

Open-loop Process Identification: Reformulation of Response Rate Calculation

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Abstract

This paper is to show an alternative way of analyzing open-loop response of a process. In the conventional tangent method, the process response rate is obtained by drawing a tangent line at the steepest point of the response curve and calculating the response rate of the tangent line. This analysis is normally performed on a chart paper or on a hard copy of a DCS. A new proposed technique transforms the process response rate calculation into a trigonometric function. A protractor will be used to measure the angle made between the base line of past steady-state level and the tangent line. This technique simplify and reduce the steps in analyzing the process response rate. Frequent analysis can be done faster and the analysis can be performed directly on console as compared to the existing method.

Key words: PID Tuning, process control, open loop process identification, tangent method.

Introduction

One of the most popular conventional method used in open loop process identification is the tangent method. This method provides two most vital information used to calculate the optimum PID values; namely, the process dead time and the process response rate. The data extraction from the tangent method requires a simple step-input's open loop test; by firstly, stabilizing the process in manual mode; secondly, making a small change to the controller's output; and finally, recording the response of the process variable until the process reaches a new steady state level. Because of the simplicity in performing this open loop test and a straight forward data extraction from the tangent method, a wide range of students competency (such as certificate, diploma and degree levels) can be taught in the process control class and laboratory.

The usual procedure of recording the response curve is by using a chart recorder; whereby, the chart recorder and the controller are close to each other. This is the practice normally being taught to the students in the laboratory. However, in industries where the chart recorder is not available close to the distributed control station (DCS), a print out of the response curve is obtained from the DCS itself.

In teaching process control, the authors observed that the students were having some difficulty analyzing the process rate for fast processes such as level, flow and pressure either on a chart paper or on a DCS. The difficulty arose from the relatively very steep (80°-85°) tangent line on the chart paper. On the other hand, the scales of the DCS for the response (measurement) and the time scales are hard to read. This paper intends to reformulate the process response rate calculation which will ease the process rate analysis on the chart paper, DCS, paperless recorder, monitor or any other console.

Reformulation of Response Rate Calculation

In the tangent method, to calculate the optimum PID, a tangent line should be drawn at the steepest point of a process response curve. The process response rate is the process change (ΔPV) per change in time (Δt) as shown below.

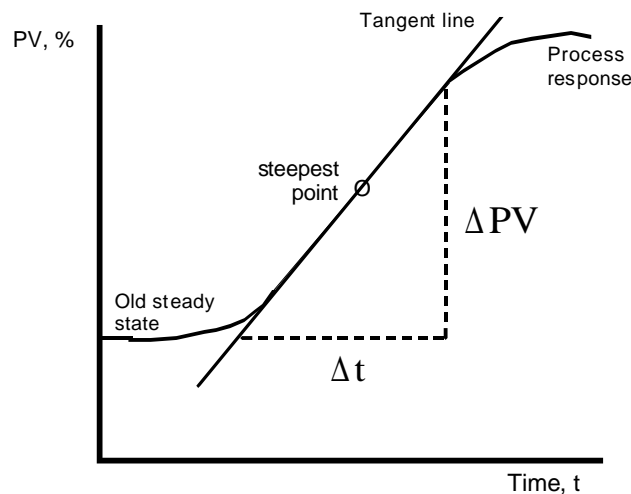


Figure 1: A tangent line is drawn to an open loop response curve.

Response rate is the slope of the open loop response curve. Therefore,

$$slope = \frac{\Delta PV}{\Delta t} \quad \dots\dots\dots (i)$$

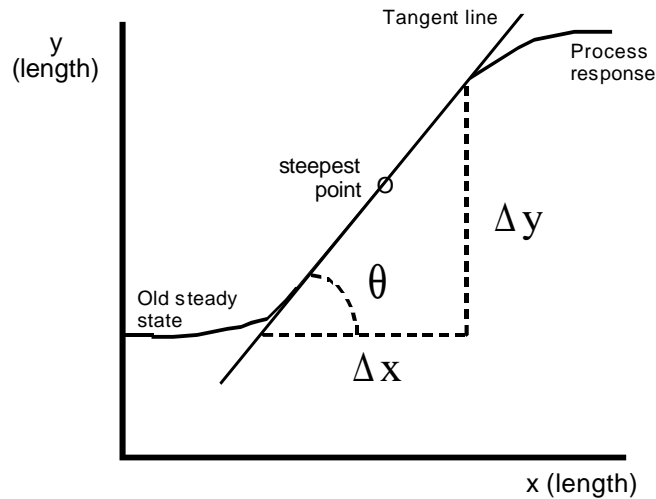


Figure 2: Changing the scale in x and y-axis of the open loop response curve.

