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Model-free Current Predictive Control of Open-winding Permanent Magnet Synchronous Motor

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ABSTRACT

Aiming at the problem that the traditional model current predictive control of open-winding permanent magnet synchronous motor with common bus is easy to change its motor parameters, the current predictive control and model-free control are combined. On this basis, a linear state observer is added to estimate the system disturbance and solve the time-consuming and complicated problem of model-free control disturbance. The improved model-free current predictive control selects the best basic voltage vector and action time through the value function and voltage vector sector. The zero-sequence voltage to be compensated is obtained by the difference between the zero-sequence voltage generated by non-zero vector and the reference zero-sequence voltage, and the mixed zero vector injected and the action time are selected and calculated, so that the system can achieve optimal compensation. Finally, Matlab/Simulink is used for simulation, which verifies the effectiveness and feasibility of the experiment.

KEYWORDS

Open-winding Permanent Magnet Synchronous Motor; Common Bus; Residual Current; Model-free Predictive Control; Linear Extended State Observer.

1. INTRODUCTION

Permanent magnet synchronous motor (PMSM) has high power density, safe and reliable working environment, high efficiency and simple operation, and is widely used in industrial production field, and is often used as the best choice for executive motor in servo system [1-3]. However, with the vigorous development of automobile, high-speed rail and electronic industry, DC power supply with lower voltage level will be more suitable for permanent magnet synchronous motor based on its safety and efficiency.

In recent years, Open-winding Permanent Magnet Synchronous Motor (OW-PMSM) has appeared in public view [4-6]. This motor has high DC voltage utilization rate and high fault tolerance rate, so it is widely used in electric vehicle power system and wind power generation. Since it was put forward, it has been widely concerned by scholars at home and abroad.

OW-PMSM system has two structures: common DC bus type and isolated DC bus type. The common DC bus type has low cost and simple structure, so this paper analyzes it. In this structure, because the neutral point of its winding is open, there is a zero sequence loop[6], which reduces the performance of the motor.

In order to effectively suppress the zero-sequence current, researchers from all over the world have put forward many methods. Literature [7] puts forward the hexagon modulation method of voltage vector, which makes the zero-sequence voltages of two groups of inverters cancel each other out and improves the utilization rate of DC bus voltage by 17 times. Literature [8] In order to suppress the zero-sequence voltage of the inverter, the switching frequency of the inverter is increased and compensated. Reference [9]uses proportional resonance controller (PR) to cancel the third harmonic back electromotive force of the motor and the zero sequence voltage of the inverter. Subsequently, because of the advantages of simple control structure, fast response and good optimization performance, analog predictive control is applied to open-winding motors. In reference [10], in order to track the zero-axis current of open-winding permanent magnet synchronous motor, the optimal switching vector can be selected. In traditional model predictive control, the value function with zero-sequence current is cited to suppress the zero-sequence current, but its effect is limited, in order to suppress the zero-sequence current in the loop and improve the utilization rate of DC bus voltage. Reference [11] designed a zero-voltage injection method to compensate the zero-sequence voltage calculated by the cost function, and did not need vector synthesis, thus making the modulation method simple.

However, the traditional model prediction method usually depends on the precise model of the motor, which will be affected by various disturbances in the actual operation of the motor, resulting in the inability to obtain accurate parameters. In order to make the prediction model independent of motor parameters and reduce the influence of parameter drift on the control model[12-14], model free control (MFC) is introduced[15]. MFC only needs to consider the input, output and disturbances of the system, including known disturbances and unknown disturbances. Compared with model control, the sensitivity to parameters is effectively reduced and the control performance is also improved. On this basis, references [16-17] put forward a method of establishing an ultra-local model-free control model, and realized on-line interference estimation by using parameter identification technology.

Ultra-local Model Predictive Control, combines the dynamic model of the system with online optimization, which can realize the optimal control of the dynamic system. When MPC is applied to open-winding permanent magnet synchronous motor (OW-PMSM), it is necessary to combine the mathematical model of the motor with MPC. This strategy does not require an accurate motor model, but predicts the current by measuring and estimating the motor state in real time. This method is robust to the changes of motor parameters and external disturbances. For the nonlinear system with model-free control, it is feasible to combine model-free control with Extended State Observer in reference [17], but it is difficult to realize in practice. In reference [18], a linear active disturbance rejection controller named linear extended state observer is introduced to simplify it.

