A Few Analysis on the Dynamic Compensation of Voltage and Frequency Modulation in the Solar PV Interface QZSI Impedances Source Network for Wind Energy

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Abstract: The generation of electricity from wind and solar Photovoltaic (PV) systems is entirely dependent on weather conditions and variable nature causes output will sag and swell. Such efficient techniques for energy transmission and distribution networks is becoming increasingly critical. In the proposed system Quasi Impedance Source Inverter (QZSI)-based Static Compensator (STATCOM), is used to enhance the quality of the electricity in a hybrid energy storage method are all components for the distributed power generating system. DFIG is made up of stator windings that are directly linked to the fixed frequency and voltage-based converters that are allowed directly in rotor windings. Given that stator voltage is doubled, the expression "doubly supplied" is obtained from the mains even though the rotor voltage is generated by the power converter. The output result of sag and swell in large transmission networks can be reduced, and the fluctuation decreased by the usage of controller technique can be improved by power quality-based simulation using MATLAB tool. In addition to supporting grid voltage with reactive power supply, this strategy reduces the stator and rotor overcurrent currents, electrical mutandis oscillations, as well as DC Transient Overvoltage Links. This way DFIG can effectively meet the latest grid code requirements for fault transmissions through FRT.

Keywords: Quasi Impedance Source Inverter (QZSI), Photovoltaic (PV), Fault Ride through (FRT).

1. INTRODUCTION

A variation of equipment can be used to improve power quality, from inexpensive (providing low security or compensation), and expensive equipment (high level of protection or compensation) to the requirements of improving power quality. For example, intermediate voltage suppressors are used to detect flotation and reduce them to safer conditions, while voltage regulators maintain voltage outputwithin a certain range, despite fluctuations in input. Isolation transformers can be useful in compensating for the high or low voltage required to change the voltage. The quality of the force depends on the network topology of the force, the amount ofenergy injected into the network of conforming non-linear loads, and the intensity ofthe transition transients. Many modern power electronics face load. Wind turbines (WTs) taken into consideration here are Doubly Fed Induction Generators (DFIGs), which may operate at various speeds.

The DFIG is equipped with an electronic converter that allows the control of both real and reactive power. In order to ensure continuous DC link voltages for each wind turbines' inverter in case of disturbances, a STATCOM was employed to control the bus voltage. This will allow each wind turbine to operate continuously in case of disturbances, enabling the wind farm to be involved in grid side voltage and power control. STATCOMs can address transient occurrences more quickly and with higherperformance at lower voltages. The system voltage does not affect the STATCOM's maximum compensating current. A STATCOM enhances the system's transientstability and offers dynamic voltage management and power oscillation damping. The current flow between the converters thus a phase angle is adjusted to control ac systems.

Filters are an integral part of many systems, especially in communications and tool systems. Filters cross one band and reject the other. It is mainly used in passive RLC filters, active RC filters and switch capacitor filters. At very high frequencies, crystallization and SAW filters are often used. The passive filters work well at high frequency, but the needed trigger elements are large, cumbersome and not suitable for low frequencies. Moreover, inductors are not easy to produce in the same form and they do not compatible with a large number of contemporary assembly systems.

Functional amplifiers, resistors, and capacitors are used in active RC filters, which are created utilizing specialized thick film and thin film technologies. The operational amplifier's capabilities (such as frequency response, bandwidth, noise, offset, etc.) have an impact on how well these filters work. Switch-capacitor filters are monolithic filters with typically greater cost-performance. Made using capacitors, switches and function amplifiers. Compared to passive LC or active RC filters, poorly performing filters generally adjust the frequency spectrum of the inputsignal according to the level of the transmission function. The signal phase properties are modulated as they go through the filter. The system's immediate reactive power sources affect how much reactive power is delivered as well. The reactive power capacity is also influenced by the size of the synchronous machine and the wind turbine.

1.1 Objective.

➢ In any analysis of load flow, the main objective shall be to obtain the information mentioned below.

➢ The magnitude and phase angle of voltage for each bus, as well as real and reactive power flowing into each element.

➢ For each generator a reactive energy load shall be applied.

➢ Causes of increased losses in the traditional STATCOM identified the creation of a control plan and design approach for a hybrid STATCOM topology that will deliver lower losses than the traditional approach Runsimulations to verify the Hybrid STATCOM's recommended design and control philosophy.

2. LITERATURE SURVEY

The multilayer STATCOM is also put to the test and contrasted with traditional PWM control to show how well the suggested controller performs. According to the simulation findings, multilayer STATCOM will eliminate the disruptions. The reliability of protection for transmission lines linking high-capacity wind farms by symmetrically supplied induction generators and corrected by Static Synchronous Compensators (STATCOM) is a drawback of fixed- impedance-based distance relaying techniques. (Hasanzadeh. S, 2022). The small wind farm system's low magnitude minimal impedance results in a substantially greater magnitude steady state than positive- and negative-sequence power supply if a TL ground fault occurs. Additionally, wind farm dependent on the power produced by the wind, influenced by the wind speed (Biswas. S, 2022).

The unusual structure of fault current brought on by the LVRT of the DFIG's control action as well as the wind farm side's low fault current but high magnitude, zero-sequence current contribution during a ground fault are the main factors affecting the performance of the distance relay on the wind farm side. The conventional electrical grid has been impacted by distributed energy resources (DERs) (Rohouma. W, 2022). For low-voltage distribution networks with considerable PV penetration, this paper examines an alternative matrix converter-based Distribution Static Synchronous Compensator (D-STATCOM). This method can lengthen the useful life of inductors by using them as an energy storage medium (Neyshabouri. Y, 2022).

The reliability of the transmission grid, as well as the quality of power delivered to customers. Future utilities must use quick-acting, solid-state-based technologies to regulate reactive power continuously and dynamically for quick voltage control and reactive power compensation. The functioning of STATCOM using a Cascaded H-Bridge (CHB) later a Sub module Failure (SMEs) (Ballestín. J, 2022). Switch failure results in bypassing of the associated defective SM. An injection of Zero-Sequence Voltage (ZSV) to the converter phases allows for the maximum line-to-line voltage possible during post-fault operation. Fundamental ZSV component (FZSV) is reduced using a clamping approach following CHB STATCOM's operating point. However, FZSV leads to inconsistent flow of electrical energy into the converter stages. Following a SM failure the method resulted in an exceptionally high line to line voltage on the CHB AC side (Mahesh, 2016).

