



IEEE Standard for Relays, Relay Systems, and Control Devices used for Protection and Control of Electric Power Apparatus—Surge Withstand Capability (SWC) and Electrical Fast Transient (EFT) Requirements and Tests

IEEE Power and Energy Society

Developed by the
Power System Relaying and Control Committee

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Power System Relaying and Control Committee
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Approved 26 September 2024

IEEE SA Standards Board

Abstract: Design tests for relays, relay systems, and control devices used for protection and control of electric power apparatus that relate to the immunity of this equipment to repetitive electrical transients are specified in this standard. Two types of tests are specified: the slow damped oscillatory test, and the electrical fast transient (EFT) burst test. For devices with communication ports, where the device does not perform protection or control functions, testing of the communication functions is covered by IEEE Std 1613™. Where the device performs protection or control functions and has communication ports, tests for all communication functions are covered by this document. For devices without communication ports, the tests are covered by this document.

Keywords: IEEE C37.90.1™, switching (surge), transient

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The following members of the individual Standards Association balloting group voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

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Introduction

This introduction is not part of IEEE Std C37.90.1-2024, IEEE Standard for Relays, Relay Systems, and Control Devices used for Protection and Control of Electric Power Apparatus—Surge Withstand Capability (SWC) and Electrical Fast Transient (EFT) Requirements and Tests.

This revision is an update of IEEE Std C37.90.1™ and has been further developed and modified with the participation of both the Power System Relaying and Control Committee and also the Electromagnetic Compatibility Society of the IEEE. Major revisions include removal of some out-of-date examples and an additional test frequency, 100 kHz, for the electrical fast transient test.

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IEEE Standard for Relays, Relay Systems, and Control Devices used for Protection and Control of Electric Power Apparatus—Surge Withstand Capability (SWC) and Electrical Fast Transient (EFT) Requirements and Tests

1. Overview

1.1 Scope

This standard specifies design tests for relays, relay systems, and control devices used for the protection and control of electric power apparatus that relate to the immunity of this equipment to repetitive electrical transients. Two types of tests are specified: the oscillatory (SWC) and electrical fast transient (EFT) tests.

For devices with communication ports, where the device does not perform protection or control functions, testing of the communication functions is covered by IEEE Std 1613™ [B8].⁶ Where the device performs protection or control functions and has communication ports, tests for all communication functions are covered by this document. For devices without communication ports, the tests are covered by this document.

1.2 Purpose

This standard establishes a common and reproducible basis for evaluating the performance of relays, relay systems, and control devices used for protection and control of electric power apparatus, when subjected to repetitive transients on supply, signal, control, and communication lines or connections. This standard establishes that an evaluation is performed during both normal (non-tripped) and abnormal (tripped) relay operating conditions.

⁶The numbers in brackets correspond to those of the bibliography in Annex A.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{7,8}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

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.

IEEE Std C37.90TM-2005, IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus.^{9,10}

3. Definitions, acronyms, and abbreviations

3.1 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.¹¹

calibration: The adjustment of a device to have the designed operating characteristics, and the subsequent marking of the positions of the adjusting means, or the making of adjustments necessary to bring operating characteristics into substantial agreement with standardized scales or marking.

common- (longitudinal-) mode voltage: The voltage common to all conductors of a group as measured between that group at a given location and an arbitrary reference (usually earth).

communications interface equipment: A portion of a relay system that transmits or receives information from a communications system, e.g., audio tone equipment or carrier transmitter-receiver, included as an integral part of the relay system.

communications system: Any system which transfers protection or other data to or from the relay interface to or from another location.

