A Single Synchronous Controller for High Penetration of Renewable Energy Resources into the Power Grid based Squirrel Cage Induction Generator

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Abstract: A new development of high penetration for Wind Energy Conversion System (WECS) for quality power enhancement based stand-alone energy system applications employing a Squirrel Cage Induction Generator (SCIG). Unbalanced voltage, low efficiency, and high harmonic distortion are major power quality problems in the renewable energy system and Wind Energy power generation Systems (WEPS) based power grid output applications. So to overcome the drawbacks of renewable energy resources into the power grid-based Squirrel Cage Induction Generator (SCIG). The squirrel cage-type induction generator's rotor winding comprises enclosed conductors such as copper and aluminum bars inserted in semi-closed spaces. In this method, a Single synchronous controller with voltage and the current Sensor for estimation, applied based on load variation and processes to provide the gain of output for smoother grid connection is possible by using a soft starter. A Voltage Source Inverter (VSI) is an Inverter circuit that converts the voltage from the DC source to an AC source; an ideal voltage source inverter keeps the voltage unbroken throughout the practice. The battery and chopper circuit is bi-directional and connected to the energy management system. The output result is a constant voltage level, distortion is low, and better efficiency gain is high in the power grid.

Keywords: *AC-DC Converter, Voltage Source Inverter (VSI), Voltage Sensor, Current Sensor, Battery, Single Synchronous Controller (SSC), Wind Squirrel-Cage Induction Generator (SCIG).*

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1. INTRODUCTION

Wind power generation is becoming more and more popular all over the world. This rapid development has attracted a large number of electrical researchers and engineers into the field. Self-excited squirrel cage induction generators (SEIGs) are widely used to convert mechanical wind energy into electricity due to their high efficiency, improved power quality, and no need for separate DC power and brushes. The present work presents a modified version of a small wind energy system, consisting of an induction generator, excitation capacitor, and consumer. When a fault occurs and the system is disconnected from the grid, the typical appropriately styles the dynamic voltage and frequency characteristics in the system provided by SGEI. Based on the proposed model, efficient analytical methods for voltage and frequency control have been established.

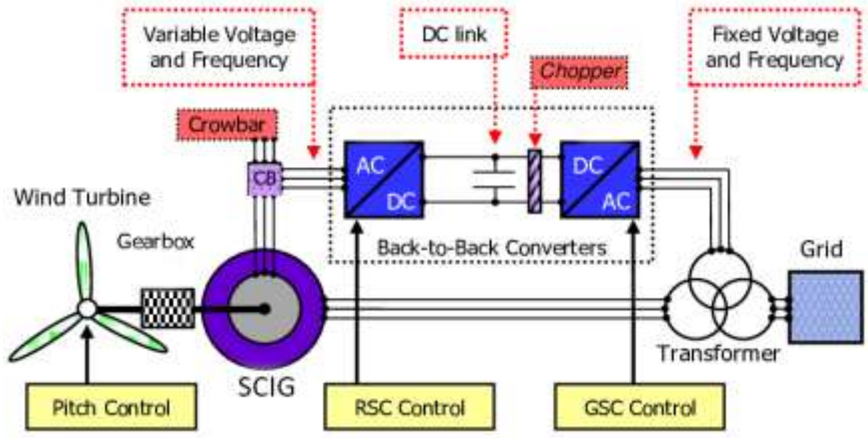

Figure 1 Model Functional Diagram Representation of the Squirrel Cage Induction Generator (SCIG)-Based Wind Energy Conversion (WEC) System.

The Squirrel Cage Induction Generator (SCIG) is coupled to the network via a Voltage Source Inverter (VSI) which is recycled to control the variable quickness Wind Energy Conversion (WEC) system.

