DIAGNOSIS OF STATOR WINDING SHORT CIRCUIT FAULT IN PERMANENT MAGNET SYNCHRONOUS MOTOR

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Abstract: ***Permanent magnet synchronous motors (PMSM) are used for high speed application, in last two decade we are see that the permanent magnet synchronous motor are used with electronics component for different uses. Those include electrical traction propulsion and other electromechanical system. Diagnosis of fault can significantly improve system availability & reliability. This paper deals with stator winding short circuit fault in permanent magnet synchronous motor. Both the fault location and fault severity are diagnosed. The performance of motor under both the condition normal and faulty condition is simulated through different parameters. Also this help to analysis the stator inter turn fault. To verify the effectiveness of the proposed scheme a test motor which allow inter turn short circuiting test of stator winding has been built to diagnosis the short circuit fault in motor.***

Key Words: *Permanent magnet synchrouns motor, stator winding fault, fault detection and dignosis, MATLAB simulation, fault model, short circuit current.*

1. INTRODUCTION

Interior permanent magnet synchronous motor become more favorable in wide speed range application due to their high efficiency and wide constant power speed range . With a hybrid torque production mechanism, IPM motor combine the reluctance torque generated by rotor saliency and magnetic torque due to the permanent magnet.

Owing to excellent performance characteristics including high power density, large constant power ratio and high efficiency IPSM have been highlighted as one of the more attractive candidates for electrical actuating system in wide variety of industrial and transit application. These applications include safety critical once where an abrupt interruption in the drive operation could result in various accident. For these reason electrical motor drive in safety critical application.

According to surway, 35-40 % motors are failure are related to stator winding insulation and core. More ever it is generally believed that the large portions of stator winding related failure are initiated by insulation failure in several turns of stator coil within the one phase. This type of fault refers to "stator turn fault". A stator turn fault in symmetric three-phase AC machine because the large current to flow and generate excessive heat in shorted turn. Without limiting the heat that proportional to the square of circulating current, the fault generally result in complete motor failure. However the worst consequence of stator turn fault in safety critical application would be serious accident involving loss of human life resulting from an abrupt shutdown of the drive operation. The main theme of this work is to increase the stator turn fault tolerance of a PMSM drive in safety critical application.

2. LITERATURE VIEW

According to S. M. A. Cruz. [1] stator winding fault are one of the most frequent IPM motor damages resulting from the degradation of the inter turns inter phase and main isolation of the motor winding. This internal fault will increase the torque ripple that detoriates machine performance. However such fault can be rapidly propagated to motor stator turn since it make large circulating current in the shorted path yielding excessive heat . The adverse condition of heat will occasionally lead to progressive deterioration and eventual breakdown of winding insulation in the phase of motor.

According to S. M. A. Cruz. And A. J. M. Cardoso [2] the author proposed two different approaches for diagnosis of fault. The first technique is base on the motor current spectrum analysis, the second technique is based on multiple reference theory .Recent pattern recognition technique has been applied for fault diagnosis. Under pattern recognition technique framework fault detection and isolation can be formulated as a classification problem which makes the fault detection a binary classification problem.

According to M. Hadef [3] the direct torque control approach for interior permanent magnet synchronous motor drives under stator winding fault has been investigated. The system operation continues without deterioration especially with fraction of shorted turn based on parks vector reorientation it shows the ability of detection and location of these fault. A pattern recognition technique based on image composition allows an automatic classification and diagnosis of stator winding fault of PMSM motor.

3. OVERVIEW OF PERMENANT MAGNET SYNCHRONUS MOTOR

More robust construction of the rotor, higher power density, lower rotor inertia and elimination of field copper loss are the main advantages of this replacement. However, this makes Some limitations, such as; ability of field flux control and Possible demagnetization effect is lost. PMSMs usually have embedded or surface magnets on the rotor, magnet's location affects on mechanical and electrical characteristic of rotor, especially on motor's inductances.

4. SIMULATION OF PMSM UNDER INTER-TURN FAULT

Simulations of PMSM under inter-turn fault avoiding unpredicted faults in engineering systems are impossible, while fault occurrence can lead to dangerous actions. Fault detection and analyzing it in PMSMs are so important, because of their sensitive applications such as airplanes and warships. The first step for all designs in fault detection systems is designing a good and accurate model that can simulate behavior of system completely.

According to equations which governs PMSM model of PMSM under fault and normal condition has been designed. In this paper a,b,c model and three phase equations have been used to model PMSM. For example inter-turn stator winding fault in phase "a" has been simulated that can be seen in Figure (1). In this condition, this fault happening causes some changes in resistance and inductance of damaged phase and also it will change mutual inductance between phases "a" and "b" and between "a" and "c". According to Figure (1), inter-turn fault in stator winding of PMSM can be simulated by a shunt resistance (Rsh) in damaged winding. This fault causes mutual inductance changes between phases, and can create mutual inductance between healthy part and unhealthy part of damaged winding, which is modeled by "Ma1a2" in Figure (1).

