network.
- To reduce THD present in the signal of voltage due to nonlinear components connected in the proposed network.

General Structure of FFB-SSC

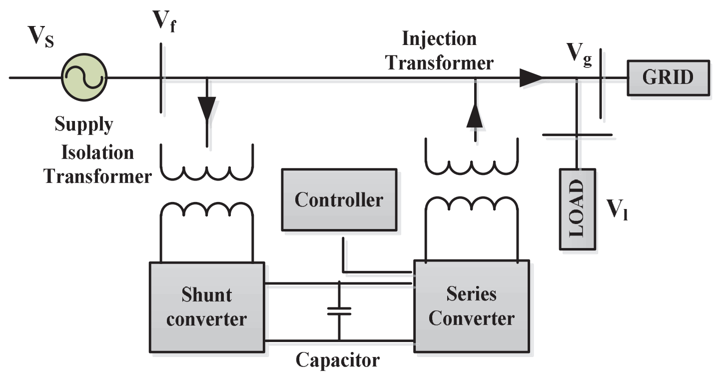

Figure 5 The general structure of FFB-SSC.

The output voltage of the series converter is depicted by Equation (11) in the FBC-SSC single-phase equivalent circuit layout as depicted in Figure 6.

$$\mathrm{V_{se} = V_l - V_s} \tag{11}$$

FFB-SSC Single Line Phase Equivalent Circuit

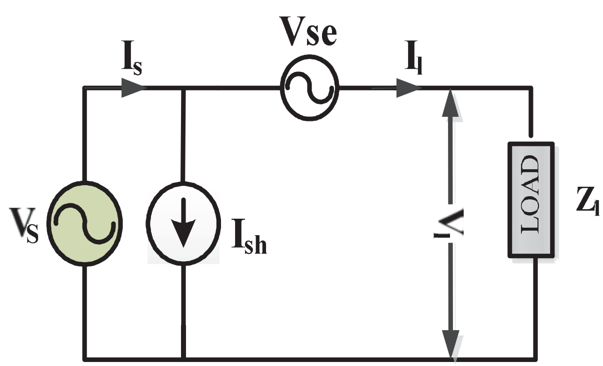

Figure 6 FBC-SSC single line phase equivalent circuit.

3.2 FBC-SSC Control Scheme

The proposed control method generates the gate trigger pulse by associating the SRF and PI controller. Generally, hysteresis regulates the error and stabilizes the controller response. In recent times, no. of controllers have been used to generate gate trigger pulses for the series converter. We have used a well-known hysteresis controller of the static series compensator to design an SSC controller which is not only used for its efficiency but also able to operate under any failure condition. The issue of both conventional controllers is poor response during failures or sudden changes in load values. This modified controller switching response is very fast, even though it can drive with several inputs and variable issues. Therefore conventional controllers are combined with hysteresis control.

The goal of this control scheme is to convert the three-phase ac supply to two axes (dq0) rotating Synchronous Reference Frame (SRF) by Clarks and Park's transformation as depicted in Equations (12) and (13) [29]. The selected control strategy accomplishes the following tasks:

- Detecting PQ issue by monitoring the magnitude and phase angle of the supplied voltage during ongoing operation. This is accomplished by the implementation of the feedforward-feedback and Phase-Locked Loop (PLL) technology.
- Estimating the corresponding voltage w.r.t reference voltage and accordingly will generate gate pulses to the inverter of FBC-SSC.

