A CURRENT-TORQUE DUAL-OBJECTIVE MODEL PREDICTIVE CONTROL STRATEGY FOR ENHANCED PMSM DRIVE PERFORMANCE

VAN THI KIEU NHI, LE VAN DAI, BACH THANH QUY*
Faculty of Electrical Engineering Technology, Industrial University of Ho Chi Minh City
** Corresponding author: bachthanhquy@iuh.edu.vn*
DOIs: https://www.doi.org/ 10.46242/jstiuh.v83i5. 6186

Abstract. In this study, a current-torque dual-objective model predictive control (CTDO-MPC) method is proposed to improve steady-state and transient performance. Unlike conventional CO-MPC, which mainly minimizes stator current errors, the proposed method integrates current-tracking error and electromagnetic torque deviation into a unified objective function. To balance the current and torque terms' sensitivity within the same objective function, a weighting factor is analytically determined under equal voltage variation conditions. All feasible inverter voltage vectors are evaluated at each sampling instant, and the vector that minimizes the objective function is applied in the next control interval. The controller is validated in MATLAB/Simulink with a 1.5 kW PMSM drive and compared with CO-MPC. Simulation results demonstrate that the proposed strategy reduces current total harmonic distortion from 5.1% to 3.6% at half-load and 2.5% to 1.8% at full-load. In addition, the RMS torque ripple is reduced from 0.31 Nm to 0.24 Nm at half-load and 0.29 Nm to 0.22 Nm at full-load. These results indicate improved current quality, reduced torque ripple, and enhanced PMSM drive performance.

Keywords. permanent magnet synchronous motor, model predictive control, weighting factor, objective function, current total harmonic distortion, torque ripple.

1 INTRODUCTION

Due to their efficiency, torque density, compact structure, and high power factor, permanent magnet synchronous motors (PMSMs) are frequently used in modern drive systems [1]. These characteristics make PMSMs appropriate for high-precision applications such as servo drives [2], electric vehicles [3], and railway traction [4]. PMSM drive control is difficult due to its precise current and torque management requirements. PMSM drives need improved control solutions to increase steady-state and transient performance.

Model predictive control (MPC) has attracted considerable attention as a promising modern control strategy for PMSM drives [5]. MPC uses a mathematical model to forecast system behavior and minimize a predetermined objective function to choose the optimal voltage vector. According to the selected control variables, MPC methods for PMSM drives can be classified into several categories, such as model predictive current control [6, 7], model predictive torque control [8], model predictive stator flux control [9], and model predictive speed control [10]. Each method focuses on a specific control objective, such as stator current, electromagnetic torque, flux, or rotor speed. Due to its simple structure, fast dynamic reaction, and direct current regulation, model predictive current control is one of the most widely used methods.

Despite its advantages, conventional current-objective model predictive control (CO-MPC) still has several limitations. Since its objective function mainly focuses on minimizing stator current errors, the electromagnetic torque behavior is not directly considered during the selection of voltage vectors. As a result, the torque ripple may not be effectively controlled, especially during rapid load changes or transient operating situations. This constraint may diminish the smoothness of the torque production and compromise the PMSM performance [11]. Therefore, relying on a single control objective may be insufficient when both current quality and torque performance are required simultaneously.

To overcome the limitations of single-objective MPC methods, several predictive control strategies have been developed that incorporate multiple control objectives within a single objective function. According to recent references, predictive torque and flux control has been reported in [12], whereas time-optimal MPC considering current and torque constraints was investigated in [13]. Although these studies have the significant advantage of incorporating multiple objectives into the control process, balancing these constraints poses a challenge. Selecting an appropriate weighting factor to accurately evaluate the error of

© 2026 Industrial University of Ho Chi Minh City

each control variable with respect to its reference value leads to a relatively complex objective function design. Therefore, ongoing efforts are needed to identify new, suitable algorithms to further advance this field.

Different from existing multi-objective MPC strategies that often rely on empirical weighting factors, the proposed CTDO-MPC is developed as a direct extension of the finite-control-set CO-MPC framework. Its novelty is the analytical torque weighting factor, which scales the torque error into a current-equivalent quantity based on the torque-current sensitivity of a surface-mounted PMSM while preserving the simple single-vector predictive control structure.

In this study, a current–torque dual-objective model predictive control strategy, referred to as CTDO-MPC, is proposed for PMSM drives. The proposed CTDO-MPC method simultaneously considers the stator current-tracking error and electromagnetic torque deviation in an objective function. By extending the objective function from a single current-based term to a dual-objective structure, the proposed method improves voltage vector selection and enhances the overall control performance of the PMSM drive.

A key feature of the proposed CTDO-MPC strategy is the analytical design of the weighting factor used to balance the current and torque terms in the objective function. The weighting factor is derived based on the sensitivity of the current-tracking error and torque deviation to be properly coordinated. At each sampling instant, all feasible voltage vectors generated by the inverter are evaluated, and the vector that minimizes the proposed dual-objective function is selected and applied in the next control interval.

The effectiveness of the proposed CTDO-MPC method is validated through MATLAB/Simulink simulations using a 1.5 kW PMSM drive system. The performance of CTDO-MPC is compared with standard CO-MPC for different operating scenarios such as half-load, full-load and transient load changes. The simulation results demonstrate that the proposed method achieves better current quality, lower RMS torque ripple, and improved PMSM drive performance compared with the conventional method. The main contributions of this study are summarized as follows:

(i) A current–torque dual-objective predictive control objective function is formulated by incorporating both stator current-tracking error and electromagnetic torque deviation for voltage vector selection.

(ii) An analytical weighting-factor design is introduced to coordinate the sensitivities of the current and torque terms, thereby reducing empirical tuning effort.

(iii) The proposed CTDO-MPC preserves the conventional single-vector finite-control-set MPC structure and is evaluated under steady-state, load-transition, full-load, and speed-transition conditions.

The remainder of this paper is organized as follows. Section 2 presents the theoretical background of the PMSM model and voltage source inverter, which provides the foundation for the proposed control algorithm. Section 3 describes the proposed CTDO-MPC strategy, including the prediction model, objective function, and weighting factor design. Section 4 presents and discusses the simulation results, comprising CTDO-MPC and conventional CO-MPC. Finally, Section 5 concludes the paper and summarizes the main findings.

