Comparative Study of Different Grid Connected Wind Generator

Vaishnavi Pachkawade and Rutuja Hiware

Abstract The primary energy needs of today's day to day life are met by conventional sources, with coal-based thermal power production making up a significant portion of those sources. It is critical to deploy alternative energy technologies that are more dependable of given rate where conventional energy source are use and that gives negative effects on the environment. A global environment to hazards the development of renewable energy sources is now under way. Among the several hydroelectricity sources, wind energy system is more popular economically viable energy sources and the ability to provide all of our energy demands. Wind energy for the production of electricity, has grown recently among the several renewable energy sources utilised to provide power, wind energy is one of the most affordable options with the ability to satisfy our demand for energy. Taking into account the difficulties of connecting big wind farms with various generation types. The researchers have tried multiple times to come up with a way to use wind energy effectively. As a result of thorough research and analysis on the subject, wind energy is widely used hydroelectricity sources of energy.

Keywords DFIG · SCIG · PMSG · Wind turbine system

1 Introduction

All across the world, wind energy is the upcoming energy source. Due to the drawbacks of non-renewable sources, such as the greenhouse effect, which damages the climate and our planet, the generation of energy from renewable sources has expanded significantly globally. Due to this the production of power from wind is the energy technique that is expanding the quickest worldwide. The amount of energy is greatly

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influenced by the wind speed [1]. Winds transport enormous amounts of energy and are mostly brought on by solar heating of the atmosphere. A wind turbine is powered by this wind energy and is connected to an electrical generator. The wind machine's blades must revolve in order to use the wind's kinetic energy. When converting wind energy into other forms of energy, the blades are crucial [2]. Generators are used to transform mechanical energy into electrical energy. A wind turbine generator and electrical grid are directly connected. There are downsides, such as reactive power, which make it impossible to manage the level of grid voltage when a wind turbine respect to induction generator is linked directly to the grid [3]. Utilising wind turbines with variable speeds prevents these issues. These turbines lessen noise at low wind speeds and enhance the turbine dynamic behaviour. Power electronic machinery is use to regulate the generator in case a wind turbine with different speed. Wind turbines can be used for acoustic noise reduction, active and reactive power regulation, and mechanical structure stresses. There are several different types of generators, including permanent magnet generators, doubly fed induction generator, and square cage induction generators [4]. Due to a number of benefits, including the most widespread DFIG that is double fed induction generator is increasingly preferred. Due to its better performance, capacity to harness the most wind energy, and affordable induction machine, variable speed double fed induction generator wind turbine (DFIG) is now the most common variant. In this study, we investigate the various system characteristics, including the active power and reactive power, rotor speed, power factor, stator speed, etc.

2 Wind Power Generator's

A wind turbine (WT) and nacelle make up the conventional WECS, i.e. is wind energy conversion system, as depicted. A speedometer is frequently used on the nacelle cover to measure wind speed. The nacelle houses the electrical generator, bearings, gear box, rotor shafts, yaw, control system, and control system. The number of blade options, rotor rotation orientation (downwind), constant of variable rotor speed, gearbox and direct drive generator, and other characteristics are now the most prevalent design criteria for wind turbines. The type of turbine tower (Lattice towers and tube tower, as shown in Fig. 1.5), the axis rotation as either horizontal or vertical, its position by aligning actions (free yaw) or direct control (active yaw) the synchronous or induction generator, the hub design (rigid, hinged), the control of power by aerodynamic stall control of variable pitch blades. The rotor, which is made up of blades coupled to a hub and used to gather wind energy, is controlled by a pitch control system to either maximise wind collection or slow the rotor's spin. Modern wind turbines may operate at variable speeds for cost savings, enhancing power quality and increased efficiency. Reduced mechanical stresses in the turbine system and islands capabilities are additional benefits of different speed wind turbines.

