

**RAGHUNATHAN RENGASWAMY**

Professor

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**1. Education**

Ph.D. (1995) Chemical Engineering, Purdue University, West Lafayette, IN 47907, USA

**Thesis:** A Framework for Integrating Process Monitoring, Diagnosis and Supervisory Control

B. Tech (1990) Chemical Engineering, Indian Institute of Technology, Madras, 600036, India

**Thesis:** An Expert System for VLE Equation Selection

**2. Professional Experience**

Jan 2009 – Present Professor, Department of Chemical Engineering, Texas Tech University, Lubbock, TX 79409.

June 2008- Dec 2008 Professor, Department of Chemical and Biomolecular Engineering, Clarkson University, Potsdam, NY 13699-5705.

Jan 2002 – May 2008 Associate Professor, Department of Chemical Engineering, Clarkson University, Potsdam, NY 13699-5705. (Awarded Tenure in 2006)

Jan 2001 – Dec 2001 Visiting Assistant Professor, School of Chemical Engineering, Purdue University, West Lafayette, IN 47907, USA.

Jan 1996 – Dec 2000 Assistant Professor, Department of Chemical Engineering, Indian Institute of Technology, Bombay, 400 076, India

Aug 1995 – Dec 1995 Senior Engineer, Asea Brown Boveri (ABB), Bangalore, India

Aug 1990 – June 1995 Research and Teaching Assistantships at School of Chemical Engineering, Purdue University, West Lafayette, IN 47907

### 3. Research Interests

- Fuel Cell Technology
  - Novel Electrode and Membrane Fabrication for PEM Fuel Cells
  - Modeling, Diagnostics and Control of PEM and Solid Oxide Fuel Cells
- Energy Systems
- Systems Biology
- Multi-Scale Modeling and Optimization
- Controller Performance Assessment and Process Fault Diagnosis

### 4. Honors and Awards

John W. Graham Jr. Faculty Research Award, Clarkson University, 2006

International Federation of Automatic Control (IFAC) Best Paper Prize, 2002-2005, for the paper "Application of Signed Digraphs-Based Analysis for Fault Diagnosis of Chemical Process Flowsheets " in Engineering Applications of Artificial Intelligence Journal in the category - Application-oriented paper on Symbolic AI Approaches (Co-authors Mano Ram Maurya and Venkat Venkatasubramanian)

Best Paper of the Session award at the American Control Conference, Boston, 2004.

Omega Chi Epsilon, Professor of the Year Award (Chemical Engineering), Clarkson University, 2003.

Keynote Lecture delivered at the 4th IFAC Workshop on On-line Fault Detection and Supervision in the Chemical Process Industries, Korea, 2001

Indian National Academy of Engineering (INAE) Young Engineer Award for the year 2000 awarded to outstanding engineers by the Academy

Awarded the "CAST Director's Award" for the best poster presented at the AIChE Annual Meeting in Los Angeles, 2000.

John Wiley & Sons, NY, USA in their Newsletter Inside R&D published a story "Networking Sensors - No Easy Task" on our work on sensor location.

A news item "*Online Cures, Online Prevention*" on my Ph.D work on Qualitative Trend Analysis was published in Hydrocarbon Online, April 27, 1999.

Guided a project "Qualitative Simulation in Process Engineering" that was selected by the Indian National Academy of Engineering (INAE) for award as one of the most innovative projects at the Bachelor's level (all disciplines), 1999.

David Ross Fellowship while at Purdue, USA, 1991-1993.

Awarded Undergraduate Merit scholarship while at IIT Madras, 1986-1990.

## 5. Editorial Boards

Associate Editor for the AIChE section of the American Control Conference, Seattle, USA, 2008.

## 6. Grants, Contracts and Consultancy

### While at Clarkson University

#### Awarded

1. "Issues in Non-Equilibrium Reactive Distillation", (With L. N. Sridhar, University of Puerto Rico at Mayaguez), **NSF**, \$281,397, 2004-2007 (My Share: \$167,000).
2. "Fuel Specific SOFC Design and Control", (With P. Pillay, EE), **DOD/Nanodynamics** \$280,000, 2005-2007 (My Share: \$123,000).
3. "Theoretical and Experimental Study of Multivariable Control of PEM Fuel Cells" **ACS-PRF**, \$80,000, 2005-2007.
4. "Advanced Diagnostics of PEM Fuel Cells", NY State Energy Research and Development Authority ( **NYSERDA**), \$62,148, 2005-2006.
5. "Productivity Improvement in Industrial Processes through Diagnosis and Compensation of Stiction in Control Valves", NY State Energy Research and Development Authority ( **NYSERDA**), \$47,148, 2005-2006.
6. "A New Control Method for Improving Part Consistency for Injection Molding" (With Greg Campbell), NY State Energy Research and Development Authority ( **NYSERDA**), \$54,648, 2005-2006 (My Share: \$27,324).
7. "PhD Program Titled Loop Scout Enhancements", **Honeywell**, \$29,935, 2004-2005.
8. "A Predictive Model for Reactor Yield", **KBR Inc. (Formerly Kellogg Brown and Root), Houston**, \$8,000, 2005.
9. "Performance Analysis of Phosphoric Acid Fuel Cells (PAFC) Using Detailed Dynamic Models", **IIT Bombay/NMRL**, \$10,400, 2005.
10. "Sensitivity Analysis of a predictive model for reactor yield", **KBR Inc.**, \$8000, 2006.
11. "GOALI: An Integrated Framework for Stiction Detection and Compensation in Control Loops", **NSF**, \$262,909, 2006-2009.

12. "Three year Collaborative Project on PEM Fuel Cells", with IIT Madras India, funded by Department of Science and Technology (**DST**), India, Approx. \$15,000, 2006-2009.
13. Supplement to the project "Theoretical and Experimental Study of Multivariable Control of PEM Fuel Cells" to fund a fellow to spend a summer at Clarkson, **ACS-PRF**, \$8000, 2007.
14. "GOALI: An Integrated Framework for Stiction Detection and Compensation in Control Loops", **REU** Supplement, **NSF**, \$12,000, 2007
15. Consultant to Reliance Industries for their participation in the Stanford Fuel Cell Consortium on Solid State Proton Conducting Direct Methanol Fuel Cells, 2007- .
16. "Modeling of Gasifiers", **Honeywell**, \$10,000, 2007.
17. "Development of Nonlinear Estimators", **Honeywell**, \$15,000, 2007.
18. "Development of Tubular PEM Fuel Cells", (With Greg Campbell, ChE), NYSERDA, \$100,000, 2008-2010.

**Awarded At IIT Bombay (1996-2000)**

19. "Development of Composite/Hybrid Lower Order Models from Process Data for Control of Chemical Processes", funded under SERC Scheme for Young Scientist, DST, India. (Rs. 250,000 – Approximate Dollar Equivalent \$5000)
20. "Studies in Control Relevant Process Identification", Co-Investigator, funded by DST, India under the scheme of SRC, Principal Investigator: R.D. Gudi. (Rs. 1,000,000 - Approximate Dollar Equivalent \$20,000)
21. "Nonlinear Model for Rotary Slosh in Fuel Tanks of Launch Vehicles", Co-Investigator, funded by ISRO, India. Principal Investigator: N. Ananthakrishnan. (Rs. 300,000 - Approximate Dollar Equivalent \$6000)
22. A consultancy project on the development of a process simulator for LPG recovery unit with ABB completed, June 1996 - May 1997, IIT Bombay. (Rs. 250,000 - Approximate Dollar Equivalent \$5000)
23. Member of the Mission Mode Project on the Development of a Multi-Purpose Simulator for the Process Industry, IIT Bombay (CAD Center Faculty). (Rs. 8,000,000 - Approximate Dollar Equivalent \$160,000)
24. Simulation of a Multi-tubular reactor for the production of MIBK from DMK for NOCIL Bombay under the mission mode project completed, March - Dec, 1996, IIT Bombay (CAD Center Faculty). (Rs. 250,000 - Approximate Dollar Equivalent \$5000)

25. Simulation of IPA production facility of NOCIL Bombay under the mission mode project completed, March 1996 - June 1998, IIT Bombay (CAD Center Faculty). (Rs. 250,000 - Approximate Dollar Equivalent \$5000)
26. Consultant to ABB, India in their Oil Movement & Storage (OMS) projects and Operator Training Simulator (OTS) projects. (Rs. 50,000 - Approximate Dollar Equivalent \$1000)
27. A consultancy project on development of an Object-Oriented Java Based Modeling Framework for the simulation of an Industrial FCCU with Madras Refineries Limited, Chennai and Invensys, Chennai. (Rs. 125,000 - Approximate Dollar Equivalent \$2,500)
28. Consultant to Aditya Internet Services Ltd., on their Project on Development of a Software for Pipeline Leak Detection. (Rs. 120,000 - Approximate Dollar Equivalent \$2,400)
29. A consultancy project on Soft Sensor Development using NN, PCA and PLS Tools for Tata Honeywell Limited (THL), Pune, India (With Profs. R. D. Gudi and K. P. Madhavan). (Rs. 700,000 - Approximate Dollar Equivalent \$14,000)