2 THEORETICAL BACKGROUND AND MATHEMATICAL MODELING

2.1. Principle of Model Predictive Control (MPC)

The MPC method predicts future control variables and optimizes operations by minimizing control constraint errors [14]. This prediction is calculated based on motor parameters, the current state variables, and the voltage vectors generated from the inverter over a future control interval. The control constraints are combined into a single objective function, which is the difference between the predicted outputs and their required values. Therefore, minimizing the objective function means that the control variable's trajectory closely aligns with the desired reference trajectory. The basic block diagram of the MPC controller is as shown in Fig. 1.

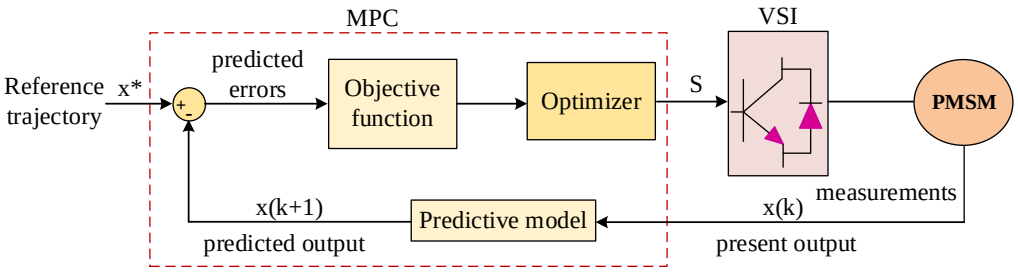


Figure 1. Basic block diagram of MPC scheme for PMSMs

2.2. PMSM Mathematical Model

In accordance with [15], the PMSM state-space model is described in the direct-quadrature (dq) rotating reference frame based on space vector theory, assuming negligible hysteresis losses. It is essential to accurately build the dynamic behavior of a motor control system. The mathematical equations used for PMSM control have been widely established in previous research; nevertheless, they are presented here to ensure completeness and clarity.

The stator current dynamics of PMSM can be expressed as the following:

$$\begin{cases} \frac{di_d}{dt} = -\frac{R_s}{L_d} i_d + \omega_e \frac{L_q}{L_d} i_q + \frac{1}{L_d} u_d \\ \frac{di_q}{dt} = -\frac{R_s}{L_q} i_q - \omega_e \frac{L_d}{L_q} i_d + \frac{1}{L_q} u_q - \omega_e \frac{\varphi_f}{L_q} \end{cases} \quad (1)$$

where i_d and i_q are the dq-axis stator currents; u_d and u_q denote the stator voltages in the dq-axis; L_d and L_q correspond to the dq-axis inductances; φ_f is the permanent magnet flux linkage; the stator resistance is R_s; and the synchronous electrical angular speed is ω_e.

The stator flux equations are presented as:

$$\begin{cases} \varphi_d = L_d i_d + \varphi_f \\ \varphi_q = L_q i_q \end{cases} \quad (2)$$

where φ_d and φ_q are the stator flux components along the dq-axis.

The electromagnetic torque T_e can be mathematically expressed:

$$T_e = \frac{3}{2} p\left[\varphi_d i_q - \varphi_q i_d\right] \quad (3)$$

in which p is the pole pair; and φ_d, φ_q are the stator flux components along the dq-axis.

The electromagnetic torque equilibrium equation on the motor shaft is given by:

$$T_e - T_L = J \frac{d\omega_m}{dt} + B_m \omega_m \quad (4)$$

where ω_m is the mechanical angular speed of the rotor, and $\omega_e = p\omega_m$; T_L, J, and B_m are the load torque, the moment of inertia, and the friction coefficient of the rotor, respectively.

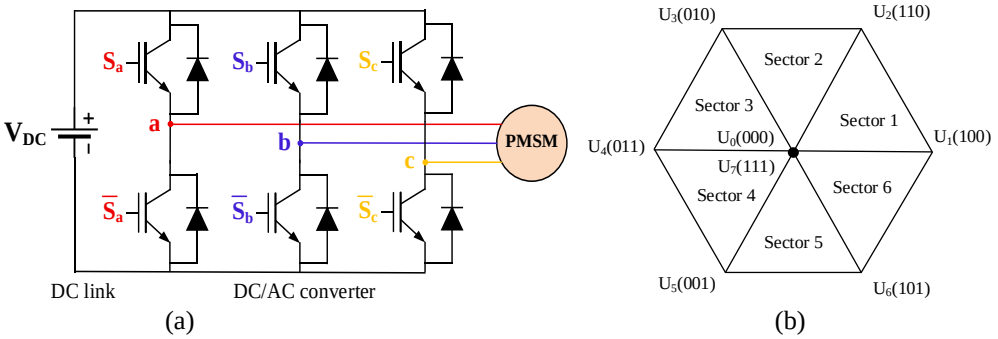


Figure 2. The three-phase two-level VSI: (a) The circuit of the VSI for the PMSM (b) The output voltages of the VSI

The voltages u_d and u_q are generated by a two-level voltage source inverter (VSI) that supplies power to

the PMSM. The three-phase two-level VSI includes a DC voltage source (V_{dc}) and six power semiconductor switches connected (Fig. 2(a)). It produces six active and two zero voltage space vectors corresponding to the switching states $S_a, S_b, S_c, \overline{S_a}, \overline{S_b}, \overline{S_c}$ as illustrated by the space-vector diagram (Fig. 2(b)).
Then, the voltages u_d and u_q are calculated as:

$$\begin{bmatrix} u_d \\ u_q \end{bmatrix} = \frac{2}{3} V_{dc} \begin{bmatrix} cos\theta_e & cos(\theta_e - \frac{2\pi}{3}) & cos(\theta_e + \frac{2\pi}{3}) \\ -sin\theta_e & -sin(\theta_e - \frac{2\pi}{3}) & -sin(\theta_e + \frac{2\pi}{3}) \end{bmatrix} \begin{bmatrix} S_a \\ S_b \\ S_c \end{bmatrix} \quad (5)$$

2.3. The current-objective model predictive control (CO-MPC) method

The CO-MPC method is built on a predictive model with stator current tracking to reduce current harmonics and RMS torque ripple in the PMSM drive. The steps implementing this control algorithm are sequentially established based on the mathematical meaning of the derivative and the stator current equation.