In order to effectively suppress zero-sequence current, reduce the complexity of model predictive control of open-winding permanent magnet synchronous motor and reduce the calculation burden of controller; In this paper, we will discuss the design and implementation of model-free current predictive control strategy for common DC bus open-winding permanent magnet synchronous motor. First, we will introduce the basic principle and characteristics of OW-PMSM, and then discuss the limitations of traditional control methods. Next, we will describe the working principle of the model-free current predictive control strategy in detail, and combine this control with the hybrid dual-vector method to suppress the zero-sequence current by selecting non-zero vectors and zero vectors and calculating their action time. We will verify that there is a zero-sequence current loop in this method through simulation, so we must fully consider the influence of rotor permanent magnet flux linkage on the third harmonic component of stator winding turn chain. It provides strong support for the practical application of open-winding permanent magnet synchronous motor. Through this research, we expect to provide theory and practice for the application of model-free control in OW-PMSM.

2. TRADITIONAL MODEL PREDICTIVE CONTROL

2.1. Mathematical Model of OW-PMSM for Common DC Bus

The structure diagram of the common DC bus open winding permanent magnet synchronous motor system is shown in Figure 1. It consists of two groups of voltage source inverters, a DC power supply and an OW-PMSM.

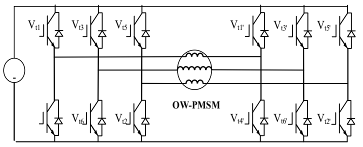


Fig 1. Structure diagram of common DC bus open winding permanent magnet synchronous moto

Because OW-PMSM has not changed the electromagnetic design and mechanical structure of the motor body except opening the neutral point, the stator voltage equation of OW-PMSM in abc coordinate system is as follows:

$$\begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} = R_s \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \frac{d}{dt} \begin{bmatrix} \psi_a \\ \psi_b \\ \psi_c \end{bmatrix} \tag{1}$$

In the formula: i_a, i_b, i_c respectively represent the stator three-phase current; Ψ_a, Ψ_b, Ψ_c represented as stator three-phase flux linkage respectively; u_a, u_b, u_c three-phase voltages of the stator respectively; R_s is the winding resistance.

As can be seen from Figure 1, because two groups of inverters share the same DC power supply, it provides a loop for zero-sequence current, so the third harmonic component in the rotor permanent magnet flux linkage of stator winding turn chain can not be ignored. Its flux linkage equation is as follows:

$$\begin{bmatrix} \psi_a \\ \psi_b \\ \psi_c \end{bmatrix} = \begin{bmatrix} L_{aa} & L_{ab} & L_{ac} \\ L_{ba} & L_{bb} & L_{bc} \\ L_{ca} & L_{cb} & L_{cc} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} \psi_f \cos\theta \\ \psi_f \cos(\theta - 120°) \\ \psi_f \cos(\theta - 120°) \end{bmatrix} + \begin{bmatrix} \psi_{3f} \cos 3\theta \\ \psi_f \cos(3(\theta - 120°)) \\ \psi_f \cos(3(\theta - 120°)) \end{bmatrix} \tag{2}$$

In the formula: Ψ_f is the amplitude of permanent magnet flux linkage; Ψ_{3f} is the amplitude of the third harmonic component of permanent magnet flux linkage; L_{aa}, L_{bb}, L_{cc} is self-inductance of three-phase winding; L_{ab}, L_{ba}, L_{ac}, L_{bc}, L_{ca}, L_{cb} is the mutual inductance of abc three-phase winding; θ is the electrical angle between the *d* axis of the motor rotor and the a phase winding.