## 7. Published Work

### a. Refereed Journal Publications (Graduate Students identified in italics):

1. R. Rengaswamy and V. Venkatasubramanian, " A Syntactic-pattern Recognition Approach for Process Monitoring and Fault Diagnosis", *Engng. Applic. Artif. Intell.*, 8(1), pp 35-51, 1995.
2. *Pankaj Doshi*, R. Rengaswamy and K. V. Venkatesh, " Modeling of microbial growth for sequential utilization in a multisubstrate environment", *Process Biochemistry*, 32(8), pp 643-650, 1997.
3. K. V. Venkatesh, *Pankaj Doshi* and R. Rengaswamy, "An optimal strategy to model microbial growth in a multiple substrate environment", *Biotechnology and Bioengineering*, 56(6), pp 635-644, 1997.
4. *Rao Raghuraj*, *Mani Bhushan* and R. Rengaswamy, "Locating Sensors in Complex Chemical Plants Based on Fault Diagnostic Observability Criteria", *AIChE J.*, 45(2), pp 310-322, 1999.
5. *R. Srinivasan* and R. Rengaswamy, "Use of Inverse Response Sequence (IRS) for Identification in Chemical Process Systems", *I & EC Research*, 38(9), pp 3420-3429, 1999.
6. *Mani Bhushan* and R. Rengaswamy, "Design of Sensor Network based on the SDG of the process for Efficient Fault Diagnosis ", *I & EC Research*, 39(4), pp 999-1019, 2000.

7. *Pramit Sarma* and R. Rengaswamy, "Multivariable Gain-Scheduled Fuzzy Logic Control of a Fluidized Catalytic Cracker Unit", *Computers and Chemical Engineering*, 24(2-7), pp 1083-1089, 2000.
8. *Mani Bhushan* and R. Rengaswamy, "Design of Sensor Location Based on Various Fault Diagnostic Observability and Reliability Criteria", *Computers and Chemical Engineering*, 24(2-7), pp 735-741, 2000.
9. R. Rengaswamy and Venkat Venkatasubramanian, "A Fast Training Neural Network and its Updation for Incipient Fault Detection and Diagnosis", *Computers and Chemical Engineering*, 24(2-7), pp 431-437, 2000.
10. R. Rengaswamy, T. Hagglund and V. Venkatasubramanian, "A Qualitative Shape Analysis Formalism for Monitoring Control Loop Performance", *Engng. Applic. Artif. Intell.*, 14(1), pp 23-33, 2001.
11. *Pramod Vachhani*, R. Rengaswamy and V. Venkatasubramanian, "A Framework for Integrating Diagnostic Knowledge with Nonlinear Optimization for Parameter Estimation and Data Reconciliation in Dynamic Systems", *Chemical Engineering Science*, 56(6), pp 2133-2148, 2001.
12. *Mani Bhushan* and R. Rengaswamy, "Comprehensive Design of a Sensor Network for Chemical Plants based on Various Diagnosability and Reliability Criteria 1. Framework", *I & EC Research*, 41, pp 1826-1839, 2002.
13. *Mani Bhushan* and R. Rengaswamy, "Comprehensive Design of a Sensor Network for Chemical Plants based on Various Diagnosability and Reliability Criteria 2. Applications", *I & EC Research*, 41, pp 1840-1860, 2002.
14. R. Rengaswamy, D. Mylaraswamy, K.-E. Arzen and V. Venkatasubramanian, "A Comparison of Model-Based and Neural Network-Based Diagnostic Methods", *Engng. Applic. Artif. Intell.*, 14, pp 805-818, 2002.
15. *Suman Roy Choudhury*, M. B. Deshmukh and R. Rengaswamy, "A Two-dimensional Steady-State Model for Phosphoric Acid Fuel Cells", *Journal of Power Sources*, 112, 137-152, 2002.
16. V. Venkatasubramanian, R. Rengaswamy, Kewen Yin and S. N. Kavuri, "Review of Process Fault Detection and Diagnosis - Part I: Quantitative Model-Based Methods", *Computers and Chemical Engineering*, 27(3), pp 239-311, 2003.
17. V. Venkatasubramanian, R. Rengaswamy and S. N. Kavuri, "Review of Process Fault Detection and Diagnosis - Part II: Qualitative Models and Search Strategies", *Computers and Chemical Engineering*, 27(3), pp 313-326, 2003.

18. V. Venkatasubramanian, R. Rengaswamy, S. N. Kavuri and Kewen Yin, "Review of Process Fault Detection and Diagnosis - Part III: Process History Based Methods", *Computers and Chemical Engineering*, 27(3), pp 327-346, 2003.
19. Sourabh Dash, R. Rengaswamy and V. Venkatasubramanian, "Fuzzy-Logic Based Trend Classification for Fault Diagnosis of Chemical Processes", *Computers and Chemical Engineering*, 27(3), pp 347-362, 2003.
20. Maurya, M. R., R. Rengaswamy and V. Venkatasubramanian, "A Systematic Framework for the Development and Analysis of Signed Digraphs for Chemical Processes. 1. Algorithms and Analysis", *I & EC Research*, 42(20), pp 4789-4810, 2003.
21. Maurya, M. R., R. Rengaswamy and V. Venkatasubramanian, "A Systematic Framework for the Development and Analysis of Signed Digraphs for Chemical Processes. 2. Control Loops and Flowsheet Analysis", *I & EC Research*, 42(20), pp 4811-4827, 2003.
22. Dash, S., M. R. Maurya, R. Rengaswamy and V. Venkatasubramanian, "A Novel Interval-halving Framework for Automated Identification of Process Trends", *AIChE J*, 50(1), pp 149, 2004.
23. Madhusudana Rao, R. Rengaswamy, A. K. Suresh and K. S. Balaraman, "Industrial Experience with Object-Oriented Modeling: FCC Case Study", *Transactions of IChemE*, 82(A4), pp 527-552, 2004.
24. Maurya, M. R., R. Rengaswamy and V. Venkatasubramanian, "Application of Signed Digraphs-Based Analysis for Fault Diagnosis of Chemical Process Flowsheets", *Engineering Applications of Artificial Intelligence*, 17(5), pp 501-518, 2004.
25. Suman Roy Choudhury, J. Rengarajan, M. B. Deshmukh and R. Rengaswamy, "Step Response Analysis of Phosphoric Acid Fuel Cell (PAFC) Cathode Through a Simplified Transient Model", *Journal of Power Sources*, 140, 274-279, 2005.
26. Vachhani, P., G. Vikrant, S. Narasimhan and R. Rengaswamy, "Recursive Estimation Techniques in Constrained Nonlinear Dynamical Systems", *AIChE J.*, 51(3), 946-959, 2005.
27. Ranganathan Srinivasan, Raghunathan Rengaswamy, Randy Miller and Lane Desborough, "Control Loop Performance Assessment. 1. A Qualitative Approach for Stiction Diagnosis", *Industrial and Engineering Chemistry Research*, 44, 6708-6718, 2005.
28. Ranganathan Srinivasan, Raghunathan Rengaswamy, Shankar Narasimhan and Randy Miller, "Control Loop Performance Assessment. 2. Hammerstein Model Approach for Stiction Diagnosis", *Industrial and Engineering Chemistry Research*, 44, 6719-6728, 2005.