$$\begin{bmatrix} \mathrm{v_{sa}} \\ \mathrm{v_{sb}} \\ \mathrm{v_{sc}} \end{bmatrix} = \frac{\sqrt{2}}{2} \begin{bmatrix} \cos(\theta) & -\sin\theta & \frac{\sqrt{2}}{2} \\ \cos\left(\theta - \frac{2\pi}{3}\right) & -\sin\left(\theta - \frac{2\pi}{3}\right) & \frac{\sqrt{2}}{2} \\ \cos\left(\theta + \frac{2\pi}{3}\right) & -\sin\left(\theta + \frac{2\pi}{3}\right) & \frac{\sqrt{2}}{2} \end{bmatrix} \begin{bmatrix} \mathrm{v_d} \\ \mathrm{v_q} \\ \mathrm{v_0} \end{bmatrix} \tag{12}$$

$$\begin{bmatrix} \mathrm{v_d} \\ \mathrm{v_q} \\ \mathrm{v_0} \end{bmatrix} = \begin{bmatrix} \cos(\theta) & \cos(\theta - 2\Pi/3) & \cos(\theta + 2\Pi/3) \\ -\sin(\theta) & -\sin(\theta - 2\Pi/3) & -\sin(\theta + 2\Pi/3) \\ 0.5 & 0.5 & 0.5 \end{bmatrix} \begin{bmatrix} \mathrm{v_{sa}} \\ \mathrm{v_{sb}} \\ \mathrm{v_{sc}} \end{bmatrix} \tag{13}$$

Block Diagram of FBC-SSC Control Scheme

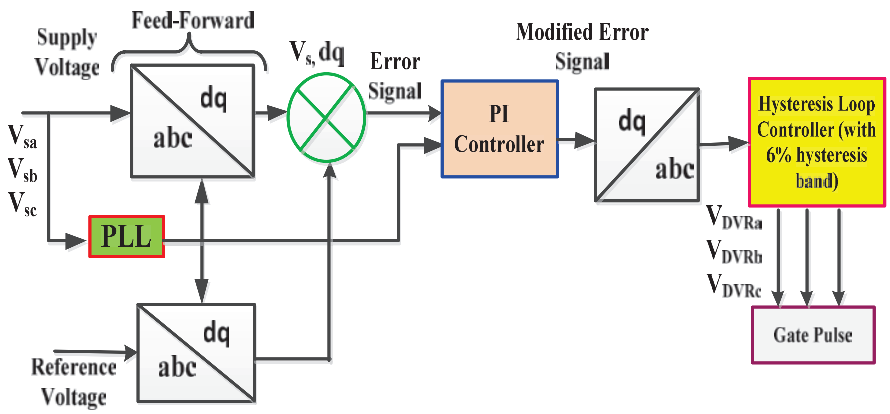

Figure 7 Block diagram of the FBC-SSC control scheme.

The PI controller adjusts the error signal and adjusts the gain settings based on the error. According to the above statement, the PI controller plays a crucial role in stabilizing. The modified error signal is compared to the grid voltage with a feedback loop as depicted in Figure 7. A PWM signal can be formed by reviewing the two values [30]. This PWM signal changes a lot depending on the active power consumption. In addition, to make a symmetrical waveform, the PWM waveform may be formed by adjusting the controller's hysteresis band. It usually ranges from around 5 to 20 %. A limit of 20% is accessible, after which the supply becomes irregular and produces additional THD in the outcome.

4 Simulink Model and Results in Discussion

This part contains deep research on the simulation work to verify the suggested concept of adaptive SRF and PI controller-based hysteresis controller of FBC-SSC. The complete model was created in the MATLAB/Simulink tool and various simulation measures based on several faults are discussed in this paper.

