Subject: Using the PID Controller on the Commander S

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Revision History

Revision	Date	Revising Author	Comments
1.0	18/07/2022	JM	Initial Release

Summary of Contents

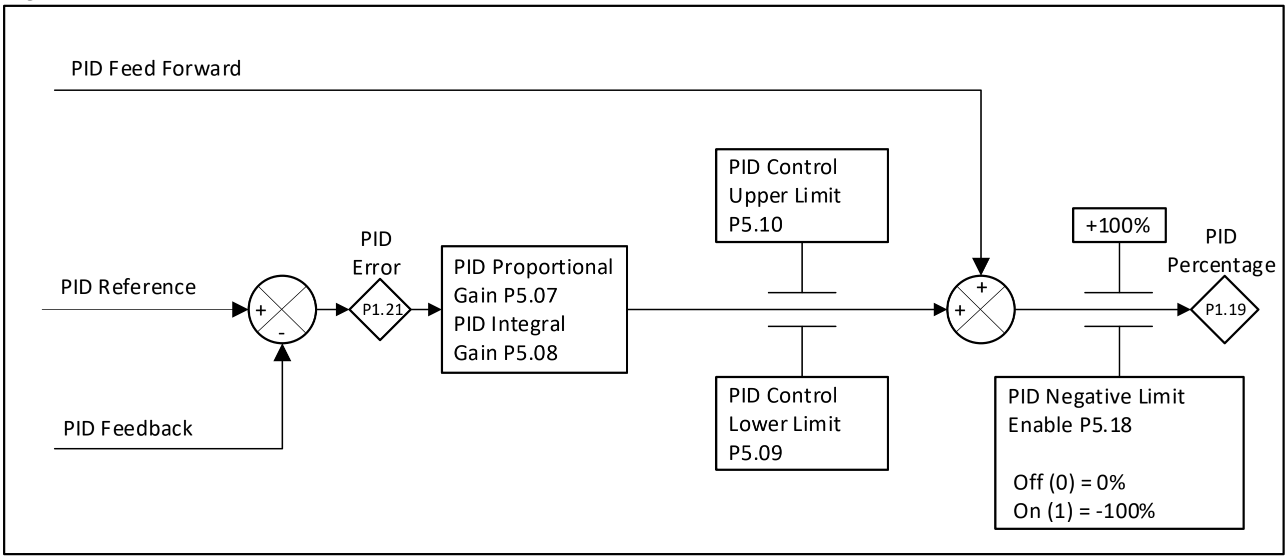
This document covers the operation of the PID Controller on the Commander S, as well as possible applications examples.

1.0 PID Overview

The Commander S has a dedicated PI (Proportional-Integral) control loop that is suitable for use in applications requiring basic closed-loop control of system or process. In PID control, the drive controls the motor speed so that the difference between the PID feedback and the PID reference is zero. The drive uses a feedback signal to determine the *PID* Error (P1.21) and this is passed through a scaling stage, a limiter and finally added to a feedforward value before its used as the main reference source of the drive. The response and the regulation accuracy of the process is dependent on the PID gain settings.

The rate of change of the *PID Reference* (P5.03) can be limited by the *PID Reference Slew Rate Limit* (P5.06). This may be useful to limit the system overshoot when the set point is changed.

Figure 1-1 PID controller overview



The output of the PID Controller, *PID Output Percentage* (P1.19), can be used to control the speed of the motor when selected as a frequency reference in P2.21 to P2.24. *Frequency Reference Configuration* (P0.05) can be set to quickly configure the PID output as the drive reference with the settings shown in Table 1-1. There is also a guided setup in Marshal with easy access to all relevant parameters.

Table 1-1 PID *Frequency Reference Configuration* (P0.05)

P0.05 Setting	Text	Description
8	PID Voltage Ref	A voltage input on T2 analog input 1 as the reference, and a current input on T4 analog input 2 as the feedback. The PID is enabled when the drive is running and the PID output is used as the drive frequency reference.
9	PID + Feed Forward	A voltage input on T2 analog input 1 as the Feed Forward, and a current input on T4 analog input 2 as the feedback, the reference is fixed. The PID is enabled when the drive is running and the PID output is used as the drive frequency reference.

2.0 Parameter Set-up

Step 0: Choose a preset PID Configuration

Set *Frequency Reference Configuration* (P0.05) to value 8 or 9 as described in table 1-1 to automatically configure the PID controller. The configurations can be modified once set so they can save overall commissioning time.

