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What's really causing your VFD's DC Bus Overvoltage Fault?

Variable Frequency Drives (VFDs) are a crucial component in industrial automation, providing precise control over a motor's speed and torque. Numerous built-in protections and fault indications are provided with modern VFDs, including the commonly seen DC Bus Overvoltage Fault. This fault has several possible causes and this whitepaper explores each one, offering solutions to ensure proper VFD operation.

By Kevin Kakascik, AutomationDirect

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Disclaimer: Troubleshooting or servicing a VFD or any electrical equipment should only be performed by qualified personnel familiar with electrical safety practices.

The DC bus overvoltage fault, also called a DC bus error or simply an overvoltage fault, is among the most common faults on an AC variable frequency drive. Because it's so common, some newer drives try to assist with locating the issue by providing more information about what the drive was doing when the overvoltage occurred (e.g., accelerating, decelerating, steady speed, stopping). This additional info can be a great asset to have when troubleshooting once you fully understand the possible causes of this fault.

Understanding how a VFD operates

To troubleshoot the drive effectively, it helps to understand the power components of an AC VFD. Every VFD's power system can be broken into three parts: the input rectifier, the DC bus, and the output inverter.

Three-phase (sometimes single-phase) power is connected to the input terminals and fed through a full-wave rectifier, converting the AC voltage to DC. After rectifying the input, the VFD uses the DC power to charge a bank of capacitors, which is the DC bus of the VFD. The DC bus voltage can be estimated by multiplying the average AC line voltage by 1.414 or $\sqrt{2}$. But this value is only an estimate, as the real calculation involves some calculus and the use of complex numbers. For the sake of troubleshooting and this document, the "estimated" calculation will be fine. For a 230 VAC drive, the DC bus is estimated to be 325 VDC, and for a 460 VAC drive, the estimate is 650 VDC. The actual DC bus voltage will always be slightly higher, and the reasons will be explained later in this paper.

The charged bank of capacitors, or DC bus, is what is used by the drive's output inverter to create a PWM (Pulse-Width Modulated) waveform which will power the motor. The inverter is made up of a network of IGBTs (Insulated Gate Bipolar Transistors). The VFD's control unit switches the IGBT gates. The control unit will be left out of this document as each brand has its own control unit. However, the power unit components are mostly identical between brands.

What exactly is a DC Bus Overvoltage Fault

A DC bus overvoltage fault simply means that the DC bus voltage exceeded the threshold for which the drive is rated. It is an instantaneous fault, meaning as soon as the voltage crosses this level, the control system detects this and trips the drive into a fault condition, disabling the drive's output. This is to protect the VFD from damage. This threshold voltage may vary slightly between manufacturers but should be similar for all drives of the same voltage class. For example, the DC bus threshold voltages for the DURApulse GS30 drive series are 410 VDC for 230 VAC models and 820 VDC for 460 VAC models. Check your drive manufacturer's documentation for the exact number, which should be close to the GS30's value. This is a number you need to know.

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Troubleshooting the DC Bus Overvoltage Fault

The DC bus overvoltage fault is typically an application error resulting from one of three conditions or a combination. These conditions are a high line voltage, the motor being back-driven by a high-inertia load, or harmonics. For the troubleshooting section of this paper, you will need to know the DC bus threshold voltage (mentioned previously) and have a voltmeter.

1. Confirm if your DC bus voltage is the problem

Consult the manufacturer's drive documentation to see how to check the DC bus voltage of your drive through the drive's control system. Whether this is from the drive's keypad or some form of drive software, does not matter, but getting the status from the VFD's control system is better than measuring the voltage at the DC bus terminals. For one, the DC bus terminals may be connected to brake chopper circuitry, and two, your digital meter may not account for harmonics and will read inaccurately. The drive's DC bus voltage measurement should be accomplished through an analog comparator and converted to a digital value. Some higher-end meters and analog meters may read this voltage fine, but it is best to trust the drive's status for this step.

While the drive is powered up and not running, read the DC bus value and compare it to the estimated value (325 VDC or 650 VDC) and the threshold voltage. If the value is already closer to the threshold voltage while the drive isn't running, there is most likely a problem with the input power, but it may also involve the other two causes. If the value is closer to the estimated voltage and the issue only happens while the drive is running, it may be an inertia or output harmonics issue.

2. Check the line voltage

Using your voltmeter, take all three voltage measurements from the VFD's power input terminals: L1-L2, L1-L3, and L2-L3. Ensure these values are all within the input voltage range that the drive manufacturer recommends for your drive model and that they aren't unbalanced. Note that a 230 VAC high-Delta power source can be the sole culprit of a DC bus overvoltage fault if the error appears when the drive isn't running. A high-Delta power source may need to be fed through a Delta/WYE isolation transformer upstream of the VFD if it is determined that this is the problem.

If the input line voltages are within specification and the DC bus voltage is still high when not running, this could be a harmonics issue with the supply power. In this case, an RFI filter is recommended to be installed upstream of the input of the VFD.

If the line voltages are high, a buck-boost transformer, configured to buck down the voltage, may need to be used.

Note that on some drives, the line voltage is monitored by the VFD's control system, and if line voltage is a problem, a different fault will be seen, making this step unnecessary.

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3. Check for a mechanical application issue

A mechanical application issue is an inertia issue. Mechanical application issues are the most common explanation for a DC bus overvoltage fault. When the motor is driving the load, things are fine. If the load is driving the motor at any time, the motor changes functions and becomes a generator. This generated voltage needs to go somewhere, so it goes back into the DC bus and increases the charge, thus raising the DC bus voltage. This is known as regeneration, and the voltage created is called regenerative voltage. Sometimes, the term is shortened to "regen."

