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PQTN BRIEF

Power Quality Testing Network

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Low-Voltage Ride-Through Performance of AC Contactor Motor Starters

Background

Faults in the power supply system typically cause momentary low voltages. The duration and severity of a low voltage depends on the type and location of the fault and the time required to remove it. Voltage sags lasting from 5 to 15 cycles (83 to 250 ms) are the most common momentary low voltages and can adversely affect end-user equipment. Because ac contactor motor starters (contactors) control induction motors, their performance during low voltages is a significant concern for industrial users that rely on continuous processing. (Figure 1 illustrates a typical industrial application of an ac contactor motor starter.) In many cases, the control voltage for the contactor coil is supplied from the plant distribution system. Therefore, the contactor coil experiences the same voltage disturbance as the motor. If the disturbance is sufficient to cause the motor supply contacts to open momentarily, the plant process may be disrupted and equipment may be damaged.

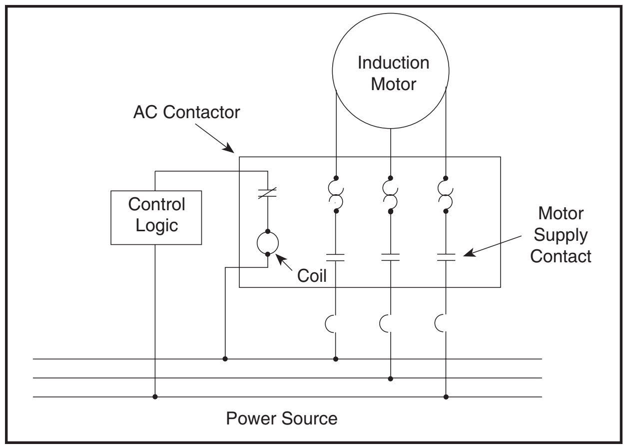

Figure 1. Schematic of AC Contactor Motor Starter Connected to an Induction Motor

Objective

The objective of the tests performed at the Electric Power Research Institute (EPRI) Power Quality Test Facility was to characterize the performance of different-sized ac contactor motor starters during typical low ac voltages.

Test Setup

Three different sizes of three-pole, 480-V_{ac}, open-type contactors were tested: NEMA size 0 (rated 0 to 5 hp @ 480 V_{ac}), size 1 (rated 0 to 10 hp @ 480 V_{ac}), and size 3 (rated 0 to 50 hp @ 480 V_{ac}). All contactors were equipped with 120 V_{ac} coils. Voltage sags were created by electronically switching from the 120 V_{ac} line to a reduced-voltage source and then back. Voltage sags were timed at zero-crossings and adjusted in half-cycle increments. The magnitude and duration of the sags were varied to determine which combinations would cause the contactor to open the motor supply contacts. During a voltage sag, the source was not disconnected from the contactor, which simulated the low source impedance of the power system during a fault. High-impedence interruptions and open circuits were not considered. Two channels of a digital storage oscilloscope monitored and recorded contactor coil voltage and current; another channel monitored and recorded continuity of the motor supply contacts. Figure 2 shows the diagram of the test setup.

Test Results

Steady-State Low-Voltage Dropout Test

This test determined the source voltage at which the motor supply contacts open (drop out). The source voltage was initially set at nominal 120 V_{ac} and then was lowered incrementally until the motor supply contacts dropped out. Among the three contactors tested, the dropout voltage ranged from 65 to 70 V_{ac}.

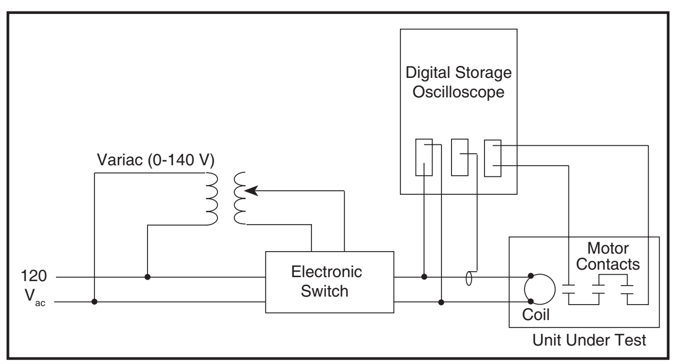

Figure 2. Diagram of Test Setup

Voltage Sag Response Test

Each contactor coil was exposed to voltage sags lasting from 0.5 to 8 cycles (8.3 to 133 ms), and with magnitudes ranging from 0 to 120 V_{ac}. The motor supply contacts were monitored during each of these voltage sags to determine which combination of duration and magnitude would cause the contacts to open. Figures 3, 4, and 5 illustrate the area of closed-contact operation for the different-sized contactors during sags initiated at the zero-crossings of the ac input voltage. With the variable ac source (variac) adjusted to give an output of 0 V_{ac}, the size 0 and size 1 contactors were able to keep their motor supply contacts closed for 4 and 3.5 cycles (67 and 58 ms) respectively. The size 3 contactor kept the motor supply contacts closed for 7 cycles (117 ms) because its larger coil retains a stronger magnetic field.

