PID Controller Application in Pumping System

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Pumping systems

Basic types of pumping systems:

1. Level control system:
   Target: providing balanced filling/emptying of water tanks.
   Process variable is Actual Level (will not be discussed here).

2. Pressure boosting systems:
   Target: holding the desired pressure at the output of pumping system.
   Process variable is Actual Pressure.

   The pressure must be controlled in order to:
   
   a. Provide a desired flow under a desired pressure to the customer. The consumer’s equipment is designed for specific pressure. If the provided pressure deviates from expected value – the equipment will be damaged.

   b. Provide a normal operating conditions of the piping line and its equipment. In case if the piping line is overloaded (the pressure is higher than the rated pressure) – its lifecycle becomes shorter.
Pumping system, Pressure control

Most efficient way to control the pressure of the pump is to modify its speed. The pressure-speed dependency can be described by affinity law:

\[
\frac{H_1}{H_2} = \left( \frac{N_1}{N_2} \right)^2
\]

Where:
H – pump’s head \( \equiv \) pressure
N – speed of pump
index 1 represents the initial state
index 2 – next state.

Other pressure control techniques (like discharge throttling) are less efficient since they are accompanied with dissipation of energy.
The control system tends to keep pressure on a desired level. The speed of a pump is changing accordingly to Pressure-Setpoint relation to provide the desired pressure.

Pressure is a feedback signal from the system.
Setpoint is actually a desired pressure value.
Feedback comes from the pressure sensor.

Typically, the PID controller is responsible for the adjustment of the speed reference. The output of PID controller is a reference value for the speed controller.

Speed increases in order to bring the pressure to desired level.

Speed decreases in order to make the pressure lower.
Speed control of motor

Most pumps are built on basis of asynchronous motors.

Most efficient way to control the rotational speed of the asynchronous motor is to modify the frequency of its supply.

Other methods are utilizing the varying of windings resistances and are recognized as inefficient (since varying the resistance of windings is accompanied by dissipation of energy around the extra resistances).

The rotational speed of asynchronous motor’s shaft is expressed as:

\[ n_s = \frac{120 \times f}{p} \]

Where:
\( n_s \) – shaft rotational speed [rpm]
\( f \) – motor supply’s frequency [Hz]
\( p \) – number of motor’s poles

Variable speed drives (VSD) provide the varying of motor supply frequency.
Variable Speed Drive, Principle

Supply power line

e.g. 400 V / 50 Hz

Input converter:
Adopts the (AC1) input from the supply power line and rectifies it (DC)

Output inverter:
generates the output as a series of pulses emulating the sinus.
The period and width of pulses can be easily modified. It provides the varying frequency at the output.
**VSD: ABB, ACQ810**

- **Power range:** 1.1 – 400 kW.
- **Control unit** provides the PLC functionality. It provides the processing of inputs and control of motor’s supply.
- **Power unit** contains input and output converters.
- **Software:** Platform + special integrated functionality for pumping applications.
- **The VSD** is parameterized using DriveStudio environment (which is also used for monitoring).
VSD in Pumping system, Connections

In the current application, following connections were made:

1. Start/stop command comes from the DI1
2. Switching between 2 setpoints is made via DI2.
3. Feedback from the system comes from the pressure sensor – AI2

Values of both setpoints will be defined in the VSD’s parameters table.
Pressure sensor

Danfoss MBS 3000 - 2011 - 1 AB04

Is used as a current-output sensor.
Pressure range: 0 – 10 bar
Output current: 4 – 20 mA
Connections of PID

PID
- Speed reference [%]
- Speed control
- Output [%]

Pressure, Scaling
- Par 13.7: AI2 max [mA]
- Par 13.8: AI2 min [mA]
- Par 13.9: AI2 max scale [bar]
- Par 13.9: AI2 min scale [bar]

Pressure Setpoint
- Max output [%]
- Min output [%]

Setpoint
- Par 29.4: Setpoint 1
- Par 29.5: Setpoint 2

DI 2
- 1
- 1.5
- 100
- 0

Par 27.12: PID gain
Par 27.13: PID integr time
Par 27.14: PID deriv time

Par 27.18: PID maximum [%]
Par 27.19: PID minimum [%]
## Parametrisation

### Analogue Inputs

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>A12 max</td>
<td>20.000</td>
<td>V</td>
</tr>
<tr>
<td>A12 min</td>
<td>4.000</td>
<td>V</td>
</tr>
<tr>
<td>A12 max scale</td>
<td>10.000</td>
<td></td>
</tr>
<tr>
<td>A12 min scale</td>
<td>0.000</td>
<td></td>
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</table>

### Process PID

<table>
<thead>
<tr>
<th>Name</th>
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<tbody>
<tr>
<td>PID gain</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>PID int. time</td>
<td>2.00</td>
<td>s</td>
</tr>
<tr>
<td>PID deriv. time</td>
<td>0.00</td>
<td>s</td>
</tr>
<tr>
<td>PID deriv. filter</td>
<td>1.00</td>
<td>s</td>
</tr>
<tr>
<td>PID max. output</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>PID min. output</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

### Proact Set

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
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<tbody>
<tr>
<td>Act val 1/s</td>
<td>Act val 1/s</td>
<td></td>
</tr>
<tr>
<td>Act val 1/me</td>
<td>A12 scaled</td>
<td></td>
</tr>
<tr>
<td>Act val 2/me</td>
<td>Zero</td>
<td></td>
</tr>
<tr>
<td>Act val func</td>
<td>Act 1</td>
<td></td>
</tr>
<tr>
<td>Act max val</td>
<td>10.00 bar</td>
<td></td>
</tr>
<tr>
<td>Act unit sel</td>
<td>bar</td>
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### Setpoint Set

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>Setpoint 1/2</td>
<td>Setpoint 1/2</td>
<td></td>
</tr>
<tr>
<td>Setpoint 1/me</td>
<td>Int sel 1</td>
<td></td>
</tr>
<tr>
<td>Setpoint 2/me</td>
<td>Int sel 2</td>
<td></td>
</tr>
<tr>
<td>Intensel 1</td>
<td>1.00 bar</td>
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</tr>
<tr>
<td>Intensel 2</td>
<td>1.50 bar</td>
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</tbody>
</table>
Running

Setpoint became higher

Valve is abruptly closed

Valve is abruptly opened

Abnormal parameters were set to PID
Manual of ACQ 810 variable speed drive:

http://www05.abb.com/global/scot/scot201.nsf/veritydisplay/4d81c5ab343fac72c1257c2b003fe4bc/$file/EN_%20ACQ810_FW_Manual_D_A4.pdf