ENHANCING WIND FARM EFFICIENCY: AN EFFICIENT CONTROL SCHEME UTILIZING BACK-TO-BACK CONVERTERS

#1 DR.ARRAMARAJU PRASAD RAJU, Professor & Principal,
#2 AKUNOORI ARAVIND
#3 POLAM SHRUTHI

Department of Electrical and Electronics Engineering,
SREE CHAITANYA INSTITUTE OF TECHNOLOGICAL SCIENCES, KARIMNAGAR, TS.

ABSTRACT: The operation of a Wind Energy Conversion System (WECS) is susceptible to the particular circumstances that are present. Consequently, the capacity of a Wind Energy Conversion System (WECS) to deliver a consistent power supply is put to the test in order to satisfy the demand. To guarantee consistent satisfaction of capacity demands, it is essential to possess the appropriate storage device. The volume department is powered by a hybrid wind-battery system, which is incredibly efficient. With the required controls in place, the burden is linked to the WECS to prevent random fluctuations in wind speed.In order to optimize the operational effectiveness of the electrical system and guarantee the well-being of users, the combined design's control logic integrates Maximum Power Point Tracking (MPPT) to govern the inclination of the wind turbine and ascertain the battery bank's charge. In order to guarantee the secure charging of the battery bank, it is the duty of the charge processor to restrict the utmost allowable electricity consumption. Additionally, it evaluates whether the discharge current of the battery remains at or below a threshold of one-tenth of its capacity. By means of control mechanisms that are tailored to the process at hand, the buck converter is safeguarded against excessive current. Nevertheless, hypothetical scenarios may arise in which the power supplied to the Maximum Power Point Tracking (MPPT) system surpasses the battery's and application's combined power demands. The pitch angle can be modified through adjustments to the pitch action during power divergence. By incorporating this modification, the output power of the wind turbine can be modified to correspond with the aggregate demand. Furthermore, it possesses the ability to modify WT freedom, and the pitch control logic averts an overvoltage situation caused by the rectifier voltage.

KEYWORDS :- DFIG, Back to Back converter, wind turbine.

1.INTODUCTION

The increased demand for electricity and environmental concerns have prompted extensive research into renewable energy sources. The acquisition of ecological resources is among the most gratifying aspects of their exploitation. Wind energy is among the most plentiful sources of renewable natural energy. An electrical engine, a power electronic converter, a wind turbine, and a control system comprise a wind energy conversion system. DFIG wind turbines are exceedingly valuable due to their variable speed characteristics, especially as wind energy becomes more prevalent in electrical networks. With regard to wind energy, they occupy a leadership position.

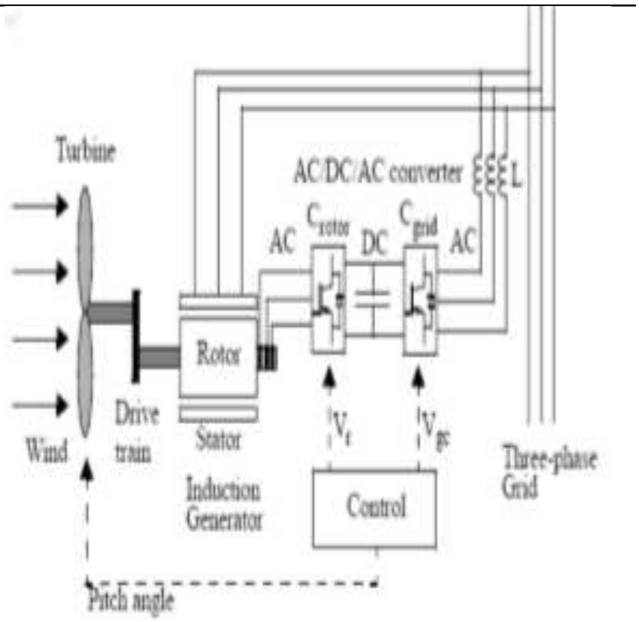

Fig 1.1 DFIG connected to Back to Back converter

Commonly, back-to-back adapters are utilized to connect the rotor to the utility in grid-connected DFIGs. Rotors are driven and magnetized with currents that are regulated by the rotorside converter. Two back-to-back converters' DC buses are coordinated by a grid-side converter. Thyristors are frequently employed in shaft generator systems as switching devices enhanced dependability, efficacy, and simplicity in attaining high ratings.

