Danfoss

Danfoss Graham

VLT® 6000 Series Adjustable Frequency Drives

Source Book

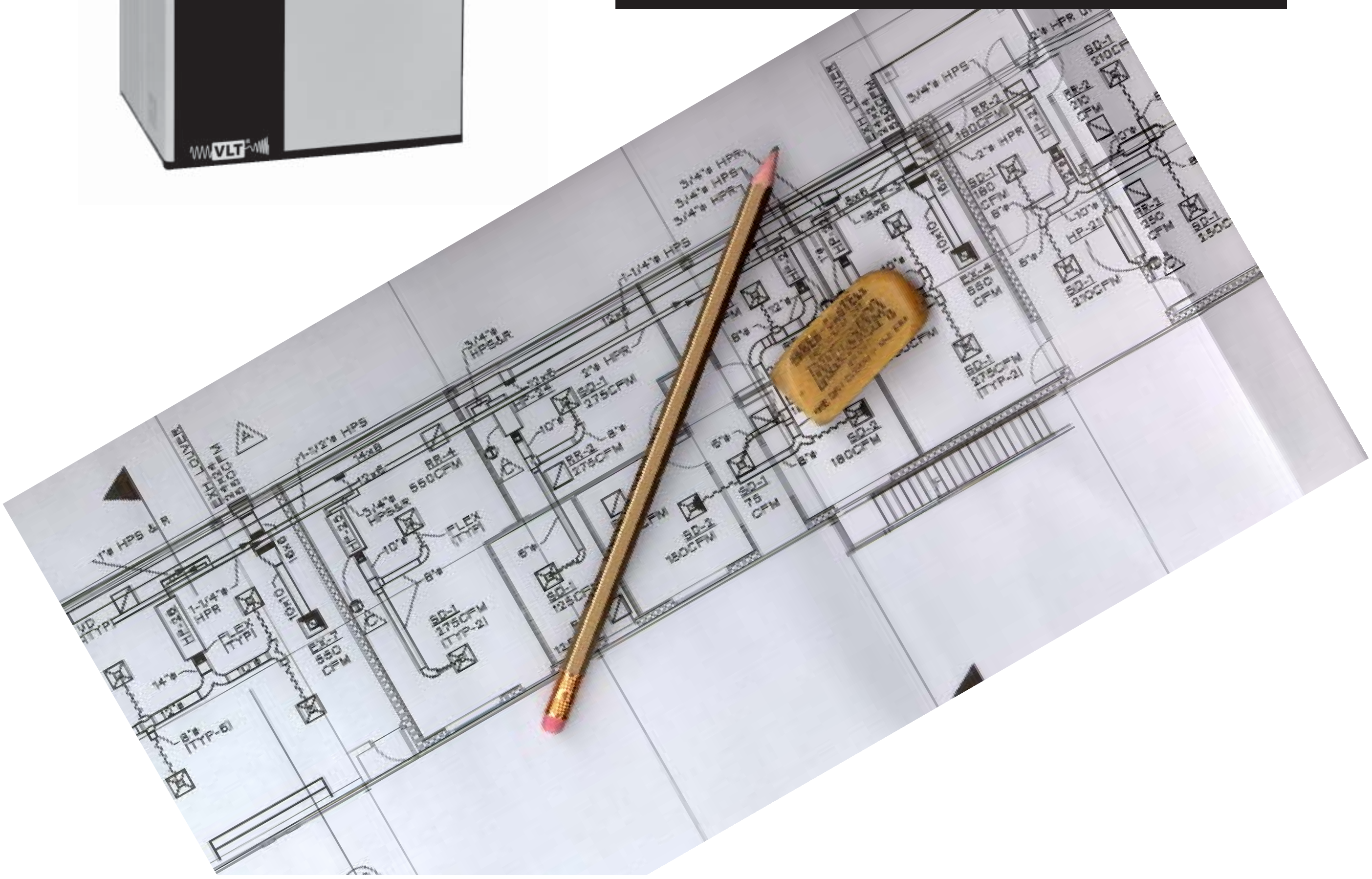

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Table of Contents

Danfoss VLT 6000 Features

The Danfoss VLT 6000 Adjustable Frequency Drive puts all you need to know about the your HVAC system up front. You want to know your system status, what the motor and drive are doing, and if there are any problems. Thatís why the VLT 6000 continuously monitors all aspects of the motor(s) and drive status and alerts you to any adverse conditions.

Drive Status

Hand start/auto start	Where start command initiated
Remote/local	Local or system control of drive
Status	22 automatic drive status messages
Set-up	Indicates which set-up is operational
Output current	Amps
Output frequency	Hz
Heatsink temperature	°C
Output status	Displays 2 analog/digital, 2 relay programmed function status

Motor Status

Operating speed	Percentage
Current	Amps
Voltage	Volts
Thermal load	Percentage

Faults, Warnings and Alarms

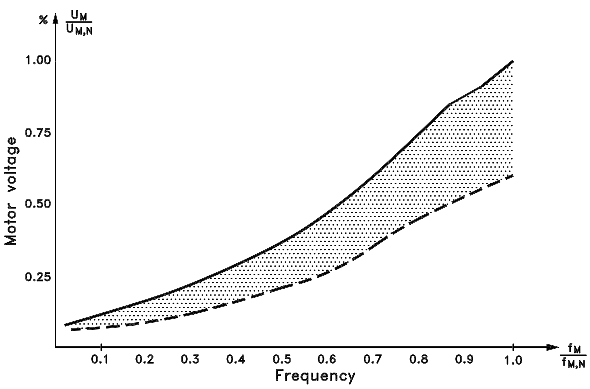
Motor phase loss	Output phase loss detection and indication of the missing phase.
Signal loss detection	Drive senses loss of various input signals.
Short circuit detection	Complete output phase-to-phase short circuit protection.
Motor overtemperature	Drive accepts an input from a motor thermostat or thermistor.
Drive overtemperature	Drive automatically measures and can display its heatsink temperature.
Undervoltage and overvoltage	Voltage protection for under or overvoltage condition.
Output frequency	Protects against too high/low an output frequency.
Output current	Protects against too high/low an output current.
Feedback signal	Protects against too high/low a feedback signal.
Remote reference signal	Protects against too high/low a remote reference signal.
Input phase loss	Input phase loss detection.
Current limit	Drive compares current to selected current limit.
External fault	Indicates added sensors signals, i.e. smoke detector, fire or freeze status.

Automated Operational Features

The Danfoss VLT 6000 is programmed with user specific options ready to go right out of the box. Many of the important cost, energy, and maintenance saving features of the VLT†6000 are built-in. Benefits from these advantages begin as soon as the drive is started.

Automatic Energy Optimization

Automatic Energy Optimization (AEO) is one of the VLT 6000's most advanced features. The drive continuously monitors the load on the motor and adjusts the output voltage to maximize motor and drive efficiency. Under light load, the voltage is reduced, as shown in the graph below. The shaded area represents the voltage reduction. Motor current is minimized. The motor benefits from increased efficiency, reduced heating and quieter operation. There is no need to select a V/Hz curve because the drive automatically adjusts motor voltage for optimum energy savings.



Energy savings with AEO

Benefits of AEO:

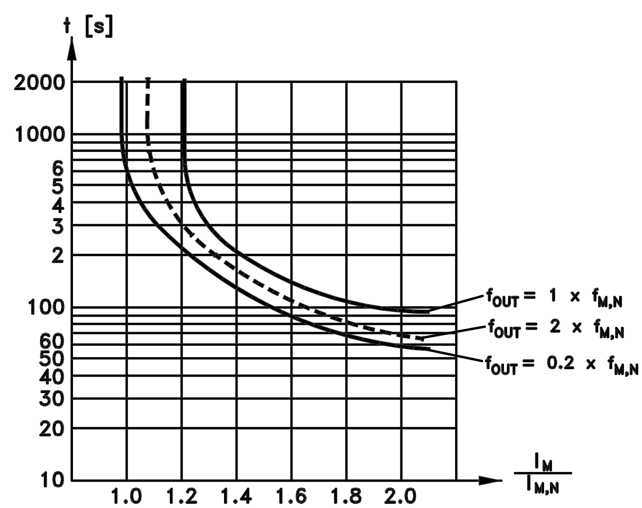
- Automatic compensation for oversized motors
- Automatic compensation for system load change
- Automatic compensation for seasonal changes
- Automatic compensation for low motor loading
- Reduced energy consumption
- Reduced motor heating
- Reduced motor noise

Motor Thermal Protection

Integrated motor thermal protection is provided by the VLT 6000 in two ways. To protect against motor overheating, input from a motor thermistor is accommodated. The drive monitors changing temperature conditions in the motor as speed and load vary to detect overheating conditions. Monitoring ensures detection of failure in the motor's cooling air supply.

The other method calculates motor temperature using current, frequency and time. In this method, the drive can predict impending motor thermal overload conditions. The drive warns of these conditions and displays the amount of thermal load in percentage until thermal overload would be reached. The prediction accounts for reduction in the speed of the motor's cooling fan. Even at low speeds, the drive meets I^2t Class 20 electronic motor overload standards.

The graph below shows the amount of time that the drive can provide a level of current to the motor at rated motor frequency (1), 20% of rated motor frequency (0.2) and 200% of rated motor frequency (2).



Current at variation in rated motor frequency

Automated Operational Features

Harmonics

Electrical devices with diode rectifiers, such as fluorescent lights, computers, copiers, fax machines, various laboratory equipment and telecommunications systems, can add harmonic distortion to a building's power line. Adjustable frequency drives which use a diode bridge input also contribute to the total harmonics of the building.

Most drives do not draw current uniformly from the power line. This non-sinusoidal current has components which are multiples of the fundamental current frequency. These components are referred to as harmonics. It is important to control the total harmonic distortion within a facility. Although the harmonic currents do not directly affect electrical energy consumption, they generate heat in wiring and transformers and can effect other devices on the same power line.

Low Harmonic Distortion

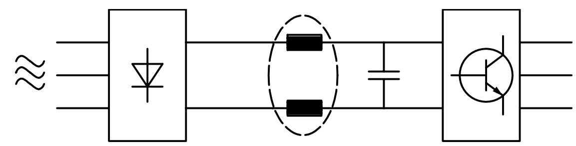
VLT 6000 drives are designed for the HVAC environment, where harmonic distortion is a concern. The level of harmonic distortion acceptable depends upon the type of facility and the amount of interaction between electrical equipment . Total harmonic distortion (THD) is a summation of harmonic distortion for a building expressed in percentage. IEEE 519 is a standard by the Institute of Electrical and Electronic Engineers which rates the THD acceptable in various building categories, as shown in the following table. VLT 6000 drives can meet the stringent harmonic level of 3% for sensitive applications. Drives designed for industrial use and adapted for HVAC applications are electronically "noisy" and may require add-on hardware to achieve similar levels.

Application Class	THD (%)
Sensitive Applications Airports Hospitals Telecommunications Facilities	3%
General Applications Office Buildings Schools	5%
Dedicated Systems Factories	10%

IEEE 519 standards for total harmonic voltage distortion

Built-in Harmonic Suppression

Limiting harmonic distortion on the power line was part of the VLT 6000 design criteria. As a result, filter reactors are internal to the drive. Connected between the input rectifier and the DC bus capacitor, these are called DC link reactors (see figure below). Two DC link reactors, one in the positive DC bus and one in the negative DC bus, provide very low power line harmonics. The DC link reactors reduce RMS input current drawn from the building power system by more than 40% compared to drives without inductors.



DC link reactors

AC Line Reactors

When an adjustable frequency drive has no built-in harmonic filtering, it is often necessary to add external filtering for use in HVAC applications. This is the purpose of AC line reactors. AC line reactors have to be sized approximately 50% larger than similar DC link reactors, and they require a separate enclosure for mounting. Current passing through external reactors causes electrical loss resulting in heat generation. AC line reactors may act as a buffer between the AC power line and the drive, however, the VLT 6000 uses metal oxide varistors (MOVs) and R/C snubber circuitry to protect the drive input from power line noise. A buffer is unnecessary. When harmonic requirements on the power line are very stringent, or if the supply power is soft, AC line reactors are available for VLT 6000 drives as an option.

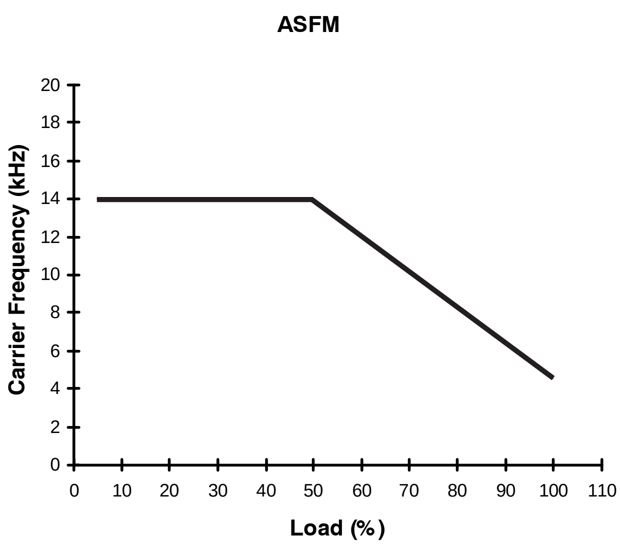
Harmonic Analysis

Various characteristics of a building's electrical system determine the exact harmonic contribution of the drive to the THD of a facility and its ability to meet IEEE standards. Generalizations about the harmonic contribution of drives on a specific facility is difficult. When requested, Danfoss Graham can provide a computerized analysis of the system harmonics to determine drive effects.

