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ANALYSIS OF FAULT ON 1.5 MW WIND POWER PLANTS

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Abstract - Large size wind farms are booming day by day. As wind energy generated is highly dynamic and dependent on only wind, the overall system's performance is important for profitable operation. Faults produced by wind turbine generator systems will impact not only the wind farms but also the interconnected system including the grid if proper protection is not ensured. In this paper it is proposed to model a 1.5MW wind farm using doubly fed induction generator and study the effects of phase to ground faults under various load conditions. For the study the vector control of the Doubly Fed Induction Generator is used.

Keywords: *DFIG, Wind farm, Phase to ground error, Simulation.*

I. INTRODUCTION

The current electrical energy are mainly depends in fossil fuels like coal, natural gas, petroleum. These fossil fuels took several years to form and the base material for the fossil fuels were organic substances. (Hence fossil fuels can be described as biomass stored for a long period). A huge amount of the fossil fuels is already depleted in the 20th century. But due to the increasing demand, the extraction of fossil fuels will become more risky and expensive at present. If the consumption of fossil fuels continues as now, all available resources of natural gas and petroleum will be exploited by 21st century. Suggests that renewable energy sources are a better alternative to foster to the increasing energy demand. Renewable energy sources are the only way by which the Earth's energy demand can be met without affecting the climatic conditions.

The conventional energy sources are limited and have pollutions to the environment. So more attention have paid to utilize the renewable energy sources such as wind, fuel cells and solar. Wind energy is the fastest growing and most promising renewable energy sources among them because it is abundant, cheap, inexhaustible, widely distributed, clean and climate benign. The environmental concerns associated with the wind power generation are noise, aesthetic impact and bird mortality. These problems can be solved by proper choice of site for wind plants. The major challenge associated with the wind power generation is due to the intermittent nature of the wind. Challenges using wind energy include that wind cannot be stored and all the energy in the wind cannot be harnessed during the time of demand. Also another issue is that the wind power plants are located in remote areas far away from the consumer ends. The major part of wind power generation is the induction generators. The different types of generators used are squirrel cage induction generators, wound rotor induction generators, permanent magnet and synchronous generators.

Among the variable speed generators the doubly fed induction generator is commonly preferred for reasons such as

- Improved efficiency under light load conditions
- Acoustic noise reduction
- Possible to control Active and Reactive Power
- Improved stability when connected to grid
- Low cost of the converters.

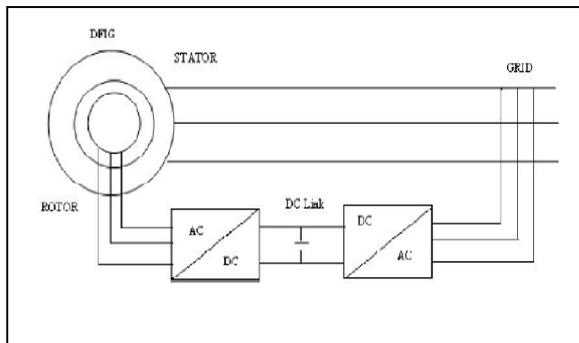
In this paper the dynamic behavior of a 1.5 MW wind farm is modeled using MATLAB. The behavior of the system for a single line to ground fault is analyzed

II. DOUBLY FED INDUCTION GENERATOR

Fig.1. shows a doubly fed induction generator connected to grid. Doubly fed induction generator is basically a wound rotor induction machine with multi phase wound rotor with multiphase slip rings assembly and brushes enabling access to the rotor. The rotor windings are connected to the grid through a AC-DC-AC converter. The rotor and the grid currents are controlled by controlling the converter. This enables the control of the active power and reactive power flow to the grid from the stator independent of the generator's speed. The number of turns on the rotor of a doubly fed induction generator is 2 to 3 times that of the stator. This means that the rotor voltages are higher and the currents are lower. Therefore in the typical operational speed range of $\pm 30\%$ of the synchronous speed, the converter has to handle lower currents thus reducing the cost of the converter. But the disadvantage is that outside the operational speed range it is impossible to control as the rotor voltages higher. Under grid disturbances, the transient voltages and currents are also magnified. To prevent the high transients from destroying the power electronic devices a crowbar circuit is provided. The rotor windings are short circuited through a small resistance by the crow bar circuit when excessive current flows through the rotor windings. A doubly fed induction generator has the advantage that power

