PC37.30.4™/D8
Draft Standard for Test Code for Switching and Fault Making Tests for High-Voltage Interrupter Switches, Interrupters or Interrupting Aids Used on or Attached to Switches Rated for High-Voltage AC Above 1000 Volts

Sponsor

<Switchgear> Committee
of the
IEEE <Power and Energy> Society

Approved <XX MONTH 20XX>

IEEE-SA Standards Board

445 Hoes Lane
Piscataway, NJ 08854, USA

Abstract: Test code is specified for switching (except capacitive current) and fault making tests for switching devices for alternating current, rated above 1000 volts and used indoors, outdoors, or in enclosures.

Keywords: Interrupting switches, high voltage switches, indoor switches, outdoor switches

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

PDF: ISBN 978-0-XXXX-XXXX-X STDXXXXX
Print: ISBN 978-0-XXXX-XXXX-X STDPDXXXXX

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading "Important Notice" or "Important Notices and Disclaimers Concerning IEEE Standards Documents."

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association ("IEEE-SA") Standards Board. IEEE ("the Institute") develops its standards through a consensus development process, approved by the American National Standards Institute ("ANSI"), which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied "AS IS" and "WITH ALL FAULTS."

Use of an IEEE standard is wholly voluntary. The existence of an IEEE standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854 USA

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

Photocopies

Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every ten years. When a document is more than ten years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE-SA Website at http://ieeexplore.ieee.org/xpl/standards.jsp or contact IEEE at the address listed previously. For more information about the IEEE-SA or IEEE's standards development process, visit the IEEE-SA Website at http://standards.ieee.org.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: http://standards.ieee.org/findstds/errata/index.html. Users are encouraged to check this URL for errata periodically.

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website at http://standards.ieee.org/about/sasb/patcom/patents.html. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this draft was submitted to the IEEE-SA Standards Board for approval, the C37.30.4 Working Group had the following membership:

<Bill Hurst>, *Chair*
<Pete Meyer>, *Vice Chair*

Frank DeCesaro	Gary Haynes	Pete Kowalic
Glenn Dorsey	Danny Ross	David McMullen
Kenneth Harless	Jim Houston	Carl Reigart
Kyle Stechschulte		
Tom Stefanski		

The following members of the <individual/entity> balloting committee voted on this<opt_trial-use><gde./rec. prac./std.>. Balloters may have voted for approval, disapproval, or abstention.

(to be supplied by IEEE)

Balloter1	Balloter4	Balloter7
Balloter2	Balloter5	Balloter8
Balloter3	Balloter6	Balloter9

When the IEEE-SA Standards Board approved this<opt_trial-use><gde./rec. prac./std.> on <XX MONTH 20XX>, it had the following membership:

(to be supplied by IEEE)

<Name>, *Chair*
<Name>, *Vice Chair*
<Name>, *Past Chair*
<Name>, *Secretary*

SBMember1	SBMember4	SBMember7
SBMember2	SBMember5	SBMember8
SBMember3	SBMember6	SBMember9

*Member Emeritus

Introduction

This introduction is not part of IEEE PC37.30.4 Draft Standard for Test Code for Switching and Fault Making Tests for High-Voltage Interrupter Switches, Interrupters or Interrupting Aids Used on or Attached to Switches Rated for High-Voltage AC Above 1000 Volts.

This standard provides test code for switching (except capacitive current) and fault making tests for switching devices for alternating current, rated above 1000 volts and used indoors, outdoors, or in enclosures.

Evolution of various standards has resulted in the need to split the content of IEEE Std 1247 – 2005 into two new proposed standards, C37.30.3 and C37.30.4. The proposed document C37.30.3 will become the basic standard for High Voltage Interrupter Switches, Interrupters or Interrupting Aids used on or attached to High Voltage Switches. The proposed document C37.30.4 will provide a common test code for equipment described in C37.30.3 and other product standards.

Contents

Contents

Draft Standard for Test Code for Switching and Fault Making Tests for High-Voltage Interrupter Switches, Interrupters or Interrupting Aids Used on or Attached to Switches Rated for High-Voltage AC Above 1000 Volts

NOTE—The editing instructions contained in this **<amendment/corrigendum>** define how to merge the material contained therein into the existing base standard and its amendments to form the comprehensive standard.

The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strikethrough~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this NOTE will not be carried over into future editions because the changes will be incorporated into the base standard.

1. Overview

1.1 Scope

This standard provides the test code for switching (except capacitive current) and fault making tests for high voltage interrupter switches, interrupters or interrupter aids for use on switches rated above 1000 V AC and used indoors, outdoors, or in enclosures for non-fault current interrupting for which an interrupting duty is assigned.

1.2 Purpose

The purpose of this standard is to provide the test code for switching and fault making tests for switching devices not covered by other standards.

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 C2-2002, National Electrical Safety Code (NESC®) [1]

IEEE Std C37.20.2, IEEE Standard For Metal-Clad And Station-Type Cubicle Switchgear (ANSI)

IEEE Std C37.20.3, IEEE Standard For Metal-Enclosed Interrupter Switchgear (ANSI)

IEEE Std C37.20.4, Standard For Indoor AC Medium Voltage Switches For Use In Metal-Enclosed Switchgear

IEEE Std C37.74, IEEE Standard Requirements for Subsurface, Vault, and Padmounted Load-Interrupter Switchgear and Fused Load-Interrupter Switchgear for Alternating Current Systems up to 38 kV.

IEEE Std C37.09-1999, IEEE Standard Test Procedure For AC High-Voltage Circuit Breakers Rated On A Symmetrical Current Basis (ANSI) [2]

IEEE Std C37.41 - 1994, Standard Design Tests For High Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches And Accessories

OSHA Rule 1910.269 - 1994, Electric Power Generation, Transmission, and Distribution: Electrical Protective Equipment [3]

---

[1] 1The NESC is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA

[2] IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

[3]OSHA publications are available from the OSHA Publications Office, U.S. Department of Labor, 200 Constitution Avenue, N.W., Room N3I0I, Washington DC 20210.

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. [4]

Allowable Continuous Current Class (ACCC) Designation (of an Air Switch): A code that identifies the composite curve relating the loadability factor (LF) of the switch to the ambient temperature θA as determined by the limiting switch part class designations.

Arc Reach: The distance from a point midway between the arc extremities to the most remote point of the arc at the time of its maximum length.

Arcing Horn: One of a pair of diverging electrodes on which an arc is extended to the point of extinction after the main contacts of the switching device have parted.

Distribution Class: A descriptive term used to denote application, restriction, or both to that part of an electric system between the substation and the customer.

Enclosed Switch: Switches designated for operation within a housing restricting heat transfer to the external medium.

Horn-Gap Switch: A switch provided with arcing horns.

Indoor Switch: Switches designated for operation inside buildings or weather-resistant enclosures which do not restrict heat transfer to the ambient.

Interrupter Switch: A switching device, designed for making specified currents and breaking specified steady state currents. (HVS, Swg)

Interrupting Aids: A current-interrupting device that can be attached to an air switch to improve its interrupting capability. (eg Quick Break Arcing horns; Vacuum, SF6 and Expulsion interrupters)

Lightning Impulse Dry Withstand Voltage: The crest value of a voltage impulse with a front duration from less than one to a few tens of microseconds that, under specified conditions, can be applied without causing flashover or puncture.

Loadability Factor: The ratio of allowable continuous current at a given ambient temperature to rated current.

Loadability: The ratio of allowable continuous current at 25º C ambient temperature to rated continuous current.

Observable Temperature Rise: The observable temperature rise of any part of the switch is the steady-state temperature rise above ambient temperature.

Outdoor Switch: Switches designated for operation outside buildings or enclosures. Outdoor switches may be exposed to the weather. Outdoor switches experience no restriction of heat transfer to the ambient.

Peak Withstand Current: The maximum instantaneous current at the major peak of an offset power frequency sinusoidal current that a switch is required to carry.

Power Frequency: The frequency at which a device or system is designed to operate.

IEEE Standards Dictionary Online subscription is available at: http://ieeexplore.ieee.org/xpls/dictionary.jsp.

Quick break Arcing Horns: commonly referred to also as a quick break whip – a conductive member mounted such that as the main switch blade opens it remains in contact then releases and quickly creates a large open gap for improved current interruption compared to arcing horns.

Making Current: The value of the available current at the time the device closes. **Short-time (Symmetrical) Withstand Current Duration:** The maximum duration of short-time (symmetrical) withstand current that a switch is required to carry.

Short-time (Symmetrical) Withstand Current: An abnormal power frequency current, the initial portion of which may have a dc offset, expressed in rms symmetrical amperes that a switch is required to carry.

Station Class: A descriptive term used to denote application or restriction or both to generating stations, switching stations, substations and transmission lines.

