Clean Power VFD

AN005 - Optimize Pump Pressure Control with Clean Power VFD's Embedded PID

Application overview

This application note provides a step-by-step guide to implementing pressure control using the Clean Power VFD's embedded PID functionality. It covers how to configure and optimize PID parameters, select appropriate feedback devices, and troubleshoot common challenges. Additionally, an annex will explain external feedback options, including how to properly scale and filter signals from pressure transducers for optimal performance. .

Pump Pressure Control
In many industrial and commercial applications, maintaining consistent pressure is critical for efficient and reliable system operation.

Pumps play a key role in these processes, and using a Variable Frequency Drive (VFD) with an embedded Proportional-Integral-Derivative (PID) controller offers a highly effective way to regulate pressure dynamically.

Traditional methods of pressure control, such as mechanical valves or bypass loops, often result in energy waste, mechanical wear, and slow response times. By leveraging the Clean Power VFD's embedded PID controller, users can precisely adjust pump speed based on real-time pressure feedback, reducing energy consumption and extending equipment lifespan.

Implementation guides

Software Compatibility

Please make sure to update your Clean Power VFD's firmware to version 2024.17.01 or later to use the embedded PID functionality.

You can find the link to download the firmware in the latest firmware release notes on the [SmartD Help Center](#).

Overview of PID-based pressure control with the Clean Power VFD

In this application, the Clean Power VFD regulates the speed of a pump motor to maintain a stable pressure setpoint.

Instead of relying on a separate controller, the VFD's embedded PID functionality continuously adjusts motor speed based on real-time feedback from a pressure transducer. This approach eliminates the need for mechanical control methods such as pressure-reducing valves, reducing energy losses, and improving system efficiency.

How the VFD Maintains Pressure Control

1. Setpoint Definition: The desired system pressure is defined as a setpoint within the VFD's PID controller. This setpoint can be manually set by an operator or received from an external system such as a PLC or HMI.

2. Feedback Signal: A pressure transducer provides real-time system pressure data, which is fed back to the VFD's PID controller. The signal is scaled and filtered for accurate processing.

3. PID Regulation: The embedded PID algorithm in the VFD compares the feedback signal with the setpoint and calculates the necessary motor speed adjustment to minimize the error.

4. Motor Speed Adjustment: The VFD dynamically modulates the motor's speed and torque, ensuring the pump only operates at the required level to maintain pressure.

VFD-only control bs PLC integration

While the Clean Power VFD can perform standalone PID-based pressure control, integrating it with a Programmable Logic Controller (PLC) offers additional flexibility and scalability. Below is a comparison of both approaches:

Standalone VFD Control:
☑ **Simpler Setup:** The Clean Power VFD's built-in PID function eliminates the need for external controllers.
☑ **Lower Cost:** No additional PLC hardware or programming is required.
☒ **Limited Functionality:** The VFD can maintain a stable setpoint but lacks advanced logic capabilities for system-wide process control.

VFD with PLC Integration:
☑ **Enhanced Control Flexibility:** The PLC can manage multiple setpoints, implement safety interlocks, and respond dynamically to system conditions.
☑ **Scalability:** A PLC can coordinate multiple VFDs, pumps, and system components, making it ideal for larger installations.
☑ **Data Logging & Remote Monitoring:** The PLC can collect and analyze performance data, enabling predictive maintenance and system optimization.
☒ **Increased Complexity & Cost:** Additional hardware and programming are required, leading to a more complex setup.

Application Scope & Considerations

This application note focuses on implementing PID-based pressure control using the Clean Power VFD as a standalone controller. It provides step-by-step guidance on configuring PID parameters, optimizing response time, and troubleshooting common issues. For applications requiring more advanced automation, PLC integration can be considered as an extension of this implementation.

By leveraging the Clean Power VFD's embedded PID capabilities, users can achieve precise pressure control, improve energy efficiency, and extend the lifespan of their pumping systems with minimal hardware and programming effort.

