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Design and Analysis of a Novel Two Phase BLDC Machine Avoiding Demagnetization.

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I. INTRODUCTION

In the family of brushless permanent magnet (PM) machines, 3-phase drive systems are the most commonly employed and are well-known for their high performance. But two-phase machines require less number of hall sensors to detect rotor position and have light weight. Over recent years, the performance comparison of two-phase and three-phase machines has also been investigated for low cost purpose in many applications as discussed in [1-2]. In PM machines, permanent magnets are the prime source of flux distribution. Normally, all conventional PM machines operate in both magnetization process and demagnetization process. During the demagnetization phenomena, the magnets lose its magnetism due to some internal and external demagnetizing fields which may fail the operation of the machine in certain fault conditions. The permanent magnets in PM machines are almost never operated at maximum energy product BH_{max} because of possible irreversible demagnetization with increasing temperature and opposing fields. To ensure the healthy operation of PM machines, it becomes necessary to operate the permanent magnets away from the coercivity in all normal and abnormal conditions. Traditionally, thick magnets are used to avoid the demagnetization of magnets which contribute a significant high cost of PM machines. The risks of irreversible demagnetization and rotor configurations to protect the magnets from demagnetization are presented in [3-4].

In this paper, a two-phase radial flux BLDC machine with concentrated winding and thin magnets is proposed which is operated in only-pull (magnetization) process and avoids the push (demagnetization) process. With this topology, while using equal amount of total copper, it is possible to achieve the same output performance as that of three-phase BLDC machine at exactly the same back-EMF for both machines and provides the protection for magnets against the loss of magnetism. As a result, thin magnets with low intrinsic coercivity and maximum energy product BH_{max} can be designed which benefits the overall magnet volume reduction as well as machine price is also significantly reduced.

II. PROPOSED TWO PHASE BLDC MACHINE

A novel design of two-phase brushless DC machine (TPBDCM) with thin magnets is investigated and performance is compared with that of three-phase BLDC machine. In the proposed topology as shown in Fig.1 (a), selection of slots and poles can be given by (1).

$$2P=2n_1n_2+n_2 = Ns+n_2 \quad (1)$$

where 2P= No. of magnet poles on rotor, n_1 is defined as the number of coils for one phase group, n_2 is the number of groups for one phase and $Ns=2n_1n_2$ is total No. of stator slots.

Stator of two-phase 16S18P machine is designed with an extra spacing of 90 electrical degrees between the phase belt of phase 'a' and phase 'b' to produce the symmetry in back EMF while the rotor has surface mounted rare earth magnets of 1.5 mm thickness in the direction of magnetization. Both the stator teeth and rotor poles are $\pi/2$ electrical degree wide such that to keep only pull process and eliminating push process. All of the magnets are pulling at the same time for one phase for 1/2 slot pitch with current applied to that phase. The operation of two-phase machine is controlled with 90 conduction angle by eight-switch inverter. Thus resultant electromagnetic torque is produced by one phase at a time. The 3-phase 18S16P BLDC machine having 6mm thick magnets on rotor, operated at 120 conduction mode is chosen as reference model for fair comparison with equal amount of copper used, same airgap length and outer dimensions. Fig.1 (b) shows basic pull-push operation for conventional PM machines, while Fig.1 (c) shows that 90 degree conduction for proposed two-phase machine will only cause linearly increasing flux linkage that is only-pull process and will not go under decreasing flux linkage which is caused by repulsion of same poles from stator and rotor.

III. RESULTS AND DISCUSSION

By the proposed only-pull operation of the magnets, the flux linkage, magnetic flux density and electromagnetic torque and magnetization behavior are mainly focused. To keep the safe operation, magnets should be operated higher than knee point. It is shown that the minimum operating flux density of magnets even under fault condition is higher than 0.2 Tesla (knee point for high grade magnets). Thus, the thin magnets can be used for BLDC machine with maximum energy product and same torque performance can be achieved as that of three-phase machine but at the expense of large value of applied current for 2-phase machine. This will produce large copper losses but the core loss is reduced due to low value of the flux density using thin magnets. Thus, the efficiency of 2-phase machine is some less and summarized in Table.1. In the presented two-phase machine, magnet volume is saved by 5.33 times than that of three phase machine which reduces the overall cost of the machine. More design details and comparison results will be presented in the full paper.

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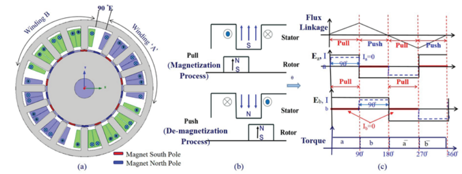

Fig. 1 (a) proposed 2-Phase16S18P BLDC machine (b) Basic Pull & push process of PM machine (c) only-pull topology for proposed 2-phase BLDC machine

Table. 1 Design data and FEA results

Items	2-Phase	3-Phase	Items	2-Phase (16S18P)	3-Phase (18S16P)
Slots/Poles	16/18	18/16	Rated Power, W	1048	1048
Airgap length, mm	0.7		Rated speed, rpm	1580	1580
Stack Length, mm	90		Output Torque, Nm	6.33	6.33
Airgap Diameter, mm	78		Magnet thickness, mm	1.5	6
Stator outer diameter, mm	138.5		Current I_{rms}, A	1.55	0.92
NdFeB Magnet Br, Hc	1.14 T, 868 kA/m		Back-EMF E_{rms}, V	442	442
Core material	S18		Efficiency	93.52 %	94.86 %