VFD Best Practices: Getting the Most from Your VFD Investment

The purpose of this document is to outline best practices for successful application and installation of VFDs. Following these recommendations should lead to better application performance, higher reliability, and maximized VFD lifespan. This document is only an outline meant to be like a checklist of considerations. More detailed information can be found in the pertinent product manuals.

Please contact a HESCO specialist at info@hesconet.com for more information.

7 Habits of Highly Successful Drive Installers:

1. Analyzing the Application.
2. Sizing the Drive Correctly.
4. Environment Considerations.
5. Designing Out “NOISE” & Other Issues.
6. Installation Considerations.
7. Set up the Drive Properly for the Application - Minimum Requirements.
Application Analysis

**Variable Torque**
Torque varies in proportion to speed.

- Motor is sized using OEM Pump / Fan Curves.
- Ideally, the fan / pump design speed should be geared-in as close to the motor’s base speed as possible.
- Energy savings can be attained by using variable speed to control flow/pressure. A 20% reduction in motor speed = 50% reduction in power.

**Constant Torque**
Torque does not vary in proportion to speed.

- Motor is sized to deliver torque for friction, accel / decal of inertia, and process requirements.
- Ideally, the machine design speed should be geared-in as close to the motor’s base speed as possible.
Drive Sizing

Use Motor Nameplate Amps.

The drive needs to have a continuous full load amp rating that is \(=/>\) the motor nameplate full load amps.

**Use the Duty Rating Wisely**

<table>
<thead>
<tr>
<th>Duty Rating</th>
<th>Continuous</th>
<th>3 Second Overload</th>
<th>60 Second Overload</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIGHT DUTY</td>
<td>Higher Cont. Amps</td>
<td>0</td>
<td>110%</td>
</tr>
<tr>
<td>NORMAL DUTY</td>
<td>Base Rating</td>
<td>150%</td>
<td>110%</td>
</tr>
<tr>
<td>HEAVY DUTY</td>
<td>Lower Cont. Amps</td>
<td>180-200%</td>
<td>150%</td>
</tr>
</tbody>
</table>

If short duration overloads are not applicable, such as a centrifugal pump/fan, Light Duty and Normal Duty give the highest available continuous amp rating.

If the application can use the 3 sec./60 sec. overload ratings, then select Normal Duty or Heavy Duty.

For example, an application requires 100HP to run steady state and 150HP to accelerate for 60 seconds. A 100HP HD Drive fits this requirement.

In many applications, it is beneficial to maximize the continuous amps for a given drive size.
Power Distribution Considerations

**Ungrounded System Normally Delta to Delta:**

- Allows dangerously high voltages between equipment and ground.
- Susceptible to excessive system overvoltages during ground faults.
- More susceptible to Common Mode Noise issues.
- Protection devices in the drive that are referenced to ground, MOV's (PEA Jumper) and Common Mode Capacitors (PEB Jumper), Must be disabled or damage may result.

**Solidly Grounded System (BEST PRACTICE):**

- Best Control of Common Mode Noise - Grounded neutral provides direct path.
- Provides re-balancing of unbalanced voltage with a 30 degree phase shift.
- Accommodates protection circuits. UL requires these circuits to be intact. PEA and PEB jumpers in position.

**Grounding and Bonding:**

- Unpainted (Galvanized or Anodized) subpanels are a better choice. Where grounding/bonding connections are made on a painted subpanel, the paint needs to be removed and a stainless steel star-washer and bolt should be used.
- IF VFD Cable is used, the appropriated connectors must be used to bond the shield to both the drive and motor.
• It is a best practice to ground everything in an enclosure to a ground bus rather than using the sub-panel to terminate grounds. The only exception to this is the motor cable ground conductor(s) and shield, they are terminated on the PE terminals on the drive product.

2500kVA Transformer:

Question:
When do I need to add a Drive Isolation Transformer or a Line Reactor in front of an AC Drive?

Answer:
If a drive is fed from a transformer that is more than 10 times the drive's kVA rating, it is a best practice to have a Line Reactor or a Drive Isolation Transformer in front of it.

If the distribution system is floating/ungrounded, it is highly recommended to put a Delta/Wye, solidly grounded Drive Isolation transformer in front of the drive(s).

A large transformer (one with a low source impedance and or high short circuit capability) feeding a relatively small drive can result in overheating of the drive's internal DC capacitor bank.

Line Reactors and DI Transformers help BUFFER the drive from line transients caused by:

• Power factor correction capacitor switching.
• “Soft” power systems.
• Changing equipment loading.
• Lightening strikes.
• Reduces peak current flow into the drives capacitor bank.

Environmental Considerations

The biggest enemies of electronic devices are:

• Power Transients
• Heat
• Humidity
• Conductive/Corrosive Dust and Gases

Follow the manufacturers environmental recommendations.

The “Max Ambient Temp” spec for industrial electronics is typically 40-50 degrees C. Up to this temperature, the device can run at full load without faulting on over-temperature.

