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Effect of various delay approximations on Hay controller performance

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ABSTRACT

Controllers are designed based on Hay tuning technique for a selected delayed integral process model. Different approximations of time delay is performed for the selected process model prior to designing controller. The designed controllers are analyzed for the set point tracking and important steady state and transient responses are compared to decide the optimal controller.

Keywords: controller design, process delay, process model, approximation

INTRODUCTION

In process control design, process dead time makes the process complicated to control and using standard response techniques. Many dynamic processes may involve in any given process and the process may be enviable to control all the dynamic response. Most of the times, for an industrial process, exact process is not known.

Model identification technique is used to estimate an approximate process model from the known input and output data. This technique is called bump test or step test. Although the model so obtained is not perfect but its behavior is near to that of the actual process. The response resembles with the known response of an established known system. This response generally includes a dead time component as the response starts little late after the excitation input is given.

In the real plant environment, the controller must be designed to handle a variety of non-ideal process conditions. Most processes are non linear, in many cases the process output and measurements are influenced by transportation lag. Most plant control requires multiple loops to control multiple outputs given multiple inputs. In most situations, these loops will interact. One common example is a chemical reactor in which the reaction rates depend on temperature and composition. In this situation, both temperature and composition are affected by level or flow control. Temperature and composition also interact with each other.

There are a number of common approaches that are used to handle multiple, interacting loops, depending on the situation. One approach to reducing the coupling between loops is through the optimal choice of loop variable pairs. A second approach is through formal loop decoupling

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techniques. The problem of optimal pair selection and loop decoupling becomes particularly vexing as the number of variables increases.

The reason that a process containing significant deadtime is difficult to control is that information is delayed in getting around the loop. The controller is responding to the state of the system as it was at some time in the past and has no knowledge of what the process is doing at the present time. This requires the controller to correct errors to avoid instability.

Setting up the controller to fit stability requirements and then simply accepting that response will be practical as long as the ratio of the delay to the dominant time constant is not too large and the control requirements are not stringent. The decision of whether to use this approach requires engineering judgment. If the cost of better but more complex control would be higher than the benefits, then PID control may be used.

If it is possible to detect and measure the disturbances before they enter the control loop. The feedforward controller cancels the disturbance as it enters the system so that the deadtime in the feedback loop doesn't matter. There are two drawbacks to this approach. First, the measurement of the disturbance may be difficult and expensive, or its measurement may not be possible at all. Second, it requires a reasonably accurate model of the system. Feedforward control is often practical and can be very useful in many situations in addition to deadtime problems.

It is not possible to measure the response of the system before the response occurs. A model of the process which does not contain any delays. If the model is accurate, then the model output will be a prediction of what the system output will be after the delay time has passed. The controller can then base its action on the model prediction and avoid the difficulties of the deadtime. There are many ways to implement this idea. One of the early methods of using model prediction to handle deadtime with delay compensator.

The system under consideration is modeled as IPDT model as the response of the system resembles with that of the pure integrating model response which is delayed by small amount.

This delay in the system is to be handled tactfully, as including this in the system may lead to anticipatory action in overall transfer function. Better results may be obtained if the delay element is approximated by some equivalent function. Although the response will little deviate but it will remain closed to that of original process.

Identifying the process transfer function is the first step to any analysis of dynamics and control. There are two approaches possible to derive the process transfer function, analysis of first principles and in-plant experiment. The analytical approach requires modeling the process dynamics from first principles and developing the differential equations which define rates of change of the particular process. In most cases, the resulting models are nonlinear and fairly complex. Such models are usually not suitable for control analysis directly, as this can only be done with any degree of ease using linear transfer function models. These nonlinear differential equations must be linearized about the operating point in order to make them suitable for control analysis.

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The experimental approach is used and it usually involves putting the loop on manual and doing a bump test. A bump test involves making a small step change in the Controller output and recording what happens to both the process and manipulated variables. To analyze such a bump test manually requires a certain skill, include an understanding of how simple, low-order transfer functions behave.

Integrating plants are very often meets in chemical industries. The control tuning is simple if the disturbances are presents in its output. And if the disturbances are in its inputs then the control tuning is difficult and controller with an integrating component must be used.

IPDT Model is represented by

$$G(s) = K\frac{e^{-s\tau d}}{s} \qquad (1.1)$$

Where K represents process gain, d represents delay time.

METHODOLOGY

An integral delayed process model is selected and its time delay is approximated by different approximation methods namely Taylor's direct, Pade I approximation and Pade II approximation. After approximating the time delay, the PI controllers are designed for the different models with the help of Hay tuning method. Step responses are then compared for important time response characteristics and analyzed for finding the best approximation method for the selected process.

RESULTS AND DISCUSSION

The step response of modified process and actual process for Taylor's model is shown in fig. 1. There is very less change in all time specification for actual model and modified model.

