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Title: VFD Application Tips

To: Commercial / Industrial Partners

Summary / Overview
This document gives a brief overview of the environmental factors affecting the performance and life expectancy of Variable Frequency Drives (VFDs) and AC induction motors. In addition, we will also discuss the proper techniques to help VFDs operate reliably over their full life span.

Variable Frequency Drives are sensitive electronic devices
Variable frequency drives are electronic devices applied in residential, commercial, and industrial environments to vary the speed of AC induction motors. In the commercial/industrial segment, Grundfos uses VFD technology in CHIE, CRE, CRE-Plus, and BoosterpaQ applications.
VFDs can be adversely affected by the following factors:

- Poor power quality
- Extreme temperatures
- High altitude

If a VFD is exposed to any or all of these adverse factors, the drive may exhibit any or all of the symptoms listed below:

- Erratic behavior
- Excessive faults and alarms
- A shortened life span

Adverse factors affecting the performance of VFDs

- **Power quality**

The power quality at an installation is a combination of these three influences:

- Utility generated events (external)
  Examples are: Over & under voltage, sags & surges, voltage imbalance, etc.
- Facility generated events (internal)
  Examples are: Voltage distortion & imbalance, grounding issues, etc.
- Equipment related events (internal)
  Examples are: Electrical noise, impulses, voltage distortion, etc.

Power quality varies from site to site due to the unique character of each installation. Therefore**,** if we want to know with certainty what the power quality is at an installation, we must measure power quality at the point of use. A trained professional with the proper instruments and skills can perform an accurate and detailed power quality assessment of a specific site.

> Ambient temperatures and VFD temperature ratings

Excessive heat has a very adverse effect on the reliability and life expectancy of any electrical/electronic device. We cannot control nature, but we can control the environment where we place our electrical/electronic devices.

Grundfos BoosterpaQ control panels are designed to provide a temperature differential of no more than 10° C (18° F) above ambient temperature, which is a common industry standard. Our panels use fans to cool the enclosure. While the fans do a good job of removing heat from the panel, they can do nothing about the ambient temperature of the air entering the panel.

For reference, we have listed the temperature ratings for the three panel mounted VFDs used in our BoosterpaQ systems.

VFD Type	Max. air temp. before derating is required F °/ C°	Absolute maximum temperature F °/ C°
Baldor ID15H VFD	104° / 40°	131° / 55°
Danfoss VLT2800	113°/ 45° (1)	131° / 55°
Danfoss VLT8000	113°/ 45°(1)	131° / 55°

(1) 24-hour average should be below 104°/ 40°

For example, if the ambient temperature at an installation reaches 100° F, the VFDs in the control panel may be exposed to temperatures as high as 118° F in a panel that is cooled by fans only. These temperatures are above the normal operating range of **ANY** standard VFD on the market. This is why steps should be taken to help keep the internal panel temperatures below 104° F.

> Altitude

Variable frequency drives and motors **must** be derated when they are installed at high altitudes since the air is thinner and the cooling capabilities of motors and VFDs are reduced. Most manufacturers recommend derating their equipment at 3300 feet (1005 meters) above sea level and higher. For example, Baldor recommends derating the output current 2% for every 1000 feet (305 meters) above 3300 feet.

There are costs associated with counteracting adverse factors.
In any applications with power quality issues, high ambient temperatures, and/or altitude issues – there are several options available to solve the problem:

- Spend resources to correct the root problem.
- Spend resources to protect the VFDs from the root problem (TVSS, line reactors, RFI filters, power conditioners, isolation transformers, voltage regulators, UPS, and etc.).
- Spend resources to derate/upsize the VFD(s).
- Spend resources repairing and/or replacing the failed drives and/or motors.

Addressing the root problem(s)

- **Power quality** - Power quality issues can be addressed several ways:
  - **Power utility equipment problem(s):** The power utility should correct the problem at no cost to the end user if they are not adhering to the ANSI C84.1-1995 standard.
  - **End user equipment problem(s):**
    - The end user may eliminate adverse contributors by repairing and/or upgrading the equipment in their facility that is causing the disturbance(s).
    - The end user may add hardware (TVSS, line reactors, RFI filters, power conditioners, isolation transformers, voltage regulators, UPS, and etc.) to protect their VFDs and other sensitive electronic devices.
- **High ambient temperatures** - High temperatures can be addressed by keeping the panel temperatures within specified limits.
- **High altitude -** The VFDs and motors **must** be derated/upsized to stay below the maximum operating temperatures of the device.

Derating VFDs for power quality, temperature, and altitude
Derating a VFD means that a larger than normal drive is used in the application to help compensate for the adverse influences. Derating a VFD can be a simple and easy upgrade if the control panel is manufactured with an upsized VFD. Field retrofits may be more difficult and costly due to space limitations.

A derated VFD does a better job of handling poor power quality because it has a larger capacitor bank than a standard VFD. This larger capacitor bank can store more energy and this allows the VFD to "ride through" more disturbances without faulting.

A derated VFD can handle higher temperatures because some of its components are now "upsized." For example the fans and heat sinks are larger and can dissipate more heat. The current carrying components are larger and are operating below full capacity.

