DESIGN AND ANALYSIS OF NEW CLASS BRUSHLESS D.C MOTOR (FSM)

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Abstract -This paper describes a new class of electric motor, with a field winding and an armature winding, both of which are on the stator. The motor has no brushes or permanent magnets. Its motor characteristics are similar to those of a DC machines. Control of the armature windings can be achieved with very simple electronic circuits resulting in a very low cost and reliable variable speed drive. Thus, this paper presents the design and analysis of the FS motor. Design equations are analytically derived for initial calculations of the main dimensions, number of turns, and inductances of the FS motor. Furthermore, a comprehensive static finite element method analysis (SFEM)-behavioral model is developed and utilized for detailed analysis and design refinements of a prototype 8/4-pole FS motor.

IndexTerms—*FluxSwitchingMotor, Finite Element Method/Analysis.*

I.INTRODUCTION

The flux switching motor (FSM) is an exciting new motor technology offering the robustness and simplicity of the switched reluctance motor with extremely low cost sensor-less electronic controller.

The flux switching motor retains the simplicity of the switched reluctance motor's low manufacturing cost but for the first time, in a reluctance machine, it employs a power converter which is extremely low cost. The power converter does not need to be rated to deliver the magnetizing energy of the motor, which is a further saving in cost. This fact coupled to the brushless operation, extremely low cost and easily programmed torque speed curves are leading to commercial opportunities for this new motor technology.

This paper describes a new class of brushless motor. The new flux switching motor requiring is a very simple motor to manufacture and, coupled with a power electronic controller only two power semiconductor switches; it has the potential to the extremely low cost in high volume applications. Furthermore, being an electronically commutated brushless motor, it inherently offers very flexible and precise control of torque, speed and position at no additional cost.

II. DESIGN

The design specifications of FSM comprises of required power output, speed, peak current and available supply voltage. Thus the torque that should be produced by the machine is given by

$$T_{req} = \frac{P}{2\pi * \frac{N}{60}}\ Nm \qquad (1)$$

A good starting point as regards the physical dimensions of the machine would be a comparison with an equivalent induction motor. A comparison with an equivalent induction motor will fix the frame size of the FSM to be designed. This is advantageous as in many applications a FSM may be used to replace other machines.

The preliminary selection of frame size automatically fixes the outer diameter of the stator. Practically, the outer diameter of the stator is fixed as follows

$$D_o = (\text{Frame size} - 3)*2$$

1. *The stator pole arc angle is less than the rotor pole arc angle, i.e.,*

$$\beta_s < \beta_r \qquad (2)$$

2. *The effective torque zone is lesser than the stator pole angle β_s but greater than the stroke angle ε. The stroke angle is defined as*

$$\varepsilon = \frac{2\pi}{qN_r} \qquad (3)$$

Where q is the number of phases,

$$q = \frac{N_s}{2} \qquad (4)$$

3. *The angle between the corners of adjacent rotor poles must be greater than the stator pole arc or there will be an overlap between the stator and rotor poles in the unaligned position. This condition is represented as* $\frac{2\pi}{N_r} - \beta_r \geq \beta_s$ (5)

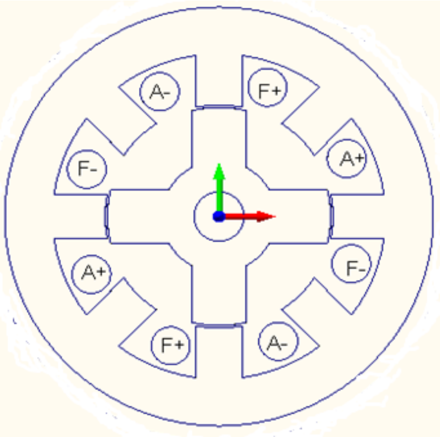


Fig 2. Structure of the FSM

With the assumptions of flux density in both stator and rotor other machine parameters are found. Figure 3 shows the magnetic equivalent ciruit.

