Performance of a Hold-In Device for Relays, Contactors, and Motor Starters

Background

Relays, contactors, and motor starters are used extensively in industrial facilities to control process equipment. However, these devices often have a low tolerance to voltage sags, and are often diagnosed as weak links in automated processes. During a common voltage sag, the coils in these devices may de-energize long enough to cause the contacts to open and connected equipment to shut down. Recognizing this Achilles' heel of the process industry, some manufacturers of power conditioners have invented hold-in devices that are marketed as improving the voltage-sag and interruption tolerance of relays, contactors, and motor starters. One such device connects between the AC source voltage and the coil. During a voltage sag, the device maintains a current flow through the coil sufficient to hold in the contacts. This PQ Brief reports the results of testing that device.

Objective

The objective of the tests performed at the EPRI Power Electronics Applications Center (PEAC) Power Quality Test Facility was to characterize the performance of a commercially available hold-in device designed to enhance the voltage-sag and interruption tolerance of relays and motor starters.

Test Setup

The voltage-sag and interruption tolerance of one relay and three motor starters was characterized with and without the hold-in device installed in the circuit. Table 1 shows their electrical characteristics. To characterize the tolerance of the devices, a sag generator was connected to each tested device as shown in Figure 1. Nominal voltage (120 AC volts) was applied to the test circuit. The particular model of hold-in device used in each trial was selected based upon the DC coil resistance of the relay or motor starter, which was measured with a common digital DC ohmmeter (see Table 1). (One motor starter required a larger-model device because the model suggested by the measured DC coil resistance could not supply enough current to pull in the contacts.) 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 the initiated voltage sag or interruption was varied from 0.25 to 60 cycles. During each trial, voltage

Table 1. Electrical characteristics of tested relay and motor starters

Name	*DC Coil Resistance (Ω)*	*Hold-In Current (A)*	*Size*	*Description*
CR1	2280	0.02	10 A	DPDT Relay
MS1	124	0.05	2 HP @ 230 V	3-Pole Motor Starter
MS2	44.5	0.25	1.5 HP @ 230 V	3-Pole Motor Starter
MS3	8.50	0.39	30 HP @ 230 V	3-Pole Motor Starter

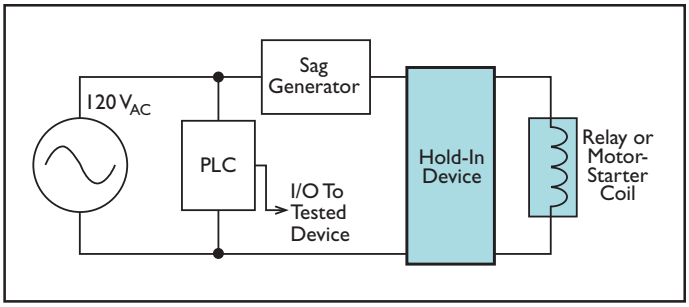

Figure 1. Test setup with hold-in device in the circuit

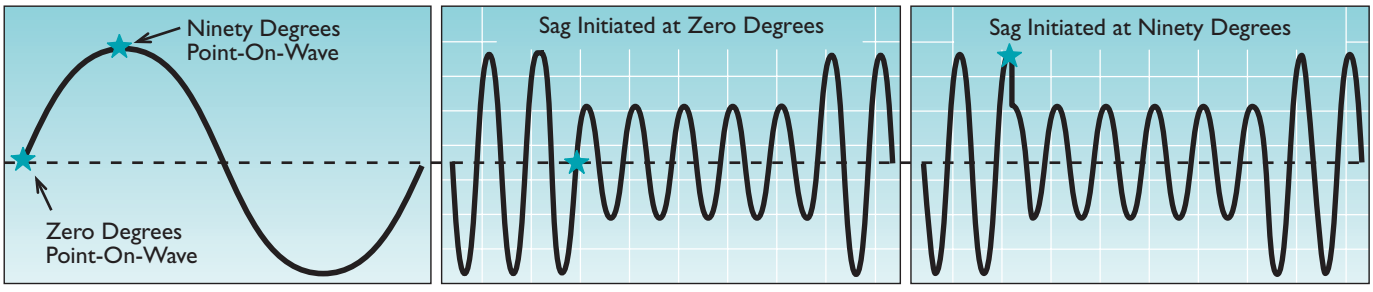

Figure 2. Five-cycle voltage sags initiated at zero degrees and 90 degrees on the sine wave

amplitude was varied for each sag duration. The amplitude of the applied voltage was reduced from 95 percent of nominal until the relay or motor starter dropped out. These dropouts were detected by a programmable logic controller (PLC), whose input/output card was connected to the tested relay or motor starter.

