Multi-stage model predictive current control with parameters-free for PMSM drives

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Introduction- To weaken the parameter sensitivity of the system, a multi-stage model predictive current control with parameters-free for PMSM drives is proposed based on the traditional model predictive current control. In this strategy, the strategy only uses the current variation to get the inductance parameters by integration, and then replaces the inductance parameters into the prediction model. This method does not require motor parameters, Many experiments have proved that this method is effective.

Figure 1 is a control block diagram of the proposed method.

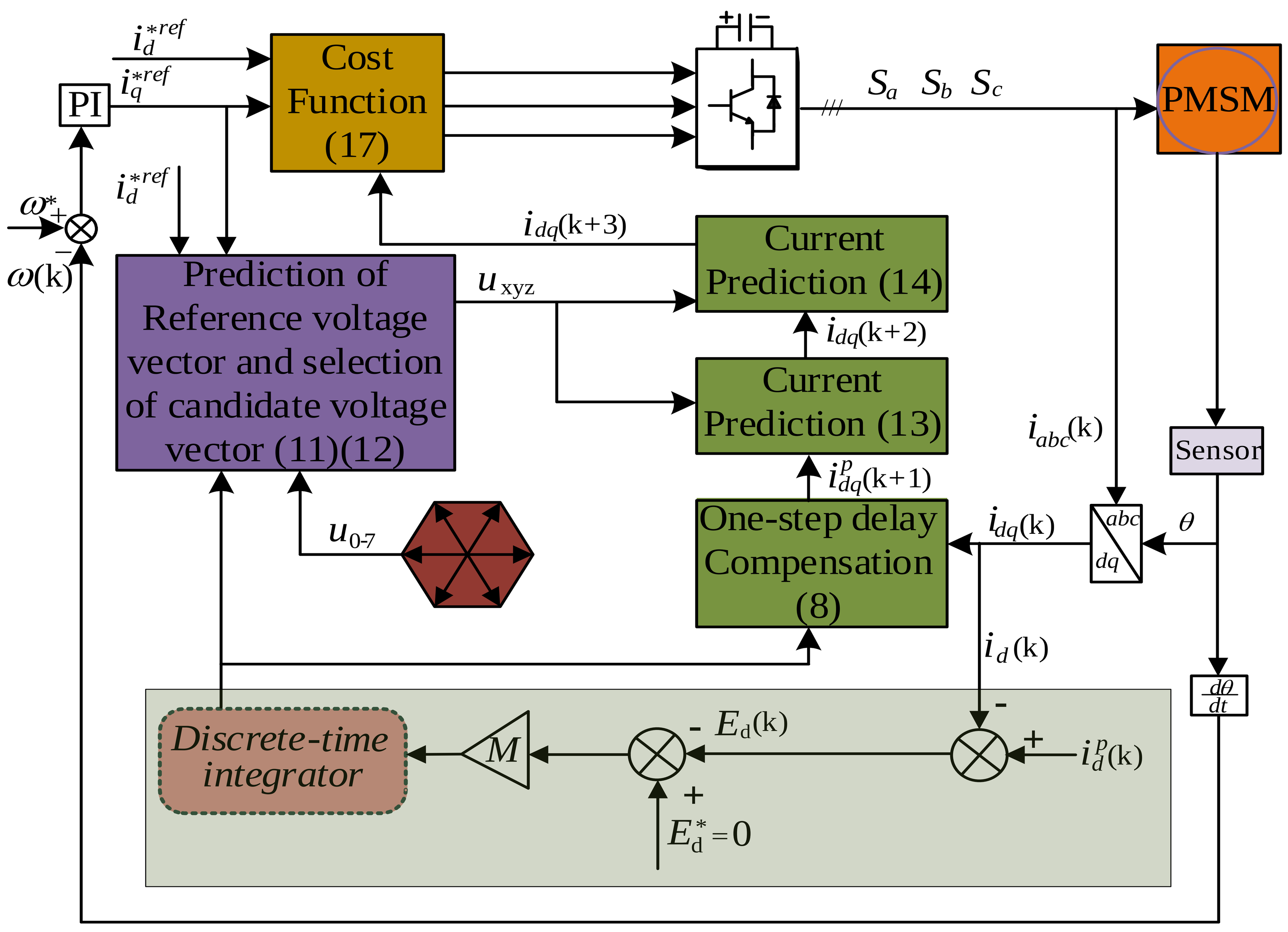

Fig.1 The control block diagram of the proposed method.