29. *M. R. Maurya*, R. Rengaswamy and V. Venkatasubramanian, "Fault Diagnosis by Qualitative Trend Analysis of Principal Components ", *Transactions I ChemE*, 83 (A9), 1122-1132, 2005.
30. *Ranganathan Srinivasan* and Raghunathan Rengaswamy," Stiction Compensation in Process Control Loops: A Framework for Integrating Stiction Measure and Compensation", *Industrial and Engineering Chemistry Research*, 44, 9164-9174, 2005.
31. *M. R. Maurya*, R. Rengaswamy and V. Venkatasubramanian, "A Signed Directed Graph-based Systematic Framework for Malfunction Diagnosis inside Control Loops", *Chemical Engineering Science*, 61(6), pp1790-1810, 2006.
32. *Gerardo Ruiz*, Lakshmi N, Sridhar and Raghunathan Rengaswamy, "The Isothermal, Isobaric Reactive Flash Problem", *Industrial and Engineering Chemistry Research*, 45(19), pp 6548-6554, 2006.
33. *Madhusudana Rao* and Raghunathan Rengaswamy, "Detailed Dynamic Model for PEMFC Based on Flooded Spherical Agglomerate Characterization of the Reaction Layer", *Journal of Power Sources*, 158, pp110-123, 2006.
34. *Madhusudana Rao* and Raghunathan Rengaswamy, "Optimization Study of an Agglomerate Model for Platinum Reduction and Performance in PEM Fuel Cell Cathode", *Chemical Engineering Research and Design*, 84(A10), pp 952-964, 2006.
35. *Pramod Vachhani*, Shankar Narasimhan and R. Rengaswamy," Robust and Reliable Estimation via Unscented Recursive Nonlinear Dynamic Data Reconciliation", *Journal of Process Control*, 16(10), pp 1075-1086, 2006.
36. *Madhusudana Rao* and Raghunathan Rengaswamy, "A Distributed Dynamic Model for Chronoamperometry, Chronopotentiometry and gas starvation studies in PEM Fuel Cell Cathode", *Chemical Engineering Science*, 61(22), pp 7393-7409, 2006.
37. *Suman Roy Choudhury* and R. Rengaswamy, "Characterization and Fault Diagnosis of PAFC Cathode by EIS Technique and a Novel Mathematical Model Approach ", *Journal of Power Sources*, 161(2), pp 971-986, 2006.
38. *Mano Ram Maurya*, R. Rengaswamy and V. Venkatasubramanian, "Fault Diagnosis Using Dynamic Trend Analysis: A Review and Recent Developments", *Engineering Applications of Artificial Intelligence*, 20, pp 133-146, 2007.
39. *Sridharakumar Narasimhan* and Raghunathan Rengaswamy, "Quantification of Performance of Sensor Networks for Fault Diagnosis in Chemical Processes", *AIChE Journal*, 53(4), pp 902-917, 2007.



40. Ranganathan Srinivasan, Raghunathan Rengaswamy and Sandra Harris, "An Introduction to Controller Performance Assessment in Process Control Class Through Stiction in Control Valves", *Chemical Engineering Education*, 41(2), pp123-130, 2007.
41. Ranganathan Srinivasan, Raghunathan Rengaswamy and Randy Miller, "A Modified Empirical Mode Decomposition (EMD) Process for Oscillation Characterization in Control Loops", *Control Engineering Practice*, 15(9), pp 1135-1148, 2007.
42. D. Bhattacharya, R. Rengaswamy and C. Finnerty, "Isothermal Models for Tubular Anode-supported Solid Oxide Fuel Cell", *Chemical Engineering Science*, 62(16), pp 4250-4267, 2007.
43. Pramod Vachhani, Shankar Narasimhan and R. Rengaswamy, "An Integrated Qualitative-Quantitative Hypothesis Driven Approach for Comprehensive Fault Diagnosis", *Chemical Engineering Research and Design*, 85(A9), pp 1281-1294, 2007.
44. M. Rao, D. Bhattacharya, R. Rengaswamy and S. R. Choudhury, "A Two-Dimensional Steady State Model Including the Effect of Liquid Water for a PEM Fuel Cell Cathode", *Journal of Power Sources*, 173(1), 375-393, 2007.
45. Mano Ram Maurya, R. Rengaswamy and V. Venkatasubramanian, "A Signed Directed Graph and Qualitative Trend Analysis-Based Framework for Incipient Fault Diagnosis", *Chemical Engineering Research and Design*, 85(A10), 1407-1422, 2007.
46. Ranganathan Srinivasan and Raghunathan Rengaswamy, "Approaches for Efficient Stiction Compensation Approaches in Process Control Valves", *Computers and Chemical Engineering*, 32(1-2), 218-229, 2008.
47. Mani Bhushan, Sridharakumar Narasimhan and R. Rengaswamy, "Robust Sensor Network Design for Fault Diagnosis", accepted, electronic version available in, *Computers and Chemical Engineering*, 32(4-5), pp 1067-1084, 2008.
48. Sridharakumar Narasimhan, Pramod Vacchani and Raghunathan Rengaswamy, "New Nonlinear Residual Feedback Observer for Fault Diagnosis in Nonlinear Systems", accepted, in print, *Automatica Journal*, 44, pp 2222-2229, 2008.
49. Abraham Gebregergis, Pragasen Pillay, Debansu Bhattacharya and Raghunathan Rengaswamy, "Solid Oxide Fuel Cell Modeling", accepted, *IEEE Transactions on Industrial Electronics*, 2008.
50. Sridharakumar Narasimhan, Raghunathan Rengaswamy and Raj Vadigepalli, "Structural properties of Gene Regulatory Networks: Definitions and Connections", accepted, electronic version available in *IEEE/ACM Transactions on Computational Biology and Bioinformatics*, 2008.

51. Debangsu Bhattacharya and Raghunathan Rengaswamy, "Transport, Sensitivity and Dimensional Optimization studies of a tubular solid oxide fuel cell (SOFC)", accepted, *Journal of Power Sources*, 2008.
52. Debangsu Bhattacharya and Raghunathan Rengaswamy, "A Detailed Dynamic Model for a Tubular Solid Oxide Fuel Cell (TSOFC)", accepted *Chemical Engineering Science*, 2008.

### **Journal Papers Under Review**

53. R. K. Mandela, L. N. Sridhar and Raghunathan Rengaswamy, "Introducing DAE Systems in Undergraduate Chemical Engineering Curriculum", under review, 2008.
54. S. Deshpande, S. C. Patwardhan, R. N. Methekar and R. Rengaswamy, "Unconstrained Nonlinear Predictive Control Formulation Based on a Class of Wiener Models: Development of a Closed Form Solution", under review, 2008.
55. R. N. Methekar, S. C. Patwardhan, R. Rengaswamy, R. D. Gudi and V. Prasad, "Control of PEMFC Using Data Driven State Space Models" under review, 2008.
56. Debangsu Bhattacharya and Raghunathan Rengaswamy, "An optimization-oriented steady state model of a tubular solid oxide fuel cell (SOFC)", under review, 2008.
57. Debangsu Bhattacharya and Raghunathan Rengaswamy, "A review of solid oxide fuel cell (SOFC) dynamic models and some recent results", under review, 2008.
58. Debangsu Bhattacharya and Raghunathan Rengaswamy, "Dimensional optimization of a tubular Solid Oxide Fuel Cell ", under review, 2008.

### **b. Refereed Publications in Conference Proceedings:**

59. R. Rengaswamy and V. Venkatasubramanian, " An Integrated Framework for Process Monitoring, Diagnosis and Control Using Knowledge-based Systems and Neural Networks", in the proceedings of IFAC symposium, Newark, Delaware, USA, pp 325-330, 1992.
60. R. Rengaswamy and V. Venkatasubramanian, " Framework for Integrated Process Supervision ", in the proceedings of ADCHEM, Kyoto, Japan, pp 120-124, 1994.
61. R. Rengaswamy, Robert S. Parker, Francis J. Doyle, "Issues in Design of Input Signals for the Identification of Nonlinear Models of Process Systems", proceedings of IFAC-ADCHEM, Pisa, Italy, pp 863-868, 2000.
62. Sourabh Dash, S. Kantharao, R. Rengaswamy and V. Venkatasubramanian, " Application and Evaluation of a Linear/Restricted Nonlinear Observer to a Nonlinear CSTR", European Symposium on Computer Aided Process Engineering - 11, Kolding, Denmark, pp 853-858, 2001.