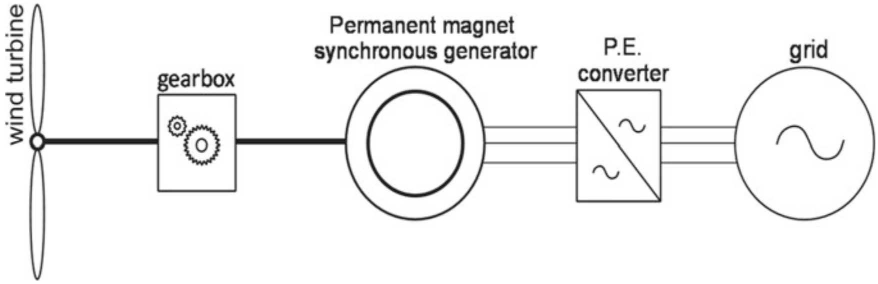

Fig. 1 Permanent magnet synchronous generator

2.1 PMSG

Permanent magnet generators that are synchronous are utilised in varying-speed wind turbines together with axles and completely rated converters, as illustrated in Fig. 1. Better power quality because of their great power density and low bulk, permanent magnet synchronous generators have become more popular recently. Additional benefits of PMSGs include enhanced efficiency and reliability owing to the lack of field winding losses and slide rings and brushes.

Though many manufacturers employ permanent magnet synchronous generators, which are thought of as the best generator for small wind turbine applications, the expense of permanent magnets can occasionally be prohibitive for bigger systems. Synchronous generators commonly have inadequate damping, which prevents unexpected gusts of wind from being adequately absorbed electrically and causes unintended oscillations in the machines, lowering the quality of the electricity. To increase the dependability of wind turbines, DD systems often forgo gearboxes and employ PMSGs with fully rated converters. The requirement for low-speed generator, which are heavier and less effective than high speed generators, arises from the lack of gearboxes.

2.2 SCIG

The resilience, simplicity, great dependability, and affordability of squirrel cage induction devices are well known. In order to produce electricity, squirrel cage induction generators, or SCIGs, revolve faster than synchronous speed. Compared to synchronous machines, squirrel cage induction machines have a higher amount of damping, which improves the rotor speed fluctuation and drive transient absorption. Squirrel cage induction machines are run by fully rated converters and gearboxes in variable speed wind turbine, as seen in Fig. 2. Due to the absence of voltage regulation, SCIGs require reactive power during operation from the utility grid. Voltage instability is another issue with SCIGs.

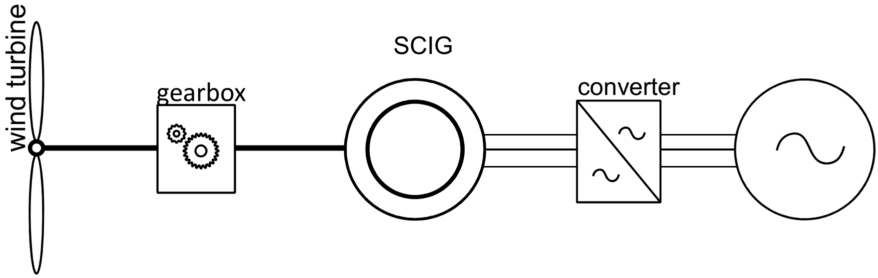

Fig. 2 Squirrel cage induction generator

2.3 DFIG

DFIGs currently outnumber their equivalents in terms of usage frequency. Simply said, DFIGs are wound rotor induction generators that typically link their stator windings to the grid directly while connecting their rotor windings through fractionally rated wires. Figure 3 shows how converters and gearboxes are used in these vehicles' drivetrains. The rotor frequency, current magnitude phase angle may be adjusted thanks to the access of an rotor windings provided by slip rings and carbon brushes [5]. They may therefore be used at a variety of speeds (usually between around 30% of the synchronous speed). Wide operating speed range, simple power factor management, reduced mechanical strains, and power fluctuations are all benefits of DFIGs [6].