Results

Voltage-Sag Tolerance

Figures 3 through 6 show the test results for the relay and three motor starters. The Institute of Electrical and Electronics Engineers (IEEE) defines a voltage sag as any low voltage between 90 and 10 percent of the nominal voltage lasting between 0.5 and 30 cycles. However, according to published power quality surveys, most voltage sags last between 5 and 30 cycles. Therefore, improvement in voltage-sag tolerance is henceforth evaluated in that range (see "Range of Interest" in the figures). Table 2 shows the improvement in voltage-sag tolerance afforded by the hold-in device (averaged between zero and 90 degrees point-on-wave).

Voltage-Interruption Tolerance

The IEEE defines a voltage interruption as any low voltage of less than 10 percent of the nominal voltage lasting between 0.5 cycles and 3 seconds. As shown in Figures 3 through 6, the hold-in device improved the tolerance of the relay and motor starters to momentary voltage interruptions. Table 3 shows the improvement in voltage-interruption tolerance afforded by the hold-in device (averaged between zero and 90 degrees point-on-wave).

Discussion

The hold-in device improved the sag tolerance of the relay and three motor starters. For the relay, improvement in voltage-sag tolerance was the same at both 5 and 30 cycles. However, improvement in the sag tolerance of the motor starters was significantly better at five cycles than at 30 cycles. Without the hold-in device installed, sag tolerance was less at zero degrees than at 90 degrees point-on-wave. However, with the hold-in device installed, point-on-wave had practically no effect on sag tolerance. On average, the hold-in device improved the sag tolerance of the tested relay and motor starters by about 52 percent at 5 cycles and by about 37 percent at 30 cycles.

Without the hold-in device installed, the relay did not tolerate a voltage interruption for any of the test durations. With the hold-in device installed, it tolerated a remaining voltage of 10 percent for a little less than two cycles and tolerated no remaining voltage for one-half cycle. Except for motor starter MS2, the

