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# MATLAB MODELING AND SIMULATION OF WIND ENERGY CONVERSION SYSTEM AS A RENEWABLE ENERGY SOURCE

Mayuri Patel[1], Prof. Janak Sorathiya[2]
[1]PG Scholar, [2]Assistant Professor, Electrical Department, Saraswati college of engineering & technology, Rajpur, Kadi, Gujarat, India

***ABSTRACT: The power electronics has played very important part for wind energy. Numerical data shows that Doubly fed Induction Generator (DFIG) based wind turbine with varying speed & varying pitch is the more communal wind turbine in the increasing market. The machine is generally used on the grid connected application for satisfied code requirements like stability, power quality, synchronization & power control. If requirement are not satisfied by the machine(DFIG), the control approach is used on both the stator and also rotor side along with power electronic converters to fulfill the mentioned requirements. For the convince of the grid code, frequently grid side converter plays a main role in the system. To get better the capacity of wind turbine utilization under precarious situation, the study of both , the machine side converter and grid side converter regulator is required .In these machine, it uses back-to-back converters at the rotor side circuit. DFIG is able to do work likes a generator in both sub synchronous and super synchronous speed. Results are obtained from the PSIM simmulation.***

## I. INTRODUCTION TO WIND ENERGY HARVESTING

*INTRODUCTION*

Air in motion is called Wind. It is due to the heating of the Earth's surface by glowing energy of the sun. Due to uneven surface of earth is completed of especially different natures of soil and water ; it engages the sun's radiation at different stage. Water doesn't make heating or cooling so quickly as land, due to their physical properties. The perfect condition for more wind is the area at where water & land meets simultaneously.

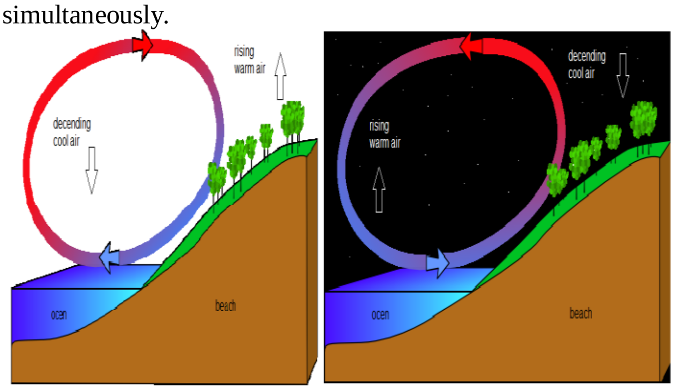


Figure 1.1 wind Generation

Wind is nothing but the movement of air masses fashioned due to the asymmetrical heating of the earth's plane by solar radiation. It is accordingly creates forces which set in motion air masses around for balancing the global temperature. Wind energy is not a continuous source of energy as other such as fuel cell. It may varies from time to time of the day of year.

*SCENARIO IN WIND ENERGY*

Power of the wind is the one type of conversion from wind energy to secondary form of energy used widely, with the use turbines and some arrangement to convert in to electrical power, wind mills for mechanical form conversion, and used wind pumps are used for pumping the water system, internal drainage system, or in sails to drag ships in sea. Huge wind conversion system consist of dozens of wind turbines that are simultaneously inter connected with together to the large electric power network. Off shore plant can combine with more dominant winds than are available at soil base project & they possess lower influence but the cost of construction is very high. Miniature wind turbine conveniences are castoff for providing electricity to inaccessible locations in country and grid companies buy surplus electrical energy produced by this household turbines at anywhere.

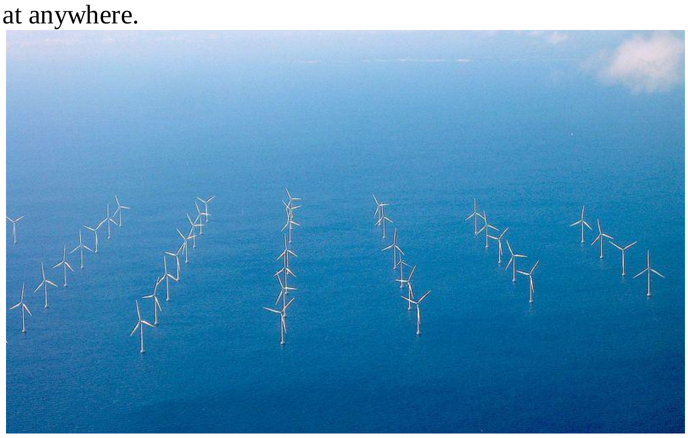

Figure 1.2 Development of windmills

Wind power, as an marvelous alternative to fossil fuels, is renewable, extensively accepted, green, clean and no productions of greenhouse gas during its operation and uses very less significant land in compare [1]. several damage on the our surrounding are generally not more challenging compare to the from the other. As in 2013, Denmark generates quite a quarter of their own electricity. Around the 85 of the countries in the world are using of wind power on a money-making basis also. In 2010 wind energy production per year was over 2.8% of the total convention of electricity, and it grown faster at more than 22% per year [2]. The economical cost per unit for energy production is comparable to the cost for new coal and natural gas projects. Although wind energy is a most fashionable form which is used for energy generation, the construction of wind farms is not generally welcomed due to the aesthetics. Wind power is extremely reliable throughout but, it has major fluctuation over shorter time. The wind intermittency scarcely creates problems at what time used to supply up to 21% of electricity requirment, but as it increases, it need to be improved grid & a lowered ability to transfer straight production may occur.

