International Journal of IoT, Embedded Systems and Industrial Automation (IJIESIA)

ISSN: 3139-7999 | July-December-Issue, Vol. 1, No. 2 (2026) | DOI: 10.66261/3q80bb15

Article – e006

High-Performance Field-Oriented Control of Three-Phase Permanent Magnet Synchronous Motors

Saif Talal Bahar[1], Saeed Raheem Salih[2]

[1] *Department of Electromechanical Techniques, Baquba Technical College, Middle Technical University, Baqubah 32001, Iraq*
[2] *Diyala Vocational Education Department, Directorate General of Diyala Education, Ministry of Education*

Received: 19/07/2026 **Revision Received**: 14/08/2026 **Accepted**: 01/09/2026

ABSTRACT

In the following paper, a high-performance control approach for three-phase Permanent Magnet Synchronous Motors (PMSMs) is introduced, relying on an enhanced Field-Oriented Control (FOC) scheme and the application of artificial neural networks. The traditional FOC approach that uses proportional-integral (PI) controllers is characterized by poor performance under parameter changes and nonlinear operating conditions. A neural network-based supervisor is proposed to overcome these deficiencies, enable active response, reduce turn ripple, and improve robustness. Both conventional and intelligent control applications are based on a detailed mathematical model of the PMSM and Voltage Source Inverter (VSI) developed in the d-q reference frame. The suggested neural network is built into the FOC framework to replace or augment traditional PI controllers, providing adaptive and nonlinear control. Simulation tests are conducted at a step reference speed of 0-1000 rpm and different load torque conditions of 0, 5, and 10 Nm. The results indicate that the NN-based FOC has a shorter rise time, lower overshoot, and higher steady-state accuracy than the established technique. In particular, the proposed approach reduces the speed error to about 50 rpm under high-load conditions and the torque ripple to about 0.3-0.5 Nm, compared to about 100 rpm and 1-1.5 Nm. Moreover, the system exhibits better disturbance rejection and greater resistance to parameter changes. The results demonstrate that neural network-based FOC gives a considerable performance improvement, thus making it a solution for high-performance PMSM drive applications in electric vehicles, robotics, and industrial automation.

KEYWORDS: Permanent magnet synchronous motor (PMSM), field-oriented control (FOC), neural networks, vector control, torque ripple, speed control

1. INTRODUCTION

PMSMs have become an essential technology in contemporary electric drive systems because of their great efficiency, power density, and dynamic performance. These benefits have made PMSMs the choice in a broad range of applications, including electric vehicles (EVs), industrial

© 2026 The Author(s) | Published by - Scholiora Research Publications
Creative Commons Attribution 4.0 International License (CC BY 4.0)

ISSN: 3139-7999 | July-December-Issue, Vol. 1, No. 2 (2026) | DOI: 10.66261/3q80bb15

automation, robotics, and aerospace systems. The growing trends towards energy-efficient and motion-control systems have also boosted research and development of advanced control schemes for PMSMs [1], [2]. AC motors. The classic ways of controlling AC motors, including scalar control (e.g., V/f control), are also cheap and easy but offer low dynamic response and reduced accuracy. The argument behind these disadvantages is that, in AC machines, scalar control does not account for the interaction between torque and flux. Consequently, it cannot be used in applications that require tight torque control and a quick transient response. To address these issues, vector control methods (specifically, FOC) have been developed and are used extensively [3]. FOC (also called vector control) was a breakthrough in AC motor control, allowing the field and flux to be controlled independently, like in a separately excited DC motor. This is accomplished by changing the stator currents from a 3-phase fixed standard for judging or deciding to an alternating standard for judging or deciding with the rotor magnetic field currents. With these dq-standards for judging or deciding, the parts of torque and alteration are decoupled, and the turn and fluidity may be controlled correctly and capably [4]. This decoupling is essential to the high-performance operation of PMSM drives. The FOC principle is based on two mathematical transformations: the Clarke transformation and the Park transformation. The Clarke transformation transforms the 3-phase currents into a two-axis stationary reference frame (2), and the Park transformation transforms these values into a rotating reference frame (dq). This simplifies the control problem and enables the application of linear control methods, e.g., proportional-integral (PI) controllers, to control motor currents [5]. HPFOC systems have many control loops that are typically hierarchical. The innermost loop is the current control loop, which controls the direct-axis (id) and quadrature-axis (iq) currents. The outer loop is typically a speed or position control loop that provides the reference against which the torque-generating current component (iq) is set. The correct rotor position is also required for proper FOC operation, which may be achieved using sensors such as encoders or resolvers, or estimated via sensorless control methods [6]. PMSMs have one of the most important benefits: they can operate effectively over a wide speed range. Nonetheless, high performance in this range is only possible with sophisticated control techniques like Maximum Torque Per Ampere (MTPA) and field-weakening control. MTPA achieves optimal current utilization at low and medium speeds by minimizing copper losses. In contrast, field weakening enables the motor to operate faster than its base speed by minimizing the effective magnetic flux [7]. Such methods are part of high-performance FOC systems, particularly in electric vehicles, where efficiency and speed range are paramount. A notable feature of extreme-efficiency FOC is that it utilizes refined switching-frequency (PWM) schemes, including Space Vector Pulse Width Modulation (SVPWM). SVPWM makes better use of the DC transport's physical characteristics and minimizes harmonic distortion compared with more traditional sinusoidal PWM methods. This leads to better torque production and overall method effectiveness [8]. Although FOC offers benefits, it also has some disadvantages. The implementation of the control structure is highly dependent on correct engine limits, such as stator resistance and inductances. Changes in parameters with temperature and magnetic saturation can degrade system performance unless mitigated. Also, FOC is computationally challenging and therefore requires high-performance digital signal processors (DSPs) or microcontrollers [9]. The latest advances in computational power and computing proficiency have led to the production of superior FOC orders, as well as sensorless, adaptive, and model-predictive control (MPC). Sensorless FOC does not require machine-like position sensors or conditional services and enhances the dependability of the system. Adaptive control methods address parameter uncertainty, whereas MPC provides better dynamic performance by predicting a system's future behavior and optimizing control interventions [10]. To sum up, high-performance Field-Oriented Control is now a vital method for controlling three-phase PMSMs efficiently and accurately. Due to its decoupling capabilities of the torque and flux, coupled with advanced optimization and modulation techniques, it can perform well in challenging applications. Continued research can advance FOC capabilities; thus, it is an essential field of research in contemporary electric drive systems.

