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### Permanent magnet synchronous motor parameter measurement method

#### Abstract

A permanent magnet synchronous motor parameter measurement method is provided. The method comprises: performing a maximum torque per ampere and a vector control on a permanent magnet synchronous motor, causing the permanent magnet synchronous motor to run stably and normally; when the permanent magnet synchronous motor is stably and normally running, an  $\alpha$ -axis current and a  $\beta$ -axis current are obtained by means of three phase current sampling of the permanent magnet synchronous motor undergoing three phase to two phase transformation, and a rotor position angle and an electrical rotational speed of the permanent magnet synchronous motor are measured and obtained by means of reading a sensor on the permanent magnet synchronous motor; the six physical quantities mentioned-above are taken and a recursive least squares method is used to simultaneously obtain four parametric results for stator resistance, d-axis inductance, q-axis inductance, and flux linkage.

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## Background/Summary

### CROSS-REFERENCE TO RELATED APPLICATION

(1) This application is a 371 of international application of PCT application serial no. PCT/CN2020/137420, filed on Dec. 18, 2020, which claims the priority benefit of China application no. 202011268499.6, filed on Nov. 13, 2020. The entirety of each of the above-mentioned patent applications is hereby incorporated by reference herein and made a part of this specification.

### BACKGROUND

#### Technical Field

(2) The disclosure relates to a permanent magnet synchronous motor parameter measurement method in the field of permanent magnet synchronous motor measurement. In particular, the disclosure provides a parameter measurement method based on voltage equation and recursive least squares (RLS) method under the  $\alpha\beta$  coordinate system of permanent magnet synchronous motor.

### DESCRIPTION OF RELATED ART

(3) Online motor parameter measurement plays an important role in real-time motor control and fault diagnosis. Generally, the motor parameters that need to be identified online in permanent magnet synchronous motors include stator resistance  $R_{sub.s}$ , d-axis inductance  $L_{sub.d}$ , q-axis inductance  $L_{sub.q}$ , and flux linkage  $\psi_{sub.f}$ . At present, most of the literature on motor parameter measurement focuses on the motor voltage equation under the dq coordinate system. However, the voltage and current under the dq coordinate system are basically constant. Typically, only one parameter may be processed and obtained by using a d-axis or q-axis voltage equation, so only two motor parameters may be processed and obtained simultaneously in the steady state under the dq coordinate system.

(4) Therefore, there is a problem of lack of rank in the parameter measurement of the permanent magnet synchronous motor under the dq coordinate system, and it is impossible to measure all parameters simultaneously. Some studies have shown that the method of signal input may increase the equation to measure all parameters simultaneously, but this approach will affect the normal

operation of the motor.

## SUMMARY

(5) In order to solve the problems in the related art, the purpose of the present disclosure is to provide a parameter measurement method based on the recursive least squares method under the  $\alpha\beta$  coordinate system. Different from the dq coordinate system, two parameters may be obtained simultaneously by a sinusoidal AC phasor equation under the  $\alpha\beta$  coordinate system (on the condition that the phase difference between the two phasors in the equation is not 0 and 180 degrees). Therefore, four motor parameters may be obtained in the  $\alpha\beta$  coordinate system. Compared with the full-parameter measurement under the dq coordinate system, the full-parameter measurement under the  $\alpha\beta$  coordinate system allows for faster convergence speed and shorter calculation time.