Additionally, DFIGs employ partially rated power converter rather than fully loaded converter used with PMSGs and SCIGs, which have reduced converter losses. Early DFIGs had poor grid-fault ride-through capabilities, but more recent research has made these capabilities better. DFIGs provide voltage constant magnitudes and frequency varying mechanical speed by supplying voltage at slip frequency of an rotor contacts to create currents adding the variations in mechanical speed [3]. All of

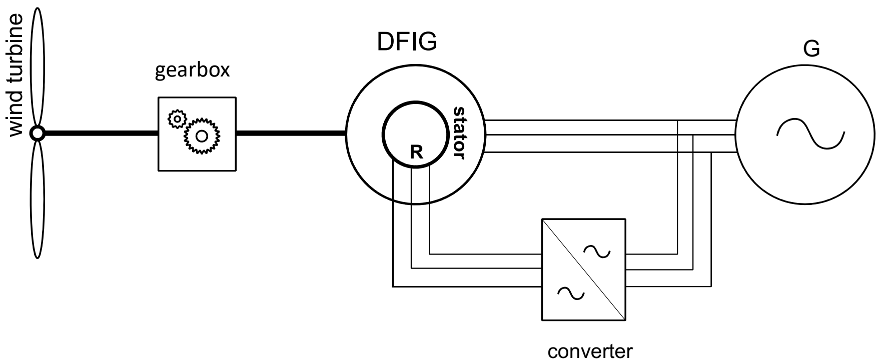

Fig. 3 Doubly fed induction generator

this is realize using DFIGs and a reliable control system that also handles jobs like tracking of maximum power points, pf management, and harmonic filter.

Without respect to power factor specifications, DFIG run in sub-synchronous or positive slip, synchronised, or zero slip and super-synchronous, or negative slip, modes. The rotor speed is slower than the synchronous rate in the sub-synchronous area than it is in the super-synchronous area. While it is in the sub-synchronous mode, the DFIG submit power of an grid throughout the rotor connections at slip frequency. The super-synchronous mode of the grid is powered by the rotor terminals. If the DFIG rotates at synchronous speed, there will be no net power supply or withdrawal and only DC current flowing through the rotor terminals. The stator terminals in all 3 instances provide electricity to the grid when the DFIGs' generating quadrants are taken into consideration.

The converter size determines the speed range that a DFIG can handle. The converter ratings are typically between a quarter and a third of the rated machine power, and they provide or draw power from the stator power at fractional levels. This equals a slip range of around 0.3.

3 Mathematical Modling of Different Wind Turbines

3.1 Modling of SCIG

Here, the 120 kV generator is grounded, and the A, B, and C points are linked to the reactor's secondary half, which is connected to the bus's primary side, according to the block diagram. Buses are used to link several gearbox systems. It serves as the connecting element that links the computer components, then provide the necessary data to them. A bus system is then linked to combine the various lines and transmit data after the secondary part of bus attached with an transformer (step down transformer) that is connected to the ground transformer. To assess the active and passive power of the scope's junction with gearbox line, the secondary side of the bus is connected to it which is linked to the bus, which is linked to the resistive load that supplies electricity to the turbine system, and the bus. We connect a scope to the system to monitor the internal measurements, which include the rotor speed, current stator current, and stator speed. We use the turbine system and the feedback loop as our reference points for measuring the rotor current, stator current, and speed (Fig. 4 and Table 1).

The synchronous reference frame, which is determined by the induction machine equations, is

