ACTIVE DISTURBANCE REJECTION CONTROL TUNING EMPLOYING THE LQR APPROACH FOR DECOUPLING UNCERTAIN MULTIVARIABLE SYSTEMS

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Abstract — The ADRC tuning is essentially a pole-placement technique and the desired performance is indirectly achieved through the location of the closed-loop poles. However, the final choice of these poles becomes a trial-and-error strategy. In contrast with pole-placement, in the LQR method, the desired performance objectives are directly and globally addressed by minimizing a quadratic function of the state and control input. ADRC tuning employing the LQR approach is then applied for decoupling uncertain MIMO systems. This is done by considering all the coupling and interference interactions between the channels of the system as disturbances, using an ESO to estimate them in real time and then canceling its effect employing the estimate as part of the control signal.

Keywords — Active Disturbance Rejection Control (ADRC), Extended State Observer (ESO), Linear Quadratic Regulator (LQR), Multiple-Input-Multiple-Output (MIMO) systems, Decoupling.

1. INTRODUCTION

In many industrial plants, the basic extension of classical PID controller design, implementation and tuning is the decentralized approach, where structural concepts are used to decouple the interaction between variables. The control effort is decomposed into two stages: first to decouple the different subsystems and then to control them. Decoupling or non-interacting control is a popular approach to dealing with control loop interactions. Here, the objective is to eliminate completely the effects of loop interactions. Decoupling control was initially developed for deterministic linear systems. Typical approaches include design of state feedback to reach decoupling of state equation (Falb and Wolovich, 1967), decoupling in frequency domain through inverse Nyquist array (Rosenbrock, 1969), decoupling via relative gain array (Bristol, 1966, Shinskey, 1979, Friedly, 1984), decoupling using Singular Value Decomposition of the transfer function matrix (Lau et al., 1989), and designing precompensators that transforms the controlled transfer function matrix into a diagonal matrix or diagonal dominance (Niederliski, 1981, Alberto and Sala, 2004, Skogestad and Postlethwaite, 2005), where the precompensator can take the form of: dynamic decoupling, steady state decoupling or decoupling at one particular frequency. All these different approaches separate the controlled multivariable system into several Single-Input-Single-Output (SISO) subsystems through a suitable decoupler that depends on accurate process model before controller design. So they are difficult to reach decoupling control of complex industrial multivariable processes characterized with strongly interactions and uncertainties. One of the main issues in control is to deal with uncertainties including internal (parameter and unmodeled dynamics) and external (disturbances). However, most uncertainties are not measurable. The extended state observer (ESO) (Han, 1998, 1999, Gao et al., 2001) has been proposed to estimate mixed uncertainties for nonlinear systems.

Active Disturbance Rejection Control (ADRC) (Han, 1998, 1999, 2009; Gao et al., 2001) is a robust control method that does not require a detailed mathematical description of the system. It is based on the extension of the system model trough a virtual state variable, representing everything that it is not included in the mathematical model of the plant. An estimate of this state provided by an ESO can be further used in the control signal to decouple the real perturbation in the plant. It is this inherent capacity of decoupling of the ADRC method that has been employed in the control of MIMO systems. This is done by considering all the coupling and interference interactions between the channels of the system as disturbances, use an ESO to estimate them in real time and then canceling its effect employing the estimate as part of the control signal. This strategy has been used in the control of particular MIMO problems by decomposing the global system into several SISO subsystems and then designing ADRC for each loop, for example: (Huang et al., 2004, Liu et al., 2008, Khani and Yazdizadeh, 2009, Shi et al., 2012, Tian et al., 2012), to cite few of them. There are also some contributions that propose a general ADRC framework to treat the MIMO systems, we can mention in this case: (Xia et al., 2007) where MIMO systems with time delay are considered by viewing the system with time delay in the input as a high-order system without time delay in the input, (Miklosevic and Gao, 2005) where it is employed a dynamic decoupling method in the control of a performance turbofan engine and (Zheng et al., 2009) where a dynamic decoupling control based on SISOADRC is used for uncertain square MIMO sys-