The frequency and voltage of the DFIG's output fluctuate in response to abrupt changes in wind speed and direction. The issue is resolved when the thyristor rectifier converts the alternating current power of the DFIG to direct current power. In doing so, the inverter ensures a consistent frequency and voltage throughout the process of converting DC power to AC. Distribution of the AC power to the electric utility or the end consumers is the subsequent step.

REASONS FOR USING DFIG

Due to their user-friendly nature, WECS based on DFIG can efficiently leverage a broad spectrum of wind velocities. Active power management is distinguished from reactive power management by its distinct regulation of rotor currents. Lastly, the WECS based on DFIG may actively regulate the voltage, permitting it to either contribute or draw power from the grid. PMSG may experience complications pertaining to power management, initialization, and synchronization due to its synchronous characteristics. Magnetic materials necessitate an additional cooling mechanism owing to their susceptibility to heat and the potential for magnetic properties to be compromised under excessive heating.

As a consequence of this, DFIG is preferred to PMSG. It is possible to convert a three-phase wound-rotor induction motor to a two-fed configuration. The device operates in this manner in a manner analogous to that of an asynchronous motor. A technique for altering the synchronous speed, which refers to the rotational speed of the motor shaft, involves making adjustments to the frequency filter that grants alternating current (AC) passage through the rotor windings.

A doubly-fed induction generator may also be constructed utilizing the wound-rotor induction machine. The stator and rotor windings convert the mechanical energy of the machine shaft into electrical power. The generated electricity is subsequently fed into the alternating current power grid. A synchronous generator serves as a fitting metaphor to describe the operation of the device. A predetermined rotational speed is necessary for the generator shaft to generate energy at the frequency of the alternating current power network. By modifying the frequency of the alternating current supplied to the rotor's windings, the speed can be altered.

The rotor of three-phase synchronous generators is frequently rotated by prime mover technologies. The rotor winding is energized by direct current, which generates a stationary magnetic field that rotates in tandem with the rotor. Through the stator windings, a fluctuating magnetic flux is transmitted as the rotor's magnetic field rotates. As a consequence, alternating current is introduced into the stator windings. From the prime mover to the generator shaft, electrical energy is transferred before being utilized by the stator windings.

MODES OF OPERATION IN DFIG

Rotor speed determines which of two modes of operation DFIG WECS has. In super-synchronous mode, the generator produces a signal at a quicker rate than in synchronous mode. Its performance degrades when carried out in sub-synchronous mode as opposed to synchronous mode. When supersynchronous mode is activated, negative sliding takes place. It facilitates operation in subsynchronous mode.

The rotor circuit determines whether electricity is transferred to or from the grid based on whether the slip is positive or negative. The stator and rotor circuits must collaborate to deliver mechanical power (Pm) from the shaft to the grid for the system to operate in supersynchronous mode. Through power converters located in the rotor circuit, the rotor power (Pr) is transferred to the grid. Conversely, stator electricity is delivered via direct transmission to the power infrastructure. In the absence of any losses attributable to the generator and inverters, the mechanical power generated by the generator (Pm) is equivalent to

the power supplied to the grid (Pg).
The rotor is powered by the grid, enabling it to function in a subsynchronous manner. This generator component provides mechanical power (Pm) and rotor power (Pr) to the grid. In contrast to super-synchronous operation, sub-synchronous operation diminishes the mechanical power of the generator shaft, thereby ensuring that the stator power, which is determined by the product of |Pm| and |Pr|, remains within its permissible range. Once losses are eliminated, the mechanical power input in the first scenario is equivalent to Pg, which represents the total power supplied to the grid.

2. MODELLING OF WIND TURBINE

In order to model a wind turbine, three fundamental components are necessary. The transmission is accompanied by the distribution and wind rotor systems.

a) TRANSMISSION SYSTEM

Conductor lines are utilized by power facilities to deliver the energy they produce to end users.