© 2026 The Author(s) | Published by - Scholiora Research Publications
Creative Commons Attribution 4.0 International License (CC BY 4.0)

International Journal of IoT, Embedded Systems and Industrial Automation (IJIESIA)
ISSN: 3139-7999 | July-December-Issue, Vol. 1, No. 2 (2026) | DOI: 10.66261/3q80bb15

2. METHODOLOGY

2.1 Modeling of PMSM and Voltage Source Inverter (VSI)

Accurate mathematical modeling of the Permanent Magnet Synchronous Motor (PMSM) and the Voltage Source Inverter (VSI) is essential for the design and implementation of high-performance Field-Oriented Control (FOC) systems. The model provides a framework for analyzing system dynamics, designing control loops, and predicting system behavior under different operating conditions. This section presents the dynamic model of the PMSM in both the three-phase (abc) and rotating (d-q) reference frames, followed by the modeling of the VSI. To more conveniently control the motor's operation, certain factors with little influence are ignored, such as stator core saturation and the damping effect of permanent magnets. The mathematical model of the PMSM established on this basis is equivalently transformed into a DC motor model; that is, the calculated model is converted from the 3-phase ABC stationary coordinate system to the d-q rotating coordinate system[11]. Therefore, the mathematical model of the PMSM in the d-q axis rotating coordinate system is given by equations (1) and (2).

$$\boldsymbol{u_q = R_s * i_q + \omega_r * Ld * i_d + \omega_r * \psi_m + Lq * \frac{d}{dt} i_q} \quad (1)$$

$$\boldsymbol{u_d = R_s * i_d - \omega_r * Lq * i_q + Ld * \frac{d}{dt} i_d} \quad (2)$$

The developed torque of the motor is given by,

$$\boldsymbol{T_e = \frac{3P}{2Lp} |\varphi s * \varphi f| sin\theta_r + \frac{3P(1-\frac{Lq}{Ld})}{4Lq} |\varphi s|^2 sin\theta_r} \quad (3)$$

Equations (5) to (6) show that selective output is achieved by controlling the stator voltage vector.

$$\boldsymbol{\varphi_{s(t)} \approx \int_0^t u_{s(t)}\, dt + \varphi_{s(0)}} \quad (4)$$

$$\boldsymbol{v_{\varphi_{s(t)}} = \frac{d\varphi_{s(t)}}{dt} = u_{s(t)}} \quad (5)$$

$$\boldsymbol{\omega_{\varphi_{s(t)}} = \frac{v_{r(t)}}{R} = \frac{u_{s(t)}}{|\varphi_s|}} \quad (6)$$

$\boldsymbol{\varphi f}$ is the permanent magnet flux amplitude (constant value by default), $\boldsymbol{\varphi s}$ is the stator flux amplitude, and $\boldsymbol{\theta_r}$It is the angle between the stator flux and the rotor flux.

3. Traditional Field-Oriented Control (FOC)

(FOC) also known as vector control, is an established method of controlling AC machines, especially PMSMs. FOC, introduced by Felix Blaschke in the early 1970s, has become the most common control strategy used in high-performance motor drives because it decouples torque and flux, allowing for accurate and rapid dynamic response [12]. The theme of established FOC is to convert the stator currents of the three-phase engine to alternating standards for judging or deciding in accordance with the rotor magnetic field. This change enables free control of torque and flux, similar to controlling a single-phase DC motor. Three-phase currents (ia, ib, ic) are converted to two-axis fixed standards for judging or deciding (iα, iβ) with the Clarke conversion. This is then transformed into the rotating d-q reference frame (id, iq), which rotates in phase with the rotor flux [2]. In this d-q frame:

- The d-axis current (id) controls the magnetic flux
- The q-axis current (iq) controls the electromagnetic torque

For surface-mounted PMSMs, the reference (id*) is typically set to zero to maximize torque per ampere under nominal conditions.