Compared to current NS-based techniques, a decrease in the basic ZSVFZV component for CHB phase voltages is observed. As FZSV declines, a smaller imbalance arises in the phase's active power. NSC is making up for FZSV's active power imbalance. To keep a balanced mean voltage of Capacitors in each phase, the reference NSC is defined by active energy flow equations at CHB stages. It is important to solve the issues that Distributed Energy Resources (DERs) are providing. Distribution networks in particular are becoming more crucial to the functioning of the power system (Patel. P. D. 2019).

Additionally, this network's three-phase, four-wire design contributes to the emergence of imbalances and several issues that result from them. Distribution System Operators (DSOs), who are primarily in charge of the distribution grid in this situation, are required to guarantee the quality of the supply to customers. To correct current imbalances in low-voltage power lines, this article uses a four-legged D-STATCOM (Ryndzionek. R, 2022). An urban distribution grid has been erected with a 35-kVA prototype. During the D-first STATCOM's month of operation, impact was examined, with the advantages studied and measured. This analysis examines the installation of a D- STATCOM prototype in an urban line where imbalances are common as part of a DER that permits the reduction of the current imbalances in a low-voltage distribution grid (Saxena 2022).

In addition to supporting grid voltage supplying reactive power to the grid, the stator and rotor over currents, electromagnetic torque oscillations, and DC link overvoltage support grid voltage. In this way, the DFIG can efficiently the Fault Ride through (FRT) requirements of the latest grid codes (Partheeban. M, 2023). The integrated photovoltaic source network with a Quasi-Impedance (QZ) Static Compensator (STATCOM) will be used to improve the power quality of the standalone wind conversion system (WECS). The Self-Excited Induction Generator (SEIG) and the Flywheel Energy Storage System (FESS) have both been used by the

standalone WECS. In order to account for voltage and frequency fluctuations over a longer period of time, the STATCOM DC-Link is integrated with the SPV power generating network. A fuzzy logic controller (FLC) and an improved second-order generalized integrator (ESOGI) are used to manage the voltages of the STATCOM DC-link and the SEIG terminal (Ramachandran. S, 2021).

A Unified Power Quality Conditioner (UPQC) based on a Quasi Z-Source Inverter (QZSI) and supported by photovoltaic is described to improve power quality. A series and parallel connection of converters makes up the UPQC. Active power filters (APFs) coupled in parallel and series are one of the adaptable bespoke power circuits to decrease current and voltage instability (Muthuvel. K, 2020). A fixed or variable voltage may be required by AC loads at their input terminals. Inverters must be properly managed in order to respond to the demands of the AC loads when used to power such loads. As the need for solar PV applications in emerging green technology increases, inverters with improved efficiency and sensitivity will become even more crucial. An inverter architecture using harmonic reduction techniques is suggested to improve power quality and offer a dependable power supply (Faris E 2020).

The incorporation of wind and solar energy into the current power system exposes the technical hurdles, such as power quality problems and non-technical concerns. Environmental concerns and the rising expense of fossil fuels have led to a major development in renewable energy sources. An electric power system called an integrated power grid is created by combining multiple separate power grids (Chelumala Nirosha, 2020). Wind turbines (WTs) powered by permanent-magnetic synchronous generators (PMSGs) typically use a two-stage power converter layout built on a voltage source inverter and DC/DC boost converter. In this study, a quasi-Z-source inverter (QZSI), an appealing option for boosting and converting the voltage from DC to AC in a single stage, is used to replace this setup (Emanuel P. P 2021).

The critical concerns, including approaches for improving voltage stability and determining the best locations and sizes for distributed generation (DG) units. Investigated is the effect of power system components on the voltage stability of transmission and distribution networks, including fixed capacitors, flexible AC Transmission Systems (FACTS), and energy storage systems (ESS) [17]. In order to improve power quality, the hybrid distributed power production system incorporates the static compensator (STATCOM) that is qZSI-based. Photovoltaic (PV), Wind Energy Conversion (WECS), and battery energy storage systems are all parts of the distributed power generating system (Karthick. R, 2020).

A 17-level QZS-CMI with fewer semiconductor switches that performs better and has reduced total harmonic distortion is perfect for high-power solar applications. QZSI is used to conduct the interface between the load and PV DC supply. Improvements have been made to the QZS-CMI design modeling, and the maximum power of the PV power generation system is now delivered. The parameters and control constraints are used to determine the goal function initially (Sankar. P, 2023). The solar grid-connected inverter serves as a crucial conduit between the photovoltaic power generating system and the electrical grid. The output power quality of the electrical grid has a direct impact on how well it operates. A fuzzy proportional complex integral control (PCI) approach was suggested for the existing internal loop control of the grid-connected solar inverter with a quasi-Z source in order to better improve the control impact (Tao Hou, 2020).

1.2 Problem Statement

➢ One of the most important problems with the production of wind power is the need for reactive power for voltage support. Designing and optimizing controllers for turbine power.

➢ Issues with wind generators connected to systems using series compensation. Difficulties with power quality, such as voltage flicker.

➢ The transmission of wind farms onto the grid is started and synchronized. Due to the interaction of the electric grid and the complex shaft and gear system of the wind turbines, the sub synchronous resonance is affected.

3. MATERIALS AND METHOD

An efficient way of improving the quality of power delivered to a distributed system may be through use of electrical energy conditioning devices that are powered electronically. The STATCOM is a custom circuit designed to compensate for the distortion of current and voltage at both source and load. This method proposes and also uses a flywheel DC motor for combined operation of the power quality conditioning system with an integrated PV and wind energy generator. The STATCOM is an active filtering-based compensator with a power electronics foundation. A series circuit, solar panels, and wind turbines coupled to a DC connection, which can account for voltage sag, swell, harmonics, and voltage interruption, have been added to the suggested framework in order to enhance it.

