The Design of Flux Linkage Measurement for Switched Reluctance Motor

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Abstract. A Back Propagation neural network (BPNN) flux linkage model was proposed based on the measured magnetization curve for 8/6 poles switched reluctance motor (SRM). A flux linkage measuring installation is set up by using a digital signal processor (DSP) and measuring the voltage of winding under different rotor positions and different current values, then obtained the value of the corresponding flux linkage and the rotor magnetization characteristics of different positions. The flux linkage has higher accuracy. The design has the actual reference value to the high performance speed control of SRM.

1 Introduction

With the development of modern power electronics technology, automatic control technology, Switched Reluctance Machine (here in after referred to as SRM) is a new speed motor [1-2], which uses pulsed power supply circuit, and is a typical brushless motor, which has been widely applied in industrial. The key to high-performance control of SRM is the magnetic chain control, and flux linkage control characteristic is an important characteristic of SRM, which is the key to achieving high performance motor speed control. Due to the saturation state work in depth, the special structure of its torque ripple of SRM, how to suppress the torque ripple from a control point of view has become a hot research for scholars today. To solve the torque ripple, there is the need for accurate and fast torque and flux linkage model. Flux linkage measurements are usually characteristic finite element method [3-4] or by experimental measurements. Finite element method ignores the role of the ends of the magnetic field of the motor, low accuracy, especially when the winding current is small, the error is relatively large [5], to facilitate the realization measurement method, high precision measurement, is taken to obtain the magnetic chain characteristics the primary method. Literature [6-9] using sinusoidal AC power to measure basic magnetization curves, this method requires a different voltage values measured for each rotor position under heavy workload. Literature [10] based on DSP measuring capacitor discharge process winding voltage and current.

On the base of study of SRM flux linkage feature detection method, it designs a SRM flux linkage
detection system based on DSP. Using serial communication functions and analog to digital conversion of DSP for different position of the motor rotor voltage and real-time sampling current, transfer to the host computer by conversion, and calculates magnetization curves of SRM. Based on the analysis of experimental results, use BPNN network to build nonlinear relationship of phase current, flux linkage and rotor position angle. As simulation and experimental results shows, that the magnetic chain model established by the method, has better generalization ability in a different position angle of the rotor and the current, and a high accuracy, and has a high reference value to the optimization of motor control.

2 SRM flux linkage detection based on DSP

SRM winding voltage equation is as follows:

\[ U = Ri + \frac{d\psi}{dt} \]  

(1)

Flux linkage equation:

\[ \psi(t) = \int_0^t [u(t) - Ri(t)] dt + \psi(0) \]  

(2)

The \((2)\) discretization:

\[ \psi(k) = \sum_{i=t}^{k} [u(k) - Ri(k)] \Delta t + \psi(0) \]  

(3)

The \((1) \sim (3)\) formula:

- \(U\)——Phase winding terminal voltage;  \(R\)——Phase winding resistance;
- \(i\)——Phase current;  \(\Psi\)——Phase winding flux linkage values;
- \(\Delta t\)——Sampling period;  \(k\)——Number of sampling points

