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Summary of the Master Thesis

Torque Estimation of Double Fed Induction Generator Using a Dynamic Model And Measured Data

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***Abstract*- A big challenge in the Wind Power industry is the breakdown of gearboxes. To increase the knowledge about Wind Power and gearbox breakdowns Vattenfall has done measurements on both the mechanical and electrical system of a wind power plant e.g. during full load and partial load. In this Master Thesis focus is on voltage and current measurements on the generator conductors and the measurements of the rotor speed. Different run scenarios for a wind power plant have been studied and analyzed briefly. Secondly a mathematical model in MATLAB/Simulink has been built, which calculates a corresponding mechanical torque based on the electrical measurements. To further improve the results from the model more accurate speed measurements have to be done. For future work it would be interesting to compare the results from an improved model with mechanical measurements**.

Introduction- There are 158 TW Wind Power installed in the world today, which correspond to approximately 2% of the world's energy production. Wind Power is one of the oldest energy sources used. It is only in recent years wind power has been taken in production for lager power production and there are still many aspects of wind power to explored and developed.

There are two main generator technologies. It is synchronous generators and double fed induction generators. The synchronous generator produces power at a varying frequency that is converted to direct current and back to altering current with the grid frequency by a full power converter. The other main technology, the double fed induction generator is connected direct to the power grid as shown in Figure 1. The generator produces power of the grid frequency.

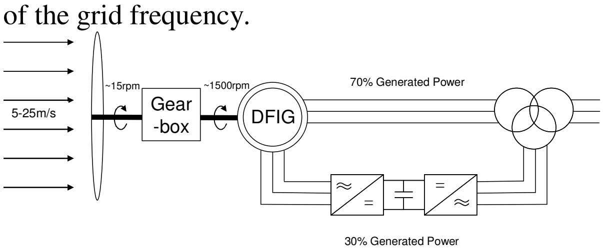

Figure 1: Double Fed Induction Generator

Because of variations in wind speed the generator speed needs is variable but the produced power from the stator must be kept constant at the grid frequency. This is solved by using a so called wound rotor. A rotor equipped with coils, placed symmetrical around the rotor, connected to a power converter via slip rings. By controlling the currents to and from the rotor via a power converter it is not only possible to keep the grid frequency constant in varying wind speeds it is also possible to compensate for some reactive power on the power grid. The induction generator can only compensate for wind variation up to 30%. The wings of the wind turbine rotates with approximately 15 rpm and a for a four pole generator the rotor speed is supposed to be slightly above 1500rpm. This means that the speed needs to be geared up approximately 100 times. The synchronous generators do not need a gearbox but there are models that use gearboxes to decrease the generator size.

Most wind power plants are equipped with gearboxes. A Wind Power Plant is constructed to have a lifetime of 20 years which corresponds to approximately 120 000 hours run time. This causes lots of fatigue on the power plant and the gearboxes. A big problem for wind power is that the gearboxes have a tendency to break before its constructed life time. This does not only cost a large amount of money to replace the gearbox there will also be a loss in income when the plant can not produce any power. The root causes for the gearbox failures are not known.

In the Master Thesis ”Torque Estimation of Double Fed Induction Generator Using a Dynamic Model and Measured Data” measured data on a 2MW wind turbine with a double fed induction generator have been analyzed.

The purpose of this Master Thesis is to contribute with new knowledge about gearbox breakdowns and present a way to analyze the electrical data and compare electrical measurements with mechanical measurements.

Current and Voltages have been measured on the stator and rotor conductors together with the angle of the rotor. The goal for this Thesis is to set up a model in MATLAB/Simulink that simulates the mechanical torque from these measurements.

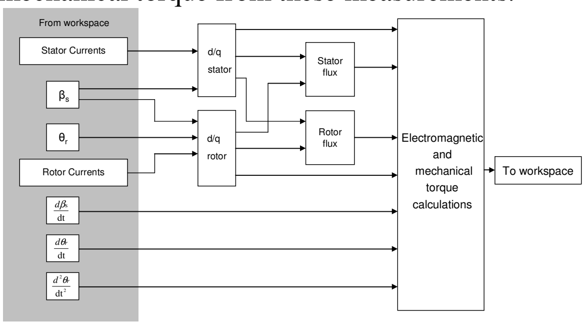

Figure 2: Schematic picture of the double fed induction generator model

This has been done according to the schematic picture of the model in Figure 1. Input to the model is the stator and rotor phase current, the angles for the rotor and the stator magnetic field, the speeds of the rotor and the stator magnetic field and the rotor acceleration and output is the simulated mechanical torque. The mechanical torque should correspond to the torque the wind has to produce.

To verify the model the simulated torque can be compared with the stationary torque:

$$T_{m=} = \frac{P}{\omega_m}$$

This is done in Figure 3.

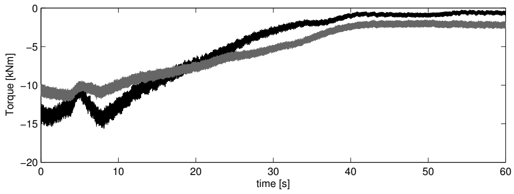

Figure 3: Stationary torque (grey) and simulated torque (black)

In Figure 4 the simulated torque and measured mechanical toque on the rotor axel are compared. This is also done to verify the model.

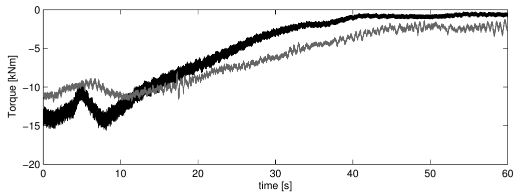

Figure 4: Measured torque (grey) and simulated torque (black)

It can clearly be seen that the different torques have the same characteristics but there is a difference in magnitude of the torque levels.

The slow characteristics of the differences in torque point towards the mechanical equations do not correspond to the machine dynamics exactly. An uncertainty in the model is the machine parameters that are not the test plants parameters due to company confidentiality. The parameters used are from an open report for a machine in corresponding same size. There are also uncertainties in the rotor and stator angles. Small consistent errors in both the rotor and the stator give large errors in the simulated output torque. A third uncertainty is that the initial angle of the rotor that is unknown and is iterated for this Thesis without any dynamics included.

Conclusions- In this Thesis a large amount of data has been handled. A method to convert the data and import it into MATLAB has been developed. A model that calculates the corresponding mechanical torque from the electrical measurements has been set up. To further improve the model the initial angle needs to be measured. The stator and rotor angles also need to be measured more accurate.

Is this done it will be possible to compare simulated torque from different run scenarios with measured mechanical torques. Comparing this two torques could give new knowledge how different run scenarios and control strategies affect the gearbox.