Step 1: Set the PID reference

PID Reference Selector (P5.03)

Value	Reference	Description
0	None	Fixed value of 0%
1*	T2 Analog 1 %	Scaled value of analog input 1
2*	T4 Analog 2 %	Scaled value of analog input 2
3*	T15 Frequency %	Scaled value of the frequency input
4*	Up/Down %	Reference set by the Up/Down control (Keypad/Terminals)
5	Fixed Ref 1	Fixed reference Set-Point 1 (P5.01)
6	Fixed Ref 2	Fixed reference Set-Point 2 (P5.02)

Step 2: Set the PID Feedback

PID Feedback Selector (P5.04)

Value	*Feedback*	*Description*
0	None	Fixed value of 0%
1*	T2 Analog 1 %	Scaled value of analog input 1
2*	T4 Analog 2 %	Scaled value of analog input 2
3*	T15 Frequency %	Scaled value of the frequency input

Step 3 (Optional): Set the PID Feed Forward

Feedforward is a value added to the output of the PID controller that can improve the responsiveness of the system by providing the major component of the output whilst the controller compensates for any error between the PID reference and the feedback. 50 % is a good starting value.

PID Feed Forward Selector (P5.05)

Value	*Text*	*Description*
0	None	Fixed value of 0%
1*	T2 Analog 1 %	Scaled value of analog input 1
2*	T4 Analog 2 %	Scaled value of analog input 2
3*	T15 Frequency %	Scaled value of the frequency input
4*	Up/Down %	Reference set by the Up/Down control (Keypad/Terminals)
5	Fixed Ref 1	Fixed reference Set-Point 1 (P5.01)
6	Fixed Ref 2	Fixed reference Set-Point 2 (P5.02)

*The inputs may need to be configured. For example, by default analog input 1 is set to 4 to 20 mA but this can be changed to a voltage input (0 to 10 V). See section 2.1 *Configuring inputs*.

Step 4: Set the PID Gains

PID Proportional Gain (P5.07)
The proportional gain is the instantaneous amplification factor that is applied to the process error. A higher value will reduce response time. However, if the value is set too high it may introduce oscillation in the system

This value is multiplied with the PID Error (P1.21).

If PID Error (P1.21) = 10 % and a proportional gain of 1.000, then the proportional term is a value of 10 %.

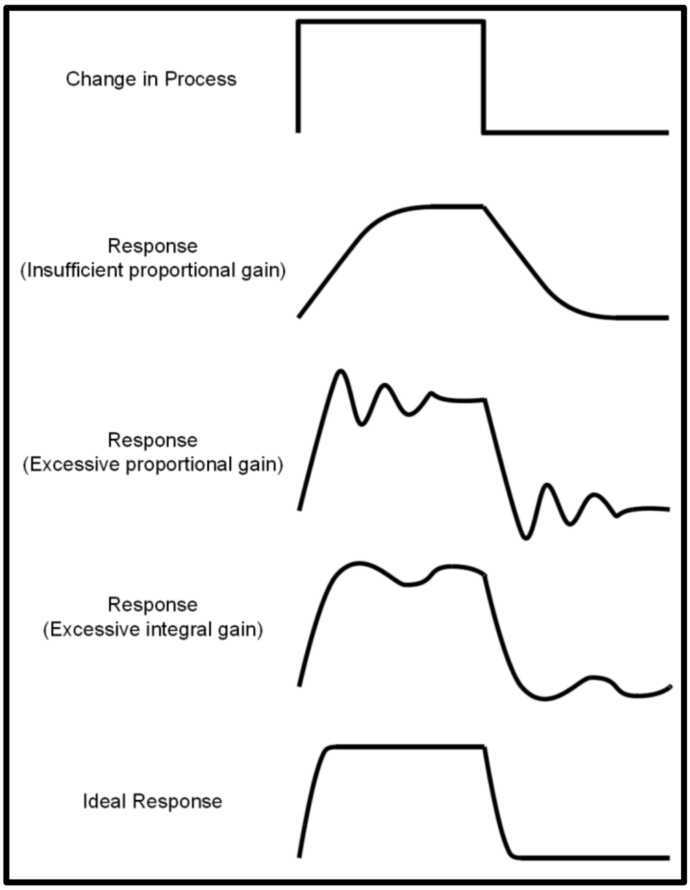
PID Integral Gain (P5.08)
The integral gain is an amplification factor of the error over time. The PID integral gain increases the *PID Output Percentage* (P1.19) at a rate proportional to the error and the gain. Setting an integral value will remove any steady state error.

