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Comparison and Simulated Result of Three and Five Phase Permanent Magnet Synchronous Motor (PMSM)

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ABSTRACT

This paper proposes the comparison of three phase and five phase permanent magnet synchronous motor (PMSM) and also explain the various types of fault accurse in the five phase (PMSM) with pentagon connection. At the end the simulation results are provided for comparison of three phase and five phase current wave form, without fault and with fault also the variation in the PMSM rotor speed at the time of single phase fault and double phase fault in the five phase stator winding is presented.

Keywords

Five-phase, Permanent Magnet Synchronous Machine, stator winding connection, faults, rotor Speed.

1. INTRODUCTION

Now a day's modern industrial drive consists of a power electronic converter, a digital controller for implementing the control algorithms, feedback sensors there for several faults can affect the machine performance or may stop the machine a fault in any of the aforementioned will stop the drive running or at least it affects the drive performance. In an applications such as power plants, aerospace, railway locomotives, automobiles, chemical plants, etc., where the single fault in a single drive can result in tremendous damages of materials and machines. The most common type of faults is open circuit faults in machine windings (phase) and inverter switches (line). But the five phase machines are advantageous over conventional three phase machines for fault tolerant operation because, in five phase machines, when faults occur in one or more of the phases the machines can still continue operations using the remaining healthy phases without additional hardware.

This paper is organized as follows. Section III explains different possible connections for five-phase motor windings and faults that may occur in feeding lines as well as motor windings. Simulation result is described in Section IV. Finally, Section V concludes this paper.

2. PAGE LAYOUT

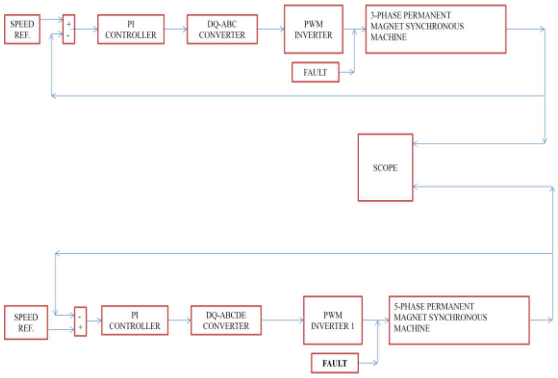

Figure 1. Block Diagram of Proposed Simulation Result

3. WINDING CONNECTIONS & FAULTS

3.1 Winding Connections

There are $(n + 1)/2$ alternatives for connecting the phases of an n-phase electric machine [02], [03]. So for 3-phase and 5-phase connection there are 2 and 3 alternating connections respectively.Fig.2 and Fig.3 shows the possible 3-phase and 5-phase connection respectively. There are so many research paper were explained about the three phase connection so hereonly the five phase possible connections are explained. In our case there is total three no. of possible connection of the stator winging of the five phase machine are *star*, *pentagon* and *pentacle* as shown in Fig.3 [11].

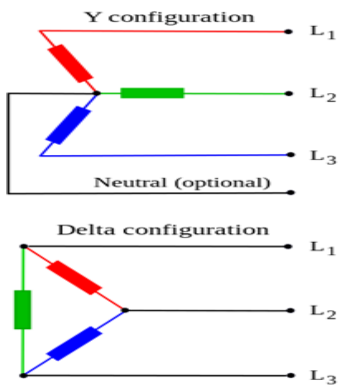

Figure 2. Possible three phase connection, Y and Delta

The operational speed range of five phase PM motors can be extended by changing the configuration of stator windings from conventional star connection to pentagon and pentacle connections.

