

Performance of an ASD Ride-Through Device During Voltage Sags

Background Adjustable-speed drives (ASDs) are often used in commercial and industrial facilities to improve process control and save energy. However, ASDs often have a low tolerance to voltage sags. During a voltage sag, the dc-bus capacitor of a typical ASD discharges and the voltage at the dc bus decreases. Depending on the setting of the drive's undervoltage protection (called the trip point), the drive may trip after the dc-bus voltage decreases below the trip point. In previous testing conducted at the EPRI Power Electronics Applications Center (PEAC), 17 commercially available 5-hp ASDs were characterized for voltage-sag tolerance. Ninety percent of the tested drives tripped during a five-cycle voltage sag down to 50% of the nominal supply voltage. Since those tests, a number of potential remedies for ASD tripping during voltage sags have been investigated, including a flying-restart technology (see PQTN Brief Number 30). This PQTN Brief reports the results of testing a device designed to maintain the dc-bus voltage during voltage sags and thereby enhance the voltage-sag tolerance of an ASD-driven process.

Objective The objective of the tests performed at the EPRI Power Electronics Applications Center was to characterize the performance of a commercially available ride-through device designed to reduce the susceptibility of an ASD-driven process to voltage sags.

Test Setup Figure 1 shows a diagram of the test setup. A 480-volt, 24-kilowatt ride-through device containing four 6-kilowatt modules was tested. Each module is designed to be installed between the three-phase power source and the ASD dc bus and consists of a three-phase ac-to-dc rectifier, a filter capacitor, and a boost converter (inductor-and-chopper regulator). The ride-through device continuously monitors the dc bus of the ASD. During a voltage sag, if the voltage at the dc bus drops below a user-adjustable trip point, then the device switches on. The device does not store energy but transfers the energy remaining in the incoming ac line to the ASD dc-bus to maintain it above the trip point. To match the power rating of one module, the output of one module was connected to the dc bus of a 5-hp ASD. A 5-hp induction motor loaded with an eddy-current brake was used as the ASD-driven load. Set for either 100% or 50% loading, the eddy-current brake was equipped with a tachometer to measure the speed of the motor shaft. The inputs of the ASD and the ride-through module were connected to a variable three-phase voltage source (three single-phase variable transformers). A computer-controlled transfer switch created voltage sags of defined duration and magnitude by switching from one tap of the transformers to another. Digitizing signal analyzers were used to record the ASD input voltage, dc-bus voltage, motor speed, and motor current during the tests.

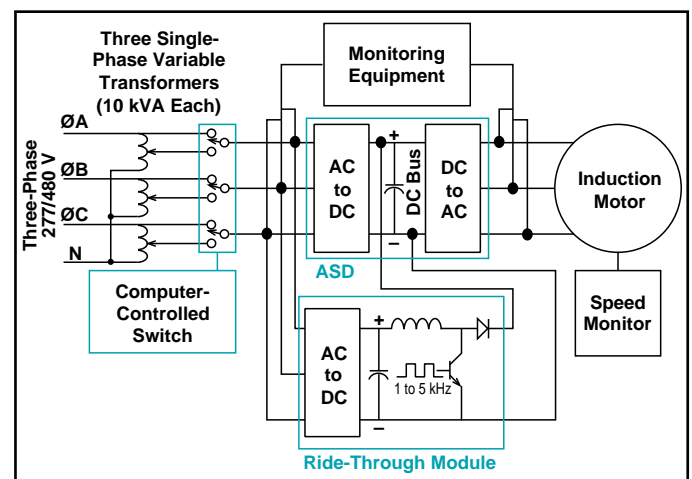


Figure 1. Test Setup

switch created voltage sags of defined duration and magnitude by switching from one tap of the transformers to another. Digitizing signal analyzers were used to record the ASD input voltage, dc-bus voltage, motor speed, and motor current during the tests.

Test Results Figure 2 shows the input ac voltage, motor current, motor speed, and dc-bus voltage at 100% loading during a 15-cycle voltage sag to 50% of the nominal voltage without the ride-through device. At the onset of the voltage sag, the dc-bus voltage began to drop from a nominal 660 volts. The dc-bus voltage continued to drop until it reached the ASD undervoltage trip point of

352 volts. At that point, the ASD tripped and the motor current decreased to zero. Figure 3 shows the same measurements taken during the same conditions for the ASD with a ride-through device connected. During the voltage sag, the dc-bus voltage dropped from 660 volts to about 575 volts, at which point the ride-through

device switched on to maintain the dc bus at 575 volts during the sag. The motor current and speed were also maintained. When the input voltage returned to normal, the ride-through device switched off and the dc-bus voltage returned to nominal 660 volts.