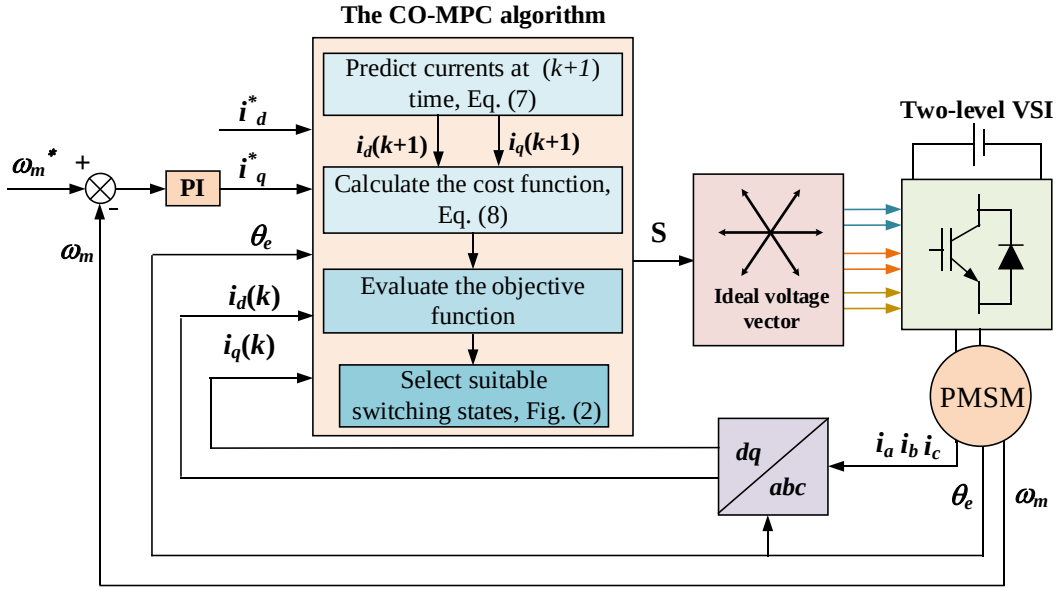


Figure 3. The CO-MPC scheme

By employing the forward Euler discretization method, the derivatives of the dq-axis stator currents are approximated over one sampling period T_s. The current derivatives are represented by the difference between the predicted current values at the next sampling instant and the measured current values at the present instant.

$$\begin{cases} \frac{di_d(t)}{dt} = \frac{i_d(k+1) - i_d(k)}{T_s} \\ \frac{di_q(t)}{dt} = \frac{i_q(k+1) - i_q(k)}{T_s} \end{cases} \quad (6)$$

in which k and $k+1$ are the current instant and the next instant; T_s is the sample period; $i_d(k+1)$ and $i_q(k+1)$ present the dq-axis predicted currents at the $(k+1)^{th}$ instant; $i_d(k)$ and $i_q(k)$ are the dq-axis currents at the k^{th} instant.
From (1) and (6), the predicted currents can be expressed as:

$$\begin{cases} i_d(k+1) = \left(1 - \frac{R_s T_s}{L_d}\right) i_d(k) + \omega_e(k) \frac{L_q T_s}{L_d} i_q(k) + \frac{T_s}{L_d} u_d(k) \\ i_q(k+1) = -\omega_e(k) \frac{L_d T_s}{L_q} i_d(k) + \left(1 - \frac{R_s T_s}{L_q}\right) i_q(k) + \frac{T_s}{L_q} u_q(k) - \omega_e(k) \frac{\varphi_f T_s}{L_q} \end{cases} \quad (7)$$

where $u_d(k)$ and $u_q(k)$ are the voltages along the dq-axis at the k^{th} current instant, $\omega_e(k)$ is the electrical angular speed at the k^{th} current instant.
The objective function of the model predictive current control method is typically based on the current constraint [16, 17]. This single-objective function represents the deviation between the reference current and the predicted current in the next cycle of the VSI:

$$F_{CO-MPC} = |i_d^* - i_d(k+1)| + \left|i_q^* - i_q(k+1)\right| \quad (8)$$

The control block diagram of the CO-MPC method is presented in Fig. 3.

All possible switching states of the VSI are evaluated during the optimization of the error function. The optimal voltage vector, which minimizes the objective function, is selected and applied at the next sampling instant $(k+1)$. In the conventional CO-MPC, the current constraint is incorporated into the objective function to reduce current ripple, decrease torque fluctuations, and improve the dynamic response of PMSM in terms of torque and speed.

3 THE PROPOSED CTDO-MPC STRATEGY

Although the conventional CO-MPC provides a simple predictive control structure, it still suffers from several limitations. In the conventional formulation, the objective function is established based on current tracking errors, whereas the electromagnetic torque is only indirectly regulated through the current control loop. Consequently, the optimal voltage vector selected by the conventional method may not always provide the most desirable torque response. This drawback may result in noticeable torque ripple and reduced robustness in the drive system. To address these drawbacks, the control objective should be extended beyond the current track. Hence, the current-torque dual-objective model predictive control (CTDO-MPC) strategy is developed by incorporating both current and torque terms into the predictive optimization process, improving the performance of the PMSM drive. The proposed method can be described as follows:

(a) At the current sampling instant, the instantaneous operating states of the PMSM, including the stator currents, rotor electrical angle, and rotor speed, are measured and updated for the predictive control algorithm.

