Enhanced Voltage Regulation of Buck Converter-Fed DC Motors Using Fuzzy Logic Control Under Dynamic Load Conditions

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Mohamed, Mawada Ahmed [a] ; Toha, Siti Fauziah [a] ; Abdullah, Muhammad [b] ;
Ahmad, Salmiah [c] ; Nor, Khairul Affendy Md. [a] ; +2 authors

[a] Department of Mechatronics Engineering, Kulliyyah of Engineering, International Islamic University, Gombak, 53100, Malaysia

Abstract

Buck converters are widely employed in power electronics for efficient DC voltage regulation, particularly in applications such as motor drives and embedded systems. However, conventional control methods, such as PID, often exhibit limitations including significant voltage ripple, overshoot, and sluggish dynamic response under varying load conditions. This study introduces a fuzzy logic controller (FLC) integrated into a buck converter system to address these challenges through adaptive and nonlinear control. The research contribution is the design and simulation of an FLC-based voltage regulation strategy that enhances output stability and improves transient performance in DC motor applications. The proposed buck converter operates in continuous conduction mode and consists of an IGBT switch, inductor, diode, and filter capacitor. The FLC employs voltage deviation and its rate of change as input variables and utilizes a 25-rule Mamdani fuzzy inference system to modulate the duty cycle in real time. Simulated in MATLAB Simulink with a dynamic DC motor load, the FLC demonstrates superior control characteristics over the PID controller. Most notably, voltage ripple is reduced by over 65%, leading to improved voltage stability and reduced fluctuations. The FLC also exhibits faster settling behavior and better handling of dynamic load variations, confirming its effectiveness in nonlinear and time-varying systems. Future work will focus on hardware validation, hybrid control integration, and deployment in renewable energy and electric vehicle systems to improve adaptability and real-world performance.

Author keywords

Adaptive Voltage Regulation; Buck Converter Control; DC Motor Drive Systems; Fuzzy Logic Controller (FLC); MATLAB Simulink Simulation

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Corresponding authors