Switch Part Class Designation: A code that identifies the curve that relates the loadability factor (LF) of a switch part material and function to the ambient temperature θA.

Switch: Within this document, the noun "switch" shall refer to switching devices, interrupters, current interrupting devices, interrupting aids or interrupter switches.

Switching Impulse Withstand Voltage: The crest value of a voltage impulse with a front duration from tens to thousands of microseconds that, under specified conditions, can be applied without causing flashover or puncture.

Visible Corona: A luminous discharge due to ionization of the air surrounding a device, caused by a voltage gradient exceeding a certain critical value.

4. Service conditions

Refer to appropriate product standard.

5. Description of ratings and capabilities

Refer to appropriate product standard.

6. Preferred ratings

Refer to appropriate product standard.

7. Construction requirements

Refer to appropriate product standard.

8. Test Code

8.1 Switching Tests

Switching tests are performed to determine the adequacy of the design of a particular type, style, or model of switch or its component parts to meet its assigned switching abilities.

8.1.1 General

The switching abilities shall be stated in terms of

a) The test voltage

b) The test current

c) The test circuit

d) The number of operations

8.1.1.1 Condition of the switch to be tested

The switch shall be new or in good condition.

8.1.1.2 Mounting of switch

The switch shall be mounted in the usual service position for which it is designed. The base, or other normally grounded metal parts, shall be grounded, except as explained in the last paragraph below.

The interrupting ability of a switch that relies on a rapidly increasing external air gap for circuit interruption (such as whip arcing horns) may be dependent on mounting position. In this case, the mounting arrangement should be recorded to assist in the application of the device.

Due consideration shall be given to the choice of source side connections. When the switch is intended for power supply from both sides and the physical arrangement of one side differs from that of the other side, the live side of the test circuit shall be connected so as to represent the lowest dielectric strength. In case of doubt, some of the operations shall be carried out with the supply connected to one side and the remaining operations with the supply connected to the other side.

If the switch is to be rated for use in enclosures, the tests shall be made in the smallest enclosure for which the switch is intended to be used, OR the tests shall be made with metallic screens placed in the vicinity of the live parts and separated from them by a minimum clearance specified by the manufacturer. The enclosure, or screens, as well as the frame and other normally grounded parts shall be insulated from ground, but connected thereto through a suitable device to indicate current to ground greater than 3 Amps. A fuse consisting of a 5 cm (2 in) long #38 AWG copper wire is one method sufficient to detect current to ground in excess of 3 Amps.

8.1.1.3 Single-phase vs. three-phase testing

Interrupting tests on three-pole, gang-operated switches are preferably made three-phase at rated maximum voltage but may be made single-phase. However, the following standards may require three-phase testing:

- IEEE Std C37.20.2
- IEEE Std C37.20.3
- IEEE Std C37.20.4
- IEEE Std C37.74

Test voltages for single-phase tests to establish a three-phase rating are given in Table 1. Test voltages for single-phase tests to establish a rating "for systems with grounded sources and loads only" shall be computed by the formula:

$$\frac{\text{rated maximum voltage}}{\sqrt{3}}$$

Single-phase testing to establish a three-phase rating performed on an integrally mounted three-pole switch shall be performed with the non-energized poles grounded.

Interrupting tests on single-pole switches (or single-pole switches combined in a three-pole assembly, but operated pole after pole) shall be performed single-phase at rated maximum voltage.

Table 1 —Test voltages for single-phase tests to establish three-phase ratings

Duty	Single-phase test voltage per unit of rated maximum voltage (unless otherwise noted)
Load Switching	$1.5 / \sqrt{3}$
Loop Switching	$1.5 / \sqrt{3}$ per unit of rated loop-switching voltage.
Unloaded Transformer Switching	1.0

8.1.1.4 Operating Mode

Tests shall be performed per the ratings of the device, interrupting, making or switching. Switching can be performed in any sequence. An unspecified time may be allowed to elapse between making the circuit and breaking it. The switch may be allowed an unspecified time to cool between operations.

Switches normally operated manually may be operated by remote control or power operating means, provided that an operating speed provided by the manufacturer is obtained. The operating method and duration of the operating cycle shall be included in the test report.

If the switch is power-operated, the switch operating device shall be operated in the manner specified by the manufacturer. In particular, if the switch is electrically, hydraulically, or pneumatically operated, and if the switch's performance is affected by the operating voltage or fluid pressure, it shall be operated at

- Nominal voltage or fluid pressure for 60% of all operations of each applicable duty
- Minimum voltage or fluid pressure for 20% of all operations of each applicable duty
- Maximum voltage or fluid pressure for 20% of all operations of each applicable duty

8.1.1.5 Frequency

The frequency of the supply voltage shall be defined by the appropriate product standard with a tolerance of +/- 5% of the specified frequency.

8.1.1.6 Test current

The test current shall be as specified in the appropriate product standard. Allowable tolerance shall be -0%, +10%.

8.1.1.7 Power-frequency test voltage

The power-frequency test voltage is the average of the phase-to-phase voltages, and shall be measured in the interval between 1 cycle and 1 1/2 cycle after the final phase arc-extinction.

The test voltage in the case of three-phase tests shall be equal to or greater than the rated maximum voltage of the switch, except for tests with closed loop breaking currents for which the test voltage shall be the rated loop-switching voltage. The individual phase voltages shall not vary more than ±10% of the average value. Test voltages for single-phase tests shall be as specified in the appropriate product standard. The tolerance of the test voltage shall be -0%, +10%.

The rated power-frequency test voltage shall be maintained for at least 0.3 s after arc extinction.

8.1.1.8 Unit testing

Subclause 4.8.2.3 of C37.09 – 1999 is applicable

8.1.1.9 Information to be included in test report.

The results of all type tests shall be recorded in type test reports containing sufficient data to prove compliance with the ratings and the test clauses of the relevant standards and sufficient information shall be included si that the essential parts of the switchgear and controlgear can be identified. In particular, the following information shall be included:

- manufacturer
- type, designation and serial number of the switchgear and controlgear tested
- rated characteristics of switchgear and controlgear tested as specified in the relevant standard
- general description (by manufacturer) of switchgear and controlgear tested, including number of poles
- manufacturer, type, serial numbers and ratings of essential parts, where applicable (for example, operating mechanisms, interrupters, shunt impedances)
- general details of the supporting structure of the switching device or enclosed switchgear of which the switching device is an integral part
- details of the operating mechanism and devices employed during tests, where applicable

- photographs to illustrate the condition of the switchgear and controlgear before and after test
- sufficient outline drawings and data schedules to represent the switchgear and controlgear tested
- reference numbers of all drawings including revision number submitted to identify the essential parts of the switchgear and controlgear tested
- details of the testing arrangements (including diagram of test circuit)
- statements of the behavior of the switchgear and controlgear during tests, its condition after tests and any parts renewed or reconditioned during the tests
- records of the test quantities during each test or test duty, as specified in the relevant standard

Note NSDDs may occur during the recovery voltage period following a breaking operation. Their number is of no significance to interpreting the performance of the device under test. They should only be reported in the test report to differentiate them from restrikes.

8.1.2 Test duties

8.1.2.1 Load-switching tests

Making and breaking operations shall be randomly timed. For three-phase, group-operated switches, the tests shall be made at the rated maximum voltage of the switch on a three-phase circuit with a parallel-connected load having a power factor between 1.0 and 0.7 lagging (except as noted in next paragraph), using one of the circuits shown in Figure 1. For single-phase or three-phase non-gang-operated switches, the test shall be made at the voltage given in Table 1 on a single-phase circuit with a parallel-connected load having a power factor between 1.0 and 0.7 lagging (except as noted in next paragraph), using the circuit shown in Figure 2.

Testing at lower power factors is allowed if the resulting transient recovery voltage (TRV) is more severe than that specified. (See Annex A.)

For rated current tests, the test current shall be the rated current –0, +10%. For lower than rated current tests, the source impedance (Zs) and TRV setting components shall be the same as for the 100% load tests. For lower than rated current tests, a tolerance of ±10% is allowed on the test current.