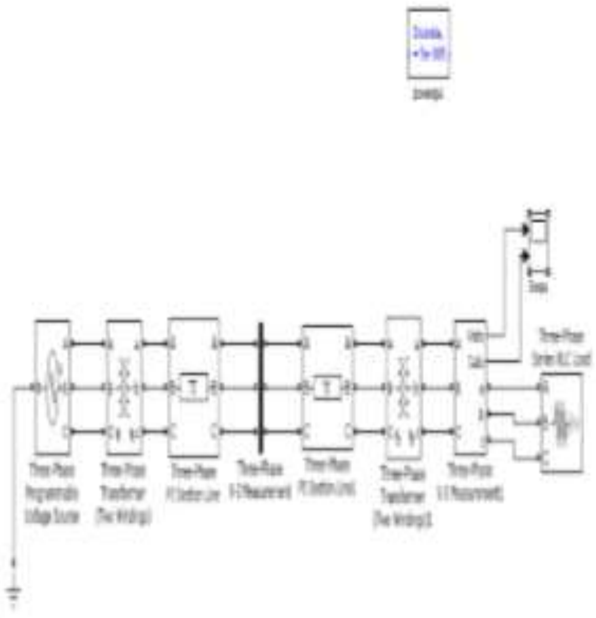

Fig 1.2 General power system

In Figure 1.2, the voltage distribution is depicted. A voltage source, transmission line, bus bar, step-down transformer, V-I measurement block, scope, and resistance load are all components of this apparatus

AC Power Supply Scheme

The extensive cable network of the power facility facilitates communication between residential and commercial properties. Two categories can be applied to these lines: distribution systems and transmission systems. Every segment possesses a unique method of transmission, encompassing both primary and secondary means.

Generating Station

A three-phase generator is utilized to produce energy at a parallel generating station. An average output voltage of eleven kilovolts is present. By utilizing three-phase transformers to raise the voltage to 132 kV, the power facility reduces the expenses associated with electricity transmission.

Primary Transmission

123.2 kilovolts of energy are transmitted via a three-conductor, three-phase overhead cable. The following is the primary stream.

Secondary Transmission

The primary transmission line is disconnected once the signal reaches the recipient site. Upon reaching the receiving location, the power is reduced to 33 kilovolts by step-down transformers. Various substations are supplied with a 33 kV, three-wire, three-phase overhead line by this station. The following illustrates secondary transmission.

Primary Distribution

At the substation, the secondary transmission line was severed. When this occurs, the voltage drops from 33 kV to 11 kV due to the three-wire, three-phase configuration. There, the principal spread is visible. At this juncture, the majority of 11kV consumers pass.

Secondary Distribution

At 11 kilovolts, the principal distribution line supplies electricity to distribution substations. For secondary distribution, these substations reduce the voltage to 400 volts using three phases and four conductors. A neutral connection of 230V is present, alongside 400V connections for the remaining phases. After the feeders receive the voltage, it is distributed to the consumers.

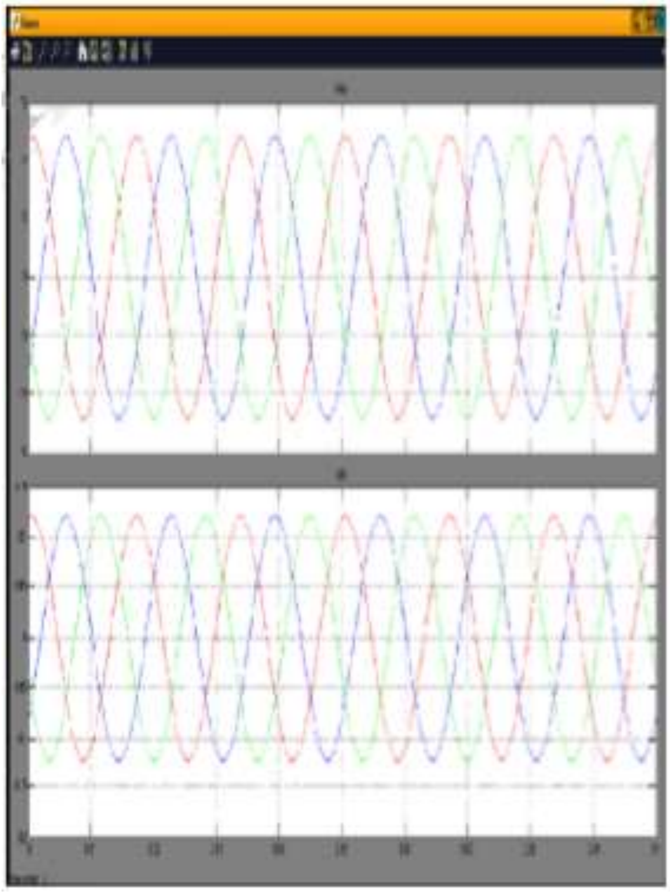

Figure 1.4 shows the output waveform of the general power system.

