Fast Fourier Transform For Estimating Process Frequency Response

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Abstract

This paper discusses the online technique to estimate the process frequency response without breaking the closed-loop control. The extended method of relay feedback using fast Fourier transform (FFT) is measured input and output responses without disconnecting the controller from the loop, which significantly reduces the time required for the autotuning test. The method utilizes step response information and one period of limit cycle oscillation that induced under tight continuous closed-loop control. The frequency domain identification method is useful for certain critical applications where it is dangerous for the control loop to be broken for tuning purposes. Simulation examples are included to illustrate the efficacy of the proposed method.

I. Introduction

It is important to know the process before it is manipulated for control purposes. To estimate the process dynamic response, a relay feedback technique is probably most successfully used in the process industry [1]. Various aspects of the relay feedback are discussed in [2]–[4]. Some of the distinct advantages of the relay feedback are *i*) it identifies process information around the important frequency, the ultimate frequency (the frequency where the phase angle is $-\pi$), *ii*) it is a closed-loop test; therefore, the process will not drift away from the nominal operating point and *iii*) for processes with a long time constant, it is a more time-efficient method than conventional step or pulse testing. The experimental time is roughly equal to two to four times the ultimate period. Therefore method has been subject of much interests in recent years and it has been field tested in a wide range of applications. Basically this conventional technique is an off-line testing, i.e. some information on the process is extracted under relay feedback after detaching the controller from the loop. It has been reported [5] that off-line testing may affect the operational process regulation which may not be acceptable for certain critical applications. Indeed, in certain key process control areas such as vacuum control, environment control, it may be too expensive or dangerous for the control loop to be broken for tuning purposes.

Many variations and refinements to the original relay feedback method have been undertaken in identifying multiple points on the process frequency response. Based on the frequency domain describing function approach, many methods have been reported [6]–[13] with improved accuracy to estimate process transfer function models. However, these approximate DF methods are basically iterative and also required some suitable initial guesses. A systematic time domain analysis was presented by Majhi [14] for identifying process dynamics with first order model. In this approach a relay is connected in series with a controller to tune the controller online. Other identification methods have been reported, using fast Fourier transform (FFT), are very useful for process response identification [15] [16]. In this method, process input and output responses are obtained first from a single relay feedback test. The logged limit cycle oscillation is decomposed into the transient parts and the stationary cycle parts. Then these parts are transformed to their frequency responses using the FFT and digital integration, respectively to estimate the process frequency response.

In this article, FFT-Relay method is modified with respect to decomposition of the transient part from stationary oscillation. Since the proposed method adopted on-line approach by keeping PI controller in the loop, the process input and output are first logged the step response data. Then whenever necessary to identify process dynamics, a relay in parallel with a PI controller is invoked to induce the small limit cycle oscillations over a limited time span. The stationary oscillation around the setpoint (reference) for one period of limit cycle are measured. The process frequencies are identified accurately from the measured data directly without removing the controller from the loop. Illustrative examples are given to demonstrate the effectiveness of the online FFT-Relay method.

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