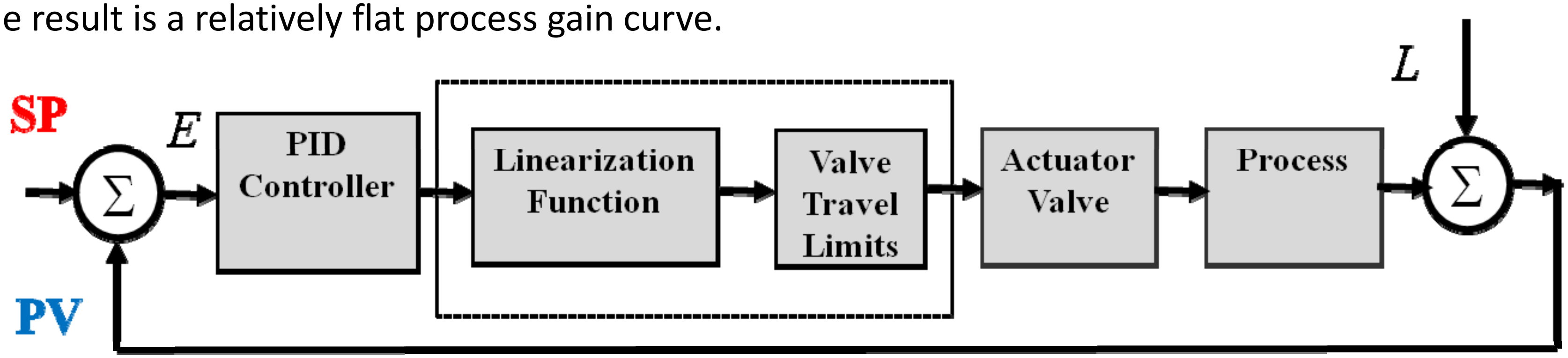
Opportunities for Output Linearization

- Highly non-linear process dynamics can severely degrade loop performance. For the majority of control loops, the tuning constants are based on the process dynamics measured at one operating condition . We hope that the tuning will ‘work’ over the entire operating range. All too frequently we get sluggish response in some operating regimes and fast/oscillatory response in others.
- Improper valve selection is frequently a source of non-linear process dynamics , resulting in an ‘installed’ process gain that varies substantially with valve position. In these cases Output Linearization should be considered as a means of compensating for the non-linear valve response.

Opportunities for Output Linearization

Overview - How does it Work?

Improper valve selection is frequently a source of non-linear process behavior, resulting in an 'installed' process gain that varies substantially versus valve position. In these cases Output Linearization should be considered as a means of compensating for the non-linear valve response. The controller output is passed through a linearization block that modifies the signal sent to the control valve. The linearization curve is essentially a mirror image of the installed process gain curve. The result is a relatively flat process gain curve.



Implementing the Strategy

- The first step is to define a best fit equation between the normalized process value (0 to 100%) and the controller output. The equation can be developed empirically (bump tests) or by developing a first principles hydraulic simulation. Developing a simulation requires more up-front effort but is an excellent platform for investigating a broad range of operating and design conditions.
- An output linearization equation is developed which is the mirror image of the normalized process value vs controller output equation. The linearized process dynamics are evaluated through field testing or simulator testing.
- Lambda tuning constants are calculated, typically based on the highest 'linearized' process gain. Aggressive tuning is possible since the process gain is relatively constant.

Opportunities for Output Linearization

Identifying Good Candidates for Output Linearization

Control loops that exhibit some or all of the following characteristics may be good candidates for an output linearization strategy.

- Fast, stable response is required over the entire operating range but the load/setpoint response is inconsistent, varying with valve position.
- There are apparent control dead zones at high or low valve positions
- The control valve is oversized but is occasionally required to operate near full open position
- The inherent valve flow characteristic is known to be incorrect for the application.

Potential Applications

- Recycle header pressure control loops fitted with an Equal Percentage control valve
- Dilution whitewater Header pressure control loops that manipulate a VFD
- Dryer Section differential control loops that manipulate a Thermocompressor
- Combustion Air Flow control loops with Quick Opening damper characteristic.

Benefits

The objective of the Output Linearization strategy is to linearize the process gain.

