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Single Phase Permanent Magnet Low Speed Synchronous Motor

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Abstract

In order to acquire a better cognition to the single phase permanent magnet low speed synchronous motor and validate the correctness of the motor mathematical model, the performances of the motor are tested with the single phase permanent magnet low speed synchronous motor whose type is 70TDY4, the corresponding simulations are done too. The resistance and the inductance of the single phase permanent magnet low speed synchronous motor are measured. According to the data of experiments and simulations, the static characteristics of the single phase permanent magnet low speed synchronous motor with the changes of the phase shift resistance and the phase shift capacitance are analysed, the results of experiments and simulations prove the correctness of the mathematics model.

Keywords: *single phase motor, permanent magnet low speed motor, parameter determination*

1. Introduction

Single phase permanent magnet low speed synchronous motor is doubly salient pole structure of stator and rotor. There is a smaller tooth in magnetic poles of the stator (Salient pole) and rotor also having it like this. Single phase permanent magnet low speed synchronous motor's stator wrapped around the pole and is a concentrated winding, giving person the feeling which is like two convex structure of magnetic resistance type motor. Winding inductance has great changes with the rotor position; single phase permanent magnet low speed synchronous motor has the permanent magnet in the rotor, which divides the rotor core into two polarity and the core of the opposite polarity dislocates from half a rotor tooth, so eliminating air gap (tooth layer) permeability's changes with the rotor position, which make it look like a hidden extremely synchronous motor. A lot of literature will also analyse it regarding it as a synchronous motor of hiding magnetic pole in certain assumptions. This shows that single phase permanent magnet low speed synchronous motor is particularity and complexity. In order to verify that single phase permanent magnet low speed synchronous motor's mathematical model is correct and in-depth understand its characteristics, author makes some tests in the light of characteristics of 70TDY4 model.the motor's rated speed is $60r/\min$ in the industrial frequency power supply.

2. Winding Inductance Characteristic

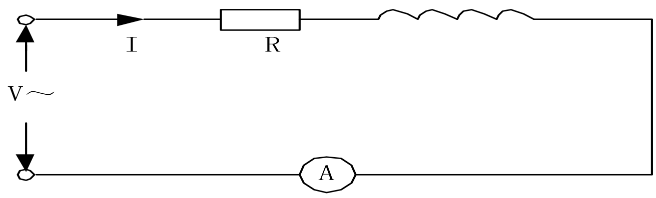

Figure 1. Current of The Stator Winding Wiring Diagram Testing Rotor Angle's Changes

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The stator winding is two phase orthogonal winding, letting one is open, another phase connects line according to Figure 1. When testing, ac voltage: $V = 53.2V$. In order to limit the winding current, we string into resistance R , $R = 300\Omega$. Slowly rotating rotor, we measure winding current. Winding current varies periodically with the rotation of the rotor and the current changes in the range of: $0.014A \sim 0.020A$. It suggests that the reluctance of motor magnetic circuit changes periodically with the rotor angle changing periodically and winding inductance also like this.

3. No-load Motor External Characteristics

Making the stator winding open, DC motor drives single phase permanent magnet low speed synchronous motor to make its do generator no-load running and measure open circuit voltage in different rotating speed. Because the winding is symmetric, two winding phase voltage is equal. It suggests that when output voltage is proportional to rotational speed in the state of no-load which is the same to the ordinary permanent magnet synchronous motor.

Emf coefficient:

$$k_e = \frac{e}{\omega_r} \tag{1}$$

According to the formula (1) and the test data, by calculating, we can get emf coefficient: $k_e = 16.5V \cdot s / rad$.

4. Winding Inductance and Resistance Test

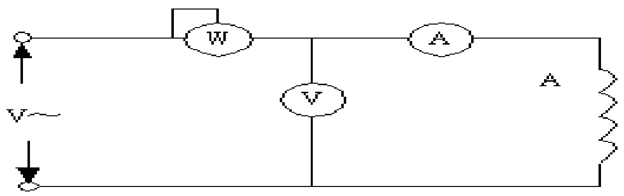

Figure 2. Winding Inductance And Resistance Test Circuit Wiring Diagram

Figure 2 is a hookup using AC power approach to measure A phase windings' the inductance, B phase windings opening, A phase windings of both ends connecting ac voltage of 50Hz. According to the following formula to compute the winding resistance and inductance:

$$L = \frac{U}{2\pi fI}\sin\phi, R = \frac{U}{I}\cos\phi, \sin\phi = \sqrt{1-(\frac{P}{UI})^2} \tag{2}$$

In the formula (2), L-winding inductance value (H); R- winding resistance (Ω); U-Winding both ends voltage value (V); I-Winding current value (A); P-power value (W); f-power frequency (Hz).