Further testing revealed that the ride-through performance during a sag to zero volts (short circuit) also depended on the phase angle of the voltage waveform at the onset of the sag. The size 1 contactor could ride through a 3.5-cycle sag when the onset of the sag occurred at the zero-crossing (see Figure 4) and could only ride through about a 0.5-cycle sag when the onset occurred at the peak (not shown). Because the voltage across and current through a contactor coil are 90 degrees out of phase, coil current and the associated magnetic flux peak at the voltage zero-crossing. When a sag occurs at this phase angle, the peaked magnetic field tends to hold the motor supply contacts closed longer than when sags occur at other phase angles.

The source voltage line impedance also determined contactor ride-through time. During sags to zero or near-zero volts, the test setup—approximating real-world fault conditions in a power system—was nearly a short circuit, which allowed maximum current and magnetic flux. As a result, contactor ride-through time was longer for sags to zero or near-zero volts than for sags below but near the trip limit (the minimum steady-state ac voltage required to keep the motor supply contacts closed).

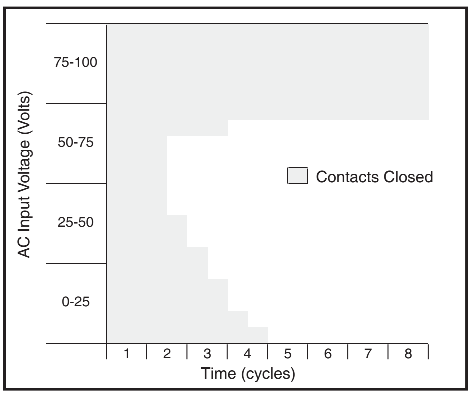

Figure 3. Size 0 AC Contactor Characteristics

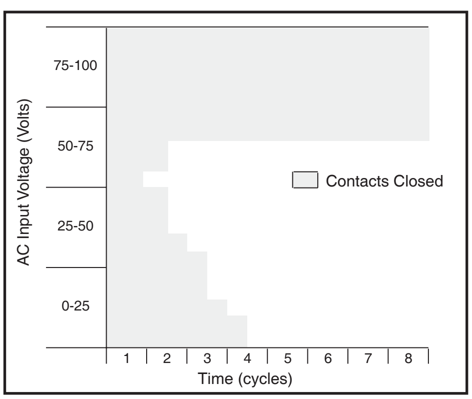

Figure 4. Size 1 AC Contactor Characteristics

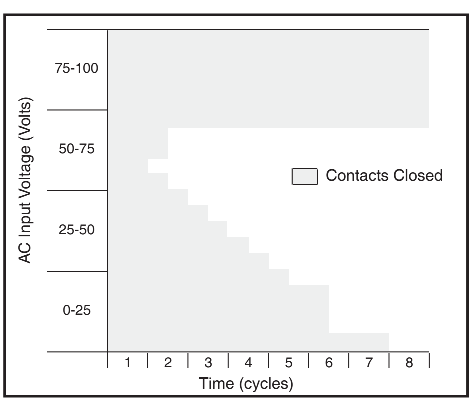

Figure 5. Size 3 AC Contactor Characteristics

DISCUSSION

Contactor dropout characteristics during voltage sags vary with the size of coil, voltage phase angle at the onset of the sag, the magnitude of the sag, and the line impedance during the sag. In general, however, contactors are expected to tolerate low voltages less than a typical induction motor load. Therefore, contactors may be the "weak link" in a plant process system's tolerance to voltage sags. One method to improve contactor ride-through performance is to modify the magnetic circuit using a rectifier, capacitor, and dc coil, which provide stored energy to keep the motor supply contacts closed during most voltage sags.

SIGNIFICANCE

Because the ac contactor controls the connection of the induction motor to the power distribution system, it is crucial for continuous plant processing. Unwanted opening of motor supply contacts while the motor is under a load can disrupt a process or initiate an overall trip command from the process controller, or both. Disruption of the plant process may result in loss or damage to the product. As process disruptions resulting from low voltages increase, so does the need for investi-gating the effects of low voltages on all motors and contactors to identify weaknesses in plant processing systems.

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