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INVESTIGATION OF THE ROBUST STABILITY OF SYSTEM WITH DELAY

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Abstract. The paper is devoted to investigation of the robust stability of system with delay. The influence of process parameters on the stability of the whole system is tested and impact to the system parameters using the Smith predictor for robust systems is defined.

Keywords: system with delay, Smith predictor.

Introduction

Modern process automation and production involves not only the introduction of new techniques and technologies, but also the implementation of effective control algorithms (Sosin 2007). One of the common problems of manageme-nt systems formation is delay. Delay is common to many facilities, like building central heating systems, various processes of technological chain production, communication systems, space systems, chemical and other processes. Delay systems require special methods for controls creation due to possibility of significant process quality degradation or even process might become unstable (Normey-Rico 2007).

The robust stability of system with delay

In this context the delay correct registration task, evaluation of its impact on the work quality, as well as management systems formation is highly demand today and does not have a final resolution yet.

Robust control considers the design of decision or control rules that fare well across a range of alternative models. Thus robust control is inherently about model uncertainty, particularly focusing on the implications of model uncertainty for decisions. Robust control originated in the 1980s in the control theory branch of the engineering and applied mathematics literature, and it is now perhaps the dominant approach in control theory. Robust control gained a foothold in economics in the late 1990s and has seen increasing numbers of economic applications in the past few years.

The basic issues in robust control arise from adding more details to the opening sentence above – that a decision rule performs well across alternative models. To begin, define a model as a specification of a probability distribution over outcomes of interest to the decision maker, which is influenced by a decision or control variable. Then model uncertainty simply means that the decision maker faces subjective uncertainty about the specification of this probability distribution. A first key issue in robust control then is to specify the class of alternative models which the decision maker entertains. As we discuss below, there are many approaches to doing so, with the most common cases taking a benchmark nominal model as a starting point and considering perturbations of this model. How to specify and measure the magnitude of the perturbations are key practical considerations.

With the model set specified, the next issue is how to choose a decision rule and thus what it means for a rule to "perform well" across models. In Bayesian analysis, the decision maker forms a prior over models and proceeds as usual to maximize expected utility (or minimize expected loss). Just as we defined a model as a probability distribution, a Bayesian views model uncertainty as simply a hierarchical probability distribution with one layer consisting of shocks and variables to be integrated over, and another layer averaging over models. In contrast, most robust control applications focus on minimizing the worst case loss over the set of possible models (a minimax problem in terms of losses, or max-min expected utility). Stochastic robust control problems thus distinguish sharply between shocks which are averaged over, and models which are not. The robust control approach thus presumes that decision makers are either unable or unwilling to form a prior over the forms of model misspecification. Of course decision makers must be able to specify the set of models as discussed above, but typically this involves bounding the set of possibilities in some way rather than fully specifying each alternative.

This study task is to analyse the robust system with delay. Let's assume we have a system (Figs 1, 2) with the following settings:

- $Kp = 0.46$; $Ki = 0.013$;
- Transport Delay, $D = 20$;
- Time constant, $C = 50$;
- Object gain, G.