Block Diagram Grid-Connected Wind Energy System With Proposed Scheme

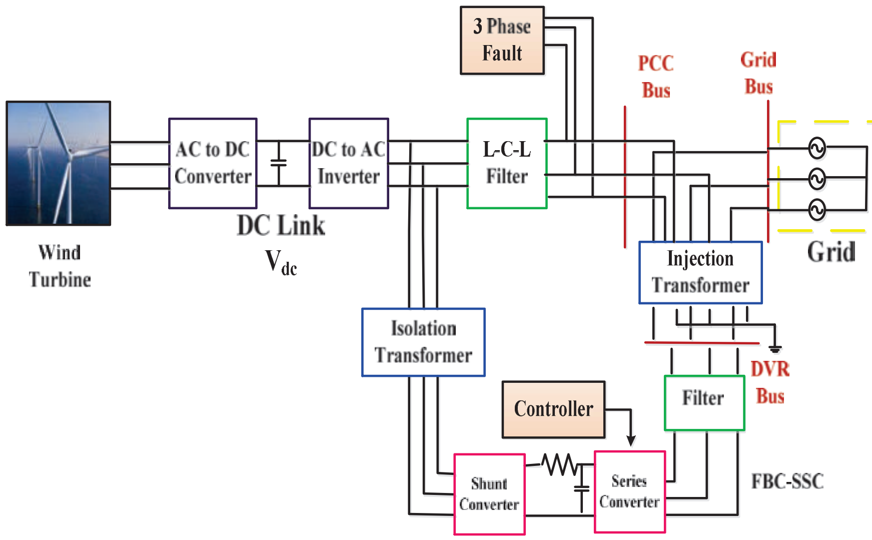

Figure 8 Block diagram of GCWES with the proposed scheme.

The measured results are acquired at each stage to validate the proposed system's operating characteristics. Figure 8 depicted the proposed model of the introduced methodology hysteresis control-based FBC-SSC system. The main parameters are described in Table 1. The performance of GCWES can be analyzed and assessed from the following cases:

Table 1 Test system parameters

Simulation parameters	Values
Base Wind Speed	100 m/sec
Stator Resistance	0.002 p.u.
Flux linkage	0.15 p.u.
Armature Inductance	0.02 H
Rated Voltage and frequency	560 V/50 Hz
Base Rotational Speed	1.1 p.u.
Max. Power at base wind speed	0.72 p.u.

4.1 Balanced Voltage Sag

Figure 9(a) depicts a 50 percent balanced voltage sag that occurs from the generator side when the grid increases the electricity demand when the wind turbine is running under low wind flow conditions, with time intervals ranging from t = 0.3 s to 0.7 s. Voltage restoration response is selected as quickly as the FBC-SSC control scheme detects a voltage loss variation in the system and inserts the necessary voltage to compensate for the PQ issue, as illustrated in Figure 9(b) and 9(c) depicts the optimized grid voltage state with minimized balanced voltage sag, ensuring the FBC-SSC performance stability.

Figure 10(a) depicts the active power (P_sPCC) and Figure 10(b) depicts the reactive power (Q_sPCC) at the Point of Common of Coupling (PCC) bus during the 50% balanced sag, Figure 10(c) depicts the active power (P_gGrid) and Figure 10(d) depicts reactive power (Q_gGrid) at grid bus after FBC-SSC operation with the proposed control scheme. Figure 10(e) depicts rotor speed after FBC-SSC operation, and Figure 10(f) depicts the stator current after mitigation of balanced sag.

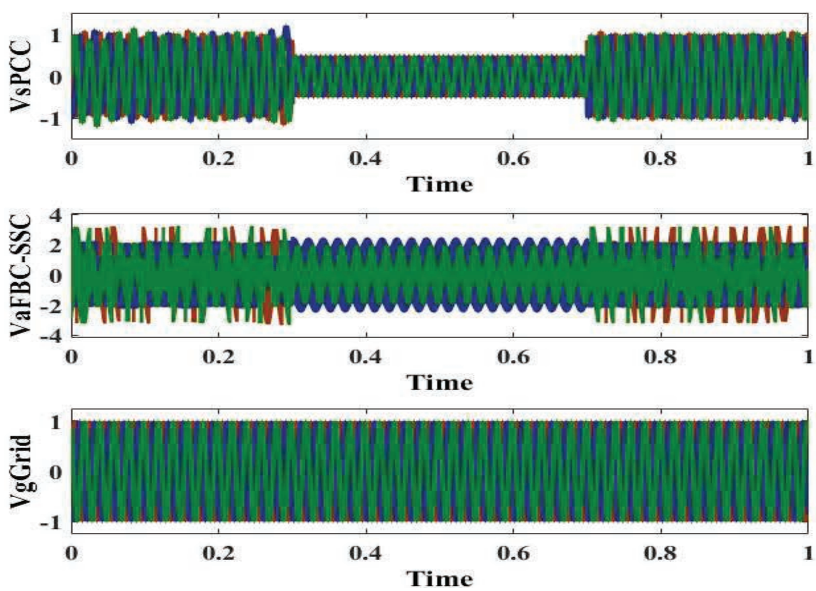

Figure 9 (a) Supply voltage during balance voltage sag, (b) FBC-SSC Injected voltage at FBC-SSC bus, (c) Grid voltage at grid bus.