(b) For each admissible voltage vector of the two-level VSI, the future d-axis and q-axis current components, as well as the electromagnetic torque, are predicted using the discrete-time PMSM model. Along with the predicted current as (7), the predicted stator flux components along the *dq*-axis at the $(k+1)^{th}$ instant are given by:

$$\begin{cases} \varphi_d(k+1) = L_d i_d(k+1) + \varphi_f \\ \varphi_q(k+1) = L_q i_q(k+1) \end{cases} \quad (9)$$

Then, the predicted electromagnetic torque $T_e(k+1)$ is also shown as follows:

$$T_e(k+1) = \frac{3}{2} p\left[\varphi_d(k+1) i_q(k+1) - \varphi_q(k+1) i_d(k+1)\right] \quad (10)$$

(c) Based on the L1-norm formulation in [14], a new objective function is evaluated for all candidate voltage vectors to reflect the dual objectives of current tracking and electromagnetic torque regulation. The proposed objective function is formulated as:

$$F_{CTDO-MPC} = |i_d^* - i_d(k+1)| + \left|i_q^* - i_q(k+1)\right| + \lambda |T_e^* - T_e(k+1)| \quad (11)$$

where λ is the weighting factor and $T_e^* = \frac{3}{2} p \varphi_f i_q^*$ is the required torque. The weighting factor balances the relative contribution of the current and torque control objectives. Under the assumption that $L_d = L_q$ for surface-mounted PMSM and $T_e(k+1)$ is estimated using (10), the weighting factor can be expressed as

$$\lambda = \frac{2}{3 p \varphi_f} \quad (12)$$

(d) The voltage vector that yields the minimum objective function value is identified as the optimal switching state and applied during the next sampling period.

The flowchart of the proposed CTDO-MPC method is presented in Fig. 4, and the MATLAB/Simulink simulation model used for performance evaluation is illustrated in Fig. 5.

By evaluating the effect of each voltage vector over dual-objective tracking, the proposed CTDO-MPC method provides a more accurate voltage vector selection than the conventional MPC method. This mechanism helps improve current quality and reduce electromagnetic torque ripple.

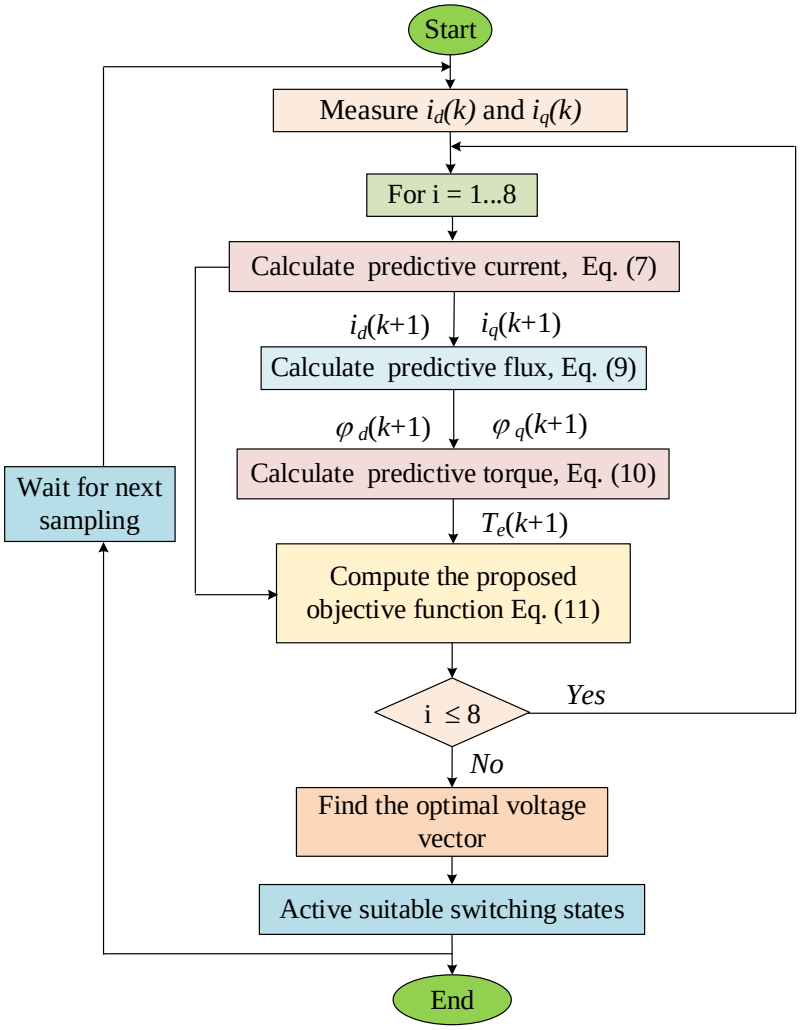


Figure 4. The flowchart of the proposed CTDO-MPC method

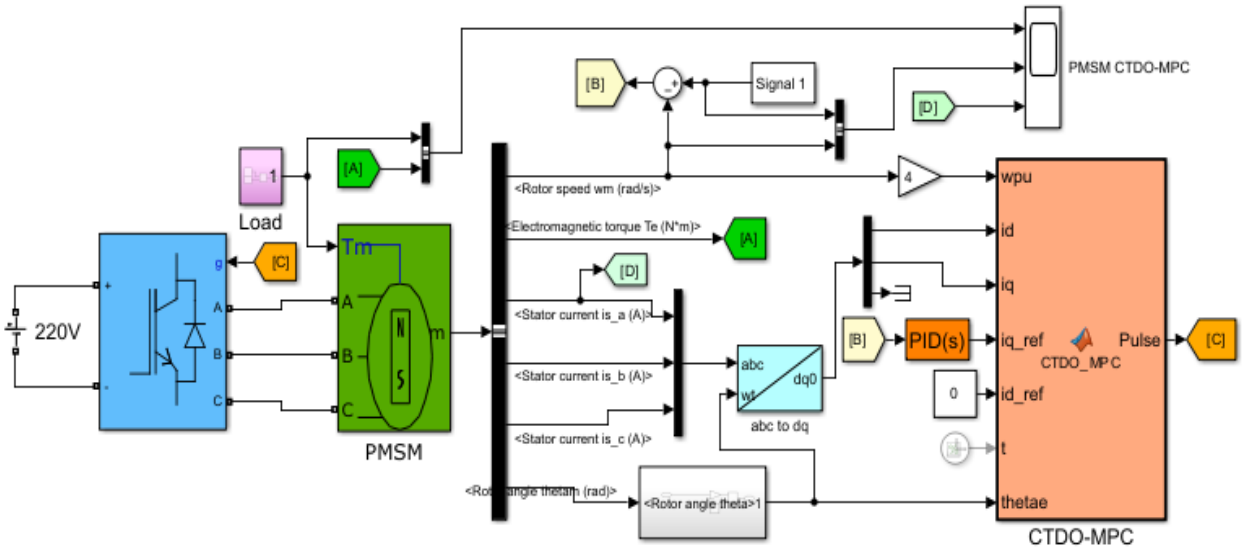


Figure 5. The MATLAB/Simulink simulation model of the proposed CTDO-MPC method

4 RESULT ANALYSIS AND DISCUSSION

The research was conducted in MATLAB/Simulink to evaluate the operational performance of the PMSM

under two control strategies: the conventional CO-MPC and the proposed CTDO-MPC. The simulation scenarios include steady-state operation, transient-state response, and high-speed conditions. For a fair comparison, both control methods were implemented using the same PMSM parameters and identical operating conditions. The evaluation focuses on key performance indices, including dynamic response, steady-state current quality, electromagnetic torque ripple, and speed-transition behavior. The PMSM parameters employed in the simulation model are summarized in Table 1.