After coordinate transformation, the mathematical expression of open-winding permanent magnet synchronous motor in dq0 coordinate system is as follows:

$$\begin{bmatrix} u_d \\ u_q \\ u_0 \end{bmatrix} = R_s \begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} + \begin{bmatrix} L_d & 0 & 0 \\ 0 & L_q & 0 \\ 0 & 0 & L_0 \end{bmatrix} \frac{d}{dt} \begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} \begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} + \omega_e \begin{bmatrix} -L_q i_q \\ L_d i_d + \psi_f \\ -3\psi_{3f} \sin 3\theta \end{bmatrix} \tag{3}$$

In the formula: i_d, i_q, i_0 is the current of each axis of stator dqo; u_d, u_q, u_0 is the stator dq0 axis voltage; L_d, L_q, L_0 is the inductance of the stator dq0 axis; ω_e stands for rotor electrical angular velocity; R_s is the stator resistance of each phase.

2.2. Traditional Model Predictive Control

The traditional model predictive control method relies on establishing predictive model and calculating cost function to select the best voltage vector and action time, and then combine inverter switches to control the motor. Firstly, the current prediction model of OW-PMSM system is obtained by forward Euler method for equation (3).

$$i_{\mathrm{dq0}}(k+1)=\begin{bmatrix}1-\frac{T_{\mathrm{s}}R}{L_{\mathrm{d}}} & T_{\mathrm{s}}\omega(k) & 0\\ -T_{s}\omega(\mathrm{k}) & 1-\frac{T_{\mathrm{s}}R}{L_{\mathrm{q}}} & 0\\ 0 & 0 & 1-\frac{T_{\mathrm{s}}R}{L_{0}}\end{bmatrix}i_{\mathrm{dq0}}(k)+\begin{bmatrix}\frac{T_{\mathrm{s}}}{L_{\mathrm{d}}} & 0 & 0\\ 0 & \frac{T_{\mathrm{s}}}{L_{\mathrm{q}}} & 0\\ 0 & 0 & \frac{T_{\mathrm{s}}}{L_{0}}\end{bmatrix}u_{\mathrm{dq0}}+\begin{bmatrix}0\\ \frac{\omega(k)\psi_{\mathrm{f}}T_{\mathrm{s}}}{L_{q}}\\ -\frac{3\omega(k)\psi_{3\mathrm{f}}T_{\mathrm{s}}\sin(3\theta)}{L_{0}}\end{bmatrix} \tag{4}$$

Equation (4) shows that the traditional MPCC control method is easily influenced by the parameters of the motor, but the parameters of the motor are time-varying, which makes the prediction robust. Because there is a zero-sequence current path in the common DC bus open-winding permanent magnet synchronous motor system, in order to suppress the zero-sequence current, the zero-sequence current error term is substituted into the value function, and the zero-sequence current is also controlled accordingly while controlling the dq axis current. The expression of the value function is as follows:

$$g=[i_{\mathrm{d}}^{*}-i_{\mathrm{d}}(k+1)]^{2}+[i_{\mathrm{q}}^{*}-i_{\mathrm{q}}(k+1)]^{2}+[i_{0}^{*}-i_{0}(k+1)]^{2} \tag{5}$$

In the formula: i_{d}^{*}、i_{q}^{*}和i_{0}^{*} is the reference voltage of dq0 axis respectively.

Therefore, the optimal voltage vector for the next control period can be determined by the minimum principle of cost function. Compared with the permanent magnet synchronous motor, the open-winding permanent magnet synchronous motor has 27 voltage vectors in the prediction process, and some of them are useless vectors, resulting in low efficiency in the operation process.

3. MODEL-FREE CURRENT PREDICTIVE CONTROL

The biggest feature of the model-free control method is that it does not depend on the parameters of the motor, but establishes a super-local equation for the input and output of the control system, thus achieving better control of the nonlinear strong coupling system.

3.1. Superlocal Model

The dependence of the control system on the high-precision model can be reduced by the ultra-local model, which is constructed by the input and output of the system. According to the idea of model-free control, it can be expressed as:

$$y^{(v)}=\beta u+F \tag{6}$$

In the formula: $y^{(v)}$ represents the A derivative of y, and v mostly chooses 1 or 2; β stands for non-physical constant gain; F is updated in real time by online parameter estimation technology, and it is not necessary to distinguish unknown parts and various disturbances in the system.

The hyperlocal model of a single-input single-output first-order nonlinear system is:

$$\begin{cases} \dot{x} = f(x) + \beta u \\ y = x \end{cases} \tag{7}$$

In the formula: $\dot{x}$ is a state variable; f is an unknown nonlinear function, which satisfies Lipschitz boundedness, including bounded disturbance part.

