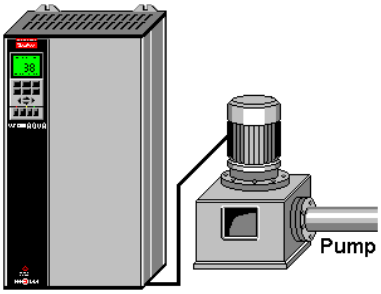
VFD 101 for Water
Lesson 1

Functions of an Variable Frequency Drive (VFD)



This lesson covers the basic functions of a Variable Frequency Drives (VFD) used with pumps.

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Here is the basics outline for this lesson.

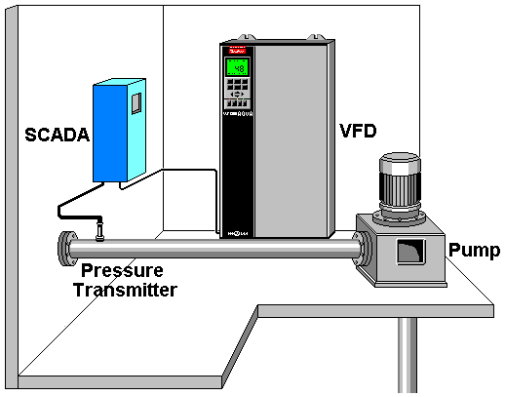
Outline:

Functions of a VFD in pumping

1. Start/Stop
2. Change Speed
3. Constant Speed
4. Limits
5. Ramping
6. Forward/Reverse
7. Save Energy

Note: There are other names for a VFD such as Adjustable Frequency Drive (AFD); Variable Speed Drive; Adjustable Speed Drive; Inverter and Frequency Converter. The name VFD is consistently used through out this lesson.

To understand the functions of a VFD better, an example of a pump is used but the same function apply to aerators and blowers.



What must the pump system do?

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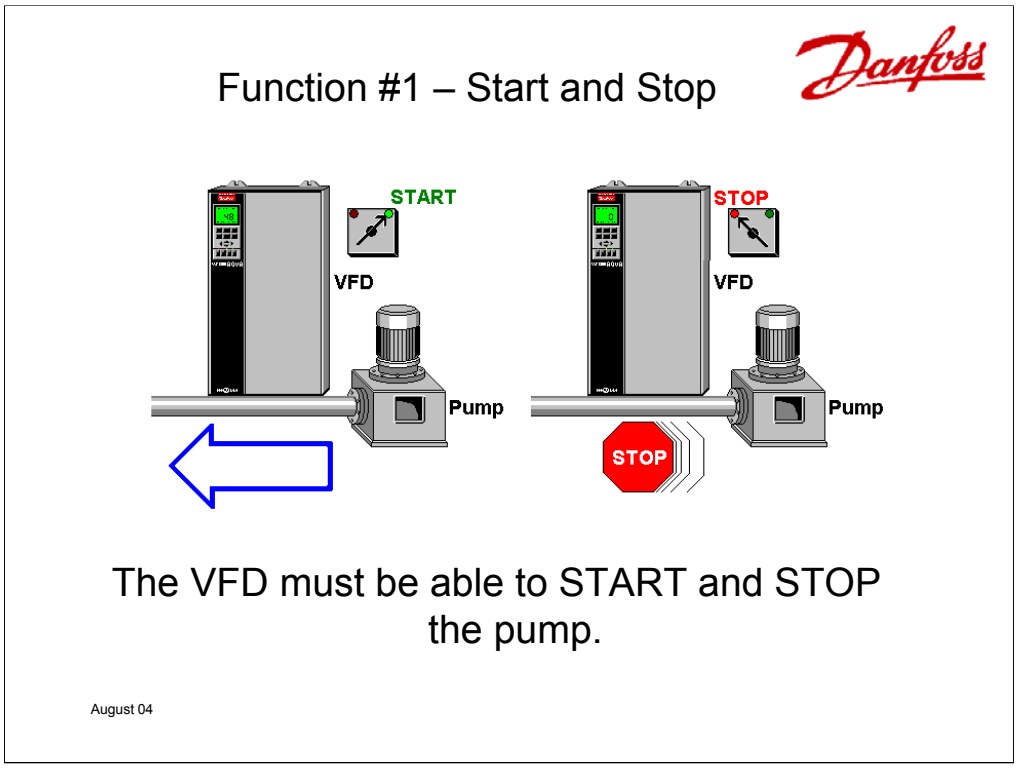
The pump system in the picture above must maintain a certain pressure perhaps 70psi (480kPa). Looking at this example, see if you can identify some of the functions that must be performed by the VFD, AC motor and pump? In other words, what must the pump do? Take a couple of minutes to think about its functions.

