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IEEE Recommended Practice for the Application of Instrument Transformers in Industrial and Commercial Power Systems

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Abstract: The selection and application of instrument transformers used in industrial and commercial power systems are covered in this recommended practice.
Keywords: CT, current transformer, IEEE 3004.1™, instrument transformer, voltage transformer, VT

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Introduction

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When this project is completed, the technical material in the thirteen IEEE Color Books will be included in a series of new standards—the most significant of which will be a new standard, IEEE Std 3000™, IEEE Recommended Practice for the Engineering of Industrial and Commercial Power Systems. The new standard will cover the fundamentals of planning, design, analysis, construction, installation, startup, operation, and maintenance of electrical systems in industrial and commercial facilities. Approximately 60 additional dot standards, organized into the following categories, will provide in-depth treatment of many of the topics introduced by IEEE Std 3000™:

— Power Systems Design (3001 series)

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— Power Systems Reliability (3006 series)

— Power Systems Maintenance, Operations, and Safety (3007 series)

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The material in this recommended practice largely comes from IEEE Std 242™ (*IEEE Buff Book™*).

IEEE Std 3004.1™

This recommended practice covers the selection and application of instrument transformers used in industrial and commercial power systems.

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1. Overview

1.1 Scope

This recommended practice covers the selection and application of instrument transformers used in industrial and commercial power systems.

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.

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IEEE Std C57.13™, IEEE Standard Requirements for Instrument Transformers[1,2]

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

IEEE Std C57.13.6™, IEEE Standard for High-Accuracy Instrument Transformers

IEC Std 60044-1™, Instrument Transformers: Part 1—Current Transformers[3]

IEC Std 60044-2™, Instrument Transformers: Part 2—Inductive Voltage Transformers

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]

burden: The load connected to the secondary terminals, which may be expressed as voltamperes and power factor at a specified value of current, total ohms impedance and power factor, or ohms of the resistance and reactive components.

composite error: The root-mean-square (rms) of the instantaneous difference between the actual primary current and the actual secondary current multiplied by the rated current transformer transformation error.

current transformer (CT): Transforms line current into values suitable for use with standard protective relays and meters while isolating these instruments from line voltages.

dynamic current rating (I_{dyn}): The crest value of the asymmetrical primary current which a current transformer must withstand without being damaged electrically or mechanically by the resulting electromagnetic forces with the secondary winding short-circuited.

knee-point voltage: (A) The voltage at which a line tangent to the secondary excitation characteristic, when drawn on log-log coordinates, is at an angle of 45° to the horizontal. **(B)** The rated-frequency secondary voltage above which a 10% increase in voltage results in an increase of 50% or more in exciting current. (adapted from IEC)

polarity: The instantaneous phase relationship between the currents flowing in the primary and secondary of a current transformer. In simple applications, polarity is not important, but it is a critical consideration whenever multiple current transformers are used in combination, or when the output of a current transformer is used in conjunction with the output of a voltage transformer.

rating: The rating of a current transformer consists of a primary current rating and an associated secondary current rating. These ratings are related by the nominal transformation ratio of the current transformer, which is usually also the physical turns ratio of the transformer.

ratio correction factor (RCF): The ratio of the true, or measured, ratio of the current transformer to the marked, or nominal, ratio.

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ratio error: The degree to which the ratio correction factor deviates from the ideal, or textbook case, and is typically expressed in percent.

short-time thermal current rating: The maximum current that the current transformer can carry for a specified period of time.

transformer correction factor (TCF): Takes into account both the magnitude of error and any associated error in phase angle. TCF tends to be more of a concern in metering applications and is the factor by which the reading of a wattmeter may be adjusted to compensate for inaccuracies.

voltage transformer (VT): Transforms line voltage into values suitable for standard protective relays and meters while isolating these instruments from the stresses associated with the primary power system.

4. Current transformers

A current transformer (CT) transforms line current into values suitable for use with standard protective relays and meters while isolating these instruments from line voltages. A typical CT has two windings, designated as primary and secondary, which are insulated from each other. Most CTs are conventional in the sense that they are transformers consisting of winding on iron cores. However, air core CTs have been used in power system applications, and CTs utilizing optical technology are becoming available. The primary winding is connected in series with the circuit carrying the line current to be measured; and the secondary winding is connected to protective devices, instruments, meters, or control devices.

Ideally, CTs change the magnitude of the current being measured without changing the phase angle or wave shape of the current. Practically, however, the output of CTs does contain some error and distortion, and dealing with these errors and distortion is one of the primary challenges in applying CTs.

4.1 Equivalent circuit for current transformers

To understand the performance and application of CTs, it is necessary to start with an equivalent circuit. The circuit shown in Figure 1 is representative, although variations on this circuit may be found in various texts.

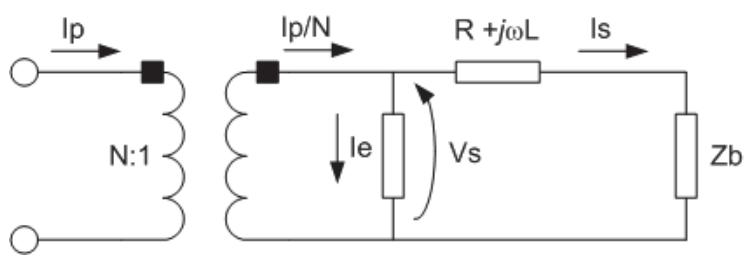

Figure 1—Equivalent circuit for a CT

In this equivalent circuit,

I_p	is the primary system current
I_s	is the secondary current fed to the meters or relays
N	is the nominal turns ratio of the CT
R+jωL	is the impedance of the CT secondary winding and leads, and the secondary wiring to the loads (meters or relays) applied to the CT

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