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Feed forward and Ratio control

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ABSTRACT
the Feedforward and Ratio control is one of the control systems that improve the performance of industrial processes in the event of a disturbance. Which enhances access to high quality products. This paper deals with the methods of designing and adjusting the strategies for controlling Feedforward and Ratio control, the field of use, and how to adjust the static Feedforward compensators, as well as adjusting the dynamic Feedforward compensators

Keywords – Feed-forward control, Ratio control**,** tunning**,** static, dynamic, compensator

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I. INTRODUCTION

In industrial processes, some processes are more controllable than others, and the variables that measure the uncontrollability of the process are the dead time variable and the time constant variable for the process to be controlled. If the ratio between the two variables is high, one or greater. The feedback controller cannot prevent disturbances from causing the variable to be controlled to deviate from the desired value. In this case, performance can be improved by following feedforward control strategies. These strategies are based on measuring disturbances and calculating the variable to be controlled. In theory, full process control is accessible unlike feedback controller which depend on the presence of errors. Feed-forward controllers need to design a process model with high accuracy. This model contains the effects of both the disturbances and the treated variable affecting the controlled variable. All disturbances must be measured and compensated. disturbances that cannot be measured or have a weak effect on the variable to be controlled can also be compensated by adding feedback pruning such as ambient conditions. Compensation can be defined simply as the ratio between two signals, and it can also require calculations that include the controlled variable and the processed variable. Using a simple delay unit, the dynamics of the process can be compensated. which we will discuss later in this paper. By comparing the feed-forward control with the feedback, the advantages of the feed-forward control are clear. The following figure shows the block diagram of the feedback control loop.

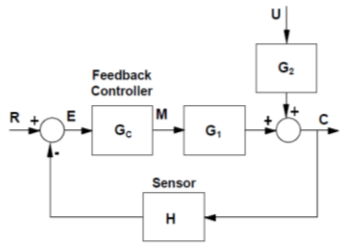

Fig: 1. Block Diagram of feedback control loop

The controller is the main component of a control system or program that uses algorithm. Adjusting the feedback controller is done by trial and error, so you do not need to design a detailed model of the processes to be controlled, unlike the feedforward controller. The integration effect of the feedback controller helps in calculating the output value of the feedback controller required to keep the controlled variable at the desired value. In addition to these highly desirable properties, there are two undesirable properties, when disturbances occur, the controlled variable deviates from the desired value before a correction from the controller occurs causing the controlled variable to oscillate around the desired value. These problems have a significant impact on the processes to be controlled, disrupting the production process, and causing multiple shutdowns and unwanted losses. To treat these problems, feed-forward organizations are used. The control of the feed-forward controller can be illustrated with a block diagram as follows.

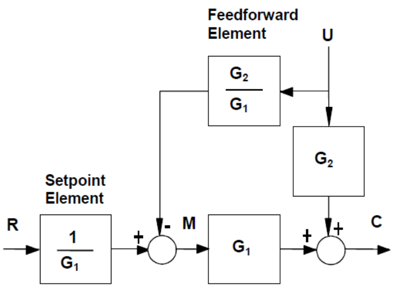

Fig: 2. Block Diagram for feed-forward control

The feed-forward control is based on the disturbance's measurement rather than the controlled variable. As soon as the disturbance enters the system, corrective action is started to prevent any deviation of the controlled variable from the desired value. The control of the feed forward also requires an accurate model of the process and its dynamics as well as an accurate compensation for all possible disturbances.

Feedforward-Feedback Control.

Practically, not all disturbances affecting the controlled variable can be measured. This system depends on the disturbance that can be measured and that have a significant effect on the controlled variable, but the disturbance that cannot be measured or have a low effect are manipulated by the feedback trim to the feed-forward element.

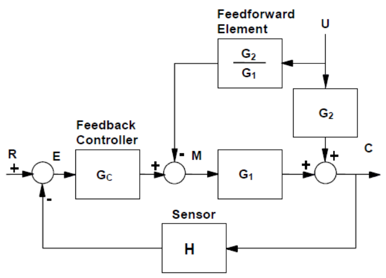

Fig: 3. Block Diagram for feedforward feedback control

Figure 3 shows the block diagram of the feed-forward feedback control system. One of the requirements for the control of the feedforward is that each disturbance has a feed-forward element. Collecting the output of the feedback controller and the feed-forward element, as in the previous figure. handles the effect of disturbances, and therefore we do not need to adjust the feedback controller completely. The feed-forward feedback control system is characterized by the following:

- the feedback controller manipulated disturbances that are not important to measure and compensate.
- The term feedback trim is an essential part of the feed-forward controllers to compensate for any unmeasured disturbances or minor errors in the model designed for the process. the ratio control is simplest form of feed-forward control. It is formed in its simplest form by the ratio of two quantities.

