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Simulation Study of Robust Backstepping Control for Five-Phase PMSM under Load Variations and Open Fault Phase

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Abstract

This study investigates the behavior of a Five-Phase Permanent Magnet Synchronous Motor (5P-PMSM) when an open-phase fault occurs. It applies a sensorless control approach that combines backstepping control with a Model Reference Adaptive System (MRAS) observer. Using measurable electrical quantities, including stator currents and voltages, the proposed method accurately estimates both rotor position and speed. The design of the backstepping controller follows a structured procedure to achieve global or semi-global stability, making it suitable for applications that demand reliable operation under changing conditions. Lyapunov theory is used to analyze and verify the stability of the combined observer and controller. The main objective of the research is to maintain motor performance and stable operation in the presence of an open-phase fault. Simulations conducted in MATLAB/Simulink compare normal motor performance with performance during the fault to evaluate the effectiveness of the control strategy. The findings show that the backstepping controller, supported by the MRAS observer, enhances fault tolerance and reduces the adverse effects. The simulation results confirm that the proposed approach sustains motor operation with minimal decline in performance, offering a dependable solution for industrial systems requiring resilience to faults.

Keywords: 5-phase permanent magnet synchronous motor; Backstepping control; Sensorless control Fault open phase; Fault tolerant; Model reference adaptative system (MRAS) Observer.

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1. Introduction

The growing use of Five-Phase Permanent Magnet Synchronous Motors (5P-PMSMs) in both industrial and automotive sectors highlight the importance of developing dependable and efficient control strategies. Ensuring high performance and operational safety requires effective fault detection and diagnosis methods, especially for faults that can compromise system functionality, such as open-phase faults. Among various electrical faults, the open-phase fault is considered one of the most frequent occurrences. [1], where one or more phases of the motor become disconnected or lose functionality, can severely degrade motor performance and its associated drive system.

This paper focuses on advanced techniques for identifying and evaluating open-phase faults in Five-Phase Permanent Magnet Synchronous Motors (5P-PMSMs). These machines are attracting significant attention due to their inherent fault-tolerant characteristics. Unlike traditional three-phase motors, a five-phase PMSM can maintain operation even if one or more phases become disconnected, though with reduced performance. This increased phase redundancy enhances system reliability and makes the motor suitable for safety-critical applications such as electric vehicles, aerospace actuators, and industrial automation. Accurately detecting an open-phase fault is essential to ensure continued operation, prevent further damage, and maintain acceptable torque and speed performance. Therefore, developing robust detection and control methods plays an important role in improving the resilience and efficiency of five-phase PMSM drive systems [2], focusing on sensorless control strategies. Conventional fault detection techniques frequently depend on physical sensors, which increase system cost and complexity and may themselves be susceptible to malfunction. To overcome these limitations, the study examines sensorless fault diagnosis methods based on backstepping control and a Model Reference Adaptive System (MRAS). Although many studies have explored sensorless observers for multiphase motors, the MRAS approach remains attractive for five-phase PMSM drives due to its relatively simple structure and ease of implementation. [3].

Backstepping control is widely recognized for its strong performance when dealing with nonlinear systems. Unlike classical control approaches such as linearization-based feedback and conventional PI controllers, which often rely on simplified or linearized models, backstepping is designed to handle system nonlinearities directly within the control structure. This allows it to provide better stability, more accurate tracking, and stronger robustness against disturbances and parameter uncertainties. Due to these advantages, backstepping control is considered a more suitable choice in applications where dynamic behavior is complex and system parameters may vary[4], the recursive structure of the backstepping control method provides strong robustness and flexibility when dealing with nonlinear dynamics and parameter uncertainties, which makes it a promising choice for use in fault detection and control applications. Meanwhile, the Model Reference Adaptive System (MRAS) approach relies on adaptive estimation to monitor the motor's operating states and identify deviations from expected performance.

By combining backstepping control with MRAS-based estimation, this research aims to improve the precision and reliability of fault detection, while also removing the dependence on additional physical sensors. This integrated approach supports stable motor operation even when faults occur and contributes to higher system efficiency and fault tolerance.