The overall emission pattern of the power system is illustrated in Figure 1.4. The document describes the output current and voltage of the power source. Each of the two is in complete harmony with the other.

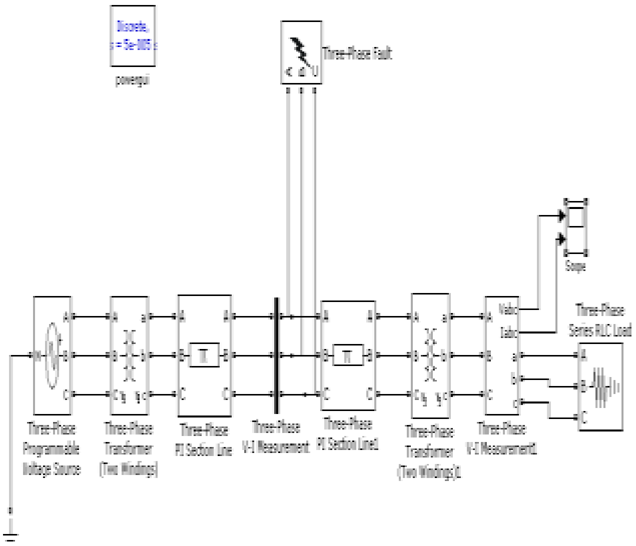

Fig 1.5 General power system with 3-phase fault

The main power system at fault is illustrated in Figure 1.5. The factor that is obstructing the overall functionality of the system is therefore most plausibly a power line in close proximity to the vehicle. Harmonics and distortion are employed to accomplish the intended effect.

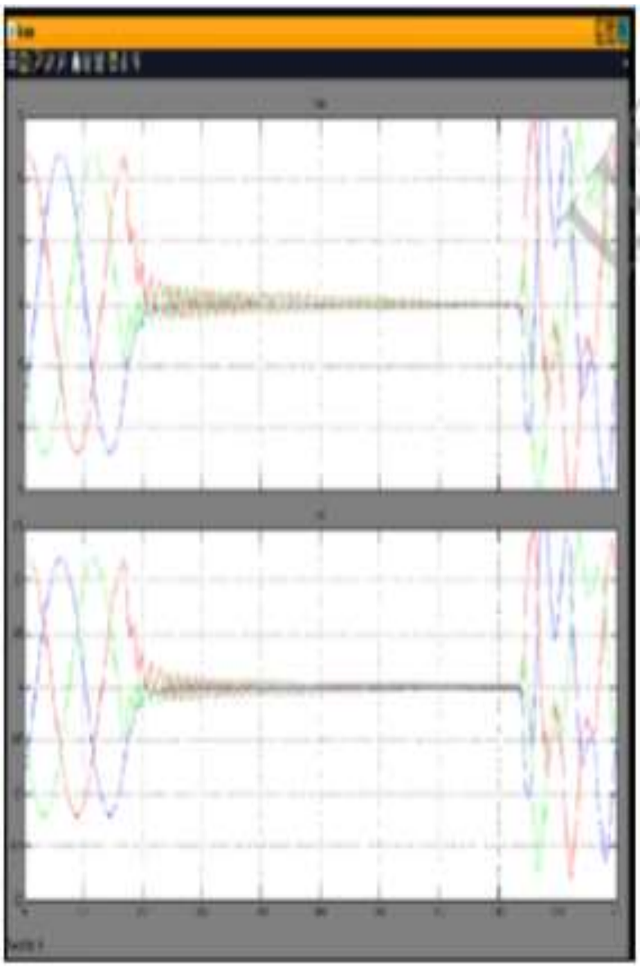

Fig 1.6 Output Waveform of a General Power System with an Occurrence of a 3-phase fault

A damaged generic power system is illustrated in Figure 1.6. Despite the gradual reduction of the issue's numerous distortions, they persistently impede the overall performance of the system.