Establishment of parameter free prediction model for motor and design of cost function

After adding one step delay compensation, the following is the improved current prediction model

$$\begin{bmatrix} i_d(k+2) \\ i_q(k+2) \end{bmatrix} = 2\cdot\begin{bmatrix} i_d^{\,p}(k+1) \\ i_q^{\,p}(k+1) \end{bmatrix} + \frac{T_s}{L}\begin{bmatrix} u_d(k+1)-u_d(k) \\ u_q(k+1)-u_q(k) \end{bmatrix} - \begin{bmatrix} i_d^{\,p}(k) \\ i_q^{\,p}(k) \end{bmatrix} + T_s\omega_e\begin{bmatrix} i_q^{\,p}(k+1)-i_q^{\,p}(k) \\ i_q^{\,p}(k)-i_d^{\,p}(k+1) \end{bmatrix} \tag{1}$$

If we can extract the real data (T_s/L) by algorithm and substitute it. Therefore, a prediction model with parameters-free for PMSM drives will be established.

Equation (2) is the formula of reference voltage vector prediction.

$$\begin{cases} U_d^{*ref} = u_d(k) + \frac{1}{H}\cdot\left[i_d^{*ref} - 2i_d^p(k+1) + i_d^p(k) - T_s\omega_e\left[i_q^p(k+1) - i_q^p(k)\right]\right] \\ U_q^{*ref} = u_q(k) + \frac{1}{H}\cdot\left[i_q^{*ref} - 2i_q^p(k+1) + i_q^p(k) + T_s\omega_e\left[i_d^p(k+1) - i_d^p(k)\right]\right] \end{cases} \tag{2}$$

where $H=T_s/L$, represents the real value acquired from the current error by the algorithm.

Phase angle calculation of the reference voltage vector.

$$U_{ref} = \begin{pmatrix} U_\alpha^{*ref} \\ U_\beta^{*ref} \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix}\cdot\begin{pmatrix} U_d^{*ref} \\ U_q^{*ref} \end{pmatrix}. \tag{3}$$

$$\theta_r = \arctan\left(\frac{U_\beta^{*ref}}{U_\alpha^{*ref}}\right). \tag{4}$$

The selection of candidate voltage vectors is described below.