This paper begins by presenting a detailed discussion of the theoretical principles underlying backstepping control and the Model Reference Adaptive System (MRAS) when applied to five-phase PMSM drives. After establishing this foundation, the work describes the formulation of a fault detection strategy that integrates both techniques, explaining each design step and its role in enhancing system robustness. The proposed approach is then validated through simulation studies, where its performance is assessed under both normal and faulted operating conditions. The results demonstrate the effectiveness of the combined method in improving fault tolerance and operational stability. Overall, the contributions of this research support the development of more reliable PMSM drive systems, offering practical benefits such as increased motor durability, reduced downtime, and lower maintenance costs in real industrial environments.

This paper is structured to guide the reader through both the theoretical development of the proposed control approach. Section 2 introduces the system configuration and presents the mathematical model of the five-phase PMSM, forming the foundation for subsequent controller design. Section 3 describes the implementation of the backstepping control strategy tailored for the 5P-PMSM drive. Section 4 focuses on the rotor position estimation method based on the Model Reference Adaptive System (MRAS), providing a detailed explanation of its structure and operation. Section 5 presents the simulation results obtained using MATLAB/Simulink, along with a thorough analysis of the motor's performance under different operating conditions. The final section summarizes the main conclusions of the study and highlights key contributions as well as potential directions for future research.

2. Mathematical Modelling of Five-Phase PMSM

In natural base, the following electrical equation describe model of Five-PMSM:

$$[V_s]=[R_s][I_s]+\frac{d[\varphi_s]}{dt} \qquad (1)$$

[Vs], [Is]: are the voltage and current of input system.

[Rs]: is the stator resistance per phase.

[Øs]:is the global flux linkage

The dynamic behavior of a Five-Phase Permanent Magnet Synchronous Motor (5P-PMSM) is first described using a set of coupled differential equations that relate stator currents, voltages, and electromagnetic torque. However, the inherent coupling between phases introduces complexity in controller design and analysis. To overcome this challenge, a fifth-order Park transformation is applied. This mathematical transformation converts the original five-phase variables from the stationary reference frame into multiple orthogonal rotating reference frames. As a result, the system dynamics are reformulated into partially or fully decoupled equations, which significantly simplifies control development, facilitates independent current regulation, and improves computational efficiency. This decoupling is essential for implementing advanced control strategies and fault-tolerant algorithms in 5P-PMSM drive systems.[6]

And, the matrix of Park transformation which defined as follow:

$$[M]=\sqrt{\frac{2}{5}}\begin{bmatrix} \cos\theta & \cos(\theta-\frac{2\pi}{5}) & \cos(\theta-\frac{4\pi}{5}) & \cos(\theta+\frac{4\pi}{5}) & \cos(\theta+\frac{2\pi}{5}) \\ \sin\theta & \sin(\theta-\frac{2\pi}{5}) & \sin(\theta-\frac{4\pi}{5}) & \sin(\theta+\frac{4\pi}{5}) & \sin(\theta+\frac{2\pi}{5}) \\ \cos\theta & \cos(\theta+\frac{4\pi}{5}) & \cos(\theta-\frac{2\pi}{5}) & \cos(\theta+\frac{2\pi}{5}) & \cos(\theta-\frac{4\pi}{5}) \\ \sin\theta & \sin(\theta+\frac{4\pi}{5}) & \sin(\theta-\frac{2\pi}{5}) & \sin(\theta+\frac{2\pi}{5}) & \sin(\theta-\frac{4\pi}{5}) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \quad (2)$$

The general model of the five-phase PMSM in the reference frame (d1- q1- d2– q2-o) continent the electrical equation can be written in the following form:

$$\begin{cases} V_{d1} = R_s I_{d1} + L_{d1}\frac{dI_{d1}}{dt} + wL_{q1}I_{q1} \\ V_{q1} = R_s I_{q1} + L_{q1}\frac{dI_{q1}}{dt} + wL_{d1}I_{d1} + w\,\varphi_m \\ V_{d2} = R_s I_{d2} + L_{d2}\frac{dI_{d2}}{dt} \\ V_{q2} = R_s I_{q2} + L_{q2}\frac{dI_{q2}}{dt} \end{cases} \quad (3)$$

And the mechanical equation in the following formule:

$$\begin{cases} J\frac{d\Omega}{dt} = T_{em} - T_L - F\Omega \\ T_{em} = \frac{5}{2}P(\varphi_m I_{q1} + (L_{d1} - L_{q1})I_{q1}I_{d1}) \end{cases} \quad (4)$$

where, θ is the electrical angle, φm is the permanent magnet flux ,W and Ω are the electrical and mechanical angular velocity respectively, J is the inertia moment, ,Tl is the load torque, Tem the electromagnetic torque and F denotes the friction coefficient.