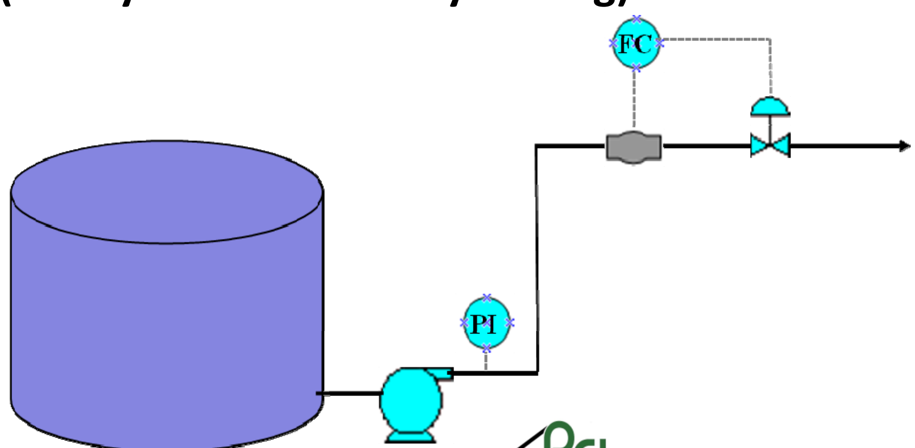
A primary benefit is that the controller response to process upsets or setpoint changes is relatively consistent over the entire operating range. More aggressive tuning can be safely installed since the process dynamics are relatively constant.

The benefits of this strategy are particularly high where there is a high degree of non-linearity and where fast, consistent speed of response is required to prevent production upsets or product quality losses.

Example

Flow Control Loop with Oversized Control Valve

(A very common survey finding)



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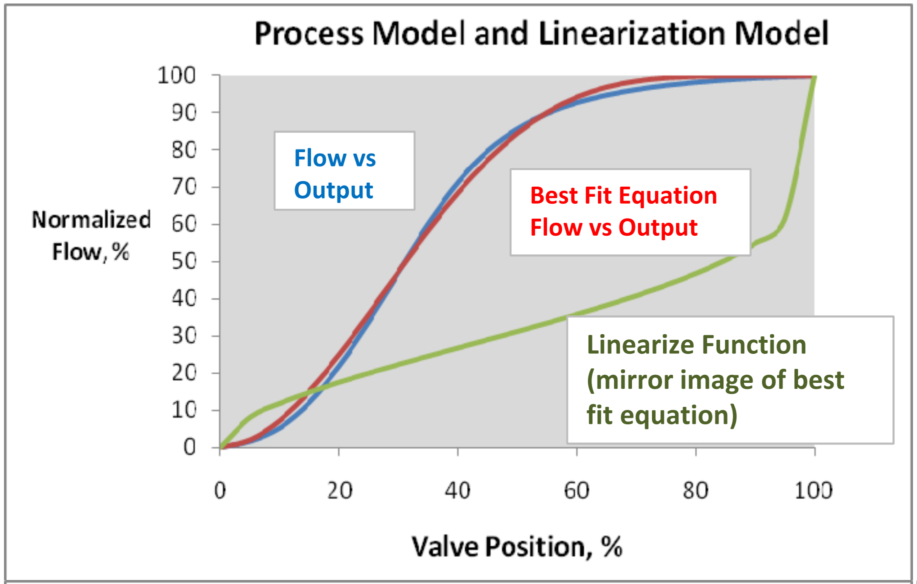
Opportunities for Output Linearization

