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IEEE Guide for Field Testing of Relaying Current Transformers

IEEE Power and Energy Society

Sponsored by the
Power System Relaying and Control Committee

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Power System Relaying and Control Committee
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Abstract: Field test methods described in this guide assure that current transformers are connected properly, are of marked ratio and polarity, and are in a condition to perform as designed both initially and after having been in service for a period of time.

Keywords: current transformers, excitation, field testing, IEEE C57.13.1™, insulation, polarity, ratio, relaying

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Introduction

ThisintroductionisnotpartofIEEEStdC57.13.1-2017,IEEEGuideforFieldTestingofRelayingCurrentTransformers.

This project revises the previous guide to keep it current with technological changes in instrument transformers and test equipment.

In the application of protective relays, a widely used input quantity is current. A multiplicity of different protective relays either utilize current directly, combine it with other currents as in differential schemes, or combine it with voltage to make impedance or power measurements. The source of relay input current is from current transformers, which may be located on the bushings of power circuit breakers and power transformers, on the bus bars of metal clad switchgear, or installed as separate items of equipment located as required.

This guide should be used in conjunction with other references, such as IEEE Std C57.13™, IEEE Standard Requirements for Instrument Transformers;[1] IEC 60044-8, Instrument Transformers—Electrical Current Transducers [B2]; and Handbook for Electricity Metering, EEI Publication No. 93-02-03 [B1].[2]

[1]Information on references can be found in Clause 2.
[2]Numbers in brackets correspond to those of the bibliography inAnnex D.

Contents

IEEE Guide for Field Testing of Relaying Current Transformers

1. Overview

1.1 Scope

The scope of this guide is to describe field test methods that assure current transformers (CTs) are connected properly, are of marked ratio and polarity, and are in a condition to perform as designed both initially and after being in service for a period of time.

Annex A describes wiring integrity checks, the use of test jacks, current-shorting switches, and relay test equipment.

Annex B illustrates excitation voltage measurement differences between rms responding voltmeters (commonly used under field conditions) and average responding voltmeters (commonly used in laboratory tests) and also discusses the effect of the source impedance.

Annex C describes the characteristics, and other pertinent information, of optical current sensor systems used with protective relaying. It provides an overview of the components used in an optical sensor system, discusses the differences from conventional CTs, and provides testing information.

Annex D is the bibliography for this guide.

1.2 Purpose

The purpose of the guide is to provide information on the current technology for field testing of instrument transformers and to more closely coordinate the information with the other industry standards, for example, the National Electrical Safety Code® (NESC®) (Accredited Standards Committee C2).[3]

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

Accredited Standards Committee C2, National Electrical Safety Code® (NESC®).[4]

[3]Information on references can be found in Clause 2.
[4]The NESC is available from the Institute of Electrical and Electronics Engineers (http://standards.ieee.org/).

IEEE Std C37.110™, IEEE Guide for Application of Current Transformers Used for Protective Relaying Purposes.

IEEE Std C57.13™, IEEE Standard Requirements for Instrument Transformers.[5,6]

IEEE Std C57.13.3™, IEEE Guide for Grounding of Instrument Transformer Secondary Circuits and Cases.

3. Definitions

For the purposes of this document, the following terms and definitions apply. The IEEE Standards Dictionary Online should be consulted for terms not defined in this clause.[7]

4. Consideration of American National Standards Institute (ANSI) accuracy classes

Relaying accuracy classes have been established in IEEE Std C57.13 to specify the performance of relaying CTs. During faults on the electric power system, relaying CTs must operate at high overcurrent levels. ANSI classifications, therefore, define minimum steady-state performance at these levels. Performance is described by using a two-term identification system consisting of a letter and a number as follows: C100, C200, C400, C800, T10, T20, T50, T100, T200, T400, T800.

The first term of this identification describes performance in terms relating to construction; C represents calculated and T represents tested. The second term specifies the secondary voltage that can be delivered by the secondary winding at 20 times rated secondary current through a standard burden without exceeding 10% ratio error. As an example, a C100 rating means that the ratio error will not exceed 10% at any current from 1 to 20 times the rated current with a standard 1.0 Ω burden. (1.0 Ω times 5 A times 20 times rated secondary current equals 100 V.) The ANSI voltage rating applies to the full secondary winding only. If other than the full winding is used, the voltage rating is reduced in approximate proportion to turns used only if the windings are evenly distributed. For more details and discussions on windings, ratings, and CT classes (see IEEE Std C37.110).

Details of low-energy devices, such as opto-electronic transducers, are not discussed in this guide. Some details are provided inAnnex C. Analog input issues are discussed in IEEE Std C37.92™ [B4].[8]

5. Precautions in field testing current transformers (CTs)

WARNING

Many of the tests called for in this guide involve high voltage and, therefore, should be performed only by experienced personnel familiar with any peculiarities and/or hazards that may exist in the test setups and test procedures. While some hazards are specifically pointed out herein, it is impractical to list all necessary precautions.

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[6]IEEE publications are available from the Institute of Electrical and Electronics Engineers (http://standards.ieee.org/). [7]IEEE Standards Dictionary Online is available at: http://dictionary.ieee.org.
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5.1 Demagnetizing CTs

If there is any reason to suspect that a CT has been recently subjected to heavy currents, possibly involving a large dc component, or has been magnetized by any application of dc voltage, it should be demagnetized before conducting any tests that require accurate measurements of current. It is also prudent to demagnetize the CT after the tests are completed.

One method used for demagnetizing the CT is to apply a suitable, variable alternating voltage to the CT's secondary winding, with an initial magnitude sufficient to force its flux density above its saturation point, and then decrease the applied voltage slowly and continuously to zero. The test connections used for this method of demagnetizing are identical to those required for the excitation test as shown in Figure 10.

Another method used by transformer analyzers to demagnetize a CT, is to vary the secondary loop resistance gradually from low to high to low at a consistent rate. The amount of variable secondary loop resistance will be determined by what resistance is required to drive the CT beyond the knee of its B-H excitation curve and demagnetize its core. This is typically a resistance that will cause a 65% to 75% reduction in secondary loop current.

As an example, provided the CT under test produces at least 2.5Asecondary loop current, a series resistance is varied gradually from 0.1 Ω to 8 Ω and back to 0.1 Ω at a consistent rate.This operation effectively overburdens the CT and demagnetizes the core. When demagnetizing a CT with less than 2.5 A secondary current, a larger resistance of up to 50 Ω may be required.

See IEEE Std C57.13 for further information on demagnetizing CTs and IEEE Std C37.110 for examples of waveforms showing magnetized CTs.

WARNING

Extreme care should be exercised when demagnetizing the core of a CT because the voltage developed across its terminals is likely to reach the secondary terminal voltage limit.

5.2 Greater primary winding turns

Test procedures in 8.1, 9.1, and 9.2 are described appropriately for the usual case where the number of turns of the secondary winding is larger than the number of turns of the primary winding. In the rare case where the number of turns of the primary winding is larger than the number of turns of the secondary winding, the words "primary" and "secondary" and "H1" and "X1" should be interchanged in 8.1, 9.1, and 9.2, as well as any related figures.

6. Types of tests and measurements

6.1 Ratio test

This test is intended to verify the stated ratio, not prove the accuracy of the ratio. The ratio, as installed, is as specified, and if taps are available, they are the correct ratio and have been wired to the correct terminals (see Clause 8).

6.2 Polarity test

This test proves that the predicted direction of secondary current flow is correct for a given direction of primary current flow. This is essential where currents are summed, compared in differential mode either electrically or magnetically, or where currents and voltages are compared within the relay or intelligent electronic device (for more details see Clause 9).

6.3 Insulation resistance test

The CT should be tested to prove that the winding-to-winding and winding-to-ground insulation is satisfactory.

6.4 Resistance measurement

This test confirms that the dc resistance of the CT secondary winding is within specification and that there is no high resistance connection in the CT or the wiring connected to it (see Clause 11).

6.5 Excitation test

This test confirms that the CT, as supplied, is of the correct accuracy rating, has no shorted turns in the CT, and that no wiring or physical short circuits have developed in the primary or secondary windings of the CT after installation. The manufacturer's design curves for the CT should be available so that the actual results can be compared with those curves (see Clause 12).

6.6 Admittance test

This test confirms the installed condition of the CT's internal burden and external burden connected to the CT (admittance is the reciprocal of impedance).

The admittance of a CT secondary loop can be measured with or without current flow in the secondary winding (CT in or out of service). The instrument used for conducting admittance tests injects an audio signal into the secondary winding of a CT and measures the reflected waveform to determine the admittance. The circuit admittance of a CT is nearly constant throughout its normal operating range unless a fault develops (see Clause 13).

6.7 Burden test

The principle of a CT burden test is to check the capability of the CT to deliver a current into a known burden and to observe the result for adequacy. This test may also detect shorted turns and loose or corroded terminals (see Clause 14).

The burden test can be done only with current flowing in the CT secondary circuit (preferably at or near the rated current).

This test confirms that the CT is capable of supplying a known current, dictated by the turn's ratio into a known burden and maintains a stated accuracy.

7. AC sources for primary current injection tests

The philosophy of primary current injection tests is directly related to the desire for simulating the actual working conditions of the protective equipment as closely as is physically possible outside a test laboratory. The primary concern usually is the availability and portability of the power supply to be used for conducting these tests. Several good quality power supplies are currently being marketed; their output ranges from 1 kVA to 15 kVA, providing high current at low voltage.

8. Ratio tests

There are two generally accepted out-of-service and two generally accepted in-service methods of checking the turns ratio of all types of CTs. A description of each method and reference information is provided in 8.1.

8.1 Voltage method

Suitable voltage, below saturation, is applied to the secondary winding (full winding), and the primary voltage is read with a high-impedance (20 000 Ω/V or greater) low-range voltmeter, as shown in Figure 1.

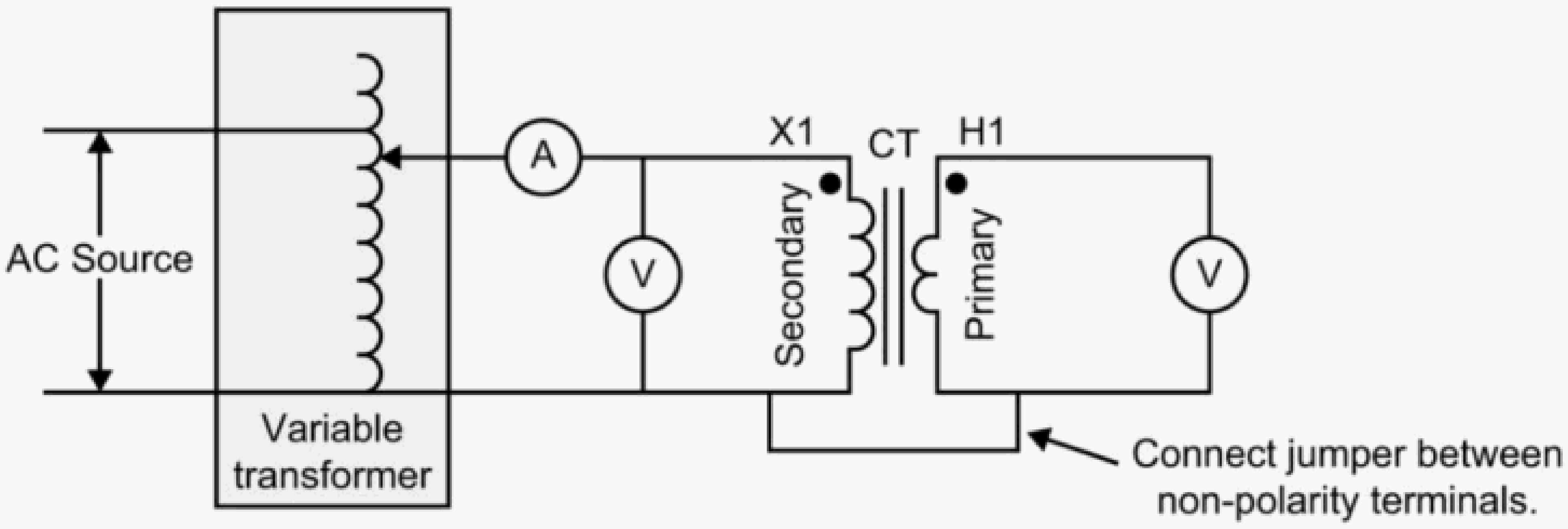


Figure 1—Ratio test by voltage method

The turns ratio is approximately equal to the voltage ratio. The saturation level is usually about 1 V per turn in most low- and medium-ratio bushing CTs. High-ratio generator CTs and window-type CTs used in metal-clad switchgear may have saturation levels lower than 0.5 V per turn.

Grounding of secondary circuits is an important issue; details of this topic are given in IEEE Std C57.13.3.

WARNING

In the case of very high ratio CTs, application of a test voltage with an even lower voltage per turn may be required to avoid harm to personnel and possible damage to equipment. The ANSI relay accuracy class voltage rating should not be exceeded during this test.

At the same time, when the overall ratio is being determined, the tap section ratios may be checked with a voltmeter by comparing tap section voltage with the impressed voltage across the full winding.An ammeter is included in the recommended test method as a means of detecting excessive excitation current.

CAUTION

If more convenient, voltage may be applied to a section of the secondary winding; however, voltage across the full winding will be proportionately higher because of autotransformer action.

8.2 Out-of-service current method

This method of determining the turns ratio requires a source of high current, an additional CT of known ratio with its own ammeter, and a second ammeter for the CT under test. Any CTs that may be connected in series with the CT under test should be short-circuited and possibly disconnected from their burdens if there is a likelihood of damage to other meters or relays, or accidental tripping of a circuit breaker. This method is not practical for CTs in an assembled power transformer or generator. See 8.3 and 8.4 for test methods recommended for these applications.

A source of current for this test could be a loading transformer rated 120/240–6 V with a secondary current rating of 1200 A for 30 min. Different loading transformers are available, some with much higher current ratings. A variable autotransformer is also required to control the primary voltage of the loading transformer. The test equipment connections are shown in Figure 2.

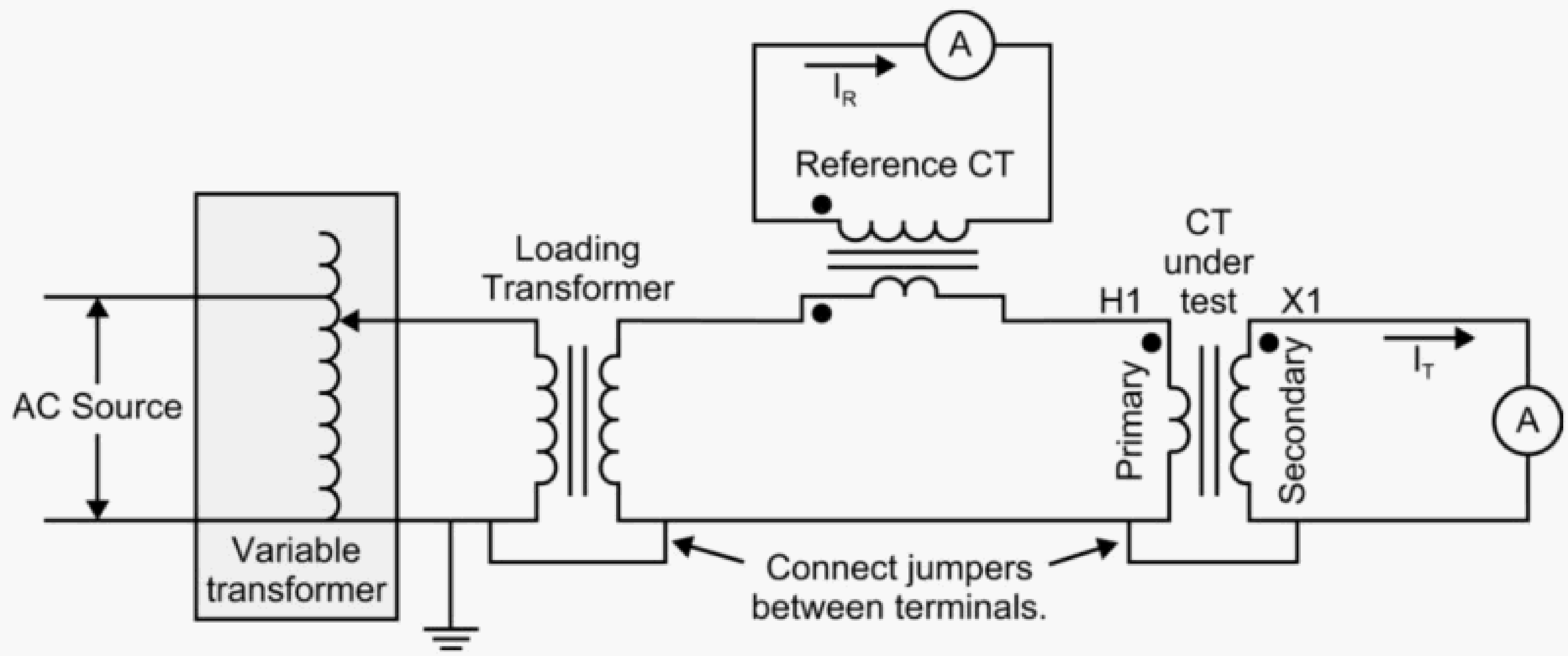


Figure 2—Ratio test current method

The test is performed by adjusting the high-current test source to a series of values over the desired range and recording currents in the secondary windings of the two CTs. The ratio of the CT under test is equal to the turns ratio of the reference CT multiplied by the ratio of the reference transformer secondary current to the test transformer secondary current, as shown in Equation (1):

$$N_T = N_R \frac{I_R}{I_R} \tag{1}$$

where

N_T is the turns ratio of the CT being tested
N_R is the turns ratio of the reference CT
I_T is the current in the CT being tested
I_R is the current in the reference CT

When performing this test, the tester should be aware that stray flux can produce significant changes in performance. Test conductors should, therefore, be extended as far as possible along the axis of the CT to minimize stray flux influence. This problem is of particular concern with window-type CTs.