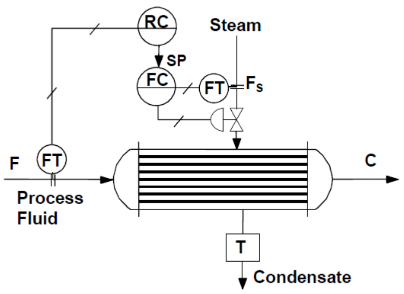

Fig: 4. Ratio Control of heat Exchanger

Figure 4 shows the ratio control system (the ratio between vapor flow and liquid flow) where the variable to be controlled is the fluid temperature, and the treated variable is steam, and the disturbance is the non-linearity of the control valve and the pressure differences and the latent heat of the steam and the vapor temperature. To maintain the temperature of the fluid, constant ratio must be maintained between the flow of vapor and liquid, when the flow of liquid changes, and when the temperature of steam remains constant. Some control engineers prefer to calculate the ratio by dividing the manipulated flow by the wiled flow and then controlling the ratio using feedback control, as in Figure 5.

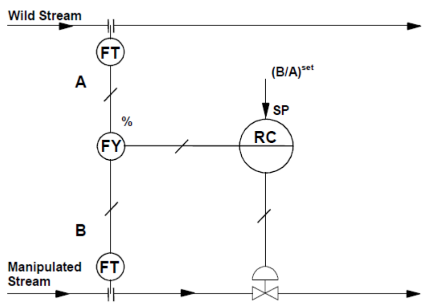

Fig: 5. Ratio control by feedback control

One of the disadvantages of this system is that it is a non-linear lube. The main disturbance in the process is the gust of flow, which is directly proportional to the gain of the feedback loop. Ratio control is used in computers, SCADA systems, and DCS., the output of ratio controller is the setpoint for flow controller, as in Figure 4.

I. Linear Feedforward controllers

the block diagram of feedforward system, as in Figure 2. The process output represents the set of disturbance responses and the processed variable as shown in the following equation.

$$C = G_1 * M + G_2 * U \qquad \text{Eq 1}$$

The value of M required to keep C equal to the desired value R is calculated from the equation

$$M=R(1/G1) - U(G2/G1) \qquad \text{Eq 2}$$

the equation above used to design element of feed-forward system that has the desired value R and the disturbance U as the input and the manipulated variable M as the output. Design equations for both the desired value component and the feed-forward control component according to Figure 2. The design equation for the desired value component is as follows:

$$G_S = 1/G1 \quad \text{Eq 3}$$

The design equation for the feedforward element is as follows:

$$G_F = G2/G1 \quad \text{Eq 4}$$

When a feedback trim is used, only the feed-forward controller necessary because the feedback controller replaces the desired value controller as in Figure 3. When the elements G1 and G2 are simply modeled as a first-order model plus dead time, you can build a feed-forward control system outside of the standard algorithms available in most business process control software. The front-end control unit consists of three components:

GF = (Gain) (Lead-Lag unit) (Dead time Compensator) Eq 4

Gain = K2/K1 Eq 5

Lead-Lag= (Lead of T1)/(Lag of T2) Eq 6

Dead time compensator = T02- T01 Eq 7

K1 = gain of G1 , k2 = gain of G2

T1, T2 = time constant of G1, G2

T01, T02 = dead time of G1, G2

the feedforward controller represented by eq.4 is derived from first-order process models, it is not necessary to use dynamic compensation limits that are of a higher order than the lead-lag. The use of a second-order compensator model with more variables may require more than one lead-lag. This would make it difficult to tune with few performance improvements compared to adjusting the performance of the lead-lag unit. the dead time compensator of Equation 7 is achieved only when the response time of the controlled variable due to the disturbance is longer than its response time due to the processed variable. Otherwise, correction must be started before the disturbance occurs, which is not possible. The dead time compensator can only be used if the lead-lag does not perform this function on its own. To implement the feed forward control system, the dead time compensator needs a digital instrument memory.

2. Tuning Linear Feed forward Controllers

In Equation No. 4, based on which the feed-forward regulators are built, only the process gain can be used without the rest of the other parameters, and therefore it is called static compensator. Gain can be adjusted automatically or manually. If the gain is incorrect, the controlled value deviates from the desired value and the system cannot be adjusted in the event of a disturbance. Thus, we need to adjust the gain until the controlled value equals the desired value. In the case of non-linear or complex operations, we need to add a feedback control system and have the integrative effect responsible for returning the controlled variable to the desired value whenever the process is disturbed. The gain of the feedforward system must be adjusted until the system stabilizes satisfactorily.

2.1 Tuning the Lead-lag Unit

One of the most important dynamic compensators is the lead-lag unit, which is an essential part of the feed-forward control system, which is usually in the form of a separate component or a module within the program if a computer is used. There are also two variables to be set, namely lag time, and lead time. To study the performance of this unit, a step type signal is entered as in Figure 6 or ramp as in Figure 7.

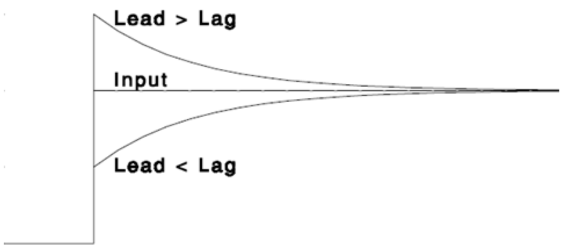

Fig: 6. Step Response of Lead-Lag Unit

in Figure 6, if the gain is equal unity, and the lead and lag times are greater than the other. The initial change in the output of this unit is always equal to the ratio of lead to lag. This ratio leads to stability of the process, excess of lead over lag leads to over correction and vice versa leads to partial correction.

