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Dissipative sampled-data controller design for singular networked cascade control systems

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Abstract

This paper is concerned with the problem of dissipative fault-tolerant cascade control synthesis for a class of singular networked cascade control systems (NCCS) with both differentiable and non-differentiable time-varying delays. By constructing the appropriate Lyapunov–Krasovskii functional using the available information about the actual sampling pattern, a new set of sufficient condition is obtained to guarantee that the singular networked cascade control systems to be admissible and strictly $(\mathcal{Q}, \mathcal{S}, \mathcal{R})-$dissipative. Based on the criterion, a design algorithm for the desired sampled-data cascade controller is formulated in terms of linear matrix inequalities. More precisely, Jensen's integral inequality together with Wirtinger-based inequality is used in derivation of the main result. From the obtained dissipative result, we deduce three cases namely H_∞ performance, passivity performance, mixed H_∞ and passivity performance for the considered singular NCCS. Finally, a power plant boiler-turbine system is given to demonstrate the effectiveness and applicability of the proposed design techniques.

1. Introduction

Networked control systems (NCSs) are feedback control systems in which sensors, controllers and actuators are connected through the networks which become more and more popular in the modern industry because of easy maintenance and installation, the large flexibility and the low

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cost and also their successful applications in a broad range of areas such as manufacturing plants, industrial problems, underwater acoustics, vehicles, aircraft, spacecraft, remote surgery and so on [1,4,13]. On the other hand, because of error in modeling or the changing operating conditions in networked control systems, an exact mathematical model of NCSs cannot be established, and also external disturbance is inevitable in practical applications [43]. Therefore, H_∞ control problems for NCSs have received considerable attention because of their excellent ability to balance the performance and robustness of a system in the presence of external disturbance [8,32,33,35,37,38,40]. Moreover, communication effects such as delay and packet loss can destabilize the NCS or deteriorate its performance [44]. Lu et al. [21] have investigated the H_∞ filtering for linear systems using quantized measurements. Therefore, in recent years research works on stability and stabilization on NCSs with time delays and packet loss have received much attention [2,3].

Singular systems are also referred to as descriptor systems have extensive applications in many practical systems such as in chemical processes, power systems, mineral industries, mechanical systems, aerospace systems, economic systems, electronic and electrical circuits and many other areas [7,9,10,19]. The singular system models are more general and natural to describe the practical dynamical systems than the standard state-space systems in the sense of modeling since a singular system model is formulated as a set of coupled differential and algebraic constraints between physical variables [24]. A great number of results related to the stability, stabilization and control problems based on the theory of state-space systems have been successfully extended to singular systems via various techniques, among which the Lyapunov approach together with linear matrix inequality technique appears to be very popular (see [5,31] and references therein). Chadli and Darouach [30] obtained a new set of necessary and sufficient conditions for the admissibility for uncertain discrete-time singular systems in terms of strict linear matrix inequalities formulation. The quantized H_∞ filtering for singular time-varying delay systems with an unreliable communication channel has been discussed in [20].

Moreover, due to the growing complexity of automated control systems, various faults will be encountered in systems, especially faults in actuators and sensors. Over the past few decades, much attention has been paid to resolve the fault-tolerant control problems for dynamic systems [6,7]. Moreover, a great number of results related to the stabilization of control problems via sampled-data approach for dynamical systems have been reported in [39,41,42]. Li et al. [15] studied stabilization problem for a class of Markovian stochastic jump systems with actuator fault and input disturbances. Fault-tolerant sampled-data control for flexible spacecraft in the presence of external disturbances, partial actuator failures and probabilistic time delays is investigated in [34]. The problem of sampled-data H_∞ control for uncertain active suspension systems via fuzzy control approach has been investigated in [14]. More recently, Sakthivel et al. [36] studied the robust reliable sample-data control problem for an offshore steel jacket platform with input time-varying delay and possible occurrence of actuator faults subject to nonlinear self-exited hydrodynamic forces.

The notion of dissipativity provides a framework for the analysis and design of control systems using an input–output description based on energy-related considerations and serves as a powerful tool in characterizing system behaviors such as stability and passivity [16,29]. Moreover, dissipativity is a more general criterion than the stability and passivity. In recent years, there have been considerable interests in the dissipativeness analysis and dissipative control for a various class of dynamical systems such as singular systems [24], TS fuzzy systems [27,29], Markovian jump systems [17,28] and stochastic systems [23]. Wu et al. [25]