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Improving the Reliability in PMSM for Wind Turbine

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Abstract:- The wind turbine converts the wind energy into electrical energy, wherein the electrical machines are coupled with wind turbines for this conversion. The electrical machines are liable to meet with faults, but to regain the system reliability the faults should be detected earlier. According to studies of electrical power research institute (EPRI) most of the faults in electrical motors are created in bushes (41%) and winding (37%).Since there is increased probability of winding fault in motors, its fault diagnosis is very important. The fault often occurs with winding isolators. Inter-turn winding fault creates short circuit in phase winding and changes the phase impedance thereby the machine becomes unbalanced. Rate of impedance reduction depends on the intensity of the fault. To diagnosis winding fault approaches based on frequency analysis are studied, MCSA is used to determine the fault in the stator winding.
Keywords:- Fault detection, MCSA , Permanent Magnet Synchronous Motors (PMSM) , Winding fault.

I. INTRODUCTION

Permanent Magnet Synchronous Motors (PMSM) are the most important electrical machines used nowadays. The advantages of PMSMs are high power density and easy control of external torque by stator's current control. The use of these machines was limited earlier due to their high manufacturing cost. But now due to thetechnological advancements and progress in new magnetic material, they are widely used in traction, automobiles, robotics and aerospace technology, electrical vehicles and ship propulsion systems.

In PMSM, magnetic field of rotor is created by one permanent magnet.Since, external torque can be controlled by tuning stators current, PMSM Motors are used widely. The most harmful outcome in any electrical machine is the fault or damage in their constitutive components. So it seems responsible for early detection of the faults,whereby the system reliability can be improved without expensive maintenance and reparations.Therefore fault detection and fault determining is very important. It gives us an idea to change the control strategy in presence of fault.

Some survey has been conducted, such as; in, a negative sequence analysis coupled with a fuzzy logic based approach has been used for fault diagnosis of a PMSM. In a fault model has been proposed for inter-turn fault of stator winding in a PMSM. And according to the fault model, a series of algorithms have been proposed for fault detection and diagnosis. In a Permanent Magnet AC drive and machine has been tested and the most critical areas have been analyzed for reliability, also, steady-state techniques like Motor Current Signatures Analysis (MCSA)as a new transient technique have been applied. This is a combination of the MCSA, the Discrete Wavelet Transformation and statistics, to the detection of inter-turn faults in a Doubly-Fed Induction Generator (DFIG).

This project focuses on inter-turn fault of winding. MCSA has been proposed. Motor Current Signature Analysis works based on frequency analysis and to determine percentage of this fault second harmonic of X_q has been utilized.

II. II. MOTOR CURRENT SIGNATURE ANALYSIS APPROACH (MCSA)

MCSA method uses signal processing algorithms (such as: FFT, wavelet and etc.) for analyzing the current waveform of motor.In coincidence Current and voltage components and power signals can also be used.

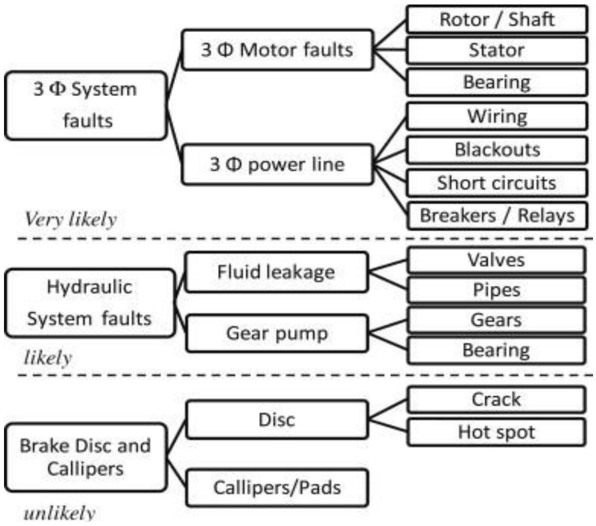

Fig.1 MCSA block diagram.