Motors with integrated drives (MLEs and Baldor SmartMotors)
Motors with integrated drives share all the same issues as panel mounted drives with one additional factor to consider. The motor and VFD **must** be covered to prolong their lives and protect them from adverse weather conditions. MLEs and SmartMotors **must** be covered for the following reasons:

- **Preventing bearing damage**. Baldor TEFC motors and SmartMotors are rated TEFC (Totally Enclosed Fan Cooled) and they **MUST** be covered if they are mounted outside in the vertical position. The top motor cover is fully ventilated and when mounted vertically, rain and sprinkler water will damage the upper bearing in a motor that is not running.
- **Preventing condensation from forming inside the VFD enclosures**. If a MLE or Baldor SmartMotor is exposed to the sky, when the drive is not running, the housing may cool down quicker than the interior components and condensation may form in the drive. A cover should be installed over the MLE and SmartMotors to avoid condensation buildup.
- **Keeping the operating temperatures in the correct range**. Shade the VFD and motor to lower the operating temperature during the summer months.

The shade/cover can take many forms. It can be a carport-like cover or it can be a cover that sits directly on top of the MLE or Baldor SmartMotor. The key concept is – prevent the MLE or Baldor SmartMotor from being directly exposed to the sky. Grundfos and Baldor both offer covers that sit on top of the MLE, BSM, or Baldor TEFC motor.

General statements concerning the life expectancy of electrical/electronic devices

- A 20° F reduction in operating temperature can double the life expectancy of an electrical component.
- Operating an electrical device below 90% of full load can double its life expectancy.

Techniques we can use to help VFDs perform better and operate longer

1. Ensure the power quality is at an acceptable level

a. The standard voltage tolerance for a 460V motor or VFD is 460V +/- 10%. The low side of this tolerance is 414V and the high side is 506V. The goal is to get the incoming voltage as close to the nominal voltage as possible (460V in this example) while the motor/pumps are running at full load. Low voltage electric motors and VFDs are also rated for 208V, 230V, and 575V in North America.

Drives and motors run cooler and more efficiently the closer the supply voltage is to the nominal rating of the drive and motor. If the supply voltage is too close to the lower or upper end of the voltage tolerance, the drive may experience erratic behavior.

There is a label inside every BoosterpaQ panel which states the proper voltage and amperage rating for the panel. In addition, the same information is found on the nameplate of each motor and VFD.

If the incoming voltage is too low or too high, the voltage should be adjusted. There are two ways to adjust the voltage to an application.

i. **Use different voltage taps.** Most transformers are equipped with voltage taps that provide a way of adjusting the voltage output from the transformer. Using the voltage taps on a transformer is a low-cost and simple technique. If the transformer is utility owned, ask the utility to select another voltage tap. If the end user owns the transformer, a qualified electrician can make the necessary adjustments.

ii. **Use a buck-boost transformer.** This type of transformer is used to make small voltage adjustments (12, 24, or 48 volts). Buck-boost transformers are relatively small and inexpensive; however, they do need to be installed by a qualified electrician.

iii. **Three phase transformers (Wye or Delta).** Three phase transformers have either a Wye (Y) or Delta secondary winding (the output winding). The Wye transformer is the best configuration for VFDs. Connecting a VFD to a Delta transformer is acceptable in most situations but the VFD may experience erratic behavior.

b. If the installation area is known to have poor power quality, be proactive and consider "upsizing" the VFD and/or adding line reactors in front of the VFD(s). The Danfoss VFDs can be purchased with RFI filters built into the VFD to help overcome power quality issues. Request the RFI filters when the BoosterpaQ is ordered. There is an additional cost for the RFI filters, therefore be sure the additional costs are accounted for in the system pricing.

If the drive(s) exhibit any "strange" behavior, investigate power quality and temperature immediately in order to prevent damage to the VFD(s). An electrician or maintenance technician/engineer can perform a basic power quality survey if they have the tools and skills for the task.

2. Keep the drives cool

a. Shade the enclosure (the entire day).
b. Clean the filters on the enclosure fans and be sure the fans run when the panel thermostat calls for them to run.
c. Install the panel indoors and air-condition the room where the VFD(s) is/are installed.
d. Install an air conditioner on the control panel in cases of extreme temperatures.

3. Derate properly for temperature, altitude, and power quality

a. It is important to include this environmental information during the specifying phase to ensure the correct equipment is designed into the system.

4. Logging the power quality and temperature

a. If a drive is having problems and the altitude issues have been addressed properly, then it is time to perform temperature monitoring/logging. The temperature of the ambient air and the temperature inside the control panel should be monitored to determine if the VFD(s) is/are being cooled properly.

5. Logging the power quality and temperature

a. If a drive is having problems and the altitude and temperature issues have been addressed properly it is time to perform a power quality evaluation. Power quality instruments can be deployed to capture/log power quality events that may be leading to power quality problems.

Recommendations

- Be aware of the adverse factors that may exist at each installation. Be proactive and make recommendations to reduce or eliminate the negative factors whenever possible.
- If you believe an installation is experiencing problems due to power quality, temperature, or altitude - act fast before the VFD(s) is/are damaged.

This document was written by:
Roger Weldon
National Electronics Application Engineer
Grundfos Pumps Corporation
Phone: 559.294.3043
Fax: 559.346.6043
Email: rweldon@us.grundfos.com

The following Grundfos Engineers contributed their time and expertise:
Michael Rasmussen, Product Engineer
Tony Radcliff, Product Specialist
Greg Bashian, Product Engineer