For a PID error = 10 % and an integral gain of 0.5, then the integral term increases linearly by 5 % per second.

Setting a value of 0 disables the integral term.

Tuning the gains
It may be necessary to adjust the proportional (P5.07) and integral (P5.08) gains to improve the system stability and response. Figure 2-1 shows the effect of incorrect P and I gain settings as well as the ideal response.

Figure 2-1 Tuning the PID gains



The proportional gain should be set up initially. The value should be increased up to the point where the PID error overshoots and then reduced slightly. The integral gain should then be increased up to the point where the error becomes unstable and then reduced slightly. It may now be possible to increase the proportional gain to a higher value and the process should be repeated until the system response approaches the ideal response as shown.

Step 5: Set the output limits

PID Output Lower Limit (P5.09)	Default = 0 %
PID Output Upper Limit (P5.10)	Default = 100 %

Step 6: Set the acceleration and deceleration rates

It is advised to set the ramp rates to a low value when using the PID output as the drive reference, such as 1 s for pumps and 20 s for fans.

Acceleration Rate 1 (P2.06)
Deceleration Rate 1 (P2.07)

Step 7: PID Enable

Enabling the PID is dependent on two conditions, the value set in *PID Enable Selector* (P5.11) and any digital input that has been set to the *PID Hardware Enable* (13) function.

PID Enable Selector (P5.11) Default = 0 (Disabled)

Value	***PID Enable Condition***	***Description***
0	Disabled	Always off
1	Drive Running	On if the drive is running
2	At Speed	On if the output speed is within 1 Hz of the reference
3	At Zero	On if the output is at 0 Hz +/- 2 Hz
4	Under Voltage	On if the drive is in the under voltage state
5	External Error	On if the external error input has been set
6	Drive Ready	On if the drive is ready to run (not inhibited by a hardware enable input)
7	Drive Healthy	On if the drive is healthy (not in error) (active alarms do not make the drive unhealthy)
8	Current Limit	On if the drive is limiting the output current
9	Reverse Running	On if the drive is running in the reverse direction
10	Current Loss	On if an analog input current loss has been detected
11	Threshold Detect	On if the threshold detector is active

Step 8: Set PID Output as the drive reference

Set *PID* Percent (9) in *Frequency Reference 1 Selector* (P2.21) and set *Frequency Reference 1 to 4 Switch* (P2.20) to *Freq Reference 1* (1).

2.1Configuring Inputs

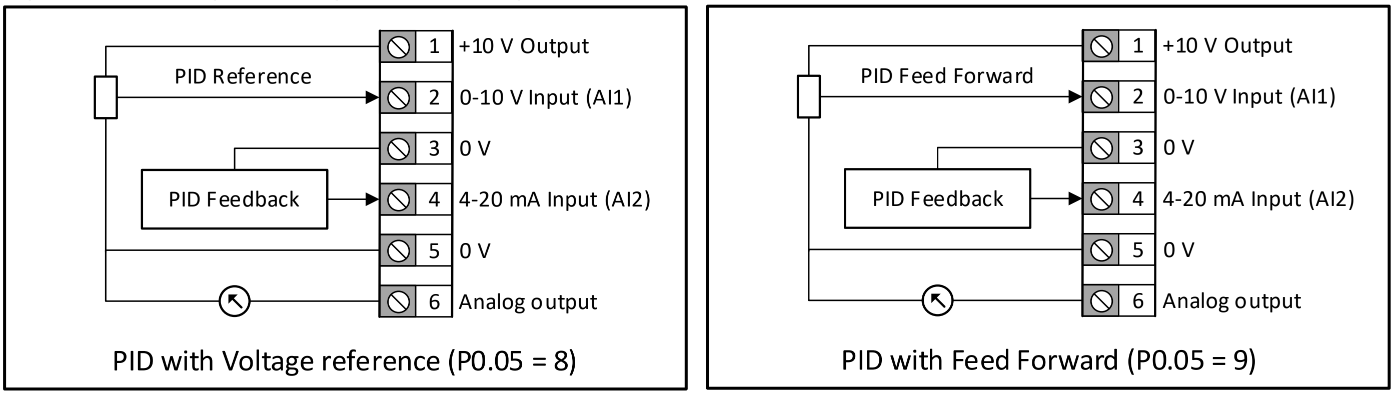
Configure Analog Inputs

If required define the type of your inputs:

- *T2 Analog Input 1 Type* (P6.01) Default = 4 to 20 mA (No Alarm)
- *T4 Analog Input 2 Type* (P6.02) Default = 0 to 10 V

Value	***Text***	***Description***
0	0-10V	A voltage input where 0 V is 0% and 10 V is 100%
1	Digital Input	Enables the digital function for this analog input where 1 is detected at 8 V and above and a 0 is detected at 7 V and below
2	0-20mA	A current input where 0 mA is 0% and 20 mA is 100%
3	4-20mA No Alarm	A current input where 4 mA is 0% and 20 mA is 100%. No action taken if current < 3mA
4	4-20mA Hold	A current input where 4 mA is 0% and 20 mA is 100%. The value is held if current < 3 mA
5	4-20mA Stop	A current input where 4 mA is 0% and 20 mA is 100%. The drive will stop if current < 3 mA and not restart
6	4-20mA Error	A current input where 4 mA is 0% and 20 mA is 100%. An error is generated if current < 3 mA

Figure 2-2 Analog IO wiring for PID configurations

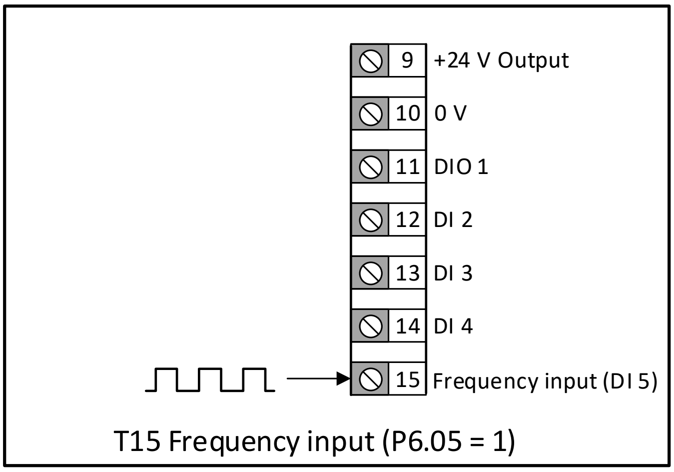


Configure the Frequency Input

- *T15 Digital Input 5 Type* (P6.05) Default = Digital Input

Value	***Text***	***Description***
0	Digital Input	The low level input must be < 9 V and the high level input > 10 V
1	Frequency Input	Frequency input with a maximum frequency of 100 kHz. The low level input must be < 5 V and the high level input > 15 V.

Figure 2-3 IO Wiring for Frequency % as PID feedback or reference



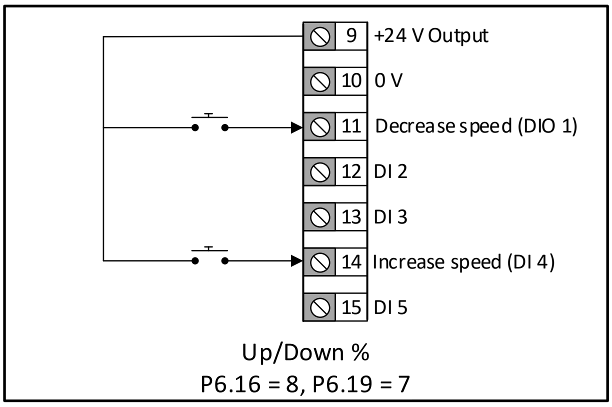
Configure the Up/Down PID Reference or Feed Forward

- *Up/Down % Configuration* (P2.14) Default = 0 (Set by digital inputs, MOP)

Value	***Text***	***Description***
0	Reset	Up/Down Percentage set to 0 at power up.
1	Last	Up/Down Percentage saved and restored at power up.
2	Preset 1	Up/Down Percentage set to Preset Reference 1 (P2.16) at power up.
3	Keypad and Reset	Keypad control enabled and Up/Down Percentage set to 0 at power up.
4	Keypad and Last	Keypad control enabled and Up/Down Percentage saved and restored at power up.
5	Keypad+Preset 1	Keypad control enabled and Up/Down Percentage set to Preset Reference 1 (P2.16) at power up.

