

## **Faults Associated With Permanent Magnet Synchronous Motor**

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### **Abstract**

*As we know that the permanent magnet synchronous motor is gaining upper hand in terms of various applications over other machines, it is necessary to us to know the faults associated with machine. So that necessary precautions can be taken prior to any machine related accidents. In this paper we have given detail study about faults occurring in PMSM.*

**Keywords:** *PMSM, PMSM faults, inter-turn, eccentricity, faults classification.*

### **I. Introduction**

For last couple of years the applications of electrical machines have been grown tremendously. As a consequence energy consumption required to run the motor is also increasing rapidly day by

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day. But due to limited constant supply of energy and poor efficiency of at present electrical motors, there is need of more advance and energy efficient motors to fulfill above said problems. And nearest so far answer to this is permanent magnet synchronous motor (PMSM). Unlike rotor wound synchronous motor in permanent magnet synchronous motor the field winding is completely replaced with permanent magnets. Therefore energy required for field winding for excitation is completely eliminated. Which means permanent magnet synchronous motor is superior to other motors in terms of higher efficiency, high power to volume ratio (power density) and high torque to current ratio. Permanent magnet synchronous motors (PMSMs) are widely used in different industries. So, protection of these motors against different faults is necessary. Faults in PMSMs are classified into magnetic, electrical and mechanical faults. However, 80% of the mechanical faults lead to the eccentricity. Therefore, the eccentricity fault should be accurately diagnosed in PMSMs. A round rotor synchronous motor under dynamic eccentricity (DE) has been modelled by winding function method. However to maximize the applications of PMSM we need to study various faults associated with PMSM, and classify them in proper way, so that we can check them prior that leads to dangerous accidents. Now the question is why the PMSM is so important? The answer is clear, the advantages of PMSM over other motors. Some of these advantages are given below.

Advantages of PMSM

- 1) Large torque to inertia ratio.
- 2) Power density is high.
- 3) High dynamic response
- 4) High efficiency providing reduction in machine size
- 5) Long operating life
- 6) Noiseless operation
- 7) High power factor
- 8) High power to weight ratio
- 9) High torque to inertia ratio
- 10) High air-gap flux density
- 11) Higher speed ranges
- 12) Better speed versus torque characteristics
- 13) Lower maintenance cost
- 14) Simplicity and ruggedness
- 15) Compact design

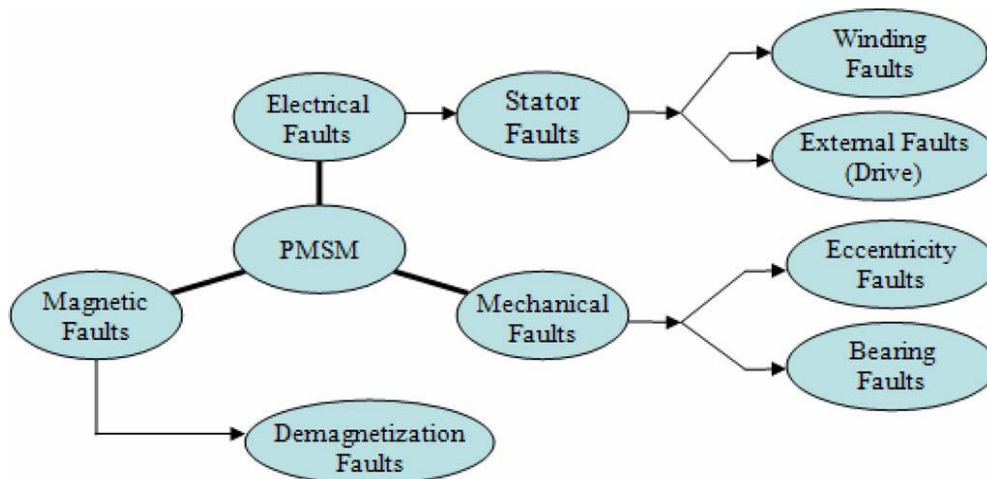
- 16) Linear response
- 17) Controlled torque at zero speed

## II. Classification of Faults

Mainly there are three types of faults mechanical faults and electrical faults and magnetic fault. Electrical faults are related to stator winding, whereas mechanical faults are related to bearing, air gap and rotor-stator alignment.

Magnetic fault is related with generation and distribution of magnetic field lines. Electrical fault is further subdivided into stator faults and external faults (drive related fault). Stator consist of winding is area for most insulation based faults. These faults generally occur due to failure of insulation. Mechanical faults are consisting of bearing fault and eccentricity fault. This fault can further subdivided into static eccentricity (SE), dynamic eccentricity (DE) and mixed eccentricity. Fig. 1 shows the schematic classification of all faults in PMSM.

In order to increase PMSM performance, raise their lifetime, and lower their high Costs, fault prediction in PMSMs is necessary. Faults in PMSMs are classified into three parts: electrical, magnetic, and mechanical faults. Due to having access to the stator of the motor, the detection of electrical fault in faulty PMSM is much easier in magnetic or mechanical faults. Vibrations and noise in PMSM are directly related to air gap and air gap flux density. Air gap itself is depends upon mechanical installation of machine and mechanical faults. Flux density in the machine is directly related to stator winding, number of poles and slots, type of winding and stator faults.