3.2. Ultra-local Model of Open-winding Permanent Magnet Synchronous Motor

Based on the model-free control theory, we take the current of dq0 axis of OW-PMSM drive system as the output and the voltage of dq0 axis as the input, and we can getBased on the model-free control theory, we take the current of dq0 axis of OW-PMSM drive system as the output and the voltage of dq0 axis as the input, and we can get:

$$\frac{di_{\mathrm{dq0}}}{dt} = F_{\mathrm{dq0}} + \alpha_{\mathrm{dq0}} u_{\mathrm{dq0}} \tag{8}$$

In the formula: *F* represents all kinds of uncertain disturbances in OW-PMSM control system, including the disturbances caused by the uncertainty of motor parameters and the nonlinearity of inverter. A represents the voltage scaling factor in the drive system. F represents all kinds of uncertain disturbances in OW-PMSM control system, including the disturbances caused by the uncertainty of motor parameters and the nonlinearity of inverter. *α* represents the voltage scaling factor in the drive system.

In this chapter, the first-order forward Euler discretization method is used to discretize the dynamic equation of the current ultra-local model established by equation (8), so as to obtain the predicted current at the next moment, and its expression is:

$$\begin{cases} i_{\mathrm{d}}(k+1) = [\hat{F}\mathrm{d}(k) + \alpha_{\mathrm{d}} u_{\mathrm{d}}(k)]T_{\mathrm{s}} + i_{\mathrm{d}}(k) \\ i_{\mathrm{q}}(k+1) = [\hat{F}\mathrm{q}(k) + \alpha_{\mathrm{q}} u_{\mathrm{q}}(k)]T_{\mathrm{s}} + i_{\mathrm{q}}(k) \\ i_{0}(k+1) = [\hat{F}0(k) + \alpha_{0} u_{0}(k)]T_{\mathrm{s}} + i_{0}(k) \end{cases} \tag{9}$$

In the formula: i_d(k+1), i_q(k+1), i_0(k+1) represents the current prediction values of the dq0 axis at the time respectively.

In each period, all candidate basic voltage vectors are substituted into Equation (9) to obtain the corresponding predicted current, and then substituted into the cost function, and the basic voltage vector with the minimum value of the cost function is selected as the optimal voltage vector.

3.3. On-line Estimation of Disturbance Term

From the above analysis, it can be seen that the key factor affecting the performance of model-free control is whether the obtained Fdq0 is accurate, so it is necessary to use linear extended state observer to estimate the unknown variable F. The unknown variable f is expanded into a new state variable, that is, X2=F, and the expanded state space expression is obtained.

$$\begin{cases} \dot{x}_1 = x_2 + \beta u \\ \dot{x}_2 = \dot{F} \\ i_d = x_1 \end{cases} \tag{10}$$

Through the expanded system, the following linear state observer can be established. Through the expanded system, the following linear state observer can be established:

$$\begin{cases} e_{rr} = \hat{x}1 - y \\ \dot{\hat{x}}1 = \hat{x}2 + \beta u - \beta_{01} f(e_{rr}) \\ \dot{\hat{x}}2 = -\beta_{02} f(e_{rr}) \end{cases} \tag{11}$$

In the formula: $\hat{x}1$ and $\hat{x}2$ represent estimated values of state variables x_1 and x_2 ; β_{01} and β_{02} represent the observer parameters; $f(x)$ stands for linear function.

The linear function expression is as follows:

$$f(x) = e^{x} - e^{-x} \tag{12}$$

3.4. Improved Zero Vector Injection Model-free Current Predictive Control

In this paper, an improved zero vector injection method is proposed for OW-PMSM system. Based on the mixed vector method, the voltage vector on axis αβ0 is controlled in three steps to achieve the optimal zero sequence current suppression. In the first step, the selected optimal voltage vector is obtained by prediction model calculation. The second step is to calculate the compensation value of zero voltage vector according to the voltage vector obtained in the first step and its action time in a switching cycle; The third step is to further analyze and optimize the zero-sequence voltage vector under the premise of considering the third harmonic back emf in the zero-sequence flux linkage, so as to achieve the global optimal effect.