1.2 Objective

A power system's ability to operate safely and affordably becomes more difficult when a huge amount of wind energy is added. An investigation is required into how wind power generation affects the aforementioned power system's active properties. This technique examines how great wind power affects small-signal stability and potential control measures to lessen the negative effects. First, a brief discussion of the fundamentals of grid-connected architectures for wind power manufacture systems concepts of various Wind Turbine Generators (WTGs) given. Finally, the method's current state regarding WTGs' effects on weak signal stability is discussed, along with potential issues to look into. The command tactics are then covered. For the production of single-phase power.

2. PREVIOUS RESEARCH WORK:

It is being investigated whether stator current spectrum analysis can be used to identify rotor bar failures in wind turbines based on Squirrel Cage Induction Generators (SCIGs). The numerical approach of this method is calculated using the Hilbert transform. It shows better fault detection in electrical devices. Squirrel cage induction generators are where this type of failure occurs most often. During normal operation, large currents may flow through the end rods or rings due to load changes, voltage changes, and torque fluctuations. As a result, ring joints or end bars generate a lot of power [1].

A modified management technique is used in a VSWEGS (Variable Speed Wind Energy Producing System). A three-phase, grid-isolated squirrel cage induction generator (SCIG) serves as the foundation for the suggested VSWEGS. Voltage and frequency control loops are used to control the SCIG. The complete power point tracking capabilities of SCIG are also guaranteed by the bidirectional converter's frequency references [2].

Active and reactive power control for a grid-connected wind power producing system based on a Squirrel Cage Rotor Three-Page Induction Generator (SCIG). Before the inductive filter, back-to-back AC/ DC/ AC power converters are employed to link the SCIG's stator terminals to the electrical grid. The rotor connections are short-circuited to demonstrate the SCIG's energetic and reactive power control mechanisms. A Grid Side Converter (GSC), which is in charge of controlling electricity and maintaining a steady DC bus voltage, is thoroughly discussed [3].

Fuzzy logic-based pitch control is provided to maintain the aerodynamic strength of the (WES) based on the Squirrel Cage Induction Generator (SCIG) at its nominal value. The proposed controller generates a control signal that compensates for the nonlinear interaction of wind speed and pitch angle. The generator output power is used as the control input of the fuzzy logic controller, limiting the output power to the nominal level, allowing the wind turbine to run smoothly [4].

Impending of green energy as an electricity source is promising. On the other hand, inverter link solar and wind energy as well as other renewable energy sources to the electrical grid. Lower integrating power and inertia are characteristics of inverter-controlled power sources. Standard synchronous generators must therefore be shut off to increase the system's integrating and inertial capacity when more renewable energy sources are added. Network failures are possible with these systems, and frequency changes can be substantial. Virtual inertia control and reactive power control are used to operate a wind farm that consists of grid-connected storage batteries, variable-speed wind turbines, and Permanent Magnet Synchronous Generators (VSWT-PMSG) [5].

Improved, model-based control algorithms for wind power conversion system control are now plausible as a consequence of developments in PC-Based computing platforms. These innovative models make it possible to increase productivity and dependability. The present study examines the parts of grid-connected, variable-speed wind energy conversion systems based on squirrel cage induction generators. On machine side, a potential supply converter control design has been developed, constructed, modeled, and evaluated. Energetic and reactive power management are thoroughly examined concerning the system described [6].

Comprehensive Sub-Synchronous Resonance (SSR) analysis was performed under different operating conditions, such as different levels of wind penetration, different series compensation, and different levels of network impedance. To explore the damping of different SSR oscillator modes, the eigenvalue technique is applied. A linear quadratic regulator has been developed to dampen these oscillations. As wind power becomes more common in the grid, transmission lines must be able to handle large amounts of power, which necessitates adjusting the series capacitors [7]

In a variety of operating scenarios, including varying wind penetration, series compensation, and network impedance, a comprehensive investigation of sub-synchronous resonance (SSR) was performed. The eigenvalue method is used to test the damping of different SSR oscillator modes. The damping of these oscillations is done using a linear quadratic regulator. All in all, an outstanding performance. Broken rotor rod faults in wind turbines based on squirrel-cage induction generators are identified using a fuzzy logic "FLS" system; stator line [8]- [9].