63. Sourabh Dash, R. Rengaswamy and V. Venkatasubramanian, "A Novel Interval Halving Algorithm for Process Trend Identification" in the proceedings of the 4th IFAC Workshop on On-line Fault Detection and Supervision in the Chemical Process Industries, Korea, 2001.
64. Manoram Maurya, R. Rengaswamy and V. Venkatasubramanian, "Systematic Development and Application of Digraphs for Process Diagnosis and Hazards Analysis" in the proceedings of the 4th IFAC Workshop on On-line Fault Detection and Supervision in the Chemical Process Industries, Korea, 2001.
65. Mani Bhushan and R. Rengaswamy, "A Framework for Sensor Network Design for Efficient and Reliable Fault Diagnosis" in the proceedings of the 4th IFAC Workshop on On-line Fault Detection and Supervision in the Chemical Process Industries, Korea, 2001.
66. Maurya, M. R. Rengaswamy and V. Venkatasubramanian, "Incipient Fault Diagnosis of Tennessee Eastman Flowsheet Using Signed Directed Graph and Trend Analysis", in the supplementary proceedings of ESCAPE-12, Hague, Netherlands, 2002.
67. Mani Bhushan, Sridharakumar Narasimhan and R. Rengaswamy, "Sensor Network Reallocation and Upgrade for Efficient Fault Diagnosis", in the proceedings of FOCAPO, Coral Springs, Florida, pp 443-446, January 2003.
68. S. Narasimhan and R. Rengaswamy, "Optimal Input Signal Design for System Identification", in the Proceedings of International Symposium of Process Systems Engineering & Control, Mumbai, India, pp 376-381, 2003
69. Maurya, M. R., R. Rengaswamy and V. Venkatasubramanian, "Consistent Malfunction Diagnosis Inside Control Loops using Signed Directed Graphs", In the proceedings of the 13<sup>th</sup> European Symposium on Computer Aided Process Engineering ESCAPE-13, Lappeenranta, Finland, June 1-4, pp. 473-478, 2003.
70. Maurya, M. R., R. Rengaswamy and V. Venkatasubramanian, "Fault Diagnosis by Qualitative Trend Analysis of the Principal Components: Prospects and some new Results", In the proceedings of the 5<sup>th</sup> IFAC symposium on Fault Detection, Supervision and Safety of Technical Processes SAFEPROCESS-2003, Washington D.C., USA, June 9-11, pp. 861-866, 2003.
71. S. Narasimhan, R. Srinivasan and R. Rengaswamy, "Multi-objective Input Signal Design for Plant-Friendly Identification", in the Proceedings of International SYSID, Rotterdam, Netherlands, pp 923-928, 2003
72. Madhusudana Rao, R. K. Shah and R. Rengaswamy, "Scope for Process Systems Engineering Studies in Proton Exchange Membrane Fuel Cells (PEMFC)", in the proceedings of Fuel Cell – Materials, Systems and Accessories, Ambarnath, India, September 25-26, pp 29-45, 2003.

73. Maurya, M. R., R. Rengaswamy and V. Venkatasubramanian, "Qualitative Trend Analysis of the Principal Components: Application to Fault Diagnosis", *The 8<sup>th</sup> International Symposium on Process Systems Engineering PSE-2003, P.R. China, January 5-10*, pp 968-973, 2004.
74. Maurya, M. R., R. Rengaswamy and V. Venkatasubramanian, "A Framework for On-line Trend Extraction and Fault Diagnosis", *The International Symposium on Advanced Control of Chemical Processes ADChEM-2003, Hong Kong, January 11-14*, pp 423-428, 2004.
75. Vachhani, P., S. Narasimhan and R. Rengaswamy, "Recursive State Estimation in Nonlinear Processes", *Proceedings of the American Control Conference, American Control Conference (ACC), Boston*, pp 200-204, 2004.
76. Narasimhan, S. and R. Rengaswamy, "Multi-objective input signal design for plant friendly identification of process systems", *Proceedings of the American Control Conference, American Control Conference (ACC), Boston*, pp 4891-4896, 2004.
77. Narasimhan, S. and R. Rengaswamy, "Multi-objective input signal design of multi-harmonic signals for system identification", *In the Proceedings of Dynamics and Control of Processing Systems, DYCOPS-7, Boston*, 2004.
78. Vachhani, P., S. Narasimhan and R. Rengaswamy, "Nonlinear residual feedback observer for process fault diagnosis", *In the Proceedings of Dynamics and Control of Processing Systems, DYCOPS-7, Boston*, 2004.
79. Vachhani, P., S. Narasimhan and R. Rengaswamy, "Robust constrained estimation via unscented transformation", *In the Proceedings of Dynamics and Control of Processing Systems, DYCOPS-7, Boston*, 2004.
80. Bhushan, M. and R. Rengaswamy," Lexicographic optimization based sensor network design for robust fault diagnosis", *In the Proceedings of Dynamics and Control of Processing Systems, DYCOPS-7, Boston*, 2004.
81. Rao, M. and R. Rengaswamy," A Dynamic Spherical Agglomerate Model for Proton Exchange Membrane Fuel Cells (PEMFC)", *Proceedings of ESCAPE-15, Barcelona, Spain*, pp 541-546, 2005.
82. Rao, M., Oh, T. and R. Rengaswamy, "Systems engineering aspects in proton exchange membrane fuel cells (PEMFCs): a review of opportunities" *Proceedings of PSE/ESCAPE, Garmisch-Partenkirchen, Germany*, pp 835-840, 2006.
83. Srinivasan, R. and R. Rengaswamy, "Integrating stiction diagnosis and stiction compensation in process control valves" *Proceedings of PSE/ESCAPE, Garmisch-Partenkirchen, Germany*, pp1233-1238, 2006.

84. Narasimhan, S. and R. Rengaswamy, "Multi-Objective Input Design for System Identification: Frequency Selection for Identification of Nonlinear Systems", **Invited Paper** in a session on Input/Perturbation Signal Design, SYSID 2006.
85. Srinivasan, R., M. R. Maurya and R. Rengaswamy, "Root Cause Analysis of Oscillating Control Loops", proceedings of ADCHEM 2006, Brazil.
86. R. Rengaswamy (**Organizer**), "Techniques for Stiction Diagnosis and Compensation in Process Control Loops", **Special Invited Tutorial Session**, American Control Conference (ACC), Minneapolis, USA, pp 2107-2122, 2006.
87. D. Bhattacharya, R. Rengaswamy and C. Finnerty, "Dynamic Simulation and Analysis of a Solid Oxide Fuel Cell", in the proceedings of ESCAPE-17, Bucharest, 2007.
88. B. Bullocks, S. Burnham, G. Campbell, R. Rengaswamy and R. K. Mandela, "Control of Temperature Profile in the Injection Molding Process for Part Consistency", in the proceedings of ESCAPE-17, Bucharest, 2007.
89. Sridharakumar Narasimhan and Raghunathan Rengaswamy, "Multi-objective Optimal Input Design for System Identification", *American Control Conference (ACC), Seattle, USA, 2008*.
90. Ulaganathan Nallasivam and Raghunathan Rengaswamy, "Blind Identification of Stiction in Nonlinear Process Control Loops", *American Control Conference (ACC), Seattle, US, 2008*.
91. Ranganathan Srinivasan, Raghunathan Rengaswamy and Vijayabaskar Rajavelu, "Issues in Modeling Stiction in Process Control Valves", *American Control Conference (ACC), Seattle, USA, 2008*.

**c. Refereed Papers as Book Chapters:**

92. V. Venkatasubramanian and R. Rengaswamy, "Statistical and Clustering Techniques in Neural Networks", Book Chapter in Neural Networks for Chemical Engineers, Abhay Bulsari(Ed), Elsevier Science, Amsterdam, 1995.

**d. Papers in Trade Journals:**

93. R. Rengaswamy, "Improve Process Operations with Online Fault Detection and Diagnosis", pp 109-113, *Chemical Industry Digest, March - April, 1999*.

**8. Invited Talks**

1. R. Rengaswamy, "Design of Sensor Locations Based on Fault Diagnostic Observability Criteria", at Rutgers University, 1999.
2. R. Rengaswamy, "Selected Topics in Integrated Process Supervision", at UOP, USA, 1999.

3. R. Rengaswamy, "A Framework for Sensor Network Design for Efficient and Reliable Fault Diagnosis ", **Keynote Lecture** at the 4th International Federation of Automatic Control (IFAC) Workshop on On-line Fault Detection and Supervision in the Chemical Process Industries, Korea, 2001.
4. R. Rengaswamy, "Abnormal Situation Management in Complex Chemical Plants: Data-Based and Model-Based Methods ", at University of Alberta, Edmonton, Canada, October, 2001.
5. R. Rengaswamy, "Observer Approaches for Fault Diagnosis in Chemical Engineering Systems" and "MPROSIM – Multi-purpose Process Simulator", at Matrikon Consulting Inc., Edmonton, Alberta, Canada, October, 2001.
6. R. Rengaswamy, "A Comprehensive Framework for Sensor Network Design for Efficient and Reliable Fault Diagnosis", at IAC, Honeywell, Phoenix, AZ, January, 2002.
7. R. Rengaswamy, "Review of Fault Detection and Diagnosis", CPMC meeting at University of Delaware, Newark, DE, January, 2002.
8. R. Rengaswamy, "Review of Process Fault Detection and Diagnosis" and "A Framework for Comprehensive Fault Detection and Diagnosis", at University of Alberta, Edmonton, Canada, July, 2002.
9. R. Rengaswamy, "Qualitative Trend Analysis (QTA) for monitoring and fault diagnosis in process industries", at Ecole Polytechnique, Montreal, Canada, October, 2002.
10. R. Rengaswamy, "PROCISS group research on Fault Detection and Diagnosis" web talk delivered to Plant Automation Services (PAS), Houston, USA, April, 2003.
11. R. Rengaswamy, " A Review of Process Fault Detection and Diagnosis" at GE Technology Center, India, September, 2003.
12. R. Rengaswamy, " Integrated Sensor Network Design" at GE Technology Center, India, September, 2003.
13. R. Rengaswamy, " A Review of Process Fault Detection and Diagnosis" at HTSL, India, September, 2003.
14. R. Rengaswamy, " Automated Non-Invasive Detection of Stiction in Control Valves for controller performance monitoring" at IIT Madras, Chennai, India, October, 2003
15. R. Rengaswamy, "Scope for Process Systems Engineering Studies in PEMFCs", at University of Puerto Rico at Mayaguez, November, 2003.