Torque is produced when wind generators convert the kinetic energy of the wind into mechanical energy. The magnitude of the wind is proportional to the product of its velocity and the surrounding air's density; thus, the wind possesses kinetic energy. Equation (1.1) computes the wind-generated power output of the turbine.

$$P = \tfrac{1}{2} C_p \rho A V^3 \qquad \text{... (1.1)}$$

May I query as to the definition of CP? Constant power coefficients are maintained. ρ (air density in kilograms per cubic meter), A (rotor blade area in cubic meters), and V (wind speed in meters per second) are the three variables utilized. The power coefficient (Cp) quantifies the capacity of a wind rotor to transform kinetic energy into mechanical energy. The operation of the pitch-controlled turbine is dictated by the λ ratio, which represents the proportion of blade pitch angle to tip speed. To determine the tip speed ratio, divide the airflow velocity by the linear velocity of the turbine blade.

$$\lambda = R\omega/V \quad \text{... (1.2)}$$

Substituting (1.2) in (1.1), we have:

$$P = ½\ C_p(\lambda)\rho A(R/\lambda)\omega^3 \quad \text{... (1.3)}$$

The output torque of the wind turbine Tturbineis calculated by the following equation (1.4)

$$T_{turbine} = ½\ \rho AC_pV/\lambda \quad \text{... (1.4)}$$

R denotes the radius of the rotor in meters. The power coefficient is at its maximum value at a specific tip speed ratio. Wind energy can be captured by variable-speed turbines through the utilization of blade velocities that optimize the tip-to-rotor speed ratio. Potentially, this could be achieved through the modification of the engine speed in accordance with fluctuations in wind velocity.

3. CONVERTER METHODOLOGY

In addition to generating electricity, wind turbines function as induction generators. A wrapped rotor induction generator and an AC/DC/AC IGBT-based pulse width modulator (PWM) converter are among its components. A variable-frequency AC/DC/AC converter provides power to the rotor, while the stator cable is hardwired into the 50 Hz grid. By modulating the turbine speed, DFIG technology improves energy extraction from low-velocity wind in order to reduce mechanical tension during wind surges. An optimal turbine speed exists at a specific wind speed, which is where mechanical energy production is maximized.

An additional benefit of DFIG technology is that it enables the generation or consumption of reactive power by power electronic converters. Therefore, capacitor banks are superfluous in comparison to induction generators employing squirrel cages. The rotor voltage is denoted by the symbol Vr, while the grid voltage is portrayed by the symbol Vgc. PWM converters function identically to AC/DC/AC converters.

To minimize frequencies, a DFIG system powered by wind turbines employs sinusoidal pulse width modulation (PWM). Crotor refers to the rotor side, whereas Cgrid denotes the grid side. The velocities of windmills may be altered via transmissions or electrical controllers.

4.RESULT AND ANALYSIS

MATLAB/SIMULINK

Prior to implementation, the SimPower System block in MATLAB/SIMULINK is utilized to evaluate the system.

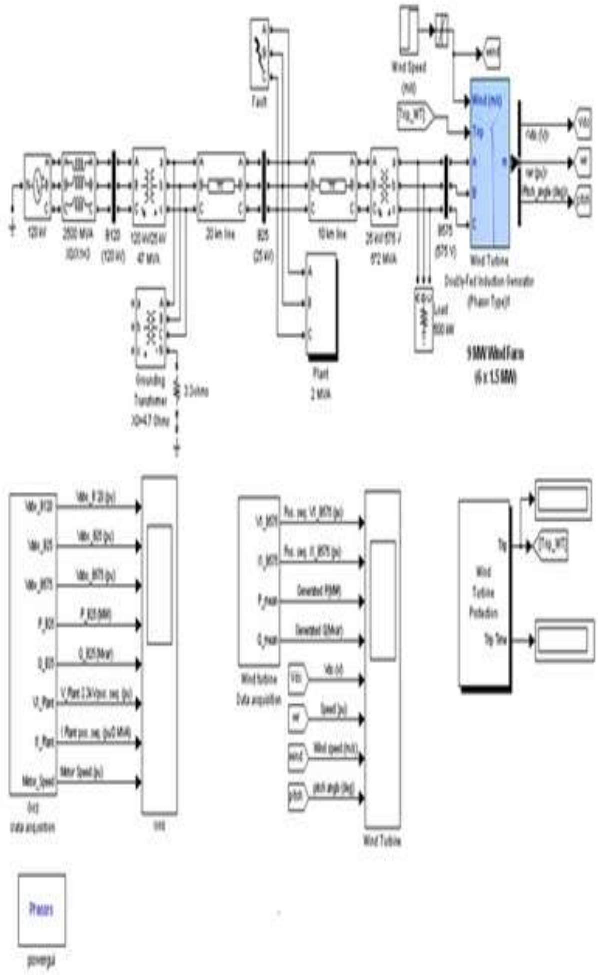

Fig 1.7 General power system embedded with wind farm using DFIG

The comprehensive electrical infrastructure, including the wind farm, is illustrated in Figure 1.7. For the development of DFIG wind farm models, induction machine and wind turbine models were employed.

