Metrology Procedure Part C

Testing and Inspection Guidelines for metering installations in the NEM

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Current version release details

Version	Effective date	Summary of changes
1.0	01 December 2025	Initial Release

Note: There is a full version history at the end of this document.

1. Introduction

1.1. Purpose and scope

This is the Metrology Procedure: Part C (Procedure) made under clause 7.16.3 and 7.16.5 of the NER, which addresses testing and inspecting of *metering installations* in the *NEM* and incorporates the *Asset Management Strategy Guidelines* (NER S7.6.1(g)).

This Procedure has effect only for the purposes set out in the NER. The NER and the National Electricity Law prevail over this Procedure to the extent of any inconsistency.

This Procedure provides a guideline for MCs applying to AEMO for approval of an asset management strategy.

1.2. Definitions and interpretation

1.2.1. Glossary

Terms defined in the *National Electricity Law* and the NER have the same meanings in these Procedures unless otherwise specified in this clause.

Terms defined in the NER are intended to be identified in these Procedures by italicising them, but failure to italicise a defined term does not affect its meaning.

1.2.2. Interpretation

The following principles of interpretation apply to these Procedures unless otherwise expressly indicated:

(a) These Procedures are subject to the principles of interpretation set out in Schedule 2 of the *National Electricity Law*.

(b) In this document diagrams are provided as an overview. If there are ambiguities between a diagram and the text, the text shall take precedence.

(c) Related documents.

1.3. Related documents

Title	Location
Retail Market Procedures – Glossary and Framework	Retail Electricity Market Glossary and Framework
Metrology Procedure: Part A	National Electricity Market (NEM) Metrology Procedure
Service Level Procedure (MP)	Service Level Procedures

2. Routine Testing of Metering Installation Components

2.1. Initial Life of new Metering Installation Components

2.1.1. Initial Life Qualification

New *metering installation* components qualify for an initial life period, provided the MC can demonstrate it has:

(a) an endorsed accuracy test report, which is covered by a *NATA* ISO/IEC 17025 accreditation or another accreditation body which is a signatory of the International Laboratory Cooperation Mutual Recognition Arrangement (ILAC MRA); or

(b) test results tested using calibrated test equipment by a *NATA* accredited testing laboratory as per the Metering Provider Service Level Procedure (MP SLP) requirement and performed by an accredited *Metering Provider* (MP), accredited for the relevant categories of registration.

2.1.2. Component Testing Before Use

Where the MC cannot demonstrate a new *metering installation* component's compliance, then the MC must ensure that the *metering installation* component is tested by the MP before use.

2.1.3. Initial Life Determination

The initial life of new *metering installation* components is determined from the last accuracy test date as per section 2.1.1 of this Procedure.

2.1.4. Component Initial Life

The following periods are the initial life of each new *metering installation* component, before the MC is required to add it to routine testing:

(a) *High voltage* connected *meters* 5 years;

(b) Low voltage *current transformer* connected *meters* 7 years;

(c) Whole current (direct connected) *meters* 7 years;

(d) *Meters* with a new pattern or type (or variant of an existing pattern type) that will form part of sample testing, must undergo compliance testing within one to three years after initial installation to validate the compliance. If compliant, the initial life of *meters* is 7 years;

(e) Voltage Transformers 10 years; and

(f) Current Transformers 10 years.

2.2. Meter Testing

2.2.1. High Voltage Connected Meters

The MC's *asset management strategy* must specify the testing of *high voltage (HV)* connected *meters* in accordance with clause 7.9 and clause S7.6 of the NER.

2.2.2. Low Voltage Current Transformer Connected Meters

The MC's *asset management strategy* must specify the testing of low voltage *current transformer* (LV *CT*) connected *meters* in accordance with:

(a) clause 7.9 and clause S7.6 of the NER; or

(b) where eligible, an alternative test strategy following section 4 of this Procedure.

2.2.3. Whole Current (Direct Connected) Meters

The MC's *asset management strategy* must specify the testing of whole current (direct connected *meters*) in accordance with section 4 of this Procedure.

2.2.4. Meters Removed From The Field

Meters that have been removed from the field may be returned to the field for use only after being reverified in accordance with the National Measurement Act requirements.

2.3. Instrument Transformer Testing

2.3.1. Voltage Transformers

The MC's *asset management strategy* must specify the testing of *voltage transformers (VT)* in accordance with clause 7.9 and clause S7.6 of the NER.

2.3.2. High Voltage Current Transformers

The MC's *asset management strategy* must specify the testing of *high voltage current transformers* (*HV CT*) in accordance with clause 7.9 and clause S7.6 of the NER.

2.3.3. Low Voltage Current Transformers

The MC's *asset management strategy* must specify the testing of low voltage *current transformers* (LV *CT*) in accordance with:

(a) clause 7.9 and clause S7.6 of the NER; or

(b) where eligible, an alternative test strategy following section 4 of this Procedure.

3. Inspections of Metering Installations

3.1. High Voltage Metering Installation Inspections

The MC's *asset management strategy* must specify the inspection of high voltage (HV) *metering installations* in accordance with:

(a) clause 7.9 and clause S7.6 of the NER; and

(b) meet the enhanced physical inspection requirements of section 6.3 of this Procedure.

3.2. Low Voltage CT Metering Installation Inspections

The MC's *asset management strategy* must specify the inspection of low voltage *current transformer* (LV *CT*) *metering installations* in accordance with:

(a) clause 7.9 and clause S7.6 of the NER; or

(b) an alternative inspection strategy following section 6 and section 7 of this Procedure; and

(c) meet the enhanced physical inspection requirements of section 6.3 of this Procedure.

3.3. Whole Current Metering Installation Inspections

The MC's *asset management strategy* must specify the inspection of whole current (direct connected) *metering installations* in accordance with:

(a) section 6 and section 7 of this Procedure; and

(b) meet the enhanced physical inspection requirements of section 6.3 of this Procedure.

4. Sample Testing Strategy

4.1. Eligible Metering Installation Components

4.1.1. Low Voltage Current Transformer Connected Meters

Low voltage *current transformer* (LV *CT*) connected *meters,* where the annual energy throughput is less than 750MWh, may be sample tested.

