PumpSmart

PumpSmart® PS220

Smart Control and Protection

ETM - Electronic Technical Manual

Contents

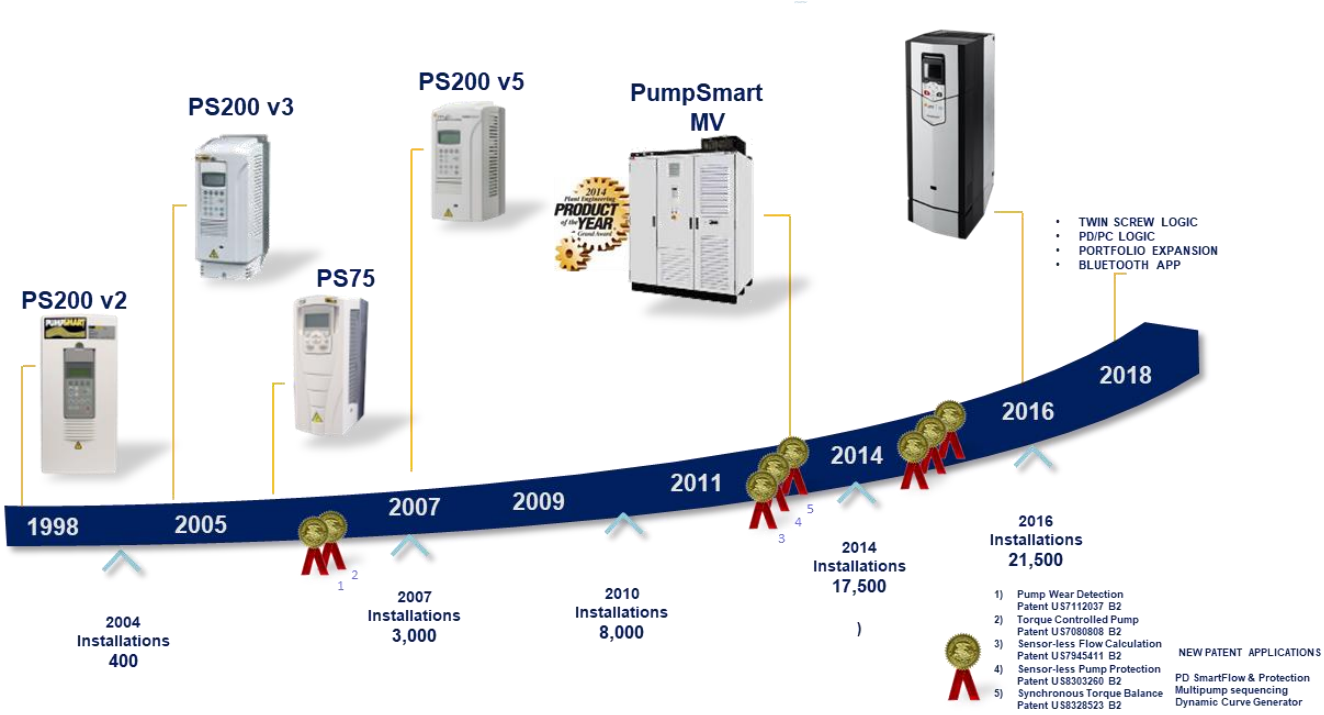
Introduction

The purpose of this PumpSmart Electronic Technical Manual (ETM) is to provide basic information to the reader in an effort to better understand the value proposition PumpSmart offers when used with a centrifugal or positive displacement pump. It will introduce variable speed pumping and pump protection concepts which will make the overall pumping system more cost efficient.

The reader is encouraged to use this information in conjunction with various PumpSmart IOMs, and with additional information found in print or on the Internet at ittmc.com.

PumpSmart

History of PumpSmart



PumpSmart was first introduced in 1998. Originally based on the Asia Brown Boveri (ABB) ACS600 platform, and for a short time on the Allen Bradley (AB) PowerFlex, the PS200 represented ITT's introduction of a centrifugal pump specific VSD (variable speed drive). Capabilities offered beyond a standard off-the-shelf VSD included torque based pump protection and process (PID) control. However, implementation of a PS200 at that time was considerably more involved in comparison to today's PumpSmart offering.

In 2000 version 2.0, and soon after version 2.1 of the PumpSmart PS200 drive was released, still based on the ACS600 drive platform. These versions introduced additional groundbreaking VSD control technology developed by ITT and specific to centrifugal pump control. In 2004 ABB released the ACS800 drive with the latest in sensorless motor control technology. Introduced as Direct Torque Control (DTC), the ACS800 provided the highest accuracy of sensorless speed and torque control available on the market. PumpSmart took advantage of this capability in its version 5 release in 2007 with its sensorless

flow calculation routine (SmartFlow). Features like Advance Pump Protection (APP), SmartFlow with an accuracy of ±5%, and SmartFlow Control, along with many other pump specific functions set a new industry benchmark for centrifugal pump variable speed control. Version 5 experienced a long life, eventually being replaced with version 6 in late 2017 on the new ABB ACS880 industrial drive platform.

Like its predecessor, PumpSmart version 6.0 again raised the bar for centrifugal pump control with new and improved features like Advanced SmartFlow, additional water based functions, integrated minimum flow bypass control, flow totalizer, and improved Condition Monitoring.

Version 6 Feature Detail

It is not the intention of this section to provide intimate detail of v6 functionality but only to introduce the reader at a high level to many of the industry leading features found in the current release of PumpSmart. Any off-the-shelf standard VSD can provide variable speed pump control. Here we describe what PumpSmart offers above a standard VSD.

Sensorless Smart Flow Calculation

Perhaps the most significant features found in PumpSmart is its ability to calculate the flow rate through its given pump with an accuracy of ±5% of the rated flow at rated speed. This is called SmartFlow. A small amount of Internet research will show that many VSD manufacturers offer some form of sensorless flow calculation. However, none are nearly as accurate as PumpSmart's SmartFlow. The reason? Well, it's in the patented SmartFlow recipe. The difference is how PumpSmart is set up and how it calculates the flow rate.

To appreciate PumpSmart's SmartFlow offering we first need to introduce how the competition sets up their sensorless flow capability. They will ask for 7-10 power values and their equivalent flow values. Together this is 14-20 points of information you have to key into their drive in order for them to calculate flow. Looking into this requirement a little closer we see these points come from a typical price curve for that pump. But price curves are generated during the design phase of a pump and are not specific to the exact pump being used. Unless the curve used was generated per a test to that specific pump the values will not take into account manufacturing inconsistencies (tolerances). Two identical pumps coming down the line are not identical! Based on acceptable tolerances during manufacturing each will have different power values for a given flow. Entering curve values as described above will not account for this. Additionally, these price curves do not have a lot of resolution. The values you interpret from the curves will likely add more error into the equation. Combine these two items and it is easy to have 15% or more error in calculated flow! ITT has conducted tests on competitive sensorless flow functions and found this error or more to be true.

PumpSmart is developed by a pump company. ITT Goulds Pump has been making centrifugal pumps for more than 160 years. It is this knowledge that enables us to take the high accuracy of torque and speed reporting found in today's VSDs and conduct a sensorless flow calculation in a different way. PumpSmart requires only four pieces of data from the price curves be entered into the drive. These include the pump's Best Efficiency Point (BEP) Power (BEP_P), BEP flow (BEP_F), Power at Shutoff (P_{SO}), and

the pump's rated speed (N_R). See Figure 1. All are found on a typical pumps' line curve. You might be inclined to think that like above, we have error due to manufacturing tolerances and curve resolution. However, there is one more step to setting SmartFlow up that is not found with any competitor. This last step is to conduct a SmartFlow tune. A SmartFlow tune requires the pump run 33%, 60% and 100% speed against a closed discharge valve. (33% and 60% only if the pump is larger than 50HP.) This tune looks at what you entered for P_{SO} and corrects the power curve based on what it actually found. This tune process compensates for the pump's manufacturing tolerances. It is likely that each like pump will have a different P_{SO} value. And it is this tune process that gives PumpSmart its ±5% accuracy. If the pump experiences wear over time you can again run the tune process to bring the accuracy back in place.

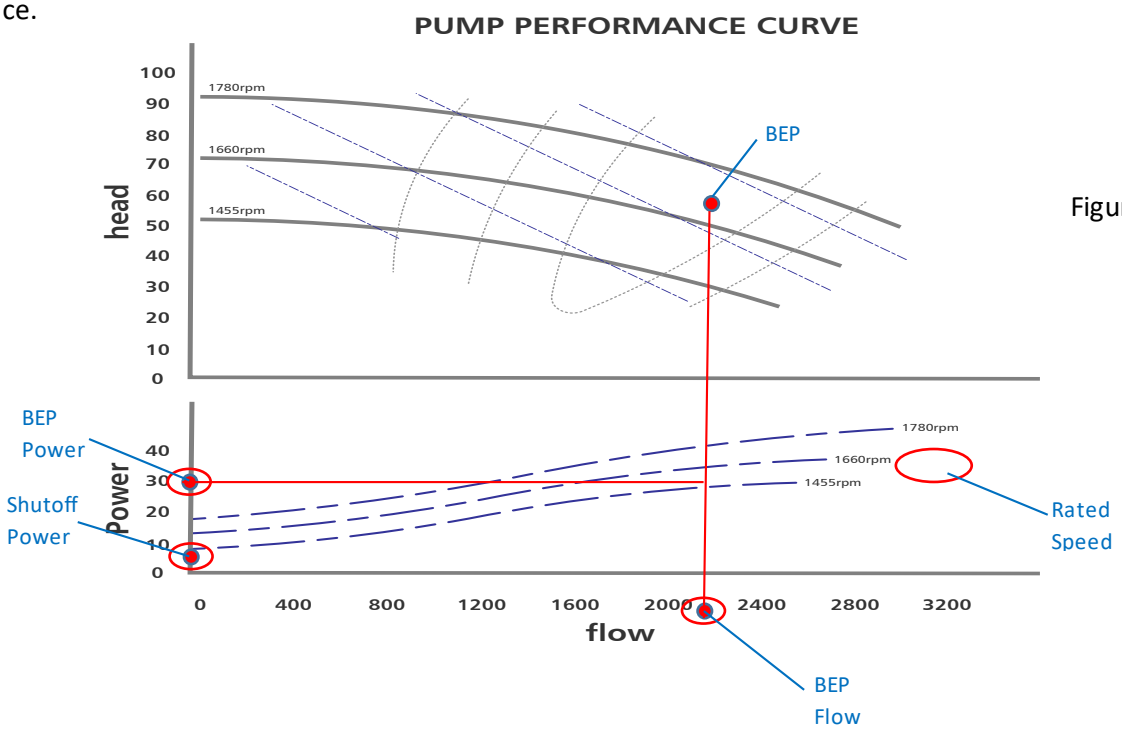


Figure 1

SmartFlow Control

SmartFlow Control is the ability to take the SmartFlow calculated flow rate value and use it as the actual flow value rate in a constant flow PID application. When able to use SmartFlow's calculated value as the PID actual flow rate input no expensive flow element is required. Eliminating a flow element can save a considerable amount of money. To date, only PumpSmart offers sensorless flow PID control, because most VSD manufacturers understand that with the high level of inaccuracy found in their sensorless flow calculation it would likely not be acceptable to run a PID algorithm using this calculated flow for the flow rate actual signal.

At this point it should be stated that SmartFlow and its associated PID control should not be used for custody transfer. Custody transfer is the action of moving (pumping) product for the purpose of selling. It is unlikely anyone will want to use a ±5% accuracy for custody transfer.

Advanced Pump Protection

Most VSD manufacturer's offer a static torque based pump protection. But there is a fundamental problem when using a static (fixed) torque value for pump protection in a variable speed application. A

specific torque value may be a disaster at one speed but perfectly acceptable at another. The protection torque value needs to shift with speed.

PumpSmart offers Advance Pump Protection (APP) which accounts for speed. APP offers protection against dry run, minimum flow, and run out conditions. In fact, it provides minimum flow and run out protection based on actual flow rate (not torque alone), as calculated by either SmartFlow or when brought in from an external flow element. Dry run is a protection that leverages the SmartFlow tune process. This tune process enables PumpSmart to know the deadhead power value at any speed. Deadhead power is power consumed by the pump to spin the process fluid in the pump but to not provide any flow rate. Using a default value of .95 (95%) of deadhead for the Dry Run Factor, should the power be less than 95% of the deadhead power at any speed then the fluid must be missing from the pump as well (dry run) since the power is 5% less than deadhead. Figure 2 shows this graphically. Adjusting the Dry Run Factor adjusts the dry run trip.

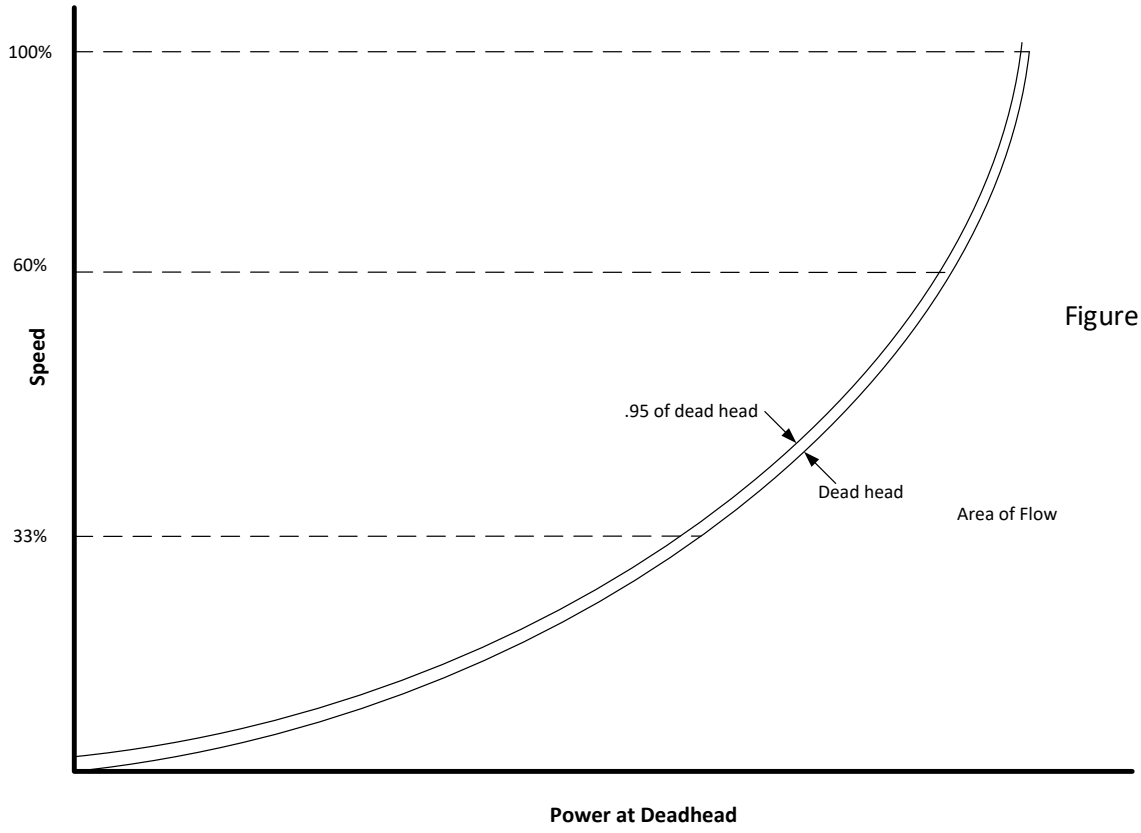


Figure 2

Multivariable Control

Multivariable Control is often referred to as *Cavitation Control*, as this is where this tool is most often used. Figure 3 shows an example of Multivariable control, where its goal is to keep the pump out of cavitation.

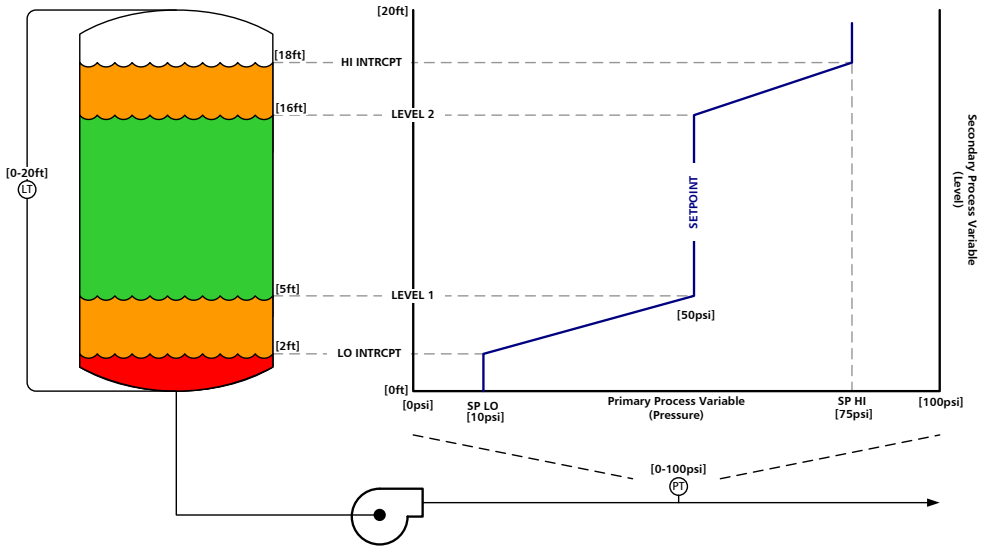


Figure 3

In this example PumpSmart is holding a discharge pressure set-point value of 50PSI. It will maintain this set-point as long as the tank level is between 5 feet and 16 feet. If however the tank level drops below 5 feet there is a danger that the pump may start to cavitate while trying to hold 50PSI due to not having enough NPSHA (Net Positive Suction Head Available). A second variable (transmitter) is measuring the level in the tank. When the tank level starts to drop below 5 feet this second variable influences the active set-point being used by PumpSmart, effectively lowering this set-point value. As the set-point is lowered it will slow the pump down. The lower the tank level the lower the active set-point will be, until the tank is at 2 feet at which time the active set-point will stay at 10PSI. We know that based on the Laws of Affinity that as a centrifugal pump slows down it needs less NPSHA to stay out of cavitation. If the relationship between the tank level and the active set-point is set up correctly then the pump should stay out of cavitation.

Multivariable control is available in speed as well as in PID control. The user must understand and accept that this tool will automatically manipulate the set-point in an effort to minimize cavitation.

Multi-pump Operation

PumpSmart has thousands of units in successful Multi-pump operation. Multi-pump operation is the process of staging and destaging multiple pumps in an effort to maintain a desired set-point (reference). The PS220 can stage as many as six pumps on and off as necessary. Staging may be based on speed and error, torque and error, or based on a process value only. Multi-pump operation is available only with PID operation. You cannot conduct Multi-pump operation when speed is set as the PS220s primary control.

Speed and Error

Out of the box PumpSmart PS220 is set up for staging based on speed and error. This is called "synchronous speed" operation. While Multi-pump operation can be used in pressure, flow, SmartFlow, level and temperature control applications, for the following example we will look at it in a pressure application. This example will use default values for staging and destaging, but you can set these values where necessary to make your particular application work.

When a demand is greater than what a single pump (in this case the lead pump) can provide for, PumpSmart will have that pump running at full speed in an attempt to meet the demand. When not able to meet this demand at full speed the pressure actual value will eventually drop below 95% (0.95) of the set-point. When the speed is greater than 98%, and the pressure actual is less than 95% of the set-point, and these two events happen for greater than 20 seconds (proof timer), then PumpSmart will stage on the first lag pump. Because Multi-pump is set up for speed and error the lag pump will not come up in PID mode but will synchronize its speed to that of the lead pump. The lead pump feels the hydraulic contribution of the lag pump and alters its speed (as well as the lag pump's speed) to maintain the set-point. If the demand continues to increase beyond the capability of the two pumps a third pump will stage on under the same criteria. As many as six pumps can be staged on/off in a Multi-pump operation. Staging a pump off (destaging) is based on the demand reducing such that all the pumps run below a defined destage speed for a destage proof timer time. Each lag pump will have a different destage speed value defined.

Torque and Error

In some cases pumps in a Multi-pump operation may have different characteristics. This might largely be due to a pump(s) being recently rebuilt while other pumps in the group have significant wear due to age. In this case if we run them all at the same synchronized speed then pumps with wear will not contribute the same flow rate of the rebuilt pumps. In this case we can set Multi-pump operation up for Synchronous Torque operation. This operation is similar to Synchronous Speed except staging and destaging is based on torque values in place of speed. Synchronous Torque operation will have pumps with wear running at higher speeds in an effort to contribute close to the newly rebuilt pumps. This is because torque more closely represents flow with pumps that have uneven wear.

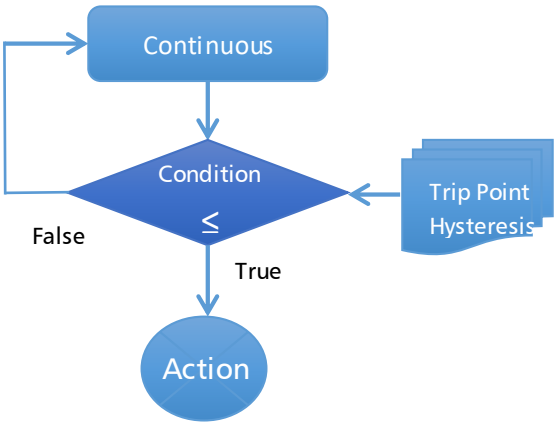
Process Value

Process value staging and destaging is new for PumpSmart. In this case PumpSmart does not care what the error (difference between set-point and actual) is or how fast the pump is running. It is monitoring the process actual value and will stage (synchronize speed) when the process value hits a set value. An

example of this type of operation would be level control in a large vessel. This example has a set-point of 2 feet. A single pump will vary its speed to keep the level at 2 feet. A second pump may be set to stage on at 4 feet. If the level goes above 4 feet then this second pump will turn on, synchronizing its speed to the first one. If its destage value is at 3.5 feet then the second pump will drop out at a level below 3.5 feet.

Condition Monitoring

Condition Monitoring is the process of monitoring a continuous signal and setting limits at which an event will take place if this signal goes either above or below a set limit. It can be used as a process alarm. Other applications include tank feed valve control and level sleep to name just a couple. Let's look at this last application, level sleep, as an example.

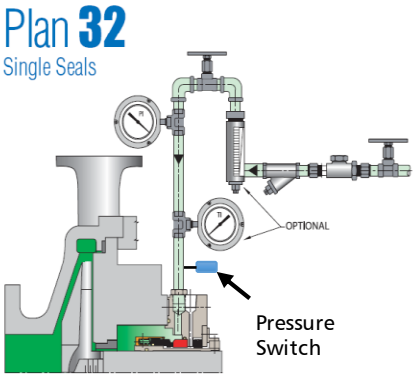


When trying to conduct suction side level control in an application where the inflow may drop below the outflow at minimum speed, then the level will continue to drop until eventually the pump may run dry. We can set a designated level, that if exceeded below this point, PumpSmart will cause the VSD to go into a sleep mode (zero speed). Different than stopping the pump, sleep stops the pump but also continues to monitor the level actual value. When this value gets above another point (called hysteresis) then PumpSmart wakes up and tries to control to set-point. This process will repeat as necessary.