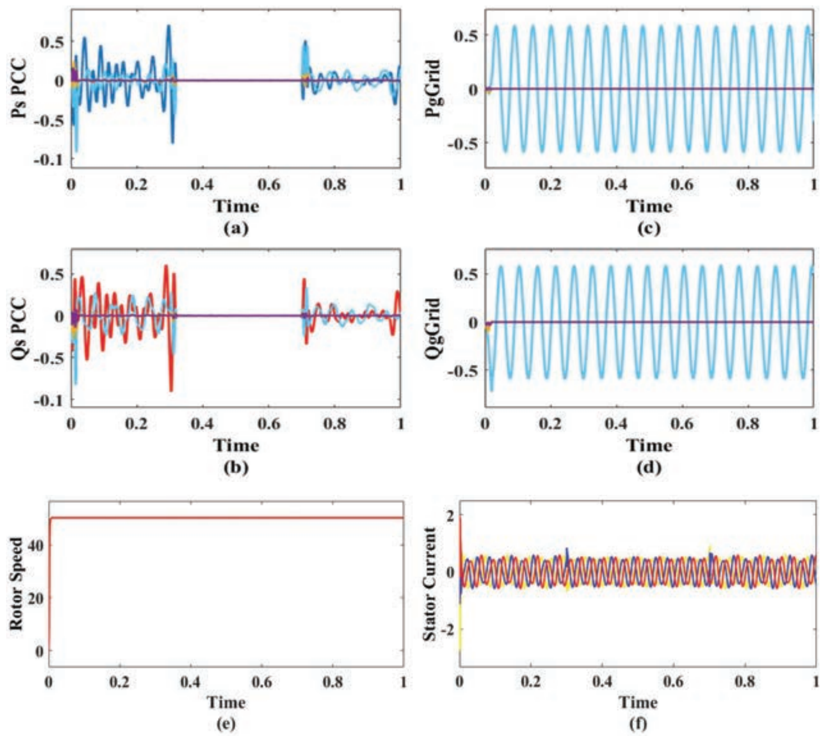

Figure 10 (a) Active power during fault without FBC-SSC, (b) Reactive power without FBC-SSC, (c) Active power with FBC-SSC, (d) Reactive power without FBC-SSC, (e) Rotor speed of PMSG with FBC-SSC control scheme, (f) Stator current of PMSG with FBC-SSC control scheme.

4.2 Balance Voltage Swell

When there is a voltage swell in the GCWES, the FBC-SSC should initiate its function by consuming grid power. Figure 11(a) depicts a 50% balanced voltage swell that occurs between t = 0.3 s to 0.7 s. As shown in Figure 11(b), the FBC-SSC detects the entering exceeding voltage from the wind generator side and inserts the voltage in phase with grid integrated system voltage but with a 180-degree phase shift, which is deducted from the additional voltage amplitude. Therefore, after the voltage settles down at its nominal limit, the FBC-SSC returns to standby mode to preserve the lowest possible switching losses. According to Figure 11(c), the proposed scheme can keep the grid voltage peak nearer to the standard rated voltage.