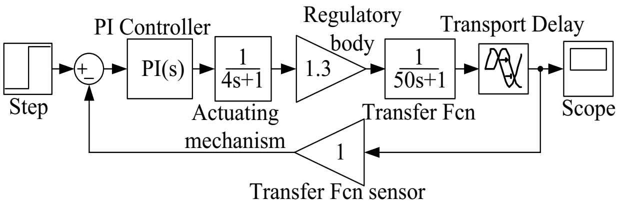

Fig. 1. Investigated system

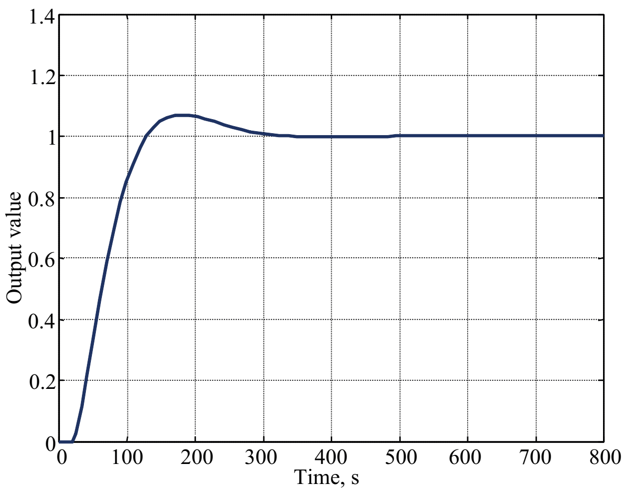

Fig. 2. Transient process gain

The gain factor, object time constant and time delay will be increased in series until stability boundary is identified.

Increasing the gain factor tenfold the system is reaching stability boundary (Fig. 3).

Increasing the object time constant more than 50 million times with current regulator settings the system is reaching stability boundary (Fig. 4).

Increasing object time delay two fold the system is reaching stability boundary with current regulator settings (Fig. 5).

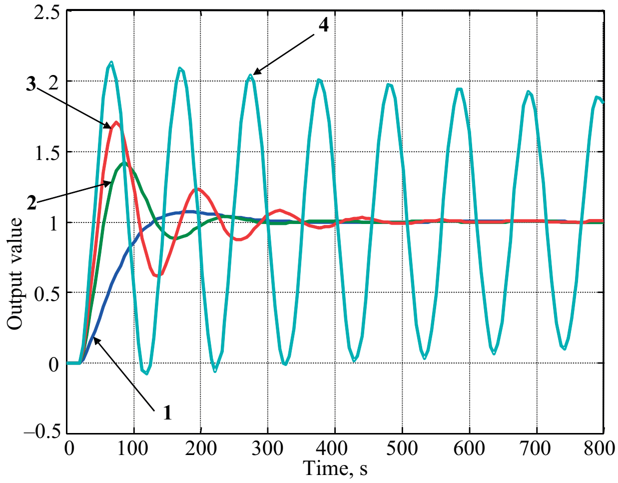

Fig. 3. Transient process with different object gain G values: 1 – G = 1; 2 – G = 5; 3 – G = 7; 4 – G = 10

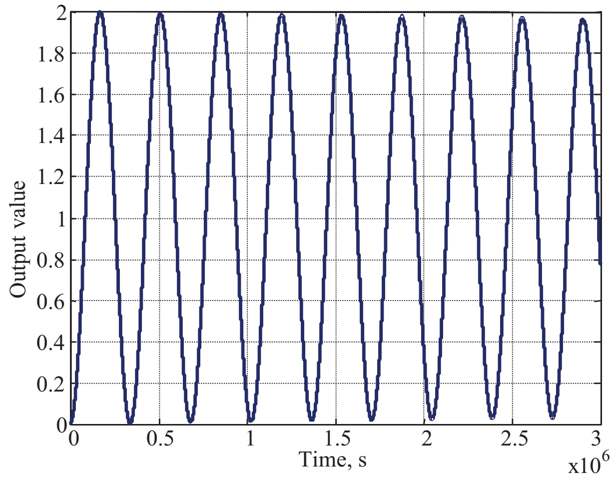

Fig. 4. Transient process with object time constant $C = 5\times10^7$

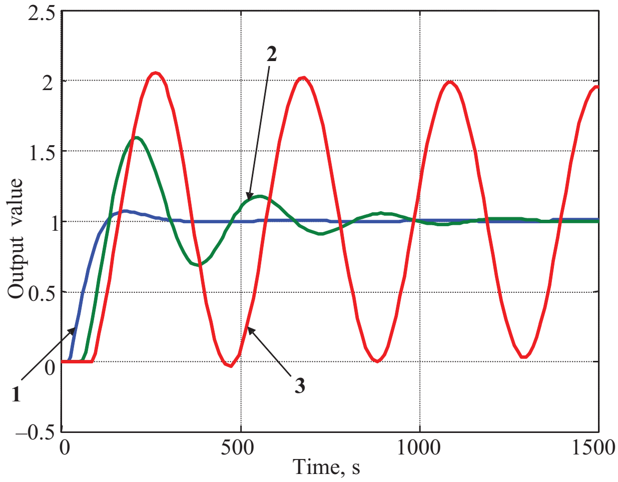

Fig. 5. Transient process with different object Transport Delay D values: 1 – D = 20; 2 – D = 30; 3 – D = 40

Our studies verify that the gain factor and object time constant have weak influence on the system stability (Kuz'mickij, Kulakov 2010). At the same time transport delay modification in two or three times leads to unstable system behaviour in general.