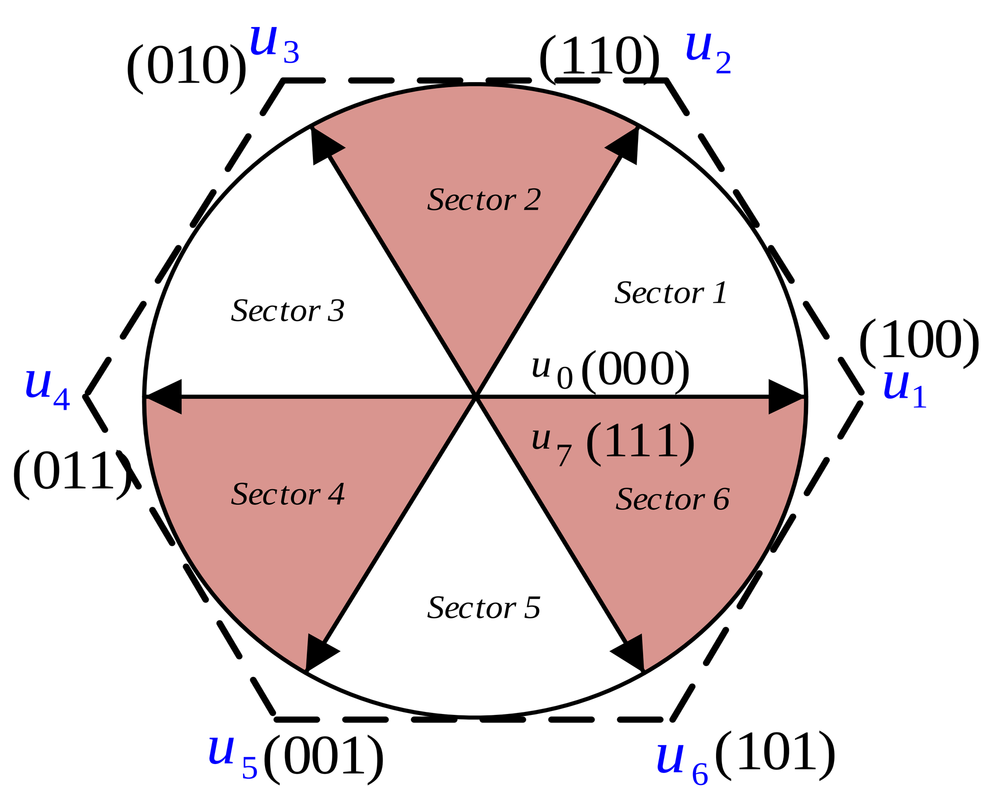

Fig. 2 Sector Distribution Map

Table.2 Selection of candidate voltage vectors

phase angle θ	Sector number	Candidate VVs
$(0,\pi/3]$	①	$u_{0,7},u_1,u_2$
$(\pi/3,2\pi/3]$	②	$u_{0,7},u_2,u_3$
$(2\pi/3,\pi]$	③	$u_{0,7},u_3,u_4$
$(\pi,4\pi/3]$	④	$u_{0,7},u_4,u_5$
$(4\pi/3,5\pi/3]$	⑤	$u_{0,7},u_5,u_6$
$(5\pi/3,2\pi]$	⑥	$u_{0,7},u_1,u_6$

The designed cost function includes the global optimality of two moments.

$$\begin{aligned} G = &\left[i_d(k+2) - i_d^{*ref}\right]^2 + \left[i_q(k+2) - i_q^{*ref}\right]^2 \\ &+ c\cdot\left[\left[i_d(k+3) - i_d^{*ref}\right]^2 + \left[i_q(k+3) - i_q^{*ref}\right]^2\right] \end{aligned} \tag{5}$$

Obtaining parameters based on current difference.

For the motor parameters, T_s /L is taken as a whole. Through the current difference, the T_s /L can be gained. This approach can weaken the sensitivity of the model predictive control to the parameters.

$$H = \frac{T_s}{L} = M \bullet \int E_d dt \qquad (6)$$

E_d represents the current difference at different moments and M is the set integration factor.

Figure 3 shows the specific steps of the proposed method.

