Lenze Pump Solutions | EN-US

Pump Application Guide

i500

Lenze pump solutions

Foreword:

Many competitors offer pump application specific drives. Lenze offers general purpose drives. Lenze drives can, however, solve the vast majority of pumping applications. The drives must simply be configured to perform those pertinent tasks. To that end this application guide serves to both discuss pumping application functional requirements and also to explain how to configure the i500 to perform those tasks.

Background:

There are fundamentally two types of pumps. Centrifugal pumps and positive displacement pumps. Each of these has many specific variants; however, all fall into these two basic classifications.

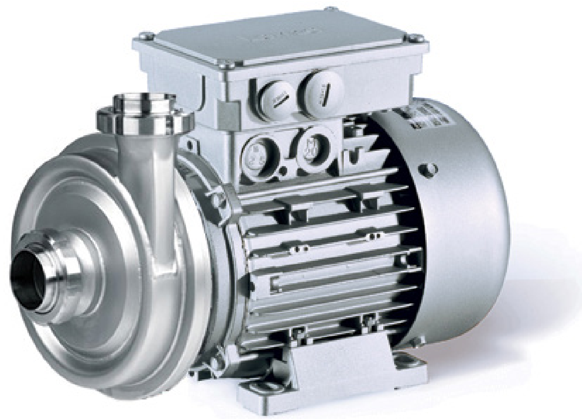
Centrifugal pumps use rotary motion on an impeller to impart pressure on a fluid. They do not cause a specific flow rate in and of themselves; however, they create a pressure differential which in turn due to the piping system in the application determines a flow rate. In these pumps pressure is a function of power and flow rate, and is defined on the pump's pump curve (supplied by the pump manufacturer).

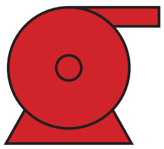
Positive displacement pumps use rotary motion to open and collapse a cavity to cause a defined flow rate. These pumps do not in and of themselves create a specific pressure. Pressure is a function of the piping system of the application and is a direct function of the pump's motor torque.

Both types of pumps have different application requirements so each will be discussed in detail separately.

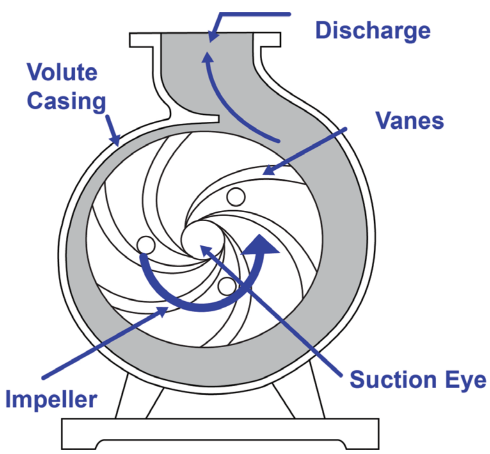
I. Centrifugal pumps

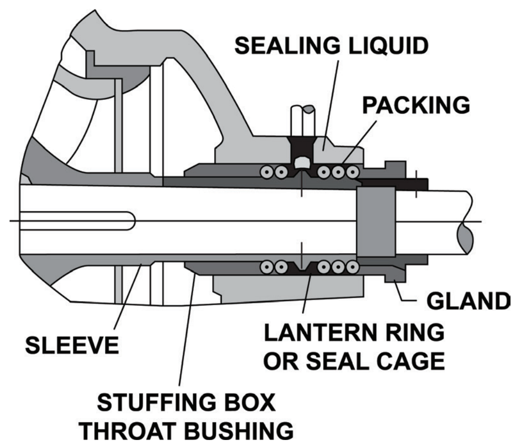
Centrifugal pumps (often referred to as "standard" pumps) are used for high flow rate with low viscosity fluids. These pumps consist of a spinning impeller in a casing. Fluid is drawn into the center and then (as the name implies) is forced to the outer edge of the casing via centrifugal force. This imparts pressure which is focused at the discharge port, which is at a tangent of the pump casing.





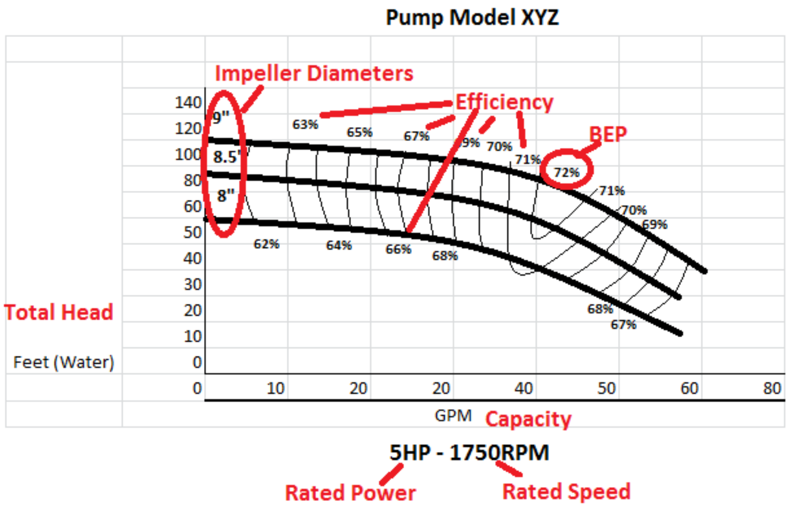
- **Casing or Volute** (includes inlet and discharge)
- **Stuffing Box** (sealing)
- **Shaft**
- **Impeller**



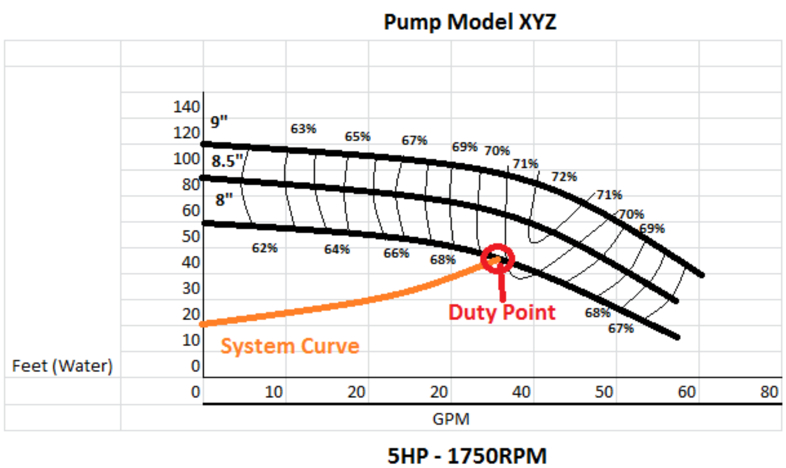


Centrifugal pumps do not create a specific flow rate — they just impart pressure upon the fluid. Flow rate is defined by the losses present in the piping system (where losses are a function of flow rate). Losses are caused by restrictions (such as valves) and also by changes of potential energy due to elevation. In the US the common term for pressure is "head" and is denoted in vertical feet of water column as opposed to pounds per square inch (PSI) or Pascals (Pa).

Manufacturers of centrifugal pumps publish performance curves for them that define pressure as a function of flow rate. These curves are referred to as "pump curves". Often several curves will be displayed for a given pump showing different curves the pump is capable of for different sizes of impellers installed.



Note: The curve denotes the required power rating and speed of the motor, as well as relative mechanical efficiency of the pump at different points along the curve including the BEP (Best Efficiency Point).



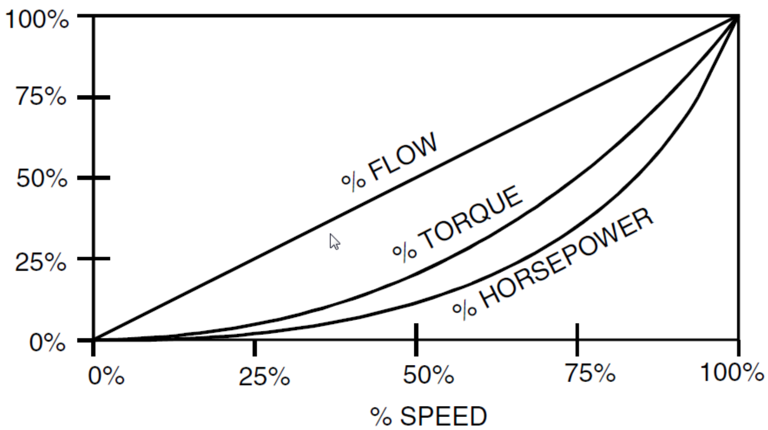
The application will be designed for a specific duty point. The duty point is the intersection of a plot of a piping system's pressure requirements as a function of flow rate of a given piping system (referred to as the system curve) and the pump's pump curve. Otherwise stated — the duty point is the pressure and flow rate that will be provided by the pump to the particular system in which it is applied.

There are a lot of terms related to pressure that are used in pumping applications and it is important to understand them to understand the application needs. Below is a brief synopsis of the common ones:

1. **PSIG** - This is just PSI as relative pressure. The "G" means "Gauge", so it is referenced to local atmospheric pressure as 0.
2. **Head** - Head is a synonym for pressure. It is often expressed in feet of water column but also will be expressed in more common units (such as PSI).
3. **Friction Head Loss** - This is the pressure loss factor as the fluid flows through the piping system. It is often expressed as PSI drop per 100 feet of pipe.
4. **Shut Off Head** - This is the maximum pressure the pump can create at 0 flow (dead head).
5. **Total Head (or Pump Head)** - This is the difference in head (pressure) from the pump's discharge to the pump's inlet. In other words, this is how much pressure the pump is creating.
6. **Suction Head** - This is the pressure present at the inlet port of the pump.
7. **Suction Static Head (or Suction Static Lift)** - This is the difference in elevation from the fluid source the pump is fed from to the centerline of the pump. The term "Suction Static Lift" is used instead of "Suction Static Head" if the pump is at a higher elevation than the fluid source.
8. **Total Static Head** - This is the difference in elevation from the fluid source the pump is fed from to the elevation of the receiving tank the fluid is pumped to.
9. **Net Positive Suction Head Available (NPSHA)** - This is the pressure present at a pump's inlet.
10. **Net Positive Suction Head Required (NPSHR)** - This is the pressure required to be present at a pump's inlet to prevent cavitation from occurring.
11. **Vapor Pressure** - This is the pressure at which a fluid boils at a given temperature. Fluids boil at a lower temperature at lower pressure. Pressure drops at the edges of a pump's impeller. As a result a fluid can boil at the inlet of a pump or in the pump casing if there is not enough Net Positive Suction Head available. This is cavitation.

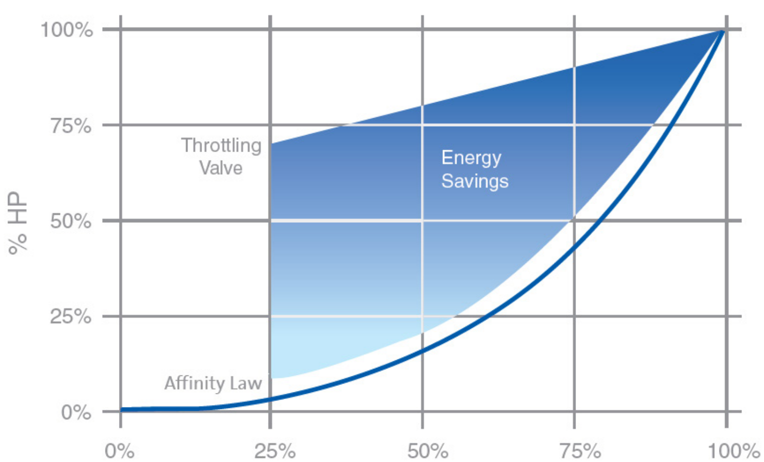
i500 is the new frequency inverter series from Lenze in the 0.33 to 177 Hp (0.25 to 132 kW) power range. Its distinguishing features: a streamlined design, scalable functionality and exceptional user-friendliness. i500 provides a high-quality frequency inverter that already conforms to future standards in accordance with the EN 50598-2 efficiency classes (IE). Overall, this provides a reliable and future-proof drive for a wide range of machine applications. The series is available in IP20, IP31, and IP66 (NEMA 4X) versions.

The i500 frequency inverter is a general purpose drive designed to be ideal for applications in pumps, fans, conveyors, formers, winders, traveling drives, tool and hoist drives. While not designed as solely a pump specific drive, the i500 can readily solve the vast majority of pumping applications. The drives must simply be configured to perform those pertinent tasks.



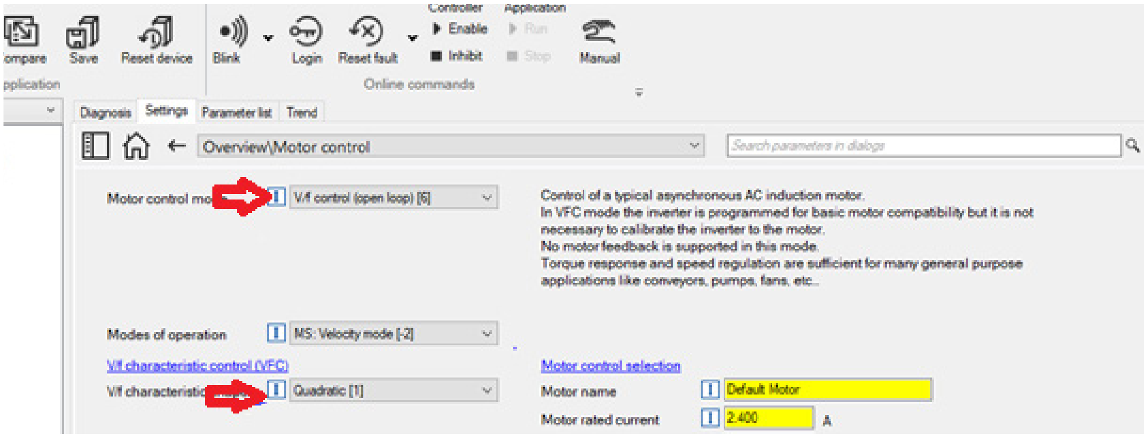
Centrifugal Pump Common Application Requirements (and how to solve them using i500):

Energy efficiency:
Centrifugal pump applications (like fans) follow the affinity laws for power consumption. In these applications as flow increases proportionally, torque required increases as a squared function and power required increases as a cubed function.



Pumps are sized for the maximum flow condition. They have to be able to handle the outliers in the requirements of the system; however, most of the time a process will not require 100% of the system's capacity. In simple terms this means that at ½ flow, only ¼ torque is required and only ⅛ of the power is required. Signficant energy savings can be accomplished by simply taking advantage of the affinity laws. To do this, drives will use a quadratic V/Hz profile to reduce the voltage supplied to the motor as a function of speed following the curve defined by the affinity law (following the torque curve).

In the Lenze i500 set the “Motor control mode” (P300.000) = “V/f control (open loop) [6]” and also set “V/f characteristic shape” (P302.000) = “Quadratic [1]” to take full advantage of the energy savings.



A) Cavitation prevention and Run Dry (Loss of Prime) protection

Centrifugal pumps should not be run without fluid in them. Doing so can cause the seals to heat and can damage them, as well as the motor and other components. This condition is called “Run Dry” or is also referred to as “Loss of Prime”. This condition can be detected via the same method used to prevent cavitation.