Automated Operational Features

Automatic Switching Frequency Modulation

An adjustable frequency drive sends short electrical pulses to a motor to control the voltage and current provided. The carrier frequency of a drive is the rate of these pulses. A low carrier frequency (slow pulsing rate) causes noise in the motor, making a high carrier frequency preferable. A high carrier frequency, however, generates heat in the drive thereby limiting the amount of current available to the motor. Automatic Switching Frequency Modulation (ASFM) regulates these conditions automatically to provide the highest carrier frequency without overheating the drive. By providing a regulated high carrier frequency, ASFM quiets motor operating noise at slow speeds, when audible noise control is critical, and produces full output power to the motor when the demand requires. Systems without ASFM can do one or the other, but not both. An important benefit is no need to derate output at high load. (See the graph below representing 15-60 HP drives at 460 VAC and 5-30 HP at 208 VAC.) ASFM adjusts the frequency based on motor current demand rather than motor speed to provide the best carrier frequency possible, matching both performance and noise control.



Carrier frequency and load with AFSM

Derating for High Carrier Frequency

All VLT 6000 drives are designed for continuous, full load operation at carrier frequencies from 3.0 to 4.5 kHz. Most drives can be set to operate at a higher carrier frequency. Since a higher carrier frequency generates more heat in the drive, the output current rating of the drive must be derated when a carrier frequency greater than 4.5 kHz is used.

For drives with a maximum carrier frequency greater than 4.5 kHz, an automatic feature of the VLT 6000 is load dependent carrier frequency control. This feature allows the motor to benefit from as high a carrier frequency as the load permits. The range of carrier frequencies are as follows:

Switching frequency [kHz]	Min	Max	Factory Set
To 3 HP, 208 V	3.0	10.0	4.5
5 to 30 HP, 208 V	3.0	14.0	4.5
40 to 60 HP, 208 V	3.0	4.5	4.5
To 10 HP, 460 V	3.0	10.0	4.5
To 10 HP, 600 V	4.5	7.0	4.5
15 to 60 HP, 460 and 600 V	3.0	14.0	4.5
75 to 300 HP, 460 and 600 V	3.0	4.5	4.5
350 to 600 HP, 460 V	3.0	4.5	4.5

Short Circuit Protection

The VLT 6000 provides inherent short circuit protection with a very fast acting fault-trip circuit by sensing current on all three drive output phases. The use of insulated gate bi-polar transistors (IGBT) in the VLT 6000 means very high-speed switching and rugged performance. And, because the VLT 6000 creates a near perfect sinusoidal current, it automatically minimizes motor noise while providing accurate motor control and smooth motor performance.

EMI Filtering and RFI Shielding

Electromagnetic interference (EMI) and radio frequency interferences (RFI) can have effects on a building power supply similar to those of harmonic distortion. EMI is conducted through the AC power line while RFI is transmitted through the air. VLT 6000 230 V and 460 V series drives are designed to comply with stringent European standards. The two standards are EN 55011-1B, for highly restrictive residential applications, and the less restricted industrial standard, EN 55011-1A. To comply with EN 55011-1A, the output wiring must be shielded, properly terminated, and not over 500 feet (150 m) long. To comply with EN 55011-1B, the output wiring must be shielded, properly terminated, and not over 155 feet (50 m).

All VLT 6000 units through 10 HP at 460 volts and through 3 HP at 208 volts have built-in EMI and RFI filtering and comply with both standards without adding options. All other VLT 6000 drives are available with optional filters to meet these standards. Consult Danfoss Graham with your requirements.

Automated Operational Features

Power Fluctuation Performance

The drive withstands powerline fluctuations such as transients, momentary dropouts, short voltage drops and surges. The drive automatically compensates for input voltages ±10% from the nominal to provide full rated motor voltage and torque. With auto restart selected, the drive will automatically power-up after a voltage trip. And with flying start, the drive synchronizes to motor rotation prior to start.

Overtemperature Protection with Automatic Derate

Automatic derate works to prevent tripping at high temperature. Temperature sensors inside the drive protect its power components from overheating. Unlike competitor's drives, the VLT 6000 can be set to automatically reduce its carrier frequency to help maintain temperature within safe limits. After reducing the carrier frequency, the drive will then reduce the output frequency and current to avoid an overtemperature trip. The drive reduces speed as much as 30% before it shuts down.

Current Measurement on All Three Motor Phases

Output current to the motor is continuously measured on all three phases. This protects both the drive and motor against short circuits, ground faults, and lost phases. Output ground faults are instantly detected. Output contactors may be repeatedly used with no damage to the drive. Current is evenly spread across the three wires. If a motor phase is lost, the drive stops immediately and reports which phase is missing.

Auto Ramping

A motor trying to accelerate a load too quickly for the current available can cause a drive to trip. The same is true for too quick of a deceleration. The VLT 6000 protects against this by extending the motor ramping (acceleration or deceleration rate) to match the available current. This automatic feature ensures no-trip operation and smooth motor starts.

Temperature Controlled Drive Fans

The internal drive cooling fan is temperature controlled by sensors within the drive. This means that the cooling fan often is not running during low load operation, in sleep mode or standby. This reduces drive noise, increases total drive efficiency and extends the operating life of the fan.

Current Limit Circuit

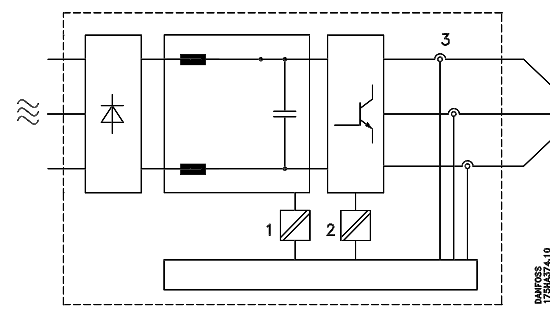
During acceleration, the current required to accelerate a load can exceed the motor current limit, damaging the motor. To prevent damage under this condition, the drive discontinues accelerating the motor until the current demand is reduced to normal levels. Acceleration then automatically continues. Should a load exceed the drive's current capability under normal operation (from an undersized drive and motor), current limit reduces the drive output frequency to slow the motor and reduce the load. An adjustable timer is available to limit operation in this condition for 60 seconds or less. The factory default limit is 110% of the rated motor current to minimize overcurrent stress. Drives intended for heavy industrial applications may have an unnecessarily high limit for HVAC applications.

Galvanic Isolation of Control Terminals

All control terminals and output relay terminals are galvanically isolated from the power line. This means the drive controller is completely protected from the input current. The output relay terminals require their own grounding. This isolation meets the stringent protective extra-low voltage (PELV) requirements for isolation and ensures safe connection to building management systems.

The components that make up the galvanic isolation are shown in the diagram below:

1. Power supply, including signal isolation.
2. Gate drive for the IGBTs, the trigger transformers and opto-couplers.
3. The output current Hall effect transducers.



Galvanic isolation

Motor Soft Start

The drive supplies the right amount of current to the motor to overcome load inertia and then brings the motor up to speed. This avoids full line power voltage being applied to a stationary or slow turning motor, which generates high current and heat. Benefits from this inherent soft start drive feature are reduced thermal load and extended motor life, reduced mechanical stress on the system, and quieter system operation.

Resonance Damping

High frequency motor resonance noise can be eliminated through the use of resonance damping. The VLT 6000 automatically adjusts the amount of damping required. Manual adjustment is also possible.

Custom Application Features

The VLT 6000 capabilities go far beyond its many automated features. The VLT 6000 has incredible flexibility and built-in advanced technology. Each system can be customized for peak performance by choosing from options at your fingertips. The VLT 6000 can expand the capability of a system while simplifying its operation, eliminating peripheral equipment and reducing cost.

Automatic Motor Adaptation

Automatic Motor Adaptation (AMA) is an advanced, automated test procedure that measures the electrical characteristics of the motor. AMA provides the drive with an accurate model of the motor to optimize performance and efficiency. Running the AMA procedure also maximizes the Automatic Energy Optimization feature of the drive. AMA is performed without the motor rotating and without uncoupling the load from the motor. This greatly simplifies the procedure.

Built-in PID Controller

The Proportional, Integral, Derivative (PID) controller is built into VLT 6000 drives, eliminating the need for auxiliary control devices. The PID controller maintains constant control of closed loop systems where regulated pressure, flow, temperature, or other system requirements must be maintained. The drive operates the motor speed in response to feedback signals from remote sensors measuring the system status.

Two Feedback Signals

VLT 6000 drives accommodate two feedback signals from two different devices. This unique feature allows regulating a system with different setpoint zones. The drive makes control decisions by comparing the two signals to optimize system performance. In open loop systems, the reference signals do not effect operation of the drive but can be displayed for system status, as warnings, or as input data for a serial network.

Self-reliance

Because the VLT 6000 is designed specifically for HVAC applications, the drive can operate without dependence on a building automation system. This can eliminate the need for an additional PID controller and I/O modules.

Automatic Restart

The drive can be programmed to automatically restart motors after a trip. This feature eliminates the need for manual reset of the drive and enhances automated operation for remotely controlled systems where having someone restart the drive is inconvenient or impossible.

Flying Start

Flying start allows a drive to synchronize with a motor rotating at any speed, up to full speed, in either direction. After synchronizing with the motor, the control smoothly brings the drive to the desired speed and in the desired direction. This prevents trips and minimizes mechanical stress to the system, since the motor receives no abrupt change in speed.

Sleep Mode

Sleep mode automatically stops the motor when demand is at a low level for a period of time. When the system demand increases, the drive restarts the motor to reach the required output. Sleep mode has great energy savings capability and reduces wear on driven equipment. Unlike a time clock setback, the drive is always available to run when the preset “wakeup” demand is reached.

Run Permissive

The drive has the capability to accept a remote “system ready” signal prior to operation. This feature is useful for a wide range of applications. When selected, the drive will remain stopped until receiving permission to start. Run permissive ensures that dampers, exhaust fans, or other auxiliary equipment are in the proper state before the drive is allowed to start the motor.

Full Torque at Reduced Speed

Unlike variable torque drives, which provide reduced motor torque at reduced output frequency, or constant torque drives, which provide excess voltage, heat and motor noise at less than full speed, the VLT 6000 follows a variable V/Hz curve to provide full motor torque even at reduced speeds. In direct drive fan systems, full torque is available for all range of operation. Full output torque can coincide with the maximum designed operating speed of drive controlled equipment, up to 60 Hz.

Frequency Bypass

In some applications, the system may have operational speeds that create a mechanical resonance. This can generate excessive noise and possibly damage mechanical components in the system. The drive has four programmable bypass frequency bandwidths. These allow the motor to stepover speeds which induce system resonance.

Motor Preheat

When a motor has to be started in a cold or damp environment, such as in a cooling tower, a small amount of DC current can be trickled continuously into the motor to protect it from condensation and the effects of a cold start. This can extend the operational life of the motor and eliminate the need for a space heater.

Custom Application Features

Four Programmable Setups

The drive has four independent setups that can be programmed. Independent setups are used, for example, to change speed references, or control multiple motors, or for day/night or summer/winter operation. The active setup is displayed on the LCP. Using multi-setup, it is possible to switch between setups through digital inputs or a serial interface. Setup data can be copied from drive to drive by downloading the information from the removable LCP.

DC Braking

Some HVAC applications may require braking a motor to slow or stop it. Applying DC drive current to the motor will brake the motor and eliminate the need for a separate motor brake. DC braking can be set to activate at a predetermined frequency or upon receiving a signal. The rate of braking can also be programmed.

Input or Output Switching Protection

The input or output may be disconnected while the drive is running without the need for interlocks to protect the drive.

Plenum Mounting

VLT 6000 drives can be plenum mounted. The drives meet the UL requirements for installation in air handling compartments. When mounting the drive in the plenum, all requirements for clearance, temperature and humidity apply.

High Breakaway Torque

For high inertia or high friction loads, high torque is available for easy starting to reach the set point operating speed. The breakaway current can be set for up to 160% and 0.5 seconds. Current limit protection reduces stress on all portions of the system.

Bypass

An automatic or manual bypass is an available option. The bypass allows the motor to operate at full speed when the drive is not operating and allows the drive to be taken off-line for routine maintenance.

LC Filters

LC filters may be specified as an option with any VLT 6000 Series drive through 300 HP.

The LC filter lengthens the voltage rise time to the motor, and reduces the peak voltage and ripple current at the motor. Depending upon the application, motor, and the length of motor leads, an LC filter may be desirable.

Motor Noise

High frequency pulsing of the drive output section can cause noise in the motor. The design of the motor determines the amount of noise. Changing the carrier frequency of the drive, by adjusting the switching frequency, may quiet a noisy motor. If this is not adequate, an LC filter may be connected. Although the noise at the motor will be reduced, there is some noise from the LC filter. Be sure that the filter is located so that its sound is not objectionable.

Motor Stress

The output of any adjustable frequency drive creates stress on the motor. The VLT 6000 controls this stress through “soft switching” IGBTs on the smaller drives and output reactors on the largest drives. However, it is still desirable to use motors designed for use with an adjustable frequency drive. Some motors, especially smaller ones, may lack phase insulation paper and other important features. Ideally, a motor should meet the specifications of NEMA MG-1, part 31.

It may be desirable to specify an LC filter for use in conjunction with motors unable to meet these standards, long motor leads, or multiple motors.