⁷The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁸The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

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¹¹*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

current circuit: An input circuit to which a current of greater than or equal to 100mA is applied, which is a measure of primary current.

digital data circuit: Any circuit that transfers data in a digitally encoded form that is essential for the proper operation of the relay system.

input circuit: Circuits with the primary intended function of sensing logical state data, such as circuit breaker position or interlocking commands between relays.

measuring unit: Any analog or digital device that analyzes input currents, voltages, or both to produce an output to the relay logic.

normal tolerance: Accuracy of the equipment, specified by the manufacturer as a numeric or percentage “plus or minus” variation. Tolerances may be general or specific to a given application.

output circuit: A circuit from a relay system that exercises direct or indirect control of power apparatus, such as tripping or closing of a power circuit breaker. Outputs convey the state of the equipment under test. They may include electrical outputs such as contacts or trip pulses, mechanical outputs such as targets, visual outputs such as indicating lights or light emitting diodes (LEDs), audio outputs such as bells or buzzers, message outputs in digital or analog form, protective communication signals, and data communication signals in analog or digital form.

power supply circuit: An input circuit to a relay system that supplies power for the functioning of the relay system.

relay interface equipment: An assembly that connects a relay system to other equipment, i.e., carrier equipment or instrument transformers. This assembly does not need to be located in the vicinity of the rest of the relay system.

relay logic: A logic network that coordinates the output of measuring units and other inputs to energize output circuits when prescribed conditions and sequences have been met.

relay system: An assembly usually consisting of current and voltage circuits, measuring units, logic, and power supplies to provide a specific relay scheme such as line, transformer, bus, or generator protection. A relay system may include connections to other systems such as data logging, alarm, communications, or other relay systems.

signal circuit: Any circuit other than a power supply circuit or an output circuit with a maximum voltage of less than 50 V and a maximum current of less than 100 mA.

surge ground: The point of external connection to the relay system reference or common bus for surge protection.

surge withstand capability (SWC): The ability of a device to withstand a voltage surge of a given wave shape under specified conditions without flashover, disruptive discharge, puncture, other electrical failure, or degradation of performance in the presence of electromagnetic disturbance.

transverse (differential) -mode voltage: The voltage between two conductors of a circuit at a given location.

voltage circuit: An input circuit to which a voltage greater than or equal to 50 V is applied, that is a measure of primary voltage.

3.2 Acronyms and abbreviations

EFT	electrical fast transient
EUT	equipment under test
SWC	surge withstand capability

4. Test wave shapes

4.1 Overview

This standard specifies two types of tests to demonstrate surge withstand capability of devices: a slow-damped oscillatory test and an electrical fast transient burst test.

4.2 Slow-damped oscillatory test waveform characteristics

The test waveform parameters (see [Figure 1](#)) for an open circuit generator condition at the generator terminals shall be as follows:

- Waveform envelope: A damped oscillatory wave, with the envelope decaying to 50% of the peak 1 value (Pk1) between the Peak 5 (Pk5) and Peak 10 (Pk10) points of the waveform.
- Frequency: 1 MHz (tolerance $\pm 10\%$).
- Rise time of the first peak: 75 ns (tolerance $\pm 20\%$), as measured between 10% and 90% of the peak value.
- Test voltage magnitude: Initial crest of 2.5 kV for common mode tests and for transverse tests (tolerance $+0/-10\%$).
- Repetition rate: 6 to 10 bursts per period of the power system frequency. Bursts shall be nonsynchronous with the power system frequency.
- Test duration: 2 s (tolerance $+10\% / -0\%$). For relays with an operating time greater than 2 s, it is recommended that the test be carried out with a minimum time setting. In such cases, the period of application of the test signal shall be at least as long as the operating time of the relay under test.
- Polarity of the first half-period: Positive and negative.
- Source impedance: 200 Ω resistive at 1 MHz (tolerance $\pm 20\%$).^{12,13}

¹²Oscillation frequency is defined as the reciprocal of the period between the first and third zero crossings after the initial peak. This period is shown as T in [Figure 1](#).

¹³Output impedance is calculated as open circuit voltage PK1 divided by short circuit current PK1.