can be imported from or exported to the grid through the power electronics converter. This allows the system to support the grid during severe voltage disturbances thus improving the system stability. By controlling the rotor voltages and currents the synchronization of the machine with the grid is maintained even when the wind speed varies. Under light load conditions, the wind energy is utilized more efficiently than a fixed speed wind turbine. Only 25 – 30 % of the power is fed to the grid through the converter while the remaining is fed directly to the grid. Due to this reason, the cost of the converter is low and the efficiency of the doubly fed induction generator is good.

Figure 1: DOUBLY Fed Induction Generator



III. VECTOR CONTROL OF DFIG

Fig.2. shows a wind turbine connected to a DFIG. The AC/DC/AC converter used has two parts namely the rotor side converter and the grid side converter implemented using IGBT's to synthesize the required AC voltage from a DC voltage source. The source of the DC component is achieved using a capacitor connected to the DC side. From figure 1 it can be observed that the stator winding is directly connected to the grid whereas the rotor winding is connected to the rotor side of the AC/DC/AC converter using slip rings and brushes. The energy generated by the wind turbine is converted to electrical energy by the DFIG and is transferred to the grid by the stator and rotor windings. Rotor speed for the experimental setup implemented runs at sub synchronous speed for wind speeds lower than 10 m/s. For sub-synchronous speed operation, rotor electrical power output is taken out of DC bus capacitor and tends to decrease the DC voltage. Grid side converter is used to generate or absorb the grid side converter electrical power output in order to keep the DC voltage constant.

The rotor-side converter is used to control the wind turbine output power. The power control is shown in figure 3. As shown in the figure the actual output power, measured at the grid terminals of the wind turbine, is added to the mechanical power loss and the electrical power loss. This is compared with the reference power obtained from the tracking

characteristic. A Proportional-Integral (PI) regulator is used to reduce the power error to zero. The output of this regulator is the reference rotor current I_{qr_ref} that must be injected in the rotor by converter C_{rotor} . This is the current component that produces the electromagnetic torque T_{em} .

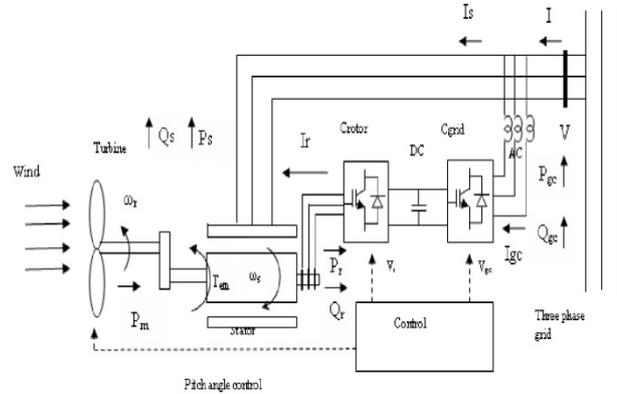


Figure 2: Wind Turbine Connected to DFIG

- P_m - Mechanical power captured by the wind turbine and transmitted to the rotor
- P_s - Stator electrical power output
- P_r - Rotor electrical power output
- P_{gc} - C_{grid} electrical power output
- Q_s - Stator reactive power output
- Q_r - Rotor reactive power output
- Q_{gc} - C_{grid} reactive power output
- T_m - Mechanical torque applied to rotor
- T_{em} - Electromagnetic torque applied to the rotor by the generator
- ω_r - Rotational speed of rotor
- ω_s - Rotational speed of the magnetic flux in the air-gap of the generator, this speed is named synchronous speed. It is proportional to the frequency of the grid voltage and to the number of generator poles.
- J - Combined rotor and wind turbine inertia coefficient

