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Mathematical Modelling of Switched Reluctance Motor

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Abstract

The SRM is a doubly salient machine with very high torque to inertia ratio and high fault tolerant capability. SRM is widely used in low, medium and high power drives and high speed drives. This paper describe a mathematical model of switched reluctance motor and its working principle. In addition to this the model is created in SOLIDWORKS and simulated in ANSYS environment.
Keywords- SRM, Switched Reluctance Motor, BLDC

I. INTRODUCTION

The switched reluctance motor are mainly used in hand power tools, fans, pumps, drives for freezers and refrigerators, automotive and transportation applications. The switched reluctance motor has simple and robust structure therefore suitable for vibrating and mining applications. The instantaneous torque developed by switched reluctance motor is independent of phase current polarity. Therefore single switch per phase converter topology can be utilized.in addition to this, no winding on rotor part enable fast speed response and cheap operation with no additional cooling requirements. The switched reluctance motor SOLIDWORKS model consist of two main parts. The shaft is linked to stator part of switched reluctance motor. The combination of this outer rotor & inner stator part can be utilized for transportation application especially in electric bicycle and can be fitted at the front or rear end. Efficient control and energizing techniques can be used to upgrade the performance of this switched reluctance motor. R Krishnan has presented the detailed switched reluctance motor drives design, simulation, modelling, analysis and applications [1].

II. CONSTRUCTION AND WORKING PRINCIPLE OF SWITCHED RELUCTANCE MOTOR

Figure [1] shows the cross sectional view of a conventional Switched Reluctance Motor with six stator poles and four rotor poles powered by three phase supply.

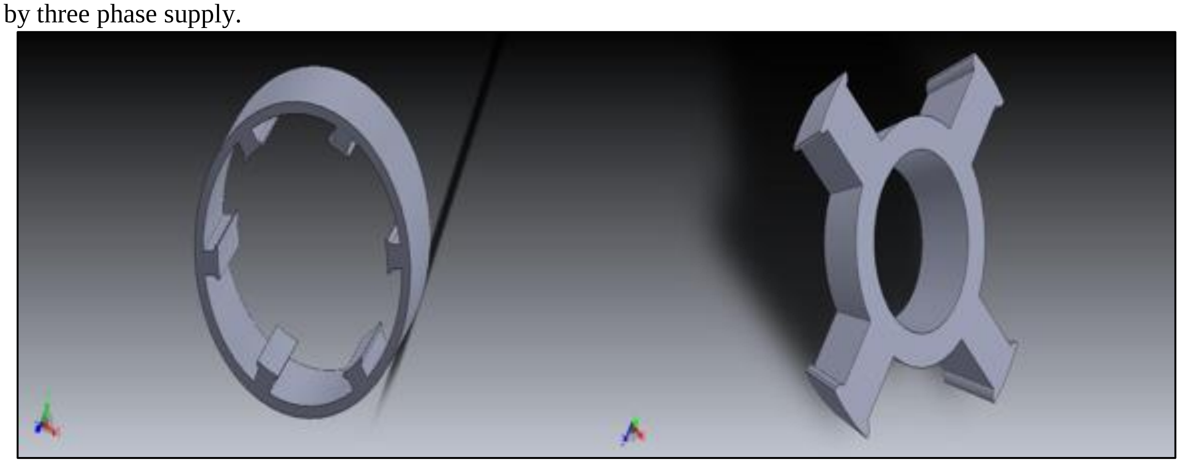

Fig. 1: Stator and Rotor of 6/4 Switched Reluctance Motor (developed in SOLIDWORKS)

Switched Reluctance Motor is a special machine when compared to other Electric Machines especially in India. Construction wise Stator consist of concentrated winding and there is no permanent magnet or winding on the rotor part. Both Stator and Rotor of Switched Reluctance Motor have salient poles and constructed from Steel Laminations as shown in figure [2]. Due to simplicity in construction, the cost of the motor is quite low as compared to other types of electric machines such as induction motor & BLDC motors. Electric machines can be classified into two types depending upon the nature of torque production.one way to produce the torque is due to electromagnet and the other way is due to variable reluctance. In SRM, the torque is produced by variable reluctance mechanism hence it is known as switched reluctance motor.

