PQTN BRIEF

Power Quality Testing Network

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Short-Circuit Current Characteristics of Single-Phase Constant-Voltage Transformers

Background

Many process industries are turning to constant-voltage transformers (CVTs) to increase voltage regulation, which mitigates the effects of voltage sags on process control equipment. End users often assume that CVTs are the same as standard isolation transformers when connecting them to loads. However, CVTs are very different from standard isolation transformers. As shown in Figure 1, the short-circuit current at the output of a typical CVT is much lower than that of a similarly sized isolation transformer.

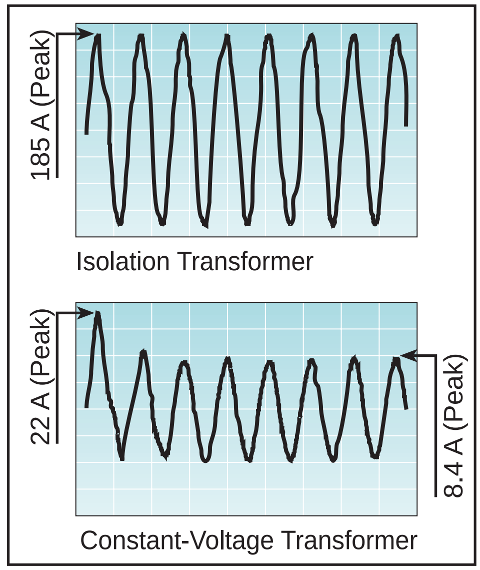

Figure 1. Short-Circuit Current of a 500-VA Isolation Transformer and a 500-VA CVT

When protecting equipment and wiring from fault current, short-circuit current is a critical variable. Normally, it is relatively easy to estimate the short-circuit current of a dry-type standard isolation transformer. A commonly used rule of thumb indicates that short-circuit current for these transformers will fall between 20 and 40 times the rated steady-state current, which the National Electrical Manufacturers Association (NEMA) requires to be displayed on transformer nameplates. Therefore, the nameplate on a dry-type standard isolation transformer supplies all the information necessary to calculate a useful range of short-circuit current. The nameplate on a CVT, however, may or may not aid the end user in calculating short-circuit current. As a result, sizing overcurrent protective devices, such as circuit breakers and fuses, may be problematic.

Objective

The objectives of the tests performed at the EPRI Power Electronics Applications Center (PEAC) Power Quality Test Facility were to 1) measure the short-circuit current of eight CVTs and 2) determine whether or not the current ratings of the CVTs can be used to predict short-circuit current.

Test Setup

Eight CVTs ranging from 250 VA to 1 kVA were tested. Table 1 shows the VA rating and output current rating for each of the tested CVTs. During each trial, rated voltage (120 V_{AC}) was applied to the input terminals of a CVT. When a switch on the output side of the CVT was thrown to create a fault, the resulting current at the transformer output (short-circuit current) and input were measured with a current transducer connected to a digitizing oscilloscope. Figure 2 shows the test setup.

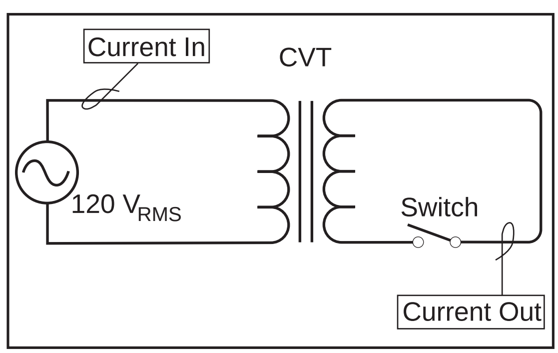

Figure 2. Test Setup

Test Results

Table 1 shows the results of the test. After measuring current at the input and output terminals of all eight CVTs during an output fault, the current rating of each CVT was compared to its measured short-circuit current. Figure 3 shows appreciable variation in short-circuit current among all of the CVTs. However, a statistical analysis revealed that rated current does not account for most of that variation. A simple linear regression of short-circuit current on rated current indicates that on average, a CVT's rated current accounts for only 50 percent of the variation in short-circuit current.* In addition, all the CVTs—except for CVT

