HIOKI

Technical White Paper

What Your VFD Waveforms Reveal

Key checks for cooling pumps and other motor-driven equipment.



MR8875
MEMORY HiCORDER

VFD | PWM

TECHNICAL PAPER | DATA CENTER COOLING & MOTOR DRIVES

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Variable frequency drives regulate motor speed by converting incoming AC power into a pulse-width-modulated (PWM) output. That output contains both the fundamental waveform that drives the motor and the high-frequency switching activity created by the inverter.

For cooling pumps and other motor-driven equipment, waveform review helps relate actual output behavior to the drive command and control mode. A focused review of frequency, voltage, phase relationship, switching frequency, and pulse width provides a practical starting point for assessing the VFD output.

Review focus

Confirm that the fundamental frequency corresponds with the commanded motor speed.	Compare the fundamental voltage with the expected output and investigate unexpected peaks.
Compare phase magnitudes and verify approximately 120° separation between the fundamentals.	Review switching frequency and pulse width in the context of the VFD setting and control mode.

VFD POWER PATH

Inside a VFD

The electrical path begins with an AC supply and passes through an EMC filter before entering the drive. The rectifier converts the incoming AC waveform to pulsating DC. The DC link provides the intermediate DC stage, and the switching stage produces the PWM output supplied to the motor through the motor cable.

Each stage has a distinct waveform: the AC input is sinusoidal, the rectifier output is pulsating DC, the DC link is substantially steadier, and the motor-side output is made of high-frequency pulses whose overall pattern follows the commanded motor waveform.

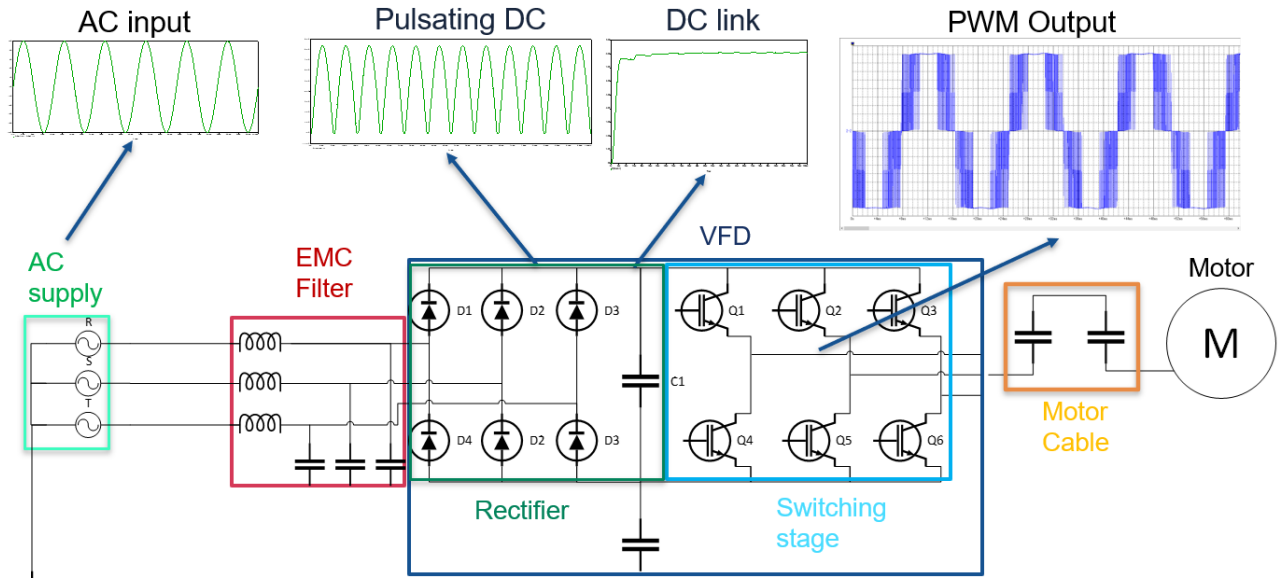


Figure 1. VFD conversion stages and representative waveforms.