It is undesirable to use multiple turns of the test conductor through the center of a window-type CT to reduce its ratio because this may produce an abnormal secondary leakage reactance and misleading results in the ratio measurement. The effect is unpredictable and, although small with modern distributed winding CTs and low secondary burdens, it may produce significant errors on older CTs, particularly when high burdens are connected.

Polarity of the CT may be checked by the method described in 9.3 after completing this test.

8.3 In-service current manual method

The manual method consists of placing clamp-on ammeters on both the primary and the secondary circuit leads of the CT to be tested and simultaneously recording the currents from the two ammeters. The simultaneous readings are required, especially if the load can vary. The ratio of the CT is calculated by dividing the current in the primary winding with the current in the secondary winding. For example, if the current in the primary winding is 350 A and the current in the secondary winding is 3.5 A, the CT ratio is $350 / 3.5 = 100$ ratio. If the nominal rating of the secondary winding is 5A, the CT ratio is 500:5.

When measuring low-value currents, consideration must be given to the accuracy of the clamp-on ammeter.

8.4 In-service current automated method

The ratio of a CT can be determined while in service using the CT analyzer described in A.3.3. This instrument uses two calibrated clip-on CTs (one for measuring the primary current and one for measuring the secondary current). Sample and hold circuits capture the simultaneous reading of primary and secondary current amplitudes and the phase angle between them. The microprocessor calculates and displays the ratio in either the measured value or the best-fit value. The measured value will show the actual ratio as seen by the secondary loop devices and the best fit will round the ratio to the nameplate value. For example, the actual measured ratio of a circuit may be 398:5, which reflects the phase shift between the primary and secondary quantities, while the best-fit value would be displayed as 400:5. Ratios can be determined on high-voltage systems using an optically coupled clip-on CT. There currently exist in-service systems capable of being installed on systems up to 500 kV.

9. Polarity test

There are four generally accepted methods of testing the polarities of CTs. These methods are described in 9.1 through 9.4.

9.1 DC voltage test

In this test, a 6 V to 10 V dc battery (typical of an old-style camping lantern, or a 9 V battery found in fire alarms or digital multimeters) is connected momentarily to the secondary of the CT under test with an analog milliammeter or an analog millivoltmeter and the momentary deflection of the milliammeter or the millivoltmeter noted. If the positive terminal of the battery is connected to terminal X1 and the positive terminal of the milliammeter is connected to terminal H1, as shown in Figure 3 and the polarity markings are correct, the meter will deflect upscale when the battery is connected and will deflect downscale when the battery is disconnected.

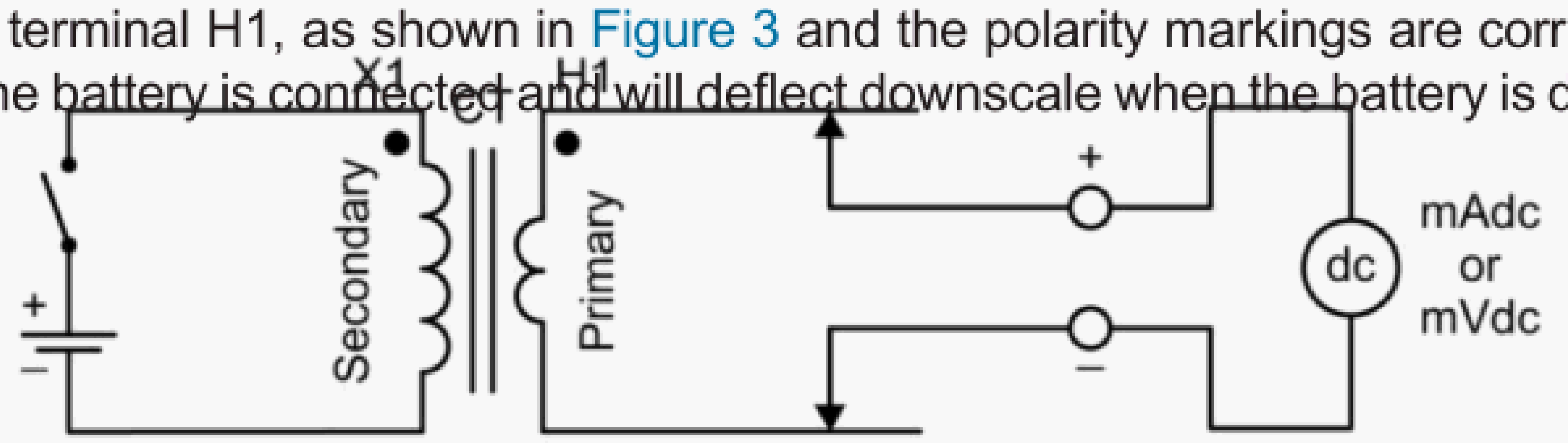


Figure 3—A polarity test with dc voltage

This test is also valid with the battery applied to the primary and the meter connected to the secondary. It is advisable to demagnetize the CT following this test.

If a bushing CT, installed in a power transformer, is being tested by connecting the battery to the power transformer terminals, the other CT windings on the same phase of the power transformer may have to be short-circuited in order to obtain a reading.

WARNING

A dangerous voltage may be generated while disconnecting the battery from the transformer winding; therefore, a resistor may be connected in parallel with the CT winding before disconnecting the dc source. The ohmic value of the resistor should be in the range of the dc resistance of the winding and should be of appropriate wattage. This would avoid overvoltage and arcing when the dc source is disconnected. After a few seconds the resistance can be disconnected. Alternatively, if a knife switch is not used, a hot stick or rubber gloves must be used for connecting and disconnecting the battery.

CAUTION

Using a dc voltage source to check breaker contacts or a simple ohm meter used to verify correct wiring at a test switch's terminals will leave remanence in the CT's core. The CT should be demagnetized after conducting any test using a dc source (see 5.1).

9.2 AC voltage test—oscilloscope

An oscilloscope can be used to check CT polarity, as shown in Figure 4. The method consists of applying an ac voltage to the secondary winding and comparing it with the voltage induced in the primary winding.

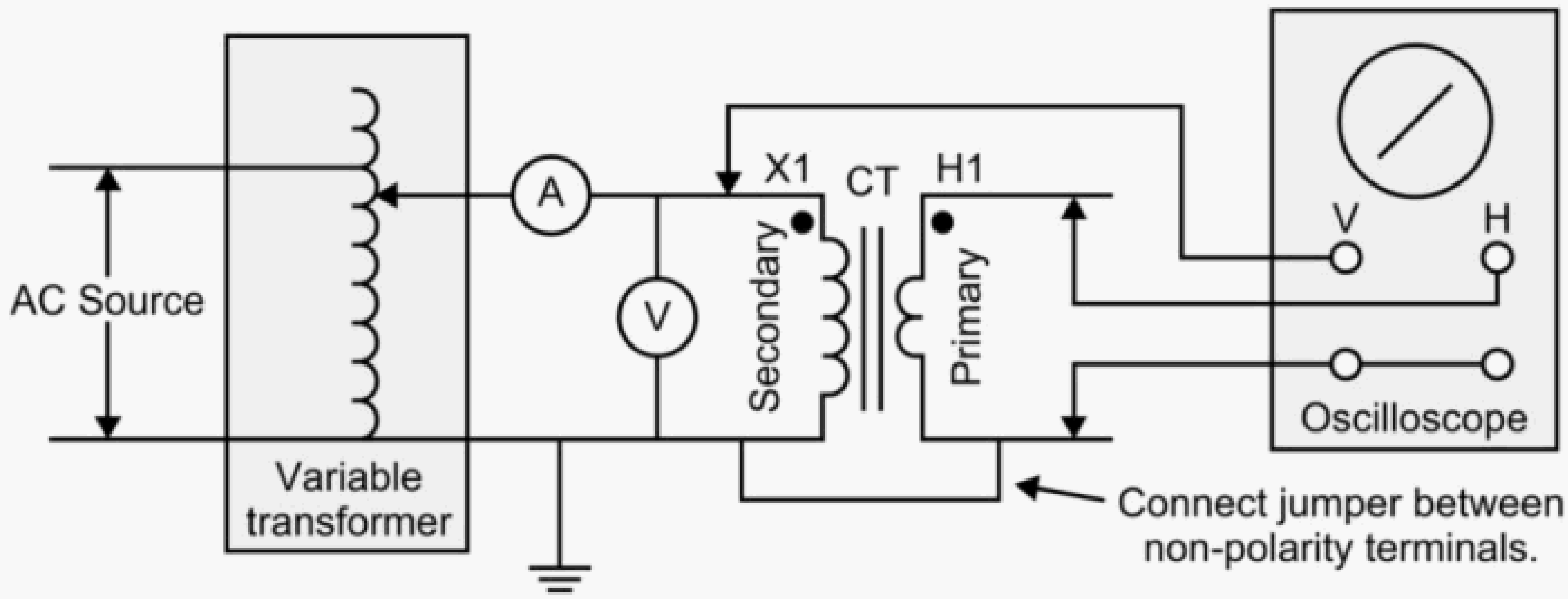


Figure 4—A polarity test with ac voltage

If only a single-channel oscilloscope is available, the preferred method is to apply secondary voltage to the vertical input terminals, V, and primary voltage to the horizontal input terminals, H, with polarities as indicated in the diagram.

If the slope of the line is positive as shown as it would be when the same voltage is applied to both inputs, then the polarity is in accordance with terminal markings.

If a dual-channel oscilloscope is available, primary and secondary voltages should be displayed on separate channels. If the resulting waveforms are in polarity agreement (as they would be when the same voltage is applied to both channels), the polarity is correct. If the oscilloscope is calibrated, the current-transformer ratio can be obtained directly by measuring the magnitude of the voltage waveforms and multiplying by the scale constants of the oscilloscope. The ammeter is provided only for indication of excessive excitation current.

This test can be made in conjunction with the ratio test of 8.1. It can also be used to test a CT in a closed delta winding of a three-phase power transformer as discussed in 16.1.

9.3 Current method

After the ratio test of 8.2, polarity can be conveniently checked by paralleling the secondary winding of the reference CT with the secondary winding of the test CT through two ammeters, as shown in Figure 5. If A2 ammeter is reading higher than A1 ammeter, the polarity is in accordance with terminal markings, provided the test CT is the same ratio or higher.

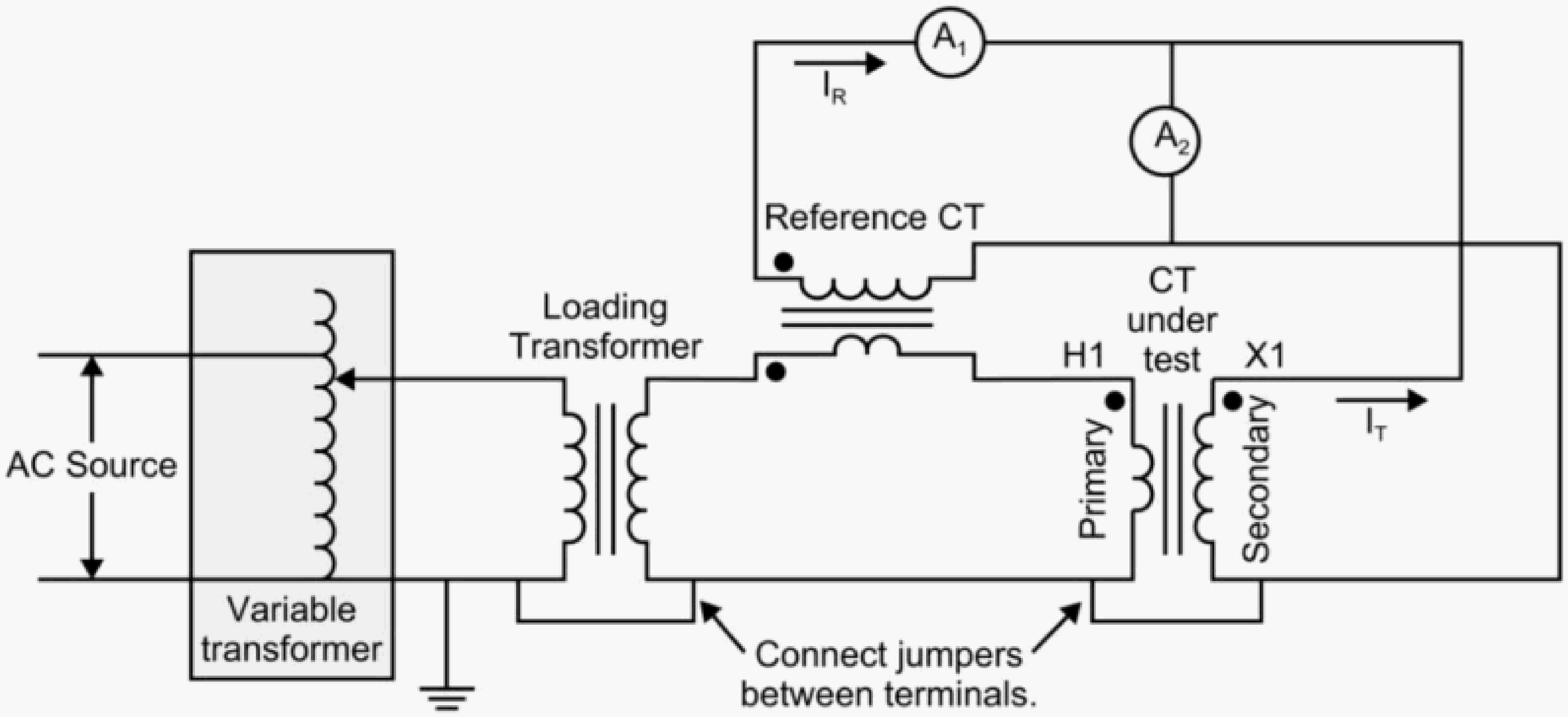


Figure 5—A polarity test with ac current

9.4 Phase angle method

In addition to the tests described in 9.1 through 9.3, some test equipment also provides phase angle readings. The phase angle measurement can also be used to verify polarity of the CT under test. Depending on the test instrument, this can be a meter reading or as a light indicating correct or reverse polarity, or as a text message on a display.

9.4.1 With voltmeter

If an ac voltage is applied to one winding of the CT the transformed voltage appears on the other winding. For direct polarity, the voltage of the secondary winding should be in-phase with the voltage of the primary winding, or lagging within a few degrees. If the CT ratio is 1:1, and a voltmeter is connected as shown in Figure 6, the voltmeter will read 0 since $V_{METER} = (V_{H1})-(V_{X1})$. If the polarity is reversed, the phase angle would be approximately 180° and the voltmeter would read approximately twice the input voltage for a 1:1 ratio CT since $V_{METER} = (V_{H1})-(-V_{X1})$. The following are examples:

a) If a 1:1 ratio CT was used and 100 V were applied to the secondary, approximately 100 V would be induced on the primary winding of the CT. A voltmeter connected as shown in Figure 6 would read as follows:

   1) Polarity in-phase: $V_{METER} = (V_{H1})-(V_{X1}) = (100)-(100) = (0) = 0\ \text{V}$

   2) Reversed polarity:

   $$V_{METER} = (V_{H1})-(V_{X1}) = (100)-(-100) = (100+100) = 200\ \text{V}$$

b) If 100:1 ratio CT was used and 100 V were applied to the secondary, approximately 1 V would be induced on the primary winding of the CT. A voltmeter connected as shown in Figure 6 would read as follows:

1) Polarity in-phase: $V_{METER} = |(V_{H1})-(V_{X1})| = |(1)-(100)| = |(-99)| = 99\ \text{V}$

2) Reversed polarity: $V_{METER} = |(V_{H1})-(V_{X1})| = |(1)-(-100)| = |(1+100)| = 101\ \text{V}$

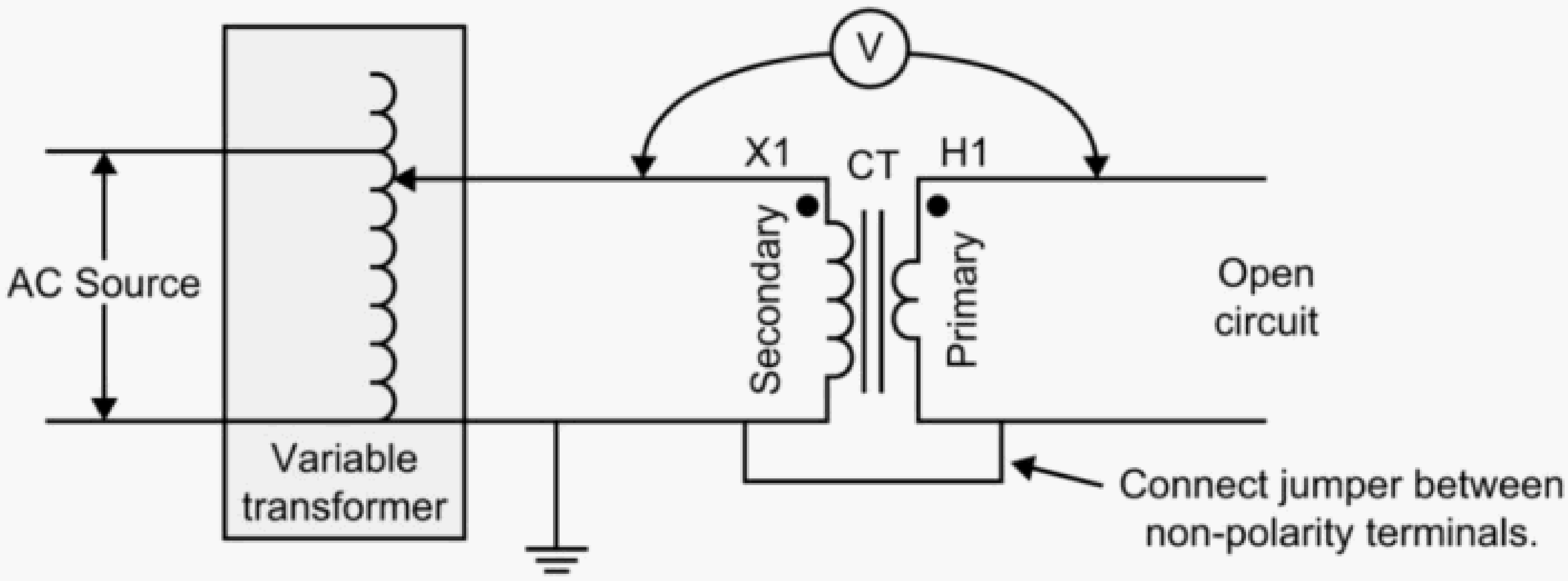


Figure 6—A polarity test with a voltmeter

9.4.2 With phase angle meter

Alternatively, an ac test voltage of magnitude less than the CT's knee point voltage can be connected to the secondary winding of the CT, as shown in Figure 7. The phase angle between voltages, Vp, and the applied test voltage can be monitored independent of the magnitude. For correct polarity, the phase angle will be nearly zero (355° to 359° are typical values). For reversed polarity, a reading of approximately 180° would be typical.