3. Backstepping Control Design

In this section, the fundamental principle of the backstepping control approach is introduced. The method constructs the closed-loop control system by sequentially stabilizing first-order subsystems, using Lyapunov-based design at each step. This recursive framework guarantees robustness and ensures global asymptotic stability of the overall system [7]. The development of the proposed backstepping controller is carried out in two main stages:

3.1. Calculation of the desired current references

To guarantee that the speed controller accurately tracks the desired reference trajectory, the speed tracking error and its time derivative are defined as follows:

$$\begin{cases} e_1 = \omega^* - \hat{\omega} \\ \dot{e}_1 = \dot{\omega}^* - \dot{\hat{\omega}} \end{cases} \quad (5)$$

To assess how effectively the actual speed follows the reference speed, a Lyapunov candidate function is introduced based on the defined speed tracking error. This function serves as a measure of system stability and tracking performance, the first Lyapunov function associated with the speed error is defined as follows:

$$V_1 = \frac{1}{2} e_1^2 \quad (6)$$

According the stability condition of Lyapunov can be write the following expression:

$$\dot{e}_1 = \dot{\omega}^* - \dot{\hat{\omega}} = -k_1 e_1 \quad (7)$$

The reference current expressions are then obtained as shown in equation (8). In this formulation, the Iq1component is responsible for generating the electromagnetic torque, while the remaining current components are set to zero since they do not contribute to torque production.

$$\begin{cases} i_{d1}^* = 0 \\ i_{q1}^* = \left(\dot{\omega}^* + \dfrac{T_L}{J} + \dfrac{f\,\hat{\omega}}{J} + k_1 e_1 \right) / \left(\dfrac{K\,\varphi_m P}{J} \right) \\ i_{d2}^* = 0 \\ i_{q2}^* = 0 \end{cases} \quad (8)$$

3.2. Calculation of the desired voltages references

Figure 1 presents the overall backstepping control structure implemented for the five-phase PMSM drive. In this scheme, the backstepping controller operating in the d−q reference frame takes the speed tracking error e_{Ω} as its input and generates the corresponding Iq_1 reference current.

Based on this current reference, the required stator voltage components are then computed according to Equation (8). To determine these voltages, the current tracking errors are formulated, which allows the control law to compute the appropriate reference voltage signals as follows :

$$\begin{cases} e_2 = i_{d1}^* - i_{d1} \\ e_3 = i_{q1}^* - i_{q1} \\ e_4 = i_{d2}^* - i_{d2} \\ e_5 = i_{q2}^* - i_{q2} \end{cases} \quad (9)$$

By Setting (3) in the previous equation, one obtains:

$$\begin{cases} e_2 = -i_{d1} \\ e_3 = \left(\dot{\omega}^* + \frac{T_L}{J} + \frac{f\hat{\omega}_r}{J} + k_1 e_1 \right) / \left(\frac{K\varphi_m P}{J} \right) - i_{q1} \\ e_4 = -i_{d2} \\ e_5 = -i_{q2} \end{cases} \quad (10)$$

