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10/8 Conventional Switched Reluctance Motor For Electric Vehicles

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Abstract : This paper presents a novel switched reluctance (SR) motor which has permanent magnets between the stator pole-tips. The proposed SR motor has large torque and high efficiency in comparison with the conventional one. Despite the permanent magnets' presence, no induced voltage nor cogging torque are generated. First, the finite element technique (FEM) is used to explain the influence of the permanent magnets. It is demonstrated that the permanent magnets increase the operating area of the suggested SR motor. The planned motor's availability is then experimentally clarified. When compared to the traditional SR motor, the maximum torque is raised by around 20%, and the efficiency at full load is noticeably enhanced. This indicates that the suggested SR motor can operate both electric and hybrid electric vehicles (HEVs), as it always requires a smooth acceleration under full load or overload conditions.

I. INTRODUCTION

The use of conventional automobiles is the main cause of the current day-to-day increase in environmental pollution. For this reason, electric vehicles are better for reducing pollution. Currently, electric cars have the option of using magnetic motors, such as brushless DC motors and permanent magnet synchronous motors. However, using these two motors causes a variety of issues, including fault tolerance, high cost, and demagnetization. Because of its many benefits, the switching reluctance motor would therefore be more advantageous for electric vehicles after considering these shortcomings of the current motor. The increasing number of internal combustion engine (ICE) vehicles on the road has resulted in increased pollution and energy problems in recent years. Using electric vehicles (EVs) can help minimise pollution, environmental stress, and the number of vehicles that require charging. Since electric motors are essential to electric cars (EVs), several types of EV electric motors were evaluated and tested to see which would function best in various conditions. [1]

The novel low-cost hybrid SRM for variable-speed pumps is made up of rectangular shard permanent magnets. Consequently, there is an increase in both the average torque and the torque ripple. However, because PMs are positioned strategically, the hybrid excitation method increases SRM's efficiency. The SRM could be tricked by the PM's acts because they deviate from their usual behaviour. Furthermore, PMs and rare-earth metals are getting harder to find.

Economical and effective motors will be essential in the age of electric vehicles. However, the cost of producing machines with PMs will rise due to the restricted supply and increasing demand for PMs. In these circumstances, the PM's electric motor integration technique is not a workable solution for maintaining a high torque/power density.[7]

II. LITERATURE SURVEY

Economical and effective motors will be essential in the age of electric vehicles. However, the cost of producing machines with PMs will rise due to the restricted supply and increasing demand for PMs. In these circumstances, the PM's electric motor integration technique is not a workable solution for maintaining a high torque/power density.

The bench test conducted in the anechoic chamber confirms the efficacy of the research methodology. The system model and stator core were created using finite element software while taking the anisotropy of the materials into account. A modal experiment was utilised to validate the simulation model. As a result, the study's findings can be applied to the creation of automobile permanent magnet synchronous motors as well as investigations into the causes of electromagnetic vibration and noise.[1]

The stator, rotor, and entire motor construction vibrate as a result of the noise produced by the magnetic field in the motor gap pulsating. The motor's design specifications and electromagnetic load define the motor's electromagnetic noise level. Structural noise accounts for the majority of electromagnetic noise; this can be caused by a variety of factors, such as an unevenly sized air gap, an eccentric stator and rotor, or an improperly fitted stator and rotor slot.

The operator's health will be impacted by the motor's noise, which is a combination of various frequencies and sound intensities that can reach up to 110 dB or higher. Consequently, the mechanism of a permanent magnet synchronous motor and the modelling approach for electromagnetic vibration and noise prediction are very crucial.[2]

Excitation modal knockout experiments are used to validate the simulation model, which includes a stator core and stator system model that takes material anisotropy properties into account. The sensitivity of anisotropic material parameters is also examined. The two main components of the stator system are the winding and the stator core. The winding is constructed of hairpin-style flat wire winding, while the stator core is composed of multilayer silicon steel sheets laminated in an axial orientation.