Step-by-step implementation

This section provides a step-by-step approach to setting up and configuring the Clean Power VFD for PID-based pump pressure control.
This approach is based on a **Cooling System in Manufacturing Plants:**

- **Pressure Range:** 5 to 8 bar
- **Application:** Factories use water-cooled systems to maintain optimal temperatures for machinery, such as in metal processing, plastics molding, and power generation. Consistent pressure ensures efficient heat exchange and prevents overheating.

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Following these steps will ensure proper installation, configuration, and optimization of the system for stable and efficient pressure regulation.

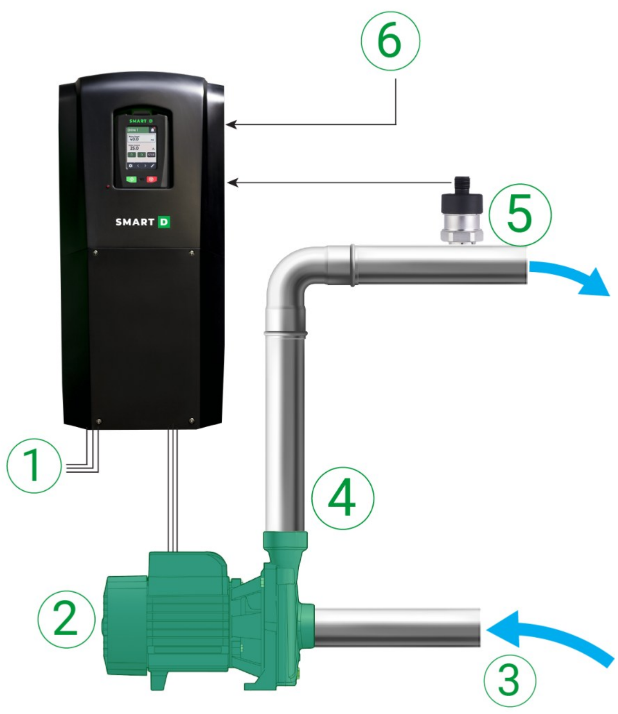
1. Prepare the Hardware: Gather all necessary components, including the Clean Power VFD, motor, pressure transducer, and safety protections, ensuring compliance with local and international regulations.

2. Connect the Hardware: Properly wire the VFD to the motor, process sensor, and setpoint source, following the user manual's instructions for correct signal routing and grounding.

3. Configure the VFD: Set up motor parameters, PID settings, and input scaling to match the application's requirements. Adjust P, I, and D gains to achieve stable pressure control.

4. Test the System: Verify that the motor responds correctly to setpoint adjustments, ensuring smooth operation and an accurate control loop. Troubleshoot any instability or delays in response.

5. Monitor and Adjust: Continuously observe system performance, fine-tune PID parameters if necessary, and ensure long-term stability through regular monitoring and maintenance.



1. Main power
2. Motor pump
3, Suction
4. Discharge
5. Pressure transducer 0 to 10 bars, output 4 to 20mA
6. Setpoint

Prepare the hardware

Selecting the right components is essential for ensuring reliable operation and achieving optimal pressure control with the Clean Power VFD's embedded PID. The following are general recommendations to guide the selection process; however, the final choice of products and solutions must be made by a qualified professional based on the specific application parameters.

These parameters include:

- **Required Pressure and Flow Rate:** The system's operational pressure and flow demand must be carefully assessed to ensure proper pump and sensor selection.
- **Motor Power and Torque Requirements:** The motor must be adequately sized to handle the pump's operational load.
- **Electrical Supply and Installation Constraints:** Voltage, frequency, available electrical protections, and compliance with local regulations must be considered.
- **Environmental Conditions:** Temperature, humidity, and exposure to dust, water, or corrosive substances can influence material selection.
- **Control and Monitoring Needs:** The level of automation, feedback accuracy, and communication with external systems (e.g., PLC, SCADA) impact component selection.

Define the pump in regards to your application

The choice of pump must align with the process requirements, ensuring optimal efficiency and reliable operation.

