PQTN BRIEF

Power Quality Testing Network

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The Effects of Point-on-Wave on Low-Voltage Tolerance of Industrial Process Devices

Background

Programmable logic controllers, adjustable-speed drives, power supplies, relays, contactors, and motor starters work in concert to automate modern industrial processes. High volumes and continuous production require that these process devices tolerate common voltage variations. Recently, researchers have begun to characterize the low-voltage tolerance of process devices—how well they behave during momentary voltage interruptions and voltage sags of various durations and magnitudes. Eventually, the manufacturers of these devices may include such information in the device specifications or even on the device itself, a practice promoted by EPRI.

Whether voltage-tolerance information comes from the manufacturer of the device or a third-party testing company, the information must be reliable and consistent with real-world electrical environments. This PQTN Brief is the first of two Briefs that describe the results of laboratory experiments to explore the effects of voltage-sag variables. This Brief focuses on how the point on the sine wave at which a sag or interruption is initiated affects the resulting low-voltage tolerance of common process devices. PQTN Brief Number 45 focuses on how phase shifts occurring during voltage sags affect the resulting low-voltage tolerance.

Objective

The objective of the tests performed at the EPRI Power Electronics Applications Center (PEAC) Power Quality Test Facility was to determine whether the point on the sine wave at which a voltage sag or interruption is initiated affects the low-voltage tolerance of common relays, motor starters, contactors, and power supplies.

Test Setup

The low-voltage tolerances of four general-purpose relays, five motor starters, seven contactors, and five DC power supplies were characterized (see Table 1). To characterize the devices, a portable sag generator was connected to each tested device, as shown in Figure 1. Nominal voltage was applied to the tested device, either 120 or 24 AC volts. Voltage to devices rated at 24 volts was stepped down from 120 volts using a 1-kVA step-down transformer. During each trial, a voltage sag or interruption was initiated by the sag generator at either zero degrees or 90 degrees on the sine wave, as shown in Figure 2. By programming the sag generator, the duration of

Table 1. Tested Process Devices and Their Ratings

Name	*Voltage (V)*	*Size*	*Description*
CR1	120	10 A	DPDT Relay
CR2	120	10 A	DPDT Relay
CR3	24	10 A	DPDT Relay
CR4	24	5 A	DPDT Relay
MS1	120	2 HP @ 230 V	3-Pole Motor Starter
MS2	120	3 HP @ 230 V	3-Pole Motor Starter
MS3	120	3 HP @ 230 V	3-Pole Motor Starter
MS4	120	1.5 HP @ 230 V	3-Pole Motor Starter
MS5	120	30 HP @ 230 V	3-Pole Motor Starter
MC1	120	10 Amp	4-Pole Contactor
MC2	120	10 Amp	4-Pole Contactor
MC3	120	3 HP @ 230 V	3-Pole Contactor
MC4	24	7.5 HP @ 230 V	3-Pole Contactor
MC5	24	10 HP @ 230 V	3-Pole Contactor
MC6	24	7.5 HP @ 230 V	3-Pole Contactor
MC7	24	40 HP @ 230 V	3-Pole Contactor
PS1	120	60 W	PLC Power Supply
PS2	120	140 W	Instrument Power Supply
PS3	120	200 W	Computer Power Supply
PS4	120	500 W	Multi-Output Power Supply
PS5	120	40 W	Unregulated Power Supply