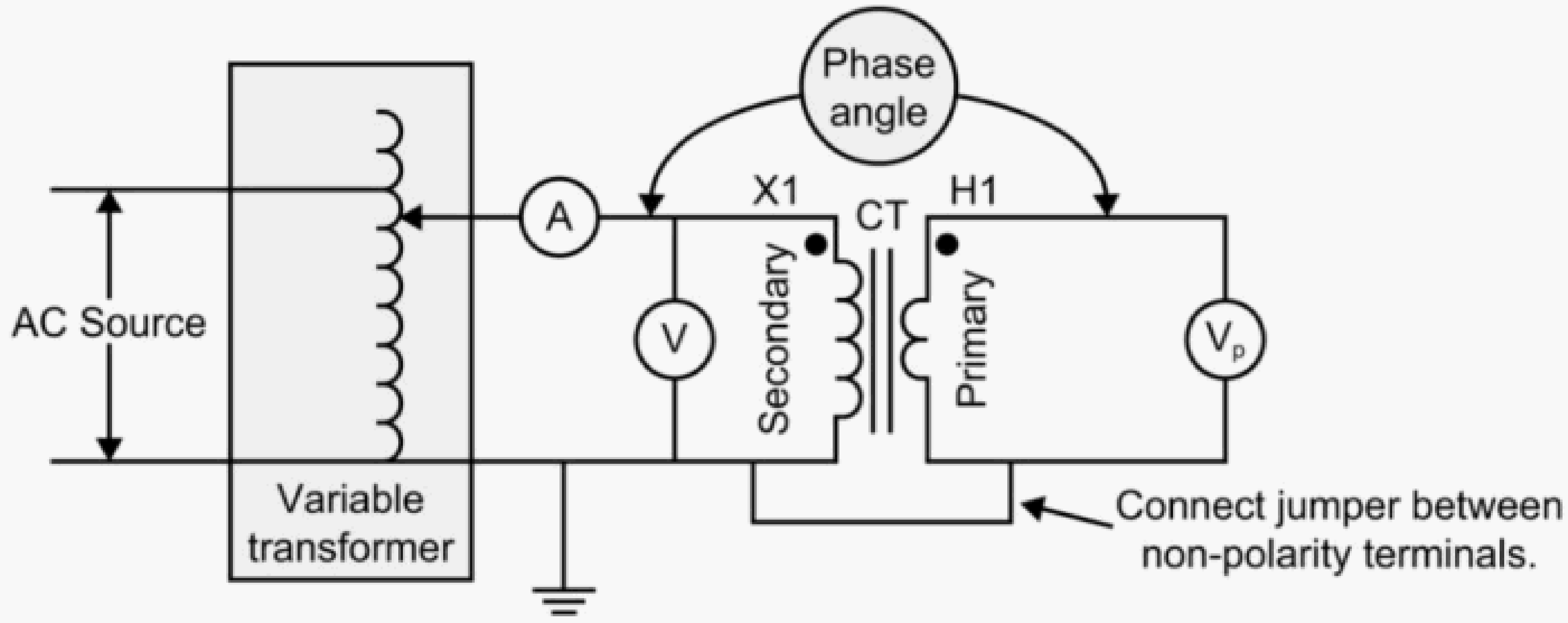


Figure 7—Polarity test with phase angle meter

Several tests can be performed using the methods shown in Figure 7. Excitation of the CT can be verified by using the voltmeter and ammeter functions of the phase angle meter. This test is performed with the primary winding open-circuited and also verifies that there are no short circuits in the CT being tested. Also, tap ratios can be verified using an additional voltmeter and the primary-to-secondary voltage ratio can be established using the phase angle meter's voltage function. By relocating the connections to other CTs associated with the same circuit breaker, those CTs can be tested as well. When conducting these tests, reversing the primary connections should produce a phase angle meter polarity reversal reading.

9.4.3 With other instruments

There are also test instruments available that can capture and record the test data as well as automatically graph and print out the excitation tests, ratio, and polarity. However, it is still up to the user to determine that all of the test leads have been correctly attached with the correct observance of test lead polarities. Note that in a circuit breaker, the primary conductor passes through the CTs, which can be an advantage when the circuit breaker is closed, providing a conductor in the primary winding that might otherwise be inaccessible.

CAUTION

When a CT provided in an environment is tested (as shown in Figure 8), precautions should be taken to ensure that the circuit breaker is taken out of service by opening the appropriate disconnects before any connections are made for this test.

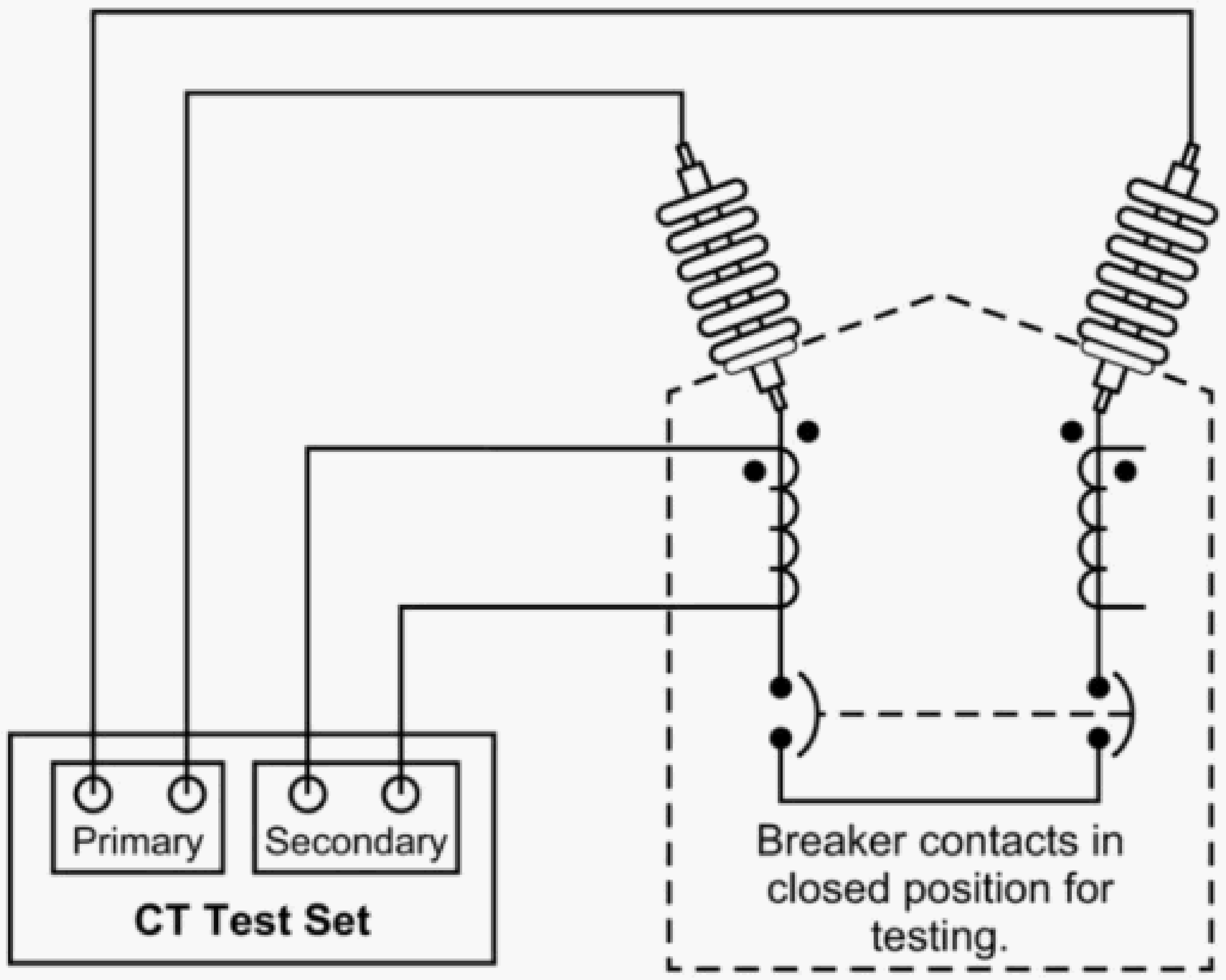


Figure 8—Polarity, turns ratio, and excitation test for a bushing-type CT

10. Insulation resistance tests

Insulation resistance between the CT winding and ground is usually checked by the use of conventional insulation test instruments. The following five tests may be conducted:

Test	Insulation tester lead connections (connected/shorted points)	
	L1	L2
A	H1, H2	X1, X2, chassis
B	H1, H2, chassis	X1, X2
C	H1, H2	X2, X2
D	H1, H2	chassis
E	X1, X2	chassis

Tests A and B can be conducted to confirm that the insulation resistance of the CT is good.Another alternative is to conduct tests C, D, and E instead of tests A and B. Connections for test A are shown in Figure 9.

CAUTION

Where high-voltage insulation tests are conducted, care must be taken not to expose solid-state and microprocessor relays/devices to the high voltage. Before operating CT shorting switches, caution should be taken to ensure that appropriate protection is maintained.

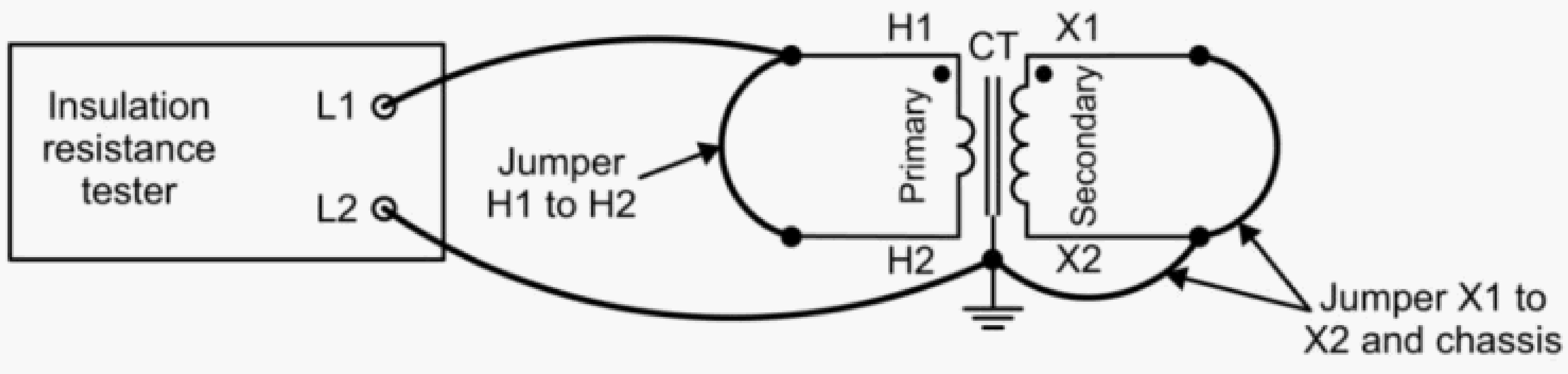


Figure 9—Insulation resistance test; connections for test A are shown

The neutral ground must be removed and the CT preferably isolated from its burden for this test. The neutral can be used to test all three phases simultaneously. To avoid damage, current transformers should never be tested while under a vacuum since there is a greater possibility of arcing when under vacuum.

If relays are left connected to the current transformers during the test, the relay manufacturer should be consulted before test values above 500 V are used. Many solid-state relay designs have surge-suppression capacitors connected from input terminals to ground, which may be damaged by use of a higher voltage.

The measured resistance should be compared with those of similar devices or circuits. Readings lower than those known to be good should be carefully investigated. The generally accepted minimum insulation resistance is 1 MΩ. One of the most common reasons for low readings is the presence of moisture; drying out the equipment and retesting it should be considered before it is dismantled.

11. Winding and lead resistance (internal resistance)

In order to calculate ratio correction for a class C CT, its internal resistance and the external impedance (including secondary lead resistance) must be known. The internal winding and lead resistance can be measured with an impedance bridge. If an impedance bridge or a specialized low-resistance ohmmeter is not available, then a traditional volt-amp circuit can be used, similar to the circuit shown in Figure 10 except utilizing a dc source. The dc millivoltmeter must have sufficient resolution to read voltages in the order of 100 mV accurately. The resistance is found by dividing the voltage by the dc current. Usually, it is sufficient to use the average value of resistance of the CTs in the three phases for calculations.All measurements should be made at the current-transformer short-circuiting terminal block. If the lead length from the CT to the shorting block is considerable and it is necessary to separate the lead resistance from the winding resistance, a two-step resistance measurement can be performed by disconnecting the external leads, measuring the resistance of the leads separately, and subtracting from the total resistance. Of good practical value is the observation that the resistance per turn of bushing CTs typically ranges from 2 mΩ to 3 mΩ. Because of possible remanence, the CT should be demagnetized after completion of this test as outlined in 5.1 and IEEE Std C37.110. As previously mentioned, proper precautions should be taken when connecting and disconnecting the bridge because of potentially dangerous spike transient voltages.Ametal-oxide varistor connected across the winding under test or across the voltmeter input terminals can protect both the operator and the test instrument. When using the volt-amp method, transient voltages can be avoided by slowly reducing the current back to zero.

12. Excitation test

12.1 Safety

Ensure that the CT is de-energized and that the CT has been de-magnetized. Applying voltage to a portion of the secondary winding will cause the proportional induced voltage across full winding due to autotransformer action. CT's should not remain energized at voltages higher than the knee-point value for times longer than that required for the readings.

12.2 Type of test

This subclause describes the various test methods used when performing the excitation test. This test verifies the operating characteristics of the current transformer when compared to manufacturer's data. The two common methods are the secondary voltage method and the primary current injection method.

Whether performing the voltage or current method, the selection of the instruments used for the measurements is especially important for this test. The ammeter should be an rms instrument and the voltmeter should be an average-reading voltmeter. This average-reading voltmeter will make the voltage less dependent on the harmonics caused by the non-linear winding impedance being connected to a source of finite impedance. It can be either an analog type consisting of a d'Arsonval instrument connected across a full-wave rectifier, or a digital one. The bandwidth of the instrument should extend at least to the third harmonic. It should be calibrated to give the same numerical indication as an rms voltmeter on sine-wave voltage (this is the case for all general-purpose meters). SeeAnnex B for illustrations of the effect of different measuring instruments.

12.2.1 Voltage method

This method is used most often as it does not require high-current test equipment.An ac test voltage is applied to the secondary winding of the CT while the primary winding is left open-circuited as shown in Figure 10. It is prudent to demagnetize the CT before performing this test (see 5.1).

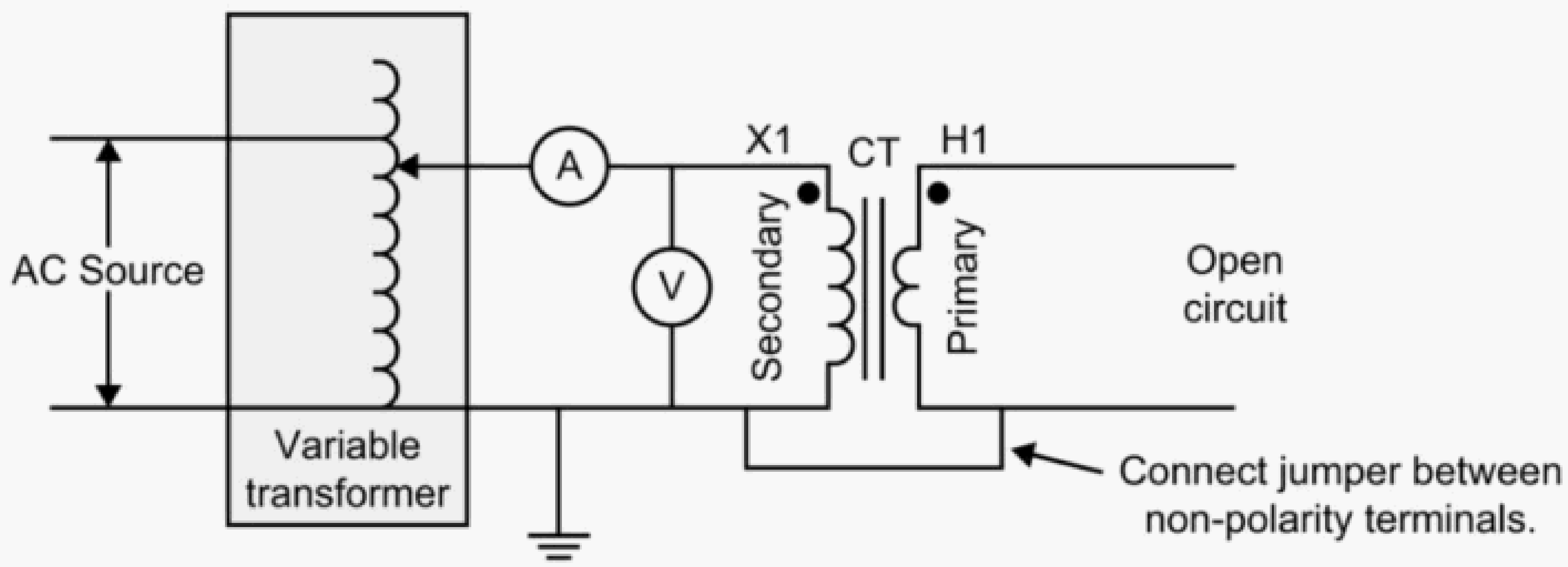


Figure 10—Voltage method (excitation test)

Avariable ac voltage is applied to the secondary winding of the CT, and the current flowing into the winding at each selected value of voltage is recorded.

