Department of Electrical Engineering

Design Of A Novel Low Cost Consequent Pole Permanent Magnet Synchronous Machine

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Introduction

PERMANENT MAGNET SYNCHRONOUS MACHINE

- Permanent Magnet Synchronous Machine(PMSM) is widely used for various industrial applications, Electric Vehicles and House hold appliances.
- PMSM is advantageous due to their high efficiency ,high torque and power density.
- The cost of PMSM directly depend on amount of Permanent Magnet(PM) used.

Objectives

- To Design a low-cost PMSM with identical torque features to conventional PMSM.
- To study and analyse different possible topologies of PMSM..

Current Advancements

- Reluctance torque can help motors to reduce amount of PM used.
- Surface PMSM have high torque density, But their reluctance torque produced is low.
- In conventional machines id=0 control is used for utilizing the reluctance torque.

Current Advancements

- Axialy sandwiched PMSM will make full use of magnetic and reluctance torque for total torque production.
- Consequent Pole PMSM(CP-PMSM) is with dovetailed consequent-pole rotor will reduce PM and provide lower harmonic distortion .
- Tangential PMs are embedded into the proposed rotors of the CPM machines to form the novel hybrid-pole PM (HPM) machines.

Current Advancements

- By using N-S iron sequences and flux barriers the output torque and efficiency can be improved

Working Principle

Conventional PMSM

- Similar to Synchronous Motor.
- Permanent Magnet is the Rotor.
- Stator winding is energised by 3 phase supply.

Working Principle

Surface Mounted PMSM

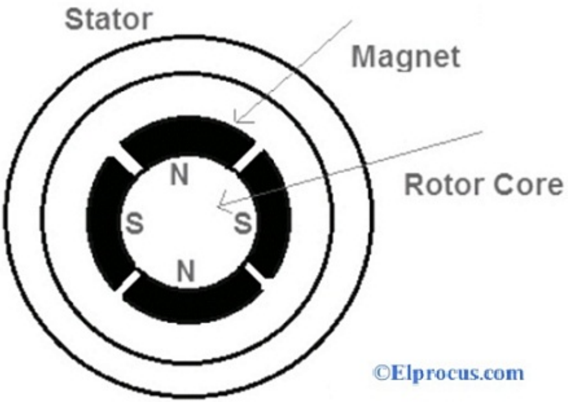

Figure: Top view of Surface Mounted Conventional PMSM

Working Principle

Interior PMSM

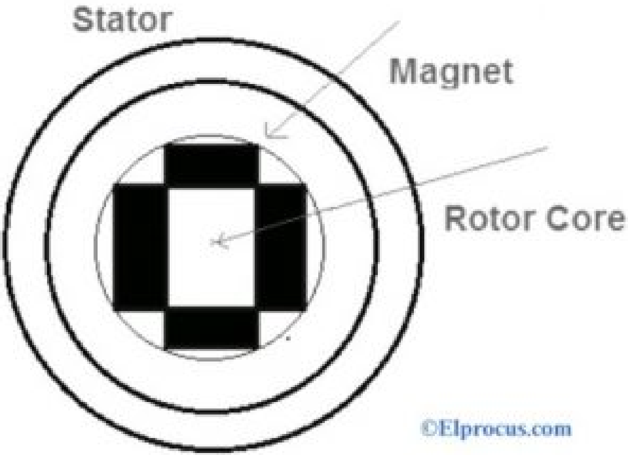

Figure: Top view of Interior Mounted Conventional

FEASIBLE PRINCIPLE OF DIFFERENT TOPOLOGIES

The following assumptions are made for analysis

- Permeance of Iron core is infinite.
- Flux leakage and end effect is neglected
- Recoil Permeability of PM is same as that of air gap

