

PID Pumping with a NEMA 4X SMVector Drive

Pump and fan applications make up the majority of the PID applications that employ the SMVector drives. The process feedback used most often is pressure. This is an application example of a SMVector drive in a pumping application using pressure control and demonstrating the capability of a wash-down enclosure.

Note: for general PID reference, please refer to application note AN0043: *Using the SMVector Drive for PID Process Control*.

System Overview

This demo uses an Emerson pump spraying water through 4 nozzles; the pressure in the water lines is measured by an Ashcroft pressure gauge and transducer. The water flow can be increased or decreased using a valve controlling flow in two of the spray nozzles, this change in flow will also cause a change in pressure causing the SMVector's PID loop to change the drive's output to maintain the system's set point. The NEMA 4X enclosure is demonstrated by spraying the drive with water coming from the 4 nozzles fed by the pump.

SMVector Demo



Major Demo Components

Drive: Lenze ESV371N01SXC

SMVector Drive

120V in, 230 V out

0.5Hp, rated to 2.4A

Pump: Emerson

Pump and motor

0.5Hp, 230V, FLA 1.8

60Hz, 3450 rpm

Pressure sensor: Ashcroft GC317M02B1NF4100G

GC31 Pressure gauge and transducer

0-100 psi

1-5Vdc analog output

Drive options: ESVZXX1

Remote keypad w/ communication module

Figure 1: Close-up SMV Shower Demo

System Block Diagram

Figure 2 illustrates the block diagram of the SMV Shower Demo in a PID pumping application.

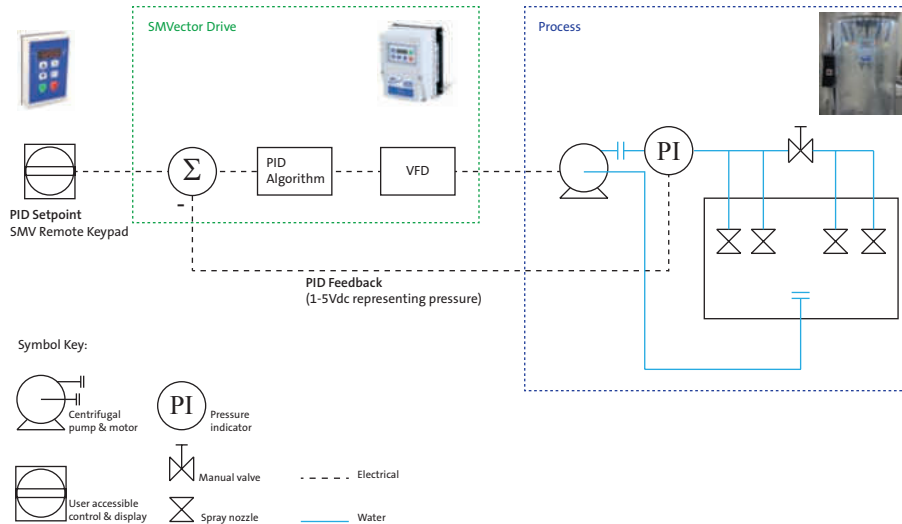


Figure 2: SMV Shower Demo Block Diagram

Shower Demo Layout

Figure 3 illustrates the layout of the SMV Shower Demo and identifies the major components.