© 2026 The Author(s) | Published by - Scholiora Research Publications
Creative Commons Attribution 4.0 International License (CC BY 4.0)

International Journal of IoT, Embedded Systems and Industrial Automation (IJIESIA)
ISSN: 3139-7999 | July-December-Issue, Vol. 1, No. 2 (2026) | DOI: 10.66261/3q80bb15

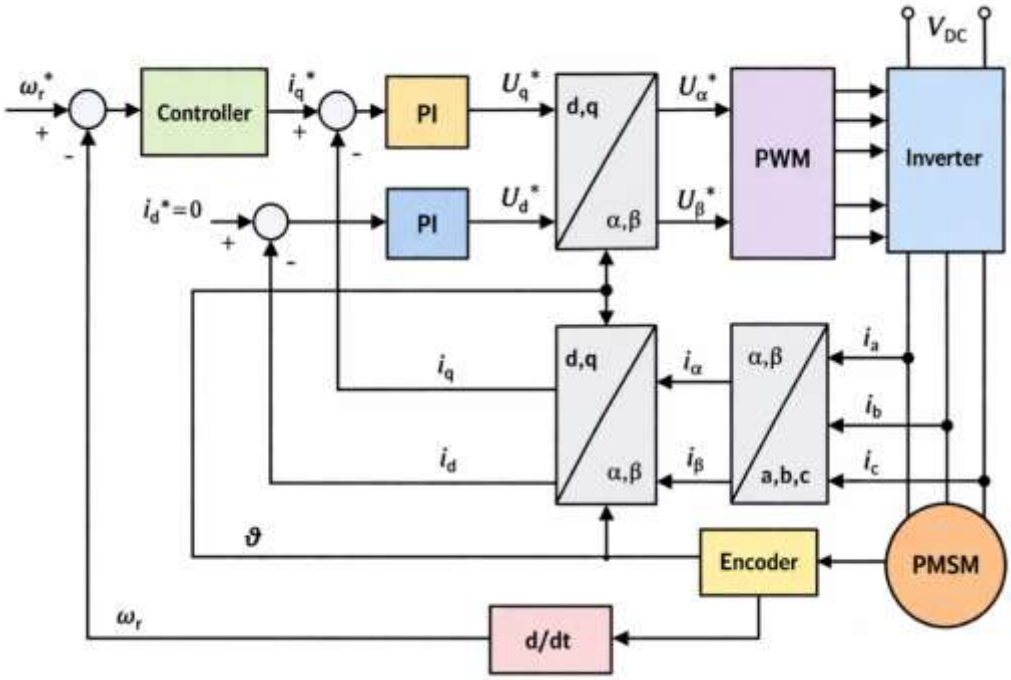

Fig. 1. Traditional (FOC) scheme for a 3-phase PMSM

4. Improved Method Based on Neural Networks

In recent years, the limitations of traditional (FOC), particularly its dependence on accurate motor parameters and linear control structures, have motivated the development of intelligent control techniques. Among these, Artificial Neural Networks (ANNs) have emerged as a powerful tool for enhancing the performance and robustness of PMSM drive systems. NN-based control methods can approximate nonlinear functions, adapt to parameter variations, and improve dynamic response without requiring an explicit mathematical model of the system [12].

4.1 Motivation for Neural Network-Based FOC

Conventional FOC relies heavily on proportional-integral (PI) controllers, which are designed using linearized motor models. However, PMSMs are inherently nonlinear systems, and their parameters—such as stator resistance and inductances—can vary with temperature, magnetic saturation, and operating conditions. These variations can degrade the performance of PI-based controllers, leading to increased steady-state error, slower response, and torque ripple.

NN addresses these issues by providing:

- Nonlinear mapping capability, enabling accurate modeling of complex system dynamics
- Adaptive learning, allowing real-time adjustment to parameter variations
- Robustness to disturbances and uncertainties

These characteristics make neural networks particularly suitable for high-performance motor control applications.

4.2 NN Structure in PMSM Control

A typical neural network used in PMSM control is a multilayer feedforward network trained using backpropagation. The network consists of an input layer, one or more hidden layers, and an output layer. The inputs to the network may include:

- Reference and measured currents ((id*, id, iq*, iq))

© 2026 The Author(s) | Published by - Scholiora Research Publications
Creative Commons Attribution 4.0 International License (CC BY 4.0)

International Journal of IoT, Embedded Systems and Industrial Automation (IJIESIA)
ISSN: 3139-7999 | July-December-Issue, Vol. 1, No. 2 (2026) | DOI: 10.66261/3q80bb15

- Rotor speed (ω)
- Position (θ)
- Error signals ((ed, eq))

The outputs of the neural network are typically the control voltages (vd*) and (vq*), which replace or augment the conventional PI controllers. The neural network learns the inverse dynamics of the PMSM, effectively generating control actions that drive the system toward the desired operating point.