Why the stages matter

A waveform measurement gains meaning when it is tied to the stage being observed. The input side reflects the AC supply and rectifier behavior, the DC link reflects the intermediate DC stage, and the motor side reflects the inverter switching pattern. Locating the measurement in the power path helps distinguish a supply-side condition from an output-side condition.

VFD OUTPUT WAVEFORM

Connect the PWM output to the drive command

The PWM output contains a fundamental waveform together with rapid inverter pulses. The three primary checks are the fundamental frequency, the fundamental voltage level, and phase balance. Reviewing these elements connects the motor-side waveform with the VFD command and expected output.

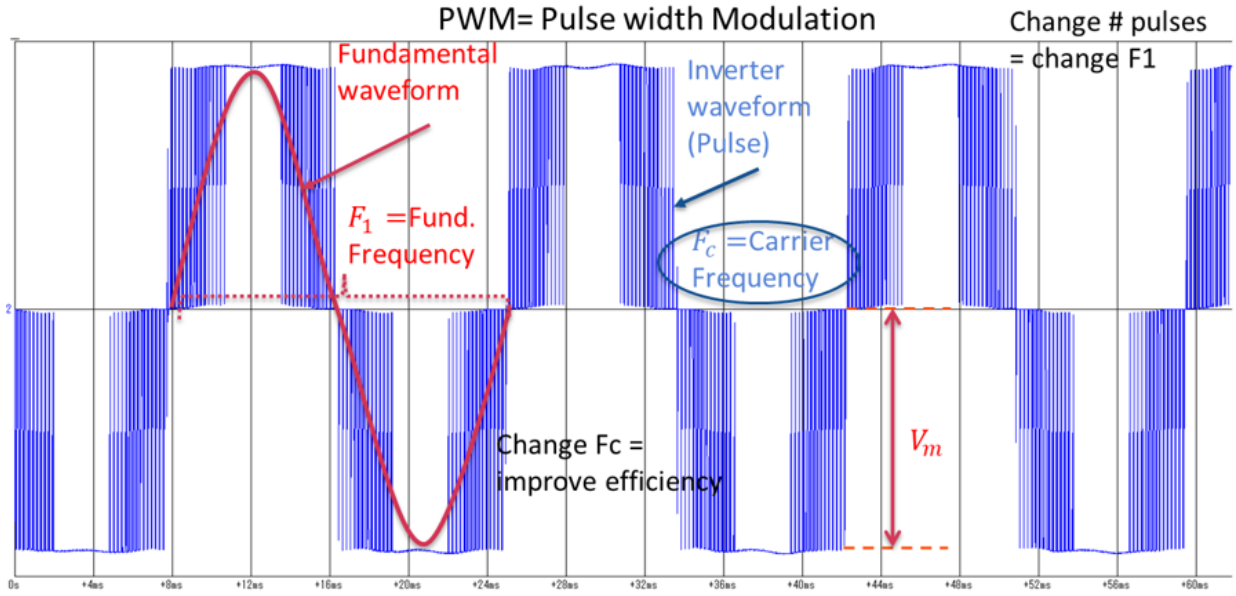


Figure 2. Fundamental frequency, voltage level, and phase balance within a PWM output waveform.

Check	What to compare	What it reveals
Fundamental frequency F1	Compare the output frequency with the VFD command.	The fundamental frequency corresponds with motor rotational speed.
Voltage level Vm	Compare the fundamental voltage with the expected output; investigate unexpected peaks.	The voltage level describes the magnitude of the fundamental output.
Phase balance	Compare phase magnitudes and check for approximately 120° separation between fundamentals.	The phase relationship indicates whether the three fundamental components are balanced.

MEASUREMENT FOCUS Read the fundamental waveform and the inverter pulses as two parts of the same output: the fundamental describes the commanded motor-side behavior, while the switching pattern reflects inverter operation.

PWM TIMING

Review switching frequency and pulse width in context

Pulse-width modulation controls the motor-side output by varying the pulse pattern. In addition to the fundamental output, timing review considers the carrier or switching frequency and the widths of individual pulses. These features should be reviewed against the VFD setting and selected control mode.