Motor Lead Length

Long motor leads can produce high peak voltages at the motor, contributing to motor stress. This should be avoided. If it is not possible to avoid long motor leads, a motor which meets NEMA MG-1, part 31, and an LC filter should be used.

In addition, if the motor lead length is longer than 500 feet (150 m), an LC filter should always be used. For multiple motor installations, the length of all the motor leads must be added. The LC filter is necessary to reduce the capacitive earth leakage currents as well as the peak voltage at the motor. If the LC filter is not used, the drive may overcurrent or ground fault trip.

CE Label

In addition to being UL and C-UL labeled, all 208 V and 460 V VLT 6000 drives are CE labeled. The CE label was introduced to show that a product complies to relevant European Economic Union directives. For AC drives, there are three directives: Machine Directive (89/392/EEC), Low Voltage Directive (73/23/EEC), and the EMC Directive (89/336/EEC). The EMC directive covers electromagnetic compatibility. The directive states that, when properly installed, the product will not interfere with other devices as defined in the directive. All VLT 6000 208 V and 460 V drives comply with all three directives. A declaration of conformity can be issued, if requested.

Fault, Warning and Alarm Responses: Additional Selectable Options

The Danfoss VLT 6000 arrives pre-programmed with various fault, warning and alarm responses. Additional alarm and warning features can be easily selected to enhance, modify or optimize system performance.

No Load/Broken Belt Warning

This feature can be used for monitoring the V-belt of a fan. After a low current limit has been stored in the drive, the drive can be programmed to trip and issue an alarm or to continue operation and issue a warning if loss of the load is detected.

Operation at Overtemperature

By default, the drive will issue an alarm and trip at overtemperature. If Autoderate and Warning is selected, the drive will warn of the condition but continue to run and attempt to cool itself by first reducing its carrier frequency. Then, if necessary, it will reduce its output frequency.

High and Low Reference Warning

In open loop operation, the reference signal directly determines the speed of the drive. The display shows a flashing reference high or low warning when the programmed maximum or minimum is reached.

High and Low Feedback Warning

In closed loop operation, the selected high and low feedback values are monitored by the drive. The display shows a flashing high or flashing low warning when appropriate. The drive can also monitor feedback signals in open loop operation. While the signals will not affect the operation of the drive in open loop, they can be useful for system status indication or as data supplied to a serial network. The drive handles 39 different units of measure for system flexibility.

Phase Imbalance or Phase Loss

Excessive ripple current in the DC bus indicates either an input power phase imbalance or phase loss. When an incoming power phase to the drive is lost, the default is to issue an alarm and trip the drive to protect the DC bus capacitors. Other options are to warn and reduce output current to 30% of full current or to continue normal operation and issue a warning of lost input phase. While operating a drive connected to a severely imbalanced line may be desirable until the imbalance is corrected, depending upon which input phase is low or missing, the cooling fans on NEMA 12 drives may not operate. An external power supply for the fans can be provided.

High Frequency Warning

Useful in staging on additional equipment such as pumps or cooling fans, the drive can warn when the motor speed is high. A specific high frequency setting can be entered into the drive. If the drive's output exceeds the set warning frequency, the drive displays a high frequency warning. A digital output from the drive can be made to signal external devices to stage on.

Low Frequency Warning

Useful in staging off equipment, the drive can warn when the motor speed is low. A specific low frequency setting can be selected for warning and to stage off external devices. The drive will not issue a low frequency warning when it is stopped nor upon start-up until after the set frequency has been reached.

High Current Warning

This function is similar to high frequency warning (see above), except a high current setting is used to issue a warning and stage on additional equipment. The drive will not issue a false warning during start-up due to a high starting current, since the function is not active until the set current has been reached.

Low Current Warning

This function is similar to low frequency warning (see above), except a low current setting is used to issue a warning and stage off equipment. The drive will not issue a low current warning when stopped nor upon start-up until after the set current has been reached.

Lost Serial Interface

The drive can detect loss of serial communication when under control of a serial bus. A time delay of up to 99 seconds is selectable to avoid a drive response due to interruptions on the serial communications bus. When the delay is exceeded, options available in response to lost serial communication are for the drive to maintain its last speed, go to maximum speed, go to a preset speed, stop, or stop and issue a warning.

Additional Drive Features

The VLT 6000 drive allows for additional customization of the internal drive control values for precise command of the drive setpoints, feedback and references. Settings can be modified for exact performance using simple data entry procedures. A reset command reestablishes factory default settings in an instant for reliable drive operation.

Inputs

- 8 programmable digital inputs
- 3 programmable analog inputs (two voltage, one current)

Digital input terminals offer 24 separate programmable on/off functions such as start, safety interlock, 4 preset references, 4 setup selections, reset, reverse, run permissive, hand or auto start and more. Analog inputs allow drive control through feedback or reference signals. Analog inputs are in voltages from 0 to 10 VDC and current from 0 to 20 mA with minimum and maximum signal levels programmable.

Outputs

- 2 programmable analog/digital outputs (4-20 mA and 0-20 mA)
- 2 programmable relay outputs (1 Form C, 240 VAC, 2 A and 1 Form A, 30 VAC, 1 A) - with four additional relays optional

Digital relay outputs present the drive status and warnings. Some 30 functions can be programmed including warning of operation out of current or frequency range, input phase imbalance, and thermal warning, or operational status such as ready, waiting for start, start, running and many others. The analog/digital outputs can be programmed for any of the relay options and, in addition, display output frequency, current or power, and external reference and feedback values. All inputs and outputs are capable of serial network communications.

Adjustable Speed Range

From minimum speed setting, or 0 Hz setting, to 120 Hz or to 1,000 Hz for motor speed adjustment.

Adjustable Acceleration and Deceleration Time

Select from 1 to 3,600 seconds to accurately regulate motor acceleration and deceleration times. The drive can respond quickly for fast acting systems, such as with pumps, or over an extended time period to minimize mechanical stress, as in cooling towers. Auto ramping, described earlier, is another option based upon motor current demand.

Preset Speeds

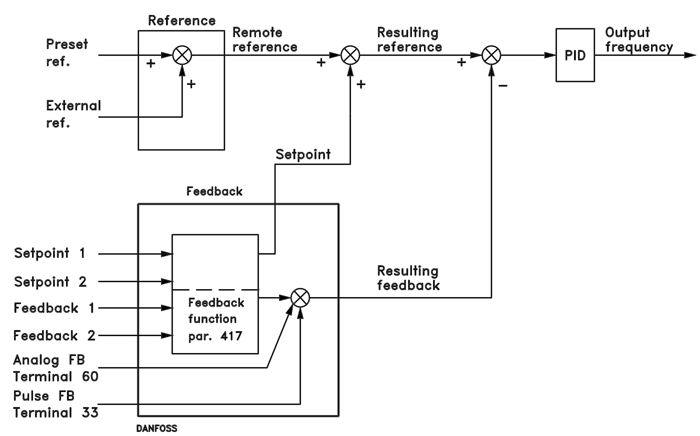
Flexible operation programming with 16 preset speeds. Also, the drive has four preset jog frequencies, one in each setup, to start the drive, in hand or auto mode, and run it at the preset jog frequency.

Setpoints and Feedback Signals

The built-in PID controller in the drive maintains the desired system condition (pressure, temperature, flow, etc.) in closed loop operation by adjusting motor speed based upon a setpoint and feedback signal.

A sensor supplies the PID controller with a feedback signal from the system to indicate its current state. The VLT 6000 offers 38 units of measure for the feedback signal for unequalled HVAC system flexibility. Feedback and setpoint values are programmed and displayed using the selected unit.

The difference between the setpoint and the feedback from the system is calculated. The PID controller then adjusts the motor's speed to satisfy the system requirements. The PID controller's setpoint can be programmed into the drive, provided by an external signal, or be the sum of both. (See the figure below.)



Only the VLT 6000 accepts two feedback signals and two setpoints, making two-zone regulation possible. In addition, voltage drop in long control cables can be compensated for by using scaling parameters for the analog inputs.

Other programmable drive features include *inverse regulation* which means motor speed will decrease when a feedback signal is high, a pre-selected *start-up frequency* which lets the system quickly reach an operating status before the PID controller takes over, and a *built-in lowpass filter* to reduce feedback signal noise.

Cascade Controller Option Card

Cascade Controller

With the cascade controller option card, the VLT 6000 can automatically control up to five pump or fan motors. Staging motors on or off can be done cyclically, in accordance with operating hours. This function assures equal use over time and eliminates concern about starting a seldom used motor. The cascade controller includes four form C, 250V, 2A relays. The controller option card installs in the VLT 6000 control card cassette and can be ordered factory installed. The cascade controller is effective in HVAC water distribution and pressure booster systems, secondary water pump installations, and for multiple-cell cooling tower fan control.

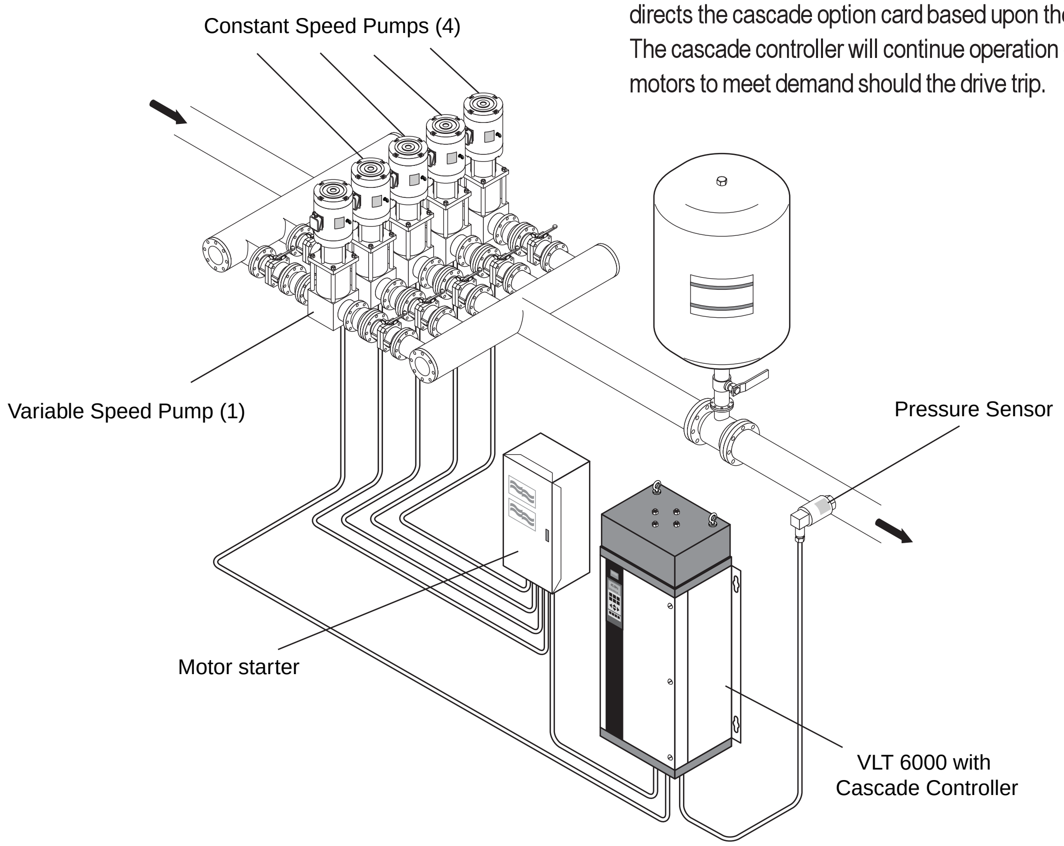
Feedback Signals

An important advantage to the cascade controller option is that it is based upon the VLT 6000's advanced PID controller. This means that programming is done in selected units of measurement appropriate to the application and that the feedback and setpoints can be displayed. Unlike drives that base staging upon frequency, feedback allows precise control in response to actual system demand. The VLT 6000's PID controller accommodates two feedback signals and two setpoints which allows regulating a system with different setpoint zones. The drive makes control decisions by comparing the two signals to optimize system performance.

In pumping applications, when a pressure feedback signal is not practicle, the feedback signal may be taken near the pump by measuring flow. When the flow rate is low, the pressure needed is low. At increased flow, the pumps need to provide greater pressure to compensate for the increased pressure drop in the piping. The setpoint should be adjusted to match the flow in these cases. While difficult to accomplish with standard PID controllers, the cascade controller provides an easy solution. By simply setting one setpoint for minimum flow and the other for maximum flow, the VLT 6000 calculates intermediate setpoints based on the flow required.

Standard Cascade Controller Mode

The cascade controller option has two modes of operation. In standard cascade control, an adjustable frequency drive with the cascade option card controls the speed of the first motor and is used to stage on and off additional constant speed motors (see figure below). By varying the speed of the initial motor, variable speed control is provided for the system. This maintains constant pressure while eliminating pressure surges, resulting in reduced system stress and quieter operation. The motors can be of equal or differing sizes. Selections allow the user to mix pumps of 100%, 200% and 300% capacity. The controller offers a selection of eight pre-defined pump combinations. This provides a dynamic capacity range, maximum to minimum, of 9:1. The VLT drive's internal PID controller directs the cascade option card based upon the feedback signal. The cascade controller will continue operation of the constant speed motors to meet demand should the drive trip.



