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Retrofit The Wind Turbine Mechanical Braking System Using Condition Monitoring System

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Abstract:

Renewable energy plays in the global energy mix as a means of reducing the impact of energy production on climate change. In that wind energy is most developed of all renewable energy technologies with more than 200GW of globally installed capacity as of 2011.Analysis of wind farm the maintenance cost shows that up to 40% of that is related to unexpected components failures that lead to costly unscheduled amendments. In wind farm the operators are looking new technologies in condition monitoring that we can contribute minimization of wind turbine maintenance expenditure. Early fault detection through condition monitoring can help prevent major breakdowns as well as significantly decrease associated costs. It enables the optimization of maintenance schedules, reduces downtime, increases asset availability and enhances safety and operational reliability. Faults in the braking system are of particularly concern since they can result in catastrophic failure of the wind turbine. The present study investigates online condition monitoring based on voltages and currents for mechanical wind turbine brake system fault diagnosis.

1. Introduction:

Mechanical braking is one of the most speed control methods in the wind turbine. It is the steel disc that will connect to the gearbox high speed shaft. Braking is achieved by engagement of the brake caliper on the disc. Wind turbine brakes experience extreme stresses, so special alloys are used in brake disc manufacture, capable of withstanding temperatures up to 700^{o}C. The braking system is a fail-safe system e brakes are applied if the power fails, or if the hydraulic pressure is out of the normal range. This braking system generally applied after the blade furling and electromagnetic braking is reduce shaft speed, in other case the mechanical brakes would rapidly wear down if used to brake the turbine from full speed. The mechanical brakes only applied in case of emergency only. Sometimes critical component will malfunctions that time turbine should stop automatically it is essential for all wind turbines. If the generator overheats or it disconnect from grid the braking system will stop the rotor. In most of wind turbines they use two independent fail safe mechanisms to stop the turbine. Otherwise failures within the braking process, for instance when the speed is over the limit, can cause serious damage to the main structure, mechanical units and blades, and failures within the hydraulic unit resulting in the brakes remaining on and increase the downtime.

1.2. Description of the mechanical braking system

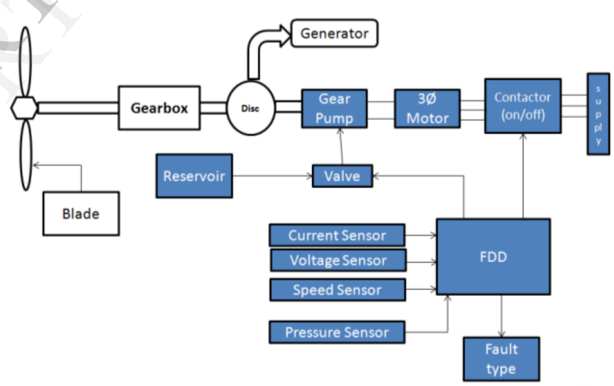

Fig.1.Basic schematic diagram of mechanical brake

The wind turbine hydraulic braking systems are shown in figure1 and 2.This system uses active hydraulic pressure to keep the wind turbine brakes disengaged. When the brake command is sent, or if the electric system drops output, the brakes will immediately be engaged to stop the rotor. The brake disc is located on the high-speed shaft, and the caliper, which consists of two swing arms, is mounted on a steel bracket bolted to the gearbox housing. The brake pads are installed at one end of the arms at either side of the disc.

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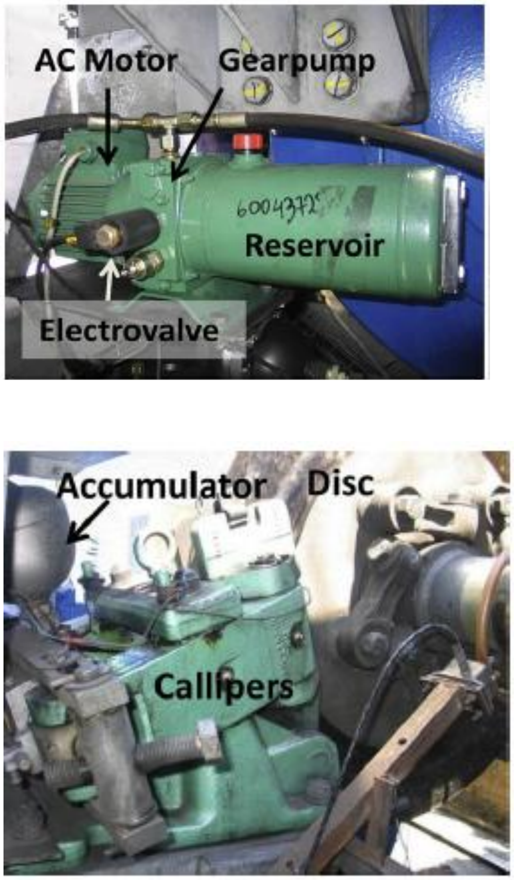

Fig.2. Photos of the hydraulic/accumulator system and calipers.