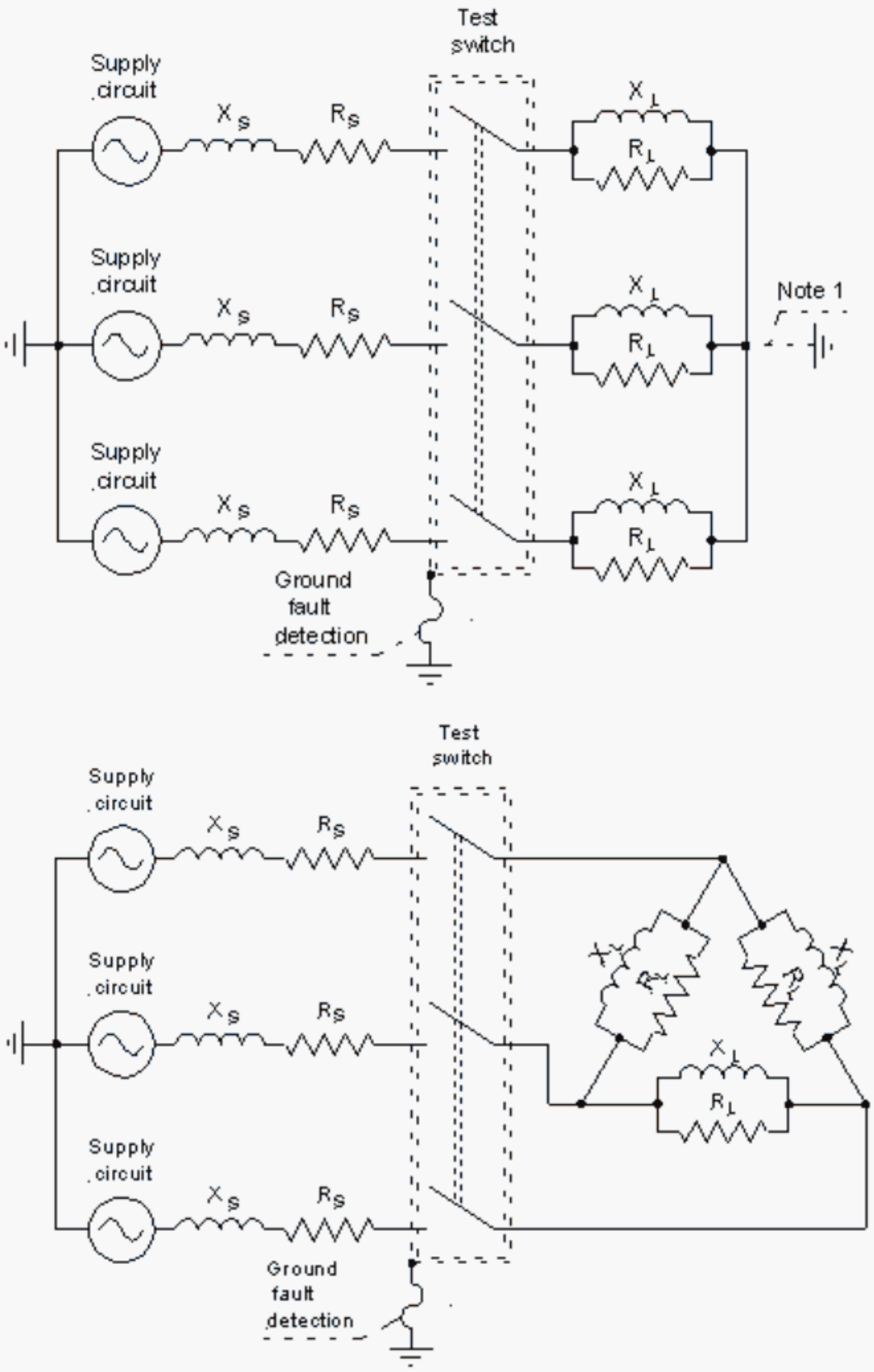


Figure 1. Three-phase alternate test circuits for load current switching.

Notes to Figure 1.

1. Either the neutral of the load ***or*** the neutral of the source may be grounded but ***not*** both.

2. ZS = 10% to 20% $\frac{\textit{Rated maximum voltage}}{\sqrt{3}\,\textit{Rated switching current}}$

3. $\frac{X_S}{R_S}$ = 5 to 7

4. Load power factor $PF_L \geq 0.7$ i.e. $\frac{X_L}{R_L} \geq 0.98$

5. Once calculated and set for 100% load switching test series, Z_S remains the same for the reduced load-switching current test.

6. TRV: per Figure 3 and Table 2.

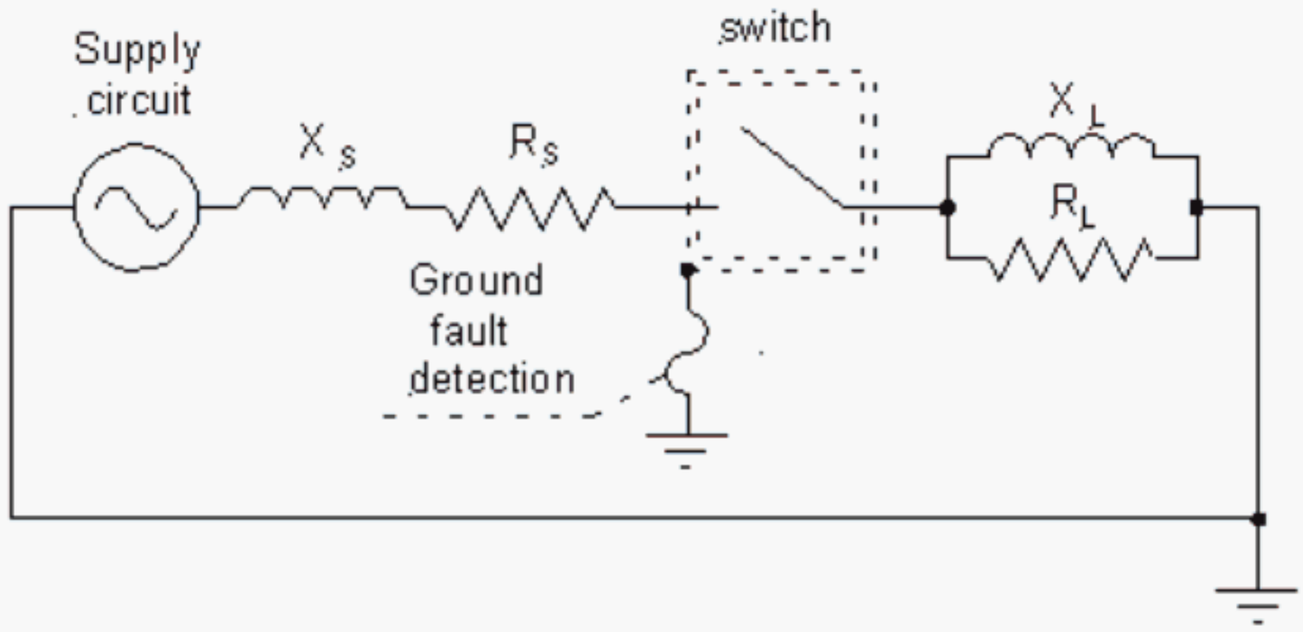


Figure 2. Single-phase load current switching test circuit.

Notes to Figure 2.

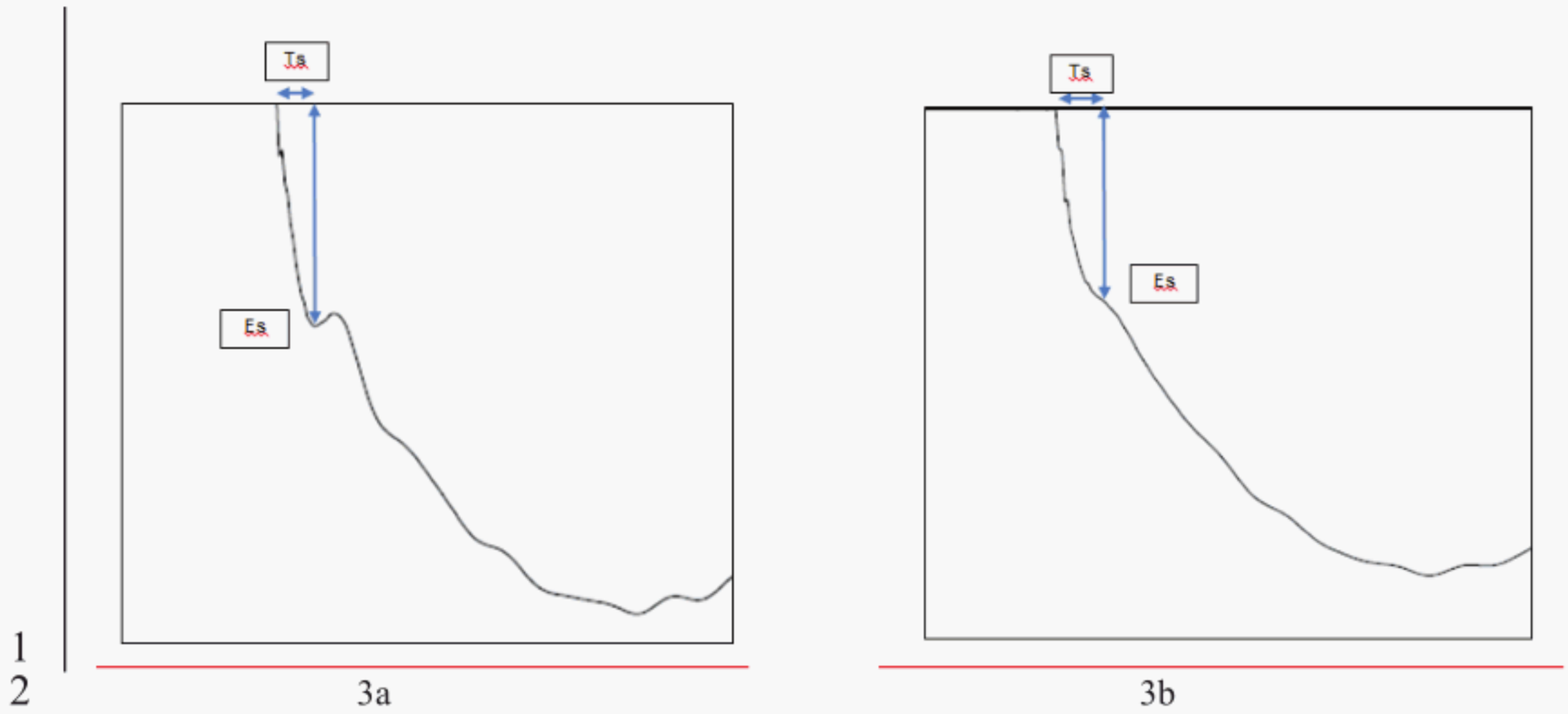
1. Z_S = 10% to 20% $\frac{Rated\ maximum\ voltage}{\sqrt{3}\ Rated\ switching\ current}$