*WIND TURBINE PARTS*

Away from each of the technical prospectus of wind power associated with the unpredictability and restricted predictability of wind power. Now the integration of wind power in electricity senario has also become a subject of interest. Since wind power prediction errors increase with the forecast lead time. wind power cannot be programmed as long in advance as conventional generation. Therefore, a number of market aspects are of significant for wind power integration, including market closure-times, the design and size of the market for balancing funds and , the geographical size of the system/market wind power is integrated. A final aspect relevant for wind power is the organization of support schemes for wind power, which can be used in wind power in excess of other generation technologies, to integrate the wind power into the market. Wind turbine parts are explained below:

Anemometer: It is used for the measurement of the wind speed and also transmits wind speed data to the controller.

Wind turbine Blades: In most of turbines they have either two or maximum three blades. Wind blowing through the blades it makes the blades to rotate.

Brake: Brake can be applied to the turbinr either mechanically or electrically, or hydraulically means to stop the rotation of wind turbine in case of emergencies.

Controller: The controller which starts up the machine at wind speeds of about 8 to 16 ms and shutting down the machines at above 65 ms speed of wind. Turbines not able to function at wind speeds at above 62 metre per seconds due to at that speed generators can be get overheated.

Gear box: Gears that are linked low speed shaft to high speed shaft & also it increases its rotational speed to 30 to 65 rotation (RPM) to about 1250-1550 (RPM). The rotational speed that required means of the generators for produce adequate energy. The gear box is a very costly component also been much heavier part of the turbine system and researcher who about to explore "direct-drive" application of generators which are operates on very low of the rotational speed & which doesn’t have gear box arrangement.

Generator: Typically its an basic induction generator is used for the generating 50 Hz cycle.

High speed shaft: It drives wind generator in system. Low speed shaft, rotor rotates the low speed shaft on about 32 to 65 rotations..

Nacolles(case) : turbine rotor attached to the nacolle; it mounted on the top of tower and it is including with the gear box mechanism ,also controller high and low speed turbine shafts, the generator, & the brake of turbine. cover that guards the entire component in the nacolle. Some nacolles which are very large sufficient for a person to work inside at period of maintenance.

Pitch of the blade: Blades are being turned, or being pitched, from out of the wind for the principle of rotor for revolving in winds that may be also high or may be very low for generating energy.

Rotor of wind turbine: Rotor blades & the rotor hub, mutually known as the rotor of turbine.

Wind Tower: They made up of steel/ cast steel, Because wind blowing speed increases with the height, as talle enough towers are enables the turbines to apprehension more and more electricity & they generating a sufficient amount of energy.

Direction of the wind: Its up turbine type wind turbine, called because they operates by facing directly in to the wind.

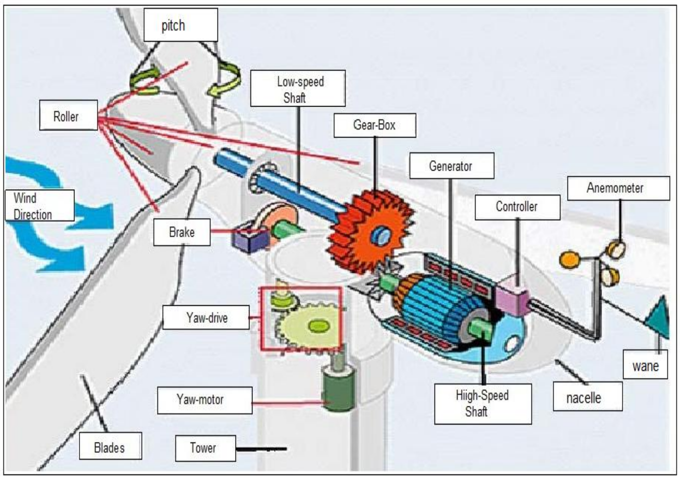


Figure 1.3 Parts of a wind turbine

Wind vane: Wind vane used to measures direction of the wind & in addition control yaw for the adjustment of the turbine with wind direction.

Drive for Yaw: Up wind turbines directly facing into the wind direction; the drive that control the Yaw are used for keeping the rotor towards wind directly as the wind direction of the wind changes time to time. Down wind turbines are not require any drive for yaw.

Yaw control motor: Power up the yaw drive.

Wind turbines generally having a some liberty to generate power. Its capability to change yaw & the direction of compass by using a drive motors to nacelle unit, so the rotor is point out straight to facing. This procedure is completed using the past data from vanes which are being used to reduce the effect of waken disorder in the wind turbines.

Angle of the turbine blades, which may be adjusted for maintaining the stable rotational speed under varying wind speed condition. Rotational rate which chosen to optimize the invention efficiency of the wind system. An additional prospectus of pitch angle control and yaw drive Mechanisms to acting like a brake at under tremendously physically powerful situation.

