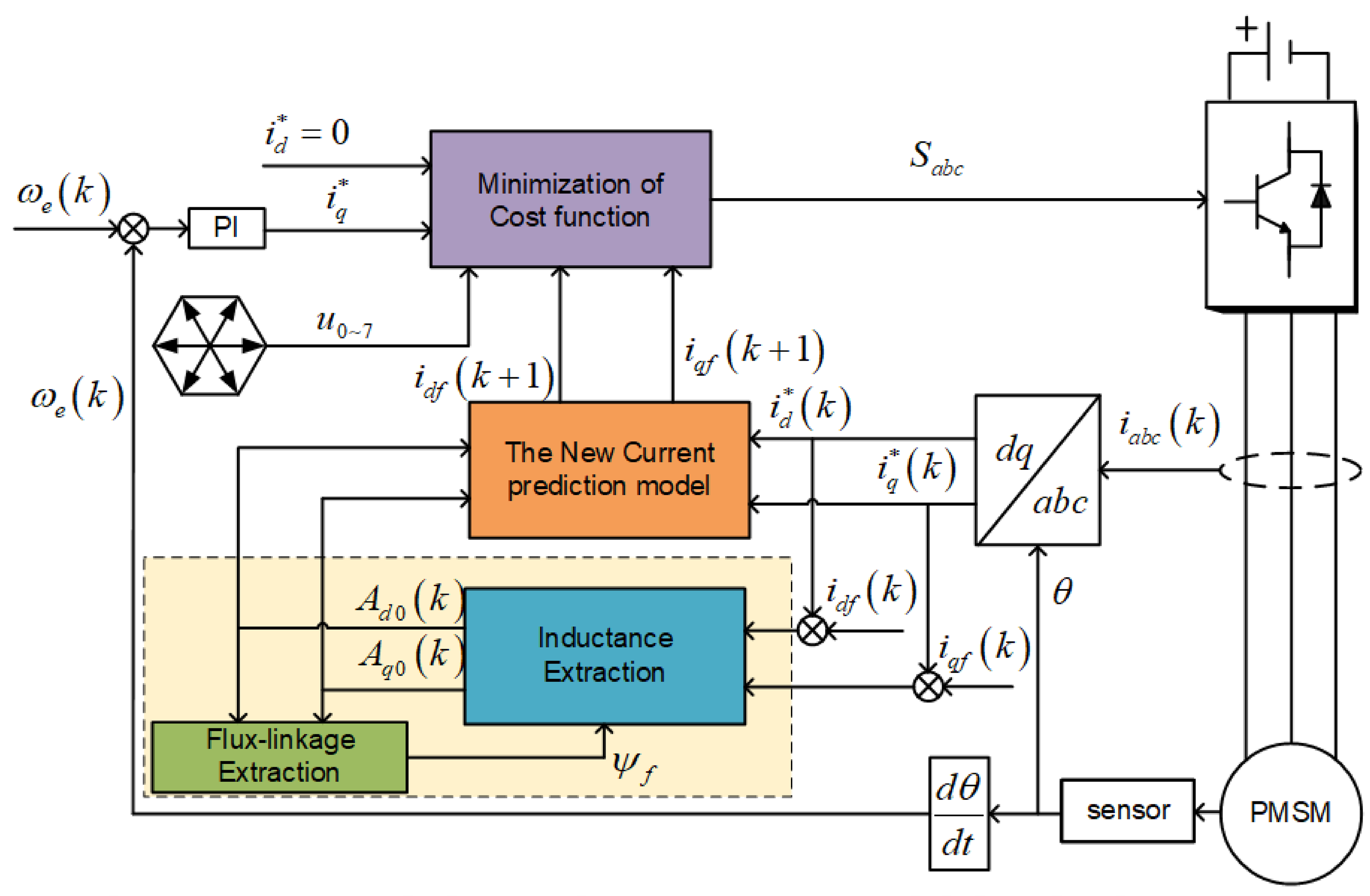
A New Parameter-free Predictive Current Control for PMSM

Xiaoguang Zhang, North China University of Technology, Beijing, China, zxg@ncut.edu.cn
Guofu Zhang, North China University of Technology, Beijing, China,412370098@qq.com

