International Journal of Power Electronics and Drive Systems (IJPEDS)
Vol. 16, No. 1, March 2025, pp. 464~471
ISSN: 2088-8694, DOI: 10.11591/ijpeds.v16.i1.pp464-471

Optimizing low-speed DTC performance for three-phase induction motors with sector rotation strategy

Nurul Syahada Muhamad Sabri[1], Siti Azura Ahmad Tarusan[1], Syed Abrar S.A. Zawawi[1,2], Auzani Jidin[1,2], Tole Sutikno[3,4]

[1]Faculty of Electrical Technology and Engineering, Universiti Teknikal Malaysia Melaka (UTeM), Melaka, Malaysia
[2]Power Electronics and Drives Research Group, CeRIA, UTeM, Melaka, Malaysia
[3]Department of Electrical Engineering, Faculty of Industrial Technology, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[4]Embedded System and Power Electronics Research Group (ESPERG), Yogyakarta, Indonesia

Article Info

Article history:

Received Sep 18, 2024
Revised Nov 21, 2024
Accepted Dec 26, 2024

Keywords:

AC drives
Direct torque control
Flux ripple reduction
Low-speed motor
Sector rotation strategy
Three-phase induction motor
Two level inverters

ABSTRACT

This paper proposes a modification to the direct torque control (DTC) strategy for induction motors, focusing on improving flux performance at lower speeds. The method employs a sector rotation strategy to address stator flux droop, which occurs in conventional DTC due to the impact of stator resistance at low speed becoming more significant. This constrains the ability of the flux vector to be tangential to the voltage vector in the default sector. Consequently, an improper flux locus leads to distortion of the phase currents which disrupts precise control of torque. The proposed approach dynamically adjusts the sector angle to mitigate flux droop while maintaining the simplicity and original structure of DTC. The new sector rotation strategy is validated through simulations in MATLAB/Simulink to demonstrate the effectiveness of the proposed method in reducing stator flux droop. These findings have potential applications in the industrial sector and electric vehicles, where stable motor operation and smoother driving performance at low speeds are crucial for precise control operation.

Corresponding Author:

Siti Azura Ahmad Tarusan
Faculty of Electrical Technology and Engineering, Universiti Teknikal Malaysia Melaka (UTeM)
76100 Durian Tunggal, Melaka, Malaysia
Email: sitiazura@utem.edu.my

1. INTRODUCTION

Three-phase induction motor plays a crucial role in diverse industrial applications, owing to its robustness, reliability, and cost-effectiveness [1]. It is widely used in applications ranging from industrial machinery to electric vehicles [2], [3]. With the growing demand for high-performance motor drives, various advanced control strategies have been developed to enhance the operation of induction motors. Field-oriented control and direct torque control are the two most widely used methods for controlling induction motor drives among these advanced control strategies [4], [5].

In 1971, F. Blaschke's introduction of FOC revolutionized motor control by decoupling the control of torque and flux [6]. However, FOC requires precise estimation of motor parameters, which can complicate its implementation [7]. In contrast, DTC, developed by I. Takahashi in 1984, provides a simpler alternative by directly regulating torque and flux without requiring current controllers or pulse-width modulation [8]-[12]. Unlike FOC, this control technique is implemented entirely in the stationary frame, using stator-fixed reference coordinates [13]. DTC provides fast torque response and reduced dependency on motor parameters, making it a preferred choice for high-dynamic applications [6], [14], [15]. However, traditional direct torque control (DTC) approaches suffer from flux droop issues, particularly at low speeds [7], [16].

To address the flux droop issue at low speeds, one promising solution is the optimization of the sector rotation strategy within DTC. The sector rotation strategy governs the selection of voltage vectors, directly influencing the torque and flux control of the motor. Research has demonstrated that optimizing the sector rotation strategy can significantly improve low-speed performance by enhancing flux stability and reducing torque ripple [17], [18].

