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DRIVE STRATEGIES FOR SWITCHED RELUCTANCE MOTOR – A REVIEW

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Abstract

A typical switched reluctance motor (SRM) drive system is made up of three basic components: power electronic converter, control logic circuit and the switched reluctance motor. The principle of operation of a SRM motor is quite simple: as current passes through one of its stator windings, torque is produced by the tendency of its rotor to align with the excited stator pole. The direction of the torque generated is a function of rotor position with respect to the phase that is energized, and is independent of direction of flow of current in that specific winding. The torque production can be made continuous by synchronizing the excitation of each phase winding with rotor position. The amount of current passing through the SRM winding is controlled by suitably making the power electronic switches on and off, which can connect each SRM phase to the DC bus. The drive strategy of a SRM motor predominantly consists of the power electronic drive topology because it largely dictates how the motor can be used. This paper presents different drive techniques for a SRM motor collected from researches of a number of technologists.

1. Introduction

The reluctance motor is one of the oldest electric motor designed conceptually during year 1830 to year 1850. Due to its complexity of control it could not find wide applications and thus slowly lost importance until mid 1960 when lots of new inventions in the areas of power electronics boosted the researchers to explore the possibility of use of SRM with a finer control. In this motor, torque is produced by the tendency of its rotating part to move to a position where the inductance of the excited winding is maximized. Switched Reluctance Motor (SRM) is a type of doubly salient synchronous machine and hence highly non-linear in characteristics.

2. Drive System

During the last years, various convertersfigurations / topologies used in SRM drive have been developed in the research laboratories. Their functionality emerges from some basic technical and economical requirements and constraints.

There are several configurations of converters used in SRM drives. Many authors have detailed the category and structures of the converter topologies.

Slobodan Vukosavid and Victor R. Stefanovid have proposed [3] different inverter power and control circuits for using as drives of SRM. Peak voltage and current ratings of the power electronic switches as well as the size and peak ratings of the dc-link components have been chosen for comparison of performance of different types of drive technologies. In [4], J Corda and M Olaca have presented a procedure for computing the losses in the switching circuit of power electronic converter of the SRM drive. Mike Barnes and Charles Pollock have classified different converter methodology [8]. A.C. Clothier, B.C. Mecrow [10] have explored the use of inverters based on the three phase bridge topology and have emphasized on their usages for both short pitched and full pitched winding SRMs. In [11], authors have made a classification of SRM converter topologies with a detailed analysis of each topology. In [26], investigation on the characteristics of asymmetric converter and full-bridge inverter was made. Zhu Yueying and others have detailed research progress of SRM drive system, as well further research topics are suggested in [35]. Lin He, Hexu Sun, Jie Gao [42] have carried out performance research of topologies of power converter for SRM.

On the light of above research and presentations, the converters may be classified into categories (topologies) like (1) half bridge (2) self commutating (3) force commutating (with extra commutation circuits).

A. Half Bridge Topology

Charles Pollock and Barry W. Williams have presented [1] a converter circuit for four phase reluctance motor, using only four power electronic switches each being rated at the motor voltage. In [2], the authors have given particular attention to the choice of converter topology while proposing a design technique for SRM drive using single-switch-per-phase converter with. Do Hyun Jang , Iqbal Husain have proposed a modification of the (n+l) switch converter topology for star-connected SRM drive, which is suitable for low speed as well as high speed operation. Freewheeling circuit with a dual time constant has been designed to reduce the current tail in decreasing inductance region, which reduces the negative torque and improves the system efficiency. In [6], R. Krishnan has proposed a new converter topology having minimum number of power switching devices each of them having same voltage rating. He also proposed that variable dc voltage should be applied to the motor windings to reduce the switching frequency of switches and hence the switching and core losses and higher and fixed dc voltage for faster commutation of phase currents. H. Chen Y. Zhu D. Zhang [13] have presented four topologies of the power converter main circuit for the three-phase 12/8 structure SRM drive. In [14], authors have proposed a single-phase power factor corrected converter to operate near unity power factor. S.J. Watkins, I. Corda and L. Zhang have proposed a new family of multilevel asymmetric power converters which are suitable for unipolar current loads [15]. In [18] a novel SRM drive is proposed, entirely based on standard industrial inverter modules. Zeljko Grbo, Slobodan Vukosavic, and Emil Levi in [19] presented a technique based on utilization of standard inverter legs, one of its most important feature is that both magnetizing and demagnetizing voltage may reach the DC-bus voltage level while being contemporarily applied during the conduction overlap in the SRM adjacent phases. In [20], authors have proposed a sensorless circuit with SEPIC for improved power factor. R. Krishnan and others gave an innovative four-quadrant SRM drive with only one controllable switch [21]. In [22], a characteristic analysis of SRM considering hard chopping and dc link voltage ripple by using time-stepped voltage source finite element method in which the magnetic field is combined with drive circuit is presented. An improved sensor less driving method for SRM using a phase-shift circuit technique is presented in [27]. In [28], a fault tolerant power converter, applied to a four phases switched reluctance motor was presented. Jui Yuan Chai and Chang-Ming Liaw have detailed [33] the development and control for a SRM drive with front-end switch mode rectifier (SMR). In [34], the authors have proposed , a new drive circuit from the bridge family circuit which uses resonant circuit during discharge period. The new topology provides faster rate of current discharge. In [36], a 32-bit digital signal processor based controller has been proposed to solve the nonlinear problems of the switched reluctance motor in which fuzzy-PI hybrid algorithm has been used to control the motor speed and the phase current. Hung-Chun Chang and Chang-Ming Liaw have presented [38] an integrated SRM drive for electric vehicles using off-the-shelf three-phase intelligent power modules. Adel Deris Zadeh [40] has developed a new converter for SRM drive which uses one switch in each phase. In [41], a new low-cost, brushless variable-speed drive requiring only a single controllable switch is presented. In [45], M Rajesh and Bhim Singh have presented the power quality improvement in the midpoint converter based SRM drive using a Vienna rectifier. Jianing Liang and others have presented [46] a simple integrated SRM drive with bridgeless PFC converter. In [47], a low cost Asymmetric Bridge Converter (ABC) is presented where a different type of MOSFET driver is used. A new and cost effective converter, for switched reluctance motor drives is proposed in [48] where new method used is component sharing, thus it significantly reduces half of the component cost.