Frequency analysis of stator current components (Xq,Xd), torque and speed in PMSM shows that sensibility of motor speed, $X_q$and X_d signals to second harmonic is more than the other signals. using these signals for frequency analysis and comparing their values can detect the fault outbreak.But this approach ishighly complicated. Simulation results on Xq and Xd and motor speed shows that second harmonic of Xq is more sensitive in fault detection is also more powerful and faster than other signals.
Motor current signature analysis (MCSA) is a system used for analyzing or trending dynamic, energized systems. Proper analysis of MCSA results assists the technician in identifying:

1. Incoming winding health.
2. Stator winding health.
3. Rotor Health.
4. Air gap static and dynamic eccentricity
5. Coupling health, including direct, belted and geared Systems.
6. Load issues.
7. System load and efficiency.
8. Bearing health.

III. III. WIND TURBINE

Wind turbines convert wind energy to electricity for distribution. The result of over a millennium of windmill development and modern engineering, today's wind turbines are manufactured in a wide range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging or auxiliary power on boats; while large grid-connected arrays of turbines are becoming an increasingly important source of wind power produced commercial electricity. The wind turbine which we are classified into two types they are,

1. Fixed Speed

The most significant characters of fixed speed wind turbine is

- ❖ Efficiency is more at a particular speed that will result in optimum tip speed ratio.
- ❖ Suitable for high wind speed.
- ❖ Induction Generator is used.

2. Variable Speed

The characteristic of variable speed wind turbine is ,

- ❖ Optimum tip speed ratio in a certain range of wind speed.
- ❖ Change rotor speed with wind speed.
- ❖ Higher Energy Capture.
- ❖ Suitable for Low wind speed.
- ❖ Requires Power effect interface.
- ❖ Either Induction Generator or Synchronous Machines.

3. Types of wind energy generators

The types of generators used in wind turbine are classified into three types,

i. Constant speed with gear box.
ii. Variable speed with gear box.
iii. Variable speed without gear box.

a) Constant speed with gear box

The constant speed with gear box uses

- Field wound Synchronous generator

Induction generators.

b) Variable speed with gear box

The variable speed with gear box uses

- Field wound Synchronous generator
- Permanent magnet synchronous generator
- Doubly fed induction generator

c) Variable speed without gear box (direct driven)

The variable speed without gear boxes uses

- PMSM
- Axial flux machines.

4. Causes of Faults In Wind Turbine

The main causes of stator winding faults in wind turine are mentioned below,

1) Due to high difference in voltage potential tends to make this fault accelerate very quickly.
2) Inter turn insulation suffer from transient over voltage during motor star up.
3) Loose bracing for the end winding.
4) Due to short circuit and electrical discharges.
5) Aggressive environmental weaken the insulation (i.e. contamination, moisture, chemical and high temperature.

IV. LV.SIMULATION CIRCUIT

The simulation circuit for the fault diagnosis is show in the below diagram. The circuit consists of two models. The first circuit represent the PMSM without fault and the second circuit represents the PMSM with fault.