Introduction-In order to address the issue of dependence on motor parameters in the traditional Model Predictive Current Control (MPCC) method, a novel model predictive current control approach has been designed. This method involves analyzing the current difference in the *dq*-axes to extract the inductance parameters of both axes and the magnetic flux parameter of the *q*-axis. Subsequently, these extracted parameters are used to replace the original motor parameters in the predictive model, effectively eliminating the errors associated with motor parameters and obtaining more accurate predictive results. By adopting this approach, the predictive model achieves independence from specific motor parameters, resulting in improved control precision and robustness.



The new model predictive control block diagram

Motor Parameter Error Analysis

Using accurate motor parameters for the predictive model

$$\begin{cases} i_d^*(k+1) = \left(1-\dfrac{TR}{L_d}\right) i_d(k) + \dfrac{T}{L_d} u_d(k) + T\omega_e i_q(k) \\ i_q^*(k+1) = \left(1-\dfrac{TR}{L_q}\right) i_q(k) + \dfrac{T}{L_q} u_q(k) - T\omega_e i_d(k) + \dfrac{T}{L_q}\omega_e \psi_f \end{cases}$$

In reality, there are errors in the motor parameters

$$\begin{cases} R_0 = R + \Delta R \\ L_{d0} = L_d + \Delta L_d \\ L_{q0} = L_q + \Delta L_q \\ \psi_{f0} = \psi_f + \Delta \psi_f \end{cases}$$

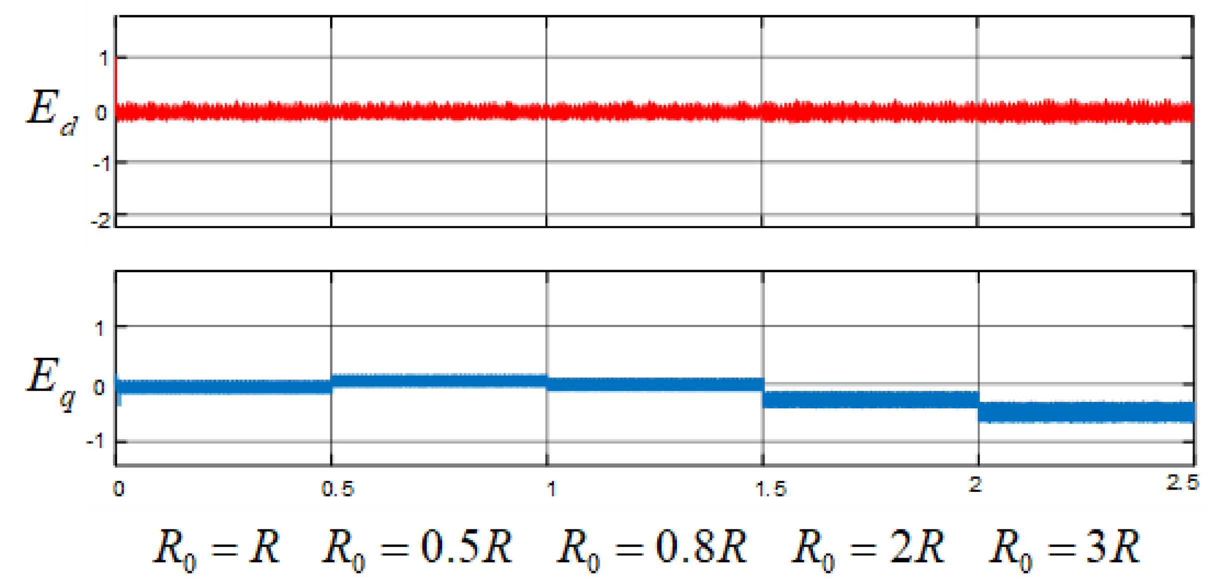
The predictive model with actual motor parameters

$$\begin{cases} i_{df}(k+1) = \left(1-\dfrac{TR_0}{L_{d0}}\right) i_d(k) + \dfrac{T}{L_{d0}} u_d(k) + T\omega_e i_q(k) \\ i_{qf}(k+1) = \left(1-\dfrac{TR_0}{L_{q0}}\right) i_q(k) + \dfrac{T}{L_{q0}} u_q(k) - T\omega_e i_d(k) + \dfrac{T}{L_{q0}}\omega_e \psi_f \end{cases}$$