16. R. Rengaswamy, "Performance Monitoring Issues" web talk delivered to Honeywell, USA, November, 2004.
17. R. Rengaswamy, "PROCISS group research on Modeling and other Topics in Process Systems Engineering", at KBR, Houston, USA, November, 2004.
18. R. Rengaswamy, "Dynamic Modeling for Proton Exchange Membrane Fuel Cells (PEMFC) for Diagnosis and Control", at Plug Power, Albany, December, 2004.
19. R. Rengaswamy, "Modeling, Diagnostics, Control and Optimization of Proton Exchange Membrane Fuel Cells (PEMFC)", Invited Faculty Speaker at Honeywell, Minneapolis, July 2005.
20. R. Rengaswamy, "Modeling, Diagnostics and Control of PEM Fuel Cells", Departmental seminar at Chemical Engineering, University of Rhode Island, September 2005.
21. R. Rengaswamy, "Modeling, Diagnostics and Control of PEM Fuel Cells", GM research center, Honoeye Falls, NY, 2007.
22. R. Rengaswamy, "Fundamental Understanding and Diagnostics of PEM Fuel Cell Behavior", talk to NY Fuel Cell Network (NYFCN), Alfred University, 2007.
23. S. Narasimhan and R. Rengaswamy, "Constrained Nonlinear Estimation" at HTSL, India, July, 2007.
24. R. Rengaswamy, "Modeling, Control and Diagnostics of PEM Fuel Cells", at GE John Welch Technology Center, India, July 2007.
25. R. Rengaswamy, "Optimization of PEM Fuel Cell Systems" at IIT Madras, Chennai, India, August, 2007
26. R. Rengaswamy, "Optimization of PEM Fuel Cell Systems" at Indian Institute of Sciences (IISc), Bangalore, India, March, 2008
27. R. Rengaswamy, "Sensor Network Design for State Awareness" at the 1<sup>st</sup> International Symposium on Resilient Control, Idaho Falls, Idaho, March, 2008

#### **At Conferences**

1. R. Rengaswamy and V. Venkatasubramanian, "Extraction of Qualitative Trends from Noisy Process Data Using Neural Networks", presented at the *AICHE* meeting, Los Angeles, 1991.
2. V. Venkatasubramanian and R. Rengaswamy, "Integrating Monitoring, Diagnosis and Control Tasks for Process Operations Management", presented at the *AICHE* meeting, Miami, 1992.

3. R. Rengaswamy, S.N. Kavuri and V. Venkatasubramanian, "An unified Framework for Integrating Data Reconciliation, Monitoring and Fault Diagnosis", presented at the *AICHE* meeting, St. Louis, 1993.
4. R. Rengaswamy, S.N. Kavuri and V. Venkatasubramanian, "Mixture Density Approximation of Process Data for Process Monitoring and Control", presented at the *AICHE* meeting, St. Louis, 1993.
5. R. Rengaswamy, "An Overview of Process Fault Diagnosis", presented at the Department of Automatic Control, Lund, Sweden, 1994.
6. D. Mylaraswamy, R. Rengaswamy and V. Venkatasubramanian, "Combining Qualitative Models and Syntactic Pattern Recognition for Process Diagnosis", presented at the *AICHE* meeting, Houston, 1995.
7. R. Rengaswamy, T. Hagglund and V. Venkatasubramanian, "A Qualitative Shape Analysis Procedure for Automatic Monitoring of Control Loop Performance", presented at the *AICHE* meeting, Miami, 1995.
8. D. Mylaraswamy, R. Rengaswamy, K. Arzen and V. Venkatasubramanian, "A Model-based Hybrid Neural Network Architecture for Fault Diagnosis", presented at the *AICHE* meeting, Miami, 1995.
9. Rao Raghuraj and R. Rengaswamy, "An framework for location of sensors in chemical plants based on diagnosability criteria" at the IChE Golden Jubilee Congress, New Delhi, 1997.
10. Sourabh Dash, R. Rengaswamy and V. Venkatasubramanian, " Fault Diagnosis Using Analytical and Knowledge-Based Redundancy", presented in Annual *AICHE* Meeting, Los Angeles, 2000.
11. Sourabh Dash, R. Rengaswamy and V. Venkatasubramanian, " Fault Diagnosis in a Nonlinear CSTR using Observers", presented in Annual *AICHE* Meeting, Reno, Nevada, 2001.
12. Manoram Maurya, R. Rengaswamy and V. Venkatasubramanian, " Systematic Development of Digraphs and Application in Process Operations", presented in Annual *AICHE* Meeting, Reno, Nevada, 2001.
13. R. Srinivasan, P. Vijaysai, R. D. Gudi and R. Rengaswamy, " Design of Input Signals for Fast Identification of Large Multivariable Systems", presented in Annual *AICHE* Meeting, Reno, Nevada, 2001.
14. Manoram Maurya, R. Rengaswamy and V. Venkatasubramanian, "Signed Directed Graph and Trend Analysis-Based Framework for Incipient Fault Diagnosis – Application to TE Case Study", presented at Annual *AICHE* Meeting, Indianapolis, 2002.



15. Mani Bhushan, Sridharakumar Narasimhan and R. Rengaswamy, "Lexicographic Optimization Based Framework for Designing Sensor Network for Reliable and Robust Fault Diagnosis", presented at Annual AIChE Meeting, Indianapolis, 2002.
16. Sridharakumar Narasimhan and R. Rengaswamy, "An Optimization Approach towards Design of Input Signals for Chemical Process System Identification", presented at Annual AIChE Meeting, Indianapolis, 2002
17. Pramod Vachhani and R. Rengaswamy, "Nonlinear Unknown Input Observer with Residual Feedback for Robust Fault Diagnosis", presented at the Annual AIChE Meeting, Indianapolis, 2002.
18. Madhusudana Rao, R. Rengaswamy, A. K. Suresh and K. S. Balaraman, "MPROSIM: A Framework for Multi-Purpose process Simulation", presented at the Annual AIChE Meeting, Indianapolis, 2002.
19. Pramod Vachhani, Shankar Narasimhan and R. Rengaswamy, "Integrating Diagnostic Knowledge with Nonlinear Programming for Comprehensive Fault Diagnosis – A Hypothesis Driven Approach", presented at the Annual AIChE Meeting, Indianapolis, 2002.
20. Suman Roy Choudhury, J. Rengarajan, M. B. Deshmukh and R. Rengaswamy, "Study of Steady-State and Dynamic Characteristics of a Phosphoric Acid Fuel Cell (PAFC) through a Two-Dimensional Model", presented at the Annual AIChE Meeting, Indianapolis, 2002.
21. Mani Bhushan and Raghunathan Rengaswamy, "An Optimization Based Approach For Designing Sensor Network for Reliable and Robust Fault Diagnosis", presented at Annual CSChE meeting, Hamilton, 2003.
22. Shankar Narasimhan and Raghunathan Rengaswamy, "Sensor Network Design for Integrated Process Management: An Overview and Recent Results ", presented at joint PRES03 and CSChE session, Hamilton, 2003.
23. Manoram Maurya, R. Rengaswamy and V. Venkatasubramanian , "Computational Aspects of Trend-Extraction and Trend-Based Similarity Estimation", presented at Annual AIChE Meeting, San Francisco, 2003.
24. Madhusudana Rao, Raghunathan Rengaswamy and Ross Taylor, "Operational Diagnostics of Proton Exchange Membrane Fuel Cells (PEMFCs) Using Detailed Dynamic Models", presented at Annual AIChE Meeting, San Francisco, 2003.
25. Ranganthan Srinivasan and Raghunathan Rengaswamy, " Automated Noninvasive Detection of Stick-slip in Control Valves", presented at Annual AIChE Meeting, San Francisco, 2003.

