ISSN 2395-1621

Design And Analysis of BLDC Motor For Different Rotor Topologies Using ANSYS Software

[#1]Omkar Ramchandra Mali, [#2]Prof. S.D.Joshi

[#12]Department of Electrical

PES's Modern College of Engineering, Pune

ABSTRACT

This paper presents a detailed comparison of five topologies for rotor permanent magnet (RPM) motors with improved fault-tolerance. The five topologies include one surface mounted topology, one surface-insert topology and three interior topologies (spoke-type, conventional and V shape). In these motors, the fault- tolerant teeth (FTT) and the concentrated winding are adopted to offer the merit of phase decoupling, which can make these motors offer the fault-tolerance. The performance characteristics, which include the flux density of air-gap, back electromotive force (back-EMF) and its harmonics, magnet mass and cogging torque are compared and analyzed. These electromagnetic characteristics of these proposed motors are analyzed by using the time-stepping finite-element method (FEM). The aim of the paper is to give some guidance and references for RPM motor designers.

ARTICLE INFO

Article History

Received: 20th July 2019

Received in revised form : 20th July 2019

Accepted: 22nd July 2019

Published online : 24th July 2019

I. INTRODUCTION

The PERMANENT Magnet Brushless DC (PM BLDC) motor, due to the presence of high energy permanent magnet (PM) materials exhibits high efficiency with compact structure, high power density and high torque to current ratio. Among the two variants of the PM BLDC motors, the Sinusoidally-fed motor commonly known as the permanent magnet synchronous motor (PMSM) has the least torque ripples . So as to get a ripple-free torque, the PMSM must have a sinusoidal flux density profile in the air gap. Several rotor topologies have been reported for these motors; the popular among these are (a) surface mounted–radially polarized, (b) surface mounted parallelly polarized, (c) interior-parallelly polarized, (d) circumferential and (e) bread loaf as shown in Fig. 1. Three rotor topologies have been analyzed for the PM motors maintaining the magnet volume constant, and it is reported that the radially-polarized surface PM rotor configuration is better in terms the air gap flux density profile. Variation in the rotor topologies is a degree of freedom available for design optimization of PM BLDC motors in terms of the average torque, torque ripples, and back-EMF profile. Design hints are suggested after taking into account some of the effects of surface mounted and interior PM rotor topologies on the sensorless PM BLDC motor drive performance [8]. Literature giving methods to determine the direct and quadrature axes inductances, Ld and Lq, using finite element (FE) method, for the PMSM, is also available [9].

In this paper, a detailed comparison of the motor performance for these five known and popular rotor topologies is presented in terms of the developed torque profiles, average and ripple torques, cogging torques and the developed back EMFs.

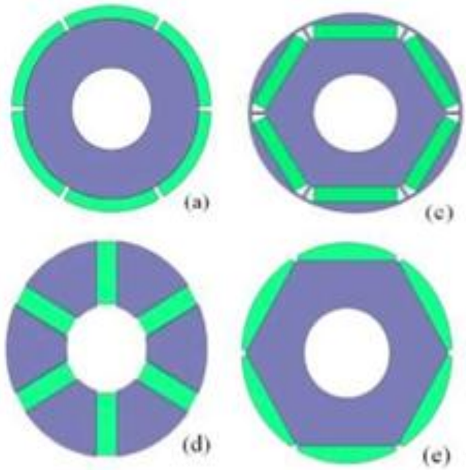

Fig. 1. Rotor topologies of PM BLDC Motors (a) Surface mounted–radially polarized (c) Interior-parallelly polarized (d) Circumferential (e) Bread-loaf