3.5. Model Predictive Tracking and Sector Selection of Reference Voltage

In order to better fit the required voltage vector, the model predictive control theory is cited, the output of the speed loop is defined as i_{qref}, and the control method of $i_{\mathrm{d}}=0$ is adopted. Suppose i_{dref} is 0, and $i_{0\mathrm{ref}}$ is also set as 0 to suppress the zero-sequence current, and it is substituted into the current predictive model of the open-winding motor system in formula (9), which not only makes:

$$\begin{cases} i_{\mathrm{d}}(k+1) = i_{\mathrm{dref}} \\ i_{\mathrm{q}}(k+1) = i_{\mathrm{qref}} \\ i_{0}(k+1) = i_{0r\mathrm{ef}} \end{cases} \tag{13}$$

The reference voltages u_{dref} , u_{qref} and $u_{0\mathrm{ref}}$ of each axis in the two-phase rotating coordinate system dq0 can be obtained. The reference voltage vectors $u_{\alpha\mathrm{ref}}$ and $u_{\beta\mathrm{ref}}$ in two-phase stationary coordinate system αβ can be obtained by coordinate transformation.

$$\begin{cases} u_{\alpha\mathrm{ref}} = u_{\mathrm{dref}} * cos\theta_{\mathrm{r}} - u_{\mathrm{qref}} sin\theta_{\mathrm{r}} \\ u_{\beta\mathrm{ref}} = u_{\mathrm{dref}} * cos\theta_{\mathrm{r}} - u_{\mathrm{qref}} sin\theta_{\mathrm{r}} \end{cases} \tag{14}$$

The phase angle (that is, the position angle θ of the reference voltage) in the plane αβ is calculated by $u_{\alpha\mathrm{ref}}$, $u_{\beta\mathrm{ref}}$ as follows:

$$\theta = arctan \frac{u_{\beta\mathrm{ref}}}{u_{\alpha\mathrm{ref}}} \tag{15}$$

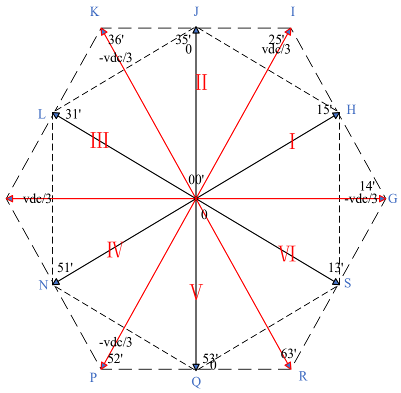


Fig 2. Sector division of double inverter voltage vector

Finally, in order to improve the efficiency of determining the candidate voltage vector range, the voltage vector distribution of the dual inverters is divided into six blocks, as shown in Figure 4. Then the sector is quickly selected according to the position angle θ of the obtained reference voltage vector, and the vector range of the candidate voltage is determined. After the sector number N is obtained, adjacent vectors V_m and V_n are selected as alternative voltage vectors.

3.6. Action Time Calculation and Zero Sequence Voltage Suppression Compensation

Considering the third harmonic in the permanent magnet flux linkage of the motor itself, there is a zero sequence voltage component in the back emf. After the obtained voltage vector V_x is determined, through calculation, the zero-sequence voltage generated by it can be obtained, which is recorded as u_x and its action time is t_x , and its calculation is as follows:

$$t_x = \frac{i_{qref} - i_q(k) - k_{q0} T_s}{k_{qx} - k_{q0}} (x = m, n) \tag{16}$$

k_{qx} and k_{q0} are the two change slopes of current i_q under the action of effective vector V_x and zero vector selected in a control period.