The material parameters exhibit clear orthogonal anisotropy, which is caused by the axial laminated structure of the stator core and results in varying mechanical properties along different directions. Accurate modelling of these properties directly influences the simulation accuracy of the electromagnetic vibration noise of the motor.[3]

This torque–speed profile cannot be produced by an internal combustion engine (ICE). Therefore, a vehicle with an ICE needs a multiple gear gearbox. Certain electric devices can produce an extended constant power range if they are properly constructed and controlled. This research aims to explore the potential applications of switching reluctance motors (SRMs) for electric and hybrid vehicle systems.

There will be two steps in the course of this study. To determine the motor's static characteristics, the machine design and finite-element analysis are used in the first phase. We will investigate the effects of various stator and rotor pole widths and pole heights on the motor's dynamic and steady state performance.[4]

III. WORKING PRINCIPLE

3.1 Switched Reluctance Motors:

A varied torque is produced as a result of the rotor part's fluctuating reluctance caused by this stimulation. The rotor rotates as a result of this created torque, aligning it with the excited stator phase. The excited coil's inductance is maximised when the rotor pole is aligned with the excited stator pole. The production of torque is independent of the direction of the current since it is directly proportional to the square of the current. If the phases are aroused successively, we can generate a torque that rotates constantly.

Reluctance torque powers an electric motor known as a switched reluctance motor (SRM). In contrast to typical brushed DC motor types, the stator's (case) windings get power delivery instead of the rotor's. Variable Reluctance Motor (VRM) is another name for Switched Reluctance Motor (SRM). A magnetic circuit's ability to block the passage of magnetic flux lines equal to the ratio of the magnetic flux to the magneto motive force.[5]

Construction of Switched Reluctance Motors:

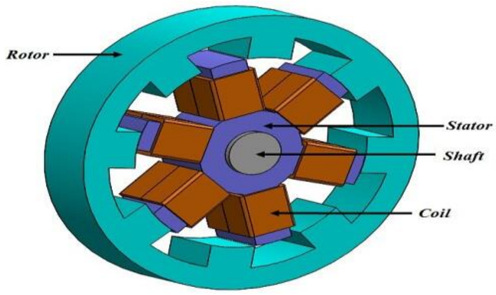


Fig 1. Switched Reluctance Motor

An electric motor that uses the ferromagnetic material's propensity to migrate towards areas of stronger magnetic fields is called a switching reluctance motor (SRM). A rotor with a set of salient poles and a stator with a set of winding coils make up the motor.[5]

3.2 Working of Switched Reluctance Motors:

The neighbouring rotor teeth are drawn towards the energised stator poles by a magnetic field created when a current is supplied to a certain set of stator windings. A change in the rotor's position causes the current to be transferred to a different set of stator windings as the rotor teeth advance towards the energised stator poles. The rotor rotates as a result of a series of magnetic attraction and repulsion forces created when the current is switched to different stator windings. A microprocessor or equivalent electronic control system manages this sequence, choosing the best time and length for the current pulses. The number of rotor teeth and the frequency of current pulses influence an SRM's rotation speed. The angle formed by the stator and rotor poles and the strength of the magnetic field both affect how much torque an SRM can produce.[5]

IV. MODELLING OF SRM DRIVES

4.1 Elementary operation of the switched reluctance motor:

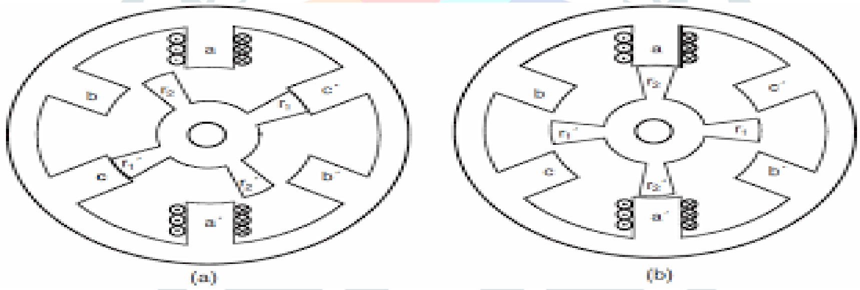
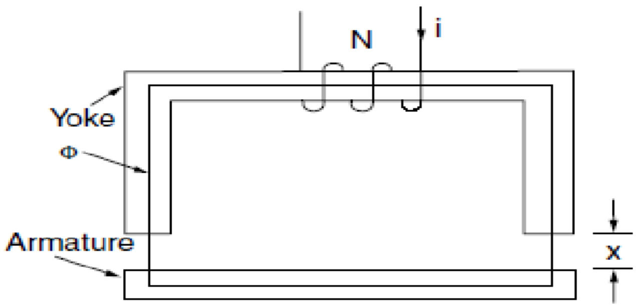