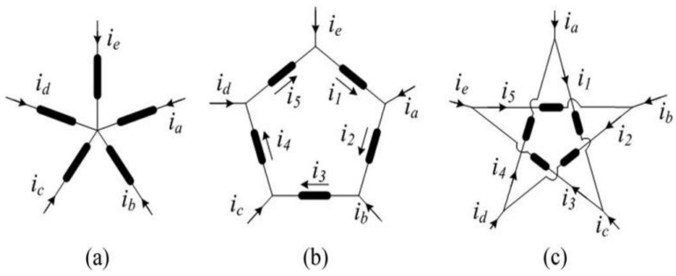

Figure 3. Possible five phase connection (a)star, (b) pentagon, and (c) pentacle

For the same power level and inverter voltage, rms current flowing in phase windings of the motor with pentagon and pentacle connections is less compared to the star connected motor.

3.2 Faults in Five Phase Winding

We have to consider the different types of fault in five phase connection of machine winding. In the star connected PM motor is possible with open circuit fault in one or two phases, whereas with pentagon or pentacle connection, it is possible to continue operation even with simultaneous loss of three phases. Therefore, *pentagon* and *pentacle* connections seem to be *advantageous* over conventional *star* connection regarding fault tolerant operation. The phase faults and line faults are treated in the same way for star connection while the pentagon/pentacle connections analyzed separately. The faults can be categorized in the following eight groups.Possible faults in the line and phase are

1. Single phase (1Ph);
2. Adjacent double phase (A2Ph);
3. Nonadjacent double phase (NA2Ph);
4. Adjacent triple phase (A3Ph);
5. Nonadjacent triple phase (NA3Ph);
6. Single line (1L);
7. Adjacent double line (A2L);
8. Nonadjacent double line (NA2L).

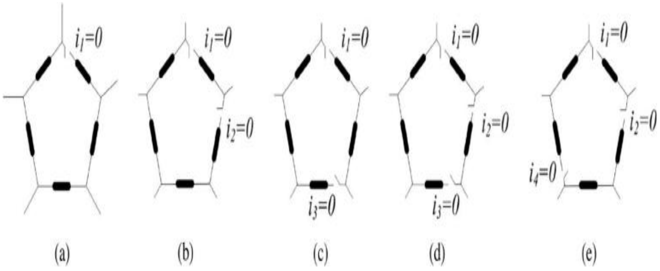

Figure 4.Open-circuit faults in phase windings of a five-phase motor with pentagon connection: (a) 1Ph, (b) A2Ph, (c) NA2Ph, (d) A3Ph, and (e) NA3Ph.

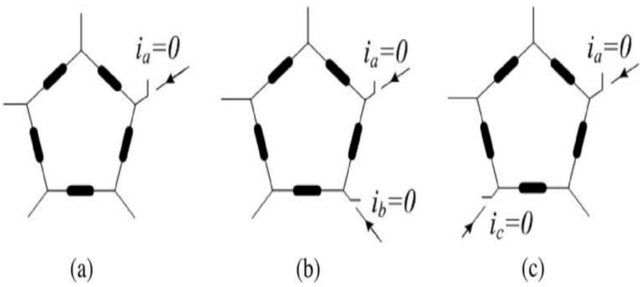

Figure 5.Open-circuit line faults in a five-phase motor with pentagon connection: (a) 1L, (b) A2L, and (c) NA2L.

From the above list, the first five cases are faults in stator windings of motor, while the last three ones are related to faults in inverter switches. For a five phase machine with pentagon connection, these faults are represented in Figs. 4 and 5 for phase and line faults, respectively.

4. SIMULATION RESULTS

The Fig.6 shows the simulated current wave forms of three phase and five phase PMSM without fault. Here for the simulation of 5-phase PMSM, mechanical input is provided as Torque Tm, armature inductance is equal to $1350*10^{-6}$ H, stator phase resistance is equal to 0.12Ω and 4 No. of pole pair is provided. A single phase open line fault is created in 3-phase and 5-phase stator winding at time of 1 sec. And second open line phase fault is created in the 5-phase PMSM stator winding at time 1.5 sec. shown in Fig. 7.