(6) As shown in FIG. 1, the technical solution of the present disclosure is as follows: (1) Maximum torque per ampere and vector control are performed on the permanent magnet synchronous motor, causing the permanent magnet synchronous motor to run stably and normally. (2) When the permanent magnet synchronous motor is stably and normally running, the  $\alpha$ -axis current  $i_{\alpha}$  and the  $\beta$ -axis current  $i_{\beta}$  are obtained through the three-phase current sampling of the permanent magnet synchronous motor undergoing three-phase to two-phase transformation. The rotor position angle  $\theta_e$ , and electric rotational speed  $\omega_e$  of the permanent magnet synchronous motor are obtained by reading the sensor measurement on the permanent magnet synchronous motor. (3) According to the  $\alpha$ -axis current  $i_{\alpha}$ ,  $\beta$ -axis current  $i_{\beta}$ ,  $\theta_e$  and  $\omega_e$ , obtained in step (2) and according to the preset input  $\alpha$ -axis voltage  $v_{\alpha}$  and  $\beta$ -axis voltage  $v_{\beta}$ , the voltage equation under  $\alpha\beta$  coordinate system of permanent magnet synchronous motor is established. The six described physical quantities are taken and a recursive least squares method is used to simultaneously obtain four estimated values  $\hat{R}_s$ ,  $\hat{L}_d$ ,  $\hat{L}_q$  and  $\hat{\psi}_f$  for four parameters including a stator resistance, a d-axis inductance, a q-axis inductance, and a flux linkage.

(7) The specific process of the step (3) is as follows: the voltage equation under the  $\alpha\beta$  coordinate system is constructed in the following form:

$$v_{\alpha} - \hat{W}_{\alpha 2} X_{\alpha 2} = \hat{W}_{\alpha 1} X_{\alpha 1}$$

$$v_{\beta} - \hat{W}_{\beta 1} X_{\beta 1} = \hat{W}_{\beta 2} X_{\beta 2}$$

$$\hat{W}_{\alpha 1} = [\hat{R}_s \quad \hat{L}_d \omega_e]$$

$$\hat{W}_{\alpha 2} = [\hat{L}_q \omega_e \quad \hat{\psi}_f]$$

$$X_{\alpha 1} = [i_{\alpha} \sin(\theta_e + \frac{1}{2}\pi) \quad i_{\beta} \sin(\theta_e + \frac{1}{2}\pi)]^T$$

$$X_{\alpha 2} = [i_{\alpha} \cos(\theta_e + \frac{1}{2}\pi) \quad i_{\beta} \cos(\theta_e + \frac{1}{2}\pi)]^T$$

$$X_{\beta 1} = [i_{\alpha} \sin(\theta_e - \frac{1}{2}\pi) \quad i_{\beta} \sin(\theta_e - \frac{1}{2}\pi)]^T$$

$$X_{\beta 2} = [i_{\alpha} \cos(\theta_e - \frac{1}{2}\pi) \quad i_{\beta} \cos(\theta_e - \frac{1}{2}\pi)]^T$$

$$\hat{W}_{\beta 1} = [\hat{R}_s \quad \hat{L}_q \omega_e]$$

$$\hat{W}_{\beta 2} = [\hat{L}_d \omega_e \quad \hat{\psi}_f]$$

(8) In the equation:  $\hat{R}_s$ ,  $\hat{L}_d$ ,  $\hat{L}_q$  and  $\hat{\psi}_f$  are respectively the estimated values of stator resistance, d-axis inductance, q-axis inductance and flux linkage; p represents the differential operator;  $X_{\alpha 1}$  represents the first electrical input of the  $\alpha$ -axis,  $X_{\alpha 2}$  represents the second electrical input of the  $\alpha$ -axis,  $X_{\beta 1}$  represents the first electrical input of the  $\beta$ -axis,  $X_{\beta 2}$  represents the second electrical input of the  $\beta$ -axis;  $\hat{W}_{\alpha 1}$  represents the estimated value between the stator resistance and the d-axis inductance,  $\hat{W}_{\alpha 2}$  represents the estimated value between the q-axis inductance  $L_q$  and the flux linkage  $\psi_f$ ; and T represents the matrix transpose.

(9) Then the recursive least squares method is used to solve the above equations simultaneously to obtain the estimated values of the four parameters, namely stator resistance  $R_s$ , d-axis

inductance  $L_{\text{sub.d}}$ , q-axis inductance  $L_{\text{sub.q}}$  and flux linkage  $\psi_{\text{sub.f}}$ .

(10) An encoder is disposed on the rotor of the permanent magnet synchronous motor.