This research aims to improve the low-speed performance of three-phase induction motors by refining the sector rotation strategy within DTC to maintain stable flux and precise torque control at low speeds, while preserving the simplicity and advantages of the original DTC structure. By addressing the flux droop issue, this study seeks to optimize the performance of induction motors across a wide range of speeds, contributing to more efficient and reliable operation in both industrial applications and electric vehicles [1], [19], [20].

2. FLUX DROOP AT LOW SPEEDS

At low speeds, DTC performance suffers from the stator flux droop phenomenon, where the motor's flux weakens, leading to poor torque control [21]-[24]. This issue arises because conventional DTC typically neglects the effect of stator resistance, R_s [25], which becomes more pronounced at low speeds. For example, in Figure 1(a), the effect of stator resistance becomes significant, causing the flux vector direction to deviate from the expected, denoted as error deviation, θ(x). As the motor operates at lower speeds, the time required for the stator flux to reach its desired value increases, and the effects of stator resistance become more pronounced substantially reduces the magnitude of the stator flux, leading to torque instability and poor performance.

In traditional DTC approaches, the stator resistance is often neglected, as shown in (1)-(3) which leads to errors in flux estimation, particularly at low speeds. The motor's flux vector trajectory unable to follow exactly suitable voltage vector in order to increase or decrease the stator flux to produce the good torque response in the DTC drive system. This issue is especially evident during low-speed operation, where stator flux and voltage vector are more susceptible to deviation.

As the motor speed increases, the impact of stator resistance diminishes, allowing the flux direction to more closely align with the voltage vector as shown in Figure 1(b). To mitigate flux droop, advanced control strategies involving optimized sector rotation are required to maintain flux stability and improve torque control at low speeds:

$$\overline{V_s} = \overline{\iota_s} R_s + \frac{d}{dt}(\overline{\varphi_s}) \tag{1}$$

$$\overline{V_s} = \frac{d}{dt}(\overline{\varphi_s}) \tag{2}$$

or,

$$\Delta\overline{\varphi_s} = \overline{V_s} \cdot \Delta t \tag{3}$$

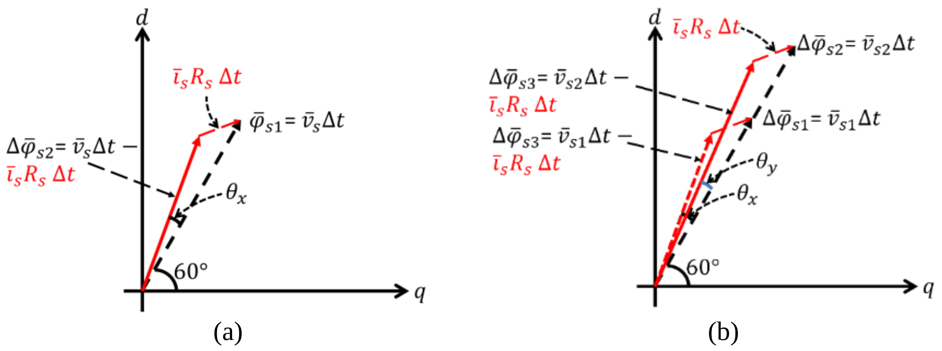


Figure 1. Flux error at (a) low speed and (b) high speed

3. MATHEMATICAL MODEL FOR INDUCTION MOTOR

The mathematical modeling of induction motors is essential for understanding their dynamic behavior and designing efficient control strategies. Induction motors are typically analyzed using a per-phase model under steady-state conditions. However, when considering variable speeds and dynamic responses, a more comprehensive approach is required. For this, the d-q model is utilized, which simplifies the motor's analysis by converting the three-phase system into a two-phase system [7], [16]. This transformation aids in eliminating time-varying inductances, making the equations more manageable and easier to handle in dynamic operation [6].

