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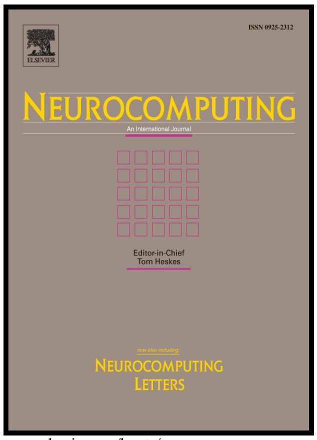

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Bounded synchronization of coupled Kuramoto oscillators with phase lags via distributed impulsive control *

Wen-Yi Zhang[1,2], Chao Yang[1], Zhi-Hong Guan[1,†], Zhi-Wei Liu[1], Ming Chi[1], Gui-Lin Zheng[3]

[1] *College of Automation, Huazhong University of Science and Technology, Wuhan, 430074, P. R. China*

[2] *Department of Electrical Engineering, Tsinghua University, Beijing, 100084, P. R. China*

[3] *Department of Automation, Wuhan University, Wuhan, 430072, P. R. China*

Abstract

In this paper, we study the synchronization of networked Kuramoto oscillators with phase lags. Distributed impulsive control strategies are developed to ensure the synchronization of coupled Kuramoto oscillators with phase lags. A sufficient condition is given to ensure bounded synchronization whose boundary can be sufficiently and arbitrary small. Especially, when oscillators are identical and phase lags are uniform, the exponential convergence criteria are derived. The proposed control strategies are valid for arbitrary distributions of phase lags with a boundary. Finally, numerical simulations are given to illustrate the effectiveness of the proposed control strategies.

Keywords Kuramoto oscillators, phase lags, distributed impulsive control, bounded synchronization, exponential convergence.

1 Introduction

In recent years, extensive interest has been devoted to consensus and synchronization problems for complex dynamical systems. The Kuramoto model [1] is regarded as one of the most representative models to characterize the synchronization of coupled oscillators [2-4]. It is broadly applied in various fields such as chemistry, biology, engineering and mathematics [5-13]. Especially, unification of brain signals [9] and the synchronization of the power grids which focus on the transient stability problems [4-6] are the typical applications of the model. Moreover, the power grids modeled as structure-preserving and network-reduced power system models can be referred to as coupled oscillators networks [14]. Therefore, considerable attention is being paid on this area. In the study of the Kuraomoto oscillators, synchronization is one of the most important topics. For example, an exact solution is given [15] for first-order synchronization transition in a generalized Kuramoto model. The synchronization condition is given [16] related to the size of the attractive and random coupling terms. The relationship of the critical coupling and synchronization is explored [17]. Although there are abundant good results about the synchronization of oscillators, but few of them discuss the synchronization with phase lags. Sometimes, the phase lags between oscillators need to be taken into consideration in practical problems, such as the lags between generators in power grids [14], and the lags between neurons [9].

Phase lag which occurs naturally in complex network models [18-21] due to the delay of communication and the limit of the inherent structure was first introduced in Kuramoto model [22] to model the synchronized oscillators in which the common frequency differs from the average of the natural frequencies. Phase lag is equivalent in synchronized systems to delay couplings which occur in biological and other systems [23],

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†Corresponding author. E-mail address: zhguan@mail.hust.edu.cn (Z.-H.Guan).