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Instrument transformers - Part 6: Requirements for protective current transformers for transient performance

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Transformateurs de mesure - Partie 6: Prescriptions concernant les transformateurs de courant pour protection pour la réponse en régime transitoire

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Instrument transformers

Part 6:
Requirements for protective current transformers for transient performance

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

INSTRUMENT TRANSFORMERS

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FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

This part of International Standard IEC 44 has been prepared by IEC Technical Committee No. 38: Instrument transformers.

The text of this part is based on the following documents:

Six Months' Rule	Reports on Voting	Two Months' Procedure	Report on Voting
38(CO)78	38(CO)81 & 81A	38(CO)83	38(CO)86

Full information on the voting for the approval of this part can be found in the Voting Reports indicated in the above table.

This part of IEC 44 is to be read in conjunction with IEC 185 and its Amendment No. 1.

Annexes A, B, C, D and E form an integral part of this part.

INTRODUCTION

Performance criteria for class P current transformers included in Chapter III of IEC 185 relate to a steady state a.c. symmetrical primary energizing current which allows the limiting secondary e.m.f. to be as defined in 34.5 of IEC 185. In this part of IEC 44, requirements for protective current transformers as classified by 3.5 take account of the additional flux linking the secondary winding due to the d.c. component of energizing current. Strictly, the limiting condition is defined by the integral of the voltage which is induced in the secondary winding of the current transformer in order to drive current in the secondary loop, inclusive of winding and secondary resistance, for the specified energizing conditions. For mathematical convenience, an equivalent sinusoidal e.m.f. is used to define the limiting condition. Refer also to annex B.

INSTRUMENT TRANSFORMERS

Part 6: Requirements for protective current transformers for transient performance

1 Scope

This part of IEC 44 covers the requirements and tests, in addition to those in Chapter I of IEC 185, that are necessary for inductive current transformers for use with electrical protective schemes in which the prime requirement for the current transformers is the maintenance of a defined performance up to several times the rated current when the current contains an exponentially decaying d.c. component of defined time constant.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of IEC 44. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of IEC 44 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 56: 1987, *High-voltage alternating-current circuit-breakers.*

IEC 185: 1987, *Current transformers.*

3 Definitions

For the purpose of this part of IEC 44, the following definitions apply.

3.1 **rated primary short-circuit current** (I_{psc}): R.M.S. value of primary symmetrical short-circuit current on which the rated accuracy performance of the current transformer is based.

3.2 **instantaneous error current** (i_ε): Difference between the instantaneous values of the secondary current (i_s) multiplied by the rated transformation ratio (K_n) and the primary current (i_p):

$$i_\varepsilon = K_n\, i_s - i_p$$

When both alternating current and direct current components are present, the constituent components are separately identified as follows:

$$i_\varepsilon = i_{\varepsilon ac} + i_{\varepsilon dc} = (K_n\, i_{sac} - i_{pac}) + (K_n\, i_{sdc} - i_{pdc})$$

3.3 **peak instantaneous (total) error** ($\hat{\varepsilon}$): Maximum instantaneous error current, for the specified duty cycle, expressed as a percentage of the peak instantaneous value of the rated primary short-circuit current:

$$\hat{\varepsilon} = 100\ \hat{i}_{\varepsilon} / (\sqrt{2}\ I_{psc}) \quad (\%)$$

3.4 **peak instantaneous alternating current component error** (ε_{ac}): Maximum instantaneous error of the alternating current component expressed as a percentage of the peak instantaneous value of the rated primary short-circuit current:

$$\hat{\varepsilon}_{ac} = 100\ \hat{i}_{\varepsilon ac} / (\sqrt{2}\ I_{psc}) \quad (\%)$$

3.5 **protective current transformer classes:** Current transformers for protection are classified according to functional performance as follows:

class P: Accuracy limit defined by composite error ($\hat{\varepsilon}_c$) with steady state symmetrical primary current. No limit for remanent flux.

class TPS: Low leakage flux current transformer for which performance is defined by the secondary excitation characteristics and turns ratio error limits. No limit for remanent flux.

class TPX: Accuracy limit defined by peak instantaneous error ($\hat{\varepsilon}$) during specified transient duty cycle. No limit for remanent flux.

class TPY: Accuracy limit defined by peak instantaneous error ($\hat{\varepsilon}$) during specified transient duty cycle. Remanent flux not to exceed 10 % of the saturation flux.

class TPZ: Accuracy limit defined by peak instantaneous alternating current component error ($\hat{\varepsilon}_{ac}$) during single energization with maximum d.c. offset at specified secondary loop time constant. No requirements for d.c. component error limit. Remanent flux to be practically negligible.

3.6 **specified primary time constant** (T_p): That specified value of the time constant of the d.c. component of the primary current on which the performance of the current transformer is based. This value may also be a rated value for class TPX, TPY and TPZ current transformers and then will be marked on the rating plate.

3.7 **permissible time to accuracy limit** (t_{al}): Time during which the specified accuracy is maintained during any specified energization period of a given duty cycle.

