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Entitled

MODELLING AND FAULT DIAGNOSIS APPROACHS FOR PROTON EXCHANGE MEMBRANE FUEL CELL SYSTEMS INCORPORATING AMBIENT CONDITIONS

by

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Abstract

Proton exchange membrane fuel cell (PEMFC) as a source of electrical power provides numerous benefits such as zero carbon emission and high reliability as compared to wind and solar energy. PEMFC operates at very low temperature, high power density and has very high durability as compared to other fuel cells. Being a non-linear power source with high sensitivity to ambient conditions variation, the prediction of PEMFC voltage and temperature is a complicated issue. The most common PEMFC models are classified as mechanistic model, semi-empirical model and purely empirical methods. The mechanistic models are complex and requires differential equations to predict the voltage and temperature of PEMFC. However, the semi-empirical models are less complicated and can be used easily for online prediction of PEMFC outputs. Therefore, the first part of this thesis attempt to model the voltage of PEMFC using simple and effective semi-empirical equations. The second part of the thesis focuses on modelling the PEMFC temperature. Previously most temperature models use complex equations incorporating PEMFC output voltage as well which is not a good option as temperature must be predicted using only load current and ambient temperature. The model proposed in this thesis is developed through an algorithm which tracks the online changes in the load current and ambient temperature. It provides accurate temperature of PEMFC by mainly using simple first order equation with the help of tracking algorithm. Quantum lightening search algorithm (QLSA) is used for optimization of constant parameters for both voltage and temperature models. The enhanced semi-empirical voltage model is verified by performing experiments on both the Horizon and NEXA PEMFC systems under different conditions of ambient temperature and relative humidity with root mean square error (RMSE) less than 0.5. Results obtained using the enhanced model is found to closely approximate those obtained using PEMFCs under various operating conditions, and in both cases, the PEMFC voltage is observed to vary with changes in the ambient and load conditions. Inherent advantages of the proposed PEMFC model include its ability to determine membrane-water content and water pressure inside PEMFCs. The membrane-water content provides clear indications regarding the occurrence of drying and flooding faults. For normal conditions, this membrane water content ranges between 12.5 to 6.5 for Horizon PEMFC system. Based on simulation results, a threshold membrane-water-content level is suggested as a possible indicator of fault occurrence under extreme ambient conditions. Limits of the said threshold are observed to be useful for fault diagnosis within the PEMFC systems.

Keywords: Proton exchange membrane fuel cell, modelling, semi-empirical, fault diagnosis, flooding, drying and algorithm.