B. Self Commutating Topology

They are consisting of H bridge, current source, series resonant configurations. Some researchers (M. M. Alaee, E. Afjei, and S. Ataei) have worked on new driver for switched reluctance motor. The driver features zero-current switching. It means all the switching operations are done when the phase current crosses the zero level, therefore it reduces the overall power loss in the switching process. Also provides faster rate of rise and fall of current which helps the motor to operate at higher speeds when the resonance phenomenon is employed. Also a new drive circuit from the bridge family which uses resonant circuit during discharge period is also worked on and presented. The new topology provides faster rate of current discharge.

However these are modified Asymmetric Bridge Drive Circuit for SRM with incorporation of several components and can be thought of extension of half bridge configuration.

C. Force Commutating Topology

This type consists of configuration with extra commutation circuits, DC link voltage boost, split DC or extra DC-DC converter, magnetic and dissipative components.

(a) Capacitive

Sayeed Mir, Iqbal Husain, and Malik E. Elbuluk have presented [7] energy-efficient converter topologies, derived from the conventional C-dump converter having specific advantages. A new split source type converter topology has been presented in [9]. A novel single-stage power factor corrected drive to achieve sinusoidal, near unity power factor input currents has been proposed by Feel Soon Kang and others in [12]. The proposed drive has no additional active switch which combines a DC link capacitor used as dc source and a drive used for driving the motor into one power stage. This structure is simple and has low cost. In [23], authors have described the buck–boost converter topology where boost converter is used to improve the input sinusoidal current and the buck converter is used to regulate the dc source voltage. Keunsoo Ha, Cheewoo Lee, Jaehyuck Kim have presented [24] a two-phase flux-reversal-free-stator SRM and a split ac converter. The authors in [25] have described a single-phase SRM drive system which includes the realization of a drive circuit for the reduction of torque ripple and PF improvement. In [29], a multilevel converter is proposed to have an enhanced performance at a high speed range. M. Gopinath, S. Ramareddy [32] have presented digital simulation of bridgeless PFC boost rectifiers, also called dual boost PFC rectifiers. Performance comparison between the conventional PFC boost rectifier and the bridgeless PFC boost rectifier is performed. In [37], authors have presented a simple, easy to fabricate power drive to minimize the speed oscillation of a switched reluctance motor. The integrated drive consists of a controlled rectifier, a split DC switched converter and a switched reluctance motor (SRM). Kenta Chimata and others have detailed [44] the authors proposed a novel drive circuit with voltage boost function without additional reactor for SRM.

(b) Magnetic

K.Y. Cho and J.Y. Lim have presented [16] a power converter circuit for a SRM motor, which consists of one switching device per phase and a dump capacitor, auxiliary switch and fly back transformer. In [17] authors proposed converter using the winding of SR motor as an input inductor for power-factor-correction. A single capacitor active snubber circuit has been designed and tested by authors of [30] for the asymmetric inverters used to drive switched reluctance motors. E. Afjei, M. Asgar, and S. Ataei have described [31] a new drive circuit where a capacitor is connected in series with the motor bifilar winding. In [39], a new bifilar drive circuit which uses dump capacitor during discharge period is presented. The new topology utilizes the bifilar winding in conjunction with the dump capacitor to produce resonance in order to provide faster rate of current discharge. This technique permits the motor to operate at higher speeds. M.Asgar, A.Siadatan and E.Afjei have proposed in [43] a new method (A Swappable Single Phase bifilar drive converter) which overcomes some problems like reliable starting without the use of permanent magnet or any other starting device.

(c) Dissipative

This converter has the disadvantage that the current in any of phases will take longer time to decay compared to recharging the source and also the energy is dissipated in a resistor, thus reducing the overall efficiency of the motor drive. It is also unable to apply zero voltage output during current conduction. However these drives are compact in size and low cost. It finds few applications in low speed and low switching frequency drive.

3. Conclusion

The subject of drive structures for SRM has been covered in the literature focused. From the discussions, it is observed that the structure of a power electronic converter useable with SRM should be capable of controlling the SRM in accordance to the rules, intervals and switching angles. Therefore, it is necessary to determine: (a) the structure of the converter, i.e. the number and the place of the switches; (b) the static and dynamic characteristics of the switches for best possible and trouble free operation of SRM. Conforming to the above, the sources of input and output of a converter being characterized (voltage or current source, reversibility) and the inter-connection rules of the sources being known, the converter structure can be deducted. The basic configuration will allow all possible interconnections between a given input and output source. Since there is a remarkable development in power electronic devices and computer aided control technologies, extremely fine control of a machine is possible. With the presently available technologies, as discussed in the above sections, drive strategies for SRM can be furthered for newer and newer applications.

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