A

Project Report

on

MODELLING AND SIMULATION OF WIND TURBINE GENERATOR IN MATLAB/SIMULINK

Submitted in partial fulfilment of the

requirement for the award of the

Degree of

BACHELOR OF TECHONOLOGY

in

ELECTRICAL ENGINEERING

by

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SCHOOL OF ELECTRICAL, ELECTRONICS AND COMMUNICATION ENGINEERING

May, 2020

DECLARATION

We declare that the work presented in this report titled “**Modelling and Simulation of Wind turbine generator in MATLAB/Simulink**”, submitted to the Department of Electrical Engineering, Galgotias University, Greater Noida, for the Bachelor of Technology in Electrical Engineering is our original work. We have not plagiarized unless cited or the same report has not submitted anywhere for the award of any other degree. We understand that any violation of the above will be cause for disciplinary action by the university against us as per the University rule.

Place:

Date:

Signature of the Student

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Avinash Tiwari (1615105007)

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GALGOTIAS UNIVERSITY

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<u>CERTIFICATE</u>

This is to certify that the project titled **"Modelling and Simulation of Wind Turbine Generator in MATLAB/Simulink''** is the bonafide work carried out by Avinash Tiwari, Gaurav Varshney students, during the academic year 2019-20. We approve this project for submission in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Electrical Engineering, Galgotias University.

Dr. Gitanjali Mehta
Project Guide(s)

The Project is Satisfactory / Unsatisfactory.

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Internal Examiner (s) External Examiner

Approved by

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ACKNOWLEDGEMENT

We are grateful to The Department of Electrical Engineering, for giving us the opportunity to carry out this project, which is an integral fragment of the curriculum in Bachelor of Technology program at the Galgotias University, Greater Noida. We would like to express our heartfelt gratitude and regards to our project guide, Dr. Gitanjali Mehta, Associate Professor, School of Electrical, Electronics and Communication Engineering, for his unflagging support and continuous encouragement throughout the project.

Special thanks to our Dean Prof. B. Mohapatra School of Electrical, Electronics and Communication engineering for ----------------------

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We are also obliged to the staff of School of Electrical, Electronics and Communication Engineering for aiding us during the course of our project. We offer our heartiest thanks to my friends for their help in collection of data samples whenever necessary. Last but not the least; we want to acknowledge the contributions of our parents and family members, for their constant and never-ending motivation.

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ABSTRACT

In this report, work done to develop generator model using MATLAB (Matrix laboratory) environment is explained. The main aim of the project was to develop an excellent Doubly fed induction generator model. The model can be used to understand, simulate and analyze transients load. The simulation of the model under different grid condition and articulation of the resonant excitation would be possible. This report also contains the technology of generator systems in wind energy conversion systems which are already in use and some of the new concepts and their technical features. The new generator technologies could generate invariable wind power and does not depends on the changes happen in the velocity of the wind. It has huge application across the globe and especially at the remote areas of the world.

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GLOSSARY

WTG	Wind Turbine Generator
DFIG	Doubly-Fed Induction Generator
MATLAB	Matrix Laboratory
WRIG	Wound Rotor Induction Generator
FAST	Fatigue Aerodynamics Structures, and Turbulence Model
VFC	Variable Frequency Converter
RSC	Rotor Side Converter
GSC	Grid Side Converter

1. INTRODUCTION

In two main categories, wind turbine is divided:

Variable speed wind turbine and Fixed speed wind turbine.

Fixed speed wind turbine have great simplicity and strength but they have disadvantage of not able to capture the energy of wind efficiently because their ability is to operate at the fixed speed and nature of speed of wind is varying . At a certain wind speed, fixed speed wind turbine is only able to work at highest aerodynamic efficiency.

In order to extract maximum amount of power from the wind the turbine should be capable to work under variable speed and go with the maximum power extraction curve.

In the DFIG system, connection of wound type induction generator is to the power system through stator terminals. Besides connection of the rotor to the power system via AC-DC-AC variable frequency converter (VFC), rated at 25% to 30% of DFIG nominal power. There is a back -to-back connection between rotor side converter (RSC) and grid side converter.

Demerit of the system is that slip rings and brushes are required and it adds extra maintenance cost and outfitting cost.

There are several advantages of variable speed wind turbine systems over fixed speed wind turbine systems. Variable speed wind turbine with doubly fed induction generator (DFIG) are most preferred in the power utilization industry because it has the numerous advantages over other existing connected schemes for generation of power. Power electronic based back to back AC/DC/AC conversion chain in the rotor circuit has made it possible for wind turbine with DFIG power plants first choice for production of power in MW level. It has the speed variations in the broad range and wastage of dissipated energy in rotor circuit is minimum. The role of equipment of power electronic is in fraction of about (20-30%) of total system power losses in those power electronic equipment will be very less or negligible and utility industry has the benefit of cost by using smaller converter instead of directly driven induction generator.

Various control schemes for performance improvement of DFIG under different operating conditions are state feedback control and stator flux oriented vector control.

Hybrid is a consolidation of two or more energy sources which bring out decisive energy power because we are added more than one energy source. Scope of Hybrid Energy System is more in rural and remote areas because of lack benefit from the grid supply and because of increasement in demand, global warming, depletion of non-renewable energy sources is compel to go for renewable energy sources. The power which we get by tame of wind energy is called wind power. Solar and Wind energies give better results because these energies sources are adulatory in nature. Both energies are adulatory in nature when there is torrent of wind there is no sun about-face.