Therefore, two kinds of control can be obtained to make the q-axis current reach a given value, and the effective vector V_m or the effective vector V_n can be selected. The predicted current of the next cycle is calculated by Equation (17) to evaluate the two control effects.

$$\begin{cases} i_{dx}{}^{p}(k+1) = i_d(k) + k_{dx} t_x + k_{d0}(T_s - t_x) \\ i_{qx}{}^{p}(k+1) = i_q(k) + k_{qx} t_x + k_{q0}(T_s - t_x) \end{cases} \tag{17}$$

In order to select the optimal vector and its time, it is evaluated by the cost function formula (18), and the candidate vector with smaller cost function J is selected as the optimal vector, which is denoted as V_x and its action time is denoted as t_0.

$$J_x = \left[i_{dx}(k+1) - i_{dref} \right]^2 + \left[i_{qx}(k+1) - i_{qref} \right]^2 \tag{18}$$

Because of the instability of motor operation, there is a certain difference between zero-sequence voltage and reference voltage u_{0ref}. In order to compensate this difference, it is necessary to generate zero-sequence voltage equal to the difference without affecting the αβ-axis voltage vector obtained before. Because dual inverters can generate three kinds of zero-voltage vectors, positive, negative and zero, the zero-sequence voltage can be compensated by mixing two kinds of zero-voltage vectors.

This method is called mixed zero-vector method in this paper. Firstly, the action time of zero-sequence voltage vector is subdivided and expressed as:

$$t_0 = t_a + t_b \tag{19}$$

Considering the back emf of the third harmonic of flux linkage in zero sequence, the zero sequence voltage compensation equation can be expressed as:

$$V_{0\text{ref}} * T_s - t_x * V_x - t_a V_2 \tag{20}$$

When $V_{0\text{ref}} * T_s - t_x * V_x > 0$, V_2 selects 111000 vector;

When $V_{0\text{ref}} * T_s - t_x * V_x = 0$, V_2 selects 000000 vector;

When $V_{0\text{ref}} * T_s - t_x * V_x < 0$, V_2 selects 00111 vector;

The remaining time t_b is filled with 000000, and finally the global optimization is achieved.

3.7. The Whole Method of Model-free Current Predictive Control

Fig. 3 is a block diagram of model-free current prediction control. First, the system adopts double closed-loop control strategy, and $i_{d\text{ref}}=0$. The Q-axis current is output as a given value of $i_{q\text{ref}}$ through the speed loop PI controller, which makes the reference current of the 0-axis zero during control, so as to realize the suppression of zero-sequence current. The motor runs and obtains the reference voltage of $i_{dq0\text{ref}}$ through the model-free current prediction equation. Then, the adjacent basic voltage vectors are selected, and the optimal voltage vector and its action time are obtained through the comparison of value functions. Then the zero-sequence voltage generated by the optimal voltage vector and the action time is calculated, and then the difference between the reference zero-sequence voltage and the calculated zero-sequence voltage is calculated. By judging the positive and negative of the difference, the zero-sequence voltage vector we choose is determined, and the action time of selecting the zero-sequence voltage vector is calculated according to the difference. Finally, the zero sequence voltage is compensated by mixed zero vector. Therefore, the model-free current predictive control in this paper has reached the optimal level.

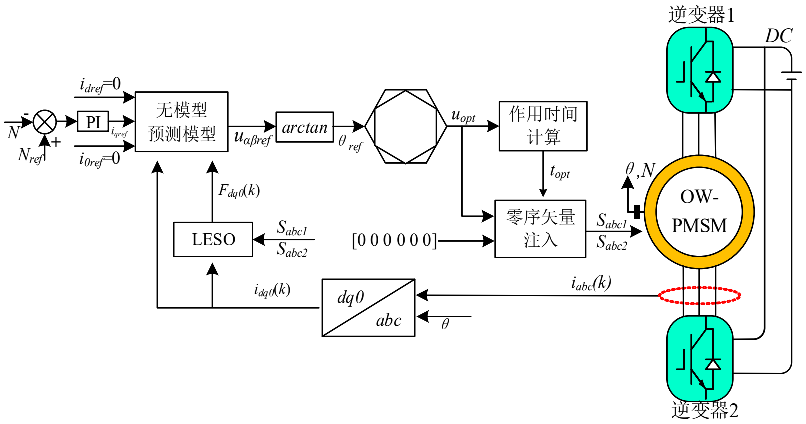


Fig 3. Block diagram of model freecurrent prediction control

4. SIMULATION VERIFICATION AND ANALYSIS

In order to verify the effectiveness of the model-free current predictive control method proposed in this paper, the actual operation test of the motor is carried out under working conditions. The traditional PI controller is used in the speed loop, and the model is built in Matlab/Simulink simulation environment. The traditional model-free current predictive control method (as shown in Figure 4) is compared with the model-free current predictive control method in this paper (as shown in Figure 3) to analyze its steady-state performance.