The response curve as in Figure 1 can be analyzed and viewed with different perspective as in Figure 2. Then, the response rate would be,

$$\text{slope} = \frac{\Delta y}{\Delta x} \quad \dots\dots\dots \text{(ii)}$$

Combining equation (i) and (ii) together,

$$\frac{\Delta PV}{\Delta t} = \frac{\Delta y}{\Delta x} \quad \dots\dots\dots \text{(iii)}$$

But equation (iii) is not dimensionally correct. Δy and Δx have units of length; while, ΔPV and Δt have units of % and time, respectively. Hence, a conversion factor must be added to the right hand side of equation (iii).

$$\frac{\Delta PV}{\Delta t} = \frac{\Delta y \text{ (\% / length)}}{\Delta x \text{ (time / length)}} \quad \dots\dots\dots \text{(iv)}$$

where,

(% / length) is the conversion factor at the response (PV) scale

(time / length) is the conversion factor at the time (t) scale

Finally, recognizing that $\Delta y / \Delta x = \tan \theta$, equation (iv) transforms into

$$\frac{\Delta PV}{\Delta t} = \tan \theta \frac{\text{(\% / length)}}{\text{(time / length)}} \quad \dots\dots\dots \text{(v)}$$

The right hand side of equation (v) provides an alternative means of analyzing process response rate.

Applications

Based on equation (v), to calculate the process rate, the angle of the tangent line must be measured using a protractor, while the conversion factors for the response's and time's scales will be measured using a ruler. The conversion factors are easily read between two known values, which are normally at the graduated marks or gridlines. This technique is applicable to a chart paper or any other display console. Application examples are provided in the Appendix.

Another merit of this technique is that the calculation of process rates at several points will be made easier, shorter and faster. The conversion factors are measured once, while at the selected points, are only needed to measure the angles.

Equation (v) can be merged with the process reaction rate equation i.e. the process response rate per controller output.

$$\text{reaction rate} = \frac{\text{process response rate}}{\text{controller output}} \quad \dots\dots\dots \text{(vi)}$$

$$\text{reaction rate} = \frac{\Delta PV / \Delta t}{\Delta MV} = \frac{\tan \theta}{\Delta MV} \frac{(\% / \text{length})}{(\text{time} / \text{length})} \quad \dots\dots\dots \text{(vii)}$$

Equation (vii) above can be used to calculate the optimum PID values as in Ziegler-Nichols's and Cohen-Coon's tuning rules.

The Appendix A.1 shows an application example of this new technique applied to a flow process. The flow response was recorded on a chart paper.

The Appendix A.2 is an example of a plot from computer console. In practical, a straight tangent line cannot be drawn at the console. However, a ruler can be placed on the console to act like a tangent line. Then, the angle made by the ruler - imating the tangent line - can be measured.