Take the centerline of the very small teeth in the stator a1 as the reference coordinate of the rotor position angle, make the angle between the centerline of the rotor core small teeth of N polarity and the reference coordinates express the rotor angular position θ. Give A phase windings to the positive direct current, B phase windings open and motor establishes magnetic field regarding A phase windings the axis as axes. Due to the rotor stable balance position is the position that it makes stator and rotor permeability under the different pole reach maximum value and makes the permeability under the same pole reach minimum value. At this moment, small teeth center line of the polarity of the rotor core in the N pole and small teeth center line of stator a1 are on the centerline of the alignment, namely $\theta=0$. Fixed rotor position, we measure the current and power under different voltage.

According to formula (2) and the test data, by calculating, $R = 120\Omega, L = 6.35H$. At this time,

$$L_d = L_0 - L_2 \cos 2\theta = L_0 - L_2 = 6.35H \tag{3}$$

Give B phase windings to the positive direct current, A phase windings open, according to its structure known when $\theta = 90°$. Fixed rotor position, B phase windings open and we measure the current and power of A phase windings under different voltage.

According to the formula (2) and the test data, by calculating, $L = 8.35H$. At this time,

$$L_q = L_0 - L_2 \cos 2\theta = L_0 + L_2 = 8.35H \tag{4}$$

From the formula (3) and (4), we can know:

$$L_0 = 7.35H, L_2 = 1.0H \tag{5}$$

5. The Motor Steady Characteristics Analysis when External Resistance and Capacitance Changing

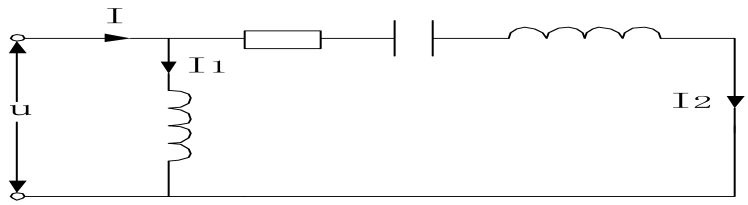

Figure 3. The Resistance-Capacitance Phase-Shift Motor Winding Wiring Diagram.

Doing the phase-shifting operation test of resistance and capacitance, the motor winding diagram are shown in Figure 3 above in the test. The AC power frequency is 50Hz.The manufacturer offers phase-shifting resistance: $R = 1.5K$ and capacitance of phase-shifting: $C = 0.8\mu F$. Doing a load torque test that: phase-shifting resistance $R = 1.5K$, capacitance of phase-shifting: $C = 0.8\mu F$ and load torque: $T_L = 0.8N \bullet m$, rotational speed is $60r/\min$ when it is in the steady-state operation. Through the oscilloscope observing two phase windings' the current, we can see that current of two phase windings is two phase orthogonal alternating current. When the voltage of the power supplying changes, we measure current value of the windings of the steady-state motor; When load torque changes, we measure current value of the steady-state motor's the windings; When phase-shifting resistance and capacitance change, we measure all kinds of experimental data of steady-state motor.

In the MATLAB, using software package, do the simulation of single phase permanent magnet low speed synchronous motor's resistance and capacitance in phase shifting and the characteristics of single-phase power supply, the characteristics of the simulation. Using simulink toolbox, we construct single-phase power supply module. Motor model uses the model of the third chapter building, and in the simulation of test, we use the parameter of single phase permanent magnet low speed synchronous motor of 70TDY4 type: the winding resistance is 120Ω, L_0 is 7.35H, L_2 is 1.0H, rotor's gear has 50, emf coefficient is 16.5V•s/rad, moment inertia is 0.00007Kg•m^2.

The experimental results show that rotational speed is $60r/\min$ when it is in the steady-state operation and two phase windings are two phase orthogonal alternating current.

When all kinds of conditions changes, do the simulation of the corresponding motor running. According to the test and the data of the simulation, and by using the least squares do the curve fitting. The results shown in Figure 4.