$$\theta\_e(t) = \sum\_(t = 0)^\wedge z 2\pi f d$$

whereas

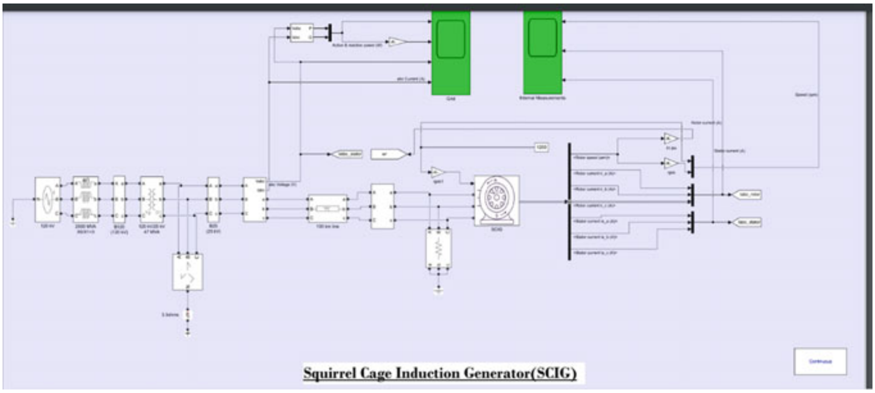

Fig. 4 Block diagram of squirrel cage induction generator

Table 1 The parameter of wind generator

Parameters	Rating
Generator	120 kV
Reactor	2500 MVA
Step down transformer	120 kV/25 kV
Transmission line	100 km
Transmission line	30 km

f the maximum electrical frequency.
θ electrical angle.

3.2 *Modling of DFIG*

The block diagram of DFIG is as shown in Fig. 5 and the parameters of the generating is similar to the table.

The formula for the connection of the stator angular frequencies and rotor is follow:

$$(w\_r + w\_m = w\_e)$$

where

Wm Angular frequency.
Wr rotor angular frequency.

The mathematical form shows the differential arrangement with respect to time:

$$\rho Q\_s = (3\iota\_(mW\_e\lambda\_ds\rho\lambda\_dr))/(2\sigma\iota\_s\iota\_r)$$

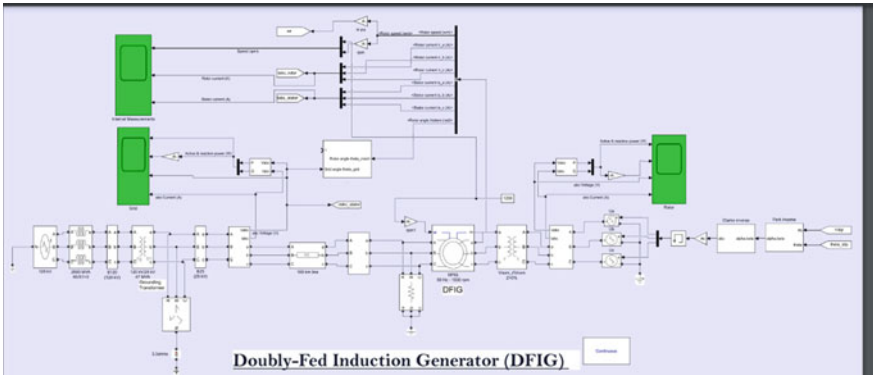

Fig. 5 Block diagram of doubly fed induction generator

3.3 Modling of PMSG

Figure 6 shows the block diagram of permanent magnet synchronous generator and the parameters are in table.

The relationship between EMF and the rotor speed is

$$f = \frac{pn_s}{120}$$

where

p no of poles in generator
f frequency
Ns rotor speed

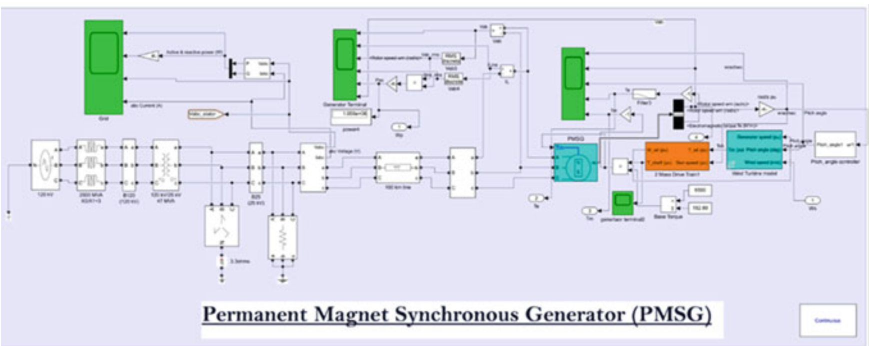

Fig. 6 Block diagram of the permanent magnet synchronous generator

4 Simulation Result

4.1 SCIG

The wave shape of a SCIG is seen in the following Figs. 5 and 7 of the SCIG block diagram illustrates. In order to test the parameters, we use MATLAB. The waveform displays the active power and reactive power over time; at first, the active power is large, but after some fluctuation, the waveform stabilises at a point with 0.9 active power and 0.5 reactive power demonstrates the abc voltage with respect to time at the initial period in two scales of [10]7 and [10]4. As we can see from the abc current measured in amper, the reactive current is strong in the upward direction while the active current is high in the downward direction. abc voltage is high up to 1.7 before becoming stable in SCIG following a 0.05-s fluctuation.

