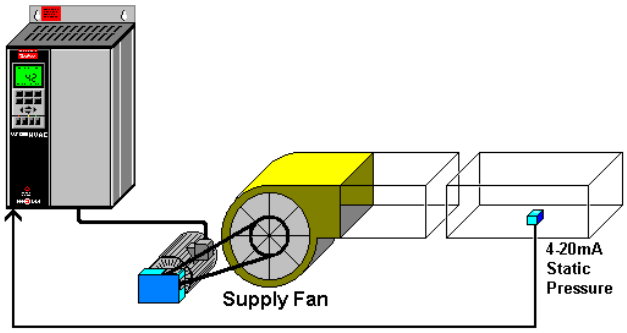
VFD 101
Lesson 1

Functions of an Variable Frequency Drive (VFD)



This lesson covers the basic functions of a Variable Frequency Drive (VFD) as it applies to fans.

10/2/2003

Here is the basics outline for this lesson.

Outline:

A. 3-phase AC Motor

B. Functions of an VFD

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

VFD 101
Lesson 1

This lesson covers the basic functions of an Variable Frequency Drive (VFD) on a 3-phase AC (alternating current) motor. Pictured above is an AC motor.

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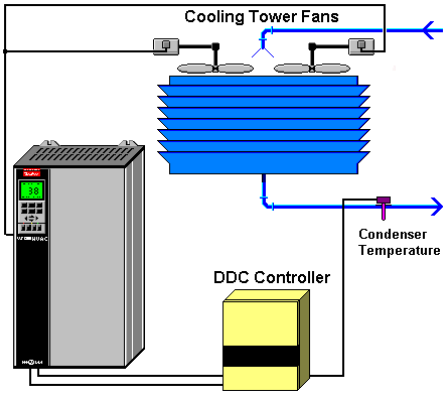
The 3-phase motor pictured above is for commercial use, but in your home, AC motors are used as well. A vacuum cleaner uses an AC motor to clean the carpet; a blender uses an AC motor to process food; and the clothes dryer uses an AC motor to dry clothes. In each of these examples, how is the AC motor controlled?

When controlling motors in the home we control them by applying AC power, and removing it, usually through a switch. Obviously when power, 120 or 240 VAC, is applied to the motor it runs. With no power, the motor stops.

With the use of a Variable Frequency Drive (VFD) not only can the AC motor be started and stopped as in the home, but more sophisticated controls are accomplished. A VFD can send a modulating signal to the motor, which allows a variety of speeds to be delivered not just an ON/OFF signal. This variety of speeds can be used to match the motor to a particular task. There are a number of functions that the VFD accomplishes with commercial 3-phase AC motors, which are covered in the pages that follow.

Motors in the home are almost always single-phase motors which require additional electric parts to rotate the magnetic field. Because of these extra parts, single-phase motors do NOT operate correctly with a VFD.

To understand the functions of an VFD better, an example of cooling tower fans is used.



What must the fans do?

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The cooling tower in the picture above must maintain a certain temperature perhaps 30°C (85°F) for the condenser water temperature. Looking at this example, see if you can identify some of the functions that must be performed by the VFD, AC motor and fans? In other words, what must the fans be able to do? Take a couple of minutes to jot down the functions.

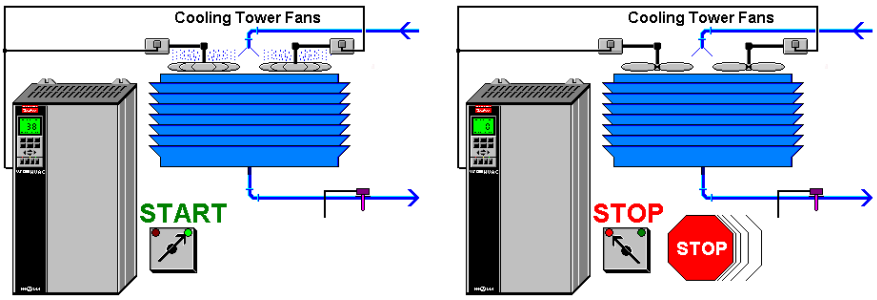
The fans must …

_____ _____

_____ _____

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

Function #1 – Start and Stop



The VFD must be able to START and STOP the cooling tower fans.

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Function #1 Start and Stop

START

One function of the VFD is to start the fans. This could be done locally off the keypad of the drive or remotely from a switch. This remote switch could be a continuous single-pole-double-throw (SPDT) switch or a momentary (push button) switch.