Fig. 2 (a) Phase c aligned **Fig. 2 (b) Phase a aligned**.

4.2 Principle of operation of the switched reluctance motor:



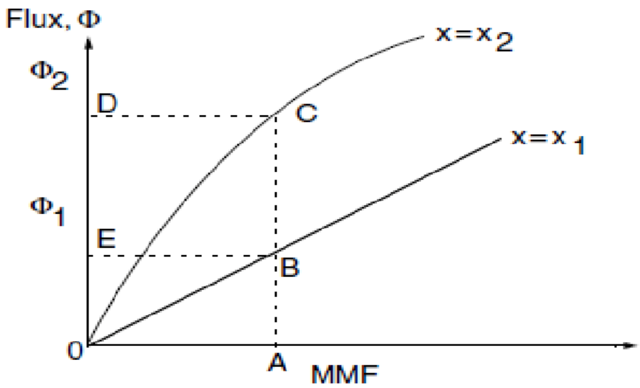


Fig.3 (a) A solenoid. **Fig.3 (b) Flux vs mmf characteristics**.

The basic idea of electromechanical energy conversion in a solenoid, as illustrated in Figure 3.3a, can be used to explain the torque output in the switching reluctance motor. The coil creates a flux φ when the solenoid, which has N turns, is energised by a current i. The armature will move towards the fixed yoke as the excitation current is increased. Figure 3.3b plots the flux vs. magneto

motive force (mmf) for two air gap values, 1 2 x and x, where x1 > x2. Due to the air gap's dominant resistance, which causes the flux in the magnetic circuit to be reduced, the flux vs. mmf characteristics for x1 are linear.
The electrical input energy is written as:

$$W_e = \int ei\,dt = \int i\,dt \cdot \frac{dN\phi}{dt} = \int Ni\,d\phi = \int F\,d\phi \quad \ldots\ldots\ldots (3.1)$$

Where e is the induced emf and F is the mmf. This input electrical energy, We is equal to the sum of energy stored in the coil, W_f, and energy converted into mechanical work, W_m. It is written as:

$$W_e = W_f + W_m \quad \ldots\ldots\ldots.. (3.2)$$

Equation (3.1) gives the value of the stored field energy when there is no mechanical effort done, such as when the armature starts at point x1. This relates to Figure 3.3b's region OBEO. The co energy, also known as the complement of the field energy, is represented mathematically as Σ ϕ dF and is provided by area OBAO in Figure 3.3b. Similar to this, area OCDO provides the field energy and area OCAO provides the co energy for the armature's position x2. Equation (3.2), for incremental changes, is expressed as follows:

$$\delta W_e = \delta W_f + \delta W_m \quad \ldots\ldots\ldots.. (3.3)$$

4.3 Torque–Speed Characteristics:

Three zones can be identified in the torque–speed plane of an SRM drive, as illustrated in Fig. The zone below the base speed ωb, or the highest speed at which the motor can run at rated voltage and maximum rated current with fixed firing angles, is known as the constant torque region. Stated differently, ωb represents the minimum speed at which the motor can function at its rated power.

