MINIMIZATION OF TORQUE RIPPLE IN SWITCHED RELUCTANCE MOTOR -A REVIEW

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Abstract – This paper presents a literature review on minimization torque ripple in Switched Reluctance Motor (SRM). Various converter topologies are available for SRM and new compact converter topologies are proposed by researchers for the further improvisation in the performance of SRM. Due to its doubly salient and non-linear characteristics, it has inherent torque ripples, which produces acoustic noise and also affect its performance.

Keywords- SRM, Torque Ripple, Compact power converter.

I. INTRODUCTION

An electromechanical device which converts electric energy to mechanical energy is called an electric motor. A device that converts mechanical energy into electrical energy is called generator. The same device is often used for both purposes.

In a rotating electric machine the part that moves is called the rotor and the part that is stationary is called the stator. A motor is based on the tendency of its movable parts to move to a position where the minimum reluctance in the applied magnetic field is called a reluctance motor.

In a motor the currents are switched between the different phases to keep the rotor in constant motion towards a position of minimum reluctance is known as Switched Reluctance Motor (SRM).

II. SWITCHED RELUCTANCE MOTOR

Since 1969, a variable reluctance motor has been proposed for variable speed applications. The origin of this motor can be traced back to 1842, but the "reinvention" has been possible due to the advent of inexpensive, high-power switching devices. Even though this machine is a type of synchronous machine, it has certain novel features. It has wound field coils of a dc motor for its stator windings and has no coils or magnets on its rotor. Both the stator and rotor have salient poles, hence the machine is referred to as a doubly salient machine. The rotor is aligned whenever diametrically opposite stator poles are excited. In a magnetic circuit, the rotating member prefers to come to the minimum reluctance position at the instance of excitation. While two rotor poles are aligned to the two stator poles, another set of rotor poles is out of alignment with respect to a different set of stator poles. Then, this set of stator poles is excited to bring the rotor poles into alignment. Likewise, by sequentially

switching the currents into the stator windings, the rotor is rotated. The movement of the rotor, hence the production of torque and power, involves switching of currents into stator windings when there is a variation of reluctance; therefore, this variable speed motor drive is referred to as a SRM drive.

SRM is an extremely simple machine with a rotor which does not have any permanent magnets or windings on it and a laminated stator with uncomplicated concentrated windings on each pole.

III. LITERATURE REVIEW

The structure of SRM including doubly salient pole with singly excited system causes the torque ripples. Many research has been carried out for the minimization the torque ripples to fully utilize the merits of SRM. There are several control methods, motor design and power converter topologies have been proposed to reduce the torque ripples and acoustic noise. This literature survey deals with the SRM topologies, principles, torque production, control methods, converter structures. The torque ripple minimization is the ultimate aim of this survey.

Motor Topologies

Paper [1] presents a unique rotor structure optimized by mistreatment the extent set methodology to boost the static torsion characteristics of a high speed SRM. It was described that metameric rotor construction improves the torsion output and potency. Paper [2] discusses a SRM with metameric rotor construction designed for direct drive application. Outer rotor is present in such type of motor. It's found that in such motors, the torsion output will increase once there are higher range of rotor segments than mechanical device poles.

SRM offers a good sort of side ratios and salient pole topologies while not poignant performance an excessive amount of. This implies that every application is probably going to be higher suited to a selected switched reluctance topology.

The costs of SRM drives are a mix of the prices of the motor and therefore the electrical converter. They powerfully rely upon the amount of phases of the motor. The terribly high torsion ripple and inability to begin in the slightest degree angular positions represents a disadvantage. They will gift interest just for terribly high speed applications.

Other Novel Motor

Paper [27] [28] show many novel SRMs configuration with higher range of rotor poles than mechanical device poles. The simulation results show that this motor produces higher torsion per unit volume and comparable torsion ripple in comparison to a standard SRM.