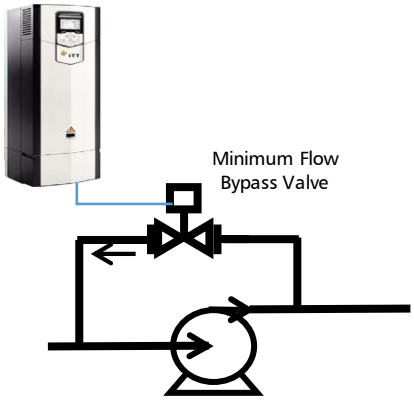
Continuous signals may come in as an analog input or may include various internal signals.

Secondary Protect

Secondary Protect is similar to Condition Monitoring except it monitors a discrete signal instead of a continuous signal. An example of its use might be in a seal flush plan monitoring application. The seal flush plan might have a flow or pressure switch (on/off) to detect when there is not sufficient barrier/buffer fluid, thereby increasing risk of damage to the seal and pump system. This switch signal is brought into one of the PS220 digital inputs for monitoring. In the event the pressure drops the switch opens, and PumpSmart will stop the pump until the pressure of the barrier/buffer fluid returns to an acceptable level. Another example of use is monitoring pressure at a press filter inlet, where primary control is constant flow. As the filter plugs up with dirt its pressure will continue to rise while PumpSmart tries to hold a required flow rate. If not monitored the pressure could get to a point where it might burst the filter.



Minimum Flow Bypass



Min Flow Bypass is new to PumpSmart with the PS220, and in fact to the VSD pump control industry in general. PumpSmart will monitor the flow rate as coming from either an external flow meter or from SmartFlow, and will operate one of its relay outputs based on the flow running below a defined minimum flow value. This relay controls a discrete valve located in a bypass line. This line is typically designed to operate at a minimum flow rate, at a design pressure. By default PumpSmart will open this valve at one flow (minimum flow) and close it at another flow (default at 2.1 times minimum flow).

Example; boiler feed water application where the pump's minimum flow value is 30GPM. At a flow rate below 30GPM PumpSmart opens the minimum flow bypass valve using its relay output, now causing the flow rate to be equal to the boiler demand plus the flow bypass flow (above 60GPM). As the boiler demand increases, eventually exceeding 2.1 times the 30GPM (63GPM) the relay output drops out closing the bypass valve. Because the bypass line was designed to flow the minimum flow rate value of 30 GPM, now the flow rate drops to the boiler's demand flow rate of 33GPM, which remains above the minimum flow value.

Water Functions

PumpSmart offered a Pump Cleaning Sequence during the PS200 days. Now the PS220 has added to this water based function with three additional features; pipe cleaning, pipe filling, and snoring.

Pump Cleaning

The Pump Cleaning Sequence provides a method for cleaning a pump from materials that might clog or impede its full operation. ***Warning – This sequence will run the pump backwards. Be sure the pump this feature is used on is permitted to run backwards.***

A Pump Cleaning Sequence may be initiated by an operator or automatically by PumpSmart itself. Operator initiated operation is accomplished by initiating a digital input of the PS220. PS220 initiation is based on exceeding a torque, based on run time, or based on both torque or run time. Detail on how to set each of these initiations up can be found in the PS220 IOM. Once initiated the operation is the same.

A Pump Cleaning Sequence consists of one or more cycles. A cycle consists of a forward speed for a defined period of time using preset acceleration and deceleration times (may be different than the values for standard operation), it then dwells for a defined period of time, then runs at a backward speed using preset acceleration and deceleration times. Acceleration and deceleration values used in this operation are typically aggressive (short) relative to the 5 second default values used under standard operation. Once the defined number of cycles are completed PumpSmart will go back into its primary control mode.

Pipe Cleaning

Pipe cleaning is the process of cleaning the pipe of scale buildup. It does this by running the pump at full speed for a set period of time. Once the Pipe Cleaning operation is complete PumpSmart can be run in its designed operation. The intent is that this high speed flow rate will scour the pipe of internal buildup. See the PS220 IOM for details on setting up and operating this feature.

Note, be sure the system can tolerate the pressure developed by full speed operation before using this feature.

Pipe Fill

Pipe fill is the process of filling an empty pipe using a controlled speed over a period of time. The intent is that this will reduce or eliminate water hammer. The pump will run at a defined speed for a period of time determined by the user. After the time elapses PumpSmart will go into its primary control (typically flow or pressure). If during the timed period PumpSmart determines the pipe is full it will automatically terminate the Pipe Fill procedure and will initiate its primary control. See the PS220 IOM for details on setting up and operating this feature.

Snore

The intent of the Snore function is to remove floating debris often found on the surface of a sump system. Classic applications might include a sewage lift station or a storm sump system. When initiated Snore will run the pump at full speed until it recognizes that the sump is empty, at which time PumpSmart will cut over to its primary control, typically level control. The name Snore comes from the sound a pump makes when the sump has been drained near empty. Snore can be initiated based on time. See the PS220 IOM for details on setting up and operating this feature.

Pump and System Curves

To best understand the value of variable speed pumping we must first understand the relationship of a particular pump's performance and its interaction with the system architecture. These are best understood when looking at the pump and system curves respectively.

Pump Curves

A pump is selected for a particular performance, i.e., to operate at a particular head (pressure) and flow rate. Figure 1 shows a typical centrifugal pump performance curve, where the pump's highest head is at deadhead (zero flow is called "deadhead").

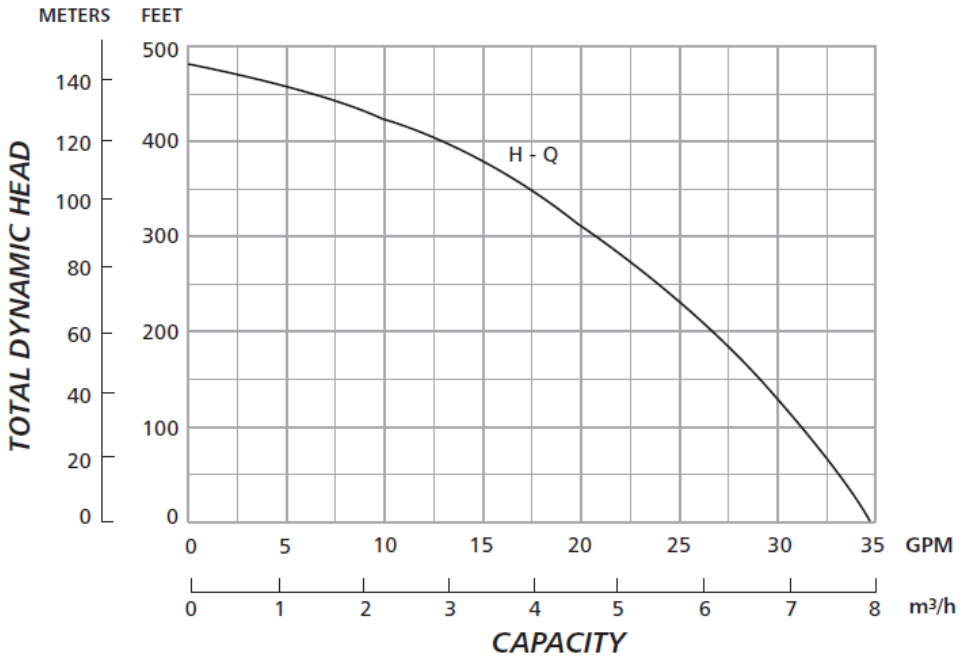


Figure 1

It is typical that as the flow rate increases the pump delivers less head. This is because as flow increases so do frictional losses, thereby reducing the head pressure. Depending on the options requested a pump curve may show several curves, each based on an impeller trim or in some cases on a pump particular speed.

System Curve

A system curve consists of two parts, a static component and a frictional component. Figure 2 shows a typical system curve along with its system graphic. Head is represented on the vertical axes and flow on the horizontal.

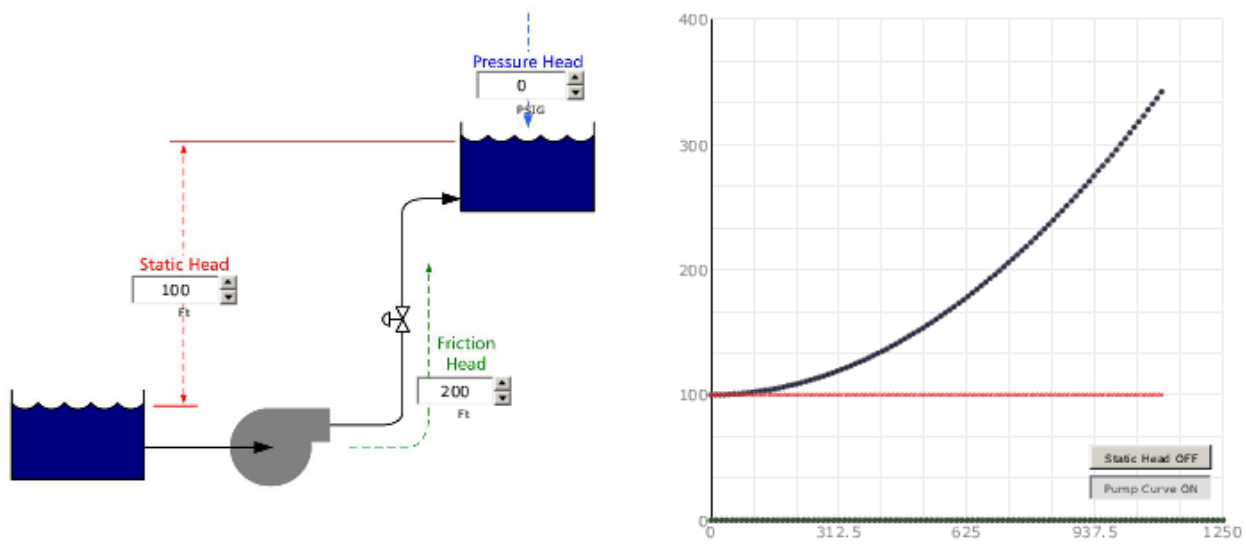


Figure 2

The static component of a system curve represents what head is required by the pump before any flow may occur. In this example the static is 100 feet. The pump must develop enough head to overcome the elevation between the two tank levels before flow may occur. This assumes that the discharge tank is open to atmosphere. If the tank is closed to atmosphere and has internal pressure then this pressure too must be overcome by the pump before flow will occur. We see the static component represented on the vertical axes, where 100 feet of head must be generated before we see any flow.

The second element of a system curve is based on frictional loss. These are losses due to friction of the internal pipe surface in addition to losses through all additional items (valves, elbows, etc.) in the system. Frictional losses increase by the square of the flow. The higher the desired flow rate the higher the head that a pump must generate to make that flow rate occur.

Overlay of Pump and System Curves

Figure 3 shows when a system and pump curve are overlaid. It is the point at which the system and pump curves meet that the pump will operate, at that particular head and flow. It is rare that this is the desired operating point. So either the pump or system curve must be altered (manipulated) to have them intersect at a desired operating point.

Historically (prior to variable speed control) the only way to get to the correct operating point was to dynamically manipulate the system curve to achieve a desired operating point. This was done using a control valve (Figure 4). As the control valve is closed it adds more frictional loss to the system, thereby steepening the system curve in order to intersect the pump curve at the desired operating point.

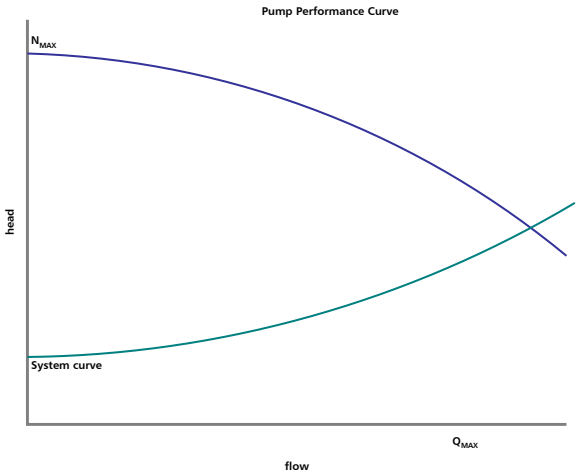


Figure 3

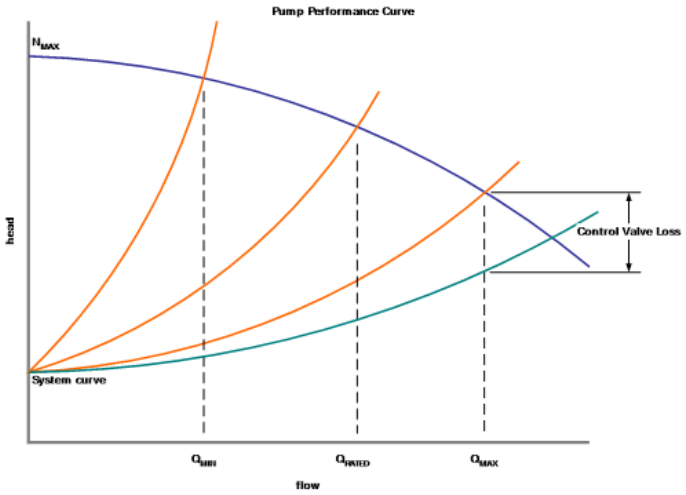


Figure 4

While this enabled us to achieve our desired operating point it also introduced some issues. When using this method of control the pump runs at full speed, generating a higher head into the system than required. This "energy" is then bled off across the control valve we used to manipulate the system curve with. It is easy to see how this is not an efficient way to control a pumping system. An analogy to this method of control is that it is like controlling the speed of your car by holding the accelerator to the floor and using the brake to control speed. Imagine the waste of gas (and energy) this causes. Moreover, a second issue, imagine the undue stress this places on the drivetrain of the vehicle! In the case of a pump, undue stress (pressure) is placed on its seals and bearings. Figure 5 shows an actual test run in the ITT lab indicating vibration as an order of magnitude while reducing flow as a percentage of the Best Efficiency Point (BEP) when using both variable speed and a control valve.

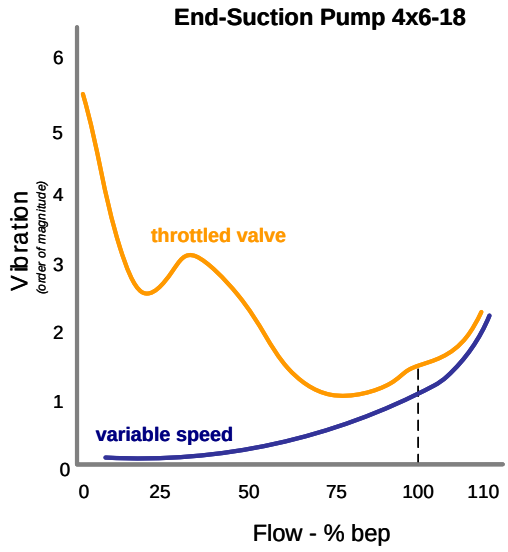


Figure 5

Variable Speed Pumping

By the early 1990s AC variable speed drives (VSD) were starting to come into their own. The technology and reliability had improved greatly and costs were coming down to a point where it was becoming affordable to employ a VSD where it could provide proper control. A VSD (often referred to as a Variable Frequency Drive – VFD) enables dynamically changing the pump performance to meet a desired operating point instead of using a control valve. Both negative issues identified above when using a control valve now are eliminated as we "right size" the pump to the application.

Figure 6 shows how changing the speed of a pump alters a pumps performance curve. In general, the curve keeps it shape, but as the speed is reduced the head it generates is reduced, permitting us to intersect the system curve where desired.

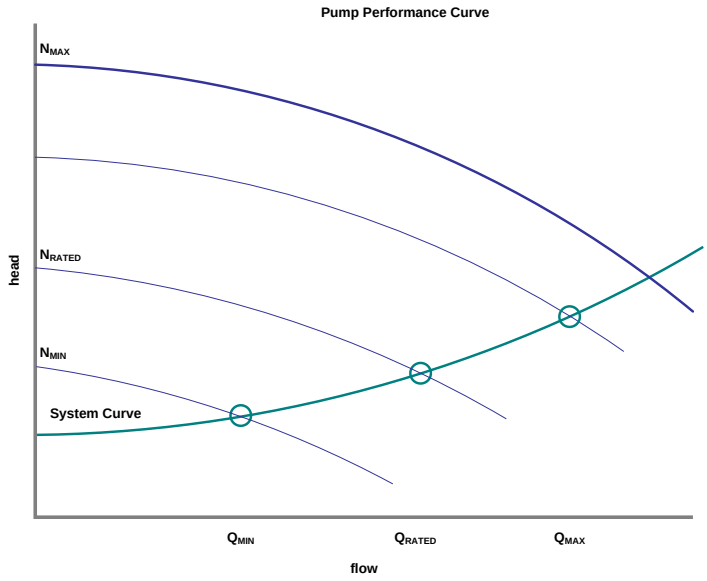


Figure 6

With this type of architecture we put into the system only the energy required to generate the desired flow rate or head, and because we are not trying to burn off excess head we are not introducing undue stress into the system.

Variable Speed vs. Control Valve Comparison

Figure 7 shows an example flow system where when the control valve is open 100% and the pump is running at 100% speed we see over a 1000GPM flow rate. Figures 8 & 9 show operating this same system to a desired operating point of roughly 600GPM when using both a control valve and variable speed respectively.

In Figure 8, note with a reduction to roughly 600GPM flow rate using the control valve, that the power at the motor has reduced from 71.4 to 55.1kW. This is expected as power is largely consumed by flow. We reduced the flow rate so we should expect a reduction in power consumed.