Note: for options 0-2 the digital inputs will need to be assigned functions to increase and decrease the reference. Set P6.16 to 8 and P6.19 to 7. See wiring guide in figure 2-4.

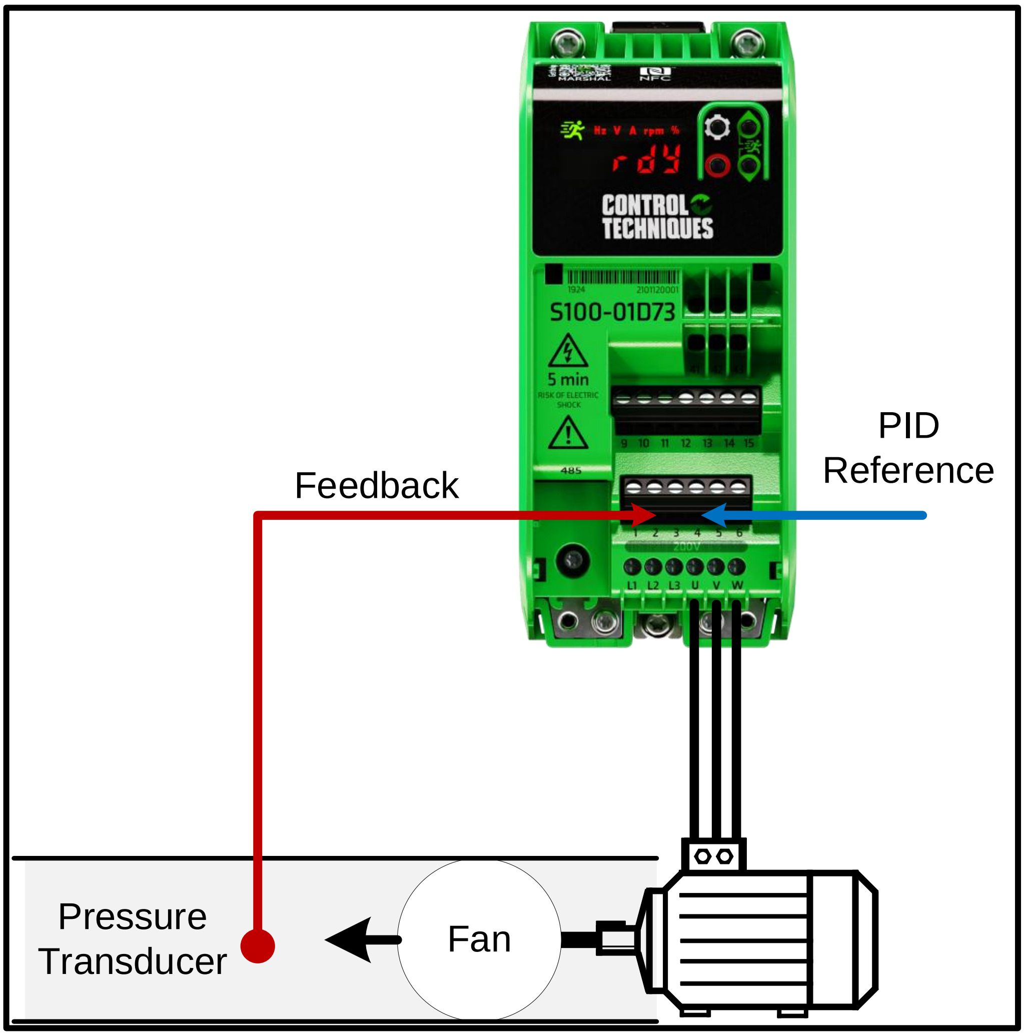
Figure 2-4 Digital IO wiring for Up/Down % as PID reference



3.0 Common PID applications

Pressure control
The system will regulate a constant pressure to a process setpoint, where an analog signal proportional to pressure is fed back to the PID loop. The speed demand for the drive should vary inversely proportional to the system process error i.e. as the pressure increases the drive speed decreases and vice versa.