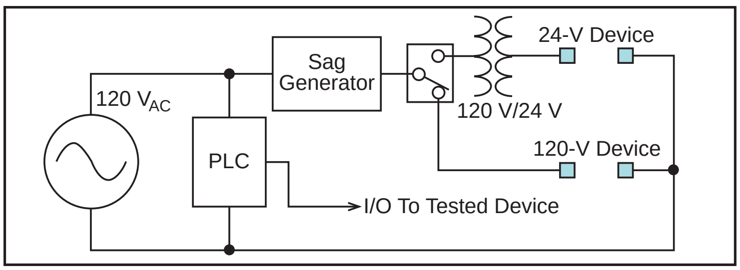

Figure 1. Test Setup

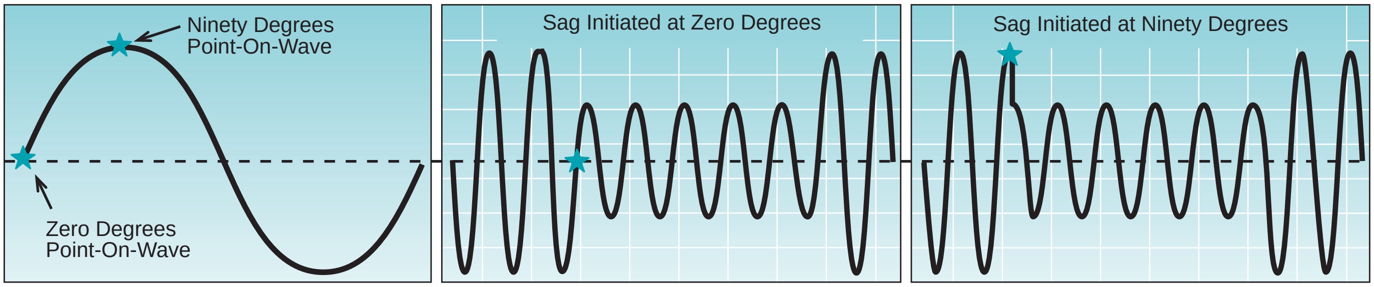

Figure 2. Five-Cycle Voltage Sags Initiated at Zero Degrees and 90 Degrees on the Sine Wave

the initiated sags was varied from 0.25 to 60 cycles. During each trial, voltage amplitude was varied while the sag duration was held constant. The amplitude of the applied sags was reduced from 95 percent of nominal until the device dropped out. Device dropouts were detected by a programmable logic controller (PLC).

TEST RESULTS

Table 2 and Figures 3 and 4 show the data collected during trials at zero and 90 degrees point-on-wave. Table 2 shows the sag magnitudes at which the devices dropped out for two sag durations: five and 30 cycles. Figure 3 shows the sag magnitudes at which the devices dropped out at a duration of five cycles. A five-cycle duration was selected as a representative duration because according to published power quality surveys, most voltage sags, especially most sags occurring at semiconductor manufacturing facilities, last about five cycles. Figure 4 shows sag durations at which a momentary voltage interruption caused the devices to drop out. Note that some of the devices could not tolerate a momentary voltage interruption of one-quarter cycle or longer.

Table 2. Voltage Magnitude at Which the Device Dropped Out During a Five-Cycle and a 30-Cycle Voltage Sag

Cycles	*P.O.W.*	*Device*																				
		CR1	*CR2*	*CR3*	*CR4*	*MS1*	*MS2*	*MS3*	*MS4*	*MS5*	*MC1*	*MC2*	*MC3*	*MC4*	*MC5*	*MC6*	*MC7*	*PS1*	*PS2*	*PS3*	*PS4*	*PS5*
5	0	73%	74%	60%	60%	57%	49%	35%	54%	57%	38%	45%	50%	51%	57%	55%	56%	78%	70%	48%	60%	95%
	90	68%	68%	52%	54%	55%	42%	33%	51%	57%	38%	43%	51%	52%	55%	50%	45%	78%	70%	48%	60%	95%
30	0	73%	74%	60%	60%	57%	49%	35%	55%	60%	38%	45%	50%	51%	58%	55%	56%	78%	70%	53%	60%	95%
	90	68%	69%	53%	53%	55%	47%	35%	52%	58%	38%	44%	51%	52%	55%	50%	44%	78%	70%	53%	60%	95%