Cavitation is the largest concern with centrifugal pumps. Cavitation damages impeller blades, bearings, and seals. Fluids change state from liquid to gas (boil) when exposed to a low enough pressure at a given temperature. Similarly, they change state from gas to liquid when subjected to a great enough pressure.

The lowest point of pressure in a pump is at the leading edge towards the center of the pump’s impeller vanes. The highest point of pressure is exerted at the outer edge of the impeller blades.

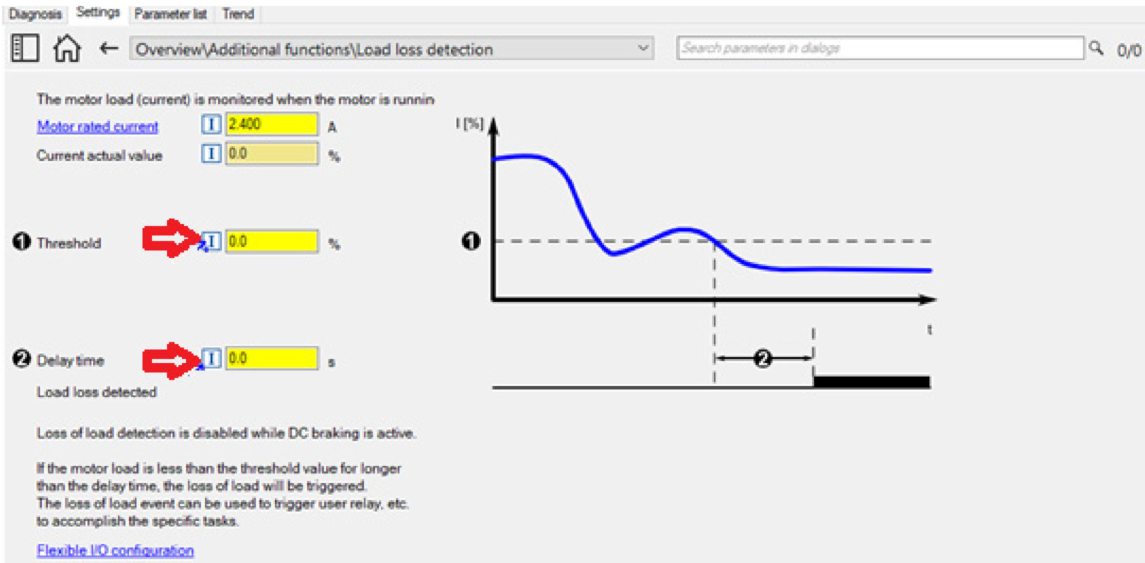
If insufficient inlet pressure feeding a pump (referred to as “net positive suction head” (NPSH)) is present, the fluid will boil as it approaches the leading edge of the pump’s impeller. The resulting bubbles will then collapse back to the liquid state as they move across the impeller vane moving from the area of lower pressure to the area of higher pressure. These rapidly forming and collapsing bubbles cause acoustic shockwaves that are very damaging to the pump; pitting can occur on the impeller, and the bearings and seals can wear. Cavitation can be felt as significant vibration on the pump and can often be audibly heard. Cavitation can lead to premature pump failure and the necessity for servicing the pump.

To prevent this, the pump must be supplied with sufficient pressure to keep the fluid from boiling. This required pressure is called the "net positive suction head required" (NPSHR). A typical application requirement is to fault the drive if the NPSH is below the NPSHR so as to not allow cavitation to occur. There are two means to do this with the i500:

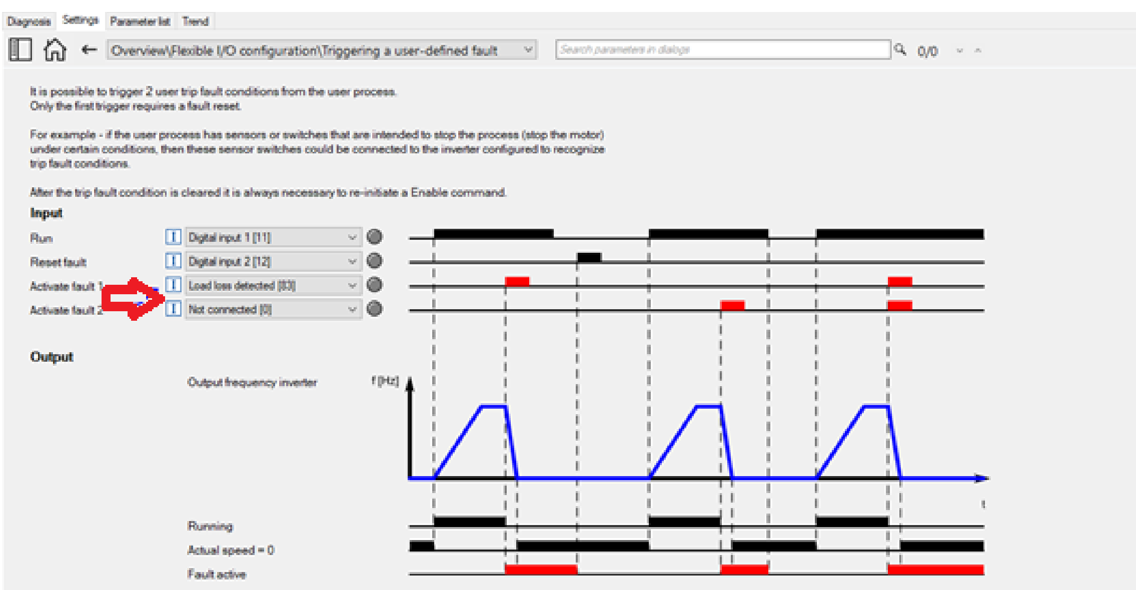
1) If the pump is always run at the same speed, a drop in NPSH can be detected as a drop in motor load.

First examine "Current actual value (P103.000)" while the pump is running in the system's normal stable condition. Then lower the inlet pressure to cause cavitation and again observe "Current actual value (P103.000)". Determine a safe value between those two levels to account for variability of the system. Enter that value into "Threshold (P710.001)".

Next, we need to add some delay to the detection to prevent trips during startup or sudden changes due to opening/closing valves. Determine a safe time period and enter that into "Delay time (P710.002)".



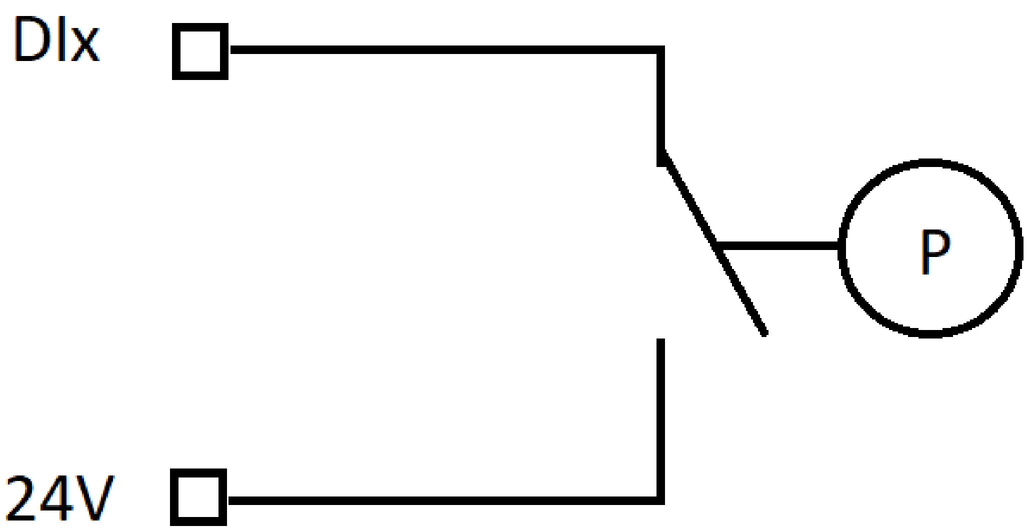
Next, assign either "Activate fault 1 (P400:043)" or "Activate fault 2 (P400:044)" to "Load loss detected [83]" to fault the drive with either "User-defined fault 1" or "User-defined fault 2" based upon the loss of NPSH.



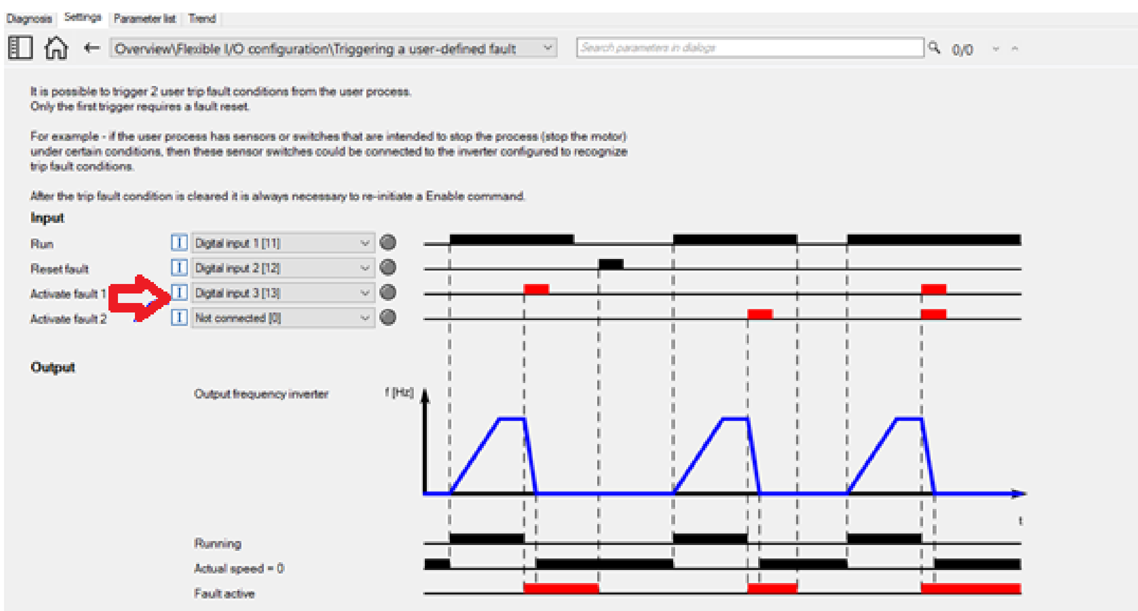
2) If the drive will be run at varying duty points then an external pressure sensor must be used. The sensor needs to be installed into the application's process piping system upstream of the pump. Good practice is to install the sensor a distance upstream from the pump, equal to between 3 and 5 pipe diameters. Do not mount the sensor to the drain port of the pump's casing as this will not produce an accurate reading.

First determine what the safe inlet pressure is for the pump (pump data will state this — usually for water). Get a sensor rated for a safe value greater than that pressure. There is no delay in this approach except for the reaction of the sensor itself, so care must be taken to choose an appropriate pressure value.

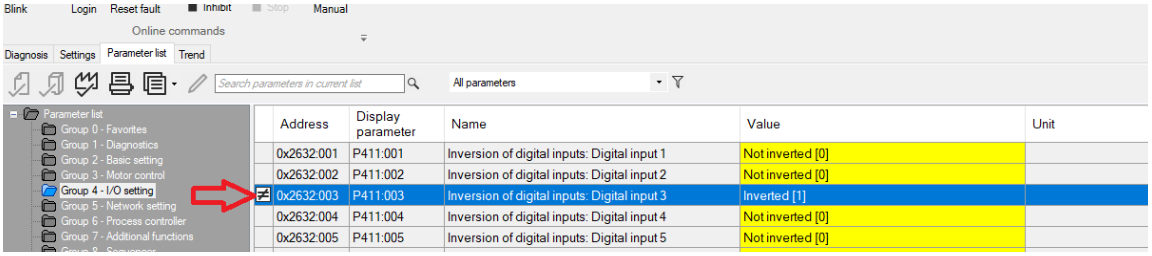
The most economical solution is to use a pressure switch (contact closure) that closes when the minimum required pressure is reached. Wire the switch between "24V" and one of the drive's digital inputs (i.e. DI3).



Next assign that DI as the trigger to either "Activate fault 1 (P400:043)" or "Activate fault 2 (P400:044)" to fault the drive with either "User-defined fault 1" or "User-defined fault 2" based upon the loss of NPSH.



As we need the open switch to trigger the fault the digital input's action must be inverted.
Set P411.00x (x is the desired DI) = "Inverted [1]".



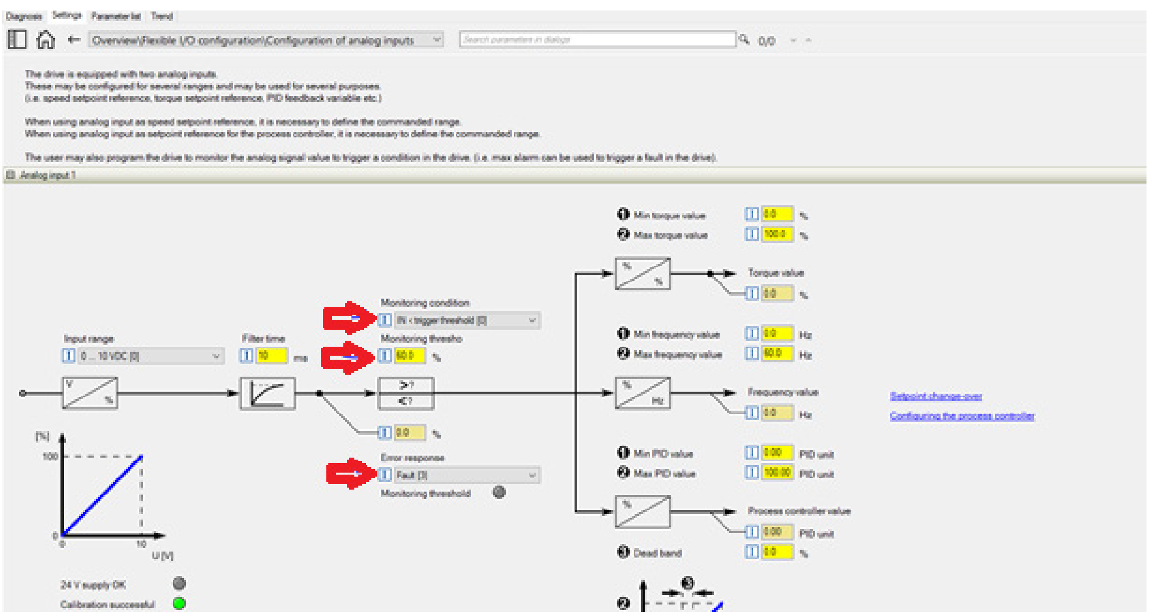
As an alternate solution, if an analog pressure sensor is used first configure that analog input's monitoring level for the value equivalent to the desired trip level.

Either Analog Input 1 (P430.xxx) or Analog input 2 (P431.xxx) may be used for this purpose.

Set "Monitoring condition (P43x:009)" = "IN < trigger threshold [0]".

Set the appropriate value in percent for the signal's monitoring level in "Monitoring threshold (P43x:008)".

Set the "Error response (P43x:010)" = "Fault [3]" to fault the drive with either "Analog input 1 fault" or "Analog input 2 fault" based upon a loss of NPSH.