(11) In the normal operation state of the permanent magnet synchronous motor, the voltage equation in the  $\Delta\beta$  coordinate system of the permanent magnet synchronous motor and the recursive least square method are used for parameter measurement. The implementation steps of the method are as follows: (1) Maximum torque per ampere (MTPA) and vector control are performed on the permanent magnet synchronous motor, causing the permanent magnet synchronous motor to run stably and normally. (2) When the permanent magnet synchronous motor is stably and normally running, the  $\alpha$ -axis current  $i_{\text{sub.}\alpha}$  and the  $\beta$ -axis current  $i_{\text{sub.}\beta}$  are obtained through the three-phase current sampling of the permanent magnet synchronous motor undergoing three-phase to two-phase transformation (abc/ $\alpha\beta$  transformation). The rotor position angle  $\theta_{\text{sub.e}}$  and electric rotational speed  $\omega_{\text{sub.e}}$  of the permanent magnet synchronous motor are obtained by reading the sensor measurement on the permanent magnet synchronous motor.

(12) An encoder is disposed on the rotor of the permanent magnet synchronous motor. The encoder is an absolute encoder. (3) According to the  $\alpha$ -axis current  $i_{\text{sub.}\alpha}$ ,  $\beta$ -axis current  $i_{\text{sub.}\beta}$ ,  $\theta_{\text{sub.e}}$  and  $\omega_{\text{sub.e}}$  obtained in step (2) and according to the preset input  $\alpha$ -axis voltage  $v_{\text{sub.}\alpha}$  and  $\beta$ -axis voltage  $v_{\text{sub.}\beta}$ , the voltage equation under  $\alpha\beta$  coordinate system of permanent magnet synchronous motor is established. The six described physical quantities are taken and a recursive least squares method is used to simultaneously obtain four parameters respectively, namely stator resistance, d-axis inductance, q-axis inductance, and flux linkage. In this way, simultaneous measurement is achieved.

(13) The  $\alpha$ -axis voltage  $v_{\text{sub.}\alpha}$  and  $\beta$ -axis voltage  $v_{\text{sub.}\beta}$  are given by the space vector pulse width modulation SVPWM input in the permanent magnet synchronous motor control.

(14) The specific process of the full parameter measurement based on the recursive least squares method in the step (3) is as follows: the voltage equation under the  $\alpha\beta$  coordinate system is constructed in the following form:

$$v_{\text{sub.}\alpha} - \hat{W}_{\text{sub.}\alpha 2} X_{\text{sub.}\alpha 2} = \hat{W}_{\text{sub.}\alpha 1} X_{\text{sub.}\alpha 1}$$

$$v_{\text{sub.}\beta} - \hat{W}_{\text{sub.}\alpha 1} X_{\text{sub.}\beta 2} = \hat{W}_{\text{sub.}\alpha 2} X_{\text{sub.}\beta 1}$$

$$\hat{W}_{\text{sub.}\alpha 1} = [\text{custom character} \text{ custom character}]$$

$$\hat{W}_{\text{sub.}\alpha 2} = [\text{custom character} \text{ custom character}]$$

$$X_{\text{sub.}\alpha 1} = [i_{\text{sub.}\alpha} (\frac{1}{2} \pi_{\text{sub.}\beta} - \omega_{\text{sub.e}} i_{\text{sub.}\alpha}) \sin 2\theta_{\text{sub.e}} + \frac{1}{2} \pi_{\text{sub.}\alpha} + (\frac{1}{2} \pi_{\text{sub.}\alpha} + \omega_{\text{sub.e}} i_{\text{sub.}\beta}) \cos 2\theta_{\text{sub.e}}]_{\text{sup.}T}$$

$$X_{\text{sub.}\alpha 2} = [\frac{1}{2} \pi_{\text{sub.}\alpha} - (\frac{1}{2} \pi_{\text{sub.}\beta} - \omega_{\text{sub.e}} i_{\text{sub.}\alpha}) \sin 2\theta_{\text{sub.e}} - (\frac{1}{2} \pi_{\text{sub.}\alpha} + \omega_{\text{sub.e}} i_{\text{sub.}\beta}) \cos 2\theta_{\text{sub.e}} - \omega_{\text{sub.e}} \sin \theta_{\text{sub.e}}]_{\text{sup.}T}$$

