Journal of Innovative Research in Engineering Technology and Management Science
Volume 01, Issue 01, May 2025
www.jiretms.com

Comparative Analysis of Multilevel Inverter-fed Brushless DC Motor Drive Speed Control Using Fuzzy Logic

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To Cite this Article
Samuel Jack, "Comparative Analysis of Multilevel Inverter-fed Brushless DC Motor Drive Speed Control Using Fuzzy Logic", Journal of Innovative Research in Engineering Technology and Management Science, Vol. 01, Issue 01, May 2025, pp:12-15

***Abstract**: This work evaluates the brushless DC motor (BLDC) speed control when operated by traditional two-, three-, and five-level diode clamped multilevel inverters. A speed controller based on fuzzy logic (FL) operates to evaluate drive system performance effectively. The mechanism of controlling the proposed drive system receives further detail. The speed and torque performance of the usual two-level inverter gets evaluated against MLI configurations including three- and five-level operation for a diversity of working conditions. The mathematical model of a BLDC motor was built in the MATLAB/SIMULINK environment using IGBTs designed to simulate three and five level diode clamped multilevel inverters. The simulation data demonstrates that speed responses are swift and discontinuities in torque do not occur with the fuzzy-based speed controller. The developed fuzzy logic model demonstrates the ability to learn and change its control parameters autonomously while maintaining minimum steady state error, overshoot, and output voltage rise time across all disturbances.*

***Keywords**: Brushless DC (BLDC) motor, Fuzzy Logic Control (FLC), Speed Control Diode, Clamped Multilevel Inverter*

I. Introduction

The main advantages of BLDC motors include high efficiency along with minimal maintenance requirements and mechanical commutator independence and a combination of lighter weight and compact design dimensions. BLDC motors gained widespread industrial adoption thanks to their natural built-in advantages which enable their use across robotics and automotive industries and medical equipment applications. The quick dynamic speed responses and simple control features combined with high operational efficiency make these motors the optimal power unit for diverse applications [1]. BLDC motor drives implement pulse width modulation to supply voltages that produce steplike waveform transitions (dv/dt) which stress the terminals [9].

High dv/dt values produce motor damage through their creation of common-mode voltage in the system. The heightened times in operation turn this disadvantage worse because of rising switching frequencies. The operational duration of these voltages spans across the entire cycle framework [2]– [4]. The application of variable-speed medium-voltage drives faces significant challenges when the applied voltage exceeds ground level significantly. Both variable voltage implementation alongside reduced dv/dt rates and multilevel inverter operation serve to resolve this anticipated problem [5].

Multilevel inverters captured significant attention for medium voltage and high-power application fields during the last few years because they provide reduced common mode voltage while also reducing power switch stress and providing lower dv/dt ratios which results in less harmonic content in output voltage and current. Multilayer inverters succeed better than traditional PWM inverters at operating with reduced switching frequencies [6]. Three major MLI configuration types include Diode clamped MLI and flying capacitor MLI and cascaded H-Bridge MLI. The use of rotating machines in current industries requires precise motor speed control as a critical step to enhance both industrial output and product quality. The speed response of BLDC motors offers both fast precisions along with immunity to parameter alterations and delivers quick speed restoration in the face of disruptions. The combination of simplicity and multiple voltage level generation through capacitor series connection makes DC-MLI the choice for this investigation among other topical multilevel inverter schemes [1].

II. Proposed Topology

The complete configuration structure of the three phase BLDC motor drive appears in Figure 1. A six-switch voltage-source PWM inverter operates with constant dc-link voltage (V_d) as its primary design. Mathematical expressions describe the analysis of a BLDC motor system. A backend low direct current motor features permanent rotor magnets together with three sets of stator windings. The combination of high resistance in magnets and stainless-steel sleeves allows researchers to neglect rotor-induced current effects and eliminate the need for calculation of damper windings.