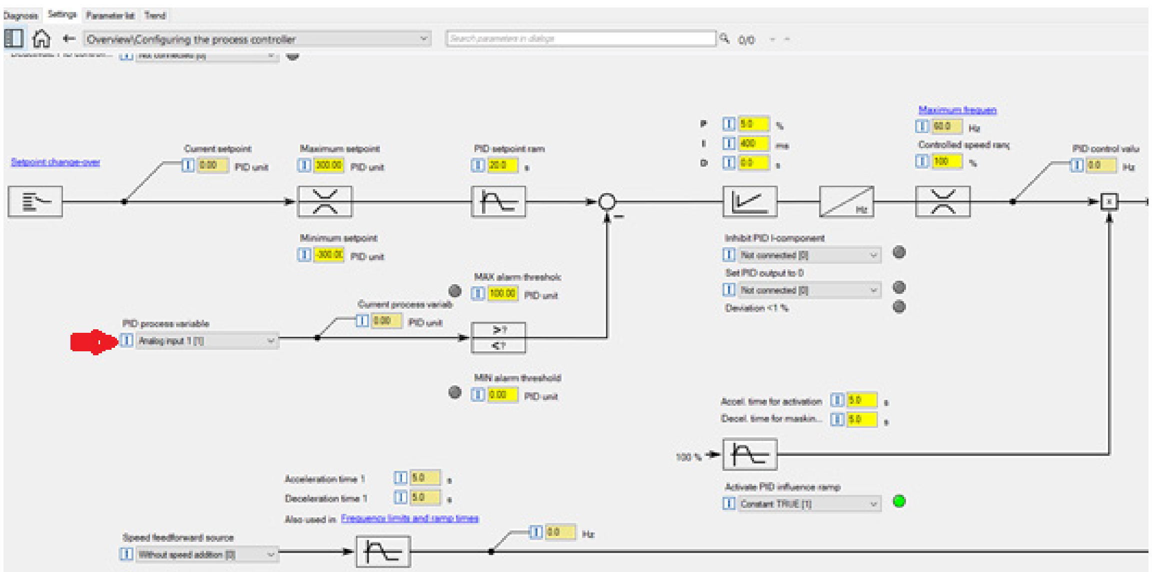
B) PID

PID is the anagram for Proportional Integral Differential control. This is a closed loop control method where the process has a process variable (such as pressure) monitored and the pump must vary its speed in order for that variable to be held to a constant value.

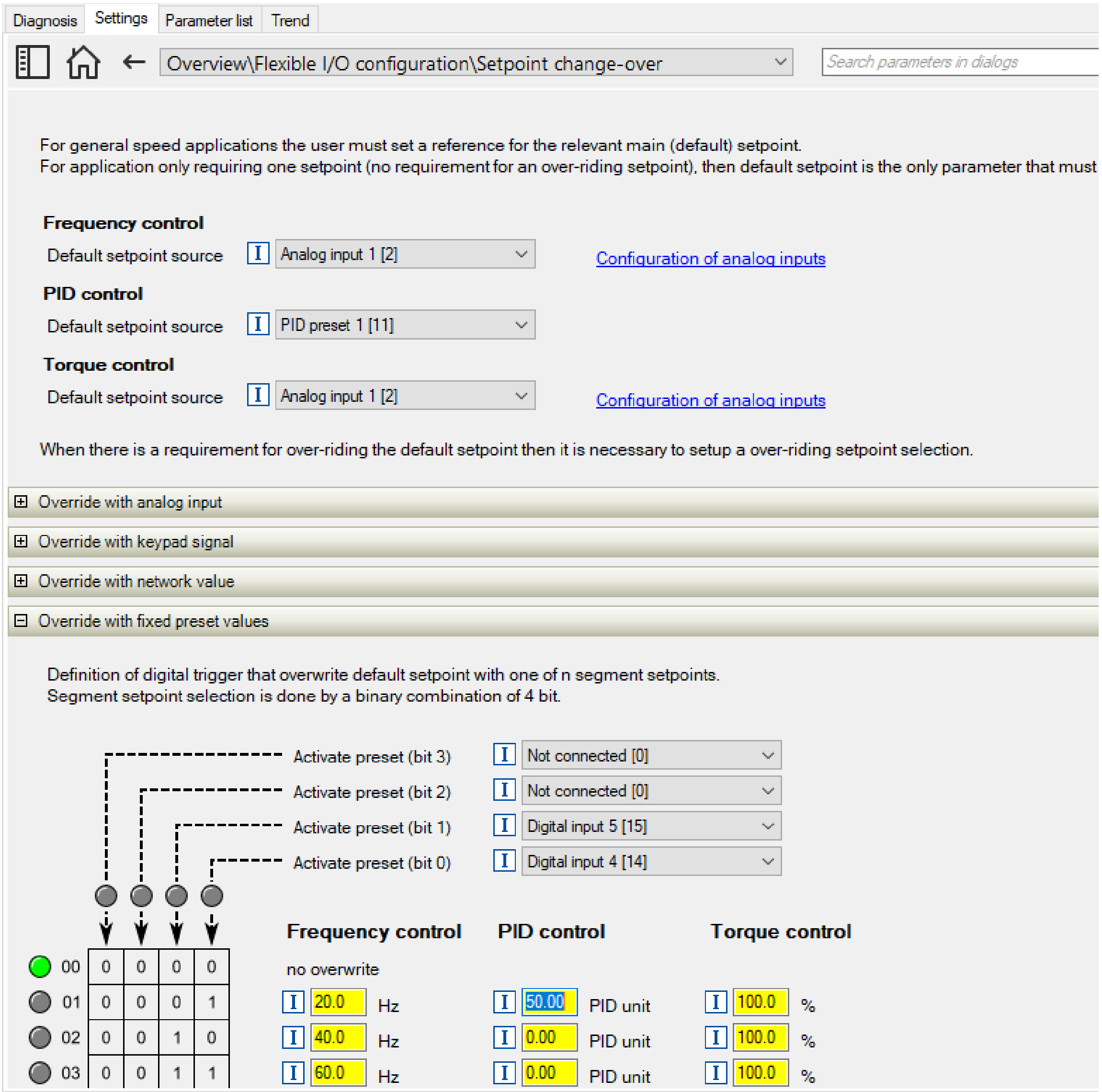
With centrifugal pumps, common applications requiring PID control include heating, cooling, or pressure control.
First an appropriate analog sensor is installed into the system. This could be a pressure senor, a thermal sensor or other.
PID applications are either "normal acting" or "reverse acting". This term is from the perspective of the pump in relation to the monitored process variable. If an increase in the speed of the pump results in an increase in the monitored process variable (such as direct pressure), then the PID application is "normal acting". If an increase in the speed of the pump results in a decrease in the process variable (such as a pump supplying coolant to a process monitoring temperature), then the process is "reverse acting".

Set the "Operating mode (P600:001)" for either "Normal operation [1]" or "Reverse operation [2]" as appropriate for the application.

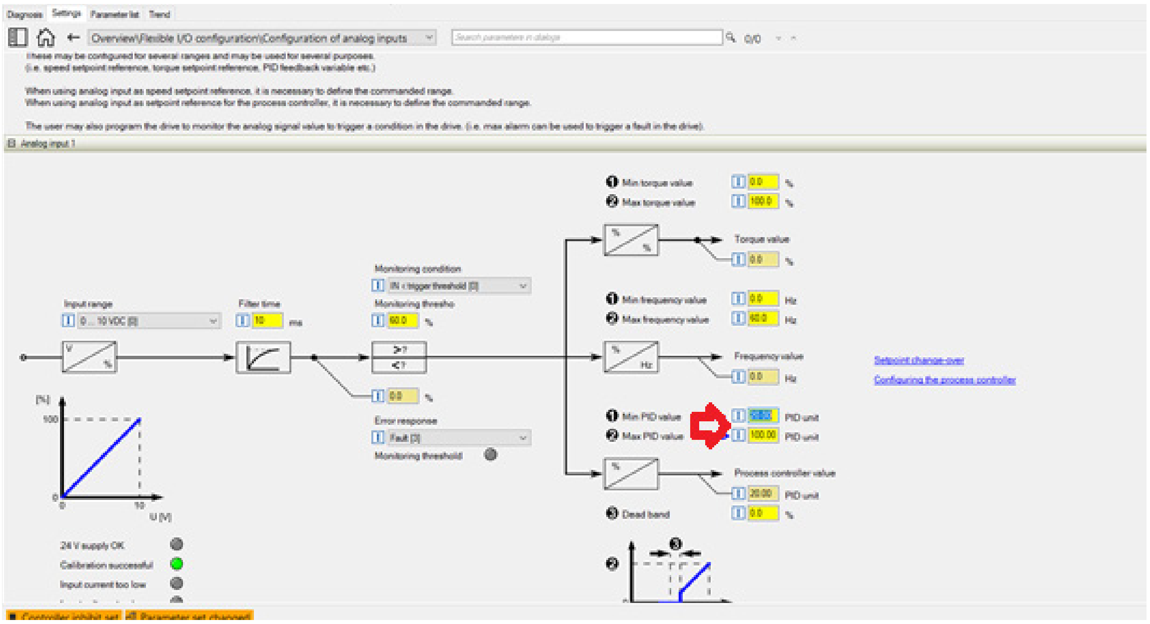
Next we need to program which drive analog input will be used as the monitored process variable. Set "PID process variable (P600:002)" either equal to "Analog input 1 [1]" or "Analog input 2[2]".



Next, we need to program the drive for where the set point source is. The set point is the command value the drive is trying to get the monitored process variable to match. Set point sources can include the keypad, an analog signal (must not be the same analog input as the monitored process variable) or a predefined internal set point. Set “Default set point source (P201:002)” to one of the following selections as appropriate: “Keypad [1]”, “Analog input 1[2]”, “Analog input 2[3]”, or “PID preset 1 [11]”. If you use “PID preset 1 [11]” as the set point ensure you also program that desired set point value in “Preset 1 (P451.001)”.

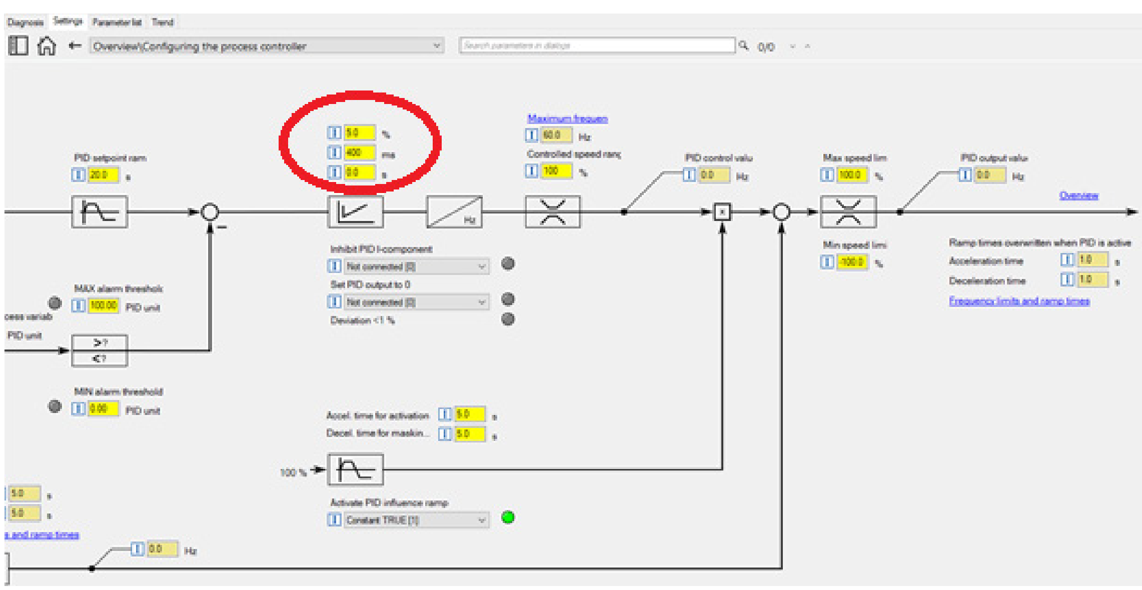


Please note, the set point value is in User defined PID units which in turn are configured in the monitored process variable's analog input channel configuration. Program both the "Min PID value (P43x:004)" and the "Max PID value (P43x:005)" to match the signal range of the analog sensor used to monitor the process variable.
Enter this value in PID units (so if the sensor was 0-10VDC = 20-100PSI, set P43x:004 = 20.0 and P43x:005 = 100).



The PID loop must then be tuned on the running system for the application. A common approach to PID tuning is the following.

1. Set the reset time for the I component to 6000 ms in "PID I-component (P602.000)" to deactivate the I component. With this setting and the default setting of "PID D-component (P603.000)", the process controller operates as P controller.
2. Increase gain of the P component step by step in "PID P-component (P601.000)" until the system becomes unstable (oscillates).
3. Reduce the gain again until the system is stable again (stops oscillating).
4. Reduce the gain by another 15 %.
5. Set reset time for the I component in "PID I-component (P602.000)". With this setting it should be noted that a too low reset time may cause overshoots, especially in case of high steps of the system deviation.
6. Optional: set the gain of the D component in "PID D-component (P603.000)".
   • With this setting it should be noted that the D component responds very sensitively to electrical noise disturbances on the feedback, as well as digitization errors. For most systems the "PID D-component (P603:000)" may be left at a value of 0. This is typically only required for extremely fast acting systems.



C) Minimum Flow Rate (Seal life and energy conservation)

Centrifugal pumps often specify a minimum flow rate be maintained through the pump while running in order to keep the seals from overheating. Similarly, if a minimum flow rate is not maintained it is often desired for the pump to shut off to conserve energy.

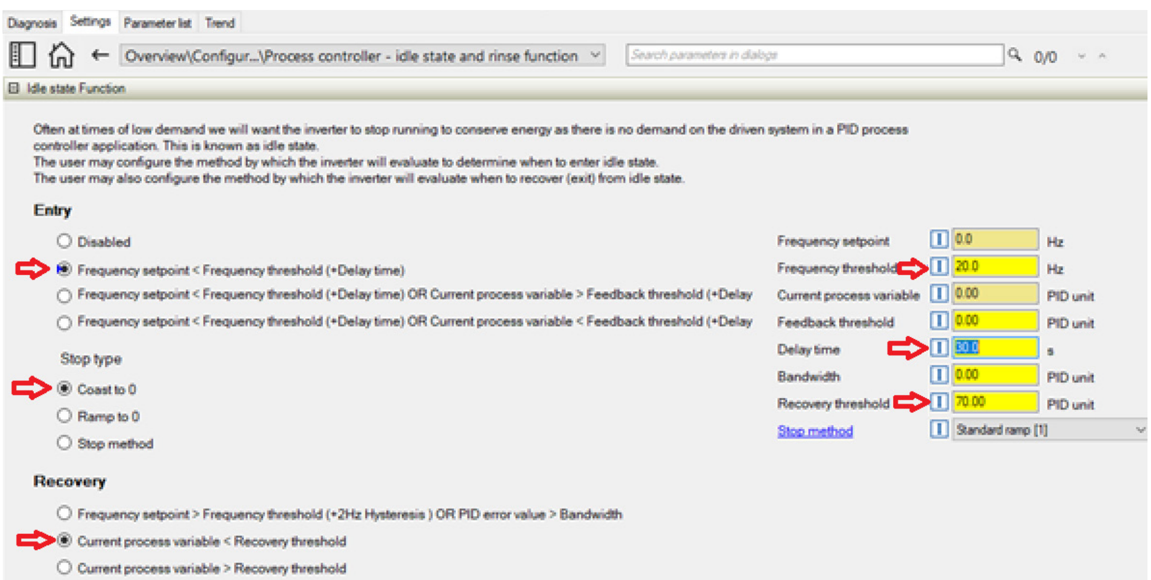
If a centrifugal pump is being used in a PID control application the Sleep function may be used for this purpose.