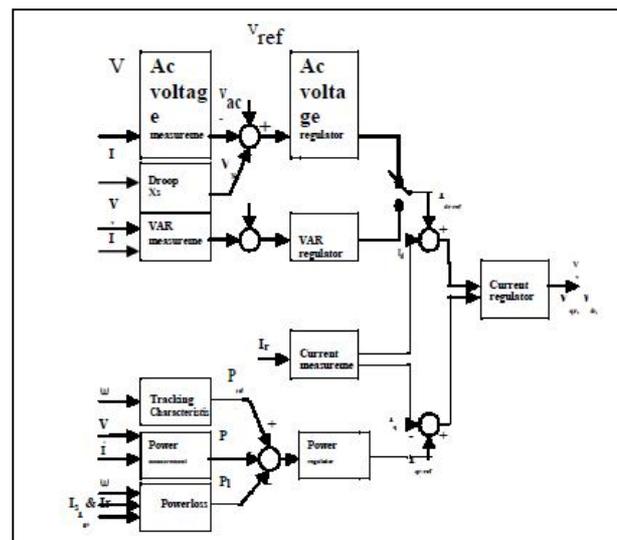


Figure 3: Rotor side converter control system

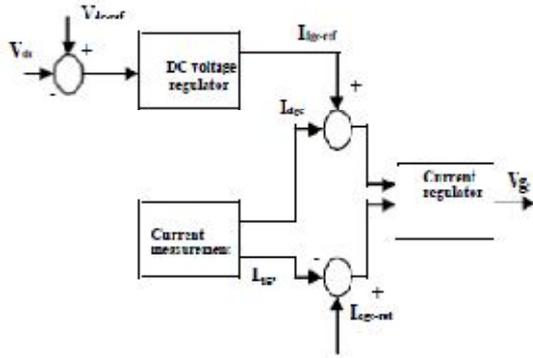


Figure 4: Grid side converter control system.

The converter C_{grid} is used to regulate the voltage of the DC bus capacitor. In addition, this model allows using C_{grid} converter to generate or absorb reactive power. The system consists of an outer regulation loop consisting of a DC voltage regulator. The output of the DC voltage regulator is the reference current I_{dgc_ref} for the current regulator. The inner current regulation loop consists of a current regulator. The current regulator controls the magnitude and phase of the voltage generated by converter C_{grid} (V_{gc}) from the I_{dgc_ref} produced by the DC voltage regulator and specified I_{q_ref} reference. The current regulator is assisted by feed forward terms which predict the C_{grid} output voltage.

IV. EXPERIMENTAL SETUP

Matlab Simulink was used to model a 1.5-MW wind farm connected to a 11-kV distribution system. The power generated is exported to a 120-kV grid through a 15-km, 11-kV feeder. The designed system consists of a 2-MVA plant consisting of a 1.68MW induction motor load along with a 100-kW resistive load at bus B25. To implement the line fault a single phase to ground fault is implemented on the 11 KV line. The fault occurs for a period of 9 cycles at $t=5$ seconds. The results obtained is shown in figure 5 and figure 6.