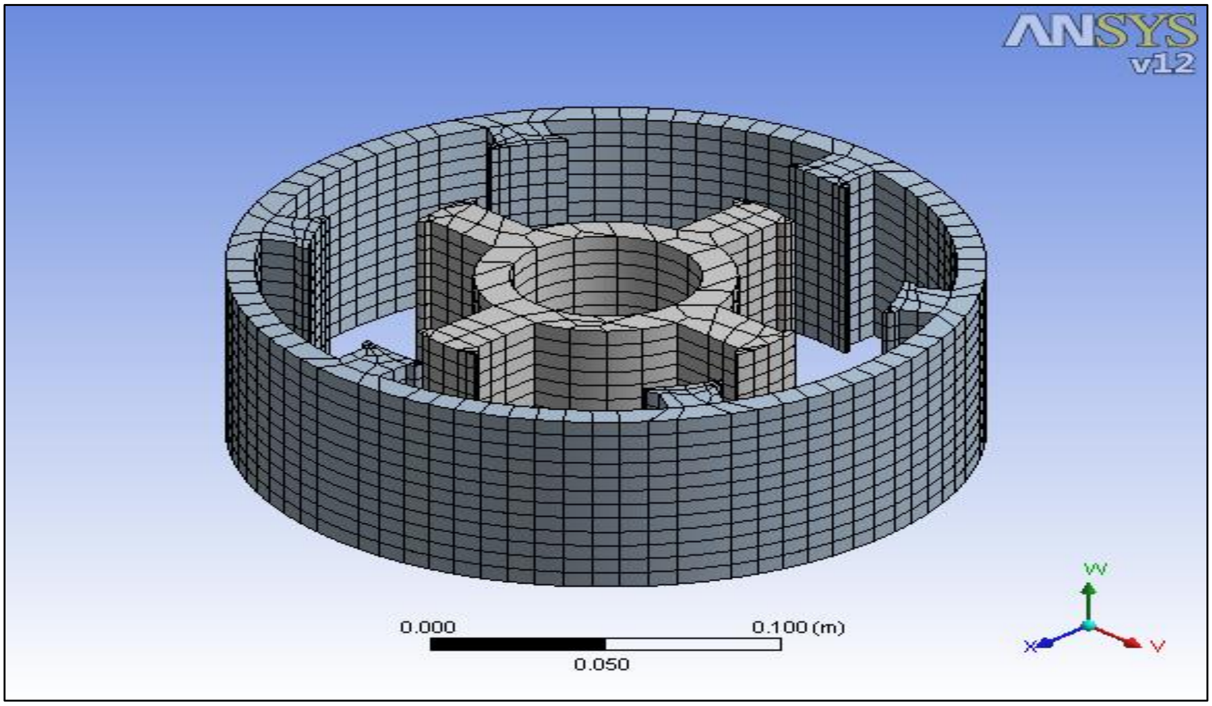

Fig. 2: 6/4 Switched Reluctance Motor Meshing in ANSYS Environment

The main working principle of switched reluctance motor is to give rise to minimum reluctance position or maximum inductance position in order to form a stable equilibrium in electromagnetic system. Stator windings on the diametrically opposite poles are connected in series to produce the torque. When the stator pole pair is energized by phase winding, nearest rotor pole try to attain the position of minimum reluctance. It is possible to develop a torque in either direction of rotation by energizing the consecutive stator poles in sequence.

III. MATHEMATICAL MODEL OF SWITCHED RELUCTANCE MOTOR

In SRM, The applied voltage to a phase is equal to the sum of the resistive voltage drop and the rate of change of flux linkages as given below.

$$v = R_s i + \frac{d\psi(\theta,i)}{dt} \rightarrow equation(1)$$

Where, R_s is the Stator Resistance per Phase and ψ is Flux Linkage per Phase

$$\psi = L(\theta,i)i \rightarrow equation(2)$$

Where, L is the inductance depends upon the rotor position as well as the phase current. Phase Voltage equations, then, is

$$v = R_s i + L(\theta,i)\frac{di}{dt} + i\frac{d\theta}{dt} \cdot \frac{dL(\theta,i)}{d\theta} \rightarrow equation(3)$$

$$v = R_s i + L(\theta,i)\frac{di}{dt} + \frac{dL(\theta,i)}{d\theta}\omega_m i \rightarrow equation(4)$$

$$e = \frac{dL(\theta,i)}{d\theta}\omega_m i = K_b.\omega_m.i \rightarrow equation(5)$$