The sleep function (also called "Process controller idle state") causes the drive to stop running as a reaction to detecting the process variable is unchanging despite the output of the inverter falling below a given frequency for a period of time. An example of an application requiring this is a booster pump in a high rise building. ***At 3AM no one in the high rise is running a faucet or a shower so we want to stop the inverter running the pump to both conserve energy and reduce wear on the seals until someone starts using the water again.***

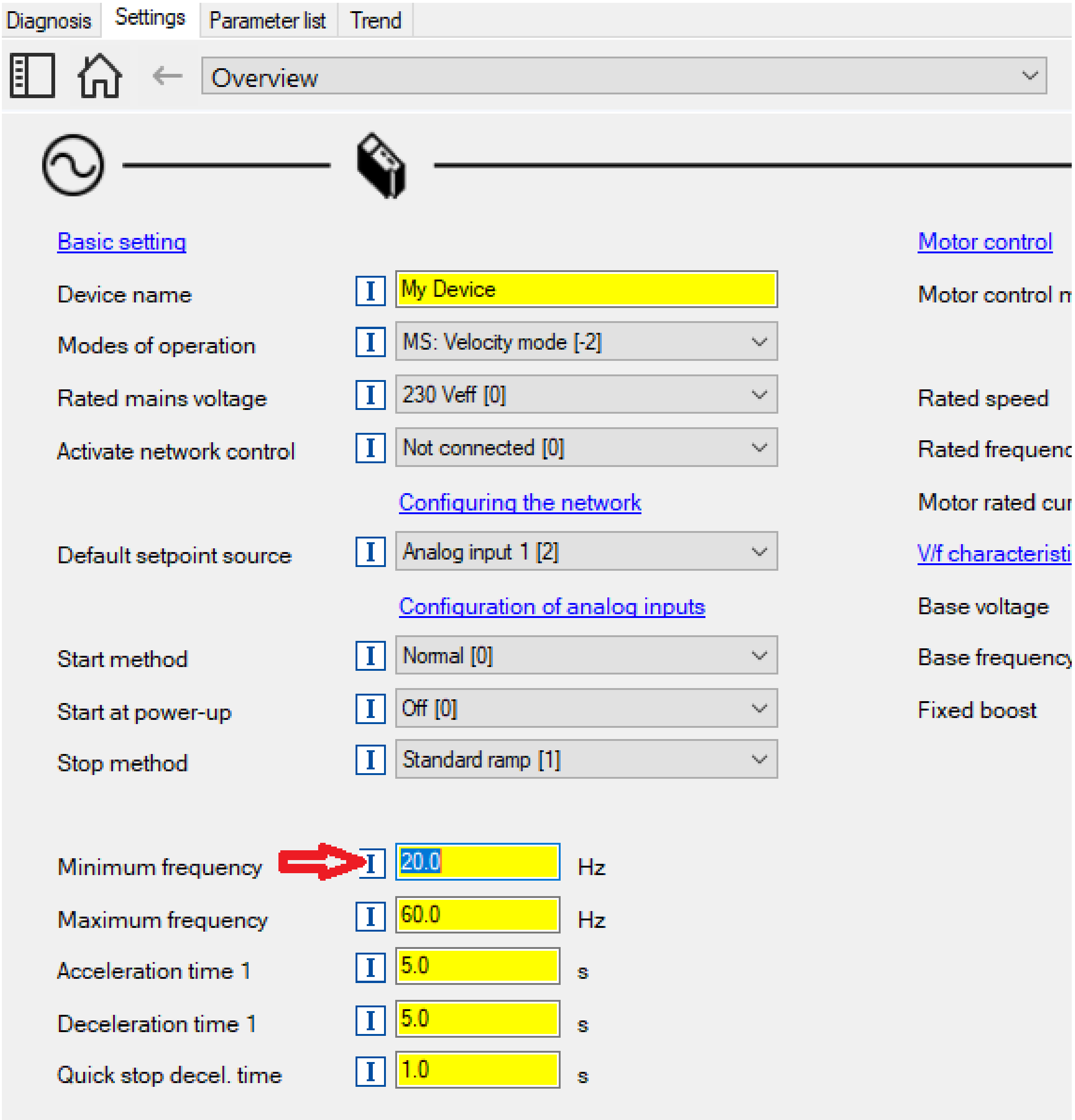
The "PID sleep mode: Activation (P610:001)" should be set to "Output freq.< threshold [1]" for a centrifugal pump application. The "Frequency threshold (P610:003)" must be set for a low value determined for the application to be just below the minimum flow rate being required. A "Delay time (P610:005)" must be entered. A value should be selected that ensures the application should indeed have the pump shut off. If too short a time period is selected the application may chatter.

A pumping application recovery is typically desired to occur based upon the monitored process variable either falling (for a normal acting PID application) or rising (for a reverse acting PID application) outside of a tolerance window. Set the "Recovery P610:006)" to either "PVar<recovery thresh. [1]" for normal acting PID applications or to "PVar>recovery thresh. [2]" for reverse acting PID applications.

Finally, set the "Recovery Threshold (P610:008)" for the maximum value which the application can tolerate as a variance for the monitored process variable. This value is entered in user defined PID units and is in scale. (i.e. if the process set point was 80 and a max drop to a value of 70 could be tolerated, enter 70).



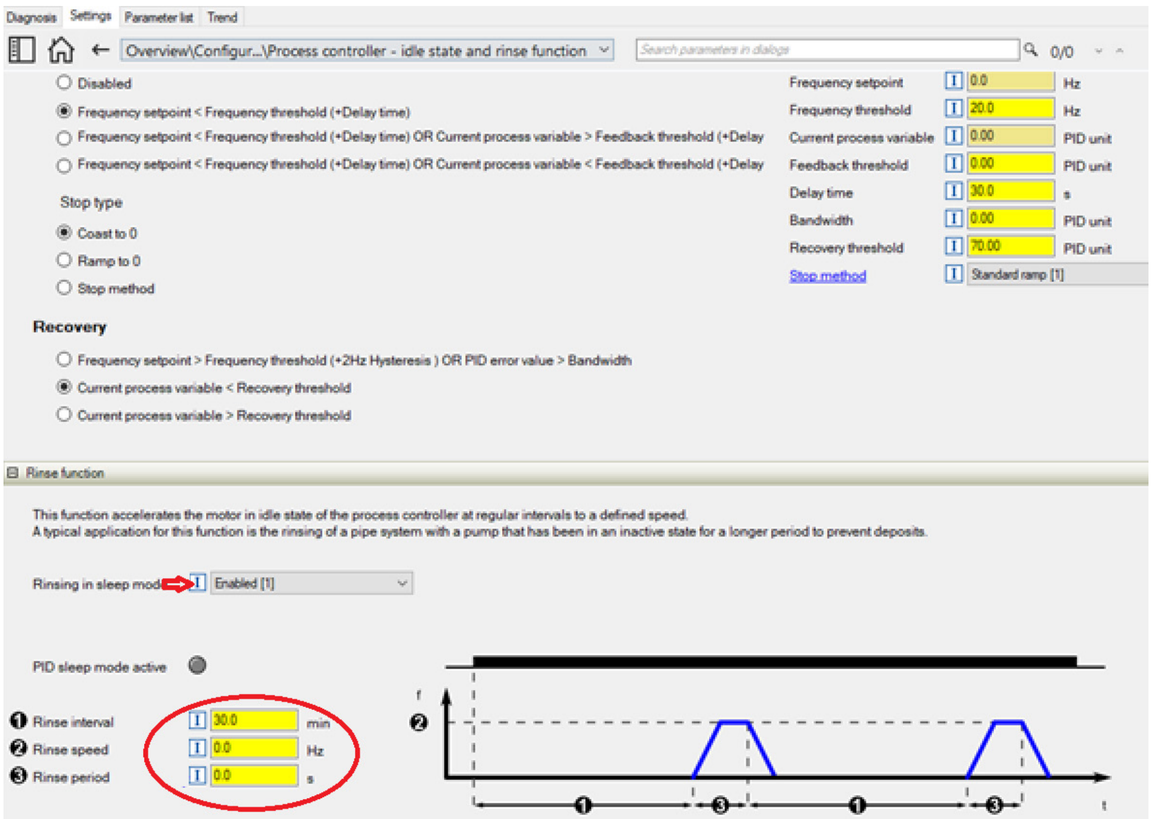
If a pump is being used in a non-PID application, the drive's "Minimum frequency (P210:000)" setting can be used for this purpose. Enter a value appropriate so that the desired minimum flow rate is expected to be maintained.



D) Rinse (in PID applications using the Sleep function)

Fluids may contain particles in suspension (i.e. drinking water may contain sediment). If a pump is stopped for long enough, these particles may fall out of suspension and build up in the pump. This, in turn, can cause wear for the pump seals and performance problems. To prevent this the i500 features a Rinse function. This periodic function runs the pump at a programmed speed and for a programmed period of time to churn back up the fluid in the pump to keep the particles in suspension within the fluid while the drive is in Sleep.

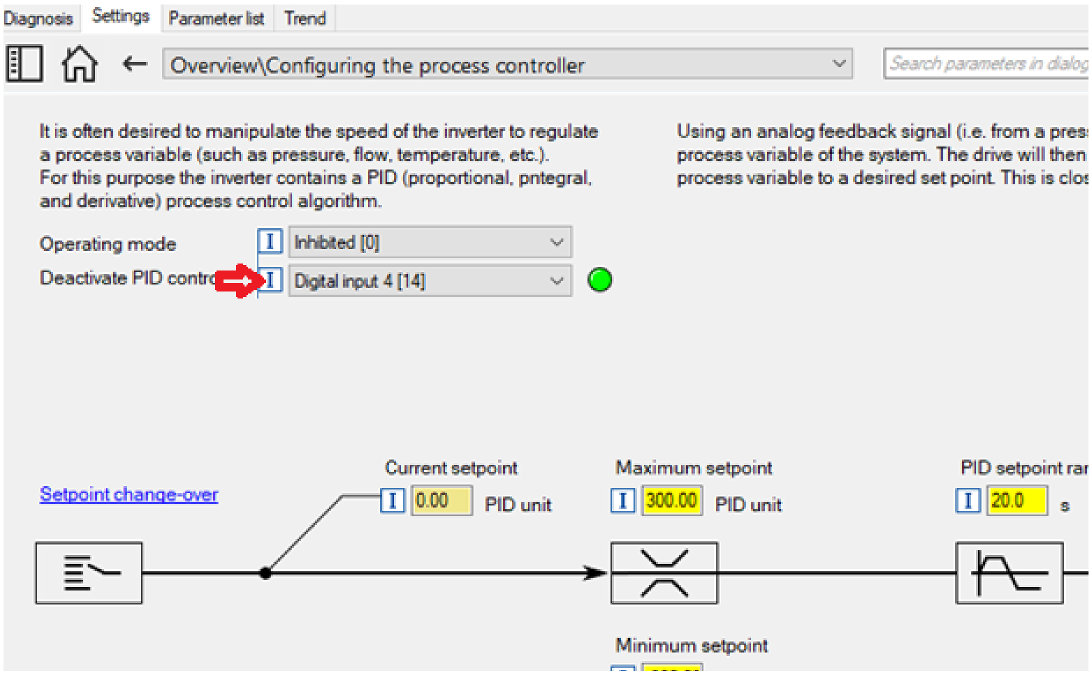
Set “Rinsing in sleep mode (P615:001)” to “Enabled [1]”. Enter the time in minutes for how often the Rinse should be executed in “Rinse interval (P615:002)”. Enter the “Rinse speed (P615:003)”. Finally enter the time in seconds for how long the Rinse should last in “Rinse period (P615:004)”.



E) **Purge (in PID applications)**

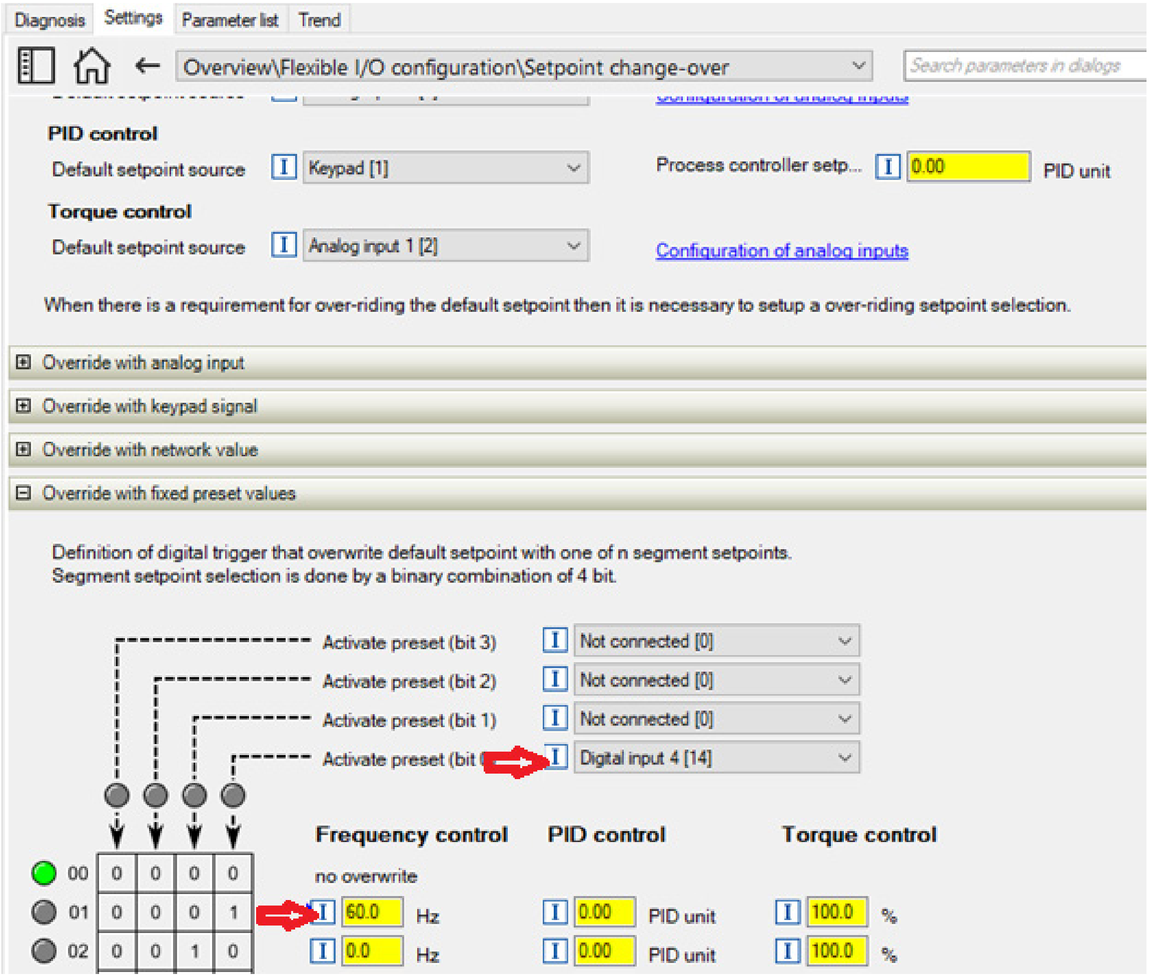
Often in pumping applications that employ PID, a Purge function is desired to clear the lines (i.e. for cleaning in place). This function temporarily overrides the PID control and sets the pump to run at a predefined speed (usually full speed).