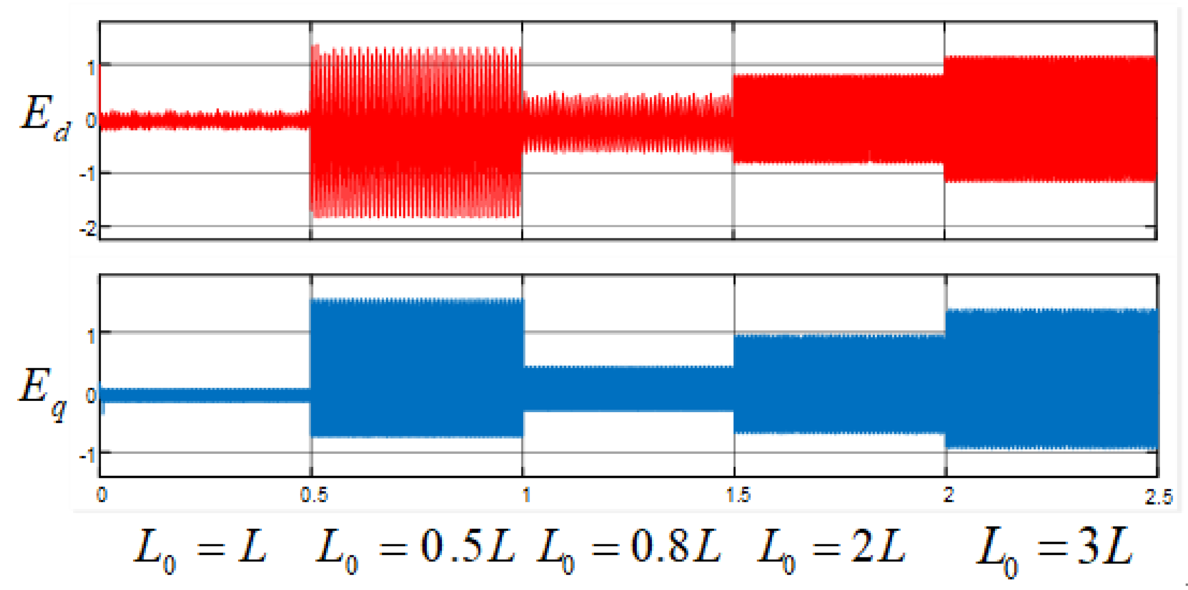
Obtaining the difference between predicted currents.

$$\begin{cases} E_d(k+1) = i_{df}(k+1) - i_d^*(k-1) \\ E_q(k+1) = i_{qf}(k+1) - i_q^*(k-1) \end{cases}$$

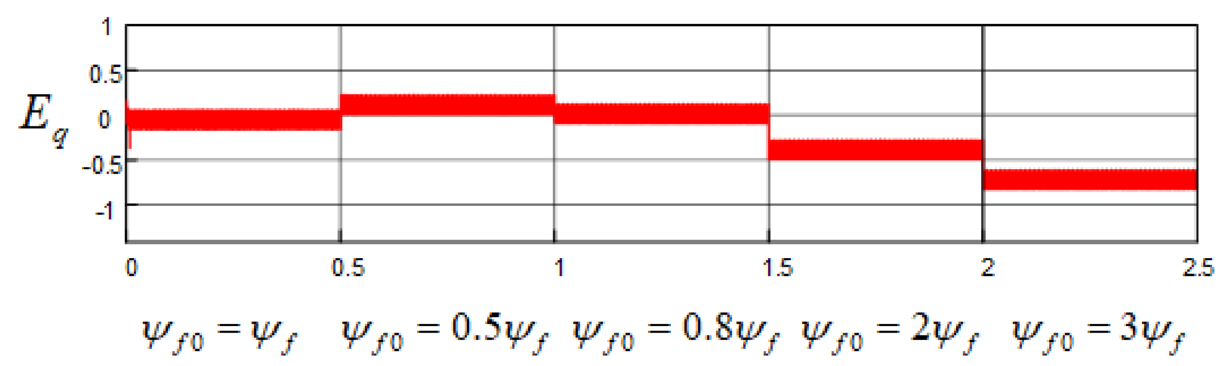
Simulating the relationship between motor parameter mismatch and the difference in predicted currents.