$$K_b = \frac{dL(\theta,i)}{d\theta} \rightarrow equation(6)$$

In equation (3), the three terms on the right hand side represent Resistive voltage drop, Inductive voltage drop & Induced EMF ‘ e ’ respectively. The instantaneous input power can be written as

$$P_i = vi = R_s i^2 + i^2\frac{dL(\theta,i)}{dt} + L(\theta,i)i\frac{di}{dt} \rightarrow equation(7)$$

$$\text{Time}, t = \frac{\theta}{\omega_m} \rightarrow equation(8)$$

Air gap power equation,

$$P_a = \frac{1}{2} i^2 \frac{dL(\theta,i)}{dt} \rightarrow equation(9)$$

$$P_a = \frac{1}{2} i^2 \frac{dL(\theta,i)}{d\theta} \frac{d\theta}{dt} \rightarrow equation(10)$$

$$P_a = \frac{1}{2} i^2 \frac{dL(\theta,i)}{d\theta} \omega_m \rightarrow equation(11)$$

$$P_a = \omega_m T_e \rightarrow equation(12)$$

By equating the equation (11) and equation (12)

$$T_e = \frac{1}{2} i^2 \frac{dL(\theta,i)}{d\theta} \rightarrow equation(13)$$

Hence in SRM, Torque depends upon the Rotor Position and the Phase Current respectively. The analytical and numerical modelling of switched reluctance machine has been explained clearly by Zhang and Somesan [2-3]

IV. Simulation model of switched reluctance motor

The simulation of a 6/10 switched reluctance motor based on ANSYS environment is shown below. Following specifications are used: Number of Stator and Rotor poles =6/10, Frequency=50 Hz, Number of phase=3, DC supply voltage=48 volts, reference current=35 amps, Unaligned inductance=1.1 mH, Aligned inductance=8.5 mH
Turn on and off angles=0 Degree and 18 Degree respectively,