First, set “Deactivate PID controller (P400:045)” = to the desired Digital Input to trigger the Purge (i.e. “DI4 [14]”).



Next, set “Activate preset (bit 0) (P400:018)” to be triggered by the same Digital Input to trigger the purge (i.e. “DI4 [14]”).

Finally, set the Purge speed (i.e. 60Hz) in “Preset 1 (P450:001)”.

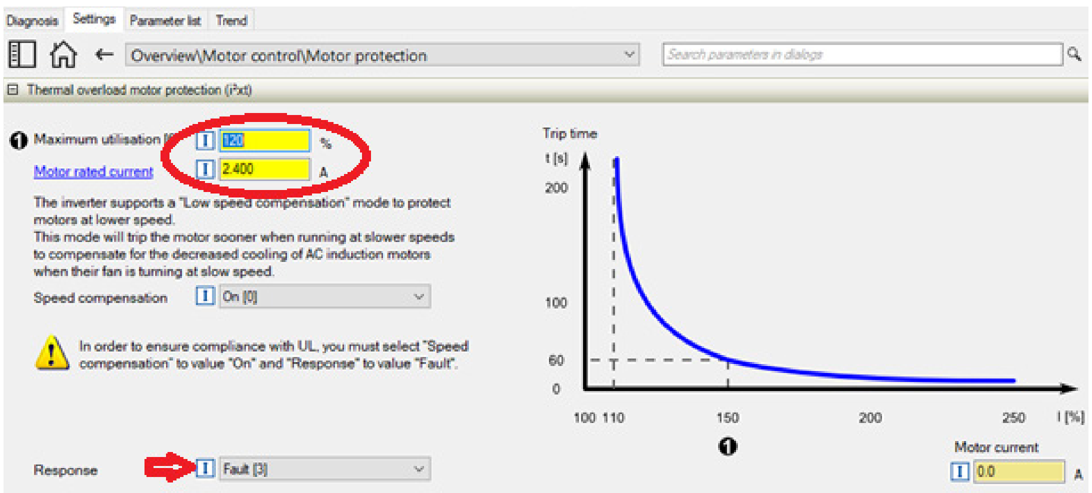


F) Pump Runout (or Zero Head or Open Flow) Detection

Running a centrifugal pump with no (or insufficient) back pressure causes excessive flow and makes the pump run off its pump curve (very inefficient) at max available power. This condition often arises due to a pipe burst or the piping system not being completely installed (or someone could have left a drain open by mistake). **Note: Certain pumps used in the agricultural industry are designed to normally operate in this condition without issue.*

The drive's Motor Overload setting can be used to detect and fault from this condition (and thereby prevent flooding) for most applications — providing the motor is not oversized for the pump. **Note: Macerator (also called "grinder " or "chopper") pumps require higher current capacity to grind down solids, so this approach does not work for those particular applications.*

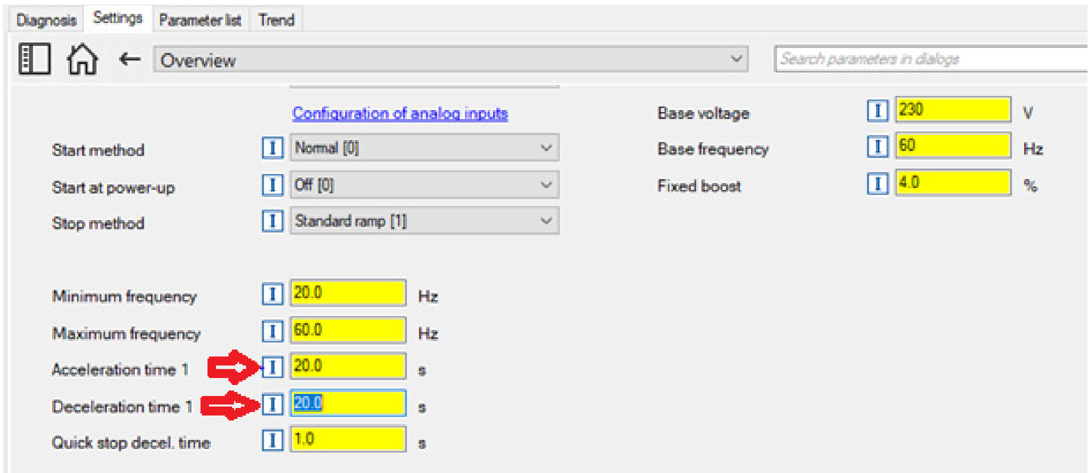
Set the "Maximum utilization (60s) (P308:001)" = 120%. Set the "Motor rated current (P323:000)" to match the motor's nameplate data. Finally set the "Response (P308:003)" = "Fault [3]".



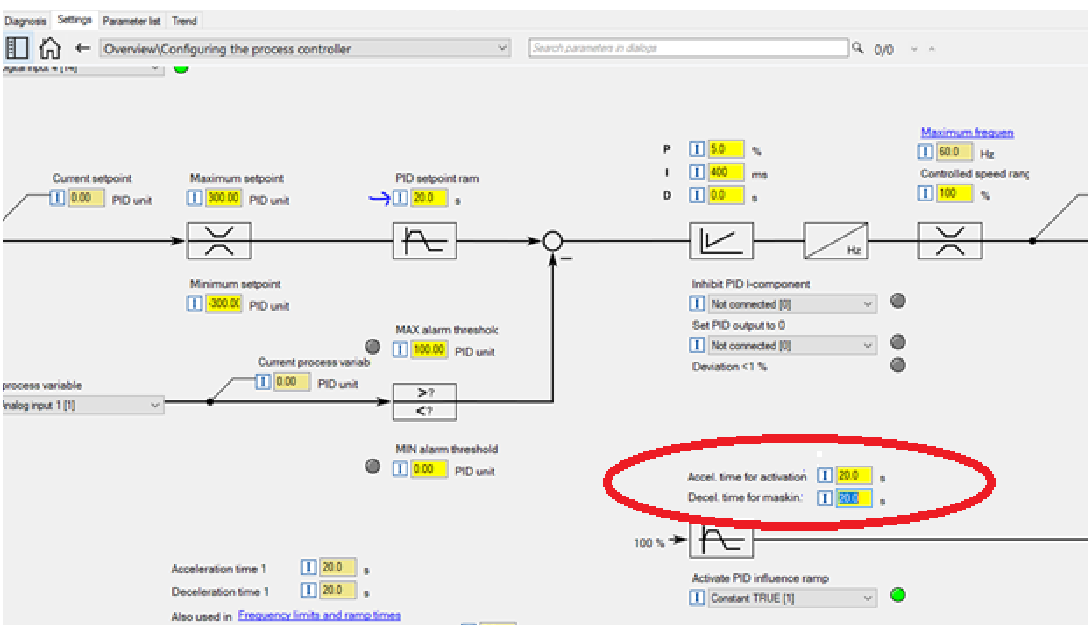
G) Water Hammer Minimization (and Pipe Fill)

Fluid accelerating or decelerating too fast within a piping system can cause pressure shocks which can stress and damage the equipment and the piping system itself. These shocks are called "Water Hammer". The i500 can help minimize these problem when the pump is changing speeds and also particularly when a pump is first started and pushing fluid into an empty piping system (Pipe Fill) by programming longer acceleration and deceleration times.

For applications not using PID, use longer times for both "Acceleration time 1 (P220:000)" and "Deceleration time 1 (P221:000)".

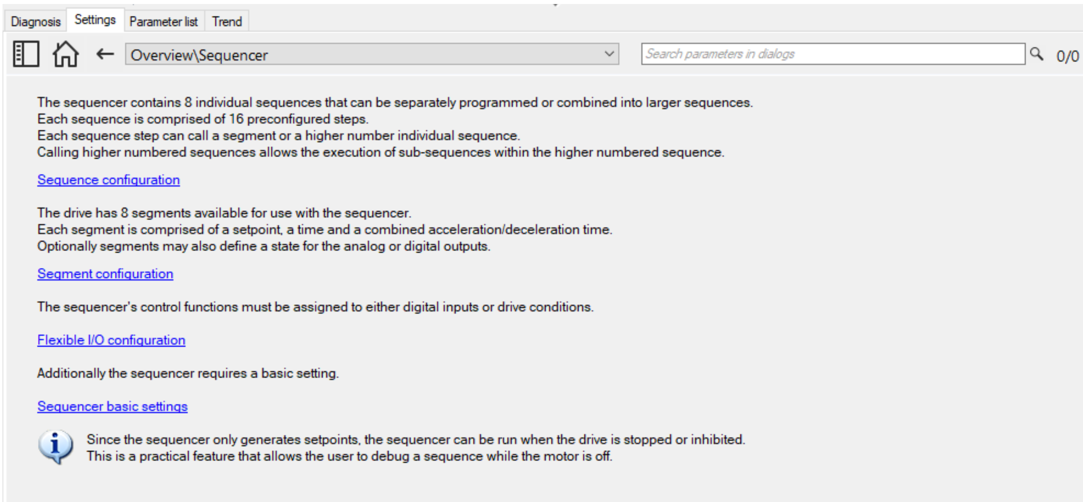


For applications utilizing PID, additionally use longer times for "PID setpoint ramp (P604:000)", "Accel time of activation (P607:001)", and Decel time for masking out (P607:002)".



H) Sequencer

The i500 features an internal advanced sequencer. This can be used to remove the need for supplementary controls in basic repetitive pumping processes. For details on this, see the i510 or i550 Commissioning manual.



I) Impeller Anti Jam

Impeller Anti Jam is a feature in some pump drives that will look for high motor currents at low speeds to determine if the impeller is jammed by some solid material. It may also perform a quick reversal to dislodge the jam. This is very commonly required for macerator pumps. The i500 can perform the same function by means of its sequencer and current limit detection capabilities. Below are the parameter settings to accomplish a basic impeller anti jam.

**Please note: For a macerator pump, "Motor control mode (P300:000)" should be set to "Sensorless Vector (SLVC) [4]" in order to handle the quick dynamic loading of the grinding operation.*

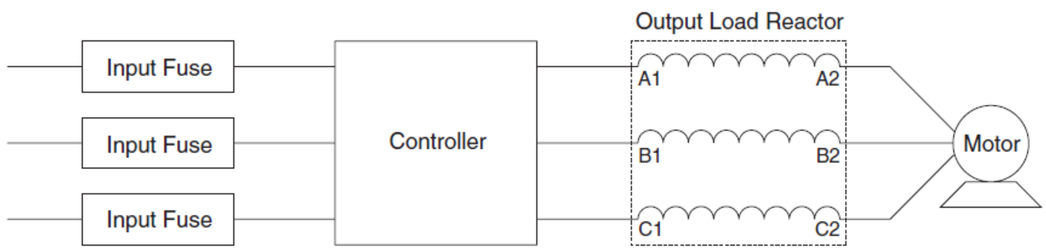
Current Limit condition starts sequencer to run reverse 50Hz 0.5 seconds Accell/Decel = 1.0 second
End of sequence operation = continue to RUN
NOTE: Drive must be configured for FWD/REV rotation
"Limit of rotation (P304:000)" = "Both rotational direct [1]"
"Max current (P324:000)" = 1800 (decimal)
"Start sequence (P400:031)" = "Current limit reached [78]"
"Select sequence (bit 0) (P400:050)" = "Constant TRUE [1]"
"Sequencer mode (P800:000)" = "Time operation [1]"
"Sequencer Segment 1: Frequency setpoint (P801:001)"= "-50.0"
"Sequencer Segment 1: Accel/deceleration(P801:002)" = "1.0"
"Sequencer Segment 1: Time (P801:003)" = "1.0"
"End of sequence mode (P824:000)" = "Abort [3]"
"Sequence 1: Step 1 (P830:001)" = "Segment 1 [1]"
"Cycles Sequence 1 (P831:000)" = "1"

J) Motor Lead Length Considerations for Centrifugal Pumps

Centrifugal pump applications can employ quite long motor lead lengths. A common application that does this is submersible well pumps where the motor may be 500 feet or more from the drive. Below are the basic motor lead length considerations. Lenze offers sinusoidal (dV/dT) filters for use with the 400/480V i500 drives. Common manufacturers of sinusoidal filters and load reactors (chokes) include MTE and TCI. Note: If either a load reactor or dv/dt filter is used, it should be installed as close to the drive output as possible per the mounting guidelines of both devices.

Motor lead length general rules:

- An output reactor should be used if the motor wiring is between 100-500 feet if the motor does not meet NEMA MG-1 Part 31 standard.
- An output reactor should be used if the motor wiring is between 300-500 feet if the motor meets the NEMA MG-1 Part 31 standard.
- If the distance is between 500 and 1000 ft, you would use a Sinusoidal (dV/dT) filter.
- Load reactors are connected in series between the VFD Controller and the motor.



K) Multi Pump Applications (Booster Pump Application Solution)

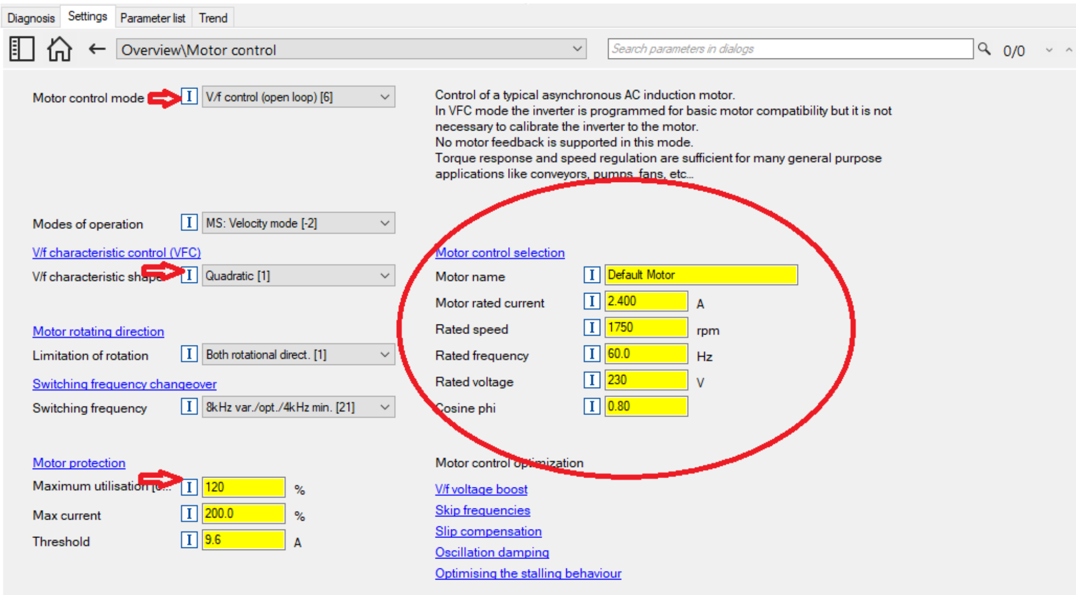
Some pump drives offer built-in logic to solve duplex and triplex pump applications. The i500 can be employed in these types of applications with the addition of an upper level controller (such as the Lenze C300) that would perform the logical tasks and use the drives as I/O.

