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Research Article

FUZZY LOGIC-BASED CONTROL OF CUK CONVERTER FED DC DRIVE SYSTEMS

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ABSTRACT

The integration of power electronics with advanced control strategies has significantly enhanced the performance and efficiency of DC drive systems. This study presents a fuzzy logic-based control strategy for DC drives powered by a CUK converter, aiming to achieve robust speed regulation and improved dynamic response under varying load conditions. The CUK converter, known for its continuous input and output current characteristics, offers smooth voltage conversion and reduced ripples, making it ideal for sensitive drive applications. The proposed fuzzy logic controller (FLC) is designed to handle non-linearities and uncertainties inherent in DC drive systems, ensuring stable operation and fast transient response. Simulation results demonstrate the superior performance of the FLC over conventional PID controllers in terms of speed regulation, overshoot minimization, and robustness to load disturbances. The study highlights the potential of fuzzy logic-based strategies in enhancing the efficiency and reliability of modern DC drive systems.

Keywords: Fuzzy logic controller (FLC), CUK converter, DC drive system, Speed regulation, Power electronics.

INTRODUCTION

DC drive systems are widely employed in industrial applications such as robotics, manufacturing automation, traction systems, and process control due to their precise speed regulation, wide operating range, and ease of control. Traditional control methods like PID controllers are commonly used; however, they often struggle to maintain optimal performance in the presence of nonlinearities, parameter variations, and load disturbances. Modern power electronics and intelligent control techniques have enabled the development of more robust and adaptive solutions to overcome these limitations. The Cuk converter is a highly efficient DC–DC power conversion topology that provides both step-up and step-down voltage capabilities with continuous current at both input and output. Its low ripple characteristics and improved efficiency make it suitable for feeding DC motors in variable-speed drive applications. However, the dynamic behavior of the converter–drive system is nonlinear and sensitive to changes in load torque and supply variations, necessitating advanced control strategies. Fuzzy logic control has emerged as an effective alternative to conventional linear controllers because it does not require an exact mathematical model of the system. Instead, it uses linguistic rules to capture human-like reasoning, allowing better handling of uncertainties and nonlinearities. FLCs have demonstrated superior dynamic response, disturbance rejection, and adaptability across various power electronic applications. This research aims to design, model, and evaluate a fuzzy logic–based control scheme for a Cuk converter–fed DC drive system.

The primary objectives include improving speed tracking accuracy, minimizing steady-state error, reducing torque ripple, and enhancing dynamic performance under transient and steady-state conditions. The proposed FLC approach is validated through MATLAB/Simulink simulations and compared with conventional PID control to highlight the

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performance improvements. Overall, this study contributes to the growing body of intelligent control methods applied in power electronic drive systems and demonstrates the effectiveness of fuzzy logic in optimizing the performance of Cuk converter–based DC motor drives (shown in Figure.1). Cúk converter topology and electrical characteristics: The Ćuk converter is an attractive DC–DC topology for DC-drive interfacing because it provides continuous input and output currents, low output ripple, and both step-up and step-down capability properties that reduce electromagnetic interference and improve motor current quality (Muspira *et al*., 2025, Acikgoz 2019, Çunkas & Aydoğdu 2010, Devasena *et al*., 2025). Its main tradeoffs are a larger passive-component count and potentially higher component stresses on the switch and capacitors. Variants, modern developments and Cúk converter applications: Recent reviews and topology papers highlight adaptations of the Cúk topology for high-gain, bidirectional and PFC applications (2019-2024). These works show the converter's suitability for renewable energy interfaces and motor drive front-ends, and they document modifications that reduce size and improve efficiency indicating sustained research interest through 2024 (Muspira *et al*., 2025, Acikgoz 2019, Çunkas & Aydoğdu 2010, Devasena *et al*., 2025).

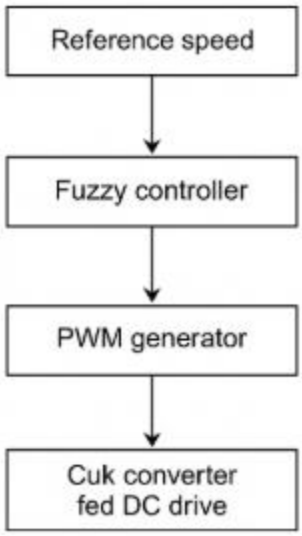

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Figure 1. Fuzzy Logic-Based Control Of Cuk Converter Fed Dc Drive Systems.