2.1. Transformation to d-q reference frame

The d-q model is based on transforming the rotor and stator variables into an arbitrary reference frame, typically aligned with the rotor flux, to simplify the analysis of the machine’s dynamics. The approach utilizes the Clarke and Park transformations to convert the three-phase quantities into two-phase components [26]. This allows the complex three-phase system to be reduced to simpler equations that describe the system's behavior in terms of the rotor flux.

$$\bar{x} = \frac{2}{3}(x_a + \bar{a}x_b + \bar{a}^{\,2}x_c) = x_d + jx_q \tag{4}$$

$$x_d = Re[x] = Re\left[\frac{2}{3}(x_a + \bar{a}x_b + \bar{a}^2x_c)\right] = \frac{2}{3}\left(x_a + \frac{1}{2}x_b + \frac{1}{2}x_c\right) \tag{5}$$

Where, x_a, x_b, and x_c are phase components of the quantity x (current, voltage, or flux linkage) and x_d and x_q represents for direct and quadrature axis components.

$$x_q = Im[x] = Im\left[\frac{2}{3}(x_a + \bar{a}x_b + \bar{a}^2x_c)\right] = \frac{1}{\sqrt{3}}(x_b - x_c) \tag{6}$$

Where, $\bar{a} = e^{j\frac{2\pi}{3}}$ is the cube root of unity used to transform into real and imaginary components.

2.2. Voltage equations in the d-q reference frame

The dynamic behavior of the induction motor in the d-q frame can be described by the voltage equations for the stator and rotor. These equations account for the voltage drop due to resistance, the inductance, and the rotating magnetic field generated by the stator and rotor.

$$v_s = R_s i_s + \frac{d\varphi_s}{dt} + j\omega_s\varphi_s \tag{7}$$

$$v_r = R_r i_r + \frac{d\varphi_r}{dt} + j(\omega_s - \omega_r)\varphi_r \tag{8}$$

Where, v_s and v_r are the rotor and stator voltage vectors, R_s and R_r is stator and rotor resistance, i_s and i_r are stator and rotor current, φ_s and φ_r are stator and rotor flux, ω_s and ω_r are stator and rotor angular velocity.

2.3. Electromagnetic torque calculation

The electromagnetic torque, T_e in an induction motor is generated due to the interaction between the stator and rotor magnetic fields, where, P is a number of poles in the motor. In the d-q model, the torque can be expressed as (9).

$$T_e = \frac{3}{2}\frac{P}{2}\cdot\frac{i_s \times \varphi_r}{\omega_r} \tag{9}$$

4. SECTOR ROTATION STRATEGY

The sector rotation strategy adjusts the sector boundaries to align the selection of voltage vectors in the DTC algorithm. In a conventional DTC system, these sector boundaries are defined by fixed angles $\emptyset_n$. However, the significant impact of the stator resistance, R_s, can disrupt the position between the flux vector and the voltage vector at low speeds. This misalignment leads to increased flux droop, which can impair the performance of the motor. The mathematical relationship governing the stator voltage vector can be expressed as (10).

$$\overline{V_s} = \frac{d}{dt}(\overline{\varphi_s}) + \overline{\iota_s}R_s \tag{10}$$

To address these challenges, the sector rotation strategy introduces a shifted angle to the conventional sector angles as shown in Figure 2. This adjustment redefines the boundaries of the voltage vector sectors, aligning the selected vectors more accurately with the actual flux vector as shown in Figure 3. The new sector angles are computed as (11).

$$\theta'_n = \theta_n + \Delta\theta \tag{11}$$

This dynamic shifted the angle $\Delta\theta_n$ adjustment is calculated based on the observed flux droop, analyzing the relationship between the stator flux vector and the applied voltage vector across varying operating conditions at low speed. By improving the flux vector with voltage vectors to be more tangential, this strategy mitigates the effects of stator resistance to improve torque control and motor efficiency. Figure 4 shows the integration to the DTC control system using sector controllers to update new sector definitions for specific operating speeds.