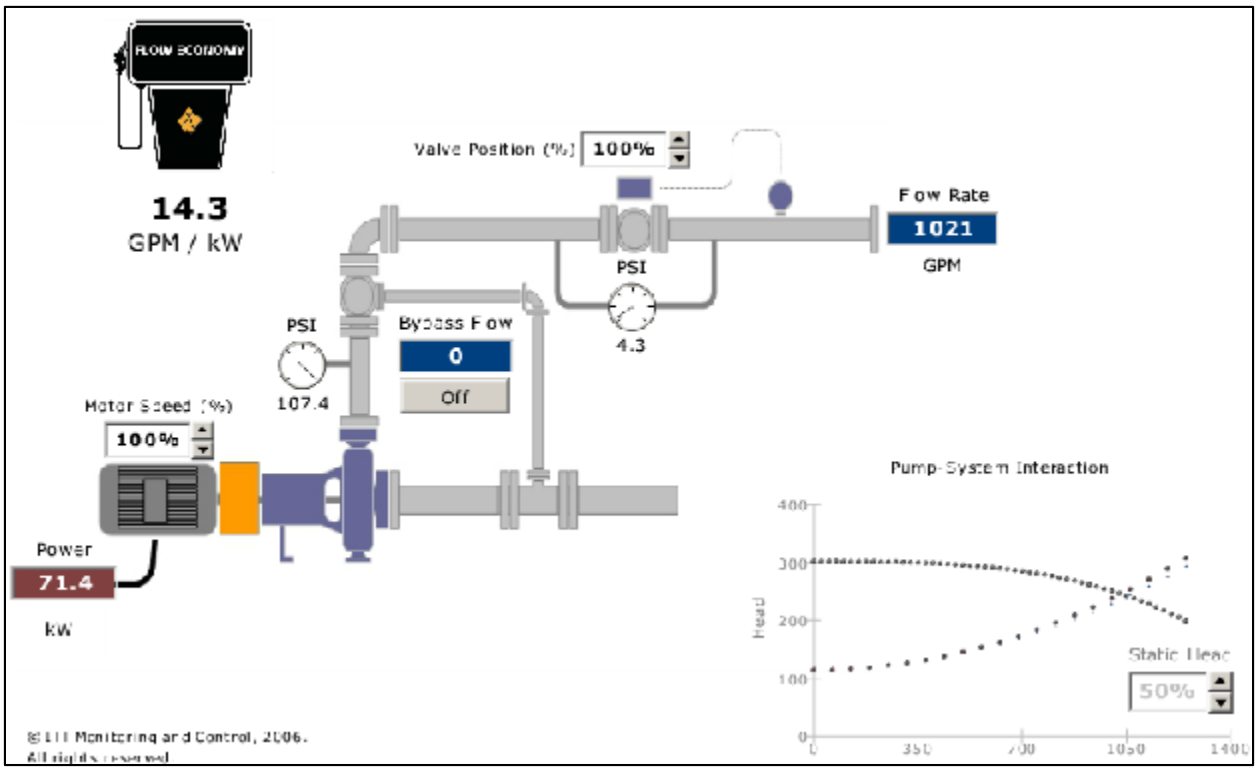


Figure 7

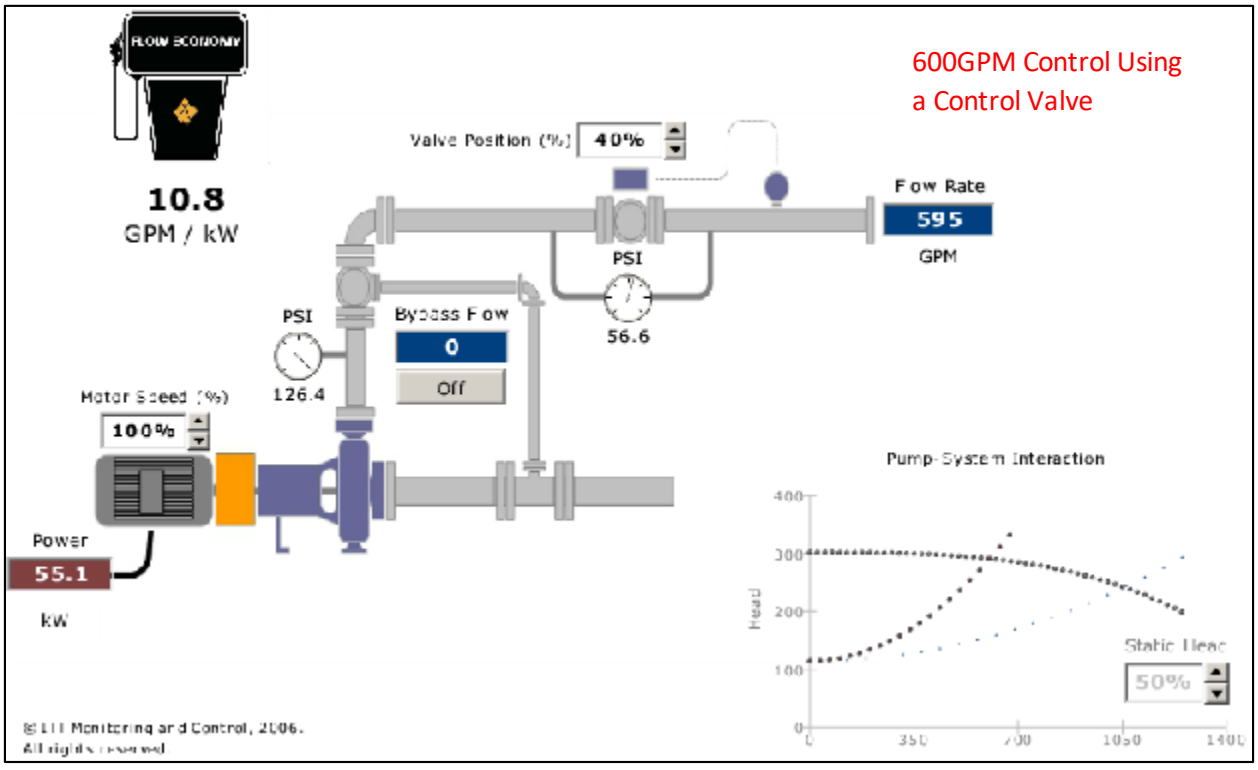


Figure 8

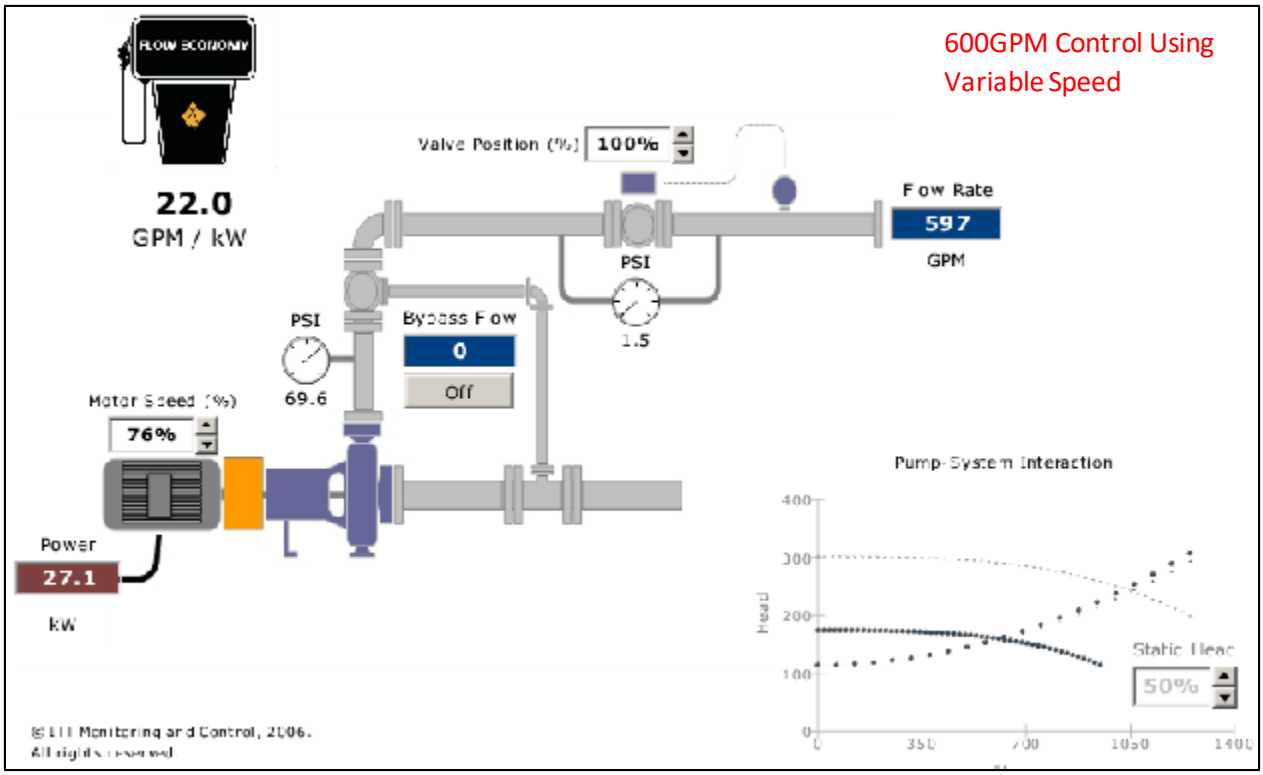


Figure 9

However, as seen in figure 9, when reducing the flow rate to roughly 600GPM by reducing the speed of the pump, for this same flow rate we see a much larger reduction in consumed power. From 55.1kW to 27.1kW! Also note between Figures 8 and 9 the difference in discharge pressures at the pump. This much lower pressure when using variable speed control represents reduced stress on the pump and piping system. Finally, in the upper left corner of each graphic we see a Flow Economy graphic. This represents effenciency of the system, and is the flow rate per kW of energy put into the system.

Based on this information we see that variable speed control to a desired control point is much more efficient, and is much less stressful on the pump and overall system then using a control valve.

Often times a VSD is justified based on its payback in power savings, as this is generally easy to calculate up front. Return on investment (ROI) for a VSD is often less than a year depending on operating conditions. However, what is not as easy to calculate up front are the savings through reduced maintenance and downtime due to properly running the pump for the application. This should not be discounted as it is real and can be a significent amount of money.

How to Size a VSD

We often select a VSD based on horse power or kW size of the motor. This selection process is relatively safe provided the motor is either two or four pole (base synchronous speed of 1800RPM or 3600RPM), and if it is not a submersible pump. VSD manufacturers size their offering based on two and four pole motor current requirements per the NEMA (or IEC) tables. Figure 4 shows a typical NEMA full load amp (FLA) requirements table for two and four pole three phase motors at 60Hz.

HORSEPOWER	THREE PHASE				
	200 V	208 V	230 V	460 V	575 V
1/6	-	-	-	-	-
1/4	-	-	-	-	-
1/3	-	-	-	-	-
1/2	2.5	2.4	2.2	1.1	0.9
3/4	3.7	3.5	3.2	1.6	1.3
1	4.8	4.6	4.2	2.1	1.7
1 1/2	6.9	6.6	6.0	3.0	2.4
2	7.8	7.5	6.8	3.4	2.7
3	11	10.6	9.6	4.8	3.9
5	17.5	16.7	15.2	7.6	6.1
7 1/2	25	24.2	22	11	9
10	32	30.8	28	14	11
15	48	46	42	21	17
20	62	59	54	27	22
25	78	75	68	34	27
30	92	88	80	40	32
40	120	114	104	52	41
50	150	143	130	65	52
60	177	169	154	77	62
75	221	211	192	96	77
100	285	273	248	124	99
125	359	343	312	156	125
150	414	396	360	180	144

Figure 4

However, as pole count goes up so does the motor's FLA requirements. A 100HP, 460Vac, 900RPM motor may have a FLA requirement of 132 amps. A 100HP VSD may not cover that high of a FLA requirement, thereby requiring that you upsize to the next larger VSD. Bottom line, it is always best to size a VSD based on meeting or exceeding the motor's FLA requirement including any service factor you may intend to use. Note - once you mount or wire to the PumpSmart VSD it cannot be returned for credit.

Motor Name Plate

A motor's FLA requirement can be found on the motor data sheet or on the motor's name plate. Figure 5 shows a typical motor name plate for a dual wound 3 HP motor. Note that this motor can be run on either 460Vac or 230Vac depending on how it is wired. Also note that each voltage rating has its own FLA current rating. At 460Vac its FLA requirement is 3.9 amps while at 230Vac its FLA requirement is 7.8 amps.

So far we have been speaking about motor speed in terms of its synchronous speed (900, 1800, 3600RPM, etc.) On the name plate example below the motor's F/L (Full Load) RPM rating is what is called its Slip Speed. This is an example of a four pole motor. Its slip speed value is what is entered into PumpSmart when entering motor data.

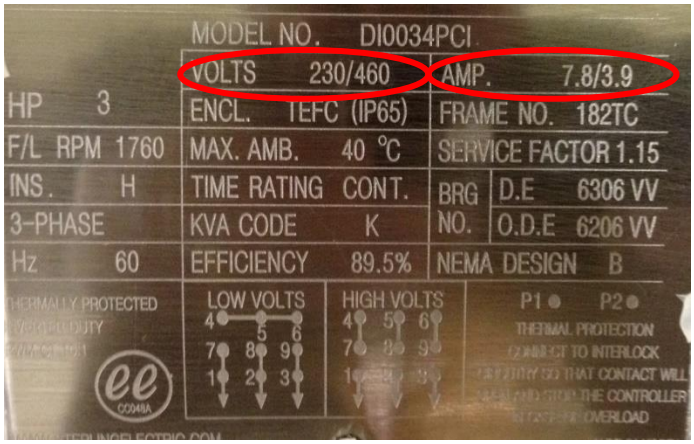


Figure 5

Selecting PumpSmart in ePrism

With few exceptions PumpSmart can be specified and quoted directly from ePrism. You may add PumpSmart to a pump quote or quote it as a standalone product. Following is detail on the various forms of PumpSmart found in ePrism.

To properly select a PumpSmart VSD at minimum you need to know a few basic customer requirements, such as NEMA (or IEC) environmental rating, horsepower (or kW) size, and mains voltage.

PumpSmart ePrism Selection Example

The following example of an ePrism PumpSmart selection assumes the user has a basic understanding of ePrism use. For the sake of expediency we will assume the user already knows how to complete the commercial section of a quote, and we will focus on the PumpSmart configuration portion of the ePrism selection process only.

In this example we will be selecting a 100HP, 460VAc, NEMA 1 wall mount drive. Selecting a larger free standing floor mount drive follows the same process, and we will point out any uniqueness to a floor mount where needed.

Expand the Configuration item in the upper left tree. Figure 1 shows a portion of the Basic Features tab.

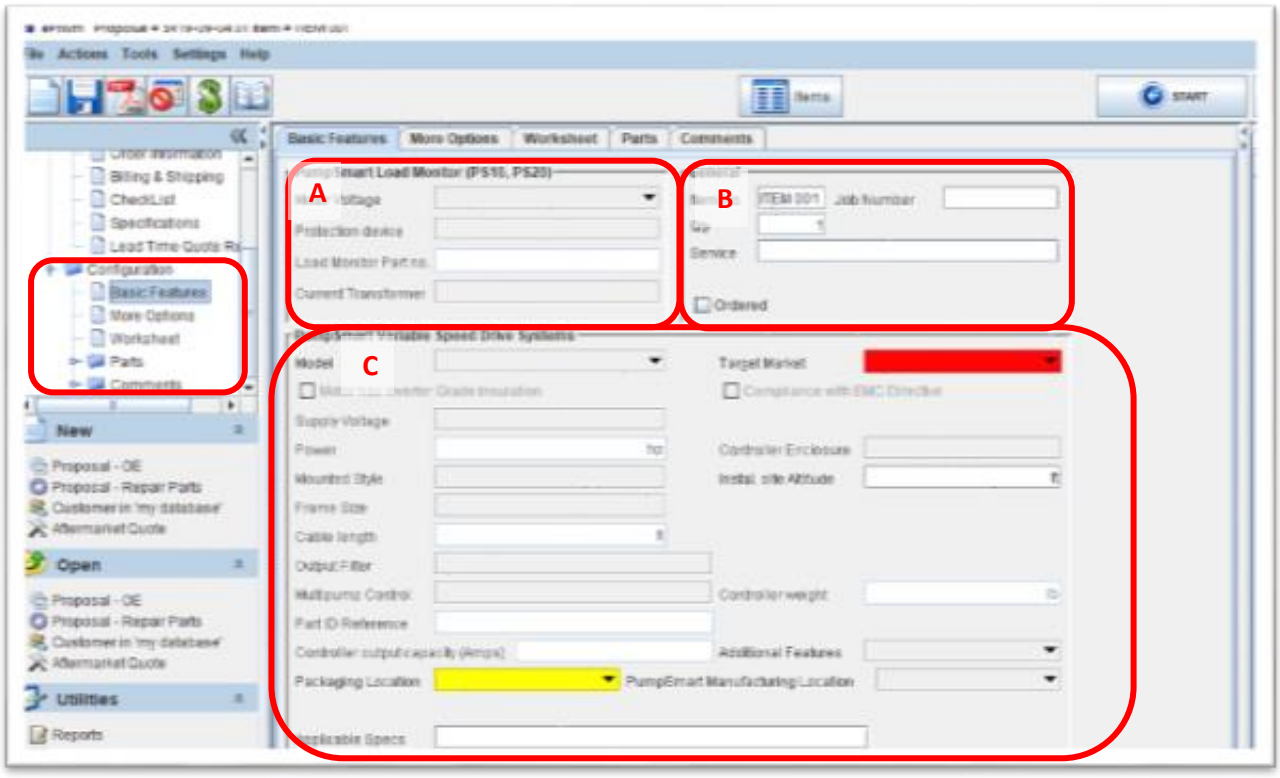


Figure 1

Section A is to be used when specifying a PS20 Load Monitor. We will not be using this section when specifying a PS220 VSD. Please see the section on the *PumpSmart PS20 Load Monitor* in this ETM if needing a load monitor. Section B can be used to define how many of this particular size VSD is required under this Item. You can also state a Service type and Job Number in Section B. It is in Section C that we will detail the PS220 we are in need of.

From the *Model* dropdown select the model of PumpSmart you are looking to provide. See Figure 2. The PS220 wall mount ULH drives will become available soon and the PS200 selection under Model will disappear completely. For detail on ULH drives and when to use them see the section entitled *Harmonics and Its Mitigation*. Other selections for Model include PS220 (the one we will select for this example), PS75 (Low Voltage), and PSMV (Medium Voltage).

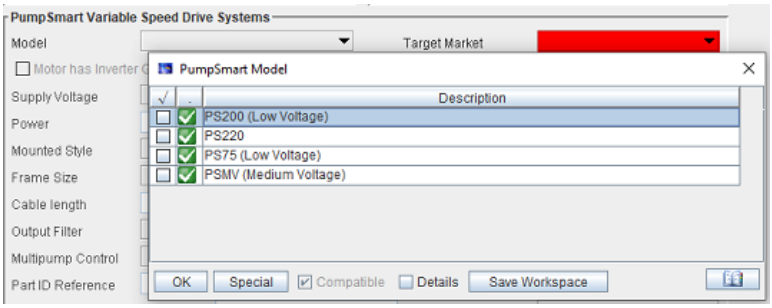


Figure 2

The *Target Market* dropdown permits selecting where the VSD final destination is. See Figure 3.

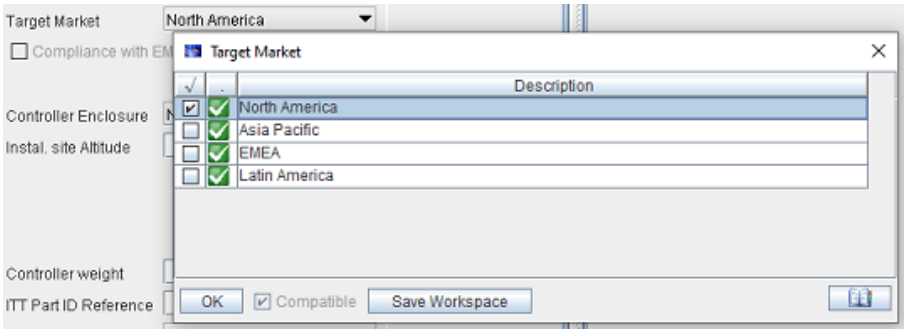


Figure 3

Selecting any location other than North America will cause ePrism to provide the VSD size in kW as oppose to HP.

From the *Supply Voltage* dropdown select the voltage group of the VSD mains voltage (Figure 4). This is the voltage being supplied to the VSD. PumpSmart is available in four mains voltage groups; 208-240Vac, 380-415Vac, 440-500Vac, and 525-690Vac. There is a fifth selection under the dropdown entitled 480VAC / Engineered Panels. We will discuss this selection when discussing Engineered Panels.

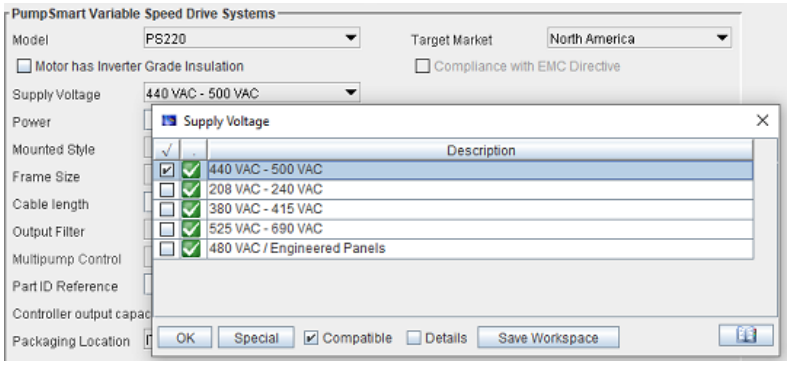


Figure 4

Next, enter the *Power* for the VSD to be supplied, see Figure 5. This defaults as horsepower and can be changed to kilowatts when selecting non-North American markets.

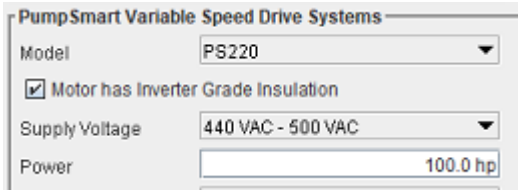


Figure 5

Again, be sure that when done with the VSD selection this power value will provide enough current to meet the motor's FLA requirements. See the section *How To Size a VSD*.

From the *Controller Enclosure* dropdown select the proper NEMA or IP rating for the VSD. See Figure 6. Factory available ratings include NEMA 1 (IP21) and NEMA 12 (IP55). For applications requiring more protection you will need to select an Engineered Panel under the Supply Voltage dropdown. See the section on *NEMA/IP Ratings* for rating detail. See *Engineered Panels* for detail on what an engineered panel will supply.

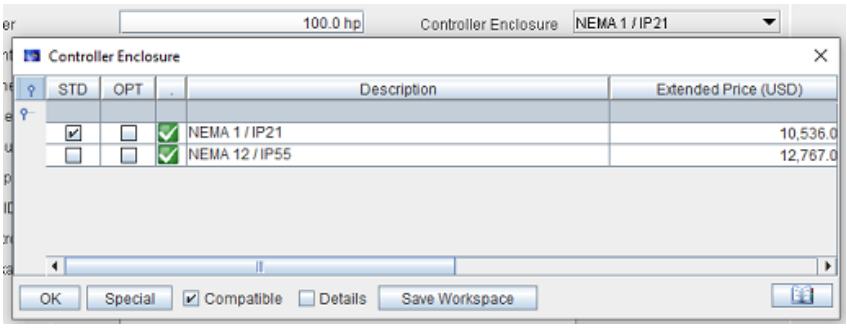


Figure 6

Once a *Power* value is entered select the type of physical architecture the VSD is to be from the *Mounted Style* dropdown (Figure 7). Drive sizes 3-60HP are available only in a wall mount, but the largest wall mount drive is 350HP (440-500Vac) and 300HP (525-690Vac). Drive sizes 75 and up (over 2000HP) are available as free standing floor mount drives. As of this writing the PS220 ULH drives are available in free standing floor mount architecture only and start at 300HP.

Unless the VSD is available in both a wall and free standing physical architecture the *Frame Size* will automatically fill in. See Figure 7. If available in both hardware packages you may need to select the proper frame size here.

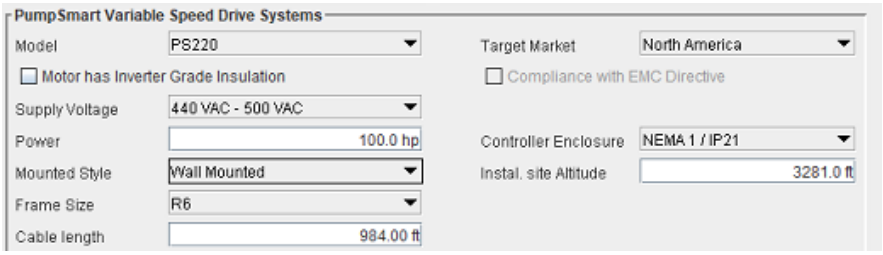


Figure 7

Cable Length defaults at the minimum length of motor cable whereby a dv/dt filter is required for the VSD output. If your motor lead is shorter than this, fill in the correct motor lead length here, else when conducting a Compatibility Check ePrism will require that you specify a dv/dt filter. Lengths under 984 feet will not automatically require a dv/dt filter. See the section *Harmonics and its Mitigation* for additional detail as to when a dv/dt filter is recommended.

The *Instal. site Altitude* field is default at the maximum altitude PumpSmart can be used at without derating its current. See the section on *Derating PumpSmart*.

From the *Output Filter* dropdown selects whether the filter is to be supplied by ITT or by the customer, Figure 8. If selecting supplied by ITT then the proper sized NEMA 1 dv/dt filter will be added to the

order. See the section entitled *Harmonics and its Mitigation* for additional detail as to when a dv/dt filter is to be recommended.

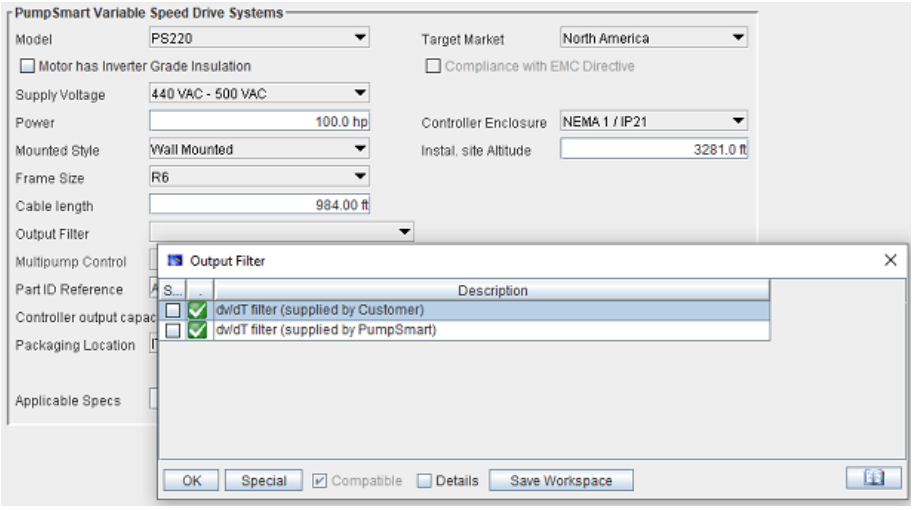


Figure 8

The *Multi-pump Controller* field is only necessary when using the PS200 ULH drive in a Multi-pump operation, where a fiber optic kit is required. This field is not used for PS220 drives as the PS220 does not require additional hardware for Multi-pump operation. See the back of the PS220 IOM for detail on connecting multiple PS220 drives together for Multi-pump operation.