3.1 Wind (Doubly Fed Induction Generator (DFIG))

It may be possible to increase the quality of the power provided to the distributed system by using power conditioning devices with an electronic basis. In order to correct for both source current and load voltage flaws, a special power device called STATCOM was created, as seen in figure 1. The design of a hybrid PV and Wind power generating system that operates in tandem with a power quality conditioner is suggested in this way.
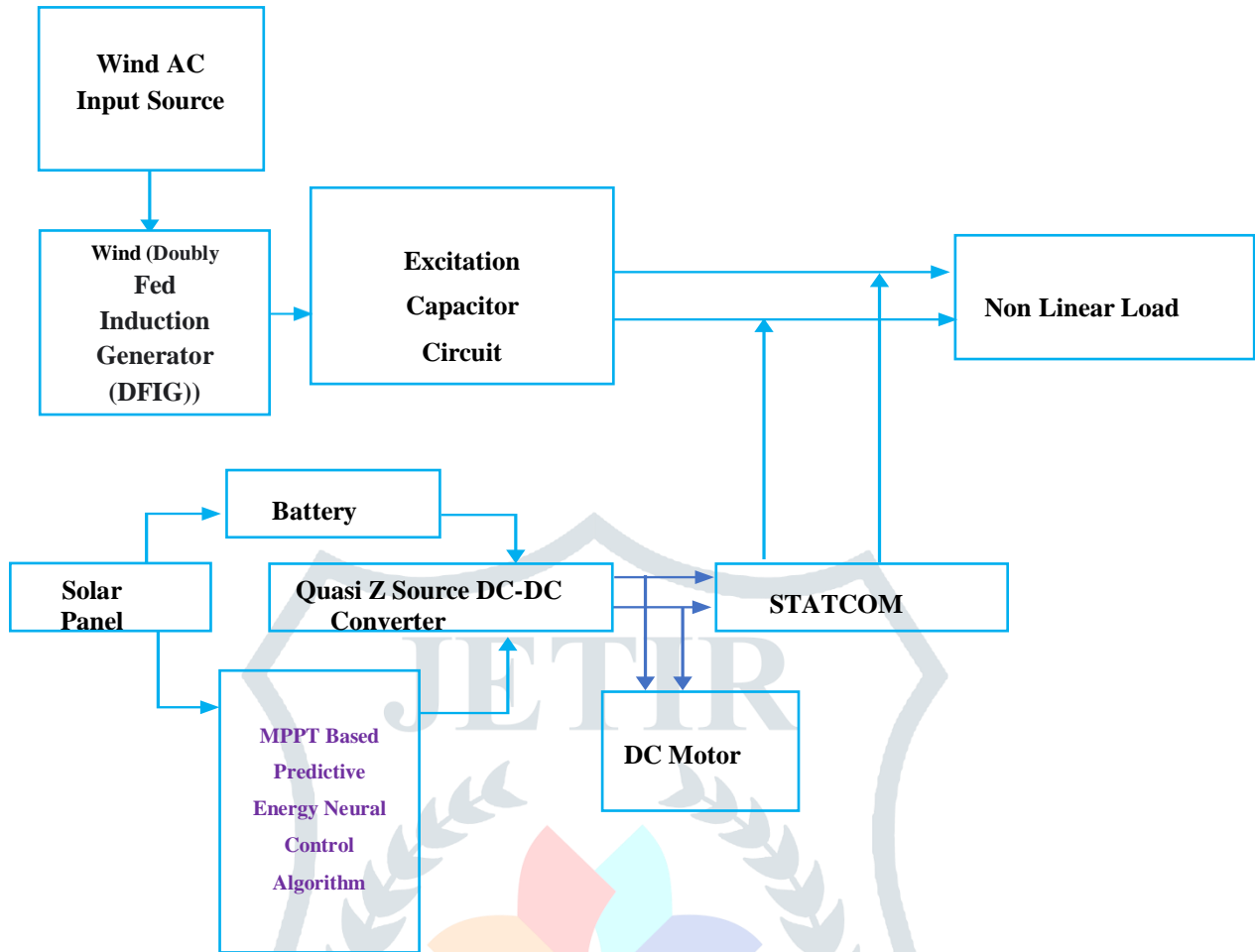
Figure 1. Developed Block Diagram

STATCOM works on the principle of Active Filter, which is a type of power electronics compensator. A fly wheel DC motor in produce energy is a device that converts direct current (electrical energy) into mechanical energy. In addition to its ability to improve the quality of energy supplied by the distribution system, it may also deliver active power onto the grid. System improvements for steady state and transient stability are possible with STATCOM. Because it can inject or absorb at its output terminals, actual and reactive power, the static compensator is regarded as a solid-state semiconductor switch.

The term "doubly fed" refers to an induction motor with a wound rotor in which the rotor and stator are connected to an electrical source. Three phase currents are used to drive a 3phase rotor winding. These circular currents produce the rotor magnet field. The stator's magnetic fields are interacting with the rotor in order to generate torque.

Fundamentally, the force that applies is produced by the magnetic interaction between the corresponding rotor and stator magnetic fields, or magnet poles of opposite polarity in this case. Both the leakage inductance of the phase winding and the resistance of the stator phase winding, are represented by two "parasitic" components on the stator side, Ls, and Rs. The φsfact that the materials used to make the windings, yet they only have limited conductivity naturally results in the stator resistance (hence resistance). The machine's production of usable flux, or flux that transitions from stator to rotor or the opposite, is modeled by magnetizing branch as shown in figure 2.

$$T \propto \psi_s \times \psi_r = |\psi_s||\psi_r|\cos\theta_i$$
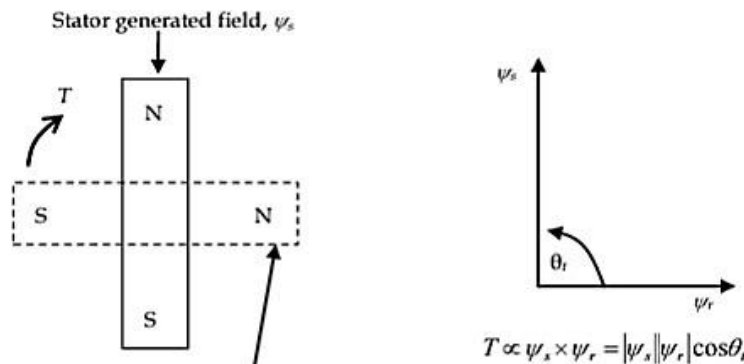
Figure 2. A magnetic pole system is powered by currents flowing through the stator and rotor windings.