To manage a separate class of objects with significant delay values the specialized management systems are being used.

If a time delay is introduced into a tuned up system, the gain must be reduced to maintain stability. The Smith predictor control scheme can help overcome this limitation and allow larger gains, but it is critical that the model parameters exactly match the plant parameters. An adaptive control system can be added to the Smith predictor to change the model parameters, so that they continually match the changing plant parameters (Marshall 1979).

This new system has good performance characteristics, but it tracks input signals with a time delay. In some circumstances it is possible to design time-delay systems that track predictable targets with no delay.

Currently the most common approach to reduce the data signal delay is Smith predictors utilization (Fig. 6). Transient process with the Smith predictor is presented in Fig. 7.

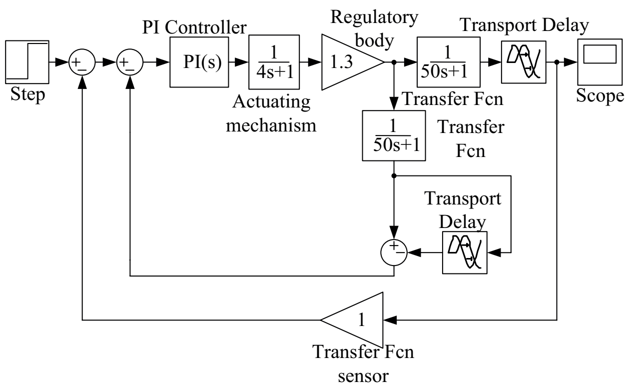

Fig. 6. Investigated system with Smith predictor

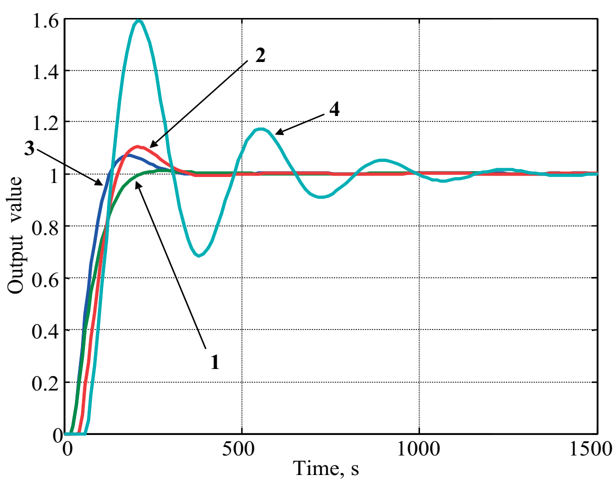

Fig. 7. Transient process gain of different investigated systems: 1 – system with Smith predictor, $D = 20$; 2 – system with Smith predictor, $D = 30$; 3 – system, $D = 20$; 4 – system, $D = 30$

Conclusions

1. To maintain stability of a control system after a time delay is introduced, the gain must be reduced.
2. The Smith predictor algorithm allows larger gains. However, it requires an exact matching of model and plant parameters.

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SISTEMŲ, KURIŲ SAVYBĖ VĖLINTI, TYRIMAS PATIKIMAM STABILUMUI NUSTATYTI

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Santrauka

Pristatomas sistemų, kurioms būdingas vėlinimas, tyrimas patikimam stabilumui nustatyti. Ištirta proceso parametrų įtaka visos sistemos stabilumui ir įvertinta Smito prognozės taikymo nauda numatant patikimas sistemas.

Reikšminiai žodžiai: sistema, vėlinimas, Smito prognozės.