The pump must …

_____ _____

_____ _____

A few of the basic functions of a VFD in controlling the AC motor and pump are covered on the pages that follow.



Function #1 Start and Stop

START

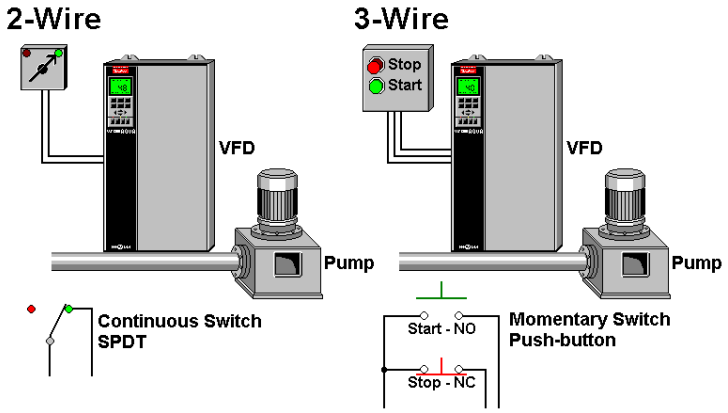
One function of the VFD is to start the pump. This could be done locally through the keypad of the drive or remotely from a switch as shown above. The difference between these 2 control arrangements, local and remote, are covered in the next lesson.

STOP

In the picture above, the same switch is used to stop the pump. If there is only 1 switch to start/stop the VFD it is known as a 2-wire Start/Stop. If there are 2 separate momentary (push button) switches, one to Start and one to Stop, this arrangement is known as a 3-wire Start/Stop.

On the next page 2-wire and 3-wire start/stop arrangements are explained in more detail.

Function #1 – Start and Stop



A 2-wire switch uses a continuous switch

A 3-wire switch uses momentary switches

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2-wire

The picture on the left shows a 2-wire start/stop. The remote switch is a continuous single-pole-double-throw (SPDT) switch. In stays in the ON or OFF position. If the VFD is started with only 1 switch it is a 2-wire.

3-wire

The picture on the right shows the 3-wire start/stop. This is considered as a standard motor starter configuration. Two momentary or push-button switches are used to start and stop the VFD. A normally-open (NO) push-button switch is used to start the VFD. A normally-closed (NC) push-button switch is used to stop it. If the VFD is started with one switch and stopped with another, it is a 3-wire.

Function #2 – Change Speed

The VFD must be able to Change the Reference, Hz.

The Reference could also be PSI if a transmitter were attached to the VFD.

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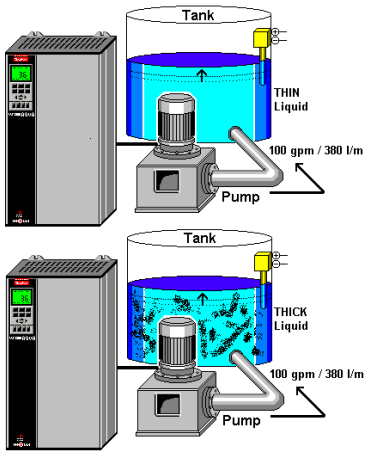
Function #2 Change Speed

The speed of the pump must be variable to allow for a slower speed when there is little demand for water and a higher speed when water is needed. This allows the operator to match the speed of the pump to a particular demand. The setting of this speed is known as the Reference. In most examples, reference refers to speed in Hertz (Hz), maximum reference of 60Hz, and minimum reference of 18Hz for pumps. It could also be used in regards to a pressure setting, maximum reference of 100psi (690kPa), minimum reference of 40psi (275kPa), if a transmitter were attached to the VFD.

In the picture above, the display of a VFD, a Danfoss VLT 8000, is shown. Speed in Hz is the reference. The plus (+) key is used to increase the reference making the pump go faster and the minus (-) is used to decrease the reference point slowing the pump down.

Function #3 – Maintain a Constant Speed



Light load or heavy, the drive should maintain the same speed.