Standard cascade control

Cascade Controller Option Card

Master Control Mode
The master control mode of operation provides maximum system efficiency. In master control (see figure below), each motor has its own adjustable frequency drive which responds to control from a master drive containing the cascade option card. The master drive sends a pulse speed reference signal to the drives under control to ensure that all operate at the same speed. The motors must be of equal size. Sequential staging of drives on or off is provided by the master drive in response to system feedback, maintaining precise setpoint control. Pressure surge and water hammer are eliminated. A free Danfoss software program is available which calculates points for the "best efficiency staging" of motors, for example, three motors providing flow at reduced speed rather than two at full speed. This often results in 10% to 15% additional savings over similar control schemes. In some applications, it may be advisable for a second drive with a cascade card to act as an auxiliary controller.

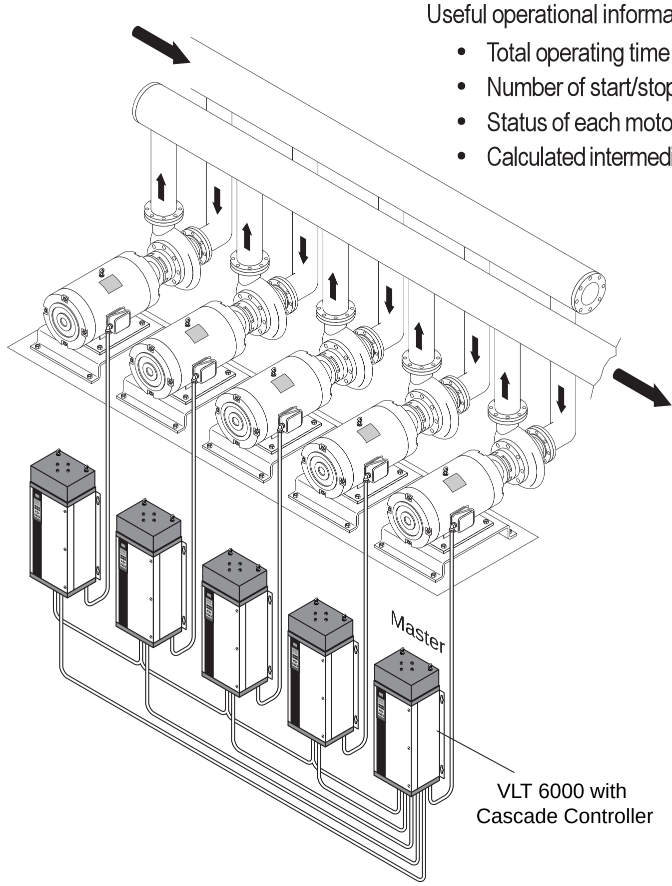
Ease of Programming
For improved convenience, an expanded Quick Menu guides the user through the parameter options to initialize the drive and to enter cascade card and PID control settings. Combined with customized factory settings, this reduces the time and expense for commissioning. Application "know how" is built into the controller.

De-stage Timer
The de-stage timer takes effect in standard control when the drive runs continuously at minimum speed with one or more constant speed motors running. Since a variable speed pump at minimum speed adds no or very limited flow to the system, it is advisable to stop a constant speed motor and allow the drive to provide the required flow. The de-stage timer is programmable to avoid frequent staging of the constant speed motors. When the master drive is the only one running, the drive's sleep mode can discontinue system operation when not needed while staying ready to start on demand. Variable speed control with fixed speed motors optimizes energy consumption and avoids "cooking" a pump running at near no flow condition.

Stop Function
The stop function acts as a monitor of the feedback signal and stops motors immediately or through a sequenced stop. Multiple stop functions are selectable. The sequenced stop powers down fans or pumps in the opposite order as staged on. Selecting a delayed sequence option delays one ramp time between each staged shut down.

Operational Information
Useful operational information is available for display to the user.

- Total operating time for each motor.
- Number of start/stop cycles is for each motor.
- Status of each motor's run or stop command.
- Calculated intermediate setpoints.



Master control

Local Control and Network Communications

The Danfoss VLT 6000 is designed for ease of operation with both local or network control in mind. Each drive comes with an easy to read and easy to use local control panel for data entry, selecting options, and display. The drive is also network ready with three serial communication protocols built-in as a standard feature. Easy to install card options are available for others.

Local Control Panel:

Display

Bright LCD with easy to read alphanumeric display. Four lines of display, each programmable, are available.

Display shows status of drive, input signals and drive settings. Fault status and history data is also available for troubleshooting.

At a glance, user can see drive frequency, current, kW output, kWh output or any selected four of twenty-six possible displays.

Process variables including °F, °C, %, HP, Pa, bar, RPM, in wg, gal/sec/min/hr, ft³/sec/min/hr, PSI, pulse/sec, kW, and others.

Easy Multiple Drive Programming

All drive parameters can be downloaded from the removable display keypad. One programmed keypad can be used to quickly program other drives. Also, parameters can be uploaded from drive to keypad. All keypads are identical, interchangeable and easy to remove.

Removable Control Panels

Drive can be operated with keypad removed to assure tamper-proof operation. Drive status ON, WARNING, and ALARM lights show even with keypad removed.

Easy Control Panel Remote Mounting

Keypad can be remotely mounted up to 10 feet from drive using a standard 9-pin cable. Remote mounting kit contains a gasket and mounting bracket for remote keypad NEMA 12 rating.

Display Languages

English, Spanish, French, German, Italian, Portuguese, Swedish, Dutch or Danish languages are selectable for information display.

Keypad Controls

Includes: Hand/Start, Off/Stop, Auto/Start, and fault Reset keys.

Plain Language Alarms and Warnings

Alarms and warnings displayed on the LCP are in plain language, with no difficult to understand codes or lookup tables needed for interpretation.

Serial Communications:

RS-485 Interface

Fully equipped for serial communication. Up to 31 drives can be connected to one serial bus as much as 5,000 feet long. With an optional repeater, additional drives can be accommodated.

Built-in N2 and FLN Communication

Fully equipped communication protocols for Johnson Controls Metasys® N2 and Siemens FLN® are built-in and ready at start-up.

PC Communication

Exclusive VLT Software Dialog allows direct communication with up to 126 VLT drives. All parameters can be changed, stored, saved to disk and printed. Desired configurations can be uploaded from drive to computer and downloaded to other drives. Drive performance can be logged for analysis.

Option cards

Easy to install option card for Modbus, Echelon LonWorks® or Profibus®.

Operational and Service Data

From time to time, precise information on the overall performance of the system is needed. This is easy to access. Since the drive performs automated, hands-off system control, cumulative data helps to realize energy savings, analyze operations and retrieve fault histories for ease of maintenance and troubleshooting.

Operational Data
Operating hours
Hours run
kWh counter
Number of power-ups
Number of overtemperature trips
Number of overvoltage trips

Data Log
Digital input
Bus command
Bus status word
Reference
Feedback
Output frequency
Output voltage
Output current
DC link voltage

Fault Log
Error code
Time
Value

Reset
kWh counter
Hours run counter

Operating Mode
Normal operation
Function with deactivated inverter
Control card test
Initialization

Nameplate
Contains eleven drive name and identification numbers for display.

Additional Features and Options

The Danfoss VLT 6000 has many additional features specifically designed for HVAC applications making it the drive of choice.

Options

- Input AC line reactors
- EMI input filter
- Output LC filter
- Pressure-to-electrical transducer
- Bypass control, manual or automatic
- Motor selection
- Multiple motor operation, including individual motor overloads
- Drive disconnect switch
- Input fuses or circuit breakers
- NEMA 12, NEMA 3R and other enclosures
- Floor stand kit
- Factory-authorized start-up
- LonWorks communications
- One or four additional Form C programmable relays

Standard Service Conditions

- Drive and options enclosure: NEMA Type 1 for clean, dry, indoor applications
- Ambient operating temperature range: 14°F to 104°F (-10°C to 40°C)
- Humidity: <95%, non-condensing
- Maximum elevation without derate: 3,300 ft. (1,000 m)
- UL listed for internal plenum mounting
- Approved for shipboard use

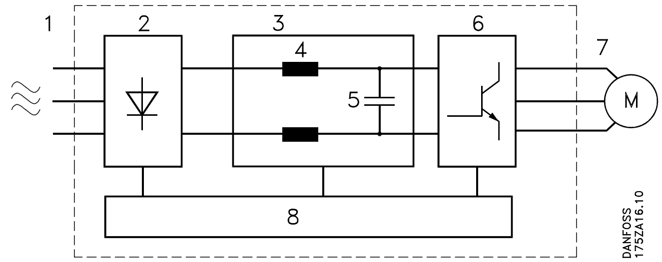
Standards

- UL 508
- C-UL
- UL Panel Shop
- CE compliance
- All drives and bypass panels are built to ISO 9001 standards
- Danfoss and Danfoss Graham meet ISO 14001 environmental standards

VLT 6000 Control Principle

An adjustable frequency drive rectifies AC voltage from the AC line into DC and then inverts this into an AC voltage with controlled voltage and frequency.

The standard, three-phase, asynchronous induction motor is then supplied with variable voltage and frequency power, allowing continuously variable motor speed. The main components of the VLT 6000 Adjustable Frequency Drive are shown to the right and described below.



1. AC Line Supply

Three series of drives allow operation at all commercial three-phase voltages from 200 to 600 volts AC.

200 to 240 VAC, 50 / 60 Hz
380 to 460 VAC, 50 / 60 Hz
550 to 600 VAC, 50 / 60 Hz

2. Rectifier

A three-phase rectifier bridge that rectifies AC into DC current.

3. Intermediate DC Circuit

DC voltage ≅ ¸ x AC RMS voltage.

4. DC Link Reactors

- Filter the intermediate DC circuit voltage.
- Provide protection against line transients.
- Reduce input RMS current.
- Raise power factor reflected back to the line.
- Reduce harmonics on the AC input.

5. DC Capacitor Bank

Smooths the DC bus voltage and provides stored energy which can be used to "ride through" short power losses.

6. Inverter

Converts DC voltage into controlled AC voltage with a variable frequency.

7. Output Current Sensors

Continuously monitors motor current in all three phases to ensure reliable and efficient motor operation under all conditions.

8. Output to the Motor

Variable voltage and frequency AC output.

Frequency range: to 60 Hz or beyond
Voltage range: to 100% of supply voltage

By controlling voltage and frequency together, the connected motor can operate the centrifugal fan or pump over a controlled speed range at the highest possible efficiency.

Voltage Vector Control Plus

The unique Voltage Vector Control, introduced with the VLT 3500, has been further developed into Voltage Vector Control Plus (VVC^+). VVC^+ provides a nearly sinusoidal output current waveform. This provides optimum motor magnetization. There is never a need to derate the motor for full speed, full load applications. For variable torque applications, there is never a need to derate the motor for any operational speed. The maximum output voltage of the VLT 6000 drive at full speed and load can be equal to the input voltage. Its exact value is not dependent on the line or the DC bus voltage. Instead, it will precisely equal the user defined output voltage established during setup. Even if the input line is up to 10% below the desired output voltage, the desired output voltage will be maintained.

In addition to monitoring and controlling the frequency and the voltage, VVC^+ continuously measures the magnitude and phase angle of the current in all three motor phases. The actual voltage requirement of the motor and the slip at the present load are calculated from a motor model. Automatic Motor Adaptation helps create an accurate motor model. The VVC^+ control then adjusts the output frequency and voltage to exactly meet the motor's needs. This optimizes the motor operation over a broad range of speeds and loads.

There is no need to choose a V/Hz curve to approximate the load demands on the motor. VVC^+ does this automatically and continuously. VVC^+ determines both the current required for torque generation and the current required for magnetizing the motor. This allows an accurate representation of the motor and its load.

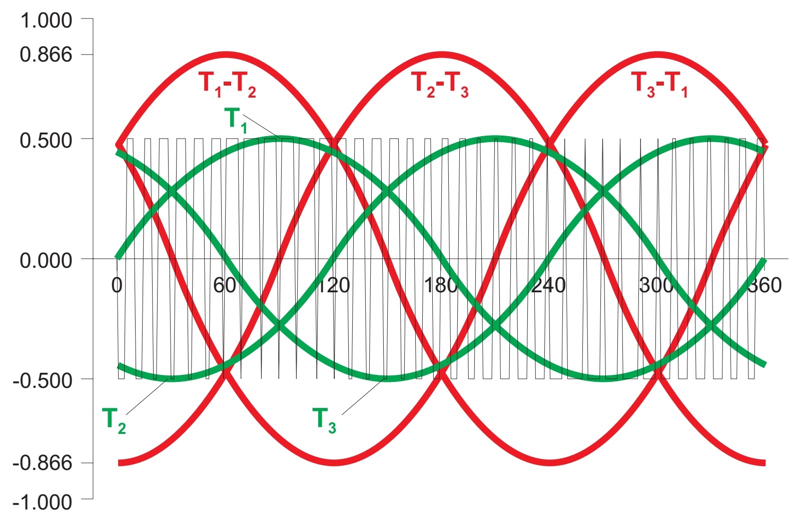
Voltage Vector Control Plus

The control scheme of the VLT 6000 uses the VVC$^+$ algorithm. VVC$^+$ is superior to traditional PWM control schemes in the following ways:

- Full rated motor voltage is provided at rated frequency.
- Full rated motor load can be produced at full speed.
- Motor current is continuously monitored in all three phases.
- The actual voltage and current requirements of the motor are continuously modeled.
- Working in conjunction with AMA, the ideal voltage level is always provided, maximizing performance and efficiency while minimizing heating.
- The output current wave shape is an almost perfect sine wave.
- Automatically chooses the ideal inverter switching pattern for the operating conditions.
  - The low speed switching pattern ensures reliable starts and smooth low speed operation.
  - The high speed switching pattern minimizes switching losses and maximizes drive efficiency.