The brake force is provided by accumulated and passive hydraulic power at one side of the hydraulic piston. The passive pressure is continuously ready to force the brake pads against the brake disc. Active hydraulic power, provided by the pump, is used periodically to maintain the pressure in the accumulator to release and keep the pads off the brake disc. In any circumstances If the active part is removed, the passive accumulated power will engage the brake to stop the turbine. In this paper the development of a voltage and current-based condition monitoring system (CMS) for the continuous operational evaluation of the three-phase hydraulic pump motor of the brake system is discussed.

2. Instrumentation and data acquisition

A data acquisition system acquires data from the sensors. Primary fault detection stages, such as peak detection and moving average calculations, of the sampled currents are also being carried out by the digital signal processor of the data logger. Data are then stored on a flash memory card along with time from a GPS system and real-time clock calendar. Light emitting diodes (LEDs) provide status information. A connection to the wind farm SCADA system is also provided by an Ethernet interface to present the raw data plus the basic analysis of the performed braking events.

The whole system is powered from the local mains supply with a battery back-up to avoid data corruption in the event of power loss. Samples of the three-phase hydraulic pump motor voltage and currents were collected to monitor its condition. The voltages and currents of the three-phase motor were obtained from the main panel.

3. Data analysis

Evaluation of the measured voltages showed that their amplitudes and frequencies remain fairly constant. This is to be expected as the voltage comes directly from the local electricity grid. The currents were found to be significantly more useful than the voltages for further analysis. This section describes the types of analyses that have been performed on the current data collected during trials. Currents flow in the three-phase pump motor only when the pump is running and charging the accumulator, a process that takes just a few seconds. The rest of the time the currents are essentially zero. For further analyses, the events where the pump was running were extracted from the recorded data. An example of one of the phase currents during a pumping event is shown in Fig. 3.

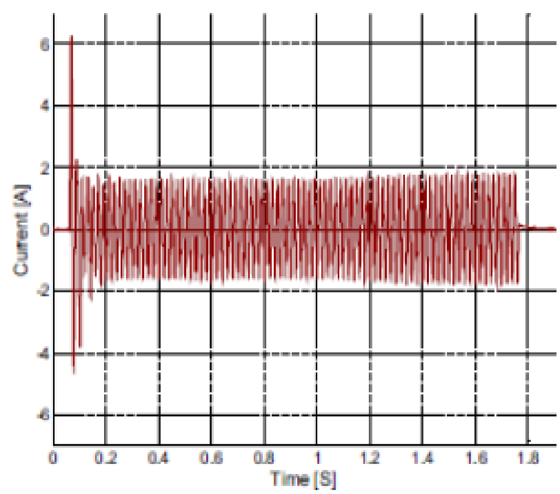

Fig.3. A detected event from the measured currents

Frequency analysis using the Discrete Fourier Transform (DFT) is the most frequent signal processing method used for three-phase motor condition monitoring as several mechanical and electrical characteristics can be determined from current signals [2].

4. Fault detection and modeling

Here we discuss about possible ways of fault detection and diagnosis (FDD) Modeling the brake system and implementing FDD methods in the model also presented.

4.1. Fault detection and diagnosis

Model-based and model-free techniques are being considered for the purpose of Fault Detection and this will also be applied to perform fault diagnosis processing. Recent improvements in current sensor technology combined with advances in data processing have led to novel techniques in the field of three-phase motor monitoring by the use of spectral analysis of the stator current signal [3]. Time-domain analysis, such as looking at the envelope of a signal, identifies changes within the machinery and its characteristics. Vibration monitoring approaches could also be used for incipient fault detection. However, stator current monitoring has been established as being able to detect such faults without requiring access to the motor [3]. Depending on the severity and importance of the fault, a model-free Fault Detection System (FDS) has to take appropriate actions [4]. The faults can be categorized with different levels of urgency (for instance: caution; warning; or, alarm) and system responses.

This can be used to generate residuals and allow detection of changes in the system behavior and lead to fault detection and possible diagnosis. This will represent the knowledge of a human expert by classifying a sequence of rules from which conclusions can be made, which could consist of simple if and then statements [5].