Paper [6] are styles of novel bearing-less SRMs. totally different from the traditional bearing-less SRMs, the suspending poles of the planned bearing-less SRMs are separated from the part torsion poles. Sheer placed suspending poles are designed to supply a continual radial force for rotor bearing. As a result of severally placed suspending and torsion poles, the created suspending force has wonderful dimensionality in keeping with rotor position and

freelance characteristics of the torsion current. The management of air gap is less complicated than the traditional one from the linear and freelance characteristics.

Paper [35] describes the planning of an axial-type SRM with the aim of up the output torsion characteristic. The axial-type structure has many benefits, as well as an outsized air-gap space thanks to the dependence on the radial length, whereas the air-gap space of the radial-type motor depends on the axial length. This advantage is anticipated to extend the inductance and therefore the output torsion.

Paper [36] [3] [37] gift the reciprocally coupled dual-channel SRMs to supply higher torsion density and reduce the noise emission and torsion ripple.

In paper [12], a unique variety of hybrid reluctance motor drive is bestowed. This new motor is characterized by a mechanical device fashioned by a mix of freelance magnetic structures, every one composed of Associate in Nursing magnet, the core with one or many coils wound on that, related to a magnet disposed between their poles. The rotor has an equivalent configuration of a SRM with none coil, magnets, or cage. This new variety of motor doesn't gift cogging torsion and has higher power and potency than a SRM of an equivalent size.

Torque Production

The torsion or force production during a SRM is also found from the variation of the hold on magnetic energy as operates of the rotor position. This relationship is additionally won't to analyze magnetic force relays, holding magnets, magnet actuators, and alternative devices wherever force is created between 2 magnetic surfaces, as well as all motors with salience. The main points of mathematical equations and torsion production within the paper [53] [18].

Flux Linkage

In paper [25], a quick measure methodology of the flux linkage profile is planned. Within the planned methodology, the rotor is initial turned to the aligned position, and then, the voltage pulses are applied to any or all phases at the same time. The DC voltage and part current waveforms are recorded to estimate the flux linkage curves at 3 totally different positions. These curves are won't to calculate the coefficients of a second-order series flux linkage model, that represents the whole flux linkage profile of a SRM.

Rotor Position

Paper [11] presents a unique methodology for position sensing element elimination for SRMs. mistreatment the voltage from every conducting part and therefore the reference current signal as inputs, the rotor speed is initial obtained because the output of a neuro-fuzzy learning system used as a "virtual" speed sensing element. Then, the rotor position is set by desegregation the calculable worth of speed.

Paper [51] presents another position estimation methodology mistreatment the primary switch harmonics through series. Paper [52] presents a technique of correct indirect position estimation for SRM is appropriate for beginning and continuous operation mistreatment pulse injection and to thresholds.

A new technique referred to as linear quadratic regression position estimation technique for sensor-less beginning of SRM has been developed in paper [34]. It's supported a polynomial model of the magnetic characteristics of the motor. The most feature is that no specific magnetic info is required and no calculation of flux linkage or current gradients is important. Solely current activity is required and therefore the tactic is powerful and might be simply custom-made to any SRM. The calculations are easy that solely involve easy matrix operation.

Converter Structures for Switched Reluctance Motor

The novel convertor topology has been planned in paper [14] for SRM. The planned convertor circuit relies on 2 pack switch modules and bifilar windings. Compared with ancient SRM converters, it solely needs the 0.5 variety of 2 pack switch modules. What is more, this convertor has the easy topology and might operate beneath charging, freewheeling, and discharging modes.

Paper [15] proposes associate degree optimization technique for a SRM fed by associate degree uneven bridge convertor. The optimized SRM produces a pair of 2.5 time's larger minimum torsion than that of the initial motor within the low speed vary.

Paper [29] investigates the energy conversion potency of SRMs with zero-voltage loop current commutation. Zero-voltage loop commutation in SRM operation may end up in an exceedingly vital improvement of their performance by lowering the flux linkage peaks and harmonic magnitudes of the magnetic flux densities inside the core of the SRM.