Urbanization and business are both contributing to the rising demand for electricity. This need for energy may be met by renewable energy sources because they are more affordable. Both straight and linear needs are met by existing grid-connected production, transmission, and distribution systems. Potential sag on the load side is one of the problems that a connected-to-the-grid program faces. [10].

When the Current Transformer (CT) circuit of the transmission line is destroyed, a backup safety lock is often used, which helps to prevent short circuits from being handled in time. As a potential solution to this problem, research and development of unique transmission line redundancy protection based on substation current data [11].

By using substation area current data and TA fault-free phase current information, a single protective measure can restore current in the TA's outage phase. The regenerative current and zero-sequence voltage of the transmission line is used to determine if backup protection is activated after the TA circuit is broken. Finally, simulation is used to confirm the effect of the measures. Improved protection [12].

The arrangement of power supply networks to regulate and expand AC transmission capacity, flexible AC transmission systems, and FACTS are extensively employed. The use of FACTS technology in the Nigerian Transmission Company's growth ambitions, as it delivers electricity over transmission lines to load centers. Load current, voltage, and economic analysis were done, and the findings illustrate how the application of FACTS would be economically and technically advantageous. [13].

A method of dispatch for pumped storage power plants and AC/ DC hybrid power systems with adaptable DC transmission lines. The goal of the suggested dispatch model includes transmission, generation, and penalty costs. Constraints on system-wide dispatch, normal generators, pumped storage power plants, and flexible DC transmission lines are all taken into account. Case studies show that the suggested model can regulate transmission power to the load center, eliminate variations in green generators, and handle unstable power outputs from pumped storage power plants. [14].

Based on the data, the analysis proposes a fuzzy assessment to appropriately evaluate the status of the transmission line and the weighting of the effects of the indicators. The "Index-Section-Review" components of the indexing system have been built. The weight of each indicator is determined using the gray correlation technique. A fuzzy rating system with a custom triangular trapezoidal distribution was also studied for the quantitative assessment of line health, and a line health index was created for use in real-world tasks. The assessment method used in this study, based on case studies, is effective in communicating the importance of each influencing factor as well as the status of the transmission. [15].

IoT systems require data transfer rates in the order of gigabits per second due to improved communication device performance and usability. The option to apply pulse transmission with multipoint transmission has been mentioned by the user. However, waveform distortion due to reflection is a major problem for high-speed applications in multipoint transmission systems. To reduce line reflections, several solutions have been reported previously, including asymmetric power dividers (APS), serial termination logic stubs (SSTLs), segmented lines (STLs), and other solutions. However, the methods mentioned above have some limitations, such as amplitude loss at the receiver or high power consumption due to very low impedance design. [16].

2.1 Problem Statement

The effectiveness of an induction machine and an asynchronous machine are combined in an electronically motivated double-fed rotor and stator winding generator. Brushes and slide rings are used to feed the wound rotor. However, because they operate at higher speeds, high-speed gears are required to change the slow-turning shaft of a wind power system, which raises maintenance requirements and makes system compliance more difficult. In situations with variable breeze speeds, it has also been suggested that SEIGs use a pole-changing mechanism to get more wind energy.

Wind turbines are outfitted with an electronic power interface that takes advantage of the efficiency of an induction generator. Induction generators often employed include squirrel cages, wound rotors, dynamic sliding control, dual-powered induction generators, and others. When the wind speed varies, voltage consolidation and voltage collapse occur in the power system, and the power system is unable to supply the reactive power demand. When wind farms linked to the grid fail, one of the most crucial factors impacting a wind farm's ability to function safely is voltage stability. An induction generator creates energy and provides reactive power to a wind turbine. As a result, operative power regulation through a single synchronous controller is required to maintain the rated voltage across the network to which the wind farm is linked.

3. MATERIALS AND METHOD:

In the field of wind energy, generators and squirrel cage induction generators (SCIGs) have grown in importance. For the benefit of the overall renewable energy industry, this energy source increases the dependability of these energy sources. Based on a single synchronous controller, this technique for squirrel-cage induction generators (SCIGs) detects, diagnoses, and deeply penetrates voltage and current sensing defects.