II. DETAILS OF THE ANALYZED MACHINES

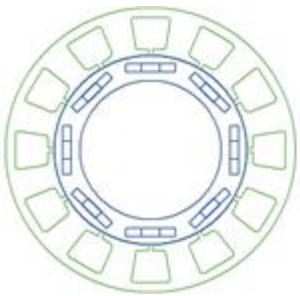

Fig.2 cross section view of IPM BLDC

Sr. No.	Specifications	Value
1.	Rated output power	1kw
2.	Rated voltage	48 V
3.	Number of poles	8
4.	Rated speed	3100 rpm
5.	Type of circuit	Y
6.	Operating temperature	75 C

Table No.1 General Data

III. DESIGN OF BLDC MOTOR

In this focuses on basic design of motor in RMxprt of Ansys Maxwell. Fixed parameters available from below Table used as input to this software. A brief introduction to RMxprt is given here first, and then details about design are given,

A] RMxprt

ANSYS RMxprt is a template-based design tool. Designers of electrical machines and generators can enhance their design with this tool. Together Maxwell and RMxprt create a truly customized machine design flow to meet market demand for higher efficiency, lower cost machines. Using classical analytical motor theory and equivalent magnetic circuit methods, RMxprt can calculate machine performance, make initial sizing decisions, and perform many analyses in a matter of seconds. RMxprt can then automatically set up the complete Maxwell project (2D/3-D) including geometry, materials, boundary conditions including the appropriate symmetries, and excitations with coupling circuit topology for rigorous electromagnetic transient analysis. Design sheets list all the relevant input and calculated parameters and a graphical display of waveforms, such as current, voltage, torque, and back emf. It uses classical electric-machine theory in combination with a magnetic circuit approach to calculate performance.

A]Stator design

Table I. shows analysis setup parameters for design. Based on these parameters RMxprt will solve for other parameters. The diameter of lamination available is stator outside diameter.

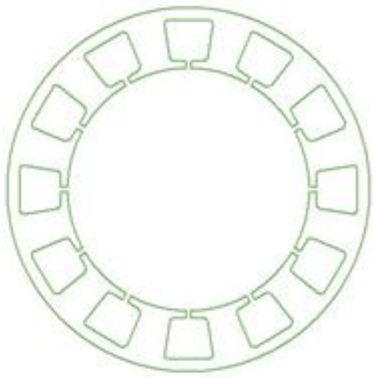

Fig.3 Stator Cross-sectional view

Sr.no.	specification	value
1.	No. of stator slot	12
2.	Outer diameter	119.92 mm
3.	Inner diameter	80.1 mm
4.	Top tooth width	9.9 mm
5.	Bottom tooth width	11.3 mm
6.	Length of stator core	50.1 mm
7.	Slot insulation thickness	1 mm

Table No.2 Stator Data

B] Rotor Design

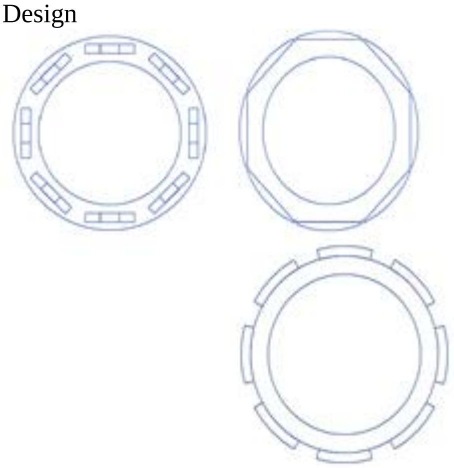

Fig .4 Different Rotor Topologies

Sr. No.	Specifications	Values
1.	Minimum air gap	1.405mm
2.	Inner Diameter	58.9mm
3.	Length of rotor	50.24mm
4.	Pole arc radius	38.58mm
5.	Maximum thickness of magnet	3.56mm
6.	Width of magnet	23.12mm