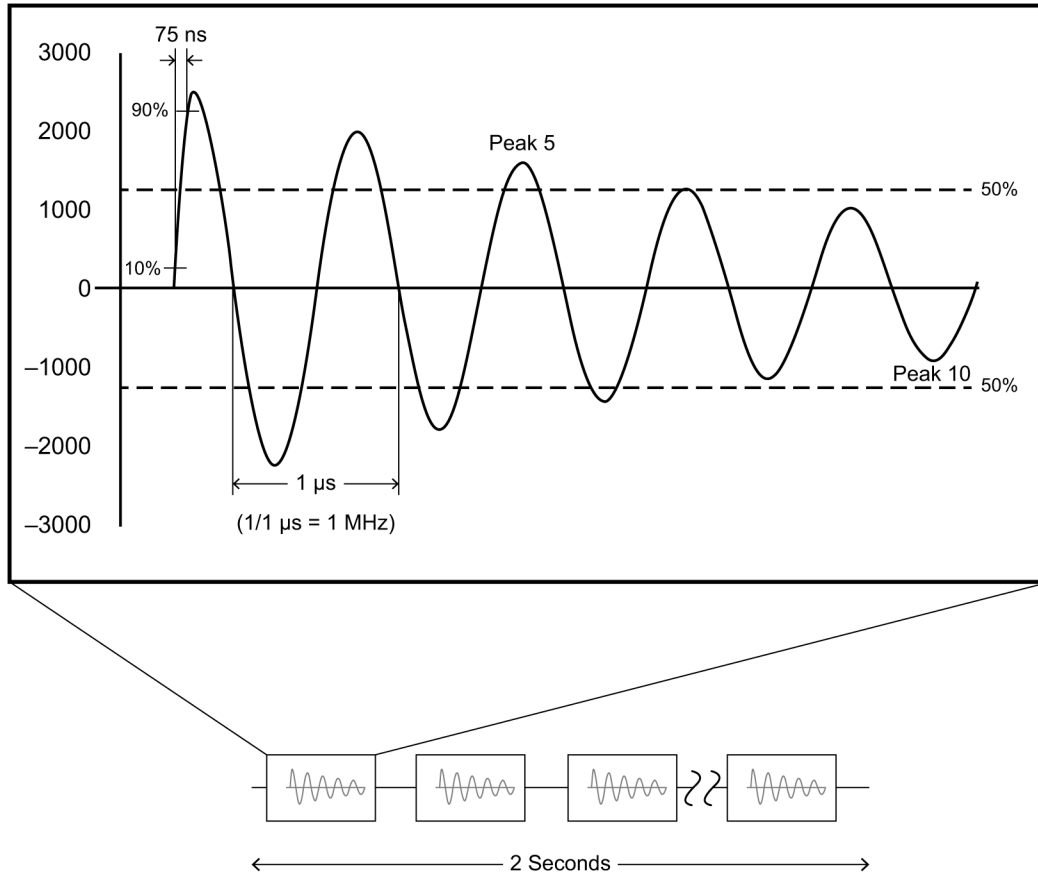


Figure 1—Slow-damped oscillatory test waveform (positive initial transition shown)

4.3 Electrical fast transient burst test waveform (see Figure 2)

The test generator waveform parameters at the generator terminals shall be as follows:

- a) Waveform polarity: positive and negative.
- b) Output type: coaxial, 50 Ω.
- c) Repetition rate: the waveform consists of bursts of pulses that repeat periodically.
- d) Burst duration: 15 ms at 5 kHz and 0.75 ms at 100 kHz (tolerance $\pm 20\%$).
- e) Repetition rate during bursts: test both at 5 kHz and 100 kHz (tolerance $\pm 20\%$).
- f) Burst period: 300 ms (tolerance $\pm 20\%$).
- g) Test duration: not less than 1 min for each polarity.
 - 1) Into 50 Ω load (see Footnote 6)
 - i) Rise time (10% to 90%) = 5 ns $\pm 30\%$
 - ii) Duration (above 50%) = 50 ns $\pm 30\%$
 - iii) Peak voltage = 2 kV $\pm 10\%$
 - 2) Into 1000 Ω load (see Footnote 6)

- i) rise time (10% to 90%) = 5 ns $\pm 30\%$
- ii) duration (above 50%) = 50 ns with a tolerance of -15 ns to $+100$ ns
- iii) peak voltage = 4 kV $\pm 20\%$ ¹⁴