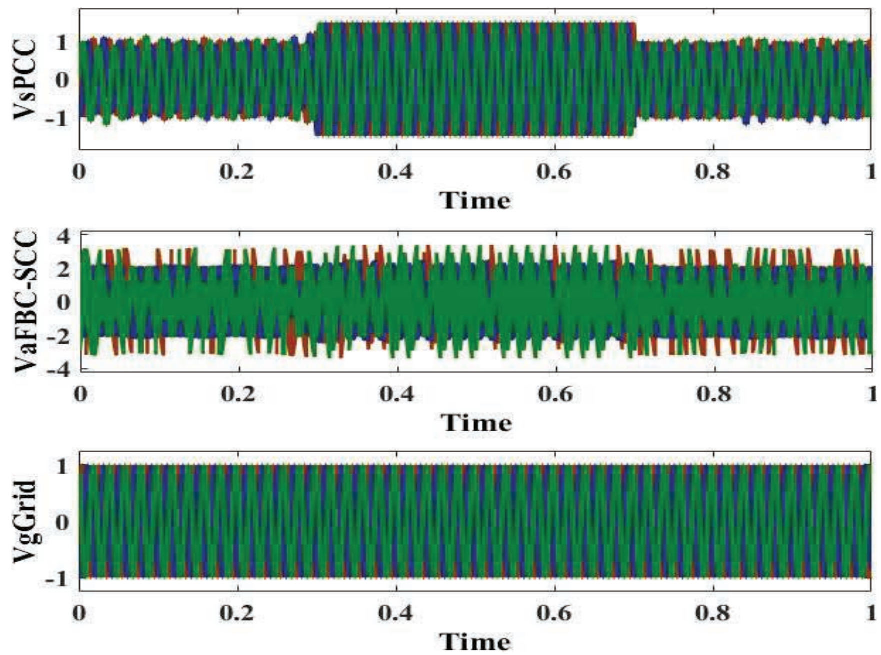

Figure 11 (a) Supply voltage at PCC bus during balanced voltage swell, (b) FBC-SSC Injected voltage at FBC-SSC bus, (c) Grid voltage at grid bus.

Figure 12(a) depicts the active power (PsPCC) and Figure 12(b) depicts the reactive power (QsPCC) at the PCC bus during the 50% balanced swell, Figure 12(c) depicts the active power (PgGrid) and Figure 12(d) depicts reactive power (QgGrid) at grid bus after FBC-SSC operation with the proposed control scheme. Figure 12(e) depicts rotor speed after FBC-SSC operation, and Figure 12(f) depicts the stator current after mitigation of balanced sag.

4.3 Power Outage (Short-circuit Fault)

A short circuit can occur when the wind energy system fails and the distributed feeder fails, resulting in zero voltage amplitude. The grid-connected load may be affected in this scenario. A power outage in one of the transmission lines from the grid-connected load side will also influence the line overall supply, resulting in voltage instability. However, in this scenario, FBC-SSC is activated at intervals of t = 0.3 s to t = 0.7 s during power interruptions from the GCWES side, as shown in Figure 13(a). Figure 13(b) depicts how the proposed scheme may handle power outages by infusing about 90% of