A new switch pattern generating algorithmic program for a single-bus star-connected SRM drive was introduced in paper [30]. This technique permits a (n+1) section uneven electrical converter to regulate associate degree n section SRM in four-quadrant modes of operation.

SRMs area unit terribly appropriate for top speed applications. However, once running at high speeds, fast braking becomes troublesome as a result of the regeneration energy might increase the DC link voltage to an important level if a diode rectifier bridge is employed for AC-DC conversion.

Paper [32] investigates the connection between the regeneration energy and therefore the DC link voltage and proposes an electrical braking theme using 2 section excitations. Throughout braking, rather than make the excessive rotor mechanical energy back to the DC link, the energy is dissipated within the mechanical device winding resistance. Therefore, the rotor will stop safely inside a brief time.

Power convertor Fault identification

In paper [9], a brand new algorithmic program for period identification of power convertor faults in SRM drives is planned. The conferred technique uses the measured section currents solely, that area unit already Simulation of Switched Reluctance Motor and management supported MATLAB setting out there for the drive management. The planned algorithmic program effectively detects the electrical converter faulty section and is capable of localizing the faulty power switch.

Paper [10] provides a scientific classification for the present position sensor-less techniques employed in SRM drives. Their performances area unit analyzed beneath section

fault condition. A family of fault resilient methods for position sensor-less techniques of SRM drives beneath single and point faults is conferred.

Paper [11] presents a brand new configuration for dual-channel SRM referred to as decoupled DCSRM beneath traditional and open-circuit fault operations. To realize fault-tolerant operation, a bearing strategy of open-circuit faults for the DDCSRM drive is conferred. The key of the fault-tolerant management strategy is to keep up the rotor speed because the traditional driving operation.

Paper [33] describes four main fault kinds of the uneven bridge power convertor in SRM drive on power transistors. 2 on-line fault identification ways for power transistors within the power convertor area unit planned. The principle of the planned identification ways is to find the important time current state from some explicit positions, then acquire the identification result and therefore the fault location by logical judgment. One fault identification technique is planned exploitation single current sensing element observation the shredded bus current; the opposite technique is exploitation twin current sensors theme observation the higher freewheeling bus current and excitation bus current.

Eccentricity Faults Identification

Paper [17] presents a comprehensive technique for eccentricity fault identification in SRM throughout offline and standstill modes. During this technique, the fault signature is achieved by process the differential currents resulted from injected high frequency diagnostic pulses

In paper [19], a comprehensive technique for eccentricity fault identification in SRM supported mechanical device voltage signature throughout offline and standstill modes is given. This sensor-less technique is in a position to observe incidence, location, direction, and severity of the eccentricity fault in SRM.

A standard mechanical device SRM for fault tolerant drive systems is planned in paper [20]. As a result of the actual construction of the mechanical device there's no mutual coupling between adjacent phases. Hence, the motor will work conjointly once a section of the coils is faulted and also the faulted modules may be replaced while not uncoupling the motor from the load or gear case.

Torque Ripple Reduction

Paper [47] presents an impression technique for force ripple diminution within the SRM drive, supported a torque-sharing operate construct. Within the planned technique, the reference force is directly translated into the reference current undulation exploitation the analytical expression. The method in paper [48] exploitation punching holes in rotor poles to switch the waveforms of flux moreover as derivatives of inductances with reference to rotor position is planned.

In paper [16], supported the output force analysis at the rotor position for the given air-gap, the air-gap is changed to cut back the force ripple. In paper [49], a SRM style that improves force output by exploitation segmental rotor topology with 5 phases is intended and evaluated.

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Vibration and Acoustic Noise

Paper [44] describes AN environmental and life cycle price (LCC) analysis of 1 SRM drive and 2 inverter-fed induction motor drives. Environmental impact and LCC were evaluated according the Methodology for the Eco-design of Energy-Using merchandise and accounting completely different operation conditions. The SRM drive was found to own less environmental impact than were the IM drives which incorporates background level and life cycle price etc.