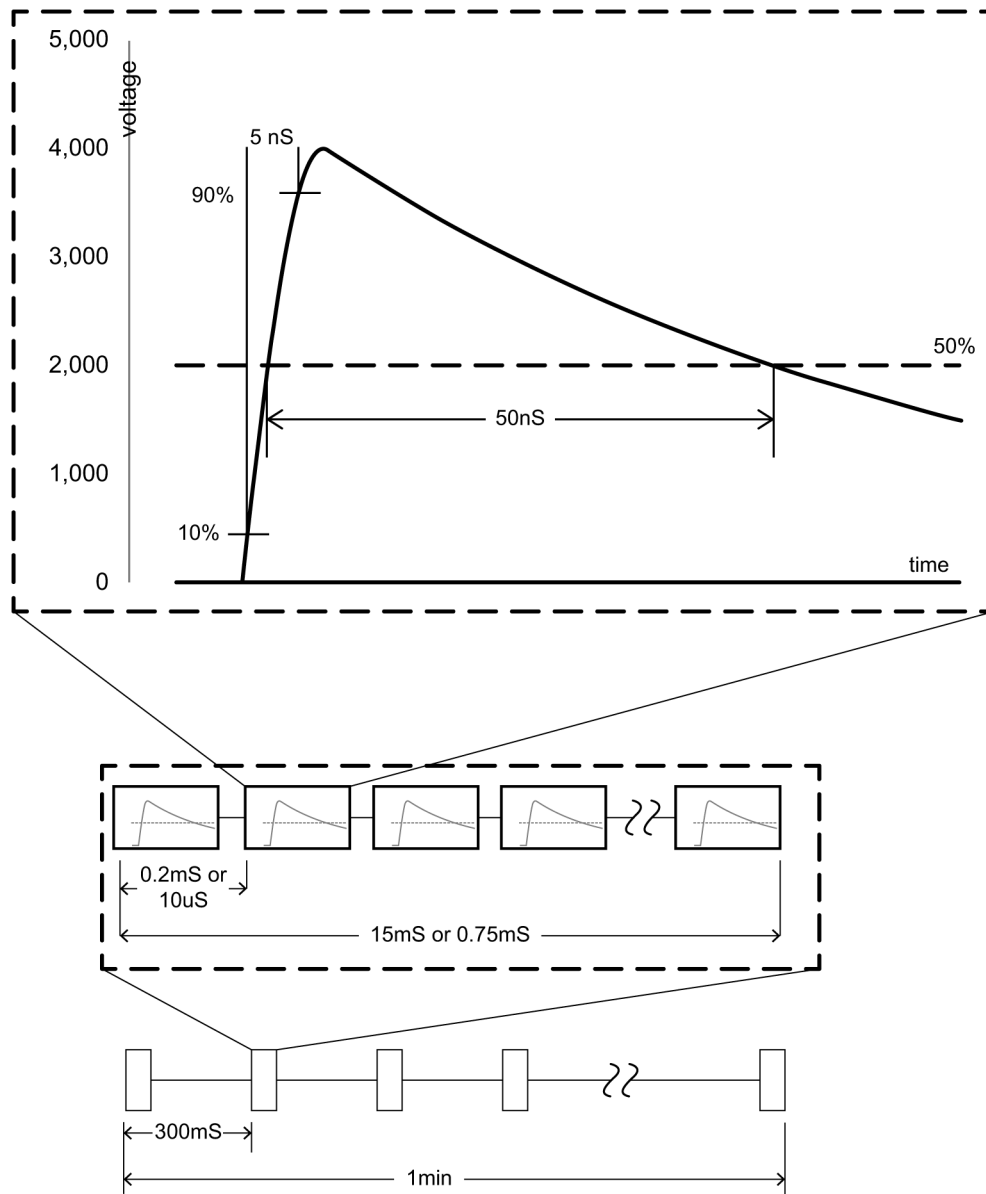


Figure 2—Electrical fast transient burst test waveform (positive polarity shown)

¹⁴Test resistive load impedances are $50 \Omega \pm 2\%$ and $1000 \Omega \pm 2\%$, non-inductive, in parallel with ≤ 6 pF. The resistance measurement is made at dc and the capacitance measurement is performed using a commercially available capacitance meter.