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Chapter

Bond Graphs for Modelling, Control and Fault Diagnosis of Engineering Systems

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Integrating Bond Graph-Based Fault Diagnosis and Fault Accommodation Through Inverse Simulation

Support

- W. Borutzky

Abstract

This chapter addresses active fault tolerant control (FTC) of engineering systems represented by a mode switching linear time-invariant model. The presented approach integrates bond graph-based fault diagnosis and inverse simulation through solving a differential algebraic (DAE) system in order to reconstruct a system input after a severe fault has occurred.In this chapter, bond graph (BG) representations of hybrid models use switches. The standard causality assignment procedure (SCAP) is used to assign fixed causalities disregarding switch modes. Equations deduced from a BG are formulated in the declarative modelling language Modelica®; as a hybrid DAE system. Causality changes at switch ports are taken into account by the Modelica implementation of switches.As to fault detection, it is known that residuals of analytical redundancy relations (ARRs) deduced offline from a diagnostic bond graph (DBG) can serve as fault indicators. It is shown that they can also be used for estimating the magnitude of parametric faults in some simple cases.Moreover, ARR residuals can also be used in the reconstruction of a system input that compensates a severe fault. To that end, the forward model of the healthy system with nominal parameters derived from a BG is considered a DAE system of the inverse model. The output of the forward model of the healthy system in response to the initial known system input serving as the desired system output of the faulty system and the ARR residuals are inputs into the inverse model. Based on these inputs the DAE system then determines the input into the faulty system required for fault accommodation. As ARR residuals are used, fault isolation and estimation are not needed for input reconstruction. Alternatively, if isolation and estimation of the faulty parameter have been performed it can replace the nominal parameter in the inverse model and ARRs as inputs can be omitted.Computation of the forward model of the healthy system, the inverse model and the evaluation of the ARRs can be performed in parallel. Advantages of the presented approach based on ARRs and inverse simulation are that neither ARRs nor the reconstructed input are needed closed analytical form. If constitutive equations of some elements do not permit an elimination of unknown variables, a DAE system deduced from a DBG has to be solved numerically in order to determine the ARR residuals used in the process of input reconstruction. The latter one also means to solve a DAE system numerically.

Keywords

Hybrid models Bond graphs Modelica®; Fault diagnosis Fault accommodation Input reconstruction Inverse simulation Power electronic systems Fault simulation

References

1. Acary, V., Bremond, M., Huber, O., Perignon, F., & Pissard-Gibollet, R. (2016). *Siconos*. http://siconos.gforge.inria.fr/users_guide/lcp_solvers.html (http://siconos.gforge.inria.fr/users_guide/lcp_solvers.html)

2. Allous, M., & Zanzouri, N. (2014). Active fault tolerant control based on bond graph approach. *Advances in Electrical Engineering*. Article ID 216153. http://dx.doi.org/10.1155/2014/216153 (http://dx.doi.org/10.1155/2014/216153)

Support lvari, M., Luo, M., Wang, D., & Zhang, D. (2011). Fault diagnosis for power electronic inverters: A l-based approach. In *Proceedings of 2011 IEEE International Symposium on Diagnostics for ic Machines, Power Electronics and Drives (SDEMPED)* (pp. 221–228). Bologna, Italy: IEEE. 0.1109/DEMPED.2011.6063627 (http://dx.doi.org/10.1109/DEMPED.2011.6063627).

lwi, H., Edwards, C., & Pin Tan, C. (2011). *Fault detection and fault-tolerant control using sliding mode*. New York: Springer. http://www.springer.com/978-0-85729-649-8 (http://www.springer.com/978-0-85729-649-8)
CrossRef (http://dx.doi.org/10.1007/978-0-85729-650-4) MATH (http://www.emis.de/MATH-item?1237.93002)

5. Arogeti, S. A., Wang, D., & Low, C. B. (2010). Mode identification of hybrid systems in the presence of fault. *IEEE Transactions on Industrial Electronics, 57*(4), 1452–1467.
CrossRef (http://dx.doi.org/10.1109/TIE.2009.2030213)

6. Baïkeche, H., Marx, B., Maquin, D., & Ragot, J. (2006). On parametric and nonparametric fault detection in linear closed-loop systems. In *Workshop on Advanced Control and Diagnosis, ACD'2006, Nancy, France, CDROM*.