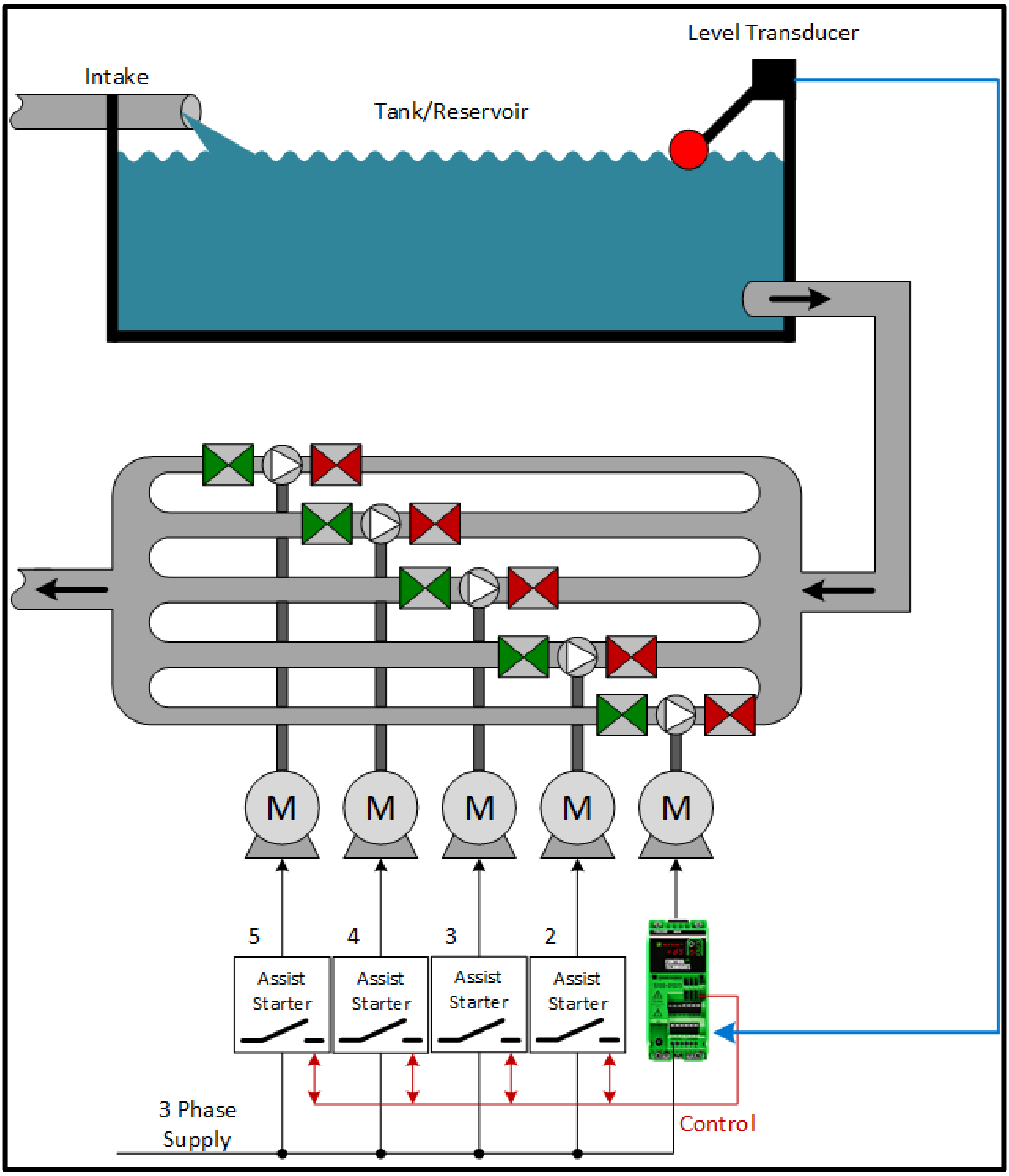
Figure 3-1 Pressure Control Example



Temperature control
The system will regulate a constant temperature to a process setpoint by varying a cooling fan speed. An analog signal proportional to temperature is fed back to the PID loop. The speed demand for the drive should vary proportionally to the system process error i.e. as the temperature increases the drive speed increases and vice versa.

Level control
The system will regulate a constant level to a process setpoint, where an analog signal proportional to a level is fed back to the PID loop. The speed demand for the drive should vary proportionally to the system process error i.e. as the level increases, the drive speed increases and vice versa (assuming level control is on the output side of the application).

Figure 3-2 Level Control Example



Please note that figures 3-1 and 3-2 are for illustration purposes only and it may note be possible to implement these exact systems with Commander S.