In this method, a fault detection method that uses voltage and current estimates for stable control operation is provided for fault detection of the wind power generation system. Matching control and battery storage has higher speed stability and control than traditional slide-mode locators, as well as better vibration reduction. The rotational speed of the rotor and stator is then calculated using the grid connection method. SCIG error is detected by comparing the actual value of the rotor current with the observed value. The second part describes three failures: network voltage drop, stator error between SCIG turns, and rotor current sensing error.

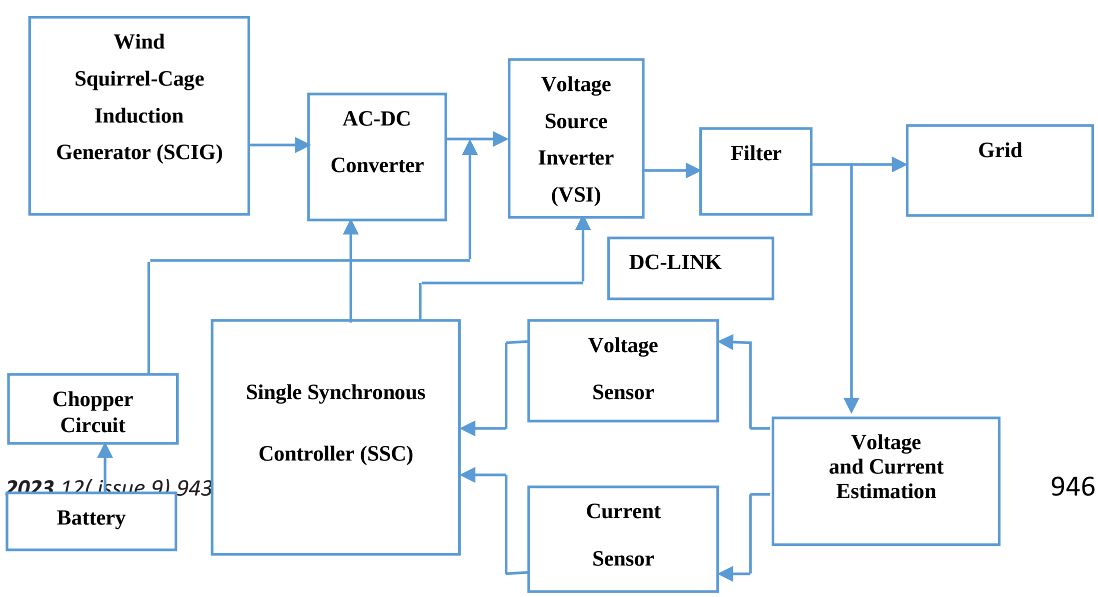

Figure 2 Block Diagram for the Proposed System

3.1 Squirrel-Cage Induction Generator (SCIG)

Fixed-speed wind turbines employ a squirrel cage induction generator (SCIG) with a multi-stage gearbox. Because the induction generator requires reactive power from the grid when it connects to the grid, a capacitor bank is connected between the grid and the SCIG. The rotor of the wind turbine is linked to the generator through a gearbox, while the stator is directly connected to the grid. SCIGs consume a lot of reactive power and rely on capacitor banks to keep the grid voltage stable. The amount of power generated influences the slip and hence the SCIG's rotor speed. The system has a restricted range of speed variations while sending electricity to the power grid. Mechanical, electromechanical, and electrical advancements have occurred.

The upgrades made use of power electronic converters, turbine blades with adjustable pitch angles, and variable numbers of pole pairs, steady and transient speed transmission systems, and wind-rotor motors with adjustable resistance. The requirements for a wind energy system are listed below. Single-phase energy has also been produced using induction generators, particularly for household or stand-alone uses. For single-phase electrical generation, a self-excited, self-regulated single-phase induction generator has been developed. The self-excitation of a dual-winding induction power source is studied on the opposing side. It uses an inverter to provide variable power regulation together with a single-phase cage induction machine with improved auxiliary winding.

