ACTIVE FAULT DETECTION AND ISOLATION AND FALSE ALARM ELIMINATION BY CONSTRAINED OPTIMIZATION OF BUILT-IN AND MAINTENANCE TEST CONDITIONS

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Abstract

In this presentation, we will outline workflows and methods for the improvement of system reliability, in terms of capability and robustness in fault detection and isolation (FDI). We will present methods that improve fault identifiability and reduce or eliminate false alarms that otherwise cannot be correctly diagnosed or detected under standard operational or maintenance testing. This work is driven by the increasing need for the elimination of false alarms and incorrectly diagnosed or intermittent faults that lead to the event called Not Fault Found (NFF) [1]. We present data from the literature and simulations that illustrate the problems of current methods of FDI in complex systems operating in uncertain environments. In particular, this work explores the issues of FDI and NFF in systems supporting aircraft operations.

A general framework is provided for the design of tests for fault detection and isolation, which is based on model-based methods for active fault diagnostics. We present the standard work and corresponding methods to treat fault detection and isolation as a set of constrained optimization problems. We consider the issues of uncertainty caused by system operations and modelling error and address them through the formulation of mathematical problems to minimize their impact on fault detection and isolation capabilities. We improve the identifiability of faults by maximizing the sensitivities of the system outputs with respect to faults and uncertain conditions through the adjustment of input trajectories. This method is based on optimal experimental design methods that improve precision and reduce correlation of estimated of model parameters [2,3]. After calculating the optimal test design for fault detection and isolation, we analyze the system at its optimal operating point(s) to assess the identifiability of faults and determine if false alarms can occur using methods of model structural identifiability [4,5]. We show that this analysis is effective at determining if there are fault-free conditions that produce similar outputs to faulty conditions, which could lead to false alarms.

We will present two separate case studies that compare the identifiability of faults at nominal and optimal operating points. In each case study, we examine a virtual system that represents part of a typical aircraft environmental control system. The first case study will focus on a built-

in test for a cross-flow plate fin heat exchanger that is prone to particulate fouling. The heat exchanger analysis comes is based on previous work on fouling identifiability with uncertain operating conditions [6]. We show how the estimation and precise quantification of heat exchanger fouling can be affected by system uncertainty and how false alarms can be eliminated by optimizing the built-in test design. The fouling extent of the nominal and optimal built-in tests is estimated from heat exchanger exit temperature measurements and then these estimates are compared to each other in terms of accuracy and confidence in the estimation. The second case study focuses on the maintenance of a cabin air compressor (CAC) system that has bias in its outlet mass flow sensor (sensor fault). We show how uncertain environmental conditions can cause false alarms when detecting faults in the CAC. We also show that the impact of these conditions can be minimized by adjusting the CAC admissible inputs, making the detection and isolation of sensor faults feasible and trustable during operation.

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