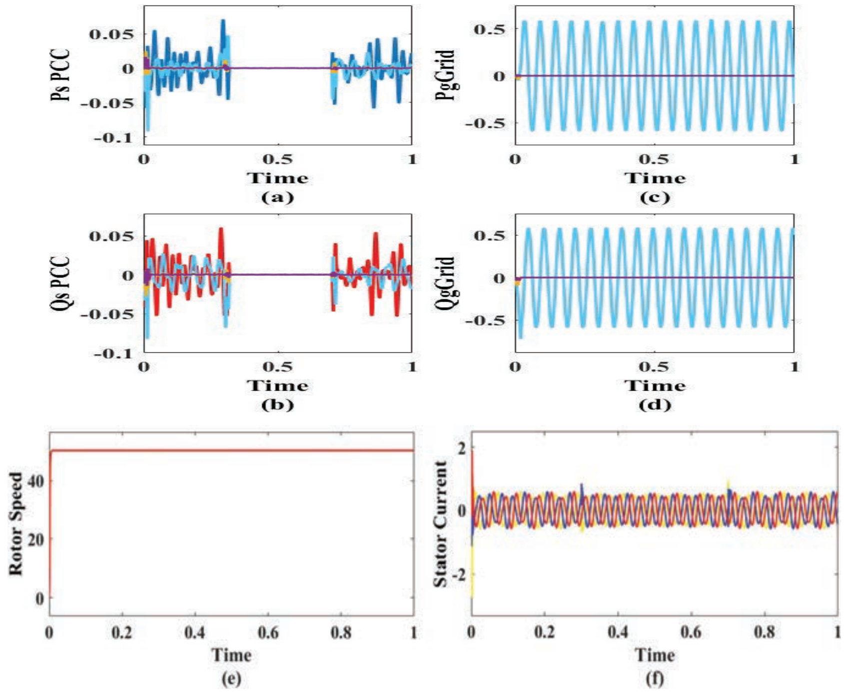

Figure 12 (a) Active power during fault without FBC-SSC, (b) Reactive power without FBC-SSC, (c) Active power with FBC-SSC, (d) Reactive power without FBC-SSC, (e) Rotor speed of PMSG with FBC-SSC control scheme, (f) Stator current of PMSG with FBC-SSC control scheme.

the system's rated voltage. The regulated voltage after mitigation is shown in Figure 13(c). The suggested system, on the other hand, functions as a distribution grid and can sustain during various three-phase fault conditions.

Figure 14(a) depicts the active power and Figure 14(b) depicts the reactive power at the PCC bus during the power outage at (L-L-LG) phase fault, Figure 14(c) depicts the active power and Figure 14(d) depicts reactive power at grid bus after FBC-SSC operation with the proposed control scheme. Figure 14(e) depicts rotor speed after FBC-SSC operation, and Figure 14(f) depicts the stator current after mitigation of three phases of short circuit fault.

4.4 THD Analysis

THD has a significant detrimental influence on the GCWES performance, and the majority of grid instabilities are associated with harmonics. The THD

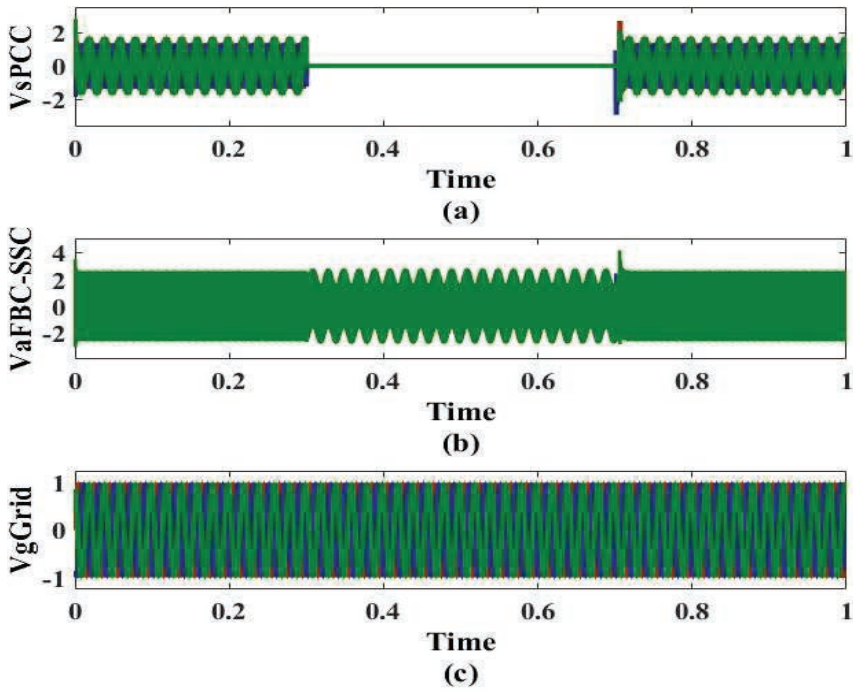

Figure 13 (a) Supply voltage at PCC bus during short circuit fault, (b) FBC-SSC injected voltage at FBC-SSC bus, (c) Grid voltage at grid bus.

analysis of GCWES during PQ issues is shown in Figure 15(a), and the THD analysis after FBC-SSC is displayed in Figure 15(b). The comparison in Table 2 demonstrates a significant improvement in FBC-SCC performance when employing the efficient control scheme. The THD percent of a GCWES without the proposed scheme is 75.03 percent, but it is 1.30 percent with Feed Forward control and 0.94 percent with the FBC-SSC control scheme.