Example - Flow Control Loop with Oversized Valve

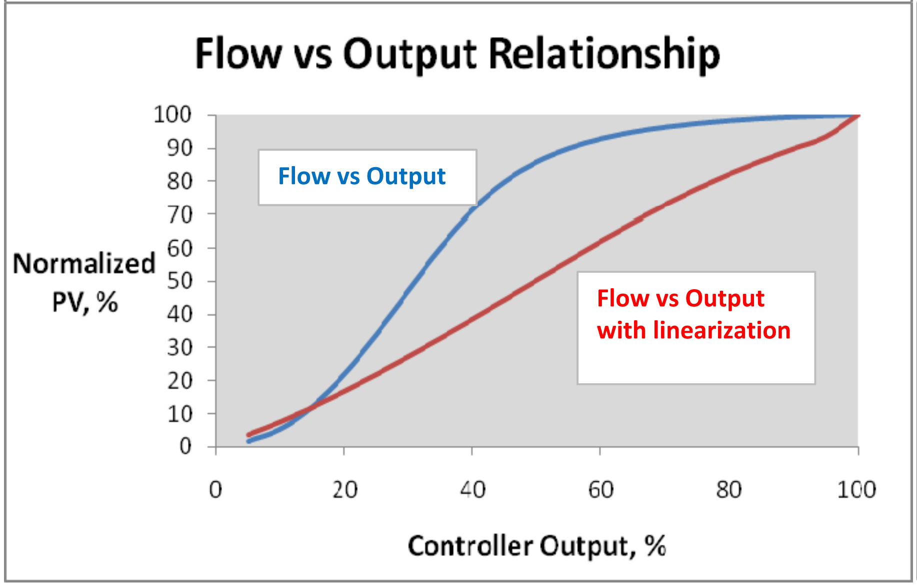


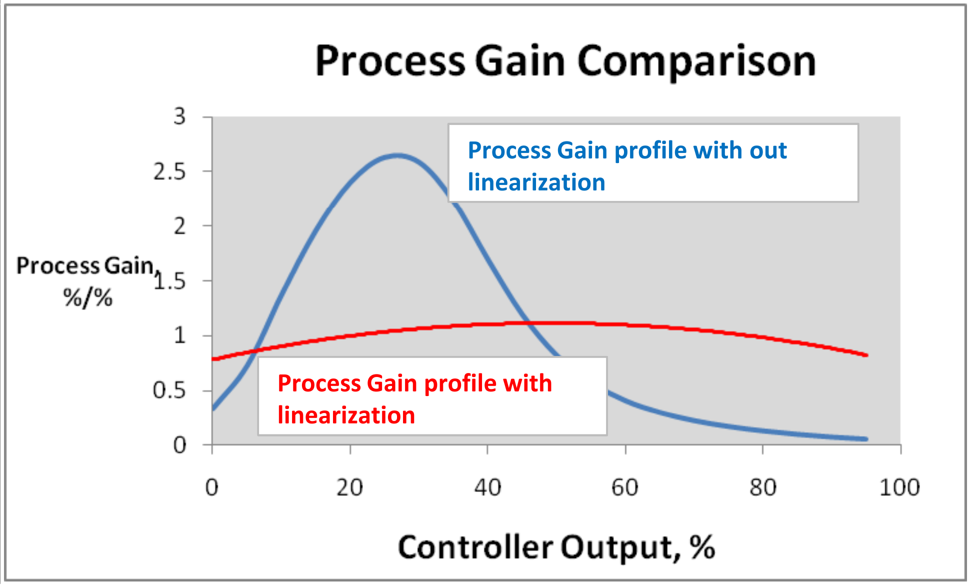
The key feature of the normalized Flow vs Output curve(left) is that the process response is very high when the valve is between 10% and 40% and very low from 50% to 100%.

The linearization function (green) is very strong between 100 and 90% output, moving the valve from 100% to 60%.

As shown below, the process gain versus output plot is relatively flat following linearization

The linearization function effectively "speeds up" controller response in regions where relative process gain is and "slows down" controller response in regions where the process gain is high.