FEASIBLE PRINCIPLE OF DIFFERENT TOPOLOGIES

Conventional PMSM Structure

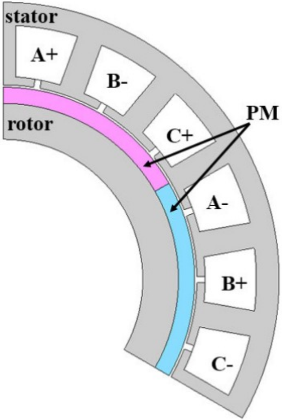

Figure: Structure of Conventional PMSM

FEASIBLE PRINCIPLE OF DIFFERENT TOPOLOGIES

Conventional PMSM Magnetic Circuit

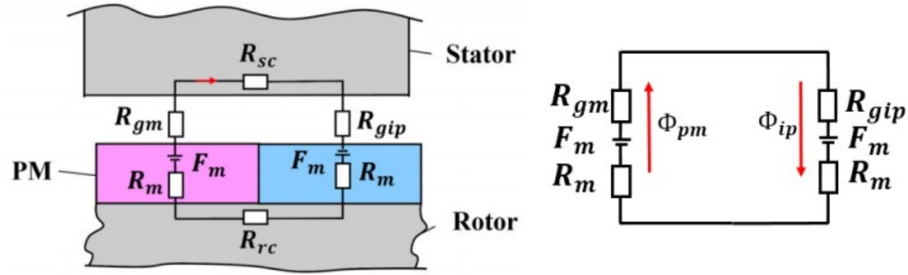

Figure: Conventional PMSM Magnetic Circuit

FEASIBLE PRINCIPLE OF DIFFERENT TOPOLOGIES

Conventional PMSM Magnetic Circuit

$$AirGapFlux = \frac{2Fm}{2Rm + Rgm + Rgip + Rsc + Rrc}$$

Which can be reduced to,

$$\frac{2Fm}{2Rm + Rgm + Rgip}$$

The resultant torque is

$$Torque = \frac{3p * [Apm * iq]}{2}$$

FEASIBLE PRINCIPLE OF DIFFERENT TOPOLOGIES

CP PMSM Structure

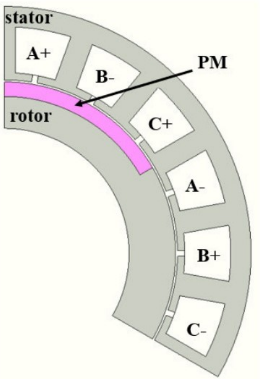

Figure: Structure of CP PMSM

FEASIBLE PRINCIPLE OF DIFFERENT TOPOLOGIES

Conventional PMSM Magnetic Circuit

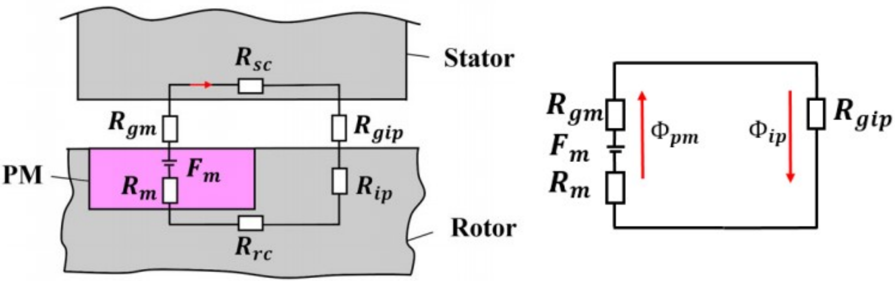

Figure: Conventional PMSM Magnetic Circuit

FEASIBLE PRINCIPLE OF DIFFERENT TOPOLOGIES

CP PMSM Magnetic Circuit

$$AirGapFlux = \frac{Fm}{Rm + Rgm + Rgip + Rsc + Rrc}$$

Which can be reduced to,

$$\frac{Fm}{Rm + Rgm + Rgip}$$

The resultant torque is

$$Torque = \frac{3p}{2}[Apm * iq + (Ld - Lq) * id * iq]$$

FEASIBLE PRINCIPLE OF DIFFERENT TOPOLOGIES

ICP PMSM Structure

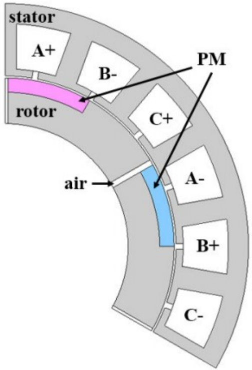

Figure: Structure of proposed ICP PMSM

FEASIBLE PRINCIPLE OF DIFFERENT TOPOLOGIES

ICP PMSM Magnetic Circuit

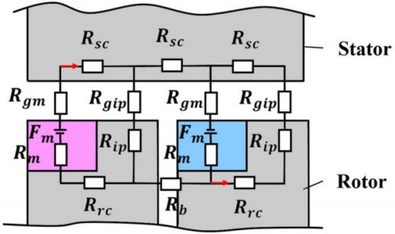

Figure: Magnetic circuit.