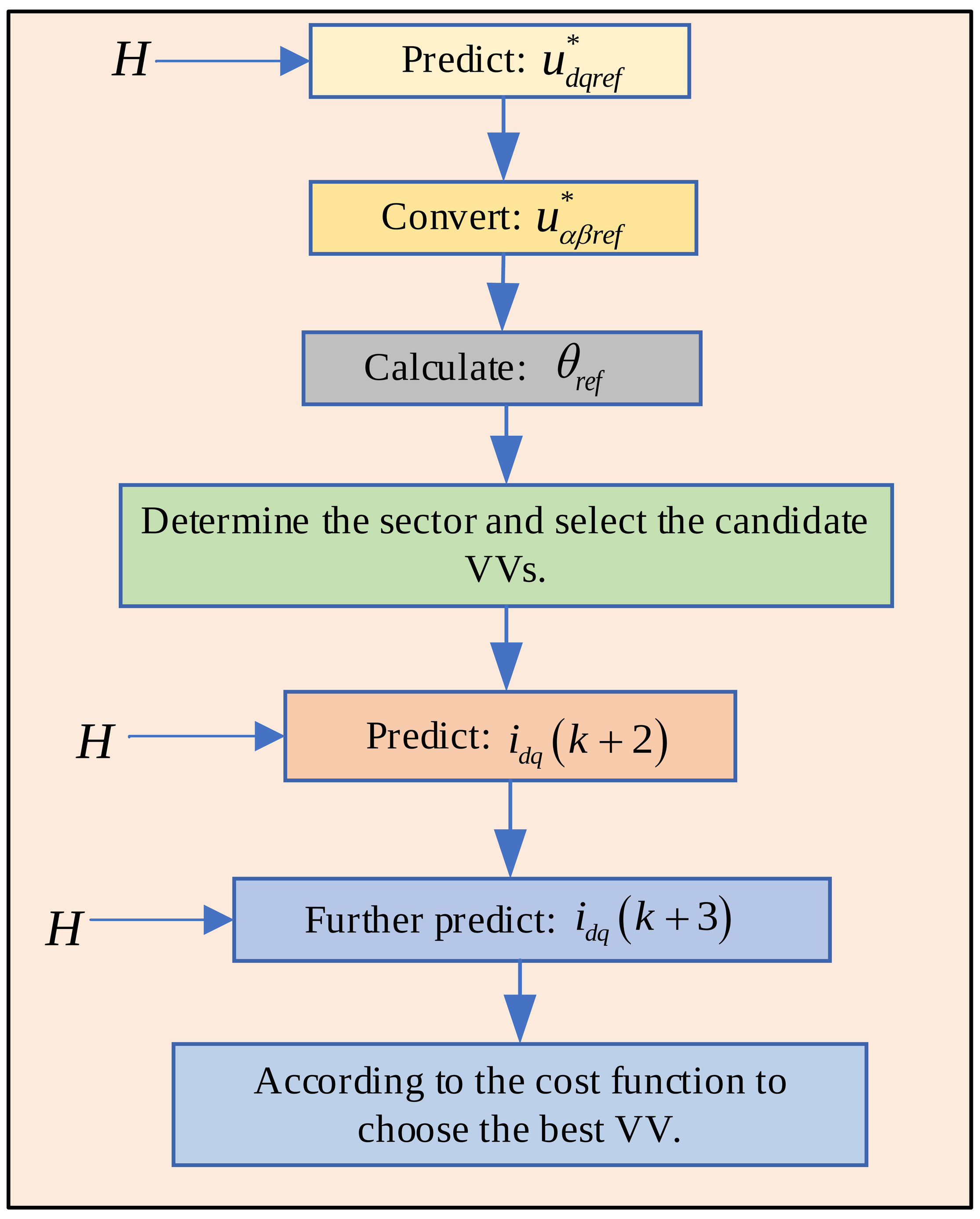

Fig.3 specific steps of the proposed method.

Experimental Result

Table.2 shows the information of the motor parameter.

Table .2 motor parameters

Parameter	Description	Value
VDC (V)	DC Voltage	277
L (H)	Inductance	1.1×10-3
J (kg.m2)	Rotational inertia	1.29×10-3
R (Ω)	Stator Resistance	3.0
ψf (Wb)	Permanent magnet flux linkage	0.24
TeL(N•m)	Load torque	6
pn	Number of pole pairs	3

Fig. 4 shows the hardware platform of this experiment.