Readings near the knee of the excitation curve are especially important in plotting a comparison curve. For CTs with taps, the secondary tap should be selected to assure that the CT can be saturated with the test equipment available. The highest tap that can accommodate the requirement shall be used. Compare the readings obtained with the manufacturer's published data.

12.2.2 Current method

This method is used rarely as this requires a primary injection test set. This test is performed by energizing the CT primary from a high-current ac test source as shown in Figure 11. The secondary open-circuit voltage is plotted against the transformed primary exciting current. The observed values of current must be divided by the CT ratio in order to compare observed data with the manufacturer's data or other reference.

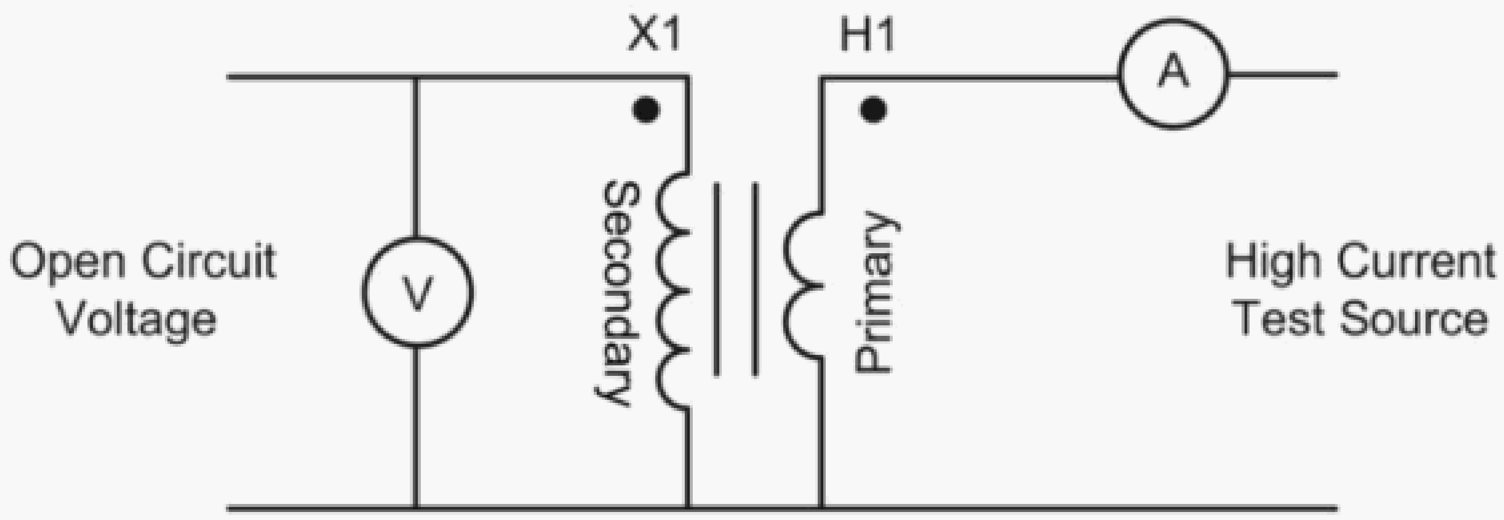


Figure 11—Current method (excitation test)

12.2.3 Variable frequency test method

An alternative to conventional methods outlined in 12.2.2 is to use a low-voltage, low-power, variable-frequency method for performing the excitation test. This eliminates the need for step-up transformers and avoids dangerous voltages during the testing.

An ac excitation voltage is applied to secondary terminals while the primary winding is left open-circuit. Voltage, current, and phase on the secondary terminals are measured simultaneously to plot the excitation curve.

When measuring below 120 V, nominal frequency (i.e., 60 Hz) is used. For voltage above 120 V, the frequency is reduced to reach the necessary flux level.

This method is available in a commercial CT analyzer. This method has been validated by an independent test lab and produces an accurate result.

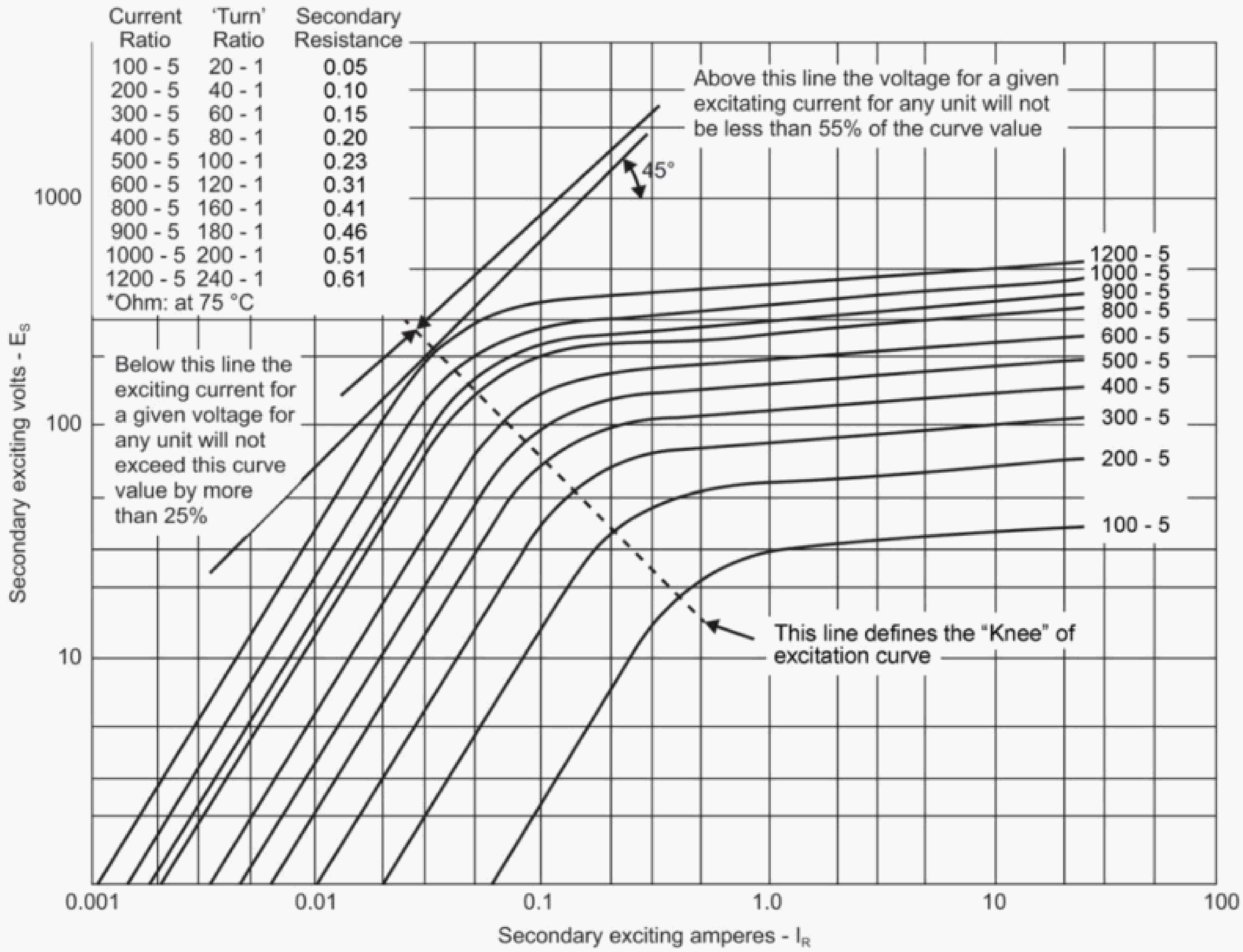
12.3 How to interpret the test results

Excitation tests can be made on both C- and T-class CTs to permit comparison with published data or previously measured data to determine if deviations have occurred.

Any substantial deviation of the excitation curve for the CT under test from curves of similar CTs or manufacturer's data should be investigated. Typical excitation curves for a multi-tap CT are shown in Figure 12, which is reproduced from IEEE Std C37.110.

CAUTION

If voltage is applied to a portion of the secondary winding, the voltage across the full winding will be proportionately higher because of autotransformer action. CTs should not remain energized at voltages above the knee of the excitation curve any longer than is necessary to take readings.



Source: Modified from IEEE Std C37.110-2007.

Figure 12—Typical excitation curve for class C multiratio CT

The excitation curve displays the relationship between the CTsecondary voltage and the CTexcitation current.

CAUTION

The excitation current that produces the magnetizing flux is on the primary of the transformer. Theoretically, the excitation test should be performed from the primary to be the most accurate; however, this is impractical due to the high voltage generated at the open secondary terminals and the high test current needed for the test. Testing from the primary should only be considered when high leakage current exists in the current transformer such as in auxiliary current transformers.

The CT performance can be evaluated using the excitation curve data and the generic CT equivalent circuit.As displayed in Figure 12, all excitation curves of C- and T-class transformers share the following same general characteristics:

a) The portion of the curve below the knee point is linear. Note that for a multi-ratio CT, the lower taps have the curves at the same angle but with a lower voltage for the same excitation current. This portion of the curve should be at a steeper angle to the x-axis than the saturated portion of the curve at higher currents than the knee point. The secondary current in this portion of the CT operation should be an undistorted reproduction of the primary with ratio error equivalent to the CT rating.

b) Knee point: Where the CT has maximum permeability (see IEEE Std C37.110).

c) Saturation region: The nearly horizontal portion of the curve at higher currents than the knee point where a disproportionate increase in exciting current occurs for a small increase in secondary voltage.

Significant distortion in the secondary current and increasing ratio error occur in this region. The secondary voltage as measured at the 10 A point for the full CT winding must be greater than the CT rating; e.g., for a C200-rated CT, the secondary voltage as measured at 10 A exciting current for the full winding must be >200 V.

The excitation curve of a CT should remain very close to the original curve when tested at the factory. A slight "lowering" of the excitation curve is normal over time with the curve shape remaining identical. The curves for all taps of a multiratio CT should be the same shape. Lowered saturation or knee point voltage (from historical values), depressions, dips, or spikes in the excitation current curve can indicate a problem. Curves appearing abnormal as in Figure 13 and Figure 14 are indicative of CT problems.

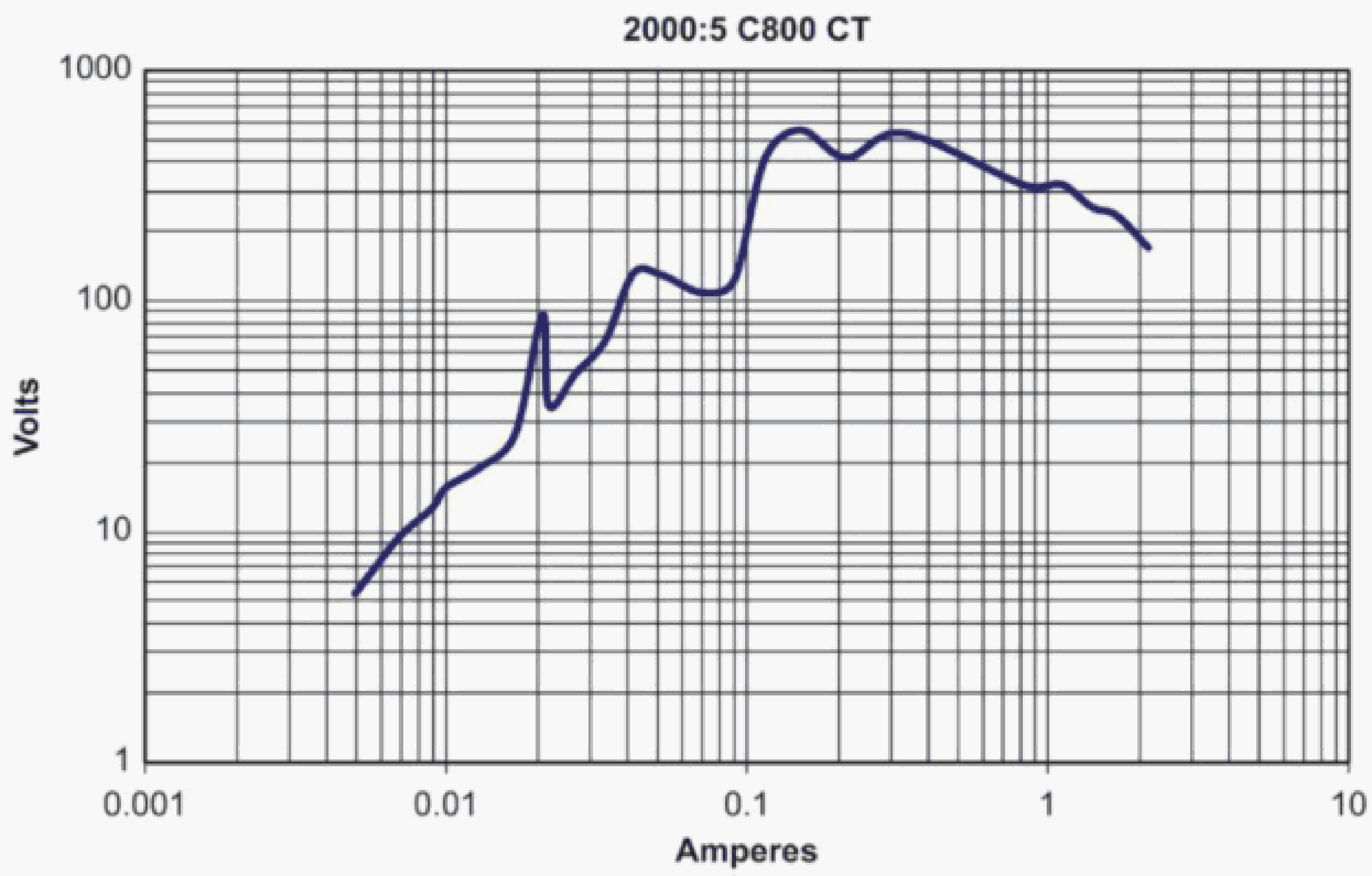


Figure 13—Bad CT

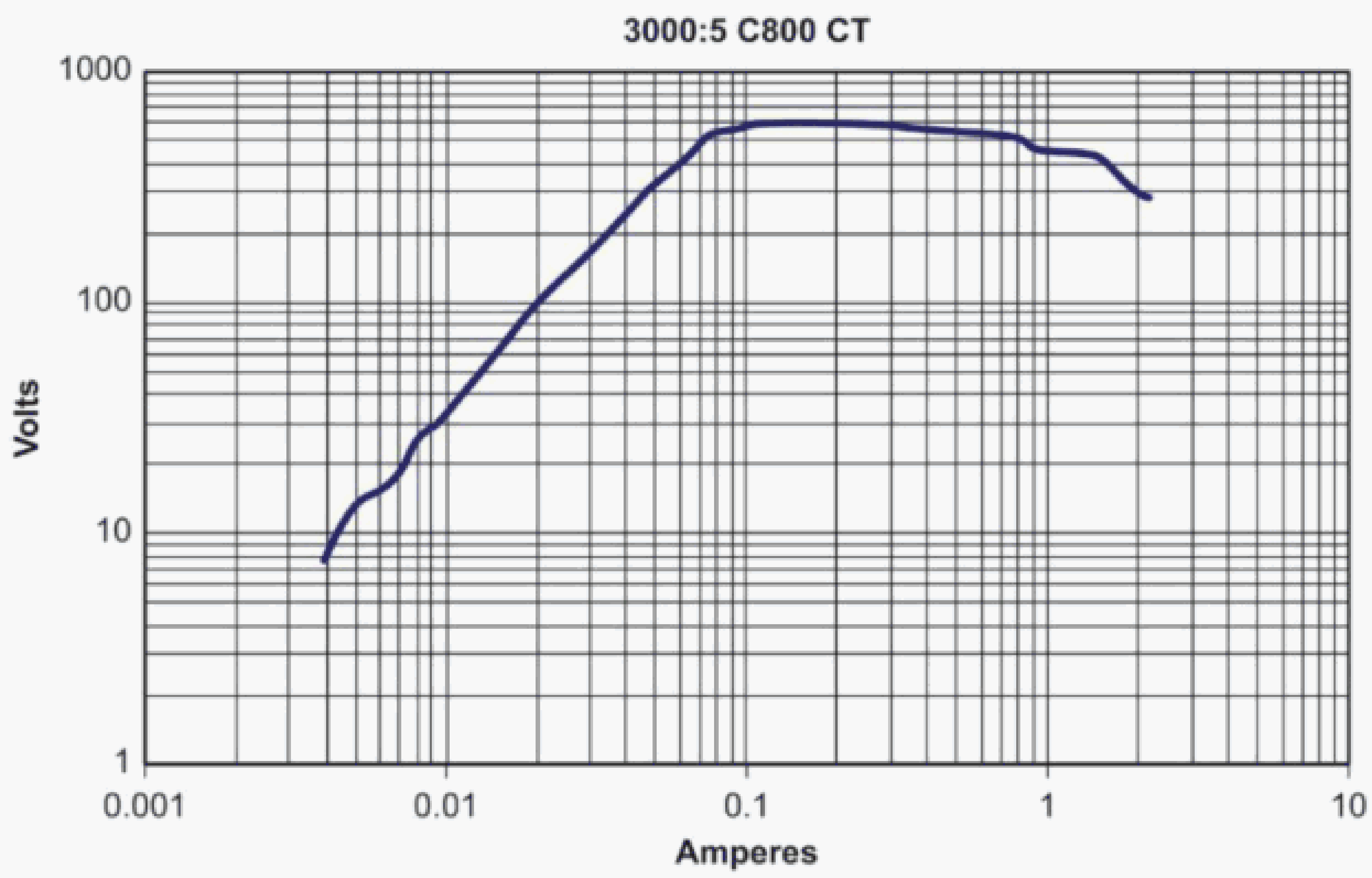


Figure 14—Bad CT, failure in the saturation region

A method used to further examine an apparent CT problem following an excitation curve evaluation would be to use an oscilloscope to view the excitation current waveform while applying a secondary excitation current greater than the knee point value. In the saturation region of the CT excitation curve, the waveform should show a typical saturation profile as illustrated in Figure 15. A fully shorted CT would exhibit a normal sine wave when viewed, as in Figure 16. A high-impedance short may exhibit a slightly skewed waveform as in Figure 17 comparable to a "saturated sawtooth" shape.