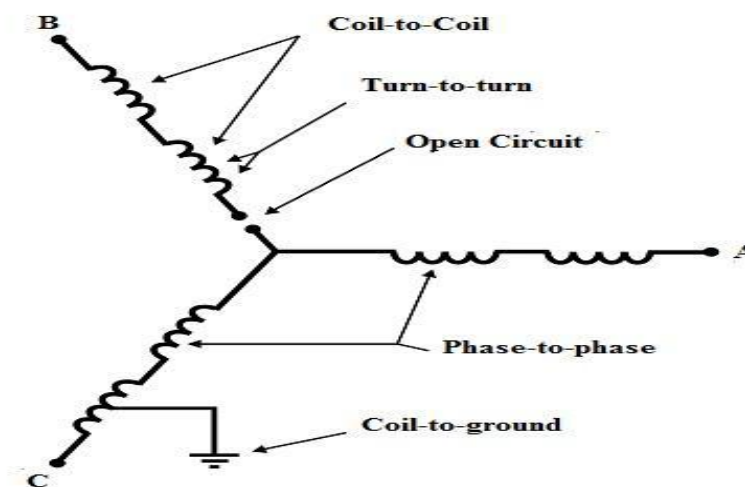
**Fig. 1 classification of faults**

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- **Electrical faults**

Stator faults, which occurs due to insulation failure, these stator winding faults are shown in fig.1 these are categorized as turn-to-turn, Coil-to- coil, phase-to-phase, open circuit fault, coil-to-ground fault and phase-to-ground fault. Above mentioned faults are shown in Fig. 2

A major turn-to-turn fault is associated with a reduction in rotor velocity. About 35-40 % motors are failure are related to stator winding insulation and core. 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. The heat that proportional to the square of circulating current may leads to complete motor failure. Results in shutdown of the drive operation. Monitoring the second-order harmonic components in the  $q$ -axis current through harmonic analysis, stator winding fault by a short-circuited turn in a permanent magnet synchronous motor can be detected.



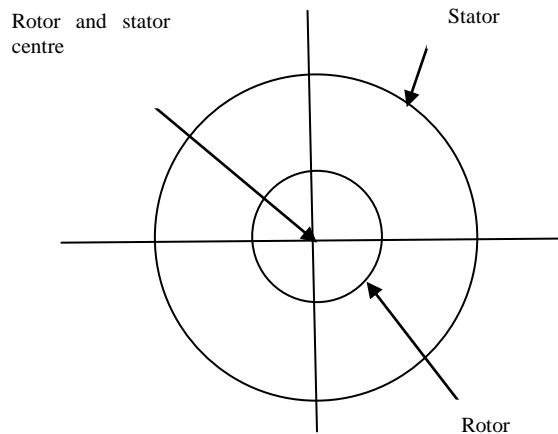
**Fig.2 Stator Winding Faults**

- **Mechanical faults**

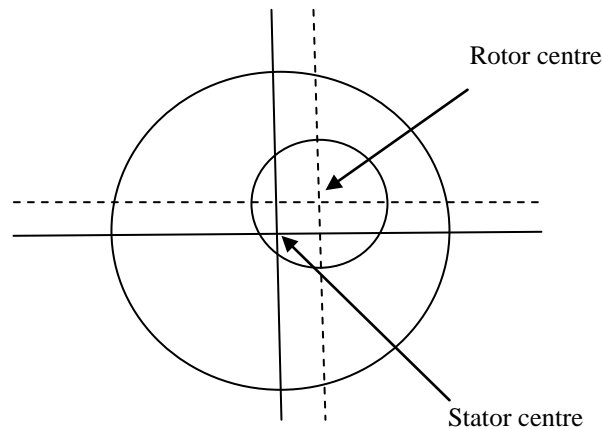
Almost 40-50 % of all motor failures are related to mechanical faults. Mechanical faults involve bearing and eccentricity faults. Tearing of bearing or false arrangement of it leads to bearing faults.. Eccentricity faults consist of static eccentricity (SE), dynamic eccentricity (DE), and mixed eccentricity (ME). They occur due to manufacturing imperfection such as unbalanced mass, shaft bow, and bearing tolerance. These reasons resulted into irregular position of rotor

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with respect to stator and hence irregular air gap. When PMSM is in operation inserts higher harmonics in the stator current.



**Fig. 3 healthy motor**



**Fig. 4 motor with eccentricity fault**

These harmonics introduced can be examined for presence of eccentricity fault. Eccentricity may cause magnetic and dynamic problems with additional vibrations, noises, and torque pulsations. Fig. 3 shows the position of rotor and stator in healthy motor, there centers are coinciding in a common point in accurate, air gap around is uniform. In Fig. 4 as shown position of rotor center is displaced with respect to stator centre position, hence the air gap between rotor and stator is irregular, as a result stator current get distorted by insertion of harmonics. Static

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eccentricity and dynamic eccentricity are differ from each other is the nature of minimum and maximum air gap. If minimum air gap distance from stator is not changing with respect to stator position then this situation is the presence of static eccentricity fault. In other hand if minimum and maximum air gap distances from stator with respect to stator position are changing then that means the presence of dynamic eccentricity fault. Mixed eccentricity is when both static and dynamic eccentricities are present at a time in single machine.

- **Magnetic faults**

Magnetic fault is related with distribution of magnetic flux around stator and in air gap. Antiparallel crossing magnetic magnetic field lines demagnetize each other and leads to irregular distribution of magnetic flux, this fault is referred as demagnetic fault.

### **III. Conclusions**

The faults we have seen in this paper are uncertain and opportunistic; they may arise in any course of time irrespective of on time and in time operations. When they arise they should be diagnosed and eliminated in order to keep system running efficiently and smoothly. Otherwise they may cause severe damage to other system and the persons working in that environment. By this study we can draw some conclusions that are.

- All faults leads to distortion of stator current ( $I_s$ ). So by analysis of ' $I_s$ ' we can detect the presence of fault.
- Air gap is important parameter in a motor, it should be uniform. Motor should be well installed.
- Conductance of winding conductor should be high. So that heat generated  $H= I^2R$  is minimum.

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