Low voltage *current transformer* (LV *CT*) connected *meters,* where the annual energy throughput is greater than or equal to 750MWh, must be 100% tested in accordance with the NER.

4.1.2. Whole Current (Direct Connected) Meters

All whole current (direct connected) *meters* may be sample tested.

4.1.3. Low Voltage Current Transformers

Low voltage *current transformer* (LV *CT*) that form part of standard *current transformer* types, as outlined in Table 1, may be sample tested.

All non-standard *current transformer* types, ones that are not identified in Table 1, must be 100% tested in accordance with the NER.

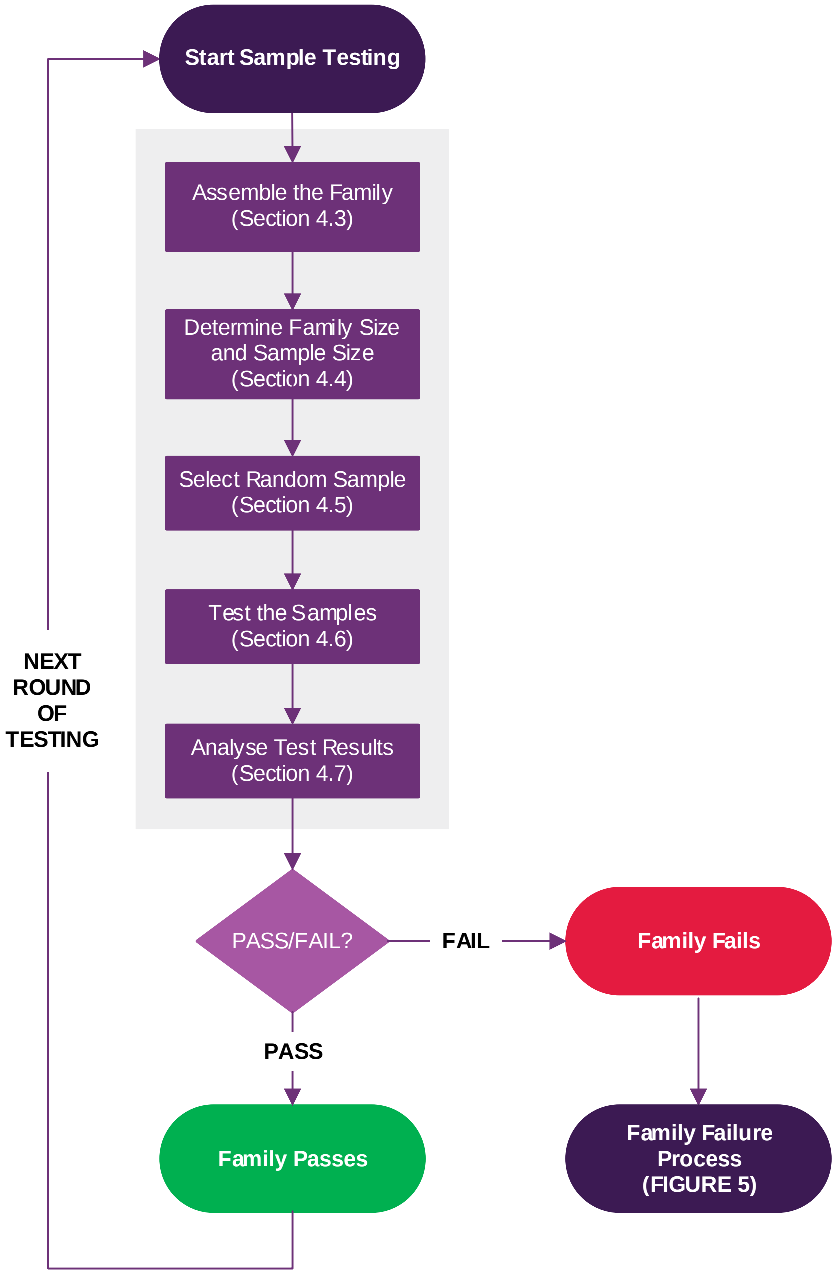
4.2. New Family Initial Compliance Life

A new family consists of new *metering installation* components, each component having its own component initial life, as defined in section 2.1 of this Procedure. The MC must ensure that the initial sample test is completed within the earliest component initial life of all the components that make up the family.

4.3. Sample Testing Process

Figure 1 presents an overview of the steps to be undertaken by an MC and subsequent actions required to complete the sample testing process.

Figure 1 Sample Testing Process



4.4. Criteria for Assembly and Delimitation of a Family

Family populations are to be selected carefully before commencing sample testing.

Where applicable, the assets must be homogeneous with respect to the characteristics listed in this section.

4.4.1. Meters

Family Characteristics

Only such *meters* that fulfil the following minimum requirements may be assembled into a family:

(a) Same manufacturer;

(b) Same type or model of the *meter*;

(c) Same year of production;

(d) Same accuracy class;

(e) Same type approval number or mark;

(f) Same date of initial or subsequent verification; and

(g) The following characteristics must be identical:

  (i) Connection Type (direct connect or low voltage *current transformer*);

  (ii) Nominal Voltage;

  (iii) Transitional Current;

  (iv) Maximum Current;

  (v) Current-carrying Capacity (maximum current/basic current proportion) up to 4 times or more than 4 times;

  (vi) Rated Current (for transformer operated *meters*) – all values mentioned in electrical energy standards; and

  (vii) Nominal Frequency.

Sub-Family Characteristics

The following are the sub-family characteristics which are to be considered for family population selection but is not limited to:

(a) Same batch number;

(b) Same geographical location; and

(c) Same installer.

4.4.2. Low Voltage Current Transformers

Family Characteristics

At a minimum, LV *CT*s must be categorised by design type. The standard *current transformer* types are listed in the below table.