To verify the overall stability of the proposed control strategy [8], a second Lyapunov candidate function is formulated. This function builds upon the previous stability analysis and accounts for the additional control terms introduced during the backstepping design process. It is expressed as follows:

$$V_2 = \frac{e_1^2 + e_2^2 + e_3^2 + e_4^2 + e_5^2}{2} \quad (11)$$

By imposing the Lyapunov stability condition on the previously defined function and expressing the tracking errors accordingly, the reference voltage signals can be derived. These expressions ensure that the control inputs drive the system states toward their desired values. The obtained reference voltages are given as follows:

$$\begin{cases} V_{d1}^* = L_s \left(k_2 e_2 + \dot{i}_{d1}^* + \frac{R_s}{L_s} i_{d1} - \omega\, i_{q1} \right) \\ V_{q1}^* = L_s \left(k_3 e_3 + k\,\varphi_m P e_1 + \dot{i}_{q1}^* + \frac{R_s}{L_s} i_{q1} + \omega\, i_{d1} + \frac{\varphi_m}{L_s} \omega \right) \\ V_{d2}^* = L_{ls} \left(k_4 e_4 + \dot{i}_{d2}^* + \frac{R_s}{L_{ls}} i_{d2} - 3\omega\, i_{q2} \right) \\ V_{q2}^* = L_{ls} \left(k_4 e_5 + \dot{i}_{q2}^* + \frac{R_s}{L_{ls}} i_{q2} + 3\omega\, i_{d2} \right) \end{cases} \quad (12)$$

Where P is the pole number, Ls and Lls are the primer end secondary stator inductances of the five-phase PMSM in the reference frame (d1- q1- d2– q2-o).

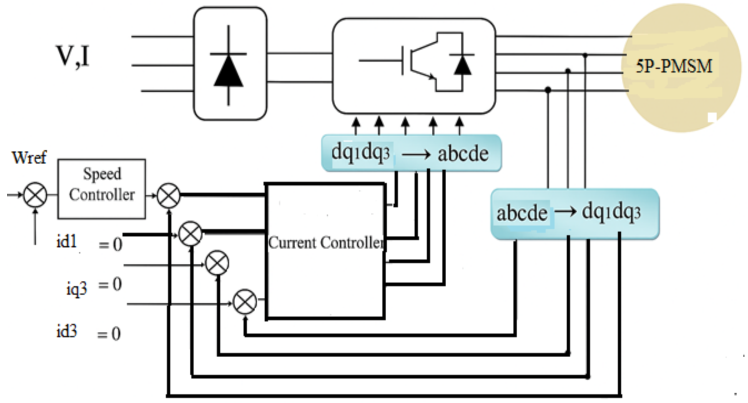


Fig 1. The Backstepping control structure of five-phase PMSM drive

4. DESIGN OF MRAS OBSERVER

To estimate both the rotor position and speed, a Model Reference Adaptive System (MRAS) is employed. The primary objective of using MRAS in the control of a five-phase PMSM is to reduce torque and speed fluctuations that may arise under variable load conditions. In this work, a sensorless control strategy based on the MRAS structure is introduced specifically for the FPMSM. The MRAS approach operates by comparing the outputs of a reference model and an adaptive model. The difference between these two outputs is processed through an adaptation mechanism, commonly implemented using a PI controller, which provides the rotor speed estimate. This concept is illustrated schematically in Figure 2

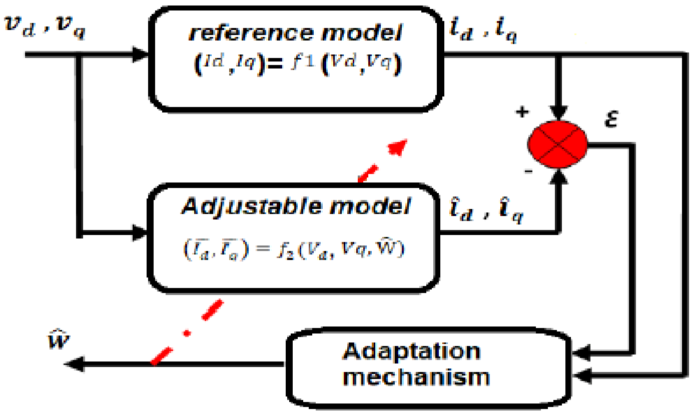


Fig 2. Structure of model reference adaptative system (MRAS)

The reference model used in the MRAS scheme is derived directly from the state-space representation of the five-phase PMSM. This model describes the expected dynamic behavior of the motor under ideal conditions, without parameter uncertainties or disturbances. It serves as the benchmark model in the adaptation process. The mathematical formulation of the reference model can therefore be expressed as follows:

$$\begin{cases}[\dot{X}] = [A][X] + [B][V] + [C] \\ [Y] = [I][X]\end{cases} \quad (13)$$

