FLUKE®

Demystifying drive anomalies

using the Fluke 190 Series II 2-Channel ScopeMeter® portable oscilloscope

Application Note

Testing Functions

Case Study

Seeing is believing? More aptly, seeing is understanding.

If anyone can wring every last ounce of functionality out of a piece of electronic test equipment, it's Chris Vogel. At Siemens Building Technologies, Vogel has his work cut out for him keeping HVAC systems running for the company's large commercial customers in Florida's tropical weather, which is marked by seemingly nonstop 90 °F temperatures and 95 % humidity levels. And that's just one of the challenges faced by technicians at Siemens Building Technologies, which plays a more sweeping role in its customers' success: ensuring energy efficiency, comfort, protection against unauthorized access, and fire safety year-round for every building or office tower entrusted to it by customers.

Measuring tools: 190 Series II 2-Channel ScopeMeter® Test Tool

Operator: Chris Vogel, HVAC Technician for Siemens Building Technologies

Measurements: Current and voltage waveform analysis, power factor

Vogel, an HVAC technician, becomes energized when discussing the return on investment in his handheld ScopeMeter® Test Tool. "Out at one large site, where we monitor and troubleshoot variable frequency drives (VFDs), component-level repair can often mean the difference between a $20 repair part and a $100,000 repair bill. I know firsthand, because we recently documented that very scenario."

On large VFDs, Vogel uses his ScopeMeter portable oscilloscope to uncover capacitance problems, transistor firing mishaps, and even bleed-throughs on a gate. "Of course, a transistor is basically a lightning-fast switch," he says. "It switches back and forth between open and closed, and it can sometimes start to break down. When that happens, motors will start doing weird things. For example, at load stage we'll actually see the motor banging back and forth as if it is not sure which way to turn."

Storing a slice of time

It's important, says Vogel, that the technician be able to characterize VFD problems by capturing a waveform from the offending drive. His premise: A signal is much more telling when presented in a waveform view than in a single, static voltage reading. The signal has a shape and value that may look right at a glance, but could just as easily have a distortion or rough "edge," or a momentary spike almost too short to be seen. Either problem, or a host of other signal anomalies, would be indistinguishable with just a numeric reading of the signal.

"The scope allows me to record information, and from a number of sources—sine waves on the inputs and outputs of VFDs, current and voltage—and, for that matter, make comparisons of current and voltage so that I can derive a power factor for the circuit."

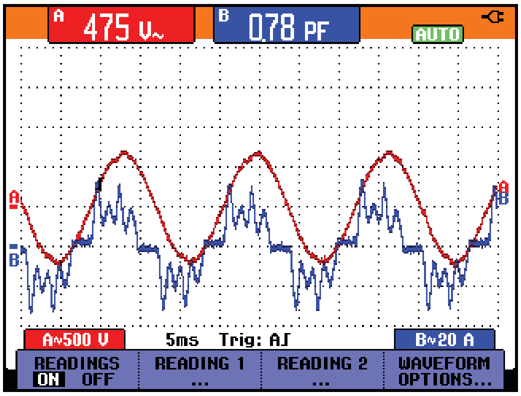

Figure 1. Nonlinear load example.

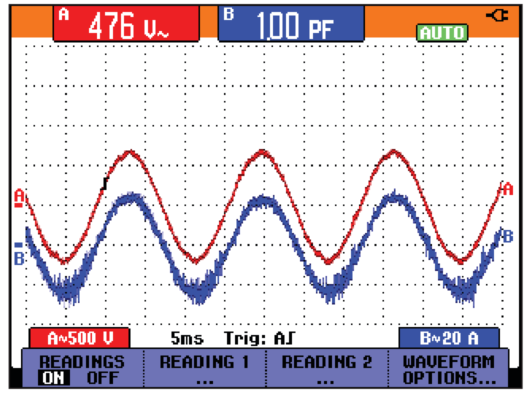

Figure 2. Distortion and line notching are real problems, but are imperceptible with just a meter reading. In this instance, the blue current line is heavily notched.

The Fluke ScopeMeter test tool allows Vogel to store up to 25 permanent records for recall at any time. "Sometimes I will see a suspect waveform and say, 'here's what it looks like during this slice of time, but here's what it should look like.'" With that, he recalls a stored image of the same waveform, recorded when the drive was operating properly. "Storage scopes create a graphical representation of the problem, versus a merely empirical value that a multimeter would show. Of course, with ScopeMeter, we get both."

Nonlinear loads abound

With the weather patterns and lightning in Florida, says Vogel, it's not uncommon for line voltages to rise and fall precipitously. "We were working on a current source drive that I wanted to retrofit, because it had taken a hit from a lightning bolt." At the time, technicians suspected that the drive had been damaged beyond economical repair, and they decided to replace the drive itself, but not the main feeds.

"Shortly after, the drive began to ground-fault and we experienced failures in the building's electrical distribution network. So they asked me to come out. After doing some low-level diagnostics—throwing amp clamps on the wires and comparing phases and phase draws—I placed a ScopeMeter on the system and discovered that we had a lot of line notching going on."

Vogel explains that nonlinear ac loads—loads in which voltage and current are out of phase—create harmonic distortion. (See Figure 1.) Examples of nonlinear loads include welders, VFDs, and battery chargers. Distortion is a result of the non-sinusoidal waveform the drive generates, notes Vogel. He goes on: "Any time you have long conduit runs, the wires create magnetic fields around themselves. With harmonic distortion, current is actually reflected back into the wiring. It becomes a self-sustaining loop. That's what we call line notching. (See Figure 2.) As you switch the ac current on and off, it's the equivalent of opening and closing a valve on a water pipe very fast, causing pulsations in the flow. Line notching is the electrical equivalent of that phenomenon."