Table 1 Current Transformer Types

Type	Ratio
A	150 / 300 / 600 : 5
B	400 / 800 / 1200 : 5
C	1000 / 2000 / 3000 : 5
S	200 : 5
T	800 : 5
U	2000 : 5
V	4000 : 5
W	1500 : 5

Sub-Family Characteristics

The following are the sub-family characteristics which are to be considered for LV *CT* family population selection:

(a) Same manufacturer (e.g. Email, Energy Controls, GEC, Nilsen, STEMAR, Warburton Franki);

(b) Same date of manufacture (or year of installation if unknown);

(c) Same design standard of manufacturer (e.g. *AS* 1675, *AS* 60044.1, *AS* 61869.2);

(d) Same accuracy class (e.g. class 0.5M, class 0.5S, class 0.5ME extended range); and

(e) Same geographical location.

4.4.3. Example of Family Assembly

The following is a simplified example using LV *CT*s to demonstrate how to assemble a family population for sample testing based on family and/or sub-family characteristics.

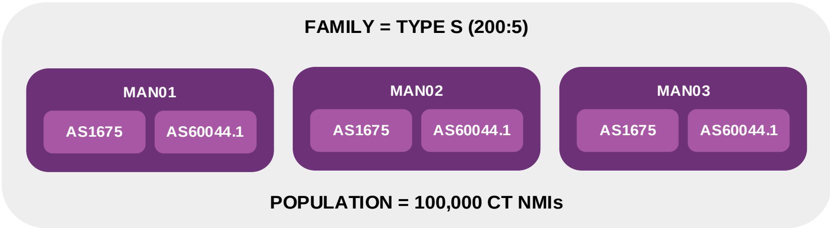
The extent a family is defined will depend on the general knowledge of a particular LV *CT* and balance between a more risk-averse approach, as it potentially means that a smaller population will fail, which results in a smaller family replacement.

For this example, there are three manufacturers (MAN01, MAN02 and MAN03) and two design standards (*AS* 1675 and *AS* 60044.1).

EXAMPLE 1 – Family Characteristics only

Under this example, only the *current transformer* type is used to define a family because there is no historical evidence to suggest that a sub-family characteristic may cause a family to fail.

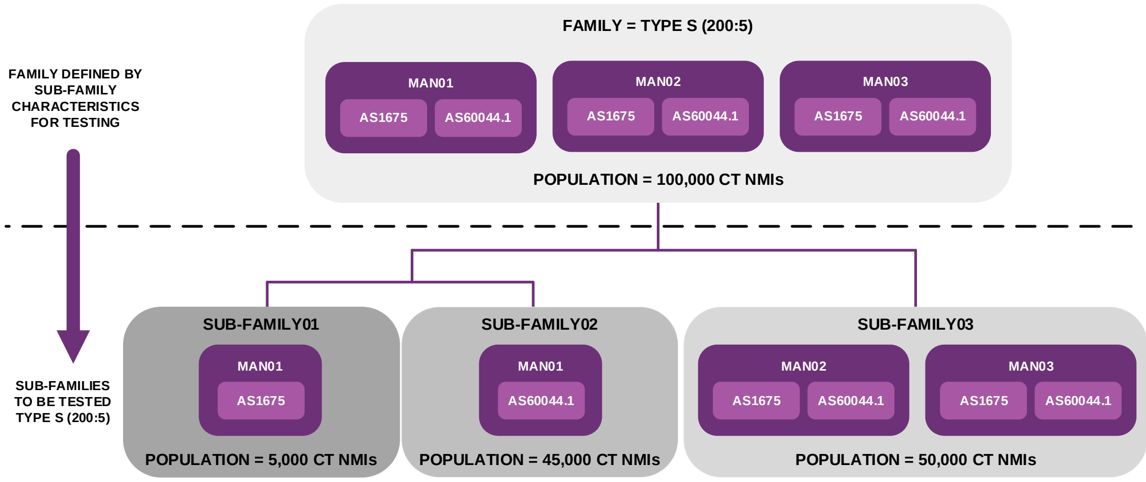
Figure 2 Example of Family selection based on Family Characteristics only



EXAMPLE 2 – Sub-Family Characteristics

Under this example, the *current transformer* type is further defined by the sub-characteristics to define the family because MAN01 has informed that their *current transformers* may not be performing as expected, so a more risk-averse approach is taken.

Table 2 Example of Family selection based on Sub-Family Characteristics



4.4.4. Redefining a Family due to family failure

It may be possible to redefine a family, due to a family failure, into sub-families if there is sufficient supporting evidence that a sub-family characteristic is the cause of the original family failure.

The MC will need to prepare the supporting evidence and present it to AEMO as a family can only be redefined into sub-families with the approval of AEMO as per section 5.3.

When a family is redefined, the original sample's test results must be retained and aligned to the new sample size and acceptance number (Ac) required for the new redefined sub-families. The sample selection order must be preserved as the redefined family may require a smaller sample.

All redefined sub-families will need to be tested in accordance with their new family population size.

Once a family has been redefined, it cannot be combined again into another family.

Below are the possible actions that can be taken after a family has been redefined into sub-families. The number of failed test results from the original family compared to the redefined sub-families' acceptance number (Ac), will determine the next course of action.

Table 3 Actions for redefined sub-families

Type	Ratio
Number of failed tests > (Ac)	FAIL FAMILY • Replace or 100% test as the number of failed test results already exceeds what is acceptable
Number of failed tests ≤ (Ac)	Test the redefined sub-families which will result in one of these two outcomes: • Number of failed tests > (Ac) = FAIL FAMILY • Number of failed tests ≤ (Ac) = PASS FAMILY (as approved by AEMO)

Using the family example provided in section 4.4.3 to come up with a typical testing scenario:

Round 1 Test = *current transformer* type (e.g. Type S - 200:5) = 100,000 CT NMIs.

Following the completion of the first round of sample testing, the results find that the family has failed. The suspected cause of the failure appears to be related to a single manufacturer and potentially an older design standard but there is uncertainty.

The next step would be to consult with AEMO to discuss the creation of potential sub-families based on the results found, to establish if a pattern can be identified.

Based on results, MAN01 is the suspected faulty sub-family and since it is uncertain whether design standards are a factor, there are two options when selecting sub-family groupings.

Round 2 Test = two options that can be taken.