Recently, wind power infiltration into the power grid has been increasing globally at a momentous rate. The flexible speed generator wind turbine (ASGWT) has decisive advantages over the fixed-speed generator wind turbine (FSGWT) in premise of less mechanical stress, enhanced power quality, high system productivity and minimised acoustic noise. One imperative class of ASGWT is the Doubly-Fed Induction Generator (DFIG), which has attained important attention from the electric power industry due to its assets over the other class of ASGWT that is fully rated converter-based wind turbines.

During the recent years, with rising advancement of wind energy alteration technology, in the End of 2004 the total installed capacity has reached up to 39.234GW and will outstrip 110GW by 2012.In Nowadays Fixed speed or Variable speed Applications available in the market heed to ingenious concepts in technology.

2. LITERATURE SURVEY

2.1 Grid Related Events:

Integrity of wind turbines and performance are greatly affected by abnormal events.

- Events of balanced voltage i.e., equal overvoltage in three phase and equal undervoltage in three phases.
- Event of unbalanced voltage i.e., undervoltage in on or two phases or overvoltage in phases except three phases.
- Transients due to fault this includes grounded, single phase fault, two phase fault and fault of three phase-to-ground fault.
- Voltage Dips is due to the loss of lines, loss of generators is direct online start-up of heavy loads such as induction motors.
- Power system oscillations.
- Transients of switching includes stuck breakers, switching of load, switching of capacitor and tap changer transformer.

2.2 Generator and power converter-related events:

Performance of wind turbines and integrity of wind turbines are affected by the abnormal events happening in the power converter and generator.

- Impedance that are unbalanced in nature.
- Unbalanced phase windings.
- Transients due to fault is basically the fault such as grounded, single phase fault, two phase fault and fault of three phase to ground.
- Failures of power switching and fluctuations of DC bus.

3. DESCRIPTION

Using toolbox of MATLAB Simpower systems, Doubly fed Induction Generator turbine model has been developed. The developed model is a phasor model where power system is treated as balanced three phase fixed frequency network. In balanced three phase fixed frequency, each phase voltage is equal in magnitude but phase difference between any two phases is 120 degrees. The differential equation representing the network with a of algebraic equations' set at a frequency which is fixed are replaced by phasor simulation. Transient stabilities studies of systems with multiple machines is also possible with the help of phasor simulation. For studying the unbalanced events, phasor simulation cannot be used. Phasor simulation is also known as positive sequence simulation. For the simulation of electromechanical oscillations of low frequency within seconds to minutes, this model is always adapted. For the simulation of generator in another way, there is a technique called three-phase representation can be used. In three phase representation, simulation of unbalanced condition is possible. Grid unbalanced voltage (such as transients, faults or dips) or unbalanced grid impedance are the main cause of unbalanced conditions. The model developed till date does not cover all these factors.

Wind turbine generators (shown in figure) are variable-speed wind turbines with DFIG. This type of turbine is the most popular type among other types that are available in market and it is being put in position in large numbers. Operation of DFIG is in variable speed mode in which power converter of partial size is connected to WRIG's rotor winding. Connection of WRIG's stator winding is to the grid at a required frequency. Normal operation of WTG is between 30 percent slip (sub synchronous speed) and -30 percent slip (super synchronous speed), converter is operated at 30 percent of the output power which is rated. The role of power converter is to perform back to back AC-DC-AC conversion with the help of two pulse width modulation-switched voltage-source inverters coupled with a DC link. For the protection purposes, crowbar circuit is deployed, allowing shorting rotor circuit, if necessary.

The nature of torque characteristics of WTG is the function (quadratic) of the rotational speed. There is possibility of maximum extraction of wind power in WTG system because output power of WTG system could be electronically controlled following optimal power curve. The optimal power curve is in form of function (Cube) of the rotational speed. Pitch Controller plays a major role in limiting the rotational speed of the rotor. Pitch controller is always put in position to control the rotational speed to the rated speed, if the speed of rotor exceeds its rated value. WTG experiences runaway event, when pitch controller is unable to control wind turbine's aerodynamic power.

Simpower systems toolbox of MATLAB/Simulink gives an example phasor model of a Doubly fed Induction generator Turbine which has most straight forward mechanics. This model has been modified, basic mechanical and aerodynamics aspects have been replaced with the FAST Simulink block.

The torque input was provided to the Doubly fed Induction Generator block (light blue in colour) model, but various calculations for two mass (generator and turbine) shaft model is handled by FAST. This is the reason speed input can be directly provided to the generator. Two-mass shaft sub-model was by passed within the generator. Crowbar or DC chopper is not included in this generator model. In the original model, pitch control subsystem was not present. So, it is added in this model.

3.1 Normal and Abnormal Events:

Manufacturers of the wind turbine have interest in the area of wind turbulence, rates of extreme ramp on the stabilities of the power system, effects of the component failures and input of the components of the turbine.

Location of the wind turbine plants are where wind resources are high and it might be away from the load centre. when the wind speed is equal or above the minimum speed of wind known as cut-in wind speed, then turbine drives the generator. There is the direct connection of the synchronous generator is to the grid in case of a conventional power plant .Synchronization is between frequency of grid and rotation of electromagnetic flux generated by the stator winding plays a important role. Existance of the direct correlation between mechanical rotor of the generator and voltage of grid and frequency is there and synchronization with grid in a great way. In electrical power system, if there is any kind of the oscillations on the grid, then it will have direct impact and will be transferred directly to the prime mover, shaft, gearbox and oscillation of the generator rotor. Hence, prime mover and the mechanical components of the generator will be directly affected due to sudden change in the grid.

