ABSTRACT

Effective temperature control in Proton Exchange Membrane (PEM) Fuel Cells and Electrolyzers is crucial to maintaining system efficiency, stability, and lifespan. Uncontrolled temperature rise can lead to performance degradation and component damage. This study aims to design and implement a fuzzy logic–based temperature control system capable of adaptively adjusting fan speed according to temperature changes, thereby keeping the operating temperature within optimal limits.

A quantitative research approach was applied through laboratory-scale prototype testing using a reversible PEM EATAD2221 module (0.6 W), ESP32 microcontroller, MLX90614 non-contact temperature sensor, and cooling fan as the actuator. The control algorithm employed three fuzzy sets (cold, normal, hot) with the Center of Gravity defuzzification method to generate PWM signals for fan speed control. Temperature data were collected under both no-load and full-load conditions and statistically analyzed to evaluate control effectiveness.

The results show that under full load, the system maintained fuel cell temperatures in the range of 36.10–38.20 °C and a maximum electrolyzer temperature of 35.65 °C, while no-load operation resulted in temperatures between 32.45–34.85 °C. The fuzzy control implementation reduced the average temperature rise by approximately 15.4% compared to the uncontrolled condition. The system also responded to temperature variations in real time without significant overshoot.In conclusion, the fuzzy logic–based temperature control system effectively maintains operating temperatures within a safe range, improves thermal efficiency, and has the potential to extend the operational life of both the fuel cell and electrolyzer.

Keywords: temperature control, fuzzy logic, fuel cell, electrolyzer, PWM, fan