2. $\frac{X_S}{R_S}$ = 5 to 7

3. Load power factor $PF_L \geq 0.7$ i.e. $\frac{X_L}{R_L} \geq 0.98$

4. Once calculated and set for 100% load switching test series, Z_S remains the same for the reduced load-switching current test.

5. TRV: per Figure 3 and Table 2.



3 - **Figure 3—Inherent total TRV for rated load-switching current tests**

4 If the prospective TRV wave shape does not provide the distinctive oscillation shown in Figure 3a, the
5 inherent total TRV defined in Table 2 is satisfied if the voltage value obtained at time TS is equal to or
6 greater than the value provided in Table 2 for a specified rated maximum voltage as shown in Figure 3b.

7 Table 2 —Inherent total TRV parameters for rated load-switching current test

8

Rated maximum voltage (kV)	**Minimum peak TRV E_s (kV)[1, 3, 4]**	**Maximum time-to-peak T_s (μs)[2, 4]**
4.8	1.04	75
8.25	1.9	110
15.0	3.9	175
15.5	4.0	180
25.8	7.2	280
27	7.6	290
38	13	310
48.3	18	550
72.5	15	33
121	25	47
145	30	52
169	35	59
242	34	77
362	50	95
550	76	115
800	110	135

9

10

Conditions applicable to Table 2 are shown below:

- 1. E_S values for distribution voltages (up to 48.3 kV) are based on: 10% source, 1.5 amplitude factor, and a 1.5 phase factor.

- 2. Time-to-peak values are based on the load-side TRV and source TRV frequencies from IEEE Std C37.41-1994 [B3], Table 3, which are indicative of substation TRV's with the system highly interconnected (note breaker TRV frequencies are based on a last device to clear and represented station TRV's with the system under normal conditions).

- 3. For transmission voltages (greater than 48.3 kV), the TRV parameters are based on IEC 60265-2 (1988-03) [B4], modified to yield time-to-peak values rather than the IEC T3 values.

- 4. Interpolation for other rated voltages is permitted.

If the prospective TRV wave shape does not provide the distinctive oscillation shown in Figure 3, the inherent total TRV defined in Table 2 is satisfied if the voltage value obtained at time TS is equal to or greater than the value of ES provided in Table 2 for a specific rated maximum voltage.

8.1.2.2 Loop-switching Tests

The switch shall be capable of making and interrupting all loop currents up to and including its rated loop-switching current. Making and breaking operations shall be randomly timed. For three-phase gang-operated switches, the tests shall be made at rated loop-switching voltage (refer to appropriate apparatus standard) of the switch on a three-phase circuit with a lagging power factor of less than 20%, using the circuit shown in Figure 4. For single-phase or three- phase non-gang-operated switches, the test shall be made at rated loop-switching voltage of the switch on a single-phase circuit with a lagging power factor of less than 30%, using the circuit shown in Figure 5.

Testing with a load-switching circuit (Figure 1 or Figure 2) that utilizes a 20% $\pm$2% source impedance may be substituted for the loop-switching test.

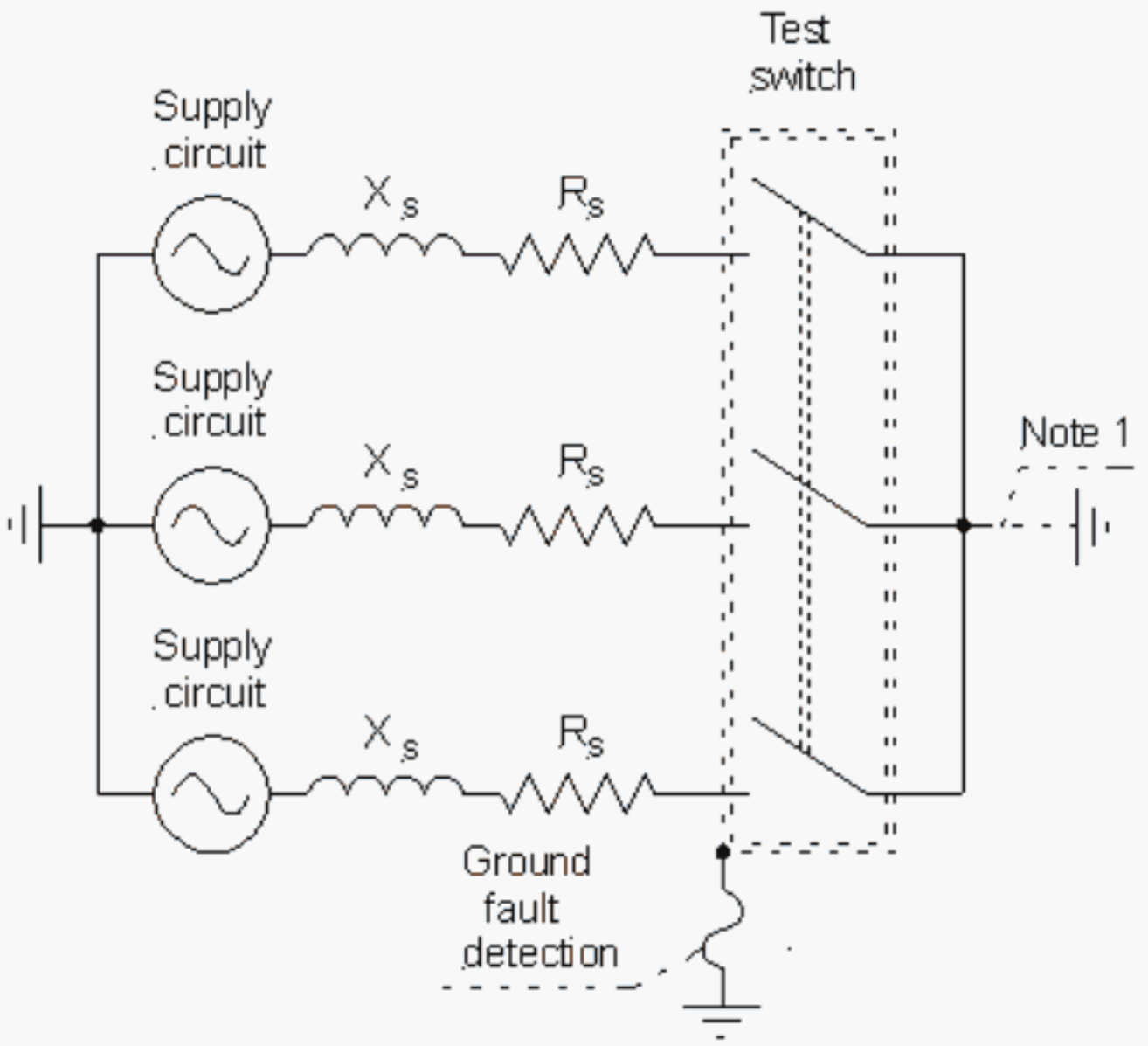


Figure 4. Three-phase loop current switching test circuit.

Notes to Figure 4.