All the types of WTG are non-synchronous in nature. Conventional generators and wind generators has this huge difference. Characteristics of WTG is non-synchronous in nature. There is damping on the electrical events on the transmission line and then it is transferred to the mechanical components of the turbine. In the wind turbine, between generator and the prime mover, there is good mechanical coupling and mechanical compliance. In the case of abnormal events in transmission line power spikes formed in the generator will not be directly transferred to the mechanical stresses. Kinetic energy is produced from the electrical power spikes and will be transferred turbine blades and generator that will reduce the expected damage.

Operation of the DFIG based wind turbine is in the variable speed move with the controller which is flux-oriented with the help of power converter. Hence, there is no compulsion of synchronous rotation of the rotor with the stator flux. Mechanical components of wind turbine generator would not be affected by any oscillations and power converter control is responsible for the compensation of any oscillations on the power system at the grid frequency.

To capture maximum aerodynamic energy, very large wide area is utilized for a wind power plant. Wind power plant has diversities within and around it. There are variations in the wind speed i.e, a turbine experiences high wind speed that is located at one corner while a turbine experiences low wind speed that is located at the another corner. Fluctuations varies from one wind turbine to another wind turbine and they are different. At the point of interconnection, power fluctuations are very less than the any individual wind turbine has. These overall reduced output fluctuations is known as smooth fluctuation and it is due to the smoothing effect. There is milder effect on the power system because of the smooth output fluctuations.

3.2 Mechanical and Aerodynamic Abnormal Events:

Vibration of components of wind turbine and its blade, wind resource and turbine control are the cause of the abnormal events and they are able to affect grid and performance of the wind turbines.

Below are following abnormal events of mechanical components and aerodynamic:

- Sluggishness of the control of blade pitch and actuator of blade pitch.
- Brake mechanism failure, pitch actuator failure or pitch control failure results the runaway events.
- Ramping which is uncontrollable in nature.
- Wind turbulence which is severe in nature.

4. CONTROL SYSTEM AND DESIGN

4.1 Control of Aerodynamic Power

First of all, kinetic energy of the wind is converted into mechanical energy through blades of rotor of the wind turbine. Then, by the generators, mechanical energy is converted into electrical energy. The developed wind turbine model is based on the steady-state characteristic. This characteristic can be obtained with some parameters and coefficient such as pitch angle of blade (β) in degree, ratio of tip speed (λ) and turbine's performance coefficient (Cp).

Turbine's inertia and generator's inertia and friction factor are combined together. Turbine drive train's stiffness is considered infinite for the purpose of calculations.

Output mechanical power expression from wind turbine can be expressed as the equation:

$$P_m = \frac{\rho}{\pi} A_r Cp(\lambda,\beta) v_w^3$$

Where,

P_m = mechanical output power of wind turbine (W)

Cp= performance coefficient of wind turbine

ρ= Air density (kg/m^3)

A_r = wind turbine swept area (m^2)

v_w= velocity of wind (m/s)

λ= ratio of tip speed of rotor blade tip speed to velocity of wind

β= pitch angle of turbine blade

In case where wind speed is high, control of power can be done is three different ways. Active stall control, passive stall control and pitch control.

This method which is most common and used for control of large turbine’s aerodynamic power is pitch control. The pitch control method allows the blade to rotate around its longitudinal axis and range of the changes lies between 0 to 90 degrees. Pitch angle is set to ensure that power generator would not be able to cross the rated value and overloading of generator doesn’t occur.

Pitch control method are deployed to prevent rotation of turbine more than the rated speed and mechanical system would be safe from damages.

4.2 Control of Varying Speed:

Connection of the system to the network, wind turbine operates at a stage named as wind turbine's varying speed control stage. By tracing the optimal power coefficient, wind turbine are able to extract optimal wind energy. Due to physical features of the mechanical structure has the influences, there are two factors that limits the output of the wind turbine:

Limitation of power and limitation of revolution speed. Hence, at this stage wind turbine will operate at two running zones: zone of constant speed and zone of constant tip speed ratio zone.

In the constant speed ratio zone, operation of wind turbine is in optimal state. Whenever there is increase in the wind speed, revolution speed also increases. When rated power of the wind turbine is lower than its rated value, and when revolution speed is at the rated value of speed of wind turbine, then its value will remain at constant.

4.3 Strategy of Pitch Control:

When speed of wind is high, pitch angle controller will be activated. Then, speed of rotor can't be limited by increasing generated power and this condition leads to the overloading converter or/and generator. Aerodynamics efficiency of the rotor is limited by changing the black pitch angle. It limits the rotor speed from increasing too much.

There will be voltage dip and output power will drop whenever there is short circuit phenomenon. Speed of rotor of generator will get increased because of unbalance power between input of wind energy and output. In order to balance mechanical power and electrical power, pitch angle must be changed. Once the fault is over, pitch angle will return to its original position and normal operation.

Changes in the pitch angle can't be made immediately, due to the size of rotor blades.