*Model: $y = 3.9 + 1.5x$; $R^2 = 0.5007$; $t = 2.453$; $df = 1, 6$; $p < 0.05$

Table 1. Input and Output Current Measured During Output Short Circuit

CVT Number	*VA Rating*	*Rated Output Current (A_{RMS})*	*Measured Input (A_{RMS})*	*Measured Output (A_{RMS})*	*Measured Output/ Rated Output*
1	250	2	3.0	5.7	2.9
2	250	2	2.5	5.5	2.8
3	250	2	3.5	10.7	5.4
4	350	3	2.6	5.9	2.0
5	500	4	7.0	14.1	3.5
6	500	4	6.3	5.9	1.5
7	750	6	10.0	17.0	2.8
8	1000	8	12.4	14.1	1.8

number 6—had significantly less input current than output current during an output fault. On the other hand, a linear transformer typically has about the same amount of input and output current during a short circuit.

Further evaluation of the data suggested that some portion the variation in short-circuit current may result from CVT design differences. Short-circuit current varied between some CVTs of the same size depending on which company manufactured the CVT. For example, models 2 and 3, which are the same size but are manufactured by different companies, have significantly different short-circuit currents. The same can be said for models 5 and 6.

DISCUSSION

Although the short-circuit current of a typical dry-type isolation transformer can be adequately calculated from its rated current, the nameplate information on a CVT is not quite as helpful. NEMA requires that the class of cooling, number of phases, frequency, VA rating, voltage rating, temperature rise, and name of manufacturer should appear on all transformer nameplates. Each of the eight CVTs that PEAC tested included this information on the nameplates, plus rated output current. However, testing showed that short-circuit current cannot be predicted from CVT current rating. Half of the variation in short-circuit current is attributable to unspecified characteristics of the tested CVTs. Therefore, it is impossible to adequately predict the short-circuit current of a CVT based upon the information required on a CVT nameplate.

CVT short-circuit current varied dramatically, even between models with the same current rating. As noted in Table 1, one 500-VA CVT had an output short-circuit current of 5.9 amps, while another 500-VA CVT had an output short-circuit current of 14.1 amps. As a function of rated current, the short-circuit current ranged from about 1.5 to 5.4 times the rated current.

SIGNIFICANCE

To properly size a circuit-breaker for overcurrent protection, short-circuit current must be determined. Because short-circuit current cannot be calculated from nameplate information, perhaps CVT nameplates should provide a value for short-circuit current. Further testing is needed to determine how circuit beakers respond when used with CVTs, whether or not circuit breakers can even clear fault current of a CVT, and what other kinds of devices may be used with CVTs to clear fault current.

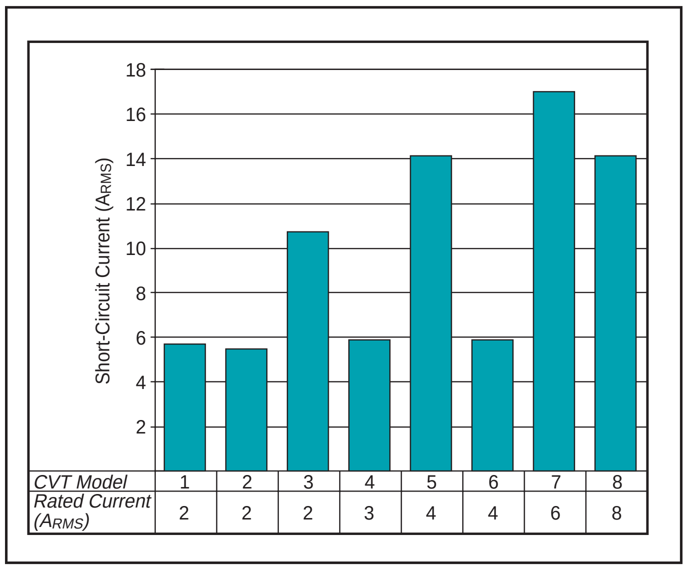

Figure 3. CVT Short-Circuit Current versus Transformer Output Current Rating

FOR MORE INFORMATION, CONTACT:

Gene Sitzlar, PEAC, (423) 974-8288
The **EPRI** Power Electronics Applications Center
10521 Research Drive, Suite 400
Knoxville, TN 37932
Fax: (423) 974-8289
Power Quality Hotline: (800) 832-7322

For ordering information, call PEAC (423) 974-8288.

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