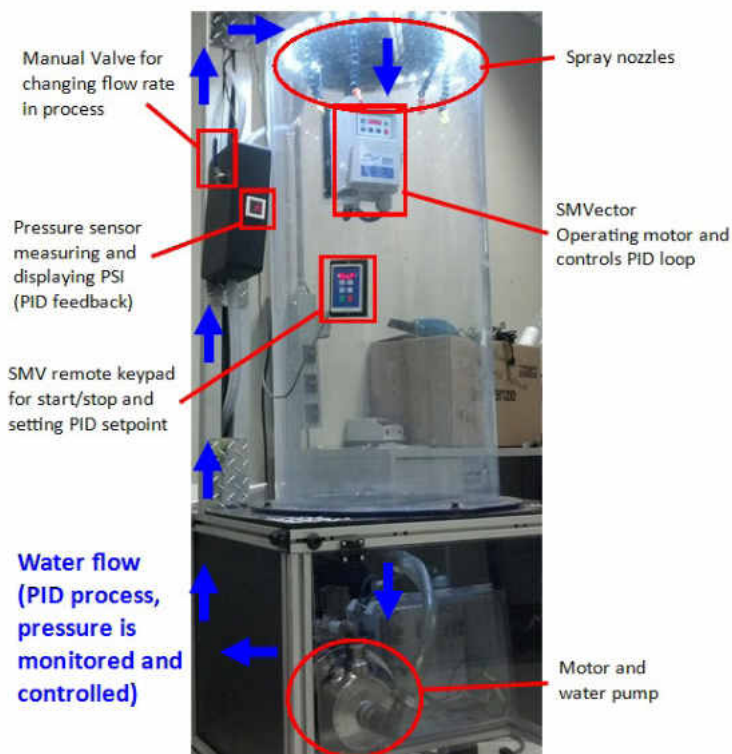


Figure 3: SMV Shower Demo Layout

Drive Wiring

Figure 4 provides the simplified wiring diagram of the SMV Shower Demo.

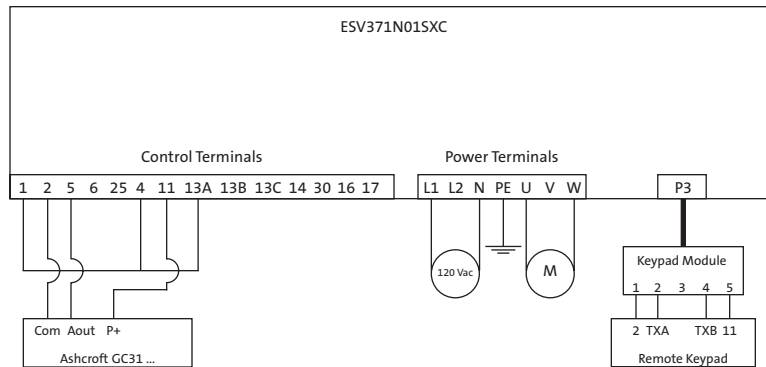


Figure 4: SMV Shower Demo Wiring

Drive's NEMA Rating

The SMVector drive in this application is a wash down enclosure. The last letter "C" in the part number ESV371N01SXC, designates the enclosure type. In this case, a NEMA 4X indoor enclosure with convection cooling. Figure 5 (courtesy of: <http://www.nema.org>) provides a summary of the conditions different enclosure types protect against. The 4X rating is protection against accidental contact, dust, direct water, and corrosive agents. The SMVector 4X indoor enclosure is made from an ABS plastic. This drive is specified as indoor duty only because the ABS plastic used is not resistant to UV light and can warp with sudden temperature swings.

Table 1
[From NEMA 250-2003]
Comparison of Specific Applications of Enclosures
for Indoor Nonhazardous Locations

Provides a Degree of Protection Against the Following Conditions	Type of Enclosure									
	1*	2*	4	4X	5	6	6P	12	12K	13
Access to hazardous parts	X	X	X	X	X	X	X	X	X	X
Ingress of solid foreign objects (falling dirt)	X	X	X	X	X	X	X	X	X	X
Ingress of water (Dripping and light splashing)	...	X	X	X	X	X	X	X	X	X
Ingress of solid foreign objects (Circulating dust, lint, fibers, and flyings **)	X	X	...	X	X	X	X	X
Ingress of solid foreign objects (Settling airborne dust, lint, fibers, and flyings **)	X	X	X	X	X	X	X	X
Ingress of water (Hosedown and splashing water)	X	X	...	X	X	...	...	...
Oil and coolant seepage	X	X	X
Oil or coolant spraying and splashing	X
Corrosive agents	X	...	...	X	...	...	...
Ingress of water (Occasional temporary submersion)	X	X	...	...	...
Ingress of water (Occasional prolonged submersion)	X	...	...	...

