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Performance of Fixed Wind Speed Wind Energy System under Various Fault Conditions

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Abstract:
This paper presents the model of a fixed speed wind energy conversion system and to analyze the performance of the system, during normal operating conditions as well as during conditions of fault,. A DC motor is used to emulate the performance of the wind turbine. Different parts of the system have been modeled using MATLAB/SIMULINK. A model of DC motor driven by a convertor is employed to emulate the performance of the wind system. A speed control loop is used to force the Dc motor shaft to follow the induction generator shaft which is coupled to the wind turbine using DIgSILENT (DIgital SImuLation and Electrical NeTwork calculation program). The simulation models of the wind farm used in this project are developed in the dedicated power system analysis tool DIgSILENT. DIgSILENT has set standards and trends in power system modeling, analysis and simulation. The proven advantages of Power Factory software are its overall function integration, its applicability to the modeling of generation, transmission-distribution and industrial networks and its comprehensive user interface. Power Factory is the ideal tool for studying of new generation-technologies.

Keywords: DIgSILENT, wind turbine, wind energy, current control.

I.INTRODUCTION

Now-a-days global warming is the most burning issue found in many of the climate summits. Many researchers and scientists are working in their own relevant areas to reduce global warming by using different techniques. Over the past few decades wind energy has shown the fastest rate of growth of any form of electricity generation with its development simulated by concerns of national policy makers over climate change, energy diversity and security of supply.

II. FIXED SPEED WIND TURBINE

Fixed-speed wind turbines are electrically fairly simple devices consisting of an aerodynamic rotor driving a low-speed shaft, a gearbox, a high-speed shaft and an induction (sometimes known as asynchronous) generator. From the electrical system viewpoint they are perhaps best considered as large fan drives with torque applied to the low-speed shaft from the wind flow. It consists of a squirrel-cage induction generator coupled to the power system through a turbine transformer.

The generator operating slip changes slightly as the operating power level changes and the rotational speed is therefore not entirely constant. However, because the operating slip variation is generally less than 1%, this type of wind generation is normally referred to as fixed speed. Squirrel-cage induction machines consume reactive power and so it is conventional to provide power factor correction capacitors at each wind turbine.

The function of the soft-starter unit is to build up the magnetic flux slowly andso minimize transient currents during the energizing of the generator. Also, by applying the network voltage slowly to the generator, once energized, it brings the drive train slowly to its operating rotational speed.

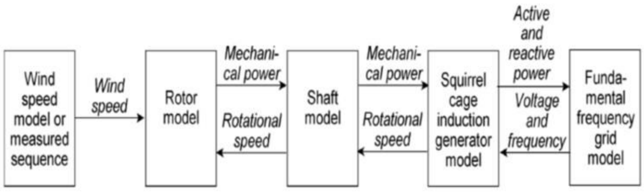

Figure.2.1 Block Diagram of Wind Energy Conversion System

III. TURBINE MODEL

The rotor is the wind turbine blades. Most of the turbines at present are three blade turbines. These blades extract the power from the wind and convert it into mechanical power, at a speed of approximately 30 rpm. Wind turbines produce electricity by using the power of the wind to drive an electrical generator. Wind passes over the blades, generating lift and exerting a turning force. The rotating blades turn a shaft inside the nacelle, which goes into a gearbox. The gearbox increases the rotational speed to that which is appropriate for the generator, which uses magnetic fields to convert the rotational energy into electrical energy. The power output goes to a transformer, which converts the electricity from the generator at around 700V to the appropriate voltage for the power collection system, typically 22 kV. A wind turbine extracts kinetic energy from the swept area of the blades.