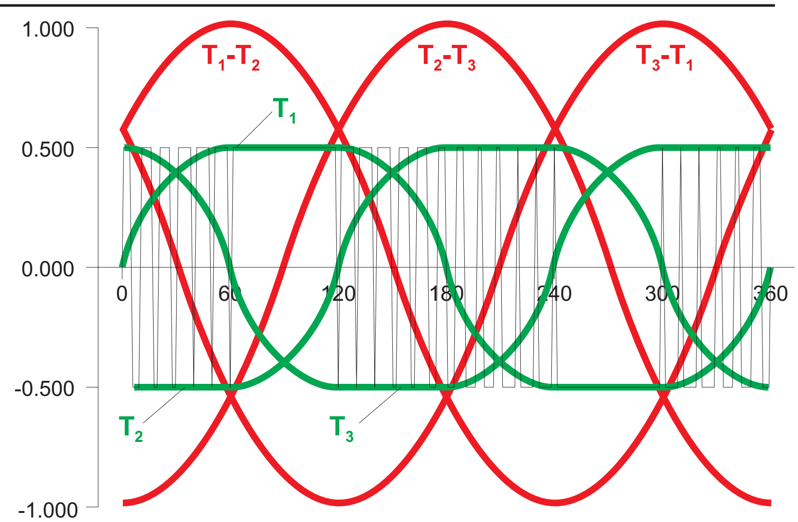
Stator Flux Asynchronous Vector Modulation (SFVM) for Low Speed Performance

Continuously pulsing all six inverter IGBTs to simulate the required output sine wave is ideal for low speed operation. It ensures smooth motor operation and allows the drive to meet the demanding requirements of starting high friction or high inertia loads. However, this switching pattern is not suited for high speed operation. Continuously pulsing all six inverter IGTBs causes excessive inverter switching losses, increased heat generation, and reduced drive efficiency. In addition, if a pure sine wave template is followed for each line-to-neutral voltage, the maximum output voltage is limited to 87% of the input voltage. This makes it impossible to produce rated motor power without exceeding rated motor current. To obtain higher full speed voltages, some conventional PWM drives add third and fifth harmonics to their reference AC wave. While this can increase the output voltage somewhat, the resulting motor harmonic currents cause additional motor heating. In either case, conventional PWM waveforms use the motor's service factor in order to produce rated output from the motor. This reduces motor life.



60 Degree Asynchronous Vector Modulation (60∞ AVM) for High Speed Efficiency and Full Motor Output

As a result of the high speed limitations of SFVM, the VLT 6000 automatically changes its switching pattern above an output frequency of approximately 19 Hz. Above this speed, the 32-bit microprocessor control holds each IGBT on for 60° of the full cycle and off for another 60° of the full cycle. By doing no switching in each inverter IGBT during 120° of each output cycle, the VLT 6000 minimizes switching losses. In addition, this unique switching pattern allows the drive to provide the motor with full rated voltage without injecting harmonics into the motor. This allows the motor to produce full rated torque at full speed without creating excessive motor heating.



GENERAL TECHNICAL DATA

Input

Voltage 200-240 V units .... 3 phase, 200/208/220/230/240 V ±10%
Voltage 380-460 V units .... 3 phase, 380/400/415/440/460 V ±10%
Voltage 550-600 V units .... 3 phase, 550/600 V ±10%
Frequency .... 50/60 Hz, ±1 Hz
Max. imbalance of supply voltage .... ±3% of rated supply voltage
Power factor / cos φ .... approx. 0.90/1.0 at rated load
Maximum number of switches on supply input L1, L2, L3 .... approx. 1/min.
Maximum short-circuit current rating of the power line .... 100,000 A

Output

Voltage .... 0 to 100% of supply voltage
Frequency .... 0 to 120 Hz, 0 to 1000 Hz
Rated motor voltage, 200-240 V units .... 200/208/220/230/240 V
Rated motor voltage, 380-460 V units .... 380/400/415/440/460 V
Rated motor voltage, 550-575 V units .... 550/575 V
Rated motor frequency .... 50/60 Hz
Switching on output .... unlimited
Acceleration and deceleration times (independently adjustable) .... 1 to 3,600 sec.

Torque Characteristics

Starting torque (parameter 110 set at *"High break-away torque"*) .... Max. torque: 160% for 0.5 sec.
Acceleration torque 100%
Overload torque 110%

Control Card — Digital Inputs

Number of programmable digital inputs 8
Terminal numbers. 16, 17, 18, 19, 27, 29, 32, 33
Common terminal number 20
Voltage level, logical ´0´ .... < 5 VDC
Voltage level, logical ´1´ .... > 10 VDC
Maximum voltage on input .... 28 VDC
Input resistance .... approx. 2 kΩ
Scanning time per input .... 3 msec.

Reliable galvanic isolation: All digital inputs are galvanically isolated from the supply voltage (PELV). In addition, the digital inputs can be isolated from the other terminals on the control card by connecting an external 24 VDC supply and opening switch 4.

GENERAL TECHNICAL DATA

Control Card — Analog Inputs

Number of programmable analog voltage and thermistor inputs 2
Terminal numbers. 53, 54
Common terminal number 55
Voltage range .... 0 to 10 VDC (scalable)
Input resistance .... approx. 10 kΩ
Number of programmable analog current inputs 1
Terminal number 60
Current range .... 0 or 4 to 20 mA (scalable)
Input resistance, R_i .... approx. 200 Ω
Resolution .... 10 bit + sign
Accuracy on input .... Max. error: 1% of full scale
Scanning time per input .... 3 msec.
Reliable galvanic isolation: All analog inputs are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

Control Card — Pulse Inputs

Number of programmable pulse inputs 3
Terminal numbers 17, 29, 33
Common terminal number 20
Maximum frequency on terminal 17 .... 5 kHz
Maximum frequency on terminals 29, 33 .... 20 kHz
Voltage level, logic ‘0’ .... < 5 VDC
Voltage level, logic ‘1’ .... > 10 VDC
Maximum voltage on input .... 28 VDC
Input resistance .... approx. 2k Ω
Scanning time per input .... 3 msec.
Resolution .... 10 bit + sign
Accuracy (100 Hz to 1 kHz), terminals 17, 29, 33 .... Max. error: 0.5% of full scale
Accuracy (1 to 5 kHz), terminal 17 .... Max. error: 0.1% of full scale
Accuracy (1 to 65 kHz), terminals 29, 33 .... Max. error: 0.1% of full scale
Reliable galvanic isolation: All digital and pulse inputs are galvanically isolated from the supply voltage (PELV). In addition, pulse inputs can be isolated from the other terminals on the control card by connecting an external 24 VDC supply and opening switch 4.

Control Card — Digital/Pulse and Analog Solid State Outputs

Number of programmable digital and analog solid state outputs 2
Terminal numbers 42, 45
Common terminal number 39
Voltage level at digital/pulse output .... 0 - 24 VDC
Minimum connected impedance at digital/pulse output (terminal 39) .... 600 Ω
Frequency ranges (digital output used as pulse output) .... 0 to 32 kHz
Current range at analog output .... 0 or 4 to 20 mA
Maximum connected impedance at analog output (terminal 39) .... 500 Ω
Accuracy of analog output .... Max. error: 1.5% of full scale
Resolution on analog output. .... 8 bit
Reliable galvanic isolation: All digital and analog outputs are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals. They share electrical common with the digital and pulse inputs if switch 4 is closed.

GENERAL TECHNICAL DATA

Control Card — 24 VDC Supply

Terminal numbers 12, 13
Common terminal number .... 39, (also 20, when switch 4 is closed)
Maximum load .... 200 mA

Reliable galvanic isolation: The 24 VDC supply is galvanically isolated from the supply voltage (PELV), but has the same electrical common as the analog outputs. It also shares electrical common with the digital and pulse inputs when switch 4 is closed.

Control Card — RS-485 Serial Communication

Terminal numbers .... 68 (TX+, RX+), 69 (TX-, RX-)

Reliable galvanic isolation: Full galvanic isolation (PELV).

Relay Outputs

Number of programmable relay outputs 2
Terminal numbers, control card .... Form A 4-5 (normally open)
Maximum terminal load on 4-5, control card for UL/C-UL applications .... 30 VAC, 1 A; 42.5 VDC, 1 A
Terminal numbers, power card and relay card .... Form C 1-3 (normally closed), 1-2 (normally open)
Maximum terminal load (AC) on 1-3, 1-2, power card and relay card .... 240 VAC, 2 A
Minimum terminal load on 1-3, 1-2, power card and relay card .... 24 VDC, 10 mA; 24 VAC, 100 mA

Cable Lengths and Cross Sections

Maximum motor cable length, conductive cable .... 500 ft. (150 m)
Maximum motor cable length, non-conductive cable .... 1,000 ft. (300 m)
Maximum motor cable length, conductive cable VLT 6011 (10 HP) 380-460 V .... 330 ft. (100 m)
Maximum motor cable length, conductive cable VLT 6011 (10 HP) 550-600 V .... 165 ft. (50 m)
Maximum DC bus cable length, screened/armored cable .... 80 ft. (25 m) from drive to DC supply
Maximum cable cross-section to motor .... *See drive specifications in Specifications section*
Maximum control wire size .... 16 AWG (1.5 mm^2)
Maximum serial communication wire size .... 16 AWG (1.5 mm^2)

Control Characteristics

Frequency range .... 0 to 1000 Hz
Resolution of output frequency .... ±0.003 Hz
System response time .... 3 msec.
Speed, control range (open loop) .... 1:100 of synchro. speed

Accuracy of Display Readout (parameters 009 to 012, *Display Readout*)

Motor current, 0 to 140% load .... Max. error: ±2.0% of rated output current
Power kW, power HP, 0 to 90% load .... Max. error: ±5.0% of rated output power

NOTE: ALL CONTROL CHARACTERISTICS ARE BASED ON A **4**-POLE ASYNCHRONOUS MOTOR.

GENERAL TECHNICAL DATA

Externals

Vibration test .... 0.7 g RMS 18 to 1000 Hz random, 3 directions for 2 hours (IEC 68-2-34/35/36)
Maximum relative humidity .... 95% noncondencing
Ambient temperature .... Max. 113°F (45°C) [24-hour average maximum 104°F (40°C)]
Ambient temperature 10 HP 460 V .... Max. 104°F (40°C) [24-hour average maximum 95°F (35°C)]
Derating for high ambient temperature .... *See Maximum Ambient Temperatures and Derates*
Minimum ambient temperature in full operation .... 32°F (0°C)
Minimum ambient temperature at reduced performance .... 14°F (-10°C)
Temperature during storage/transport .... -13°F to 149/158°F (-25 to 65/70°C)
Maximum altitude above sea level without derating .... 3,300 ft (1,000 m)
Derating for altitude .... *See Derate at High Altitude*
*EMC standards applied, Emission: .... EN 50081-1/2, EN 61800-3, EN 55011, EN 55014
Immunity: .... EN 50082-2, EN 61000-4-2, IEC 1000-4-3, EN 61000-4-4
EN 61000-4-5, ENV 50204, EN 61000-4-6, VDE 0160/1990.12

*600 V units do not comply with PELV, EMC or Low Voltage Directives.

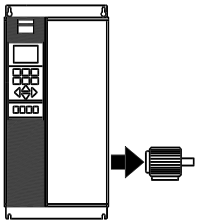
Protection

- Electronic motor thermal protection against overload.
- Temperature monitoring of heatsink ensures that the drive trips off at 194°F (90°C) for NEMA 1. For NEMA 12, the trip temperature is 176°F (80°C). An overtemperature can only be reset when the temperature of the heatsink has fallen below 140°F (60°C).
- The drive is protected against short circuits on the motor terminals.
- The drive is protected against ground fault on the motor terminals.
- Monitoring the DC bus voltage ensures that the drive trips off when the voltage becomes either too high or too low.
- If a motor phase is missing, the drive will fault to protect the motor and show a which phase is missing.
- If there is a significant input phase imbalance, the drive may be able to operate at 30% of rated output current. This requires software version 2.0 or higher.