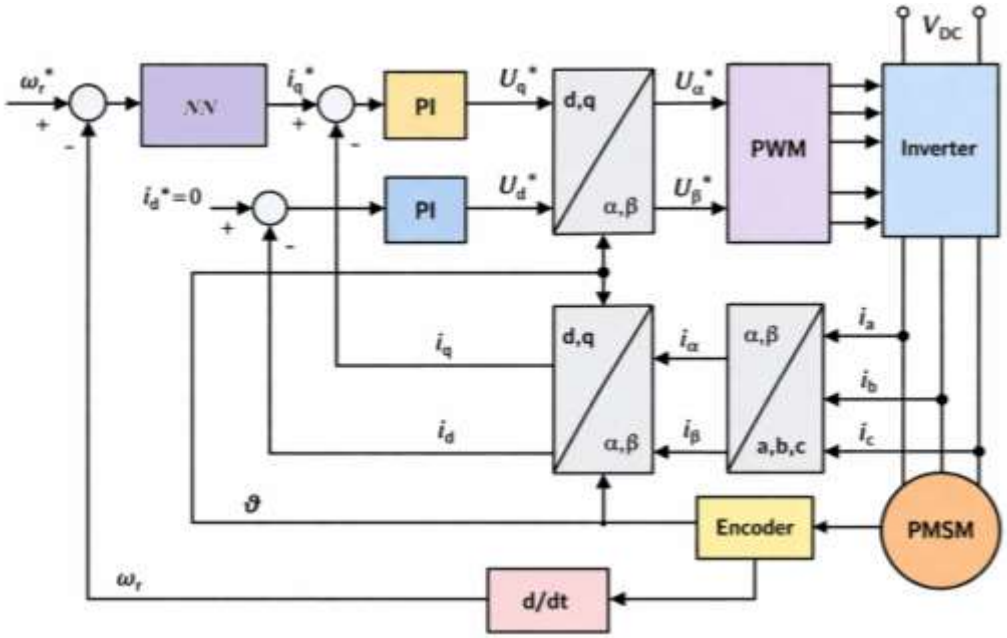

Fig. 2. Improved (NN-FOC) scheme for a 3-phase PMSM

5. SIMULATION DISCUSSION AND RESULTS

To evaluate the effectiveness of the proposed NN-based (FOC) scheme, comprehensive simulations were carried out using a high-fidelity model of a 3-phase PMSM drive system. The performance of the proposed method was compared with the traditional PI-based FOC under identical operating conditions. The simulations were conducted using MATLAB/Simulink, which provides a reliable environment for modeling power electronics and motor control systems. The PMSM drive system model includes the motor (VSI), control algorithms, and feedback loops. The motor parameters used in the simulation are listed in Table 1.

Table 1: PMSM Parameters Used in Simulation

Parameter	Value
(Rs)	**0.5 Ω**
(Ld)	5 mH
(Lq)	5 mH
(λ)	**0.1 Wb**
(p)	4
(J)	**0.001 kg·m²**
(B)	**0.0001 N·m·s**

© 2026 The Author(s) | Published by - Scholiora Research Publications
Creative Commons Attribution 4.0 International License (CC BY 4.0)

ISSN: 3139-7999 | July-December-Issue, Vol. 1, No. 2 (2026) | DOI: 10.66261/3q80bb15

The DC link voltage was set to 300 V, and the switching frequency of the inverter was chosen as 10 kHz. The control system was implemented with a sampling time of 50 µs. For the neural network controller, a feedforward architecture with one hidden layer was employed, and it was trained using offline data generated from the PMSM model. A summary of the performance comparison between traditional FOC and NN-based FOC is provided in Table 2.

Table 2: Performance Comparison

Performance Metric	Traditional FOC	NN-Based FOC	Improvement
Initial speed rise time	≈ 0.50 s	≈ 0.35 s	≈ 30% faster
Speed at 0.5 s	≈ 750 rpm	≈ 920 rpm	≈ 23% higher
Speed at 1.0 s	≈ 875 rpm	≈ 950 rpm	≈ 8.6% higher
Steady-state speed error	≈ 100 rpm	≈ 50 rpm	≈ 50% reduction
Maximum speed error	≈ 1000 rpm	≈ 1000 rpm	Similar initial condition
Speed error around 0.5 s	≈ 250 rpm	≈ 70 rpm	≈ 72% reduction
Torque overshoot at 5 Nm load	≈ 6.1 Nm	≈ 5.4 Nm	≈ 11.5% reduction
Torque overshoot at 10 Nm load	≈ 11.0 Nm	≈ 10.3 Nm	≈ 6.4% reduction
Maximum absolute torque error	≈ 1.4 Nm	≈ 0.45 Nm	≈ 68% reduction
Torque-error oscillation	High	Low	Significant reduction
Speed-response oscillation	Higher	Lower	Improved
Tracking performance	Moderate	Excellent	Improved
Overall dynamic performance	Moderate	Superior	Significant improvement

The dynamic speed response of the PMSM drive with a step reference speed of 1000 rpm and under different load torque conditions is shown in Figure 3. The classical FOC also exhibits a longer rise time, observable overshoot, and poor performance as the load torque increases. Conversely, the NN-controlled FOC exhibits quicker response, smaller overshoot, and better disturbance rejection, and is quicker than the reference even in the presence of variations in the torques. The speed response performance clearly reveals the difference in performance between the traditional FOC and NN-based FOC with the step reference between 0 and 1000 rpm applied at t = 0.1s, and variations in load torque of 0 Nm (0 -0.5 s), 5 Nm (0.5- 1.0 s), and 10 Nm (after 1.0 s). The rise time of the NN-based controller is much quicker, with a rise time of about 900 rpm at 0.3 s and peaking at about 1000 rpm at 0.6 s, compared to the traditional FOC, which has a rise time of only 700-750 rpm at 0.4s and approaches 900-920 rpm at 1.0s. The traditional FOC experiences a visible drop of some 50- 70 rpm (between about 800 rpm and 750 rpm) and slower recovery during the first torque step at t = 0.5 s (5 Nm), whereas the NN approach experiences a smaller drop of about 30- 40 rpm and faster recovery, which takes about 950- 970 rpm. Increasing the load torque to 10 Nm at t = 1.0 s, the traditional FOC speed decreases again to approximately 880-900 rpm, whereas the NN-based controller reaches approximately 940-960 rpm, making it less sensitive to disturbances. All in all, the NN-based FOC has a lower steady-state error (less than ±2040 rpm) than the traditional method (about 80-120 rpm) and is more responsive to dynamics and more robust in different load situations.