7. Battle, C., Fossas, E., Merrillas, I., & Miralles, A. (2005). Generalized discontinuous conductionmodes in the complementarity formalism. *IEEE Transactions on Circuits and Systems, 52*(8), 447–451.
CrossRef (http://dx.doi.org/10.1109/TCSII.2005.849010)

8. Bergero, F., Floros, X., Fernández, J., Kofman, E., & Cellier, F. E. (2012). Simulating modelica models with a stand-alone quantized state systems solver. In *Proceedings of 9th International Modelica Conference, Munich, Germany* (pp. 237–246).

9. Blanke, M., Frei, C., Kraus, F., Patton, R., & Staroswiecki, M. (2000). What is fault-tolerant control? Aalborg University, Department of Control Engineering. http://www.iau.dtu.dk/secretary/pdf/safeprocess_02h.pdf (http://www.iau.dtu.dk/secretary/pdf/safeprocess_02h.pdf)

10. Blanke, M., Kinnaert, M., Lunze, J., & Staroswiecki, M. (2006). *Diagnosis and fault-tolerant control*. Berlin: Springer.
MATH (http://www.emis.de/MATH-item?1126.93004)

11. Borutzky, W. (2010). Bond graph methodology – Development and analysis of multidisciplinary dynamic system models. London, UK: Springer. ISBN: 978-1-84882-881-0 (print).

12. Borutzky, W. (Ed.). (2011). Bond graph modelling of engineering systems – Theory, applications and software support. New York, NY, USA: Springer.
MATH (http://www.emis.de/MATH-item?1220.05002)

13. Borutzky, W. (2015). *Bond graph model-based fault diagnosis of hybrid systems*. Switzerland: Springer International Publishing.

CrossRef (http://dx.doi.org/10.1007/978-3-319-11860-4) MATH (http://www.emis.de/MATH-item?1298.93124)

14. Borutzky, W. (2015). Fault accommodation by inverse simulation through solving a differential algebraic system obtained from a bond graph. In A. Bruzzone, G. Dauphin-Tanguy, S. Junco, & F. Longo (Eds.), *Proceedings of the 8th International Conference on Integrated Modelling and Analysis in Applied Control and Automation (IMAACA 2015), part of the I3M Multiconference, Bergeggi, Italy* (pp. 29–38).

15. Borutzky, W., & Cellier, F. E. (1996). Tearing algebraic loops in bond graphs. *Transactions of the SCS, 13*(2), 102–115.

16. Buchholz, J. J., & von Grünhagen, W. (2008). *Inversion impossible?* Tech. rep., Bremen University of Applied Sciences and DLR Braunschweig, Germany.

17. Camlibel, K., Iannelli, L., & Vasca, F. (2004). Modelling switching power converters as complementarity systems. In *IEEE Conference on Decision and Control* (pp. 2328–2333). Piscataway: IEEE.

18. Cellier, F. E., & Kofman, E. (2006). *Continuous system simulation*. New York: Springer. MATH (http://www.emis.de/MATH-item?1112.93004)

19. Cellier, F. E., & Krebs, M. (2007). Analysis and simulation of variable structure systems using bond graphs and inline integration. In *Proceedings of ICBGM 07, 8th SCS International Conference on Bond Graph Modeling and Simulation, San Diego, CA, USA* (pp. 29–34).

20. Cellier, F. E., & Nebot, A. (2005). The Modelica bond graph library. In *Proceedings of 4th national Modelica Conference, Hamburg, Germany* (Vol. 1, pp. 57–65).

Chen, J., Patton, R., & Zhang, H. (1996). Design of unknown input observers and robust fault tion filters. *Journal of Control, 63*(1), 85–105. doi:10.1080/00207179608921833 ://dx.doi.org/10.1080/00207179608921833) SciNet (http://www.ams.org/mathscinet-getitem?mr=1650539) CrossRef ://dx.doi.org/10.1080/00207179608921833) MATH (http://www.emis.de/MATH-item?0844.93020)

22. Controllab Products. (n.d.). *20-sim the power in modeling*. http://www.20sim.com (http://www.20sim.com)

23. Cormerais, H., Buisson, J., Leirens, S., & Richard, P. Y. (2002). Calcul symbolique de l'ensemble des équations d'état pour les graphs en commutation. In *Personnel of CIFA 2002, Nantes, France*.