$$X_{\text{sub.}\beta 1} = [\frac{1}{2} \pi_{\text{sub.}\beta} + (\frac{1}{2} \pi_{\text{sub.}\beta} - \omega_{\text{sub.e}} i_{\text{sub.}\alpha}) \cos 2\theta_{\text{sub.e}} - (\frac{1}{2} \pi_{\text{sub.}\alpha} + \omega_{\text{sub.e}} i_{\text{sub.}\beta}) \sin 2\theta_{\text{sub.e}} + \omega_{\text{sub.e}} \cos \theta_{\text{sub.e}}]_{\text{sup.}T}$$

$$X_{\text{sub.}\beta 2} = [i_{\text{sub.}\beta} (\frac{1}{2} \pi_{\text{sub.}\alpha} + \omega_{\text{sub.e}} i_{\text{sub.}\beta}) \sin 2\theta_{\text{sub.e}} + \frac{1}{2} \pi_{\text{sub.}\beta} - (\frac{1}{2} \pi_{\text{sub.}\beta} - \omega_{\text{sub.e}} i_{\text{sub.}\alpha}) \cos 2\theta_{\text{sub.e}}]_{\text{sup.}T}$$

(15) In the equation:  $\text{custom character}$ ,  $\text{custom character}$ ,  $\text{custom character}$  and  $\text{custom character}$  are respectively the estimated values of stator resistance, d-axis inductance, q-axis inductance and flux linkage;  $p$  represents the differential operator;  $X_{\text{sub.}\alpha 1}$  represents the first electrical input of the  $\alpha$ -axis,  $X_{\text{sub.}\alpha 2}$  represents the second electrical input of the  $\alpha$ -axis,  $X_{\text{sub.}\beta 1}$  represents the first electrical input of the  $\beta$ -axis,  $X_{\text{sub.}\beta 2}$  represents the second electrical input of the  $\beta$ -axis;  $\hat{W}_{\text{sub.}\alpha 1}$  represents the estimated value between the stator resistance and the d-axis inductance,  $\hat{W}_{\text{sub.}\alpha 2}$  represents the estimated value between the q-axis inductance  $L_{\text{sub.q}}$  and the flux linkage  $\psi_{\text{sub.f}}$ ; and  $T$  represents the matrix transpose.

(16) Then the recursive least squares method is used to solve the above equations simultaneously to obtain the estimated values of the four parameters, namely stator resistance  $R_{\text{sub.s}}$ , d-axis inductance  $L_{\text{sub.d}}$ , q-axis inductance  $L_{\text{sub.q}}$  and flux linkage  $\psi_{\text{sub.f}}$ .

(17) The measurement method of the present disclosure is different from the dq coordinate system.

Under the  $\alpha\beta$  coordinate system, the voltage and current quantities are all sinusoidal AC phasors. When using linear regression strategies such as the recursive least square method for parameter measurement, two parameters may be obtained simultaneously by a sinusoidal AC phasor equation (provided that the phase difference between the two phasors in the equation is not 0 and 180 degrees). Therefore, four motor parameters may be obtained in the  $\alpha\beta$  coordinate system. Compared with the full-parameter measurement under the dq coordinate system, the full-parameter measurement under the  $\alpha\beta$  coordinate system allows for faster convergence speed and shorter calculation time.

(18) Advantageous effects of the present disclosure are as follows:

(19) The disclosure combines the voltage equation set under the  $\alpha\beta$  coordinate system and the recursive least square method, and is able to directly perform full-parameter measurement on the permanent magnet synchronous motor. Compared with the full-parameter measurement under the dq coordinate system, the full-parameter measurement under the  $\alpha\beta$  coordinate system of the present disclosure allows for faster convergence speed and shorter calculation time, and achieves higher instantaneity.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

- (1) FIG. 1 is an overall control block diagram of realizing a motor of the present disclosure.
- (2) FIG. 2 is a block diagram realizing the recursive least square method algorithm of the present disclosure.
- (3) FIG. 3 is a simulation verification diagram for realizing the algorithm of the present disclosure.