* These enclosures may be ventilated.

** These fibers and flyings are nonhazardous materials and are not considered Class III type ignitable fibers or combustible flyings. For Class III type ignitable fibers or combustible flyings see the National Electrical Code, Article 500.

Figure 5: Table 1 from NEMA 250-2003 - Enclosure Types

When installing the drive and wiring it is important to include glands. The glands allow wiring to get to the drive, but still maintain a seal against the environment. The glands are installed into the knockouts in the drive enclosure and have a rubber gasket that is tightened around any incoming or outgoing wires.



Figure 5: Glands maintain seal

Drive parameters

For this specific example, the following SMV drive parameters must be set accordingly.

P100= 02	Drive set for remote keypad start/stop
P102= 15	Min frequency to 15Hz
P103= 75	Max frequency to 75Hz
P104= 10	Accel to 10s
P105= 10	Decel to 10s
P108= 75	Motor overload = (motor FLA / drive output I) * 100
P121= 06	Terminal 13A activates PID control and makes remote keypad PID set point source
P156= 01	Analog input on terminal 5 will look for a 0-5V signal
P200= 01	Normal acting PID
P201= 01	PID feedback set to terminal 5 (analog Vin)
P204= -12.5	Min value for scaling of drive to PSI from transducer
P205= 50	Max value for scaling of drive to PSI from transducer
P207= 6	PID Proportional gain
P208= 0.5	PID Integral gain
P209= 0	PID Derivative gain
P241= 10	Time delay for entering sleep mode
P243= 40	Pressure in PSI for entering sleep mode
P244= 01	Drive will enter sleep mode (stop motor) if feedback > 243
P246= 0.2	Pressure in PSI for leaving sleep mode
P247= 1	Drive will leave sleep mode (start motor) if feedback < 246
P400= 01	Activates communication for remote keypad

Explanation of parameters and setting up the PID loop

In this application the pressure in the water lines increases the faster the pump spins. This is an example of normal acting PID control. In a normal acting system, as the system feedback increases the motor should slow down, maintaining the process set point. Normal acting PID is set on P200 with a value of 01. With P200 set, when one of the digital inputs set to an auto-reference is activated, the drive will enter PID mode. Setting up the digital input for auto-reference in this particular application is discussed in the next section.

Process feedback and set point

In a PID system there are two signals required: a system set point and a system feedback. The PID set point tells the PID control in the SMVector what pressure should be maintained. The PID feedback is a signal that tells the PID controller in the SMVector what the actual pressure in the system is. The PID loop in the SMV compares the two signals and adjusts the speed of the motor (using the VFD portion of the SMV) to maintain zero error between the set point and feedback.

In this demo, the system feedback is setup with P201, P156, P204 and P205. The Ashcroft sensor used has a total range of 0-100 psi, but has been set for 0-50 psi; the sensor's output to the SMVector is a 1-5Vdc signal. P201 tells the drive to look at terminal 5 to read the system pressure as an analog voltage input, P156 means the input will be read as a 0-5Vdc signal. P204 and P205 are used to scale the feedback so the drive can read and display the feedback as PID units (psi in this case). P204 has been set to -12.5 psi and P204 is set to 50 psi. This means the drive reads 0 psi at 1Vdc and 50 psi at 5Vdc (transducer output is 1-5V).

The other required signal is the system set point. This has been setup by P121 = 06. That means that the jumper wire between terminal 4 and 13A does two things. First of all this activates the PID loop, and the secondly this selects the remote keypad as the set point source. This means the pressure maintained by the PID loop can be changed on the SMV remote keypad.

Figure 6 shows where the set point and feedback are in the block diagram for a PID loop.