The feasibility of the suggested scheme in terms of balance voltage sag/swell, power outage, and regulated active and reactive grid power is demonstrated in the simulation model and results in the discussion section. The key advantages of FBC-SSC over FBC-SSC are the drop in shunt and series converter rating, and compensating the issues related to energy storage devices as in FBC-SSC. The proposed topology highlights how the GCWES relies on FBC-SSC to increase PQ. The MCUPQC FBC-SSC with the proposed control scheme is used in this strategy to eliminate PQ concerns. In the results section, the suggested Simulink model and measures are shown.

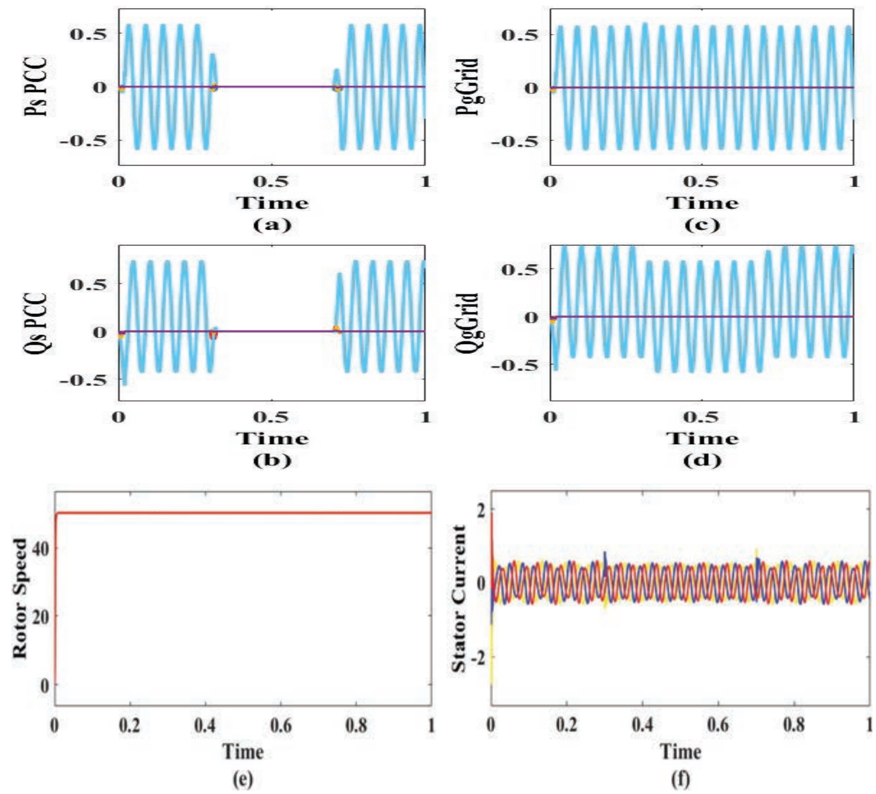

Figure 14 (a) Active power during fault without FBC-SSC, (b) Reactive power without FBC-SSC, (c) Active power with FBC-SSC, (d) Reactive power without FBC-SSC, (e) Rotor speed of PMSG with FBC-SSC control scheme, (f) Stator current of PMSG with FBC-SSC control scheme.