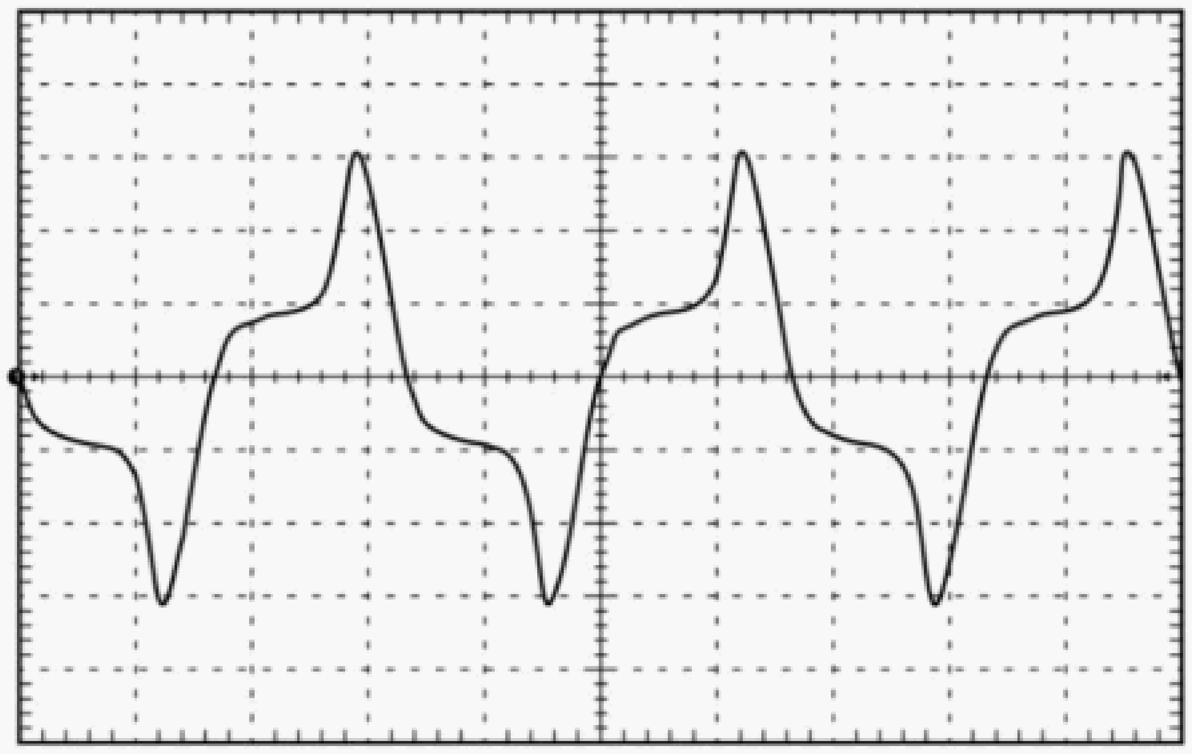


Figure 15—Saturation region excitation current waveform

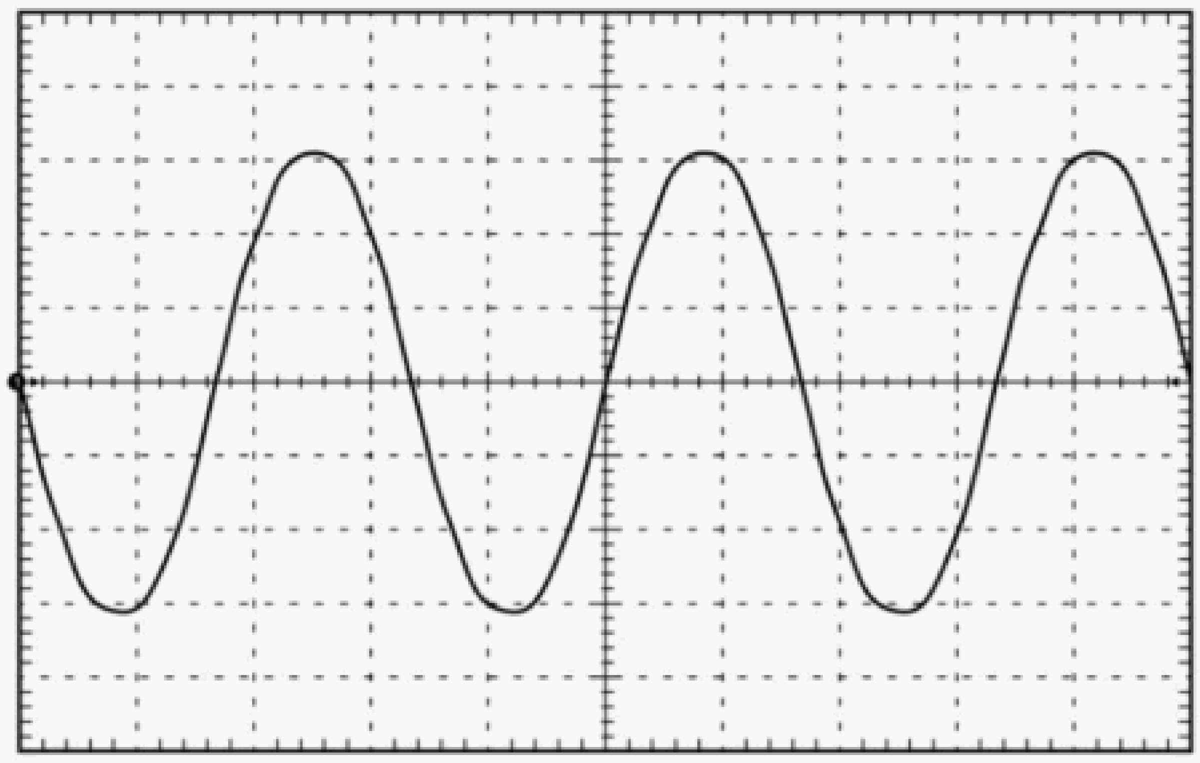


Figure 16—Excitation current in the saturation region of a fully shorted CT

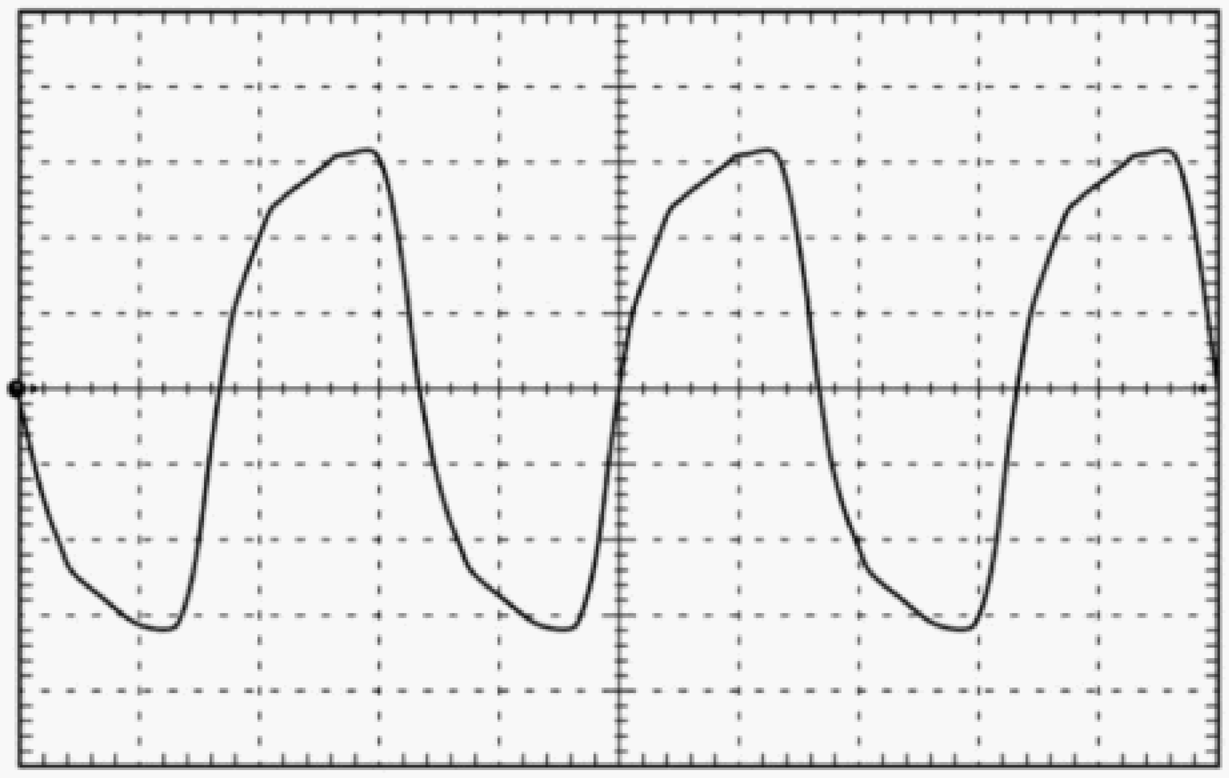


Figure 17—Single-shorted turn CT, with excitation current in saturation region

Asingle-shorted turn within a CT can often not be found by viewing the excitation waveform at high CT ratios until high currents during faults or testing cause arcing or insulation failure that propagates further damage. A single-shorted turn may be identified on a low ratio or multi-ratio CT at lower ratios by performing an excitation test or a turns ratio test.

13. Admittance test

A CT analyzer with admittance testing capability checks for abnormal admittance by injecting an audio frequency into the secondary winding of an in-service CT, and by detecting the circuit admittance. Any audio frequency signal between 1 kHz and 2 kHz would probably be satisfactory. One analyzer uses an audio frequency of 1575 Hz to avoid the probability of any multiple harmonic of the fundamental system frequency being present in the system, and possibly causing a false signal in the audio frequency-detecting circuitry.

Relaying or metering accuracy CTs have very small errors when operated within the specified current and burden ratings. Therefore, it is known that the circuit admittance of any particular CT and the circuit connected to it is very nearly constant throughout the normal operating range unless a fault condition develops. If the admittance measurement shows a deviation from normal while the CT is in service, it is likely that the CT has: 1) an internal short (usually a shorted turn); 2) an abnormal internal or external resistance (such as a high-resistance connection—loose or corroded); or 3) the CT is operating under abnormal conditions (such as a dc component in the primary current). Serious faults are immediately obvious due to an abnormally high admittance reading, usually at least 1.5 times the normal reading. A CT with an incorrect ratio, or connected to the wrong tap will provide readings substantially different than the normal readings.

The best way to establish the “normal” reading is to record measurements taken during installation and at subsequent test intervals.Admittance values depend on core design, burden rating, ratio, etc., but changes due to non-fault conditions (temperature, operating point, etc.) are small in comparison to the change caused by fault conditions. In-service CTs are usually tested in groups; a high admittance reading obtained on one CT in the group strongly implies that a fault condition does exist. If all readings in the group are high, it could be caused by a capacitive load on both sides of the CT, high system noise, or the presence of dc in the primary circuit.

14. Burden tests

CTs are designed to supply a known current, dictated by the turns ratio, into a known burden and maintain a stated accuracy. The principle of a CT burden test is to measure the capability of the in-service CT to deliver a current into the existing known burden (and any additional burden expected from the relay during a fault).

The burden is presented to the in-service CT secondary in the form of a known ohmic resistance value that is added in series with the CT secondary loop. The total burden of the CT secondary loop is made up of all devices connected, connection resistances, and wiring lead resistance. Assuming that the technician or engineer has properly sized the CT to match the loop burden, the CT will provide currents according to its accuracy class rating. Some relays add additional burden during the fault. Should the burden exceed the design burden capability of the CT, the transformer will not be able to supply the same level of current to the increased burden and the net result is a drop in CT secondary loop current.

The amount of this current drop is dependent on a number of factors and is not absolutely definable. The operating current level of the CT secondary loop is a major factor. CTs operating at very low percentage of their ratings can support several times the burden rating because at low currents the flux density of the core is very low, leaving a considerable margin for additional flux before saturation. Therefore, a performing burden test on a CT, at a very low percentage of its rating, is not very accurate or conclusive. The most accurate and revealing burden tests are performed at the full-rated secondary current. At the upper end of the current range, additional burden quickly pushes the CT out of its operating range and causes dramatic drops in output current.

15. Burden measurements

Burden measurements and system short-circuit current provide data for calculating ratio-correction factors for class C CTs. Using these factors it is possible to analyze relay performance. The total burden of the circuit is the sum of the internal CT burden and the external burden connected to the CT.

The internal burden is the resistance of the secondary winding plus the lead resistance from the winding to the short-circuiting terminal block converted to volt-amperes at rated secondary current. The procedure for measuring internal resistance is described in Clause 11.

The external connected burden can either be calculated or measured. To determine the external connected burden in volt-amperes, measure the voltage required to drive rated current through the connected burden.

If both resistive and reactive components of the burden are desired, a suitable phase angle meter can be connected.

Burden measurements, when compared with calculated values, help to confirm circuit wiring and satisfactory contact resistance of terminal blocks and test devices.

The following reminders have been found useful in obtaining correct burden data:

a) To represent in-service burden, the relays and other external devices must be on the correct tap.

b) Parallel CTs should be disconnected.

c) Phase-to-neutral measurements in relay circuits can be high, particularly if ground relays with sensitive settings are involved.

d) Phase-to-neutral and phase-to-phase measurements of bus differential circuits can be high because of the impedance of the differential relay operating coil.

16. Specialized situations

From time to time, the tester will encounter assembled equipment that cannot be tested by the “normal” test methods outlined in Clause 6 through Clause 15. In some cases, partial testing may be accomplished prior to complete assembly.Alternate methods for testing assembled equipment are described in 16.1 through 16.3.

16.1 CT in a closed-delta transformer connection

Ratio and polarity tests must be made prior to assembly if the delta winding terminals are not brought out, unless a test set is used that can compensate for this. Ratio tests must be made by the voltage method of 8.1. Main power transformer excitation requirements and impedance would require a test set with much higher capacity than is normally found in order to use the current method.

The tester should be made aware that it is necessary to short circuit the unused winding of the affected phase of the power transformer when making the polarity test of 9.1. The reason for shorting the unused windings is to prevent induced high voltages. When connecting the test set to the secondary of a bushing CT, it is necessary to access the primary lead.As this is not accessible directly, it is needed to connect the relevant bushing and the neutral terminal (transformer winding in between) in Figure 18.

During the measurement, the secondary of the CT is energized, resulting in a voltage across the transformer winding where the test set primary leads are connected. Thus, a flux is induced in the transformer core. This flux is distributed in the whole transformer core. If the other windings (bushings) were not shorted, a voltage would be induced in the other windings resulting in a magnetic flux disturbing the resulting measurement.

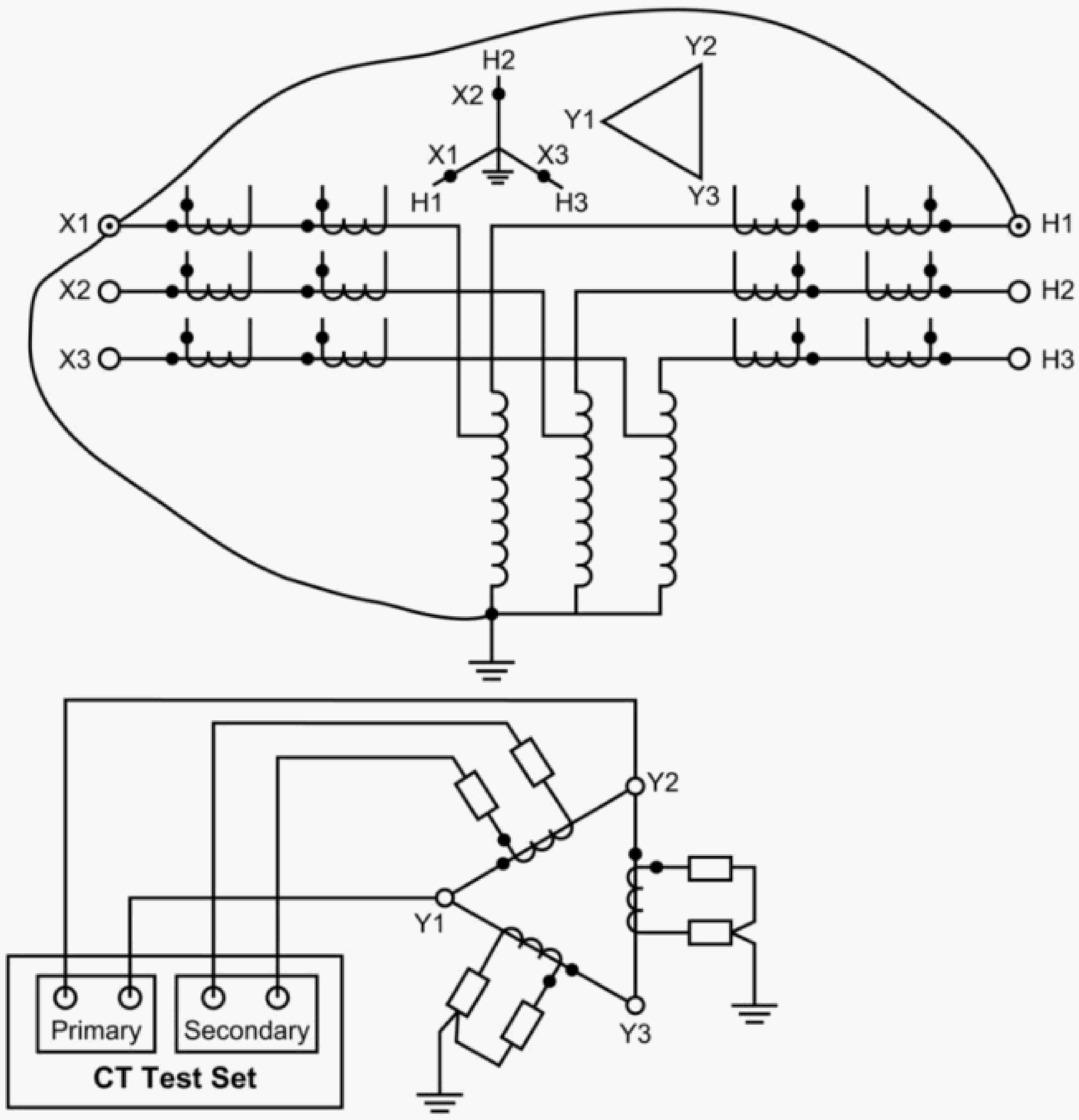


Figure 18—CT in a closed-delta connection

Additionally, the capacitive influence through the additional "antenna structure" can be increased if the other windings are not shorted.

