

Why Use Variable Frequency Drive?

written by Filtrex, Inc.

distributed by Paddock Pool Equipment Company, Inc. & Filtrex, Inc.

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Variable Frequency Drives (or VFDs) are becoming almost standard part of aquatic equipment room packages. Most VFDs are fairly simple to install and operate however, they are quite complex with respect to their sophisticated hardware and software implementations. VFD functionality and operation can be greatly improved by understanding basic VFD theory, terminology and interfacing options.

What is a VFD?

Simply put, a VFD is a power conversion device. The VFD converts a basic fixed-frequency, fixed voltage sine-wave power (line power) to a variable-frequency, variable-voltage output used to control speed of induction motors. A basic block diagram of this process is depicted in Fig. 1.

Why use a VFD?

Primary function of a VFD in aquatic applications is to provide energy savings. By controlling speed of a pump rather than controlling flow through use of throttling valves, energy savings can be substantial. By way of example, a speed reduction of 20% can yield energy savings of 50%. The following included document (IS5893A) describes speed reduction and corresponding energy savings. In addition to energy savings, impeller, bearing and seal life is greatly improved.

Adjustable Speed Drives

Available in many different types, adjustable speed drives offer optimum method for matching pump and fan flow rates to system requirements. Adjustable frequency drive (inverter) is most commonly used. It converts standard plant power (230 or 460 V, 60 Hz) to adjustable voltage and frequency to power AC motor. The frequency applied to AC motor determines motor speed. The AC motors are usually same standard motors that can be connected across AC power line. By incorporating bypass starters, operation can be maintained even if inverter should fail.

Adjustable speed drives also offer an additional benefit - increased bearing and pump seal life. By maintaining *only* pressure needed in pump to satisfy system requirements, pump is not subjected to any higher pressures than necessary. Therefore, the components last longer.

The same benefits - but to a lesser extent - also apply to fans operated by adjustable speed drives.

To obtain optimum efficiencies and reliability, many specifiers obtain detailed information from manufacturers on drive efficiency, required maintenance, diagnostic capabilities within drive, and general operational features. Then, they make detailed analysis to determine which system will give the best return on investment.

Pump Energy Savings

Pumps are generally grouped into two broad categories, positive displacement pumps and centrifugal pumps. The vast majority of pumps used today are centrifugal type, and they are the only type discussed in this paper.

Centrifugal fans and pumps are sized to meet maximum flow rate required by the system. System conditions frequently require reducing flow rate. However, throttling devices - dampers and valves - are installed to adjust pump and fan output. Throttling devices are effective, but not energy efficient. Another method can vary flow and also reduce energy losses. The method: adjust fan and pump impeller speeds so units deliver required flow.

Centrifugal pump operation is defined by two independent curves. One is the pump curve, which is solely a function of pump characteristics. The other is system curve, which depends on size of pipe, length of pipe, number and location of elbows, etc. The intersection of these two curves is called natural operating point, because pump pressure matches system losses.

Additional Benefits of VFDs

In addition to energy savings and better process control, VFDs can provide other benefits:

- A VFD may be used for control of process temperature, pressure or flow without use of a separate controller. Suitable sensors and electronics are used to interface driven equipment with VFD.
- Maintenance costs can be lowered, since lower operating speeds result in longer life for bearings and motors.
- Eliminating throttling valves and dampers also does away with maintaining these devices and all associated controls.

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- A soft starter for motor is no longer required.
- Controlled ramp-up speed in a liquid system can eliminate water hammer problems.
- Ability of a VFD to limit torque to a user-selected level can protect driven equipment that cannot tolerate excessive torque.

Analyze System as a Whole

Since process of converting incoming power from one frequency to another will result in some losses, energy savings must always come from optimizing performance of the complete system. First step in determining energy savings potential of a system is to thoroughly analyze operation of entire system. Detailed knowledge of equipment operation and process requirements are required in order to ensure energy savings. In addition, type of VFD, features offered, and overall suitability for application should be considered.

Internal Configuration (see Fig. 2)

VFDs contain (3) primary sections:

1. Rectifier Circuit - consists of diodes, SCRs, or insulated gate bipolar transistors. These devices convert AC line power to direct current.
2. DC Bus - consists of capacitors that filter and store the DC charge.
3. Inverter - consists of high-voltage, high-power transistors that convert DC power to a variable-frequency, variable-voltage AC output delivered to load.