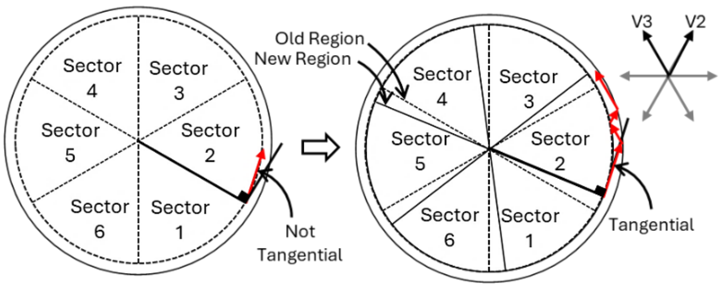


Figure 2. The transition of conventional to a new definition of the sector rotation strategy

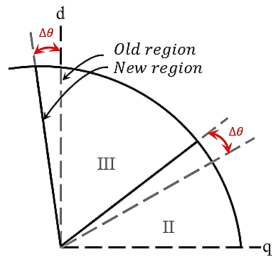


Figure 3. Proposed sector rotation strategy

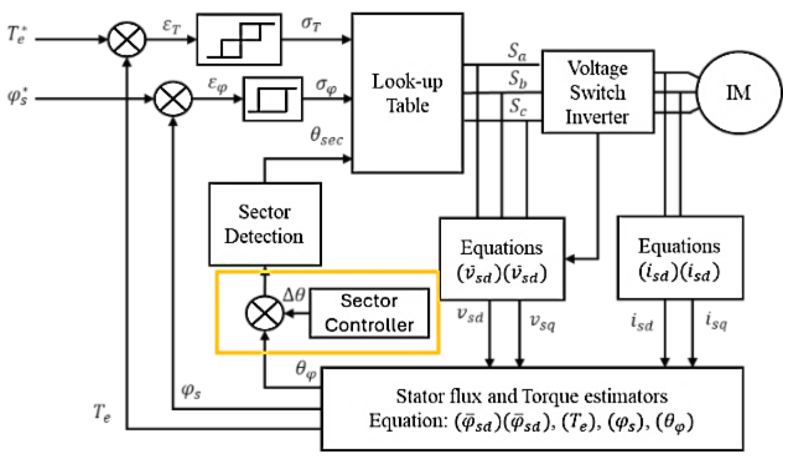


Figure 4. The proposed modification system for the DTC method

5. SIMULATION RESULT

The results section presents a detailed analysis of the effectiveness of the sector rotation strategy in improving the low-speed performance of three-phase induction motors using DTC. The simulations were conducted with the parameters outlined in Table 1. This section presents simulation results of 50 rpm, 150 rpm, and 250 rpm, comparing the conventional DTC method with the proposed sector rotation strategy.

For example, in Figure 5(a), at 50 rpm, the sector changes of the applied voltage vector for both the conventional at 1-2 second and proposed methods at 2-3 second are illustrated. At this speed, the proposed method introduces a 40° sector angle shift to compensate for the significant flux droop observed in the conventional method, which is more pronounced at lower speeds due to the reduced effectiveness of the voltage vector in maintaining flux. The flux droop correction achieved with the proposed method is 15%, as shown in Table 2, reflecting the need for greater compensation at lower speeds. This relationship can be explained by (12), which shows that the flux droop ($\Delta\varphi$) is inversely proportional to the motor speed (ωm) and proportional to the sector angle shift ($\Delta\theta$).