16.2 Generator CTs

High-ratio generator CTs present a special type of problem. The voltage method affords the only practical method of performing a ratio test. A convenient method of checking both ratio and polarity is to use a dual-channel or dual-trace oscilloscope to measure the magnitudes and phase relationships. The procedure is outlined in 9.2.

16.3 Inter-core coupling check

In many cases, such as circuit-breaker bushings and separately mounted extra-high-voltage CTs, several secondary cores are mounted in close proximity on the same primary lead. It is possible to have coupling between these cores that may not appear as a short-circuited turn in the excitation test (see Clause 12), but which can cause a detectable imbalance in a bus differential relay circuit. Examples are shown in Figure 19 and Figure 20.

Inter-core coupling occurs when a spurious metallic conducting path is established that encircles more than one CT. It may not be detectable with the excitation test if enough resistance is present in the conducting path.

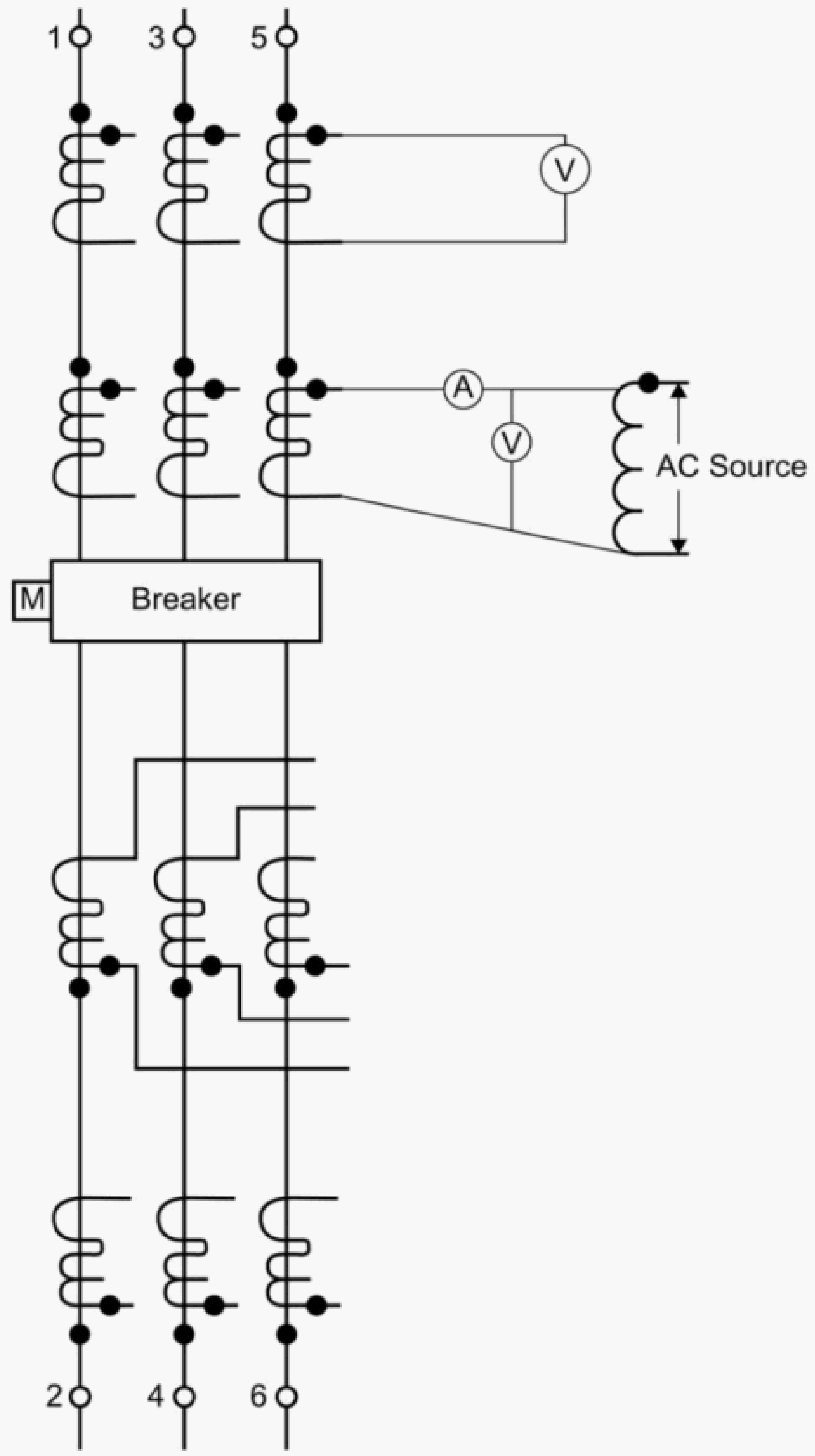


Figure 19—CTs in bushings

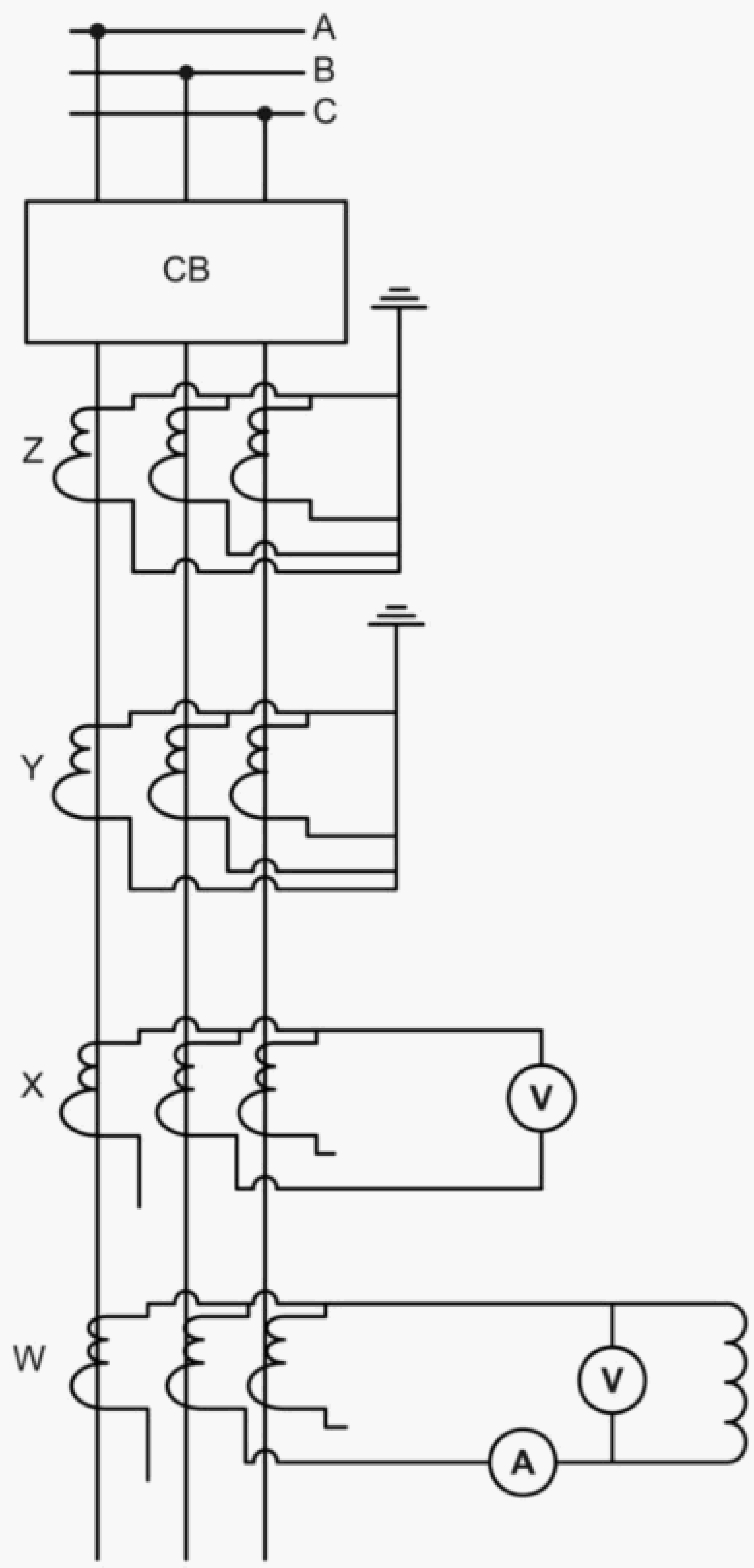


Figure 20—CTs in stack

Inter-core coupling will occur if one of the following conditions is present:

a) If the CT support is in contact with the bushing ground sleeve, making a single-turn conducting path around the bushing CT.

b) If a surge protector across the H1–H2 terminals of an oil-filled CT is short circuited or if the H2 insulation fails.

c) If the insulation of grading shields surrounding the cores of an SF_6-filled CT fails.

d) If the insulation on the metal support for the primary insulation on an oil-filled CT fails and establishes a conducting path through the support.

To determine if there is coupling between cores, the excitation test should be repeated, and the voltage across the full winding on each of the adjacent cores should be measured one at a time with all other current-transformer secondary windings shorted. A high-impedance voltmeter (20 000 Ω/V or greater) will read less than 1 V or 2 V if there is no inter-core coupling. If there is coupling, the voltage will be substantially higher.

Annex A

(informative)

Wiring integrity, test switches, and test equipment

Field testing of relaying CTs frequently includes verification of wiring integrity, use of test switches, and multipurpose test equipment. This annex describes wiring integrity checks, test switch uses, and test equipment applicable to field testing of relaying CTs.

A.1 Wiring integrity

Some verification procedures assume that a detailed check of the wiring for agreement with the elementary diagram should be carried out prior to injection testing. Other verification procedures assume that any wiring errors will be disclosed by the actual injection tests. It is true that actual injection testing will disclose some wiring errors, but it should be realized that this procedure can also result in damage to equipment because the wiring error may result in accidental injection of test quantities that exceed the rating of the inadvertently connected equipment. Also, errors may not be detected until incorrect operation occurs in service. Selector switches in current circuits, such as ammeter switches, should be checked for proper contact development and operation.

When performing a single-phase injection, three-phase and neutral-current circuits shall be monitored to verify presence of current where it should be and absence of current where it should not be. The three-line, elementary, or schematic diagrams should be used for the purpose of checking the connections.

Whichever verification philosophy is used on wiring checks, a test should be performed to prove that multiple grounds do not exist. This test is best performed by removing the known or desired ground and checking insulation to ground at the same location.

WARNING

If the CT secondary circuit ground is removed without the CT primary being de-energized, dangerous voltages may result in the secondary circuit. This is due to electrostatic coupling even with no primary current flowing in the CT. (For detailed discussions, see IEEE Std C57.3.3™.)

A.2 Test switches

Current switches consisting of a test jack and current shorting elements are placed in current circuits to facilitate checkout, troubleshooting, calibration, and periodic testing of relays, meters, transducers, and instrumentation. These switches permit testing to take place without de-energizing the primary circuit and may be a separate unit or built into a protective relay case.

A.2.1 Test jacks

The test jack is used to allow current measurements to be taken without opening the circuit by inserting a test plug into the test jack. The test plug is a two-wire device connected to an ammeter. Inserting the test plug into the test jack places the ammeter in series with the current circuit. Before the test plug is inserted into the jack, extreme care should be taken to make sure that a complete low-impedance circuit exists through the ammeter. This can readily be accomplished by using an ohmmeter. A low resistance from the polarity blade to non-polarity blade of the test plug indicates a complete current path. A minimal amount of time is required to perform this test, and its usefulness in preventing the inadvertent opening of a CT secondary makes its frequent use worthwhile.

A.2.2 Current shorting switch

The current shorting switch is usually found mounted on the test jack. The purpose of this switch is to disconnect the current coil of the device to be tested from the current circuit or CT secondary winding. As its name implies, it does this by shorting the source-side circuit and disconnecting the load-side circuit, in that sequence, by means of make-before-break contacts. The use of the make-before-break switch bypasses and open-circuits the device to be tested. An important point to remember is that this switch does not ground the CT. Also, depending upon the switch configuration, total isolation of the load-side circuit may require insertion of a "dummy" test plug in the test jack. With the switch in the shorted position, a closed current circuit still exists. When a test plug is inserted into the test jack without the shorting switch operated, the circuit from the test plug must be complete in order to keep the CT circuit closed.

WARNING

Most CTs are shipped with the secondary terminals shorted. The short circuit must be removed and the connection made to the secondary loop or current shorting switch before energizing the primary. Open-circuited energized CTs can develop voltages high enough to damage the insulation and possibly cause failure.

A.3 Test equipment

Test equipment should include equipment such as ratio meters, winding resistance ohmmeters, and excitation test sets, including the following:

a) Insulation resistance meters are capable of measuring the insulation resistance of the installed CT.

b) Ratio meters measure the ratio and verify the polarity of CTs.

c) Micro-ohmmeters are capable of measuring the resistance of CT windings and connecting leads using the four-terminal connection.

d) Phase angle meters are capable of measuring the ratio and verifying the polarity of CTs.

e) Excitation test sets are capable of determining the excitation characteristics of CTs as well as their ratios and polarities.

f) Excitation test sets are capable of plotting the excitation characteristics.

g) Relaying CT test sets are capable of measuring the ratio, the winding resistance, and the insulation resistance, as well as verifying the polarity and providing the excitation characteristics.

The relays should have been tested in accordance with the IEEE Power System Relaying Committee Report, "Relay Performance Testing" [B6] prior to the testing of the circuit by primary or secondary injection tests.

A.3.1 Transformer load box

This type of test set derives its test voltages and/or currents from a variable autotransformer and loading transformers. The technique is especially useful in high-current testing since the test currents are developed with a lower test voltage, thus reducing the power requirements for the test source. The output is relatively constant low voltage, and therefore may be subject to some current wave-shape error. This is minimized by using the lowest current output tap (highest source voltage) that will deliver the required test current for the time interval required.

A.3.2 Resistance load box

The lightweight load box consists of switched non-inductive resistance units and a variable resistor. It is connected in series with a suitable test voltage source and the relay under test. The test source must be capable of supplying the required current. The current wave shape is good since the resistance tends to swamp out the non-linear impedance of the load.

A.3.3 Transformer analyzer (for field or in-service testing)

The lightweight, for portability or field testing, transformer analyzer consists of a CT burden tester, CT ratio tester, and a voltage transformer burden tester (includes a CT admittance tester and a CT demagnetizer from one manufacturer). The instrument is designed for testing CTs and voltage transformers while in service. These are commercial devices available from more than two manufacturers.

A.3.4 Electronic techniques

This principle uses electronic circuitry to accurately control and maintain the magnitude, wave shape, and phase angle relationship of the various test quantities using active feedback from the analog signal. Errors are generally less than 1%.

There are available digital multifunction CT analyzers that also may provide the following functions:

a) Manual or automated test procedure
b) Accuracy limiting factor (ALF) and instrument security factor (FS) (direct and indirect)
c) Determination of unknown CT data
d) Definition of CT model elements and calculation of CT parameters
e) Data handling and reporting
f) Field verification of CTs up to the 0.1 accuracy class due to extremely high accuracy (0.02% typical)
g) Automatic assessment in accordance with IEEE and IEC standards
h) High noise immunity for on-site testing

Annex B

(informative)

Excitation voltage measurement considerations

CT excitation curve verification tests are frequently performed under field conditions where access to test equipment is typically restricted to general-purpose meters and portable voltage sources. Since rms responding digital voltmeters tend to be more common than average responding meters, the test results are likely to deviate from the manufacturer's data and consequently lead to unnecessary investigations.

The purpose of this annex is to illustrate the difference between rms and average responding meters in actual laboratory tests and for a synthetic waveform. The effect of the source impedance is also considered.

B.1 Why average?

The voltage in the CT secondary winding is proportional to the average of the flux created by the primary current.

B.2 Typical test results

Tests performed by a CT manufacturer under normal production conditions are reported in this clause. In this test, the magnetizing current was passed through 15 turns of #10 wire through the core window of a 1200/5 single-ratio CT. The measured voltage is the open-circuited secondary. The effective turns ratio was $1200/(5 \times 15) = 16/1$.

The excitation curves shown in Figure B.1 illustrate the results obtained with rms and average responding voltmeters. Before the saturation knee, the instruments yield essentially the same results. Beyond the knee, the rms reading is higher than the average. The knee point occurs at approximately 45 V or $45/16 = 2.8$ volts/turn.

Since the manufacturer's published data is recorded with an average responding meter, the field test curve, when obtained with an rms meter, will differ from the reference curve. In this particular case, the error exceeds 10% for currents above 10 A, as shown in Figure B.2. This error depends on the source impedance.

Figure B.3 shows the distortion level at 20 Aof excitation current.

B.3 Effect of source impedance

The voltage distortion is caused by the non-linear magnetizing impedance. If the high-voltage source for the excitation test in Figure B.3 was ideal (i.e., zero source impedance), no distortion would occur. In practical terms, this means that the highest distortion will occur with the smallest (and most portable) voltage source. This, of course, is typical in field situations. The following test results illustrate the effect of source impedance on average and rms responding meters.

Figure B.4 illustrates that the results from the average responding meter are only slightly affected by the source impedance. The two sources for this test are rated 1 kA and 7.5 kA.