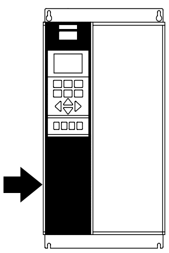
Danfoss

SPECIFICATIONS

Input ó 3 phase, 200 to 240 V

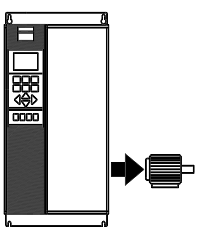


208 Volt Model Number		VLT6002	6003	6004	6006	6008	6011
Output current,[1] continuous	amps	6.6	7.5	10.6	16.7	24.2	30.8
Maximum 60 sec.	amps	7.3	8.3	11.7	18.4	26.6	33.9
Output (240 V)	kVA	2.7	3.1	4.4	6.9	10.1	12.8
Typical shaft output	HP	1.5	2	3	5	7.5	10
Maximum wire size to motor and DC-bus[2]	AWG	10	10	10	10	6	6

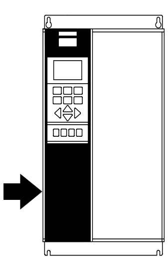


Maximum rms input current, continuous	amps	6.0	7.0	10.0	16.0	23.0	30.0
Maximum wire size	AWG	10	10	10	10	6	6
Maximum input fuses	UL[3] amps	10	20	25	50	50	50
Efficiency[4]	%	95%					
Weight, NEMA 1	lbs	15	15	20	51	51	51
Weight, NEMA 12	lbs	25	25	30	77	77	84
Power loss at maximum load	W	76	95	126	194	426	545

Input ó 3 phase, 200 to 240 V



208 Volt Model Number		VLT6016	6022	6027	6032	6042	6052	6062
Output current,[1] continuous	amps	46.2	59.4	74.8	88.0	114	143	169
Maximum 60 sec.	amps	50.6	65.3	82.3	96.8	125	157	186
Output (240 V)	kVA	19.1	24.7	31.1	36.6	41.0	52	61
Typical shaft output	HP	15	20	25	30	40	50	60
Maximum wire size to motor and DC-bus	AWG	6	2	2	0	1/0	3/0	4/0
Minimum wire cross-section to motor and DC-bus[2]	AWG	8	8	8	6	8	8	8

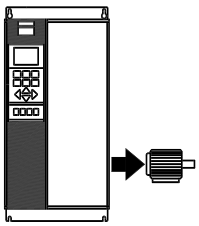


Max. input current (208 V), continuous	amps	46.0	59.2	74.8	88.0	101.3	126.6	149.9
Maximum wire size	AWG	6	2	2	0	1/0	3/0	4/0
Maximum input fuses	UL[3] A	60	80	125	125	150	200	250
Efficiency[4]	%	95%						
Weight, NEMA 1	lbs	51	66	66	106	222	222	222
Weight, NEMA 12	lbs	84	108	110	121	229	229	229
Power loss at maximum load	W	545	783	1042	1243	1089	1361	1613

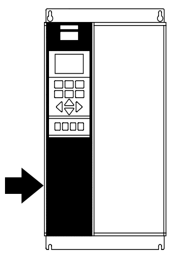
1. Current ratings fulfill UL requirements for 208 to 240 V.
2. Minimum wire size is the smallest gage that should be used with the drive's terminals. Always follow all national and local codes.
3. To meet UL/C-UL requirements, Bussmann KTN-R, JJN or similar input fuses must be used. Use FWX or FWH for 150 amps or higher. Ferraz-Shawmut type ATMR, class CC, may be used for 30 amps or less.
4. Measured using 100 feet (30 m) shielded motor cable at rated load and rated frequency.

SPECIFICATIONS

Input ó 3 phase, 380 to 460 V

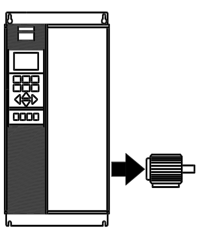


460 Volt Model Number		VLT6002	6002	6003	6004	6006	6008	6011
Output Current[1], 440 to 460 V Continuous	amps	3.0	3.0	3.4	4.8	8.2	11.0	14.0
Maximum 60 sec.	amps	3.3	3.3	3.7	5.3	9.0	12.1	15.4
Output, 440 to 460 V	kVA	2.4	2.4	2.7	3.8	6.5	8.8	11.2
Typical shaft output	HP	1.5	1.5	2	3	5	7.5	10
Maximum cable size to motor[2]	AWG	10	10	10	10	10	10	10

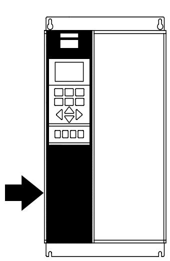


Maximum input current, 460 V	A	2.5	2.5	3.4	4.8	8.3	10.6	14.0
Maximum wire size[2]	AWG	10	10	10	10	10	10	10
Maximum input fuses	UL[3] A	6	6	10	10	20	25	30
Efficiency[4]	%	- - -	- - -	- - -	96%	- - -	- - -	- - -
Weight NEMA 1	lbs/kg	18/8	18/8	18/8	19/8.5	23/10.5	23/10.5	23/10.5
Weight NEMA 12	lbs/kg	25/11.5	25/11.5	25/11.5	26/12	31/14	31/14	31/14
Power loss at maximum load	W	67	67	92	110	198	250	295

Input ó 3 phase, 380 to 460 V



460 Volt Model Number		VLT6016	6022	6027	6032	6042	6052	6062	6072
Output Current[1], 440 to 460 V Continuous	amps	21.0	27.0	34.0	40.0	52.0	65.0	77.0	106
Maximum 60 sec.	amps	23.1	29.7	37.4	44.0	57.2	71.5	84.7	117
Output, 440 to 460 V	kVA	16.7	21.5	27.1	31.9	41.4	51.8	61.3	84.5
Typical shaft output	HP	15	20	25	30	40	50	60	75
Maximum cable cross-section to motor and DC-bus	AWG	6	6	6	6	2	2	0	1/0
Minimum cable cross-section to motor and DC-bus[2]	AWG	8	8	8	8	8	8	6	8



Maximum input current, 460 V	A	21.0	27.6	34.0	41.0	53.0	64.0	77.0	103
Maximum wire size[2]	AWG	6	6	6	6	2	2	0	1/0
Maximum input fuses	UL[3] A	40	40	50	60	80	100	125	150
Efficiency[4]	%	- - -	- - -	- - -	96%	- - -	- - -	- - -	
Weight, NEMA 1	lbs	51	51	51	66	66	106	106	106
Weight, NEMA 12	lbs	106	106	106	112	134	147	154	154
Power loss at maximum load	W	419	559	655	768	1065	1275	1571	1851

1. Current ratings fulfill UL requirements for 460 V.
2. Minimum wire gage is the smallest size that should be used with the drive's terminals. Always comply with national and local regulations on minimum wire size.
3. To meet UL/C-UL requirements, Bussmann KTN-R, JJS or similar input fuses must be used. Ferraz-Shawmut type ATMR, class CC, may be used for 30 amps or less.
4. Measured using 100 feet (30 m) shielded motor cable at rated load and rated frequency.

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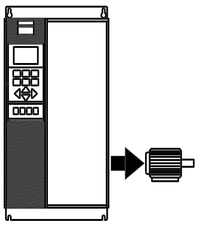
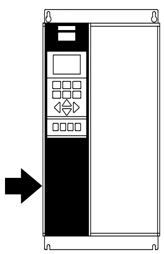
SPECIFICATIONS

Input ó 3 phase, 380 to 460 V

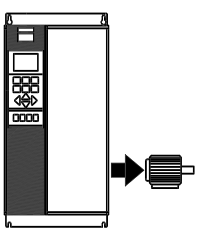


460 Volt Model Number		VLT6100	6125	6150	6175	6225	6275
Output current[1], 440 to 460 V, continuous	amps	130	160	190	240	302	361
Maximum, 60 sec.	amps	143	176	209	264	332	397
Output, 460 V	kVA	104	127	151	191	241	288
Typical shaft output 440 to 460 V	HP	100	125	150	200	250	300
Maximum wire size to motor and DC-bus (440-460 V)	AWG	2/0	3/0	2x1/0	2x1/0	2x3/0	2x4/0
Minimum wire size to motor and DC-bus[2]	AWG	8	8	8	8	6	6

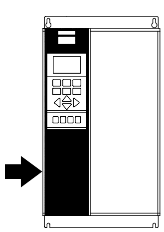


Maximum input current 440 to 460 V, continuous	amps	145	174	206	256	317	366
Maximum wire size to power 440-460 V	AWG	2/0	3/0	2x1/0	2x1/0	2x3/0	2x4/0
Minimum wire size to motor and DC-bus[2]	AWG	8	8	8	8	6	6
Maximum input fuses	UL[3] A	220	250	300	350	400	500
Weight NEMA 1	lbs	266	266	354	354	354	354
Weight NEMA 12	lbs	273	273	389	389	389	398
Efficiency[4]		96% to 97%					
Power loss at maximum load	W	1970	2380	2860	3810	4770	5720

Input ó 3 phase, 380 to 460 V



460 Volt Model Number		VLT6350	6400	6500	6550
Output current[1], 440 to 460 V, continuous	amps	443	540	590	678
Maximum, 60 sec.	amps	487	594	649	746
Output, 460 V	kVA	384	468	511	587
Typical shaft output 440 to 460 V	HP	350	450	500	600
Maximum wire size to motor and DC-bus (440-460 V)[2]	AWG	3x1/0	3x3/0	3x3/0	3x4/0

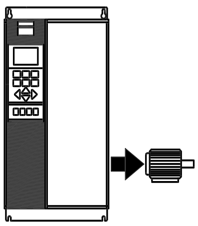


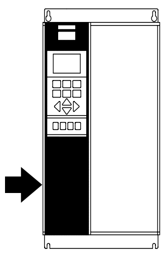
Maximum input current 440 to 460 V, continuous	amps	356	431	526	581
Maximum wire size to power 440-460 V[2]	AWG[2]	3x1/0	3x3/0	3x3/0	3x4/0
Maximum input fuses	UL[3] A	600	700	800	800
Weight, NEMA 1	lbs	1312	1389	1488	1543
Weight, NEMA 12	lbs	1334	1411	1510	1565
Efficiency[4]		97%			
Power loss at maximum load	W	7500	9450	10,650	12,000

1. Current ratings fulfill UL requirements for 460 V.
2. Minimum wire gage is the smallest size that should be used with the drive‘s terminals. Always comply with national and local regulations on minimum wire size.
3. To meet UL/C-UL requirements, Bussmann FHW or similar input fuses must be used.
4. Measured using 100 feet (30 m) shielded motor cable at rated load and rated frequency.

SPECIFICATIONS

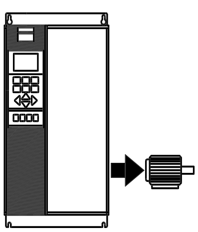
Input ó 3 phase, 600 V

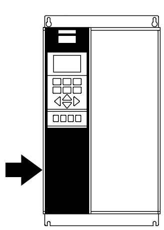




600 Volt Model Number			VLT6002	6003	6004	6005	6006	6008	6011
Output current[1], 575 V,	continuous	amps	2.4	2.7	3.9	4.9	6.1	9.0	11
	Maximum, 60 sec.	amps	2.6	3.0	4.3	5.4	6.7	9.9	12.1
Output, 575 V		KVA	2.4	2.7	3.9	4.9	6.0	8.9	10.9
Typical shaft output		HP	1½	2	3	4	5	7½	10
Maximum wire size to motor and DC-bus		AWG	10	10	10	10	10	10	10
Minimum wire size to motor and DC bus[2]		AWG	---	---	---	---	---	---	---
Maximum input current 600 V,	continuous	amps	2.2	2.5	3.6	4.6	5.7	8.4	10.3
Maximum wire size to power		AWG	10	10	10	10	10	10	10
Maximum input fuses		UL[3] A	3	4	5	6	8	10	15
Weight, NEMA 1		lbs	23	23	23	23	23	23	23
Efficiency[4]			- - - - - - - - - - - - - - 96% - - - - - - - - - - - - - -						
Power loss at maximum load		W	63	71	102	129	160	236	288

Input ó 3 phase, 600 V



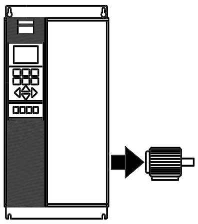


600 Volt Model Number			VLT6016	6022	6027	6032	6042	6052	6062	6072
Output current[1], 575 V,	continuous	amps	17	22	27	32	41	52	62	77
	Maximum, 60 sec.	amps	19	24	30	35	45	57	68	85
Output, 575 V		KVA	16.9	22	27	32	41	52	62	77
Typical shaft output		HP	15	20	25	30	40	50	60	75
Maximum wire size to motor and DC bus		AWG	6	6	6	2	2	1/0	1/0	1/0
Minimum wire size to motor and DC bus[2]		AWG	20	20	20	8	8	6	6	6
Maximum input current 600 V,	continuous	amps	16	21	25	30	38	49	58	72
Maximum wire size to power[2]		AWG[2]	6	6	6	2	2	1/0	1/0	1/0
Maximum input fuses		UL[3] A	20	30	35	45	60	75	90	100
Weight, NEMA 1		lbs	51	51	51	66	66	106	106	106
Efficiency[4]			- - - - - - - - - - - - - - 96% - - - - - - - - - - - - - -							
Power loss at maximum load		W	446	576	707	838	1074	1362	1624	2016

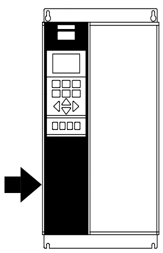
1. Current ratings fulfill C-UL requirements for 600 V.
2. Minimum wire gage is the smallest size that should be used with the drive's terminals. Always comply with national and local regulations on minimum wire size.
3. To meet UL/C-UL requirements, VLT6002 - 6072 use Bussmann KTS-R or JJS type or exact equivalent.
4. Measured using 100 feet (30 m) shielded motor cable at rated load and rated frequency.