When wind turbine is connected to the grid, it is able to work in two modes: when speed of wind is above the rated speed of wind and another is when speed of wind is below the rated value of wind speed. Output power of the wind turbine will be less than its rated value when speed of wind is slow. In this case, zero degree will be pitch angle and generator speed is being controlled when wind turbine is made to run at optimal speed, hence absorbing the maximum amount of wind energy as possible. Output power will exceed the value of rated power, when speed of wind is above the rated speed. Wind turbine has the electrical limitations and mechanical limitations and because of that output power and speed of rotor will not be able to exceed the rated value. These days output power is maintained by the regulation of the generator speed and it has become possible due to the wind turbines with the variance speed pitch-control has been given a constant value of electromagnetic torque. PI control method for the regulation of the generator speed is the most common method. PI method is easy and simple for application purposes in engineering pitch controller becomes aweary and complicated because PI controller shows overshoot problems.

4.4 Control of DFIG

Wind turbines that are based on DFIG, its operation entirely depends on the control system deployed for grid converters and rotor converters.

Control algorithm which is most common is known as vector control with proportional integral controllers. Lower converter switching frequency and less power ripple are some of its advantages.

Regulation gains of PI controllers, high online computation owing to the pulse width modulation, sensitive to changing parameters of machine and parameters transformation to the frame of reference are some of the disadvantages.

A method called Direct Torque Control (DTC) was presented as a substitute for vector control method that minimizes complexity.

Less time of computation, easy implementation, robustness contrary to variant of machine parameters and very fast dynamic response are advantages of DTC method.

Converters variable switching frequency, power ripple and torque ripple in steady-state are some of the disadvantages. Strategy which is known as direct power control (DPC) was introduced so that active power and reactive power can be controlled directly by selecting voltage vector from a look up table.

In active power and reactive power, oscillations is created by this method.

DPC method and vector control method, when combined is known as CVDPC method. Because it is the combined method, so it has the advantages of both method such as very less harmonic distortion, easy implementation, computation time is low and not sensitive to the machine parameters changes.

Wind turbine systems are non-linear system. Sliding mode control (SMC) method is a non linear control method and it is used to take over the non-linearity of the system. To control the wind turbine, vector control method is used. For grid side converters and rotor, two vector control schematics are used. The main aim of the vector control method at rotor side converter is to independent control reactive power and active power with the help of rotor.

4.5 Electrical Linkage

Inductor, capacitor, power converter, generator, etc. are the different components that makes electrical linkage. Mechanical torque is the input at the shaft of generator and electrical power is the output. Voltage and current are the electrical stresses in the wind turbine and they are diverse in nature.

- **Transmission Lines-Grid Sides**

  Natural events such as high wind causes sagging lines, shorted, falling trees or animal causes short circuits, lightning etc. or man-made events such as loss of loads, loss of generators, loss of lines during fault clearing, switching of capacitors etc. are the events that causes normal voltages, unbalanced voltages, undervoltages, overvoltages and creation of overload currents. Circuit breakers are activated in case of most severe events in transmission lines for the minimization of affected lines. Abnormal event causes irreversible damage on the components of turbine such as power converters, generators, gearbox, etc.

- **Intersection Point-Substation**

Installing of meter and calculation of the revenue is done at the high side of the transform of substation which is interconnection point of a transformer. Protection such as fuse, transient voltage suppressors, circuit breaker etc. are deployed to avoid any abnormal events that generator, switch gear and transformer may experience.

- **Power Converters and Generators**

  Connection of power converters and generators is made to the grid. Wind turbine components are directly and instantly affected by the voltage and frequency because connection of the generator winding is to the power grid.

- **Power Converter**

  Because connection of the power converter to the grid, hence, generator directly receives whatever happens on the grid. There is impact of generated torque on the mechanical components due to the abnormal events that happens on grid. So, there will be effect of turbulence and ramping rates on the wind power plant and also to the power system.

4.6 Mechanical Linkage

Aerodynamic power is the input and electrical power is the output.

- Aerodynamic input.
- Mechanical output.
- Inherent short-term storage and damping.
- Aerodynamic and Mechanical Model.

4.7 Safeguard Function of Control System

- **Function of Brake**

  One of the most important link in wind turbine safeguard system is the brake system. Brake on main shaft, yaw brake and pitch brake are the components of the hardware which is driven by the system of hydraulic pressure. The system of brake function is designed on the principle of protecting whenever there is power off. In the case of errors where wind turbine needs to stop, the error is identified by the controller and sends command accordingly to drive brake system such as emergency stop wind turbine, to stop or pause.

- **Safety Chain**

  One of the device in the system known as hardware safeguard device that is not dependent on the centre control system. The safety chain of the system will be able to work normally, when control system program does not work normally. In the safety chain, design adopted is the reverse logic mode, all switches have been linked to form a loop, each one of the switches responds to the fault that are transnormal in nature and may cause fatal harm to the wind turbine. There would be urgent stop in the operation of machine, there would be cut off of power supply from all actuating mechanism, hence protecting maximum of the power supply.

- **Function of Lightning Protection**

  There is possibilities that wind turbine gets struck by the lightning and the thunder, specifically hindered in the thunderstorm districts because at the places such as mountaintops of the islands or draught in valleys, they are generally stalled.

Lightning and thunder causes over voltage that damages the control system. So special lightning protection system is deployed in the design of MW wind turbine.

4.8 Simulation of DFIG during Grid Fault

One of the major weakness of wind turbine with DFIG is that they have low voltage ride through sufficiency. In wind turbine system, voltage dip at the connection point is the result of grid fault. There is overcurrent production in the DFIG's stator winding due to this situation. Across stator and rotor, magnetic coupling is there and because of this magnetic coupling, this over current flow in the rotor circuit. This overcurrent is able to cause damage to the converter. To prevent this damage to the converter, crowbar circuit is used for shorting of the rotor windings of DFIG. Whenever fault is within grid, by means of crowbar circuit, rotor circuit is shorted and RSC is blocked.