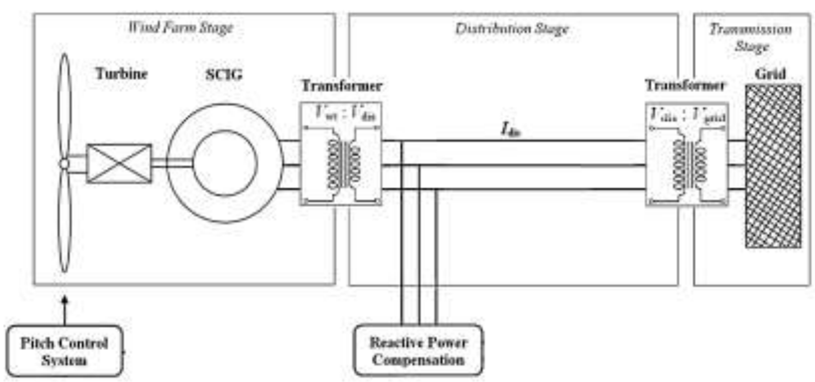

Figure 3 Working Principle of Squirrel-Cage Induction Generator (SCIG)

3.2 Voltage Source Inverter (VSI)

Direct current (DC) is converted to Alternating Current (AC) using an electrical equipment known as an inverter. The input voltage, output voltage and frequency, as well as overall power management, are all influenced by the device or circuitry's design. Since the inverter doesn't generate any power, it must be obtained from another source. The components of a power inverter can be both mechanical and electrical, like spinning equipment, or they might be totally electronic. The components of a power inverter can be both mechanical and electrical, like spinning equipment, or they might be totally electronic. Diagram of a voltage source inverter's circuit Figure 4.

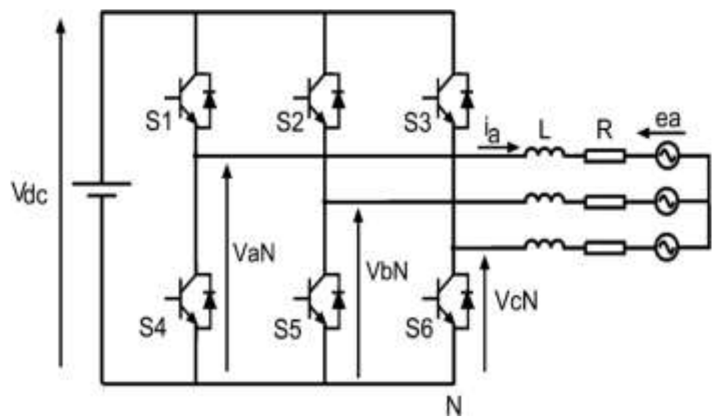

Figure 4 Circuit diagram of Voltage Source Inverter

A dependable DC source that can provide the system's required power is needed by a conventional inverter circuit. Compared to regular inverters, power inverters are better able to handle power, voltage, and current. An inverter can produce a square wave, modified sine wave, pulsed sine wave, pulse width modulated wave, or sine wave depending on the circuit design. There are two main ways to convert a lower-voltage DC source into residential plug-in voltage. The first produces a higher-voltage DC with the aid of a switching boost converter before converting to AC. The output voltage is created using a line-frequency transformer in the second approach, which transforms DC to AC at the battery level.

In power electronics, an inverter is a converter that converts Direct Current (DC) at one frequency to Alternating Current (AC) at another frequency using solid-state electronics. Harmonic converters and inverter rectification techniques are two traditional methods for static AC frequency conversion. The cyclic converter converts direct current at one frequency into alternating current at another frequency. In contrast, an inverter rectifier first converts alternating current to direct current before converting direct current to alternating current at variable frequency. The rectifier inverter consists of two components: one rectifier and one inverter.