24. Dauphin-Tanguy, G., & Kam, C. (1999). How to model parameter uncertainties in a bond graph framework. In G. Horton, D. Möller, & U. Rüde (Eds.), *Simulation in Industry, 11th European Simulation Symposium, ESS'99, Erlangen, Germany* (pp. 121–125).

25. de la Calle, A., Cellier, F., Yebra, L., & Dormido, S. (2013). Improvements in bondlib, the modelica bond graph library. In *Proceedings of the 8th EUROSIM Congress on Modelling and Simulation* (pp. 282–287). Cardiff: IEEE.

26. Djeziri, M., Merzouki, R., Ould Bouamama, B., & Dauphin-Tanguy, G. (2007). Bond graph model based for robust fault diagnosis. In *Proceedings of the 2007 American Control Conference* (pp. 3017–3022). New York City, USA: IEEE. CrossRef (http://dx.doi.org/10.1109/ACC.2007.4282195)

27. Djeziri, M. A. (2007). Diagnostic des Systèmes Incrementains par l'Approche Bond Graph. Ph.D. thesis, Ecole Centrale de Lille, France. http://hal.archives-ouvertes.fr/docs/00/20/00/30/PDF/These-Djeziri-07-12-2007.pdf (http://hal.archives-ouvertes.fr/docs/00/20/00/30/PDF/These-Djeziri-07-12-2007.pdf)

28. Djeziri, M. A., Ould Bouamama, B., & Merzouki, R. (2009). Modelling and robust FDI of steam generator using uncertain bond graph model. *Journal of Process Control, 19*, 149–162. CrossRef (http://dx.doi.org/10.1016/j.jprocont.2007.12.009)

29. Ducreux, J., Dauphin-Tanguy, G., & Rombaut, C. (1993). Bond graph modelling of commutation phenomena in power electronic circuits. In J. Granda & F. Cellier (Eds.), *International Conference on Bond Graph Modeling, ICBGM'93, Proceedings of the 1993 Western Simulation Multiconference. Simulation Series* (Vol. 25, No. 2, pp. 132–136). San Diego, CA, USA: SCS Publishing. ISBN: 1-56555-019-6.

30. Elmqvist, H., Cellier, F. E., & Otter, M. (1993). Object-oriented modeling of hybrid systems. In *Proceedings of the 1993 European Simulation Symposium, Ghent* (pp. xxxi–xli).

31. Elmqvist, H., Otter, M., & Cellier, F. E. (1995). A new mixed symbolic/numeric approach for solving differential-algebraic equations systems. In *Proceedings of European Simulation Multiconference, ESM'95, Prag* (pp. xxiii–xxxiv).

32. Fritzson, P. (2004). *Principles of object-oriented modeling and simulation with Modelica 2.1*. Hoboken: Wiley. ISBN: 0-471-47163-1.

33. Gawthrop, P. (1995). Bicausal bond graphs. In F. Cellier & J. Granda (Eds.), *ICBGM'95, International Conference on Bond Graph Modeling and Simulation: Vol. 27(1). Simulation series* (pp. 83–88). San Diego: SCS Publishing.

34. Ghoshal, S., Samantaray, A., & Mukherjee, A. (2005). Improvements to single fault isolation using estimated parameters. In J. Granda, & F. Cellier (Eds.) *Proceeding of the International Conference on Bond Graph Modeling, ICBGM'05, SCS Publishing, New Orleans, LA, USA: Vol. 37. Simulation series* (No. 1, pp. 301–306). ISBN: 1-56555-287-3.