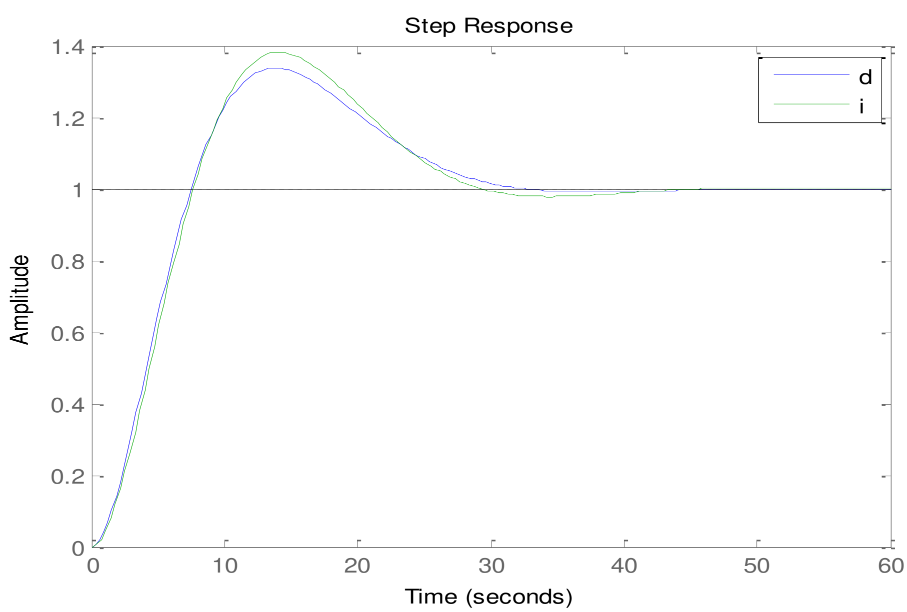

Figure1: step responses for Taylor's approximation

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The step response of modified process and actual process for Pade's I order model is shown in fig. 2. There is a slight change in rise, peak and settling time and large variation in peak overshoot.

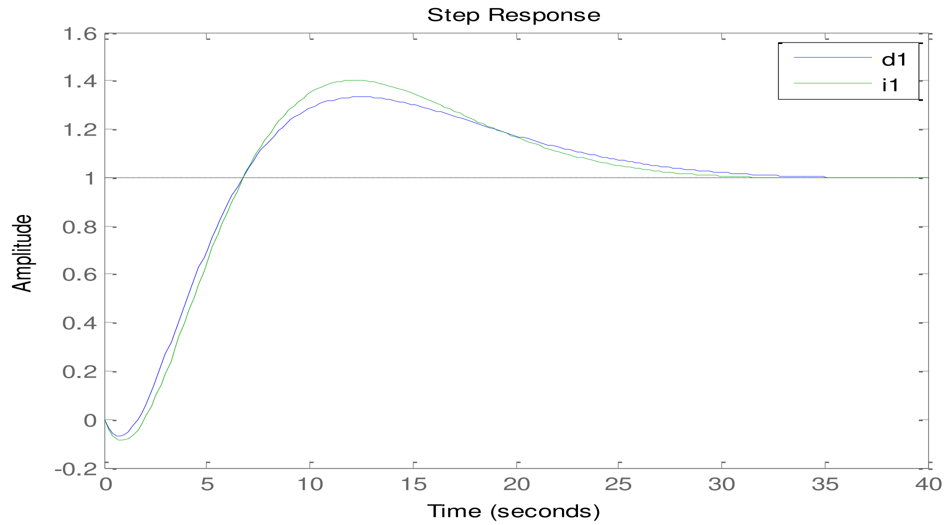

Figure 2 simulation result for Pade I order approximation

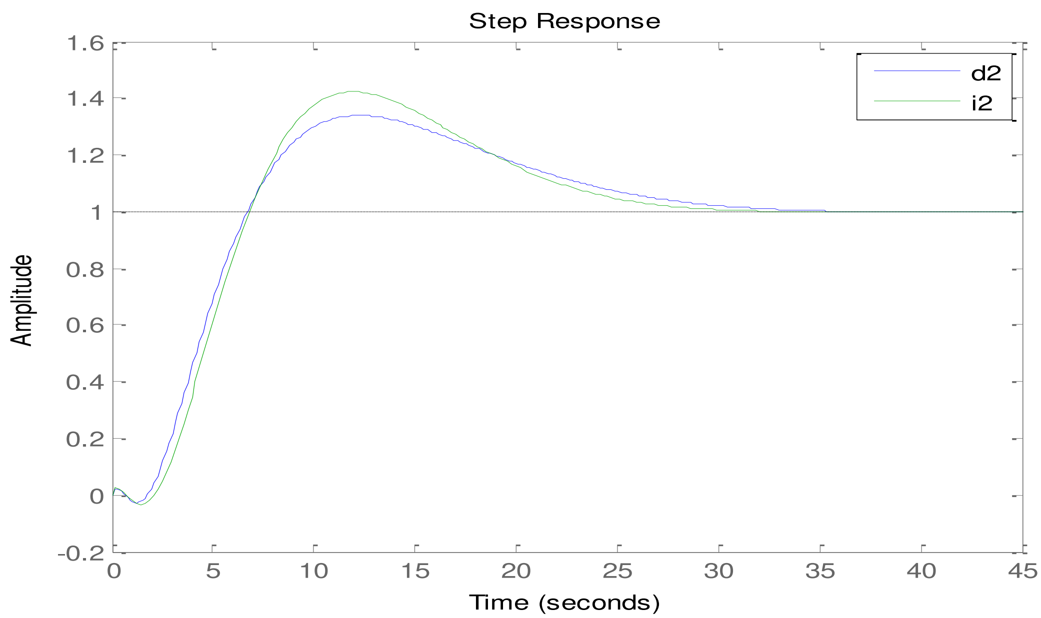

Figure 3: simulation result for Pade II approximation

The step response of modified process and actual process for Pade's II order model is shown in fig. 3. Table 1 indicates all the response characteristics values in systematic way.

Table 1: table for comparative analysis of all approximations for Hay tuning techniques

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Approxi-mation technique	Tr(sec)	Tp(secs)	Ts(secs)
Taylor's	5.1	14	29.3
Pade I	3.9	12.6	30
Pade II	3.6	12	30.3

CONCLUSION

It is evident that rise time is least in case of Pade II approximated model. Peak time is minimum also for Pade II approximated model. Settling time is minimum for Taylor's series approximated model. Overall Pade II approximation model gives best transient response but with little compromise in steady state response.

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