  

Cut in speed: Cut in speed of the turbine is the lower speed of the wind turbine begin to start to produce utilizable power . cut in speed in wind turbine 4mt/sec.

Cut out speed: higher speed of the winds on at a wind turbine stop to produce power, which is known as a cut out speed of turbine it may be 32 mt/second.

## II. DOUBLY FED INDUCTION GENERATOR

*INTRODUCTION TO DFIG*

DFIG is electrical generators which having a winding on both stator and rotor, where both of the windings transfers power towards shaft to electrical system. Doubly fed generators are used in many application, which needs unstable speed control of the machine for a fixed system frequency.

*Features of Doubly Fed Machine*

In practice, wound rotor with a doubly fed generator (DFIG) have an issue of unsteadiness, maintenance & it also have lower efficiency of the fundamental slip ring gathering & also variation in speed somewhere cease to occur. A applicable doubly motor doesn't dependent on asynchronous induction ideology while, the generating symmetrically power above its full range has never been substantialized. As like all electrical machines, doubly fed induction machine needs to torque current to produce torque in the machine, Because of permanent magnets are not placed, but controlled flux density in the doubly fed machine is also considered necessary to yield flux. Rotor currents requires to produce darg to magnetization. Therefore active power is also present in the rotor. The generated frequency and rotor voltage magnitude are proportional to the variation between the speed of the machine and the synchronous speed. At standstill condition, the generated frequency matching as the frequency generated in the stator. The voltage is resolute through the ratio of the stator turns and rotor turns. Thus if the number of turns is same as to each other, the rotor have been the equal as in the stator. The DFM unlike a transformer on this condition. The transformer unlike behavior are present in the machine when it rotates, particularly during transient condition in the grid. Because of the voltage and current performance illustrated above the rotor will whichever consume, or generates active power depending on the speed and torque characteristic. if turbine speed is below the synchronous speed, the machine is producing negative torque and operating as a motor, and the rotor will generate power. The magnitude of the active power generated depends on the torque of the motor. Thus if the motor has rated torque input, rated power is produces through the stator & rotor but as in the case of all the electrical equipments have same rating ,also the efficiency is based on the circulating current characteristics. Do all electric machines, the efficiency is low at lower speed of the machine, because the current in rotor is essential for torque production but there is no drag power is generated in it.

*DOUBLY FED INDUCTION GENERATOR*

Doubly Fed Induction Generator (DFIG), a generating principle extensively used in the application wind turbines. It is based on an induction generator principle with a multi-phase wound rotor, and also a multiphase slip ring assembly with brushes for accessing the rotor windings. It is likely to neglect the multiphase slip ring assembly but it has troubles with efficiency, cost and also size.Compare a brushless wound-rotor doubly fed electric machine is batter option. Unpredictable speed process is vital for large wind turbines for the optimization of the energy confine under varing wind situation. A variable speed wind turbines have need of interface, back to back converter to allow connection of the machine with the grid. The power electronics has two types, it can be either fully or partially rated [8]. A widespread interface technique for huge wind turbine that rely on the partially rated interference is used in the DFIG construction system. In that DFIG system, the power electronic interface is used for controlling the rotor currents to make the control on electrical torque and also speed. The power electronics circuits only deal with the rotor power , which is characteristically laser than 30% of the whole output power of machine. the DFIG lead to the advantage of speed control of DFIG. A electrical model, that including the back to back converter execution of the rotor side of power electronics, it also given by $d_q$ model. The aerodynamics of the wind turbine generator and the mechanical design of the induction machine are integrated to develop the use of the electrical model for the simulating system procedure under erratic (variable) wind speed environment.

*POWER IN WIND*

The power that obtained from the wind turbine given by following equation[14]

$$P_w = 1/2( \varrho A C p V^{3})$$

Where ϱ is density of air, A is the area covered by turbine, $C_p$ is wind turbine power coefficient , and v is velocity of the wind in m/s. A characteristic curve displaced in Figure, β is pitch angle of wind blades. The use of a power electronics interfacing is favored , it allows varying speed procedure and also increasing power swing from the wind. Typical coefficients vs tip speed curve ratio shows the cause of unstable blade pitch angle is shown in fig-3.1 given below:

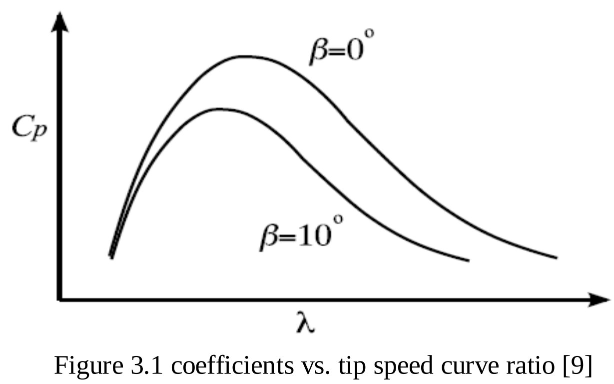


Figure 3.1 coefficients vs. tip speed curve ratio [9]

  

The performance coefficient of the depend on the TSR of given by,

$$\lambda = \frac{\omega t R}{v}$$

Where, ωt is the turbine speed and R is radius of the turbine. It may be seen that λ should be held on stable to control highest output power of the wind. . When the wind turbine is reaching its max rotating speed though, pitch angle control method must be in employment to shed the excess of wind power. With the increasing the blade pitch angle we can seen deficiency the optimal Cp and λ value as displayed in Figure 3.1 above.