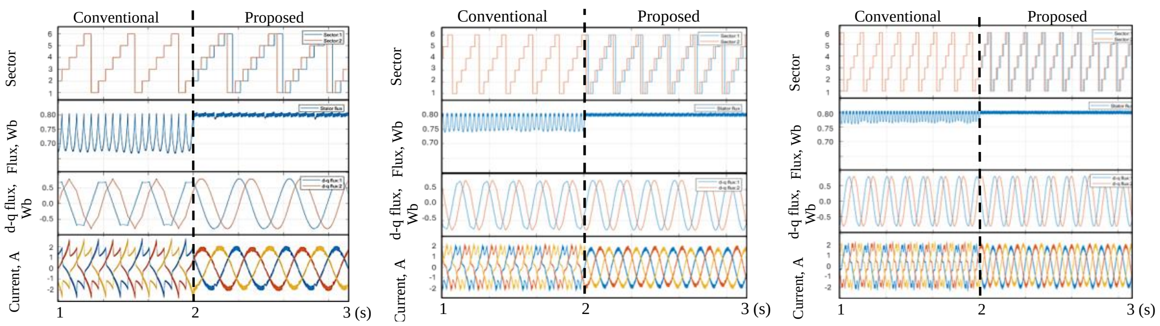
The second subplot Figure 5(b) reveals that the conventional method struggles to maintain flux due to the increased impact of stator resistance, which limits the effectiveness of the applied voltage. In contrast, the proposed strategy reduces flux droop by applying a sector-shifted voltage vector, improving overall voltage control. The third subplot Figure 5(c) demonstrates that the conventional method exhibits significant distortion in the d-q flux components, whereas the proposed strategy better aligns these flux components, thereby minimizing distortion. The fourth subplot reveals that the proposed method produces smoother stator phase currents compared to the conventional approach. Compared to the proposed strategy, the conventional method displays fluctuating currents, leading to increased torque ripples and reduced operational efficiency.

Table 1. Specification of induction machine

Parameter	Value
Nominal power Pn (VA)	2425 W
Voltage (line-line) Vn (Vrms)	400 Vrms
Frequency fn (Hz)	50 Hz
Stator resistance Rr (ohm)	6. 1 Ω
Stator inductance Lls (H)	0.01639 H
Rotor resistance Rr' (ohm)	6.2298 Ω
Rotor inductance Llr' (H)	0.01639 H
Mutual inductance Lm (H)	0.4634 H
Inertia J (kg.m^2)	0.01 kg.m^2
Pole pairs	1
Slip	1
Rated speed	2800 rpm
Rated torque	4 Nm

Table 2. Result of improvement flux droop at different speed

Speed, ω_m(rpm)	Angle (°)	Flux droop correction, Wb (%)
50	40	15
150	30	12
250	20	5



(a) (b) (c)

Figure 5. Graph of the sector, stator flux, and phase current for (a) 50 rpm, (b) 150 rpm, and (c) 250 rpm

Figure 6 illustrates the flux locus graphs for Figure 6(a) 50 rpm, Figure 6(b) 150 rpm, and Figure 6(c) 250 rpm, comparing both conventional and proposed methods. At 50 rpm, the flux locus appears hexagonal due to ineffective voltage vector control, indicating poor current management and fluctuating flux levels, which degrade torque performance. The proposed shifted angle strategy improves this, allowing the flux locus to approximate a circular form and enhance flux control. At 150 rpm, although the flux locus remains somewhat non-circular, the proposed method reduces sharp boundaries, facilitating better voltage vector control and smoother current waveforms. At 250 rpm, while the conventional method shows minimal sharp borders, the proposed sector rotation strategy further optimizes the flux locus shape, indicating enhanced voltage control and improved synchronization between current and flux, resulting in more efficient motor performance across varying speeds.