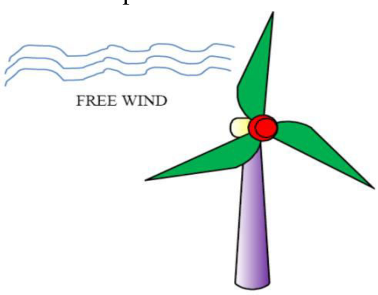

Figure.3.1 Horizontal axis Wind Turbine

IV. ANALYSIS IN DIGSILENT

The simulation models of the wind farm used in this project are developed in the dedicated power system analysis tool DIgSILENT. DIgSILENT has set standards and trends in power system modelling, analysis and simulation. The proven advantages of Power Factory software are its overall function integration, its applicability to the modelling of generation, transmission-distribution and industrial networks and its comprehensive user interface. Power Factory is the ideal tool for studying of new generation-technologies. DIgSILENT also provides the ability to either simulate with a fixed time step or a variable time step for the simulations. With variable time steps, DIgSILENT enables reduction of the simulation time increasing the simulation time steps to what is possible with respect to keep a stable simulation. DIgSILENT also supports modelling of saturation, but only in the transformers.

V.MODELING OF GRID CONNECTED SQUIRREL CAGE INDUCTION GENERATOR DRIVEN BY WIND TURBINE

The general structure of a model of a constant-speed wind electric generation system consists of models of the rotor, the drive train and the generator including wind speed model and grid. Each one of the blocks is shown in Figure 5.1 will be discussed in the subsequent sections. The grid model is a conventional load-flow model of a network. The individual models are connected to the grid model to realize a simulation model of WECS. The important functional blocks of wind turbine are: Wind model, Aerodynamic model, Transmission model and Blade angle model. The dynamic interaction between wind farm and power system are studied both under normal operation and grid fault events.

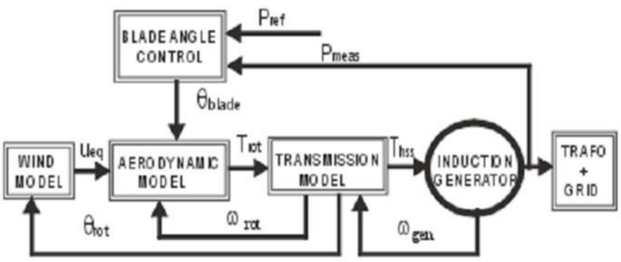

Figure.5.1 General Structure of fixed speed wind electric system

VI. WIND MODEL

The output of the first block in Figure 2.1 is a wind speed sequence. One approach is to model the wind as a sequence of wind speed or time series. The advantage is that the real wind speed measured in the wind mast is used. In the analytical approach, the wind speed is assumed to be a sum of the four components as given in equation (2.1)

$$Vw(t) = Vwa + Vwr(t) + Vwg(t) + Vwt(t) \qquad (2.1)$$

Where,

Vw(t) - wind speed at time t;
Vwa - average value of the wind speed;
Vwr(t) - ramp component;
Vwg(t) - gust component; and
Vwt(t) - turbulence component.

VII. SHAFT MODEL

The model of the shaft used for constant speed wind energy generating system is very important for proper operation. Drive train model of two mass shafts is selected. First, the shaft model including various sub blocks is implemented in DIgSILENT. This model takes Pwind, speed_gen as input signal and gives Omega_tur, pt as the output signals. The Internal variables of the shaft model are J_int, Tmec, Twind, Omega_gen and tdif. The parameter variables are Pbase, D_turb, J_turb, K_shaft, D_shaft and RPMnom. The values of the parameter variable are entered using common model of the shaft as shown in Figure 7.1