1. Either the neutral of the load ***or*** the neutral of the source may be grounded but ***not*** both.

2. Power Factor PF ≤ 0.2 i.e. $\frac{X_S}{R_S} \geq 4.9$

3. TRV: per Figure 6 and Table 3.

4. Part or all of the source impedance, R_S and X_S may appear on either side of the switch

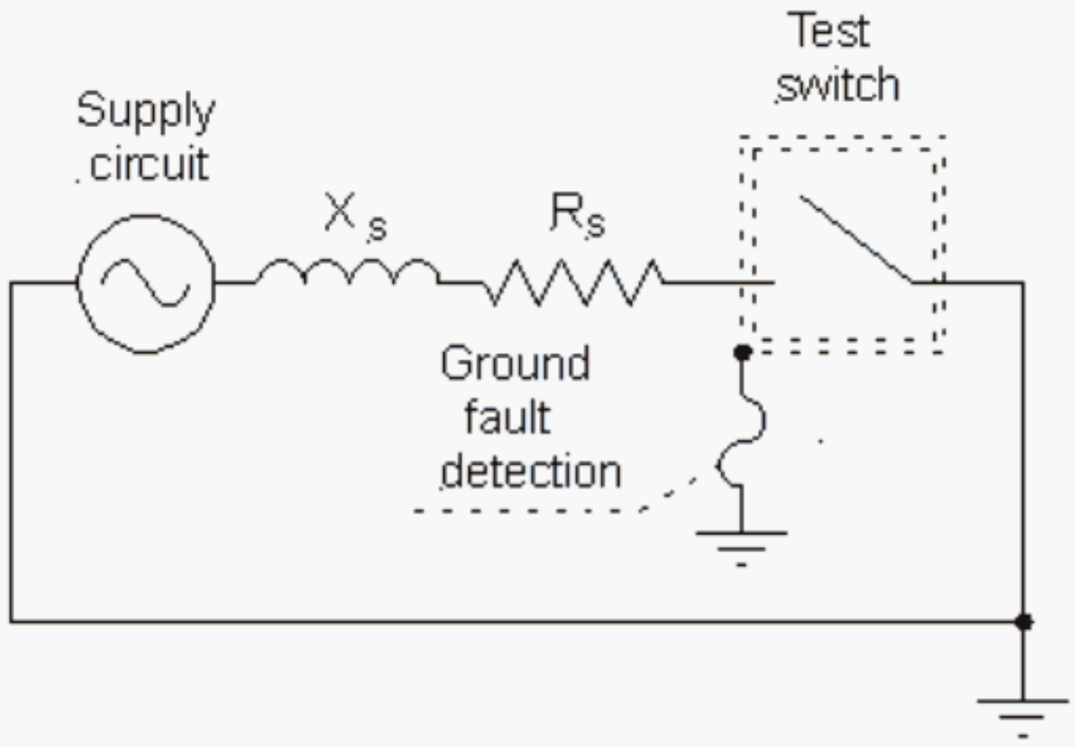


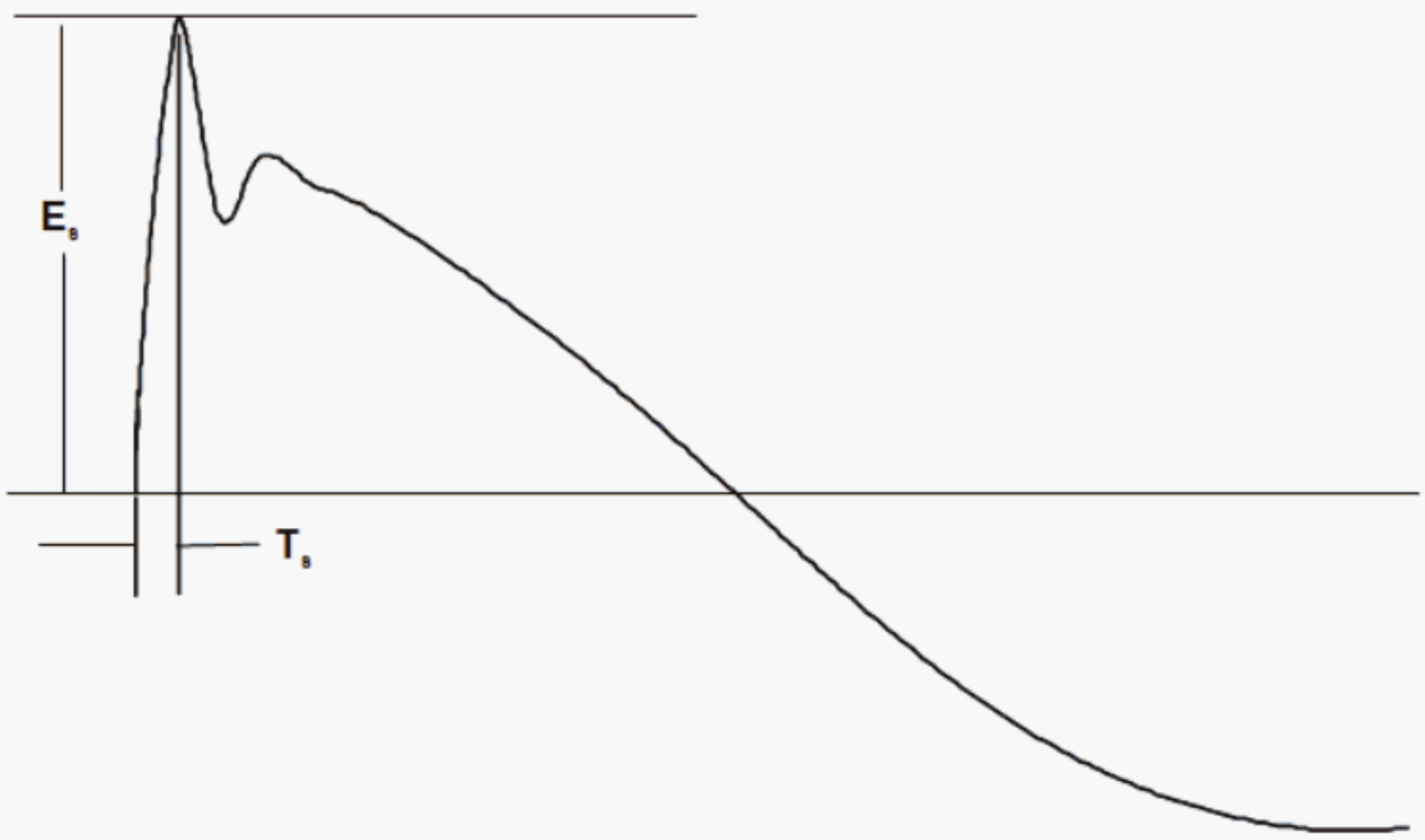
Figure 5. Single-phase loop current switching test circuit.

Notes to Figures 5.

1. Power Factor PF ≤ 0.2 i.e. $\frac{X_S}{R_S} \geq 4.9$

2. TRV: per Figure 6 and Table 3.

3. Part or all of the source impedance, R_S and X_S may appear on either side of the switch



Note – E_S and T_S per Table 3 or 4

Figure 6 —Loop-switching TRV first pole to open

8.1.2.2.1 Line or cable loop-switching

For the line or cable loop-switching test, the transient recovery voltage shall be equal to or greater than that specified in Table 3.

Note: This is a load current switching requirement and not to be considered as capacitor switching.

Table 3—TRV parameters for line or cable loop-switching

Rated voltage (kV)[3]	Minimum peak TRV,	Maximum time-to-peak, T_s
4.76	1.7	120
8.25	2.9	150
15.0	5.1	211
15.5	5.3	215
25.8	8.9	285
27	9.3	295
38	13	335
48.3	17	370
Rated voltage (kV)	**Minimum peak TRV, E_s (kV)**	**Minimum time-to-peak factor, K [9] [1]**
72.5	29	0.267
121	48	0.267
145	57	0.267
169	66	0.267
242	95	0.267
362	107	0.205
550	165	0.205
800	240	0.205

Conditions applicable to Table 3 are shown below:

- 1. E_S values for distribution voltages are based on 20% recovery voltage, a 1.4 amplitude factor, and 1.5 phase factor.
- 2. The time-to-peak values are based on TRV frequencies IEEE Std C37.41-1994 [B3], Table 6 and are representative of TRV's on distribution systems, away from substations.
- 3. Values for transmission voltages are based on IEC 60265-2 (1988-03) [B4], modified to yield time-to-peak values rather than the IEC T3 values.
- 4. Interpolation for other rated voltages is permitted.

[9] $T_S = E_s / (K_1 \times I)$

8.1.2.2.2 Parallel transformer loop-switching

For the parallel transformer loop-switching test, the transient recovery voltage peak shall be equal to or greater than that specified in Table 4 and the time to peak shall be less than or equal to that specified in Table 4.