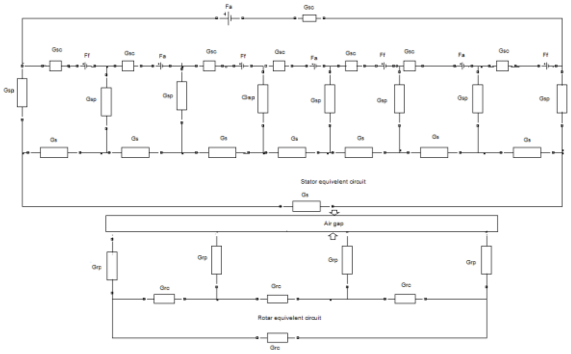
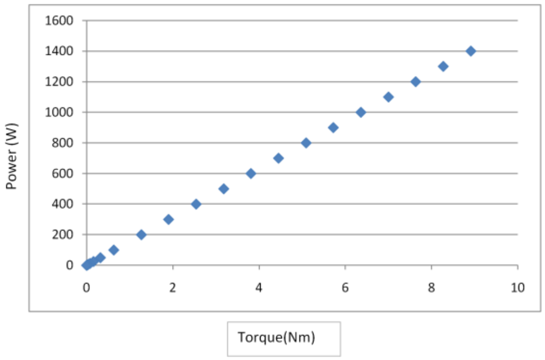


Fig 3. Per phase equivalent circuit

The specification of the machine designed are, power 2.6Hp, speed 1500 rpm, supply voltage 230V, rated current 12A, number of turns per phase 70..

III. PERFORMANCE OF THE MOTOR



V. POWER CONVERTER

The first IGBT is switched on and current from the supply flows through the corresponding armature winding. The rotor turns to align itself with the energized stator poles as a consequence of the resultant combined flux produced by both the armature and field windings. As rotation continues the position sensor detects the point at which to turn on the second IGBT. The first switch must be turned off prior to, or at the same time as the second turns on to avoid a large short circuit current. At first the stored magnetic energy transfers to the second armature winding. As this is wound in the opposite direction to the first armature winding, the current now flowing in this winding is negative and reduces to zero as energy is returned to the supply via the fast recovery freewheel diode.

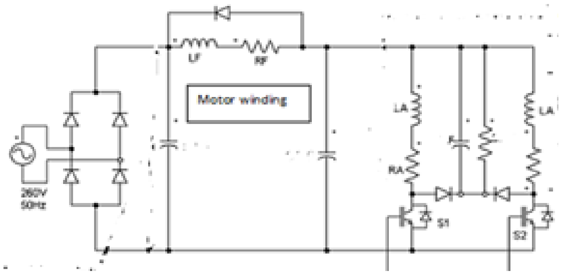
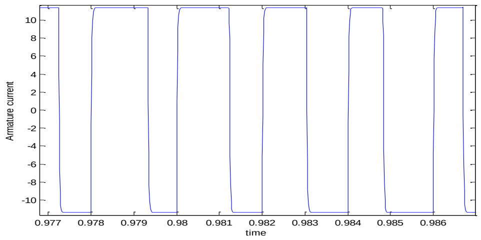


Fig 4 switch power converter

The current in the second half of the armature winding now reverses to provide the reverse MMF allowing the motor to continue to rotate. Incomplete coupling between the two armature windings requires that the leakage energy be dissipated in a R-C snubber that is referenced to the positive supply rail. This commutation process continues in synchronism with rotation.

B. SIMULATION RESULT OF ARMATUR CURRENT



VI. FINITE ELEMENT RESULTS

The model developed in Magnet solver 7.13 is shown in figure 5. The default meshes and the meshes after the placement of nodes at air gap and pole tip for refinement is also compared as the following figures.