The following three fields are automatically filled in by ePrism based on the previous detail you supplied; *Controller Reference* (manufacturer's part number), *Part ID Reference* (ITT part number), and *Controller Output Capacity (AMPS).* Again, it cannot be overstated that the *Controller Output Capacity* value must cover the motor's FLA requirements including any expected use of safety factor.

The *Packaging Location* dropdown permits you to select where the product is packaged at. See Figure 9. Typically this is left at ITT Monitoring & Control (PumpSmart).

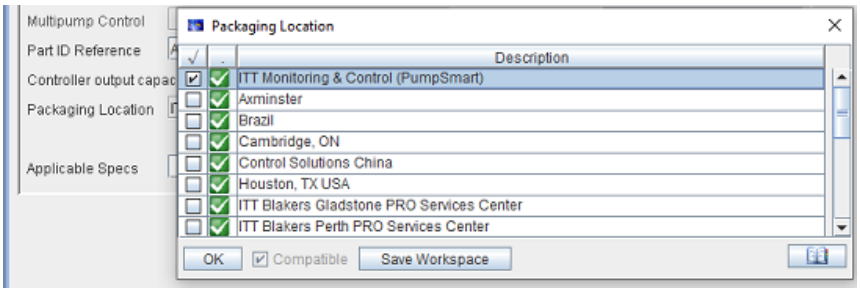


Figure 9

The *Additional Features* dropdown permits adding various options to the PumpSmart VSD. See Figure 10.

- As of this writing the DDCS Optical Module is not required. This item is used to connect fiber optics capability to the PS220. If and when backward compatibility for Multi-pump connection to existing PS200 drive installations becomes available this module will be used to permit peer-to-peer connection between the PS200 and the PS220.
- EMC/RFI Filters, 1st and 2nd environment may be integrated into the PS220 by selecting one or the other here. These filters are not for mitigating harmonic noise but are for mitigating radio

frequency (RF) noise in an effort to reduce any interference to radios. Add only if requested by the customer.

- FIO-11 Analog I/O module may be added to provide an additional (3) analog inputs, (1) analog output, and (2) digital inputs/outputs.
- PS220 Keypad Mounting Kit may be added to permit mounting the PS220 keypad in a remote location from the drive, up to 100 meters apart. The keypad that comes with the VSD is removed and installed in this kit once the kit is mounted in a panel surface.
- A keypad with Bluetooth comes installed in every PS220 VSD. However, in some cases the customer does not permit any form of wireless communications in their facility. In these cases a PS220 keypad without Bluetooth may be ordered. The customer is to then remove and discard the keypad that comes on the VSD and replace it with the keypad that does not have Bluetooth.
- A spare PS220 keypad with Bluetooth may be ordered. It is not required that a keypad be ordered when specifying a PS220 VSD if a spare is not required as a keypad comes with every VSD.

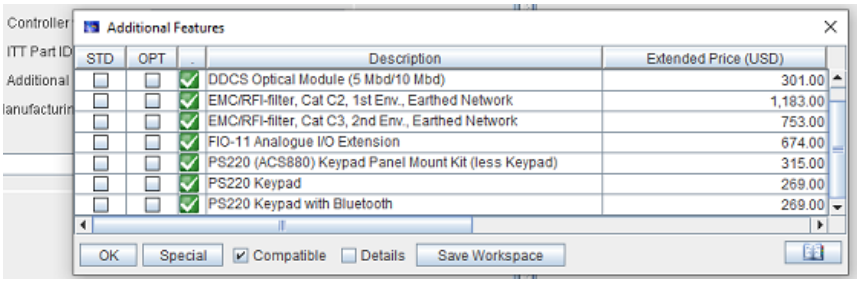


Figure 10

The *PumpSmart Manufacturing Location* permits selecting where the PS220 will be manufactured. This should be selected as New Berlin, Wisconsin USA. See figure 11.

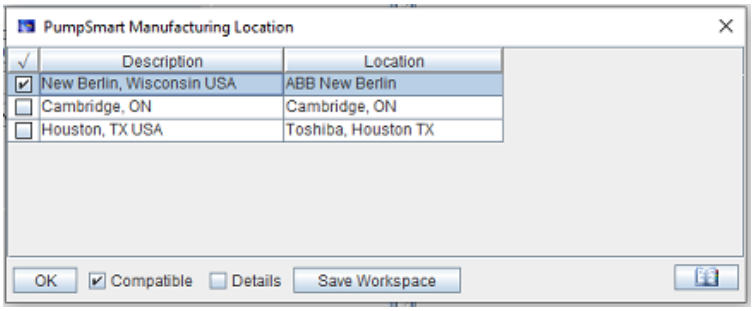


Figure 11

At this point the PS220 VSD is specified. You may desire to add other options such as process transmitters or serial communications modules (fieldbus modules). To do this select the All Options tab. Next select PumpSmart Options under the Groups field.

PS220 Options

When *Fieldbus Adapters* is selected, Figure 12 shows a list of available serial communications adapters for the PS220 VSD. The customer will need to inform you which protocol is required. Any of these modules may be added to PumpSmart either at the time of order or at any time later. These modules are shipped separate and are to be installed into slot 2 of the VSD by the customer. See the section entitled Serial Communications for various protocol details.

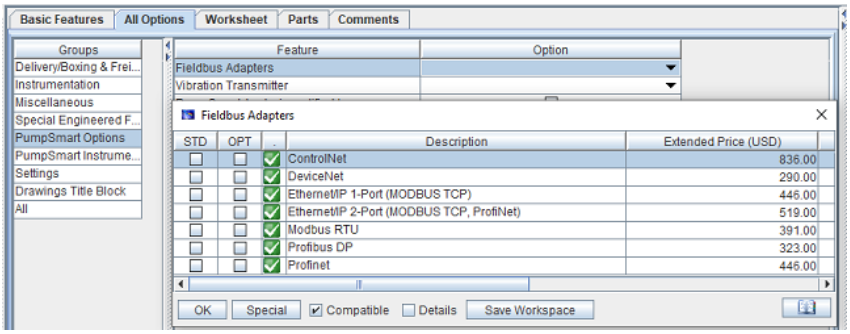


Figure 12

A Vibration Transmitter may be ordered if required by selecting the *Vibration Transmitter* dropdown. This is a single axis vibration transmitter. Its output is 4-20mA signal and is wired into one of the PS220 analog inputs. Use the Condition Monitoring feature within the PS220 VSD to monitor and take action on this axis of vibration. See Figure 13.

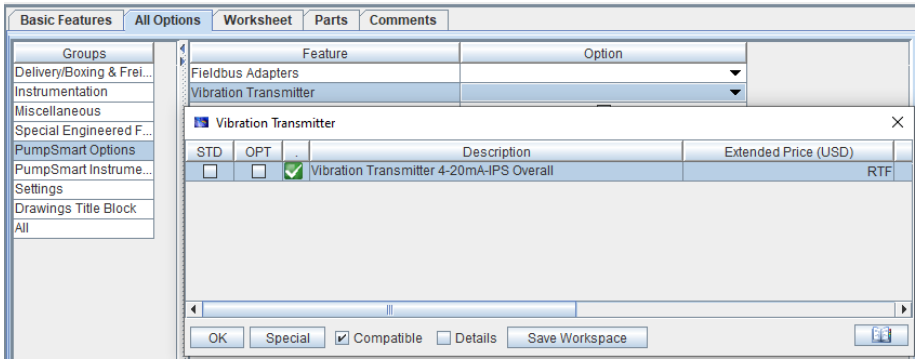


Figure 13

The PS220 VSD is capable of conducting PID process control (see the section entitled Process Control). This is the process of the PS220 automatically varying the speed of the pump to keep a process actual value equal to a desired set-point. Example, the pressure must be kept at 100PSI regardless of the flow demand. In this case an external pressure transmitter is required to measure the pressure actual value. PumpSmart can control pressure, flow, level, or temperature using its integrated PID algorithm. You may select the required transmitter type under *PumpSmart Instrumentation*, found under the *Groups* column.

There are two dropdowns relative here; *Primary Control Mode*, *Multi Variable Offset Parameter*. To select the proper transmitter type you must first select the Primary Control Mode (pressure, flow, level, temperature). See Figure 14. Once the Primary Control Mode is selected its associated transmitter type field will become available. In our above pressure example the Pressure Transmitter dropdown becomes available, Figure 15.

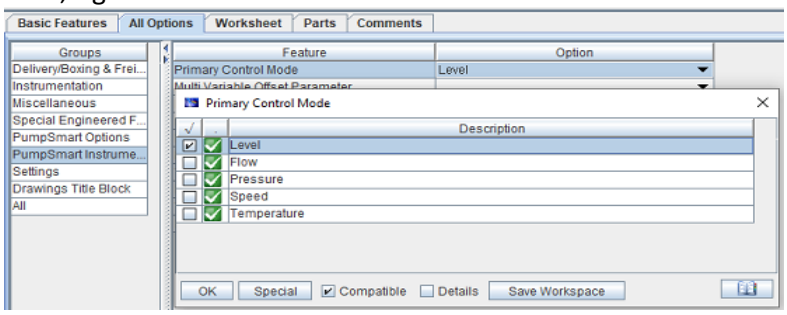


Figure 14

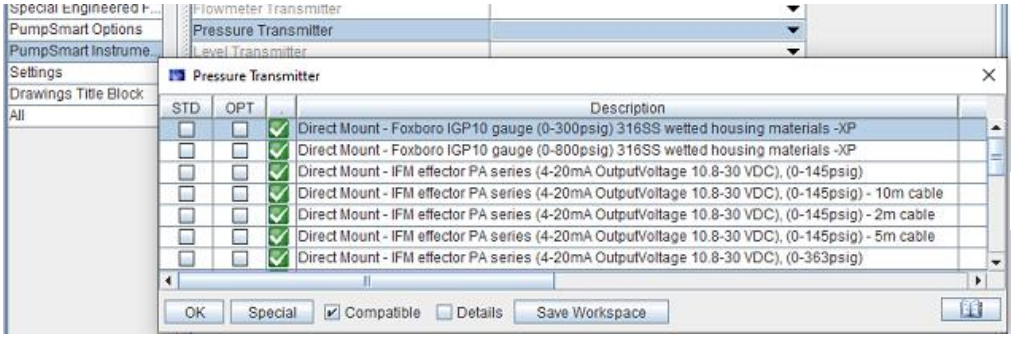


Figure 15

Select a pressure transmitter based on the pressure range required for your application. Note: all transmitters are 316 stainless steel wetted parts which is good for water at a minimum. If your process fluid is not water you must verify that 316 stainless steel wetted materials are sufficient for your application. See the ETM section on Process Control for additional detail on transmitters.

If conducting Multi Variable control (see section on *Multivariable Control*) you may need an additional transmitter for the second variable. In this case, from the Multi Variable Offset Parameter dropdown, select the process type for this second variable. It may be pressure as well, or may be any one of the other types remaining. The type selected here will permit selecting the correct type of transmitter for the second variable.

At this point you have likely completed your PumpSmart VSD selection process for this item. You should conduct a compatibility check, resolving any issues that do not give you a green checkmark.

Selecting the Worksheet tab provides you with access to the results of all you work. You can set multipliers here and add comments.

You may want to add a ROI (return on investment) section to your proposal as well. This shows the customer what the expected payback will be when using a PumpSmart on their pump. See the section entitled *ePrism and the PumpSmart Calculator* for details on how to add this feature.

Engineered Panels

Engineered panels are required when the environmental conditions are beyond NEMA 1 or NEMA 12, or when your customer has special requirements that might go beyond a standard factory PumpSmart drive offering. See the ETM section entitled *NEMA/IP Ratings* for detail on various NEMA/IP ratings.

Engineered Panels are available standard in ePrism in the following NEMA ratings; 12, 3R, 4, and 4X. They may include one PS220 VSD (Simplex), two PS220 VSDs (Duplex), or three PS220 VSDs (Triplex) when ordered in ePrism. ePrism offers Engineered Panels in 460Vac only. Other mains voltages are available as an Engineered Panel but you will need to contact the factory for pricing. A panel will include the following.

Simplex Enclosure

- NEMA rated enclosure
- Lockable fused disconnect
- PS220 VSD
- Hand-Off-Auto selector switch
- E-Stop pushbutton
- Reset pushbutton
- Input and output fused 120Vac control transformer
- Proper NEMA rating and heat load based cooling

Duplex Enclosure

- NEMA rated enclosure
- Lockable fused disconnect (x2)
- PS220 VSD (x2)
- Hand-Off-Auto selector switch (x2)
- E-Stop pushbutton (x2)
- Reset pushbutton (x2)
- Input and output fused 120Vac control transformer
- Proper NEMA rating and heat load based cooling
- Peer-to-peer wiring for Multi-pump operation
- 24Vdc transmitter power supply

Triplex Enclosure

- NEMA rated enclosure
- Lockable fused disconnect (x3)
- PS220 VSD (x3)
- Hand-Off-Auto selector switch (x3)
- E-Stop pushbutton (x3)
- Reset pushbutton (x3)
- Input and output fused 120Vac control transformer
- Proper NEMA rating and heat load based cooling
- Peer-to-peer wiring for Multi-pump operation
- 24Vdc transmitter power supply

With this offering all the customer needs to do is bring in their 3 phase mains feed and three wires out to the motor.

In some cases an Engineered Panel may be required because the end user has additional requirements beyond what the standard PumpSmart panel offers. This might include special operators (switches, relays, etc.), warning/alarm lights, horns, etc. If your offering has special needs you will need to contact the factory for pricing on a panel to meet these needs.

Finally, if you have a specification that calls out requirements that you are unsure of it is best to send that specification into the M&C Group to have them verify a PumpSmart offering to meet the requirements.

ePrism Ordering of Engineered Panels

Ordering an Engineered Panel in ePrism is similar to ordering a standard PS220 drive in ePrism. Options and VSD detail for the VSD itself is provided in the same way as for a stand-alone VSD. Therefore the following information will focus only on the differences between ordering an engineered panel vs. ordering a stand-alone VSD.

Figure 1 shows the PumpSmart Basic Features tab where the selection for *Supply Voltage* is made as *480V Engineered Panels*. When selected this way the *Controller Enclosure* dropdown changes its content (Figure 2). Select the Engineered Panel required, including the number of PumpSmart drives and the NEMA/IP requirement.

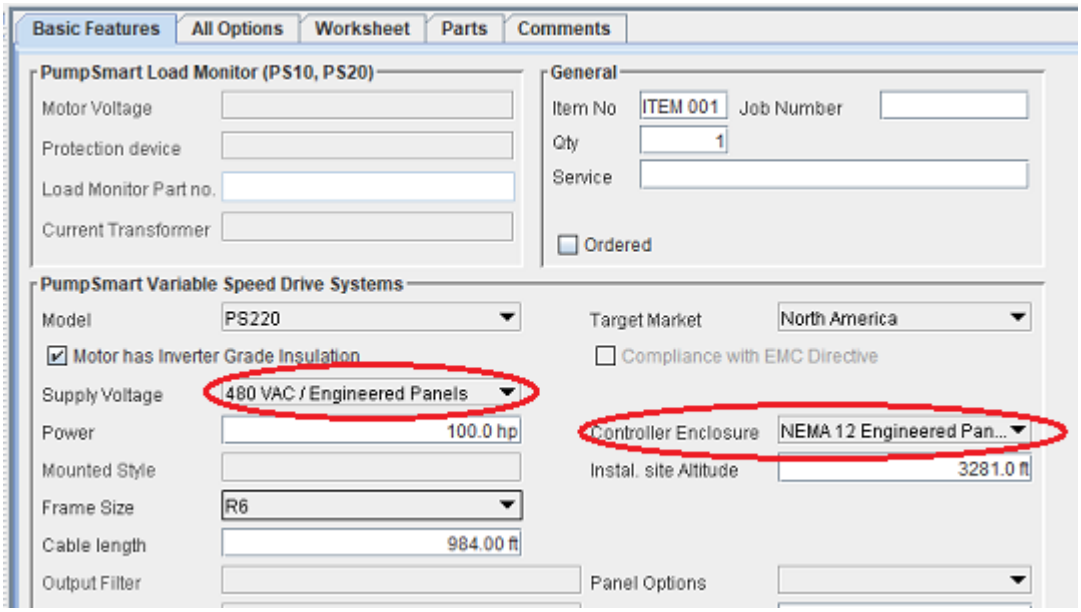


Figure 1

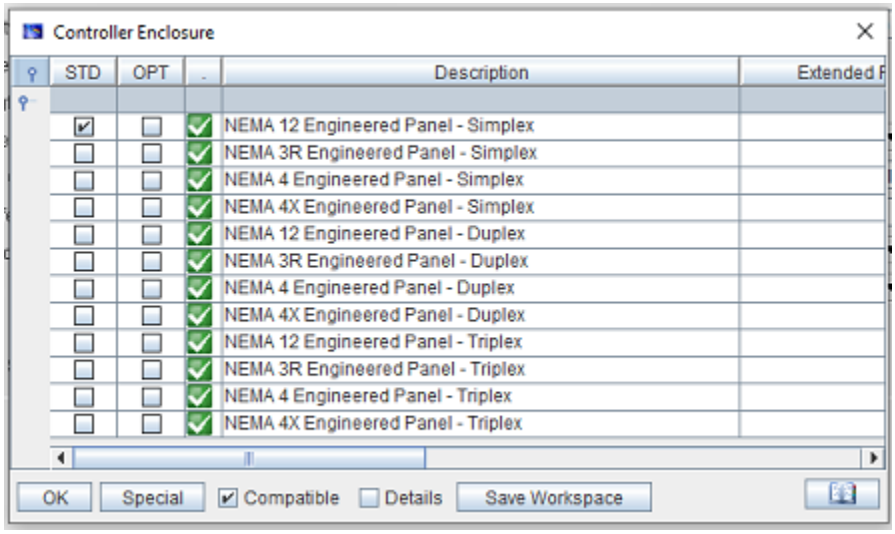


Figure 2

When 480VAC Engineered Panel is selected in the *Supply Voltage* dropdown a new dropdown field is added to the Basic Features tab called *Panel Options*. Figure 3 shows the contents to this dropdown.

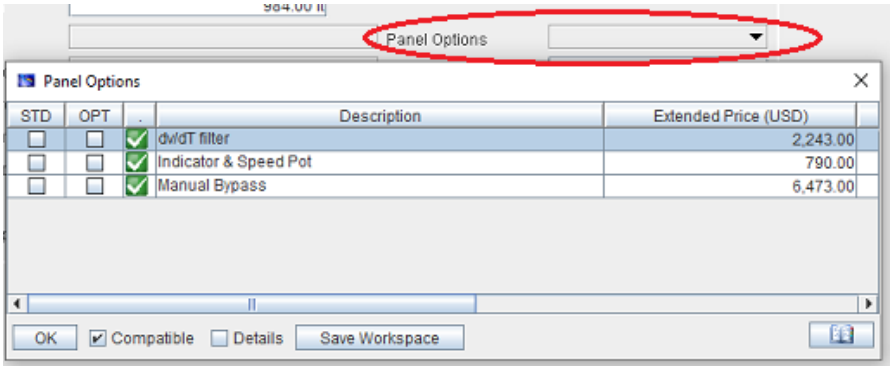


Figure 3

These represent options that can be integrated into an Engineered Panel. To follow is a brief description of each option.

- dv/dt filter – A dv/dt filter may be required to mitigate harmonics from damaging the motor. See the section on *Harmonics and its Mitigation* for detail as to when it is suggested to use a dv/dt filter between a VSD and motor. When selected a dv/dt filter will be installed (integrated in the panel) for each VSD.
- Indicator & Speed Pot – Three indicators are included per VSD. One to indicate Power, one to indicate Ready, and one to indicate Fault. A speed pot per VSD is included as well and is typically used as a speed override reference source, but may be used as a primary set-point source.
- Manual Bypass – A manual bypass provides a method whereby the pump may be run across the line should the VSD need to be taken out of service. The pump will run at full speed. This option is a 3-contactor bypass, complete with overloads, Bypass/Off/VFD selector switch, and Bypass indicator light. One bypass is included per VSD. Example, a Duplex panel will have a 3-contactor bypass with its operators for each of the two VSDs.

ePrism and the PumpSmart Calculator

ePrism offers a tool called the PumpSmart Calculator. This tool easily enables the user to predict an expected cost savings based on energy costs when using variable speed over fixed speed control. While this tool will work on any centrifugal pump (including non-IP pumps), it is most easily applied to IP pumps. To access this tool open ePrism and select a pump that meets the design requirements. Then select the PumpSmart Calculator tab. See Figure 1.

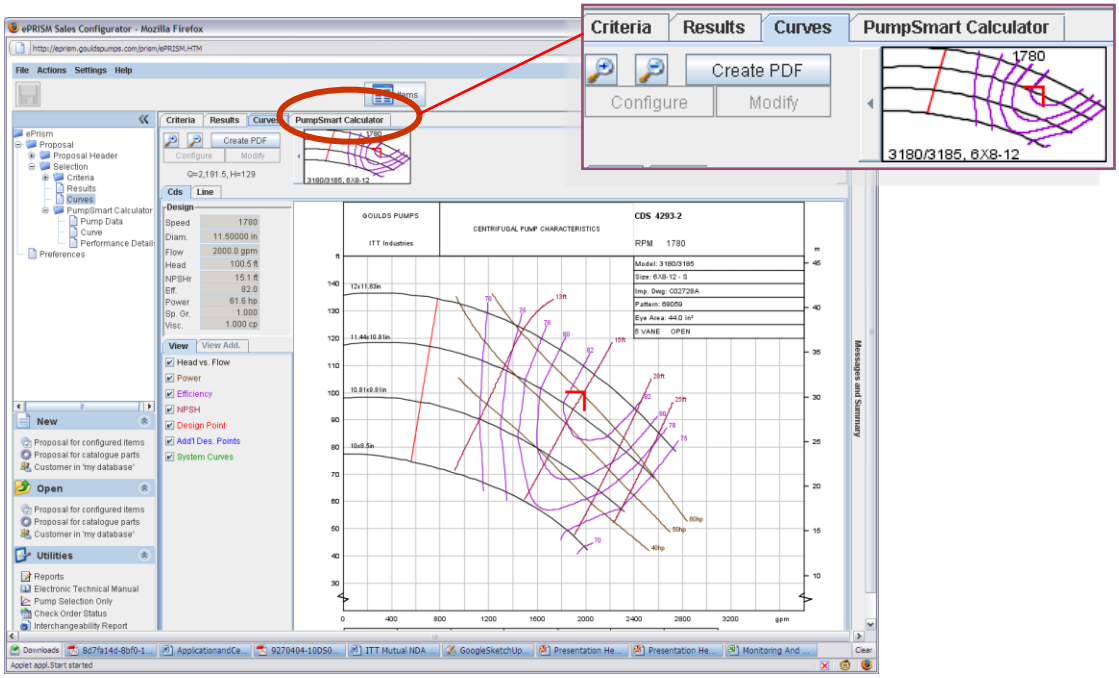


Figure 1

Once the PumpSmart Calculator tab is selected you will see a screen that enables you to customize the variables specific to your customer's application. You will need to know some specific detail about the application including its variable system flow points, system curve points, and the customer's cost of energy. See Figure 2.