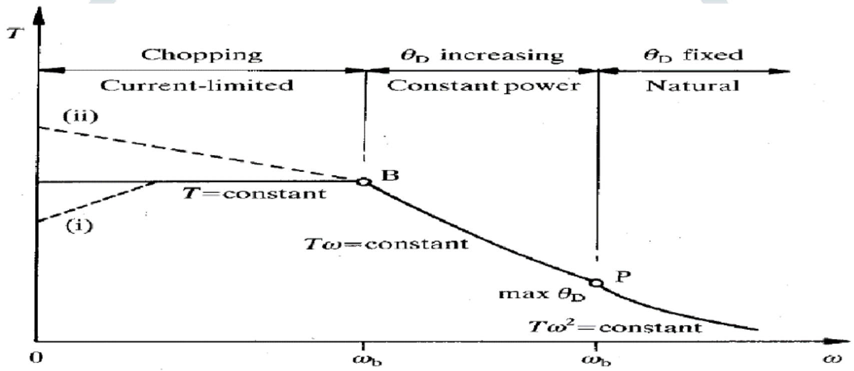


Fig.4 Torque Speed Characteristics of SRM

Region 1:

Due to the low back-emf in the low-speed operating range, the current increases practically instantly upon turn-on. With the use of regulators, such as voltage PWM controllers or hysteresis controllers, the current can be adjusted to any desired level. Phase advance the turn-on angle to allow the current to grow to the required level against a lower back-emf. As the motor speed increases, the back-emf quickly approaches the DC bus voltage. To sustain the greatest torque production, PWM or chopping control can still drive the maximum current into the motor.[5]

Region 2:

Pole overlap initiates when the back-emf in high-speed operation surpasses the DC bus voltage, at which point PWM or chopping control is no longer feasible and the current starts to drop. When the SRM is operated with a fixed conduction angle (θdwell), or dwell angle, and a fixed supply voltage, its inherent feature is that the current and phase excitation time decrease inversely with speed. Given that the torque is approximately proportional to the square of the current, T α 1/ω2 defines the natural torque–speed relationship. It is possible to increase the effective amps delivered to the phase by increasing the conduction angle. By modifying the conduction angle θdwell in conjunction with the single-pulse mode of operation, the torque production is kept at a sufficiently high level in this area. The constant power area is named thus because the controller keeps the torque inversely proportional to the speed. By moving the turn-on angle forward, the conduction angle is raised until the □ dwell hits its maximum at a speed of ωp. It is possible to maintain constant power operating throughout a fairly large medium speed range and reach very high maximum speeds.[5]

V. RESULTS AND DISCUSSION:

5.1 Design model for Conventional 10/8 Switched reluctance Motor:

Fig 5.1 shows the design model for conventional 10/8 switched reluctance motor. In this fig the model represents various blocks such as Five phase converter, Regulator, Battery supply etc.

Table no.1 represents various parameters of switched reluctance motor which includes stator resistance, inertia, Friction, stator and rotor poles, input DC voltage etc. The simulations are results are obtained and are shown as in Fig 5.2 and 5.3.
Fig 5.2 shows the simulation results of conventional 10/8 switched reluctance motor. The results show 4 waveforms i.e. Flux-Time, Current -Time, Torque-Time, Speed-Time. Fig 5.3 shows the zoomed results of the simulation results.

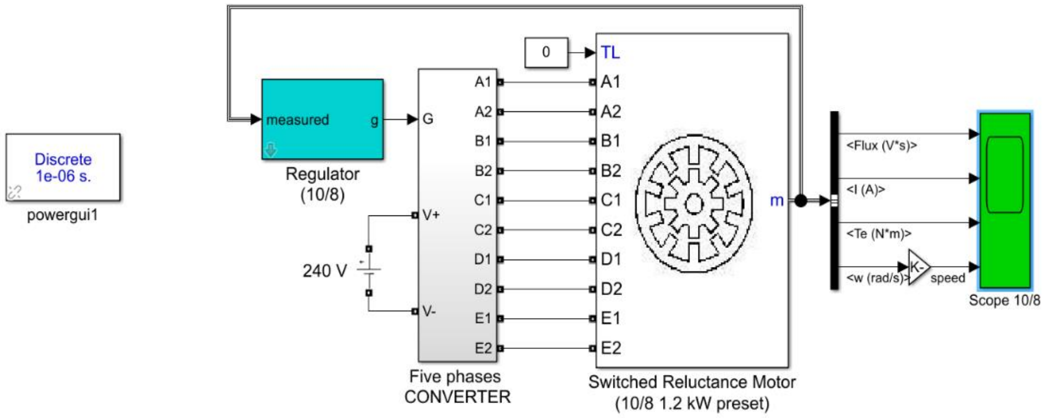


Fig.5.1 Design model for Conventional 10/8 Switched reluctance Motor:

Table No. 1 Parameters of SRM used in simulation.