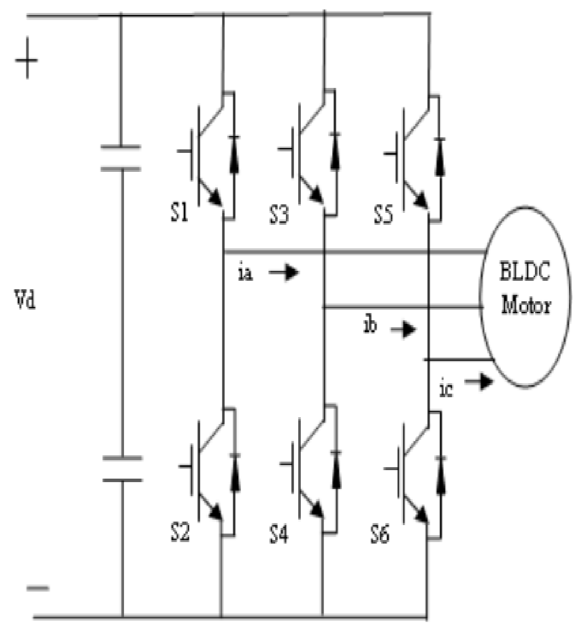

Fig 1: BLDC motor drive system

During the last decade multilevel inverters have transformed into a favored technology for controlling high-power and medium-voltage energy systems. The multilayer inverter technology produces a cleaner output waveform by maintaining its initial inverter power level. The multilevel technique presents multiple advantages including enhanced voltage handling capacity alongside decreased switching losses and robust electromagnetic compatibility and superior power quality performance. The three-level inverter introduced the "multilevel" terminology into power system technologies. The three-level inverter provides superior performance when compared to conventional two-level inverters [9-10].

III. Control Strategy

A detailed view of the BLDC drive system's control scheme appears in Figure 2. The BLDC motor drive runs through a control mode which manages both speed and current parameters. A reference speed measurement between motor output and reference speed produces reference current which is generated through a reference current generator. The current controller uses reference current signals and actual phase current measurements to generate inverter switching pulses that minimize the difference value. Industrial applications choose the PI controller as their primary control system since it has a basic structure and simple configuration design. Overshooting occurs in this system therefore a fuzzy logic controller functions as the speed controller to decrease both overshoot effects and settling time duration.

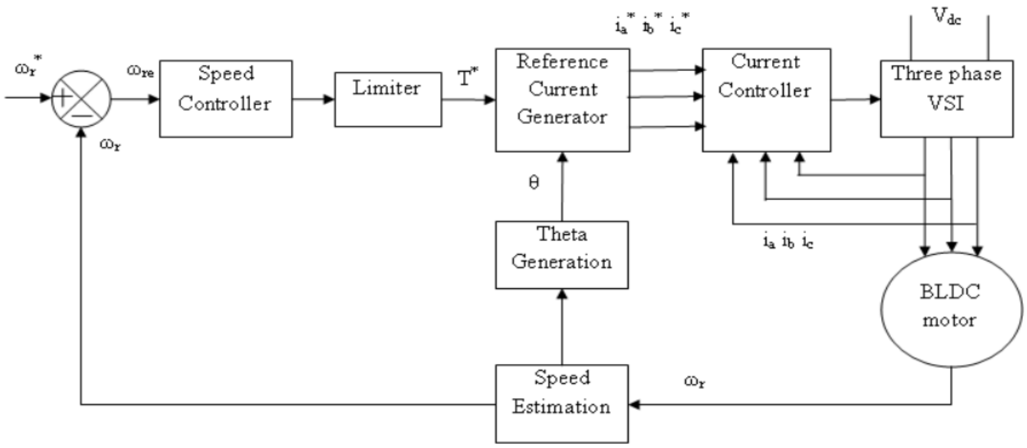

Fig 2: BLDC control scheme

FLC represents a control method based on linguistic control which functions without mathematical models to incorporate human-operational knowledge [7, 8]. The basic structure of fuzzy logic controller systems appears in Figure 3. A non-fuzzy nature exists in the system's input and output elements [10]. The basic design of the FLC can be seen in Figure 4.