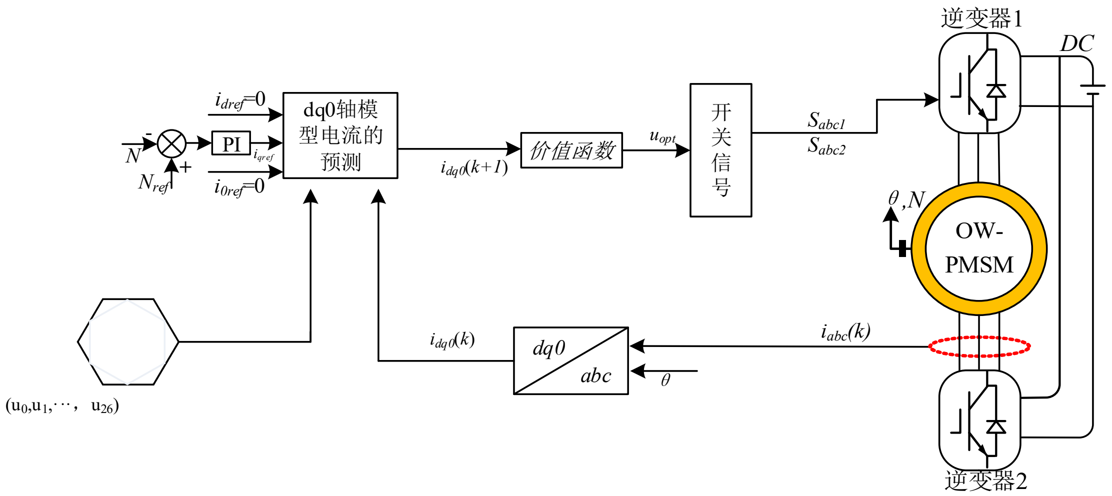


Fig 4. Block diagram of traditional model current prediction control

The main parameters of the open-winding permanent magnet synchronous motor with common DC bus in the simulation are shown in Table 1. Control period T=50us:

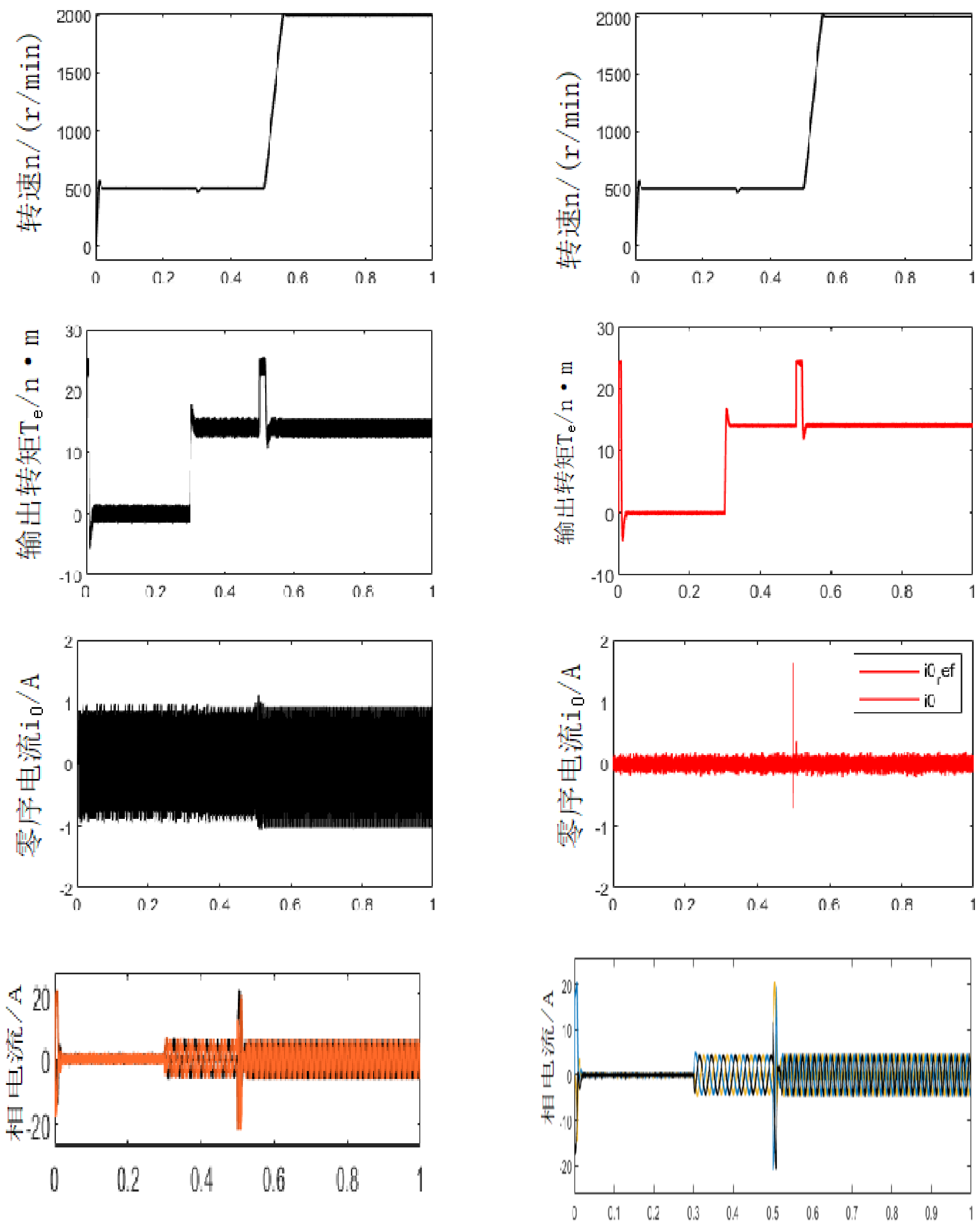
Table 1. Simulation model parameters

parameter	numerical value
Rated power /KW	5.5
Rated speed/(r • min^{-1})	2000
Rated current /A	14
Rated torque/(N·m)	14
number of pole-pairs	4
Winding inductance Ld, Lq/mH	5
Zero-axis inductance L0/mH	2
Stator resistance RS/ Ω	2
Permanent magnet flux linkage Ψ f/Wb	0.2
3rd harmonic component of permanent magnet flux linkage Ψ 3f/Wb	0.005

4.1. Simulation Verification of Zero Sequence Current Suppression

Given the speed command 500r/min for low-speed operation, add a torque of 14N·m to the motor in 0.3s, and increase it to a high speed of 2000r/min at 0.5s until it runs. Speed, electromagnetic torque and three-phase stator current waveforms under two different control methods. As shown in fig. 5.

As can be seen from Figure 5, when the mixed zero-vector model-free current predictive control is adopted, compared with the traditional model-free current predictive control (MPCC), the fluctuation amplitude of zero-sequence current is obviously reduced, and the effect of restraining zero-sequence current is remarkable. When TL = 14 N·m load torque is added to the motor at 0.3s, it takes only 0.015s for the torque to reach the given value and restore stability at a faster speed. Therefore, the mixed zero-vector model-free current predictive control is superior. The ability to suppress zero sequence current is also stronger and has stronger anti-interference ability. It is proved that the model-free current control strategy of open-winding permanent magnet synchronous motor with mixed zero vector injection is better than the traditional model current prediction.



(a) Traditional MPCC (b) Improved MFPP CC

Fig 5. Simulation comparison of two methods

5. CONCLUSION

This paper introduces a hybrid two-vector model-free current predictive control strategy suitable for common bus open-winding permanent magnet synchronous motor. By using ultra-local equation to predict the current, substituting value function to select the optimal basic voltage vector and injecting mixed zero voltage vector, the zero-sequence current is suppressed, the anti-interference performance of the motor is effectively improved, and the torque ripple under different working conditions is effectively suppressed, the number of candidate voltage vectors is reasonably reduced, and the steady-state control performance is better.

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