*TYPES OF INTERFERENCE FOR WIND TURBINE*

Even though generators of wind turbine can directly interfaced to the power system, for the variable speed operation of the DFIG machine, power electronic interface system can be chosen to use it, and it demands more power absorbsion from the wind. Varying speed procedure allows also gusts of wind to be less due to the mechanical area of the large turbine, in the output power also dropping torque pulsations and fluctuations. Power electronic interfaces are of two type fully rated and partially rated type. The fully-rated interface controller is shown in Figure, it operates all the power produced by the wind turbine. That type of interface is repeatedly used with permanent magnet type generators.

The fully-rated interface allows for the control of flexibility over the operating range of the wind turbine; nonetheless, the converter and filter are much costly compared to a partially rated interface. The partially rated interface processes is a part of all generated power output of the turbine , and it can also offers to manage the flexibility of the operating range of the wind turbine. Partially rated interface is usually used with a DFIG, where the power electronic interface only processes the rotor rated power. This system is shown in Fig. 3.2(b). The main merit of this scheme is to reduced the size of converter and also reduced cost of converter interface and also following reduction in all over converter losses in it. The varying wind speed operation is important for large wind turbines in order to optimize the energy collect under variable speed conditions.

Variable speed wind turbines has necessity of a power electronic interface converter circuit to permit connection with the grid. When the wind turbine takes its highest rotational speed. however, blade pitch angle control can be employ to shed the overload wind power .A partially rated interface is generally used for DFIG system , where the power electronic interface circuits only processes the rotor power. This system is shown in Figure 3.2

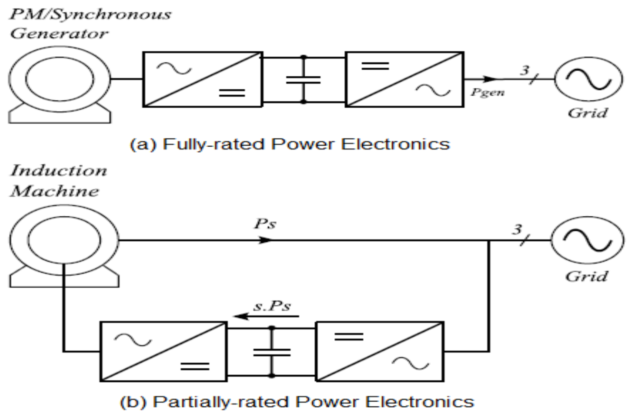


Figure 3.2 Interference options for wind turbines

## III. POWER GENERATION IN DOUBLY FED INDUCTION GENERATOR SYSTEM

The construction of doubly fed induction generator( DFIG) is like a wound rotor induction machine . The torque speed characteristics of a representative induction machine with a short circuited in rotor are depicted in Figure 3.3. The induction machine operated at two point or mode, sub synchronous and super synchronous mode, that correspond to rotation below or above the synchronous speed of that machine. The synchronous speed of the generator in rpm is given as:

$$Ns = \frac{f}{Zp} \times 60$$

Where f is the frequency of grid in hertz, and Zp is the number of pole pairs. A 50 Hz generator with 2 pole, Ns = 1500 rpm.

To operating as a generator mode, the machine generally operate in the super synchronous mode, while the negative torque is needed for the generation of power is in general realized in this mode. If rotor is not in short circuit but power supplied by a back to back converter used as a slip ring adjustment, the torque control of the torque is achievable in that case. At a given wind speed, rotor current permitted to optimal -ve torque generation. Consequently, operation at the optimum rotational speed is obtained. Rotor current control allows alteration of torque characteristics in sub synchronous and super synchronous mode is shown in figure 3.3 given below:

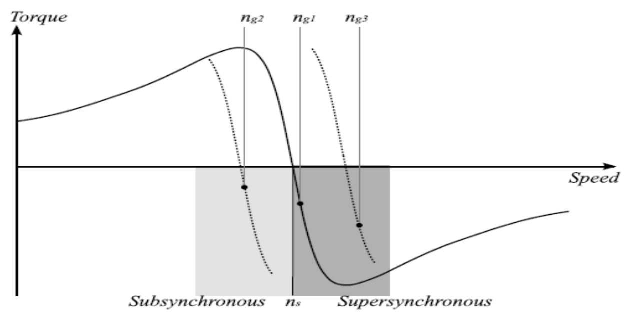


Figure 3.3 Torque vs speed characteristic of induction machine shorted rotor

  

The block dia. of the DFIG system presented in the most of the research paper is shown in Figure 3.4. The supply of rotor includes a grid-side converter and rotor-side converter that are connected via a dc bus. The dc bus capacitor connects the two converters, and permits them to be separately controlled. Note that the inertia reduced by a factor of five in order to the increased speed of the mechanic dynamic reaction of the turbine and allowing closed simulation. This has a negligible crash on the selection of parameters for the speed controller in the rotor side converter control loop. Wind turbine generators directly connected to the power system, with the using power electronic interface, it allows varying speed operation and, also rises power extraction from the wind. Varying speed function also permits wind gusts to be wrapped up in the mechanical inertia of the turbine, reduce torque pulsations and also reduced fluctuation of the output power. Without using damper windings in synchronous machines, the wound rotor double fed electric motors are responsible to be instable with no stabilizing control DFIG wind turbine system construction is shown in figure 3.4 given below:

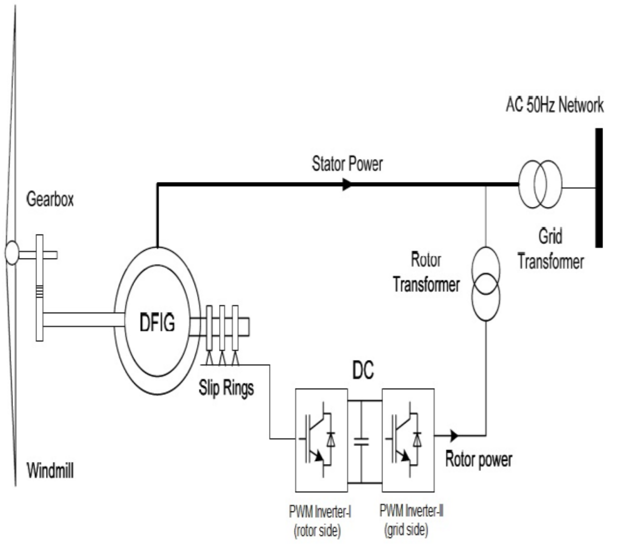


Figure 3.4 DFIG wind turbine system [10]

Figure 3.4 shows block diagram of DFIG which consists of twice individual bi-directional voltage source converters (VSC) with a back-to-back DC-link, a wound rotor induction machine, and the wind turbine itself.

## IV. OPEN LOOP SIMULATION OF DFIG

### *INTRODUCTION*

DFIG is electrical generators which having a winding on both stator and rotor, where both windings transfers power between shaft to electrical system. Doubly fed machines are used in many applications which require varying speed control of the machine for a fixed frequency.

### *WIND TURBINE SIMULATION*

For the simulation on PSIM of DFIG system, simulation system of wind turbine that is used is compulsory The mechanical power absorbed from a turbine is given by

$$P_w = ½( ϱACpV^{3})$$

Where ϱ is the density of air, A is the swept area of turbine, $C_p$ is the performance index coefficient and, V is the wind velocity in m/s. even if wind turbine generator, coupled directly to the system through back to back converter. The use of a power electronic interfacing is best when it allows varying speed operation and also permite an increased power withdrawal from the wind. Modeling of a wind turbine is shown in figure 4.1 given below:

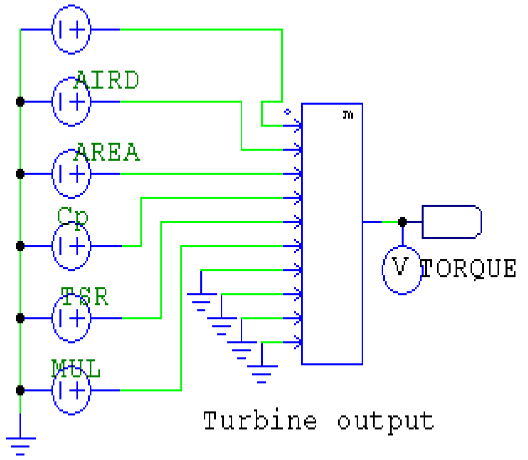


Figure 4.1 Modeling of wind turbine

As shown in figure 4.1, wind turbine is simulated and torque produced in turbine is given in figure 4.2 below:

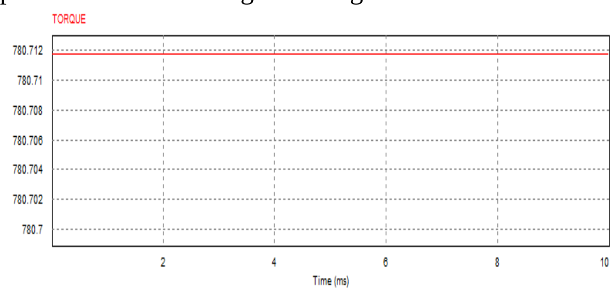


Figure 4.2 Generated torque in wind turbine

### *SIMMULATION OF DFIG*

In practical, the traditional wound-rotor double fed induction electrical motor or generator system have an issues of high maintenance , instability, and the efficiency of an integral multiphase slip-ring assemblage, and hesitation regarding synchronous speed. A wound-rotor doubly fed electric machine system that does not depend on synchronous principle ,while generating or motoring . over its range and it has never be materialize from the electrical machine concern, regardless of being of research for finding an evolutionary synchronous, brushless machine, and constant control method. Rotor current needs to produce torque for magnetization.[16] Thus active power is also be presented in the rotor, in additional with the reactive power. Magnitude and frequency of the rotor output voltage are in proportion to the variation between the speed observable of machine and at the synchronous speed (the slip power).