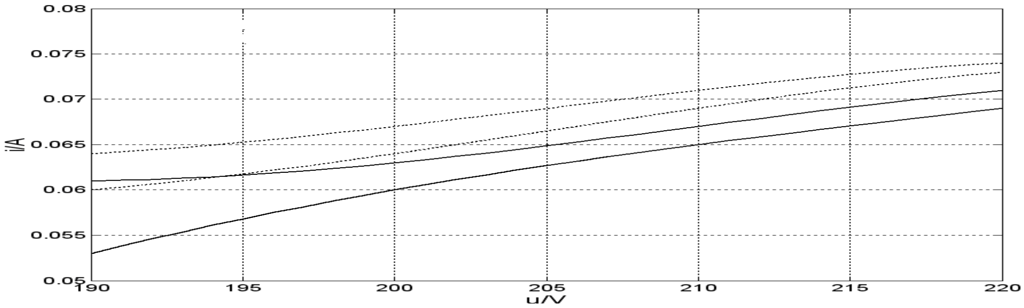

Figure 4. The Winding Current Curve When The Source Voltage The Winding Current Curve Changing

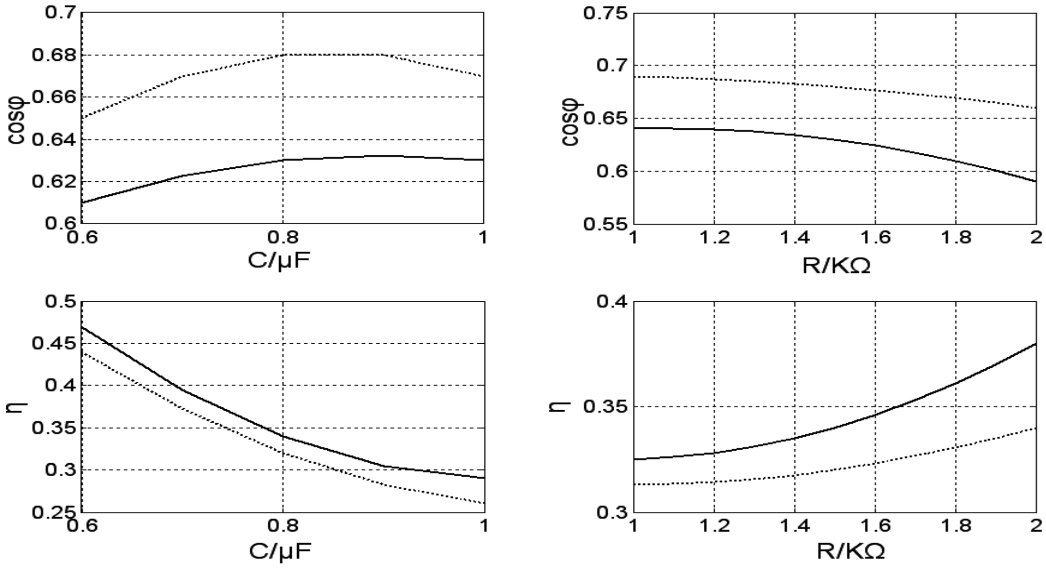

Figure 5. The Power Factor and Efficiency Curve when the Resistance and Capacitance Changing

In the Figure 5, the left half part is the supply voltage $u = 220V$ 、 $R = 1.5K\Omega$ 、 $T_L = 0.8N \bullet m$, the power factor and efficiency curve when the resistance and capacitance changing. In the Figure 5, the right half part is the supply voltage $u = 220V$ 、 $C = 0.8\mu F$ 、 $T_L = 0.8N \bullet m$ and the power factor and efficiency curve when the resistance and capacitance changing. The experimental curves is very close to the simulation curve.

In the Figure 5, the simulation results coincide with the experiment results. In the Figure 4 and 5, the test curve very coincides with the simulation curve, the results show that the model of motor is right.

6. Conclusion

This chapter introduces various tests of single phase permanent magnet low speed synchronous motor of the 70TDY4 type, including: winding inductance characteristic test、no-load motor external characteristics test、winding inductance and resistance test and the phase-shifting operation test of capacitance changing. According to the test of the motor parameters, do the simulation of the motor running when the resistance and capacitance changing. The test data and the simulation data curve is fitting, test results and simulation results prove the second chapter's mathematical model of single phase permanent magnet low speed synchronous motor is correct.

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