That being said, the i500 can be employed in a simple booster pump application without the addition of an upper level controller. In this example system two i500 drives will be utilized. One to drive the main pump and another that will run the fixed speed booster pump. The first application consideration that must be noted is that the combination of both pumps (main and booster) must have more capacity than is required by the total system.

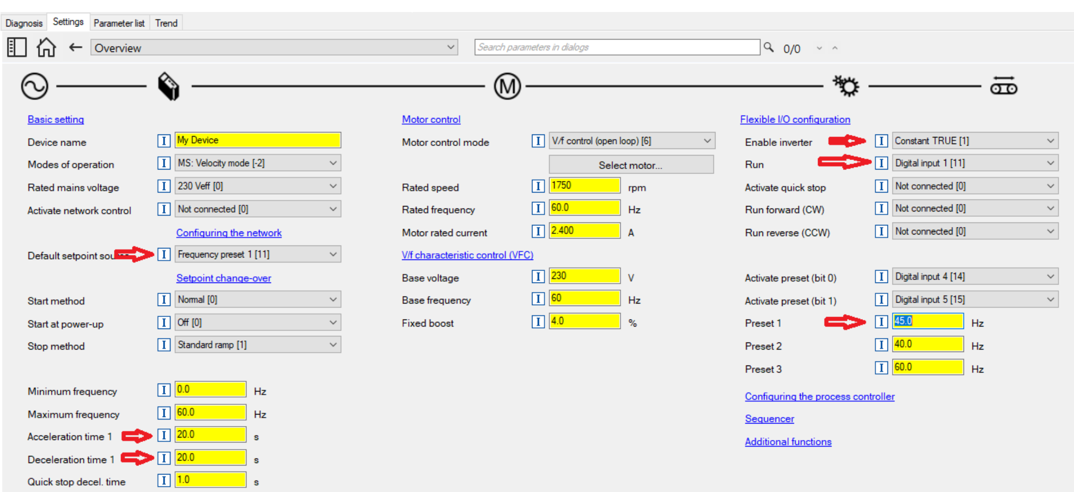
The second application consideration that must be noted is the main pump needs to have more capacity than the booster pump so that controllability of the system can be achieved. If both pumps are physically identical this can be achieved by running the booster pump at a slightly reduced speed (i.e. 45Hz).

Set up the booster pump's drive as follows:

- Set the "Motor control mode (P300:000)" to "V/f control (open loop) [6]".
- Set the "V/f characteristic shape (P302:000)" to "Quadratic [1]".
- Set the "Maximum utilization (P308:001)" to "120"%.
- Set the Motor data per the motor's nameplate.

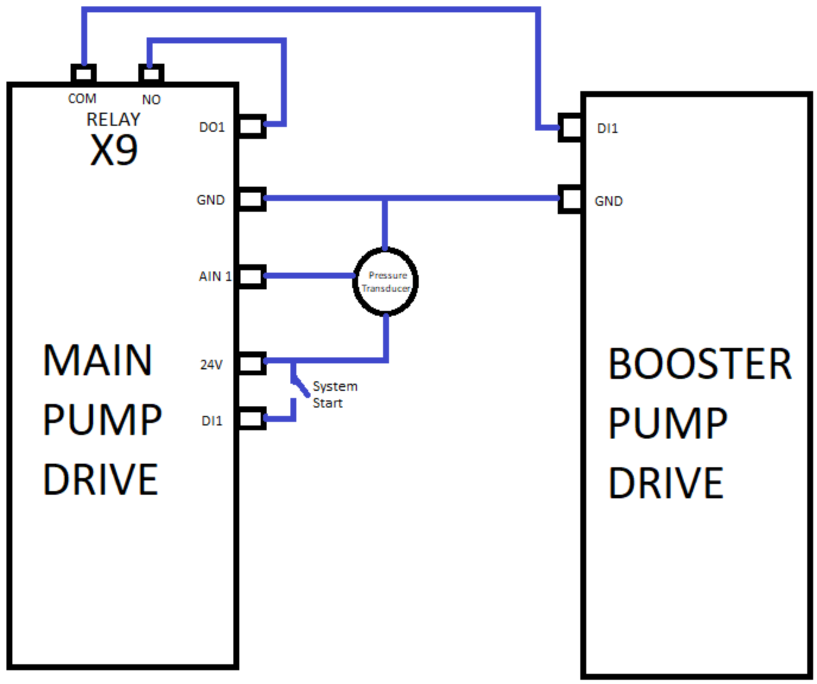


- Next, set the "Default setpoint source (P201:001)" to "Frequency preset 1 [11]".
- Set "Enable inverter (P400:001)" to "Constant TRUE [1]".
- Set "Run (P400:002)" to "Digital input 1 [11]".
- Enter an appropriate frequency into "Preset 1 (P450:001)" that ensures that both the combination of both the booster and main pumps' capacity exceeds the overall system capacity and is still a lower value so that the capacity of the booster pump is smaller than the capacity of the main pump (i.e. If both pumps are physically identical and both combined have sufficient capacity, then set the frequency to 45 Hz).
- Enter a long enough time into both "Acceleration time 1 (P220:000)" and "Deceleration time 1 (P221:000)" to ensure water hammer is minimized during pipe fill for system startup (i.e. 20 seconds).



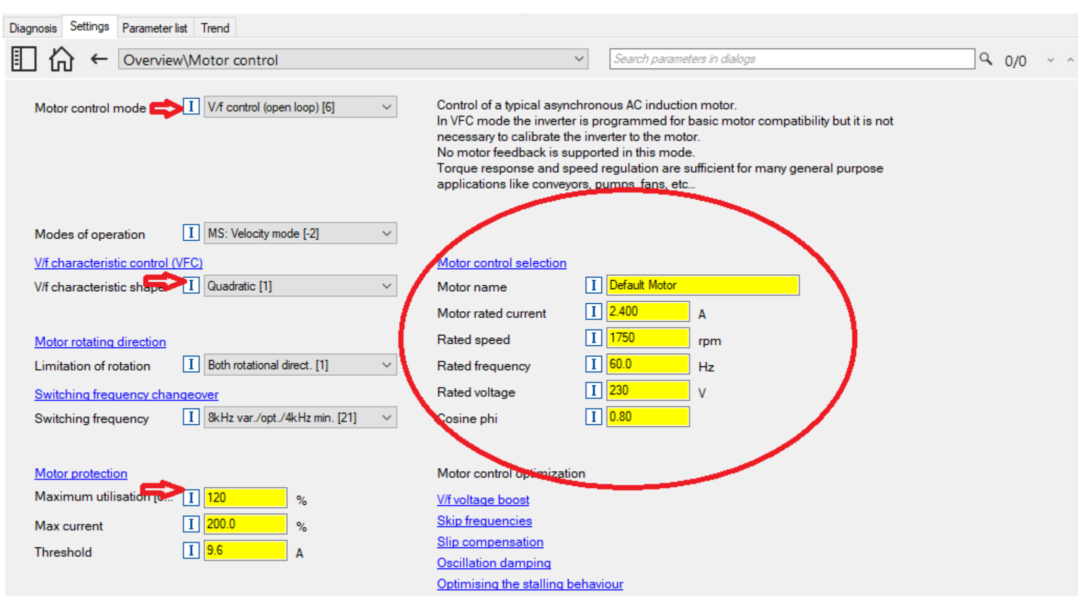
- Next, wire the booster pump's drive DI1 to be triggered by the combination of both the main pump's drive DO1 and Relay output. This will be a series circuit. We will use the combination of both outputs to ensure the booster is only turned on when called for by the main pump's drive and also to ensure the booster is not turned on if the main pump's drive is not running.

The wiring diagram is shown below:

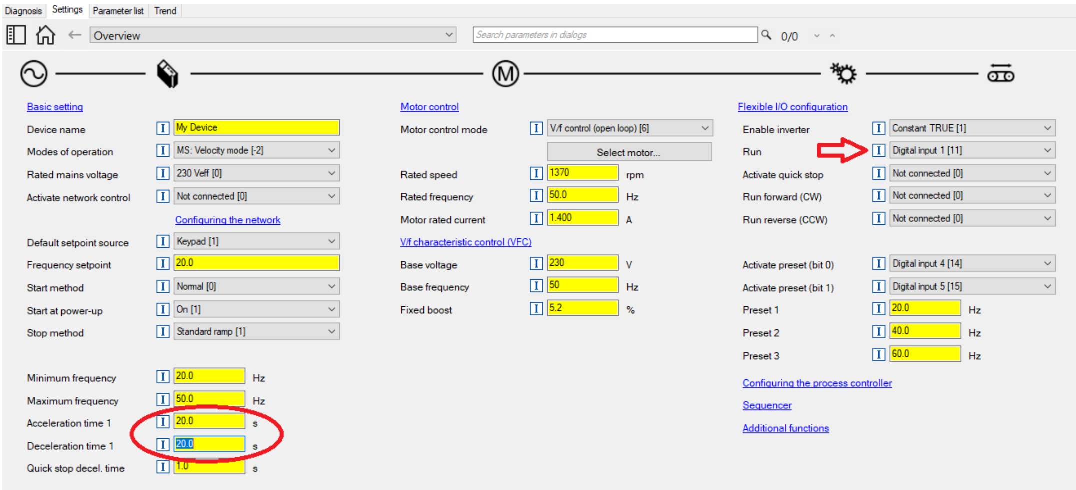


For the Main Pump Drive:

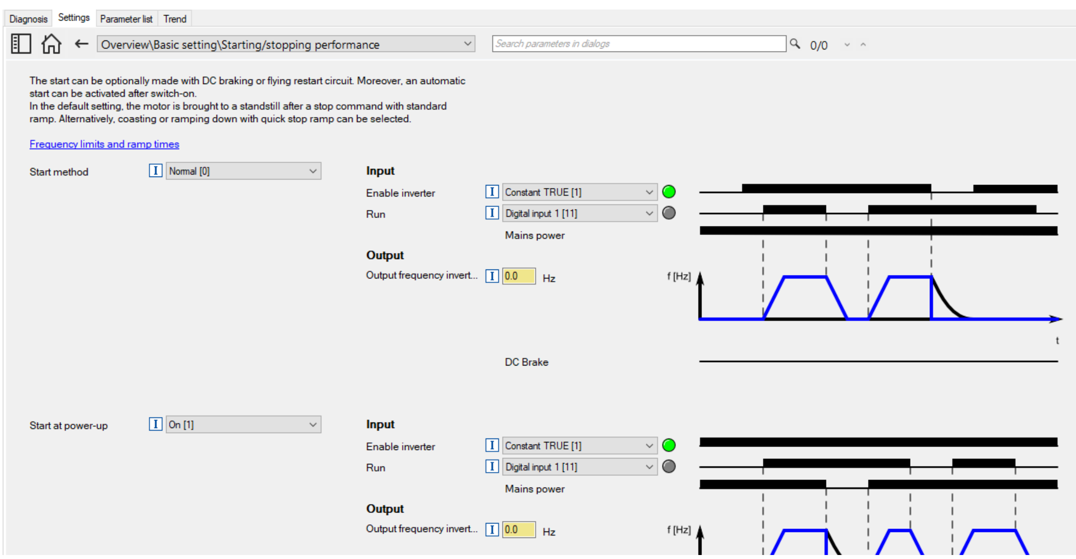
- Set the "Motor control mode (P300:000)" to "V/f control (open loop) [6]".
- Set the "V/f characteristic shape (P302:000)" to "Quadratic [1]".
- Set the "Maximum utilization (P308:001)" to "120"%.
- Set the Motor data per the motor's nameplate.



- Next, set “Enable inverter (P400:001)” to “Constant TRUE [1]”.
- Set “Run (P400:002)” to “Digital input 1 [11]”. You will wire your system RUN/STOP contact to DI1 of the Main Pump Drive.
- Finally, enter a long enough time into both “Acceleration time 1 (P220:000)” and “Deceleration time 1 (P221:000)” to ensure water hammer is minimized during pipe fill for system startup (i.e. 20 seconds). Use the same value for these times as was entered in the Booster Pump Drive.

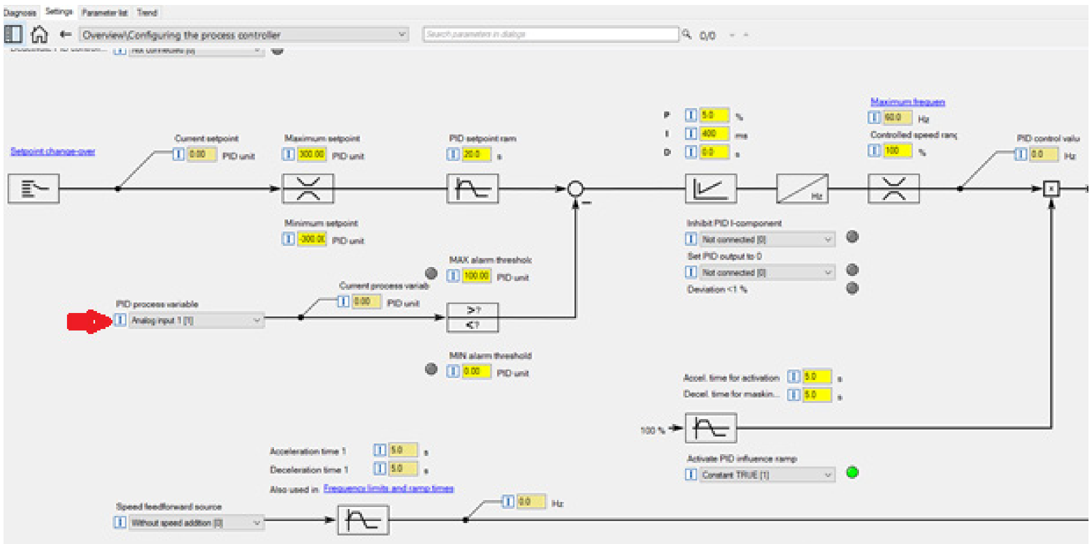


- Set “Start at power-up (P203:002)” to “On [1]”.