In this situation, DFIG starts to absorb reactive power and behaves as conventional induction generator.

Active power is supplied by the operation of wind turbine and reactive power is being regulated by the use of GSC.

Voltage and frequency in the grid will be restored when fault is cleared and WTS returns to normal operation and RSC starts again. In case of weaker power network, when capacity of GSC is low power, then GSC will be unable to support voltage within grid fault and reactive power .There will be chances of voltage collapse also. Nevertheless, system of wind turbine gets disconnected from the grid and RSC refuses to start again. For supplying support voltage and reactive power to the wind form with DFIG and power system within fault grid, a static synchronous compensator can be used.

4.9 Power Fluctuation Emission

Continuous operation of the variable speed wind turbines with DFIG causes power fluctuation. Power fluctuations emission is affected by the factors such as tower shadow and turbulence intensity known as wind characteristics , grid impedance angle and short circuit capacity are grid conditions and wind turbine type. Wind drop and tower shadow factors affects the output power. For a system of three bladed wind turbine, there is always wind speed drop three times per revolution.

4.10 Drive Train

Gear box, generator and turbine are the components of the drive train which is mechanical system of the wind turbine. Generator and turbine are the major sources of the inertia of the whole system. There is the very small contribution of the tooth wheels of the gearbox which is in fraction.

Model of the drive train is the two mass model in which there is connecting shaft with shaft elements and whole inertia directed to the two side of the gearbox.

5. CONTROL SYSTEM REQUIREMENT

5.1 Requirement of Wind Turbine

5.1.1 Grid Interface Requirement

Penetration level of wind power in the grid was very less at the early stages of wind power. In the event of abnormal grid condition, connection of wind turbine is cut-off from the grid to make sure that no harm is done to the wind turbine. There are many requirements and standard condition that for the interfacing of the grid were developed at the early stage and is also being developed these days to make wind energy conversion system very efficient and highly reliable.

5.1.2 Voltage Related Requirement

The wind turbine generators must have capability of fault ride-through and capability of low voltage ride-through. There is need of envelope of voltage and envelope of frequency to wind turbine to stay connected to the grid. Turbine will be disconnected the range of this envelope.

5.1.3 Frequency Rated Requirements

DFIG based wind turbine are operated in mode of variable speed and they have control capabilities of flexible nature. There will be more energy yield and higher aerodynamic efficiency in comparison with wind turbine of constant speed. Power converter is responsible for controlling the output power of DFIG based wind turbines and it follows cubic function of rotational speed. Sudden frequency changes has the great impact on the conventional synchronous generators but it can't effect the variable speed wind turbines. Balance between the demand and generation affects the grid

frequency. There will be rise in the frequency of grid if generation of power is higher than the demand of power. In the same way, if the generation power is lower than the power demand, then there will be drop in the frequency of grid. Total inertia of rotating mass that is connected to the grid affects the rate of change of the frequency. Difference between the load and the generation will lower and rate of change of frequency will be lower, if the inertia available in the grid will be higher. Result will be change in grid frequency of the grid is maintained at the constant level through governor control and automatic generation control, hence there is balance between generation and load all the time.

5.1.4 Inertia Response Requirement

Conventional power plant are being retired from the generation system and penetration of wind power is increasing day by day and hence total inertia in the grid will be reduced. To support stability of frequency in the grid and power system, total inertia must be too high because penetration of wind power at higher level inertia is too low. For providing additional inertial response and increasing the capability of wind turbine, research have been going on and experiment is being conducted.

5.1.5 High-Wind Ride-Through Requirement

It is the future requirement of the utility industries that wind turbine remains connected to the grid anyhow in the case of high speed of winds to prevent the sudden drop in the generation where wind speed exceeds its rated value. Manufacturers of wind turbine design in such a way that they defines the cut-off speed of wind for safeguard and normal operation of the wind turbines. In the future, wind turbine will have the choice of high-wind ride-through capability for the operation of wind turbine at speed more than the rated speed.

5.1.6 Impact of Grid Interface Requirement

Manufacturers provide all the impact and effects of strains, magnetic, electrical, thermal and structural stress on the electrical components of wind turbines and mechanical components of wind turbine, on their lifetime period and its integrity period. They provide all this reliable information on basis of years of experience that have gathered. There is the perfect way to analyze and simulate the behaviour of different components of the wind turbine. There is also the possibility for enhancing the design.

5.1.7 Requirement of Electrical Component

Voltage limits and current limits are the basic criteria for the requirement of electrical component. Insulation that can bear the electric field effect and to level of dielectric is considered in setting the voltage limit. Different component has the different voltage blocking capability and it can't be operated above the allowed voltage level chances of insulation damage of components and degradation of the dielectric if current passing through device is not limited and produces heat in large amount. This is the purpose of the current limit. Linkages formed by the electrical components and purpose of the linkage is to transmit the mechanical energy and to convert it into electrical, should be able to bear stress and load of the process. Magnetic characteristics and electrical insulation gets highly damaged if temperature rises above a critical point. The damaged caused is irreversible degradation. The maintenance of electrical machines such as inductors, transformers, rotating machineries, etc. are easy because of the technology used, transmitting thermal losses directly to the ambient air, dissipation of heat, screen filtering and dust screen are very well cared. Conditions such as overvoltage and overloads is better tolerated by the electrical machines.