System flow points are the expected flow points for the application. Three points are provided by default but by using the Add button you can enter detail for more points. The more points you have the more accurate your results will be. Enter a percentage of use for each point. These must all add up to 100%.

System curve points define the relatioship between the flow and head requirements. Like system flow points, the more detail entered the better your results are likely to be.

Finally, enter the annual operating hours for the pump and the cost of energy that the customer pays. Selecting the Curve tab will permit you to see your information graphically. Select Calculate and select the Performance Details tab. Here you will see the results, including expected energy cost savings.

When selecting the Print button you will get a clean report in PDF format that can be included in your proposal to the customer. Note the savings at the top center. See Figure 3.

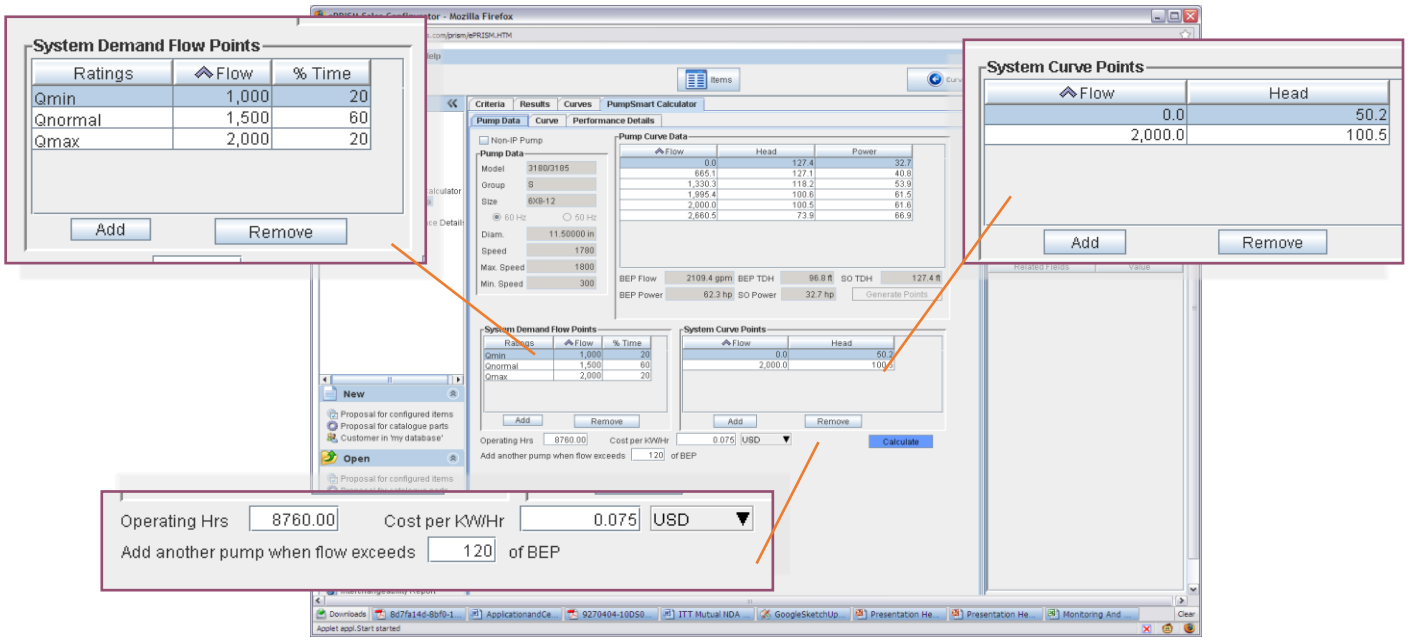


Figure 2

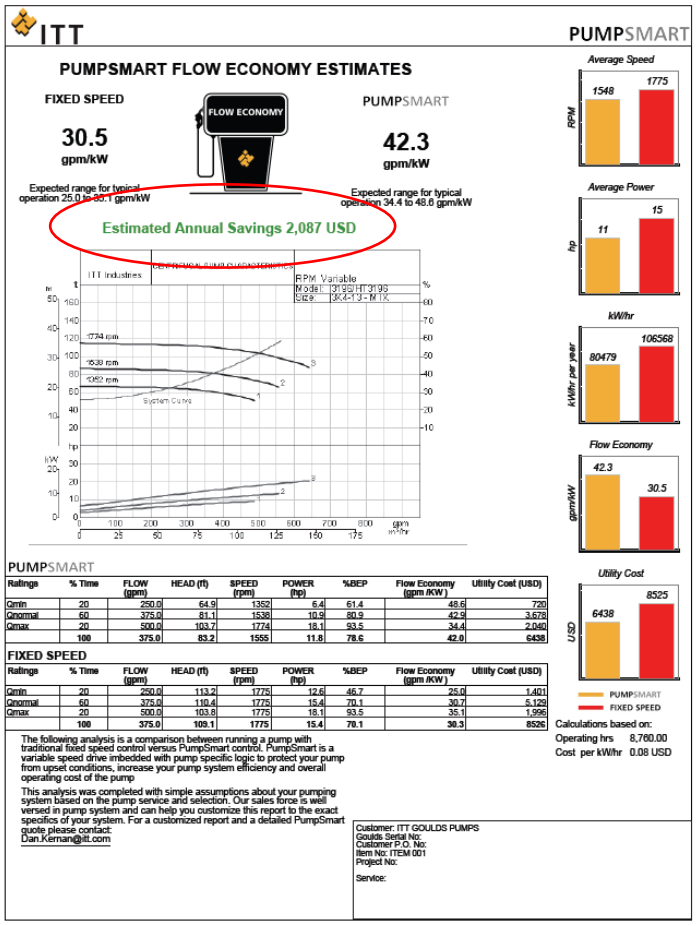


Figure 3

NEMA/IP Ratings

NEMA ratings identify what kind of environment the VSD may operate in. PumpSmart is available standard from the factory in NEMA 1 and NEMA 12 formats. But what happens if you need to mount the VSD outdoors or in a hostile environment? To Follow are the four most often specified NEMA ratings and what type of environments they may include.

NEMA 1 (IP10)

General-purpose. Protects against dust, light, and indirect splashing but is not dust-tight; primarily prevents contact with live parts; used indoors and under normal atmospheric conditions. This rating may be installed in indoor environments where there will be no water or dust. Cooling for NEMA 1 is by fan and as so exchanges air with the external environment. This rating is available with PumpSmart as standard from the factory. It is not available as an engineered panel. Suggest using NEMA 12 when specifying an engineered panel.

NEMA 12 (IP52)

General-purpose. Intended for indoor use, provides some protection against dust, falling dirt, and dripping non-corrosive liquids. Meets drip, dust, and rust resistance tests. Cooling for this rating is by fan and as so exchanges air with the external environment. This rating is available with PumpSmart as standard from the factory or when using an Engineered Panel.

NEMA 3R (IP14)

Weather-resistant. Protects against falling dirt and windblown dust, against weather hazards such as rain, sleet and snow, and is undamaged by the formation of ice. This rating does not protect against wind driven rain or dust. It is suggested that if this rating is used outdoors the enclosure be placed under a canopy of some type. Cooling for a NEMA 3R enclosure is by fan with NEMA 3R shrouds and as so exchanges air with the external environment. This rating is available with PumpSmart only when using an Engineered Panel.

NEMA 4 (IP66)

Weathertight. Intended for both indoor and outdoor use. Protects against both vertical and wind driven horizontal rain and dust. Cooling for NEMA 4 enclosures is by either air-to-air heat exchangers or by air conditioner. No internal air is exchanged with the external environment. This rating is available with PumpSmart only when using an Engineered Panel.

NEMA 4X (IP66)

304 stainless steel materials. Weathertight. Intended for both indoor and outdoor use. Protects against both vertical and wind driven horizontal rain and dust. NEMA 4X will protect against harsh environments including salt (near the sea) and H_2S. Cooling for NEMA 4X enclosures is by either air-to-air heat exchangers or by air conditioner. No internal air is exchanged with the external environment. This rating is available with PumpSmart only when using an Engineered Panel.

Harmonics and Its Mitigation

What Are Harmonics and Where Do They Come From?

VSD are considered non-linear devices. As such they generate harmonics (electrical noise). This noise occurs on both the mains and motor side of the VSD. If not properly accounted for or mitigated when required, these harmonics can cause damage to electrical devices around the VSD.

Harmonics and mitigation techniques is a very in depth subject. Many sources of various levels of description and understanding for this subject can be found online. It is the intent of this section to introduce the reader to the very basics of the subject only.

Mains Side Harmonics

A harmonic is electrical noise generated at a multiple of the fundamental frequency. The fundamental frequency is the primary supply frequency, example; 50 or 60 hertz (Hz). In a 60Hz supply the third harmonic is 3 times 60Hz, or 180Hz. The fifth harmonic would be 300Hz, and so on. This harmonic energy is added to the fundamental frequency, changing its shape. Figure 1 shows a fundamental frequency, the second harmonic, along with the resultant waveform.

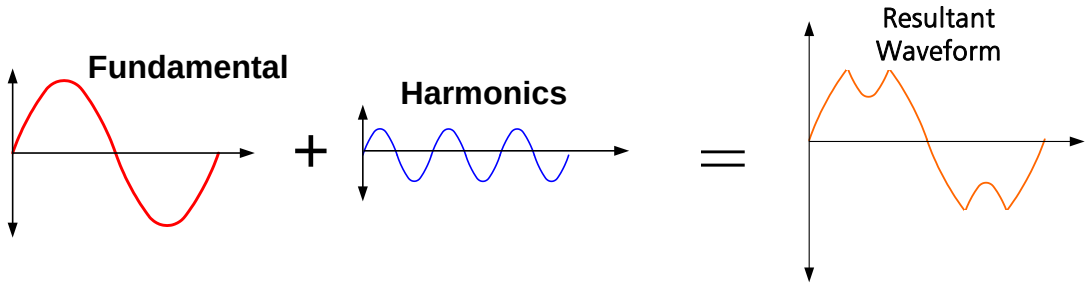


Figure 1

With a 6-pulse VSD the most noticeable harmonics are the 5th, 7th, and 11th. Figure 2 shows a fundamental along with these harmonics, and the resultant waveform. Note that this figure is an actual screen capture from a power quality meter showing the actual waveforms. Remember that the resultant fundamental waveform should be a sine wave as seen in Figure 1. You now see how these harmonics have a negative impact on the fundamental frequency.

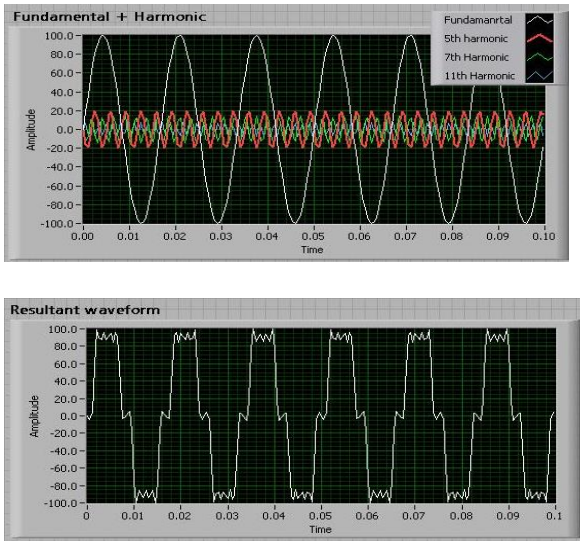


Figure 2

These harmonics (excess energy) can get absorbed inside and outside of the plant by other electrical devices. The result is that these other devices turn this excess energy into heat and in many cases will cause premature failure of the equipment due to heat overload.

Line Side Harmonic Mitigation

There are various types of filters designed to mitigate harmonics. Each filter design will have a specific mitigation affect. Realize, a 6-pulse VSD will typically have 60-80% Current Total Harmonic Distortion (ITHD) when no filter is applied. To follow are various filter designs, from lowest cost to highest cost, and their typical mitigation effectiveness.

- 3%, 5% or 10% Line Reactor – This is the lowest cost solution, but also provides the least amount of harmonic mitigation. A line reactor is placed between the mains source and the VSD mains connection. ITHD can be brought down to between 29% and 49% with a 3% line reactor. A downside of this type of mitigation technology is that the percent value represents the amount of voltage loss across the line filter. In the case of a 5% line reactor 5% of the mains voltage is lost before it get into the VSD. At low mains voltage sites this might voltage starve the motor at full speed. It should be noted that the PS220 has an integrated 3% line or DC choke as standard. Adding a 5% filter in front will drop the mains voltage by 8% and provide little gain on harmonic mitigation. It is not recommended to add an additional line reactor to the front of a PS220 drive.
- Passive Filter – This type of filter has a line reactor plus capacitors and resistors, designed in such a way as to be what is called a low pass filter. ITHD can be brought down to between 19% and 29%. The same issues as stated for the line reactor can apply here as well.
- Tuned Passive Filter – This type of filter has a line reactor plus capacitors and resistors, designed in such a way as to be what is called a low pass filter. The primary difference between this and a Passive Filter above is that the components are selected specifically to tune out the 5^{th}, 7^{th}, and 11^{th} harmonics. ITHD can be brought down to between 7% and 9%.
- External Active Filter – This type of filter analyzes the harmonics and recreates the same harmonics 180° out of phase. When added to the original harmonics they come close to canceling each other out. ITHD can be brought down to between 4% and 7%. An active filter is connected (in parallel) to the three phase mains bus, which may have more than just the VSD on it for non-linear loads. The issue is that it tries to cancel out all harmonics on the bus that it is attached to. While this sounds good at first the issue becomes that it must be sized properly to mitigate all non-linear sources on that bus or it may not do the expected job. Also, this type of filter often requires a minimum of 5% line impedance. If your VSD does not have this you must also add a 5% line reactor in front of each VSD.

Other Line Side Mitigation Technologies

Multi-phase VSD

Another type of line side mitigation design is what is called a multi-pulse VSD. Instead of being a 6-pulse drive it might be either a 12-pulse, 18-pulse or 24-pulse design. Figure 3 shows an 18-pulse design.

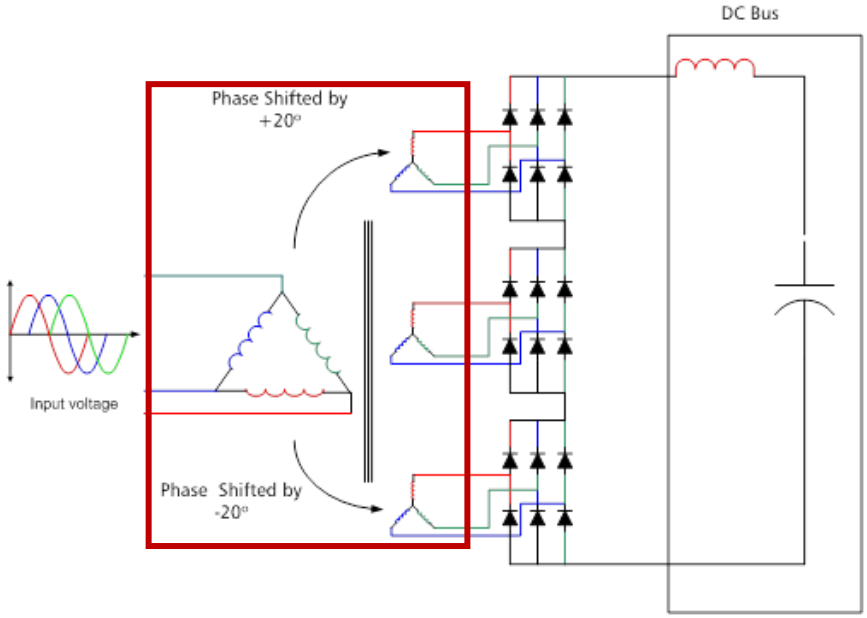


Figure 3

The design of a multi-pulse VSD requires multiple phases for its mains input. As an example, a 12-pulse VSD requires six phases in, an 18-pulse VSD requires nine phases, and so on. However, the power coming into the plant is only three phase. To meet this multiphase input requirement this VSD design requires using a multiphase transformer which takes in the three phases from the power company and produces the required number of phase out for the VSD design. The maroon box in figure 3 identifies a phase shift transformer for an 18-pulse VSD. The size of these phase shift transformers is often the size of the VSD itself and sometimes even larger. If real estate for the VSD is tight this solution might not be the right one. An 18-pulse VSD will provide in the neighborhood of 4%-13% ITHD. If the customer is requiring this type of technology you must contact the M&C Group for proper pricing. Additionally, installation cost will be higher with this technology as significant wire must be used between the phase shift transformer and the VSD.

Active Front End Design

Perhaps the best mitigation solution for line side harmonics is what is called an Active Front End (AFE) design. PumpSmart offers an AFE product called the Ultra Low Harmonic (ULH) VSD. An AFE drive uses IGBTs in its rectifier section in place of diodes and uses special phase-angle firing of these IGBTs to reduce line side harmonics to a minimum. This technology is often not any larger than a standard 6-pulse VSD of the same HP size and will provide 3%-5% ITHD. Installation is similar to that of a 6-pulse drive, requiring three lines in and three lines out.

Motor Side Harmonics

Like the mains side, a VSD generates electrical noise on the motor side as well, often worse than that of the mains side. If not properly managed it can cause bearing damage or even motor failure.

Motors are designed to run on a sinusoidal voltage and current waveform. However, while the output of a VSD is a primarily a sine current waveform its voltage waveform is pulse width modulated (PWM). Figure 4 shows these.

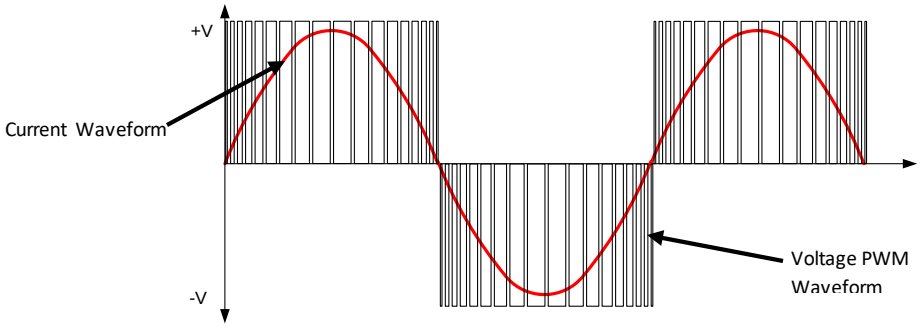


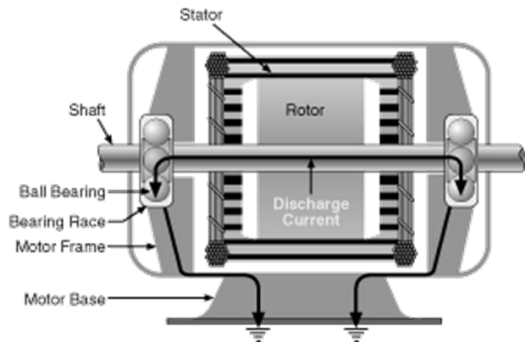
Figure 4

What is not shown is that due to the very fast rise times (0.1 µsec) of the IGBTs there are overshoots in voltage output, often time at 2-3 times or more of the DC bus voltage. A 460VAc mains VSD has a 670Vdc DC bus voltage. This means the noise going out to the motor can be 1200 to 1400 volts! The insulation of both the motor windings and the motor leads must be able to withstand this voltage or you will experience insulation breakdown.

Motors designed for VSD use are typically labeled for inverter use or may be called premium efficiency. The NEMA Standard MG- I (part 31) indicates that inverter duty motors shall be designed to withstand 1600 volts peak and rise times of >0.1µsec.

Aggravating this insulation breakdown will be long motor lead lengths. PumpSmart is good for up to 300 meters motor lead length before requiring motor side mitigation (typically dv/dt filter) when the mains are under 500Vac. As the motor lead length increases above this the impedance (resistance) of the motor leads cause higher voltage spikes due to the current harmonics. This can be seen when using Ohms Law (E=IxR). As the resistance (R) goes up for a given current (I) the Voltage will be larger (E).

Additionally, square wave outputs like that of PWM contain all frequencies. This includes frequencies in the radio frequency (RF) range. These higher frequencies can "jump energy through the air" causing what is called Common Mode Currents that travel through the armature – through the bearings – and to ground. When going through the bearings this current causes miniature arcing that etches the balls and the bearing raceway. This is called fluting. Figure 5 shows a picture of this process. It is only a short time before the bearings are damaged to the point of failure when this is occurring.



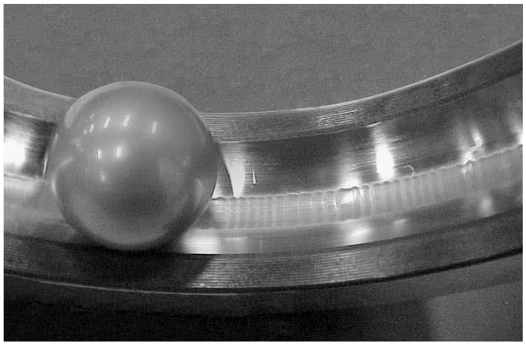


Figure 5

Motor Side Harmonic Mitigation Techniques

There are various types of filters designed to mitigate motor side harmonics. Each filter design will have a specific mitigation affect. To follow are various filter designs, from lowest cost to highest cost, and their typical mitigation effectiveness.

- Motor Side Reactor – This item is much like the Line Side Reactor, working the same way. It is the lowest cost solution and provides minimal protection against motor side harmonics.
- dv/dt Filter – This is the most common used motor side mitigation filter. It uses series of inductors, capacitors, and resistors to develop a low pass filter. PumpSmart offers this filter type in ePrism in a NEMA 1 format. NEMA 3R is available by contacting M&C for pricing and delivery.
- The most aggressive form of motor side mitigation is the use of a Sine Filter. This design uses active technology whereby the result is a near perfect sine wave output for both the voltage and current. It would stand to reason that this is also the most costly solution.

When Should You Use Motor Side Mitigation?

There are a few general rules to when you should apply motor side mitigation. These are suggested with the use of a dv/dt filter in mind.

- Whenever the intended use motor is not inverter duty rated.
- VSD mains voltage of 208-240vac – no need in most cases to use a filter is required. An exception to this might be if the motor is not inverter rated. In this case you should consider using a dv/dt filter.
- Mains voltage 380-500Vac – Suggest using a dv/dt filter if [1]the motor lead length is greater than 300 meters or, [2]if the motor is not inverter rated.
- Mains voltage is above 500Vac – Always use a dv/dt filter. Remember, the output harmonics can be 2x the DC bus voltage. For a 575Vac drive this can be 1725 volts!
- If the application is using a submersible pump it is suggested a dv/dt filter be used. These pumps often do not withstand the harmonics of a VSD without using a filter.
- If the application is in a hazardous location it is suggested you use a dv/dt filter. This reduces extraneous energies that might be turned into heat high enough to cause ignition.