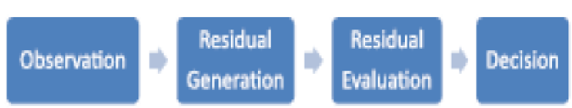

Fig. 4 .Model-based FDD structure and some of the methods

4.2. Faults in the brake system

The possible fault-tree of the brake system demonstrates in Fig.5. The faults within the three-phase system, such as three-phase supply and motor, can mostly be detected and diagnosed by using model-based FDD methods and current signature analysis (CSA). The faults within the hydraulic section, such as gear pump and its surrounding parts are likely to be detected by the CSA since the gear pump is a load for the motor; therefore it is likely that some effects can be seen within the current signature. The faults within the brake disc and calipers are unlikely to be detected using CSA, as there would be no current to be measured while they are functioning. Further instrumentation is required to monitor these parts of the system, which involve the physical engagement of the brake discs.

4.3. Modeling and FDD methods

Modeling can be used as a facility to develop designs or improve control algorithms. For the purpose of modeling the brake system, following subsystems were considered:

- Three-phase power supply including contractor and circuit breaker,
- Three-phase asynchronous motor,
- Gear pump and the existing hydraulic pressure,
- Sensors and control signals.

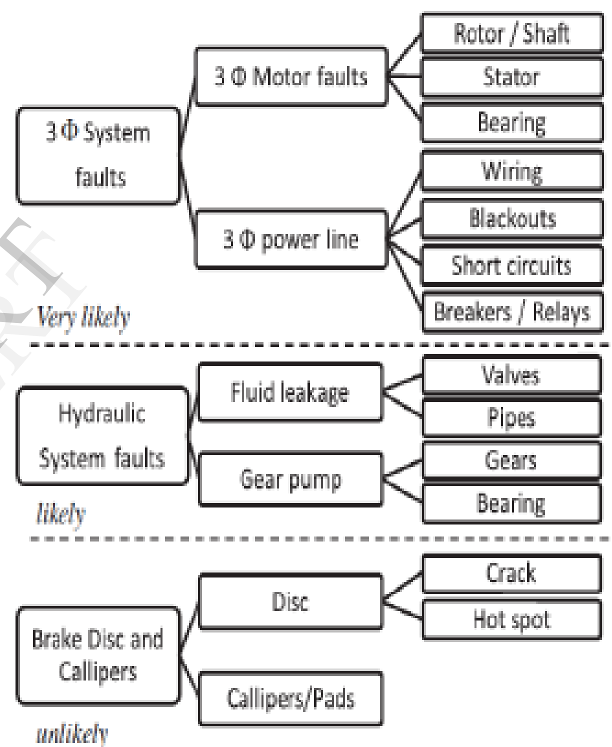

Fig.5.Some of the possible braking system faults and

Fig.6 is the simulated hydraulic unit in Simulink. The behavior of the gear pump has been simulated via an embedded function and applied to the motor shaft torque. A fault-free situation was carried out; the results and its signal analysis were used first to improve the subsystem parameters, and then to check the model.

In that model we give the three phase supply to the AC motor through the contactor, through that only that motor will starts rotating and the hydraulic pump will create the pressure in the reservoir. So because of this only the turbine will stop rotating, so now we create the fault in that three phase system and also in hydraulic system.