Resistance mismatch



Inductance mismatch



Flux-linkage mismatch

- ◆The *q*-axis current is greatly affected by the resistance mismatch, whereas the *d*-axis current is minimally affected by it.
- ◆Both axes are significantly influenced by inductance mismatch,
- ◆Only the *q*-axis current is affected by flux-linkage mismatch.

Note $1-\dfrac{TR_0}{L_0} \approx 1$

The predictive model has been updated to:

$$\begin{cases} i_{df}(k+1) = i_d(k) + \dfrac{T}{L_{d0}} u_d(k) + T\omega_e i_q(k) \\ i_{qf}(k+1) = i_q(k) + \dfrac{T}{L_{q0}} u_q(k) - T\omega_e i_d(k) + \dfrac{T}{L_{q0}}\omega_e \psi_f \end{cases}$$

A New Parameter-free Predictive Current Control for PMSM

D-axis inductance extraction

The current difference for the d-axis can be rearranged as:

$$E_d(k+1)=\left(A_d(k)-A_{d0}\right)u_d(k)$$

T/L_{d0} with actual operating conditions' parameters.

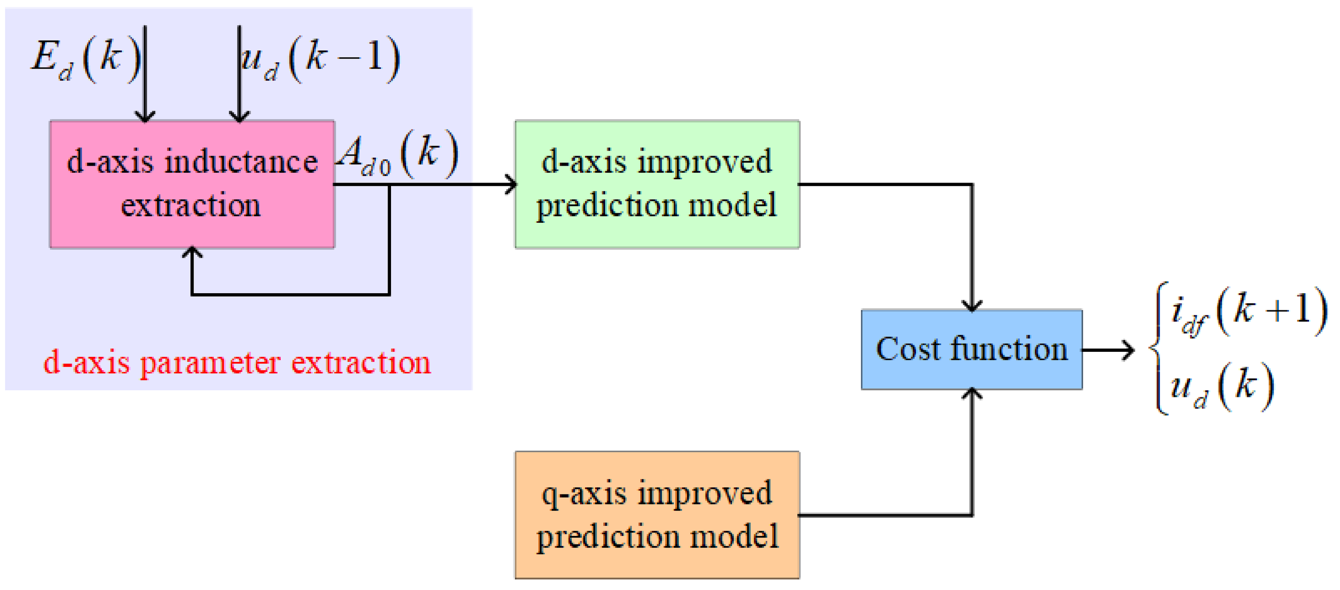
T/L_d with accurate parameters.