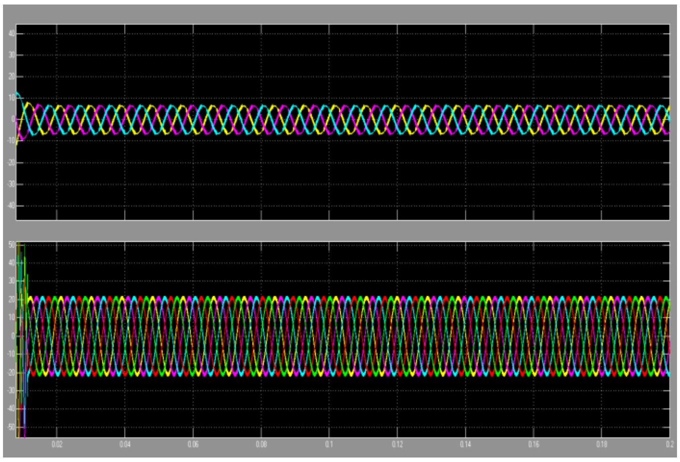

Figure 6. Three phase and Five phase current wave form without fault, (time Vs current).

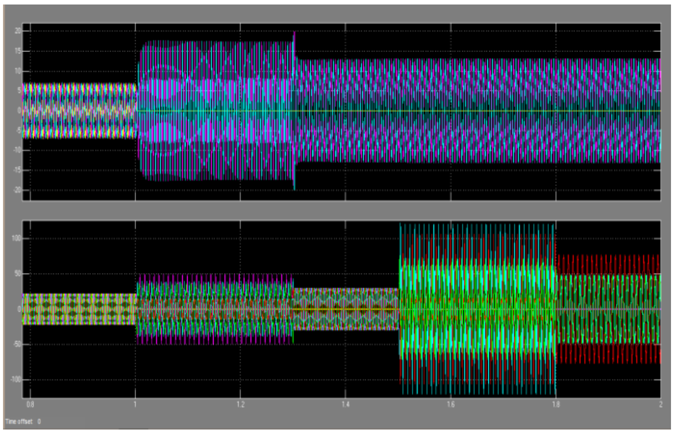

Figure 7. In 3-phase current waveform at 1sec and 5-phase current waveform at 1sec and 1.5sec fault, (time Vs current).

Fig. 7 can show that at the time of the fault the value of the stator current is increase in the remaining healthy phase to maintain the rotor speed constant. Fig.8 shows the PMSM rotor speed waveform in the 3-phase and in the 5-phase.

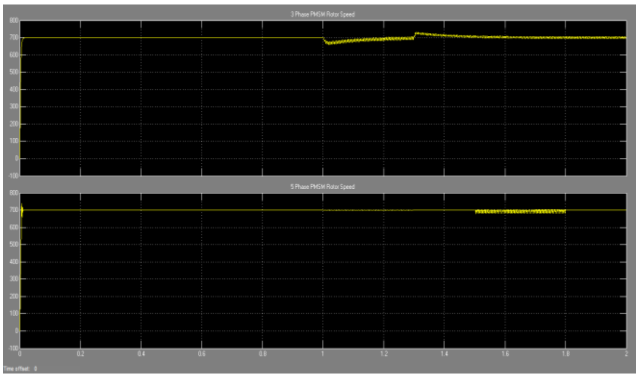

Figure 8. Rotor speed in 3-phase and 5-phase PMSM, (time Vs speed.)

Fig.8 shows the rotor speed in 3-phase and 5-phase PMSM. The variation in speed is accurse at the time of fault but as we compare the result of the both the waveforms we can easily say that the variation in the 5-phase rotor speed is much lower or we can say it's almost constant after the fault.

5. CONCLUSION

This paper has presented a comparison between the 3-phase and 5-phase Permanent Magnet Synchronous Motor (PMSM) with its stator winding and different types of fault. And from simulation result of the stator current and rotor speed waveform we can say that the variation in the 5-phase PMSM is less as compare to 3-phase PMSM or it's negligible

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