TERMINOLOGY

Extracts from American National Standards Institute (ANSI) for Instrument Transformers, ANSI C57.13—1968

Accuracy Classes for Metering. The limits of transformer correction factor, in terms of percent error, that have been established to cover specific performance ranges for line power factor conditions between 1.0 and 0.6 lag.

Accuracy Classes for Relaying. The limits, in terms of percent ratio error, that have been established.

Accuracy of Instrument Transformers. The means of expressing the degree of conformity of the actual values obtained from the secondaries of the instrument transformers to the values that would have been obtained with the marked ratio.

The performance characteristics associated with accuracy of an instrument transformer are expressed either in terms of correction factors or in terms of percent errors.

Accuracy Ratings of Instrument Transformers. The means of classifying transformers in terms of percent error limits under specified conditions of operation.

Accuracy Ratings for Metering. The accuracy class followed by a standard burden for which the accuracy class applies.

The accuracy rating applies only over the specified current or voltage range and at the stated frequency.

Accuracy Ratings for Relaying. The secondary terminal voltage which the transformer will deliver to a standard burden at 20 times normal secondary current without exceeding 10 percent ratio error, preceded by a letter denoting whether the accuracy can be obtained by calculation or must be obtained by test.

Burden for an Instrument Transformer. That property of the circuit connected to the secondary winding which determines the active and reactive power at the secondary terminals. The burden is expressed either as total ohms impedance with the effective resistance and reactance components, or as the total volt-amperes and power factor at the specified value of current or voltage, and frequency.

Continuous-Thermal-Current Rating Factor. The specified factor by which the primary current of a current transformer can be multiplied to obtain the maximum primary current that can be carried continuously without exceeding the limiting temperature rise from 30 C ambient temperature.

Current Transformer. An instrument transformer intended to have its primary winding connected in series with the conductor carrying the current to be measured or controlled.

Note: The term "primary" when applied to certain types of current transformers denotes the cable or bus bar which links with the magnetic circuit to form a single effective primary turn.

Instrument Transformer. A transformer which is intended to reproduce in its secondary circuit, in a definite and known proportion, the current or voltage of its primary circuit with the phase relations substantially preserved.

Marked Ratio. The ratio of the rated primary value to the rated secondary value as stated on the nameplate.

Percent Ratio. The true ratio expressed in percent of the marked ratio.

Percent Ratio Error of an Instrument Transformer. The difference between the ratio correction factor and unity expressed in percent.

Note: The percent ratio error is positive if the ratio correction factor is greater than unity.

If the percent ratio error is positive, the measured secondary current or voltage will be less than the primary value divided by the marked ratio.

Percent Transformer Correction Factor Error. The difference between the transformer correction factor and unity expressed in percent.

Note: The percent transformer correction factor error is positive if the transformer correction factor is greater than unity.

If the percent transformer correction factor error is positive, the measured watts or watthours will be less than the true value.

Phase Angle Correction Factor. The ratio of the true power factor to the measured power factor. It is a function of both the phase angles of the instrument transformers and the power factor of the primary circuit being measured.

Note: The phase angle correction factor is the factor which corrects for the phase displacement of the secondary current or voltage, or both, due to the instrument transformer phase angles.

The measured watts or watthours in the secondary circuits of instrument transformers must be multiplied by the phase angle correction factor and the true ratio to obtain the true primary watts or watthours.

Phase Angle of an Instrument Transformer. The phase displacement, in minutes, between the primary and secondary values.

Note: The phase angle of a current transformer is designated by the Greek letter beta (β) and is positive when the current leaving the identified secondary terminal leads the current entering the identified primary terminal.

The phase angle of a potential transformer is designated by the Greek letter gamma (γ) and is positive when the secondary voltage from the identified to the unidentified terminal leads the corresponding primary voltage.

Polarity. The designation of the relative instantaneous directions of the currents entering the primary leads and leaving the secondary leads during most of each half cycle.