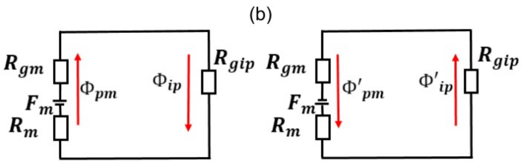

Figure: Equivalent magnetic circuit

FEASIBLE PRINCIPLE OF DIFFERENT TOPOLOGIES

ICP PMSM Magnetic Circuit

$$AirGapFlux = \frac{Fm}{Rm + Rgm + Rgip}$$

The resultant torque is

$$Torque = \frac{3p}{2}[Apm * is * cos(\delta) + 0.5 * (Ld - Lq) * is^2 * cos(2\delta)]$$

ICP PMSM Torque

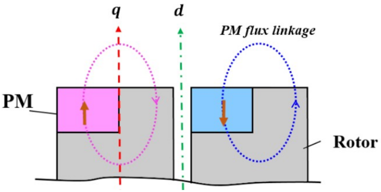

Figure: PM Torque

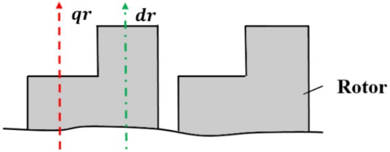

Figure: Reluctance Torque

FEASIBLE PRINCIPLE OF DIFFERENT TOPOLOGIES

ISCP PMSM Structure

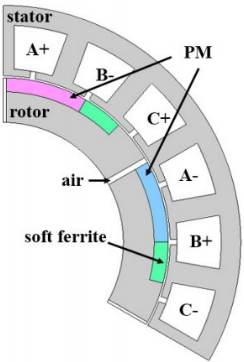

Figure: Structure of proposed ISCP PMSM

- The PM arc ratio is

$$\alpha p = \frac{\Theta pm * p}{2\pi}$$

- By Optimizing PM arc ratio we obtain the maximum Torque at

$$\alpha p = 0.68$$

- And minimum Torque at

$$\alpha p = 0.5$$

- CP PMSM cannot reach the torque and torque ripple similar to Conventional PMSM.

OPTIMIZATION DESIGN OF ROTORS

CP PMSM Rotor

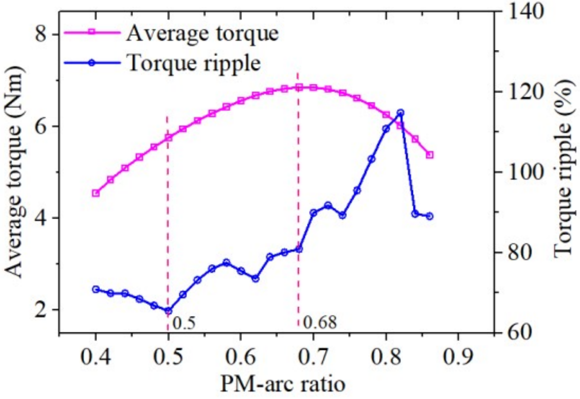

Figure: Average torque and torque ripple with variable αp

- PM-arc ratio and air barrier width are complex for maximum torque.
- By using GA method optimal design results are obtained.
-

$$b = 1.423mm$$

$$\alpha p = 0.6275$$

- By using GA method optimal design results are obtained.
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$$b = 1.20mm$$