PumpSmart Used With Generators

Occasionally PumpSmart is required to run from a mains source that is a generator. Because VSDs are non-linear devices that generate a fair amount of harmonics, these harmonics tend to play havoc with the regulators used in generators. If the VSD has no form of harmonic mitigation then it is suggested that the generator be sized twice that of the non-linear load (all VSDs on the generator). If harmonics are reduced to about 5% or less the generator may be sized to about 1.5 that of the non-linear loads.

Be aware that when automatically switching from a power company mains source to a generator mains source there may be a delay in the process. This delay may likely cause the VSD to trip on a loss of power. PumpSmart can be set up to automatically try to recover from a loss of power event. See the PS220 IOM for detail on how to implement this feature.

Derating PumpSmart

PumpSmart is identified and rated for use as what is referred to as Normal Duty, and sometimes referred to as Light Overload. What this means is that it may provide up to its base current continuously, with a 110% overload for one minute out of every five minutes. That is to say you may use 110% of the base current for one minute then let it cool down (by running at or below base current) for the next four minutes. If your application might run higher than 110% for short periods of time then contact the M&C Group for advice on what size drive should be used. They can provide the correct current rating for a VSD when sized for Heavy Duty use (150% for 1/5 minutes).

Altitude Derate

PumpSmart also is rated for a maximum elevation of 1000 meters (3,281 feet). It may be used in applications higher than this, up to a maximum of 4000 meters if properly derated. Derating is against the drives base current rating not horse power rating. The derate is 1% for every 100 meters (328 feet) above 1000 meters. Example; if a drive is rated for 96 amps and the elevation is 1500 meters then the derate is 5% (1500M-1000M=500M, 500M/100M=5%). This same VSD is now rated for 91.2 amps (.95x96mps). At this point you must confirm that the derated current value will meet or exceed the motor's Full Load Amp requirement (FLA).

Temperature Derate

PumpSmart is rated for an ambient temperature between -15°C and 40°C (5-104°F). It may be used in applications as high as 55°C (131°F) if properly derated. Like that for altitude derating you must derate the VSD's base current rating, not its HP rating. The derating is 1% for every degree C above 40°C. Example; if a drive is rated for 96 amps and the maximum ambient temperature is 45°C (113°F) then the drive's new current rating is 91.2 amps. (45°C-40°C=5°C, 1%/°C=5% derate). At this point you must confirm that the derated current will meet or exceed the motor's Full Load Amp requirement (FLA).

Compound Derating

Compound derating is not necessary. For example, if the same 96 amp rated VSD is to be used in an application at 1500 meters where the temperature could get up to 45°C then the derated VSD current will be 91.2 amps. You do not need to add the 5% derate for temperature to the 5% derate for altitude coming up with a total derate of 10%. If a derating is required for altitude and for temperature take the largest derate for use.

PumpSmart PS20 Load Monitor

Introduction

The PS20 PumpSmart Load Monitor is a device designed to be used for centrifugal pump protection against dry run, minimum flow, and run out conditions. It is used in fixed speed applications only where the pump is running at its rated speed. Note: the PS20 cannot be used in variable speed applications.

The PS20 can be used in single phase or three phase applications. Voltage groups include 100-240VAc, 380-500VAc, and 525-600Vac. The monitor may be mounted using any of the following methods, MCC Bucket, DIN rail, or Panel Mount. See Figure 2.

When ordering only one part number is required to get the PS20 monitor and its associated CT. You must know the motor voltage and full load amp requirement to order. The PS20 is available through ePrism on the Basic Features tab of PumpSmart.

How It Works

The PS20 monitors the power being used by the pump motor. When physically mounted, one of the motor's three phase leads is run through a current transformer (CT). See Figure 1. This phase is monitored and the PS20 calculates the motor's power from this lead. The user sets the PS20 up using the units display and keys. No PC is required. The PS20 can trip the pump motor's contactor based on exceeding a power high limit, low limit, or both. Once tripped the unit can be set up to auto reset or require operator intervention to restart the pump motor.

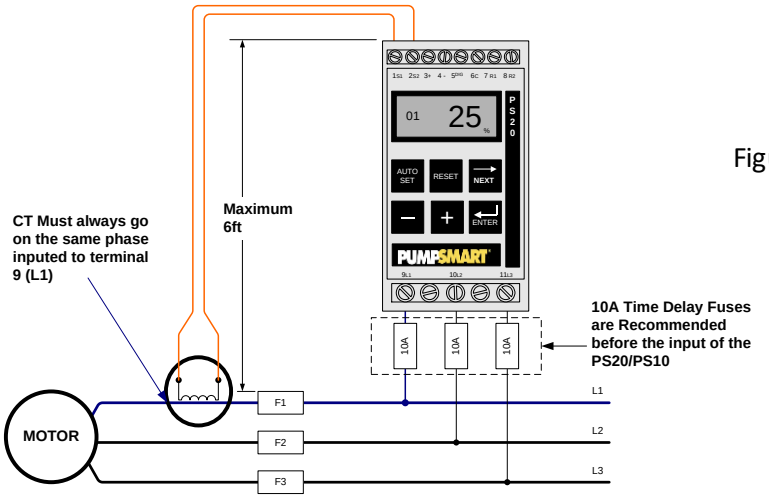
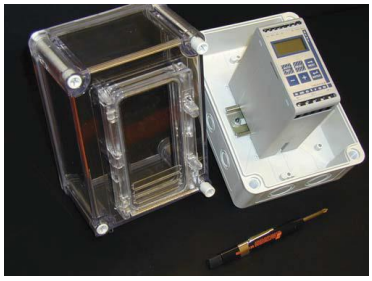


Figure 1

PS20 Mounting Options

Figure 2

Panel Mount Kit
Part#: A08181A02



NEMA 4X Kit
Part#: A08181A01

MCC Mounting Kit
Part#: A08181A03

Process Control

PumpSmart offers PID process control as one of its two primary control types, the other being speed control. PID Process Control is the process of setting a reference, or set-point (example: desired pressure) and permitting PumpSmart to automatically vary the speed of the pump to maintain this set-point value under varying demand conditions. This process is called PID control, where **P** stands for Proportional, **I** stands for Integral, and **D** stands for Derivative. We often interchange the terms Proportional with Gain. In reality gain is the inverse of proportional. In the PumpSmart world, like with most other VSD manufacturers we use the term gain in place of proportional. One last point about PID, and that is that in the pump world we rarely if ever use (adjust) Derivative. From this point forward we will refer only to Gain and Integral adjustments.

How Does PID Work?

Figure 1 illustrates a block diagram of how PumpSmart conducts PID control.

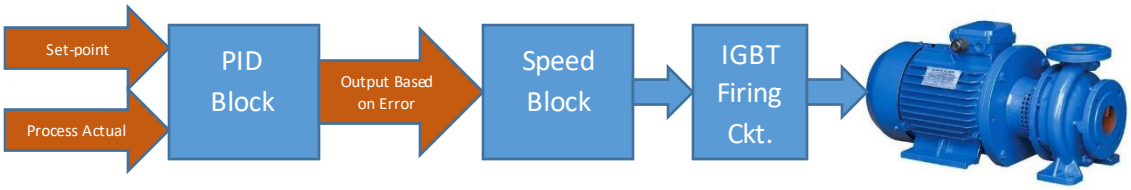


Figure 1

The PID block receives a user set-point value from either the VSD keypad, analog input, or from serial communications. It also receives the process actual value, typically from a remotely mounted process transmitter. The PID block compares these two signals and outputs a value based on the error between these two inputs. This output signal from the PID block becomes the input (or reference) to the Speed block which in turn uses proprietary internal algorithms to determine the actual speed and torque of the motor. No external speed or torque transmitters are required. In turn, the Speed block sends a signal to the IGBT Firing circuit which sequentially energizes each of the motor's three phases to run the motor at the proper speed and torque in order to eventually eliminate any error (difference between the set-point and the process feedback).

PID Tuning

A system's response to changing demand conditions will be based on PID tuning, that is, the values of Gain and Integral. This section provides a basic understanding of how Gain and Integral interact and what might be considered best practices for PI tuning. The method of explaining here will be fairly black and white. There are several PID algorithms used in industry, each having a variation on the performance of the PID result. It is well beyond the scope of this document to detail exactly how a particular algorithm works.

In its simplest explanation gain is multiplied times the error and this result is the change in output. Example, if the error is 5 percent and the Gain value is 0.5 then the change in output will be 2.5%. However, if the Gain step was executed only once then this 2.5% change in output may get closer to eliminating the error between the set-point and process actual, but there would likely still be some error that would remain. This is where Integral comes into the picture. Integral repeats the Gain step in an effort to fully eliminate the error. The units of measurement in the PS220 for Integral is seconds. In effect, the Integral integrates the gain step again over the number of seconds entered for an Integral

value. If the Integral value was 2 seconds then the next gain step will be integrated over the next two seconds. Each time this integral step happens the error should become smaller and thereby the output change will also be smaller. Eventually the error will essentially be zero and we have reached steady state.

People often ask; "What are the correct Gain and Integral values to use?" Every application will have a best set of values. There is no one set of values that cover all applications. PumpSmart will preload Gain and Integral values based on the type of PID process control selected (pressure, flow, level, temperature) during the Process Control wizard setup. These are typically good starting values but may well need adjustment to get to an optimum response.

A good tune is what is called *quarter wave decay*. That is, the maximum peak of each cycle is one quarter the size of the last cycle. Typically, when using this concept, you reach steady state within three cycles. See Figure 2.

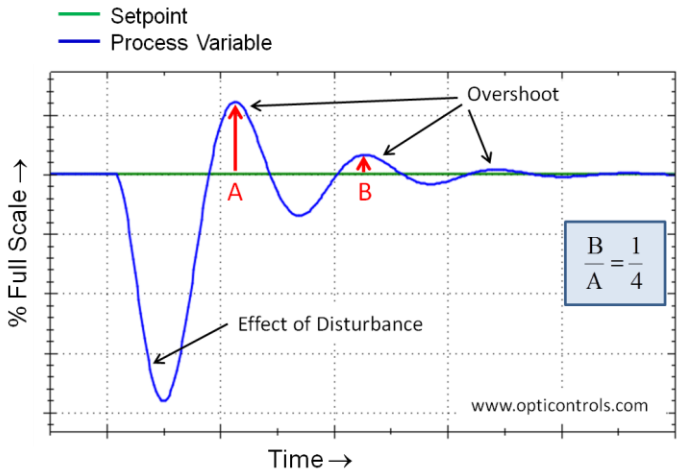


Figure 2

Also realize that when tuning we must tune for both *steady state* and *upset* conditions. A steady state condition is defined as where the process seems to be running along with few swings about the set-point. An upset condition is where there is an all of a sudden major change in demand and the system must recover as quickly as possible without going out of control. When tuning it is advisable to check and tune the systems response under both conditions. You can simulate an upset condition by turning off the pump and then starting it again.

Basic Rules of Tuning

As stated above there is no single set of Gain and Integral values that will cover all applications. What follows is a set of basic rules to help tune an application.

- Change only one item at a time, either Gain or Integral. Do not make a change to the Gain and the Integral at the same time. Once a change is made watch for the response. While it likely did not get where you need to be, did it get you closer to where you need to be? There is no rule as to which element you change first and by how much.
- Once changing one element appears to not help any longer, or may start to cause instability, look at the other with the same process of adjustment to see if it helps.

- Remember, increasing the Gain causes the output to swing greater. Decreasing causes the output to swing less.
- Increasing the Integral causes the output to take longer to respond while decreasing the Integral causes it to respond quicker.

PID Pressure Control

We refer to controlling pressure as a *constant pressure* application. That is to say that regardless to a varying flow demand or system curve PumpSmart will vary the pump speed to maintain the pressure at a desired set-point value. Figure 3 shows a system operational curve demonstrating this.

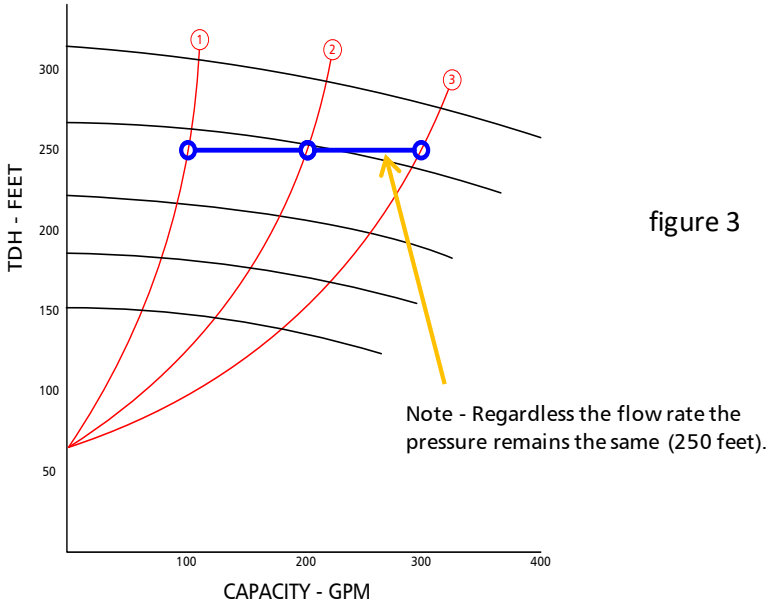


figure 3

Constant pressure systems make up the majority of PumpSmart PID applications. In this type of system an external pressure transmitter is required to measure the actual system pressure. Typically the transmitter is of a 2-wire design where transmitter power and signal are on the same pair of wires. In this case 4 milliamps (mA) equals minimum measured pressure and 20 milliamps equals maximum measured pressure. A transmitter ranged for 100PSI will regulate the current (4-20mA) between a process pressure of 0PSI and 100PSI. See the PS220 IOM for detail on how to wire a pressure transmitter to the VSD and how to set up pressure PID control.

Pressure transmitters come in a variety of types. We will look at just a few technologies here. The reader is encouraged to research further for detail on various pressure technologies if desired.

Rosemount 2088 Gage or Absolute Transmitter

- Gage/Absolute/Vacuum/Differential Transmitters – This was perhaps the first level measurement transmitter technology. Every pressure transmitter is by nature a differential pressure transmitter. That is to say the high side, or leg, measures pressure in reference to the other side (low side). With a gage pressure transmitter connection is made to the high side and the low side is typically vented to atmosphere. This vent can be very small making it difficult to tell the difference between a gage and absolute transmitter by just looking at them. By doing this the transmitter is truly measuring the pressure at its high side relative to its local atmospheric pressure. Absolute and vacuum transmitters have a full vacuum drawn on the low side and then this low side is sealed. In this case the high side is measuring in reference to an absolute vacuum. The difference between a vacuum and absolute transmitter is only how they are calibrated. Finally, differential pressure transmitters require the user to connect both the high and low side legs to the process. In this way if the reference is changing it is automatically subtracted from the high side leg. An example of this is measuring level in a pressurized tank.

Foxboro Direct Connect Differential Pressure Transmitter, Model IDP10

- Transmitter electronics are typically good for temperature up to about 100°C. In some applications the process fluid may be too hot to permit direct connection of a transmitter due to this temperature limitation, or may require that the user make a process connection away from the transmitter. In these applications process connection tubing can be used to run between the transmitter which is remotely mounted and the hot process, permitting the process to cool some before touching the transmitter. Another way to manage this is to purchase the transmitter with *remote seals*. These systems have higher temperature fluids in the capillary between the remote seal and the transmitter itself. Transmitters can be purchased with one or two seals and with various lengths of capillary length.

ABB Absolute Pressure Transmitter with Remote Seal

- Low cost transmitter solutions are available as well. These are typically all direct mount (no offering of a remote seal) and tend to have a lower temperature rating (max 90°C). For most water applications these transmitters provide a good low cost solution to measuring pressure, either gage pressure or absolute.

Low cost IFM Effector PT2434 Pressure Transmitter

All of the transmitters shown here are of the 2-wire design. The 24Vdc to power the transmitter is carried down the same pair of wires that the 4-20mA signal is.

PID Flow Control

Constant Flow applications are ones that regardless to changing system pressures or NPSHa values, PumpSmart will vary the pump speed to maintain a specific flow rate. See figure 4 for a system operational curve of a constant flow application. This curve might be typical for a tank car unloading application where as a tanker car is pumped down the NPSHa will become less while the holding tank head will become greater. Under these changing NPSHa and head conditions PumpSmart will maintain a constant flow rate, whether the flow actual signal comes from an external flow meter or from SmartFlow.

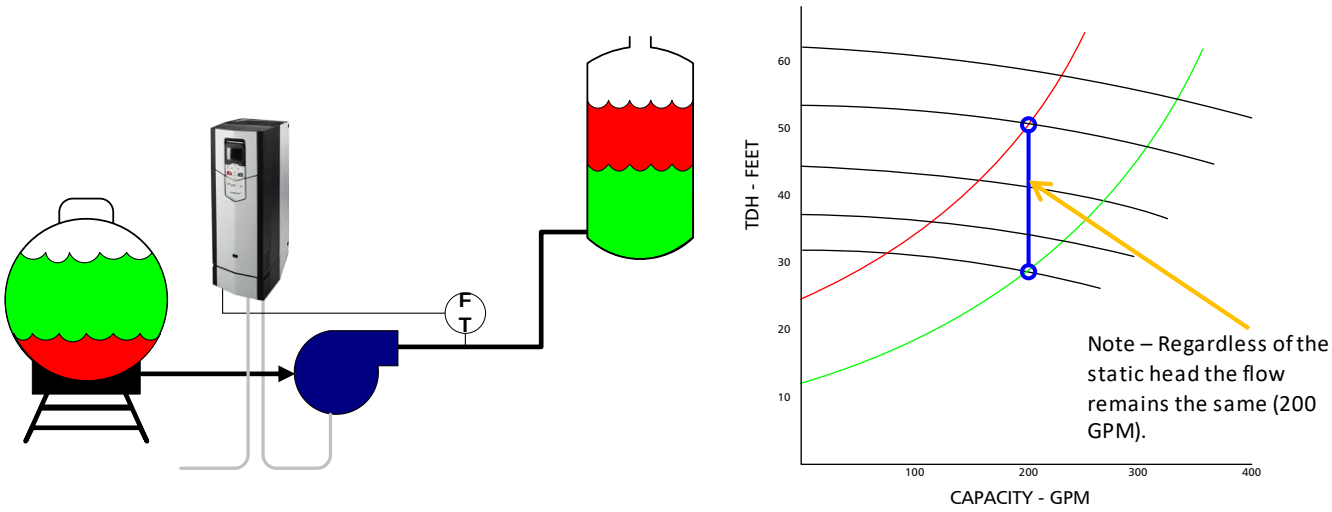


figure 4

Flow applications often use an external flow transmitter. There are many types of flow transmitters, some of which use *2-wire* feedback and others use *non 2-wire* feedback, sometimes referred to *as 4-wire* feedback. Selecting one type of flow measurement technology over another is based on several factors including but not limited to; process temperature, degree of accuracy required, dynamically changing specific gravity or viscosity values, pipe diameter, connection type, etc.

Flow Measurement Technologies

Most common technologies used today for flow measurement include magnetic meters, coriollis meters, and differential flow meters. It is beyond the scope of this document to provide a side-by-side comparison of each flow measurement technology. Only a general cite of information is provided here. Use the Internet to find additional detail on each technology.

- Coriolis Meter – Coriolis flow measurement is pure mass flow measurement. There is no need to correct for changing viscosity or specific gravity. They tend to be the most accurate flow meter available today. Additional information like process fluid temperature and density is available from a Coriolis meter. If your pump is pumping different fluids then a Coriolis meter might be the right meter for you. This technology is typically a non 2-wire signal.

Endres & Hauser Proline Promass F 100 Coriolis Flow Meter

- Magnetic Flow Meter – Magnetic flowmeters use Faraday's Law of Electromagnetic Induction to determine the flow of liquid in a pipe. They represent about 23% of the flow meters used today and are good in applications that require less than perfect accuracy. Therefore they are typically not used in custody transfer applications. The process fluid must be conductive. Because they produce a signal linear with flow they will achieve a turndown of 20:1 or better. This technology is typically a non 2-wire signal.

EMERSON Magnetic Flow Meter

- Several different types of differential flow meters exist. These technologies tend to be on the lower cost side of flow measurement. In all cases there is an element that obstructs the process flow, causing a differential pressure across this obstruction. A differential pressure transmitter is used to measure this pressure difference. Flow is equal to the square of this signal, therefore square root extraction must be applied to the signal to get the actual linear flow. Be aware that PumpSmart does not provide square root extraction on its analog inputs so this must be done in the differential pressure transmitter itself. This should not be an issue as most smart differential transmitters provide this function when turned on. A few of the differential measurement devices include wedge and orifice plate.

  Wedge - The wedge technology has been around for several decades and was first developed and perfected by Taylor Instrument Co. (now ABB Kent Taylor). It consists of a pipe that has a wedge shape obstruction welded in place between two measurement taps. The wedge is sized based on the process fluid type, SG, and viscosity and desired differential pressures. This makes the wedge specific to an application. Changing the process material will likely require changing the wedge element itself which is not practical. Applications include processes that are dirty, viscous, hot, clean, abrasive, or if it tends to foul. A differential pressure transmitter is placed across the wedge to measure the pressure developed by the obstruction. As mentioned above, flow is the square of this differential pressure and must have a square root extraction applied to get the actual linear flow rate. Two-wire transmitters are used for measurement.

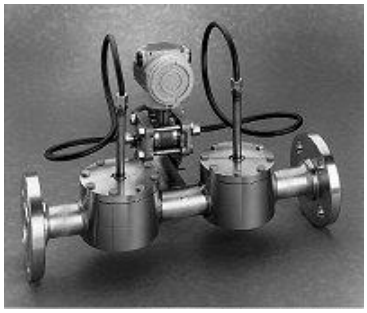
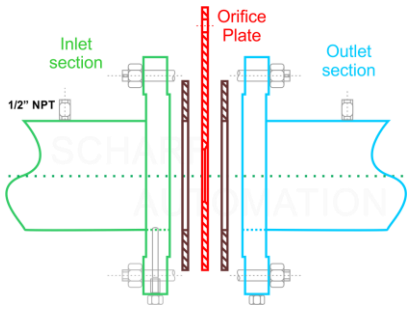


ABB Kent Taylor Wedge Flow Meter

  Orifice Plate - Orifice plate technology is another lower cost flow technology that has also been around for a long time as well. Applications best served using an orifice plate technology include single phase gaseous or clean liquids, where the flow is smooth (not pulsating), and where the pipe is full. Like that of the wedge design an obstruction is placed in the pipe to create a differential pressure that is the square of the flow rate. A differential 2-wire pressure transmitter is used to measure this pressure difference.



