Design & Speed Regulation of Linear Switch Reluctance Motor
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Abstract:
Switched reluctance motor is the simplest of all electrical machines in constructional aspects. The main advantages are structural simplicity, high reliability and low cost. However, the SRM has some limitations as it should be perfectly electronically commutated, the motor should have good speed regulation and it is overcome by enhancing the controller. The switched reluctance machine motion is produced because of the variable reluctance in the air gap between the rotor and the stator. When a stator winding is energized, producing a single magnetic field, reluctance torque is produced by the tendency of the rotor to move to its minimum reluctance position. In this project, our objective is to reduce the losses in the motor and give accurate speed regulation. Switched reluctance motors have been extensively studied by researchers for their unparalleled advantages in many applications. The linear versions have been developed around the world in the last couple of decades because of attributes similar to that of rotary switched reluctance motor (RSRM). Owing to their frugal design, robust built and high force density, the linear switched reluctance motor (LSRM) has had significant stages of development and optimization. The flexibility in design and operation makes LSRM a prime contender for any linear motor-actuator application.

Keywords: Switched Reluctance motor, speed regulation, rotary switched reluctance motor, losses controller.

I. INTRODUCTION

Majority of industrial drives use AC Switched reluctance motor (SRM) drives are simpler in construction compared to induction and synchronous motors. Their combination with power electronic controllers may yield an economical solution. The structure of the motor is simple with concentrated coils on the stator and neither windings nor brushes on the rotor. This apparent simplicity of its construction is deceptive. SRM drives present several advantages as high efficiency, maximum operating speed, good performance of the motor in terms of torque/inertia ratio together with four-quadrant operation, making it an attractive solution for variable speed applications. The very wide size, power and speed range together with the economic aspects of its construction, will give the SRM place in the drives family.

The performances of SRM strongly depend on the applied control. Three main parts can be identified: the motor itself, the power electronic converter and the controller. The drive system, comprising signal processing, power converter and motor must be designed as a whole for a specific application.

There is one converter unit per phase. A battery or a rectifier supplies the DC power. The basic principle is simple: each phase is supplied with DC voltage by its power electronic converter unit as dictated by the control unit, developing a torque, which tends to move the rotor poles in line with the energized stator poles in order to maximize the inductance of the excited coils. An important fact is that the torque production is independent of the direction of current, which contributes to the reduction of the number of switches per phase.

II. Problem Specifications

SRM drive is known to provide good adjustable speed characteristics with high efficiency. However, higher torque ripple and lack of the precise speed control are drawbacks of this motor. These problems lie in the fact that SRM drive is not operated with an mmf current specified for dwell angle and input voltage. To have precise speed control with a high efficiency drive, SRM drive has to control the dwell angle and input voltage instantaneously. The advance angle in the dwell angle control is adjusted to have high efficiency drive through efficiency test.

Block diagram

<table>
<thead>
<tr>
<th>AC SOURCE</th>
<th>RECTIFIER</th>
<th>CONVERTER</th>
<th>SRM</th>
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<tr>
<td></td>
<td></td>
<td>CONTROLLER</td>
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Research Article
Volume 8 Issue No.5

International Journal of Engineering Science and Computing, May 2018
http://ijesc.org/
A DC supply voltage of 240 V is used. The converter turn-on and turn-off angles are kept constant at 45 deg and 75 deg, respectively, over the speed range. The reference current is 200 A and the hysteresis band is chosen as 10 A. The SRM is started by applying the step reference to the regulator input. The acceleration rate depends on the load characteristics. To shorten the starting time, a very light load was chosen. Since only the currents are controlled, the motor speed will increase according to the mechanical dynamics of the system. The SRM drive waveforms (phase voltages, magnetic flux, windings currents, motor torque, motor speed) are displayed on the scope. As can be noted, the SRM torque has a very high torque ripple component which is due to the transitions of the currents from one phase to the following one. This torque ripple is a particular characteristic of the SRM and it depends mainly on the converter’s turn-on and turn-off angles. In observing the drive’s waveforms, we can remark that the SRM operation speed range can be divided into two regions according to the converter operating mode: current-controlled and voltage-fed.

**Brief about converter**

The selection of converter topology for a certain application is an important issue. Basically, the SRM converter has some requirements, such as:

1) Each phase of the SR motor should be able to conduct independently of the other phases. It means that one phase has at least one switch for motor operation.
2) The converter should be able to demagnetize the phase before it steps into the regenerating region. If the machine is operating as a motor, it should be able to excite the phase before it enters the generating region. In order to improve the performance, such as higher efficiency, faster excitation time, fast demagnetization, high power, fault tolerance etc.
3) The converter should be able to allow phase overlap control.
4) The converter should be able to utilize the demagnetization energy from the outgoing phase in a useful way by either feeding it back to the source (DC-link capacitor).
5) In order to make the commutation period small the converter should generate a sufficiently high negative voltage for the outgoing phase to reduce demagnetization time.
6) The converter should be able freewheel during the chopping period to reduce the switching frequency. So the switching loss and hysteresis loss may be reduced.
7) The converter should be able to support high positive excitation voltage for building up a higher phase current, which may improve the output power of motor.