$$\Delta\varphi \propto \frac{1}{\omega_m} \propto \Delta\theta \quad (12)$$

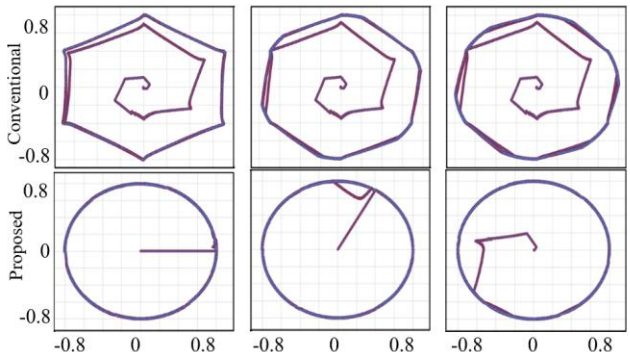


Figure 6. Graph of flux locus: (a) 50 rpm, (b) 150 rpm, and (c) 250 rpm

6. CONCLUSION

In summary, the simulation results validate the proposed sector rotation strategy as a viable enhancement to direct torque control, particularly in low-speed. The proposed strategy achieves smoother control, reduces flux ripple, and optimizes current behavior, demonstrating its effectiveness over the conventional approach. The finding shows clear relationship between motor speed, flux droop, and the necessary shifted angle to mitigate this droop. This study suggests that the shifted angle is inversely proportional to motor speed. The improved torque control and reduced flux ripple across different operating speeds demonstrate the strategy's effectiveness and potential for practical implementation in three-phase induction motors.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support provided by the Ministry of Higher Education, Malaysia, (MOHE) and Universiti Teknikal Malaysia Melaka (UTeM) through the Kesidang scholarship.

REFERENCES

[1] A. Z. Ahmad Firdaus *et al.*, "Assessment of control drive technologies for induction motor: industrial application to electric vehicle," in *Journal of Physics: Conference Series*, 2021, doi: 10.1088/1742-6596/1878/1/012047.

[2] S. K. Gudey, M. Malla, K. Jasthi, and S. R. Gampa, "Direct torque control of an induction motor using fractional-order sliding mode control technique for quick response and reduced torque ripple," *World Electric Vehicle Journal*, vol. 14, no. 6, 2023, doi: 10.3390/wevj14060137.

[3] T. E. Sola, H. J. Chiu, Y. C. Liu, and A. N. Rahman, "Improved direct torque control of induction motor for torque ripple minimization," *IEEE Access*, vol. 10, pp. 131980–131995, 2022, doi: 10.1109/ACCESS.2022.3230139.

[4] M. L. De Klerk and A. K. Saha, "A comprehensive review of advanced traction motor control techniques suitable for electric vehicle applications," *IEEE Access*, vol. 9, pp. 125080–125108, 2021, doi: 10.1109/ACCESS.2021.3110736.

[5] Y. Tarmizi, A. Jidin, K. A. Karim, and T. Sutikno, "A simple constant switching frequency of direct torque control of brushless DC motor," *International Journal of Power Electronics and Drive Systems*, vol. 10, no. 1, 2019, doi: 10.11591/ijpeds.v10.i1.pp10-18.

[6] A. Raj and R. Sharma, "Improved Direct torque control for induction motor in electric vehicle application," in *8th IEEE Power India International Conference, PIICON 2018*, 2018, doi: 10.1109/POWERI.2018.8704469.

[7] M. Z. Aihsan, A. Jidin, S. A. A. Tarusan, and T. Sutikno, "The simulation analysis of stator flux droop minimization in direct torque control open-end winding induction machine," *International Journal of Electrical and Computer Engineering*, vol. 13, no. 3, pp. 3561–3571, 2023, doi: 10.11591/ijece.v13i3.pp3561-3571.

[8] T. Isao and O. Youichi, "High-performance direct torque control of an induction motor," *IEEE Transactions on Industry Applications*, vol. 25, no. 2, pp. 257–264, 1989.

[9] N. El Ouanjli *et al.*, "Modern improvement techniques of direct torque control for induction motor drives-A review," *Protection and Control of Modern Power Systems*, vol. 4, no. 1, 2019, doi: 10.1186/s41601-019-0125-5.

[10] H. B. Marulasiddappa and V. Pushparajesh, "Review on different control techniques for induction motor drive in electric vehicle," in *IOP Conference Series: Materials Science and Engineering*, 2021, p. 012142, doi: 10.1088/1757-899x/1055/1/012142.