Table 4—TRV parameters for parallel transformer loop-switching

Rated voltage (kV)	Minimum peak TRV,	Maximum time-to-peak
4.76	0.8	0.27
8.25	1.3	0.35
15.0	2.3	0.48
15.5	2.4	0.49
25.8	4.0	0.62
27	4.2	0.64
38	5.9	0.76
48.3	7.5	0.87
Rated voltage (kV)	**Minimum peak TRV,**	**Maximum time-to-peak**
72.5	11.5	1.05
121	19	1.35
145	23	1.48
169	27	1.60
242	26	1.91
362	38	2.34
550	58	2.88
800	84	3.48

Conditions applicable to Table 4 are shown below:

- 1. E_S values are based on a 1.7 amplitude factor, a 1.5 phase factor for non-grounded systems below 242 kV or a 1.0 phase factor for systems with grounded sources and loads at or above 242 kV; and a transformer impedance of 15% bassed on its forced cooling rating.

- 2. Time-to-peak factor is based on TRV frequencies obtained by low voltage current-injection of transformers (see Harner, Rodriguez [B1]).

- 4. Interpolation for other rated voltages is permitted.

[10] $T_S = K_2 \times \sqrt{(1480+1187 \times I)} / (13.3 \times I)$

[11] $T_S = K_3 \times \sqrt{(1650+2240 \times I)} / (13.3 \times I)$

8.1.2.3 Unloaded transformer switching tests

It is assumed that a switch that has passed the required load-switching tests will also interrupt unloaded transformer magnetizing currents corresponding to a distribution transformer, rated 38 kV or less and also rated 2500 kVA or less; therefore, no tests are specified.

Because of the variety of transformers and associated circuits, it is not possible to define a rated no-load transformer breaking current. Due to the non-linearity of the transformer magnetizing current core, it is not possible to correctly model the switching of transformer magnetizing current using linear components in a test laboratory. Tests conducted using an available transformer will only be valid for the tested transformer and cannot be representative of other transformers. If a special test is necessary, test circuits and test procedures have to be agreed between customer and manufacturer.

8.1.3 Condition of the switch during the switching tests

During operation, the switch shall neither show signs of excessive distress nor endanger the operator.

There shall be no outward emission of flame from liquid-filled switches and the gases produced together with the liquid carried with the gases shall be allowed to escape in such a way as not to cause electrical breakdown.

For other types of switches, flame or metallic particles that might impair the insulation level of the switch shall not be projected beyond the boundaries specified by the manufacturer.

There shall be no indication of current greater than 3 Amps to the grounded structure, or screens when fitted, during the tests.

8.1.4 Condition of the switch after the switching tests

The switch shall meet the conditions outlined in 8.6.

8.2 Fault-making current test

Fault-making current tests are performed to confirm the ability of the switch to close and carry short-time withstand current driven by a voltage up to its rated maximum voltage.

8.2.1 General

The fault-making current ability of a switch shall be stated in terms of the following:

- The test voltage
- The peak value of the fault-making current
- Speed of operation
- The rms value of the ac component of the fault-making current
- The fault-making current duration
- The number of fault making operations

8.2.2 Test conditions

The switch shall be mounted in the usual service position for which it is designed. The base, or other normally grounded metal parts, shall be grounded, except as explained for switch to be rated for use in enclosures (see 5th paragraph of this section). The switch shall be operated in the manner specified and in particular, if it is electrically, hydraulically, or pneumatically operated, operations shall be made at minimum voltage or fluid pressure and at maximum voltage or fluid pressure.

Switches with manual operation may be operated by remote control or power operating means, provided that the operating speed within 10% to that of the manual operator is obtained at contact make.

Due consideration shall be given to the choice of source side connections. When the switch is intended for power supply from both sides and the physical arrangement of one side differs from that of the other side, the live side of the test circuit shall be connected to the side that represents the most onerous conditions. In case of doubt, some of the operations shall be carried out with supply connected to one side and the remaining operations with the supply connected to the other side.

Fault-making current tests may be made three-phase (unless otherwise specified) or single-phase. Fault-making current tests on three-pole switches, where the pole-to-pole electromagnetic forces are expected to challenge the mechanical strength of the switch supports , and the poles of which are operated simultaneously, shall be made three-phase. The preferred test circuits are shown in Figures 7a and 7b.

If the switch is to be rated for use in enclosures, the tests shall be made in the smallest enclosure for which the switch is intended to be used, or the tests shall be made with metallic screens placed in the vicinity of the live parts and separated from them by a minimum clearance specified by the manufacturer. The enclosure, or screens, as well as the frame and other normally grounded parts, shall be insulated from ground but connected thereto through a suitable device to indicate any significant current to ground. A fuse consisting of a 5 cm (2 in) long #38 AWG copper wire is one method sufficient to detect significant current to ground.

8.2.3 Conditioning of the test sample

The switch shall be conditioned prior to performing the fault-making current test. This shall consist of

10 close/open operations of the switching duty for which the switch has the highest rated current as outlined in 8.1, or the switch may be subjected to the total test sequence as outlined in 8.1.2.

If it is evident or if it can be proven that the fault-making current is not influenced by conditioning, for testing convenience, the fault-making current test may be made on a new switch of the same type.

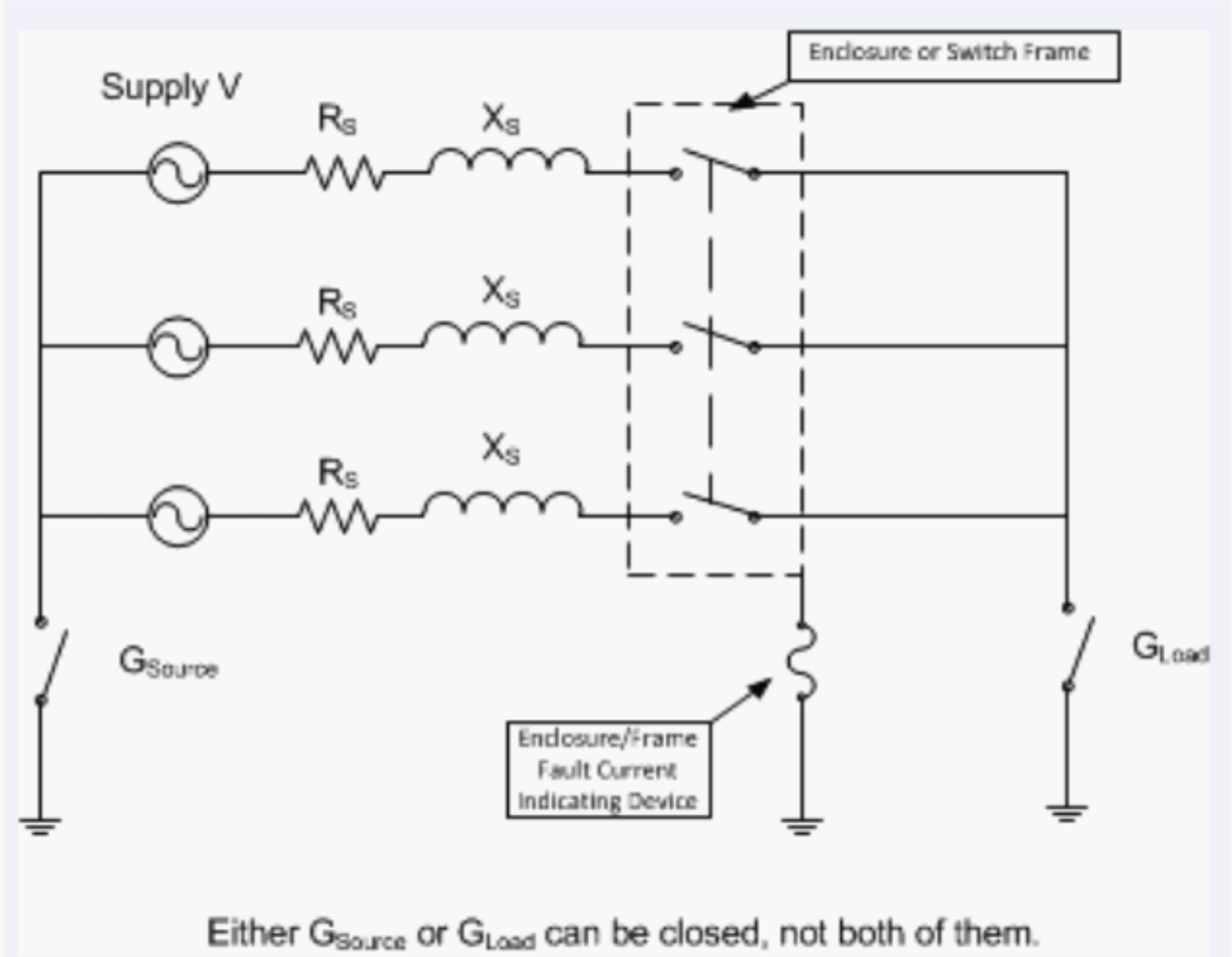
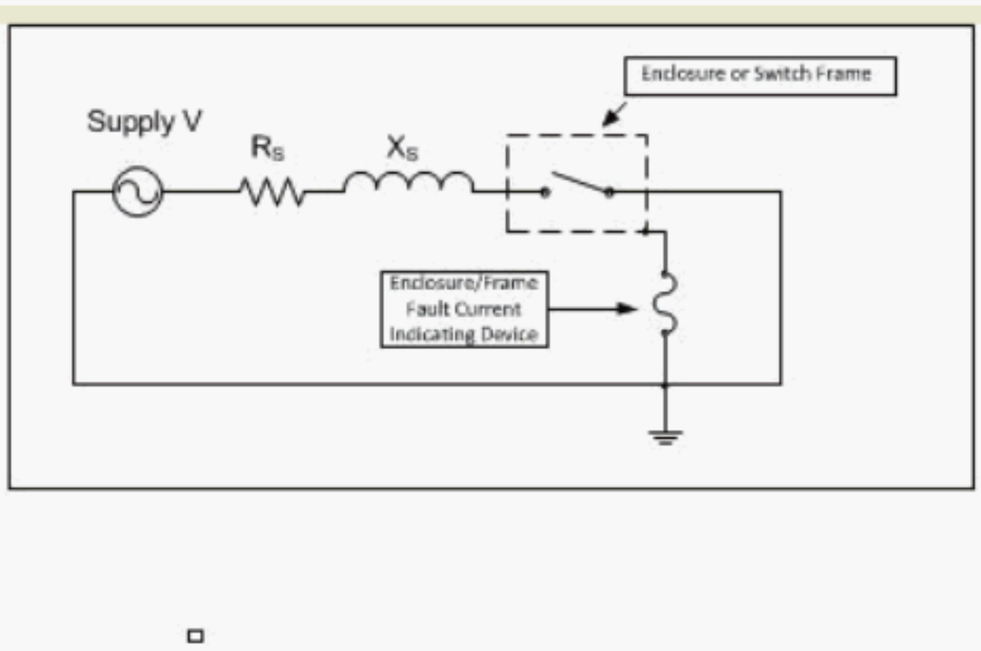