NOTE - This time will usually be defined by the critical measuring time of the associated protection scheme. When stable operation of the protection scheme is a limiting requirement, it may also be necessary to consider the time taken by the circuit breaker to interrupt the current.

3.8 **time to maximum flux** (t_{max}): Elapsed time during a prescribed energization period at which the transient flux in a current transformer core achieves maximum value, it being assumed that saturation of the core does not occur.

3.9 **dead time (during auto-reclosing)** (t_{fr}): Time interval between interruption and re-application of the primary short-circuit current during a circuit breaker auto-reclosing duty cycle (refer also to IEC 56).

3.10 **specified duty cycle (C-0 and/or C-0-C-0):** Duty cycle in which, during each specified energization, the primary energizing current is assumed to be "fully offset" (see note below), with the specified decay time constant (T_p) and be of rated amplitude (I_{psc}).

Duty cycles are as follows:

Single energization: C - t' - 0

Double energization: C - t' - 0 - t_{fr} - C - t'' - 0

(both energizations in the same polarity of flux)

where:

t' is the duration of first current flow: specified accuracy being maintained during time t'_{al}

t'' is the duration of second current flow: specified accuracy being maintained during time t''_{al}.

NOTE - Specification of partial offset would reduce the required transient factor by an amount approximately proportional to the reduction. For this reason specification of full offset parameters is recommended.

3.11 **rated resistive burden** (R_b): Rated value of the secondary connected resistive burden in ohms.

3.12 **secondary winding resistance** (R_{ct}): Secondary winding d.c. resistance in ohms, corrected to 75 °C or such other temperature as may be specified.

3.13 **secondary loop resistance** (R_s): Total resistance of the secondary circuit, inclusive of the secondary winding resistance corrected to 75 °C, unless otherwise specified, and inclusive of all external burden connected.

3.14 **rated secondary loop time constant** (T_s): Value of the time constant of the secondary loop of the current transformer obtained from the sum of the magnetizing and the leakage inductances (L_s) and the secondary loop resistance (R_s):

$$T_s = L_s / R_s$$

3.15 **rated symmetrical short-circuit current factor** (K_{ssc}): The ratio:

$$K_{ssc} = I_{psc} / I_{pn}$$

3.16 **transient factor** (K_{tf}): Ratio of the theoretical total secondary linked flux to the peak instantaneous value of the a.c. component of that flux, when a current transformer is subjected to a specified single energization and the secondary loop time constant (T_s) is assumed to have retained a constant value throughout the energization period.

3.17 **rated transient dimensioning factor** (K_{td}): That theoretical value representative of the transient dimensioning necessary to satisfy the specified duty cycle.

Mathematical relationships between T_p, T_s, K_{tf} and K_{td} are given in annex A.

3.18 **low leakage flux current transformer:** Current transformer for which a knowledge of the secondary excitation characteristic and secondary winding resistance is sufficient for an assessment of its transient performance for any combination of burden and duty cycle at rated or lower value of primary symmetrical short-circuit current up to the theoretical limit of the current transformer capability determined from the secondary excitation characteristic.

3.19 **high leakage flux current transformer:** Current transformer which does not satisfy the requirements of 3.18 and for which an additional allowance is made by the manufacturer to take account of influencing effects which result in additional leakage flux. Such a current transformer is expected to satisfy a specified duty cycle.

NOTE - In general, if the theoretical transient dimensioning factor (K_{td}) is satisfied for a C-0-C-0 duty cycle, then the accuracy is maintained during a C-0 duty cycle at least up to the time at which the rated equivalent limiting secondary e.m.f. (E_{al}), defined in 3.20, is reached.

3.20 **rated equivalent limiting secondary e.m.f.** (E_{al}): That r.m.s. value of the equivalent secondary circuit e.m.f. of rated frequency necessary to satisfy the specified duty cycle and derived from the following:

$$E_{al} = K_{ssc} K_{td} (R_{ct} + R_b) I_{sn} \qquad (V, \text{r.m.s.})$$

3.21 **rated equivalent excitation limiting secondary voltage** (U_{al}): That r.m.s. value of sinusoidal voltage of rated frequency necessary to ensure that the rated equivalent limiting secondary e.m.f. will be attained after due account is taken of the current transformer construction and which, when applied to the transformer secondary winding, would result in a magnetizing current not exceeding the maximum permissible error current appropriate to the current transformer class.

$$U_{al} = E_{al} F_c \qquad (V, \text{r.m.s.})$$

where F_c is the factor of construction defined in 3.29.

3.22 **equivalent secondary accuracy limiting e.m.f.** (E_{alc}): That equivalent r.m.s. e.m.f. of rated frequency determined during a direct test when the observed error current corresponds to the appropriate limit for the class.

NOTE - The error current is an absolute value based on the specified primary current value and is thus not affected by any parametric changes which may have been necessary to attain the secondary error limiting condition.

3.23 **equivalent secondary accuracy limiting voltage** (U_{alc}): That r.m.s. value of sinusoidal voltage of rated frequency which, if applied to the secondary winding of a current transformer, would result in an exciting current corresponding to the maximum permissible error current appropriate to the current transformer class.