**MATLAB SIMULATION**

Low cost converter for Switched Reluctance Motor (SRM) control. Many types of converters are implemented to drive SRM. Generally Asymmetric Bridge Converter (ABC) is selected in which two switches are used per phase to excite the winding. The upper transistor in ABC faces a problem in gate-source voltage which prevents SRM phase to be excited properly. Some methods are used to solve the problem which are usually increases the cost and also decreases the efficiency of the converter circuit. The problem is basically related to the custom Mosfet drivers.

![An Asymmetric bridge converter is adopted here, it's function is implemented by using MATLAB/SIMULINK. The simulation model of converter block for one phase is shown. The asymmetric bridge converter is the most used converter. Eachmachine phase is connected to an asymmetric half bridge consisting of two power switches and two diodes. Figure 11 illustrates the asymmetric bridgeconverter circuit for a 6/4 SRM. The complete DC voltage can be used to energize and de-energize amachine phase in hard chopping mode. When a pair of switches is closed, aphase will be energized from the](http://ijesc.org/)
positive DC voltage supply. When both switches are opened, the current commutates from the switches to the diodes. The voltage across the phase is now the negative DC voltage. These asymmetric half bridges permit soft switching operations as well, thus obtaining a zero voltage freewheeling state (i.e.) the phase is energized from the positive DC voltage and de-energized at zero voltage. No restriction exists to prevent energizing two phases at the same time, thus achieving a higher torque. The disadvantage of this converter is the higher number of power semiconductor elements as each half bridge needs two switches and two diodes.

**Full simulation model**

![Simulation Model Diagram]

In this example, a DC supply voltage of 240 V is used. The converter turn-on and turn-off angles are kept constant at 45 deg and 75 deg, respectively, over the speed range. The reference current is 200 A and the hysteresis band is chosen as ±10 A. The SRM is started by applying the step reference to the regulator input. The acceleration rate depends on the load characteristics. To shorten the starting time, a very light load was chosen. Since only the currents are controlled, the motor speed will increase according to the mechanical dynamics of the system. The SRM drive waveforms (phase voltages, magnetic flux, windings currents, motor torque, motor speed) are displayed on the scope. As can be noted, the SRM torque has a very high torque ripple component which is due to the transitions of the currents from one phase to the following one. This torque ripple is a particular characteristic of the SRM and it depends mainly on the converter's turn-on and turn-off angles. In observing the drive's waveforms, we can remark that the SRM operation speed range can be divided into two regions according to the converter operating mode: current-controlled and voltage-fed.

**Current-controlled mode**

From stand still up to about 3000 rpm, the motor's emf is low and the current can be regulated to the reference value. In this operation mode, the average value of the developed torque is approximately proportional to the current reference. In addition to the torque ripple due to phase transitions, we note also the torque ripple created by the switching of the hysteresis regulator. This operation mode is also called constant torque operation.

**Voltage-fed mode**

For speeds above 3000 rpm, the motor's emf is high and the phase currents cannot attain the reference value imposed by the current regulators. The converter operation changes naturally to voltage-fed mode in which there is no modulation of the power switches. They remain closed during their active periods and the constant DC supply voltage is continuously applied to the phase windings. This results in linear varying flux waveforms as shown on the scope. In voltage-fed mode, the SRM develops its 'natural' characteristic in which the average value of the developed torque is inversely proportional to the motor speed. Since the hysteresis regulator is inactive in this case, only torque ripple due to phase transitions is present in the torque waveforms.

**Optimization of the Torque Characteristic - Adaptive Switching Angle**

In SRM drives, both the average torque and torque ripple are affected by the turn-on and turn-off angles and by the current
waveforms in the motor phases. And these characteristics change as a function of the motor speed. In many applications, electric vehicle drives for instance, it is highly desirable to have highest torque/ampere ratio and lowest torque ripple and this over a widest speed range possible. The SRM torque characteristic can be optimized by applying appropriated pre-calculated turn-on and turn-off angles in function of the motor current and speed. The optimum values of optimum angles can be stored in a 2-D lookup table.

Simulation result

![Simulation results](image)

Conclusion

The goal of this report is to introduce the basic principles of switched reluctance motor, main motor and converter topologies, and mathematical approach. Also this report has described and discussed in detail how from MATLAB one can achieve the simulation environment for SRM. Torque or force production in a reluctance motor is developed from the variation of the stored magnetic energy as a function of the rotor position. Torque production, interval control and switching angles have been described. From the simulation results, it can be seen that the switching angle has a significant impact to the SRM output (torque, speed, phase current and back EMF etc.). The current control and speed control works well, but it only works with the low motor speed. By comparing the simulation results based on different simulation environment, it can be seen that the MATLAB environment and Simulink environment will significant impact the simulation results.

REFERENCES