Figure 7a. Three-phase test circuit for fault-making current tests.



NOTE 1: Either the neutral of the load ***or*** the neutral of the source may be grounded but ***not*** both

Figure 7b. Single-phase test circuit for fault-making current tests.

8.2.4 Test procedure

8.2.4.1 Frequency

The frequency of the applied voltage shall be the rated power frequency of switch being tested with a tolerance of ±2%.

8.2.4.2 Applied voltage for fault-making current test

The applied voltage for the fault-making current test is the rms value of the rated maximum voltage immediately before current flow.

In the case of three-phase tests, the average value of the applied voltages shall not be less than the rated voltage and shall not exceed this value by more than 10%.

The difference between the average value and the applied voltages of each phase shall not exceed 5% of the average value.

For single-phase or three-phase non-gang-operated switches, the applied test voltage shall not be less than the rated voltage of the switch.

8.2.4.3 Current magnitude

The peak fault-making current shall be no less than 2.6 times the rated rms symmetrical fault-making current. When testing a three-pole device with a single-phase circuit, the return current path shall be positioned such that forces equivalent to those produced with a three-phase circuit are generated in an outside pole.

8.2.4.4 Degree of asymmetry

For three-phase testing, at least one phase shall have peak current of the first major current loop equal to 2.6 times the rated rms symmetrical fault-making current, except as noted below. For single-phase or three-phase non-gang-operated switches, the tests shall be repeated o until at least one phase experiences a peak current of the first major current loop equal to 2.6 times the rated rms symmetrical fault- making current, except as noted below.

Due to pre-arcing it is not always possible to reach the peak current value; in this case, the current shall be considered satisfactory if the prospective peak current of the test circuit is equal to or greater than 2.6 times the rated rms symmetrical fault-making current.

8.2.4.5 Duration of current flow

The duration of the current flow shall be no less than 10 cycles.

8.2.5 Condition of the switch after the fault-making current test

During the test, the switch shall have functioned without failure and without maintenance or replacement of parts.

After performing the specified making test duties, arcing contacts or any other specified renewable parts may be worn. The quality of the oil, used for arc extinction in oil switches, may be impaired and its quantity reduced from the normal level. There may be deposits on insulators caused by the decomposition of the arc extinguishing medium.

The switch shall be capable of operating normally, carrying its rated continuous current without experiencing a thermal runaway. Unless the current tests have consumed the switch's life, as defined by the switch manufacturer, the switch shall be capable of performing its rated switching duties. The switch shall be capable of withstanding 80% of the power- frequency dry withstand voltage for one minute. Visual inspection and no- load operation of the used switch after tests are usually sufficient for checking these

requirements. For switches having contact structures not readily visible, a no-load open-close operation should be performed followed by a contact resistance check to determine the switch's current carrying ability, with a direct current of at least 100 amperes. The value of contact resistance shall be less than 200% of that before the test.

If the switch has not passed the resistance test:

- A continuous current test with no thermal runaway shall be performed at rated current. Thermal runaway means that the temperature does not stabilize and continues to increase as a trend.

- A rated power-frequency dry withstand voltage test shall be performed in the open position by applying 80% of the rated power-frequency dry withstand voltage to each terminal with all other terminals grounded.

There shall be no indication of current greater than 3 Amps to the grounded structure, or screens when fitted, during the tests.

Annex A

(informative)

Load-switching TRV

The Electromagnetic Transient Program (EMTP) study illustrates the effect that the power factor of a load has on the TRV associated with load-switching. The study is based on the TRV parameters for 27 kV load-switching, but the trend thus illustrated is applicable to all voltage classes. The TRVs shown below were generated utilizing the EMTP to model the circuit of Figure A.1 utilizing parameters in Table A.1.

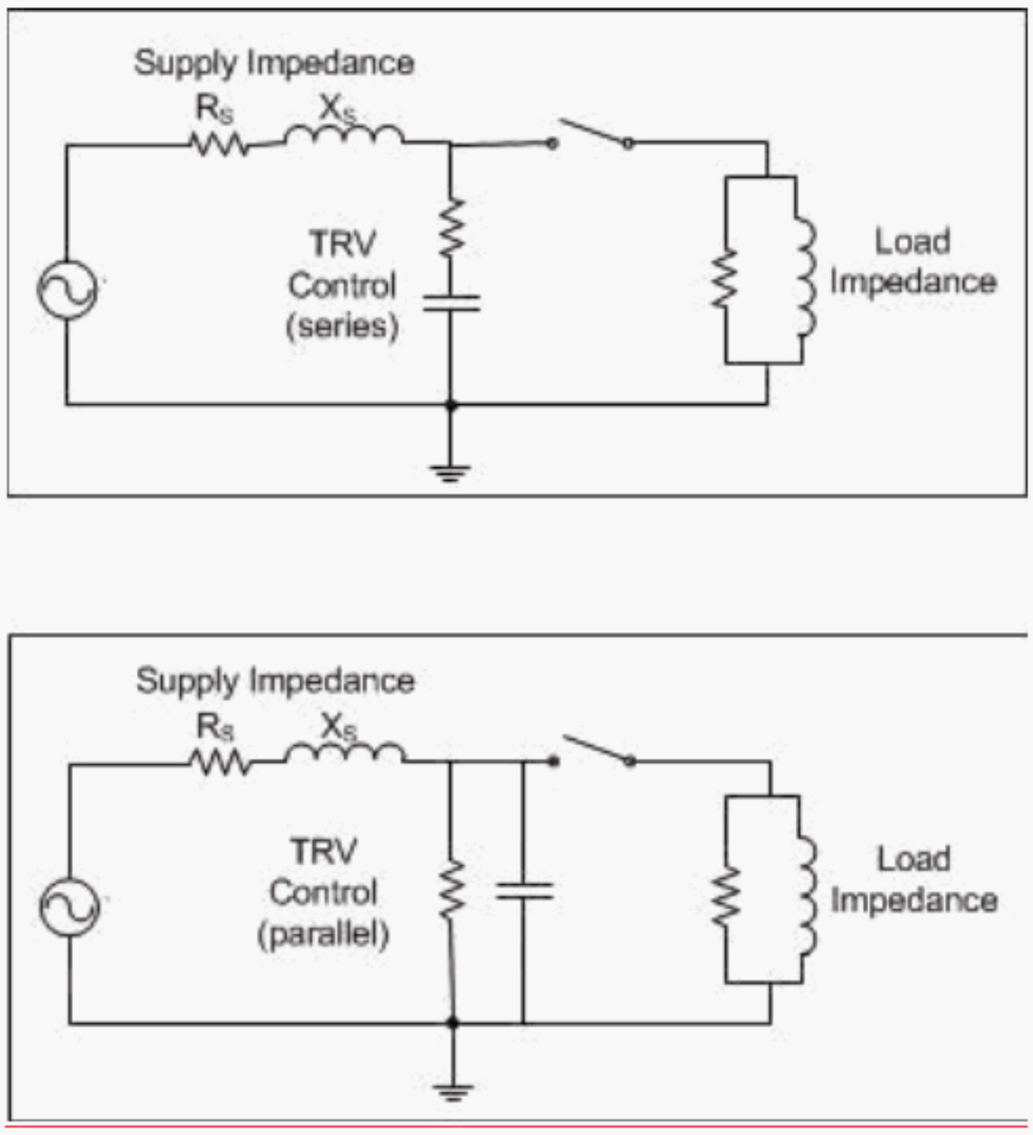


Figure A.1—Circuit diagram used for switching simulation

The TRVs generated by the EMTP program are shown in Figure A.2. Note that the initial portion of the TRV is virtually the same for power factors between 1.0 and 0.8. The initial recovery peak is substantially higher for unity power factor, making it the most severe TRV of the lot.