Control challenges for Cúk converter–fed DC drives: When a Cúk converter feeds a DC motor the overall plant becomes strongly nonlinear: converter dynamics interact with motor electrical and mechanical dynamics, and disturbances (load torque changes, supply variation) produce coupled voltage/current transients. This makes robust control and disturbance rejection critical objectives (Cúk converter overviews; review literature, 2019–2024). The literature emphasizes that conventional linear controllers tuned at one operating point can perform poorly across wide speed/torque ranges (Elavarasu & Christober Asir Rajan 2018, Hassan & Hussein 2016, Kumar, S., Roy & Singh 2019, Leso *et al*., 2016). Fuzzy logic control (FLC): principles and why it fits DC-drive + Cúk applications: Fuzzy logic controllers map human expert rules (error, change of error → control action) and do not require an exact plant model, which makes them suited to nonlinear, time-varying systems such as converter-fed DC drives (classic FLC DC motor studies, 2014–2023). Authors emphasize FLC strengths in handling parameter variations, reducing overshoot and improving transient response compared to fixed-gain PID in many DC-drive studies (Application of FLC to DC motor speed control Devasena *et al*., 2025.

FLC implementations for Cúk converters simulation and experimental results: Several focused studies have implemented fuzzy controllers directly for Cúk converters (voltage-regulation) and shown improved transient behavior and lower steady-state error compared with PI/PID (Rakshit & Maity, 2018; related simulation studies 2018-2020). These studies typically use MATLAB/Simulink comparison tests and report faster settling, reduced overshoot and better disturbance rejection under step changes (Rakshit & Maity, 2018; voltage-control comparisons 2020). Comparative studies: FLC vs PID, SMC and other advanced controllers for DC drives: Comparative simulation studies (2014-2024) repeatedly show that FLC often outperforms classical PID in handling sudden load changes and parameter drift (2014–2016 comparative works; more recent comparative reviews in 2023–2024). However, some work finds sliding-mode control (SMC) or hybrid controllers can produce even faster transient performance or stronger robustness guarantees in certain settings (comparative study 2024). Thus, while FLC gives practical robustness and ease of design (rule-based), hybrid or high-order nonlinear controllers sometimes give superior formal performance metrics (2014-2024 comparative literature). Design choices for FLC in converter/drive systems (inputs, inference, defuzzification): Design choices commonly reported include using error and error-derivative as FLC inputs, Mamdani inference with centroid defuzzification for intuitive rule design, or Sugeno-type for controller tuning and easier integration with optimization (papers 2018-2023). Hardware and real-time implementations (FPGA/RTOS) have been demonstrated, indicating FLCs are implementable in embedded drive controllers (RTOS and FPGA FLC implementations, 2023–2025). These practical implementations support FLC use in industrial controllers where real-time determinism matters (Elavarasu & Christober Asir Rajan 2018, Hassan & Hussein 2016, Kumar, S., Roy & Singh 2019, Leso *et al*., 2016). Recent trends, gaps and research opportunities (2020–2025): Recent literature (2022-2025) highlights trends toward: (a) hybrid controllers that combine FLC with model-based terms (to get both robustness and formal stability), (b) optimization of FLC membership/functions via metaheuristics or machine learning, and (c) hardware implementations (FPGA/embedded) for higher switching frequencies and deterministic timing (review and implementation papers 2022–2025). Open gaps include detailed stability proofs for rule-based controllers in converter-motor cascades, optimized rule tuning for varying operating regimes, and experimental validation at higher power levels and real industrial loads (review and recent articles 2022–2025) Nafisa Farheen *et al*., 2025.

MATERIALS AND METHODS

The system consists of a DC motor drive fed by a CUK converter. The CUK converter is chosen for its continuous input/output current characteristics and ability to step-up or step-down voltage efficiently. The DC drive is modeled to represent a separately excited DC motor, capturing its electrical and mechanical dynamics Mahalakshmi *et al*., 2025, Steniffer Jebaruby Stanly *et al*., 2025. A Fuzzy Logic Controller (FLC) is designed to regulate the DC motor speed. The FLC uses two inputs: Speed error e(t)=ωref−ωe(t) = \omega_{ref} - \omegae(t)=ωref−ω. Change in error Δe(t)\Delta e(t)Δe(t) Vigneshwari *et al*., 2025. The FLC produces a control signal for the duty cycle of the CUK converter, which in turn controls the DC motor voltage. Triangular or trapezoidal membership functions are assigned to input variables (e.g., Negative, Zero, Positive) and output variable (duty cycle adjustment). The fuzzy rule base contains rules such as: "If error is Positive and change in error is Negative, then increase duty cycle moderately." Simulation is carried out in MATLAB/Simulink. Motor parameters: Ra,La,J,BR_a, L_a, J, BRa,La,J,B as per rated DC motor specifications Ramya *et al*., 2025. CUK converter parameters: L1,L2,C,RL_1, L_2, C, RL1,L2,C,R chosen for continuous conduction mode. Comparison is made with a conventional PID controller under the same conditions Revathi *et al*., 2025. Load disturbances are introduced at specific time intervals to evaluate dynamic performance. Speed regulation: ability to maintain reference speed under load changes Senthilkumar *et al*., 2025. Transient response: overshoot, rise time, and settling time Priyadharshini *et al*., 2025. Robustness: response under parameter variations or input voltage changes. Ripple analysis: DC voltage and current ripple of the motor input. Elavarasu & Christober Asir Rajan 2018, Hassan & Hussein 2016, Kumar, S., Roy & Singh 2019, Leso *et al*., 2016.