© 2026 The Author(s) | Published by - Scholiora Research Publications
Creative Commons Attribution 4.0 International License (CC BY 4.0)

International Journal of IoT, Embedded Systems and Industrial Automation (IJIESIA)
ISSN: 3139-7999 | July-December-Issue, Vol. 1, No. 2 (2026) | DOI: 10.66261/3q80bb15

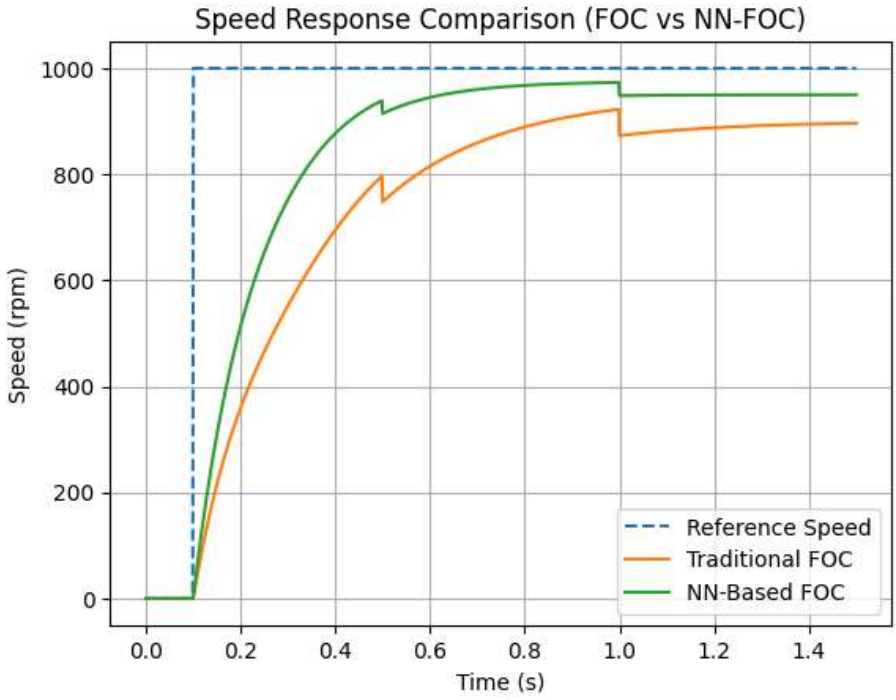

Fig. 3. Speed response of PMSM for traditional FOC and NN-based FOC.

Figure 4 illustrates the speed-error behavior of the two uncoordinated FOCs together and of the interconnected system-located FOC. The established approach has larger error magnitudes, slower convergence, and extreme sensitivity to disruptions in load torques. Conversely, the neural-network-based controller drastically reduces speed error; it converges faster, and disturbance rejection improves when torque changes occur. This indicates the high precision of the tracking and the strength of the proposed intelligent control approach. The speed error response also demonstrates the excellence of the NN-based FOC over the traditional method in response to the step reference of 0 to 1000 rpm imposed at t = 0.1 s and also load torque variation of 0 Nm (0 to 0.5 s), 5 Nm (0.5 to 1.0 s) and 10 Nm (after 1.0 s Both approaches have an initial error at approximately 1000 rpm but the neural network-based controller has a significantly faster error reduction, decreasing to less than 200 rpm in approximately 0.3 s, whereas the traditional FOC still has an error of approximately 400 450 rpm. At t = 0.5 s, when the first torque disturbance occurs, the NN error is reduced to about 80100 rpm, whereas the traditional method remains high at about 220260 rpm. At t = 0.5 s, as the load torque increases to 5 Nm, the traditional FOC error returns to its original high value of approximately 250 rpm.

In contrast, the neural network-based approach increases only slightly to approximately 100 rpm, after which the error decreases significantly. When the load torque is changed to 10 Nm at t = 1.0 s, there is an apparent error jump to about 120 to 140 rpm with the traditional controller, but the NN-based controller only has an error of about 50-60 rpm. Traditional FOC, in the steady state following 1.2 s, stabilizes within an error of approximately 100 rpm. In contrast, the NN approach attains a much lower steady-state error of approximately 50 rpm, showing superior tracking accuracy, convergence speed, and robustness to load disturbances.