Table A.1—Values used to compute EMTP circuit elements[12]

Load power factor	Source	Load	TRV resistor	TRV capacitor
Unity	0.00583 + j 0.0991	0.991	8.53	–j 136.4
97% lag	0.00569 + j 0.0968	0.939 + j 0.235	8.33	–j 133.2
92% lag	0.00561 + j 0.0954	0.878 + j 0.374	8.216	–j 131.4
80% lag	0.00551 + j 0.0937	0.749 + j 0.562	8.06	–j 128.9

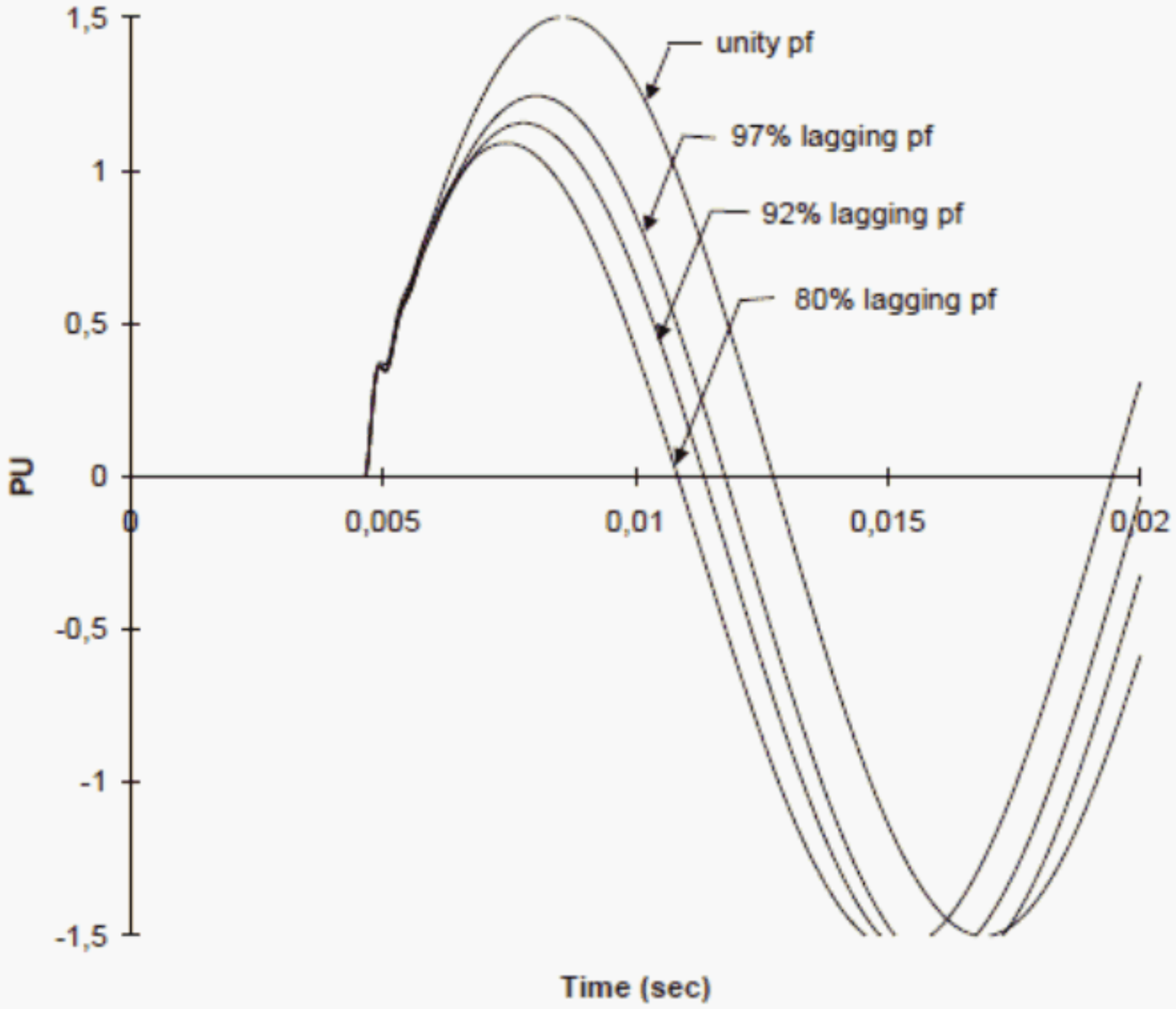


Figure A.2 – Switch recovery voltage for various load power factors

Annex B

(informative)

Test Code Comparison 1247 vs C37.30.4/D8

IEEE 1247	C37.30.4/D8
8.1 Withstand voltage tests	Not included in C37.30.4 (Included in C37.30.1)
8.2 Continuous current tests	Not included in C37.30.4 (Included in C37.30.1)
8.3 Switching tests	8.1 Switching tests included
8.3.1 General	8.1.1 General included
8.3.1.1 – 8.3.1.7	8.1.1.1 – 8.1.1.7 Included
8.3.1.8 Test sequence (including Table 5)	Not included (moved to C37.30.3)
8.3.1.9 Unit testing	8.1.1.8 Unit testing included (simplify to C37.09)
8.3.2 Test duties	8.1.2 Test Duties included
8.3.2.1 Load-switching tests	8.1.2.1 Load-switching tests included
8.3.2.2 Loop-switching tests	8.1.2.2 Loop-switching tests included
8.3.2.2.1 Line or cable loop-switching	8.1.2.2.1 Line or cable loop-switching included
8.3.2.2.2 Parallel transformer loop-switching	8.1.2.2.2 Parallel transformer loop-switching included
8.3.2.3 Cable-charging switching tests	Not included in C37.30.4 (Included in C37.100.2)
8.3.2.4 Line-charging switching tests	Not included in C37.30.4 (Included in C37.100.2)
8.3.2.5 Unloaded transformer switching tests	8.1.2.3 Unloaded transformer switching tests included
8.3.2.6 Shunt capacitor switching tests	Not included in C37.30.4 (Included in C37.100.2)
8.3.3 Condition of the switch during switching tests	8.1.3 Condition of the switch during switching tests included
8.3.4 Condition of the switch after the switching tests	8.1.4 Condition of the switch after the switching tests included
8.4 Short time withstand current tests	Not included in C37.30.4 (Included in C37.30.1)
8.5 Fault-making current tests	8.2 Fault-making current tests included
8.6 Condition of the switch after each test of 8.3, 8.4 and 8.5	8.2.5 Condition of the switch after fault-making tests
8.7 Ice loading test	Not included in C37.30.4 (Included in C37.30.1)
8.8 Mechanical operations tests	Not included in C37.30.4 (Included in C37.30.1)
8.9 Corona tests	Not included in C37.30.4 (Included in C37.30.1)
8.10 Radio-influence voltage tests	Not included in C37.30.4 (Included in C37.30.1)
8.11 Partial discharge test	Not included in C37.30.4 (Included in C37.30.1)
8.12 Production tests	Not included
Annex A – Altitude correction factors	Not included
Annex B – Load-switching TRV	Included as Annex A – Load-switching TRV included
Annex C – Restrike-free performance	Not included
Annex D – Capacitive current switching	Not included

Bibliography

[B1] Harner, R. H. and Rodriguez, J., "TRVs Associated with Power System, Three-Phase Secondary Faults", T-PAS, pp. 1887-1896, Sept/Oct 1972.

[B2] IEC 265-2 (1988-03), High-voltage switches. Part 2: High-voltage switches for rated voltages of 52 kV and above.

[B3] IEEE Std C37.41-1994, IEEE Standard Design Tests for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches and Accessories.