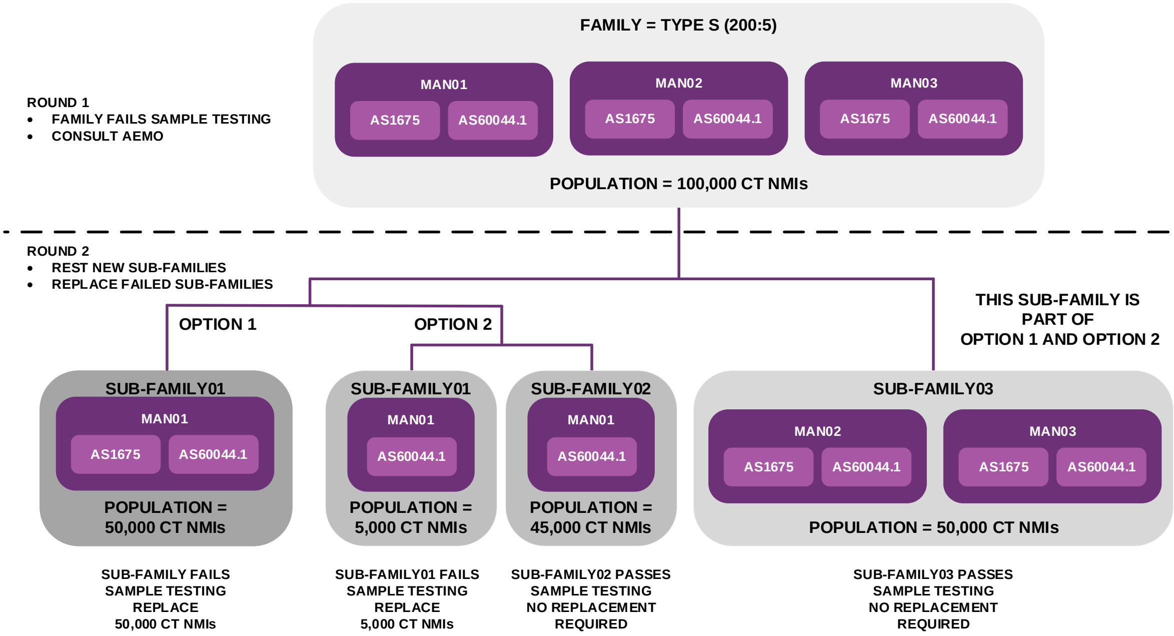
(a) Option 1 = MAN01 and MAN02 / MAN03

(b) Option 2 = MAN01 / *AS* 1675 and MAN01 / *AS* 60044.1 and MAN02 / MAN03

By choosing to retest the sub-family using the option 1 grouping, the whole population for the manufacture will need to be replaced if the sub-family fails.

By choosing to retest a sub-family using the option 2 groupings, there is an equal chance that the manufacturer will fail in one or both the design standards. Option 2, although it requires more testing, is the more risk-averse approach as it potentially means that a smaller population will fail, which results in a smaller family replacement.

Figure 3 Example of redefined Sub-Families



4.5. Determine Family Size and Sample Size

4.5.1. Meters

Sample testing approach chosen is based on *Australian Standard AS* 1199.2-2003, using Procedure A (in line with OIML G 20:2017 requirements) with the chosen Limiting Quality (LQ) of 8.

(a) Each MC must ensure the following steps are taken when determining their sample test strategy:

(i) Determine the family size based on the number of *meters*. The family size must include all untested and already sample tested *meters*;

(ii) For a new family, test using the single sample inspection criteria (as defined in Table 4 below);

(iii) For an existing family, test using either the single sample inspection criteria or the double sample inspection criteria (as defined in Table 4 and Table 5 below). The method that the MC choses will be determined by the MC's confidence level of how healthy that *meter* family is; and

(iv) Once testing of the family has commenced for that round of testing, the MC cannot change the criteria for testing and must complete testing as selected by either single sample inspection or double sample inspection.

Table 4 Sample Sizes and Acceptance and Reject Levels (Single Sample Inspection) Meters

Family Size (Population (p))		LQ = 8.0		
Min	**Max**	**Sample Size (*n*)**	**Accept (Ac)**	**Reject (Re)**
1	50	ALL	N/A	N/A
51	1200	50	1	2
1201	3200	80	3	4
3201	10000	125	5	6
10001	35000	200	10	11

* Sample Size and Acceptance and Rejection Levels tables are based on *AS* 1199.2 (Procedure A)

Table 5 Sample Sizes and Acceptance and Reject Levels (Double Sample Inspection) Meters

Family Size (Population (p))		LQ = 8.0					
Min	**Max**	**Sample**	**Sample Size (*n*)**	**Cumulative Sample Size (*n*)**	**Accept (Ac)**	**Reject (Re)**	**2nd Sample**
1	32	N/A	ALL	N/A	N/A	N/A	N/A
33	1200	First Second	32 32	32 64	0 1	2 2	1
1201	3200	First Second	50 50	50 100	1 4	4 5	2 to 3
3201	10000	First Second	80 80	80 160	2 6	5 7	3 to 4
10001	35000	First Second	125 125	125 250	5 12	9 13	6 to 8

* Sample Size and Acceptance and Rejection Levels tables are based on *AS* 1199.2 (Procedure A)

4.5.2. Low Voltage Current Transformers

Sample testing approach chosen is based on *Australian Standard AS* 1199.2-2003, using Procedure A with the chosen Limiting Quality (LQ) of 5.

(a) Each MC must ensure the following steps are taken when determining their sample test strategy:

(i) Determine the family size (must include previously sample tested LV *CTs*) based on the number of *NMIs*. The family size must include all untested and already sample tested LV *CTs*.

(ii) For a new family, test using the single sample inspection criteria (as defined in Table 6 below).

(iii) For an existing family, test using either the single sample inspection criteria or the double sample inspection criteria (as defined in Table 6 and Table 7 below). The method that the MC choses will be determined by the MC's confidence level of how healthy that LV *CT* family is.

(iv) Once testing of the family has commenced for that round of testing, the MC cannot change the criteria for testing and must complete testing as selected by either single sample inspection or double sample inspection.