INTERNAL BYPASS PANEL

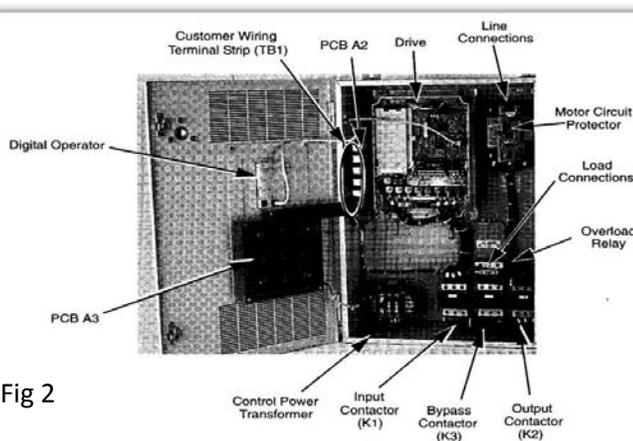


Fig 2

Secondary Section

VFDs also contain a powerful microprocessor which controls inverter circuit to produce an almost pure variable-frequency sinusoidal voltage delivered to load. The microprocessor also controls input / output configurations, drive settings, fault conditions and communication protocols.

TYPES OF VFDS

Basic Configuration (See Fig 3)

This configuration, sometimes referred to as a “shoebox on the wall” is the least expensive option of the three major types. It features a basic drive connected between the line and the load. Speed control is generally operator initiated either through a front panel keypad or speed potentiometer. Functionality and features on this type of drive are generally limited. It should be noted that an external disconnect is required and that this type of drive may not be suitable for filter room applications due to the harsh environment and the lack of a secondary enclosure. One major issue with this type of drive is that being the sole load driving component, a failure of the drive will bring the entire system down until the drive is removed from service for repair or replacement.

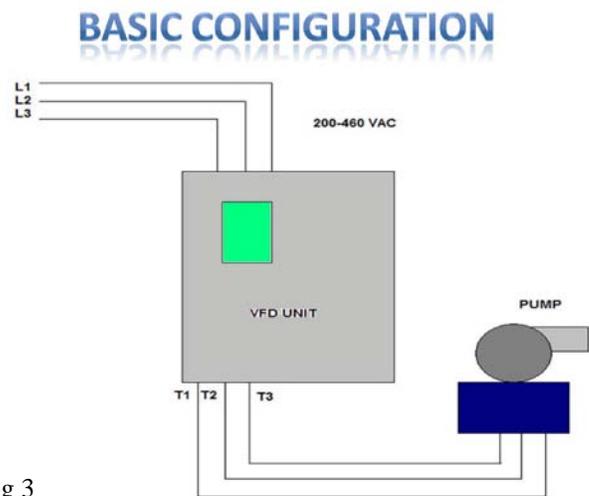


Fig 3

Two Contactor Bypass (See Fig 4)

This configuration is a step up from basic “shoe box”. It generally features a secondary enclosure (NEMA 1 or 12) with additional control circuitry and (2) contactors which can bypass drive circuitry allowing manual control of load through conventional across the line motor starter control in many cases. It should be noted that while the output

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sections of the drive are isolated from the load, the drive input sections are not and that failure of input section components may still prevent manual system operation. This type of drive may or may not include a service disconnect and additional load protection.

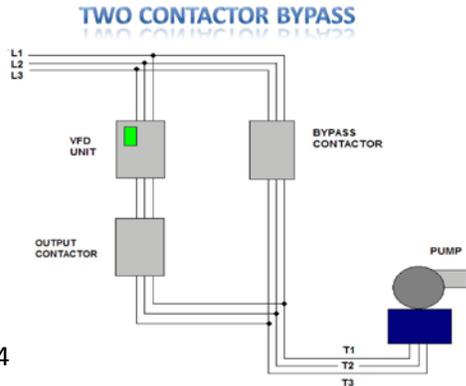


Fig 4

Three Contactor Bypass (See Fig 5)

A three contactor bypass features a secondary enclosure (NEMA 1 or 12), additional control circuitry and (3) contactors which in bypass mode completely isolate the drive unit ensuring functionality in case of drive failure. In addition, virtually all of this type of unit feature a code compliant service disconnects and "rapid trip" input circuit breaker which affords the drive substantial protection in the event of power surges and lightning strikes.