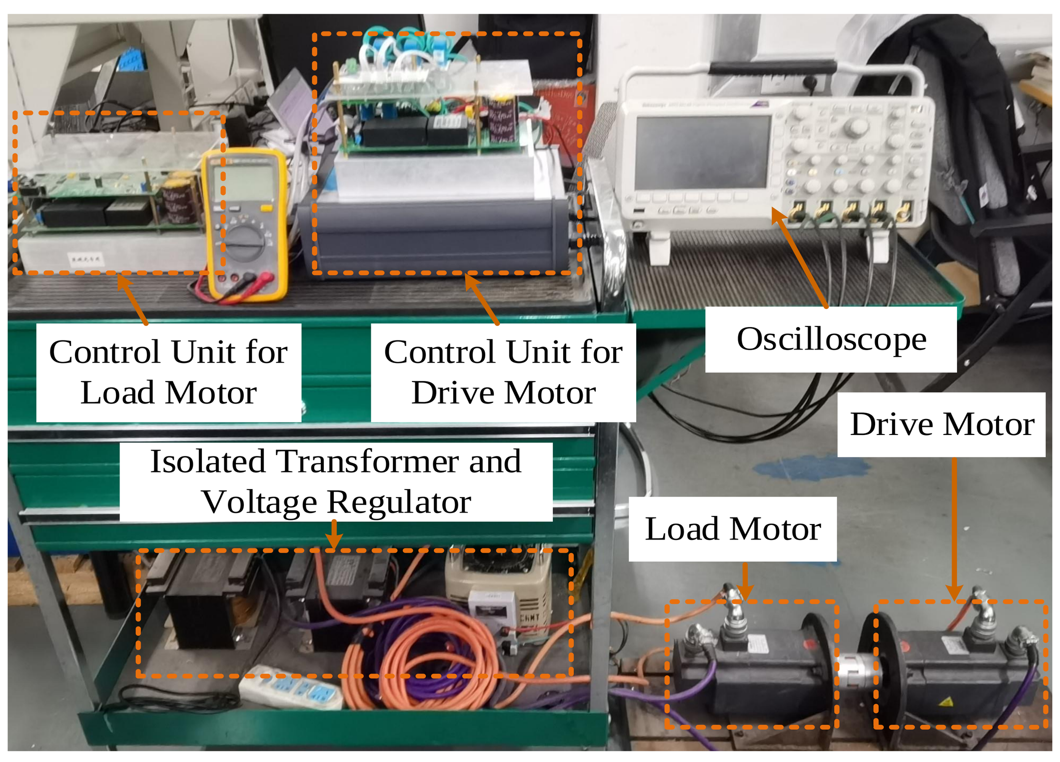

Fig. 4. Relevant equipment for the experiment

The experiments are conducted with normal parameters and parameter mismatch, where the mismatch parameters are triple inductance, triple resistance and triple flux linkage. Fig. 5 shows the experimental waveforms and THD for different methods at load torque (6N•m) and speed of 1500 r/min.