  

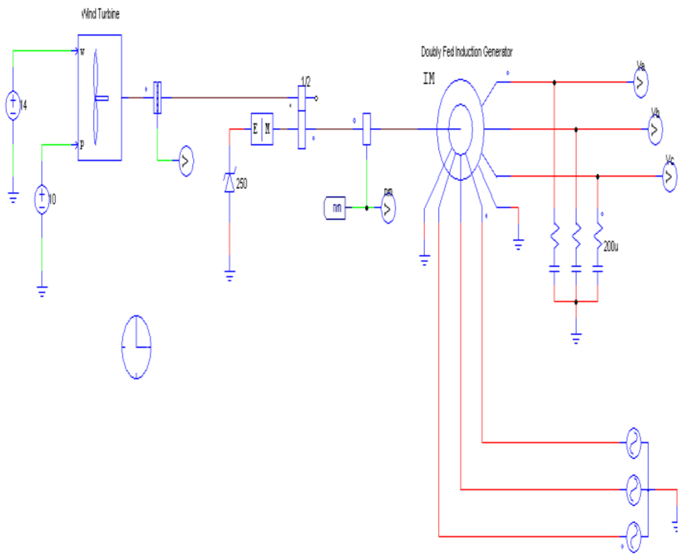


Figure 4.3 PSIM Simulations on Doubly Fed Induction Generator

Simview Of this simulation is displaye in figure 4.4 given below:

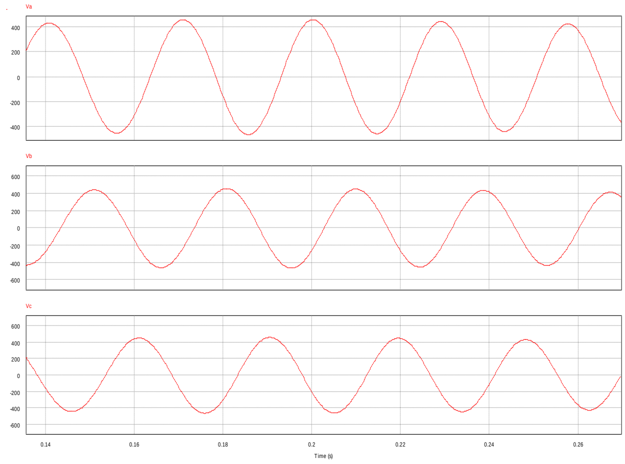

Figure 4.4 simulation output of DFIG system (y axis div. 1 section=200volts)

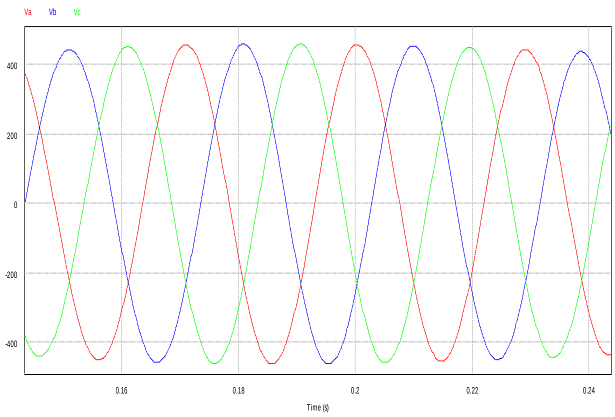


Figure 4.5 Simulation view of phase angle between voltages (y axis div. 1 section=200 volts)

