

# Keysight Technologies

## Troubleshooting VFDs with Low Pass Filter

### Application Note



## Introduction

Today, three-phase induction motors are the most important workhorses in industry and commercial facilities. An AC induction motor is commonly used as a constant-speed drive when fed from a voltage source of fixed frequency. Unfortunately, running a motor at maximum speed, regardless of the varying demands of production, means a great deal of electric power is wasted. In many motor applications, energy use can be reduced considerably if the speed of the motor varies in response to the changing process conditions. With the advent of solid state electronics, variable speed drives can regulate the speed of a three-phase AC electric motor by converting three-phase AC line voltage to a quasi-sinusoidal pulse width modulated (PWM) waveform in which the frequency and voltage level can be varied.



## Benefits of Variable Frequency Drives

Variable frequency drives (VFDs) provide many benefits. Energy savings is among them since the VFD allows precise speed control of a standard induction motor and, in many applications, that ability improves process control. Other benefits include that VFDs can maintain torque at levels to match the needs of the load, reduce mechanical stress on three-phase induction motors by providing a soft start, and improve an electrical system's power factor. This also reduces the voltage sag that can occur when a large motor starts quickly. Voltage sags can dim lights and cause other equipment to shut down or restart.

Because of the benefits mentioned above, VFDs are becoming prevalent in a wide range of applications throughout industry: from motion control applications to ventilation systems, from wastewater processing facilities to machining areas, and many others. For example, VFDs are used in ventilation systems for large buildings where air flow requirements change according to the humidity and temperature in the room. Fan speeds in power plants are adjusted according to the varying demands for power at different times of the day, week, or year.

However, the increased use of VFDs presents the maintenance and service community with both the opportunity and challenge of learning to maintain, troubleshoot, and operate this equipment. Technicians consistently face the challenge of getting accurate voltage, current, and frequency measurements that match what is shown on the VFD's control panel display.

## Principles of Operation

As shown in Figure 1, a VFD consists of three sections: rectifier, DC link or DC bus, and inverter. The three-phase incoming AC power is rectified to a rippling DC voltage. The rectifier is made up of a group of gated diodes (silicon rectifiers or SCRs). This AC-to-DC conversion is necessary in order for the power to be shaped into a variable frequency signal.

The DC link connects the rectifier to the inverter, and smooths and holds the DC voltage at a constant level for the inverter. There are two major components to the DC link section: capacitors and coils. Extra care should be taken when dealing with VFDs as the DC link can produce up to 620 VDC at 750 A.

In the inverter, VFDs use insulated-gate bipolar transistors (IGBT) to vary output frequency to the U, V, and W terminals of the motor. (Refer to Figure 2 for VFD output voltage and current.) Using PWM, the speed of the motor and torque characteristics can be adjusted to match the load requirements.