35. Hairer, E., & Wanner, G. (1996). *Solving ordinary differential equations II, stiff and differential-algebraic problems* (2nd ed.). Berlin: Springer-Verlag.
CrossRef (http://dx.doi.org/10.1007/978-3-642-05221-7) MATH (http://www.emis.de/MATH-item?0859.65067)

36. Hao-Yuan Chou, H. (2000). Fault diagnosis of a heat exchanger system using unknown input observers. Master's thesis, University of Toronto, Graduate Department of Electrical and Cornputer Engineering.

37. Heemels, W. P. M. H., Lehmann, D., Lunze, J., & De Schutter, B. (2009). Chapter: Introduction to hybrid systems. In *Handbook of hybrid systems control: Theory, tools, applications*. Cambridge: Cambridge University Press (pp. 4–30).

Support

38. HighTec Consultants. (n.d.). SYMBOLS Sonata^{TM} . http://www.htcinfo.com/ (http://www.htcinfo.com/)

39. Isermann, R., & Ballé, P. (1997). Trends in the application of model-based fault detection and diagnosis of technical processes. *Control Engineering Practice, 5*(5), 709–719.
CrossRef (http://dx.doi.org/10.1016/S0967-0661(97)00053-1)

40. Kofman, E. (2004). Discrete event simulation of hybrid systems. *SIAM Journal on Scientific Computing, 25*(5), 1771–1797. doi:*10.1137/S1064827502418379* (http://dx.doi.org/10.1137/S1064827502418379) . http://dx.doi.org/10.1137/S1064827502418379 (http://dx.doi.org/10.1137/S1064827502418379)

41. Levy, R., Arogeti, S., & Wang, D. (2013). Improving mode-change and fault isolation of hybrid systems using instantaneous sensitivity matrices. In *Proceeding of the 1st International and 16th National Conference on Machines and Mechanisms (iNaCoMM2013)* (pp. 116–123).

42. Loureiro, R. (2012). Bond graph model based on structural diagnosability and recoverability analysis: Application to intelligent autonomous vehicles. Ph.D. thesis, L' Université Lille 1.

43. Lundvall, H., Fritzson, P., & Bachmann, B. (2008). *Event handling in the OpenModelica compiler and runtime system*. Tech. rep., Linköping University, Department of Computer and Information Science, PELAB - Programming Environment Laboratory, Series: Technical reports in Computer and Information Science. ISSN 1654-7233; 2.

44. Lunze, J. (2004). Control reconfiguration. In *Control systems, robotics and automation* (Vol. XVI, pp. 320–333). Oxford, UK: Eolss Publishers [Encyclopedia of Life Support Systems (EOLSS) edn.].

45. Lunze, J., & Richter, H. (2008). Reconfigurable fault-tolerant control: A tutorial introduction. *European Journal of Control, 5*, 359–386.
MathSciNet (http://www.ams.org/mathscinet-getitem?mr=2477705) CrossRef (http://dx.doi.org/10.3166/ejc.14.359-386) MATH (http://www.emis.de/MATH-item?1293.93248)

46. Margetts, R. (2013). Modelling and analysis of hybrid dynamic systems using a bond graph approach. Ph.D. thesis, University of Bath, UK.

47. Modelica Association. (n.d.). *Modelica and the modelica association*. http://www.modelica.org (http://www.modelica.org)

48. Murray-Smith, D. (2012). *Modelling and simulation of integrated systems in engineering – Issues of methodology, quality, test and application*. Cambridge, UK: Woodhead Publishing.
CrossRef (http://dx.doi.org/10.1533/9780857096050)

49. Murray-Smith, D. J. (2011). Feedback methods for inverse simulation of dynamic models for engineering systems applications. *Mathematical and Computer Modelling of Dynamic System[illegible]*5), 515–541.

MathSciNet *(http://www.ams.org/mathscinet-getitem?mr=2842728)* *CrossRef* *(http://dx.doi.org/10.1080/13873954.2011.584323)* *MATH* *(http://www.emis.de/MATH-item?1302.93033)*

50. Nacusse, M., & Junco, S. J. (2011). Passive fault tolerant control: A bond graph approach. In: A. Bruzzone, G. Dauphin-Tanguy, S. Junco, & M. A. Piera (Eds.), *Proceedings of the 5th International Conference on Integrated Modelling and Analysis in Applied Control and Automation (IMAACA 2011), DIPTEM Università di Genova, Rome, Italy* (pp. 75–82).