26. Sridharakumar Narasimhan and Raghunathan Rengaswamy, "Characterization of Value of Sensor Networks for Process Fault Diagnosis", presented at the Annual AIChE meeting, Austin, Texas, 2004.
27. Miguel Bagajewicz, Donald Chmielewski and Raghunathan Rengaswamy, "Integrated Process Sensor Network Design", presented at the Annual AIChE meeting, Austin, Texas, 2004.
28. Madhusudana Rao and Raghunathan Rengaswamy, "Multivariable Inferential Control of PEM Fuel Cells", presented at the Annual AIChE meeting, Austin, Texas, 2004.
29. Sridharakumar Narasimhan, Rajan Mariappan, Gregory Campbell and Raghunathan Rengaswamy, "Analytical and Numerical Computation of Velocity Profile and Pressure Gradient for Prescribed Volume Flowrate – Application to Flow Dynamics of Aortal Blood Flow", presented at the Annual AIChE meeting, Austin, Texas, 2004.
30. Pramod Vachhani, Sridharakumar Narasimhan and Raghunathan Rengaswamy, "A New Nonlinear Residual Feedback Observer for Process Fault Diagnosis – Theoretical and Computational Results", presented at the Annual AIChE meeting, Austin, Texas, 2004.
31. Sridharakumar Narasimhan and Raghunathan Rengaswamy, "A Novel Integer Programming Approach to System Identification", presented at the Annual AIChE meeting, Austin, Texas, 2004.
32. Ranganathan Srinivasan, Raghunathan Rengaswamy and Randy Miller, "Detection of Sticky Control Loops: Data Driven Qualitative Approach", presented at the Annual AIChE meeting, Austin, Texas, 2004.
33. Ranganathan Srinivasan, Raghunathan Rengaswamy, Shankar Narasimhan and Randy Miller, "Stiction Detection and Estimation from Routine Operating Data: A Hammerstein Model Approach", presented at the joint IChE/AIChE conference, December, Mumbai, India, 2004.
34. Madhusudana Rao and Raghunathan Rengaswamy, "Study of Proton Exchange Membrane Fuel Cells (PEMFC) Using Detailed Models for Electrode Structure Optimization", presented at the Annual AIChE meeting, Cincinnati, Ohio, 2005.
35. Madhusudana Rao and Raghunathan Rengaswamy, "Study of Dynamic Interactions of Various Phenomena in Proton Exchange Membrane Fuel Cells (PEMFC) Using Detailed Models for Multivariable Control", presented at the Annual AIChE meeting, Cincinnati, Ohio, 2005.
36. Sridharakumar Narasimhan and Raghunathan Rengaswamy, "Development of a Utility Function for Sensor Networks from a Fault Diagnosis Perspective", presented at the Annual AIChE meeting, Cincinnati, Ohio, 2005.

37. Sridharakumar Narasimhan and Raghunathan Rengaswamy, "Nonlinear Diagonal Input Observers for Fault Diagnosis", presented at the Annual AIChE meeting, Cincinnati, Ohio, 2005.
38. Sridharakumar Narasimhan and Raghunathan Rengaswamy, "Optimal Input Design for Identification of Nonlinear Systems", presented at the Annual AIChE meeting, Cincinnati, Ohio, 2005.
39. Taehoon Oh, Dongil Shin and Raghunathan Rengaswamy, "A Neural Network-Based Reduced Order Model for Repetitive and Time-Efficient Prediction of the Behavior of PEM Fuel Cells", presented at the Annual AIChE meeting, Cincinnati, Ohio, 2005.
40. Ranganathan Srinivasan, Raghunathan Rengaswamy and Randy Miller, "A Novel Procedure for Oscillation Detection and Characterization of Oscillation in Control Loops", presented at the Annual AIChE meeting, Cincinnati, Ohio, 2005.
41. Ranganathan Srinivasan and Raghunathan Rengaswamy, "An Integrated Framework for Stiction Diagnosis and Compensation", presented at the Annual AIChE meeting, Cincinnati, Ohio, 2005.
42. Lakshmi Sridhar, Raghunathan Rengaswamy and Gerardo Ruiz, "The Isothermal Reactive Flash Problem" presented at the Annual AIChE meeting, San Francisco, 2006.
43. Himabindu Sunnam, Allan Shapiro, Vikas Agarwal, Prasad Dhurjati and Raghunathan Rengaswamy, "Programmed Cell Death in Plant Defense Against Bacterial Pathogens", presented at the Annual AIChE meeting, San Francisco, 2006.
44. Gerardo Ruiz, Lakshmi Sridhar and Raghunathan Rengaswamy, "Singularities in Modeling Reactive Flash Systems", presented at the Annual AIChE meeting, San Francisco, 2006.
45. Madhusudana Rao and Raghunathan Rengaswamy, "Optimization Study of Proton Exchange Membrane Fuel Cells (PEMFC) for Platinum Reduction and Performance", presented at the Annual AIChE meeting, San Francisco, 2006.
46. Ranganathan Srinivasan and Raghunathan Rengaswamy, "Stiction Compensation in Process Control Loops", presented at the Annual AIChE meeting, San Francisco, 2006.
47. Sridharakumar Narasimhan, Raghunathan Rengaswamy and Raj Vadigepalli, "Structural Analysis of Biological Regulatory Networks", presented at the Annual AIChE meeting, San Francisco, 2006.
48. Debansu Bhattacharya, Raghunathan Rengaswamy and Caine Finnerty, "Validation of a Phenomenological Steady-State Model for Solid Oxide Fuel Cell (SOFC)", presented at the Annual AIChE meeting, San Francisco, 2006.

49. Debangsu Bhattacharya, Raghunathan Rengaswamy and Caine Finnerty, "A Two-dimensional Dynamic Model for Tubular Solid Oxide Fuel Cell", presented at the Annual AIChE meeting, San Francisco, 2006.
50. Sridharakumar Narasimhan and Raghunathan Rengaswamy, "A Convex Programming Approach to Plant Friendly Input Design for System Identification", presented at the Annual AIChE Meeting, Salt Lake City, 2007.
51. Sridharakumar Narasimhan and Raghunathan Rengaswamy, "Nonlinear Diagonal Observers for Fault Diagnosis", presented at the Annual AIChE Meeting, Salt Lake City, 2007.
52. Debangsu Bhattacharyya, Raghunathan Rengaswamy and Caine Finnerty, "Optimization Studies on Anode-Supported Tubular Solid Oxide Fuel Cells", presented at the Annual AIChE Meeting, Salt Lake City, 2007.
53. Debangsu Bhattacharyya, Raghunathan Rengaswamy and Caine Finnerty, "Dynamics and Volterra-Model Based Control of a Tubular Solid Oxide Fuel Cell", presented at the Annual AIChE Meeting, Salt Lake City, 2007.
54. Ulaganathan Nallasivam, Debangsu Bhattacharyya, Madhusudana Rao and Raghunathan Rengaswamy, "Modeling of Liquid Water in PEM Fuel Cells", presented at the Annual AIChE Meeting, Salt Lake City, 2007.
55. Ulaganathan Nallasivam and Raghunathan Rengaswamy, "Diagnostics of PEM Fuel Cells", presented at the Annual AIChE Meeting, Salt Lake City, 2007.
56. Ulaganathan Nallasivam, Madhusudana Rao and Raghunathan Rengaswamy, "Optimization of PEM Fuel Cells", presented at the Annual AIChE Meeting, Salt Lake City, 2007.
57. Debangsu Bhattacharyya, Greg Campbell, Raghunathan Rengaswamy and Don Rasmussen, "Simulation, Economics and Sensitivity Study of Ethanol Synthesis from CO<sub>2</sub>", presented at the Annual AIChE Meeting, Salt Lake City, 2007.
58. Brian Bullecs, Debangsu Bhattacharyya, Greg Campbell and Raghunathan Rengaswamy, "Development of a Tubular Proton Exchange Membrane Fuel Cell", presented at the Annual AIChE Meeting, Salt Lake City, 2007.
59. Ravi Kumar Mandela, Shankar Narasimhan, Raghunathan Rengaswamy and Lakshmi N. Sridhar, "Recursive Nonlinear Estimation in Constrained Reactive Distillation Systems", presented at the Annual AIChE Meeting, Salt Lake City, 2007.
60. Miguel Bagajewicz, Don Chmielewski, Raghunathan Rengaswamy, "Realizing Smart Plants Through Smart Design/Upgrade of Instrumentation Networks", presented at the Annual AIChE Meeting, Salt Lake City, 2007.