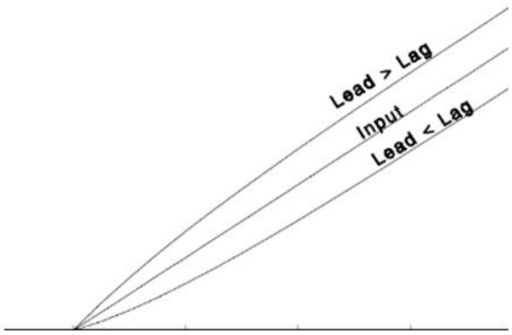

Fig: 7. Response Lead-Lag Unit to a Ramp

Figure 7 shows the response of the lead and lag unit to the ramp input, both for the lead scenario longer than the lag and for the lag scenario longer than the lead, assuming the gain equals unity. The figure shows where the lead and lag come from: After a transient period, the output of the lead and lag unit presents the input ramp by the difference between lead and lag or lags by the difference between lag Looking at Figure 7, we notice the effect of the ramp input signal on the lead-lag unit in the event that the lead is ahead of the lag or vice versa with a gain equal unity. The output of unit is ramp, either ahead or lagging by time difference between lead and lag. When you think about the process's response to the step function and the ramp function, Setting the lag and lead unit becomes very easy. First: We determine the quantity that leads or lags correction because of the disturbance. Second: The amplification or attenuation of changes in the measured disturbance depends on the amount of lead to lag ratio. If the disturbance represents interference, we choose the amount of the ratio (not more than 10) that works to reduce the disturbance to get rid of the interference. To simplify unit tuning, the lead time is zero when a leg is required but the reverse cannot happen. which simplifies the task of tuning.

2.2 Tuning the Compensator of Dead time unit

n this paragraph we define when to use the dead time unit and how to make the appropriate correction. We use the dead time compensation module only if it is much longer than the lead-lag delay time. The appropriate patch is stored in memory at each update of the control and is retrieved later when the unit is set.. The dead time compensator output is equal to its N input samples previously:

$$Y_k = X_{k-N} \qquad \text{Eq 8}$$

Where N is the number of samples for the dead time, given that the gain is equal to one.

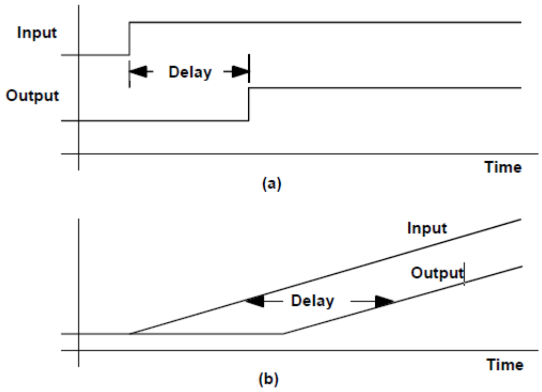

Fig: 8. Response Dead Time Compensator: (a) to a Step, (b) to a Ramp

Figure 8 shows a diagram of the dead time compensation responses to the step function and the ramp function. The response of this unit depends on the appearance of the process output lag when there is a change in the input or when there is a lag without a lead in relation to the immediate response of the feed-forward control system. It is easy to adjust the unit because there is only one variable in it. It is also necessary to adjust the parameters of the feedback control system to eliminate the effect of dead time, which always works to destabilize the process to be controlled, before using the unit in the feedforward control system.

Ⅲ . Conclusion

From the previous section we can decide the outline of the design procedure for feedforward control system as flowing:

1- Determine which variable should be controlled and at what point it should be set. Controlled variables must equal the setpoint. The set point is adjustable by the operator and not fixed. c

2- Identifying measurable disturbances. What is the amount and speed of each disturbance? How much will it cost to measure each disturbance.

3- Determine the variable treated by the feedforward controller. When using it in series with the feedback controller, the manipulated variable must be used as a desired value for the feedforward controller.

4- Equations of the variables must be written in a simple way. Calculate the manipulated variable from the measured disturbances and from the variable to be controlled. Equations are programmed for computer execution.

5- The list of measured disturbances must be re-evaluated with the calculation of the expected change and its effect on the controlled variable. If the disturbances are difficult to measure and have a significant impact, you can modify them with a feedback trim.

6- Collecting the unknown and unmeasured disturbances as much as possible and adjusting the feedback controller to treat these disturbances. This is done by making the output of the feedback controller as a desirable value for the front feedback controller. This is considered in the design equations.

7- The compensators we need must be determined and how they can be included in the design equations, and a compensator must be developed for each measured disturbance.

8- A block diagram should be drawn for the feedforward controller, explaining the arithmetic operations and the relationships between the different signals.

9- The feedforward controller is programmed into a computer, or a distributed control system is configured.

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