Circling back to the original problem, Vogel notes that the high-current for each of the three phases had led the original installers to use four parallel conduits for each phase. In such a configuration, a smaller conductor for each phase would typically have been run down a single conduit, with multiple conduits going to the equipment and each smaller conductor terminated on a terminal block for its appropriate phase. But, instead, the installers had run feeds A and B in one conduit, B and C in another, and C and A in the third. "The drives were passing almost 42 A to ground, causing them to trip on ground faults and overvoltages," said Vogel. "Of course, with the phase conductors running through conduits and the sheer number of conductors (sixteen 500 MCM runs), they were concealed, and nobody had thought to look further."

Power factor issues

Vogel recently was called on to solve a power factor problem in a large commercial building. "A number of 250-horsepower chiller motors were in place, but they were super old. In high ambient weather conditions the chillers would load up, and I could use ScopeMeter to see the phases moving farther and farther apart." (See Figure 3a.)

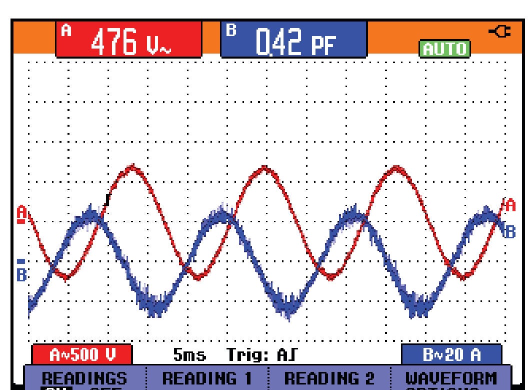

Figure 3a. Compare the waveform alignment and power factor reading between these two examples.

As chill water temperature came down, the power factor would drop nominally from about 0.7, which was acceptable, to about 0.32—"The lowest I've ever seen it." Then, as Vogel 'staged' the equipment down—namely, drives on the cooling towers, drives on the primary loop pumps, and drives on the primary chill water system—the phases would come back in sync and the power factor would rise again.

"You can view readings on the meter, but you don't understand what's causing the power-factor drop until you look at the waveform itself. You can see the field collapsing as the motor winds down, and you can see the current and voltage phases come closer to being in sync. (See Figure 3b.)

"As the power factor comes back and approaches 1.0, it's fascinating to watch, even for me, and the customer is more likely to understand the problem. More importantly, he can understand how to correct it."

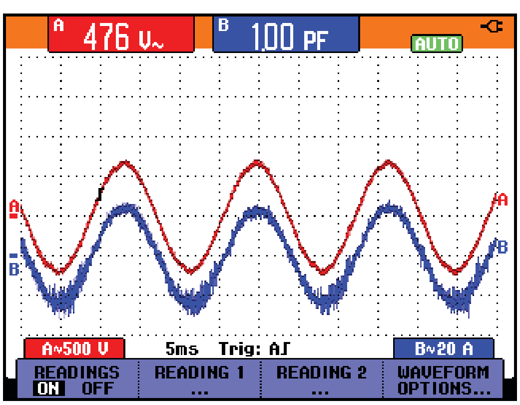

Figure 3b. Good power factor example.

Payback time

One of Vogel's new projects is to install power-factor correction capacitors on an MCC (Motor Control Center) panel at a utility customer's site. The capacitors will be installed in parallel with the connected circuits. This is not just about improving power factor, but about keeping costs in line.

Many electric utilities charge building owners a penalty for low power factor. (One utility, for example, charges building owners $0.14 per kVAR hour when power factor drops below 0.97.)

"According to our calculations, with an added 65 KVARs of capacitance, it's about a $200,000 proposition to add these caps. The customer is running two 800-ton machines fully loaded during the peak of summer here in the 95 °F Florida heat and 90 % humidity."

Essentially, the customer's air conditioning plant is running at 100 % electrically but not mechanically, says Vogel, noting that the customer's electric bill varies from $50,000 to $60,000 a month. "We determined that, if we can increase the power factor on this panel to 0.85, the customer's electrical consumption will drop by almost one-third. That correction, considering the utility's high power consumption, will give them a payback period of less than one year. And, they could get additional capacity without any work on the mechanical system!"

The ScopeMeter, he says, identified the problem. "We took it to the customer and said 'Hey, as we stage these motors down, as we shut things off, your power factor starts to rise again.' First, we measured the signal on the MCC panel, and then we measured the signal on their main power panel. We set the same function up on the chiller plant, and we could see the power factor clean up."

Today the customer understands the nature of the problem, he says, noting that he had also directed the customer to an Internet site where he could calculate his own energy savings from improving power factor. "Next, we stood by as he observed the current dropping with modifications to the panel, not to mention that they started to see immediate reductions in total kilowatts used. So, down here you can't beat the heat, but you can make it a little bit more palatable."

"You'll laugh, but I'm a union pipefitter by trade," says Vogel, "and here I am doing high-end electrical troubleshooting. The ScopeMeter has taken my trade in a whole new direction."

What is Power Factor?

The power factor of an ac electric power system is defined as the ratio of the real power to the apparent power, and is a number between 0 and 1.

Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit.

Due to energy stored in the load and returned to the source, or due to a nonlinear load that distorts the wave shape of the current drawn from the source, the apparent power can be greater than the real power.

Low-power-factor loads increase losses in a power distribution system and result in increased energy costs.

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