With:

The MRAS observer input is $[V] = [V_{d1}, V_{q1}, V_{d2}, V_{q2}]^T$,the output variable of system is $[X] = [I_{d1}, I_{q1}, I_{d2}, I_{q2}]^T$, and [I] the unitary matrix. Then the state-space matrices of model defined as:

$$[A] = \begin{Bmatrix} -\frac{R_s}{L_{d1}} & \frac{L_{q1}W}{L_{d1}} & 0 & 0 \\ -\frac{L_{d1}W}{L_{q1}} & -\frac{R_s}{L_{q1}} & 0 & 0 \\ 0 & 0 & -\frac{R_s}{L_{d2}} & 0 \\ 0 & 0 & 0 & -\frac{R_s}{L_{q2}} \end{Bmatrix} [B] = \begin{Bmatrix} \frac{1}{L_{d1}} & 0 & 0 & 0 \\ 0 & \frac{1}{L_{q1}} & 0 & 0 \\ 0 & 0 & \frac{1}{L_{d2}} & 0 \\ 0 & 0 & 0 & \frac{1}{L_{q2}} \end{Bmatrix} and [C] = \begin{Bmatrix} 0 \\ -\frac{\varphi_m W}{L_{q1}} \\ 0 \\ 0 \end{Bmatrix}$$

Similarly, the adaptive (or adjustable) model is obtained from the mathematical representation of the five-phase PMSM, but it incorporates the estimated parameters rather than the actual ones. This model produces output signals that depend on the estimated rotor speed, which allows the MRAS algorithm to adjust and refine the estimation. The adjustable model can therefore be expressed in the following form:

$$\begin{cases}\dot{\hat{X}} = [\hat{A}][\hat{X}] + [B][V] + [\hat{C}] \\ [\hat{Y}] = [I][\hat{X}]\end{cases} \quad (14)$$

Where $[\hat{X}] = [\hat{I}_d, \hat{I}_q, \hat{I}_x, \hat{I}_y]^T$ is the estimated state vector, so the state-space matrices of adjustable model written in the form :

$$[\hat{A}] = \begin{Bmatrix} -\frac{R_s}{L_{d1}} & \frac{L_q\hat{W}}{L_{d1}} & 0 & 0 \\ -\frac{L_d\hat{W}}{L_{q1}} & -\frac{R_s}{L_{q1}} & 0 & 0 \\ 0 & 0 & -\frac{R_s}{L_{d2}} & 0 \\ 0 & 0 & 0 & -\frac{R_s}{L_{q2}} \end{Bmatrix} [\hat{C}] = \begin{Bmatrix} 0 \\ -\frac{\varphi_m \hat{W}}{L_{q1}} \\ 0 \\ 0 \end{Bmatrix} (15)$$

In this configuration, the outputs correspond to the measured stator currents and their estimated counterparts generated by the adaptive model. The purpose of the identification process is to minimize the discrepancy between these two sets of outputs, that is, to reduce the modeling error. Consequently, the error signal can be expressed as follows:

$$[\varepsilon] = \begin{cases} \varepsilon_d = I_{d1} - \widehat{I_{d1}} \\ \varepsilon_q = I_{q1} - \widehat{I_{q1}} \\ \varepsilon_x = I_{d2} - \widehat{I_{d2}} \\ \varepsilon_y = I_{q2} - \widehat{I_{q2}} \end{cases} \quad (16)$$

Once the reference and adjustable models have been formulated, a PI adaptation mechanism is incorporated to perform the parameter adjustment within the MRAS framework. The adaptive law continuously updates the estimated rotor speed by driving the model error toward zero. To ensure stable convergence of the estimation process, the speed adaptation law is derived based on the Popov stability criterion. The resulting expression for the estimated speed can be written as follows:

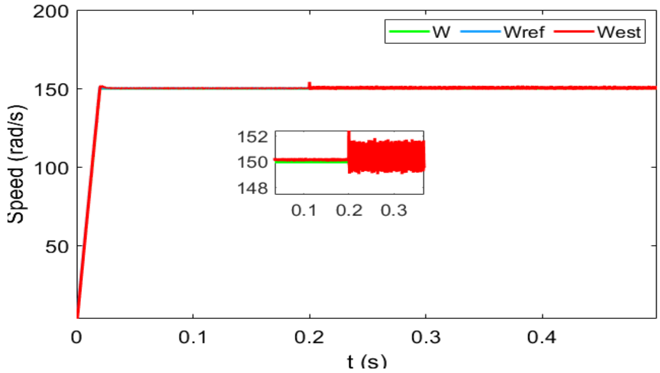
$$\widehat{W} = (K_P + \frac{K_i}{\rho})\left(\frac{L_{q1}}{L_{d1}}\varepsilon_{d1}I_{q1} - \frac{L_d1}{L_{q1}}\varepsilon_{q1}I_{d1} - \frac{\varphi_m}{L_q1}\varepsilon_{q1}\right) \quad (17)$$

5. DISCUSSIONS OF SIMULINK RESULTS

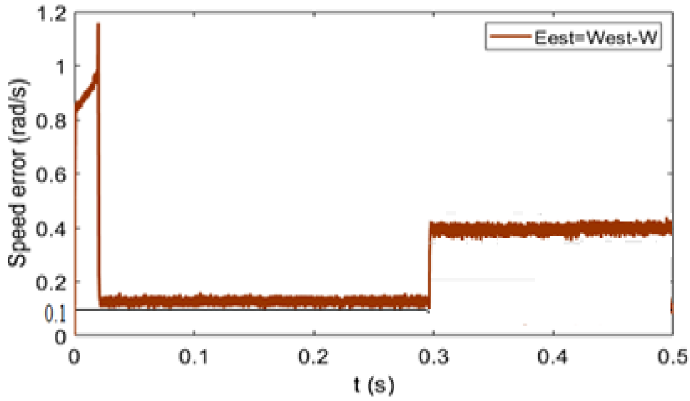
In this section, MATLAB/Simulink simulations are carried out to evaluate the performance of the five-phase PMSM drive using the proposed backstepping control combined with the MRAS observer. The motor is operated with a reference speed of 150 rad/s, and a load torque of 0.4 N·m is applied at t=0.2 s to assess dynamic response. The simulation sampling period is set to 0.5 s. In addition, a fault scenario is introduced at t=0.3 s to examine the behavior of the drive under open-phase fault conditions while maintaining the same sampling period. This allows a direct comparison between load variation and faulty operating modes. The 5P-PMSM (Five-Phase Permanent Magnet Synchronous Motor) was subjected to two different tests: one under load variation operating mode and another with a fault in the open phase. Simulations results have been carried out in MATLAB Simulink power environment to check whether the suggested control strategy works.

5.1. Simulink Results of load variation operating conditions

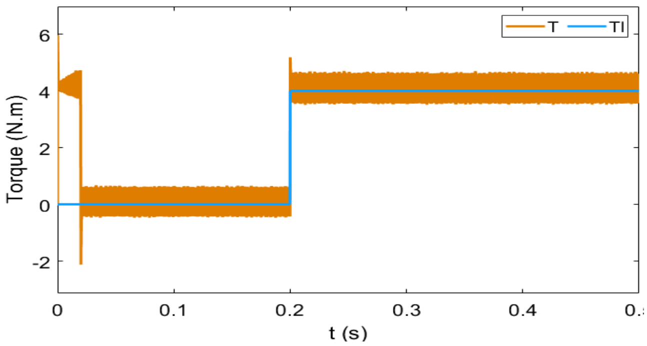
In this initial test, the five-phase PMSM drive is evaluated under normal operating conditions with load variation using the proposed Backstepping controller together and the MRAS-based observer, without introducing parameter uncertainties or faults. The reference speed is maintained at 150 rad/s, while the load torque is varied from 0 N·m up to 4 N·m. As shown in Fig. 3(a), the estimated speed closely follows the actual rotor speed. The corresponding speed estimation error displayed in Fig. 3(b) remains very small, within the range of approximately 0.11 to 0.3 rad/s at steady state, which is considered acceptable and aligns well with results reported in [9] and [10]. Similarly, Fig. 3(c) illustrates that the estimated load torque accurately tracks the applied reference torque, indicating that the five-phase PMSM maintains stable and efficient performance under changing load conditions. These results confirm that the MRAS-based observer provides reliable speed and torque estimation during normal operation and under load variations when integrated with the Backstepping control strategy.