Opportunities for Output Linearization - Quiz

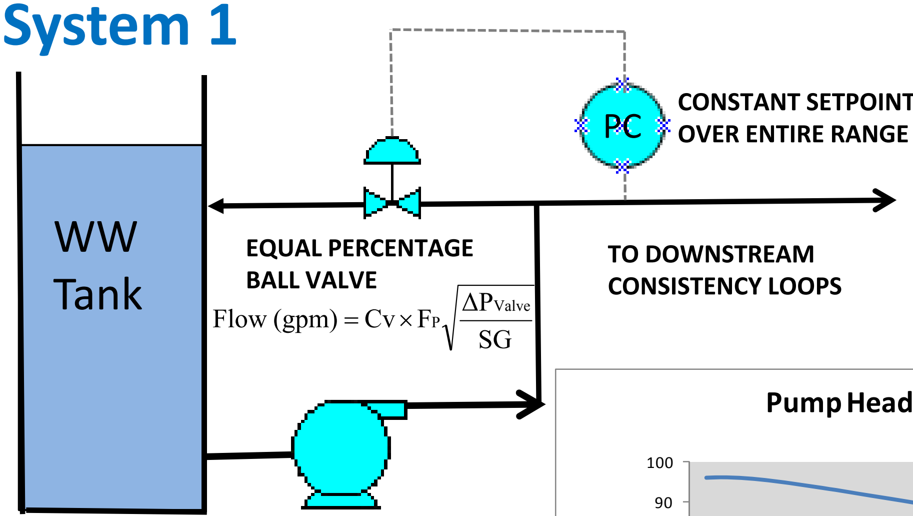
Process Description

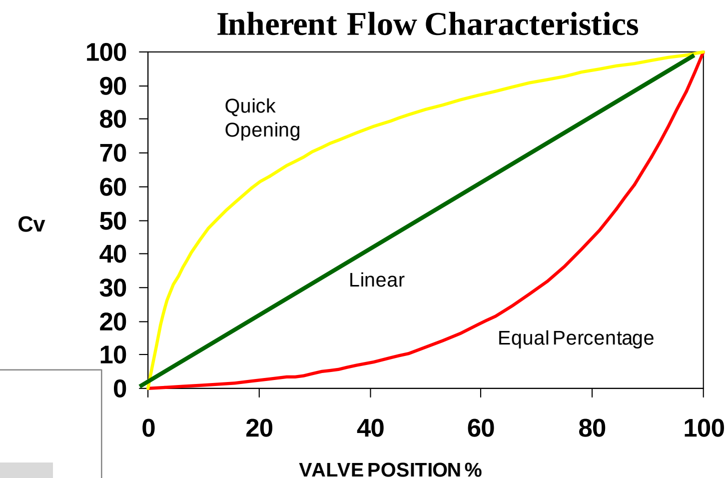
There are 3 dilution header pressure control systems shown below. This is an application where fast pressure response is required over a wide dilution flow range, primarily in order to stabilize downstream consistency loops.

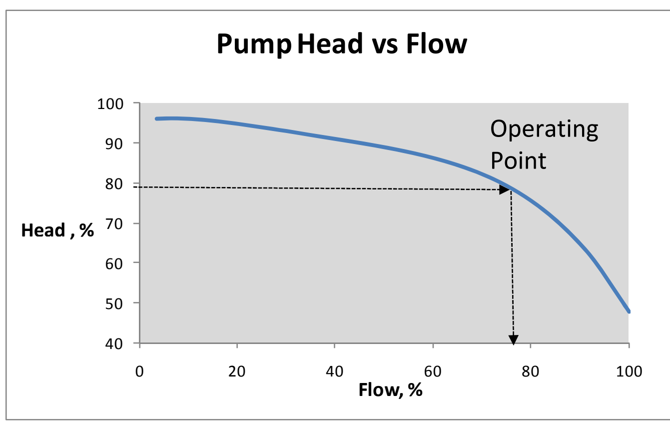
Evaluate each system in terms of the potential benefits of output linearization.

1. Sketch the shape of the normalized pressure versus output curve. Explain.
2. Sketch the shape of the process gain versus output curve.
3. Sketch the shape of the required 'Linearization curve'.
4. Identify the benefits / potential pitfalls of implementing the linearization strategy

System 1







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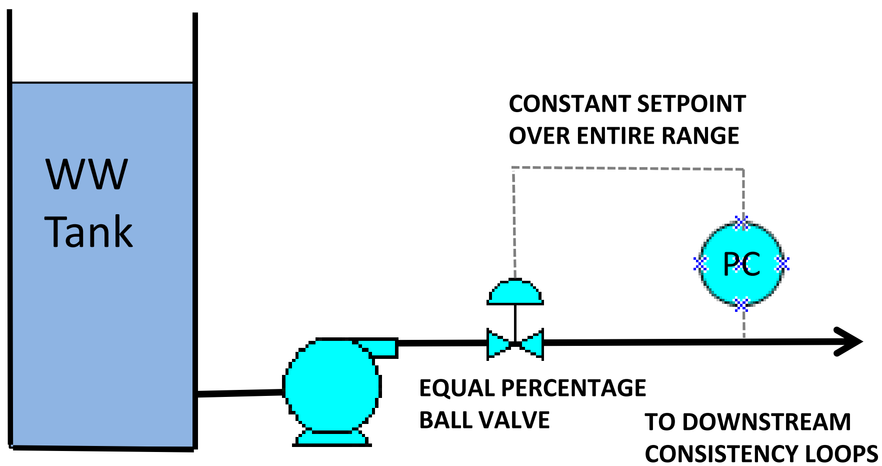
Opportunities for Output Linearization - Quiz

System 2



System 3