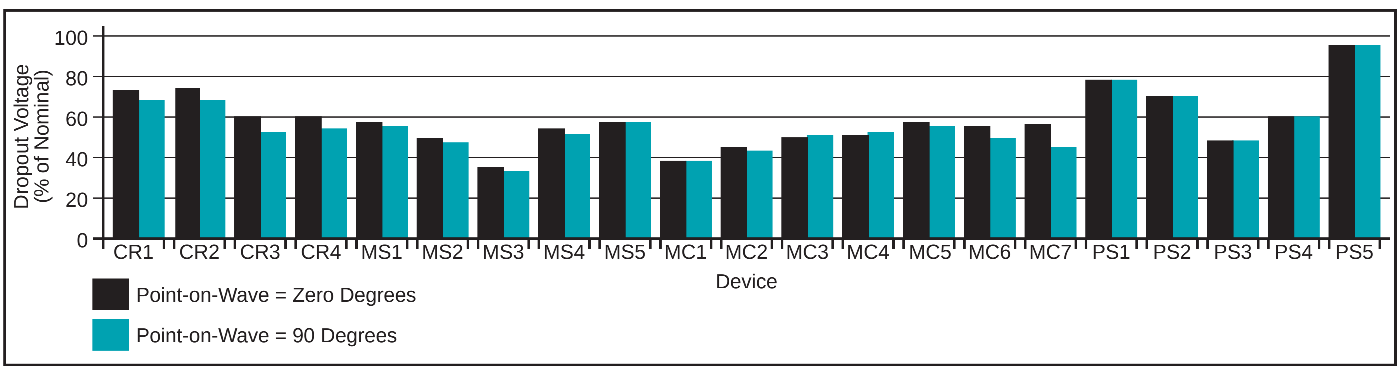

Figure 3. Voltage Magnitude of a Five-Cycle Voltage Sag at Which the Device Dropped Out

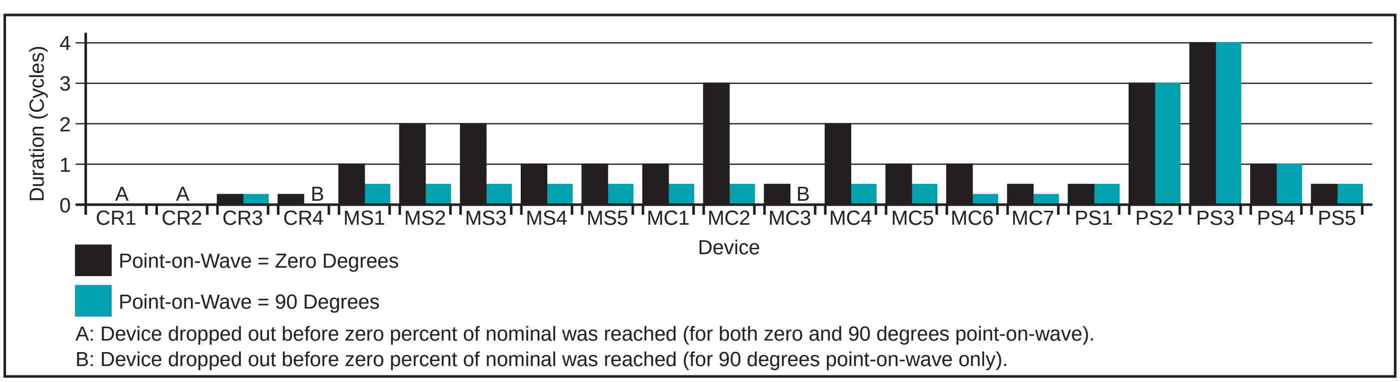

Figure 4. Duration of Momentary Voltage Interruption at Which the Device Dropped Out

Although the point-on-wave did not affect the low-voltage tolerance of the power supplies, it did affect the tolerance of the relays, motor starters, and contactors. Figures 5, 6, and 7 show the composite low-voltage-tolerance graphs (average of the duration-magnitude data points) for those three types of devices at zero degrees and 90 degrees point-on-wave.