Table 6 Sample Sizes and Acceptance and Reject Levels (Single Sample Inspection) LV CTs

Family Size (Population (p))		LQ = 5.0		
Min	**Max**	**Sample Size (*n*)**	**Accept (Ac)**	**Reject (Re)**
1	28	ALL	N/A	N/A
29	50	28	0	1
51	90	34	0	1
91	150	38	0	1
151	280	42	0	1
281	500	50	0	1
501	1200	80	1	2
1201	3200	125	3	4
3201	10000	200	5	6
10001	35000	315	10	11

* Sample Size and Acceptance and Rejection Levels tables are based on *AS* 1199.2 (Procedure A)

Table 7 Sample Sizes and Acceptance and Reject Levels (Double Sample Inspection) LV CTs

Family Size (Population (p))		LQ = 5.0					
Min	**Max**	**Sample**	**Sample Size (*n*)**	**Cumulative Sample Size (*n*)**	**Accept (Ac)**	**Reject (Re)**	**2nd Sample**
1	50	N/A	ALL	N/A	N/A	N/A	N/A
51	1200	First Second	50 50	50 100	0 1	2 2	1
1201	3200	First Second	80 80	80 160	1 4	4 5	2 to 3
3201	10000	First Second	125 125	125 250	2 6	5 7	3 to 4
10001	35000	First Second	200 200	200 400	5 12	9 13	6 to 8

* Sample Size and Acceptance and Rejection Levels tables are based on *AS* 1199.2 (Procedure A)

4.5.3. Double Inspection Criteria Process

Where the MC has chosen to use the double sample inspection criteria for their *meter* families or LV *CT* families, the MC must ensure the following steps are taken:

(i) If the first sample's number of non-conforming items equals the Accept (Ac) number of the first sample, then assess the family for compliance as per section 5 of this Procedure;

(ii) If the first sample's number of non-conforming items equals or exceeds the Reject (Re) number of the first sample, then fail the family;

(iii) If the first sample's number of non-conforming items equals the 2nd Sample number, then start to randomly draw a second sample and continue testing for family acceptance;

(iv) The Accept (Ac) and Reject (Re) numbers of the second sample are cumulative and must include all the test results (conforming and non-conforming) from the first sample; and

(v) Once the second sample is completed, assess the family for compliance in accordance with section 5 of this Procedure.

4.6. Select Random Sample

4.6.1. Randomisation Requirements

Before commencement of sample testing, the sample from each family must be drawn (i.e., sample list created) at random as outlined in section 4.6.3, without replacement (i.e., each site chosen as part of the sample will be excluded from the next round of sample testing), until the population is exhausted.

The random selection must be made in compliance with the rules of mathematical statistics. Random selection is where a sample (s) is taken from a population (p) in such a way that each item of interest has an equal probability of being chosen from population (p).

Metering components returned from BAU activities are not to be used as replacements for the defined sample.

4.6.2. Sample Size

Selected sample size is to be in accordance with the minimum required sample size n + 150% for the population (p) as outlined in section 4.5.

An additional 150% is chosen to cater for situations where reasonable endeavours have failed to facilitate the necessary testing, such as ‘access issue’, ‘isolation not possible’, ‘installation decommissioned’, or ‘physical damage’.

4.6.3. Randomisation Method

Unless the MC has an alternative method approved for random selection by AEMO in their *asset management strategy*, the method for random selection is as follows:

(a) For selection of *meters*:

(i) All *meters* from the same family to be assigned number 1 to population (p);

(ii) Using a random number generator, generate numbers at random between 1 and population (p), until sample size (n) + 150% is reached (or population (p) where sample size (n) is > 50% of population (p));

(iii) The sample of size (n) will be determined by the sequential order of the assigned number against each item of interest; and

(iv) If a *meter* was tested in the previous round of sample testing, it is to be skipped for the current round of sample testing and the next item of interest in the sequence is to be selected for testing. (**Note:** the *meter* that was skipped is eligible for random selection in the following round).

(b) For selection of LV *CTs*:

(i) All *NMI*s from the same family to be assigned number 1 to population (p);

(ii) Using a random number generator, generate numbers at random between 1 and population (p), until sample size (n) + 150% is reached (or population (p) where sample size (n) is > 50% of population (p));

(iii) The sample of size (n) will be determined by the sequential order of the assigned number against each item of interest;

(iv) If an LV *CT* was tested in the previous round of sample testing, it is to be skipped for the current round of sample testing and the next item of interest in the sequence is to be selected for testing. (**Note:** the LV *CT* that was skipped is eligible for random selection in the following round);

(v) If a *NMI* is for a *metering installation* that has multiple metering points and those multiple metering points each have a sets of LV *CT*s from the same family, then randomly select one set of LV *CT*s to test and identify which meter the set of LV *CT*s is connected to; and

(vi) If a *NMI* is for a *metering installation* that has multiple metering points and those multiple metering points each have a set of LV *CT*s from different families, that *NMI* is eligible for selection for each family that is installed at that *metering installation*.

4.7. Criteria for Testing

4.7.1. Meters

Display Test

The physical display (where a physical display is required under the requirements of the NER) shall be checked for legibility and correct operation. A *meter* with a failed physical display will not count as a non-conformance towards family acceptance, unless the *meter* has also failed accuracy testing. Instead, the MC must gather information (i.e., that might help find a faulty batch) about the *meters* where displays have failed and present the information to AEMO to determine what approach should be taken for the family.

Running with No Load Test

When the voltage is applied with no current flowing through the current circuit (the current circuit shall be an open circuit), the *meter* shall not register energy at any voltage between 0.8 U_{nom} and 1.1 U_{nom}.

The term I_{tr} (transitional current) is the declared value of current at and above which the *meter* purports to lie within the smallest maximum permissible error corresponding to the accuracy class of the *meter*.

The ratio $\frac{I_{max}}{I_{tr}}$ must be equal to or higher than 50 for whole current (direct connected) *meter* and must be equal or higher than 24 for a LV *CT* connected *meter*.

Accuracy Test

To accommodate a cohesive sample testing regime, testing of *meters* must be done in-situ or in a laboratory using *NATA* traceable test equipment to the limits of error outlined at the various power factors.

