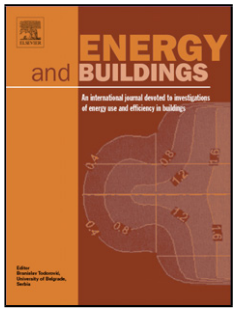


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# Estimation of an incipient fault using an adaptive neurofuzzy sliding-mode observer

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**Abstract**

A fault, especially an incipient fault has to be detected as early as possible to avoid serious damage occurring in the controlled system. A fuzzy relational sliding mode observer (FRSMO) is proposed to estimate the magnitude of slowly evolving faults in information-poor and non-linear systems. To reduce modelling errors, an on-line learning fault identification scheme is used to update the model and identify the fault in a periodical mode. The performance of the proposed methods is evaluated using a cooling-coil subsystem of an air-conditioning plant in a simulated environment. The simulation results of the actuator fault and flow reduction fault estimation confirm the effectiveness of the proposed methods.

Key words: Fuzzy relational sliding mode observer, On-line learning scheme, Cooling-coil, Actuator fault, Flow reduction fault

## 1. INTRODUCTION

There has been considerable interest in fault detection and identification in recent years due to the increasing complexity and degree of automation of technical processes. A more suitable strategy of using knowledge-based techniques instead of traditional linearization techniques is used to produce a model of a non-linear system. The neurofuzzy approach is a good alternative way of describing the relationship between the input and output variables.

Along with the complexity of modern control systems, the issue of availability, cost efficiency, reliability, operating safety and environmental protection are of major importance. The consequence of faults can be extremely serious for safety-critical systems. A fault is defined as an unacceptable deviation from the nominal system behaviour [Simani *et al.*, 2003]. It can disturb the normal operation of a system, thus causing an unacceptable deterioration of the performance of the system or even leading to dangerous consequences. Early indications of faults can help avoid drastic conditions such as system breakdown, mission abortion and catastrophes [Frank, 1990]. Moreover, the size of the fault needs to be known so as to reduce more energy consumption [Montgomery, 2006] and improve efficiencies, as seen in chemical composition procedure processes, air conditioning systems and biological industries.

Fault diagnosis has been recognized as an independent discipline in the last decades and many methods have been developed. In early times, hardware redundancy was regarded as the main method to diagnose faults. Along with the development of science and technology in control engineering, hardware redundancy has gradually been replaced by analytical redundancy due to the requirement of extra equipment and maintenance costs.

Fault diagnosis using analytical redundancy is currently a subject of extensive research and numerous surveys can be found in the literature [Gertler, 1988; Frank, 1996; Frank and Ding, 1997; Leonhardt, 1997; Frank *et al.*, 2000; Patton *et al.*, 2002; Isermann, 2005]. In analytical redundancy schemes, signals **(residuals)** which carry the fault information are used for diagnosis. The residual should be zero when the system is normal, and should diverge from zero when a fault occurs in the system. This zero and non-zero property of the residual is used to determine the existence of the fault in the monitored system. The residual signals are normally generated by comparing the measured signals with their estimates obtained from a model of the fault-free system. There are three commonly used methods for residual generation in practice [Patton *et al.*, 2000] :

(1) Comparison between the measured system outputs and prediction from a nominal model of the system;
(2) Comparison between the parameters of the nominal plant model and those of a model of the plant estimated on-line;
(3) Examination of the measured signals, which carry the fault information.