BUT continuously running at this temperature will likely shorten the devices life significantly.

Drives should be installed in a clean, cool, controlled environment for long term reliability.
“NOISE” and Other Issues

**Harmonics:**

Switching power supplies, converters, and inverters, create distortion on the line supply. Some users and applications are sensitive to this in that is can cause equipment to overheat, and erratic operation or failure in sensitive equipment.

Below, the line current (green) is distorted as a result of the non linearity of the input rectifier. The voltage (purple) distortion is the result of the circulation of the distorted current through the line impedance.

IEEE-519 specifies the maximum current distortion as a guideline for power system engineers - it is not an enforceable law. The general guidance is to keep the current distortion < 5%.

In terms of VFDs there are a few solutions:

- Multi - pulse rectifier(18-pulse is most common).
- Passive Harmonic Filter.
- Active Harmonic Filter.
- Active Front End.
- Line Reactors and/or DC Link Choke will NOT get you below 5%.

**Common Mode Noise:**

Common mode noise is the ac disturbance from one or more signal or power lines and an external conduction path, such as an earth ground or chassis or other conductive material not intended to conduct the power or signals.

Common mode noise currents often follow a large loop area which then radiate to the environment adding to the system electromagnetic emissions.

A VFDs’ switching Power Semiconductors create Common Mode Noise.

**Problems Caused By Common Mode Noise:**

- Communications errors and malfunctions due to signal disturbances. Erroneous data or analog signals.
- Motor bearing failures due to “fluting.”

**Solutions:**

- Good installation & grounding/bonding practices.
- Solidly grounded distribution system.
- Shaft grounding brushes and/or insulated bearings.
- EMC Filters.
- Use of VFD Cable and matching couplings.
Reflected Waves, Standing Waves, or Transmission Line Effect:

VFD's generate an approximated sine wave using Pulse Width Modulation (PWM). The switching frequency is typically 2kHz to 4kHz. The voltage waveform looks like this:

![Voltage Waveform](image)

When the motor cables are long, over 300-400 feet, this waveform can get reflected back upon itself. The magnitudes of these waveforms are added together, causing the voltage to double. On a 460vac drive with a DC Bus voltage of 650vdc, this would be 1350vdc. On an older motor with 1200v insulation, this could cause a failure.

“Inverter Duty” motors are insulated for 1488 v minimum (CIV) as specified by NEMA MG1 part 31. 1600 v or higher is better.

The variables that determine the risk of reflected waves are:

- Motor insulation rating, particularly its Corona Inception Voltage (CIV) rating.
- Motor cable length.
- Inverter power rating.
- Output filters are available for at-risk applications.
- Refer to the manufacturers publication for guidance.

Installation Considerations

- Follow the manufacturer’s published guidelines for installation.
- Choose the right enclosure type for the environment - NEMA?/IP?
- The enclosure must be able to dissipate the heat generated inside of it.
- Neatness Counts: As much as possible, keep different classes of wiring separated, noisy components/wiring away from sensitive ones.
- Follow spacing guidelines. Typically, VFDs have a heatsink in the back that cools the power components. Cooler air is drawn in from the bottom and exits out the top. If clearances around this cooling path aren't maintained, the drive will cook itself ... even if the enclosure is air-conditioned.

This enclosure has a full wireway directly below it prohibiting airflow to the heatsink ... not good. The second picture points out where the heatsink fan is located on the bottom of the drive. This fan needs unrestricted flow of cooling air.

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Basic Drive Setup

What are the "minimum" requirements?

Motor Nameplate Data:
- Voltage
- Frequency
- Full Load Amps
- # Poles

Motor Control Mode Selection:
- Volts/Hertz - Basic Performance/Lowest Torque per Amp
- Sensorless Vector - Higher Performance/Higher Torque per Amp
- Flux Vector / Field Oriented Control - Highest Performance/Highest Torque per Amp
- Permanent Magnet

Limits:
- Accel/Decel Ramp Rates
- Current Limits
- Speed Limits
- Torque Limits
- Power Limits

Commissioning:
- Motor Direction Verification
- Motor Feedback Direction verification (if used)

Motor ID Tests:
- Calculate - Basic Performance/Lowest Torque per Amp
  ~ Drive doesn’t modulate, No Motor Rotation.
  ~ OK for V/Hz—Fans, Pumps

- Static - Higher Performance/Higher Torque per Amp
  ~ Drive modulates, No Motor Rotation.
  ~ OK for V/Hz—Fans, Pumps
  ~ OK for SV if load can't be uncoupled.

- Rotate - Highest Performance/Highest Torque per Amp
  ~ Drive modulates, Motor rotates.
  ~ Required for best performance.
  ~ If Flux Vector/Field Oriented Control w/ encoder, the load can be coupled.

- Inertia Tune:
  ~ Sets gain values if running as a speed regulator.

Learn More About VFDs

For more information in regards to the VFDs, contact your local HESCO specialist at info@hesconet.com, (860) 236-6363.