TUNING FEEDBACK CONTROLLER WITH THE ULTIMATE METHOD

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Abstract

A feedback control system is of little value if it is improperly tuned; the analogy to an improperly tuned automobile is instructive. It is important to have an understanding of how the controller in a feedback control system should be tuned. One of the all methods for tuning feedback controllers was the ultimate method proposed by Ziegler and Nichols. The term ultimate was attached because it is use required the determination of the ultimate gain (sensitivity) and ultimate period for the loop.

Keywords: tuning, control.

1. Introduction

A feedback control system is of little value if it is improperly tuned, the analogy to an improperly tuned automobile is instructive. It is important to have an understanding of how the controller in a feedback control system should be tuned, For any feedback control system, if the loop is closed (if the controller is on automatic), we can increase the controller gain and, as we do so, the loop will tend to oscillate more and more. As we continue to increase the gain further, we will observe countinuous cycling or countinuous oscillation in the controlled variable. This is the maximun gain at which the system may be operated before it becomes unstable, this is the ultimate gain. The period of these sustained oscillations is the ultimate periode. If we increase the gain further, the system wil become unstable.

2. Tuning a Controller

The need in tuning a controller is to determine the optimum values of the controller gain $K_c$ (or proportional band PB), the reset time $T_r$ (or the reset rate as repeats per minute), and the derivative time $T_d$ The adjustment of this tuning parameters on feedback controllers is one of the least understood and most poorly practiced-yet extremely important-aspects of automatic control theory.
Problems, What is a good control?
The first problem encountered in tuning controllers is to determine what good control is and, as might be expected, it does differ from one process to the next. The most common criterion employed is to adjust the controller so that the system’s response curve has an amplitude ratio or decay ratio of one quarter means that the ratio of the overshoot of the first peak in the process response curve to the overshoot of the second peak is four to one.
Basically, there is no direct mathematical justification for requiring a decay ratio of one quarter but it represents a compromise between a rapid initial response and fast line-out time. In many cases, this criterion is not sufficient to specify a unique combination of controller setting, i.e., in two mode or three mode controllers there are an infinite number of settings which will yield decay ratio of one quarter, each with a different period. This illustrates the problem of defining what constitutes good control.
In some cases, it is important to tune the system so that there is no overshoot; in other cases, a slow and smooth response is desired; some cases warrant fast response and significant oscillations are no problem.

3. The Tuning Concept
The feedback controller is only one piece of hardware in the entire loop; there are many other hardware items connected to form the balance of the loop. For the purposes of adjusting the feedback controller, it is convenient and sufficient to view everything else within the feedback loop as being “one big lump”. Actually, this is the way in which the feedback controller sees the balance of the loop.

4. Closed-Loop Tuning Methods
Techniques for adjusting controllers may be classified as either open loop or closed loop methods. One of the first methods proposed for tuning feedback controllers was the ultimate method proposed by Ziegler and Nichols.
To determine the ultimate gain and the ultimate period, the following steps:
1. Tune out all the reset and derivative action from the controller, leaving only the proportional mode, set $T_i$ equal to infinity and $T_d$ equal to zero.
2. Maintain the controller on automatic.
3. With the gain of the proportional mode of the controller at some arbitrary value, impose an upset on the process and observe the response. On easy method for imposing the upset is to move the set point for a few seconds and then return it to its original value.

4. If the response curve from step 3 does not damp out, the gain is too high (proportional band setting to low). The gain should be increased (proportional band setting should be increased) and step 3 repeated.

5. If the response curve in step 3 damps out the gain is too low (proportional band is too high), the gain should be increased (proportional band setting should be decreased) and step 3 repeated.

The ultimate gain and the ultimate period are then used to calculate controller setting. Ziegler and Nichols correlated in the case of proportional controllers that a value of operating gain equal to one-half of the ultimate gain would often give a decay ratio of one quarter, and they therefore proposed a tuning rule of thumb for proportional controller:

$$K_c = 0.5 \ S_u \ ...........(1)$$

By similar reasoning and testing, the following equations were found to represent good rules of thumb for controller settings for more complex controllers.

Proportional plus reset:

$$K_c = 0.5 \ S_u \ ...........(2)$$

$$T_i = \frac{P_u}{1.2} \ ...........(3)$$

Proportional plus derivatif:

$$K_e = 0.6.S_u \ .........(4)$$

$$T_d = \frac{P_u}{8} \ .............(5)$$

Proportional plus reset plus derivative:

$$K_e = 0.6.S_u \ .........(6)$$

$$T_i = 0.5.P_u \ .........(7)$$

$$T_d = \frac{P_u}{8} \ .............(8)$$
The above equations are empirical and exceptions are inherent. They generally are intended to achieve a decay ratio of one-quarter.

5. Temperature system with ultimate control

For a temperature control system whose ultimate sensitivity $S_u$ is 0.4 psi/°C and ultimate period is two minutes.

To determine settings for various controllers using the Ziegler-Nichols ultimate method yield,

Proportional:
$$K_c = 0.5.S_u = 0.2 \text{ psi/°C}.$$ 

Proportional plus reset:
$$K_c = 0.45.S_u = 0.18 \text{ psi/°C}$$

$$T_i = \frac{P_u}{1.2} = 1.67 \text{ min}$$

Proportional-plus-derivative:

$$K_c = 0.6.S_u = 0.24 \text{ psi/°C}$$

$$T_i = 0.5.P_u = 1.0 \text{ min}$$

$$T_d = \frac{P}{8} = 0.25 \text{ min}$$

6. Summary

There are literally scores of different tuning techniques available and they vary considerably in philosophy and implementation. Generally speaking, they vary in terms of their inherent definition of good control, whether they are open loop or close loop, how complex they might be mathematically, etc. Quite often, they give widely varying results. It is virtually impossible to say that one technique is clearly superior to all others. The ultimate gain is the maximum allowable value of gain (for a controller with only a proportional mode in operation) for which the close loop system is stable.

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