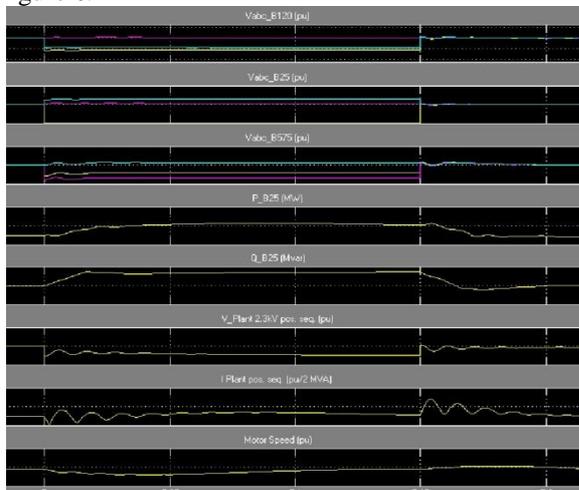


Figure 5: Graphs of measured parameters on the grid side for a fault in phase A

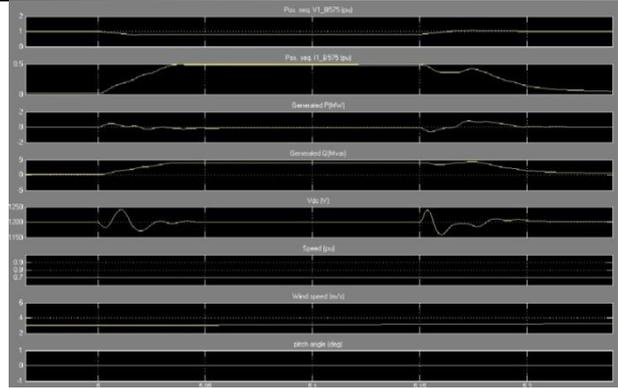


Figure 6: Graphs of measured parameters in the wind turbine side for a fault in phase A

From figure 5 it is observed that the positive-sequence voltage at wind-turbine terminals (First graph in figure 4) drops to 0.8 pu during the fault whereas the positive sequence current increases. The real power generation has flickers at the fault instant and the generated reactive power increases. The Dc voltage has spikes both at the instant of fault and at the instant of fault recovery.

For a fault in phase A, on the grid side, the voltage of one phase is maintained whereas the voltage of the other two phases drops. At B17, the voltage of phase A is zero and the voltage of the phase B is maintained and the voltage of phases C increases to 1.3 p.u. At B234, the voltage of phase C increase to 1.06 p.u, the voltage of phases A increases to 0.75 p.u and the voltage of phase B decreases to 0.65 p.u. There is an increase in both real and reactive power.

If phase A and B has line to line fault the positive sequence at wind turbine terminals (first graph in figure 7) drops to 0.35 pu and the system trips.

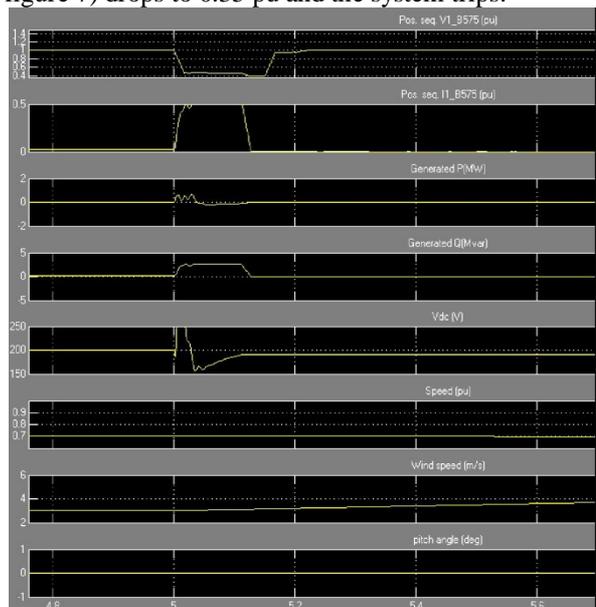


Figure 7: Graphs of measured parameters in the wind turbine side for a line to line fault in phase A and phase B

V. CONCLUSION

In this paper 1.5 MW wind farm is modeled using MATLAB. The effect of Phase to Ground Fault in phase A is analyzed for the 1.5 MW doubly fed Induction Generator wind farm unit. Even though the per unit value falls the system will recover it. In case Line to Line fault occurs the system will recover it up to 0.35 p.u voltage drop (drips it) and increases the Active power and decrease the reactive power. This gives the profitable operation and the interconnected systems are protected.

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