Diagnosis of Water Management in PEM Fuel Cells Based on Electrical Parameter Analysis of a Randles Equivalent Circuit

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Abstract

Water management strongly influences the performance and durability of proton exchange membrane fuel cells (PEMFCs). Insufficient hydration causes membrane dry-out and increases ohmic resistance, while excess water floods porous layers and limits reactant transport. This study proposes a hydration-diagnosis method based on a Randles equivalent circuit and the analysis of characteristic electrical parameters.

The method evaluates three key indicators: membrane ohmic resistance (Rs), activation resistance (Ract), and double-layer capacitance (Cdl). Normal, dry-out, and flooding scenarios were developed to assess parameter sensitivity to membrane-hydration variations.

Results show that dry-out significantly raises Rs from 0.08 Ω to 0.14 Ω, whereas flooding mainly increases Ract from 0.15 Ω to 0.32 Ω. Tracking parameter evolution also clearly identifies water-management transitions at 3 s and 7 s, corresponding respectively to the onset of membrane dry-out and the development of flooding.

The approach demonstrates that PEMFC water-management conditions can be monitored and diagnosed online using electrical measurements alone. Electrical parameter-based indicators therefore offer a practical route for real-time detection of dry-out and flooding, supporting future advanced control strategies and predictive maintenance for PEMFC systems. This framework provides robust diagnostic insight without additional sensors, helping improve system reliability, operational efficiency, and durability under dynamically changing load conditions.

Keywords

PEMFC, Water Management, Hydration Diagnosis, Randles Equivalent Circuit, Hydration Control.