Fuzzy-Direct Torque Control of The Squirrel-Cage Motor Fed on The PEMFC Fuel Cell System: Design and Simulation

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ABSTRACT

In this paper, we present the fuzzy logic control (FLC) applied to the direct torque control (DTC) of the asynchronous machines in a fuel cell system. Using the FLC and PI controllers, we studied the response of the asynchronous motor at a variable reference speed and charge. Subsequently, we introduce the principles of control of fuzzy logic by justifying our choice of this method to control asynchronous machines. To confirm its efficiency, we use a simulation under several operating conditions in order to show the robustness of the applied controller in terms of ripple reduction, tracking speed, switching loss, and parameter sensitivity.

Keywords: PEMFC fuel cell system, Fuzzy logic, Direct torque control

1 Introduction

The article explores challenges in controlling squirrel-cage induction motors for electric and hybrid vehicles. Induction motors, though pivotal due to their ruggedness and high-speed capabilities, are complex nonlinear systems affected by uncertain parameters and unknown load disturbances. Researchers have focused on optimizing direct torque control (DTC) through methods like improved switching tables and fuzzy logic integration. Despite DTC's robustness, issues such as intense inverter switching and torque ripple persist. To address these challenges, the study proposes a novel hybrid system controller (PI-fuzzy) that integrates fuzzy logic with conventional controllers and DTC methodologies. The objective is to achieve stability, precision, speed, and robustness in varying load conditions. The proposed approach is validated through MATLAB/SIMULINK simulations [1–15].

2 Methodology

To enhance the control strategy, we incorporate fuzzy logic control into the DTC system. We designed a fuzzy speed controller using the Mamdani method and defined fuzzy rules based on expert knowledge [10]. The fuzzy logic controller is integrated into the DTC system, which includes a fuel cell, inverter, gearbox, and motor [5]. In this study, we present a dynamic model of the PEMFC fuel cell system and implement the hybrid system controller using MATLAB/SIMULINK [3].

2.1 Modeling system

The model of fuel cell used in this study is based on the dynamic proton exchange membrane fuel cell (PEMFC) developed in references [16], [17]. The DC/DC boost converter used is inserted between the source and the inverter [18]. The proposed DTC PEM fuel cell system model is shown in Figure 1.

- **DTC classical simulation** results: The proposed fuzzy-DTC scheme (see Figure 2) has been implemented in Matlab/Simulink to evaluate its performances [19]. The squirrel-cage asynchronous machine parameters used for the simulations are given in Table 1.

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- **Fuzzy-DTC simulation** results: The evolution of the behavior of the asynchronous machine (AM) under variable load conditions is illustrated in Figure 2.

3 Results and Discussion

This study evaluates a fuzzy direct torque control (DTC) strategy through simulations under diverse operating conditions, including variable loads and speed reversal [9]. The results indicate satisfactory speed tracking and disturbance rejection under variable loads, but a notable torque overshoot is observed [10]. The implementation of a fuzzy logic controller significantly improves the system's response, as demonstrated in the simulation results with varying speed references.

4 Conclusion

In conclusion, this article presents a comprehensive study on the application of fuzzy logic control to the direct torque control of asynchronous machines in a fuel cell system. The hybrid control strategy, integrating fuzzy logic, exhibits promising results in terms of speed tracking and disturbance rejection. However, challenges remain, particularly regarding torque overshoot. The study offers valuable insights for researchers and practitioners in electric motors and torque control, suggesting future work in areas such as power quality analysis, motor efficiency enhancement through flux control, and the exploration of optimization algorithms.

5 Declarations

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5.2 Competing Interests

The authors declare that no conflict of interest exists in this work.

How to Cite

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