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Model-based fault diagnosis in PEM fuel cell systems

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ABSTRACT

In this work, a model-based fault diagnosis methodology for PEM fuel cell systems is presented. The methodology is based on computing residuals, indicators that are obtained comparing measured inputs and outputs with analytical relationships, which are obtained by system modelling. The innovation of this methodology is based on the characterization of the relative residual fault sensitivity. To illustrate the results, a non-linear fuel cell simulator proposed in the literature is used, with modifications, to include a set of fault scenarios proposed in this work. Finally, it is presented the diagnosis results corresponding to these fault scenarios. It is remarkable that with this methodology it is possible to diagnose and isolate all the faults in the proposed set in contrast with other well known methodologies which use the binary signature matrix of analytical residuals and faults.

1. Introduction

The energy generation systems based on fuel cells are complex since they involve thermal, fluidic and electrochemical phenomena. Moreover, they need a set of auxiliary elements (valves, compressor, sensors, regulators, etc.) to make the fuel cell works at the pre-established optimal operating point. For these reasons, they are vulnerable to faults that can cause the stop or the permanent damage of the fuel cell. To guarantee the safe operation of the fuel cell systems, it is necessary to use systematic techniques, like the recent methods of fault tolerant control (FTC), which allow to increase the fault tolerance of this technology described in [1,2]. The first task to achieve active tolerant control consists of the inclusion of a fault diagnosis system operating in real-time. The diagnosis system should not only allow the fault detection and isolation but also to the fault magnitude estimation. In this paper, a model-based fault diagnosis is proposed as a way to diagnose faults in fuel cell systems. The model-based fault diagnosis is based on comparing on-line the real behaviour of the monitored systems obtained by means of sensors with a dynamic model of the same simulated system. In case of a significant discrepancy (residual) is detected between the model and the measurements obtained by the sensors the existence of a fault is assumed. If a set of measurements is available, it is possible to generate a set of residuals (indicators) that present a different sensitivity to the set of possible faults. Analyzing in real-time how the faults affect to the residuals, it is possible, in some case, to isolate the fault, and even in some cases it is also possible to determine its magnitude. The innovation of the proposal of this paper is based on the use of the residual fault sensitivity analysis that allows to isolate faults that otherwise would not be separable.

The structure of this paper is the following: in Section 2, the foundations of the proposed fault diagnosis methodology are recalled. In Section 3, the proposed model-based fault diagnosis methodology is described. In Section 4, the PEM fuel cell system used to illustrate the proposed fault diagnosis methodology is presented with the fault scenarios that can appear. Finally, in Section 5, the application results of the proposed methodology of diagnosis are presented.

2. Foundations of the fault diagnosis methodology

2.1. Model-based fault diagnosis

The methodology of fault diagnosis which is used in this work is mainly based on classic theory of model-based diagnosis described for example in [3–6]. Model-based diagnosis can be divided in two subtasks: fault detection and fault isolation. The principle of model-based fault detection is to check the consistency of observed behaviour while fault isolation tries to isolate the component that is in fault.

The consistency check is based on computing *residuals*, $r(k)$. The residuals are obtained from measured input signals $u(k)$ and out-

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