Pump Type:

- Centrifugal Pumps: Suitable for applications with varying flow demands, such as water distribution and cooling systems.
- Positive Displacement Pumps: Used in applications requiring precise flow control, such as chemical dosing.

Key Selection Factors:

- Pressure & Flow Rate: The pump must meet the system's maximum expected pressure and flow rate.
- Efficiency Considerations: Higher-efficiency pumps reduce energy consumption.
- Material Compatibility: Ensure pump materials are suitable for the type of fluid being handled.

A professional should evaluate pump curves and process requirements to ensure proper selection.

Selecting the Motor

The motor must be chosen based on the pump's power requirements and the operating environment.

Key Selection Factors:

- Power Rating & Torque: The motor must handle peak loads without excessive overheating.
- Voltage & Frequency Compatibility: Match motor ratings with the VFD and electrical supply.
- Cooling Method: Consider the need for TEFC (Totally Enclosed Fan Cooled) vs. ODP (Open Drip Proof) motors based on environmental conditions.

A motor selection specialist should ensure the correct power, efficiency class, and protection level for long-term performance.

Selecting the Clean Power VFD

The Clean Power VFD must be appropriately sized and configured for the specific application.

Key Selection Factors:

- Power & Current Ratings: Ensure the VFD can handle the motor's full load current.
- Voltage Compatibility: The VFD should match the supply voltage (480V, 600V).
- Control Features: Verify that the VFD has enough analog inputs for sensor feedback and setpoint adjustment.

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Selecting the Pressure Transducer

The pressure transducer provides the feedback necessary for the PID loop and must be carefully chosen based on system conditions.

Key Selection Factors:

- Operating Pressure Range: The transducer should handle the expected pressure variations without exceeding its rated capacity.
- Output Signal Type:
  - 4-20mA: Preferred for long cable runs and high noise immunity.
  - 0-10V: Suitable for shorter distances but more susceptible to noise.
- Power Supply Compatibility: Ensure the transducer operates within the VFD’s available voltage range (e.g., 24V DC).
- Mounting & Material: Stainless steel is preferred for durability in industrial applications.

A process engineer should assess the pressure transducer specifications based on system requirements and installation constraints.

Selecting Electrical Protections

Electrical protection devices are essential for safeguarding system components and personnel. Their selection must align with regulatory standards and system operating conditions.

Input Protection:

- Circuit breakers or fuses must match the VFD’s input power requirements.
- Surge protection devices (SPD) prevent voltage spikes.
- Motor Protection:
- Overload relays and thermal protection devices ensure motor longevity.
- Ground fault detection enhances safety.
- Emergency Stop Circuit:
- A hardwired E-stop or safety relay should be included in compliance with local safety regulations.

A licensed electrical professional should design and implement electrical protections to meet safety and performance requirements.

Configure the VFD for PID control

Pre-requisite:

- Familiarity with the Clean Power VFD App: You should already be comfortable navigating and configuring parameters using the Clean Power VFD’s mobile app.
- Drive Pre-Configuration & Autotuning: The VFD must already be set up and autotuned for the connected motor to ensure optimal control. The control mode V/f (Hz) is sufficient to drive a centrifugal pump.

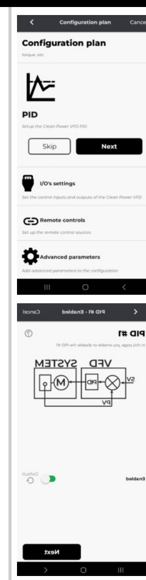
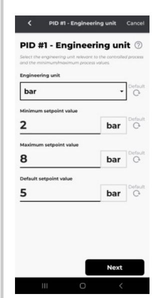
System Configuration Assumptions

The following settings are used in this guide. If your application differs, adjustments may be necessary:

- Request to implement sleep mode to save energy when demand is low and fine-tune ramp rates to prevent water hammer effects.
- Process Feedback Input: Analog Input 2 is used to receive the 4-20mA pressure transducer signal.
- Sensor Scaling: 0 to 10 bar pressure transducer.
- Signal Range: 4mA corresponds to o bar, and 20mA corresponds to 10 bar pressure.
- Setpoint Control: The process setpoint is defined via the HMI interface, it is set at 8 bar.
- Operator Control Range: The setpoint can be adjusted between 20% and 80% of the full scale.
- Initial Setpoint Value: 50% of full scale.
- Setpoint Ramping: To prevent sudden changes in pressure, the setpoint is ramped with:
  - Acceleration Rate: 0.5 bar per second.
  - Deceleration Rate: 1 bar per second.
- PID Output Limits:
  - Minimum Frequency: 10 Hz.
  - Maximum Frequency: 45 Hz.
- Acceptable small deviation around the setpoint: +/- 1 bar
- Sleep Mode & Wake-Up Functionality:
  - Sleep Condition: If the motor frequency remains below 13 Hz for 120 seconds, the VFD enters sleep mode.
  - Wake-Up Condition: If the PID error exceeds 2 bars for 30 seconds, the VFD exits sleep mode and resumes operation.

These prerequisites ensure that the Clean Power VFD operates within the intended design constraints while maintaining smooth pressure control.

Configuration of the PID using the configuration wizard

Step-by-step on the mobile application	
Enable the PID: Navigate to PID in the configuration plan and enable the PID, sliding the toggle switch. Click Next to accept the change, and move to the following page for engineering unit. Once enabled, all PID setup parameters can be edited	
PID Engineering Units and Setpoint Limits You need to select a predefined engineering unit or create your Own In this application, the pressure is measured in bar: drop down the engineering unit list and select bar In the application assumption, we defined: The setpoint can be adjusted between 20% and 80% of the full scale. Initial Setpoint Value: 50% of full scale. So, enter 2 for the minimum setpoint value (20% of 10 bars), 8 for the maximum setpoint value (80% of 10 bars), and 5 (50% of 10 bars) as the default setpoint value Click Next to accept the change, and move to the following page for the ramp-up	

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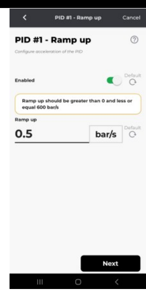
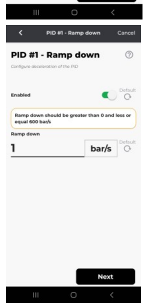
Step-by-step on the mobile application



Setpoint ramp up and ramp down.
These parameters define the rate at which the control variable transitions between setpoints. This feature ensures smooth and controlled changes, preventing sudden spikes or drops in the process variable, which could potentially disrupt system stability or cause damage.

Slide the toggle switch to enable the ramp-up, and enter the acceleration rate: 0.5 bar per second.

Click Next to accept the change, and move to the following page for the ramp-down.



Slide the button to enable the ramp down, and enter the deceleration Rate: 1 bar per second.

Click Next to accept the change, and move to the following page.

PID gain,
This page is about the P, I, and D parameters. details are given in the following section : Tuning P, I , and D.

Control mode
Just keep the default value "Reverse mode"
The VFD output is active when the process value is smaller than the setpoint value. PV < SV
The output of the VFD decreases as the process variable increases.
Click Next to accept the change, and move to the following page Output limits.

Output limits

Enter the minimum and maximum output limits as per the application requirements.

In our application assumptions, the limits are 10Hz and 45Hz, respectively the minimum and maximum.

For a 60 Hz rated motor, enter 16.66 % (10Hz of 60 Hz) for the minimum, and enter 75% (45Hz of 60 Hz) for the maximum.

Click Next to accept the change, and move to the following page for deadband parameters

Step-by-step on the mobile application

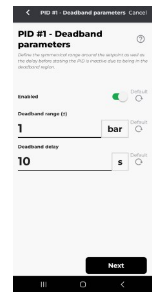
Deadband parameters
The deadband is a range of input-measured process values that do not produce a change in the PID controller's output.

When the process value is within the deadband range, the PID control output is "frozen" and remains constant, preventing unnecessary adjustments and wear on the system components.