### DESCRIPTION OF THE EMBODIMENTS

- (4) The present disclosure will be further elaborated below in conjunction with the accompanying drawings and embodiments.
- (5) According to the content of the present disclosure, the practical embodiment and the implementation of the complete embodiment is as follows.
- (6) In order to verify the reliability of this method, related experiments were carried out. The parameters of the interior permanent magnet motor (IPMSM) used as an example in the experiment are shown in Table I below.
- (7) TABLE-US-00001  
TABLE 1 Motor Parameters  
Motor type IPMSM Stator resistance 0.065  $\Omega$   
Flux linkage 0.02 Vs d-axis inductance 37.3  $\mu\text{H}$  q-axis inductance 48.8  $\mu\text{H}$  DC bus voltage 60 V  
Rated torque 5 Nm Rated speed 1500 rpm
- (8) The process flow is as follows. (1) Maximum torque per ampere (MTPA) and vector control are performed on the permanent magnet synchronous motor, causing the permanent magnet synchronous motor to run stably and normally. (2) An absolute encoder is provided on the rotor of the permanent magnet synchronous motor. When the permanent magnet synchronous motor is stably and normally running, the  $\alpha$ -axis current  $i_{\text{sub}.\alpha}$  and the  $\beta$ -axis current  $i_{\text{sub}.\beta}$  are obtained through the three-phase current sampling of the permanent magnet synchronous motor undergoing three-phase to two-phase transformation ( $abc/\alpha\beta$  transformation). The rotor position angle  $\theta_{\text{sub}.\text{e}}$  and electric rotational speed  $\omega_{\text{sub}.\text{e}}$  of the permanent magnet synchronous motor are obtained by reading the sensor measurement on the permanent magnet synchronous motor. (3) According to the  $\alpha$ -axis current  $i_{\text{sub}.\alpha}$ ,  $\beta$ -axis current  $i_{\text{sub}.\beta}$ ,  $\theta_{\text{sub}.\text{e}}$  and  $\omega_{\text{sub}.\text{e}}$  obtained in step (2) and according to the preset input  $\alpha$ -axis voltage  $v_{\text{sub}.\alpha}$  and  $\beta$ -axis voltage  $v_{\text{sub}.\beta}$ , the voltage equation under  $\alpha\beta$  coordinate system of permanent magnet synchronous motor is established. The six described physical quantities are taken and a recursive least squares method is used to simultaneously obtain four parameters respectively for stator resistance  $R_{\text{sub}.\text{s}}$ , d-axis inductance  $L_{\text{sub}.\text{d}}$ , q-axis inductance  $L_{\text{sub}.\text{q}}$ , and flux linkage  $\psi_{\text{sub}.\text{f}}$ . The voltage equation under the  $\alpha\beta$  coordinate system

is constructed in the following form.

$$v_{\alpha} - \hat{W}_{\alpha 2} X_{\alpha 2} = \hat{W}_{\alpha 1} X_{\alpha 1}$$

$$v_{\beta} - \hat{W}_{\beta 1} X_{\beta 1} = \hat{W}_{\beta 2} X_{\beta 2}$$

$$\hat{W}_{\alpha 1} = [\text{custom character}]$$

$$\hat{W}_{\alpha 2} = [\text{custom character}]$$


$$X_{\alpha 1} = [i_{\alpha} (\frac{1}{2} \pi - \omega_e) \sin 2\theta_e + (\frac{1}{2} \pi + \omega_e) \cos 2\theta_e] T$$

$$X_{\alpha 2} = [\frac{1}{2} \pi - (\frac{1}{2} \pi - \omega_e) \sin 2\theta_e - (\frac{1}{2} \pi + \omega_e) \cos 2\theta_e - \omega_e \sin \theta_e] T$$

$$X_{\beta 1} = [\frac{1}{2} \pi + (\frac{1}{2} \pi - \omega_e) \cos 2\theta_e - (\frac{1}{2} \pi + \omega_e) \sin 2\theta_e \omega_e \cos \theta_e] T$$



$$X_{\beta 2} = [i_{\beta} (\frac{1}{2} \pi + \omega_e) \sin 2\theta_e + (\frac{1}{2} \pi - \omega_e) \cos 2\theta_e] T$$