61. Sang Youp Chae, Debangsu Bhattacharyya, Raghunathan Rengaswamy, "Detailed Steady State Modeling of An Anode-Supported Solid Oxide Fuel Cell (SOFC)", presented at the Annual AIChE meeting, Philadelphia, 2008.
62. Debangsu Bhattacharyya, Raghunathan Rengaswamy, Finnerty Caine, "Identification and Control of a Tubular Solid Oxide Fuel Cell ( SOFC)", presented at the Annual AIChE meeting, Philadelphia, 2008.
63. Brian Bullocks, Debangsu Bhattacharyya, Raghunathan Rengaswamy, Gregory A. Campbell, "Development of a Tubular Proton Exchange Membrane Fuel Cell (PEMFC) – Experimental and Modeling Studies", presented at the Annual AIChE meeting, Philadelphia, 2008.

## **Work in Progress**

### **Books:**

1. Working on a Book on "Process Fault Detection and Diagnosis" (Co-authors: Prof. Venkat Venkatasubramanian, Purdue University and Prof. Shankar Narasimhan, IIT Madras, India)

### **9. Commercialization/Patents**

"Title of the Invention: Stiction Compensation in Process Control Valves", Ranganathan Srinivasan and Raghunathan Rengaswamy, Provisional Patent, Clarkson University.  
**International Patent filed by Honeywell.**

"Title of the Invention: Performance Monitoring of Control Valves in Control Loops: Stiction detection using shape-matching approach", Ranganathan Srinivasan, Raghunathan Rengaswamy, Randy Miller and Lane Desborough, Provisional Patent, Clarkson University.

"Title of the Invention: Performance Monitoring of Control Valves in Control Loops: Stiction detection using simultaneous estimation of stiction model and plant model", Ranganathan Srinivasan, Raghunathan Rengaswamy, Randy Miller and Lane Desborough, Provisional Patent, Clarkson University.

"Title of the Invention: Transient diagnostics method to predict fuel cell failures using Wavelet analysis", Ulaganathan Nallasivam and Raghunathan Rengaswamy, Provisional Patent, Clarkson University.

"Title of the Invention: Transient diagnostics method to predict fuel cell failures using EMD and Hilbert Huang Spectrum Analysis", Ulaganathan Nallasivam and Raghunathan Rengaswamy, Provisional Patent, Clarkson University.

"Title of the Invention: Transient diagnostics method to predict fuel cell failures using Amplitude Ratio Spectrum Analysis", Ulaganathan Nallasivam and Raghunathan Rengaswamy, Provisional Patent, Clarkson University.

“Title of the Invention: Blind Identification of Stiction in Nonlinear Process Control Loops”, Ulaganathan Nallasivam and Raghunathan Rengaswamy, Provisional Patent, Clarkson University.

Co-inventor (With Prof. Venkatasubramanian, Dr. Hiranmayee Vedam and Sourabh Dash) of "B-Splines Based Qualitative Trend Analysis System for Process Monitoring and Fault Diagnosis", developed at Purdue

## 10. Graduate Student Supervision

### Current Graduate Students

1. Vidyashankar Kuppuraj, PhD, Texas Tech University, “Fault-tolerant Control of PEM Fuel Cell Systems”, in progress.
2. Babji Srinivasan, PhD, Texas Tech University, “Hybrid Static and Dynamic models for diagnosis and control”, in progress.
3. Brian Bullocks, PhD, Clarkson University, “Synthesis and Modeling of Tubular PEM Fuel Cells”, in progress.
4. Ulaganathan Nallasivam, PhD, Clarkson University, “Root Cause Analysis of Multivariable Control Systems”, in progress.
5. Ravi K. Mandela, PhD, Clarkson University, "Nonlinear State Estimation of Constrained Chemical Systems", in progress.
6. Sang Youp Chae, MS, Clarkson University, “Non-isothermal models for anode-supported tubular solid oxide fuel cells”, in progress.

### Completed PhD (with current position)

7. Debangsu Bhattacharya, PhD, Clarkson University, "Steady State and Dynamic Modeling, Optimization and Control of an Anode-supported Tubular Solid Oxide Fuel Cell", Clarkson University, 2008. **(currently a post-doctoral fellow in a NETL DOE, WVU joint project)**
8. Madhusudana Rao, PhD, Chemical Engineering, Clarkson University, "Modeling and Optimization of PEM Fuel Cells", Clarkson University, 2006. **(currently with UTC Power, Connecticut)**
9. N. Sridharkumar, PhD, Chemical Engineering, Clarkson University, "Methods and Sensor Placement for Fault Detection and Diagnosis with Novel Applications", Clarkson University, 2006. **(Currently Assistant Professor at IIT Madras, India)**

10. S. Ranganathan, PhD, Chemical Engineering, Clarkson University, "Control Loop Performance Monitoring: Modeling, Diagnosing and Compensating Stiction Phenomenon in Process Control Valves", Clarkson University, 2005. (**Currently with Honeywell**)
11. Pramod Vachhani, PhD, Chemical Engineering, Clarkson University, "Integrating Diagnostic Knowledge With Nonlinear Estimation for Comprehensive Fault Diagnosis", Clarkson University, 2004. (**Currently with Bloom Energy, a Solid Oxide Fuel Cell Company**)
12. Mani Bhushan, PhD, Chemical Engineering, IIT Bombay, "A Comprehensive Framework for Sensor Network Design for Efficient and Reliable Fault Diagnosis", IIT Bombay, 2001. (**Currently Assistant Professor at IIT Bombay, India**)
13. P. Sarma, PhD, "Intelligent Control of Nonlinear Processes With Genetic Fuzzy Logic and Gain-Schedule Structures", Chemical Engineering, IIT Bombay, 2000. (**Currently with Infosys Systems, India**)

### **Completed MASTERS**

14. N. Apte, MS, Statistics & Informatics, Department of Mathematics, IIT Bombay (1997), "Tearing for solving large systems in equation oriented simulators", Co-guide Kannan Moudgalya.
15. R. Raghuraj, MTech, Chemical Engineering, IIT Bombay (1998), "Fault Diagnosis and Location of Sensors Based on Diagnosability Criterion in Complex Chemical Plants".
16. S. Ranganathan, MTech, Systems & Control group, IIT Bombay (1998), "Design of Input Signals for System Identification and Control".
17. K. Sathyakant, Mtech, Systems & Control, IIT Bombay (1998), "Process Fault Diagnosis Using Nonlinear Robust Observers".
18. S. Mukherjee, MTech, Chemical Engineering, IIT Bombay (1999), "A Knowledge-based System for Generation of Operating Procedures".
19. Gupte, Mtech, Chemical Engineering, IIT Bombay (1999), "Optimal Control of Bioreactors".
20. Manu Varma, MTech, Chemical Engineering, IIT Bombay (1999), "Design of a Process for Concentration of Nitrogen in Oxidizers Off-gas".
21. S. Anisha, Mtech, Chemical Engineering, IIT Bombay (2000), "A Software for Integrated Safety Analysis in Process Plants".
22. V. Pramod, MTech, Chemical Engineering, IIT Bombay (2000), "Data Reconciliation and Parameter Estimation in Chemical Engineering Systems".

23. Karthik Iyer, MTech, Systems & Control group, IIT Bombay (2000), "Evaluation of an Observer Based Identification Method For a Special Class of Nonlinear Systems".
24. Pradeep Autale, MTech, Chemical Engineering (2001), "A Software for Simulation of Crude Distillation Units".
25. Kunal Shah, MTech, Computer Aided Design and Engineering (2001), "Multipurpose Simulator - A Fuel Cell Case Study".
26. Archis Ghate, MTech, Computer Aided Design and Engineering (2001), "Strategies for solving Algebraic, Differential Algebraic system of equations in process simulators".
27. Himabindu Sunnam, ME, Chemical Engineering (2007), Clarkson University, "Technology Assessment and Modeling of PEM Fuel Cells".
28. Hardik Shah, (co-guide Prof. Ratan Jha), MS, Mechanical Engineering (2008), "Synthesis of Highly Efficient Reaction Layers for PEM Fuel Cell Applications".

#### **Visiting Graduate and Other Students**

1. Taehoon Oh (Myongji University, June 2004 – December 2005), "Reduced Order Models for Fuel Cells", funded by Korean National Science Foundation.
2. Sam Burnham (U. of Newcastle upon Tyne, Summer 2006), "Models for Injection Molding".
3. Gerardo Ruiz (Univ. of Puerto Rico at Mayaguez, Summer 2006), "Modeling of Dynamic Nonequilibrium Reactive Separation Systems".
4. Brian Bullocks (Research Assistant, Summer 2007), "Control of Injection Molding Process".
5. Modekurti Srinivasarao (IIT Madras, Fall 2007), "Heat Integration of PAFC Systems".
6. Ravi Namdeo (IIT Bombay, Fall 2007), "Dynamics and Control PEM Fuel Cells".
7. Kesamreddy Tirupathireddy (IIT Delhi, Fall 2008), "Modeling of PEM Fuel Cell systems".