[11] M. Pena, M. Meyer, O. Wallscheid, and J. Bocker, "Fade-over strategy for use of model predictive direct self-control with field-oriented control," in *2023 IEEE International Electric Machines and Drives Conference, IEMDC 2023*, 2023, doi: 10.1109/IEMDC55163.2023.10239056.

[12] M. Depenbrock, "Direct self-control (DSC) of inverter-fed induction machine," *IEEE Transactions on Power Electronics*, vol. 3, no. 4, pp. 420–429, 1988, doi: 10.1109/63.17963.

[13] Y. Zahraoui, M. Akherraz, C. Fahassa, and S. Elbadaoui, "Induction motor DTC performance improvement by reducing flux and torque ripples in low speed," *Journal of Robotics and Control (JRC)*, vol. 3, no. 1, pp. 93–100, Jan. 2022, doi: 10.18196/jrc.v3i1.12550.

[14] K. Bouhoune, K. Yazid, M. S. Boucherit, and B. Nahid-Mobarakeh, "Simple and efficient direct torque control of induction motor based on artificial neural networks," in *2018 IEEE International Conference on Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles and International Transportation Electrification Conference, ESARS-ITEC 2018*, 2018, doi: 10.1109/ESARS-ITEC.2018.8607747.

[15] A. Damiano, G. Gatto, I. Marongiu, S. Meo, A. Perfetto, and A. Serpi, "A predictive direct torque control of induction machines," *International Review of Electrical Engineering*, vol. 7, no. 4, 2012.

[16] S. A. A. Tarusan, A. Jidin, M. L. M. Jamil, and K. A. Karim, "An investigation of flux characteristic in direct torque control using sector rotation strategy," *International Journal of Power Electronics and Drive Systems*, vol. 12, no. 4, pp. 1978–1986, 2021, doi: 10.11591/ijpeds.v12.i4.pp1978-1986.

[17] N. R. N. Idris and T. Sutikno, "High performance direct torque control of induction motor drives: Problems and improvements," in *International Conference on Electrical Engineering, Computer Science and Informatics (EECSI)*, 2017, doi: 10.1109/EECSI.2017.8239073.

[18] S. A. A. Tarusan, A. Jidin, M. L. M. Jamil, and K. A. Karim, "Stator flux in direct torque control using a speed and torque variation-based sector rotation approach," *International Journal of Power Electronics and Drive Systems*, vol. 12, no. 3, pp. 1326–1334, 2021, doi: 10.11591/ijpeds.v12.i3.pp1326-1334.

[19] L. Di Leonardo, M. Popescu, G. Fabri, and M. Tursini, "Performance evaluation of an induction motor drive for traction application," in *IECON Proceedings (Industrial Electronics Conference)*, 2019, pp. 4360–4365, doi: 10.1109/IECON.2019.8927006.

[20] H. Aberkane, D. Sakri, and D. Rahem, "Comparative study of different variants of direct torque control applied to induction motor," in *2018 9th International Renewable Energy Congress, IREC 2018*, 2018, pp. 1–6, doi: 10.1109/IREC.2018.8362484.

[21] I. M. Alsofyani and K. B. Lee, "Enhanced performance of constant frequency torque controller-based direct torque control of induction machines with increased torque-loop bandwidth," *IEEE Transactions on Industrial Electronics*, vol. 67, no. 12, pp. 10168–10179, 2020, doi: 10.1109/TIE.2019.2959477.

[22] X. Wu, W. Huang, X. Lin, W. Jiang, Y. Zhao, and S. Zhu, "Direct torque control for induction motors based on minimum voltage vector error," *IEEE Transactions on Industrial Electronics*, vol. 68, no. 5, pp. 3794–3804, May 2021, doi: 10.1109/TIE.2020.2987283.

[23] E. Mouna, K. Mohamed, C. Hamid, and E. Afia, "An experimental comparison between conventional and new direct torque control strategies of induction machine using DSPACE TMS 320F2812," *Communications on Applied Electronics*, vol. 4, no. 1, pp. 26–30, 2016, doi: 10.5120/cae2016652013.