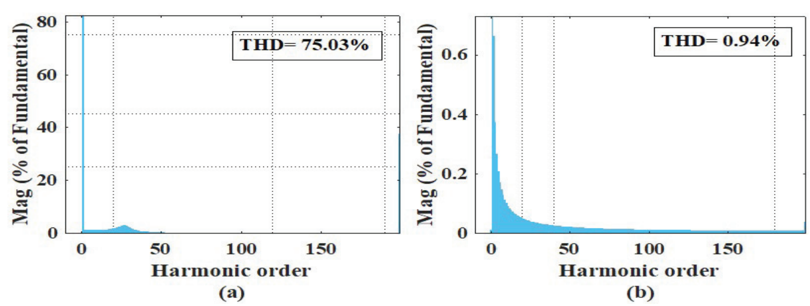

Figure 15 (a) Harmonic spectrum of GCWES without FBC-SSC, (b) Harmonic spectrum of GCWES with FBC-SSC.

Table 2 Comparative analysis of FBC-SSC controllers

Parameters	PI Controller	PWM Controller	Proposed Controller
Source Voltage THD% without FBC-SSC	75.03	75.03	75.03
Grid Voltage THD% With FBC-SSC	2.80%	1.03%	0.94

5 Conclusion

This study proposes a hybrid of PI and PWM controller-based hysteresis control scheme with FBC-SSC. It is used to improve the PQ of GCWES. In comparison to a traditional FBC-SSC, the new configuration is capable of protecting sensitive and valuable loads against disruptions, abnormalities, and imbalance. The effectiveness of the FBC-SSC has been assessed under various fault conditions. This study proposes a hybrid of PI and PWM controller-based hysteresis control scheme with FBC-SSC. The entire procedure is simulated in MATLAB/SIMULINK. It is used to improve the PQ of GCWES. In comparison to a traditional FBC-SSC, the new configuration is capable of protecting sensitive and valuable loads against disruptions, abnormalities, and imbalance. The efficacy of the FBC-SSC has been assessed under various fault conditions. The various PQ issues assessed in this study such as balance voltage dip, swell, power outage as well as THD. To prevent these PQ issues, and also to reduce THD, the FBC-SSC with a hybrid control scheme-based hysteresis controller is described. Furthermore, voltage regulation was accomplished by shielding the loads from any disruptions. The findings are also compared to current methods such as PI controllers and PWM controllers to demonstrate the superior performance of the suggested technique shown in Table 1.

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Biographies

Preeti Rani received her B.Tech. degree in Electrical Engineering in 2012 from GZSCCET, PTU, Bathinda. She received her M.Tech in Power Electronics and Derives from the University of HISAR in 2014 respectively. She worked as Assistant Professor, Department of Electrical Engineering, Chandigarh University from 2014 to 2019. She is currently research scholar in electrical engineering department in MRSPTU, Bathinda, Punjab. Her research interests are in the area in the field of Renewable energy system, optimization, active filter, passive filter micro/smart grid and power quality.

Ved Parkash Arora received his B. Tech. degree in Electrical Engineering in 1999 from Kurukshetra University, Kurukshetra. He received his M. Tech from GNDEC Ludhiana in power system in 2007 and Ph.D. degree in Power System from National Institute of Technology Hamirpur (H.P.)-India, in 2015. He has vast industrial as well as teaching experience. Presently he is working as Assistant Professor, Department of Electrical Engineering, Maharaja Ranjit Singh Punjab Technical University Bathinda, Punjab. His research interests are in the area of power market, renewable energy sources, frequency-based pricing.

Naveen Kumar Sharma received his B.Tech. degree in Electrical & Electronics Engineering in 2008 from UPTU Lucknow (U.P.). He received his M. Tech and Ph.D. degree in Power System from National Institute of Technology Hamirpur (H.P.)-India, in 2010 and 2014 respectively. He worked as Lecturer in Department of Electrical Engineering, N. I. T. Hamirpur (H.P.) from March 2014 to May 2017. He is currently working as Assistant Professor, Department of Electrical Engineering, I. K. G. Punjab Technical University, Kapurthala, Punjab. His research interests are in power market, renewable energy sources, power system optimization, micro/smart grid, power quality.