Table No.3 Rotor Data

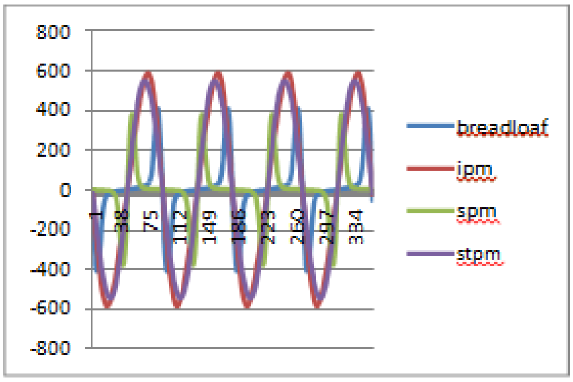

Fig.5 Cogging Torque of BLDC for Different Topologies

- **SPM topology is more superior to other two topologies because it has less cogging torque.**

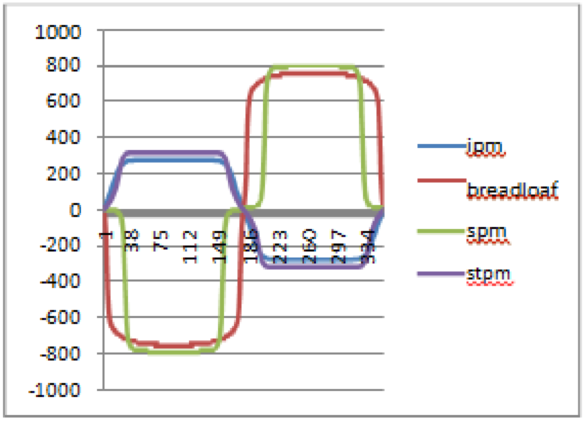

Fig. 6 Air Gap Flux Density of BLDC for Different Topologies

- **SPM topology is more than all other topologies so this topology is suitable for high torque applications**

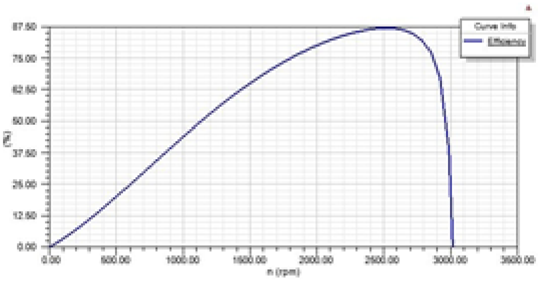

Fig. 7 Efficiency Vs Speed of BLDC for SPM Topology

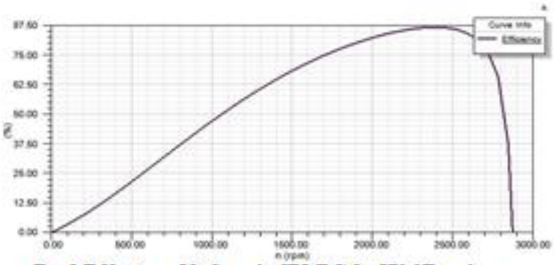

Fig.8 Efficiency Vs Speed of BLDC for IPM Topology

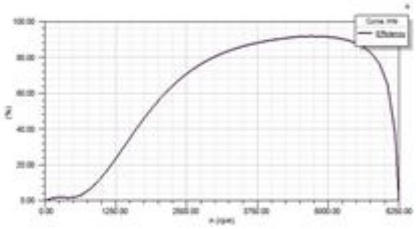

Fig.9 Efficiency Vs Speed of BLDC for STPM Topology

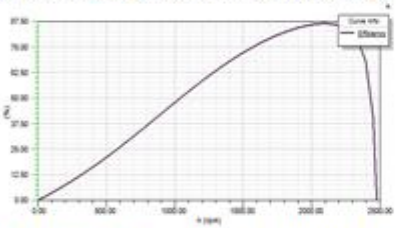

Fig.10. Efficiency Vs Speed of BLDC for Bread loaf Topology

- **STPM topology suitable for wide range speed variation applications.**
- **SPM topology is not suitable for application beyond rated speed, because efficiency decreases beyond rated speed.**