System improvements for steady state and transient stability are possible with STATCOM. Because it can inject or absorb Actual and reactive power are present at its output terminals, the static compensator is regarded as a solid-state semiconductor.
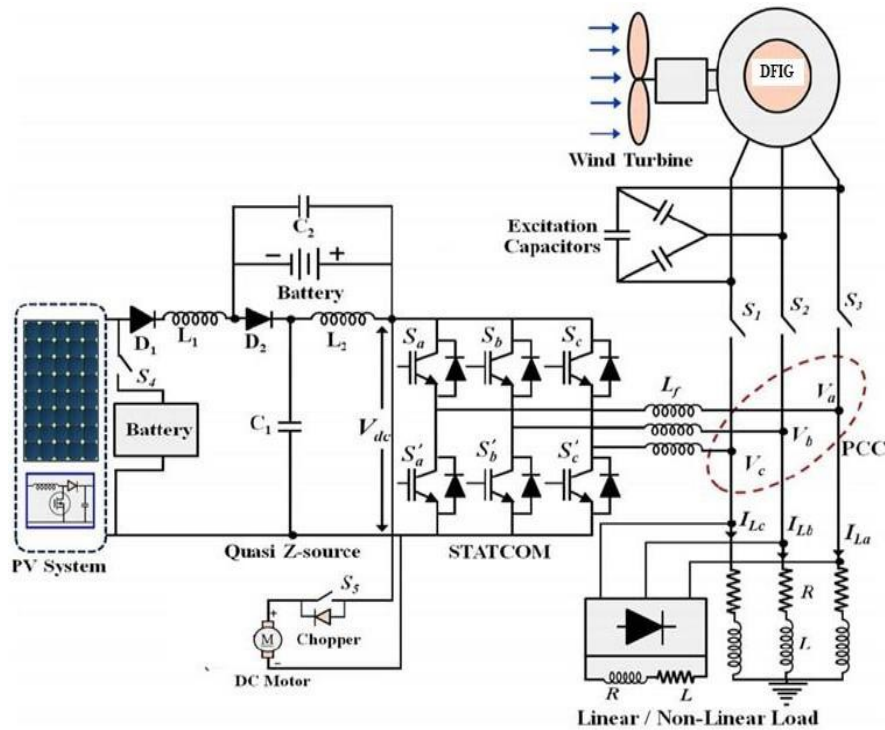

Figure 3. Proposed Circuit Diagram

The figure 3 shows that the circuit diagram, it represent numerous voltage swells, which are reduced using the Advanced. The bus R.M.S. voltage measurement is all that is required for the control system, which relies on Sinusoidal Pulse Width Modulation (SPWM). The controller selects the best gains depending on the size of the voltage swell, regulates the variation between the real and reference voltages, and then creates the necessary angle to reduce the difference to an acceptable amount. The signal is phase-modulated in PWM generators using the angle that the controller produces.

3.3 Excitation Capacitor Circuit

The oscillations occur at a specific frequency when the generator's inductive and capacitive impedances are equal. If the R-L load is withdrawn at startup and switched back on after a normal voltage gain, the oscillations are more apparent. Fluctuations are started by residual magnetism in the induction generator, which results in low voltage output are shown in figure 4. A variation in capacitance will alter the machine's speed by altering the frequency of oscillation. It is discovered that at a specific shaft power input, a reduction in capacitance leads to a rise in speed. For big loads, the change is more significant than for load variations.
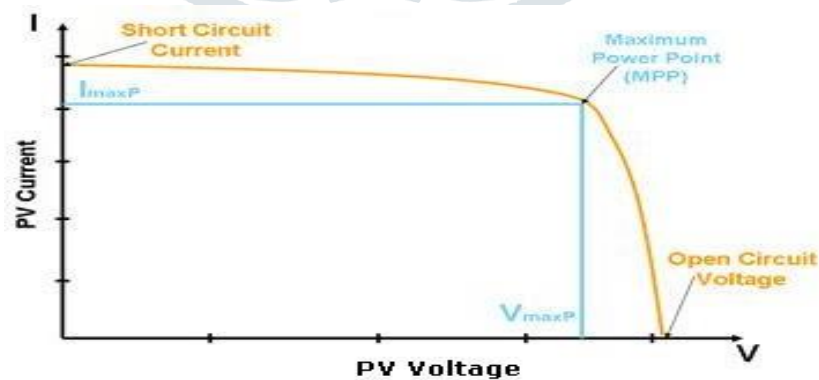

Figure 4. Circuit architecture of Excitation Capacitor Circuit

3.4 MPPT Controller

The maximum power capacity available shall be monitored by the MPPT solar charging controller. This will convert the PV module's energy to battery voltage. The interesting fact about the MPPT is that it's not a device, but an algorithm and software. This applies to the controller.
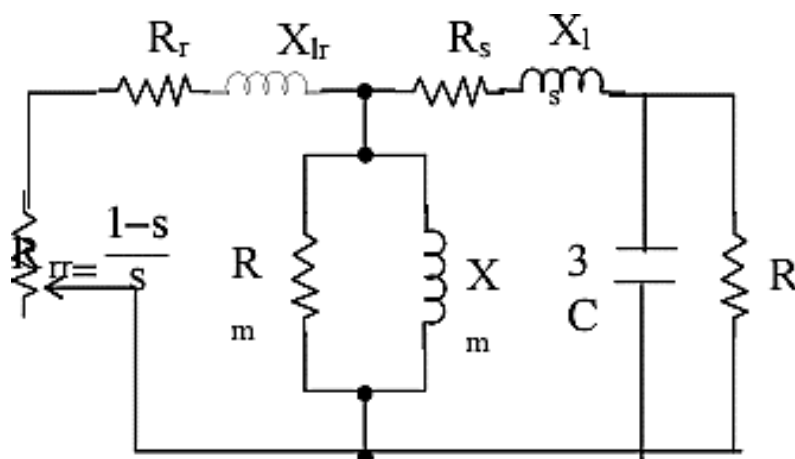

Figure 5. Voltage and Current characteristic of MPPT

For the purpose of generating maximum power at a specified time, the current and the voltage are combined at the maximum power point. The MPPT charging controller is tracking this energy and optimizing its voltage between batteries and Solar Panels. As shown in Figure 5, this control device is used for ungird system that run with no grid mechanism. The sun irradiance, temperature, and load impedance all affect how much power a solar panel can produce. A converter is used to increase the performance of a solar panel because the load impedance varies depending on the application. The temperature and sun irradiation are constantly changing. As a result, an online algorithm that dynamically determines the solar panel's working point is needed. The Maximum Power Point Tracking (MPPT) method makes effective solar energy conversion possible. Swarm Integral Neural Controller technique algorithms have been proposed, including Perturb and Observe and Incremental Conductance.