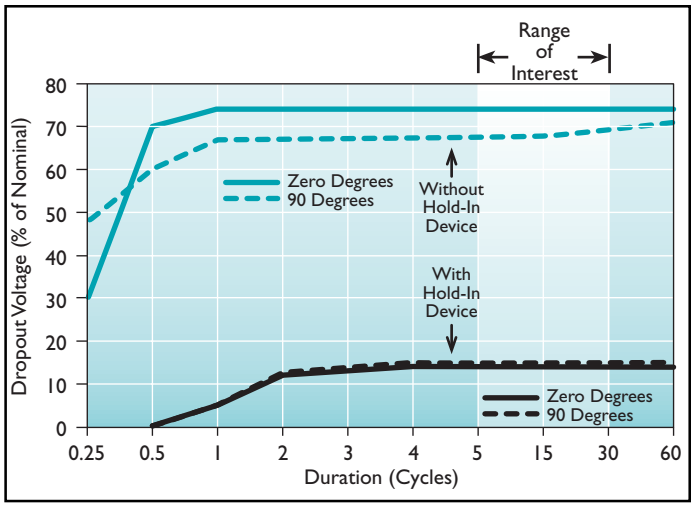

Figure 3. Voltage-sag and interruption tolerance of relay CR1

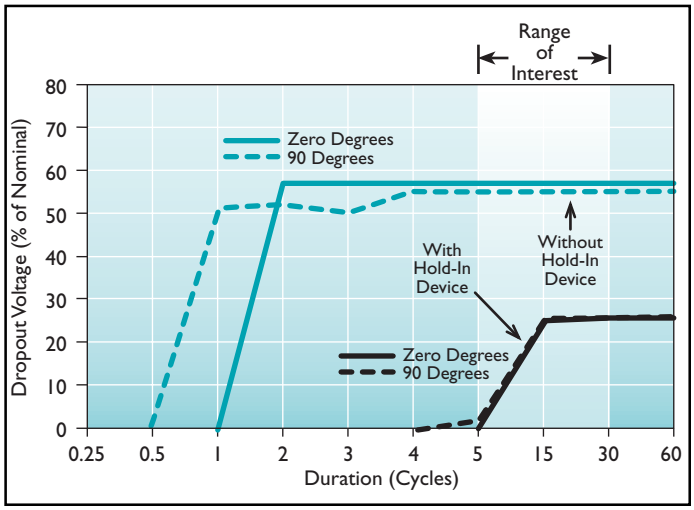

Figure 4. Voltage-sag and interruption tolerance of motor starter MS1

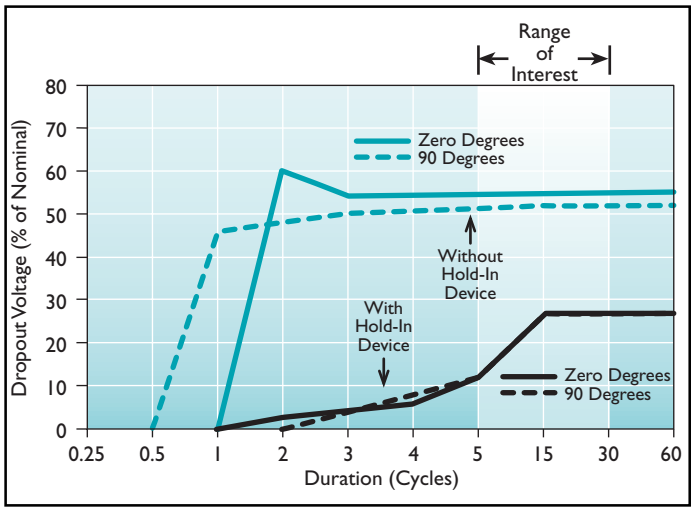

Figure 5. Voltage-sag and interruption tolerance of motor starter MS2

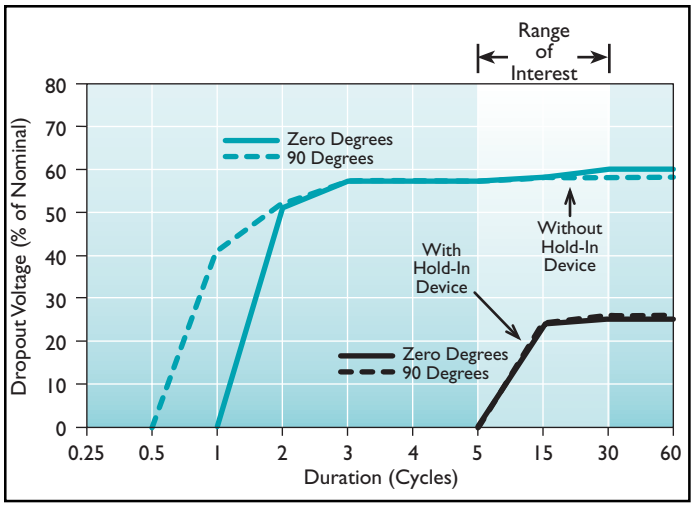

Figure 6. Voltage-sag and interruption tolerance of motor starter MS3

Table 2. Improvement in voltage-sag tolerance (averaged between tolerance at zero degrees and 90 degrees point-on-wave) calculated in percent of nominal voltage

Sag Duration	*CR1*	*MS1*	*MS2*	*MS3*
5 Cycles	57%	56%	41%	57%
30 Cycles	57%	30%	27%	34%

Table 3. Improvement in voltage-interruption tolerance (averaged between tolerance at zero degrees and 90 degrees point-on-wave) calculated in cycles*

Remaining Voltage	*CR1*	*MS1*	*MS2*	*MS3*
10% of Nominal	1.8	9.0	3.8	9.0
0% of Nominal	0.5	3.8	0.5	4.3

**Calculations at 10-percent remaining voltage are approximate.*

tolerance for interruptions was greater for the motor starters than for the relay. The average tolerance to momentary voltage interruptions was about 6 cycles for a 10-percent remaining voltage and about 2.5 cycles for a zero-percent remaining voltage.

Significance

End users of industrial process equipment have many options for increasing voltage-sag and interruption tolerance. Power conditioners such as uninterruptible power supplies and constant-voltage transformers can be expensive remedies for shutdown problems caused by voltage sags. In fact, they may be more expensive than the equipment they are designed to fortify. Additionally, they are bulky and may interfere with emergency-stop operations because they support entire control circuits and may mask signals from emergency-stop circuits. The hold-in device tested for this PQ Brief increased the voltage-sag and interruption tolerance of a relay and motor starters typically used to control motors and power circuits in industrial processes. The device does not interfere with emergency-stop operations because it supports only the coil of a contactor or relay and allows the coil to de-energize when the voltage is removed. It is small and can be easily installed next to a relay, contactor, or motor starter. However, because coil resistances vary considerably among manufacturers, sizing the hold-in device may require assistance from the device manufacturer or vendor.

Acknowledgments

Special recognition goes to Clemson University for development of their research under the sponsorship of Duke Power Company. Testing was conducted at the Power Electronics Applications Center in Knoxville, Tennessee. Special thanks to Larry Morgan of Duke Power for his assistance in the development, testing, and creation of this publication.

The EPRI Power Electronics Applications Center (PEAC) supports electric utilities in their efforts to understand and resolve power quality problems and system compatibility issues; help utilities solidify durable, beneficial relationships with their customers, manufacturers, and standards organizations; and empower utilities with knowledge via power quality training and publications.

For information about the EPRI Power Electronics Applications Center, call 423-974-8288. To order EPRI publications, call the EPRI Customer Assistance Center at 800-313-3774 or, if outside the U.S., 1-650-855-2121.

PB-111613

♻*Printed on recycled paper in the United States of America.*

EPRI • 3412 Hillview Avenue, Palo Alto, California 94304
PO Box 10412, Palo Alto, California 94303 USA
askepri@epri.com • www.epri.com

Brief Number 46, October 1998