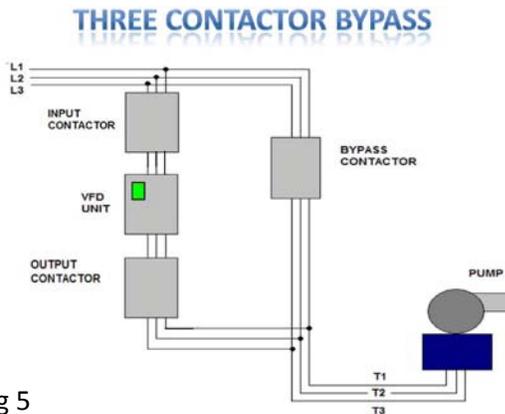


Fig 5

Control Methodologies

Stand Alone

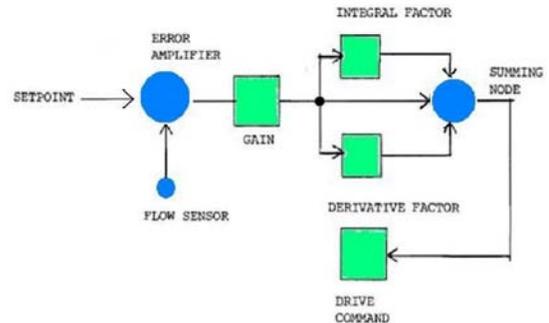
In this configuration, speed commands for the drive are entered through a panel mounted keypad or a manual speed potentiometer. System flow rates must be monitored by facility operator and manually

adjusted as required much as they may be when manual throttling valves are employed. This can be problematic as it requires continual adjustment to compensate for filter loading and pressure drops following filter regeneration. Similarly sand systems generally require periodic adjustment following backwashing and during the filter run to compensate for filter loading.

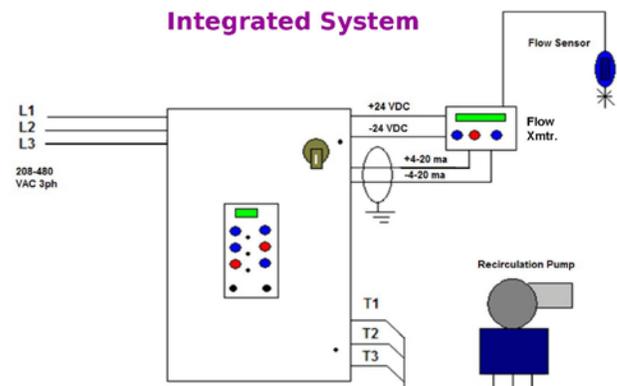
Closed Loop Control

Closed loop or integrated control employs a feedback signal to the drive allowing the drive to compensate for filter loading conditions, valve sequencing, and other downstream conditions that may affect system flow rates. The feedback element in aquatic systems is typically via the use of a flow sensor placed in the pump discharge line (preferred) or the return line to the pool or water feature. This configuration virtually eliminates operator error and routine adjustment to the system. (See Below)

PID LOOP CONTROL



INTERCONNECTION DIAGRAM



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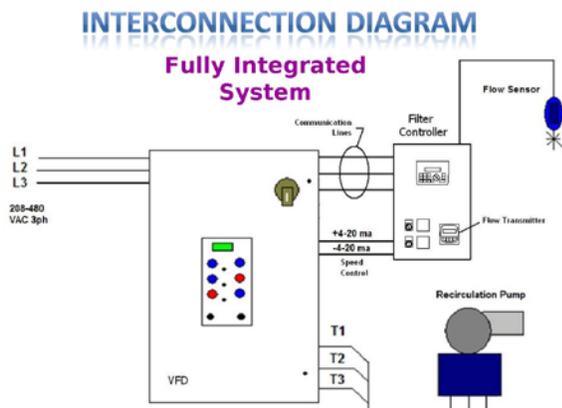
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While this is the preferred method of control, careful consideration should be given to the selection of components (flow sensor, flow transmitter, and VFD) to ensure compatibility and reliability. There are many factors involved in putting together this type of system. A few equipment features to be considered are type of sensor (paddle wheel/magnetic), flow transmitter features (programmable loop range, signal averaging, test/diagnostic functions, English/metric display, low/high flow alarms & etc, and VFD control functions (20 Ma follower, PI/PID control, signal high/low default options and others). While the above may seem a bit more complex, it (if implemented properly) takes advantage of the power and features of individual components while making system transparent and friendly to user.