3.3 Voltage Sensor

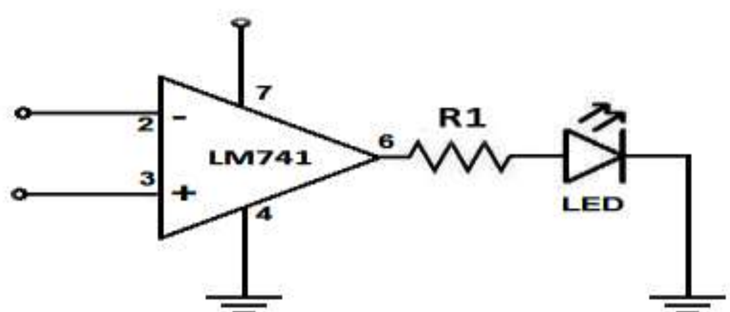

Figure 5 Circuit diagram of Voltage Sensor

This sensor measures, calculates, and determines the supply voltage. This sensor can detect the amount of AC or DC voltage. The input of this sensor can be voltage and its output can be a switch, analog voltage signal, current signal, audio signal, etc. Some sensors provide outputs such as sine waveform or pulse waveform, while others can produce outputs such as AM (amplitude modulation), PWM (pulse width modulation), or FM (frequency modulation).

The voltage divider can affect the measurement of these sensors. This sensor has both input and output. The input side is mainly composed of two pins, positive and negative. The two pins of the device can be connected to the positive and negative pins of the sensor. The positive and negative pins of the device can be connected to the positive and negative pins of the sensor. The output of this sensor mainly consists of the supply voltage (Vcc), ground (GND), and analog o/p data.

3.4 Current Sensor

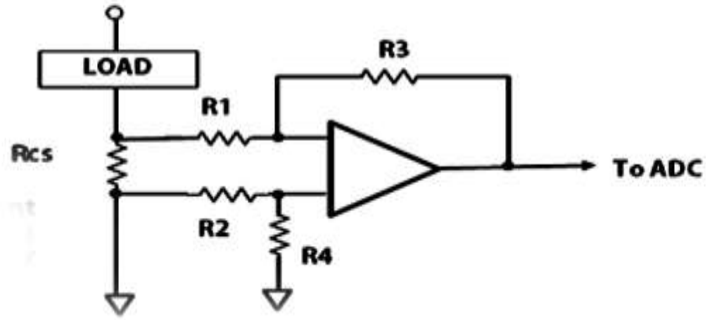

Figure 6 Circuit diagram of Current Sensor

Many electrical systems must detect fluctuating current flow, and the best ways to achieve this depend on the technology being used. A sensor is a tool that can compute a physical phenomenon and detect it; in other words, it offers quantified proof of the wonder on a certain scale or range. When a cable or system has electrical current flowing through it, whether it is high or low, a current sensor can detect it and produce an indicator. The measured current might then be displayed on an ammeter, recorded for later classification in a data collection system, or used for control purposes. It is “disturbing” because the present sensor incorporates several sensors, as this might affect system performance. The measuring of current, whether it be alternating or direct, is necessary for many applications, whether they be in the industrial, automotive, or residential sectors.

3.4 Chopper Circuit

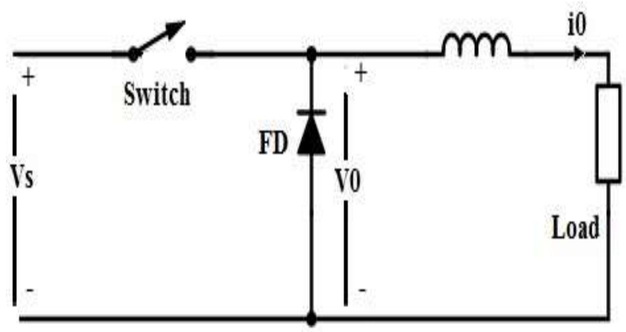

Figure 7 Chopper Circuit diagram

However, electricity supplied to residential areas through the mains is alternating current (AC) and has a defined voltage of approximately 240 volts. Then a converter is needed to run the DC-powered gadgets. Another type of circuit called a chopper circuit, should draw only a small amount of power from a 240V source. Chopper circuits are also known as DC-DC converters. Circuit breakers, like transformers in AC circuits, are used to increase and decrease DC power.

