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Diagnosability of hybrid systems using hybrid bond graphs

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If a system contains both discrete events and continuous parameters, it is called a hybrid system. Faults of such a system can be of three types; abrupt faults which are discrete, incipient faults which are small drifts of parameters and intermittent faults which may be corrected by small manipulation like a loose wire connection. In this research, the first two types of faults were considered and Hybrid Bond Graphs (HBGs) were used as the main modeling tool. HBG is a modeling tool which can model electric, mechanical, hydraulic, thermal or any kind of dynamic system.

Three simple electric circuits were modeled using HBGs and investigated for fault diagnosability of each circuit. First, state space equations were generated from HBG models and Global Analytical Redundancy Relationships (GARRs) were derived. For this, use two methods were used / can be used; covering path method or causality inversion. These were then used to obtain Fault Signature Matrix (FSM) for each circuit. Using the FSM, fault detectability and isolability of each fault was investigated. Finally, with the observations received from case studies, following necessary conditions were derived for a fault to be detectable and isolable. Control junctions model discrete events in the system. Modes of the system represent discrete states and therefore, by modeling the discrete behaviour of the system as a finite state machine, it is possible to diagnose discrete faults.

For any component connected to a junction to be detectable, there should be a sensor connected to that junction or to the junction just upstream of the power flow of the HBG. In such a junction, if only one component is connected, then a fault of that component is detectable and isolable but if there is more than one component connected, then they may be isolable as a fault class but not as individual faults. If two adjacent junctions do not have sensors, then it is not possible to generate GARRs and hence, detectability and isolability cannot be evaluated. Adding more sensors to the system will enhance fault detectability and isolability: the minimal necessary number in this case.

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