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An extended approach of inverted decoupling

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ABSTRACT

This paper presents an extension of the inverted decoupling approach that allows for more flexibility in choosing the transfer functions of the decoupled apparent process. In addition, the expressions of the inverted decoupling are presented for general $n \times n$ processes, highlighting that the complexity of the decoupler elements is independent of the system size. The realizability conditions are stated in order to select a proper configuration, and the different possible cases for each configuration are shown. Comparisons with other works demonstrate the effectiveness of this methodology, through the use of several simulation examples and an experimental lab process.

1. Introduction

Multi-input multi-output (MIMO) processes consist of several measurement and control signals, and there are often complicated couplings between them, which can cause difficulties in feedback controller design. Control engineers traditionally solve these problems using single-loop PID controllers because they can be easily understood and implemented [1]. These decentralized approaches have evolved through years of experience, and they are adequate when the interactions in different channels of the process are modest [2,3]. Nevertheless, when interactions are significant, the decoupling is often treated inefficiently, e.g., by detuning control loops. In these cases, a full matrix controller (centralized control) is advisable.

There are two approaches of centralized control: a pure centralized strategy [4–9] or a decoupling network combined with a diagonal decentralized controller [10–14]. A decentralized control system with a decoupling matrix can be designed by combining a diagonal controller $C(s)$ with a block compensator $D(s)$ in such a way that the controller sees the apparent process $G(s){\cdot}D(s)$ as a set of n completely independent processes. The essence of decoupling is the imposition of a calculation net that cancels the existing process interaction, allowing for independent control of the loops. Although model predictive control (MPC) is becoming the standard technique to solve multivariable control problems in the process industry, several authors [6,7,12] claim that when MPC is used today, it is mostly used on a higher level to give setpoints to the PID controllers that are operating on the basic level. They are operating in a supervisory mode with sampling times that are longer than in the PID controllers at the lower level. And there are some difficulties in dealing with the interaction at the MPC level because the bandwidths of the MPC loops are limited. Therefore, the centralized control using PID controllers and decoupler networks is an interesting strategy in the process industry.

The theory of decoupling control has been addressed in the literature [15–18]. Some decoupling schemes are static [19], and others are dynamic [6,13,14,20]. Most of these methodologies focus on systems with two inputs and two outputs (TITO systems).

Most decoupling approaches use a conventional decoupling scheme in which the process inputs are derived by a time-weighted combination of feedback controller outputs (Fig. 1). In this case, the design of the decoupler network for an $n \times n$ process is obtained from (1), generally specifying n elements of the decoupler $D(s)$ or the n desired transfer functions of the apparent process $Q(s)$. The most extended forms of conventional decoupling were termed ideal and simplified decoupling in [10]. This approach has received considerable attention in both control theory and industrial practice for several decades.

$$D(s) = G^{-1}(s) \cdot Q(s) \tag{1}$$

In ideal decoupling, the goal is to make the apparent processes as simple as the diagonal elements of the process matrix $G(s)$. The main inconveniences of this method are the complexity of the

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