3.24 **saturation flux** (Ψ_s): That peak value of the flux which would exist in a core in the transition from the non-saturated to the fully saturated condition and deemed to be that point on the B-H characteristic for the core concerned at which a 10 % increase in B causes H to be increased by 50 %.

3.25 **remanent flux** (Ψ_r): That value of flux which would remain in the core three minutes after the interruption of an exciting current of sufficient magnitude as to induce the saturation flux (Ψ_s) defined in 3.24 above.

3.26 **remanence factor** (K_r): The ratio $K_r = \Psi_r / \Psi_s$

3.27 **accuracy limit flux** (Φ_{al}): That peak value of the secondary linked flux corresponding to E_{al}:

$$\Phi_{al} = \sqrt{2}\, E_{al} / (2\pi f)$$

When E_{al} is given in volts, r.m.s., Φ_{al} is expressed in weber.

3.28 **accuracy limiting secondary exciting current** (I_{al}): Peak value of the exciting (error) current appropriate to the current transformer class.

3.29 **factor of construction** (F_c): Factor declared by the manufacturer for the design. The factor of construction is determined from the ratio:

$$F_c = U_{alc} / E_{alc}$$

4 Ratings and performance requirements

4.1 *Standard values for rated symmetrical short-circuit current factor* (K_{ssc})

Standard values of K_{ssc} for protective current transformers for transient performance are:

3 - 5 - 7,5 - <u>10</u> - 12,5 - <u>15</u> - 17,5 - <u>20</u> - 25 - 30 - 40 - 50

The preferred values are underlined.

4.2 *Standard values for symmetrical short-circuit current*

4.2.1 *Rated short-time thermal current* (I_{th})

Standard r.m.s. values, expressed in kiloamperes, are:

6,3 - 8 - 10 - 12,5 - 16 - 20 - 25 - 31,5 - 40 - 50 - 63 - 80 - 100

4.2.2 *Rated primary short-circuit current* (I_{psc})

Preferred values are derived from the product of I_{pn} and K_{ssc} selected from the values given in 4.1 of IEC 185 and 4.1 of this part of IEC 44 respectively. The product need not be exactly equal to I_{th}.

4.3 *Standard values for rated primary time constant* (T_p)

Standard values, expressed in milliseconds, are:

40 - 60 - 80 - 100 - 120

NOTE - For some applications, higher values of rated primary time constant may be required. Example: large turbo-generator circuits.

4.4 *Standard values for rated transient dimensioning factor* (K_{td})

At present there are no standard values for the rated transient dimensioning factor because the values of this factor depend upon the application.

4.5 *Standard values of rated resistive burden* (R_b)

Standard values of rated resistive burden in ohms for class TP current transformers, based on a rated secondary current of 1 A are:

2,5 - 5 - 7,5 - 10 - 15

The preferred values are underlined. For current transformers having a rated secondary current other than 1 A, the above values should be adjusted in inverse ratio to the square of the current.

4.6 *Error limits for TPS current transformers*

The turns ratio of a TPS current transformer shall be numerically equal to $1/K_n$. The error in this turns ratio shall not exceed ±0,25 %.

The accuracy limiting conditions are defined by the magnetization characteristic and the excitation limiting secondary voltage U_{al} shall not be less than the specified value. The value shall be such that an increase of 10 % in magnitude does not result in an increase in the corresponding peak instantaneous exciting current exceeding 100 %.

When specified by the purchaser, the measured value of the peak exciting current at the excitation limiting secondary voltage shall not exceed the specified value. If no limit is set, the exciting current shall, in any case, not exceed that value corresponding to 10 % of I_{th} referred to the secondary side (see TPX CTs, table 1).

The excitation limiting secondary voltage defined by the purchaser is generally expressed as follows:

$$U_{al} \geq K\, K_{ssc}\, (R_{ct} + R_b)\, I_{sn}$$

in which K is a dimensioning parameter assigned by the purchaser. R_{ct} is defined by the manufacturer's design except that for some applications limits may need to be set by the purchaser to enable co-ordination with other equipment.

4.7 *Error limits for TPX, TPY and TPZ current transformers*

With the secondary loop resistance adjusted to the value $R_s = R_{ct} + R_b$, the errors shall not exceed the values given in table 1.

Table 1 – Limits of error

Class	At rated primary current			At accuracy limit condition
	Ratio error %	Phase displacement Min	Phase displacement Centirad	Maximum peak instantaneous error %
TPX	±0,5	±30	±0,9	$\hat{\varepsilon}$ = 10
TPY	±1,0	±60	±1,8	$\hat{\varepsilon}$ = 10
TPZ	±1,0	180 ± 18	5,3 ± 0,6	$\hat{\varepsilon}_{ac}$ = 10

NOTE - For some applications, deviation from the above values may be necessary (refer also to annex D.3). Similarly, the absolute value of the phase displacement may in some cases be of less importance than achieving minimal deviation from the average value of a given production series.

5 Methods of specification

The methods of specification for the different CT classes are illustrated in table 2.