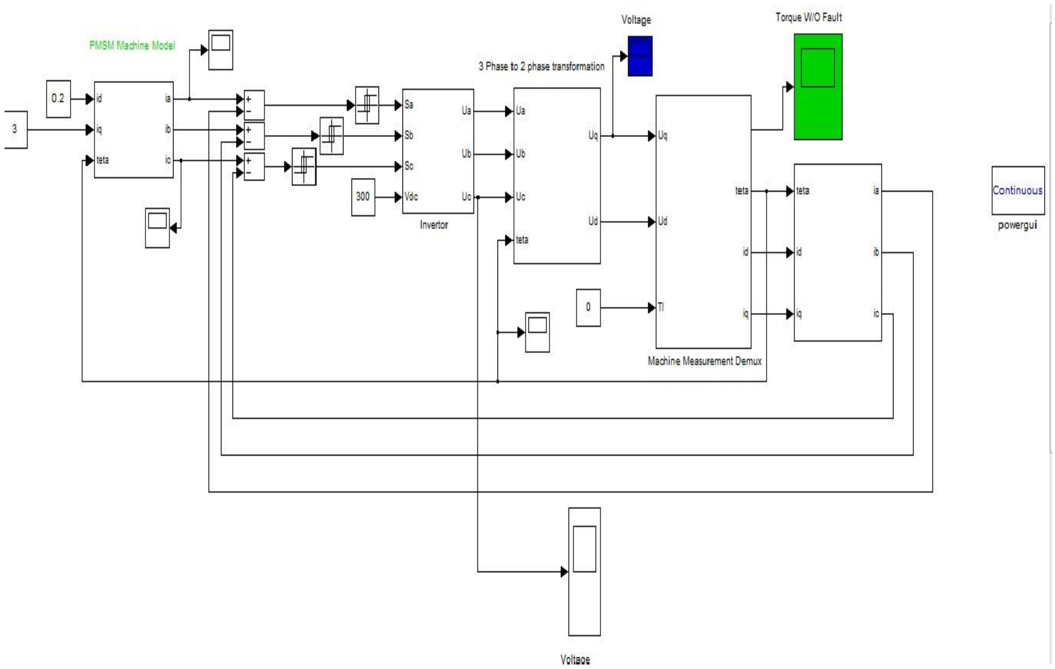

Fig.2 Simulink Model for PMSM without fault.

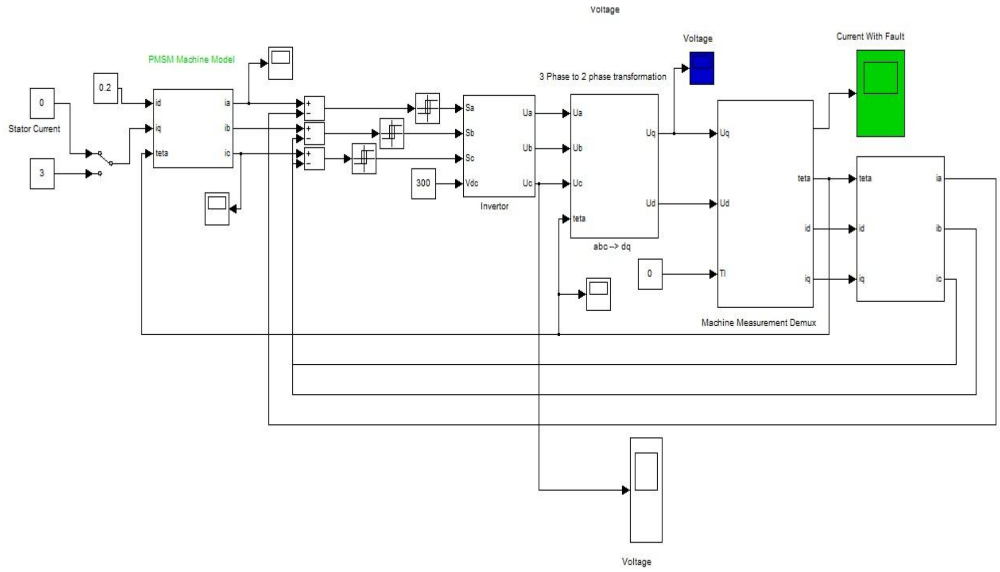

Fig.3 Simulink Model for PMSM with fault.

The PMSM machine model is connected to an invetor, the invertor is then connected with an 3phase to 2phase transformer. From the transformer the connection is made to the machine measurement demux. The scope is connected to the transformer for voltage measurement and to the machine measurement Demuxfor torque measurement without fault condition.

For the fault circuit, the scope is connected to the transformer for voltage measurement and to the machine measurement demux for measuring the current with the fault.