Variable DC power is switched for continuous DC power. By using them, the devices' DC power supply may be adjusted. We need more electricity as more contemporary products are developed and used. To satisfy the need for constant electricity, many strategies and technologies are being developed. There are both AC and DC currents used to power various devices and equipment. The quantity of power needed to operate different devices varies.

3.5 AC-DC Converter

The AC-DC converter is an essential component of power electronics. Many real-world applications rely on these adjustments. AC-DC converters are circuits that convert alternating current (AC) input to direct current (DC) output. They are employed in power electronics applications where the power input is a 50 Hz or 60 Hz sinusoidal AC voltage and a power conversion is required for the DC output. Rectification is the process of converting alternating electricity to direct current. At the load-side terminal, the rectifier converts AC electricity to DC. Similarly, transformers are frequently used to increase the voltage level of an AC source in order to increase the operational range of a DC power supply.

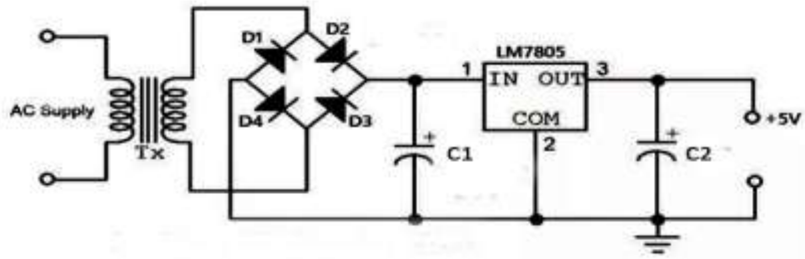

Figure 8 AC-DC Converter Chopper Circuit diagram

3.6 Grid

A power grid is a networked system that distributes electricity from sources to consumers. Power grids can span an entire continent or country and come in a variety of sizes. It includes power plants that are often located away from densely populated areas and near energy sources. Increase and decrease voltage in substations. Power transmission over long distances. The individual consumer receives electricity before it is reduced to the required utility voltage(s). Since the three-phase Alternating Current (AC) frequencies used in all distribution areas are synchronized, voltage changes almost always occur at the same time. This allows the transmission of alternating current through the network, in addition to connecting a large number of energy sources and customers.

4. RESULT AND DISCUSSION

Induction generators with fixed and variable speeds are increasingly used to produce wind energy. Voltage and transient stability problems arise when they are introduced into the grid. The features of the turbines, generators, and controllers affect the stability of the power system. They affect the stability of transients and small signals. Figure 9 depicts the results of many studies that were recently carried out to determine the necessity of network strengthening, the requirement for reserves, and the impact of wind energy on the stability of the power system.