Extract A_{d0}: $$A_{d0}=A_d(k)-\frac{E_d(k+1)}{u_d(k)}$$

The extracted A_d(k) should be the same as A_{d0}.

$$A_d(k)=A_{d0}$$
$$=A_d(k-1)-\frac{E_d(k)}{u_d(k-1)}$$

low-pass filtering: $$A_{d0}(k)=\mu_d A_d(k)+(1-\mu_d)A_{d0}(k-1)$$



Q-axis parameter extraction

$$i_{qf}(k+1)=i_q(k)+\frac{T}{L_{q0}}u_q(k)-T\omega_e i_d(k)+\frac{T}{L_{q0}}\omega_e\psi_f$$

contains two motor parameters: L_{q0} ψ_f

Flux-linkage:

$$\psi_f=\frac{u_q(k)-Ri_q(k)}{\omega_e}-L_q\frac{i_q(k)-i_q(k-1)}{T\omega_e}-L_d(k)i_d(k)$$

unknown

known

$$\psi_f=f(L_q)$$

Q-axis inductance:

The current difference for the q-axis can be rearranged as:

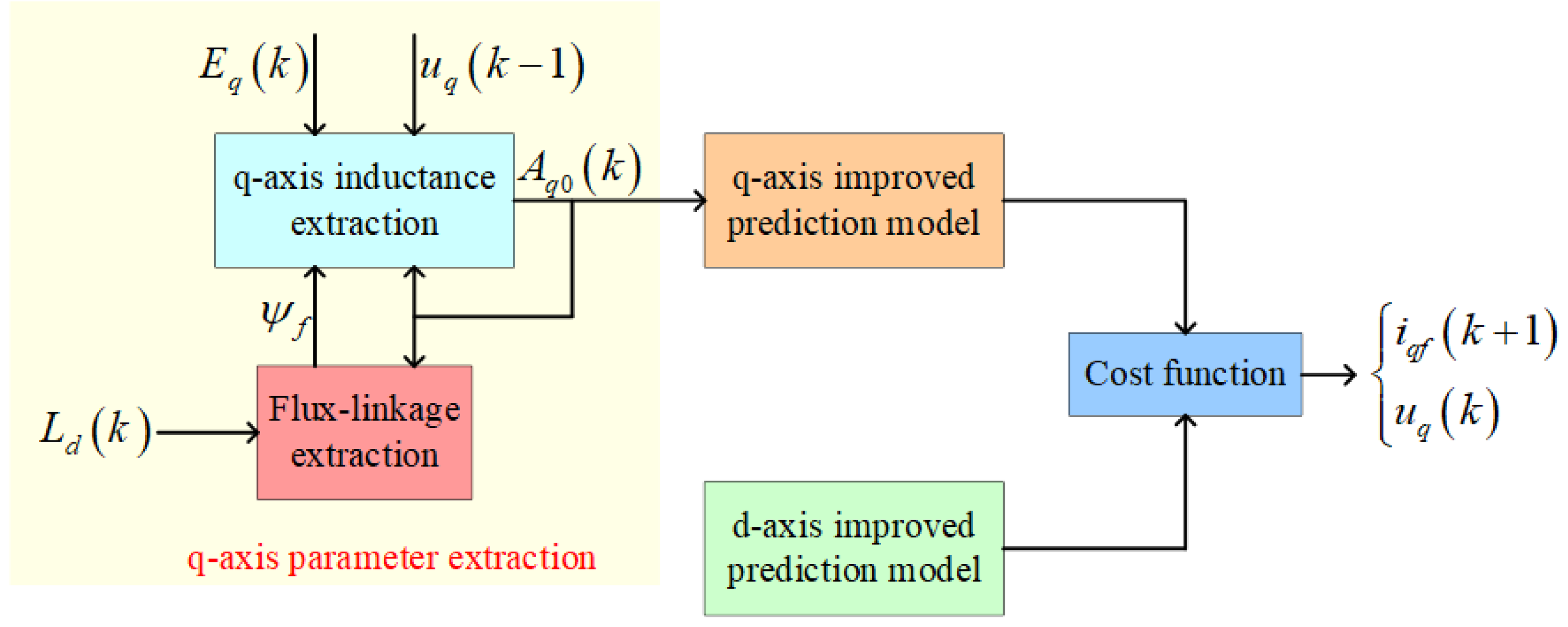
$$E_q(k+1)=\left(A_q(k)-A_{q0}\right)\left(u_q(k)-\omega_e\psi_f\right)$$

