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IS 2705 (Part 4) : 1992

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भारतीय मानक

धारा ट्रांसफार्मर – विशिष्टि

भाग 4 विशेष प्रयोजन अनुप्रयोगों के लिए संरक्षी धारा ट्रांसफार्मर

(दूसरा पुनरीक्षण)

Indian Standard

CURRENT TRANSFORMERS — SPECIFICATION

PART 4 PROTECTIVE CURRENT TRANSFORMERS FOR SPECIAL PURPOSE APPLICATIONS

(Second Revision)

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

August 1992

Price Group 3

FOREWORD

This Indian Standard (Part 4) was adopted by the Bureau of Indian Standards, after the draft finalized by the Instrument Transformers Sectional Committee had been approved by the Electrotechnical Division Council.

This standard was first published in 1964 and revised in 1981. This revision has been undertaken to bring it in line with the latest developments at the international level.

Indian Standards on current transformers have been published in four parts:

Part 1 General requirements,

Part 2 Measuring current transformers,

Part 3 Protective current transformers, and

Part 4 Protective current transformers for special purpose applications.

This standard applies to protective current transformers intended for use in balanced protective schemes, for example, biased differential protection, restricted earth-fault protection and distance measuring protection, where the required characteristics of the current transformers cannot be conveniently expressed in terms of accuracy class, accuracy limit factor and rated burden. Some more information on these transformers is given in Annex A.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis. shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

CURRENT TRANSFORMERS — SPECIFICATION

PART 4 PROTECTIVE CURRENT TRANSFORMERS FOR SPECIAL PURPOSE APPLICATIONS

(Second Revision)

1 SCOPE

This standard (Part 4) gives requirements and test for protective current transformers for special purpose applications such as balanced protective systems and distance protection schemes. It also applies to protective cores of multi-core current transformers for such applications.

2 TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply in addition to those covered in Part 1 and Part 2 of this standard.

2.1 Knee-Point Voltage

That sinusoidal voltage of rated frequency applied to the secondary terminals of the current transformer, all other windings being open circuited, which when increased by 10 percent, causes the exciting current to increase by 50 percent.

2.1.1 *Rated Knee-Point Voltage*

The minimum knee-point voltage specified on which the performance of the current transformer is based.

2.2 Turns Ratio

The ratio between the number of turns on the secondary winding and the number of turns on the secondary.

3 DESIGNATION AND CHARACTERISTICS

3.0 Protective current transformers for special purpose applications shall be designated 'Class PS'.

3.1 Class PS current transformers are of low reactance (*see* Annex A of Part 3 of this standard) and their performance shall be specified in terms of the following characteristics.

3.1.1 *Turns Ratio,* which shall be numerically the same as the rated transformation ratio.

NOTE — Turns ratio may also be specified separately in relation to a specified rated primary current.

3.1.2 *Minimum Knee-Point Voltage* (V_k), specified in accordance with a formula of the type:

$$V_k = K.\ I_s\ (R_{ct} + R_b)$$

where

V_k is the minimum knee-point voltage in volts,

K is a parameter to be specified by the purchaser which depends on the system fault level and the characteristics of the relay intended to be used,

I_s is the rated secondary current of the current transformer (or the secondary current as derived from a specified turns ratio and primary current),

R_{ct} is the resistance of the secondary winding corrected to 75°C

R_b is the impedance of the secondary circuit as specified by the purchaser.

In the above formula, the purchaser shall specify the values of 'K', 'I_s' and 'R_b'. The value of 'R_{ct}' shall be to the discretion of the manufacturer.

NOTE — It is recognized that for certain special requirements, a limitation on the value of 'R_{ct}' may be required. In such cases, the purchaser may specify a maximum value for 'R_{ct}' at 75°C. In other cases, the choice of 'R_{ct}' should be left to the manufacturer.

3.1.3 *Maximum Exciting Current,* at the rated knee-point voltage or at any specified fraction of the rated knee-point voltage.