STOP

In the picture above, the SPDT switch is used to stop the pump. If there are 2 separate push button switches, one to Start and one to Stop, this arrangement is known as a 3-wire Start/Stop. If only one switch, a continuous switch, is used, then it is referred to as a 2-wire Start/Stop. In the picture above, since there is one switch, so this is a 2-wire Start/Stop.

Function #2 – Change Speed

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

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

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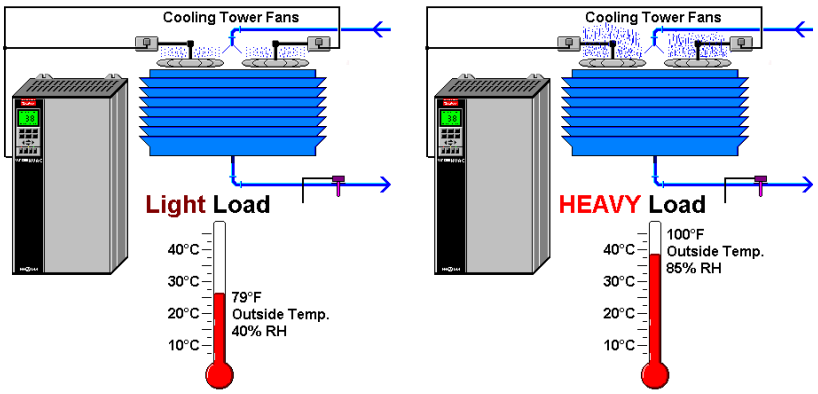
Function #2 Change Speed

The speed of the cooling tower fans must be variable to allow for a slower speed when there is little demand for cooling and a higher speed when more cooling is needed. This allows the operator to match the speed of the fans 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 6Hz for fans and 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 an VFD, a Danfoss VLT 6000, is shown. Speed in Hz is the reference. The plus (+) key is used to increase the reference making the fans go faster and the minus (-) is used to decrease the reference point slowing the fans down.

Function #3 – Maintain a Constant Speed



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

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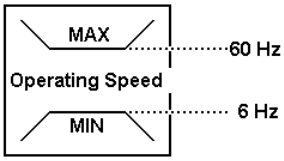
Function #3 Maintain a Constant Speed

Another function of the VFD is to maintain the speed of the fans regardless of the temperature and humidity in the air. The VFD automatically compensates the current and torque to accommodate changes in the load.

Function #4 – Limits



Limits on current, torque, speed, heat and voltage and others protect the VFD & motor.

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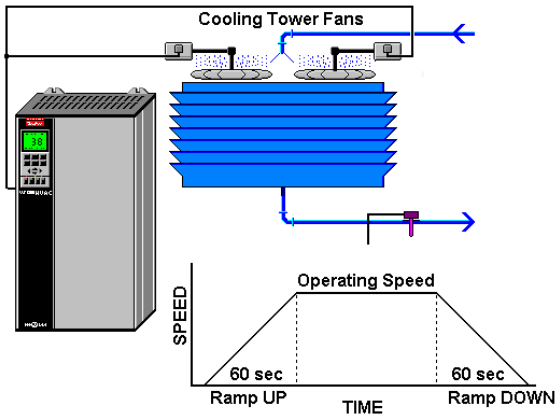
Function #4 Limits

It is important that limits be placed on an 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 fans should not exceed 60Hz, due to excessive power consumption. Because of the possibility of overheating, fans should not be run less than 6Hz. For the same reason as the fans, pumps should not be run more than 60Hz. For lubrication purposes a pump should have a minimum speed of at least 18Hz.

If the fans 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 Hz. Notice that in the diagram there is a minimum reference of 6Hz.

Function #5 – Ramping



To reduce mechanical wear, it is important to control the acceleration, ramp up and deceleration, ramp down.

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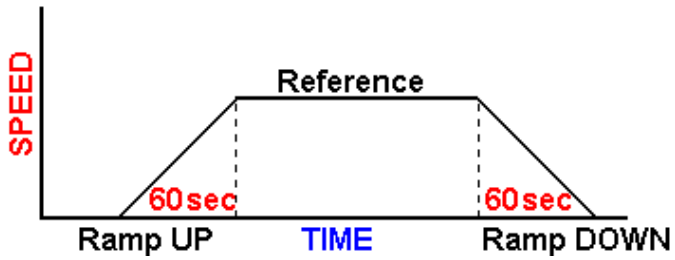
Function #5 Ramping

The VFD also ramps the fans up and ramps them down. When the fans starts, acceleration, it is important that there is no sudden jump to the reference speed, or there can be stress on the gear boxes. 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 seconds perhaps 10. 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 fans stop and it might require an operator to manually reset the VFD. Many VFDs have an automatic reset setting of 1 time to infinite times. Ramping is very important for pumps, to avoid water hammer.