3.5 Predictive Energy Neural Control Algorithm

Particle Swarm Optimization is combined with the Predictive Energy Neural Control Algorithm to track MPP and simulation results are presented in this chapter to evaluate PV array performance under uniform and partial shade conditions. The main aim of combining Neural Network with Practical Swarm is to track the better PWM duty with faster convergence. The proposed PV system consists of four PV panels connected in a series under different shaded condition, DC-DC boost converter, DC load and MPPT controller employing PENCA to track MPP and determine the best Pulse Width Modulation (PWM) duty for boost converter.

Measure voltage and current in a PV panel and multiplied to get power supplied to controller. Predictive Energy Neural Control Algorithm controller determines the best duty and sends to PWM generation unit which compares the best duty with switching signal and generates PWM pulses. These PWM pulses are used to switch ON and OFF the MOSFET power switch in order to vary load voltage and the load output power. The proposed PV system is analyzed purely on resistive load as shown in figure 6.
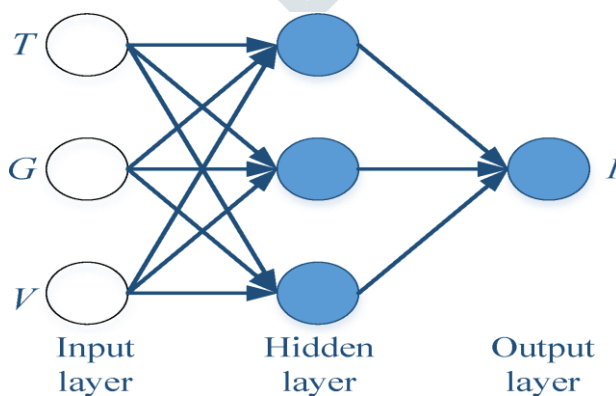

Figure 6. Predictive Energy Neural Control Algorithm

Given that the maximum power point of a Photovoltaic (PV) array is changing, a detection technique based on the Current-Voltage (I-V) and Power-Voltage (P-V) characteristics of the solar cell is required. The Perturbation and Observation (P&O) MPPT

method is widely used because of its implementation dependability. It is based on the fact that additional perturbation of the operating voltage must be made in the same direction if a PV array's operating voltage is changed in one direction and power consumption from the array increases, showing that the operating point is heading toward the MPP. Experiments conducted in a controlled setting can gather the operating points that make up the training set.

To prevent over fitting or under fitting in the ranges with more/less training data, the environmental data must be evenly distributed. Due to extrapolation qualities, it's crucial to account for all G and T values that could appear in real-world situations. If there are only a few experimental results or manufacturer datasheets, it is first necessary to identify the corresponding circuit's parameters. The P&O method is used to conduct impedance matching between a boost converter and a PV array in order to perform the MPPT function.

Here, in order to increase the MPP voltage forecast accuracy, we provide a low-complexity MPPT method with an irradiance estimator. When compared to other NN-based algorithms that employ the same input data, the suggested solution is less computationally demanding. The suggested method depends on the NN-model that can be properly trained with 4 neurons in the hidden layer, unlike existing methods that employ one multilayer NN or two single-layer NNs. However, the suggested technique features an adjustable parameter that may be used to regulate the trade-off between tracking speed and computing complexity. Although the proposed algorithm cannot instantly discover the best voltage, it can follow a signal quickly. The P&O method is used to conduct impedance matching between a boost converter and a PV array in order to perform the MPPT function.

3.6 Features of a Predictive Energy Neural Control Algorithm

The advantages of MPPT solar charge controllers are numerous. Let's examine each in turn, the fluctuation in voltage and current in the solar cell is adjusted by the MPPT charge controller.

➢ It guarantees that the solar panels are used to their full potential.
➢ Wind turbines and small water turbines can be fitted with this controller.
➢ It simplifies the intricate operation of the system.

A solar system is an essential equipment that generates DC electricity using photovoltaic panels to keep track of solar panel maximum output the Maximum Point Tracking Control for this system shall be used. Control systems used to monitor solar panels and battery systems. A DC-DC converter converts DC power to the panel via a controller, which provides steady DC power to the battery system. Once the battery has finished charging, the controller reduces charge current and tells the user of the discharge current. The State of Charge (SOC) is a critical metric in this system for increasing battery efficiency.

4. SIMULATION RESULT:

4.1 Output 1:

4.1.1 Non-Linear Load based Simulation and output waveforms

By correctly changing the phase and magnitude of the STATCOM output voltages as indicated in figure 7, it is feasible to regulate the active and reactive power exchanges between the STATCOM and the ac system. A succession of three-phase ac output voltages are created from the DC voltage of the inverter device. Due to the reactance of the coupling transformer, these voltages are in phase with the AC system.
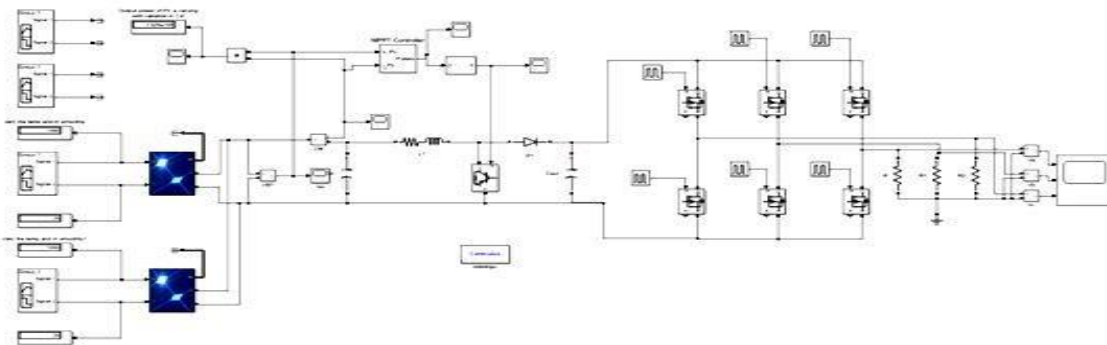

Figure 7. Simulation Diagram

4.1.2 Sag and Swell Input waveform

The above figure 8 shows, although less often than voltage sag, voltage swell can also result from Simulink. Swell might be brought on by a single line to ground failure, which would raise the other phases' voltage.