4 REQUIREMENTS

4.1 The error in turns ratio shall not exceed ± 0.25 percent.

4.2 The knee-point voltage shall not be less than the specified rated knee-point voltage.

4.3 The exciting current(s) shall not be greater than the specified value(s) required in accordance with **3.1.3.**

4.4 When specified, the resistance of the secondary winding, corrected to 75°C, shall not be greater than the specified value.

5 MARKING

Every current transformer shall be indelibly marked with the following information, in addition to that required by Part 1 of this standard:

a) A reference to this standard,

b) Class designation,

c) Secondary winding resistance at 75°C,

d) Rated knee-point voltage in volts, and

e) Maximum exciting current at rated knee-point voltage, or at the specified fraction thereof.

6 TESTS

6.0 All Class PS current transformers shall be subject to the routine tests as given in **6.1** to **6.3**, in addition to the type and routine tests given in Part 1 of this standard.

6.1 Knee-Point Voltage and Exciting Current

A sinusoidal voltage at rated frequency equal to the rated knee-point voltage shall be applied to the secondary terminals, all other windings being open-circuited and the exciting current shall be measured. The voltage shall then be increased by 10 percent and the exciting current shall not increase by more than 50 percent. The voltage shall then be reduced to the values corresponding to the specified percentages of the knee-point voltage and the exciting current shall be measured at each such voltage. The exciting currents at the knee-point voltage and the specified percentages thereof shall not exceed the specified limits.

6.2 Secondary Winding Resistance

The resistance of the secondary winding shall be measured and the value, when corrected to 75°C shall not exceed the value specified (if any).

6.3 Turns Ratio

The turns ratio shall be determined and shall not differ from the specified ratio by more than ± 0.25 percent. For the method of measurement of turns ratio, *see* Annex B.

ANNEX A

(*Foreword*)

NOTES ON PROTECTIVE CURRENT TRANSFORMERS FOR SPECIAL PURPOSE APPLICATIONS

A-1 Protective current transformers covered in this standard are intended mainly for use in applications where the required characteristics of the current transformers cannot be conveniently expressed in the terms used for Class 5P, 10P and 15P current transformers. The knee-point voltage, exciting current(s) and secondary winding resistance are so dependent on the protective gear involved and the requirements are so numerous and varied that useful guidance in the application of current transformers cannot be given in this Annex. However, the manufacturers of the protective gear stipulate the requirements in terms of minimum knee-point voltage and maximum exciting current and it should be ensured that current transformers with adequate knee-point voltage are supplied. The exciting current should not exceed the value stipulated, otherwise it will affect the primary fault settings of the protection scheme.

A-2 It should be noted that as the turns ratio error is limited, transformers of this class are suitable for protective schemes requiring close balance of the secondary currents from different phases or circuits. Such current transformers should be so designed that balance is maintained within the protective system when maximum through-fault current is flowing through the primary windings of the current transformer used for this system, that is, stability of the protection should be assured, whether in the transient or in the steady state, up to the maximum through-fault current which can be passed in service through their primary windings.

A-3 Current Transformers of class PS type are of low reactance and this may be established in any of the ways described below.

A-4 All class type PS current transformers are deemed to be of the low reactance if:

a) The core is of the jointless ring type (including spirally wound cores).

b) The secondary turns are substantially evenly distributed along the whole length of the magnetic circuit except that a circumferential spacing which does not exceed 20 mm on the outer periphery or which subtends an angle between radii not exceeding 30 degree, whichever is greater, is permissible between the two ends of the winding.

c) The primary conductor(s) passes through the approximate centre of the core aperture or is approximately evenly distributed along the whole length of the magnetic circuit.

d) Flux equalizing windings, where employed to meet the requirements of design, consist of at last four parallel connected coils, evenly distributed along with whole length of the magnetic circuit, each coil occupying one quadrant.

Such an arrangement ensures substantially even flux distribution within the core irrespective of the presence of stray flux which may result from such conditions as the close proximity of the return primary conductor.