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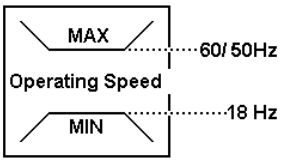
Function #3 Maintain a Constant Speed

Another function of the VFD is to maintain the speed of the pump regardless of the type of liquid in the lines. In the example above 100 gpm (380 l/m) is pumped whether it is clear water or sludge. The VFD automatically compensates for the current and torque needed to accommodate changes in the texture of the load.

Function #4 – Limits



Limits on current, torque, speed, heat and voltage, to name a few, protect the VFD & motor.

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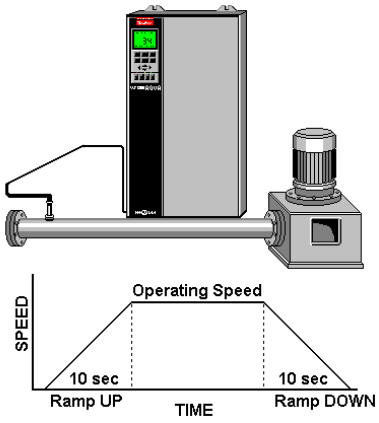
Function #4 Limits

It is important that limits be placed on a VFD. Speed limits can be placed in the program of the VFD so an operator can not go beyond a maximum speed or less than a minimum speed. The maximum speed of the pump should not exceed 60Hz in North America (50Hz in the rest of the world), due to excessive power consumption. For lubrication purposes the pump should have a minimum speed of at least 18Hz. Because of the possibility of overheating, fans and blowers should not be run less than 6Hz. For the same reason as the pump, fans should not be run more than 60/50 Hz.

If the pump gets stuck, there are torque limits that the VFD monitors stopping the motor if they are exceeded. Current limits are also important for protection of the drive and motor. In the picture above the maximum reference is set to 60/ 50 Hz. Notice that in the diagram there is a minimum reference of 18Hz.

Function #5 – Ramping



To avoid water hammer, it is important to control the acceleration, ramp up and deceleration, ramp down.

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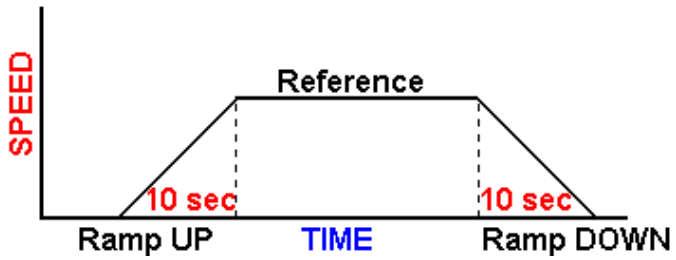
Function #5 Ramping

The VFD also ramps the pump up and ramps it down. When the pump starts, acceleration, it is important that there is no sudden jump to the reference speed, or water hammer occurs. Older pipes have great difficulty with rapid pressure changes and can break. In the example above, a ramp-up slowly increases the speed from stopped or 0Hz up to the reference, 34Hz, over a certain amount of time perhaps 10 seconds. If this ramp up is too short, the drive can trip on an over current alarm or torque limit. If the VFD is tripped, the pump stops and it might require an operator to manually reset the VFD. Many VFDs have an automatic reset setting from 1 restart or reset per alarm, up to an infinite number of resets per alarm.

Many submersible pumps require 2 startup ramps. One very quick initial start up ramp (say 1 second) for pump lubrication, up to its minimum speed, say 20Hz. Then a much slower ramp up (say 20 seconds) from the minimum speed up to the operating speed of 45Hz.

Function #5 – Ramping



All ramp times are based on motor speed, 60Hz in North America, 50Hz in the rest of the world.

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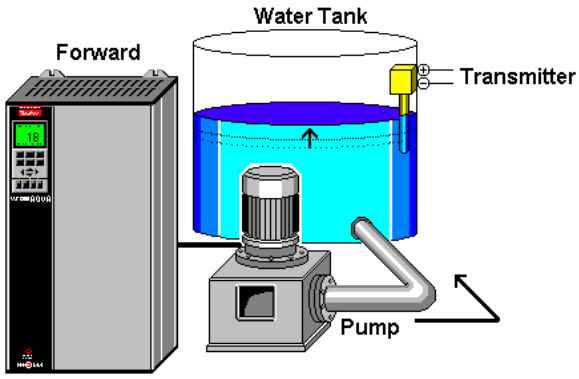
A ramp is also present on the stop side. This is referred to as a ramp down or deceleration. It is important that the pump is NOT stopped abruptly. A ramp-down of 10 seconds might be entered into the program for this application. If the ramp is too short, the drive can trip on over voltage.

