Asian Journal of Control, Vol. 22, No. 2, pp. 1–10, March 2020
Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/asjc.1974

OPTIMAL CONTROLLER DESIGN WITH COMMUNICATION DELAY FOR SOLID OXIDE FUEL CELL

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ABSTRACT

Development of distributed control algorithms has attracted significant attention for control of large-scale processes. In distributed control systems, there are signal transmissions between local subsystems. One subsystem does not have complete knowledge of the whole system and interactions between subsystems are not completely considered. Communication delay also places limitations on achievable best performance. In this paper, considering communication delay, a distributed method is proposed to design an optimal controller using a discrete linear model. The advantage of the proposed method is in taking communication delay into account and being robust against subsystem failure. The proposed approach has been applied on a solid oxide fuel cell, which is extremely nonlinear and has a huge number of state variables. The results show the advantages and applicability of the proposed method.

Key Words: Distributed controller, discrete ARMAX model, solid oxide fuel cell, linear optimal control.

I. INTRODUCTION

Large-scale complex systems are common in modern industry (e.g., chemical and petrochemical processes), which are composed of distributed and interconnected subsystems that are tightly integrated through material, energy, and information flows. Traditionally, control of large-scale systems has been studied primarily within the centralized or decentralized framework.

These large scale systems are often composed of many interacting subsystems and can be difficult to control with a centralized control structure due to the inherent computational complexity, robustness consideration, reliability problems, and communication bandwidth limitations. For all these reasons, distributed control structures have been developed over the last 40 years. Among them, the most common is the completely decentralized structure, that is, distributed control systems without exchange of information among local regulators [1].

The main advantage of the distributed control system concept is increasing reliability and reducing installation costs by localizing control functions near the process plant, and further enabling monitoring and supervisory control of the process remotely. If a sub-control fails, it will only affect a part of the plant process, as opposed to a failure of a centralized framework that would affect the whole process.

In distributed control structures, it is assumed that some information is transmitted among local regulators, so that each of them has some knowledge about the behavior of others. Among different types of distributed control systems, cooperative distributed predictive control has been proved to achieve the performance of corresponding centralized control systems in the context of linear systems [2], when there is a perfect communication network (no communication delay).

Although, there are transmissions of local subsystem states and control actions, a subsystem does not have complete knowledge of the whole system and interactions between subsystems may only be considered to a certain degree. Communication delays and data losses caused by wireless network, bandwidth limits, and triggered communication are also factors that affect the control performance in a distributed case [3,4].

Although, there are many published articles on distributed optimal control especially on a multi agent framework, such as [4–8], in this study, a novel cooperative control based distributed optimal control will be designed. Previous published papers have mostly focused on the distributed structure without considering the impact of communication delay. The proposed framework takes communication delays between different subsystems into account, and each local controller minimizes corresponding local output costs subject to the constraints introduced by the distributed control structure. This method is applied on a solid oxide fuel cell (SOFC). This system is extremely nonlinear and has many state variables and can be regarded as a large scale system.

Controller designing for a SOFC has been investigated in many studies. For instance, [9] provides an artificial neural network model for a SOFC based on experimental data. A1-D dynamic modeling of a SOFC and a fixed

Manuscript received August 14, 2017; revised June 29, 2018; accepted September 23, 2018.

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