A-5 Alternatively, any current transformer may be shown to be of low-reactance by a type test comprising the determination of the composite error of the current transformer by the direct test in accordance with **7.1.2.1** of Part 3 of this standard and comparing it to the composite error determined by the indirect test in accordance with **7.1.2.2** of Part 3 of this standard. If the composite error obtained by the direct test is less than 1.3 times the error obtained by the indirect test, the current transformer shall be accepted as of low reactance. However, since in the case of Class PS current transformers, there is no rated burden and accuracy limit current, the burden and primary current for the direct test, and the voltage to be applied to the secondary winding for the indirect test, should be agreed between the manufacturer and the purchaser.

ANNEX B

(*Clause* 6.3)

RECOMMENDED METHODS OF DETERMINATION OF TURNS RATIO

B-1 METHOD 1

B-1.1 There is no simple and positive method of measuring turns ratio on a completed current transformer. This is due to the fact that the actual transformation ratio (for the measurement of which there is readily available equipment) differs from the rated transformation ratio by an amount which depends upon the following three factors:

a) The difference between the turns ratio and the rated transformation ratio,

b) The core exciting current, and

c) The currents which flow in stray capacitances associated with the windings.

B-1.2 In power frequency current transformers with less than about 1 000 turns in either or both windings, only factors (a) and (b) need normally be considered. The usual method is to measure the current error at about the rated primary current with as low a value of non-inductive burden as possible. In some instances, however, it may be difficult to decide whether this error is due the core exciting current or in part to an error in turns ratio. In such circumstances, the following method is applicable. In the equivalent circuit of such a current transformer, shown in Fig. 1 the core exciting current I_e is non-linear with respect to the core magnetic flux, and hence with respect to E_s, the voltage induced in the secondary winding. However, if in a number of tests E_s is maintained constant, then I_e will also be constant.

Thus, if the actual transformation ratio K_s, is measured with two values of burden, Z_{b1} and Z_{b2} so that the value

$$E_s = I_s (Z_s + Z_b)$$

remains constant, then the turns ratio is given by:

$$\frac{N_s}{N_p} = \frac{I_{p2} - I_{p1}}{(I_{p2}/K_{s2}) - (I_{p1}/K_{s1})}$$

where

E_s = voltage induced in secondary winding
I_s = secondary current
Z_s = leakage impedance of secondary winding
Z_b = burden (in ohm)
N_p = number of turns in primary winding
N_s = number of turns in secondary winding
I_{p1} = actual primary current in test with burden Z_{b1}
I_{p2} = actual primary current in test with burden Z_{b2}
K_{s1} = actual transformation ratio in test with burden Z_{b2}
K_{s2} = actual transformation ratio in test with burden Z_{b2}

B-1.3 Since many current transformer testing sets are scaled, so that the more convenient quantity 'E_c' is obtained in place of the actual transformation ratio. it is preferable to reduce the above equation to a form which is consistent with E_c.

Furthermore, this form of the equation is simplified if there is a two-to-one relationship between I_{p1} and I_{p2}.

Thus, when $I_{p2} = 2I_{p1}$, and if

E_{c1} = percentage current error in test with I_{p1}, and
E_{c2} = percentage current error in test with I_{p2}

the percentage error in the turns ratio E_t is approximately equal to $E_{c1} - 2E_{c2}$ if E_{c1} and $2E_{c2}$ are small compared with 100.

B-1.4 It is, therefore, convenient to carry out the test using rated current and minimum external burden in one test, and half rated current and such additional external burden as would double the total burden for the other test. The leakage impedance of the secondary winding of a current transformers is not easily

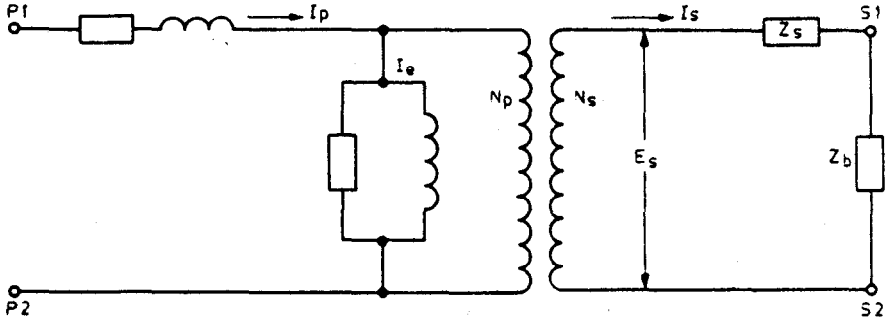

FIG. 1 EQUIVALENT CIRCUIT FOR THE DETERMINATION OF TURNS RATIO (CURRENT TRANSFORMERS HAVING FEWER THAN APPROXIMATELY 1 000 TURNS)

measured, but except for unusually shaped current transformers, it is sufficient to use the resistance alone of the secondary winding to obtain satisfactory results.