To create a sag-tolerance envelope for a typical ASD with and without the ride-through device, the ASD was subjected to voltage sags ranging from 0% to 90% of the nominal voltage and from one to 100 cycles. These sags were applied at 50% loading and at 100% loading, with and without the ride-through device. With the device installed, the steady-state (longer than 100 cycles) voltage tolerance increased from 80% of nominal to 40% of nominal. Figures 4 and 5 present the test results in a CBEMA-type curve.

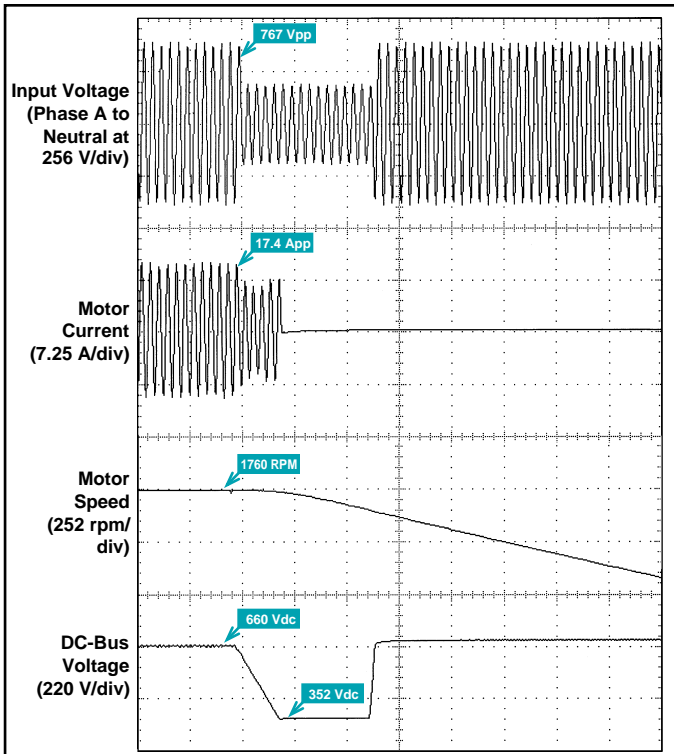


Figure 2. Without Ride-Through Device: Input Voltage, Motor Current, Motor Speed, and DC-Bus Voltage During a 50% Voltage Sag (100% Loading)

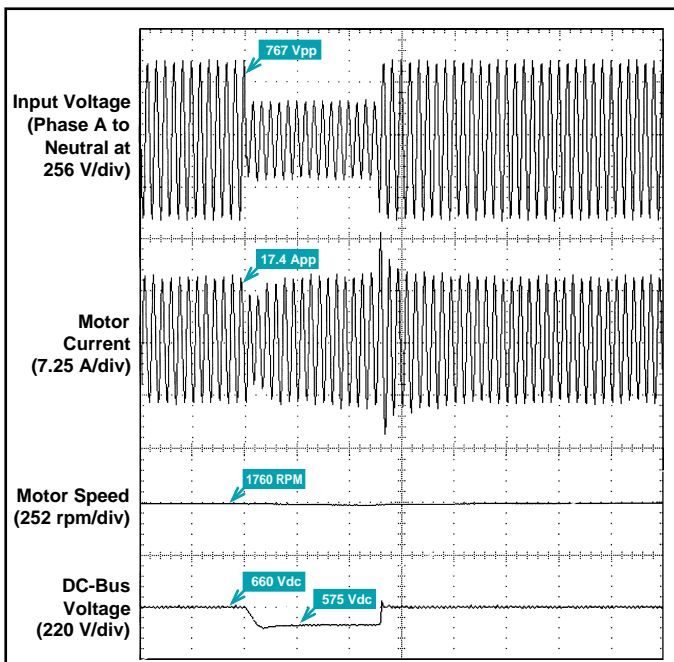


Figure 3. With Ride-Through Device: Input Voltage, Motor Current, Motor Speed, and DC-Bus Voltage During a 50% Voltage Sag (100% Loading)

DISCUSSION

The ride-through device greatly increased the ASD voltage-sag tolerance. Because it does not store energy, it could not provide protection against voltage sags below 30% of nominal voltage. However, recent power quality surveys indicate that in almost 80% of all voltage sags, the lowest phase voltage is greater than 50% of nominal voltage. Motor load affected the ASD voltage tolerance more significantly for voltage sags to zero than for sags above 30% of nominal voltage. As the load increased, the ASD voltage tolerance decreased—with and without the ride-through device.