## V. ROTOR SIDE CONVERTER CIRCUIT FOR DFIG

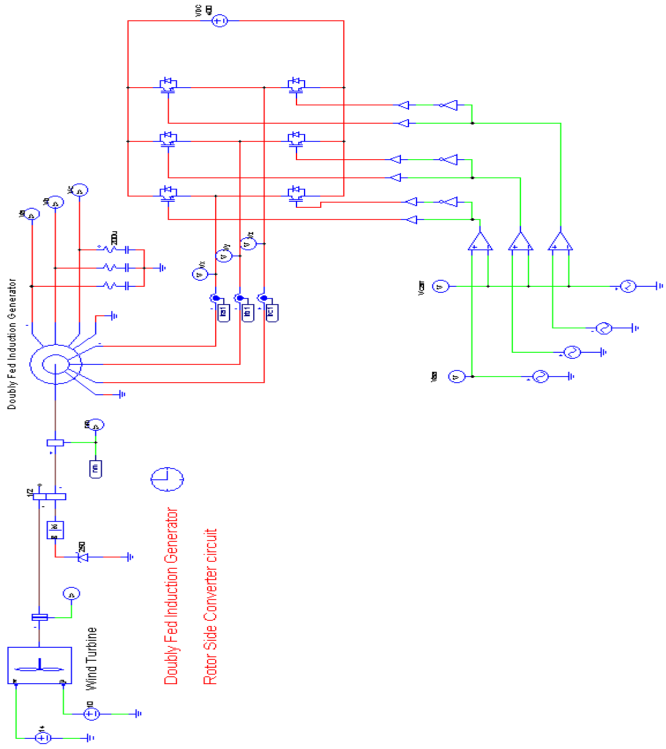


Figure 4.6 Rotor side converter circuit using PSIM

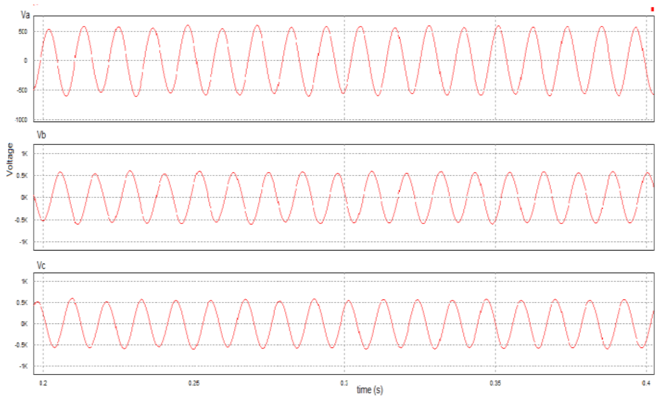


Figure 4.7 simulation view of waveform of RSC (y axis div. 1 section=500 Volts)

Phase angle between output voltages

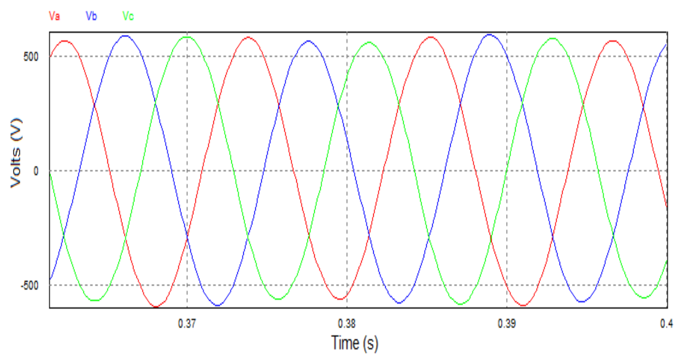


Figure 4.8 Simulation of phase angle of output voltages (y axis div. 1 section=500 Volts)

  

## VI. GRID SIDE CONVERTER CIRCUIT

Grid Side converter circuit

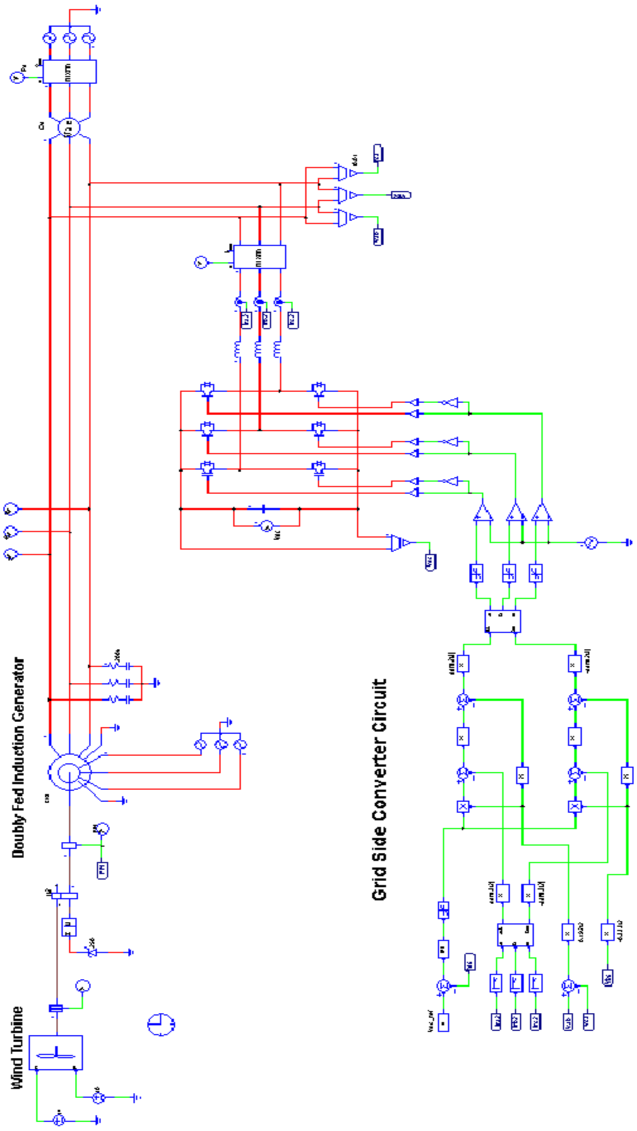


Figure 4.9 PSIM circuit Grid Side Converter

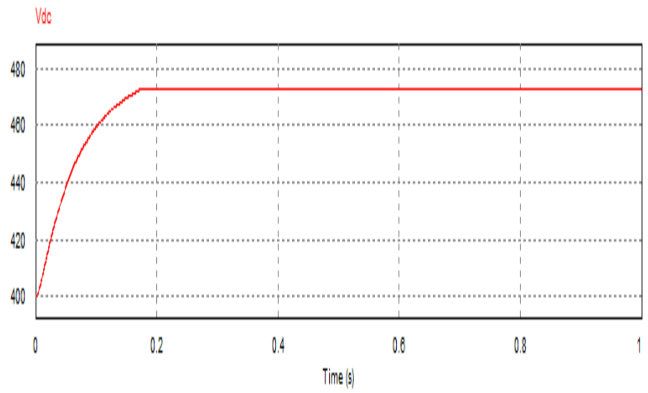


Figure 4.10 DC Link capacitor constant voltage (Vdc=468 volt) (Scale: X-axis div=0.2 sec, Y-axis div=20volts)