51. Ngwompo, R., Scavarda, S., & Thomasset, D. (1996). Inversion of linear time-invariant SISO systems modelled by bond graph. *Journal of the Franklin Institute, 333*(B)(2), 157–174.

52. Ngwompo, R., Scavarda, S., & Thomasset, D. (2001). Physical model-based inversion in control systems design using bond graph representation part 1: Theory. *Proceedings of the IMechE Part I Journal of Systems and Control Engineering, 215*(2), 95–103.
CrossRef *(http://dx.doi.org/10.1243/0959651011540888)*

53. Ngwompo, R., Scavarda, S., & Thomasset, D. (2001). Physical model-based inversion in control systems design using bond graph representation part 2: Applications. *Proceedings of the IMechE Part I Journal of Systems and Control Engineering, 215*(2), 105–112.
CrossRef *(http://dx.doi.org/10.1243/0959651011540897)*

54. Niemann, H., & Stoustrup, J. (1997). Robust fault detection in open loop vs. closed loop. In *Proceedings of the 36th IEEE Conference on Decision and Control* (Vol. 5, pp. 4496–4497).

55. Noura, H., Sauter, D., Hamelin, F., & Theilliol, D. (2000). Fault-tolerant control in dynamic systems: Application to a winding machine. *Control Systems 20*(1), 33–49. doi:*10.1109/37.823226*
://dx.doi.org/10.1109/37.823226) .
Ref *(http://dx.doi.org/10.1109/37.823226)*

OpenModelica Consortium. (n.d.). *OpenModelica*. *https://www.openmodelica.org/*
s://www.openmodelica.org/)

Otter, M., Elmqvist, H., & Mattson, S. E. (1999). Hybrid modeling in modelica based on the synchronous data flow principle. In *Proceedings of the 1999 IEEE Symposium on Computer-Aided Control System Design, CACSD'99, IEEE Control Systems Society, HI, USA*

58. Otter, M., Elmqvist, H., & Mattsson, S. E. (1999). *Modeling of mixed continuous/discrete systems in modelica*. Tech. rep.

59. Pantelides, C. (1988). The consistent initialization of differential-algebraic systems. *SIAM, Journal of Scientific and Statistical Computation, 9*, 213–231.
MathSciNet *(http://www.ams.org/mathscinet-getitem?mr=930042)* *CrossRef* *(http://dx.doi.org/10.1137/0909014)* *MATH* *(http://www.emis.de/MATH-item?0643.65039)*

60. Provan, G. (2009). Model abstractions for diagnosing hybrid systems. In *Proceedings of the 20th International Workshop on Principles of Diagnosis, DX-09, Stockholm, Sweden* (pp. 321–328). *http://www.cs.ucc.ie/ccsl/GP-papers/2009/Provan_DX_2009_2.pdf* *(http://www.cs.ucc.ie/ccsl/GP-papers/2009/Provan_DX_2009_2.pdf)*

61. Rahmani, A., Sueur, C., & Dauphin-Tanguy, G. (1992). Formal determination of controllability/observability matrices for multivariable systems modelled by bond graph. In *Proceeding of IMACS/SICE International Symposium of Robotics, Mechatronics and Manufacturing, System'92* (pp. 573–580)

62. Samantaray, A., Medjaher, K., Ould Bouamama, B., Staroswiecki, M., & Dauphin-Tanguy, G. (2006). Diagnostic bond graphs for online fault detection and isolation. *Simulation Modelling Practice and Theory, 14*(3), 237–262.
CrossRef *(http://dx.doi.org/10.1016/j.simpat.2005.05.003)*

63. Samantaray, A., & Ould Bouamama, B. (2008). *Model-based process supervision – A bond graph approach. Advances in industrial control*. London: Springer.

64. Staroswiecki, M. (n.d.). Fault tolerant systems. In *Control systems, robotics and automation* (Vol. XVI). Oxford, UK: Eolss Publishers [Encyclopedia of Life Support Systems (EOLSS) edn.].