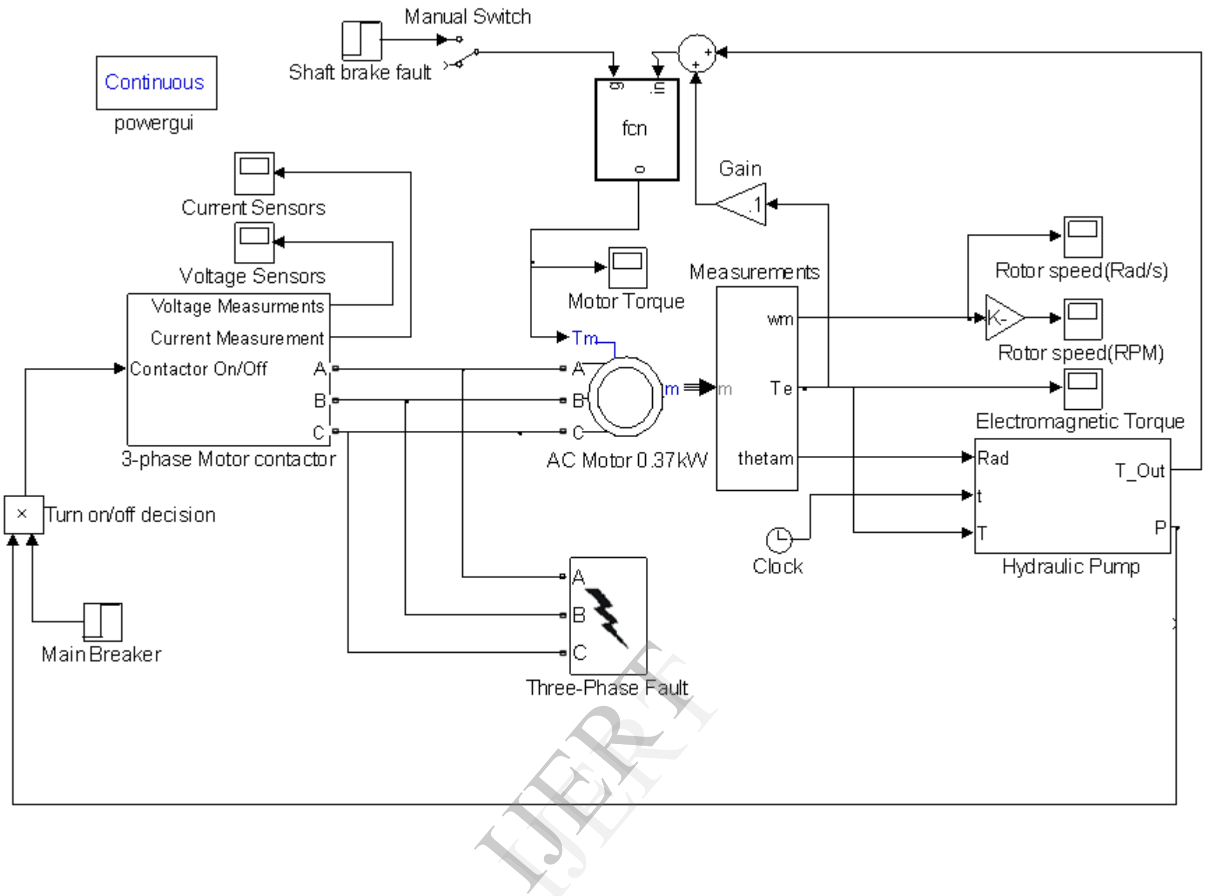

Fig.6 Model of the hydraulic brake system in Simulink.

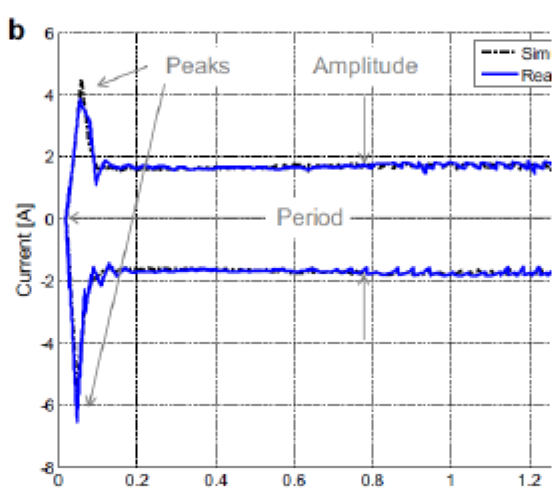

Fig.7 Current envelope of the simulation and real data and their categorization.

The condition monitoring procedure can be carried out by splitting the signal into different segments and in conclusion the comparison of the real signal measurements and the free-fault situation will lead to online fault detection.Peaks, envelope assessments and the period of the event are used for classifying the pumping events, demonstrated in Fig.7. The resulting spectrogram for the simulation which illustrates the similar effects is shown in Fig.7. Any changes within these segments can be considered as a fault and then further FDD approaches will be applied to diagnose the fault. For further improvements in the fault detection process, the RMS value of every five cycles of the signal is compared.

Leakage in the hydraulic system is a common failure mode. The consequence of a leakage in the brake system is that there is a reduction in pressure within the hydraulic pipes and therefore an increase in motor operation time to get to the desired pressure. The results of this failure can be observed in Fig8 and 9.