Parameters	Value	Unit
Stator Resistance	0.05	Ohm
Inertia	0.05	Kg/m2
Friction	0.02	N-m-s
Initial Speed	0	Rad/sec
Initial Position	0	
Stator Pole	10	
Rotor Pole	8	
Input DC Voltage	240	volt

5.2 MATLAB Simulation Results:

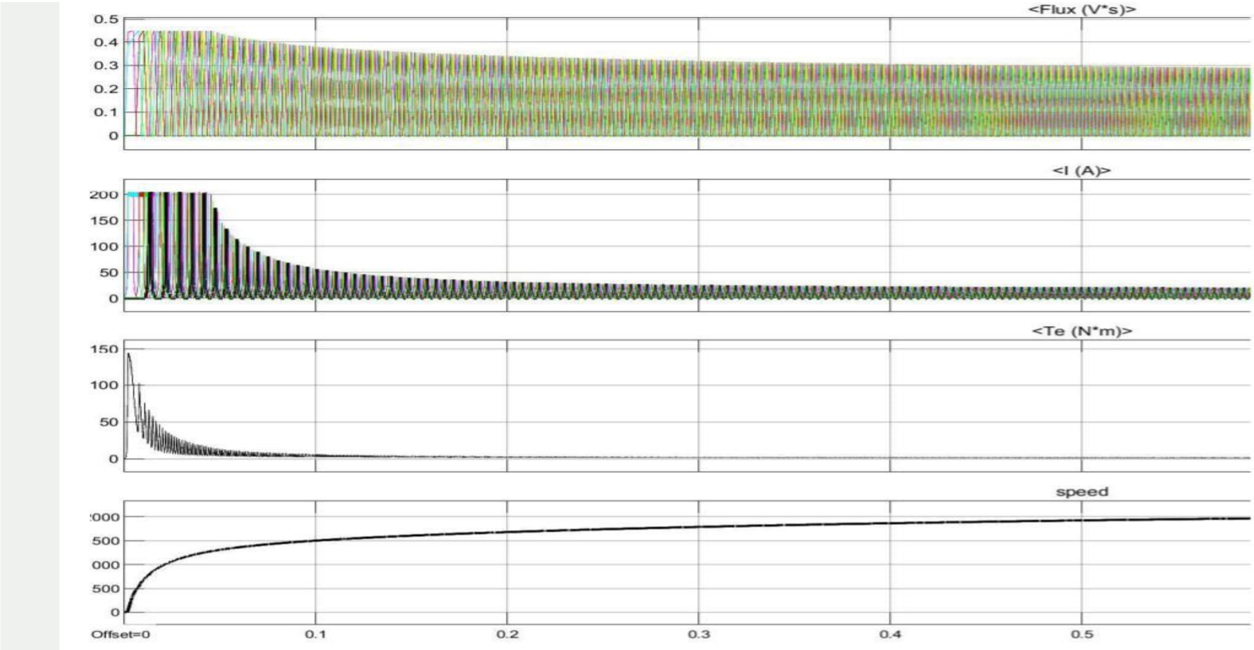


Fig 5.2 MATLAB Simulation Results:

5.3 MATLAB Simulation Zoomed Results:

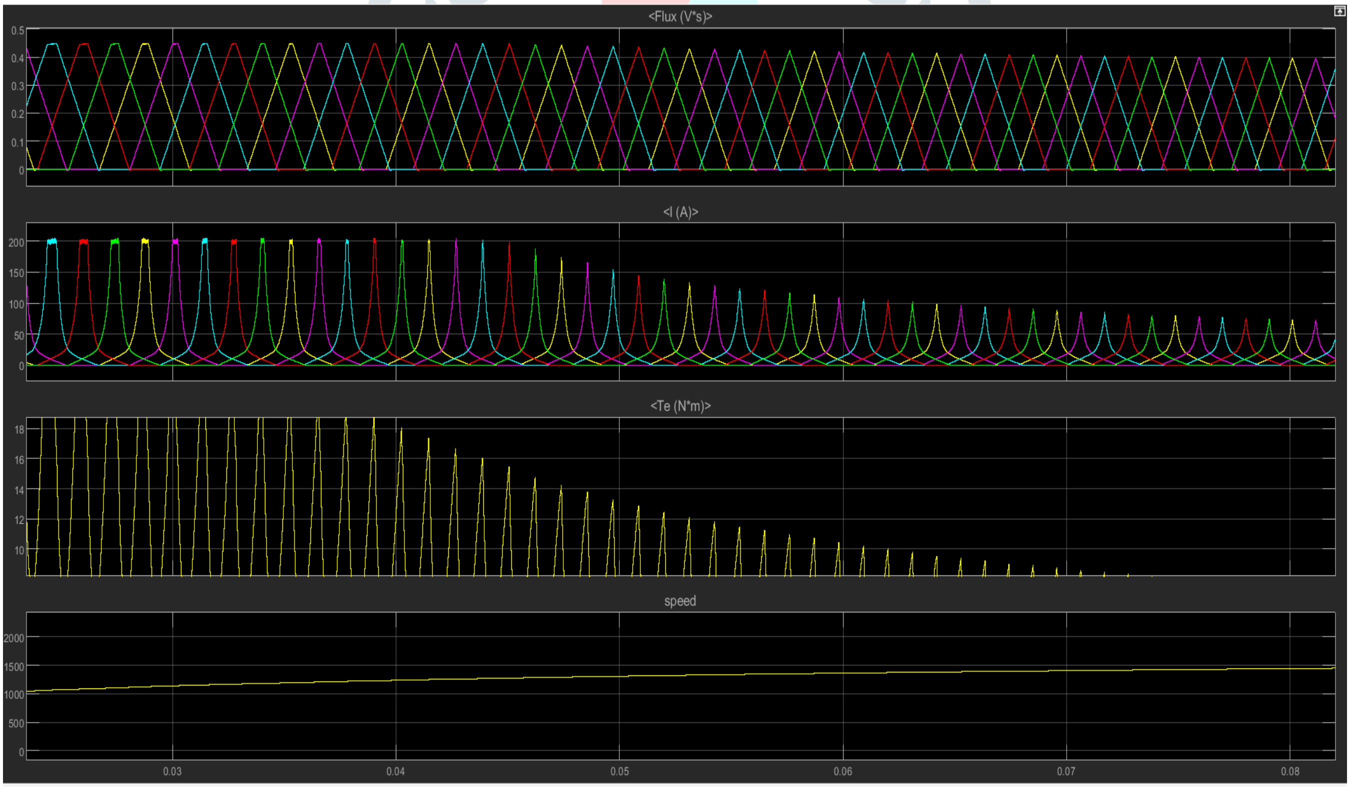


Fig 5.3 MATLAB Simulation Zoomed Results:

The torque ripple and average torque in SRM drives are influenced by the motor phase current waveforms as well as the turn-on and turn-off angles. Furthermore, these attributes vary in relation to the motor speed. It is very desirable to have the lowest torque ripple and the best torque/ampere ratio over the widest speed range in many applications, such as electric car drives. By applying the proper pre-calculated turn-on and turn-off angles in function of the motor current and speed, the SRM torque characteristic may be optimised.

6. Conclusion

In this study, an EV model is created by fusing the vehicle dynamic equations with the SRM dynamic simulation model. Based on the motor operation zones and accelerator pedal coefficient, the motor drive system's command torque is determined. The paper has the design of a 10/8 SRM displayed. The design considers factors such winding excitation voltage, slot filling factor, and switching pattern. The modelling results validated the projected high efficiency of SRM, specifically its back emf and harmonic components.

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