The system uses step signal method to measure the voltage and current of phase winding, and the system block diagram shows in figure 1. In figure 1, performed on 220V AC power electronic converter after treatment to obtain the DC voltage, which is in charge for a capacitance C until the completion, as the switch S is closed, and when the main switch MOSFET is turned on, the capacitor C supply the stator phase winding. Series resistor R is to limit the rise rate of amplitude and phase current, to prevent damaging the windings of SRM for overheating. SRM rotor terminal socket a disc which fixes on the bench with the identity of angel and a pointer, which indicates the position of the rotor, and the above two are concentric with the shaft. DSP, as the control center of the entire system, provides on-off signals for the power control MOSFET, to control the on-off of phase windings. After the phase windings are energized, collect and storage in real time winding voltage and current signals through isolation amplifier. After sampling is completed, send the data to the host computer. DSP in this system uses TMS320LF2407 produced U.S. TI company, and its ADC converter module has a faster switching speed, which can meet the real-time acquisition, conversion and storage of winding voltage and current. When carrying out detection, first fixes rotor salient pole in the fully aligned position, then provides opening signals for MOSFET by the controller's I/O port, supplies winding from a fully charged capacitor C, ADC converter module collects winding voltage and current values in real-time, which temporarily are stored in the RAM; when the acquisition is completed, turn off the MOSFET immediately, the collected data is sent to the host computer by SCI module ; when the winding is discharged, winding temperature drops to room temperature, then uses the same method multiple to collect sets of data from the same sample rotor position; then rotate the rotor to proper angle, and repeat the above steps to complete collection of all data. Process data, transferred to the host computer, such as filtering, conversion and calculation, and finally draw the magnetization curves of prototype at different position of the rotor.
3 Flux linkage characteristics measurement results and analysis

In experiment, SRM rotor poles is 8/6 pole, rated power is 500W, stator winding resistance is 2.4Ω. The experimental system is shown in Figure 2. Because of the symmetrical structure of the SRM, ignoring the differences in the manufacturing process, each phase of the motor can be considered as having the same magnetic properties of the chain, so actually choose optionally a phase to do the experiment. In the experiment, rotor samples is 6-pole, just detect the magnetization curve of stator and rotor saliency from never aligned position (0°) to the fully aligned position (30°).

By experimental measurement, SRM voltage and current curves is shown in Figure 3 for the 30° position of the rotor. In experiments, in order to ensure adequate excitation of phase winding, set electrifying period of 22 ms of windings, and sampling period of 12μs for the measuring.

The measured values of voltage and current is fed to the SCI serial port of DSP, after digital filtering, according to equation (3) can be calculated the value of the motor flux linkage at a constant current and angle, finally get the magnetization curve shown in Figure 4.
Figure 4 shows the alignment position of the rotor, and because of the minimum gap, the part of core is relatively large, SRM magnetization characteristic curve reflects the magnetization characteristics of the magnetic circuit core, flux linkage saturates with stator current gradually increasing, and it shows significant nonlinearity in flux linkage - the current plane.

Change the position of the rotor, and repeat the above procedure to obtain the magnetization curves of different specified positions of the motor, as shown in Figure 5.

In Figure 5, it shows that with relative deviation of the rotor salient pole, the angle of rotor position is gradually decreased, the air gap portion of the magnetic circuit is gradually increased, saturation characteristics are gradually waning, magnetization characteristic curve is almost a straight line in totally misaligned position, flux linkage and current approximate are approximately linear relationship. Therefore, the flux linkage is a nonlinear function of rotor position and phase current.

According to above-mention of the flux linkage characteristic curve, we can get the regulation of the SRM’s change about winding inductance. The following equation (4) from which we can get the flux linkage characteristic curve is shown in Fig.6.

\[ \psi(i, \theta) = L(i, \theta)i \quad (4) \]
From the Fig.6 we can know, when the stator salient pole aligns the rotor salient pole absolutely, having the maximal corresponding of inductance. On the contrary, when the stator salient pole doesn’t aligns the rotor salient pole absolutely, having the minimum corresponding of inductance. The higher magnitude of current through the winding, the lower the inductance is shown in the same place and the more absolutely the align position between stator salient pole and the rotor salient pole, this phenomenon is more obvious.

4 Conclusion

It is very important to get SRM’s flux linkage characteristic and nonlinear model for the motor structure design and high-performance speed control. The article founds a SRM flux linkage characteristic detecting system with TMS320LF2407 mode DSP as controller. Handling this system is very convenience and it is at a lower cost. Experiments show that, flux linkage characteristic detecting system can obtain motor’s flux linkage characteristic faithfully. It has actual significance for SRM’s high-performance speed control and online prediction and also provide basis of nonlinear modeling and optimal control for the motor.

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