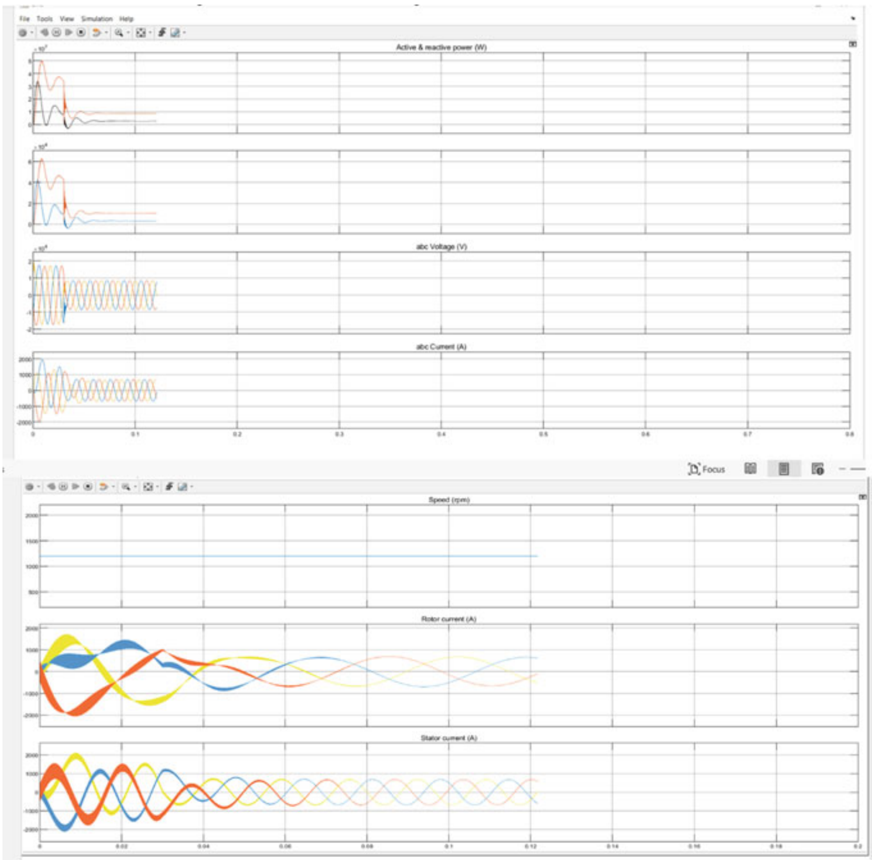

Fig. 7 The wave form of squirrel cage induction generator (with a transmission line of 100 km)

4.2 PMSG

The waveform of a PMSG parameter is shown in Fig. 8 as a function of time. The active power is high, up to 5, and the reactive power is 3.5. The active and reactive power rapidly decline to 0.3 and − 0.1, stabilise for a moment, and then quickly increase to 4 and 2, respectively. After some time, the fluctuation stabilises at 0.2 s. In the case of the abc voltage starting point, the voltage is stable at the span of 0.04; nevertheless, the magnitude decreases until 0.13, at which point it stabilises. Similar to how current at the starting point of a fluctuation happens up to 0.05, becomes unstable up to 0.13, its amplitude drops, and then becomes stable. The highest level of variation in the PMSG system's voltage at startup is up to − 2 to 2 with regard to time. The turbine's rotor speed is similarly variable at startup up to 0.34 before becoming stable, although at the point of 0.04 it climbs abruptly up to 0.15. The highest level of variation in the PMSG system's voltage at startup is up to − 2 to 2 with regard to time. The turbine's rotor speed is similarly variable at startup up to 0.34 before becoming stable, although at the point of 0.04 it climbs abruptly up to 0.15. The highest level of variation in the PMSG system's voltage at startup is up to − 2 to 2 with regard to time. The turbine's rotor speed is similarly variable at startup up to 0.34 before becoming stable, although at the point of 0.04 it climbs abruptly up to 0.15. The highest level of variation in the PMSG system's voltage at startup is up to − 2 to 2 with regard to time. The turbine's rotor speed is similarly variable at startup up to 0.34 before becoming stable, although at the point of 0.04 it climbs abruptly up to 0.15.