Table 1. PMSM parameters

Constants	Values
DC-link voltage	220 V
Pole pairs	4
Stator phase resistance	1.4 Ω
Stator inductance	0.0066 H
Flux linkage	0.1546 Wb
Moment of inertia	0.00176 kg.m^2
Rated torque	18 Nm

4.1. Transient Dynamic Performance

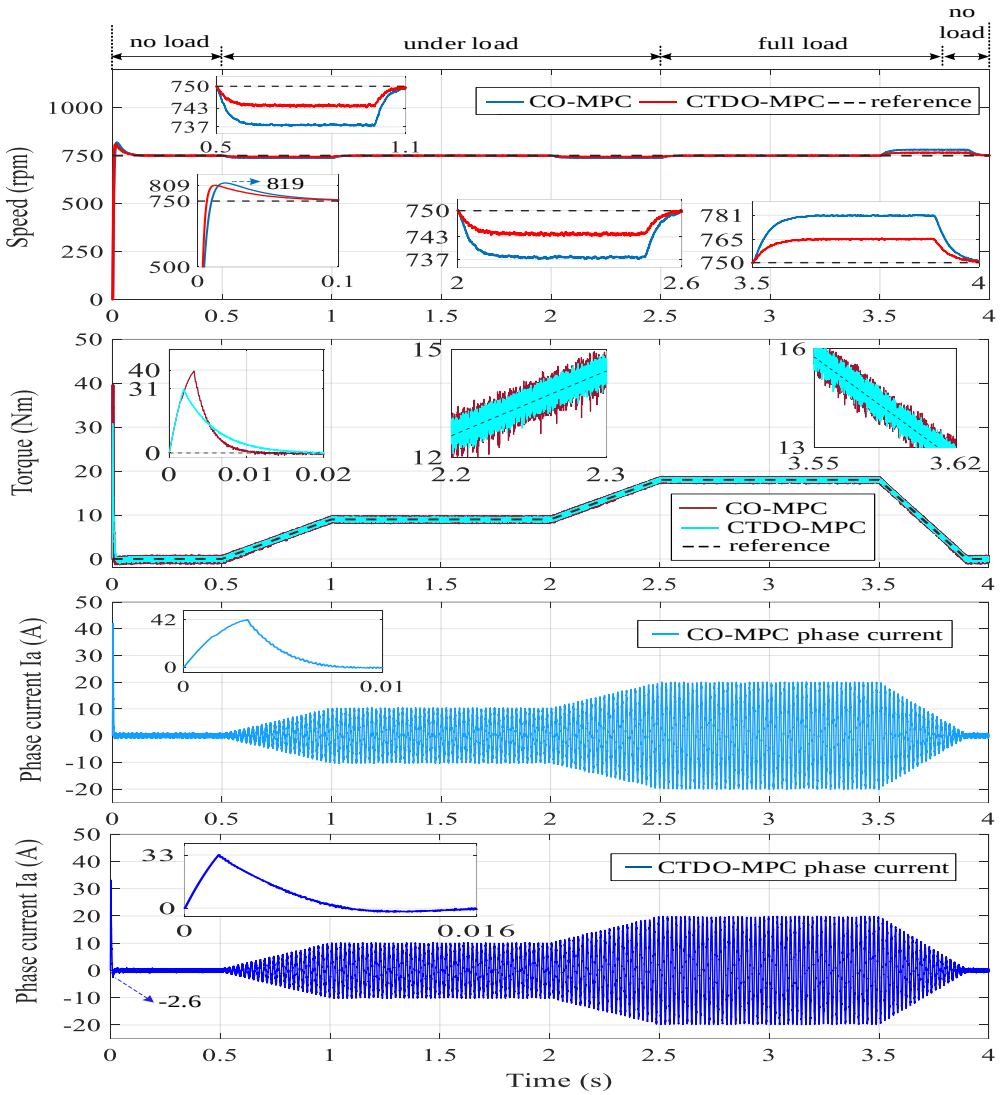


Figure 6. Transient performance comparison of the two methods.

Fig. 6 compares the transient responses of the conventional CO-MPC and the proposed CTDO-MPC under different operating intervals, including start-up, load variation, full-load operation, and load removal. It can

be observed that both controllers are able to track the reference speed during the whole operating process. However, the proposed CTDO-MPC provides a smoother torque response and smaller oscillations than the conventional CO-MPC, especially during load changes.

In the conventional CO-MPC, the voltage vector is selected mainly according to the current-tracking error. Therefore, the electromagnetic torque is only indirectly regulated through the stator current response. This may lead to relatively larger torque fluctuation during transient operation. In contrast, the proposed CTDO-MPC directly incorporates the electromagnetic torque deviation into the objective function. As a result, the selected voltage vector is not only suitable for current tracking but also favorable for torque regulation. This explains the improved transient torque behavior obtained by the proposed method.

The phase-current responses shown in Fig. 6 also indicate that the CTDO-MPC produces a more stable current envelope during load transitions. This confirms that the addition of the torque term does not deteriorate the current control performance. Instead, it helps improve the overall coordination between current quality and torque smoothness.