65. Tan, S., & Vandewalle, J. (1988). Inversion of singular systems. *IEEE Transactions on Circuits and Systems, 35*(5), 583–587.
CrossRef *(http://dx.doi.org/10.1109/31.1788)* *MATH* *(http://www.emis.de/MATH-item?0653.93014)*

66. Thümmel, M., Looye, G., Kurze, M., Otter, M., & Bals, J. (2005). Nonlinear inverse models for control. In *Proceedings of the 4th International Modelica Conference, Hamburg, Germany* (pp. 267–279).

Support

67. Tiller, M. (2001). *Introduction to physical modeling with modelica*. Boston, MA: Kluwer Academic Publishers. ISBN: 0-7923-7367-7.
CrossRef (http://dx.doi.org/10.1007/978-1-4615-1561-6)

68. Touati, Y., Merzouki, R., & Ould Bouamama, B. (2011). Fault detection and isolation in presence of input and output uncertainties using bond graph approach. In A. Bruzzone, G. Dauphin-Tanguy, S. Junco, & M. Piera (Eds.), *Proceedings of the 5th International Conference on Integrated Modeling and Analysis in Applied Control and Automation (IMAACA 2011), DIPTEM University of Genoa* (pp. 221–227).

69. Touati, Y., Merzouki, R., Ould Bouamama, B., & Loureiro, R. (2012). Detectability and isolability conditions in presence of measurement and parameter uncertainties using bond graph approach. In *8th IFAC Symposium on Fault Detection, Supervision and Safety of Technical Processes (SAFEPROCESS), Mexico City, Mexico* (pp. 958–963).

70. van der Schaft, A. J., & Schuhmacher, M. (1998). Complementarity modeling of hybrid systems. *IEEE Transactions on Automatic Control, 43*(4), 483–490.
MathSciNet (http://www.ams.org/mathscinet-getitem?mr=1617571) CrossRef (http://dx.doi.org/10.1109/9.664151) MATH (http://www.emis.de/MATH-item?0899.93002)

71. Venkatasubramanian, V., Rengaswamy, R., Yin, K., & Kavuri, S. (2003). A review of process fault detection and diagnosis, part I: Quantitative model-based methods. *Computers and Chemical Engineering, 27*, 293–311.
CrossRef (http://dx.doi.org/10.1016/S0098-1354(02)00160-6)

72. Venkatasubramanian, V., Rengaswamy, R., Yin, K., & Kavuri, S. (2003). A review of process fault tion and diagnosis, part II: Qualitative models and search strategies. *Computers and Chemical eering, 27*, 313–326.
Ref (http://dx.doi.org/10.1016/S0098-1354(02)00161-8)

Venkatasubramanian, V., Rengaswamy, R., Yin, K., & Kavuri, S. (2003). A review of process fault tion and diagnosis, part III: Process history based methods. *Computers and Chemical Engineering, 27*, 327–346.
CrossRef (http://dx.doi.org/10.1016/S0098-1354(02)00162-X)

74. Wainer, G. A. (2009). *Discrete-event modeling and simulation – A practitioner's approach*. Boca Raton, FL, USA: CRC Press, Taylor and Francis Group.
CrossRef (http://dx.doi.org/10.1201/9781420053371)

75. Wang, D., Yu, M., Low, C., & Arogeti, S. (2013). *Model-based health monitoring of hybrid systems*. New York: Springer.
CrossRef (http://dx.doi.org/10.1007/978-1-4614-7369-5)

76. Wolfram, S. (2003). *The mathematica book* (5th ed.). Champaign: Wolfram Media, Inc.
MATH (http://www.emis.de/MATH-item?0924.65002)

77. Young, P. C. (1981). Parameter estimation for continuous-time models – A survey. *Automatica, 17*(1), 23–39.
MathSciNet (http://www.ams.org/mathscinet-getitem?mr=607192) CrossRef (http://dx.doi.org/10.1016/0005-1098(81)90082-0) MATH (http://www.emis.de/MATH-item?0451.93052)

78. Zimmer, D. (2010). Equation-based modeling of variable-structure systems. Ph.D. dissertation no. 18924, ETH Zürich.

79. Zimmer, D. (2013). A new framework for the simulation of equation-based models with variable structure. *Simulation, 89*(8), 935–963.
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