## VII. CLOSED LOOP SIMULATION ON DFIG DOUBLY FED INDUCTION GENERATOR CLOSED LOOP CIRCUIT

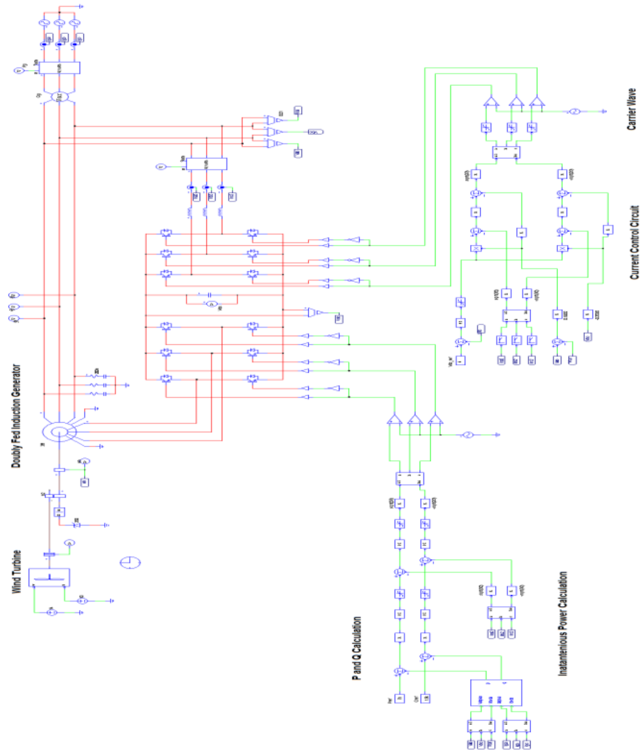


Figure 5.1 PSIM simulation of DFIG Closed loop Simulation results are displayed in figure given,

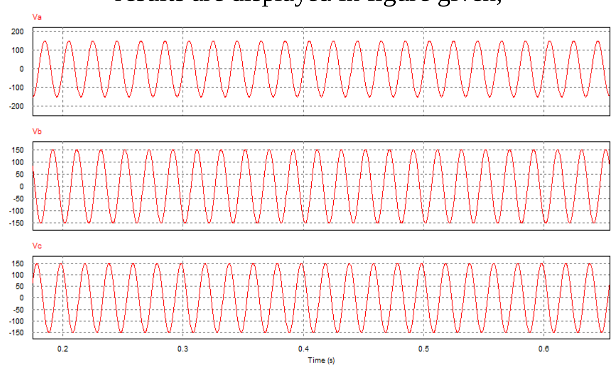


Figure 5.2 Closed loop PSIM simulation of DFIG results for voltage (Scale: X-axis div=0.02 sec, Y-axis div=50 volt)

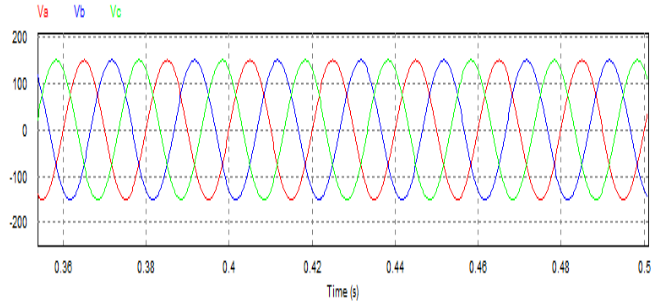


Figure 5.3 DFIG Closed loop simulation results for voltage Va-Vb-Vc (Scale: X-axis div =0.2 sec, Y-axis div=100 Volt)

  

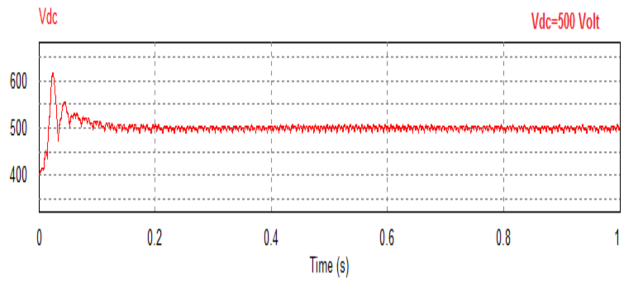


Figure 5.4 Simulation results of DFIG wind turbine
(Scale: X-axis div=0.2 sec, Y-axis div=20 Volts)

## VIII. CONCLUSION & FUTURE SCOPE

wind energy utilization is a best over the other renewable sources as it is available throughout the day except its variation in speed DFIG is a best machine among the others as it can provide control on wide range of the speed so it help to nullify the demerits of wind variation. DFIG provide a constant frequency voltage which can directly fed to grid. Though, the control of DFIG is not so easy to design but it is worth as we can get clean green energy from nature. In this project modeling of the wind turbine and simulation of characteristics of machine is studied for further improvement of design can be done by using fault analysis and by control techniques.

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