SPECIFICATIONS

Input ó 3 phase, 600 V



600 Volt Model Number		VLT6100	6125	6150	6175	6225	6275
Output current[1], 575 V, continuous	amps	99	125	144	192	242	289
Maximum, 60 sec.	amps	109	138	158	211	266	318
Output, 575 V	KVA	99	124	143	191	241	288
Typical shaft output	HP	100	125	150	200	250	300
Maximum wire size to motor and DC-bus	AWG	4/0	4/0	4/0	2x4/0	2x4/0	2x4/0
Minimum wire size to motor and DC bus[2]	AWG	8	8	8	2x8	2x8	2x8

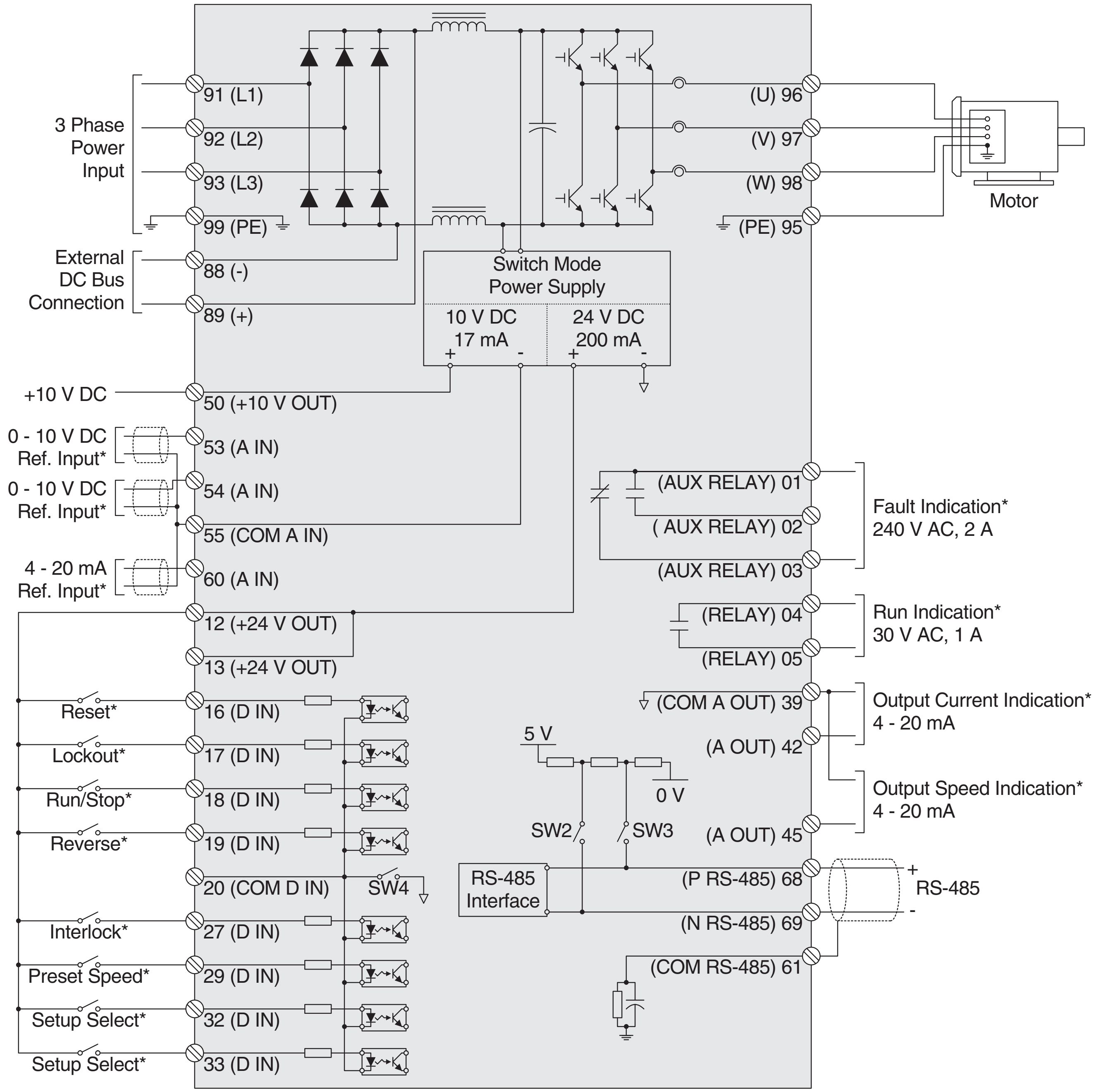


Maximum input current 600 V, continuous	amps	92	117	134	179	226	270
Maximum wire size to power	AWG	120	120	120	2x120	2x120	2x12
Maximum input fuses	UL[3] A	125	175	200	250	350	400
Weight, NEMA 1	lbs	267	267	267	355	355	355
Efficiency[4]		- - - - - - - - - - 96% to 97% - - - - - - - - - -					
Power loss at maximum load	W	2560	3275	3775	5030	6340	7570

1. Current ratings fulfill C-UL requirements for 600 V.
2. Minimum wire gage is the smallest size that should be used with the drive's terminals. Always comply with national and local regulations on minimum wire size.
3. To meet UL/C-UL requirements, VLT6100 - 6275 use FWP semi-conductor type or exact equivalent.
4. Measured using 100 feet (30 m) shielded motor cable at rated load and rated frequency.

Typical Control Connections

Shown below are typical interfaces between the VLT 6000 and other components in the HVAC system. The terminal numbers and the functions of the terminals are identical on all VLT 6000s. An optional relay card, not shown, can provide one or four additional Form C output relays. The RS-485 connections allow direct communication through built-in Johnson Controls Metasys® N2, Siemens System 600 FLN® protocol, or VLT Software Dialog®. Modbus, LonWorks® and Profibus® are available through option cards that fit into the relay output card location.



*The operation of all control inputs and outputs is programmable. Typical terminal functions are shown.

Typical VLT 6000 Wiring

Use with Isolated Input Source

Most utility power in the United States is referenced to earth ground. Although not in common use in the United States, the input power may be an isolated source. All VLT 6000 drives, except the VLT6011 (10 HP), may be used with isolated input source as well as with ground reference power lines.

Ground Leakage Current

It is normal for there to be some leakage current from the drive to earth ground. Paths of current leakage are shown on the drawing below. The leakage current will exceed 3.5 mA.

Calculation of Air Flow Required for Cooling the Drive

The air flow required to cool a drive, or multiple drives in one enclosure, can be calculated.

1. Determine power loss at maximum output for all drives from data tables in Specifications section.
2. Add power loss values of all drives that can operate at same time. Multiple total by 3.3.
3. Determine highest temperature of air that will enter enclosure. Subtract this temperature from 113°F.

> **NOTE:** MAXIMUM AIR TEMPERATURE TO ENTER ENCLOSURE MUST NEVER EXCEED 104°F. DAY/NIGHT AVERAGE TEMPERATURE MUST NOT EXCEED 95°F.

4. Divide answer from step 2 by answer from step 3.
5. When sizing components to provide calculated air flow, be sure to allow for pressure losses as air filters become filled with dirt.
6. Outlet for ventilation must be placed higher than top of highest drive in enclosure.

Example:

What is the airflow in CFM required to cool (1) VLT6011 and (1) VLT6072, both running at the same time, mounted in an enclosure with an ambient temperature peak of 100° F.

From tables in Specification section, heat loss of drives is 295 and 1430 watts for a total of 1725 watts. Multiplying by 3.3 gives 5693.

Subtracting 100°F from 113°F gives 13.

Dividing 5693 by 13 gives 438 CFM.

Harsh Environments

The mechanical and electrical components of the VLT 6000 Series drives can be adversely affected by the environment. Contaminants in the air, either solid or liquid, are difficult to quantify and control.

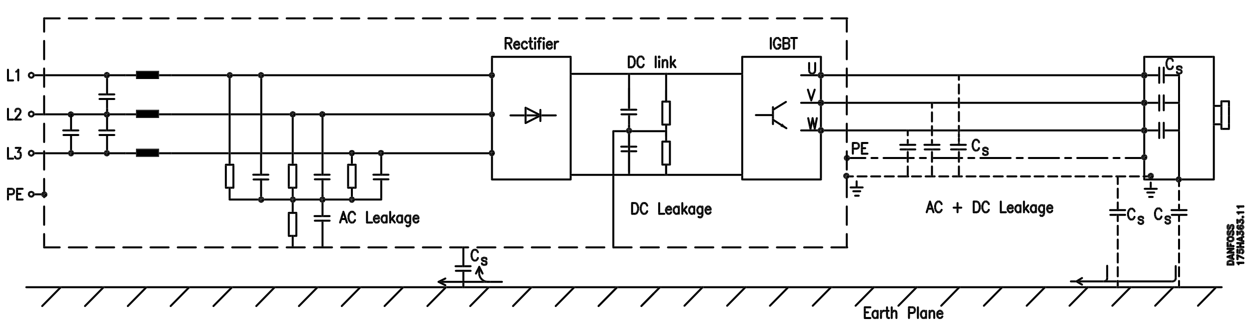
> **NOTE:** HIGH TEMPERATURES, HIGH ELEVATION AND HARSH ENVIRONMENTS MAY INCREASE NUMBER OF DRIVE FAULTS AND MAY REDUCE LIFE OF DRIVE IF PROPER PRECAUTIONS ARE NOT TAKEN.

Airborne Liquids

Liquids in the air can condense in the drive. Water carried in the air is easily measured as relative humidity, but other vapors are often more difficult to measure or control. Steam, oil and salt water vapor may cause corrosion of components. In such environments, use NEMA 12 enclosures rather than NEMA 1. NEMA 12 enclosures limit the exchange of outside air into the drive enclosure. Extremely harsh environments may require a higher level of protection than NEMA 12. Consult Danfoss Graham for complete information.

Airborne Solids

Particles in the air may cause mechanical, electrical or thermal failure in the drive. A NEMA 1 enclosure provides a reasonable degree of protection against falling particles, but it will not prevent the drive fan from pulling dirty air into the drive. A typical indicator of excessive levels of airborne particles is dust around the fan. In dusty environments, use NEMA 12 enclosures.



Paths of normal current leakage to ground

Corrosive Chemicals

In environments with high temperatures and humidity, *corrosive gases* such as sulphur, nitrogen and chlorine compounds cause corrosion to occur in the drive. Such chemical reactions rapidly affect and damage electronic components. An indication of corrosion is blackened copper or oxygenation of steel or aluminum. In such environments, it is recommended that the equipment be mounted in a cabinet with fresh air ventilation and that corrosive compounds be kept away from the drive. A non-ventilated cabinet fitted with an air conditioner as a heat exchanger may be used. Conformal coated circuit boards may be specified to reduce the corrosive effects of a harsh environment. Consult Danfoss Graham with complete information on the environment for selection of the proper enclosure or cabinet.

Extreme Operating Conditions

Short Circuit Protection

Current is measured in each of the three output phases. After 5 to 10 ms, if the current exceeds the permitted value, all transistors in the inverter turn off. This provides the most rapid current sensing and the greatest protection against nuisance trips. A short circuit between two output phases will cause an overcurrent trip.

Ground Fault Protection

The drive can sense a ground fault on any of the output phases and will shut down and display a fault within 100 ms.

Motor-generated Overvoltage

The DC voltage in the intermediate circuit (DC bus) increases when the motor acts as a generator. This can occur in two ways:

1. The load drives the motor when the drive is operated at a constant output frequency. This is generally referred to as an overhauling load.
2. During deceleration, if the inertia of the load is high, the load is light, and the deceleration time of the drive is set to a short value.

The VLT 6000 cannot regenerate energy back to the input. Therefore, it limits the energy accepted from the motor when set to enable autoramping. The drive attempts to do this by automatically lengthening the decel time, if the overvoltage occurs during deceleration. If this is unsuccessful, or if the load drives the motor when operating at a constant frequency, the drive will shut down and display a fault when a critical DC bus voltage level is reached.

Power Loss Ride-through

During a power loss, the drive continues to drive the motor until the intermediate circuit (DC bus) voltage drops below the minimum operating level, which corresponds to 15% below the lowest rated drive voltage. There are three series of VLT 6000 drives. One drive is rated for operation on 200 to 240 volts, another is rated for 380 to 460 volts, and a third for 550 to 600 volts. The power loss ride-through time depends upon the load on the drive and the line voltage at the time of the power loss.

Overload

When the torque required to maintain the set frequency, or to accelerate to the set frequency, exceeds the set current limit, the drive will attempt to continue to operate. It automatically reduces the rate of acceleration, or if running at set frequency, reduces the output frequency. If the overcurrent demand cannot be reduced in this manner, the drive shuts down and displays a fault within 1.5 seconds. The current limit level is programmable. Also,the amount of time that the drive will operate in current limit before shutting down can be set by the overcurrent trip delay. This can be set from 0 to 60 seconds, or for infinite operation which is subject to the drive and motor thermal protection.

Output Contactor

Although not generally a recommended practice, operating an output contactor between the motor and the drive will not cause damage to the drive. Closing a previously opened output contactor may connect a running drive to a stopped motor. This may cause the drive to trip and display a fault.

Input Power Delay

To ensure that the input surge suppression circuitry performs correctly, a time delay between successive applications of input power must be observed.

The table below shows the minimum time that must be allowed between applications of input power.

Input voltage	380 V	415 V	460 V	600 V
Waiting time	48 sec	65 sec	83 sec	133 sec

Voltage Rise Time and Peak Voltage on the Motor

Voltage rise time is the amount of time for a voltage pulse at the motor to go from 10% to 90% of the DC bus voltage. The rise time is determined by:

1. The switching speed of the inverter's power components.
2. The motor leads (type, size, length, and shielding).
3. Inductors or filters wired between the drive and the motor.

Peak voltage is the maximum voltage that will be applied to the motor windings. Self-inductance of the motor's stator windings causes an instantaneous voltage overshoot when an electrical pulse is applied to the motor. The voltage level at this instantaneous overshoot is the peak voltage. The peak voltage is determined by:

1. The rise time of the pulse.
2. The DC bus voltage.

Motor insulation is stressed by both excessively short rise time and high peak voltages. Motors without phase coil insulation are especially susceptible to damage.

Short motor leads help keep the peak voltage levels down.