Figure 8. Sag and Swell Input waveform

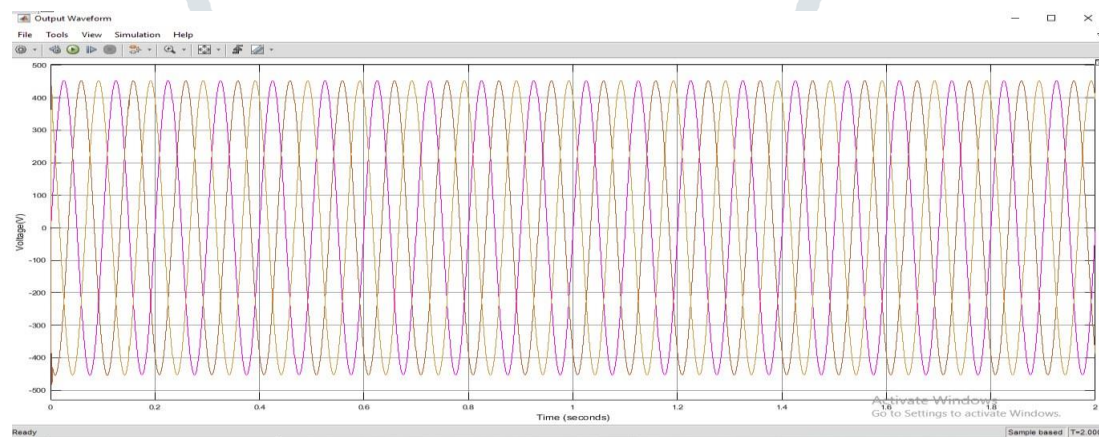**4.1.3 Without Sag and Swell Output waveform using Non-Linear Load**

Figure 9. Without Sag and Swell Output waveform using Non-Linear Load

Figure 9 above illustrates this; it is obvious from the wave form that the phase to phase voltage in the uncompensated system is sinking during this time where an inductive load is attached.
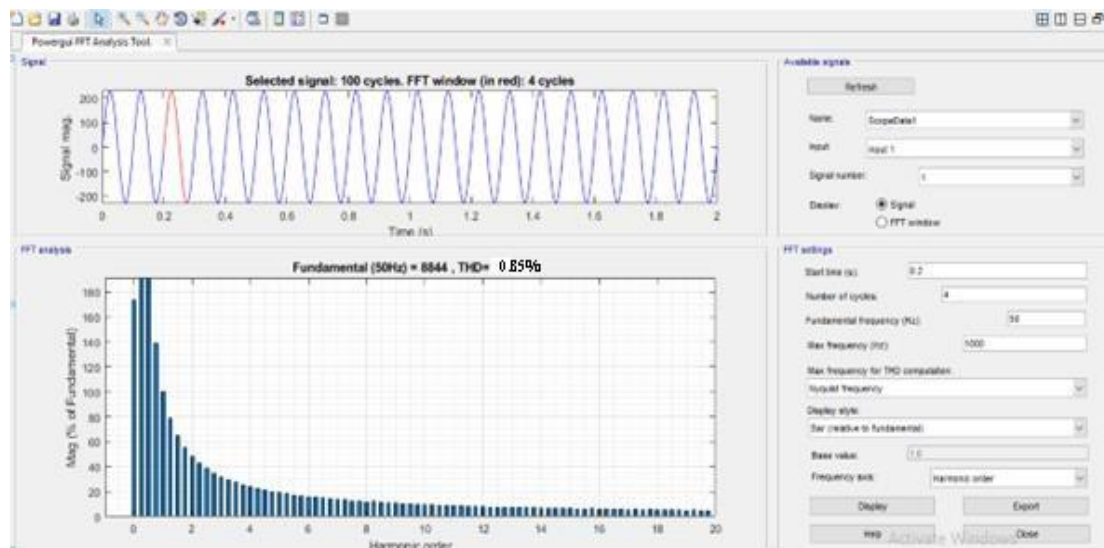
4.1.4 THD Output.

Figure 10. THD output

THD calculated as shown in figure 10 based on PWM techniques provide a more flexible alternative to the Fundamental Frequency Switching (FFS) methods favored in FACTS application since custom power is a comparatively power-efficient application.
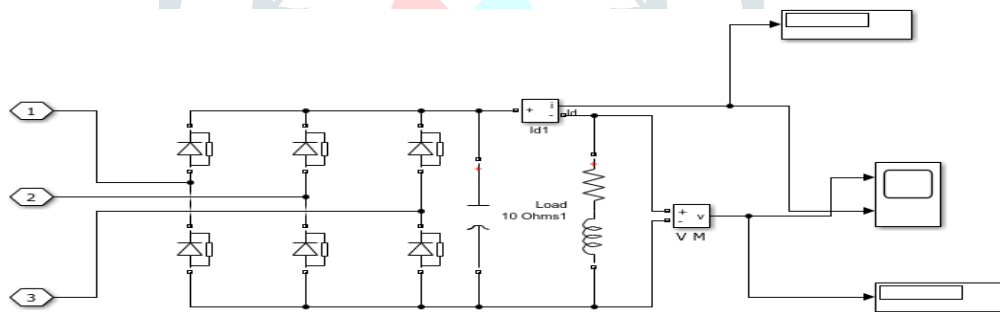
4.1.5 Non-Linear Simulink Circuit

Figure 11. THD Non-Linear Simulink Circuit

Effective management of the active and reactive power exchanges between the STATCOM and the AC system is made possible by appropriately changing the phase and amplitude of the STATCOM output voltages, as illustrated in figure 11.