SIGNIFICANCE

Most continuous processes require adjustable-speed drives to precisely control motor speed. However, voltage sags and interruptions can trip a typical, unprotected ASD. Lowering the trip point will slightly increase sag tolerance. Recent advances in ASD technology make it possible to restart an ASD driving a spinning motor as soon as voltage recovers (see PQTN Brief No. 30). However, when changing the undervoltage trip point or enabling the restart parameter of an ASD is not a viable option, then a ride-through device such as the one tested for this Brief was found to be an

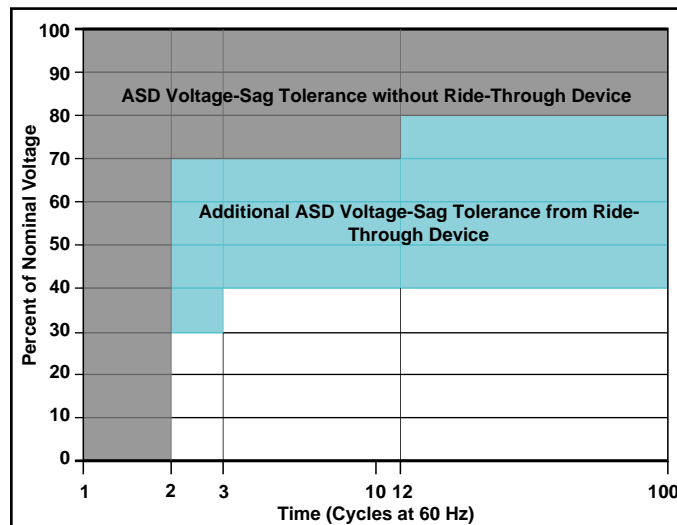


Figure 4. ASD Voltage-Sag Tolerance Envelope for 100% Loading

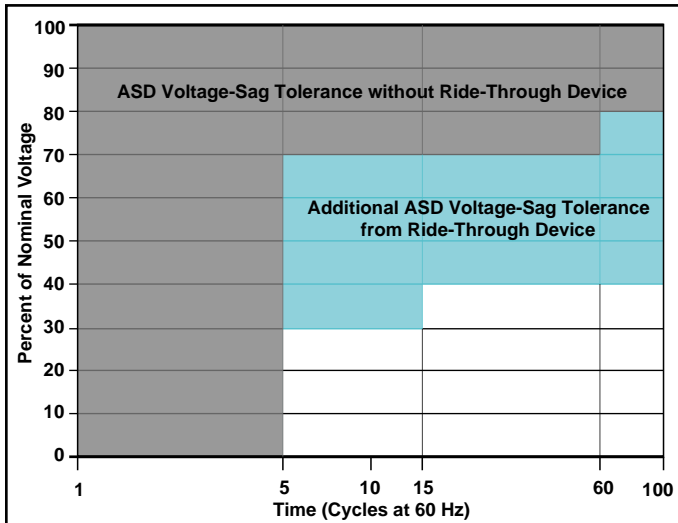


Figure 5. ASD Voltage-Sag Tolerance Envelope for 50% Loading

effective way to increase sag tolerance. Such a ride-through technology is offered as an add-on feature by most ASD manufacturers but can also be purchased separately and retrofitted to an existing ASD. The device tested for this Brief, which is available in sizes from four to 200 kilowatts, costs less and is smaller than energy-storage options such as add-on capacitors, batteries, uninterruptible power supplies, and motor-generator sets. However, unlike energy-storage devices, the tested ride-through device requires a residual ac input voltage and therefore cannot protect ASDs against momentary interruptions of power.

ACKNOWLEDGMENTS

This work was conducted at the Power Electronics Applications Center in Knoxville, Tennessee, and was sponsored by EPRI and Puget Sound Power & Light Co.

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PB-106541

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