Function #5 – Ramping



All ramp times are based on motor speed, 60Hz in Western Hemisphere, 50Hz in the Eastern Hemisphere.

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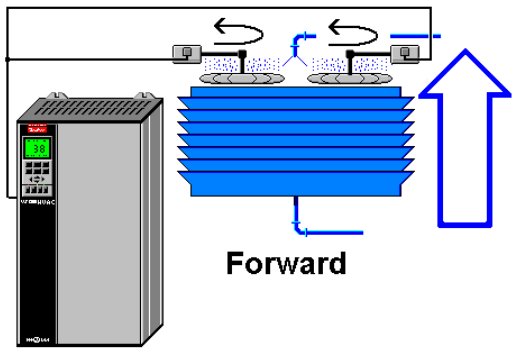
A ramp is also present on the stop side. This is referred to as a ramp down or deceleration. It is important that the fans do NOT stopped abruptly. A ramp-down of 60 seconds might be entered into the program for this application. If the ramp is too short, the drive can trip on over voltage.

All ramp times are based on the motor speed, 60Hz in the Western Hemisphere. This means if the the ramp time is set for 60 seconds as in the picture above, but the reference is set to 30Hz (1/2 of 60Hz), it takes 30/60 x 60seocnds (½ the time) or 30 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 60seconds or 36 seconds to ramp up to 30Hz. Calculations for the ramp down time would be the same.

A special feature of the Danfoss VLT 6000 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 cool water

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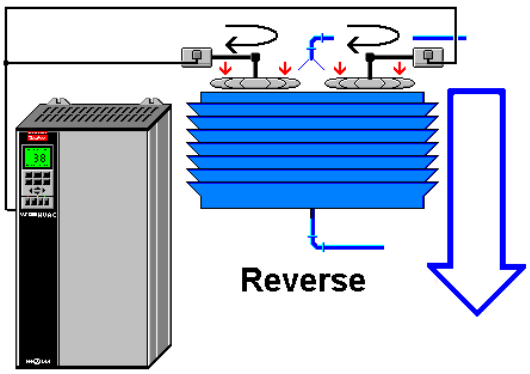
Function #6 Forward/Reverse Operation

FORWARD

One function of the VFD is to operate the motor in a forward direction, to move the air through the cooling tower and out the top. In its default (factory set) condition the VFD is only allowed to go forward. Some fans if driven backwards may have problems.

Function #6 – Forward/Reverse



- Reverse to defrost cooling tower

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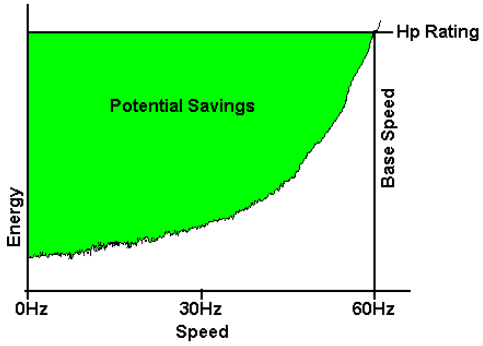
REVERSE

In the cooling tower example the fans need to operate in Reverse in order to complete a defrost cycle, when the outside temperature is very cool. Power going to the motor must be changed to move the fans backwards (Reverse). If there were no VFD, 2 of the 3 leads of the 3-phase motor would be switched in order for the motor to change its direction and go backwards. This switching of the motor leads is done inside the VFD.

Function #7 – Saving Energy



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

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Function #7 Saving Energy

In many applications, particularly involving fans and pumps, the major function of the VFD is to save energy. Before VFDs, cooling tower fans might have been cycled On at full power, when a temperature setting in condenser water of 32°C (90°F), was reached. When the water cooled to 28°C (82°F) the fans were turned OFF coming back ON when the temperature rose again to 32°C (90°F). 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 fans, which slows the fans down to perhaps 30Hz to constantly maintain the required condenser water temperature. The fans speed up or slow down following demands. On the chart above, if the fan is running at 30Hz, half of the full speed, assuming no friction losses, the energy level is $1/8^{th}$ the HP at full speed. This same energy savings is seen on pump applications.

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