Measurement Based Control Structure Assessment of Ordinary Control Loops

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MEASUREMENT BASED CONTROL STRUCTURE ASSESSMENT OF ORDINARY CONTROL LOOPS

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Abstract This paper describes a control structure assessment method in an industrial control system. The method uses available signals to evaluate if a given signal can be used for additional feedforward control action to improve the performance of a control loop.

Keywords Process control, PID control, control structure selection, feedforward control

1. INTRODUCTION

In the highly automated process industry, the control loops outnumber by far the number of operators and people in the maintenance and instrumentation departments. Since a typical process plant has thousands of control loops, it can not be expected that these are tuned very often, if ever (Bialkowski, 1993). Moreover, the processes in the industry often change over time, e.g. modification of different process sections. Unfortunately, these changes do not always propagate correctly to the control system resulting in performance loss. A conclusion is that there is a need for a monitoring tool that can alert the staff when a control loop has deteriorated.

During the last decade much research has been done on monitoring control loop performance using normal operating data, see for example (Harris *et al.*, 1999) for a survey. Several performance assessment products are now available on the market, and their usage in the industry is increasing. With this in mind, a tool for analysing the control loop structure has been developed. This tool is based on mainly measurements, and not rigorous models of the process.

The goal is to incorporate this tool in an environment for control loop and structure assessment. Such a tool could be used to determine whether the control loops are well tuned, to verify if an appropriate control strategy has been chosen, and, when not, to hopefully get a measure on how much better control is achievable using another control strategy.

This paper describes the first steps toward such a tool. The tool is able to evaluate if feedforward control action should be added to a SISO loop. Given the signals of the loop and one or several extra measurable signals, the tool evaluates the influence of these extra signals on the loop. The result is presented as an index. The indices of different loops can be compared in order to focus the maintenance on the worst control loops.

The tool for assessing additive disturbances and their use for feedforward control action was presented in (Petersson *et al.*, 2001). The questions that came up during an implementation in Java was presented in (Petersson *et al.*, 2002a). In (Petersson *et al.*, 2002b) the aspects of implementing the tool in a commercial control system was discussed. Here we give an overview of the method and the tool implemented in an industrial control system.

2. THE FEEDFORWARD ASSESSMENT METHOD

The starting point for this research project is an ordinary control loop in the process industry. The loop is assumed to be tuned, which is reasonable when most commercial control systems offer a tuning feature. In addition to the signals

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present in the loop, at least one measurable signal, x, should be available. The nature of the additional signals is not considered to be known, but it is of interest to determine their effect on the control loop.

The feedforward index, presented in (Petersson *et al.*, 2001), evaluates the influence on a single control loop from an additional measurable signal by analysing the transient responses of the controller output. The calculated index gives an idea of where in the process the disturbance enters, and is based on a comparison between the time constants of the process and disturbance paths.

2.1 *Definition*

The idea is to compare the controller's response, $u(t)$, to a disturbance, with two reference responses. The references are the controller's response to the same disturbance entering before and after the process respectively, i.e. the two extreme entry points of a disturbance in the control loop. See Figure 1 for an example of how these references can be obtained. The two control reference responses are denoted $u_{\text{before}}(t)$ and $u_{\text{after}}(t)$.

The index calculation consists of taking the ratio between an area depending on the measured disturbance, and a reference area. The area between the two reference responses constitutes the reference area. The disturbance dependant area is the area between the *after*-reference and the response due to the disturbance, see Figure 2.

The signals need to be scaled before calculating the index, as reported in (Petersson *et al.*, 2001). The scaling is depending on the process gains, the size of the measured disturbance, and the size of the disturbance used to generate the references. The index is given by the following

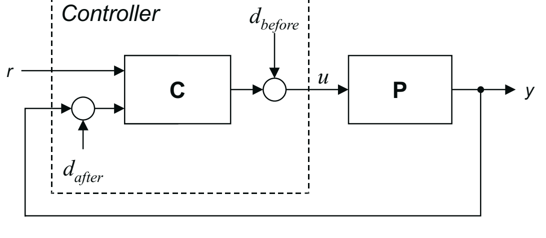

Fig. 1 An example of generation of the controller reference responses. In this case the measured disturbance is introduced into the loop at d_{before} and d_{after} to generate the *before*- and *after*-references, respectively.

equation

$$\eta_{\text{FF}} = \frac{\int_0^{T_{\text{ar}}} (\bar{u}(t) - \bar{u}_{\text{after}}(t))\, dt}{\int_0^{T_{\text{ar}}} (u_{\text{before}}(t) - \bar{u}_{\text{after}}(t))\, dt} \qquad (1)$$

where T_{ar} is the average residence time, which for a first-order plus deadtime model is the sum of the time constant and the deadtime (Åström and Hägglund, 1995; Marlin, 1995).