A.STATIC 2D SIMULATION RESULTS

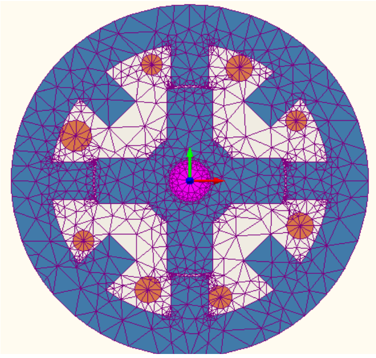


Fig 5. Meshes refinement

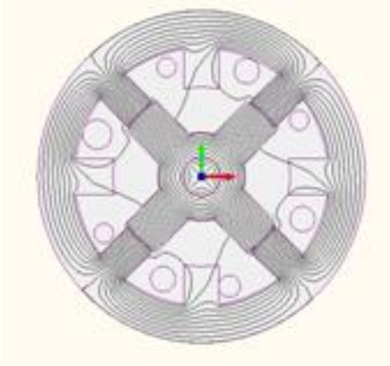


Figure 7a Flux Paths in Aligned

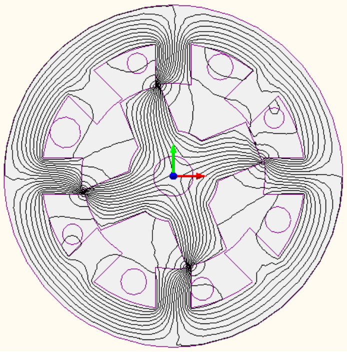


Figure 7b Flux Paths Unaligned Positions

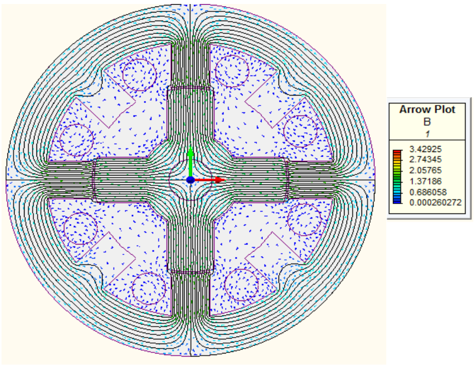


Fig.7c Arrow plot of flux density

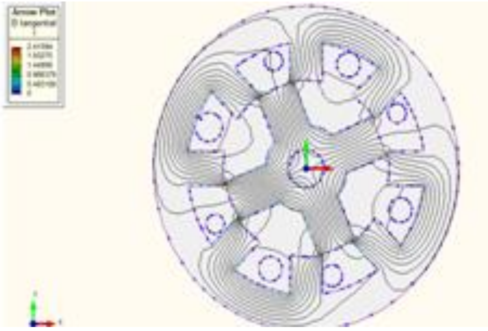


Fig.7d Mutual inductance at 67.5 degree rotor position

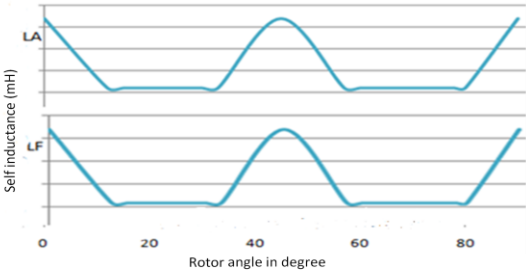


Fig. 7e Self inductace of phase ‘A’ and’F’ for 90 degree rotor postion

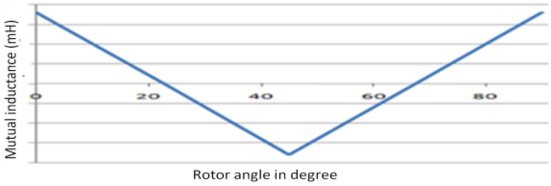


Fig.7f

Mutual inductance as position of rotor varying

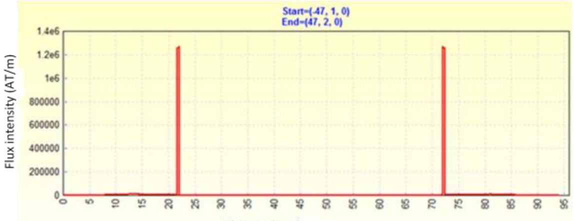


Fig.7g

Magnitude of flux intesity in air gap vs distance across the machine diameter

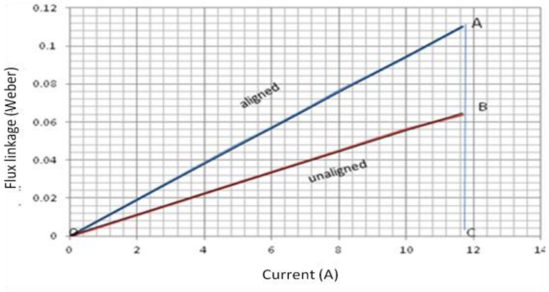


Fig.7h

Flux linkage vs. current plot for self inductance

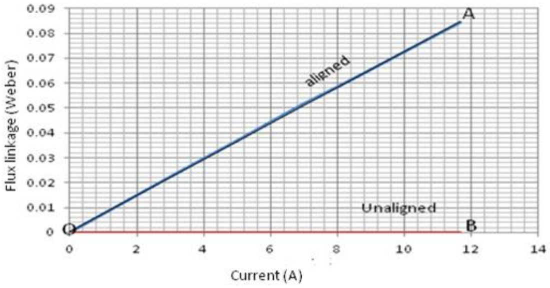


Fig.i Flux linkage vs. current plot for mutual inductance

VII.RESULTS

N.S	Notations	Energy stored and torque
1	W_1	0.545J
2	W_2	1.9983J
3	W	2.5433J
4	T_{av}	12.953Nm