4.2. Steady-State Current Quality

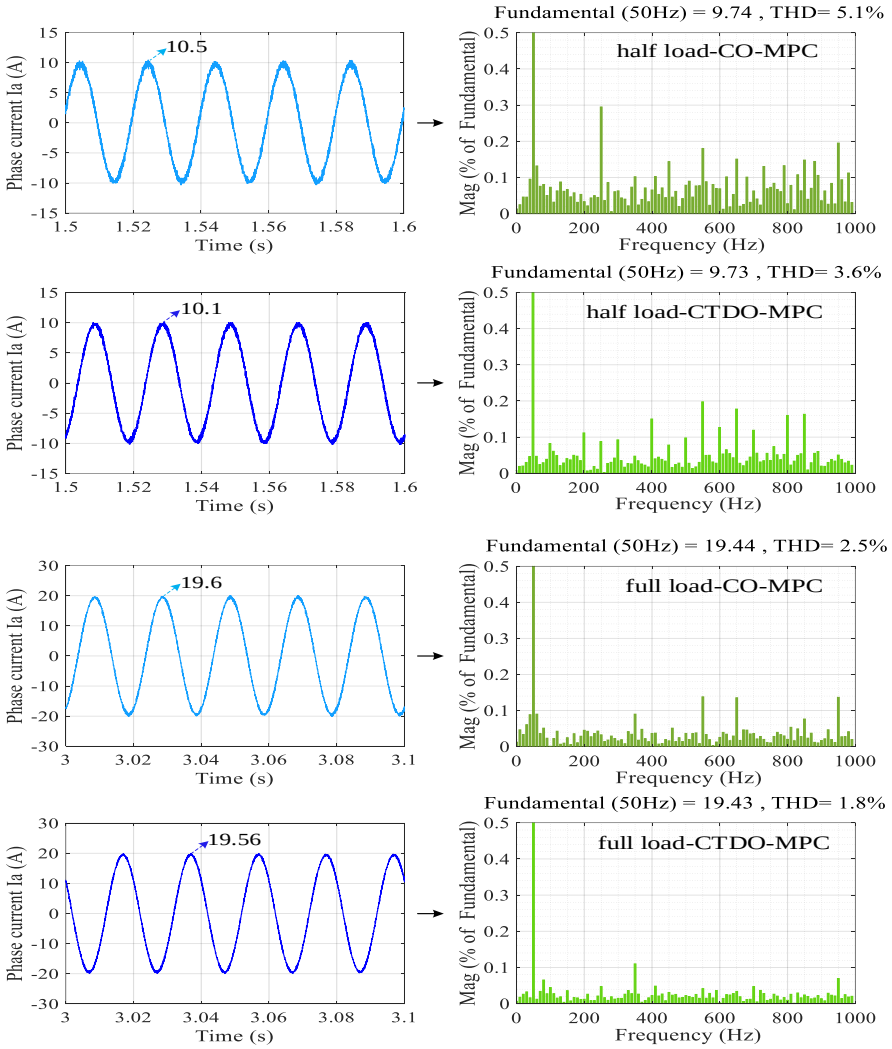


Figure 7. Current waveform and THD of the two methods at 50 Hz.

The steady-state phase-current waveforms and their harmonic spectra at 50 Hz are presented in Fig. 7. Under half-load operation, the current total harmonic distortion is reduced from 5.1% with CO-MPC to 3.6% with CTDO-MPC. This corresponds to a relative THD reduction of approximately 29.4%. Under full-load operation, the current THD is reduced from 2.5% to 1.8%, corresponding to a relative reduction of approximately 28.0%.

It should be noted that the fundamental current components of the two methods remain nearly unchanged

under the same load condition. Therefore, the THD reduction achieved by the proposed CTDO-MPC is mainly attributed to the suppression of high-frequency harmonic components rather than a reduction in the fundamental current magnitude. This result demonstrates that the proposed dual-objective function improves the voltage vector selection process and enhances the steady-state current quality of the PMSM drive.

Compared with the conventional CO-MPC, the CTDO-MPC considers both current error and torque deviation at each sampling instant. This allows the controller to avoid voltage vectors that may produce acceptable current tracking but cause unnecessary torque disturbance. Consequently, the phase-current waveform becomes smoother, and the current harmonic distortion is reduced.

4.3. Electromagnetic Torque Ripple Evaluation

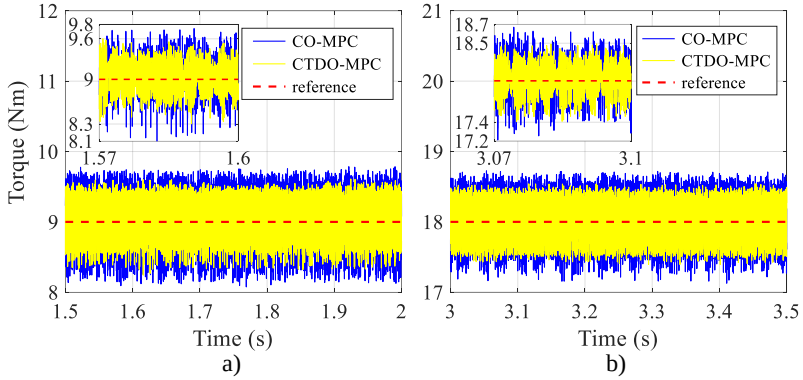


Figure 8. Torque response of the two strategies: (a) half-load and (b) full-load.

Table 2. RMS Torque Ripple (Nm)

Time (s)	CO-MPC	CTDO-MPC
0.1 ÷ 0.4	0.3485	0.2513
1.1 ÷ 1.9	0.3131	0.2362
2.6 ÷ 3.4	0.2859	0.2176

Fig. 8 shows the electromagnetic torque responses of the two control strategies under half-load and full-load conditions. The conventional CO-MPC exhibits larger RMS torque ripple around the reference torque, whereas the proposed CTDO-MPC produces a narrower torque ripple band. This improvement is mainly due to the direct inclusion of the torque deviation term in the objective function.

The RMS torque ripple values are summarized in Table 2. During the interval of 0.1–0.4 s, the RMS torque ripple decreases from 0.3485 Nm with CO-MPC to 0.2513 Nm with CTDO-MPC, corresponding to a reduction of approximately 27.9%. During the interval of 1.1–1.9 s, the RMS torque ripple is reduced from 0.3131 Nm to 0.2362 Nm, corresponding to a reduction of approximately 24.6%. During the full-load interval of 2.6–3.4 s, the RMS torque ripple decreases from 0.2859 Nm to 0.2176 Nm, corresponding to a reduction of approximately 23.9%.