Table 8 Limits of Error Meters

	Unity	0.866 Lagging		0.5 Lagging		Zero
% Ib / In	**Active**	**Active**	**Reactive**	**Active**	**Reactive**	**Reactive**
5	± Nameplate Class	± Nameplate Class	± 2 x Nameplate Class			± 2 x Nameplate Class
20	± Nameplate Class	± Nameplate Class	± 2 x Nameplate Class	± Nameplate Class	± 2 x Nameplate Class	± 2 x Nameplate Class
100	± Nameplate Class	± Nameplate Class	± 2 x Nameplate Class	± Nameplate Class	± 2 x Nameplate Class	± 2 x Nameplate Class
20 Imax / 200	± Nameplate Class	± Nameplate Class	± 2 x Nameplate Class			± 2 x Nameplate Class

* Limits of Errors are based on NER

The 20% I_{max} test point is for whole current *meters* and the 200% I_n test point is for *meters* that are connected to *CT*s.

The value of the extended range test point is to be determined from the LV *CT* nameplate. If the extended range rating exceeds the *meter*'s operating capability, then the *meter* needs to be replaced with a suitable *meter* that can operate under the extended range conditions of the connected LV *CT*s.

Starting Current Test

An *meter* is deemed to be non-conforming if it does not start to register energy at 1.5 times the starting current.

4.7.2. Low Voltage Current Transformers

To accommodate a cohesive sample testing regime, testing of LV *CTs* must be done by either primary or secondary injection testing in-situ using *NATA* traceable test equipment to the limits of error outlined at 25% of rated burden resistive - unity power factor (i.e., pf = 1.0).

Table 9 Limits of Error LV CTs

% Rated Current	Current Error Limits	Phase Displacement Limits (Minutes)	Phase Displacement Limits (Crad)
5	± 1.5	± 90	± 2.7
20	± 0.75	± 45	± 1.35
100	± 0.5	± 30	± 0.9
Extended Range	± 0.5	± 30	± 0.9

* Limits of Errors are based on *AS 61869.2* and in line with the NER

LV *CTs* must be **demagnetised** before the commencement of testing. LV *CTs* may be tested before demagnetisation; however, the results can only be used to investigate effects of magnetisation and **will not** be considered part of the sample testing analysis by AEMO.

Multi-tap LV *CT*s must have all tap ratios tested.

4.8. Criteria for Test Result Analysis

A test item is deemed to have passed accuracy if the test results are within the limits of error outlined in section 4.6.

A test item is deemed to have failed accuracy if the test results are outside the limits of error outlined in section 4.6.

As the LV *CT* family size is determined by the number of *NMI*s, then all failed test results for that *NMI* will count as one failure towards family acceptance.

4.9. Testing Frequency

Assuming a family or sub-family has passed sample testing the following will apply.

4.9.1. Meters

Sample testing for low voltage current transformer connected *meters* (where eligible) and whole current (direct connected) *meters* will be required to be undertaken using the following maximum compliance periods, so long as MC demonstrates that drift performance of the family doesn't require testing earlier.

Table 10 Compliance Periods and Compliance Timeline

Test Cycle ID	Compliance Period (Years)	Age of Meter at Start of Test Cycle (Years)
Initial Test (New Family)	7	~ 3
1st Ongoing Test	5	10
2nd Ongoing Test	5	15
3rd Ongoing Test	3	20
4th Ongoing Test	3	23
Nth Ongoing Test	3	Previous Age + 3

<table>
<tr><th colspan="24">Year (Compliance Timeline)</th></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>3 YRS</td></tr>
<tr><td colspan="7">Initial Test</td><td colspan="5">First Test</td><td colspan="5">Second Test</td><td colspan="3">Third Test</td><td colspan="3">Fourth Test</td><td>Nth Test</td></tr>
<tr><td colspan="24">Maximum Compliance Period of Each Test Cycle</td></tr>
</table>

If the MC finds evidence that the collective performance of the family is projecting to exceed the boundaries of accuracy performance for that compliance period, the period must be reduced, so that the next round of compliance testing for that family is completed before that point in time.

Unless the MC has an alternative method approved for demonstrating drift performance of a family by AEMO in their *asset management strategy*, the method to determine drift performance of a family must be in accordance with Appendix B of this Procedure.

For metering families established under legacy sample testing arrangements prior to the effective date of this Procedure, the new test cycle will commence from the time that family's existing compliance period ends and must be placed in the relevant Test Cycle ID as identified in Table 10 based on age of the family. These families will need to be validated and checked to ensure they meet the requirements of section 4.4.1 of this Procedure. If not, they will need to be redefined to meet these requirements.

4.9.2. Low Voltage Current Transformers

Sample testing will be required to be undertaken on a 5 yearly rolling test cycle. This will ensure that testing resources can be scheduled across the NEM more efficiently.

Should a family or sub-family during the 5 yearly rolling test cycle show early indicators that it is likely to fail (or has failed), AEMO must be notified promptly to assess what further action will need to be taken for that family or sub-family prior the current test cycle ending.

5. Rules for Acceptance and Non-Acceptance

5.1. Acceptance

A family or sub-family is accepted if the number of non-conforming items found during sample testing is equal to or less than the acceptance number (Ac).

5.2. Non-conforming Items

Notwithstanding family or sub-family acceptance, any non-conforming items found during testing, whether part of sample or not, must be replaced with a like for like. If no like for like can be found, all items must be replaced.

Non-conforming items must be analysed to check for possible sub-family characteristic failures. The reasons that the non-conforming item failed the accuracy test are to be determined through analysis, the results of which are to be recorded.

5.3. Non-Acceptance and Resubmission

For sample testing, a family or sub-family is deemed unacceptable and a failure if the number of non-conforming items found during sample testing is greater than the acceptance number (Ac).

In the event of a family or sub-family failure, the consequences of which are family or sub-family replacement, the MC must consult with AEMO to develop a strategy, including the period, for the rectification of the family non-compliance. The strategy, including the period, for the rectification of the family non-compliance, is subject to approval of AEMO.