This feature is particularly useful in systems where minor deviations from the setpoint are acceptable. In this application example: 1 bar

Slide the toggle switch to enable the deadband, and enter the deadband range 1 bar. Set a reasonable time delay, here we set 10s for the example.

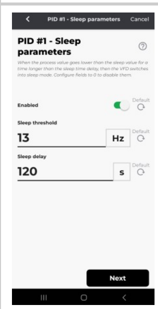
Click 3 times on Next to accept the change, and move to the page for the sleep parameters (here we skip the parameters forced output and compensation)



Sleep parameters
The application requires that if the motor frequency remains below 13 Hz for 120 seconds, the VFD enters sleep mode.

Slide the toggle switch to enable the sleep function, and enter the threshold and delay as defined.

Click Next to accept the change, and move to the following page for the wake-up parameters

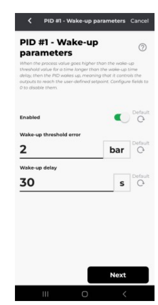


Wake-up parameters
The requested condition is if the PID error exceeds 2 bars for 30 seconds, the VFD exits sleep mode and resumes operation.

Slide the toggle switch to enable the wake-up function, and enter the threshold and delay as defined.

Click Next to accept the change, and move the next page that shows the summary of all the settings you just did.

Each setting can be modified by entering its edit mode clicking on the pencil
Then click on Next to move the I/O's setting.

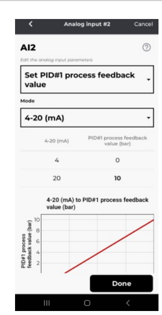


I/O's setting: Process feedback
Activate the edit mode of the analog I/O's by clicking on the related pencil, then edit the analog input 2 (AI2). Select the function ‘Set PID#1 process feedback value’

Select the mode to 4-20 mA.
Click and write 0 for 4 mA.
Click and write 10 for 20 mA.

Click on Done to accept the changes.

Do not forget to assign one Digital Input to run and one to stop in order to start/stop your process



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Tuning P, I and D

Tuning the PID controller parameters—**proportional gain (KP), integral time (TI), and derivative time (Td)**—is essential for achieving optimal closed-loop control performance. Proper configuration ensures precise response, stability, and efficient process control.

- **Proportional (P)**: Adjusts reaction strength to errors.
- **Integral (I)**: Eliminates steady-state error but can cause oscillations.
- **Derivative (D)** : Reduces overshoot but may introduce noise.

Tip:

- *Start with default values and fine-tune based on system response.*
- *Temporarily set the ramp-up and ramp-down times*

Step 1: Apply a Setpoint Step and Observe System Response

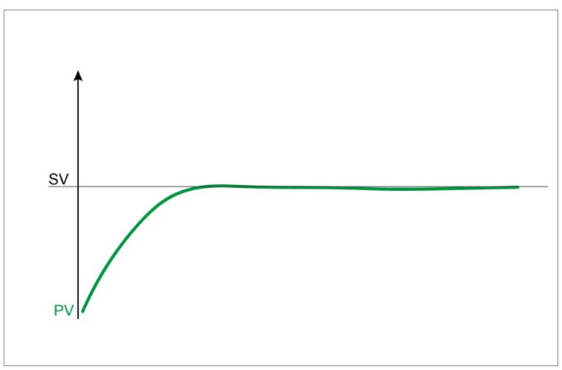
Introduce a **step change** in the setpoint and monitor the actual process value. The duration of observation depends on system dynamics:
Enter a setpoint step and monitor the actual process value.

Step 2: Identify the System’s Response Type

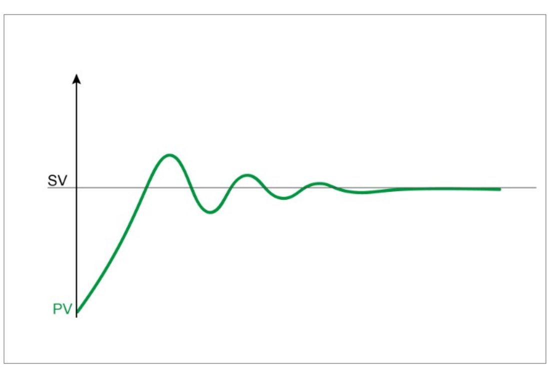
The system’s response to the setpoint change provides key insights into controller performance. Adjustments should be made based on the observed behavior:

1. No Overshoot – Optimal for Applications Requiring Smooth Transitions
The actual value approaches the setpoint in a controlled manner with minimal deviation.