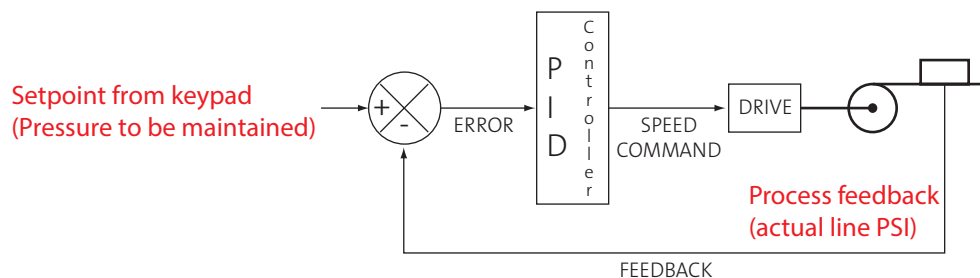


Figure 6: Setpoint and Feedback in the PID Loop

Sleep mode

Sleep mode is part of the PID control of the drive. This can be used to start and stop the motor if the process is getting outside of the acceptable operating range. In this case if the water pressure gets too high the drive will shut the motor off and restart the system once the pressure has dropped. P244 has been set to 01; this means if pressure gets above a threshold for a set amount of time, set in P243 and P241, the drive will go to sleep. P243 has been set to 40 psi for the pressure limit; P241 is a time delay of 10 seconds for entering sleep mode. P247 sets up the drive to leave sleep mode; with P247 = 01 the drive will leave sleep mode if the pressure drops below a value set in P246. P246 is set at 0.2 psi, meaning once the water pressure is below 0.2 psi the drive will restart the pump motor.

PID gain values

PID control has 3 gain values associated with it: proportional gain (P207), integral gain (P208), and derivative gain (P209). These gain values mathematically tell the PID loop in the drive what the physical process actually is. This allows the drive to speed up or slow down the motor to maintain pressure at the desired set point. The gain values affect the system in different ways. Proportional gain is the main value; it is a constant value used as a multiplier for the error between the feedback and set point. The integral gain is a time constant in seconds for the integration of the error signal. The error is summed over a period of time, this helps remove error between the feedback and set point that can't be taken care of with proportional gain alone. The final gain value is derivative gain, with derivative gain the PID loop is looking at the rate of change of the error signal. D gain is used in systems that have very rapid changes in the process that the PID loop needs to respond to quickly.

For most applications in which the SMVector is as a PID controller, derivative gain is left set to 0. Since D gain is used to respond to rapid changes in a process this value can easily make a system unstable. For a PID system to operate properly the gain values of the system must be tuned, because every system is physically different the values can be drastically different. One of the simplest ways to tune P207, P208, and P209 is to use a guess and check method.

Tuning the PID loop

In this demo, use the keypad to set the desired pressure, in this case 25 psi was used. Look at the actual value measured for pressure, if this is below 25, increase the P gain (P207) until 1: the system reaches a stable 25 psi or 2: the system becomes unstable. You can tell the system is unstable in a couple ways. One is watch the pressure, if the pressure is oscillating up and down, the P gain is set too high; the other is the motor speed. P527 show the actual output frequency, small fluctuations in speed are not a problem for most systems, however large changes can cause the drive to trip into an overload condition because the oscillation in speed uses more current. If increasing P207 has made the system unstable, decrease P207 to about $P207 \cdot .90$ or $P207 \cdot .85$, the system should be stable at this level, but the actual pressure may not be equal to the set point. This is where the integral gain (P208) can be used. Increase P208 until the system pressure reaches the 25 psi (set point). The I gain can stably remove the last bit of error because it looks at the error over time. For the final gain value, derivative gain (P209), leave that set at 0.

Summary

This application note is a specific example of using an SMVector drive as a PID controller to control the pressure in a pumping system. The SMVector used in conjunction with an Ashcroft sensor and an Emerson pump/motor combo is used to control the PSI of water lines feeding spray nozzles with a variable flow rate. The wiring and parameters are specific to this set up but can be used as a guideline for any pumping system. The installation and use of the drive in a wash-down environment is also demonstrated by spraying the drive with the water flow controlled by the drive's PID loop.