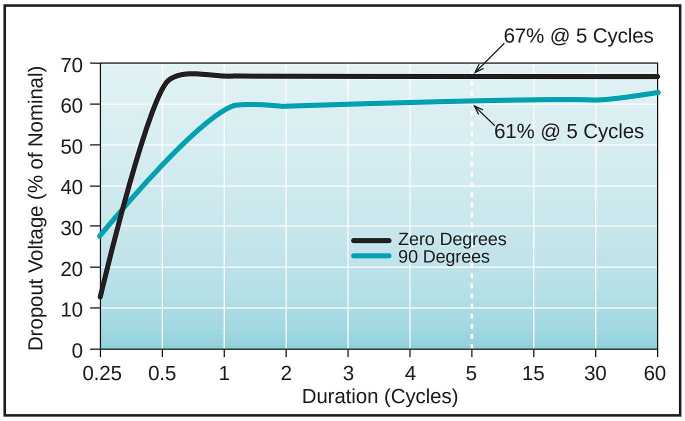

Figure 5. Composite Low-Voltage Tolerance of Relays

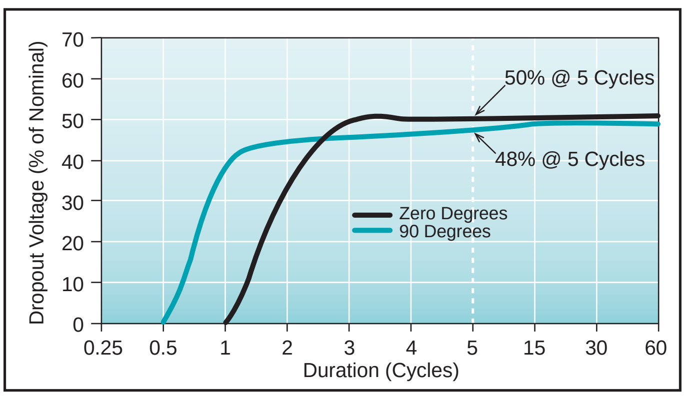

Figure 6. Composite Low-Voltage Tolerance of Motor Starters

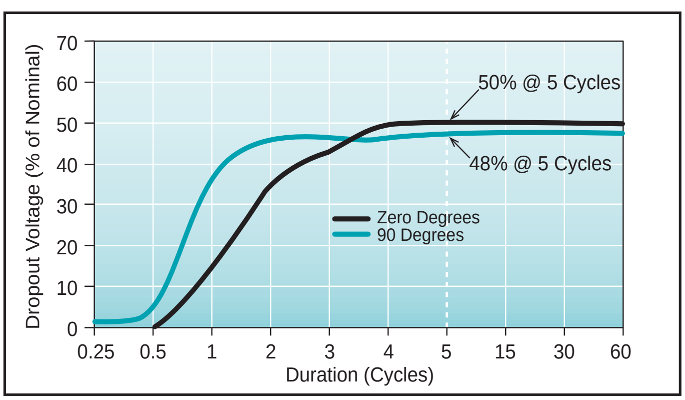

Figure 7. Composite Low-Voltage Tolerance of Contactors

DISCUSSION

Except for the power supplies, the average low-voltage tolerance at zero degrees point-on-wave was worse than the tolerance at 90 degrees during voltage sags lasting longer than four cycles. Of the relays, motor starters, and contactors, only two demonstrated no difference between zero and 90 degrees, and only two demonstrated better tolerance at zero degrees. The average percent difference at five cycles between zero-degree tolerance and 90-degree tolerance was 9.6 percent for the relays (6.9 to 13.3 percent), 5.8 percent for the motor starters (zero to 14.3 percent), and 5.9 percent for the contactors (zero to 20 percent). Excluding the power supplies, the overall average difference at five cycles between zero-degree and 90-degree tolerance was 6.8 percent. For sags less than three or four cycles, the trend reversed: Tolerance at zero degrees point-on-wave was better than tolerance at 90 degrees. However, sags of such durations are much less frequent than sags lasting five cycles or more. Point-on-wave variation did not affect the power supplies. For all five power supplies, the tolerance for zero degrees equaled the tolerance for 90 degrees.

Point-on-wave had a different effect on the duration of momentary voltage interruptions that caused a device to drop out. Including the power supplies, the average duration of momentary interruptions that dropped out a device was 1.2 cycles at zero degrees point-on-wave but only 0.7 cycles at 90 degrees. Because almost all voltage sags last longer than one cycle, this finding is likely insignificant when voltage sags originate from the utility system. However, the finding may be noteworthy when devices are protected by power conditioners such as small uninterruptible power supplies with static switches, which may pass or initiate sags and interruptions lasting less than one cycle.

SIGNIFICANCE

Manufacturers of industrial control devices and third-party testing companies should consider characterizing the low-voltage tolerance of control devices by initiating voltage sags at zero degrees on the sine wave. Such a method will generally yield a worst-case low-voltage tolerance of the device for the most common sags. For end users, these test results may go a long way to explain why the same process devices seem to respond differently to voltage sags having the same magnitude and duration. When devices inconsistently drop out, end users tend to be confused about the source of incompatibility, perhaps blaming both the devices and the utility supply. Therefore, it is important for electric utilities to educate manufacturers and end users about point-on-wave effects.

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