This configuration is suitable for **processes where overshoot is undesirable**, such as pressure or temperature regulation in sensitive systems.



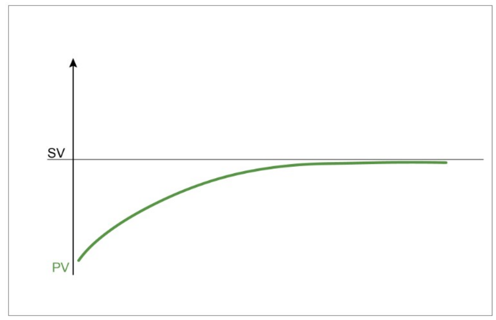
2. Best for Rapid Disturbance Compensation
The actual value reaches the setpoint quickly, with **a slight overshoot** (maximum 10% of the setpoint step).
Recommended for applications that **prioritize responsiveness**, such as motion control or liquid level adjustments.



Step 3: Adjust Parameters Based on Response Analysis

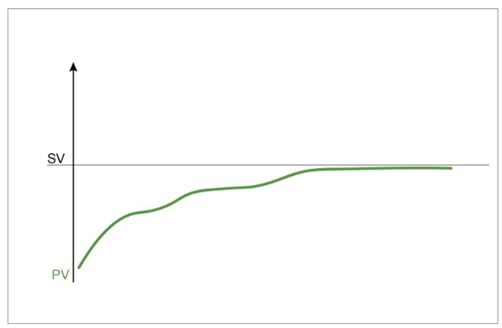
If the system does not respond optimally, refine the PID parameters accordingly:

A. Slow Response, Setpoint Reached Gradually



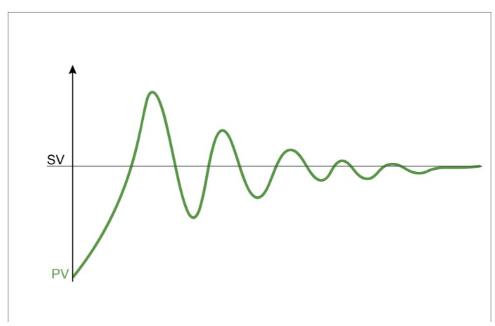
Increase KP to enhance proportional control.
Decrease TI to reduce integral accumulation time and accelerate response.

B. Slow Response with Minor Oscillations



Increase KP to strengthen proportional influence.
Reduce Td to decrease derivative action and stabilize system behavior.

C. Fast Response with Excessive Overshoot



Decrease KP to reduce proportional gain and prevent aggressive corrections.
Increase TI to slow down integral action and minimize overshoot.
Effective PID tuning is a balance between **fast response, minimal overshoot, and stability**.

The adjustment process should be iterative, with careful **monitoring of system behavior** after each modification. By systematically tuning **KP, TI, and Td**, performance can be optimized for both precision and efficiency

Document Settings:
Record all PID and device settings, including IP address, subnet, gateway, device ID, and mapped points, for future maintenance and troubleshooting.

Conclusion

This application note has outlined the substantial benefits and enhanced performance capabilities provided by SmartD Technologies' Clean Power VFD.

By leveraging its advanced control algorithms and maintaining optimal motor function, the Clean Power VFD ensures superior efficiency, reliability, and sustainability in motor control applications.

We encourage industries looking to upgrade or install new motor control systems to consider the Clean Power VFD for its exceptional benefits.

For further information, and detailed specifications, or to initiate an implementation in your operations, please visit our website: https://smartd.tech/ or contact us at +1-866-776-2783

Let SmartD help you achieve operational excellence with cleaner, more efficient power solutions.