(a)



(b)



(c)

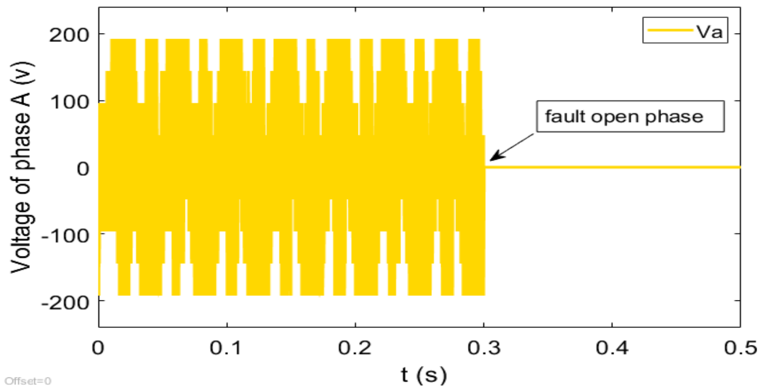
Fig 3. Result of Sensorless backstepping control of 5P-PMSM using MRAS under load torque variation in normal condition

5.2. Simulink results of 5P-PMSM fault open phase

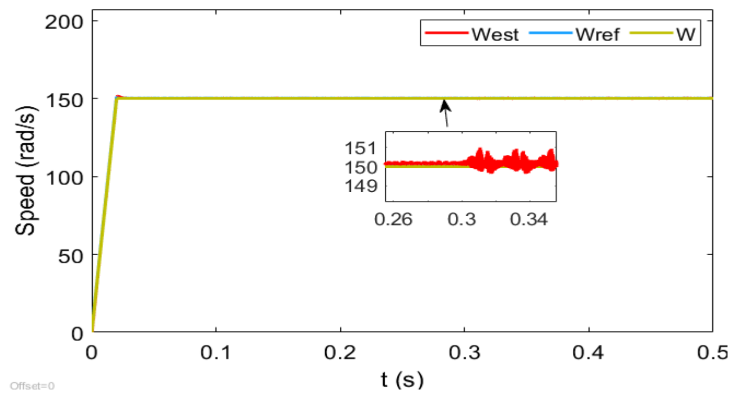
In the second test, an open-phase fault is deliberately introduced in the five-phase PMSM to assess the fault-tolerant capability of the proposed control scheme. The operating conditions are kept identical to the normal-mode test: the reference speed is set to 150 rad/s and a load torque of 4 N·m is applied at t=0.2 s. The open-phase fault is triggered at t=0.3 s, as illustrated in Fig. 4(a).

The corresponding speed response in Fig. 4(b) demonstrates that the estimated speed continues to track the actual rotor speed, although small fluctuations appear due to the fault condition. The associated speed estimation error, shown in Fig. 4(c), remains limited within approximately 0.1 to 0.3 rad/s, which is considered acceptable. A similar oscillatory behavior is also observed in the electromagnetic torque response, as presented in Fig. 4(d).

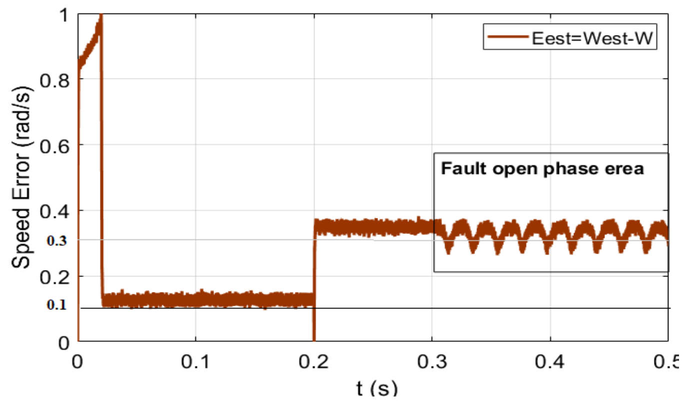
When compared to the outcomes reported in [5] and [11], the obtained results indicate an improved level of fault tolerance for the five-phase PMSM. These results further confirm the effectiveness of the Backstepping control combined with the MRAS observer, even when external disturbances such as load variations or phase faults occur.