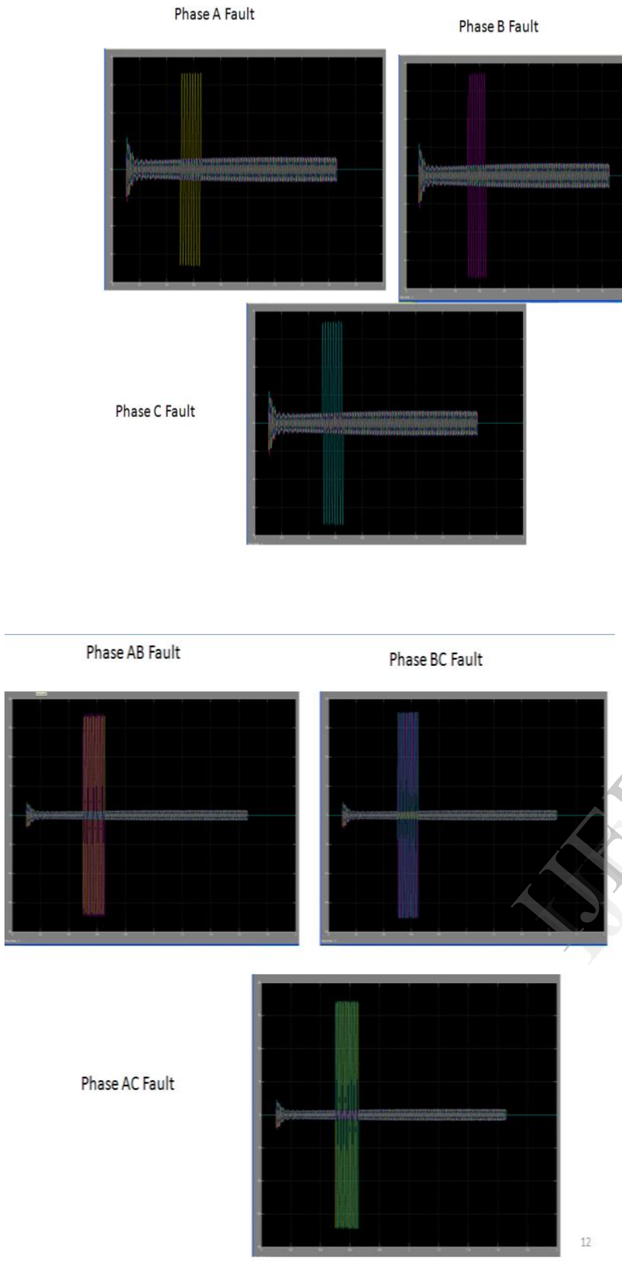

Fig.8. Faults created in phase A,B,C& AB,BC,CA in above system.

The difference between the new results and the fault-free data can be considered as a fault. Further approaches and appropriate analyses will be applied for diagnosis purposes.

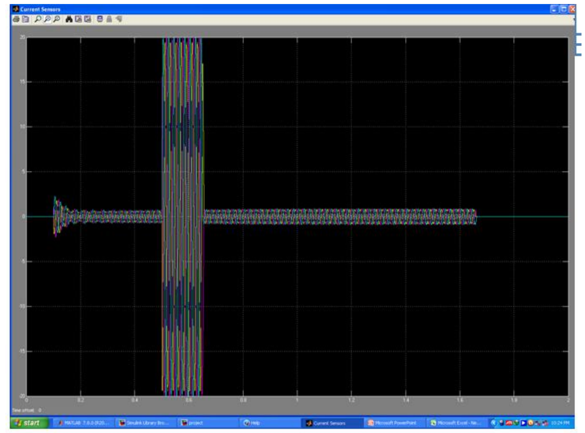

Fig.9.Fault Created in phase ABC

3 Ø System Faults			
Type of fault	**Peak (A)**	**Amplitude(A)**	**Period(S)**
Free Fault	2.3	1.6	1.66
A	7	1.5	1.662
B	7.2	1.8	1.662
C	7.3	1.7	1.662
AB	17.5	2	1.662
BC	17.5	2	1.662
CA	2.5	1	1.662
ABC	20	2	1.662

Table:1-Comparisions of 3Ǿ system faults using performance metrics

5. Conclusions

This paper presented the results of the experiments to date which have led to the implementation of an acceptable model, the testing of a number of failure modes and the study of different FDD mechanisms. It has been mentioned that the current measurements cannot be applied for the FDD in some part of the system. To overcome this, a noncontact temperature and displacement measurements of the disc pads and calipers will be considered and finally investigation for the possible improvement of the FDD algorithms. The high-speed shaft rotation rate and wind speed will be applied in the next stages of condition and performance monitoring of the brake system. The application of online condition monitoring systems can contribute to the optimization of maintenance scheduling by evolution of condition based maintenance procedures rather than corrective maintenance and minimize the risk of catastrophic failures. Moreover, by obtaining clear indications regarding the actual condition of the braking system and other components downtime can be reduced

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considerably leading to improved 'sweating' of wind turbine assets and thus reducing the price of the electricity being produced. The condition monitoring system architecture discussed herewith is sufficiently versatile to be used for the evaluation of other wind turbine components such as the yaw system or pitch control thus increasing its potential for application in the field.

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