All ramp times are based on the motor speed, 60Hz in North America 50Hz in the rest of the world. This means if the the ramp time is set for 10 seconds as in the picture above, but the reference is set to 30Hz (1/2 of 60Hz), it takes 30/60 x 10seocnds (½ the time) or 5 seconds to ramp up. In the rest of the world 50Hz is used for the motor speed. Using the same ramp up time (10) and reference (30), the motor then takes 30/50 X 10seconds or 6 seconds to ramp up to 30Hz. Calculations for the ramp down time would be the same.

A special feature of the Danfoss VLT 8000 is automatic ramping. The VFD automatically extends the ramp times, during ramp up and ramp down, to avoid tripping of the drive.

Function #6 – Forward/Reverse



- Change of Direction
- Forward to fill the tank

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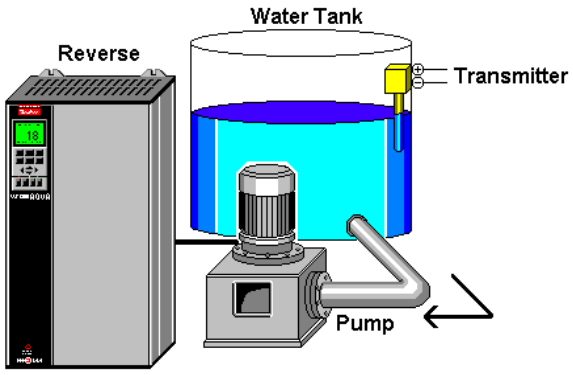
Function #6 Forward/Reverse Operation

FORWARD

One function of the VFD is to operate the motor in a forward direction, to move the supply water to the needed areas. In its default (factory set) condition the VFD is only allowed to go forward. Some pumps must never be operated backwards. If driven backwards they have problems, including unscrewing their impellers.

On startup, if it is discovered that the pump is operating backwards. Remove power from the drive and swap 2 of the 3 output wires. As an example exchanging the wire attached to terminal U of the VFD with the wire on terminal V. This changes its direction. If a Bypass switch, which bypasses the VFD, is involved you must also check to insure that it operates the pump in the correct direction.

Function #6 – Forward/Reverse



- Reverse to clear the impeller
- Be careful – this may unscrew impeller

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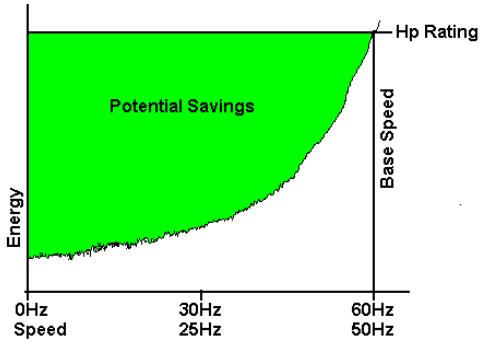
REVERSE

If something is stuck in the impeller of the pump, and it is allowed by the pump manufacturer, it might be of advantage to turn the pump slowly backwards. From the last page power going to the motor must be changed between 2 terminals of the motor to move the pump backwards (or Reverse). When a Reverse command is given to the VFD, it automatically swaps 2 of the 3 leads of the 3-phase motor to change directions, going backwards.

Function #7 – Saving Energy



The most important function for the VFD with this pump application is to save energy.

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Function #7 Saving Energy

In many applications, particularly involving fans, blowers and pumps, the major function of the VFD is to save energy. Before VFDs, a pump was turned ON to full speed, 60Hz (50Hz), then perhaps a butterfly valve downstream from the pump might be used to throttle the pressure back to a useable level. Or the pump might have been cycled on at full power, until a pressure setting, 80psi (550kPa), was reached. When 80psi (550kPa) was reached the pump was turned OFF coming back ON when the pressure dropped to perhaps 60psi (410kPa). This arrangement uses a great deal of energy and the frequent cycling causes a great deal of wear on equipment.

A drive is placed on the pump, which slows the pump down to perhaps 30Hz to constantly maintain the required pressure. The pump speeds up or slows down following demands. On the chart above, if the pump is running at 30Hz (25Hz), half of the full speed, assuming no friction losses, the energy level is $1/8^{th}$ the HP (kW) at full speed.

This concludes Lesson 1. There is a Post-test to review this information.