AEMO, in assessing the proposed strategy, will consider a:

(a) Retest of a sub-family, provided that sub-family characteristics have been identified and are the cause of the family failure;

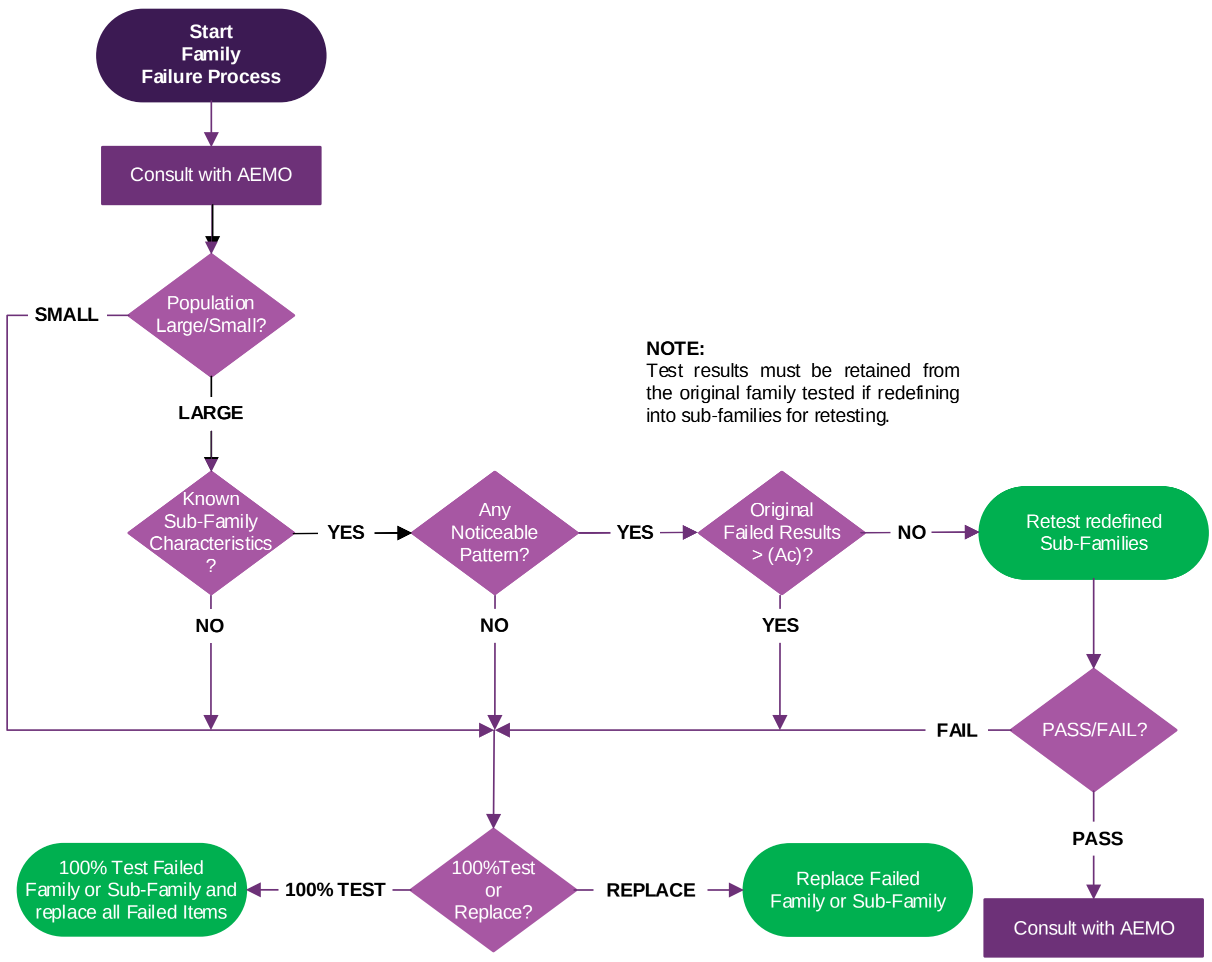
(b) 100% retest of the family and replace all failed items; or

(c) Full family replacement.

5.4. Family and Sub-Family Failure Process

The process that AEMO will follow in determining the appropriate course of action in the event of a family or sub-family failure is as follows.

Figure 4 Family Failure Process



6. Enhanced Physical Inspection Requirements

6.1. Inspection Methodology

To support a regimen of demonstrated compliance of *metering installations* through sample testing, an enhanced physical inspection program of the *metering installations* must be incorporated as part of the alternative testing practice.

The following inspection program items must be conducted as a minimum.

6.2. Inspection Frequency

Where the MC is testing in accordance with this Procedure, the MC must meet the following inspection frequencies:

(a) Where the MC does not have an alternative inspection practice approved by AEMO as part of an *asset management strategy*, as outlined in Section 7 of this Procedure, the inspection frequency is:

  (i) LV *CT metering installations* greater than or equal to 750MWh, no later than every 2.5 years.

  (ii) LV *CT metering installations* less than 750MWh, no later than every 5 years.

  (iii) Whole Current *metering installations*, no later than every 10 years.

(b) Where the MC does have an alternative inspection practice approved by AEMO as part of an *asset management strategy*, as outlined in Section 7 of this Procedure, the inspection frequency is:

  (i) LV *CT metering installations* greater than or equal to 750MWh, no later than every 5 years.

  (ii) LV *CT metering installations* less than 750MWh, no later than every 10 years.

  (iii) Whole Current *metering installations*, no later than every 15 years, unless otherwise agreed with AEMO.