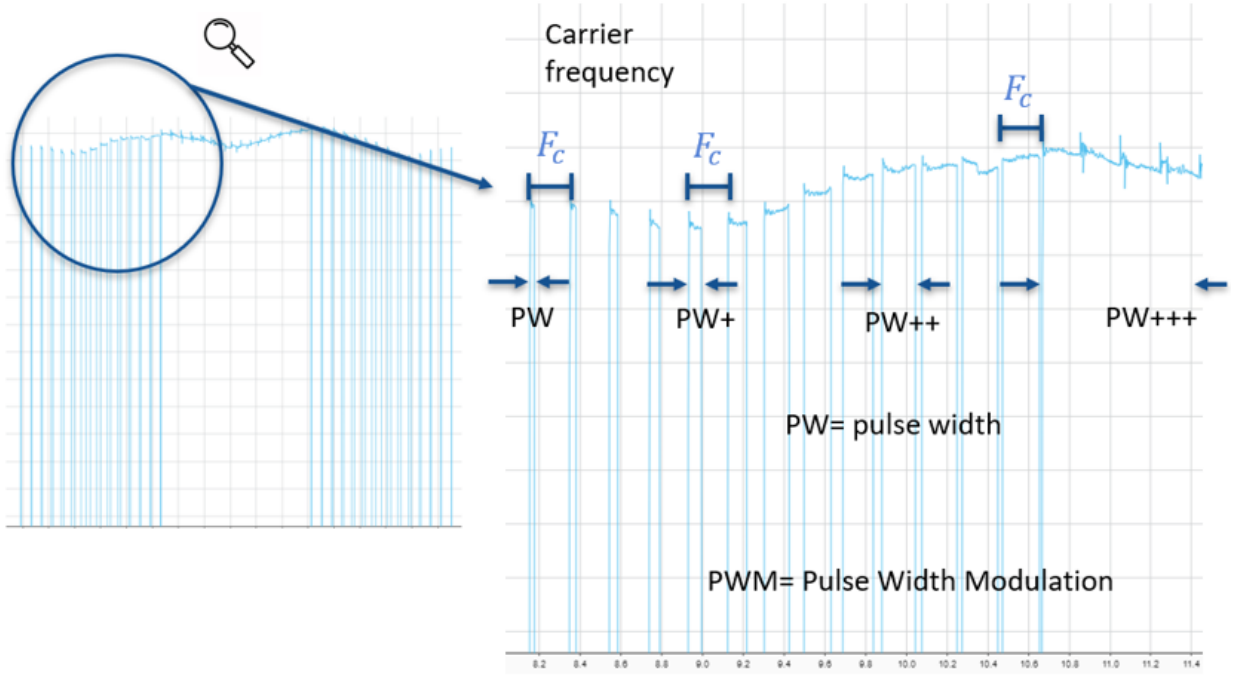


Figure 3. Carrier frequency and pulse width within a PWM waveform.

Feature	Review	Measurement consideration
Switching frequency Fc	Compare with the VFD setting.	Allow for automatic adjustment by the drive.
Pulse width PW	Look for modulation consistent with the drive control mode.	Observe how pulse widths vary across the PWM pattern.
KEY POINT Carrier frequency and pulse width should be interpreted in the context of the VFD configuration rather than as isolated values.		

MEASUREMENT PLATFORM

VFD analysis with the MR8875

The MR8875 provides a modular measurement platform for VFD analysis. Its isolated analog channels, module slots, sampling capability, and direct high-voltage input option support waveform capture across voltage, current, temperature, and related measurement needs.



Figure 4. MR8875 measurement capabilities for VFD analysis.

Capability	Specification
Isolated analog channels	Up to 16 with four MR8901 units.
Module capacity	Four module slots for voltage, current sensors, temperature, and more.
Sampling	500 kS/s sampling, equivalent to 2 microseconds, with MR8901 or MR8905.
Direct high-voltage input	1000 V DC or 700 V AC RMS with MR8905. MR8905 is rated CAT II 1000 V and CAT III 600 V; observe module and lead ratings.

Putting the checks together

A useful review begins by confirming that the fundamental frequency and voltage match the expected operating condition. Phase comparison then verifies the relationship among the three fundamentals. Finally, switching frequency and pulse width are examined in the context of the drive configuration. Taken together, these checks provide a clear view of the VFD output supplied to cooling pumps and other motor-driven equipment.