These results confirm that the proposed CTDO-MPC can effectively reduce RMS torque ripple under different load conditions. The average reduction in RMS torque ripple is about 25.5%, which demonstrates the effectiveness of the proposed current-torque dual-objective formulation. Since torque ripple is closely related to mechanical vibration, acoustic noise, and speed fluctuation, this improvement is beneficial for high-performance PMSM drive applications.

4.4. Low- and High-Speed Operating Performance

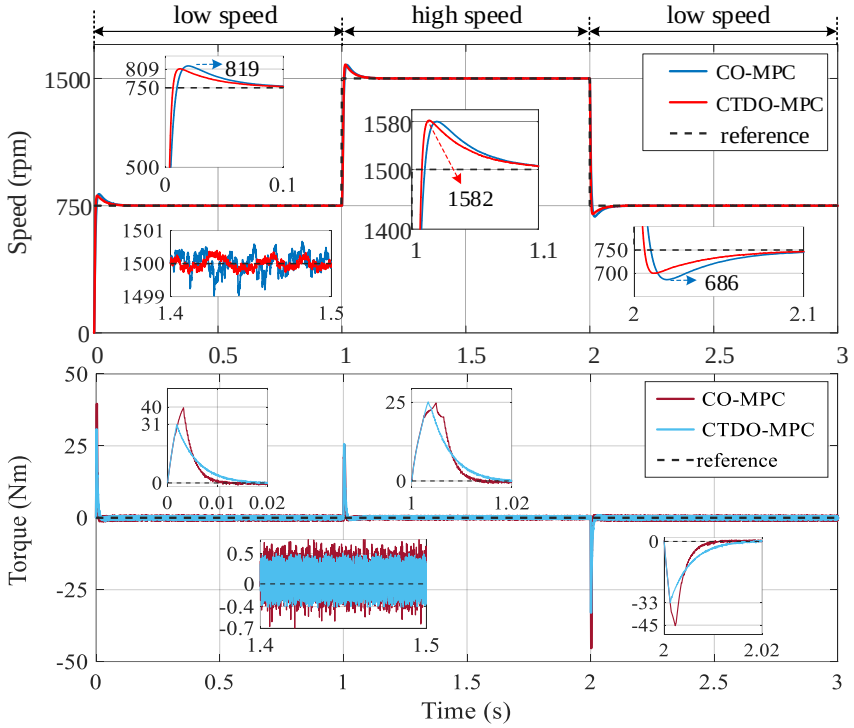


Figure 9. Torque and speed responses under low- and high-speed operation.

Fig. 9 illustrates the torque and speed responses of the PMSM drive when the operating condition changes from low speed to high speed and then returns to low speed. Both control methods can maintain stable speed tracking during the whole test profile. However, the proposed CTDO-MPC shows a smoother torque response during acceleration and deceleration intervals.

At high speed, the available voltage margin of the inverter becomes more limited, making the voltage vector selection more critical. The results indicate that the CTDO-MPC remains effective under this condition. The speed response is stable, and the RMS torque ripple is lower than that of the conventional CO-MPC. During the deceleration interval, the negative torque pulse is generated as the braking torque required to reduce the rotor speed. The proposed CTDO-MPC provides a more controlled torque transition, which helps reduce oscillation after the speed command changes.

Overall, the simulation results verify that the proposed CTDO-MPC improves both steady-state and transient performance of the PMSM drive. Compared with the conventional CO-MPC, the proposed method achieves lower current THD, smaller RMS torque ripple, and better torque smoothness under different operating conditions. These improvements are obtained because the proposed objective function simultaneously evaluates the current-tracking error and the electromagnetic torque deviation, leading to a more appropriate voltage vector selection at each sampling instant.

5 CONCLUSIONS

This paper has proposed a current-torque dual-objective model predictive control strategy for PMSM drives. Unlike the conventional CO-MPC method, which mainly minimizes the stator current-tracking error, the proposed CTDO-MPC incorporates both current error and electromagnetic torque deviation into a unified objective function. The weighting factor was designed to balance the relative effects of the current and torque terms during the voltage vector selection process.

The proposed method was validated through MATLAB/Simulink simulations using a 1.5 kW PMSM drive system and compared with the conventional CO-MPC strategy. The simulation results show that the CTDO-MPC improves the steady-state current quality by reducing the current THD from 5.1% to 3.6% under half-load operation and from 2.5% to 1.8% under full-load operation. In addition, the RMS torque ripple is reduced from 0.3131 Nm to 0.2362 Nm at half-load and from 0.2859 Nm to 0.2176 Nm at full-load. The

proposed method also provides smoother transient torque response and stable operation under high-speed conditions.

These results confirm that the proposed CTDO-MPC can enhance the overall performance of PMSM drives by improving current quality and reducing electromagnetic torque ripple. Future work will focus on real-time implementation of the proposed control algorithm on an embedded digital controller, experimental validation with a laboratory PMSM drive setup, and further investigation of parameter sensitivity and computational burden.

REFERENCES

[1] L. Guo, Y. Wang, H. Wang, Z. Zhang, "Design of high power density double-stator permanent magnet synchronous motor," *IET Electric Power Applications,* vol. 17, no. 4, pp. 421–431, 2023.

[2] K. Yang, H. Li, and S. Li, "Composite model predictive current control for PMSM servo system," *2025 IEEE International Conference on Predictive Control of Electrical Drives and Power Electronics (PRECEDE)*, 2025.

[3] P. T. Giang, V. T. Ha, V. H. Phuong, "Drive Control of a Permanent Magnet Synchronous Motor Fed by a Multi-level Inverter for Electric Vehicle Application," *Engineering, Technology & Applied Science Research,* vol. 12, no. 3, pp. 8658-8666, 2022.

[4] S. Lin, X. Fang, X. Wang, Z. Yang, F. Lin, "Multiobjective Model Predictive Current Control Method of Permanent Magnet Synchronous Traction Motors With Multiple Current Bounds in Railway Application," *IEEE Transactions on Industrial Electronics,* vol. 69, no. 12, pp. 12348-12357, 2022.

[5] T. Li, X. Sun, G. Lei, Z. Yang, Y. Guo, J. Zhu, "Finite-Control-Set Model Predictive Control of Permanent Magnet Synchronous Motor Drive Systems — An Overview," *IEEE/CAA Journal of Automatica Sinica,* vol. 9, no. 12, pp. 2087-2105, 2022.