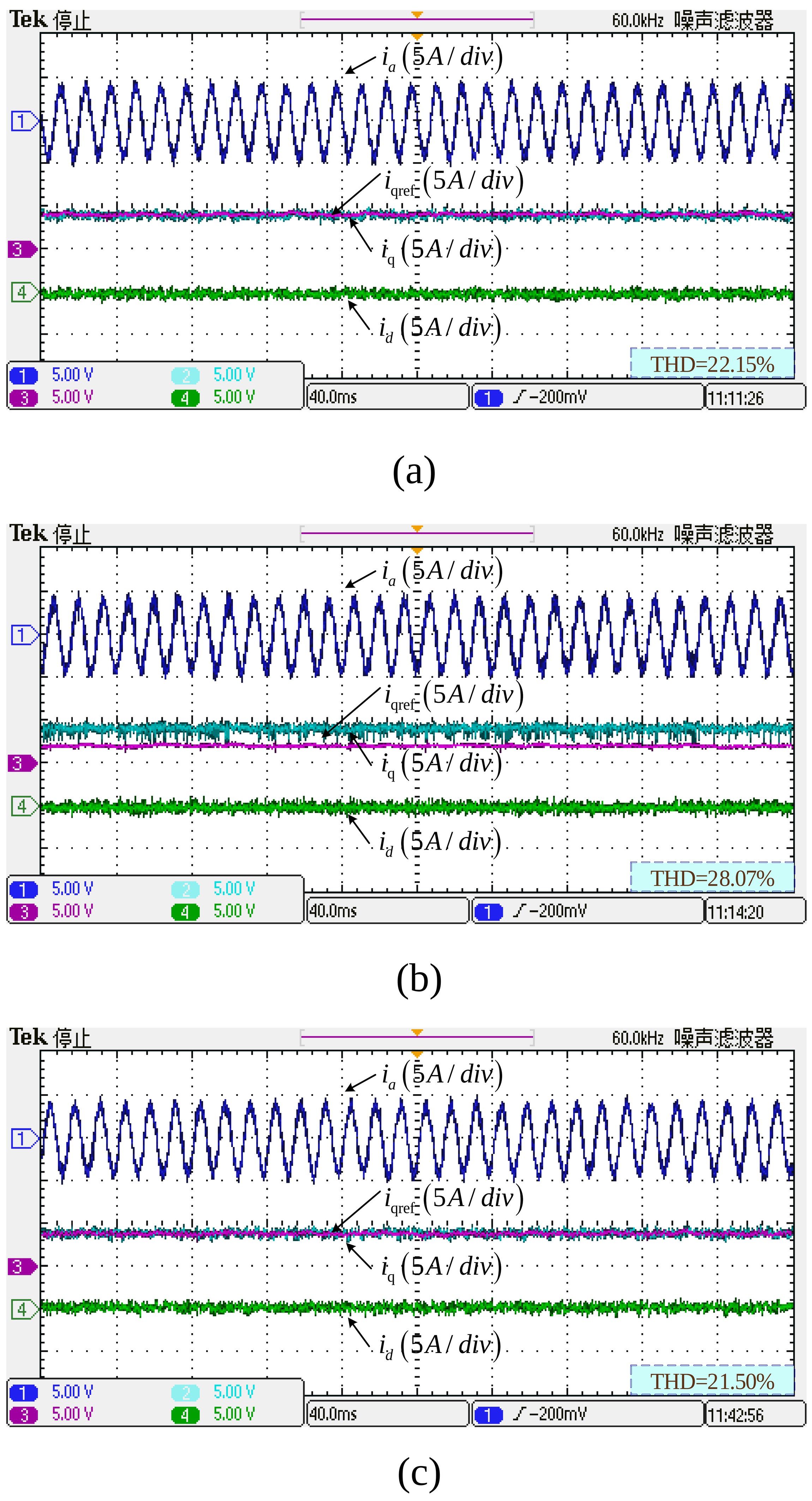

Fig. 5. is the waveform diagram and THD of different methods with load torque (6N • m) and speed of 1500r/min. (a) Traditional MPCC. (b) Traditional MPCC with parameter mismatch. (c) The proposed method.

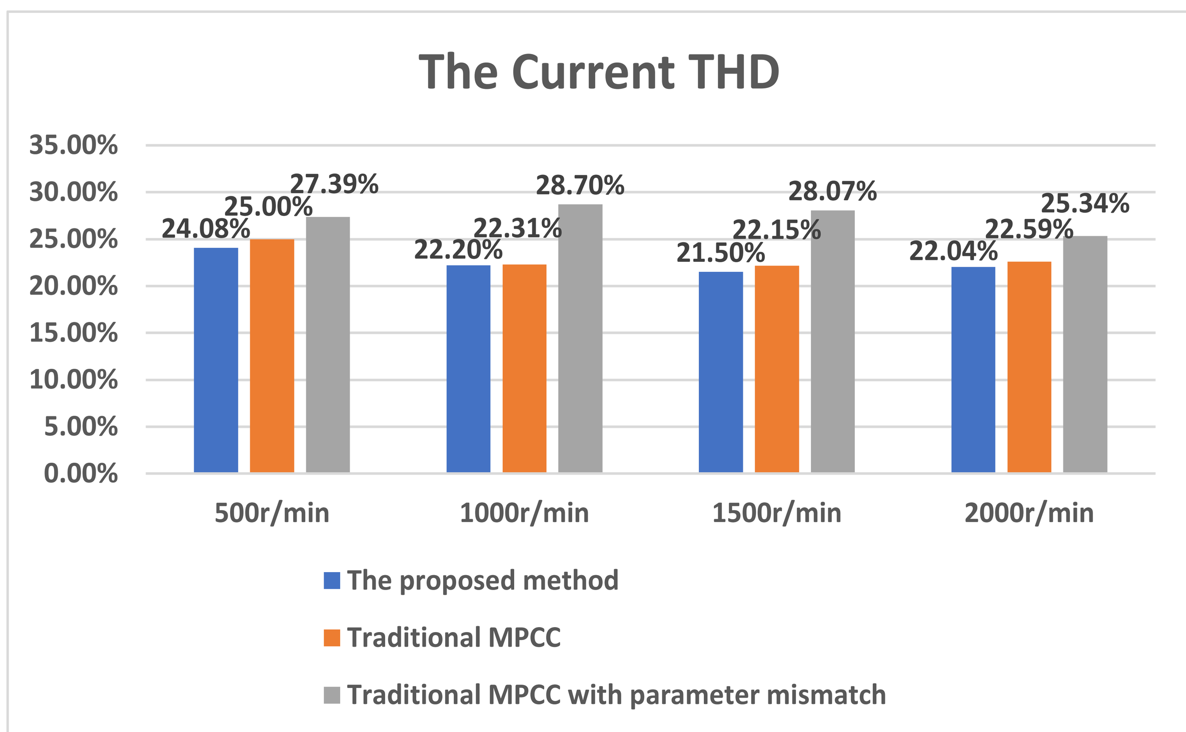

Fig. 6. The THD of different methods

The proposed method also has the ability to resist parameter mismatch and ideal switching frequency. Also, the improved method has good control effect through the above experiments.