Extract A_{q0} (k):

$$A_q(k)=A_{q0}$$
$$=A_q(k-1)-\frac{E_q(k)}{\left(u_q(k-1)-\omega_e\psi_f\right)}$$

filtering $$A_{q0}(k)=\mu_q A_q(k)+(1-\mu_q)A_{q0}(k-1)$$

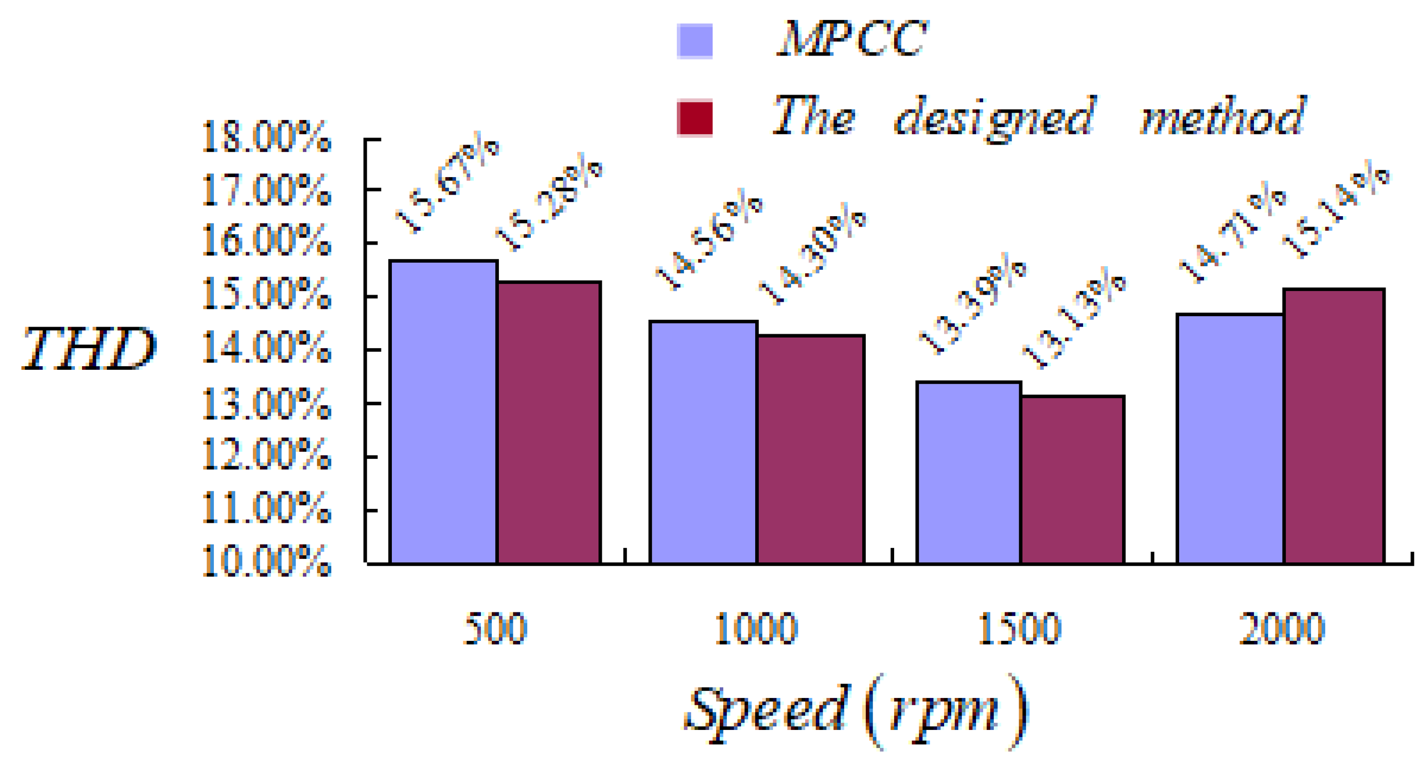
$$\psi_{f-3}=\frac{\psi_f(k)+\psi_f(k-1)+\psi_f(k-2)}{3}$$