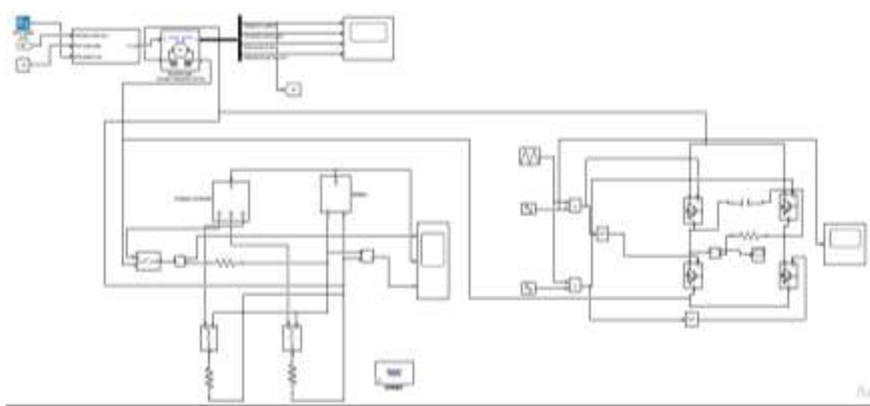

Figure 9 Mat Lab Simulation Output

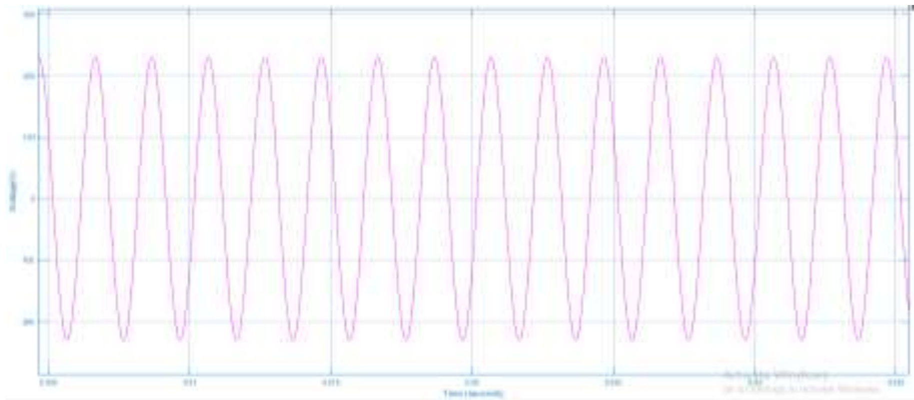

Figure 10 Single Phase Output Waveform

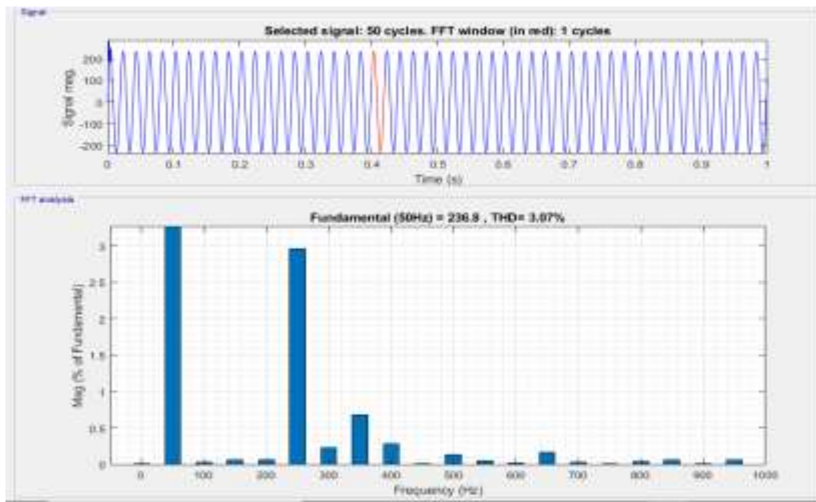

Figure 12 Proposed THD Output

Table 1. Comparison analysis of THD and Output power

Method	Power Source	THD (%)
Existing Wind (Doubly-Fed Induction Generator (DFIG)) Source	DC input source	4.31 %
Proposed Wind (Single Synchronous Controller (SSC))	PV input source	3.07 % (the distortion is low when compared to existing method)

6. CONCLUSION:

To detect and diagnose problems, an effective squirrel cage induction generator (SCIG) was required. Voltage and current sensors estimate voltage and current. Fault isolation logic distinguishes between failures caused by stator and rotor current sensing. The single synchronous controller of the dual-powered induction generator is converted to open-loop control for enhanced fault detection and high penetration times. The control loops are modified using the output of the observer as soon as the defect is discovered. Closed-loop control is reestablished, and a malfunctioning sensor is located. Outputs are for both active and reactive power control, and wind renewable energy sources (Dual Charge Induction Generator (DFIG)) may provide efficient and dependable output into the power grid.

6.1 Future Scope

In the future, it is also necessary to study the wind speed limit characteristics and control mechanisms to handle the situation when the wind speed decreases or fluctuates below the speed at rated conditions.

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