An index close to or larger than one indicates a signal that enters before or early in the process. Such disturbances can preferably be used in an additional feedforward control action in order to improve the performance of the loop. Disturbances receiving indices close to zero are considered to enter late in the process and they are best handled by feedback control.

3. ASSESSMENT EXPERIMENTS

The control structure assessment tool has been implemented in ABB's new family of control hardware, software and tools, called Control^{IT}. The tool resides in the controller and has been implemented in the IEC 61131-3 language Structured Text.

Some experiments will be presented. They have been carried out on a control system consisting of an ABB Control^{IT} AC800C controller (ABB, 2001) with analogue I/O-module capable of handling 0-10 V signals, and two KI-100 Dual Process Simulators (Ken, 1993). The control system has also been connected to the laboratory equipment at the department of Automatic Control at Lund Institute of Technology.

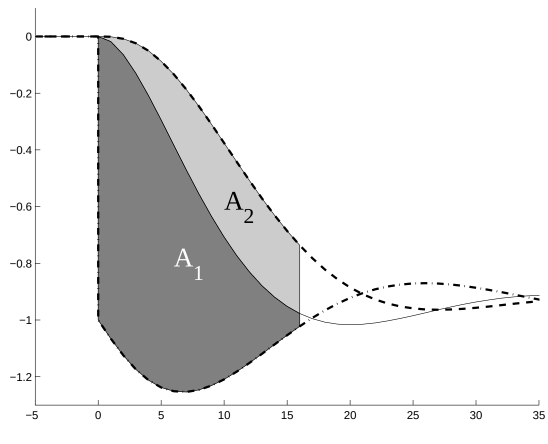

Fig. 2 Comparison of control signals. The response to the disturbance is shown in solid, the after-reference is dash-dotted, and the before-reference is dashed. The area generated by the disturbance is labelled A_1, and the reference area is the sum of the two areas, $A_1 + A_2$. The feedforward index is the ratio between A_1 and the reference area.

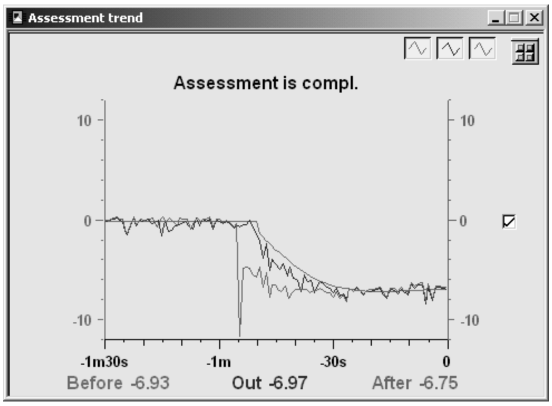

Fig. 3 The trend curve during the assessment. The middle curve is the controller response to the detected disturbance, the upper curve is the *before*-reference, and the lower curve is the *after*-reference.

An example of a controller response, along with the references, is shown in Figure 3. The index calculated for this disturbance is 0.82, which qualifies the signal to be used for an additional feedforward control action.

4. CONCLUSIONS

The presented method enables the control engineer to decide if an additional feedforward control action should be added. The tool presented still needs aid from the operator and the forthcoming work will include automating the methodology. The goal is to automate the assessment as far as possible, and bring other control structures, e.g. cascade control, into the framework.

The implementation allows the use of different detection, monitoring and identification methods. There are implementation issues such as the tradeoff between robustness of methods used against the computational burden it poses on the system the code resides in. The final decision, of which algorithms will be recommended for a possible product, depends not only on the robustness of the different algorithms, but also on where in the control system the tool will be implemented.

Keeping history of indices may help in identifying the root cause of the performance loss, and gain better insight in how future maintenance and reconstructions should be carried out in the plant.

It is clear that improved control can be achieved, by either tuning or changing structure. There are other interesting questions that is to be answered: How much improvement is possible? Can it be achieved by better control, or is it the process that needs to be modified?

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