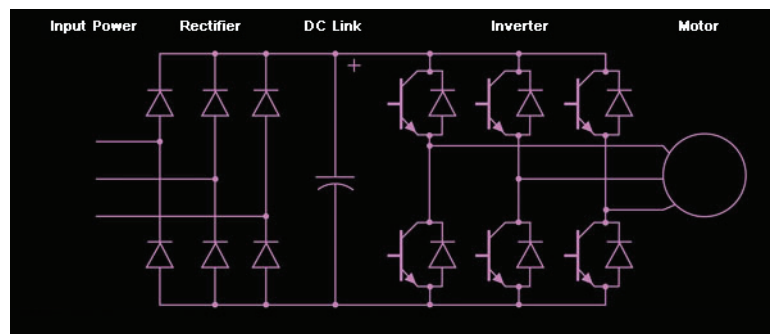


Figure 1. VFD block diagram

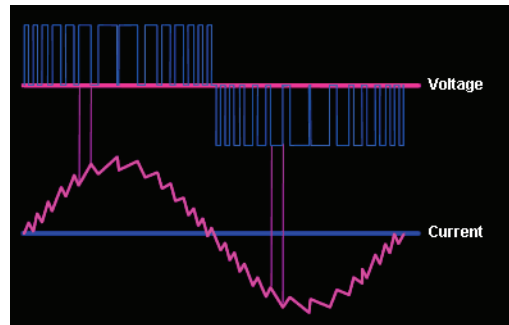


Figure 2. VFD output voltage and current

## VFD Measurements and Solutions

In the manufacturing plant, when a VFD goes down, production often grinds to a halt. Facility workers are then under pressure to get the drive back online. In order to prevent downtime and keep the VFD running, periodically measuring the VFD's input and output allows proactive corrective action to be taken as needed.

When dealing with modulated PWM output, using a conventional digital multimeter (DMM) makes it difficult to obtain accurate frequency and voltage measurements. Typically the readings obtained will be around 20 to 30% higher than the actual output shown on the VFD's display.

Depending on the drive manufacturer, the switching frequencies of a VFD ranges from a few kilohertz to as high as 30 kHz. Most of the true RMS handheld multimeters (HH DMM) in the market have high AC bandwidth and are able to capture all the unwanted high frequency switching components generated by the VFD. Using a HH DMM with a switchable 1-kHz low pass filter feature, such as the Keysight Technologies, Inc. U1271A, U1272A, and U1273A, the HH DMM is able to obtain accurate voltage and frequency measurements on VFDs. This eliminates the need for technicians to guess the VFD output.

### Low pass filters

Basically, an electrical filter is a circuit that can be designed to modify, reshape, or reject all unwanted frequencies of an electrical signal and pass on only the desired signals. Low-pass filters allow only low frequency signals to pass unaltered while attenuating all other signals that are not wanted. A simple passive low pass filter (LPF), can be easily made by serially connecting a single resistor with a single capacitor (Figure 3).

**Safety precaution:** When measuring mains power or other high voltages, safety is very important. Do not compromise personal safety for any reason. For your own safety and the safety of those near you, you must choose a HH DMM that is designed and tested to protect you against the electrical hazards you might encounter. When troubleshooting a drive in operation, choose a CAT III 1000 V or CAT IV 600 V-rated HH DMM. Adhere to all safety procedures while taking these measurements.

For more information on selecting a HH DMM that is safe for your application, read the application note, Think Safety When Selecting a Handheld Multimeter, publication number 5990-4578EN.

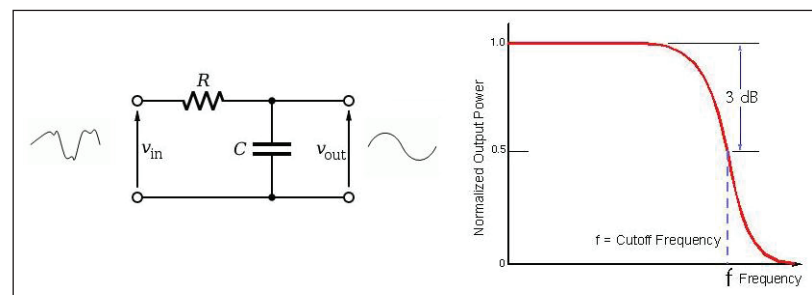


Figure 3. Low pass filter circuitry and frequency response



Figure 4. Inaccurate VFD output frequency measurement without low pass filter



Figure 5. Accurate VFD output frequency measurement with low pass filter

## Summary

The unexpected breakdown of rotating machinery is the single biggest cause of emergency downtime in all types of businesses and facilities. Once a VFD has been installed, regular maintenance should be carried out periodically to avoid premature failure of the motor drive. Early detection of machinery failures relies on the accuracy of the measurements obtained using a HH DMM. Troubleshooting VFDs also requires accurate information. The U1270 Series HH DMMs provide accuracy and offer the low pass filter feature which expedites the troubleshooting of VFDs to restore equipment to optimum operating efficiency.

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