Fully Integrated System

A further enhancement of the above is a fully integrated system (see fig). In a fully integrated system the individual components are incorporated into the filter control scheme, effectively utilizing the power and features of the filter controller, further expanding the capabilities of the complete package. In essence all of the individual components function as a whole, communicating with each other to take advantage of their combined features. In the Filtrex system, the flow meter is incorporated into the filter controller cabinet eliminating external power supplies minimizing field wiring requirements. In addition, low flow alarm outputs are routed to the internal computer to afford system shutdown in the event of valve/pump failure or other flow related faults. The internal computer also communicates with the VFD over communication lines to monitor faults/status, operator control settings (preventing operator errors), and other internal drive conditions. This methodology can add features such as time of day flow control, building management system communications, text message status reporting, power failure restart and



many others. Again, this greatly enhances the capabilities of the system while preserving transparency and ease of use.

Drive Features

No discussion of Variable Speed Drives would be complete without taking into account drive features. Drive features vary widely among classes of drives and various manufacturers of same. Filtrex, Inc. has been supplying variable speed drive to the aquatics industry for over 20 years. It is our belief that we are among the most knowledgeable in the industry and based on experience provide the most sophisticated and fully integrated packages available with the features that are necessary for a simple and successful plug and play installation.

Among the features we recommend are:

1. Code compliant disconnect with “instant trip” motor protection breaker
2. Full 3 contactor bypass
3. Built in Hand-Off-Auto-Bypass mode selection
4. Full NEMA 1 or 12 secondary enclosure – (depending on application)
5. Coast to stop/ramp to stop option
6. Programmable ramp speeds
7. Loss of feedback detection/default speed operation
8. Phase loss/ground fault detection
9. Low torque detection – (dry pump/loss of prime)
10. High torque detection – (pump/motor/bearing failure)
11. Full PID flow control functions
12. Sequence input for precoat recycle control
13. Multiple (2 or more) safety interlock inputs
14. Building automation/communications (RS-422/485, CANBUS, LONWORKS, APPOGEE, BACNET, ETHERNET, etc.)
15. DC injection braking
16. Programmable jump frequencies
17. Programmable voltage/frequency pattern – (allows wider selection of pump motors)
18. Programmable carrier frequency – (allows longer wire runs to pump where necessary)
19. Energy saving mode – (monitors motor flux and maintains minimum slip for additional electrical savings)

Engineered Systems Approach

We at Filtrex have always felt that filter room equipment should always be considered a system

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rather than a collection of “appliances” strung together (sometimes successfully, sometimes less so). By providing a complete package of equipment, engineered to work seamlessly together, the combination can fully utilize individual strengths of component parts. In addition, because individual components have been designed and programmed to work together, installation, startup, and user operation are greatly simplified. This translates into savings for installing contractor and yields long term benefit to system owner with respect to simplicity of operation, protection of investment, and a single source for technical support and service.

The Filtrex/Paddock Advantage

Our drive package is a fully integrated preprogrammed system specifically designed to work in conjunction with our MOD I SSC filter controller line. Some of the major features and advantages are:

1. Full 3 contactor bypass operation
2. Code compliant disconnect
3. Rapid trip motor protection breaker
4. NEMA rated secondary enclosure
5. Prewired easily accessible field wiring terminals
6. Fully preprogrammed and hardware configured for specific pump/motor combinations. All dip switches, jumper settings, and option boards (where required) are installed and tested by Filtrex prior to shipment.
7. Simple single cable interconnection to MOD I controller (3 pair)
8. 1 amp 24 VDC power supply to support external loop devices
9. Magnetic flow sensor (included)
10. Flow display/transmitter (included) preprogrammed for loop range, units, signal averaging & etc. Pre mounted and wired in MOD I enclosure.
11. Sensor mounting saddle (included)
12. True plug and play installation. Installing electrician only needs to check pump rotation.
13. 5 yr warranty on drive unit (excludes cooling fans)
14. Free single source tech support for life of product.
15. No additional engineering or startup cost.