[6] X. Yuan, S. Zhang, C. Zhang, A. Galassini, G. Buticchi, M. Degano, "Improved Model Predictive Current Control for SPMSM Drives Using Current Update Mechanism," *IEEE Transactions on Industrial Electronics,* vol. 68, no. 3, pp. 1938-1948, 2021.

[7] X. Sun, M. Wu, G. Lei, Y. Guo, J. Zhu, "An Improved Model Predictive Current Control for PMSM Drives Based on Current Track Circle," *IEEE Transactions on Industrial Electronics,* vol. 68, no. 5, pp. 3782-3793, 2021.

[8] Z. Yang, Ch. Miao, X. Sun, D. Guo, "Robust Model Predictive Torque Control of Interior PMSM Drives With Kalman-Based Disturbance Observer," *IEEE Transactions on Transportation Electrification,* vol. 10, no. 2, pp. 2434-2444, 2024.

[9] Y. Xu, Y. Zhang, Q. Gao, Zh. Yin, "A Wide-Speed Range Three-Vector-Based Model Predictive Flux Control With Improved Predictive Model for PMSM Drives," *IEEE Transactions on Transportation Electrification,* vol. 10, no. 2, pp. 2689-2700, 2024.

[10] A. R. Raut, S. V. Jadhav, "Model Predictive Speed Control of Permanent Magnet Synchronous Motor," *2022 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES)*, 2022.

[11] J. Rodriguez, C. Garcia, A. Mora, P. Acuna, M. Novak, et al., "Latest Advances of Model Predictive Control in Electrical Drives—Part II: Applications and Benchmarking With Classical Control Methods," *IEEE Transactions on Power Electronics,* vol. 37, no. 5, pp. 5047-5061, 2022.

[12] X. Wu, M. Yang, T. Wu, K. Lu, Y. Wang, X. Liu, Sh. Huang, H. Cui, "Parameter-Free Predictive Torque and Flux Control for PMSM Based on Incremental Stator Flux Predictive Model," *IEEE Transactions on Industrial Informatics,* vol. 20, no. 2, pp. 2715-2726, 2024.

[13] A. Brosch, O. Wallscheid, J. Böcker, "Time-Optimal Model Predictive Control of Permanent Magnet Synchronous Motors Considering Current and Torque Constraints," *IEEE Transactions on Power Electronics,* vol. 38, no. 7, pp. 7945-7957, 2023.

[14] J. Rodriguez, P. Cortes, *Predictive Control of Power Converters and Electrical Drives*, John Wiley & Sons, 2012.

[15] Z. Q. Zhu, X. M. Wu, *Sensorless Control of Permanent Magnet Synchronous Machine Drives*, John Wiley & Sons, Inc., Hoboken, New Jersey, 2023.

[16] Y. Zhuang, Q. Du, W. Huang, Zh. Wang, R. Wang, "Model Predictive Current Control for PMSM Drives With Calculation Delay Compensation," *IEEE 5th International Electrical and Energy Conference (CIEEC)*, 2022.

[17] S. G. Petkar, K. Eshwar, V. K. Thippiripati, "A Modified Model Predictive Current Control of Permanent Magnet Synchronous Motor Drive," *IEEE Transactions on Industrial Electronics,* vol. 68, no. 2, pp. 1025-1034, 2021.

CHIẾN LƯỢC ĐIỀU KHIỂN MÔ HÌNH DỰ BÁO ĐA MỤC TIÊU DÒNG ĐIỆN – MÔ MEN NHẰM NÂNG CAO HIỆU SUẤT TRUYỀN ĐỘNG CHO ĐỘNG CƠ PMSM

VĂN THỊ KIỀU NHI, LÊ VĂN ĐẠI, BẠCH THANH QUÝ*

[1] Khoa Công Nghệ Kỹ Thuật Điện, Trường Đại học Công nghiệp Thành Phố Hồ Chí Minh

** Tác giả liên hệ: bachthanhquy@iuh.edu.vn*

Tóm tắt. Bài báo đề xuất phương pháp điều khiển mô hình dự báo đa mục tiêu gồm dòng điện và mô-men xoắn (CTDO-MPC) nhằm cải thiện hiệu suất truyền động cho động cơ PMSM ở hai chế độ làm việc gồm xác lập và quá độ. Khác với phương pháp CO-MPC truyền thống, thường chủ yếu tập trung giảm thiểu sai số dòng điện stator, phương pháp CTDO-MPC được đề xuất tích hợp sai số bám dòng điện và độ lệch mô-men xoắn điện từ vào chung một hàm mục tiêu. Để cân bằng độ nhạy giữa hai thành phần này trong cùng một hàm mục tiêu, thông qua phân tích lý thuyết điều kiện biến thiên điện áp, một hệ số trọng số cân bằng được đề xuất. Các vectơ điện áp của bộ nghịch lưu đều được đánh giá tại mỗi thời điểm lấy mẫu, vectơ có hàm mục tiêu tối thiểu sẽ được chọn làm vector điều khiển cho chu kỳ kế tiếp. Phương pháp đề xuất được mô phỏng bằng MATLAB/Simulink với hệ thống truyền động động cơ PMSM công suất 1,5 kW, kết quả được so sánh với phương pháp CO-MPC. Kết quả mô phỏng cho thấy chiến lược đề xuất giúp giảm tổng độ méo dạng sóng hài (THD) của dòng điện từ 5,1% xuống 3,6% ở chế độ nửa tải và từ 2,5% xuống 1,8% ở chế độ đầy tải. Ngoài ra, giá trị hiệu dụng (RMS) của độ gợn sóng mô-men xoắn cũng giảm từ 0,31 Nm xuống 0,24 Nm ở chế độ nửa tải và từ 0,29 Nm xuống 0,22 Nm ở chế độ đầy tải. Những kết quả này cho thấy chất lượng dòng điện được cải thiện, độ gợn sóng mô-men xoắn giảm và hiệu suất của hệ thống truyền động PMSM được nâng cao.

Từ khóa. động cơ đồng bộ nam châm vĩnh cửu, mô hình điều khiển dự đoán, hệ số trọng số, hàm mục tiêu, tổng dòng hài, gợn sóng mô-men.

Received on August 22 – 2026
Revised on October 08 – 2026