© 2026 The Author(s) | Published by - Scholiora Research Publications
Creative Commons Attribution 4.0 International License (CC BY 4.0)

International Journal of IoT, Embedded Systems and Industrial Automation (IJIESIA)
ISSN: 3139-7999 | July-December-Issue, Vol. 1, No. 2 (2026) | DOI: 10.66261/3q80bb15

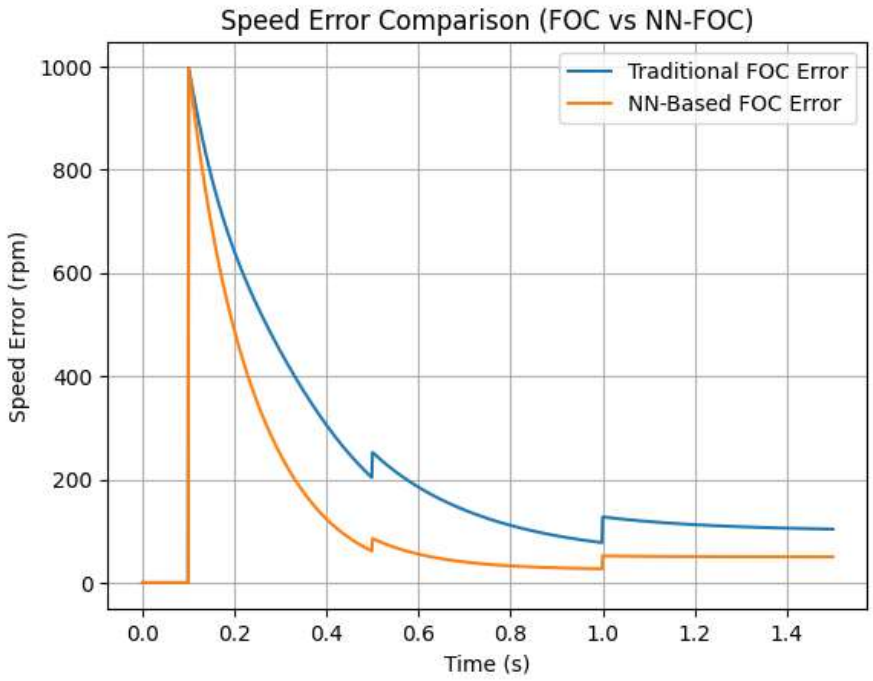

Fig. 4. Speed error response of PMSM for traditional FOC and NN-based FOC.

Figure 5 indicates the response of the electromagnetic torque of the PMSM drive to changes in load torque in steps. The conventional FOC exhibits detectable torque ripple and oscillations, especially during transient conditions following load disturbances. By comparison, the NN-based FOC yields a smoother torque response with much lower ripple and quicker settling. Also, the proposed approach monitors the load torque with higher precision, with enhanced dynamic performance and stability. A comparison of torque responses shows the dynamic behavior of the two controllers under load torques of 0 Nm (0-0.5 s), 5 Nm (0.5-1.0 s), and 10 Nm (after 1.0 s). In the first period (0-0.5 s) with a reference torque of 0 Nm, the traditional FOC exhibits significant oscillations, with a peak of about +1.5 Nm and a dip of about -0.8 Nm.

In contrast, the oscillations in NN-based FOC are contained within the range of about -0.5 Nm. With a step in the load torque to 5 Nm at t = 0.5 s, the traditional FOC shows a large overshoot of about 6.0 Nm (≈ +1 Nm overshoot), then an undershoot of about 4.5 Nm, and then stabilizes at 5 Nm after about 0.9 s. The NN-based controller, on the other hand, demonstrates a significantly smaller overshoot of approximately 5.3 Nm (+0.3 Nm) and settles more quickly, at approximately 0.70-0.80 s, with very little oscillation. In the second torque step to 10 Nm at t = 1.0 s, the traditional FOC once again shows a larger overshoot of about 11.2 Nm and an undershoot of around 9.8 Nm, with an approximate period to stabilize of about 1.31.4 s. In the meantime, the NN-based FOC reduces the overshoot to approximately 10.3 Nm (≈ +0.3 Nm) and reaches the reference quickly in approximately 1.2 s. In general, the NN-based approach significantly lowers the torque ripple (from approximately ±1-1.5 Nm to approximately ±0.3-0.5 Nm), reduces overshoot, and shortens the settling time compared to conventional FOC, resulting in better dynamic performance and disturbance rejection.

© 2026 The Author(s) | Published by - Scholiora Research Publications
Creative Commons Attribution 4.0 International License (CC BY 4.0)

International Journal of IoT, Embedded Systems and Industrial Automation (IJIESIA)
ISSN: 3139-7999 | July-December-Issue, Vol. 1, No. 2 (2026) | DOI: 10.66261/3q80bb15