(9) In the equation: , , , and





 are respectively the estimated values of stator resistance, d-axis inductance, q-axis inductance and flux linkage; p represents the differential operator:  $X_{\alpha 1}$  represents the first electrical input of the  $\alpha$ -axis,  $X_{\alpha 2}$  represents the second electrical input of the  $\alpha$ -axis,  $X_{\beta 1}$  represents the first electrical input of the  $\beta$ -axis,  $X_{\beta 2}$  represents the second electrical input of the  $\beta$ -axis;  $\hat{W}_{\alpha 1}$  represents the estimated value between the stator resistance and the d-axis inductance,  $\hat{W}_{\alpha 2}$  represents the estimated value between the q-axis inductance  $L_q$  and the flux linkage  $\psi_f$ ; and T represents the matrix transpose.

(10) Then the recursive least squares method is used to solve the above equations simultaneously to obtain the four parameters, namely stator resistance  $R_s$ , d-axis inductance  $L_d$ , q-axis inductance  $L_q$  and flux linkage  $\psi_f$ .

(11) The specific block diagram of the full-parameter measurement method is shown in FIG. 2, and the solution process is as follows.

(12) First,  $i_{\alpha}$ ,  $i_{\beta}$ ,  $\theta_e$ , and  $\omega_e$  obtained by measurement and calculation were used to calculate  $X_{\alpha 1}$ ,  $X_{\alpha 2}$ ,  $X_{\beta 1}$ , and  $X_{\beta 2}$ . According to  $v_{\alpha}$  and  $X_{\alpha 2}$  as well as  $\hat{W}_{\alpha 2} = \hat{W}_{\beta 1}$ ,  $v_{\alpha} - \hat{W}_{\alpha 2} X_{\alpha 2}$  was calculated, and  $v_{\alpha} - \hat{W}_{\alpha 2} X_{\alpha 2}$  and  $X_{\alpha 1}$  were used as the input of the recursive least squares method to obtain  and ; according to  $v_{\beta}$  and  $X_{\beta 2}$  as well as  $\hat{W}_{\beta 2} = \hat{W}_{\alpha 1}$ ,  $v_{\beta} - \hat{W}_{\beta 2} X_{\beta 2}$  were calculated.

$v_{\beta} - \hat{W}_{\beta 2} X_{\beta 2}$  and  $X_{\beta 1}$  were taken as the input of the recursive least squares method to obtain  and .

(13) Then the  $\alpha$ -axis voltage equation is used to process the stator resistance  and d-axis inductance  and the  $\beta$ -axis voltage equation is used to process the q-axis inductance  and flux linkage .  $\hat{W}_{\alpha 1} = [\text{custom character}]$  obtained by processing the  $\alpha$ -axis voltage equation is used to calculate  $\hat{W}_{\beta 2}$  on the left side of the  $\beta$ -axis voltage equation.  $\omega_{\beta 1} = [\text{custom character}]$  obtained by processing the  $\beta$ -axis voltage equation is used to calculate  $\hat{W}_{\alpha 2}$  on the left side of the  $\alpha$ -axis voltage equation.





(14) In this way, all parameters may be processed and obtained simultaneously.

(15) FIG. 3 is the simulation result of the full-parameter measurement by the method of the present disclosure when the motor speed is 1500 rpm and the torque is 5 Nm. Based on the results, it can be seen that the method of the present disclosure is able to quickly obtain four motor parameters, and the error is very small while the convergence time is very short.

