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The stability margin of Smith controller on the system with Time-delay

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Abstract

Feedback controll is a method that modifies amount of the control to make the deviation of output smaller,accoding to the deviation between input and output. But time delay in signal path of control prevents amount of the from being modified with accuracy, even if using the difference between input and output at the same time, because the effect of control works immediately.

It's the smith method that is one of the famous method of controlling to the system with time delay. The smith method controlls the plant $G_r(s)e^{-sL_r}$ using a compensator with a minor feedback loop including a model $G_m(s) - G_m(s)e^{-sL_m}$ of plant. That eliminate the element of time delay that prevents the controlling from the characteristic polynomical, and the control system design can be achieved as normal linear control. However the error of modeling causes between the plants because of using the model of plant for control. The influence of the error that broke the system stability should be estimatied. Analysis of robustness is investigated to keep to the stability of the system against the error. Past reserch have discussed only the error of time delay.

This reserch mention robust stability for the error of the smith control system with time delay. We assumued that is the error for time delay and gain of system parameter. The foundation of stability sriteria to state predictive control by Bao showed the permited range of the error.we test permited range using an exercise.

At the beginning, Smith controling is described using state equation. The parametors for the controled object are (Ar, Br, Cr, Lr) ,and the parametors of the model are (A, b, c, L) . The system is stable in the study, and (A, b) are controlable and (A, c) is observable. The error of gain as a error of modeling is ϵ . The error of the delay time is

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ζ . The controled object is represented as $[A, b, (1+\epsilon)c, L+\zeta]$ using the parametor of the model.

When the characteristic polynomial without errors is $f(s)$, the one with parametor of errors can be expressed as $f(s) \times [1 + M(s)N(s)]$,where $M(s)$ is a transfer function of Smith controling without errors, $N(s)$ is a term related to errors, and $N(s)$ when no error.

Considering the charactoristic equation, $f(s)$ is stable with assumption. So, when error is coming, the stability of Smith controling is determined only using root of $[1 + M(s)N(s)] = 0$. Behaviors of $M(s)$ locus and $N(s)$ locus are observed, and are considered with the relation. Then the stability is estimated from $M(s)N(s)$ locus with the method of determining of Nyqist. As preparing, it is thought where the control becomes the stable limits. Then stable condition is calculated quantitavely.

And then applying the stable condition to the issue,the characteristic of response is calculated by the simulation and the validness is verified. When the mismatch is included only in the gain, the system changes unstable with the boundary as the gain margin, and the boundary becomes stable. It shows that the gain margin by stable distinction becomes the boundary of system stability. When the mismatch is included only in the delay time, the point being the delay time margin have various values by the number of the intersection point of the locuses of $M(s)$ and $N(s)$. If the number of the point is one, the system change into unstable with the boundary as the delay time margin. This means that the point of the delay time is the boundary of system stability. If the number of the point is three, the point of the delay time is never the stable condition. Then the points out of the range which become stable simultaneously are stable. The result shows that the range of the delay time margin calculated is very useful.

When there are some mismatch in the delay time and the gain, the stability range of interaction between the delay time and the gain is calculated on the ϵ–ζ domain by applying the procedure to various ϵ-value. The characteristic is verified with the simulation. Next, the stability range to the controlled subjects with various time constant is calculated on the ϵ–ζ domain. This indicates the transition of quantitative stable condition using the time constant. Then the transition is inspected. As the result, while the time constant is changing, the time delay margin is also changing but the gain margin is not. The controlled subject with small time constant and higher response is very sensitive to the mismatch of the time delay, and even very little mismatches make the system unstable. The controlled subject with large time constant makes the relation between the gain and the time delay strong. It is found that there is the possibility to make the system stable by the transition of the mismatch of the gain for the large mismatch of the delay time which is difficult to treat.

Using the stable condition can analyze the interaction of the stability of the mismatch between the gain and the delay time.