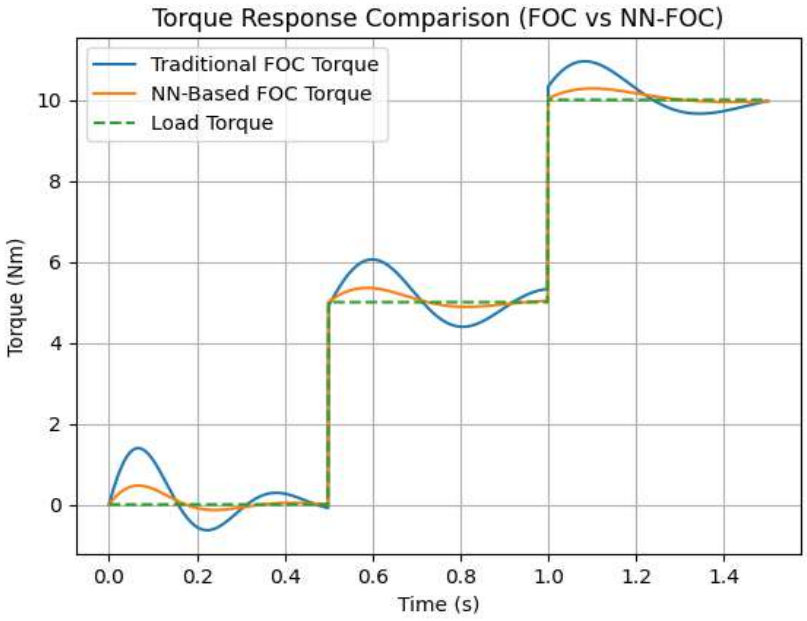

Fig. 5. Torque reaction of PMSM for traditional FOC and NN-based FOC.

Figure 6 shows how the torque error varied as the load torque was changed under both control strategies. The traditional FOC exhibits a higher torque error amplitude and more pronounced oscillations, especially under transient conditions during torque steps. Conversely, the NN-based FOC offers a significant reduction in torque error and dampens oscillations much faster. This improved performance demonstrates the efficiency of the proposed technique in achieving accurate torque tracking and enhancing disturbance rejection. The torque error response clearly indicates better performance of the NN-based FOC than the traditional method, with load torque steps of 0 Nm (0-0.5 s), 5 Nm (0.5-1.0 s), and 10 Nm (after 1.0 s). In the first period (0-0.5 s), the traditional FOC has large oscillations, with a negative peak of about -1.4 Nm at approximately 0.1 s and a positive peak of about +0.6 Nm at approximately 0.25 s. Still, the NN-based controller restricts the error to about -0.5 Nm to +0.15 Nm. The traditional FOC, at the first torque step (5 Nm at t = 0.5 s), has a strong negative error of approximately -1.0 Nm at approximately 0.6 s, followed by a positive peak of approximately +0.6 Nm at approximately 0.8 s, and then decreases gradually. The NN-based FOC, on the other hand, has a significantly smaller error variation, ranging from -0.35 Nm to +0.1 Nm over the same period. As the torque rises to 10 Nm at t = 1.0 s, the traditional controller again exhibits large oscillations, with a minimum of about -0.9 Nm at 1.1 s and a maximum of about +0.35 Nm at 1.35 s. At the same time, the NN-based controller maintains the torque error within a narrower range, about -0.3 Nm to +0.05 Nm. At steady-state conditions following 1.3 s of operation, the traditional FOC has an error of about ±0.3 Nm, whereas the NN-based approach keeps it within about ±0.05 Nm. In general, the NN-based FOC can considerably reduce the magnitude of twisted-item errors or oscillations and enhance disturbance rejection compared to conventional methods.

© 2026 The Author(s) | Published by - Scholiora Research Publications
Creative Commons Attribution 4.0 International License (CC BY 4.0)

ISSN: 3139-7999 | July-December-Issue, Vol. 1, No. 2 (2026) | DOI: 10.66261/3q80bb15

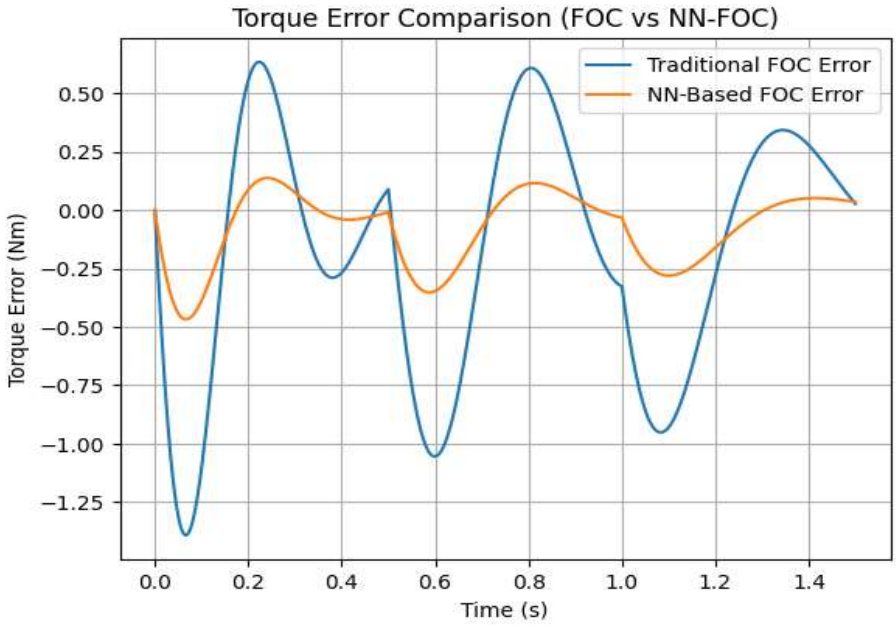

Fig. 6. Torque error response of PMSM for traditional FOC and NN-based FOC.