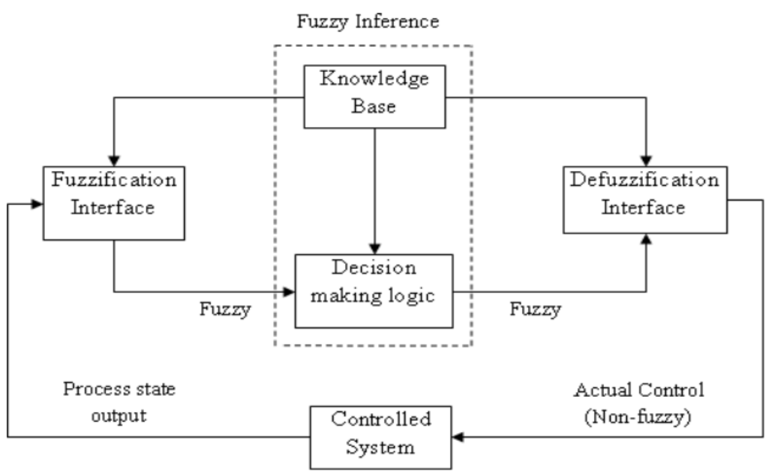

Fig 3: Structure of Fuzzy Logic Controller

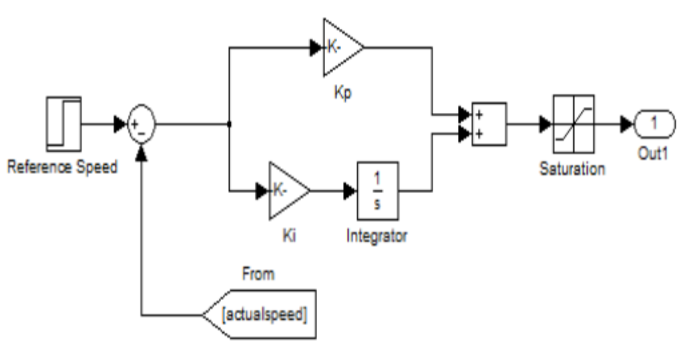

Fig 4: Block diagram of Fuzzy control system

The control method of Pulse Width Modulation finds its way into many practical applications. The method operates at a constant switching frequency pattern. The PWM control implementation requires evaluation of control signal errors against a triangular signal of specific switching frequency. The error signal emerges from adding the generated reference signal to a negative value of motor current. A control voltage signal emerges from the comparison process to direct VSI gates for producing the desired output. The controller's actions depend on detected system faults. After the error signal surpasses the triangular carrier signal the inverter legs upper switch maintains its position. When the error signal value is less than the triangle signal value the lower switch on the inverter legs remains active. These PWM signals emerge from the process. The output voltage matches the current error command because the inverter leg operates at the triangle wave switching frequency. High-frequency PWM ripples are added to reference currents that underwent regeneration to create regulated output current [9-10].

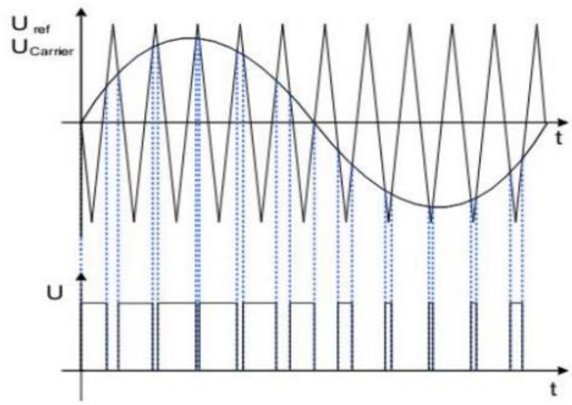

Fig 5: PWM switching signals

IV. Conclusion

A comparative analysis examines BLDC motor drives fed by traditional two-, three-, and five-level diode clamped multilevel inverters and their speed control implementation based on fuzzy logic techniques. The performance characteristics of the BLDC drive enhanced while voltage level rise led to decreased output voltage and current harmonics according to simulation results. The BLDC drive produces speed and torque characteristics that show reliable dynamic responses during both stable and transient operations. The fuzzy logic controller demonstrates rapid learning abilities together with low error generation while shortening computational times.

References

[1] Shang Lee Chei. “XZ-YZ-Source Technology Inverter SMPS”. Springer Proceedings Ind. Appl. 2013; 32(5): 210–218.

[2] Hugh Man, Diesel, Shang Chie and Naresh Kumar. “Pulse width modulation of Z-source inverters”. IEEE Trans. Control Power Systems. 2015; 22(8): 12–22.

[3] J Liu, J Hu, and L Xu. “Dynamic modelling and analysis of Z-source converter—Derivation of ac small signal model and design-oriented analysis”. IEEE Trans. Power Electron. 2007; 22(5): 1786–1796.

[4] Chie Lee and Yadav Kumar. “An Matrix Converter using Array System in Power Electronics in Communication Systems”. Springer Conference in Hindustan University, Chennai, VOL. 2, NO. 3, March 2009

[5] Saritha, Srikanth, Subhakar and Sunitha, “A Process control system in Industrial Applications using Thyristors in power electronics for PMSG”,”. Elsevier 2011. China, 7 – 9, January 2012.

[6] A Muetze and A Binder. “Calculation of circulating bearing currents in machines of inverter-based drive systems”. IEEE Trans. Ind. Electron. 2007; 54(2) 932–938.

[7] A Purna Chandra Rao, YP Obulesh and Ch Sai Babu. “High performance Cascaded multilevel inverter fed brushless dc motor drive”. International Journal of Engineering Sciences & Emerging Technologies. 2013; 5(2): 88-96.

[8] J Rodriguez, JS Lai, and FZ Peng. “Multilevel inverters: A survey of topologies, control and applications”. IEEE Trans. Power Electron. 2002; 49(4): 724–738.

[9] C, Wang Chie. “An LC Filter and IGBT-Based High Regulated Low Ripple DC Supply.” Journal of Science Engineering Technology and Management Sciences, vol. 2, no. 5, Apr. 2025, pp. 20–25. Crossref, https://doi.org/10.63590/jsetms.2025.v02.i05.pp20-25.

[10] Venugopal, “SVC Reactive Power Management Using Genetic Algorithms”, Journal of Engineering Technology and Sciences, Vol. 02, Issue 06, June 2025, pp:08-11, Crossref, http://doi.org/10.63590/jets.2025.v02.i06.pp08-11.