[24] M. Z. Aihsan, A. Jidin, A. Alias, and T. Sutikno, "A simple duty cycle control technique to minimize torque ripple in open-end winding induction motor," *International Journal of Power Electronics and Drive Systems*, vol. 14, no. 2, pp. 1270–1279, 2023, doi: 10.11591/ijpeds.v14.i2.pp1270-1279.

[25] S. Karpe, S. A. Deokar, and A. M. Dixit, "Switching losses minimization by using direct torque control of induction motor," *Journal of Electrical Systems and Information Technology*, vol. 4, no. 1, pp. 225–242, 2017, doi: 10.1016/j.jesit.2016.08.007.

[26] N. Farah *et al.*, "Analysis and investigation of different advanced control strategies for high-performance induction motor drives," *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 18, no. 6, pp. 3303–3314, 2020, doi: 10.12928/TELKOMNIKA.v18i6.15342.

BIOGRAPHIES OF AUTHORS

Nurul Syahada Muhamad Sabri received the B.Eng. degree (Hons.) in Electrical Engineering from Universiti Teknikal Malaysia Melaka, Melaka, Malaysia, in 2023. She is currently pursuing the M.Sc. degree in Electrical Engineering at the same university. Her research interests include motor control, optimization techniques for drive systems, and advanced electric drive technologies. She can be contacted at email: nurulsyuhada@utem.edu.my.

Siti Azura Ahmad Tarusan received the B.Eng. degrees from Universiti Teknologi Malaysia, Johor Bahru, Malaysia, in 2008 and M.Eng. degrees from Universiti Malaya, Malaysia, in 2012. She is currently pursuing Ph.D. under Power Electronics and Drives Research Group (PEDG) in the Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Melaka, Malaysia. Her research interests include power electronics and motor drive systems. She can be contacted at email: sitiazura@utem.edu.my.

Syed Abrar S.A. Zawawi received the B.Eng. degree (Hons.) in Electrical Engineering from Universiti Teknikal Malaysia Melaka, Melaka, Malaysia, in 2023. He is currently pursuing the M.Sc. degree in Electrical Engineering at the same institution. His research interests include control of high-speed motor operation, optimization strategies, and electric vehicle motor drives. He can be contacted at email: m112310034@student.utem.edu.my or sywd7288@gmail.com.

Auzani Jidin received the B.Eng. degrees, M.Eng. degrees, and Ph.D. degree in power electronics and drives from Universiti Teknologi Malaysia, Johor Bahru, Malaysia, in 2002, 2004, and 2011, respectively. He is currently an academician in the Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Melaka, Malaysia. He is also an active researcher in the Power Electronics and Drives Research Group (PEDG) that was established under the same faculty. His research interests include power electronics, motor drive systems, field-programmable gate arrays, and DSP applications. He can be contacted at email: auzani@utem.edu.my.

Tole Sutikno is a lecturer and the head of the master program of Electrical Engineering at the Faculty of Industrial Technology at Universitas Ahmad Dahlan (UAD) in Yogyakarta, Indonesia. He received his bachelor of engineering from Universitas Diponegoro in 1999, master of engineering from Universitas Gadjah Mada in 2004, and doctor of philosophy in Electrical Engineering from Universiti Teknologi Malaysia in 2016. All three degrees are in Electrical Engineering. He has been a Professor at UAD in Yogyakarta, Indonesia, since July 2023, following his tenure as an associate professor in June 2008. He is the Editor-in-Chief of TELKOMNIKA and head of the Embedded Systems and Power Electronics Research Group (ESPERG). He is one of the top 2% of researchers worldwide, according to Stanford University and Elsevier BV's list of the most influential scientists from 2021 to the present. His research interests cover digital design, industrial applications, industrial electronics, industrial informatics, power electronics, motor drives, renewable energy, FPGA applications, embedded systems, artificial intelligence, intelligent control, digital libraries, and information technology. He can be contacted at email: tole@te.uad.ac.id.