While several flow technologies exist, ePrism offers only magnetic flow meters manufactured by two respected names, Rosemount and Foxboro. If a different technology is required, or if your customer specifies a specific manufacturer other than the two mentioned here please contact the M&C team for pricing. Remember, you will need to provide process fluid type and temperature, degree of accuracy required, dynamically changing specific gravity or viscosity values, pipe diameter, connection type, etc.

PID SmartFlow Control

SmartFlow Control is another form of constant flow control. It works just like the flow description above, with one difference. SmartFlow Control does not require an external flow meter as it uses PumpSmart' s internal sensorless flow calculation capabilities to provide a flow actual signal. Refer to the section entitled *Version 6 Feature Detail* to learn more about SmartFlow.

PID Level Control

Constant level PID control is the process of PumpSmart varying the pump speed to maintain a desired level set-point. Typical applications include tank farms, sewage lift stations, and various sump systems. Figure 5 shows a suction side sump system where on the left side we have varying inflow. PumpSmart is to maintain the sump level regardless to the rate of inflow. As this flowrate increases PumpSmart will increase the speed of the pump, and slow the pump down when the sump level is lower than set-point. Looking at the system operational curve for a constant level control system we see that the discharge flow rate and head varies based on the inflow flow rate and how responsive the pump is at matching this inflow.

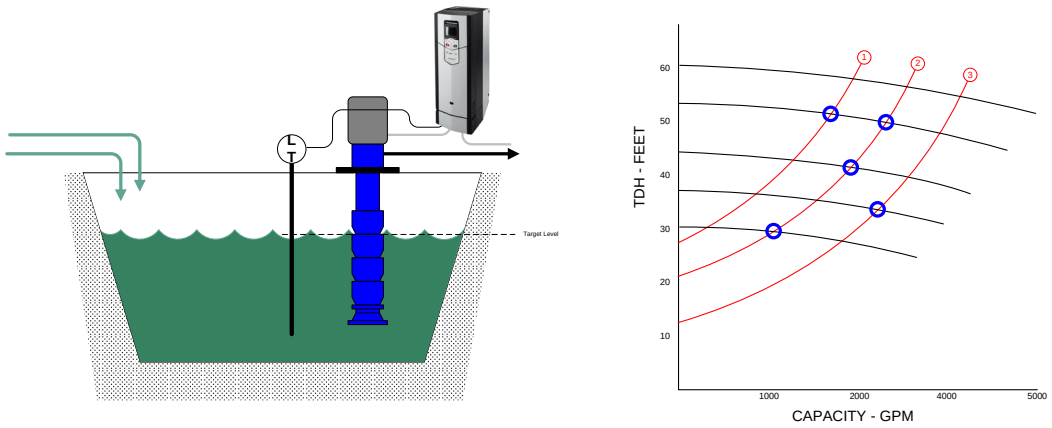


figure 5

Level Measurement Technologies

Level applications require the use of an external level transmitter. Like that of flow, there are many different types of level measurement technologies including pressure transmitter, submersible pressure, ultrasonic, and radar just to name a few.

- External Pressure Transmitter – Pressure transmitters are covered under the *PID Pressure Control* section of this document. The primary difference between standard pressure transmitters described earlier and that of a level pressure transmitter is that while standard

pressure transmitters typically measure in PSI, BAR, etc., level pressure transmitters are often calibrated in inches H_2O or inches Hg (mercury). Example, 100"H_2O is equal to 8.33 feet of water.

When ordering a level transmitter you will need to know the process temperature, highest level in the vessel, and specific gravity. Most transmitters are calibrated to water at 70 degrees F. Pressure transmitters used in level applications require the SG to remain constant. If your SG is different you will need to get the transmitter calibrated accordingly.

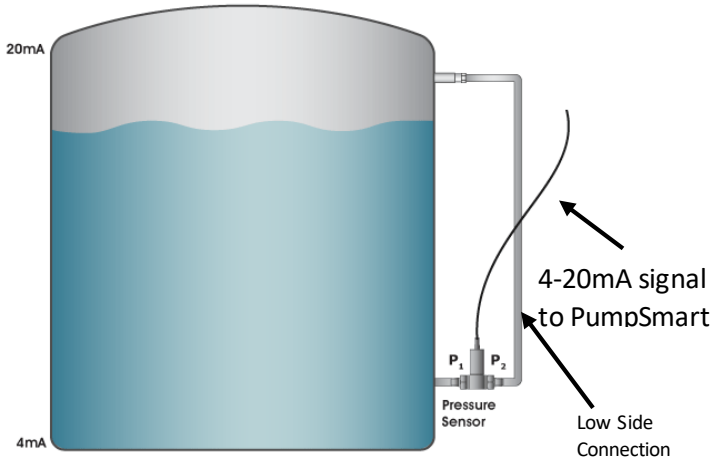


figure 6

Figure 6 shows a closed tank with an external level transmitter. The low side connection offsets any tank pressure from the actual water height. If the tank were open to atmosphere then there would be no need for a low side connection to the top of the tank.

- Submersible Pressure Transmitters - Submersible level transmitters, like the above externally mounted pressure transmitter, measure the weight of the fluid. The difference is that this transmitter is located in the fluid to be measured (figure 7). These transmitters must be used in open tanks. Submersible level transmitters are ordered with its signal cable already connected to the transmitter, and with a length that must be long enough to locate the end of the signal cable outside the fluid. This signal cable will also contain a low side (reference) vent tube. The vent tube must be open to atmosphere in such a way that it cannot be plugged by dirt or insects.

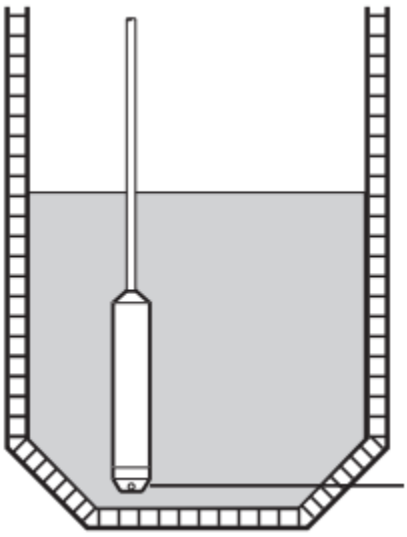


figure 7

IFM Effector PS3208 Submersible Level Transmitter

ePrism offers the IFM Effector submersible transmitter in several spans, and includes several options for mounting the transmitter.

- Ultrasonic Level Transmitter – Ultrasonic transmitters are located above the process fluid and shoots an ultrasonic signal at the fluid. The length of time it takes for the signal to get to the process and return to the transmitter is measured and represents the distance between the two. The transmitter can be set up so that it reports the distance between the transmitter and the fluid, or if it knows the distance to the bottom of the tank it can report the process level relative to the bottom of the tank.

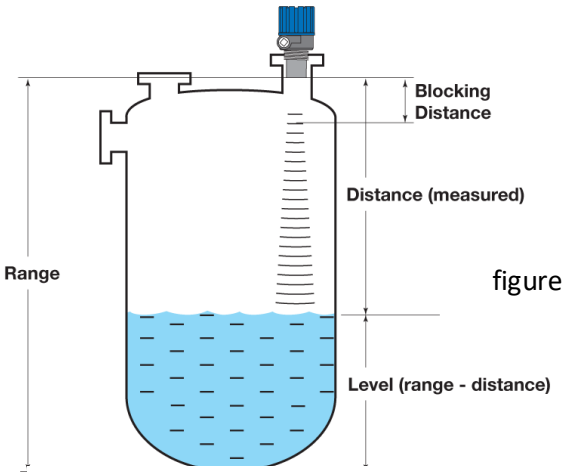


Diagram by Magnetrol

figure 8

Ultrasonic Level transmitters (figure 8) are considered a non-contact measurement device as the transmitter does not touch the process fluid. They are not affected by color or transparency of the fluid, can be used in a dark environment, and are not highly affected by dust, dirt or high moisture environments. Limitations of this technology include; they cannot be used in a vacuum or under water. Soft fluids or 10-15 degree temperature changes of the fluid will affect the accuracy. Finally, they typically range out at about 10 meters. Ultrasonic transmitters are relatively low cost compared to radar. While ultrasonic transmitters are not available through ePrism, you may contact ITT M&C for pricing and delivery.

- Radar Level Transmitters – Radar level transmitters use a radio wave technology to measure the fluid distance, and may or may not be a non-contact technology. While radar itself is non-

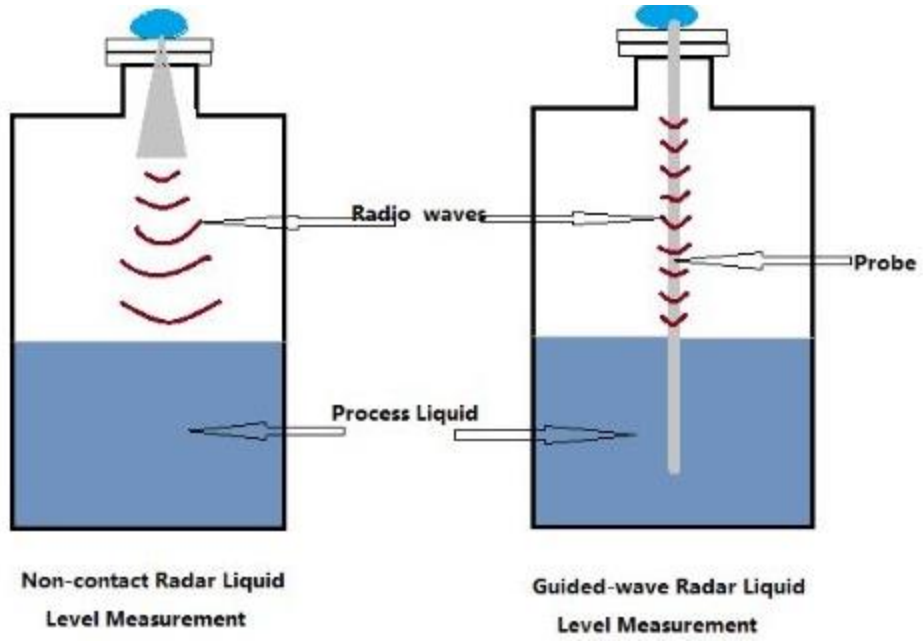


figure 9

contact, guided wave radar rides a rod that does come in contact with the process fluid. See figure 9.

Radar is more accurate than ultrasonic measurement. Other pros for radar measurement include accurate readings that are independent of dielectric constants, densities and conductiveness of the process fluid. This means that changing from one process fluid to another does not require recalibrating the transmitter. This technology is good for processes with high temperatures, high pressures, fine powders, or sticky fluids. Like the ultrasonic transmitter, radar transmitters are typically located above the process fluid, making mounting relatively easy. Perhaps the biggest con towards using radar level measurement is if the process develops foam or a mist above the fluid. Turbulent surfaces may confuse readings as well.

Rosemount Model 5400 Radar Level Transmitter
Diagram by AutomationForum.co

Radar transmitters are not available through ePrism. Please contact ITT M&C for pricing and delivery.

PID Temperature Control

The two most common methods for measuring temperature include a Resistive Thermal Device (RTD) and Thermocouple. Of these two, RTDs are most commonly used because they are more rugged and do not require junction compensation like that of a thermocouple.

Both devices are typically mounted in the process using a thermowell. This protects the measuring component from actually touching the process fluid itself. Thermowells are made of a material that is designed to uphold in the measured fluid. When specifying either a thermocouple or RTD that is to be used in a well, the length of the RTD or thermocouple must be such that it physically bottoms out in the well.

Dwyer Instruments Thermowell

The signal from both the RTD and thermocouple probe is not one that can be connected directly into PumpSmart. You must connect the RTD or thermocouple to a transmitter which takes the sensor signal and converts it to a 4-20mA signal, which is then connected to the PS220 VSD. Transmitters also provide linearization, and can be located on the measuring device itself or if the temperature is high enough, would likely be mounted remotely from the measuring device.

Ocean Controls RTD with Integral Transmitter

When ordering either a RTD or thermocouple and associated well you will need to know the process fluid type, temperature range, the depth the well must go into the vessel, and the vessel thread type and size. RTDs and thermocouple are not available through ePrism. Please contact M&C directly for price and delivery.

Serial Communications

What Is Serial Communications?

Note: Before we get started with this subject, we at M&C tend to interchange the term *fieldbus communications* with *serial communications*. However, we must be cautious in that there is a *Fieldbus* serial communications protocol used in the process control industry. So using the term fieldbus communications may confuse your customer if they are aware of this protocol. We will talk more about protocols shortly.

There are two ways to "communicate" with the PS220, via hardwire or serial communications. Hardwire is the process of connecting to the PS220 inputs and outputs (digital and analog). It is limited by the number of input/output connections on the PS220, and by the information each of these points can provide access to within the VSD. Based on the numbers of I/O points you have, anywhere from two to twenty or more wires are connected between the VSD and a host control system. Additionally, each VSD must have its own set of these wires. VSDs cannot be ganged together over common wires to the host.

Serial communications does not use the PS220 I/O connections but rather a separate module that is plugged into slot 2 of the VSD. Depending on the module protocol a single pair of wires are connected to this module from the host control system. Multiple VSDs may be ganged together and connected to a host control system using this same pair of wires. While wiring is typically simpler with serial communications, the real power is that virtually everything in the drive is now accessible.

Protocols

Now, for Protocols. A protocol consists of two concepts, the electrical highway that the data transfers over and the data format, sometimes referred to as a stack. While there are many forms of this electrical highway, the most common electrical highways used today are RS-485 and Ethernet. RS-485 is the older of these two but Ethernet is the fastest, and it is gaining a larger part of the market today. To follow are the protocols available for PumpSmart. These are the most common protocols used in PumpSmart markets. Don't worry about picking a protocol for your customer, as the customer should tell you what protocol they need for their particular system. Be aware that a serial communications module is required for each PS220 VSD. The embedded RS-485 port on the PS220 is for peer-to-peer communications when setting up Multi-pump operations and cannot be used for serial communications to a host device.

What follows is a very high level introduction to each of the protocols used with the PS220. Greater detail on each protocol can be found on the Internet.

Ethernet IP

Ethernet IP is largely used with Allen Bradley Programmable Logic Controllers (PLCs) and many Distributive Control Systems (DCS). This protocol is similar to that connected to your office PC. Its baud rate (how fast it sends bits of information) is anywhere from 10 million bits per second (Mb) to 1giga bit per second (Gb). Several VSDs can be connected to the host using an Ethernet switch or router. An Ethernet IP connection requires either the FENA-11 or FENA-21 module. Figure 1 shows common Ethernet architectures using either the FENA-11 or the FENA-21 module (part numbers K03560A05 (single port), K03560A06 (dual port)).

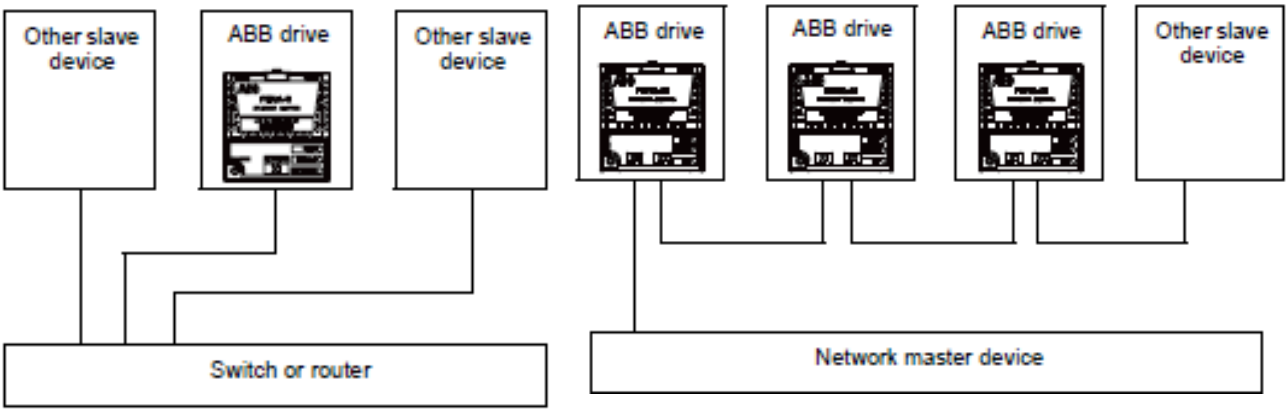


ABB FENA-11

ABB FENA-21

figure 1

DeviceNet

DeviceNet was largely propagated by Allen Bradley (Rockwell Automation) and was their device level communications protocol prior to Ethernet IP taking the lead. This network system is used mainly in the USA and in Asia. It is managed by the independent North American Open DeviceNet Vendors Association (ODVA). The hardware platform uses the RS-485 protocol. Baud rates (data speed) include 125 kbps, 250 kbps and 500 kbps (kbps = kilobytes per second). It includes a main line with separate buses for signal and power (see figure 2), and support of up to 64 network nodes in a single logical network. It supports master/slave as well as peer-

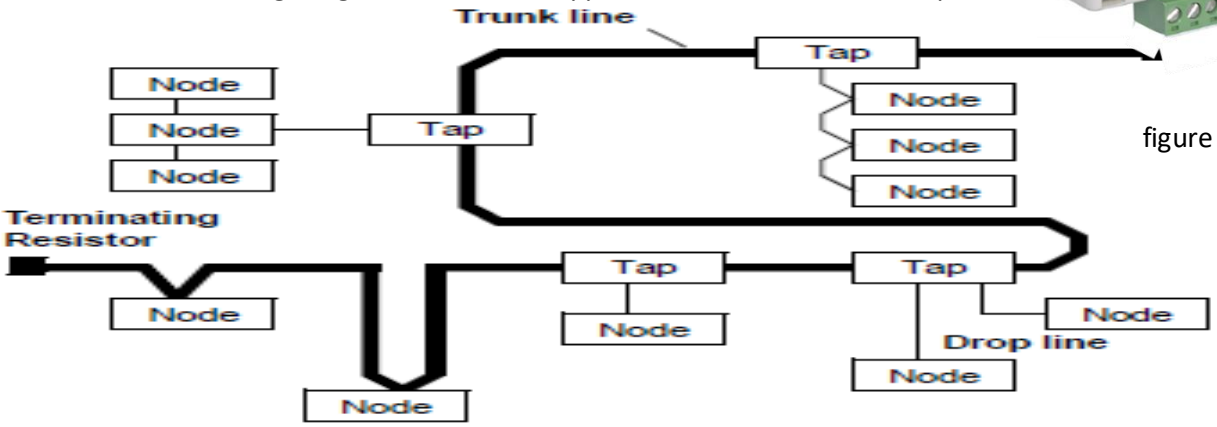


figure 2

to-peer communication, but in most cases the devices are operated in master/slave model. Use the FDNA-01 module (part number K03560A01) on the PS220 for DeviceNet.

ControlNet

Like that of DeviceNet, ControlNet too was developed and promoted by Allen Bradley (Rockwell Automation), and is now managed by the independent North American Open DeviceNet Vendors Association (ODVA). ControlNet cables consist of RG-6 coaxial cable with BNC connectors, though optical fiber is sometimes used for long distances. Maximum cable length without repeaters is 1000m and maximum number of nodes on the bus is 99. However, there is a tradeoff between number of devices on the bus and total cable length. Repeaters can be used to further extend the cable length. The network can support up to 5 repeaters (10 when used for redundant networks). Figure 3 shows a common ControlNet hardware architecture. The PS220 uses the FCNA-01 module (part number K03560A04) to communicate ControlNet.

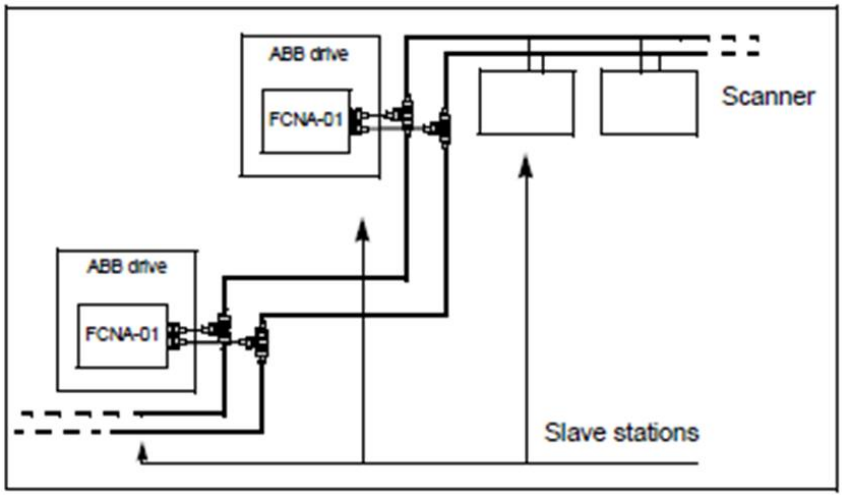


figure 3

PROFIBUS

PROFIBUS was developed in 1989 and is managed by PROFIBUS&PROFINET International (PI) organization. While not developed by Siemens, its growth was largely due to Siemens. Its physical layer is RS-485, with baud rates between 9.6 Kbit/s and 12 Mbit/s depending on the quality of wire and wire length.

There are two variations of PROFIBUS; PROFIBUS DP and PROFIBUS PA. It is the PROFIBUS DP type that is used with the PS220. PROFIBUS DP only allows 31 devices to be connected at once; however, more devices (up to 126) can be connected or the network expanded with the use of hubs or repeaters (4 hubs or repeaters to reach 126). Figure 4 shows a typical PROFIBUS DP physical layer. The PS220 uses the FPBA-01 module (part number K03560A02) to communicate PROFIBUS DP. A GSD file, supplied by M&C, may be required for the host controller.

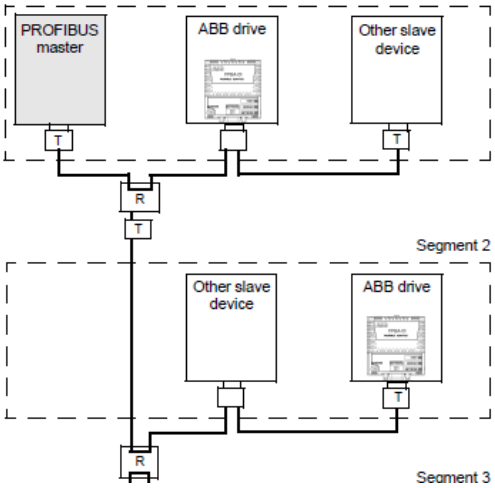


figure 4

PROFINET

PROFINET, like that of PROFIBUS, is managed by PROFIBUS&PROFINET International (PI) organization. It was promoted worldwide by Siemens Automation. The hardware layer is based on Ethernet and has many of the same characteristics of Ethernet as discussed earlier, including its wiring and the use of MAC and IO addresses. Maximum cable lengths of 100 meters between switches. The PS220 uses either the FENA-11 or FENA 21 module (part numbers K03560A05 (single port), K03560A06 (dual port)) to communicate PROFINET. A GSD file, supplied by M&C, may be required for the host controller. See figure 5 for a typical physical layout used in a PROFINET application.