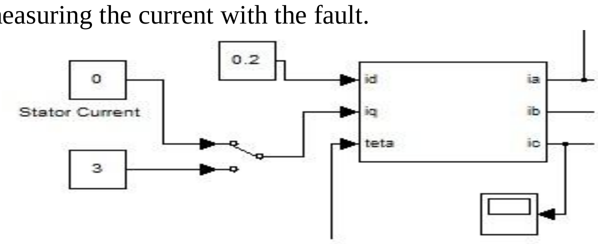

Fig.4 Stator Current Switch.

The stator current switch is used for creating a short circuit in the winding. When this switch is turned on, a short circuit is created in the circuit which affects the winding. With the use of the stator current switch the fault in the winding is analyzed.

V. SIMULATION RESULTS

The analyses were made up of the procedure and efficiency has been calculated by using MATLAB. The model shown in Fig 2 and 3 was simulated using SIMULINK and MATLAB. The plots obtained in the different scopes have been shown below. The simulation was first run with the normal condition with the stator current switch in off mode.

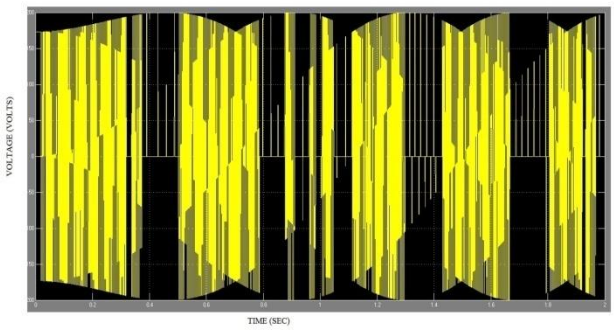

Fig.5 voltage waveform without fault

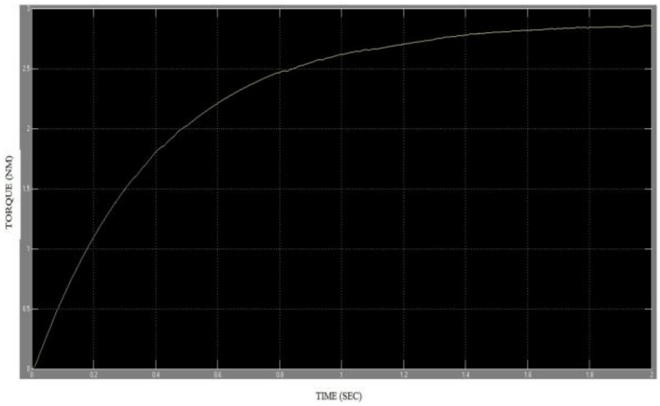

Fig.6 Torque waveform without fault

Fig 5 and 6 shows the voltage and torque characteristics of PMSM without fault. It was seen that without fault the voltage and torque increase with respect to the speed of the PMSM. They varies with respect to time. Rise and falls in the curve is due to the variation of speed and current.