4.2 Output 2

4.2.1. Linear load based Simulation and Output Waveforms

A Simulink model is shown here to show how a power rectifier, a nonlinear load, affects the power quality in terms of harmonic distortions. Figure 12 illustrates how the quality of the power decreases when a load, such as an electronic appliance, is connected to a power supply in one of the various uses for which it is designed. The deformed current wave shape is used to illustrate the problems with applying a nonlinear load.
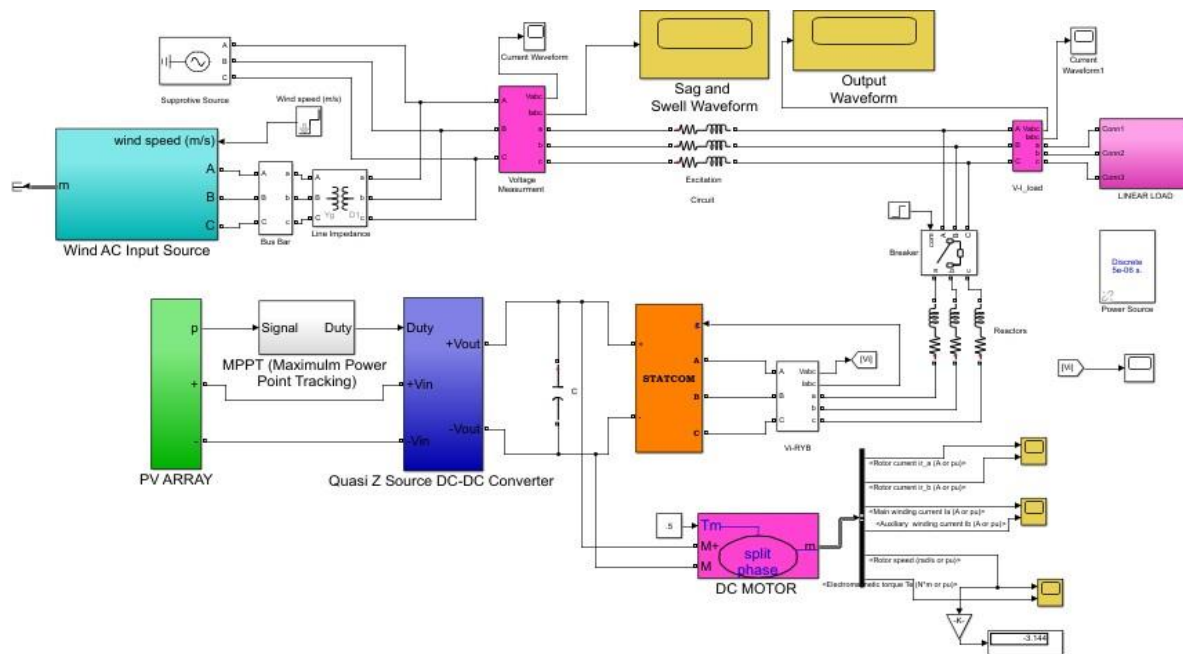

Figure 12. Linear load based Simulation and Output Waveforms

4.2.2. Sag and Swell Input waveform using Linear Load

Voltage dips, commonly referred to as "sags," are drops in voltage of 10% or more from the usual or advised level of use. For example, a 120-volt outlet could drop to 90 volts as shown in figure 13. The reverse of dips, voltage swells are spikes in voltage that are 10% or more over typical or advised consumption. When a powerful motor or other heavy load is shut off, the voltage on the power line suddenly rises, which can cause swells.
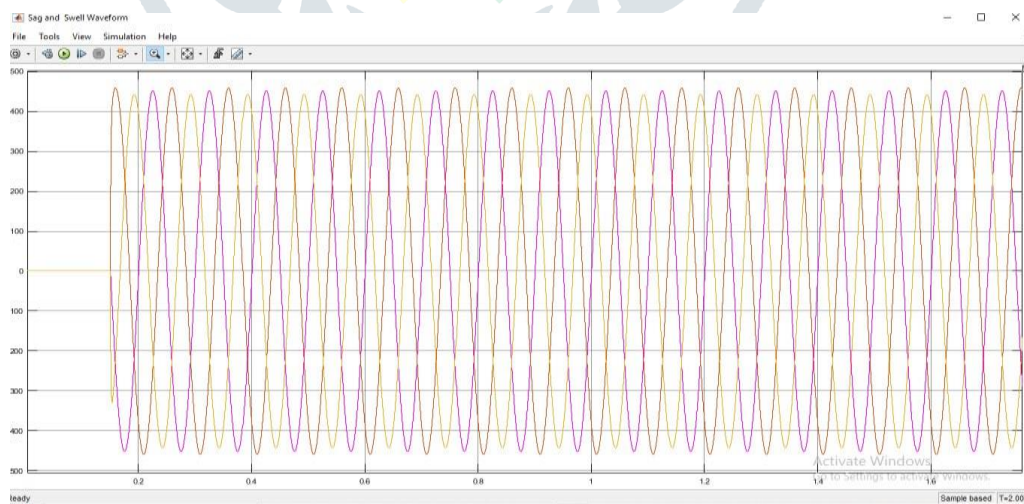

Figure 13. Sag and Swell Input waveform using Linear Load

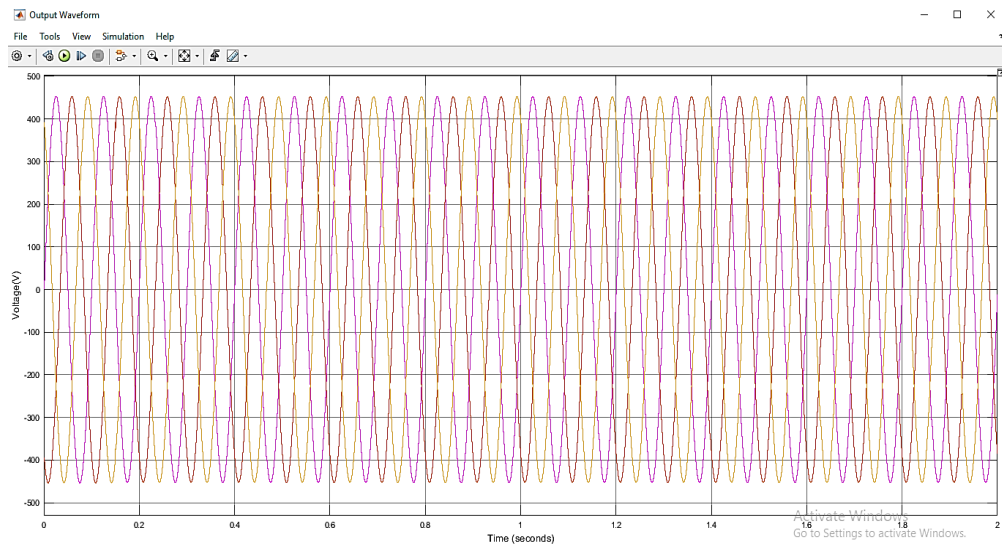### 4.2.3. Without sag and swell output waveform using linear load

Figure 14. Without sag and swell output waveform using linear load

The above figure 14 represent, STATCOM continuously creates the error voltage and checks the load voltage. Either load switching or a three-phase failure might result in a voltage sag.