$$\alpha p = 0.592$$

$$\beta s = 0.770$$

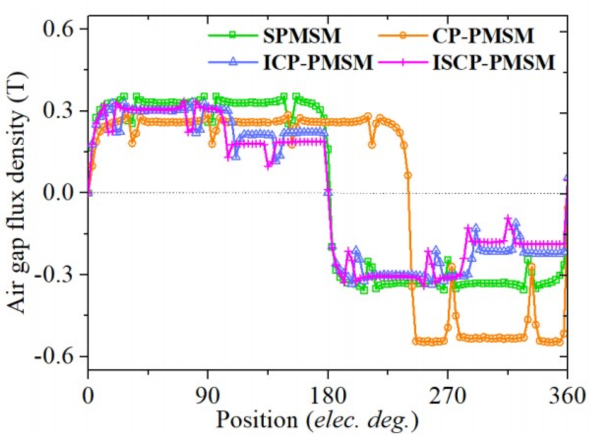

Figure: Air-gap flux density distribution of investigated

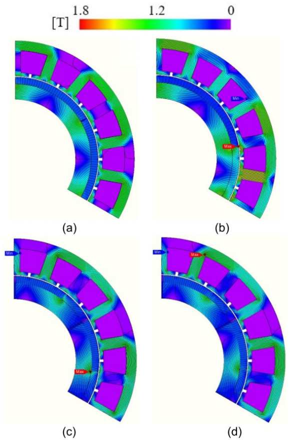

Figure: Magnetic Flux

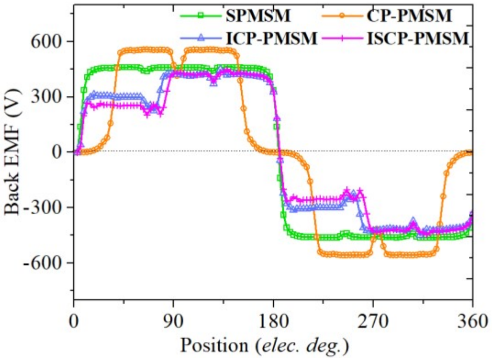

Figure: Air-gap flux density distribution of investigated machines

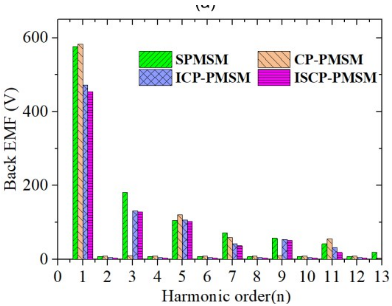

Figure: Magnetic Flux Distribution

Performance Analysis and Comparison

Torque Performance

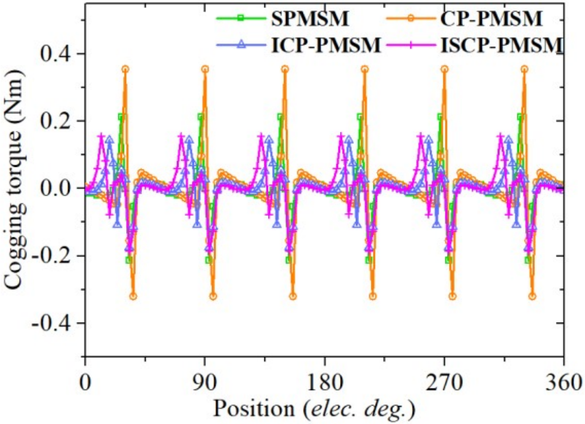

Figure: Variation of cogging torque with rotor positions.

CONCLUSION

- Based on conventional PMSM CP-PMSM is presented.
- ICP-PMSM is proposed and optimized using reluctance torque.
- ISCP PMSM is proposed and optimized.
- It is established that ISCP PMSM can completely replace the conventional SPMSM at a lower cost.

References

- K. T. Chau, C. C. Chan, and C. Liu, “Overview of permanent-magnet brushless drives for electric and hybrid electric vehicles,” IEEE Trans. Ind.Electron., vol. 55, no. 6, pp. 2246–2257, Jun. 2008.
- .Ooi, S. Morimoto, M. Sanada, and Y. Inoue, “Performance evaluation of a high-power-density PMASynRM with ferrite magnets,” IEEE Trans.Ind. Appl., vol. 49, no. 3, pp. 1308–1315, May 2013.
- .H. Zhang, K. Wang, and J. Li, “Torque ripple suppression of consequent-pole permanent magnet machine by magnet shifting,” in Proc. 22nd Int. Conf. Electr. Mach. Syst. (ICEMS), Harbin, China, Aug. 2019, pp. 1–6.
- .-J. Li, G. Jewell, and Z.-Q. Zhu, “Performance investigation of hybrid excited switched flux permanent magnet machines using frozen permeability method,” IET Electr. Power Appl., vol. 9, no. 9, pp. 586–594, Nov. 2015

Thankyou!