Table 1Average torque and work done Approximately

B. DYNAMIC 2D SIMULATION RESULTS

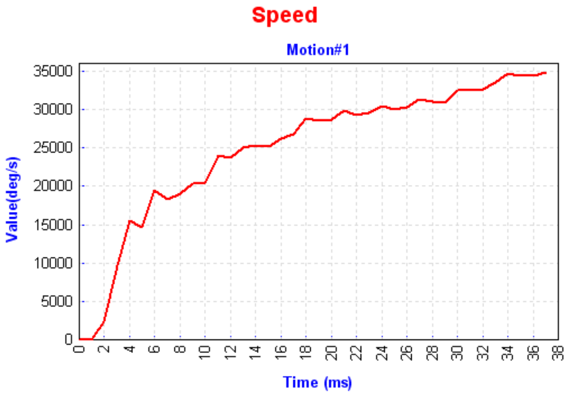
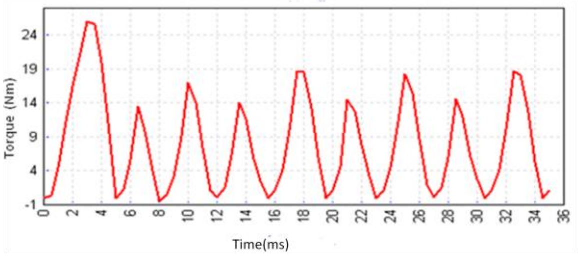


Fig.8a No load speed curve for forward motoring



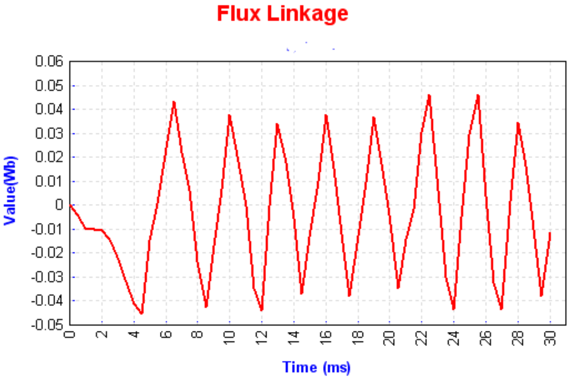


Fig 8b Torque vs time and flux characteristics of the machine

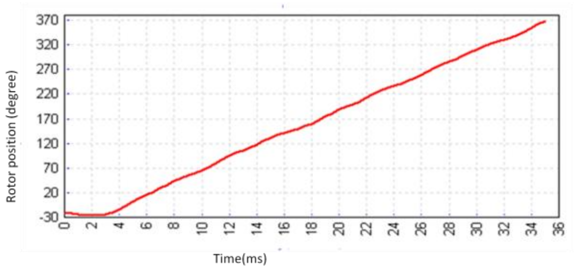


Fig .8c

Position of the rotor vs time characteristics(forward motoring)

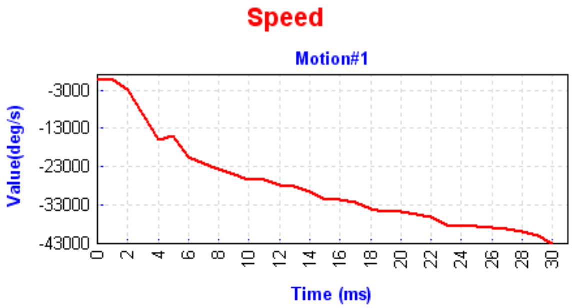


Fig.8e No load speed curve for reverse motoring

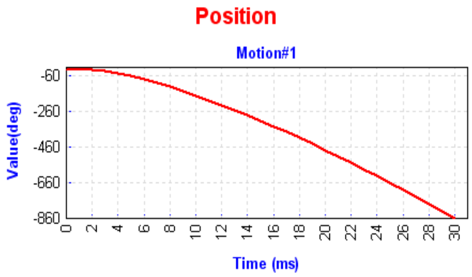


Fig .8f Position of the rotor vs time characteristics(revese motoring)

VIII. CONCLUSION

The paper identifies the features of the powerful simulation software MAGNET 7.13 for the analysis of the field. Analysis of various parameters like co-energy, flux linkages and torque plot reveals that different types of configurations of FSM can be modeled, and analyzed for improving the performance. The simulated solutions have shown that the model is advantageous however in practical situations various other parameters have to be taken into considerations.

VII. REFERENCES

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VIII. BIO GRAPHIES

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Dr.A.Kavitha,assintantProfesor received her B.E. degree from Kamaraji University, and M.E degree and Ph.d from IIT, Madras University and CEG, Anna University respectively. She is a member of ISTE. She is presently working as an assistant professor in the department of electrical engineering in Anna University.