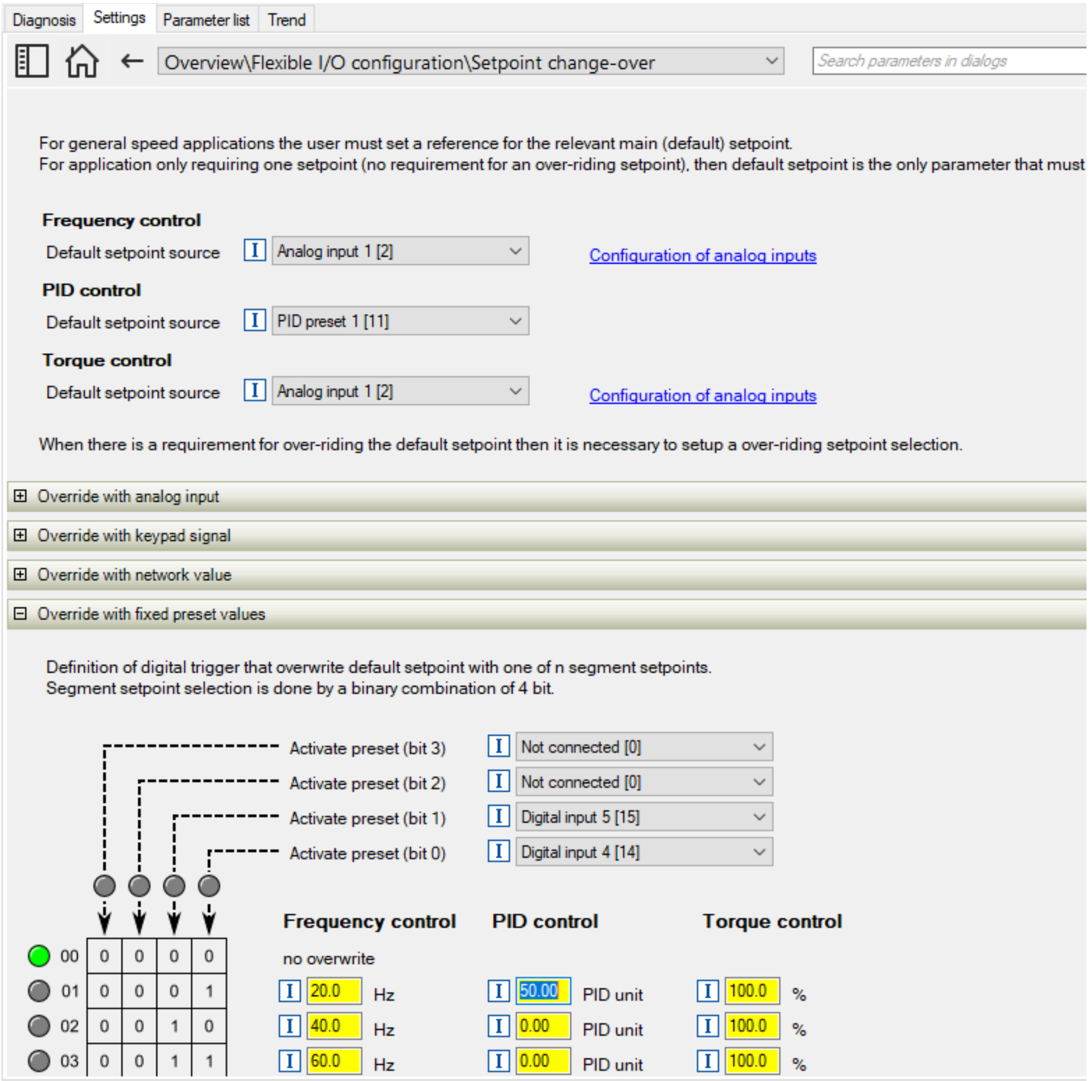


Now PID must be set up for the application:

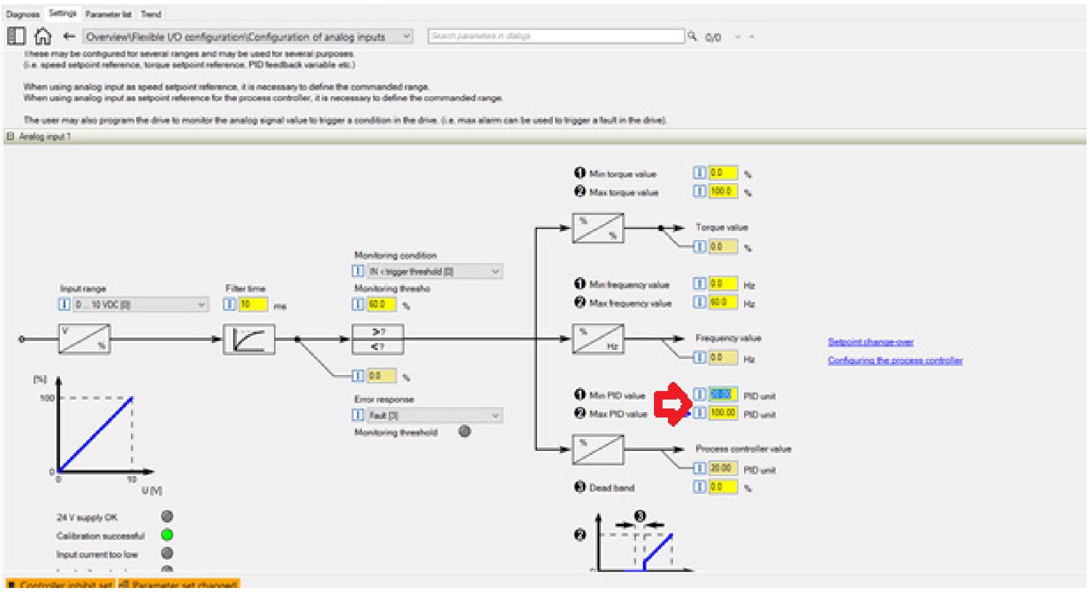
- First, an appropriate analog sensor is installed into the system. Wire this pressure transducer to AIN1 of the Main Pump Drive. Pressure control from a centrifugal pump is a "normal acting" PID application.
- Set the "Operating mode (P600:001)" for "Normal operation [1]".
- Next, we need to program which drive analog input will be used as the monitored process variable. Set "PID process variable (P600:002)" either equal to "Analog input 1 [1]".



- Next, we need to program the drive for where the set point source is. The set point is the command value the drive is trying to get the monitored process variable to match. Set point sources can include the keypad, an analog signal (must not be the same analog input as the monitored process variable) or a predefined internal set point. Set "Default set point source (P201:002)" to one of the following selections as appropriate: "Keypad [1]", "Analog input 2 [3]", or "PID preset 1 [11]". If you use "PID preset 1 [11]" as the set point, ensure you also program that desired set point value in "Preset 1 (P451.001)".

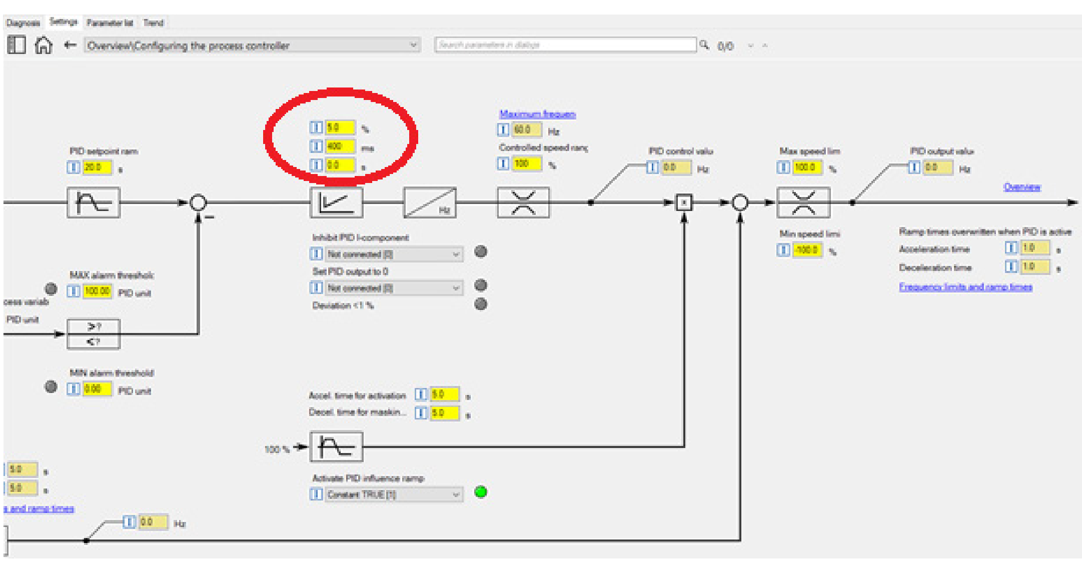


Please note the set point value is in User defined PID units, which in turn are configured in the monitored process variable's analog input channel configuration. Program both the "Min PID value (P43x:004)" and the "Max PID value (P43x:005)" to match the signal range of the analog sensor used to monitor the process variable. Enter this value in PID units (so if the sensor was 0-10VDC = 20-100PSI, set P43x:004 = 20.0 and P43x:005 = 100).



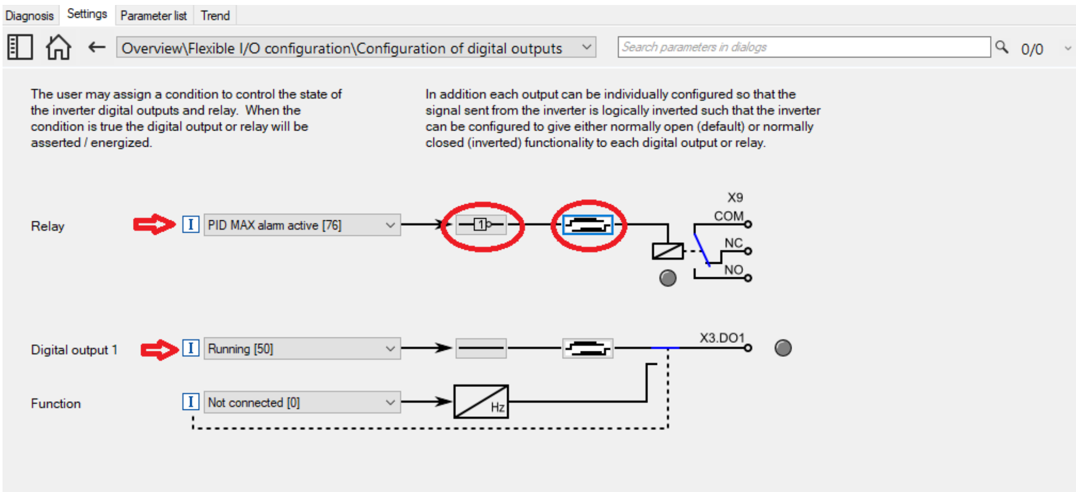
The PID loop must then be tuned on the running system for the application. Do this under a load that can be sustained by the Main Pump running alone. A common approach to PID tuning is the following.

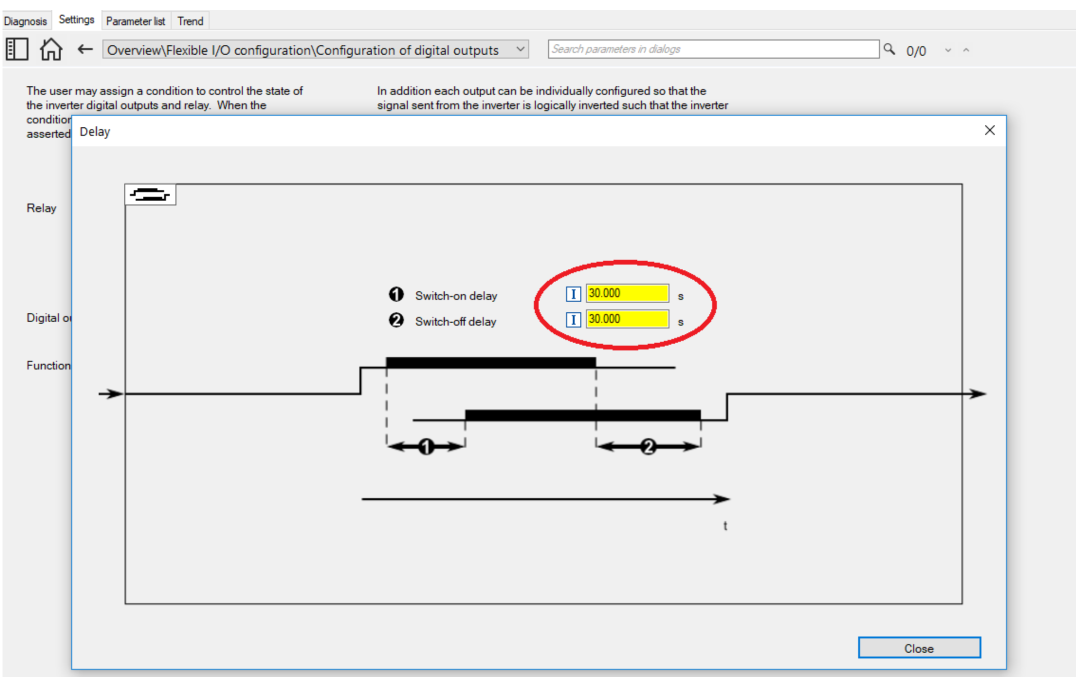
1. Set the reset time for the I component to 6000 ms in "PID I-component (P602.000)" to deactivate the I component. With this setting and the default setting of "PID D-component (P603.000)", the process controller operates as P controller.
2. Increase gain of the P component step by step in "PID P-component (P601.000)" until the system becomes unstable (oscillates).
3. Reduce the gain again until the system is stable again (stops oscillating).
4. Reduce the gain by another 15%.
5. Set reset time for the I component in "PID I-component (P602.000)". With this setting it should be noted that a too low reset time may cause overshoots, especially in case of high steps of the system deviation.
6. Optional: set the gain of the D component in "PID D-component (P603.000)".
   • With this setting it should be noted that the D component responds very sensitively to electrical noise disturbances on the feedback as well as digitization errors. For most systems the "PID D-component (P603:000)" may be left at a value of 0. This is typically only required for extremely fast acting systems.



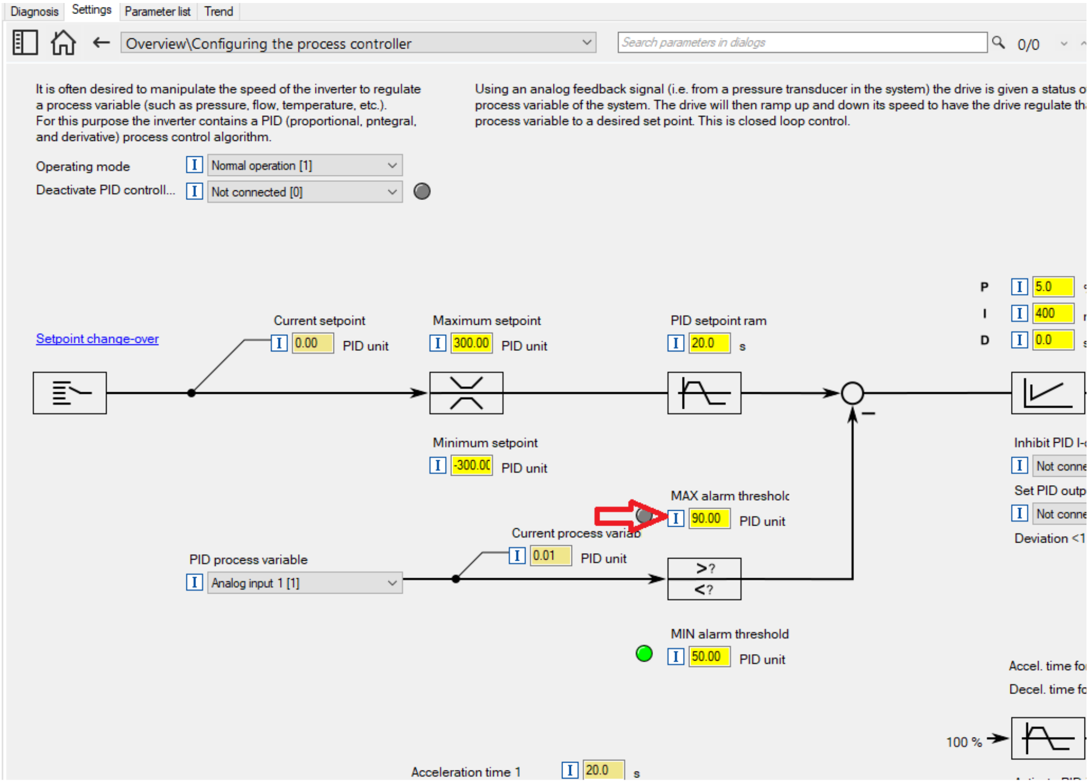
Now we must create the triggering conditions to control DO1 and the Relay output of the Main Pump drive to start and stop the Booster Pump drive.