Potential Transformer. An instrument transformer intended to have its primary winding connected in shunt with a power supply circuit, the voltage of which is to be measured or controlled.

Rated Primary Current. The current selected for the basis of performance specifications of a current transformer.

Rated Primary Voltage of a Potential Transformer. The voltage selected for the basis of performance specifications of a potential transformer.

Ratio Correction Factor. The ratio of the true ratio to the marked ratio. The primary current or voltage is equal to the secondary current or voltage multiplied by the marked ratio times the ratio correction factor.

Note: If both a potential transformer and a current transformer are used in conjunction with a wattmeter or watthour meter, the resultant ratio correction factor, for use with the wattmeter or watthour meter, is the product of the individual ratio correction factors.

Transformer Correction Factor. The ratio of true watts or watthours to the measured watts or watthours, divided by the marked ratio.

Note: The transformer correction factor for a current or potential transformer is the ratio correction factor multiplied by the phase angle correction factor for a specified primary circuit power factor.

The true primary watts or watthours are equal to the watts or watthours measured, multiplied by the transformer correction factor and the marked ratio.

The true primary watts or watthours, when measured by both current and potential transformers, are equal to the current transformer correction factor times the potential transformer correction factor multiplied by the product of the marked ratios of the current and potential transformers multiplied by the observed watts or watthours.

True Ratio. The ratio of the root-mean-square (rms) primary value to the rms secondary value under specified conditions.

ABBREVIATIONS

Ratio Correction Factor .... RCF
Instrument-transformer Correction Factor .... TCF
Continuous-Thermal-Current Rating Factor .... RF

TECHNICAL DATA

STANDARDS

I. Current Transformers
   a. I.E.E.E./ A.N.S.I. Publication C57.13–1993
   b. I.E.C. Publication No. 185
   c. British Standard Publication BS 3938

II. Voltage Transformers
   a. I.E.E.E./ A.N.S.I. Publication C57.13–1993
   b. I.E.C. Publication No. 186
   c. British Standard Publication BS 3941

There are too many standards to list them all. Those listed are the ones we most commonly seen. It should be understood that standards are not laws but, are suggested guidelines for users and manufactures alike. The standards usually suggest test and testing procedures, as well.

The following is based on U.S.A. standards (C57.13–1993) which is the standard of choice in the U.S.A.

I.E.C. (International Electrotechnical Commission) is the standard of choice of the international community.

CURRENT TRANSFORMERS

Accuracy & Burden – Accuracy is defined for two different types of applications (metering and relaying).

The following table defines metering accuracy classes.

TABLE 1
STANDARD ACCURACY CLASSES – The limits of transformer correction factor in standard shall be as shown in table.

METERING ACCURACY CLASS	VOLTAGE TRANSFORMERS (at 100% rated voltage)		CURRENT TRANSFORMERS			
	RATIO CORRECTION FACTORS					
			At 100% rated current*		At 10% rated current	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
0.3	0.997	1.003	0.997	1.003	0.994	1.006
0.6	0.994	1.006	0.994	1.006	0.988	1.012
1.2	0.988	1.012	0.988	1.012	0.976	1.024

* For current transformers the 100% rated current limit also applies to the current corresponding to the continuous thermal current rating factor.

Accuracy statement (0.3, 0.6, 1.2) is not complete unless it is stated at a given burden. The following table defines the standard burdens for metering and relaying as well.