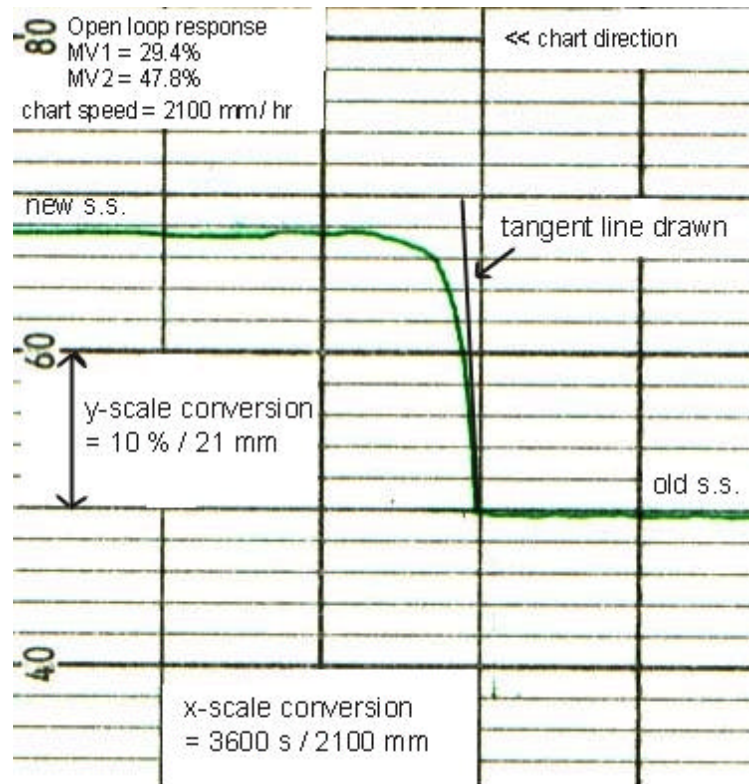
Concluding Remark

Performing open loop test is simple but extracting the data from the "small-sized" open loop response either on a chart paper or a DCS is tedious and laborious task. The new technique presented offers easier and faster calculation of process response rate. This technique enable student to acquire more skill on open loop process identification. Later, when the students work in the industries they will be well equipped with the task of process identification and control loop tuning.

References

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A.1 : Example of an application of the new method being applied to a chart paper

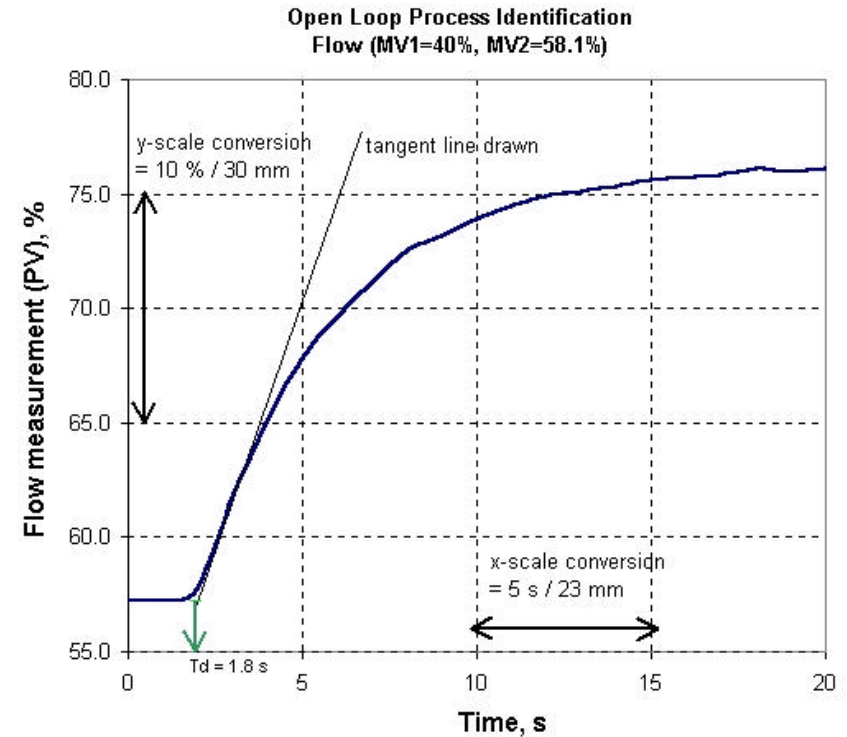


$$\theta = 86^\circ$$

$$\frac{\Delta PV}{\Delta t} = \tan 86^\circ \frac{10 \% / 21 \text{ mm}}{3600 \text{ s} / 2100 \text{ mm}} = 3.97 \% / \text{s}$$

Note: x-scale conversion = chart speed

A.2 : Example of an application of the new method. Data was captured using a paperless recorder and the curve was plotted using a spreadsheet.



$$\theta = 70^\circ$$

$$\frac{\Delta PV}{\Delta t} = \tan 70^\circ \frac{10 \% / 30 \text{ mm}}{5 \text{ s} / 23 \text{ mm}} = 4.21 \% / \text{s}$$