Fault Detection in Linear Descriptor Systems Via Unknown Input PI Observer

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Abstract

This paper deals with a fault detection algorithm for linear descriptor systems via unknown input PI observer. An unknown input PI observer is presented and its realization conditions is proposed by using the rank condition of system matrices. From the characteristics of unknown input PI observer, the states of system with unknown inputs are estimated and the magnitude of failures are detected and isolated easily by using integrated output error under the step failures. Finally, a numerical example is given to verify the effectiveness of the proposed algorithm.

1. Introduction

The core element of model based fault detection is the generation of residuals which act as the indicators of faults in real application processes [1]-[5]. For the design of the residual generators, there have been various kinds of approaches, among which the class of observer-based approaches have been most widely considered [1]-[2]. The basic idea behind observer-based approaches is to estimate the outputs of the system from measurements by using some type of observer, and then construct the residual by a properly weighted output estimated error. This residual is then examined for the likelihood of faults.

Recently a fault diagnosis method to detect and isolate the actuator and sensor failures was presented by using multiple PI observers [6]. It was based on intensive use of knowledge on the characteristics of PI observer, which estimates and cancels the step actuator failures.

Almost of fault diagnosis method was designed in linear regular system, but only a few results about descriptor system are reported [7]. The descriptor system can be described in mature form of differential and algebraic equation in practical system and control system design [8]-[9]. The form of descriptor system also appears in many systems, such as engineering systems, social economic systems, network analysis systems, biological systems, and so on. As similar problem in regular system, the problem of detecting the faults of descriptor system is important.

In this paper, we propose an unknown input PI observer for constructing the fault detection algorithm in linear descriptor systems. Firstly, the descriptor system and its boundary conditions are described, and the faults of system are defined. Secondly, the unknown input PI observer is introduced and its properties are shown. The fault detection algorithm is proposed by using monitoring the integrated error between actual output and estimated output using the observer. Lastly, a numerical example is given to verify the effectiveness of the unknown input PI observer.

2. Problem Formulation

Consider a multivariable linear descriptor system with the disturbance input and the state failure as

$$\Sigma_F : \begin{cases} E\dot{x}(t) = Ax(t)+Bu(t)+Dd(t)+Ff(t) \\ y(t) = Cx(t) \end{cases} \quad (1)$$

where $x(t) \in \Re^n$ is the state vector, $y(t) \in \Re^p$ is the output vector, $u(t) \in \Re^m$ is the input vector, $d(t) \in \Re^q$ is the unknown disturbance vector, and $f(t) \in \Re^r$ is the fault vector; A and E are square real matrices of order n, $E \in \Re^{n \times n}$ and rank $E = l(\leq n)$; B, C, D and F are matrices of appropriate dimensions. And we assume that

(i) rank $D = q$

(ii) System Σ_F is solvable, i.e., there exists a scalar λ such that

$$\det (A - \lambda E) \neq 0$$

(iii) System Σ_F is R-observable [10] (observable in the sense of Rosenbrock) if and only if

$$\text{rank} \begin{bmatrix} E \\ C \end{bmatrix} = n$$

$$\text{rank} \begin{bmatrix} A - sE \\ C \end{bmatrix} = n, \quad \forall s \in \mathbf{C}$$

where $\mathbf{C}$ denotes the complex plane.

The aim of this paper is to design an algorithm for fault detection in linear descriptor systems via unknown input PI observer. This means that the failure vector $f(t)$ in Σ_F should be detected and isolated effectively.

3. Unknown Input PI Observer for Descriptor Systems

3.1 Unknown Input PI Observer

Consider a linear descriptor system without failure vector($f(t) = 0$) in Σ_F as

$$\Sigma_D : \begin{cases} E\dot{x}(t) = Ax(t) + Bu(t) + Dd(t) \\ y(t) = Cx(t) \end{cases} \quad (2)$$

and consider a PI observer as represented by