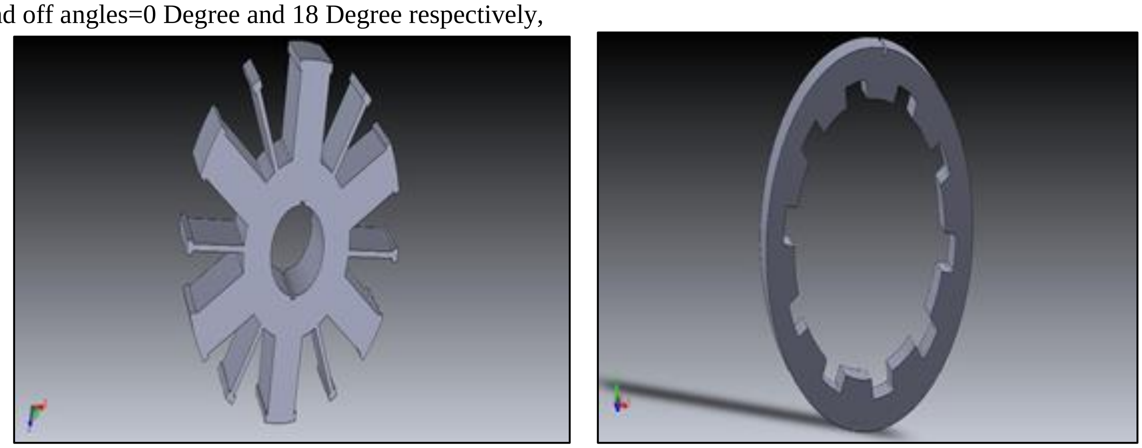

Fig. 3: Stator & Rotor Model developed in SOLIDWORKS

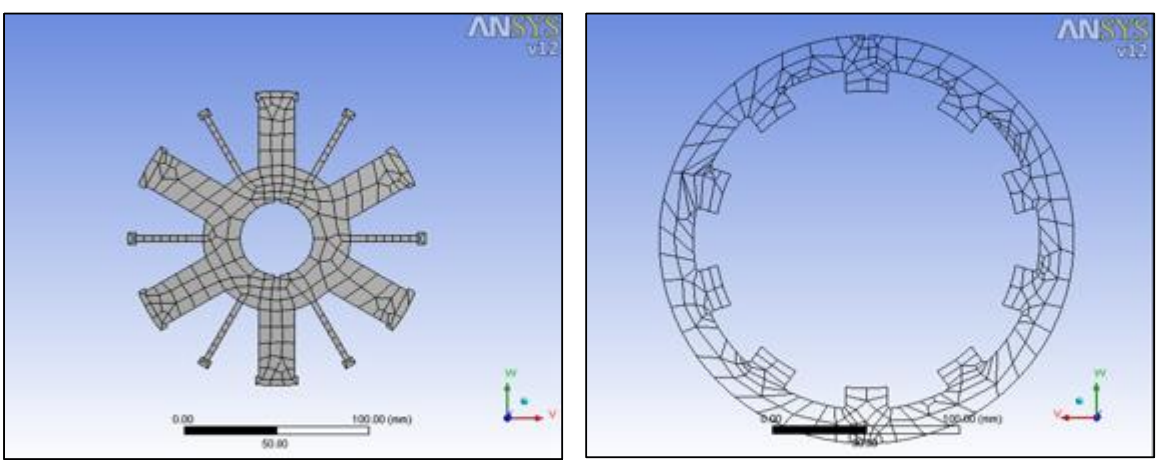

Fig. 4: Stator & Rotor Meshing in ANSYS environment

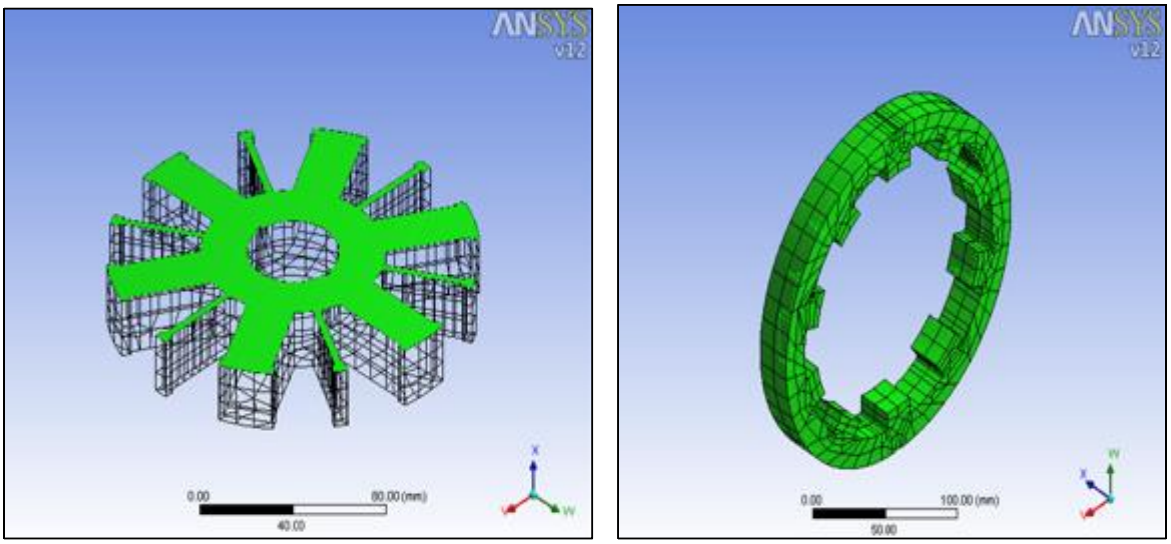

Fig. 5: Stator and Rotor Wireframe in ANSYS environment

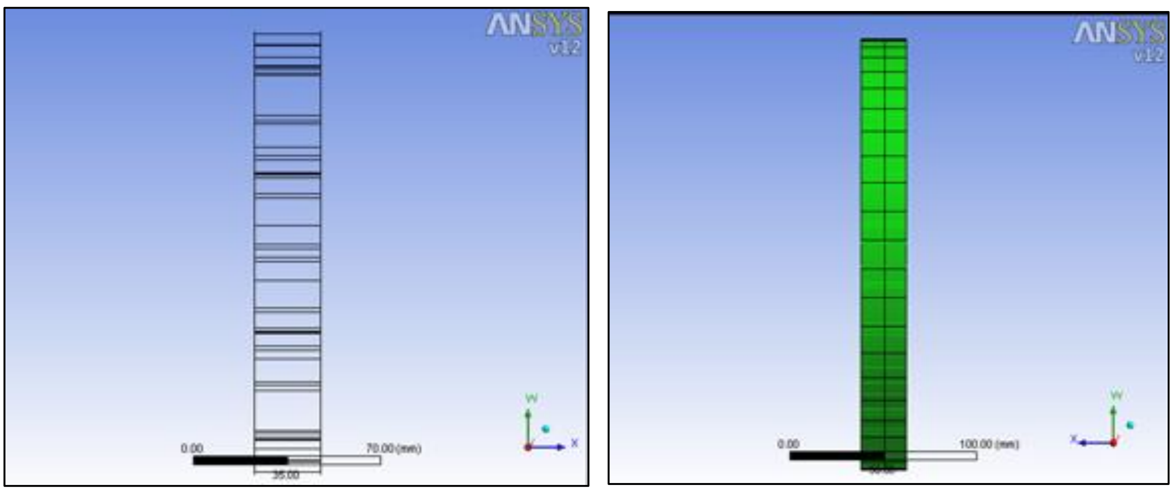

Fig. 6: Stator & Rotor Wireframe in ANSYS environment (Side View)

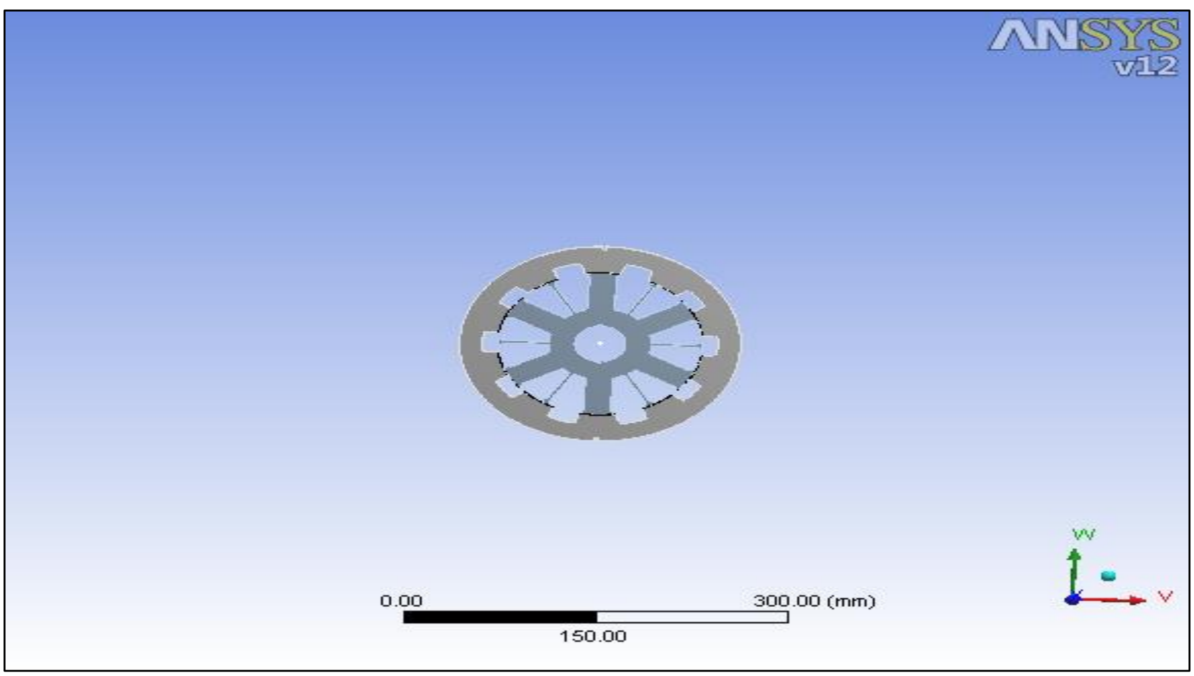

Fig. 7: Realization of Mathematical Model in ANSYS environment

V. CONCLUSIONS

The potential of switched reluctance motor is highly greater in variable speed applications. At the same time. SRM can operate in all the four quadrants. In this paper, switched reluctance motor model is developed in SOLIDWORKS and also tested successfully with the help of finite element analysis in ANSYS environment.

REFERENCES

[1] R.krishnan, "Switched Reluctance Motor drives modelling", London, CRC press, 2001.
[2] Zhang and Li, "Numerical and Analytical modelling of Switched Reluctance Machine", Journal of computers, Vol.7, No 12, Dec 2012.
[3] Somesan and Emil, "simple analytical model of switched reluctance motor for design and control purpose", journal of computer science and control system, Vol-4, No-1, May 2011
[4] Umar & Hilwadi, "modelling & simulation of switched reluctance motor based on COMSOL"2013 IEEE,DOI-10.1109/AIMS.2013.67