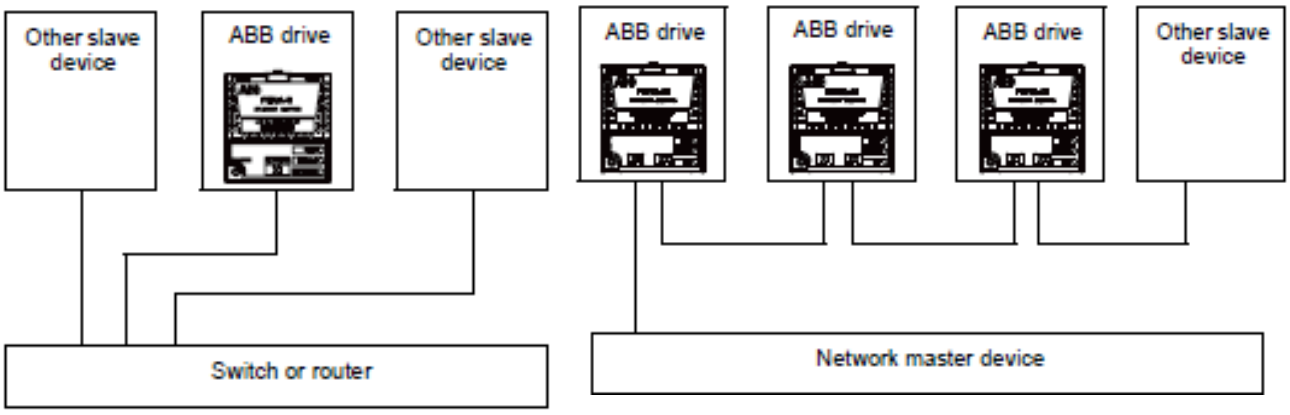


ABB FENA-11

ABB FENA-21

figure 5

MODBUS RTU

MODBUS RTU is one of many variations of MODBUS and was originally developed by Modicon (now Schneider Electric) in 1979 for use on the Modicon Programmable Logic Controller (PLC), MODBUS RTU is perhaps the oldest of the fieldbus protocols used by the PS220. Since 2004 this protocol has been managed by the MODBUS Organization. The physical layer uses RS-485 and requires termination resistors at the ends of the network. MODBUS RTU in the PS220 uses 16 bit registers, where each bit has a specific meaning. Modbus is restricted to addressing 254 devices on one data link. Figure 6 shows a typical physical layout of a MODBUS RTU application. The PS220 uses the FSCA-01 module (part number K03560A03) to communicate MODBUS RTU.

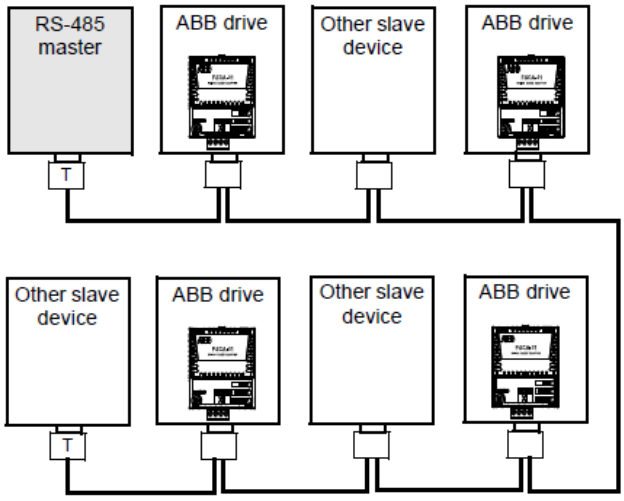


figure 6

MODBUS TCP

MODBUS TCP is an Ethernet based version of MODBUS. Its electrical architecture is Ethernet, and like MODBUS RTU it uses 16 bit registers for communications. The PS220 uses either the FENA-11 or FENA 21 module (part numbers K03560A05 (single port), K03560A06 (dual port)) to communicate MODBUS TCP. Behind Ethernet IP, MODBUS TCP is the largest used protocol with the PS220 VSD. See figure 7 for a typical physical layout used in a MODBUS TCP application.

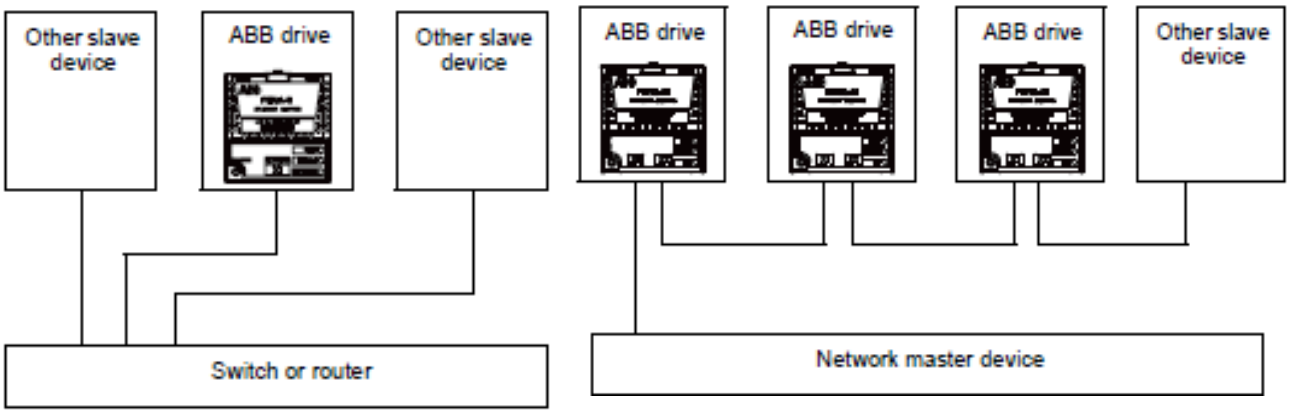


ABB FENA-11

ABB FENA-21

figure 7

PumpSmart Medium Voltage

Basic MV Architecture

PumpSmart was introduced in a Medium Voltage (MV) platform in 2014. MV voltage is defined as 2300Vac to 35,000Vac. However, MV for PumpSmart limits out at 13,000Vac. PumpSmart' s MV architecture is different than its Low Voltage (208Vac – 690Vac) cousin in that where the low voltage (LV) drives have their PumpSmart Intellectual Property embedded into the drive itself, the MV platform places its PumpSmart IP in a Programmable Logic Controller (PLC) which is then physically located in the low voltage bay of the MV drive. This PLC then monitors and controls the MV drive using PumpSmart intelligence.

While PumpSmart LV is based on the ABB ACS880 drive, the PumpSmart MV offering is not fixed to any particular VSD hardware platform. Because the PumpSmart IP lives in a PLC this PLC can be placed into the low voltage bay of any manufacturers MV drive. M&C has MV installations using drives from ABB, Toshiba, Schneider, and more.

PumpSmart MV offers everything found in the LV and more. The PLC permits flexibility in providing not only the traditional pump specific PumpSmart functionality but also any special requirements that the customer may have. The pallet is wide open. Standard features include specialized screens and Advanced Pump Protection capability. Figure 1 shows the Dynamic Curve Generator screen and figure 2 shows a typical operator touch screen.

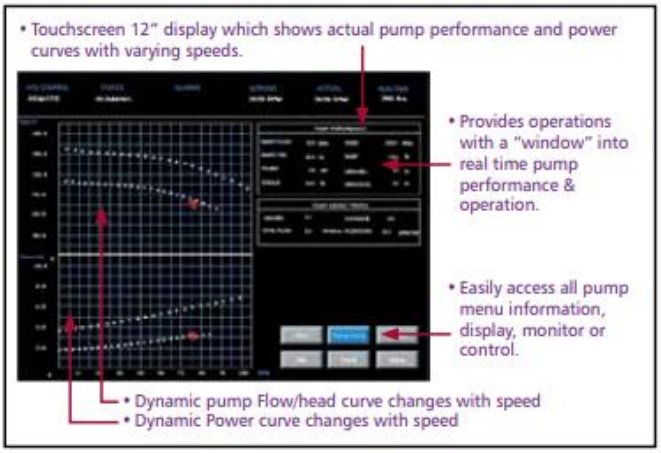


figure 1

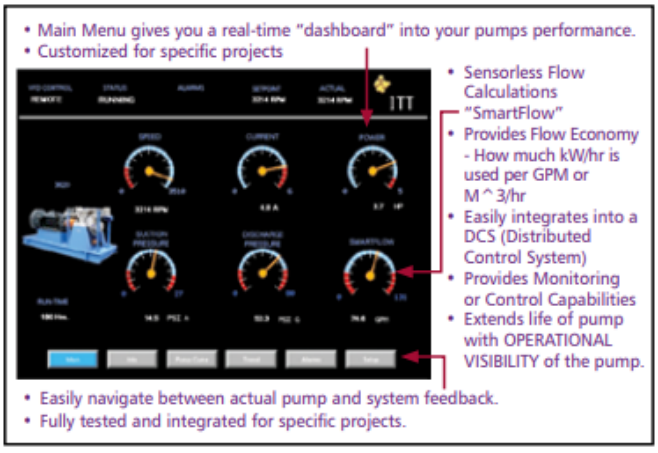


figure 2

PumpSmart MV functionality includes the following features.

- Monitoring
  - Dry run protection
  - Min flow protection
  - Run out protection
- Multi-pump Operation
- Torque Control (Load Balancing)
- Multivariable control

As mentioned above, special customer requirements can also be provided.

When to Use MV Over LV?

Low voltage PumpSmart is available up through 2000HP. However, as the HP increases so does the size of the cables required to bring in mains power, and between the VSD and the motor due to the amount of current that passes through the cable. When a LV drive gets above 200HP (380-500Vac) multiple large cables per phase may be required.

Ohms law (E=IxR) shows us that as the voltage increases the current decreases linearly. Example, a 500HP LV motor generally requires about 723 amps, requiring 2×700 MCM or 3×350 MCM cables per phase. A 500HP, 4160Vac motor requires generally under 70 amps and can be managed with a single #4 wire per phase. These are rough estimations as true cable size takes in to account several considerations including current, length, if run in conduit or free air, and more. Cables between the VSD and motor must be sized to carry the required current.

In general, the customer will tell you they want a MV or LV drive. Experience shows that many companies have a general rule that above 300HP they want a MV VSD.

How to Order PumpSmart MV

ePrism offers access to several MV PumpSmart drives. It is a good place to start for a budgetary quote. If your application requires special considerations or a firm quotation then it is advised to contact your local Monitoring & Control person. M&C personnel are available to meet with your customer to help in the sales process as well.

When quoting a MV system it is mandatory that commissioning services be quoted as well. Commissioning a MV system generally requires personnel from the VSD manufacturer and from ITT.

Field Services

Monitoring & Control offers field services for commissioning, troubleshooting and training. The last page of this section provides detail on costs for these services. Costs are generally per day and must be calculated to include travel time and expenses as well.

Services Offered

Commissioning

Commissioning of a PumpSmart system that is conducted by a certified PumpSmart technician can provide a 36 month from date of shipment warranty on the pump and on the PumpSmart VSD (see section on PumpSmart Warranty). This service includes verifying the physical installation of the VSD, confirming wire connections, programming the VSD, enabling Advance Pump Protection where possible, and running it to customer expectations. When complete the technician will provide a copy of the parameters in the VSD. Quoting commissioning services can be done through ePrism.

M&C commissioning is quoted per the Field Services rate sheet. When quoting be sure to count not only the expected days on site but travel as well, typically 1 day each way. Expenses for travel including flights, hotel, meals, rental cars, and gas are in addition to the hourly rate.

The site must be ready for the service technician when they arrive. This includes having the VSD fully wired for the type of service intended (power, motor connections, control signal connections, and fieldbus if being used). The pump should be flooded and ready for operation. A copy of the pump curve should be provided in advance. If the site is not ready when the technician arrives and additional time is required to commission the VSD then the additional time and expenses will be added to the original quote. See the section on Field Services Rates for service rates.

Troubleshooting

If your customer is having issues with a PumpSmart system then M&C can help. Our technicians have in depth knowledge of PumpSmart operation and can diagnose what might be causing the trouble. See the section on Field Services Rates for service rates.

To secure a PumpSmart certified technician for site troubleshooting contact M&C in Seneca Falls. Be ready to provide detail on the issue, physical address of the site, site contact name and phone number, and what safety equipment is required. If safety training is required to be on site please inform M&C details of this training including how long it should take.

Training

M&C offers PumpSmart training in the form of a certification school. This course is intended for Sales Engineers and Field Engineers/Technicians who will be performing PumpSmart PS220 start-ups. Schools are normally conducted in Seneca Falls, NY, and are held quarterly. To sign up for a PS220 Certification School contact Mary Batson at mary.batson@itt.com. Schools are three days in length, start on a Tuesday, and consist of a series of lectures and hands-on

labs. Class size is limited to between 8 and 12 students so signing up as early as possible is recommended. Students must take tests at the end of the program to become certified. Tests consist of a hands-on section and a written test, for a combined total time of 4 hours or less. Students are permitted to use their student and PS220 IOM manuals during both tests. Certification enables the student to commission PumpSmart low voltage systems, and to extend the VSD warranty from 1 month to 36 months from date of shipment. Additionally, if the application is qualified by Seneca Falls pump management, a certified technician will enable offering a Three Year Reliability Challenge extended warranty (see the section on warranty).

Field site certification schools are available as well. In this case hardware is shipped to a customer's site where the school is to be conducted. Customer is to provide a classroom adequate for the size of the class and lab equipment, PC projector, lunches, and if desired, morning continental breakfast. Class size is typically held to 8 students but may be as large as 12. Like the program held in Seneca Falls students are required to take tests at the end of the program to become certified. Contact M&C in Seneca Falls for pricing and availability.

Typical Course Outline and Schedule

PumpSmart PS220 installation and programming

- Drive installation and wiring
- Programming basic and advanced applications
- Tuning the control system
- Fault diagnosis
- Installation certification

Other session highlights

- Introduction to VFD and process control fundamentals
- Basic electrical safety considerations
- Advanced diagnostic tools
- Effects drives have on power quality

You will participate in hands-on sessions:

- Verify mechanical installation
- Control wiring
- Drive set-up programming

Schedule

Day 1 (Tuesday) -- 8:00 AM - 5:00 PM

- Introduction to ATL vs. variable speed pump control
- Understanding pump and system curves and their relationship
- Drive and Motor Fundamentals (quick review)
  - PS220 hardware overview
- Basic wiring
  - Example control connections
  - Mains and motor connections
- Keypad and display operation
- Basic, Process Control, and Pump Protection wizards
- (2) labs

Day 2 (Wednesday) -- 8:00 AM - 5:00 PM

- SmartFlow
  - Basic & Advance
- SmartFlow lab
- Multi-pump and Multivariable wizards
- PS220 Options & Features
- Lab marathon*
  - Electric
  - Multi-pump
  - Speed control
  - Multivariable
  - Troubleshooting

Day 3 (Thursday) -- 8:00 AM - 5:00 PM

- Water Functions
- Condition monitoring
- Locks, backup, and restore features
- Power quality
- Fieldbus communication (quick review)

Day 3 (Thursday afternoon) – 12:30:00 PM – 4:00 PM

- Certification exams

*This schedule is subject to changes based on program developments.

Field Service Rates

Includes PumpSmart ®, ProSmart ®, iAlert ® products, training, service, commissioning or startup related services as needed for successful implementation of any of the Monitoring and Control products globally where applicable. Additional charges/expense may apply in certain regions and areas of the global coverage of ITT. Hazardous regions, regions under conflict, war or countries on embargoed list may not be available for service(s) performed by ITT and is subject to current corporate laws, restrictions as outlined by ITT or governments. It is required that ITT personnel verify subject country, state; region is approved for authorized product startup, commissioning, service or training.

1. SUPERVISION OF INSPECTION, START -UP, FIELD TESTING AND/OR PROGRAMMING SERVICE FOR DOMESTIC ORDERS

1.1. The equipment shall be installed and put into operation by and at the expense of the Purchaser. Upon request of the Purchaser, the ITT Monitoring & Control group will furnish the services of a Field Service Engineer or qualified Technician to advise and assist the Purchaser/owner/operator in the inspection and/or startup of the machinery. The Purchaser shall furnish safe and proper working conditions and safe storage of any special tools. The Purchaser shall furnish all necessary labor, cranes, cribbing; oil, supplies, station operating force, steam, electricity, extensions, water, and other material and supplies required to install and operate the equipment to desired load and shall furnish free available crane and switching service and the service of operators and other employees that may be deemed necessary for full load pump testing and operation.

1.2. ITT Monitoring & Controls shall not be responsible for material furnished by the Purchaser or for acts, or failures to act, site delays out of control of M&C, personnel furnished by Purchaser nor shall Goulds Pumps be responsible for the construction of foundations or for the soil conditions upon which

they are built. Goulds Pumps provides no warranties, either expressed or implied, in construction with this service.

1.3. Additional outside of scope technical support by site shall be (if necessary) by owner and site responsibility. Outside of scope changes or additions shall be billed according to charges below by ITT M&C and/or with outside contracted ITT companies as necessary and proposed in writing.

1.4. Unless otherwise stipulated or agree upon in writing, the Purchaser shall pay for:

1.4.1. At the rate of $1840 per day for each standard (8) eight-hour day worked or spent in travel to and from the job site, plus all travel and living expenses of the Field Service Engineer/Technician from the time of leaving base location until return and all shipping charges and rentals for any special tools and materials as may be required.

1.4.2. Hours worked in excess of the standard eight-hour (8) days, Monday through Friday, and hours worked on Saturday, Sunday and holidays, will be billed in accordance with the following schedule:

Monday through Friday over eight hours…… $345 per hour *

Saturday all hours……$345 per hour *

Sundays and holidays all hours…….. $460 per hour *

* Other countries and regions may have different weekly schedules and can be adjusted based on in country work week and specified weekend.

1.4.3. Overtime rates will be charged for time spent in travel as such if requested by Purchaser.

1.4.4. The rates specified in Items 1.3.1 and 1.3.2 above are not subject to change provided the Engineer/Technician begins to perform these services within one year from the date of proposal.

1.4.5. Minimum billing for less than four hours worked or spent in travel will be 50 percent of the daily rate.

1.4.6. The minimum billing for more than four hours but less than eight hours worked or spent in travel will be the full daily rate.

1.4.7. The time when the Engineer/Technician is ready, willing and able to work at the job site Monday through Friday shall be considered to be time worked for the purpose of this paragraph, even if services are not utilized or site is not ready.

1.4.8. All travel and living expenses will be billed at actual cost-plus a 15% handling charge. Domestic air travel will be via tourist, coach or economy class when available. Travel via company car will be billed at $0.55 per mile.

1.5. When a per diem rate is stipulated in lieu of the rate shown in Paragraph 1.3.1, it will include local travel and living expenses at the jobsite only. Travel expenses between base location and jobsite, and shipping charges and rentals for any special tools and materials will be billed to Purchaser. Overtime charges will be in accordance with Paragraphs 1.3.2 and 1.3.3.

1.6. Invoices rendered to the Purchaser are payable upon receipt of the invoice. Sales or other applicable taxes shall be charged to the Purchaser.

1.7. The Buyer shall be required to contact Field Service (1-800-327-7700 x 7468) two (2) weeks prior to initial start-up of pumps in order to schedule Field Engineer/Technician to the jobsite. If time sheets are required by the customer, they shall be provided by the customer and signed after services are performed by both the customer and Field Engineer/Technician.

1.8. Before initial startup of the equipment a preliminary check of the pump and installation will be conducted by the field Engineer / Technician. Follow the guide lines established in the Attached “Field Service Installation and Startup Checklist”.

1.9. After startup has been successfully completed the field Engineer / Technician will follow-up with a field report of observations / conclusions and recommendations.
2.0 Official owner signoff shall be performed after successful operation of equipment as stated releasing ITT M&C of site requirements. Future returns to the site (including warranty calls) will be billed at same rates as section 1.4.

PumpSmart Warranty

PumpSmart PS220 and PS75 Warranty
WARRANTY (a) Company warrants that on the date of shipment the goods are of the kind and quality described herein and are free of non-conformities in workmanship and material. This warranty does not apply to goods or parts delivered by Company but manufactured by others.
(b) Buyer's exclusive remedy for nonconformity in any item of the goods shall be the repair or the replacement (at Company's option) of the item and any affected part of the goods.
Company's obligation to repair or replace shall be in effect for a period of one (1) year from initial operation of the goods but not more than eighteen (18) months from Company's shipment of the goods, provided Buyer has sent written notice within that period of time to
Company that the goods do not conform to the above warranty. Warranty period can be extended for a period of thirty (30) months from initial operation of goods but not more than thirty-six (36) months from date shipment, if goods are commissioned by a Certified ITT
PumpSmart Field Technician. Extended warranty is valid only when the PumpSmart Warranty Registration Form is completed and registered with the ITT Monitoring and Control group.
Repaired and replacement parts shall be warranted for the remainder of the original period of notification set forth above, but in no event less than 12 months from repair or replacement.
At its sole expense, Buyer shall remove and ship to Company any such nonconforming goods and shall reinstall the repaired or replaced goods or parts. Buyer shall grant Company access to the goods at all reasonable times in order for Company to determine any nonconformity in the goods. Company shall have the right of disposal of items replaced by it. If Company is unable or unwilling to repair or replace, or if repair or replacement does not remedy the nonconformity, Company and Buyer shall negotiate an equitable adjustment in the order price, which may include a full refund of the order price for the nonconforming goods. (c) COMPANY
HEREBY DISCLAIMSALL OTHER WARRANTIES, EXPRESS OR IMPLIED, EXCEPT THAT OF TITLE.
SPECIFICALLY, IT DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR APARTICULAR PURPOSE, COURSE OF DEALING AND USAGE OF TRADE. (d) Buyer and successors of Buyer are limited to the remedies specified in this article and shall have no others for a nonconformity in the goods. Buyer agrees that these remedies provide Buyer and its successors with a minimum adequate remedy and are their exclusive remedies, whether Buyer's or its successors' remedies are based on contract, warranty, tort (including negligence), strict liability, indemnity, or any other legal theory, and whether arising out of warranties, representations, instructions, installations, or non-conformities from any cause. Buyer shall assume all responsibility and expense for removal, reinstallation and freight in connection with these remedies. (e) Company neither assumes, nor authorizes any person to assume for it, any other obligation in connection with the sale of its goods. This warranty shall not apply to any goods that: (1) have been repaired or altered outside of Company's factories or authorized service centers, in any manner; or (2) have been subjected to misuse, negligence or accidents; or (3) have been improperly stored or handled or used in a manner contrary to Company's instructions or recommendations; or (4) have design errors due to inaccurate or incomplete information supplied by Buyer or its agents.