- Configure the "Digital outputs function: Relay (P420:001)" for "PID MAX alarm active [76]" also configure the "Inversion of digital outputs: Relay (P421:001)" to be "Inverted [1]". This is a default setting and we will be using parameter change over to switch the assignments to complete the application control in a later step.
- Set "Digital outputs function: Digital output 1 (P420:002)" to "Running [50]".
- Set the "Relay: Switch on delay (0x4018:004)" and the "Relay: Switch off delay (0x4018:003)" to a value LONGER than that which was set for the "Acceleration time 1 (P220:000)" and "Deceleration time 1 (P221:000)". Recommend the value be at least 50% more (so if Acceleration time 1 is set to 20 seconds, set the Switch on and Switch off delays to at least 30 seconds). This is necessary to create a hysteresis and have controllability of the system.

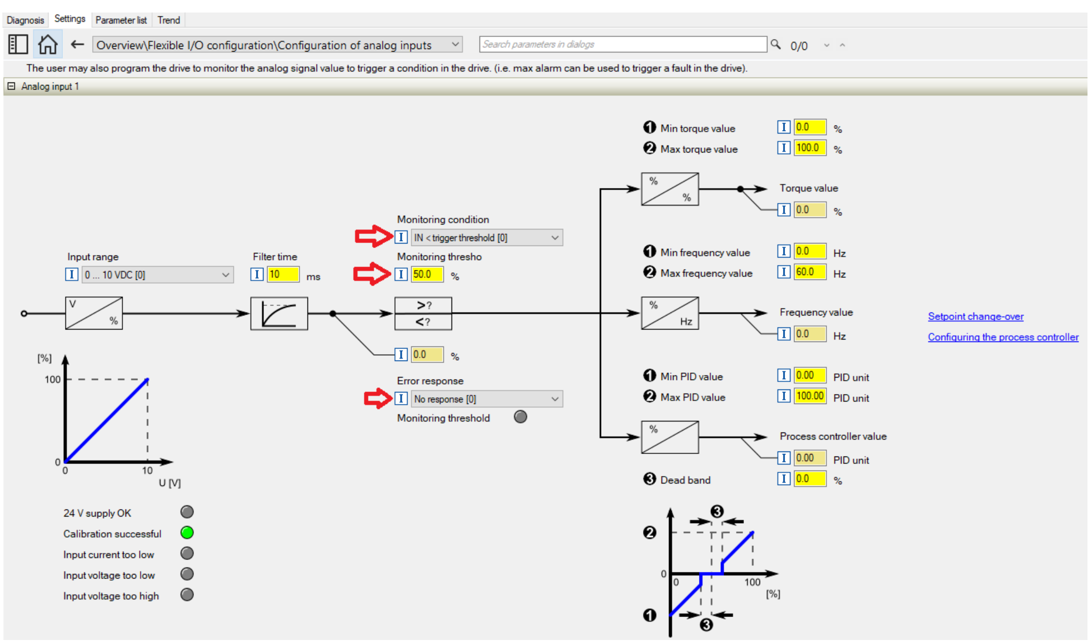




- Set the “MAX alarm threshold (P608:002)” to the highest level the system can tolerate above the setpoint to define the pressure at which the Booster pump should turn off. This value is entered in PID units.

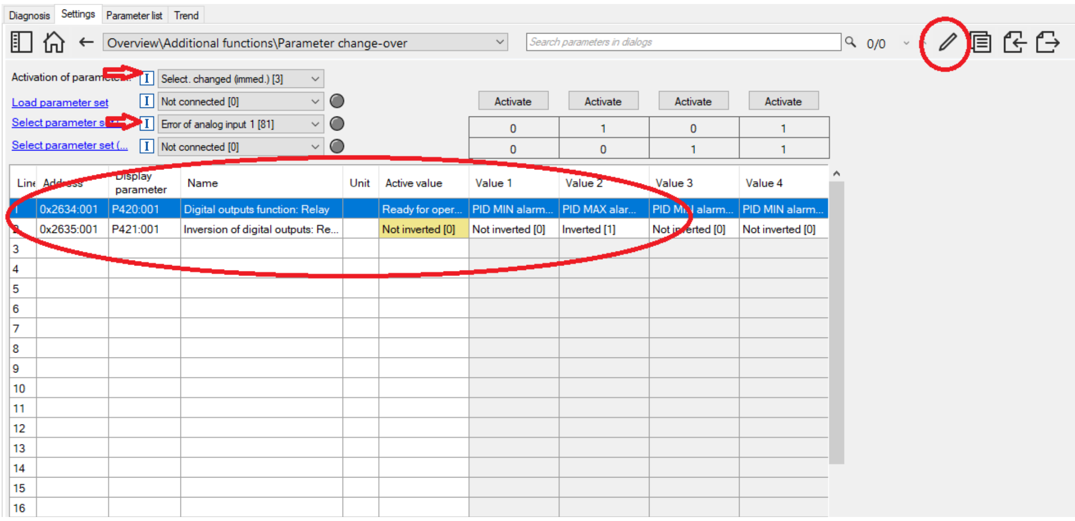


- Set the “Analog input 1: monitoring condition (P430:009)” to “IN< trigger threshold [0]”.
- Then set the value of the “Analog input 1: monitoring threshold (P430:008)” to the minimum allowable value for the pressure transducer to fall to in the application to define the point at which the Booster Pump should come on. Note: This value is set as a percentage of the Analog input 1’s overall range. It is NOT in PID units.
- Set the “Analog input 1: Error response (P430:010)” to “No response [0]”.



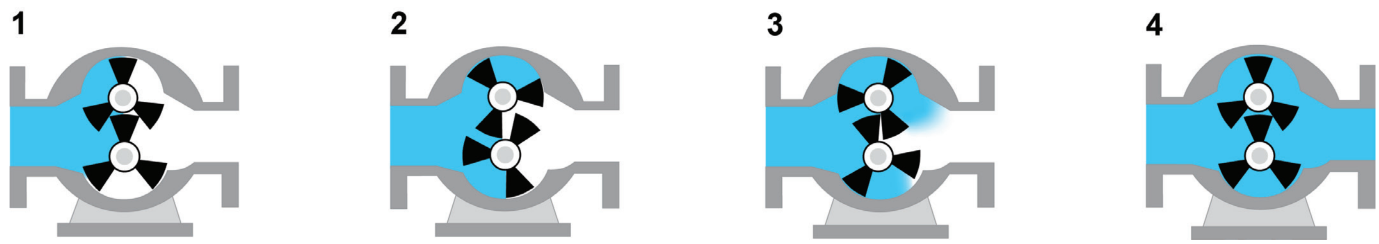
Lastly, the Parameter change-over function must be configured to achieve the control action.
Set the following:

- "Activation of parameter set (P755:000)" = "Select. changed (immed) [3]"
- "Select parameter set (bit 0) (P400:041)" = "Error of analog input 1 [81]"
- Configure both the "Digital output function: Relay (P420:001)" and the "Inversion of digital outputs: Relay (P421:001)" parameters to be switched as shown below for BOTH "Value 1" and "Value 2":



II. Positive displacement pumps

There are many, many types of positive displacement pumps. Some common examples include rotary lobe pumps, peristaltic pumps, progressive cavity pumps, piston pumps, external gear pumps, internal gear pumps and liquid ring pumps. They all have one thing in common. They operate by opening and closing voids to create a definitive flow. Below is an example of a rotary lobe pumps operation:



Positive displacement pumps are used in applications where any of the following applies:

- **The pump itself must perform metering (or dosing).**
- **Highly viscous fluids need to be pumped (i.e. peanut butter).**
- **Gentle fluid handling is required.**
- **High pressures are required.**
- **Fluids must have entrained solids.**
- **Fluids are non-Newtonian.**

These applications have comparatively lower flow rates than those in which centrifugal pumps are employed.

There are some basic terms associated with positive displacement pumps to be aware of:

Entrained Solids - Simply put, these are solid pieces of material in the fluid. For example, if piping apple pie filling, apple slices would be the entrained solids in the pumped fluid.

Gentle Fluid Handling - Some fluids (such as emulsions) can be damaged by too much shear. For example, mayonnaise can form oil droplets in it if it excessively worked while pumping. Gentle fluid handling is simply moving the fluid with a minimal amount of shear introduced. Positive Displacement pumps are often used for gentle fluid handling applications.

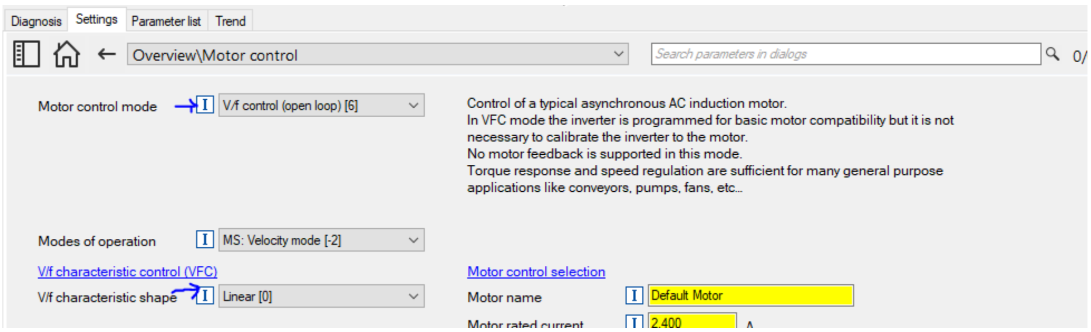
Non-Newtonian Fluid - In general consideration when used with pumps; a Non Newtonian fluid is a fluid that changes its viscosity with the duration of stress (or shear). There are two basic types of Non-Newtonian Fluids:

- **Pseudoplastic fluids** decrease viscosity with the duration of stress. For example, it takes a bit of effort to get ketchup in a bottle to start to flow, but not much to keep it flowing.

- **Dilatant fluids** increase viscosity with the duration of stress. For example, corn starch in water flows easily when poured slowly; however, turns into a nearly solid substance when vibrated. Try putting it on top of plastic saran wrap on top of a subwoofer and kick up the base to watch it harden and flow with the beat.

A) Motor Control Method

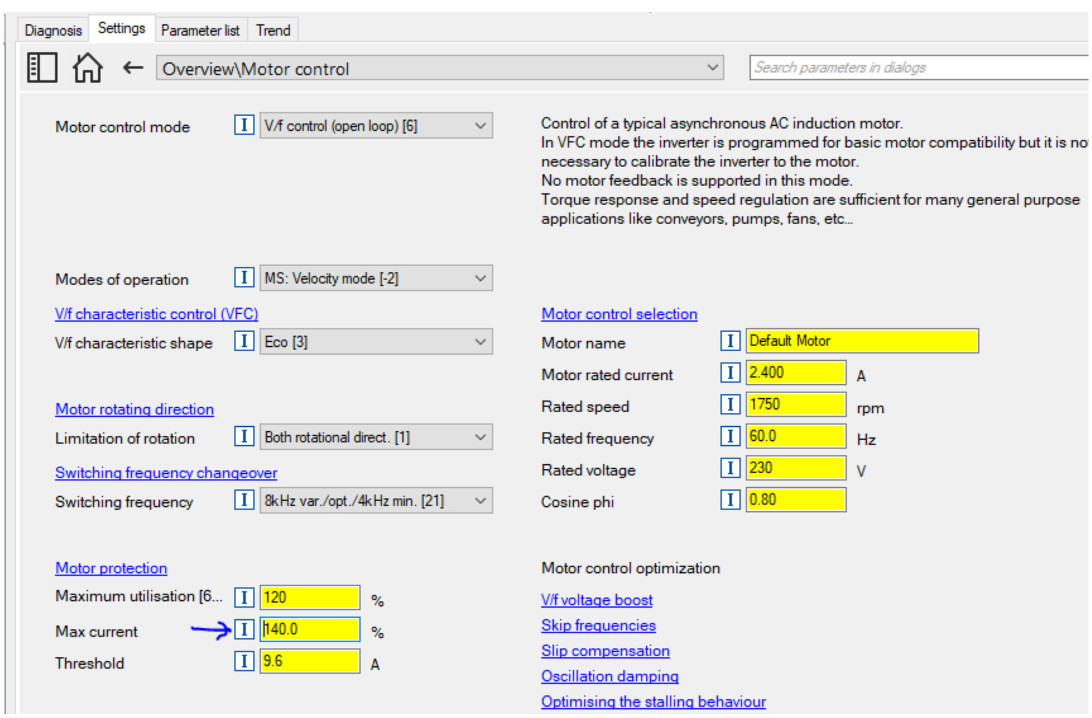
Positive displacement pumps do not follow the affinity laws. They are a constant torque application. As such “Motor control mode (P300:000)” should be set to “Sensorless Vector (SLVC) [4]” for the most accurate flow control. This will also facilitate easy starting of fluids that either have a constant viscosity or fluids which are pseudo plastic where viscosity drops as a function of shear rate. “Motor control mode (P300:000)” can also be set to “V/f control (open loop) [6]” with the “V/f characteristic shape (P302.000)” also set to either “Linear [0]” or “Eco [3]” for less demanding applications. The “Eco [3]” setting has the advantage that energy savings can be achieved by reduction of the voltage supplied to the motor in light loading. This is useful in applications where the fluid pumped is shear-thinning and does not require significant force to get flow started.



B) Pressure Limitation

It is extremely important to understand that with a positive displacement pump the fluid must always have a path to follow. If the discharge is shut off (dead head) the fluid will continue to try to pump to the maximum pressure that either the motor’s available torque can create or to the point of a failure within the piping system (should it rupture).

Most piping systems in such applications are equipped with either rupture disks or pressure relief valves to ensure breakage is at a defined pressure low enough to protect equipment and limited to a defined location. This is good practice and should be used. That said, the i500’s “Max current (P324:000)” setting can be used to limit the available motor torque.



C) PID and Purge

Positive displacement pumps can be used in PID applications. A common example is dosing a solution to maintain a given pH level. The need for a Purge function in PID also can occur with positive displacement pump applications. The setup is identical to those used with centrifugal pumps. See sections I.B and I.E above.