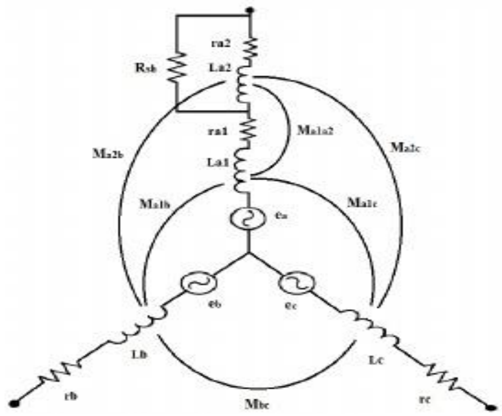

Figure 1. PMSM under inter-turn fault

Where, X is amount of inter-turn fault based on the number Of winding's turns/rings, N is the total number of windings Turns and Nf is the number of shorted turns. Based on Equation, resistance and inductance are related to the number of turns. Where, A is area of winding surface, ρ is resistivity and l is length of winding, N is the number of winding turns and R m is magnetic reluctance of magnetic path. According to this equation, resistance has a direct relation with l and the N; also, L has direct relation with square of number of winding turns. Therefore, resistance and inductance of damaged phase are calculated and PMSM has been simulated,using SIMPOWER toolbox in MATLAB, under inter-turn fault. Simulated model has been presented in Figure (2).

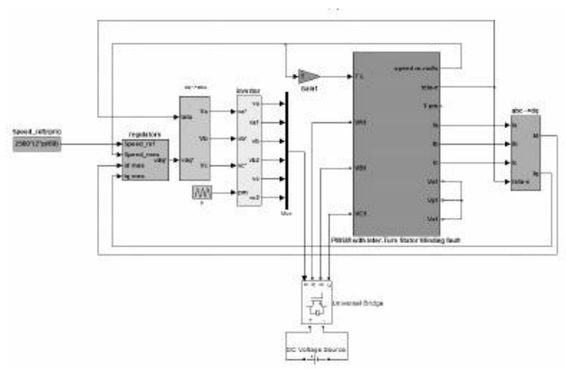

Figure 2. Simulated model of PMSM under inter-turn fault

5. CALCULATING REACTIVE POWER IN SIMULATION

As mentioned before, in this paper magnitude of reactive power has been introduced to detect inter-turn stator winding fault. Since, in experimental applications and laboratory test, neutral point of motor is not available, line voltages, namely; Vab, Vbc and Vca have been used instead of phase voltages. Figure (3) and (4) show designed block for calculating active and reactive powers. line voltages. above equations will change to Equations (1) and (2).

Psc = Vab Ia cosθ (1)

Qc = Vab Ia sinθ (2)

Where, Vab is line voltage between phase a and b, Ia is current of phase a, angel θ is the angel between Vab and Ia.

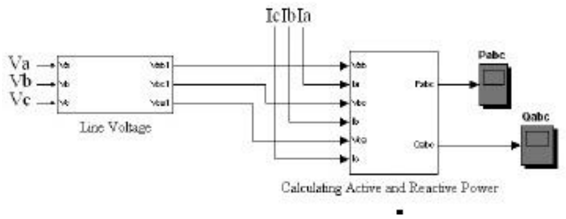

Figure 3. Designed block of calculating active and reactive power

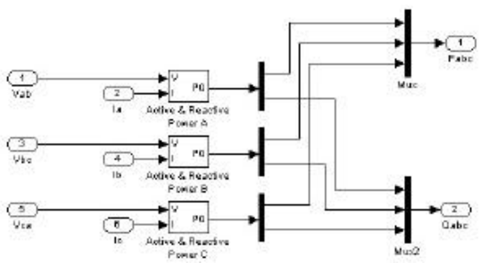

Figure 4. Calculating active and reactive power

As Figure (4) shows, active and reactive powers are calculated using MATLAB active and reactive power calculator. When phase voltages are used, active and reactive powers for each phase can be calculated by Equations given above. These equations average VI product with a running average window over one cycle.

$P_i = V_i I_i \cos\phi$

$Q_i = V_i I_i \sin\phi$

Where, V is rout mean square of phase voltage, I is rout mean square of phase current and φ is the angel between V and I without natural point.

6. RESULT AND DISCUSSION

In order to simulate inter-turn fault in stator winding of PMSM, configuration of Figure (5) and mentioned equations has been considered. In addition using proper short-circuit resistance in designed model can present more real patterns in comparison with experimental test. Therefore, it is considered 0.1Ω. A. Simulation when null of PMSM is available Simulating designed model by MATLAB, following results have been obtained. As it can be seen in Figures (5) , for fault occurrence in phase "a" when percent of inter-turn fault is 30%. Neither current, speed can reveal this fault, nor torque and other available signals/patterns. But magnitude of reactive power and active power can shows inter-turn fault, perfectly.

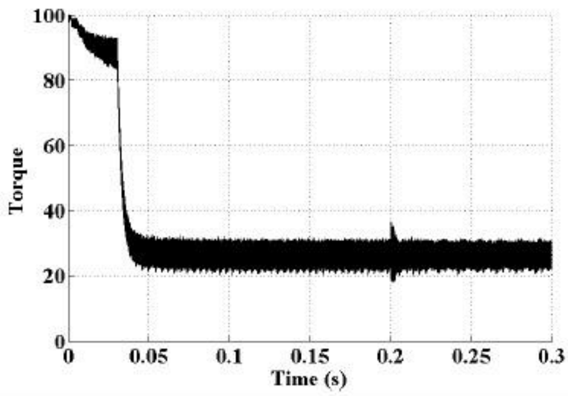

Figure 5. magnitude of reactive power and active power

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