
Contents

1	Background and Introduction	1
1.1	Fuel Cell	2
1.2	Fuel Cell Propulsion System for Automobiles	6
1.3	System Interactions	8
1.3.1	Reactant Flow Subsystem	8
1.3.2	Heat and Temperature Subsystem	9
1.3.3	Water Management Subsystem	9
1.3.4	Power Management Subsystem	10
1.3.5	Fuel Processor Subsystem	10
1.4	Literature Review	11
2	Fuel Cell System Model: Auxiliary Components	15
2.1	Compressor Model	17
2.2	Lumped Model of the Manifold Dynamics	21
2.2.1	Supply Manifold	23
2.2.2	Return Manifold	24
2.3	Review of the Thermodynamics of Gas Mixtures	26
2.4	Air Cooler (Static) Model	27
2.5	Humidifier (Static) Model	28
3	Fuel Cell System Model: Fuel Cell Stack	31
3.1	Stack Voltage Model	32
3.1.1	Fuel Cell Open Circuit Voltage	32
3.1.2	Activation Loss	35
3.1.3	Ohmic Loss	37
3.1.4	Concentration Loss	37
3.1.5	Cell Terminal Voltage	38
3.1.6	Fuel Cell Dynamic Electrical Effect	42
3.2	Cathode Flow Model	45
3.3	Anode Flow Model	50
3.4	Membrane Hydration Model	53

4	Fuel Cell System Model: Analysis and Simulation	57
4.1	Humidifier and Hydrogen Flow Controls.....	58
4.1.1	Humidifier Control	58
4.1.2	Hydrogen Valve Control.....	59
4.2	Steady-state Analysis	60
4.3	Dynamic Simulation	61
5	Air Flow Control for Fuel Cell Cathode Oxygen Reactant .	65
5.1	Control Problem Formulation	68
5.2	Control Configurations	69
5.3	Linearization.....	70
5.4	Dynamic Feedforward	72
5.5	Feedback Control Design	76
5.5.1	State Feedback with Integral Control	76
5.5.2	Observer Design.....	81
5.6	Closed Loop Fuel Cell Impedance.....	85
5.7	Tradeoff Between Two Performance Objectives	87
6	Natural Gas Fuel Processor System Model	91
6.1	Fuel Processing System (FPS)	92
6.2	Control-oriented FPS Model	93
6.2.1	Modeling Assumptions	93
6.2.2	Model States and Principles	95
6.2.3	Orifice	95
6.2.4	Blower (BLO)	95
6.2.5	Heat Exchanger Volume (HEX)	96
6.2.6	Hydro-desulfurizer Volume (HDS)	97
6.2.7	Mixer (MIX).....	97
6.2.8	Catalytic Partial Oxidation (CPOX).....	98
6.2.9	Water Gas Shift Converter and Preferential Oxidation Reactor (WROX)	105
6.2.10	Anode (AN)	105
6.3	Simulation and FPS Model Validation	106
7	Control of Natural Gas Fuel Processor	113
7.1	Control Problem Formulation	114
7.2	Analysis of FPS Linearized Models	115
7.3	Input-output Pairing.....	119
7.4	Decentralized Control	120
7.5	Multivariable Control	124
7.5.1	Full-state Feedback with Integral Control.....	125
7.5.2	State Estimator	128
7.5.3	Insight Gained by the Multivariable Design	130
7.5.4	Effect of Measurements	136

8 Closing Remarks 139

 8.1 Fuel Cell Stack System 140

 8.2 Natural Gas Fuel Processor System 141

 8.3 Future Study 142

A Miscellaneous Equations, Tables, and Figures 145

 A.1 FCS Air Flow Control Design 145

 A.2 FPS Control Design 147

References 151

Index 159



<http://www.springer.com/978-1-85233-816-9>

Control of Fuel Cell Power Systems
Principles, Modeling, Analysis and Feedback Design
Pukrushpan, J.T.; Stefanopoulou, A.G.; Peng, H.
2004, XVII, 161 p., Hardcover
ISBN: 978-1-85233-816-9