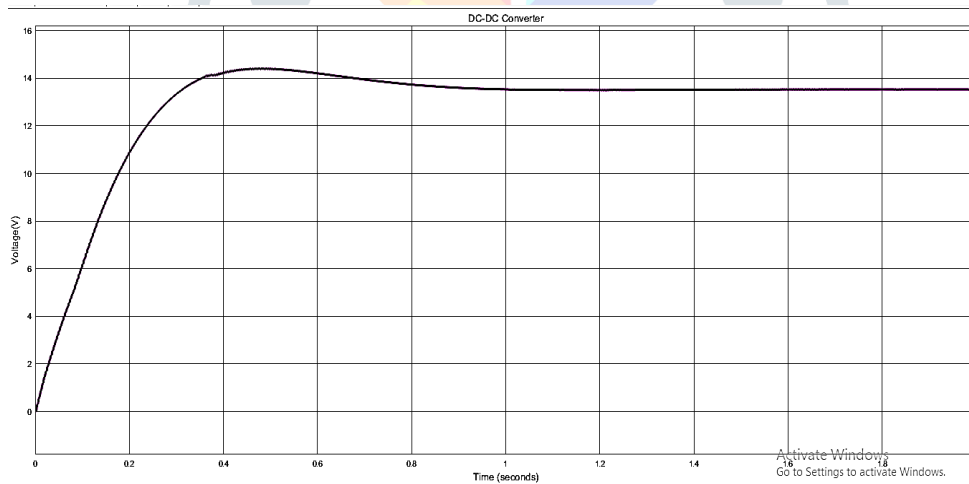### 4.2.4. DC-DC Converter (Both Non-Linear Load and Linear Load)

Figure 15. DC-DC Converter (Both Non-Linear Load and Linear Load)

The PV output shown in figure 15 above is based on a specific, highly demandable nonlinear load. In order to manage the speed of the nonlinear load and understand its behavior, the appropriate procedures must be used.

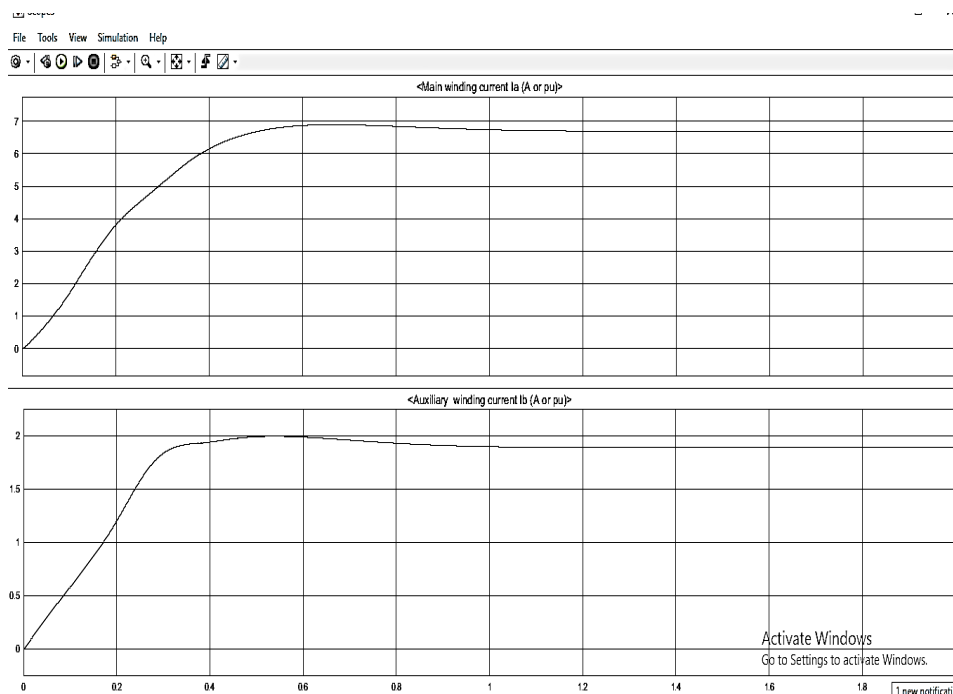**4.2.5. Wind Output (Both Non-Linear Load and Linear Load)**

Figure 16. Wind Output (Both Non-Linear Load and Linear Load)

Figure 16 shows the peak amplitude voltage and frequency of the AC single phase power supply being used here.

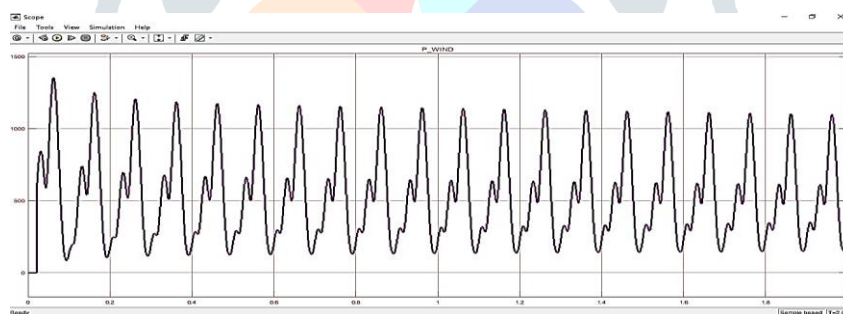**4.2.6. Motor output waveform for flywheel Both Non-Linear Load and Linear Load**

Figure 17. Motor output waveform for flywheel Application Both (Non-Linear Load and Linear Load

Another name for a motor is an asynchronous motor. Here, a single-phase motor is being used with a frequency and nominal power, acting as both a linear and a nonlinear load as seen in figure 17.The controller selects the best gains depending on the size of the voltage swell, regulates the variation between the real and reference voltages.

5. Conclusion:

This study enhanced the transient voltage stability, allowing the wind turbine to ride over grid failures to maintain uninterrupted operation. It is based on a PV/wind DFIG hybrid that was suggested and constructed utilizing STATCOM technology. In order to optimize the generation of active power in the presence of STATCOM, the power factor of wind (Double Fed Induction Generator, or DFIG) power can be regulated. The Static Compensator STATCOM is a power electronic-based switch used to regulate reactive power, which in turn affects bus voltages. It is a Flexible AC Transmission System (FACTS) device.

The transformer and solar module are connected by a capacitor-inductor network in a quasi-Z-source at each stage of the power stabilizer. This Excitation Capacitor Circuit produces additional support during the voltage drop and keeps the voltage normal. In this proposed MPPT Based Swarm Integral Neural Controller technique is used to give the control pulse of the compensator and it reduces the harmonics and improves the power quality of this system and reduces Total Harmonics Distortion THD.

5.1 Future Scope

Numerous aspects of STATCOM's performance are superior, including response time, grid voltage stabilization, system power loss

and harmonic reduction, transmission capacity expansion, and transient voltage limit. Additionally, it benefits from being smaller in size.

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