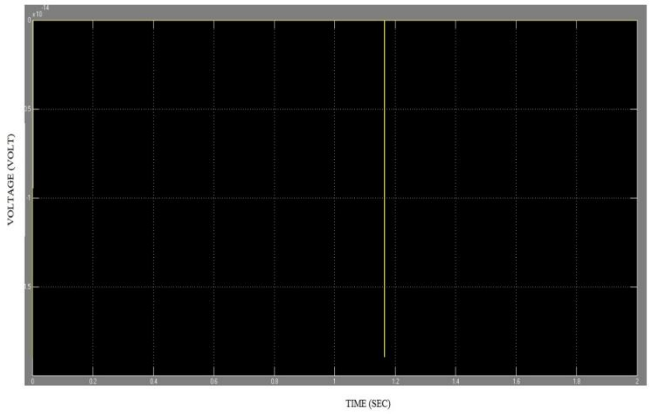

Fig.7 voltage waveform with fault

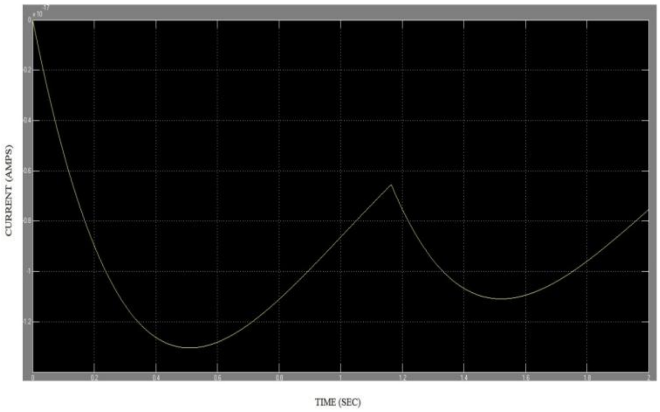

Fig.8 current waveform with fault

Fig 7 and 8 shows the voltage and current characteristics of PMSM with fault. It was seen that with fault the voltage decrease and move to the negative region and current in the winding becomes zero. Due to this the speed of the motor decrease and the whole system becomes unbalance. The variation in the voltage and current can be seen in the fig 7 and 8.

VI. VL. FABRICATION

The fabrication of inter-stator fault diagnosis can be done with the help of simulation. The block diagram of the model used for fault diagnosis in PMSM is shown in fig 9.

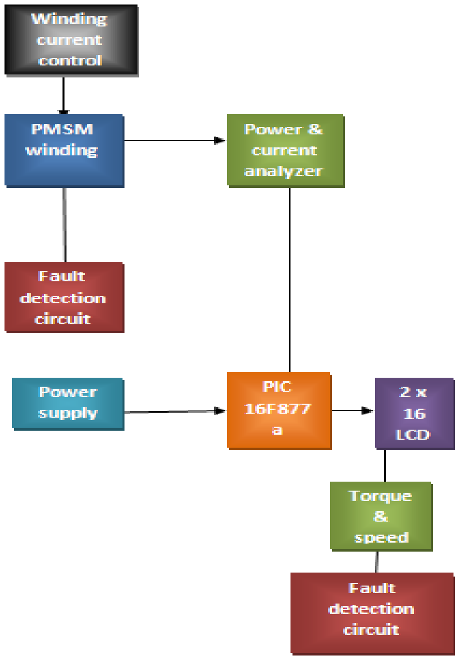

Fig. 9 Block diagram of fault detection

The design procedure used for detection of the fault in PMSM for wind turbine can be explained clearly by the block diagram shown below. The primary steps involved in the fault diagnosis are based on the block diagram.

The block diagram consists of the following components:
1. Winding current control section,
2. PMSM winding
3. Fault detection circuit
4. Power supply
5. Power and Current analyzer
6. Micro controller
7. Torque and speed measurement
8. 2x16 LCD display

The winding current control section helps in identifying the current in the winding. The fault detection circuit helps in detecting the faults in the circuit. The use of power and current analyzer is to monitor the power and current with respect to time.The power supply helps in supply of the power to the circuit and microcontroller. The results of the fault diagnosis can be seen in the LCD display unit

There are a number of steps that can be used for analysis using MCSA. The following steps are to be followed while caring out the fault detection in PMSM

- Map out an review of the system being analyzed
- Determine the complaints related to the system. For instance, is the reason for analysis due to improper operation of the equipment, etc and is there other data that can be used in an analysis
- Taking the data for analysis
- Review the10 second snap short current to view the operation over that time period
- Review high frequency demodulated current and voltage in order to determine other faults including electrical and mechanical health.

VII. CONCLUSION

The paper proposes a simple method to diagnosis the inter-turn faults in the PMSM. In MCSA method the frequency and its amplitude of second harmonic can be applied for fault detection. If MCSA system is designed well, it will be capable to prepare very quick and correct diagnosis of faults for machines so that the reliability can be improved. Accuracy of this method depends on the load of machine, noise and variation of speed. The proposed method offers different advantages which are: good efficiency, response is high and well control for the high load condition.

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