4.3 DFIG

The stator power, as well as the reactive recording with respect of equation set points shown in Fig. 9. The results highlight how serious the system simulation was during the drop in voltage phase, when both the reactive and active power fluctuated and lost control. The active power decreases virtually to nothing as the machine absorbs the reactive power. Once the voltage dip starts, the rotor-side converter's vector control is momentarily lost. Figures show that the fast magnetic detachment of the DFIG, which is followed by strong, fluctuating reactive and active energies, is the cause of the temporary rise in power production [4]. After the problem is fixed, it takes the power controller 20 ms to normalise the output, which is quite erratic. The DFIG begin to re-magnetise after a fault clearance. This impact, though, only lasts for a fraction of a system cycle.

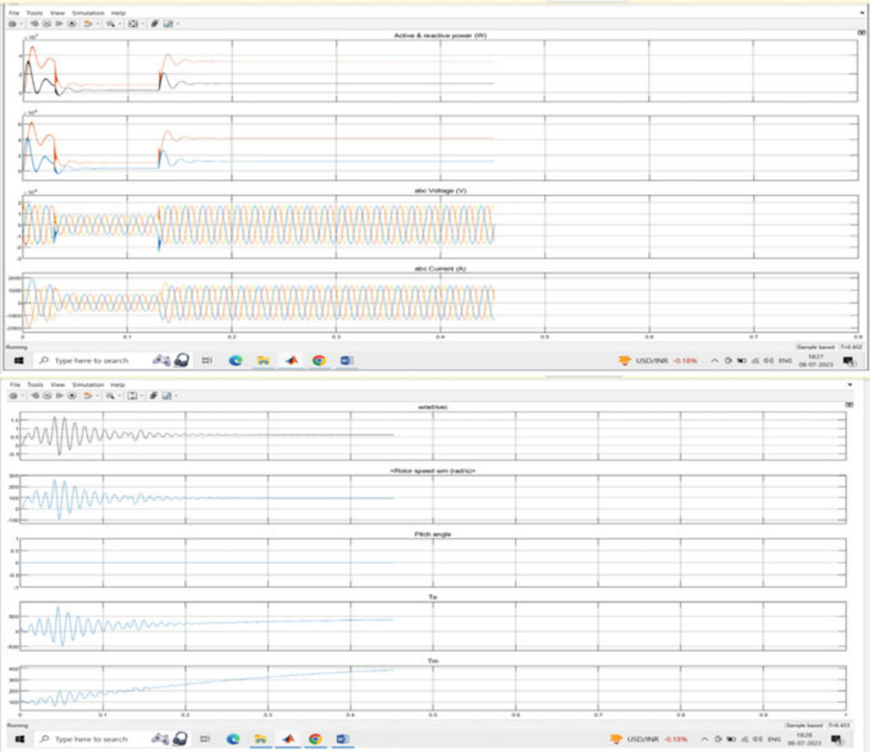

Fig. 8 The wave form of permanent magnet synchronous generator (with a transmission line of 100 km)