6. CONCLUSION

This paper has introduced a high-performance control scheme for 3-phase PMSMs that can be improved by an enhanced FOC scheme using an NN. Our work commenced with modeling the PMSM and VSI, then proceeded to implement the traditional FOC method and the proposed NN-based improvement. The limitations of the conventional PI-based FOC were demonstrated in simulation results under conditions of a step reference speed of 01000 rpm and a load torque of 0510 Nm, especially with slower dynamic response, high steady-state error, and disturbance sensitivity. Conversely, the NN-based FOC exhibited much better performance, including reduced rise time, decreased overshoot, improved speed-tracking accuracy, and increased robustness to load changes. In particular, the proposed approach decreased the steady-state speed error from about 100 rpm to about 50 rpm when the load was high, whereas the torque ripple decreased from about ± 1 1.5 Nm to about ±0.3-0.5 Nm. Also, the torque and speed error responses showed faster convergence and reduced oscillations, demonstrating the excellent disturbance-rejection capability of the NN-based controller. In general, the neural network implementation of the FOC system can address the drawbacks of standard linear controllers. The authors have shown that the suggested method is adequate for high-performance applications that need performance, accuracy, and durability. Subsequent research can focus on real-time execution, experimental validation, and the exploration of sophisticated learning methods, such as deep learning and adaptive online training, to further improve performance.

ACKNOWLEDGMENTS

The authors declare that no financial or institutional support was received for this research.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

© 2026 The Author(s) | Published by - Scholiora Research Publications
Creative Commons Attribution 4.0 International License (CC BY 4.0)

ISSN: 3139-7999 | July-December-Issue, Vol. 1, No. 2 (2026) | DOI: 10.66261/3q80bb15

REFERENCES:

[1] E. Hezare, M. Ataei, and M. Jafarboland, “Application of Vector Control to Permanent Magnet Synchronous Motors Using Chaos Control”, *Eng. J.*, vol. 18, no. 2, pp. 101-118, Apr. 2014. doi: 10.4186/ej.2014.18.2

[2] S. T. Bahar and H. Qiu, “Direct torque control constructed on FCS-MPTC of five-phase PMSM drive,” *International Journal of Advances in Electrical Engineering*, vol. 7, no. 1, pp. 01–07, Jan. 2026, doi: 10.22271/27084574.2026.v7.i1a.110.

[3] K. Thangarajan and A. Soundarrajan. "Performance comparison of permanent magnet synchronous motor (PMSM) drive with delay compensated predictive controllers". Microprocess. Microsyst. 75, C, 2020. doi: 10.1016/j.micpro.2020.103081

[4] S. Talal Bahar, H. Qiu, D. Rahman Neama, F. Fawzi Hashim, and H. Yasseen, “An Improved Cost Function Based on Model Predictive Current Control for Five-Phase PMSM,” *Edison Journal for Electrical and Electronics Engineering*, pp. 32–38, Jan. 2026, doi: 10.62909/ejeee.2025.004.

[5] G. Park, K. Han, K. Nam, H. Kim, and S. B. Choi, "Torque Vectoring Algorithm of Electronic-Four-Wheel Drive Vehicles for Enhancement of Cornering Performance," in *IEEE Transactions on Vehicular Technology*, vol. 69, no. 4, pp. 3668-3679, 2020.doi.org/10.1109/TVT.2020.2978099

[6] S. Talal Bahar and F. Hamode, “Three-phase PMSM Comparison between DTC and MPTC,” *Edison Journal for Electrical and Electronics Engineering*, pp. 9–15, July 2026, doi: 10.62909/ejeee.2026.002.

[7] K. Li and Y. Wang, “Maximum Torque per Ampere (MTPA) Control for IPMSM Drives Using Signal Injection and an MTPA Control Law,” *IEEE Transactions on Industrial Informatics*, vol. 15, no. 10, pp. 5588–5598, Oct. 2019, doi: 10.1109/tii.2019.2905929.

[8] S. Talal Bahar and D. Rahman Neama, “Improved Direct Torque Control Utilizing Model Predictive Control Approach for Permanent Magnet Synchronous Motor”, IJSER, vol. 3, no. 2, pp. 57–64, 2024.doi.org/10.58564/IJSER.3.2.2024.179

[9] Keon Young Kim, Yeongsu Bak, and Kyo-Beum Lee, "Predictive current control for indirect matrix converter with reduced current ripple," Journal of Power Electronics, 443–454, 2020. doi: 10.1007/s43236-020-00048-0

[10] M. Aguirre, S. Kouro, C. A. Rojas, and S. Vazquez, "Enhanced Switching Frequency Control in FCS-MPC for Power Converters," in IEEE Transactions on Industrial Electronics, vol. 68, no. 3, pp. 2470- 2479, 2021.DOI:10.1109/TIE.2017.2777385

[11] L. Alberti, O. Bottesi, S. Calligaro, P. Kumar and R. Petrella, "Self-adaptive high-frequency injection based sensorless control for IPMSM and SynRM," *2017 IEEE International Symposium on Sensorless Control for Electrical Drives (SLED)*, Catania, pp. 97-102, 2017. doi: 10.1109/SLED.2017.8078437

[12] H. Li, D. Ke, R. Zu, P. Tao, and F. Wang, "Sensorless Control of Permanent Magnet Synchronous Motor Based on an Improved Sliding Mode Observer," *2018 IEEE Student Conference on Electric Machines and Systems*, Huzhou, China, pp. 1-6, 2018. doi: 10.1109/SCEMS.2018.8624897.

© 2026 The Author(s) | Published by - Scholiora Research Publications
Creative Commons Attribution 4.0 International License (CC BY 4.0)