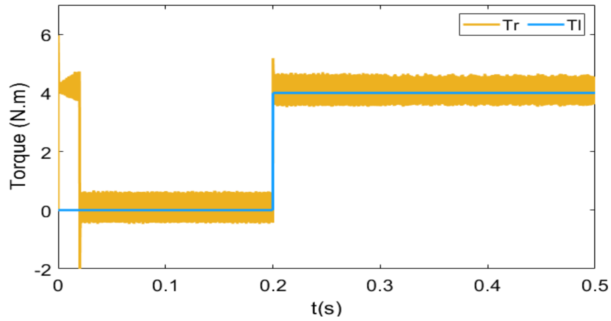
(a)



(b)



(c)



(d)

Fig 4. Result of Sensorless backstepping control of 5P-PMSM using MRAS under fault open phase operating mode

6. CONCLUSION

The study conducted on open-phase fault analysis in a Five-Phase Permanent Magnet Synchronous Motor (5P-PMSM) using a backstepping controller combined with a Model Reference Adaptive System (MRAS) observer confirms the effectiveness of this control strategy in preserving drive performance under fault conditions. Due to its multi-phase structure, the 5P-PMSM inherently provides higher efficiency and natural fault tolerance, allowing the motor to continue operating even when one or more phases become open-circuited. This characteristic significantly enhances operational reliability.The simulation results further show that the integration of the MRAS observer with the backstepping controller enables accurate estimation of motor states during the fault, allowing the controller to properly adjust the control signals and mitigate performance degradation. As a result, the motor maintains stable speed and torque responses with only minor deviations when the fault occurs. Overall, the combination of backstepping control and MRAS estimation forms a robust fault-tolerant control approach, improving the resilience and reliability of 5P-PMSM drives in industrial environments where continuous and safe operation is essential.

The parameters of tested 5P-PMSM are listed in flowing Table.

Table 1:parametres of 5P-PMSM drive

P	L_s	L_{ls}	R_s	φm	J
2	2.1 mH	0.13 mH	0.18 Ω	0.163 T	0.0011Kg.m2

References

[1] H. Eldeeb, A. Berzoy, and A. Emadi, "Fault-tolerant control of five-phase permanent-magnet motors: A review," *IEEE Transactions on Transportation Electrification*, vol. 4, no. 1, pp. 86–102, Mar. 2018. J.

[2] J. Zhao, X. Gao, B. Li, X. Liu, and X. Guan, "Open-phase fault tolerance techniques of five-phase dual-rotor permanent magnet synchronous motor," *Energies*, vol. 8, no. 11, pp. 12810–12838, Nov. 2015..

[3] I. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.

[4] M. Jamma Mustapha et al., "Comparative study of PI and backstepping with integral action for three-phase PWM rectifier," *International Journal of Electrical and Electronics Engineering (IJEEE)*, vol. 9, no. 2, 2017..

[5] R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.

[6] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].

[7] M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

[8] K. A. Hosseynia, R. Trabelsi, A. Iqbal, and M. F. Mimouni, "Backstepping control for a five-phase permanent magnet synchronous motor drive," *International Journal* of *Power Electronics and Drive Systems (IJPEDS)*, vol. 6, no. 2, pp. 851–862, Jun. 2015.

[9] D. P. *Kingma and M. Welling, "Auto-encoding variational Bayes," 2013, arXiv:1312.6114. [Online]. Available: https://arxiv.org/abs/1312.6114*

[10] S. Liu, "Wi-Fi Energy Detection Testbed (12MTC)," 2023, gitHub repository. [Online]. Available: https://github.com/liustone99/Wi-Fi-Energy-Detection-Testbed-12MTC

[11] "Treatment episode data set: discharges (TEDS-D): concatenated, 2006 to 2009." U.S. Department of Health and Human Services, Substance Abuse and Mental Health Services Administration, Office of Applied Studies, August, 2013, DOI:10.3886/ICPSR30122.v2