Where,

Trot = Turbine rotor torque
KTgen = Generator Torque
s = Spring

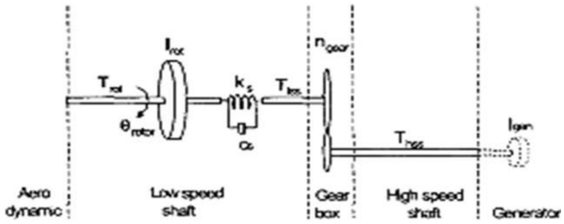

Figure 7.1 Drive train model of two mass shaft

VIII. MOTOR DRIVER

During the high wind velocity, the blades of wind turbine have to be pitched away from the wind to produce constant power output. This can be achieved by using a slewing drive which precisely angles the blade to withstand high wind velocity. In this design, servomotors are incorporated on each blade, which is controlled by a precision PID controller. The Optimal beta control block sets the appropriate value of pitch angle for the given wind velocity. The DIgSILENT model of the pitch controller is shown in the Figure 2.14.The input signal is Vw and output signal is B. The internal variables are yi, bref, xe and y. The parameter variables are array Beta, K, T, Kp and Ti. With the help of common model block, the values of the parameter variable are entered as shown in Figure 8.1.

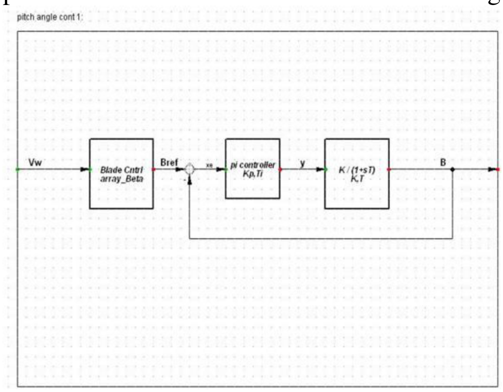

Figure 8.1 Pitch angle block

IX. STIMULATIONS AND RESULTS

With help of power system component in DIgSILENT, the wind farm is built similar to the substation layout diagram. The Figure 9.1 shows the simulated load flow data of the peedampalli substation. Each generator generates 0.6MW real power; total power flow at the110kV feeder is 3.6MW. The Figure 9.1 shows the load flow analysis of the entire grid connected wind farm and shows the Real and Reactive power flow in generators 4, 5 and 6. The Figure 9.1 shows the Real and Reactive power flow produced by the generators 1, 2 and 3.

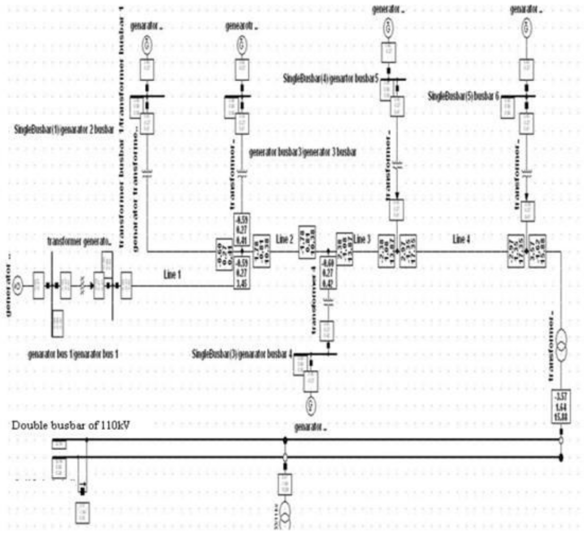

Figure 9.1. Simulation Model of the Peedampalli substation in DIgSILENT

XI. CONCLUSION

With a view to getting a better understanding of a wind electric system, a generic model is introduced, where the various independent elements of a wind turbine and their interaction are explained. The individual blocks such as turbine BlkDef (block), shaft BlkDef, pitch angle control BlkDef were designed with mathematical model using DSL. All the individual blocks were connected together with help of frame definition block including built-in model of ASM BlkDef . The values of the parameter variable in each block are entered using common model. The composite model (ElmComp) connects the frame slot and common model. Finally, the grid connected fixed wind turbine was built with help of power system component such as bus bar, transformer, cable, feeder etc from the software. The power electronics based soft starter present in the library was used to interface the wind generator with the grid. It is used to reduce the starting transient current when the generator is synchronized with the grid. The induction generator absorbs the reactive power from the grid and this may affect the grid voltage profile. The amount of reactive power absorbed will be reduced by connecting a capacitor bank near to the generator bus bar.

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