Better grid interface is provided by the wind turbines of modern era. They have the excellent capability of fault ride-through. Requirements of the wind turbine varies from region to region because different modification and enhancements are required to according to the region.

5.1.8 Energy Harvesting Requirement

The aim of the wind power generation is to extract maximum possible energy from the wind. Implementation of the maximum power point tracking is done indirectly by mapping of output power passively. Because reliability of the power system is affected by the requirement of grid interface and disturbances that are electrical in nature remains for very less period. For maintaining the reliability of the power system, output of the plant of wind power should be reduced when penetration level of wind power increases. When the capacity of transmission of the transmission line is above the rated value, then it is called curtailment. There is the need of this phenomenon called curtailment when production of wind power is high, output power of conventional generator is at its minimum and load at the grid is low. This happens usually at nights.

5.1.9 Mechanical Component Requirement

Wind Energy is transferred and converted into electrical energy with the help of mechanical components. Components and devices such as high-speed shaft of generator, yaw devices, gearbox, shaft of low speed and blades are the mechanical linkage between the generator and turbine rotor. Very rigid mechanical linkage is there and the electro-magnetic conversion is responsible for the transformation of mechanical energy into electrical between the air gap of the generator.

6. MODEL DIAGRAM AND MATLAB/SIMULINK MODEL

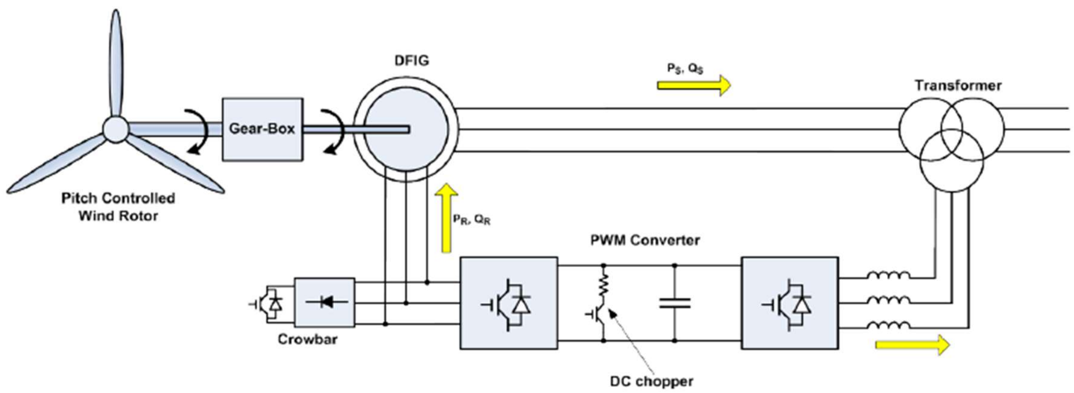

Fig 6.1 Wind turbine connection diagram

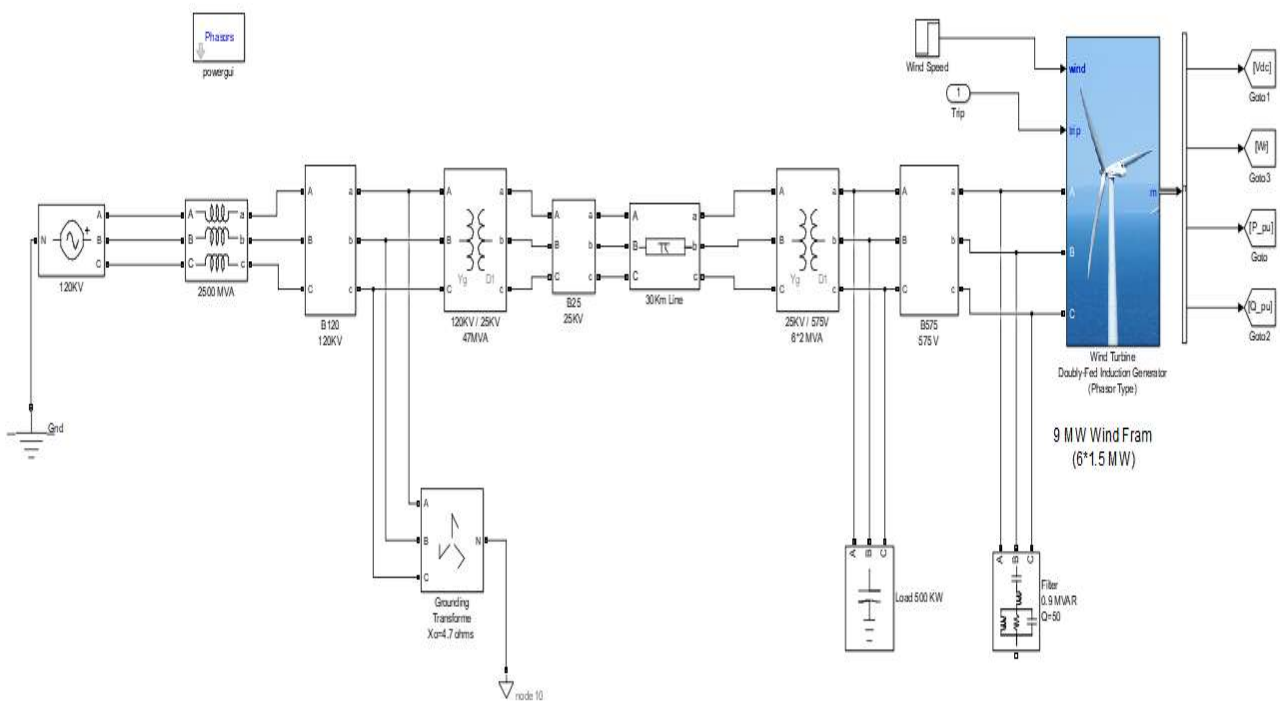

Fig 6.2 Doubly Fed Wind Power Generation System Simulation Model

Wind turbine generators (shown in above figures) are variable-speed wind turbines with DFIG. This type of turbine is the most popular type among other types that are available in market and it is being put in position in large numbers. Operation of DFIG is in variable speed mode in which power converter of partial size is connected to WRIG's rotor winding. Connection of WRIG's stator winding is to the grid at a required frequency. Normal operation of WTG is between 30 percent slip (sub synchronous speed) and -30 percent slip (super synchronous speed), converter is operated at 30 percent of the output power which is rated. The role of power converter is to perform back to back AC-DC-AC conversion with the help of two pulse width modulation-switched voltage-source inverters coupled with a DC link. For the protection purposes, crowbar circuit is deployed, allowing shorting rotor circuit, if necessary.

The nature of torque characteristics of WTG is the function (quadratic) of the rotational speed. There is possibility of maximum extraction of wind power in WTG system because output power of WTG system could be electronically controlled following optimal power curve. The optimal power curve is in form of function (Cube) of the rotational speed. Pitch Controller plays a major role in limiting the rotational speed of the rotor. Pitch controller is always put in position to control the rotational speed to the rated speed, if the speed of rotor exceeds its rated value. WTG experiences runaway event, when pitch controller is unable to control wind turbine's aerodynamic power.

Simpowersystems toolbox of MATLAB/Simulink gives an example phasor model of a Doubly fed Induction generator Turbine which has most straightforward mechanics. Simulation and modelling of the diagram is shown in the figure 6.2 and figure 6.1. 25KV distribution system is connected to a 9MW wind farm. Power is exported to a 120KV grid through 25KV, feeder line of 30KM. Protection system of plant load and turbine monitors various parameters. If the speed of the wind goes beyond the safe limits, pitch angle is increased.

The torque input was provided to the Doubly fed Induction Generator block (light blue in colour) model, but various calculations for two mass (generator and turbine) shaft model. This is the reason speed input can be directly provided to the generator. Two-mass shaft sub-model was by passed within the generator.