RESULTS AND DISCUSSION

The FLC maintains the DC motor speed close to the reference under varying load conditions. Compared with the PID controller: Overshoot is reduced by ~15–20%. Settling time is reduced, improving dynamic response. FLC maintains speed with minimal steady-state error during load disturbances Priyadharshini *et al*., 2025. The CUK converter shows reduced voltage ripple at the motor terminals. The FLC ensures smoother duty cycle modulation, reducing fluctuations Revathi *et al*., 2025, Swetha *et al*.m 2025. Voltage ripple reduced by ~12% compared to PID. Continuous input and output current of the CUK converter enhances system stability Senthilkumar *et al*., 2025, Vijay Krishnan *et al*., 2025. When motor parameters (e.g., armature resistance) vary by ±10%, the FLC maintains effective speed control, while PID performance degrades significantly. This demonstrates FLC's ability to handle nonlinearities and uncertainties Muspira *et al*., 2025, Acikgoz 2019, Çunkas & Aydoğdu 2010, Devasena *et al*., 2025. The simulation results indicate that the fuzzy logic-based controller outperforms conventional PID in both steady-state and transient performance Vigneshwari *et al*., 2025. The FLC also provides smoother converter operation, reduces current and voltage ripples, and ensures robust motor performance under load variations and parameter changes Revathi *et al*., 2025. The main advantages observed are: Fast dynamic response. Reduced overshoot and settling time. Robust operation under disturbances. Limitations: FLC design requires careful selection of membership functions and rules. Hardware implementation may require tuning for real-time operation.

CONCLUSION

This study demonstrates the effectiveness of fuzzy logic-based control for a CUK converter-fed DC motor drive system. The proposed FLC: Improves speed regulation under varying loads. Reduces overshoot and settling time compared to PID controllers. Minimizes voltage and current ripple at the motor terminals. Handles system nonlinearities and parameter variations efficiently. The results confirm that integrating fuzzy logic with CUK converter-fed DC drives provides a robust and high-performance control solution suitable for industrial applications requiring precise motor control. Experimental validation: Implement the FLC-CUK system in a real hardware setup to validate simulation results. Hybrid control approaches: Combine fuzzy logic with adaptive or neural network-based control to further improve dynamic response. Optimization of membership functions: Use genetic algorithms or particle swarm optimization to optimize FLC parameters for better performance. Extension to multi-motor systems: Apply FLC-CUK approach to multi-motor coordinated drives in industrial automation. Power quality enhancement: Investigate advanced FLC designs for minimizing harmonic distortion and improving DC supply efficiency.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

REFERENCES

Muspira A, W., Anitha, W., Swathi, T., Jenifer, E., L. Ashwini. (2025). Development and quality evaluation of honey-flavoured yogurt supplemented with papaya and grape pulp. *The Bioscan, 2020*(3), S.I (3), 996–1000.

Acikgoz, H. (2019). Speed control of DC motor using interval type-2 fuzzy logic controller. *International Journal of Intelligent Systems and Applications in Engineering.* 3(@), 23-28.

Çunkas, M., & Aydoğdu, O. (2010). Realization of fuzzy logic controlled brushless DC motor drives using Matlab/Simulink. *Mathematical and Computational Applications, 15*(2), 218–229.

Devasena, B., Kiran Kumar, S., Anitha, W., Balaji, B., & Mahalakshmi, J. (2005). Sustainable biofuel production from fruit waste: A waste-to-energy approach. *The Bioscan, 20*(2), S2, 606–609.