## Claims



1. A driving method for real-time control a permanent magnet synchronous motor, comprising: (1) performing a maximum torque per ampere and a vector control on the permanent magnet synchronous motor, causing the permanent magnet synchronous motor to run stably and normally, wherein the permanent magnet synchronous motor is coupled to an inverter; (2) when the permanent magnet synchronous motor is stably and normally running, obtaining an  $\alpha$ -axis current  $i_{\alpha}$  and a  $\beta$ -axis current  $i_{\beta}$  through three-phase current sampling of the permanent magnet synchronous motor undergoing a three-phase to two-phase transformation, and obtaining a rotor position angle  $\theta_e$  and an electric rotational speed  $\omega_e$  of the permanent magnet synchronous motor by reading a sensor measurement on the permanent magnet synchronous motor; (3) establishing a voltage equation under a  $\alpha\beta$  coordinate system of the permanent magnet synchronous motor according to the  $\alpha$ -axis current  $i_{\alpha}$ , the  $\beta$ -axis current  $i_{\beta}$ , the  $\theta_e$  and the  $\omega_e$  obtained in the step (2) and according to a preset input  $\alpha$ -axis voltage  $v_g$  and a preset input  $\beta$ -axis voltage  $v_{\beta}$ , wherein six physical quantities mentioned above are taken and a recursive least squares method is used to simultaneously obtain four estimated values

, , ,  for four parameters, wherein the four parameters are a stator resistance  $R_s$ , a d-axis inductance  $L_d$ , a q-axis inductance  $L_q$ , and a flux linkage  $\psi_f$ , wherein a process of step (3) is as follows: constructing the voltage equation under the  $\alpha\beta$  coordinate system in the following form:

$$v_{\alpha} - \hat{W}_{\alpha 2} X_{\alpha 2} = \hat{W}_{\alpha 1} X_{\alpha 1}$$

$$v_{\beta} - \hat{W}_{\beta 1} X_{\beta 1} = \hat{W}_{\beta 2} X_{\beta 2}$$

$$\hat{W}_{\alpha 1} = [\text{custom character} \text{ custom character}]$$





$$\hat{W}_{\alpha 2} = [\text{custom character} \text{ custom character}]$$









$$X_{\alpha 1} = [i_{\alpha} (\frac{1}{2}\pi - \theta_e - \omega_e) \sin 2\theta_e + (\frac{1}{2}\pi + \theta_e + \omega_e) \cos 2\theta_e]^T$$

$$X_{\alpha 2} = [\frac{1}{2}\pi - (\frac{1}{2}\pi - \theta_e - \omega_e) \sin 2\theta_e - (\frac{1}{2}\pi + \theta_e + \omega_e) \cos 2\theta_e]^T$$

$$X_{\beta 1} = [\frac{1}{2}\pi + (\frac{1}{2}\pi - \theta_e - \omega_e) \cos 2\theta_e - (\frac{1}{2}\pi + \theta_e + \omega_e) \sin 2\theta_e]^T$$

$$X_{\beta 2} = [i_{\beta} (\frac{1}{2}\pi + \theta_e + \omega_e) \sin 2\theta_e - (\frac{1}{2}\pi - \theta_e - \omega_e) \cos 2\theta_e]^T$$

wherein , , , and  are the estimated values of the stator resistance

$R_s$ , the d-axis inductance  $L_d$ , the q-axis inductance  $L_q$ , and the flux linkage  $\psi_f$ , respectively;  $p$  represents a differential operator;  $X_{\alpha 1}$  represents a first electrical input of an  $\alpha$ -axis,  $X_{\alpha 2}$  represents a second electrical input of the  $\alpha$ -axis,  $X_{\beta 1}$  represents a first electrical input of a  $\beta$ -axis,  $X_{\beta 2}$  represents a second electrical input of the  $\beta$ -axis;  $\hat{W}_{\alpha 1}$  represents an estimated value between the stator resistance and the d-axis inductance,  $\hat{W}_{\alpha 2}$  represents an estimated value between the q-axis inductance  $L_q$  and the flux linkage  $\psi_f$ ; and  $T$  represents a matrix transpose; using the recursive least squares method to simultaneously solve above-mentioned equations to obtain the four estimated values , , ,  for the four parameters; and (4) using the four estimated values , , ,  as control parameters to control the inverter to generate a driving current, and using the driving current to drive the permanent magnet synchronous motor.

2. The driving method for real-time control the permanent magnet synchronous motor according to claim 1, wherein an encoder is disposed on a rotor of the permanent magnet synchronous motor.