7. RESULT AND DISCUSSSION

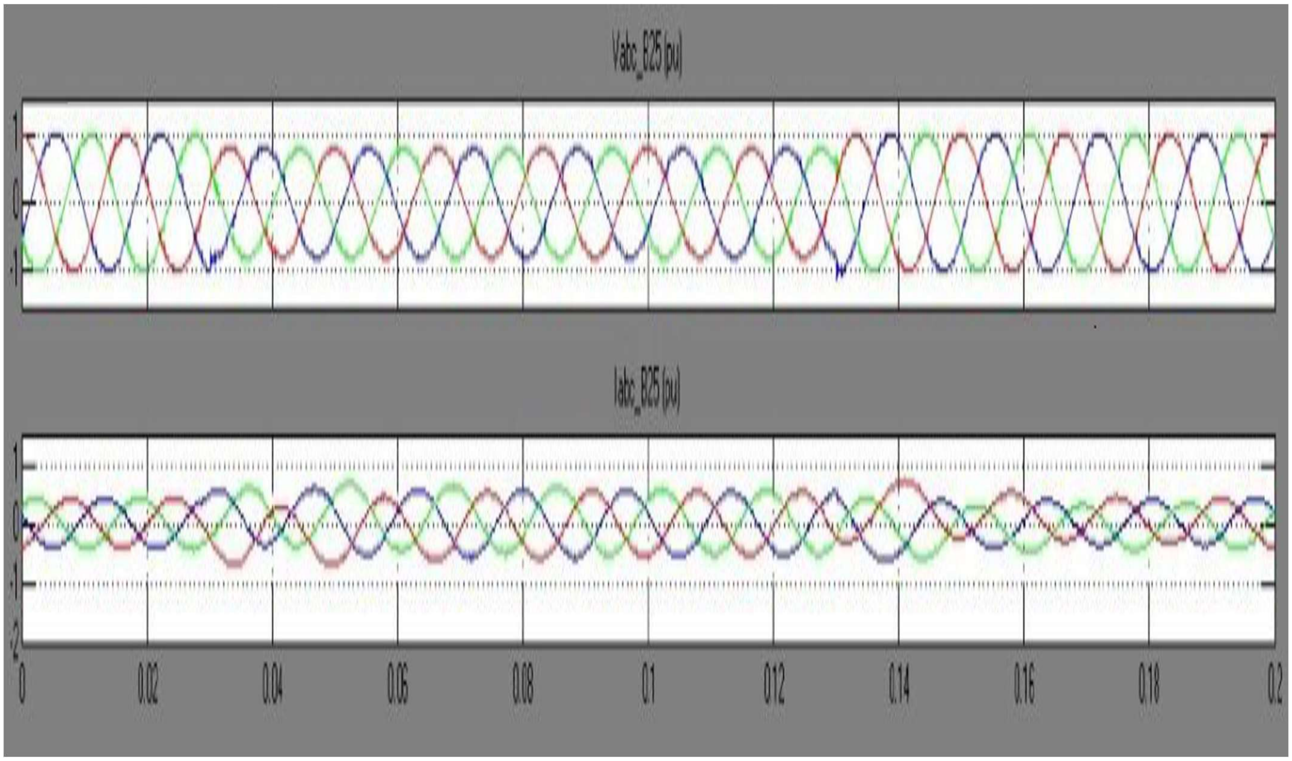

Fig 7.1 Voltage and Current Waveform

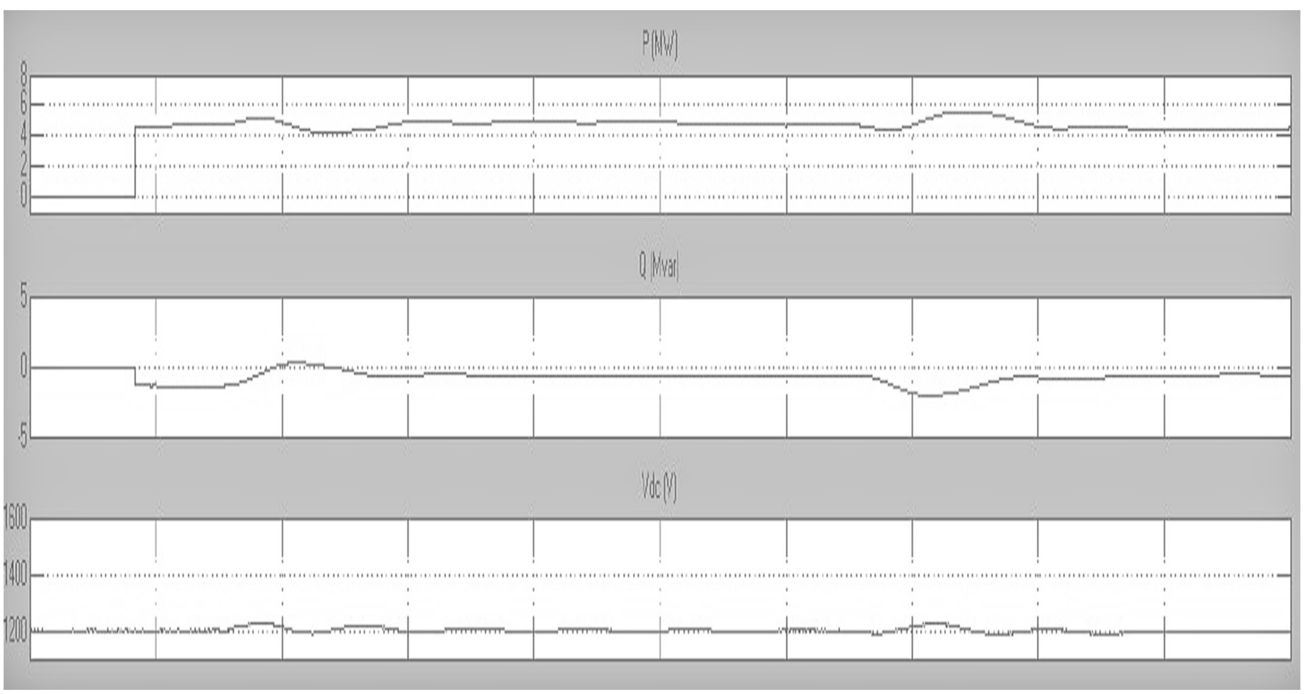

Fig 7.2 Power and Voltage Waveform

Our fig no.7 shows simulated observations that when the wind turbine is in stall conditions, GSC employed as an active filter. When the stator current are zero there is no power production, Grid supplied the load power. So the Grid Power (Pg) is attended to be negative. Now at this time GSC provender for reactive power and harmonics current. So the observed Reactive power(Qg) from the grid is zero. When load current is nonlinear Grid current is sinusoidal and balanced.

In this we are getting outcomes of Single-phase power generation system engaging DWAG and delivering 0.7 lagging power factor, 1.85 KW single-phase loads at constant wind speed of 10 m/s. Under Single-phase load it is recognised that three-phase stator currents are balanced. When we completely switched off our loads then the DWAG frequency, stator current, stator voltages, rotor currents are constant in between 2s and 2.1s. It is found that the battery got charged through stator converter during the course of load disruption. These observations determine that the advanced system is balanced under large transients in load powers.

8. CONCLUSION

The role of wind power generation in the age of early power generation was considered to be minor. As the technology grows and expands, there has been a lot of progresses in the field of wind power generation that will lead to better generators with excellent interfaces of grid. Wind power generation is considered as crucial type of generation by the utility industry. The demand and requirement of WTGs are increasing day by day. As the demand and requirement of wind power increases, wind power plants must have capabilities of have fault ride-through to make sure that wind power generation remains connected to the grid in the situation of minor disturbances. Manufacturers of wind turbine are required to analyse the consequences of the disturbances occur in the grid and new requirements which will impact on the design of wind turbine generators in order to support power system reliability. Similarly, to provide adherent services to support the grid, a planner of the power system is required to analyse the limitation of wind turbine generators. Various requirements consisting of inertial response, spinning reserves capability and governor response capability are being enforces by transmission system operators. Inspiration of this project was to conduct a better approach for designing and analysing the wind turbines in both ways i.e., impact of turbine on grid and impact of grid on turbine.

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