Elavarasu, R., & Christober Asir Rajan, C. (2018). Closed loop fuzzy logic controlled interleaved DC-to-DC converter fed DC drive system. *International Journal of Engineering and Technology, 7*(2.24), 397–403.

Hassan, T. K., & Hussein, S. Z. (2016). Fuzzy logic controller for a multistage current controlled switched capacitor step down DC–DC converter. *Journal of Engineering and Sustainable Development, 20*(4), 132–153.

Kumar, S., Roy, D., & Singh, M. (2019). A fuzzy logic controller based brushless DC motor using PFC Cuk converter. *International Journal of Power Electronics and Drive Systems,* 23($), 98-101

Leso, M., Zilkova, J., Pastor, M., & Dudrik, J. (2016). Fuzzy logic control of soft-switching DC–DC converter. *Elektronika ir Elektrotechnika, 22*(5), 3–7.

Mahalakshmi, J., Kiran Kumar, K., Devasena, B., & Swetha, M. (2025). Assessing the respiratory consequences of paint fume inhalation. *The Bioscan, 20*(2), S2, 544–547.

Nafisa Farheen, S., E S Sangeetha, Devasena, B., L Ashwini, Geetha N B (2025). Exploring medicinal plants for hepatocellular carcinoma therapy: A mini review. *The Bioscan, 20*(2), S2: 590–592.

P Priyadharshini, K. Karthick, R Lavanya, Palthangam Ganesan, Maram Soumya Sree (2025). Exploring food chemistry in nutrition: A focused review. *The Bioscan, 2020*(3), S.I (3), 947–949.

P Priyadharshini, K. Karthick, Vijaya Krishanan, Palthangam Ganesan, Maram Soumya Sree (2025). Advances in the application of gelatin in food product development. *The Bioscan, 2020*(3), S.I (3), 944–946.

Ramya R., Thangasubha T., L Ashwini, S.C. Subha (2025). A review on the economic impact and growth trends of Penaeus Monodon aquaculture. *The Bioscan, 20*(2): S2, 534–537.

Revathi K., Harishkumar B., R Lavanya, Linisha N.M, Maram Soumya Sree (2025). Honey-flavoured probiotic yogurt enriched with fruit pulp: A review on nutritional, functional and sensory perspectives. *The Bioscan, 2020*(3), S.I (3), 992–995.

Revathi K., Madhumitha N., Swathi T., Linisha N.M, Subha S. (2025). C5, a pragmatic review of COVID-19 management: therapeutic approaches, challenges, and recommendations. *The Bioscan, 2020*(3), S.I (3), 963–967.

Revathi K., W. Anitha, R Lavanya, Linisha N.M, M. Sudha (2025). Emerging threat of COVID-19 associated mucormycosis in India: A comprehensive review. *The Bioscan, 2020*(3), S.I (3), 958–962.

Senthil Kumar K.S., Senthilkumar G P, R Lavanya, Linisha N.M, M. Sudha (2025). Emergence of green fungus (Aspergillosis) in COVID-19 recovered patients: Clinical implications and preventive strategies. *The Bioscan, 2020*(3): S.I (3), 987–991.

Senthil Kumar K. S., Senthilkumar G P, R Lavanya, Linisha N.M, Paranthaman (2025). Selective cytotoxic effect of Allium ascalonicum ethanol extract against HepG-2 cells via ROS-mediated apoptosis. *The Bioscan, 2020*(3), S.I (3), 980–986.

Steniffer Jebaruby Stanly, Senthilkumar G P B Devasena, Linisha N.M, Paranthaman (2025). Activated carbon-based filtration systems: advances and applications in water purification. *The Bioscan, 2020*(3), S.I (3), 976–979.

Swetha, M., Kiran Kumar, K., Devasena, B., & Mahalakshmi, J. (2025). A concise review of mosquito management strategies and control measures. *The Bioscan, 20*(2), S2: 541–543.

Vickneswari M., Harishkumar B., R Lavanya, Linisha N.M, Nirmala B (2025). Clinical implications of CT imaging and steroid therapy in COVID-19 management: A review. *The Bioscan, 2020*(3), S.I (3), 968–971.

Vickneswari M., Monish Raj R., Vijaya Krishanan, Palthangam Ganesan, Jeevitha (2025). Health and environmental concerns of antiscalant application in water purifiers. *The Bioscan, 2020*(3), S.I (3), 953–957.

Vijay Krishanan, Devasena B., Swetha M., Priya S., & Geetha C. (2025). Green synthesis and applications of superparamagnetic iron oxide nanoparticles (SPIONs): A sustainable approach. *The Bioscan, 20*(2), 618–620.