Control Parameters

The utilization of the block diagram depicting the control factors is multifaceted. Alternating between voltage and variable regulation regimes is possible. By setting the external reactive current Iq ref on the grid side to zero, it is also possible to simulate a range of fault scenarios. The absolute and relative change rates of the requisite power, current, and voltage regulator gains are specified in detail.

Induction machine model

As a fifth-order model, the IG model includes complete order one instantaneous values and integrates the stator flow derivative. The accuracy of this method for simulating power system transients is maximized when the electrical dynamics of the IG are the primary concern. The IG's specifications were established in accordance with the provided requirements. The DFIG wind farm is composed of six distinct modules, collectively possessing a capacity of 1.5 MW.

Gridside converter

The GSC contains a model of a universal bridge. In series with the IG and IGBT terminals is an RL filter. A constant voltage is maintained across the DC link capacitor by the GSC. It has no effect on reactive power generation or grid energy management when Iq equals zero. Maximum output of the converter is half of what the IG is capable of producing.

Rotor side converter

By utilizing a power-speed curve, the RSC determines the optimal torque, which functions as the foundational value for DFIG active power regulation. The torque reference and an approximation of the flux are utilized to compute the reference rotor current Id. Utilizing the RSC paradigm, it has been modified to manage reactive power injection for grid voltage regulation. A PI determines the standard for reactive power by comparing measured grid voltage to a reference.

Network model

Six 1.5-MW generators comprise a 9-MW wind farm that is linked to a 120-kV infrastructure via a 25-kV feeder extending thirty kilometers. Connected to a 25 kV distribution grid is the wind farm. Through bus B25, the identical feeder is linked to a 2300V, 2-MVA plant. It is powered by a 1.68 MW induction motor with a resistive capacity of 200 kW and a power factor of 0.93.

5.RESULTS AND DISCUSSIONS

Enter the wind speed measurement into the "Wind Speed" field. The wind velocity is initially established at 8 meters per second. The terrifying wind speed increases to 14 meters per second after five seconds.

