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A novel model-based fault detection method for temperature sensor using fractal correlation dimension

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ABSTRACT

The direct residual-based fault detection method compares the difference between measured and estimated data of a process variable. Its correct fault detection rate is low due to the noise in measured signals. A novel method using fractal correlation dimension (FCD) is developed, in which FCD deviation is adopted instead of direct residual. The method is validated by detecting fixed and drifting bias faults generated in supply air temperature sensor of air handling unit (AHU) system. The setting of three main parameters including embedding dimension, time delay parameter and length scale, is investigated to find out the influence on calculating FCD values. The results show that it is more efficient to detect relatively small bias fault under noise conditions, although it needs a period of time to collect measured data. As a promising and practical tool, a hybrid fault detection technique combining FCD with direct residual should be conducted in further investigation to identify the generated fault under inevitable noise conditions.

1. Introduction

As the key components in heating, ventilation and air conditioning (HVAC) systems, sensors provide the basic information for operation and control system. It is very important to maintain an accurate and reliable operation without any faults in sensors. Unfortunately, sensor fault may occur in sensing device or its electronic components after long-term operation [1]. The common sensor faults can be classified as four different categories including fixed bias, drifting bias, precision degradation and complete failure [2]. All of them may decrease the control efficiency of controller, and result in poor operation or the invalidation of advanced optimal strategies.

Dozens of different methods have been applied to detect faults and their major differences are the knowledge used for formulating the diagnostics. The state-of-the-art fault detection and diagnosis (FDD) methods can be divided into four categories, including redundancy related [3], quantitative model-based [4–6], qualitative model-based and process history based [7] methods. Each method possesses some strengths as well as some weaknesses and suitability [8], and none is generic and perfect for any desirable cases. Only a few have actually been employed in FDD implementations although a number of physical models were developed for HVAC systems over the decades.

According to the engineering literatures, some of the FDD methods directly compare the residuals or deviations between measured and estimated values, and these tools can be defined as direct residual-based methods. For the widespread use of these methods, a crucial step is the ability to develop an accurate reference model of the equipment or system characterizing its fault-free operation [9–12]. Then, such a model can detect faulty operation by tracking the residuals or deviations between measured and estimated performance, and by identifying fault occurrences when these deviations exceed pre-selected thresholds.

There are some reference models to acquire the accurate fault-free parameters. Using the first law of thermodynamics with steady-state mass or energy conservation, a robust fault diagnosis method [13] can examine and minimize the sum of squared deviations over a period. This method is validated to evaluate soft sensor faults (biases) for temperature sensors and flow meters in central chilling plant. Other mathematical models including black-box multivariate polynomial methods, specifically radial basis function and multilayer perceptron, the generic physical component model [11,12], artificial neural network [14], rough set approach [15], transient pattern analysis [16] and others, are used to get deviations for well suited automated FDD in HVAC equipments and systems.

Residuals or deviations are always obtained by data processing of measured variable [17] about the actual process. This processing

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