Paper [8] uses a multi-physic analysis to check mechanical vibration between a double-stator SRM (DSSRM) and a standard SRM with a similar outer diameter, yoke thickness, and output power. It's been shown that not solely is that the radial force amplitude smaller within the DSSRM, the force distribution during this motor tends to supply a lower vibration level. Prediction of acoustic noise distribution generated by electrical motors has become AN integral a part of style and management in noise sensitive applications.

In paper [7], a quick and precise technique for prediction of acoustic noise in SRM is given. Exploitation this technique, acceleration of the inquiring network on the mechanical device frame may be calculated from the rotor position and part current/voltage waveforms. Consequently, magnetism and transient structural finite-element analysis may be bypassed for his or her low computation potency. With the acceleration of the inquiring network accessible, full structural response may be enlarged for BEM that permits for effective computation of acoustic noise in SRM drives.

Paper [6] presents a multi-physics analysis to predict the acoustic radiation properties of a SRM. The planned technique uses a 2-D finite-element model of the motor to simulate its magnetic properties and a multi-physics mechatronic model of the motor and controls to simulate operative conditions.

In paper [43], magnetism interference in operated SRM drive is analyzed, which incorporates mechanism of magnetism interference (EMI) noise generation in SRM drive, performance comparison of noise supply internal resistivity extraction ways. Moreover, the answer of SRM drive EMI noise is optimized by creating use of economic integration based mostly higher cognitive process parameters modelling technique.

Paper [31] presents one part SRM with inclined mechanical device and rotor in order that the acoustic noise and vibration are considerably reduced. During this paper, the distribution of the RF with reference to the skew angles is analyzed through the finite-element technique simulation to style one part SRM with the considerably reduced vibration and noise.

Applications

In paper [26] [5], it's been shown that a SRM may be designed to be competitive to the IPM motor utilized during a HEV within the purpose of read of force density, efficiency,

and torque-speed vary. It absolutely was shown that force may be enhanced because the variety of poles is enhanced. It's conjointly found that the fictional SRM includes a smart correspondence to the designed worth within the purpose of read of inductances and potency in lightweight load tests.

Paper [21] [41] [22] gift the applying of the SRMs with the next variety of rotor poles in electrical vehicles. And also the results show the planned motor has been ready to guarantee enough mechanical strength to work at the desired high speed and bring home the bacon higher force and power densities compared to existing motors.

Paper [4] presents a completely unique 3 part SRM drive with integrated charging functions (including burning engine and grid charging) for plug-in hybrid electrical vehicles. Paper [40] compares the dynamic performance computation for a 12/8 dual-channel switched reluctance generator underneath single- and dual-channel operation modes.

Paper [24] describes the developed 3 part 6/8 poles switched reluctance external rotor motor drive for a follower in air conditioning. The 3 part uneven bridge power convertor was utilized in the drive system.

Paper [38], a standard mechanical device construction is planned for a SRM to be used for the air and water pumps of chemical analysis instrumentality. Paper [28] presents the planning, implementation and driving management of a SRM for driven cooling fan.

Paper [39] presents the planning, analysis and management of a high speed SRM with round shape magnetic bearings for craft application. The main points of modelling and controller style procedures for the round shape magnetic bearings-rotor system supported a voltage controlled model while not electrical circuit square measure planned.

IV. CONCLUSION

The torque ripples of the SRM are due to the doubly salient structure of the machine. The above literature studies suggested many techniques to control the torque ripple .However, it has been concluded that the torque ripples can be minimized up to 5% -10%. One of the suitable ways to control the torque ripple and acoustic noise is the selection of appropriate power converter to the SRM. In the future it will be interesting to obtain the low cost and efficient power converter for minimization of torque ripple during high speed operation. SRM will plays a vital role and surprisingly it replaces the place of induction motor in the industries by its inexpensive and smoothening operation.

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