TECHNICAL DATA

TABLE 2

STANDARD BURDENS FOR CURRENT TRANSFORMERS WITH 5 A SECONDARY WINDINGS*

BURDENS	BURDEN DESIGNATION**	RESISTANCE (Ω)	INDUCTANCE (mH)	IMPEDANCE (Ω)	VOLTAMPERES (at 5 A)	POWER FACTOR
Metering burdens	B–0.1	0.09	0.116	0.1	2.5	0.9
	B–0.2	0.18	0.232	0.2	5.0	0.9
	B–0.5	0.45	0.580	0.5	12.5	0.9
	B–0.9	0.81	1.040	0.9	22.5	0.9
	B–1.8	1.62	2.080	1.8	45.0	0.9
Relaying burdens	B–1	0.50	2.300	1.0	25.0	0.5
	B–2	1.00	4.600	2.0	50.0	0.5
	B–4	2.00	9.200	4.0	100.0	0.5
	B–8	4.00	18.400	8.0	200.0	0.5

* If a current transformer secondary winding is rated at other than 5 A, ohmic burdens for specification and rating shall be derived by multiplying the resistance and inductance of the table $[5/(\text{ampere rating})]^2$, the VA at rated current, the power factor, and the burden designation remaining the same.

** These standard burden designations have no significance at frequencies other than 60 Hz.

There is another factor which must be considered, that is, phase error. The following table gives the maximum acceptable phase error associated with the standard accuracy classes.

TABLE 3

ACCURACY CLASSES	± PHASE ERROR AT 100% PRIMARY CURRENT	± PHASE ERROR AT 10% PRIMARY CURRENT
0.3	15 MINUTES	30 MINUTES
0.6	30 MINUTES	60 MINUTES
1.2	60 MINUTES	120 MINUTES

In summary, if you have a metering accuracy statement of "0.3 B0.5" it means the following:

(0.3) maximum ratio error of 0.3% at 100% of rated primary current or ±0.6% ratio error at 10% of rated primary current. With a maximum phase error of ±15 minutes at 100% rated primary current or ±30 minutes maximum phase error at 10% of rated primary current. All of the above is based on a burden of (B0.5) 0.5 OHMS at power factor of 0.9.

TECHNICAL DATA

CURRENT TRANSFORMERS RELAYING ACCURACY

All relaying accuracies are ±10% maximum ratio error when there is 20 times current flowing in the CT secondary (20 x 5A=100A). There are two designations, which are "C" and "T". Designations "C" stands for "Calculate" this type of CT's performanced can be very accurately calculated. The "T" designation stands for "Test". This type of CT's performance must be verified by testing. The following table gives the relaying accuracy designations:

TABLE 4

DESIGNATION	BURDEN	POWER FACTOR	SECONDARY VOLTAGE
C 10 or T10	0.1 Ω	0.5	10V
C 20 or T20	0.2 Ω	0.5	20V
C 50 or T50	0.5 Ω	0.5	50V
C 100 or T100	1.0 Ω	0.5	100V
C 200 or T200	2.0 Ω	0.5	200V
C 400 or T400	4.0 Ω	0.5	400V
C 800 or T800	8.0 Ω	0.5	800V

VOLTAGE TRANSFORMERS

Voltage transformers have the same accuracy classes as indicated in Table 1 (ie 0.3, 0.6 & 1.2). These accuracy classes must be given at a stated burden in order to be meaningful. The following table gives the standard burden data:

TABLE 5

VOLTAGE TRANSFORMER BURDEN DATA

BURDEN	VOLT AMPERES	POWER FACTOR	P.F. ANGLE
W	12.5	0.10	84.3°
X	25	0.70	45.6°
M	35	0.20	78.5°
Y	75	0.85	31.8°
Z	200	0.85	31.8°
ZZ	400	0.85	31.8°

In summary if you have a "0.6Y" accuracy and burden statement this means: (0.6) maximum ratio error of + 0.6% at a burden of 75VA with a power factor of 0.85.

TECHNICAL DATA

CURRENT TRANSFORMERS RATIO MODIFICATION

Relatively large changes in ratio may be acheived through the use of primary turns, For example:

TABLE 6

CT RATIO	NUMBER OF PRIMARY TURNS	MODIFIED RATIO
100:5A	2	50:5A
200:5A	2	100:5A
300:5A	2	150:5A
100:5A	3	33.3:5A
200:5A	3	66.6:5A
300:5A	3	100:5A
100:5A	4	25:5A
200:5A	4	50:5A
300:5A	4	75:5A

A primary turn is the number of times the primary conductor passes through the CT's window. The main advantage of this ratio modification is you maintain the accuracy and burden capabilities of the higher ratio. The higher the primary rating the better the accuracy and burden rating.