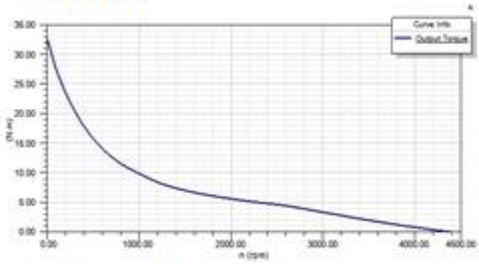

Fig.11 Torque Vs Speed of BLDC for IPM Topologies

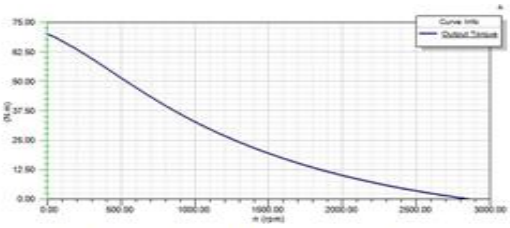

Fig.12 Torque Vs Speed of BLDC for SPM Topology

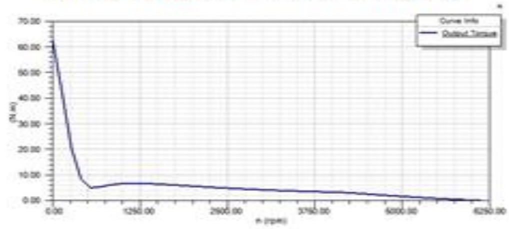

Fig.13 Torque Vs Speed of BLDC for STPM Topology

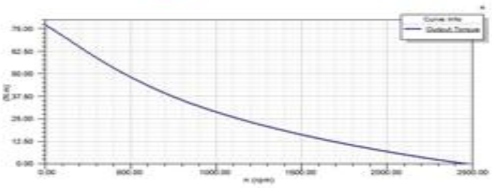

Fig.14 Torque Vs Speed of BLDC for Bread loaf Topology

- **SPM & Bread loaf have high starting torque.**

TOPOLOGY	REMARK	APPLICATION
SPM	❖ Air gap flux density of SPM topology is more than other two Topologies.	Traction motor (high torque)
STPM	❖ Less Cogging Torque ❖ Less Air gap Flux Density due to limitation of D/L	Bore well submersible pump
IPM	❖ IPM topology is more superior to other two topologies because it has less cogging torque ❖ Low weight	Ceiling Fan
BREADLOAF	❖ High Torque and High efficiency at low speed	Electric Bus

IV. CONCLUSION

This paper has demonstrated an approach to brushless DC motor design and to analyze it. . RMxprt tool of ANSYS solves basic motor design equations and gives crude design data. It is necessary to undergo simulation through Finite Element Analysis tool of ANSYS that is Maxwell 2D.It is seen that SPM & Bread loaf have high Starting torque, Also seen that the SPM have less Cogging torque. IPM have less starting torque but High efficiency above rated speed. By comparing all the performance characteristics of various topologies, We find out superior Topology for particular application.

REFERENCES

[1] Pinaki mukharjee, Mainak Sengupta, “Design, analysis and fabrication of BLDC motor”.

[2] Gaurang I. Vakil and K. R. Rajagopal S, “Performance Comparison of Sinusoidally-Fed PM BLDC Motors Having Different Rotor Topologies”

[3] Qian Chen, Guohai Liu, Longgang Sun, “comparison of five topologies rotor permanent magnet motor with improved fault- tolerance”.

[4] D Kamalakannan, N Jeyapaul Singh, M Karthi, V Narayanan and N S Ramanathan, “Design and development of DC powered BLDC motor for Mixer-Grinder application”

[5] S. Sashidhar, and B. G. Fernandes, Member, “Spoke-Type BLDC Motor for PV BoreWell Submersible Water Pumps”