Figure B.5 illustrates that the rms readings increase with increasing source impedance.

Due to the fact that rms measurements give more weight to the harmonics than the average measurement, the distortion will increase the value of the rms reading, as seen in Figure B.5.

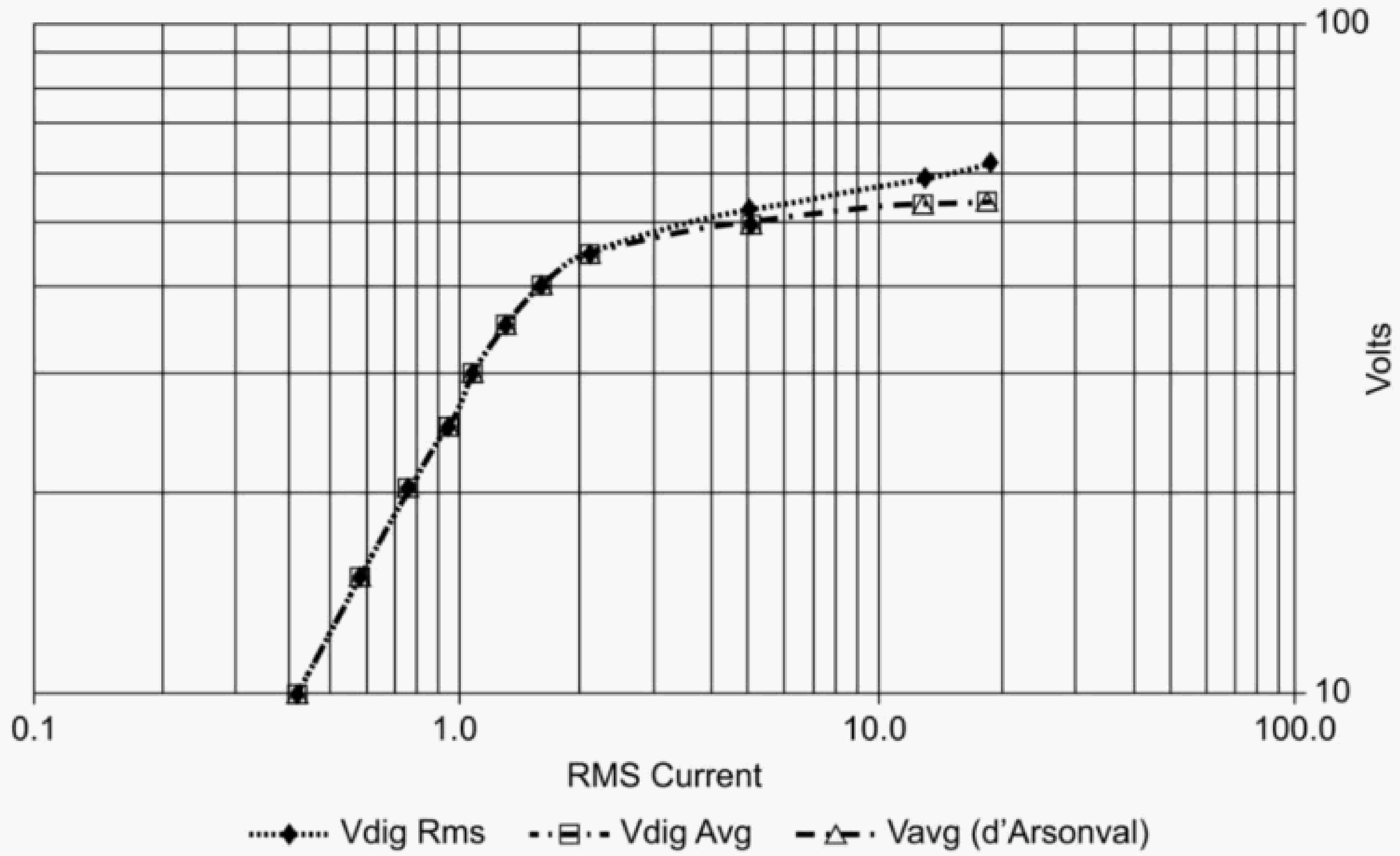


Figure B.1—CT excitation curve rms current versus average responding voltmeter

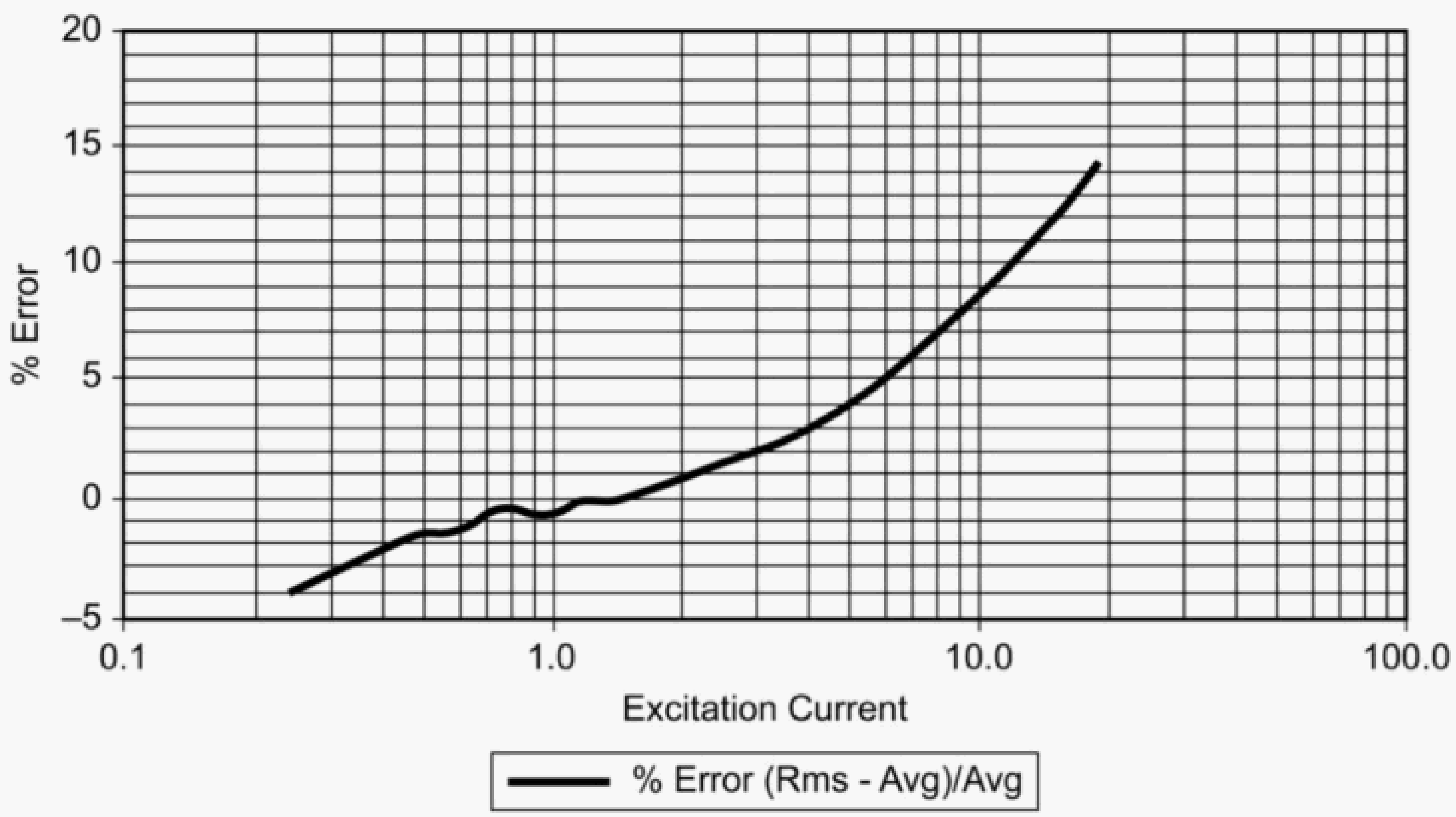


Figure B.2—RMS versus average responding voltmeter measuring error

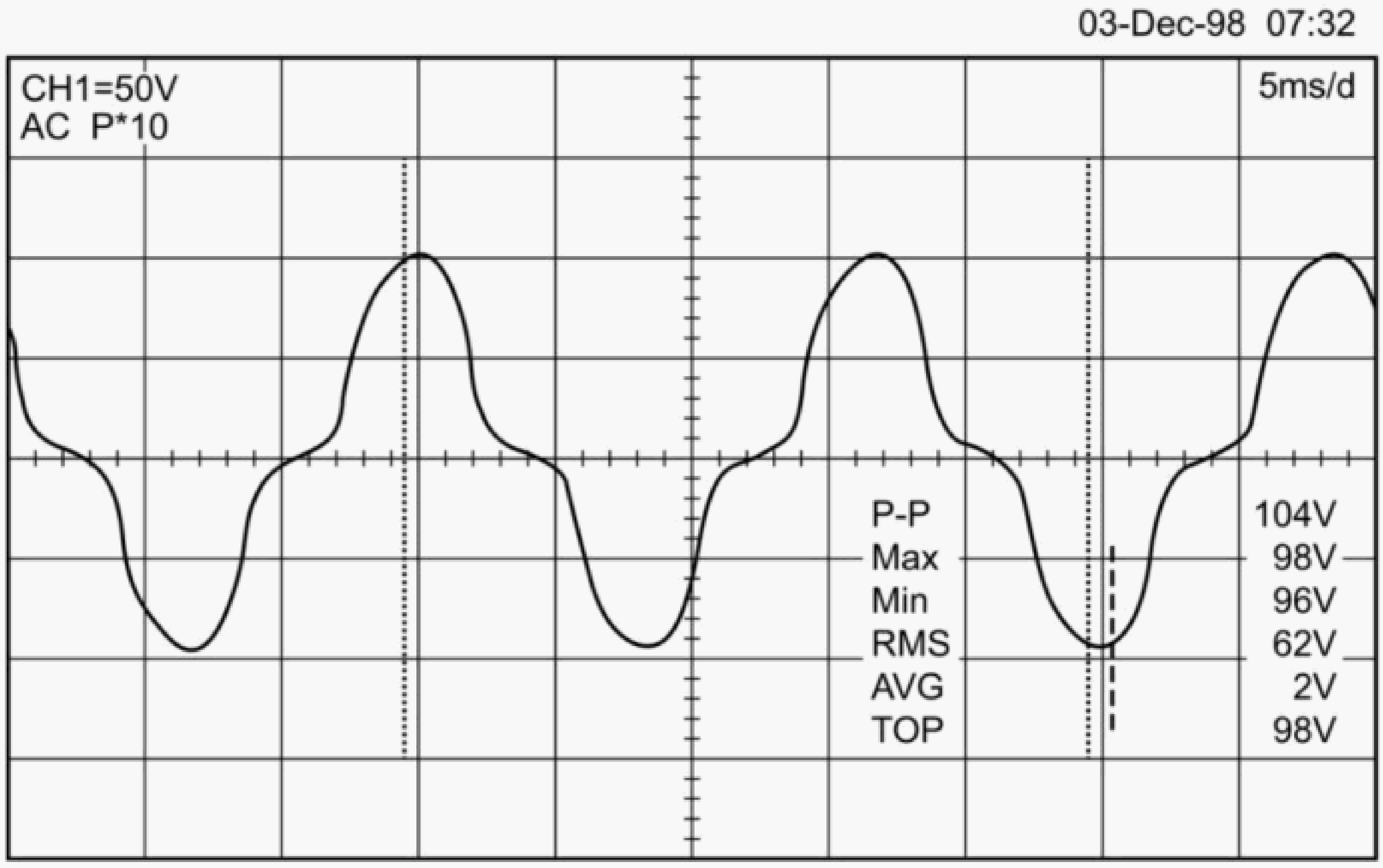


Figure B.3—Test voltage waveform at 20 A

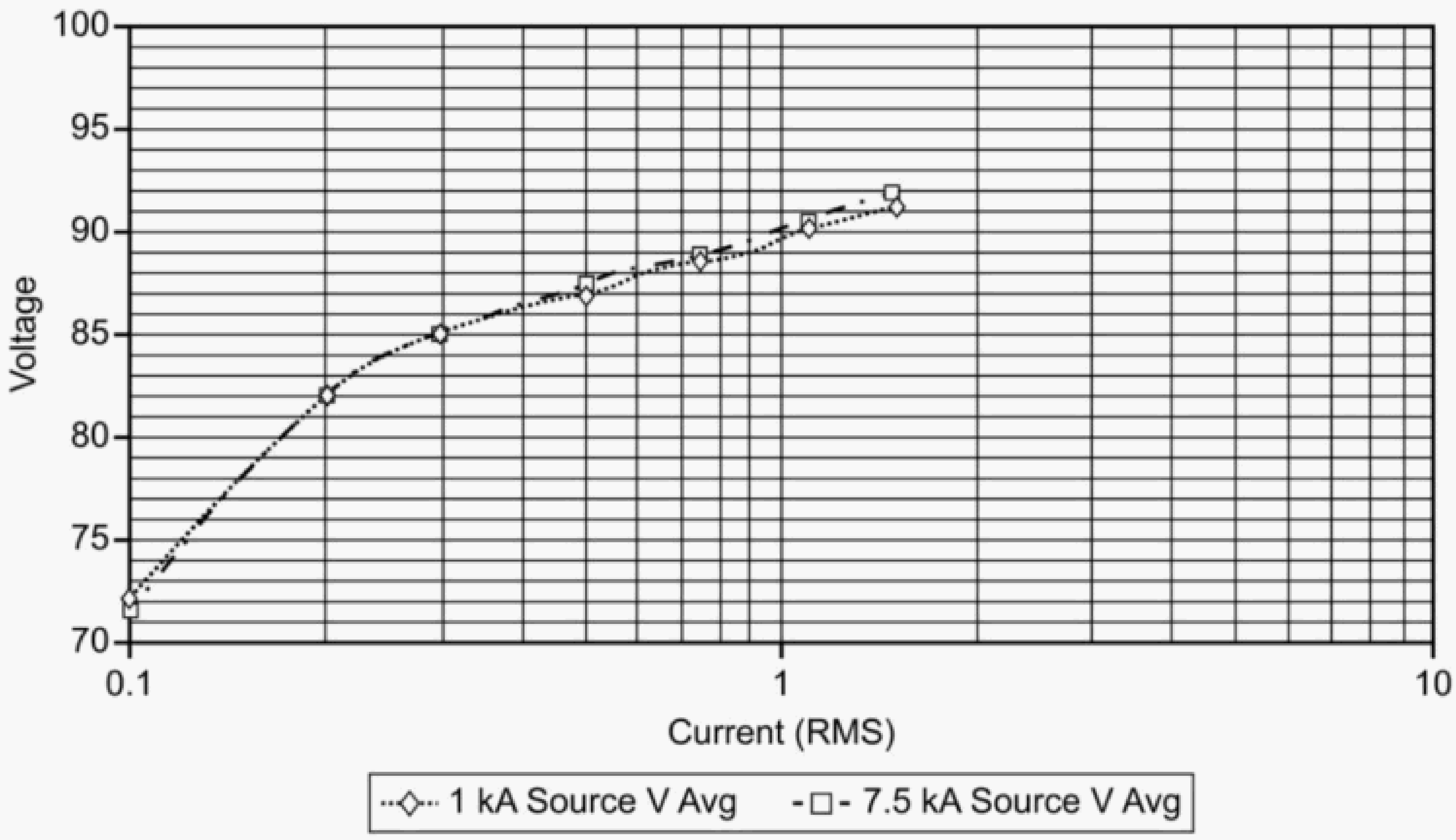


Figure B.4—Effect of source impedance on average responding voltmeters

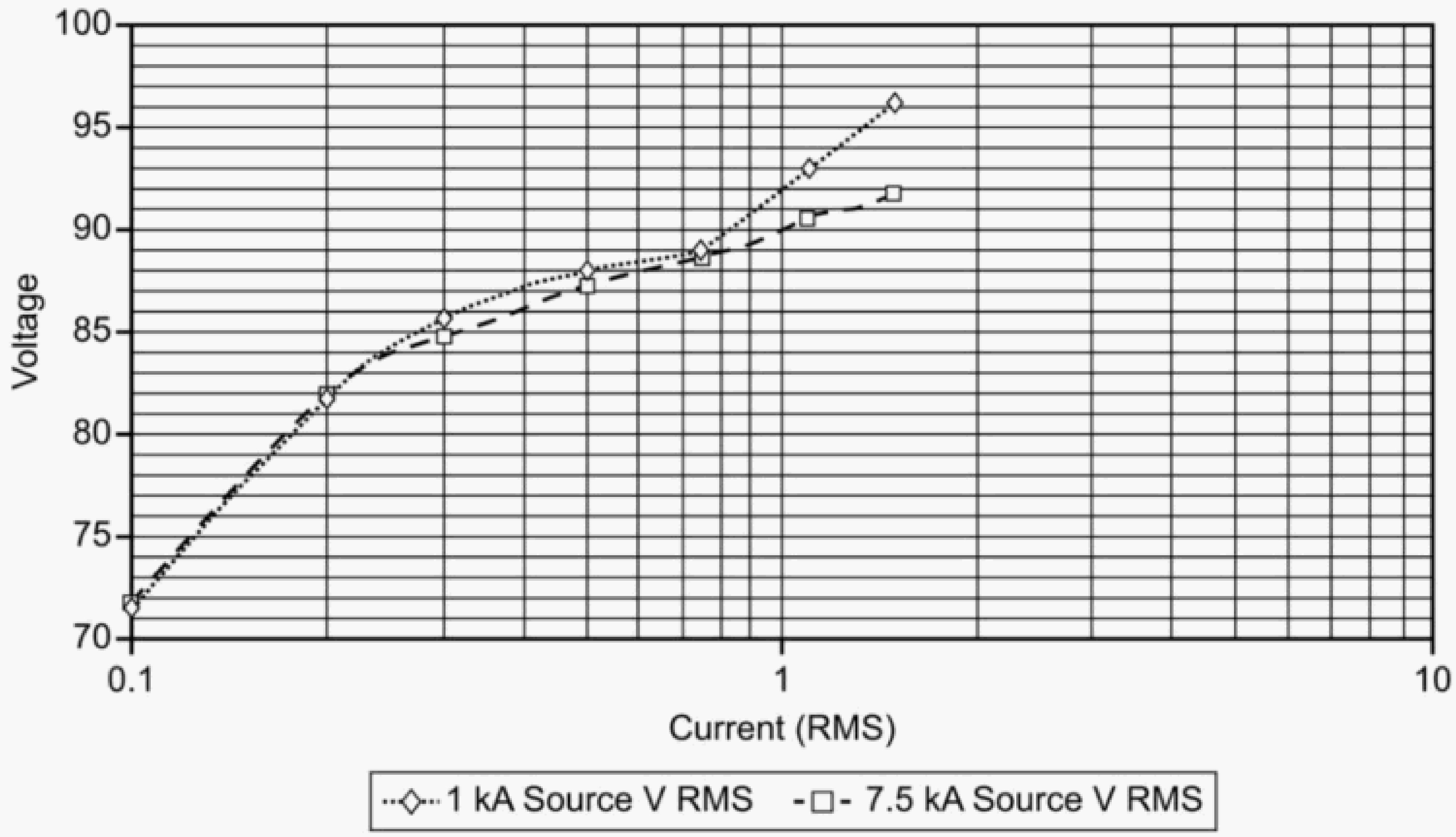


Figure B.5—Effect of source impedance on rms meters

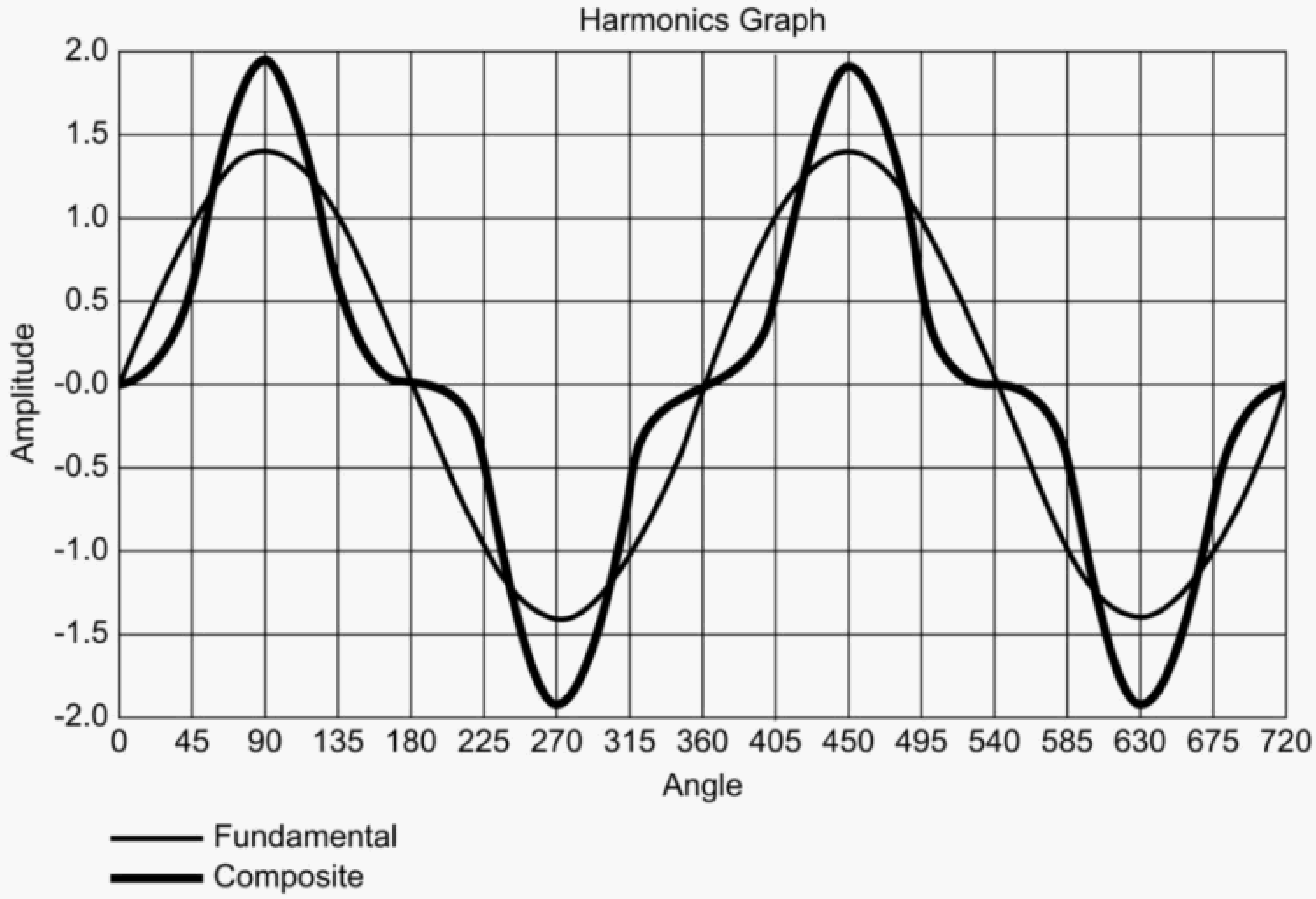


Figure B.6—Fundamental and composite waveforms

B.4 Waveform simulation

The difference between the readings from different measuring instruments can be easily investigated by calculating the theoretical values of conveniently modifiable synthetic waveforms, using the algorithms for rms and average responding rms-calibrated instruments. Sample results are shown in Figure B.6 and Figure B.7.

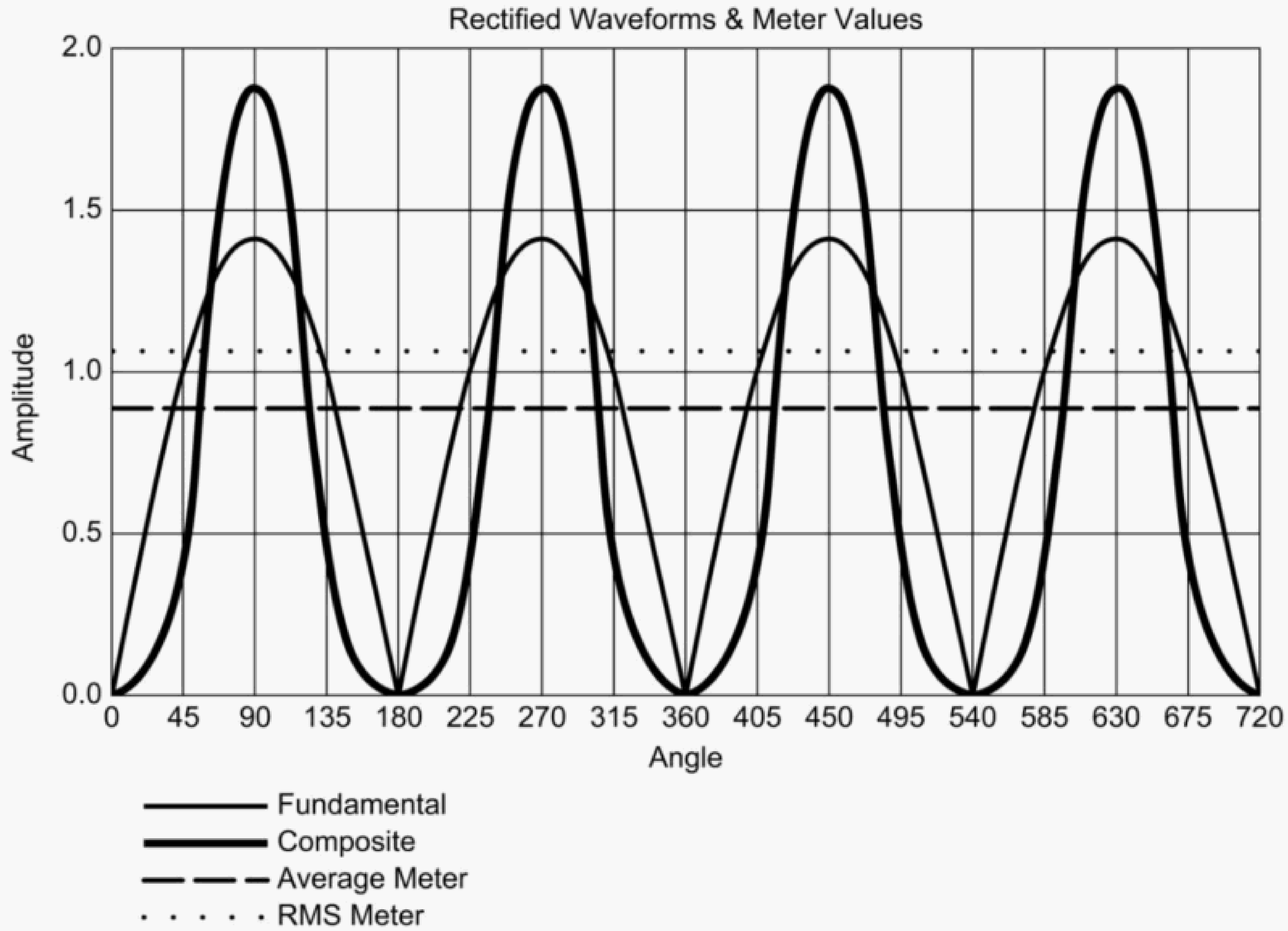


Figure B.7—Metered value from wide band instruments

Table B.1 shows the harmonic content of the waveform that is used to compare the performance of the average and rms responding meters. The first row lists the order of the harmonic and the second row lists the peak value of the harmonic of the corresponding order. The peak value of the fundamental component is $\sqrt{2}$. This composite waveform, shown in Figure B.6, is similar to the waveform shown in Figure B.3.

Table B.1—Amplitudes of the harmonic components of the test waveform

2	3	4	5	6	7	8
0.05	-0.80	0.01	0.02	0.01	0.03	0.05

Figure B.7 shows the difference between the readings from an average and an rms responding meter.

Annex C

(informative)

Optical current sensor systems

This annex describes the characteristics and other pertinent information for optical current sensor systems used with protective relaying. It provides an overview of the components used in an optical sensor system, discusses the differences from conventional CTs, and provides testing information.

Optical current sensors have been successfully used in high-voltage field applications since the late 1980s. Basic optical sensor systems offer benefits not available with conventional CTs. Optical current sensor systems are used by the electric utility industry to replace oil-filled and SF_6-filled CTs.

Optical current systems operate differently from conventional wound-type CTs and users must possess knowledge of the various components of the system to understand the theory of operation and to assist in testing and troubleshooting. This annex is intended to provide the relay engineer with an introduction to this new optical current sensor technology to aid them in applying optical sensor systems when the opportunity occurs.

C.1 Components of optical current sensor systems

While there are multiple technologies that can be applied to build optical sensor systems, only one technology is presently employed in sufficient quantities to warrant discussion in this annex. As other technologies begin to be utilized they will subsequently be described.

In describing conventional high-voltage CTs, it would consist normally of a stand-alone single-phase oil-filled unit—that is connected into the high-voltage line—with secondary leads that run to the control house and are connected to the relay, providing a nominal 5 A (or 1 A) output. It is recognized that here are other technologies available such as SF_6 insulated CT.

With optical sensors, a different technology is used to do essentially the same function—deliver an output to the relay that represents the current in the line. However, in discussing an optical system, it must be discussed as a “system” that consists of the following four major components:

a) Optical sensor: Connected to the high-voltage line.

b) High-voltage insulator: Mounted on a stand and has the optical sensor mounted on the top of the insulator; the optical unit can also be mounted upside down or in a horizontal position.

c) Optical fiber: Runs from the electronic module in the control house to the sensor in the line through an insulator and back to the control house.

d) Electronic module: Mounted in the control house, it sends light via optical fiber to the sensor.

The returning light has been modulated by the sensor and is demodulated and converted to an electrical signal, which is processed, analyzed, and used to provide a signal output, or amplified to provide a conventional 1 A output.

C.2 Why optical sensor systems are used—characteristics and benefits

C.2.1 Operating considerations

An optical sensor system provides increased isolation with optical fiber interface, instead of copper leads, between the unit in the yard and the control house.

There are no environmental problems; no oil or SF_6 is used.

There is no risk of open secondary; elimination of violent failures.

C.2.2 Typical performance

a) Accurate waveform reproduction through 100 kA
b) Wide primary metering accuracy range from 4000 A to less than 5 A
c) IEC metering accuracy class 0.2 over the full metering range
d) Total isolation from surges for microprocessor relays and meters
e) No magnetic core ferroresonance or saturation limitations

In most cases, discussions on the performance of optical sensor systems are manufacturer dependent. For example, the optics part of the system is generally capable of the ratings described above, but the electronic module may have limitations in meeting all of these performance ratings due to optimization of the design for a specific application.

C.3 Conventional transformers characteristics and issues that are not applicable in the field testing of optical current sensors

a) Residual magnetism
b) Insulation resistance tests
c) Winding and lead resistance
d) Excitation test

C.4 Field testing of optical current sensor

C.4.1 Attenuation measurement

This is a measurement of light-loss in the optical fiber and the optical sensor portions of the system. Optical sensing systems are typically designed to operate within a specific optical attenuation range. The electronic module may have built-in alarms that will provide notification if the attenuation exceeds the desired level during normal operations. Attenuation level outside of the manufacturer’s specified limits would generally indicate an optical path problem with the system.

Attenuation measurement should be made when the system is received, and also after the installation is completed. The field measurements should be compared to the factory-measured results. The attenuation measurement is relatively simple and does not require expensive equipment. This test can be done using a commercially available optical light source and an optical power meter. The light is injected into the fiber at the electronic module and is measured at the connector of the return fiber.

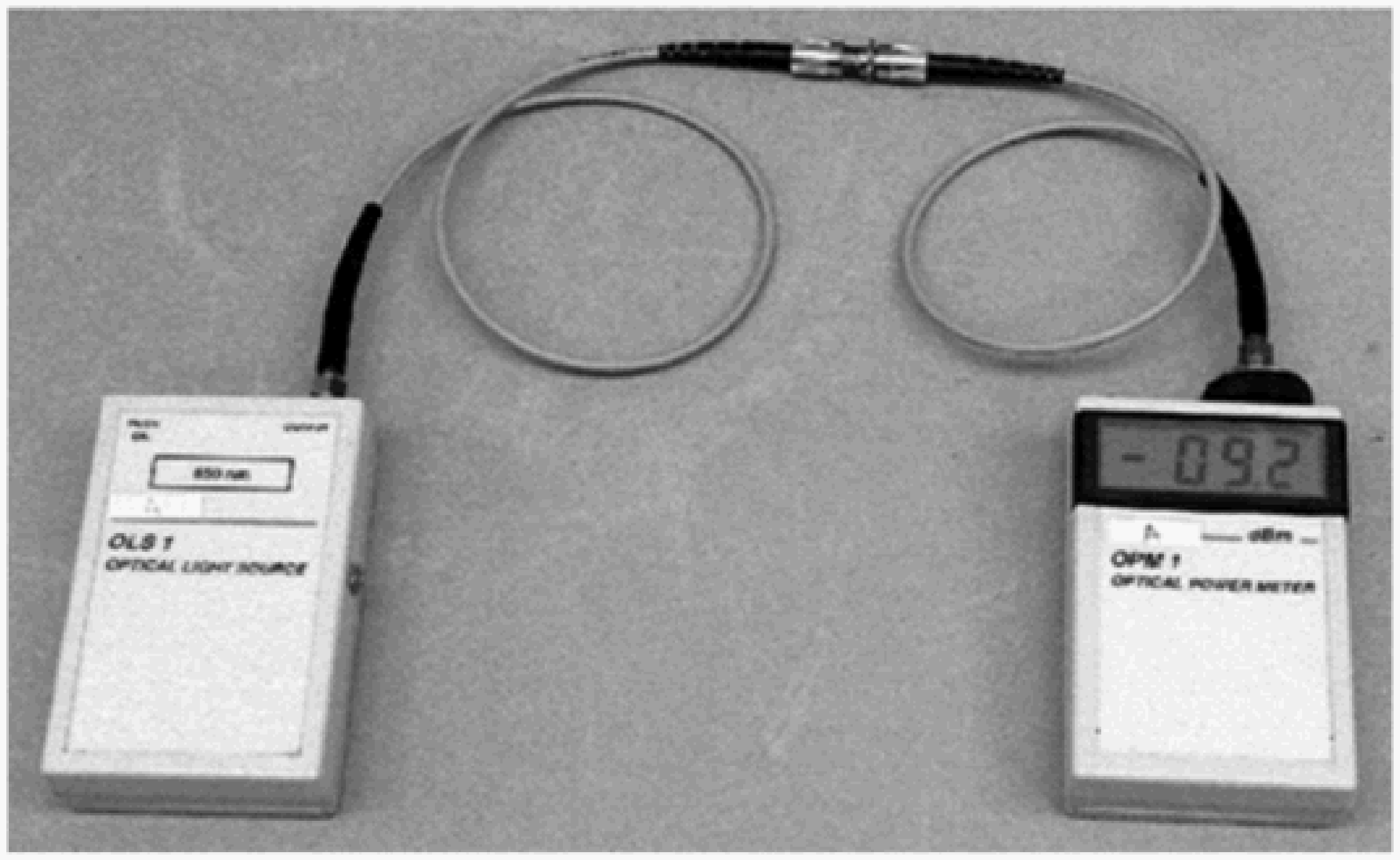


Figure C.1—Optical light source and power meter

Figure C.2—Light source and power meter connected to an optical CT

Annex D

(informative)

Bibliography

Bibliographical references are resources that provide additional or helpful material but do not need to be understood or used to implement this standard. Reference to these resources is made for informational use only.

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[B5] IEEE Std C37.100™-1992, IEEE Standard Definitions for Power Switchgear.

[B6] IEEE Power System Relaying Committee Report, "Relay Performance Testing," Special Publication No. TP 115-0, 1996.

[9]IEC publications are available from the International Electrotechnical Commission (http://www.iec.ch) and theAmerican National Standards Institute (http://www.ansi.org/).
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