If motors without phase coil insulation must be used, or if lead lengths are long, an output inductor or LC filter should be added to the drive.

Due to all the variables involved that determine voltage rise time and peak voltage, it is difficult to quantify the values applied to the motor. Every installation will be different.

Typical values are given here. Peak voltage is measured at the motor terminals between two phases.

To 10 HP			
Motor lead length	Input voltage	Rise time	Peak voltage
160 feet	460 V	0.4 µsec.	950 V
500 feet	460 V	1.3 µsec.	1300 V
100 feet	600 V	0.36 µsec.	1360 V

15 through 60 HP			
Motor lead length	Input voltage	Rise time	Peak voltage
160 feet	380 V	0.1 µsec.	900 V
500 feet	380 V	0.2 µsec.	1000 V
100 feet	600 V	0.38 µsec.	1430 V

75 through 300 HP			
Motor lead length	Input voltage	Rise time	Peak voltage
45 feet	460 V	0.78 µs	815 V
65 feet	460 V	0.84 µs	915 V
35 feet	600 V	0.80 µs	1122 V

350 through 600 HP			
Motor lead length	Input voltage	Rise time	Peak voltage
65 feet	460 V	1.2 µs	760 V

Audible Noise from the Drive

The audible noise from the drive comes from two sources:

1. DC intermediate circuit coils
2. Integral fan

Below are the typical values measured at a distance of 1 meter (39 inches) from the unit at full load:

To 5 HP 208 V; to 10 HP 460 V	
NEMA 1	50 dB
NEMA 12	62 dB

7.5 to 25 HP 208 V; 15 to 60 HP 460 V	
NEMA 1	61 dB
NEMA 12	66 dB

30 to 60 HP 208 V; 75 to 300 460 V	
NEMA 1	70 dB
NEMA 12	65 dB

350 to 600 HP 460 V	
NEMA 1	81 dB
NEMA 12	81 dB

To 10 HP 600 V	
NEMA 1	62 dB
15 to 75 HP 600 V	
NEMA 1	66 dB
100 to 300 HP 600 V	
NEMA 1	75 dB

Maximum Ambient Temperatures and Derates

Graphs A, B, and C show the percent of full output current that can be obtained continuously at various ambient temperatures. The temperatures given are the maximum ambient temperatures for the drives. The average ambient temperature over a 24 hour period must be at least 9°F below the maximum value. This is to ensure no degradation in the life expectancy of the drive's components.

If a drive is operated at temperatures above the rated temperature, a derating of the continuous output current is necessary. The following graphs show the required derating.

Figure A

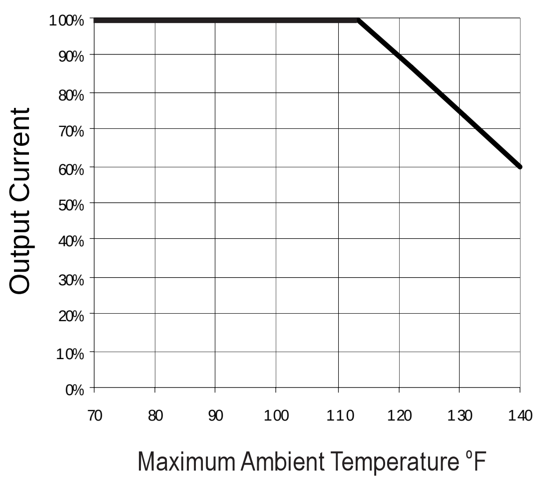


FIGURE A		
Drive	Current	Power
NEMA 1	208 & 230 VAC	All Sizes
NEMA 1	460 VAC	1 - 60 HP
NEMA 1	600 VAC	1 - 60 HP

Figure B

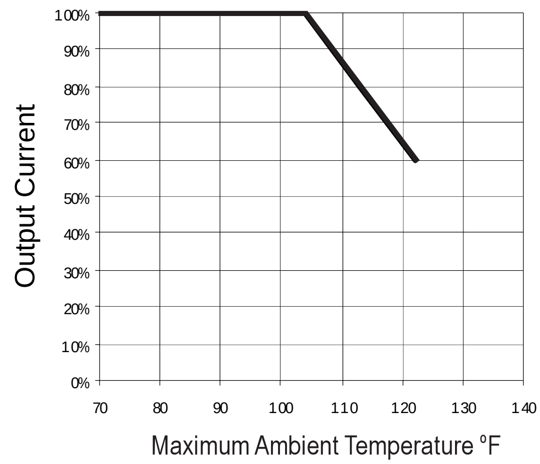


Figure B		
Drive	Current	Power
NEMA 12	208 & 230 VAC	All Sizes
NEMA 12	460 VAC	1 - 60 HP

Figure C

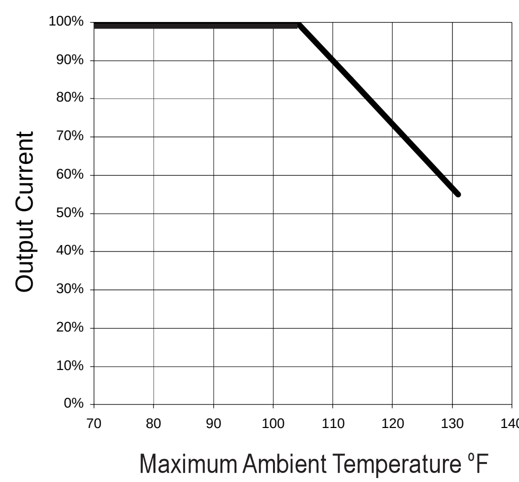
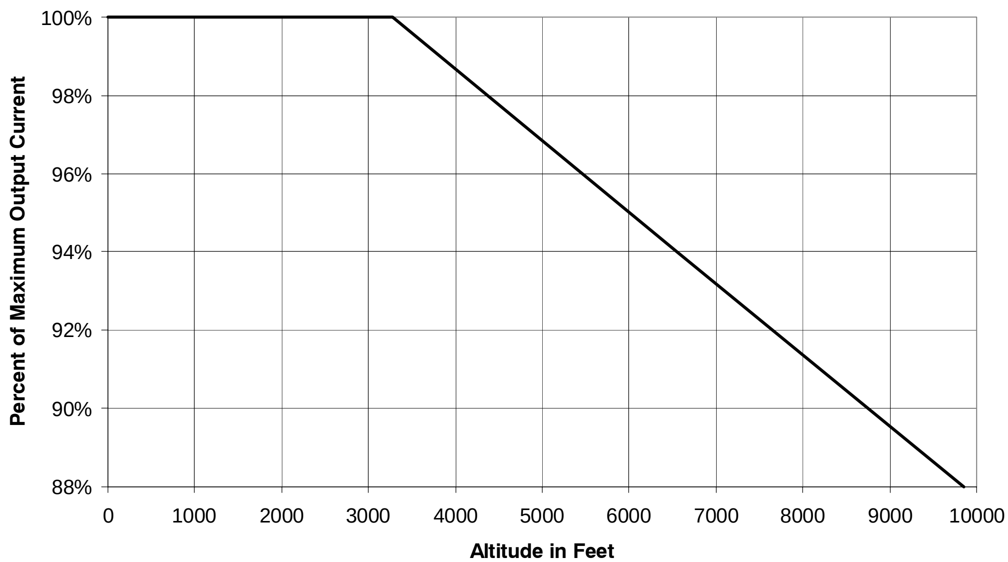


Figure C		
Drive	Current	Power
NEMA 1	460 VAC	75 - 600 HP
NEMA 12	460 VAC	75 - 600 HP

Derate at High Altitude

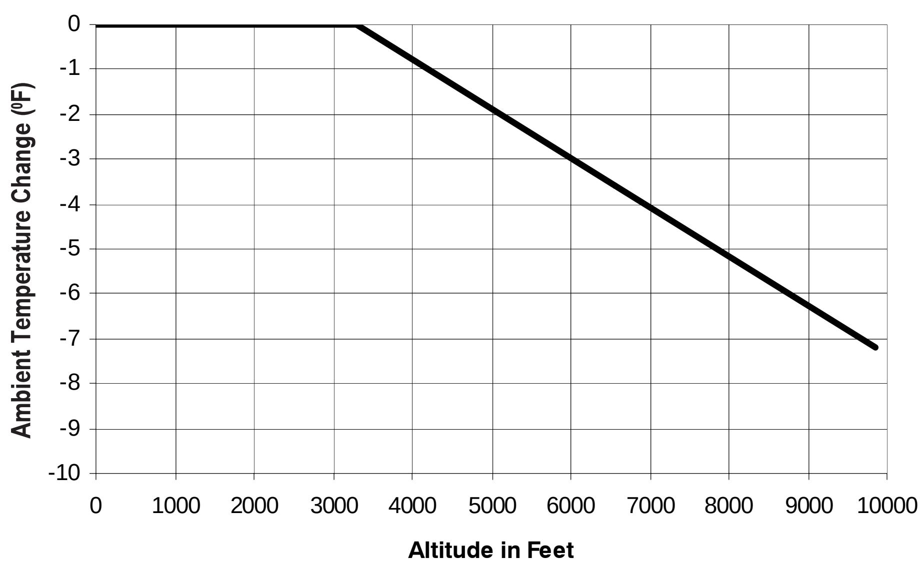
The VLT 6000 is designed to provide full rated output current at full rated ambient temperature for altitudes up to 3,300 feet (1000 meters). Below 3,300 feet altitude, no derating for altitude is necessary. Above 3,300 feet, the ambient temperature, or the maximum continuous output current must be derated.

The most common solution is to reduce the output current from the drive when it is used at high altitudes. The graph below shows that the output current from the drive must be reduced by about 1.8% for every 1000 feet above 3,300 feet.



Ambient Temperature at High Altitudes

The other possible solution for full rated output current operation at high altitude is to reduce the ambient temperature. The cooling capacity of the ambient air improves at lower air temperatures. Therefore, providing a reduced ambient temperature for the drive allows it to produce full output current without any reduction in its output current rating. The graph below shows the amount of reduction in ambient temperature, about 1° F per 1,000 feet, that is required to provide full output at altitudes above 3,300 feet.



Derating for Running at Low Speed

When a centrifugal pump or fan is driven by a VLT 6000, it is generally not necessary to protect the motor from overheating at low speed, as is often the case with constant torque loads. The reduced power requirement of the load at low speed automatically provides the load reduction that the motor requires.

This assumes that the maximum output frequency of the drive closely corresponds with the maximum normal line frequency of the motor. If the system is designed for full torque at a reduced motor frequency, provision for adequate motor cooling may have to be made. Consult Danfoss Graham with application details.

Derating for Long Motor Leads or Leads of Excessive Gage

All VLT 6000 drives may use unshielded leads up to 1000 feet long, and shielded leads up to 500 feet long without derate. Metallic conduit should be considered shielded for this purpose.

The VLT 6000 has been designed to be operated with motor leads of a range of gages. Using leads of a smaller gage may overheat the conductors and be in violation of electrical codes. Using leads of a larger gage may not properly fit the terminal blocks. They may also cause excessive ground current leakage, which may require derating the drive's output current. The derate is 5% per gage size larger than the maximum shown in the *Specifications* section.

Vibration and Shock

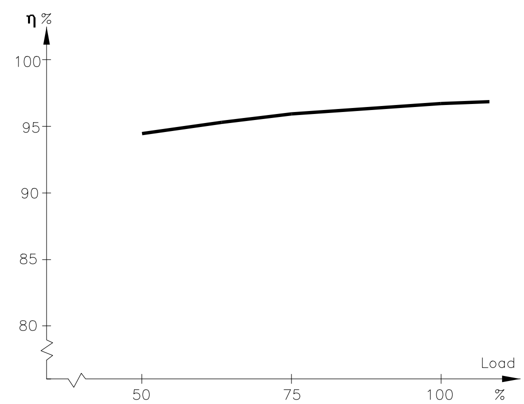
The VLT 6000 drive has been tested according to a procedure based on the IEC 68-2-6/34/35 and 36. These tests subject the drive to 0.7 g forces, over the range of 18 to 1,000 Hz random, in three directions for two hours. All VLT 6000 drives comply with requirements that correspond to these conditions when the unit is wall or floor mounted, as well as mounted within panels bolted to walls or floors.

Displacement Power Factor

0.98 or greater at all speeds and loads.

Efficiency

The efficiency percentage of the VLT 6000 shown in the following graph is based upon a carrier frequency of 4.5 Hz. The efficiency is relatively constant over the normal operating range of the drive. The efficiency of the drive decreases slightly as the carrier frequency is increased. It also decreases slightly as motor leads are lengthened. Although a higher carrier frequency will decrease the VLT 6000 efficiency slightly, it actually improves the efficiency of larger motors. This is because, at higher carrier frequencies, the output wave form more closely approximates a pure sine wave. System efficiency for both drive and motor can be determined by multiplying the drive efficiency (from the graph below) times the motor efficiency.



The efficiency of the motor connected to the drive depends on how closely the output from the drive resembles a sine wave. The sine wave output generated by the VVC+ of the VLT 6000 very closely approximates a pure sine wave. The efficiency generally is just as high as when operated from the power line.

Because of the drive's Automatic Energy Optimization feature, the efficiency and power factor of the motor at light load will likely be better when run from the drive than if the motor were operated directly from the AC power line. Being able to reduce the V/Hz ratio of a lightly loaded motor improves the efficiency of the motor. The Automatic Energy Optimization feature of the VLT 6000 takes full advantage of this system efficiency increase. The advantage is even more significant in larger motors than in small.

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