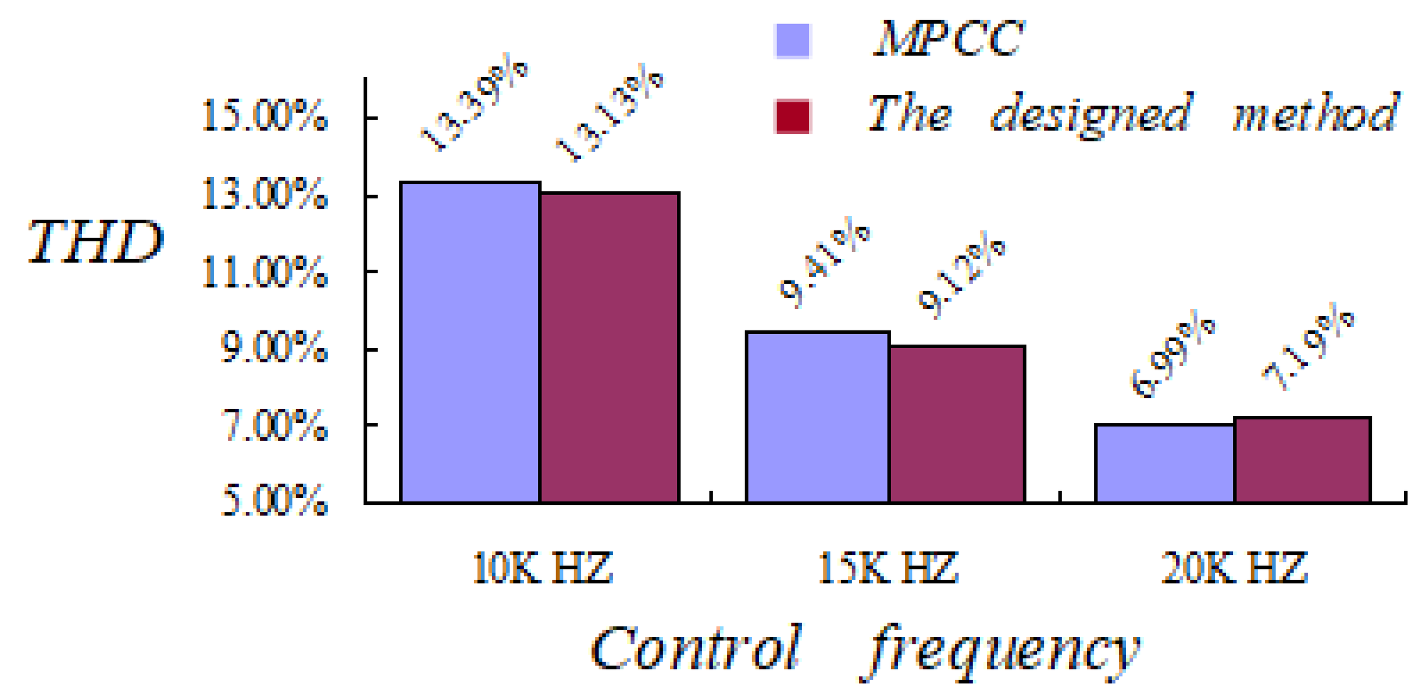
Updated predictive model:

$$\begin{cases} i_{df}(k+1)=i_d(k)+T\omega_e i_q(k)+A_{d0}(k)u_d(k) \\ i_{qf}(k+1)=i_q(k)-T\omega_e i_d(k)+A_{q0}(k)u_d(k)-A_{q0}(k)\omega_e\psi_{f-3} \end{cases}$$

Simulation Results



THD comparison of different speed under rated load torque(10kHZ).



Speed 1500rpm and rated load torque THD comparison of different control frequencies.