There are several instances when the load will drive a motor, such as when a fast stop is desired. If a high-speed conveyor belt decelerates too quickly, the bus voltage will spike due to regeneration (Figure 1). If the DC bus overvoltage faults only occur during quick stops of the load, then increasing the deceleration time may solve the issue. If increasing the deceleration time isn't an option, a brake resistor and/or brake chopper/resistor combination or another mechanical means of controlling the load will need to be installed.

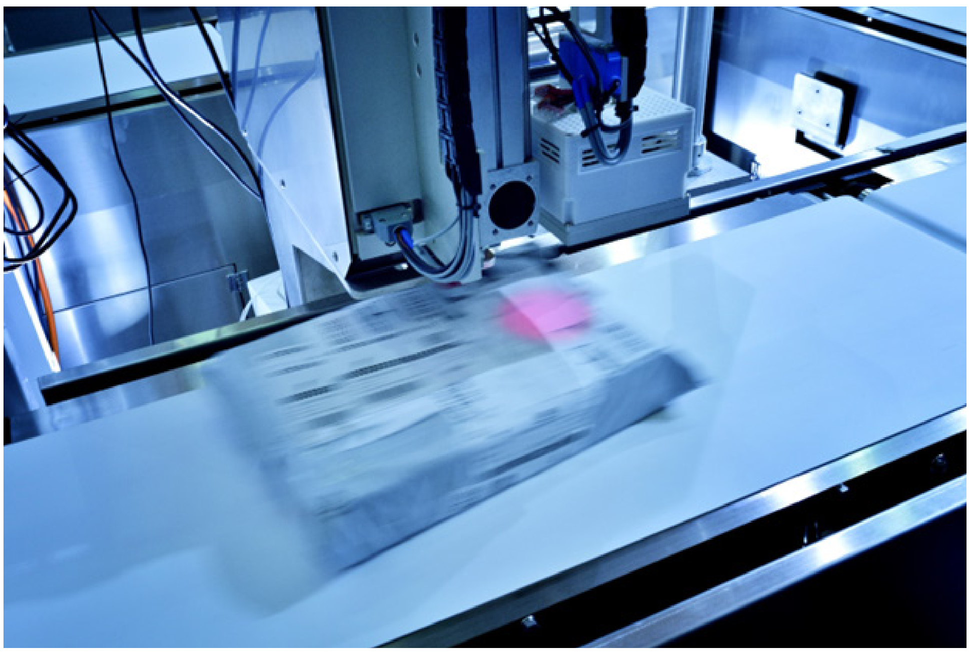

Figure 1: A high-speed meter belt will start and stop quickly possibly causing regenerative voltage and a DC bus voltage fault.

It's also important to pay attention to the load. If a high inertia load, like a heavy flywheel, the load will store mechanical energy which can back-drive to the VFD, causing regeneration whenever the speed changes (Figure 2).

Figure 2: A high inertia load can cause regeneration even at a steady speed.

If the DC bus overvoltage fault occurs during acceleration, try increasing the acceleration time. A brake resistor (Figure 3) and/or brake chopper/resistor combination must be installed if changing an acceleration value doesn't solve the problem.

Sometimes, a DC bus overvoltage fault can even happen at a steady speed if the inertia is high enough. One thing to note in these instances, is that any installed brake components could be active quite often. So be sure to check the braking duty cycle of the brake resistor and drive being used. A change of VFD manufacturers or models may be required to provide a higher-end solution for constant regeneration.

Figure 3: Brake resistors come in many styles and capacities to assist with high inertia loads

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4. Suspect harmonics

If everything checks out to this point, the input line voltage is within specification and is balanced, it isn't a high-Delta power system, harmonics have been dealt with on the input power feed, and a brake resistor and/or brake chopper and resistor have been installed, then the next possible cause of a DC bus overvoltage fault is harmonics on the VFD output.

Electrical harmonics are a form of electrical noise that is non-acoustical, meaning the human ear can't hear it. However, harmonics will increase the DC bus voltage. The switching of the IGBTs causes this electrical noise. Throw in the fact that motor leads act as an antenna, and a noisy system with a boosted DC bus voltage may result. This is why the DC bus value will be slightly higher than what is calculated from the line voltage measurements. There will always be some harmonics, and the DC bus voltage will always be slightly higher than what you calculate.

If all other troubleshooting methods haven't solved the problem of DC bus overvoltage faults, then harmonics must be suspected. The first thing that should be done is to install an output reactor immediately after the drive. Output reactors (line reactors installed on the drive's output) are always recommended for any VFD installation. However, they only help with motor leads up to 100 feet long. An output filter is recommended when motor leads are longer than 100 feet, and motor leads should never exceed 300 feet.

Another trick that may help is to lower the carrier frequency of the VFD. A line reactor is always recommended, but lowering the carrier frequency will often solve the problem of harmonics generated from a drive's output. One thing to consider with this approach is the application of the VFD. Never lower the carrier frequency of a drive controlling an HVAC system. Lowering the VFD's carrier frequency will lower the amount of electrical noise generated, but it will also increase the audible noise. This noise may even affect the safety or comfort of personnel working near the equipment. Consult your VFD manufacturer's documentation to determine how to lower your drive's carrier frequency.

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