You can make smaller ratio modification adjustments by using additive or subtractive secondary turns. For example if you have a CT with a ratio of 100:5A.. By adding one additive secondary turn the ratio modification is 105:5A, by adding on subtractive secondary turn the ratio modification is 95:5A. Subtractive secondary turns are acheived by placing the "X1" lead through the window from the H1 side and out the H2 side. Additive secondary turns are acheieved by placing the "X1" lead through the window from the H2 and out the H1 side. So, when there is only one primary turn each secondary turn modifies the primary rating by 5 amperes. If there is more than one primary turn each secondary turn value is changed (i.e. 5A divided by 2 primary turns = 2.5A). The following table illustrates the effects of different combinations of primary and secondary turns:

TABLE 7

CT RATIO 100:5A

PRIMARY TURNS	SECONDARY TURNS	RATIO ADJUSTMENT
1	–0–	100:5A
1	1+	105:5A
1	1–	95:5A
2	–0–	50:5A
2	1+	52.5:5A
2	2–	45.0:5A
3	–0–	33.3:5A
3	1+	34.97:5A
3	1–	31.63:5A

TECHNICAL DATA

In summary, with the use of primary/secondary turns it is possible to modify any CT ratio. Since low ratio CT's generally have poorer performance characteristics and high ratio CT's have better performance. By using added primary/secondary turns you can modify a higher ratio CT to have a lower ratio and enjoy the better performance of the higher ratio.

TABLE 8

USE THIS TABLE TO DETERMINE SIZE WINDOW NEEDED FOR NUMBER AND PRIMARY CONDUCTOR(S)

WINDOW DIAMETER		1/2"	3/4"	1"	1 1/2"	2"	2 1/2"	3"	3 1/2"	4"	5"	6"
INSULATION TYPE RHW	AWG MCM											
	14	3	6	10	25	41	58	90	121	155	–	–
	12	3	5	9	21	35	50	77	103	132	–	–
	10	2	4	7	18	29	41	64	86	110	–	–
	8	1	2	4	9	16	22	35	47	60	94	137
	6	1	1	2	6	11	15	24	32	41	64	93
	4	1	1	1	5	8	12	18	24	31	50	72
	3	1	1	1	4	7	10	16	22	38	44	63
	2	–	1	1	4	6	9	14	19	24	38	56
	1	–	1	1	3	5	7	11	14	18	29	42
	0	–	1	1	2	4	6	9	12	16	25	37
	00	–	–	1	1	3	5	8	11	14	22	32
	000	–	–	1	1	3	4	7	9	12	19	28
	0000	–	–	1	1	2	4	6	8	10	16	24
	250	–	–	–	1	1	3	5	6	8	13	19
	300	–	–	–	1	1	3	4	5	7	11	17
	350	–	–	–	1	1	2	4	5	6	10	15
	400	–	–	–	1	1	1	3	4	6	9	14
	500	–	–	–	1	1	1	3	4	5	8	11
	600	–	–	–	1	1	1	2	3	4	6	9
	700	–	–	–	1	1	1	1	3	3	6	8
	750	–	–	–	–	1	1	1	3	3	5	8

BURDEN

Burden is the opposition to the flow of current from the transformers secondary. Burden may be expressed in terms of resistance or voltamperes. The following table may be used to convert voltampere values to resistance values for 5 amp secondary CT's:

TECHNICAL DATA

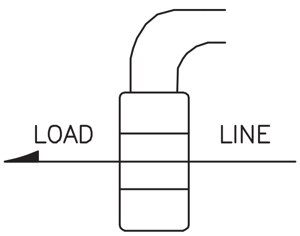
TABLE 9

VOLTAMPERE (VA)	RESISTANCE (Ω OHMS)
0.5	0.02
1.0	0.04
1.5	0.06
2.0	0.08
2.5	0.10
3.0	0.12
3.5	0.14
4.0	0.16
4.5	0.18
5.0	0.20
5.5	0.22
6.0	0.24
6.5	0.26
7.0	0.28
7.5	0.30
8.0	0.32
8.5	0.34
9.0	0.36
9.5	0.38
10.0	0.40
12.5	0.50
15.0	0.60
20.0	0.80
25.0	1.00
45.0	1.80
50.0	2.00
75.0	3.00
100.0	4.00

APPLICATION GUIDE

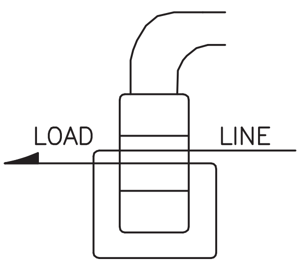
Primary Turn Ratio Modification

The nameplate of the current transformer is based on the condition that the primary conductor will be passed once through the transformer opening. The rating can be reduced in even multiples by looping this conductor two or more times through the opening. A transformer having a rating of 200 to 5 amperes will be changed to 50 to 5 amperes if four loops or turns are made with the primary cable as illustrated.



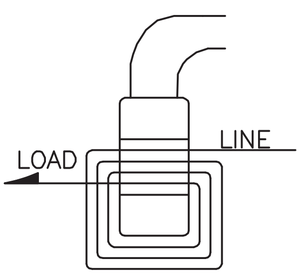
1 Primary Turn

NAMEPLATE RATIO	ACTUAL RATIO
100:5	100:5
150:5	150:5
200:5	200:5
300:5	300:5
400:5	400:5
500:5	500:5
600:5	600:5
800:5	800:5



2 Primary Turns

NAMEPLATE RATIO	ACTUAL RATIO
100:5	50:5
150:5	75:5
200:5	100:5
300:5	150:5
400:5	200:5
500:5	250:5
600:5	300:5
800:5	400:5



4 Primary Turns

NAMEPLATE RATIO	ACTUAL RATIO
100:5	25:5
150:5	37.5:5
200:5	50:5
300:5	75:5
400:5	100:5
500:5	125:5
600:5	150:5
800:5	200:5

Secondary Turn Ratio Modification

Formula: $$\frac{Ip}{Is} = \frac{Ns}{Np}$$

Where:
Ip — Primary Amperage
Is — Secondary Amperage
Np — Number of Primary Turns
Ns — Number of Secondary Turns

Example: A 300:5 Current Transformer —

$$\frac{300\ p}{5\ s} = \frac{60\,s}{1\,p}$$

(In practicality one turn is dropped from the secondary as a ratio correction factor).

The ratio of the current transformer can be modified by altering the number of secondary turns by forward or backwinding the secondary lead through the window of the current transformer.

By adding secondary turns the same primary amperage will result in a decrease in secondary output. By subtracting secondary turns the same primary amp-erage will result in greater secondary output.

Again using the 300:5 example adding five second-ary turns will require 325 amps on the primary to maintain the 5 amp secondary output or

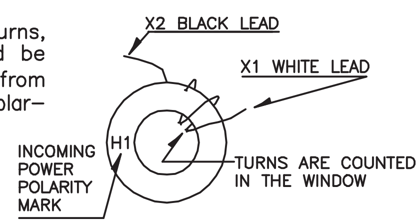
$$\frac{325\ p}{5\ s} = \frac{65\,s}{1\,p}$$

Deducting 5 secondary turns will only require 275 amps on the primary to maintain the 5 amp secondary output or

$$\frac{275\ p}{5\ s} = \frac{55\,s}{1\,p}$$

The above ratio modifications are achieved in the following manner:

To add secondary turns, the white lead should be wound through the CT from the side opposite the polar-ity mark.



To subtract secondary turns the white lead should be wound through the CT from the same side as the polarity mark.