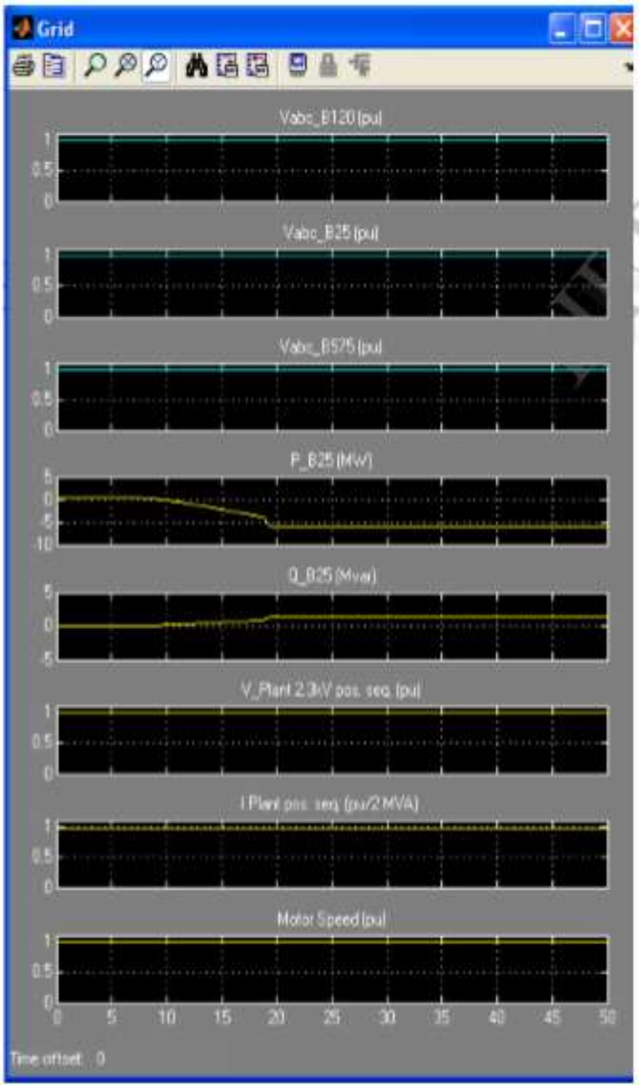

Fig 1.8 Output waveform of a Grid

Commence the model while utilizing the "Wind Turbine" scope to search for signals. Apart from providing information on the active and reactive energy output, the aforementioned signals also serve to signify the DC bus voltage of the wind turbine. Starting at time t = 5 s, the generated active power and turbine speed increase progressively. By increasing its pace from 0.8 PU to 9, the device will achieve its rated output in approximately 20 seconds.

PU is 1.21. At point D, according to the red curve representing the power characteristics of the turbine, it is operational. Upon initial operation, the turbine blades are positioned at a pitch angle of zero degrees.

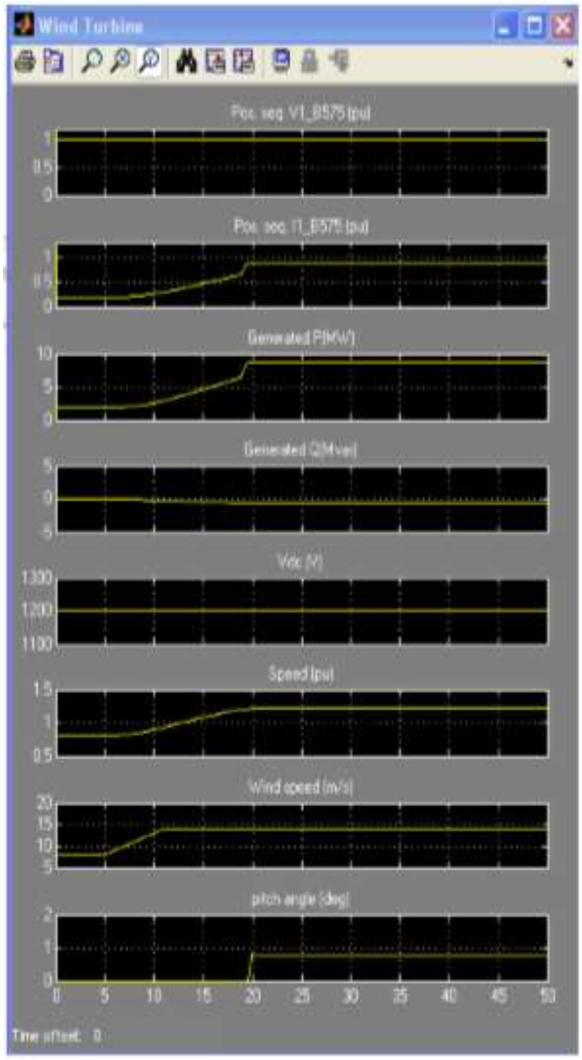

Fig 1.9 Output waveform of a wind turbine

Subsequently, transition from zero degrees to 0.76 degrees to modify the capacity of the machine. Additionally, we evaluated the longevity of the Capacity for rapid response. Reactive power management permits the preservation of one PU of voltage. Q = is the utmost output of 0.68 Mvar generated by the wind turbine. Utilize 0.68 Mvar to establish the voltage at 1PU.

6.CONCLUSION

Reliable, cost-effective, and efficient semiconductors and inverters were utilized throughout the wind farm's construction. The grid side converter (GSC) maintains the DC-link voltage, while the rotor side converter (RSC) regulates the active and reactive power of the machine. The grid and wind turbine side parameter simulation outcomes are displayed below. The model is constructed using the discrete-time version of the Wind Turbine Doubly-Fed Induction Generator (Phasor Type) provided by Matlab/SimPowerSystems. Also investigated in this specific instance were safety mechanisms. A trip signal will be generated in the event that a single phase to ground connection fails within this system. If the wind speed fluctuates frequently or descends below a specific threshold, complications may ensue. Grid power support is significantly impacted by DFIG in the event of a brief circuit. When the doubly fed induction generator is connected to the grid and controlled by the appropriate converters, it exhibits enhanced dependability and stability.

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