4.4 Result

In this paper analyte study with the different types generator of the wind turbine system, i.e. the SCIG, PMSG, and the DFIG. As we compare this three we get to know that, the superiority of the fixed-speed wind generator study is simple, dependable, steady, and well-tested, and the price of its electrical parts is not too high. Mechanical force, unpredictable passive power consumption, and limited control over power quality are some of its drawbacks. As a result of ongoing any differences in wind speed are further conveyed as changes in mechanical torque and electrical power on the grid during speed operation. By using variable wind energy systems, the majority of the problems of constant wind energy system are avoided. Power electronics converters are needed in wind energy systems with varying transmission line and speed. In essence, a wind energy system probably fitted with any three-phase generator, i.e. synchronous generators. Out of them, the DFIG is more favoured due to its many benefits. By optimising the turbine speed, the DFIG technology uses low wind speeds to capture the most energy possible from the wind, as we decrease

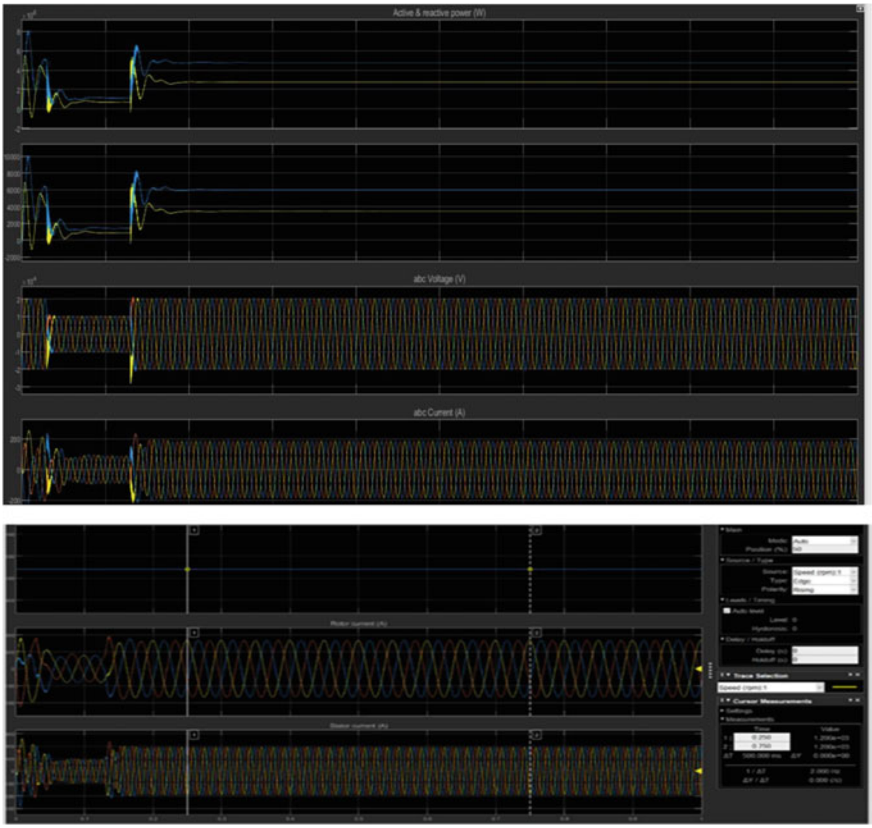

Fig. 9 The wave form of doubly fed induction generator (with a transmission line of 100 km)

mechanical loads attach turbine during a wind burst. Power electronic converters are utilised in DFIG technology to produce or absorb reactive power, negating the need to construct capacitor banks as in SCIG and PMSG. SCIG has two drawbacks: the capacitance value must be adjusted with the generator speed, which reduces efficiency since the generator for the stable of voltage because saturation of iron core. The advantages of PMSG are its compact size, light weight, low losses, excellent efficiency, and lack of a need for a gearbox or external excitation current. The downsides include the need to raise the wind's speed and the permanent magnets' demagnetization as a result of meteorological conditions.

5 Conclusion

This three generator types and their associated characteristics, such as active power, reactive power, power factor, employed by the wind turbine system were discussed in this paper. We compare these three generators of the wind turbine system using MATLAB. The primary goal of comparing these three generators is to determine which one enhances the generator's performance when the transmission line changes and speed as well. Based on our research, the DFIG performs better than the SCIG and PMSG.

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