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Fault Classification Method for PEMFC Based on Equivalent Circuit and SVM

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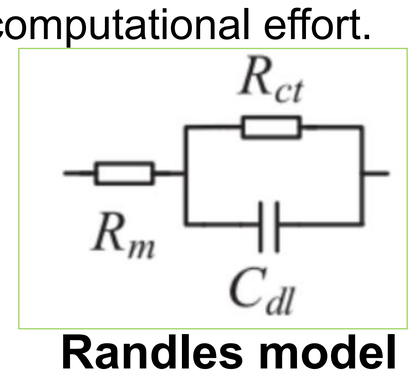
introduction

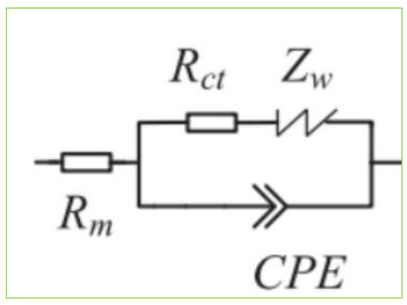
Objective: Enhance safety, reliability & stability of hydrogen fuel cells through intelligent fault diagnosis enabling predictive maintenance.
Method: Developed an SVM-based fault detection system.Extracted key features using an Equivalent Circuit Model .Applied correlation coefficient method for feature reduction.Used z-score normalization for data preprocessing.Implemented dynamic parameter optimization & closed-loop training for model robustness.
Fault Classes: Classifies Normal Operation, Flooding, Membrane Drying, and Oxygen Starvation.
Key Results:①High Accuracy: >97% accuracy per fault class; >98% overall test accuracy.②High Performance: F1-score of 0.98 for Normal Operation.③High Speed: Diagnosis time of only 0.33 seconds.
Superiority: Outperforms CNN & BP models in speed while maintaining high accuracy.
Significance: Provides an efficient, robust solution with significant engineering application potential for HFC intelligent fault diagnosis.

equivalent circuit

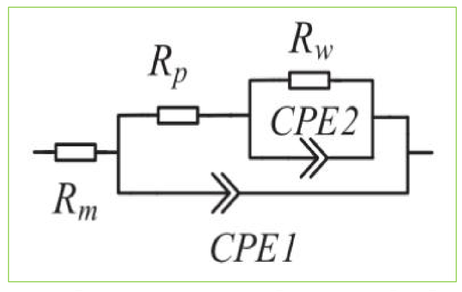
Randles: The Randles model is the most practical and typical electrochemical equivalent circuit, widely used for fundamental fuel cell analysis.However, the model's representational ability is not prominent.
Fouquet: Fouquet et al. replaced the double-layer capacitance with a Constant Phase Element (CPE) and introduced an additional Warburg element into the circuit, creating the Fouquet model. Compared to the Randles model, this configuration exhibits enhanced characterization capabilities.However, the Fouquet model's computation is relatively complex.
Improved: Since the Zw equation contains many parameters, it takes longer to calculate compared to CPE. Therefore, the equivalent circuit is proposed, using the circuit structure of the CPE and resistor in parallel instead of Zw. Compared with the Randles model, the model has more complex characterization capability. Compared with the Fouquet model, this model requires less computational effort.



Randles model

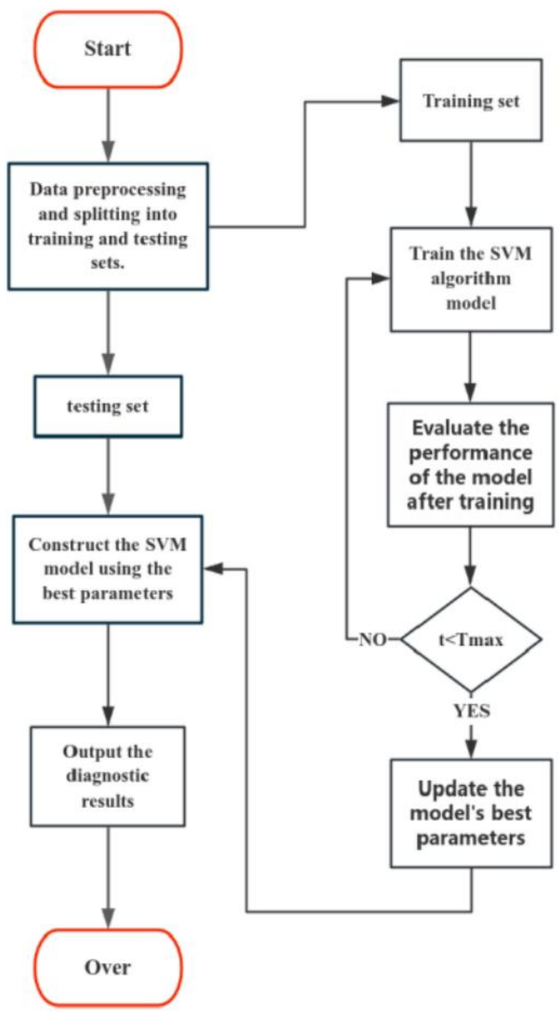


Fouquet model



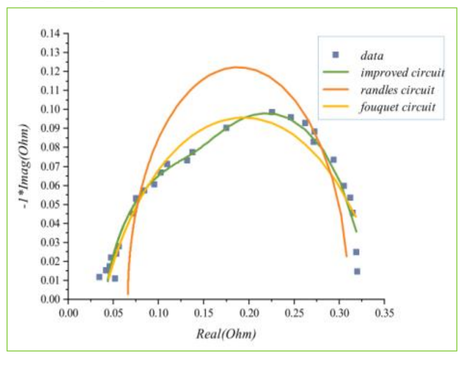
Improved model

Algorithm flowchart

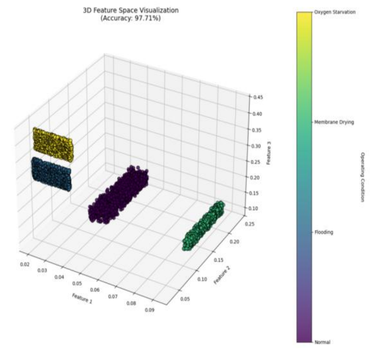


conclusion

The conclusions obtained by fitting under the other three fault conditions are the same as those obtained under normal operating conditions.
Through comparison, the SVM algorithm demonstrates fast and accurate advantages in fault diagnosis for this circuit model.



Working Condition	Precision	Recall	f1-score	Support
Normal	0.99	0.98	0.98	1101
Flooding	0.97	0.98	0.98	1077
Membrane Drying	0.97	0.98	0.97	1065
Oxygen Starvation	0.97	0.98	0.98	1077



		SVM	CNN	BP
Accuracy	Normal	0.99	0.99	0.99
	Flooding	0.97	0.97	0.97
	Membrane Drying	0.97	0.97	0.96
	Oxygen Starvation	0.97	0.97	0.96
Time(s)		0.33	2.2	0.78