#### **Undergraduate Research at Clarkson University**

1. Sean Sutton (Clarkson), Honors Thesis, "Mathematical Modeling of Proton Exchange Membrane Fuel Cells for Diagnostic Purposes", 2004.
2. John Solsky (Clarkson, jointly with Prof. Ian Suni, Summer 2006), Undergrad Research, "Fabrication and Modeling of Nanostructured Fuel Cell".



3. Pedro Cardona (Univ. of Puerto Rico at Mayaguez, Summer 2006 ), Undergrad Research, “Signed Directed Graph (SDG) model of Programmed Cell Death (PCD)”.
4. Brian Bullocks (Clarkson, Summer 2006), Undergrad Research, “Model Based Control of Injection Molding Process”.
4. Andrew Vackel (Clarkson, Summer 2006), Undergrad Research, “Fabrication and Modeling of Nanostructured Fuel Cell”.
5. Kaitlynn Penoyer (Clarkson, Summer 2007), Undergrad Research, “Three Tank Experimental Setup”.
6. Matt Debrowski (Clarkson, Summer 2007), Undergrad Research, “Three Tank Experimental Setup”.
7. Nate Jean (Clarkson, Summer 2007), Undergrad Research, “Catalyst Preparation for PEM Fuel Cell Applications”.

## 11. Teaching

### a. Courses Taught

CH 250	Chemical Process Calculations, Fall 2005, 2006, 2007
CH 561	Chemical Engineering Analysis, Clarkson University, Fall 2004
CH 480	Design I, Clarkson University, Fall 2003.
CH 485	Process Dynamics and Control, Clarkson University, Fall 2002.
CH 481	Design II, Clarkson University, Spring 2002, 2003, 2004, 2005, 2006, 2007
CHE 456	Process Dynamics and Control, Purdue University, Fall 2001.
CHE 450	Design and Analysis of Processing Systems, Purdue University, Spring 2001. (Co-taught with Profs. Venkatasubramanian and Reklaitis)
CHE 435	Chemical Engineering Design Laboratory, Purdue University, Spring 2001. (Co-taught with Prof Wang and Dr. Muench)
CL 460	Mathematical Methods in Chemical Engineering, Undergraduate level, IIT Bombay, Spring 1997, 1998, 1999, 2000.
CL 351	Mass Transfer-I, Undergraduate level, IIT Bombay, Fall, 1996. (Co-taught with Prof. K. V. Venkatesh)

- CL 352      Mass Transfer-III, Undergraduate level, IIT Bombay, Fall, 1996. (Co-taught with Prof. K. V. Venkatesh)
- CL 453      Computer Aided Design Laboratory, Undergraduate level, IIT Bombay, Fall, 1999, 2000.
- CL 211      Computational Laboratory, Undergraduate level, IIT Bombay, Fall, 1998.
- CL 688      Artificial Intelligence in Process Engineering, Postgraduate level, IIT Bombay, Fall, 2000.
- CL 694      Artificial Intelligence & Statistical Techniques in Process Control, Postgraduate level, IIT Bombay, Spring, 1998.
- CL 691      Computational Laboratory, Postgraduate level, IIT Bombay, Fall, 1999
- CL602      Mathematical & Statistical Methods in Chemical Engineering, Postgraduate level, IIT Bombay, Fall 1997, 1998, 1999

**b. Participation in Summer Institutes and Other Programs**

Participated in a Fuel Cell short course and workshop in Calgary, Canada, February 26 –28, 2003.

Visiting Professor at University of Alberta, Edmonton, Canada June 26 – July 24, 2002. Delivered lectures in a summer course on “Fault Detection and Diagnosis”.

Participated in SACHE 2002 workshop, April 21-24, 2002.

Short-term scholar at Department of Chemical Engineering, Purdue University, USA, June-July, 2000

Series of lectures in Process Systems Engineering, University of Delaware, USA, July - Aug, 1999.

Short-term scholar at Department of Chemical Engineering, Purdue University, USA, Aug - Sep, 1999.

A CEP course on "Optimization and Optimal Control in Aerospace Systems", Guest Instructor (Linear Programming and Constrained Optimization), IIT Bombay, Jan 1998.

A course on "Process Control" for refinery personnel conducted at IPCL, Baroda, India, Guest Instructor, Jan 1998.

A CEP course on "Nonlinear Control of Aerospace Dynamics", IIT Bombay, Guest Instructor (Feedback Linearization), Jan 1998.

A Continuing Education Program (CEP) course on "LQG/LQR in the Aerospace Dynamics and Control", Guest Instructor, IIT Bombay, 1997.

Lectures on applications of "Differential Equations in Chemical Engineering" at University of Bombay, Mathematics department for the University Faculty, 1996.

Visiting Research Scholar at Dept. of Automatic Control, Lund, Sweden, Sept - Dec, 1994. Worked on a research project "Knowledge-based Real-time Control Systems".

### **c. Contributions to Course, Curriculum and Laboratory Development**

#### **At Clarkson University**

Introduced a Fuel Cell-Electrolyzer Experiment in the Senior Lab at Clarkson University

Enhanced the Liquid Level Control Experiment to perform computer control to be used in the Junior Lab at Clarkson University. Taught the undergraduate students nonlinear phenomena such as stiction in control loops through this experiment. In the process of developing a three tank experimental setup to teach the whole gamut of controller performance assessment problems to the Undergraduates.

Introduced a Biological case study (co-protein manufacture) in the senior design (Design II) course at Clarkson University

Co-taught a Honors Problem Solving Course on Feasibility of fuel cell cars by 2010. Mentored a group of students on the technology aspects. Arranged for a visit to a fuel cell company as a part of the course. The final outcome of the course was a public forum for the local community on fuel cell cars organized completely by the students with participation from the principal engineer in charge of the fuel cell development program at GM.

#### **At IIT Bombay**

Developed a new course, CL 688, on *Artificial Intelligence in Process Engineering* at IIT Bombay. This inter-disciplinary course introduces AI concepts and techniques in the context of various problems in process engineering, thus demonstrating the utility of AI as a framework for engineering problem-solving.

Developed a new course, CL 694, on *Artificial Intelligence & Statistical Techniques in Process Control* at IIT Bombay. This course is geared towards exploring emerging new techniques in the area of process control.

Organized a *Workshop on Multivariable Model Predictive Control in Process Industry* for ABB India, held on October 13-18, 1997 at IIT Bombay.

Organized (with Profs. Gudi and Madhavan) a *Workshop on Inferential Property Prediction and Fault Diagnosis Using Neural Networks and Statistical Methods* held on November 8-10, 2000 at IIT Bombay. It was attended by 15 external participants from industry.

## 12. Professional Services

Organizer: Tutorial session on Oscillation Diagnosis and Controller Performance Assessment in the American Control Conference (ACC 2006) held in Minneapolis. Other Participants: Alexander Horch, ABB Germany; Sirish Shah, U. of Alberta, Canada; Sachi Dash, Honeywell, Phoenix; Kostas Tsakalis, ASU.

Co-chairman: A session on Process Operations in the PSE conference held at Colorado, 2000. Sessions in the IFAC conference, CHEMFAS held at Korea in 2001.

Member: Committee for reviewing All India Council for Technical Education (AICTE) projects.

Reviewer: ACS-PRF proposals  
DOE proposals  
AIChE Journal  
Computers and Chemical Engineering  
I&EC Research  
Chemical Engineering Science  
IEEE transactions on Systems Man and Cybernetics  
IEEE transactions on Control Systems Technology  
Control Engineering Practice  
Journal of Process Control  
Chemical Engineering Communications  
Nonlinear Dynamics  
Engineering Applications of Artificial Intelligence  
Information Sciences  
IEEE Transactions on Industrial Electronics

## 13. Professional Memberships

Member: American Institute of Chemical Engineers (AIChE)

Member: American Chemical Society (ACS)

## 14. University Services

Member and Secretary: Departmental Post-Graduate Committee (DPGC) (IIT Bombay)

Advisor: Omega Chi Epsilon – Delta Chapter (2002 - ), Class of 2006 (Clarkson)

Member of School of Engineering Web Committee, 2004 (Clarkson)

Member, Graduate Committee, Fall 2006 – 2007  
Chair, Graduate Committee, Fall 2007 - Current  
Participated in every open house since Spring 2005  
Ph.D Graduate Committees