B-1.5 In power frequency current transformers with more than about 1 000 turns in either winding, all of the three factors (a), (b) and (c) given in B-1.1 have to be considered, the equivalent of such a current transformer may be shown in Fig. 2.

B-1.6 If E_s is kept constant, as is required for the tests with different values of secondary current for each burden, the voltage across say, C_4 (Fig. 2) is kept constant by a link between appropriate points on primary and secondary circuits, then the currents flowing in each stray capacitance will be constant. These capacitance current will, together, cause a current to flow in the primary circuit which may be considered as I_e in parallel with I_s, so that I_e may be regarded as part of the exciting current.

The results of tests carried out as before will be valid.

B-2 METHOD 2

B-2.1 Another usual method is to measure the current error at about the rated primary current with as low a value of non-inductive burden as possible. The relationship between this error and the turns ratio error depends on the magnitude of the component of exciting current affecting the error. In many designs, the current error measured under these conditions, with the turns ratio equal to the rated transformation ratio, is much less than the error due to a one-turn error of the secondary winding and there is no difficulty in deciding whether the turns ratio is within the specified limits.

In some instances, however, it may be difficult to decide whether a certain value of measured current error is due wholly to the error component of the exciting current or in part to an error in turns ratio. This doubt can be dispelled by measuring the current error with two or three values of non-inductive burden. Those errors are then plotted against the corresponding values of total burden, that is, including that due to the secondary winding resistance, and extrapolated to zero burden to give the error in turns ratio.

B-2.2 In the majority of cases, it will be sufficiently accurate to assume a linear relationship between current error and total burden and to calculate the current error corresponding to zero burden (assumed to approximate to the turns ratio error) from measurements of current error at two low values of burden only, as follows:

$$\text{Turns ratio error (approximately)} = y\left(\frac{(A+R)}{(B-A)}\right) - x\left(1+\frac{(A+R)}{(B-A)}\right)$$

where

y = current error with burden B,

A = lower value of external burden in ohms,

R = resistance of the secondary winding,

B = higher value of external burden in ohms, and

x = current error with burden A.

NOTE — A positive current error at zero burden indicates a negative turns ratio error and vice-versa.

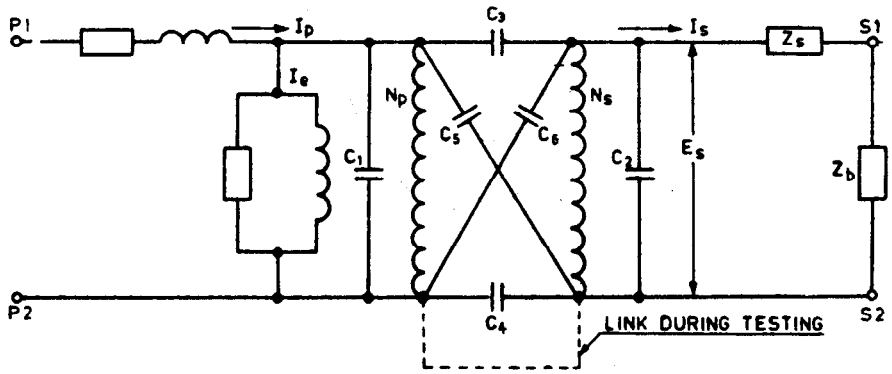

FIG. 2 EQUIVALENT CIRCUIT FOR THE DETERMINATION OF TURNS RATIO (CURRENT TRANSFORMERS HAVING MORE THAN APPROXIMATELY 1 000 TURNS)

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