6.3. Minimum Physical Inspection Requirements

The minimum requirements for a physical inspection are as follows:

Table 11 Minimum Physical Inspection Requirements

#	Inspection Item	WC	LV CT	HV
1	Ensure label applied to the *meter* is visibly displayed and information populated	✓	✓	✓
2	Ensure the *meter* display is working correctly	✓	✓	✓
3	Ensure the *meter* time is accurate	✓	✓	✓
4	Check that the *meter* status is in normal operating condition and that the correct *meter* program and firmware is installed for the required registers	✓	✓	✓
5	Check that stored *metering data* in the *meter* is correctly aligned with the *metering data* collected by the MDP for the relevant *metering installation* and *NMI*	✓	✓	✓
6	Check that security seals (or equivalent) are in place and ensure not broken	✓	✓	✓
7	Check for corrosion, damage, and atrophy	✓	✓	✓
8	Check the condition of the wiring and terminals	✓	✓	✓
9	Check position and tightness of metering links		✓	✓
10	Check secondary voltage circuit electrical protection (e.g. potential fuses or other protection devices) are functional, adequate, and rated appropriately for the *metering installation*		✓	✓
11	Measure the connected burden of *instrument transformers* and ensure within rated operating range (if safe to do so)		✓	✓
12	May undertake admittance test of *CT* (if test equipment available)		✓	✓
13	Undertake primary/secondary ratio check of *CT* (if safe to do so) or alternative available measurements and validate against available metering single line diagrams (SLDs)		✓	✓
14	Compare the secondary current value at *CT* test block against *metering register*.		✓	✓
15	Ensure correct polarity of all voltage and current connections and phase relationships		✓	✓
16	Ensure correct applied ratio to *meter* for connected *CT* ratio and *VT* ratio (where applicable)		✓	✓
17	Record the Power Factor of the *meter* (per phase)		✓	✓
18	Confirm *VT* ratio by inspecting the installation arrangement and validate against available metering single line diagrams (SLDs)			✓

6.4. Information Gathering and Reverification

The MC must ensure the following information, where applicable for each *metering installation* component, is gathered or reverified as part of the enhanced inspection:

(a) Installation date;

(b) Serial number;

(c) Manufacturer and model;

(d) Accuracy class;

(e) Design standard of manufacture;

(f) Connected ratio;

(g) Available ratios and type/form;

(h) *Meter* multiplier;

(i) Rated burden; and

(j) Encapsulated or exposed.

Additional comments where *metering installations* are subjected to non-standard installations and environments should be recorded as this may assist in sub-family analysis.

Where applicable, this information should be validated against MSATS and be amend where incorrect.

6.5. Unknown Assets

In situations where a physical inspection is unable to ascertain details that would allow the asset(s) to be classified into a family as outlined in section 5.3, those assets must at a minimum be either:

(a) Accuracy tested for compliance to the relevant test points in this Procedure; or

(b) Replaced with new asset(s) that can be classified into a family.

6.6. Isolated Failures

All assets which are found to have failed or to be non-compliant, including those found because of activities outside the alternative testing practice, must be analysed further to determine the cause of the non-compliance.

All information about the non-compliance must be recorded and stored for review for future family grouping considerations. These records of random failures may assist in identifying potential failure patterns across the *NEM*.

7. Alternative Inspection Practice Requirements

7.1. Alternative Inspection Practice Methodology

AEMO will assess whether the MC's proposal for an alternative inspection practice, that may include the use of remote condition monitoring to supplement a reduced physical inspection, demonstrates that it meets the intent of clause S7.6 of the NER and provides the same or better level of assurance that is provided in the NER for time-based testing and inspection.

AEMO will consider and assess each MC's *asset management strategy* on a case-by-case basis.

7.2. Alternative Inspection Practice Approval

For an alternative inspection practice in an *asset management strategy* to meet the intent of clause S7.6 and to be approved, the MC must demonstrate that their proposal is:

(a) Equivalent, or superior to the current arrangements set in clause S7.6 of the NER;

(b) Verifiable and auditable, with traceable results and record keeping; and

(c) Assessed and reported on at regular intervals to provide all parties confidence of ongoing suitability and applicability.

7.3. Alternative Inspection Practice Evidence

The MC must provide the following evidence to support the alternative inspection practice approval:

(a) Processes and Procedures for alternative inspection practices (e.g. remote condition monitoring events, other events, power quality, or other initiated triggers):

  (i) What are they?

  (ii) Why do these get monitored?

  (iii) At what frequency do they get monitored?

  (iv) How are these actioned?

(b) Systems (e.g. manual user requirements and any automated inputs and outputs);

(c) Feedback Loop Process (e.g. the findings that continually adjust the alternative inspection practice, which triggers a physical inspection or no physical inspection requirement for that *metering installation*);

(d) User Acceptance Testing (UAT)results of alternative practice working (e.g. where applicable simulation results of loss of power/phase, tamper, reverse current, over current, or malfunction etc.);

(e) Details of what reduced physical inspections are performed; and

(f) Summary report of annual findings from remote condition monitoring and physical inspections that is auditable and can be provided to AEMO on request.

7.4. Remote Condition Monitoring

For AEMO to consider the MC's alternative inspection practice with a reduced physical inspection, the MC must be able to, at minimum, have the following remote condition monitoring events available:

(a) Tamper (e.g. terminal cover removal);

(b) Over Current;

(c) Voltage Failure (e.g. Phase Failure);

(d) Power Failure (e.g. *meter* loss of supply);

(e) Reverse Power Flow (e.g. load only installation, night generation when not expected);

(f) *Meter* Hardware Check (e.g. *meter* or remote diagnosis of *meter* memory, instrumentation, program or other failure); and

(g) Time Tolerance.

7.5. Reduced Physical Inspection

The MC must provide information on what comprises a reduced physical inspection program. What type of physical inspection will be undertaken (e.g. 100% extended time-based, or combination of opportunistic inspections like proactive, reactive, sample inspections, and activities within other metering work programs, and what are they for each).

7.6. Alternative Inspection Practice Approval

AEMO will assess the evidence provided by the MC to support the proposed alternative inspection practice. AEMO will make a determination on whether the proposed alternative inspection practice will be approved as written in the MC's MAMS, if an alteration needs to be made to the MAMS by the MC, or not accepted.

8. Overall Error Requirements

The MC must ensure that a *metering installation* meets the overall error requirements for *active energy* and *reactive energy* as set out by the clause S7.4.3 of the NER. Unless the MC has an alternative method approved for Overall Error by AEMO in their *asset management strategy*, the Overall Error for each '% Rated Load' specified in the tables of clause S7.4.3 of the NER, must be determined as detailed below in this section.

The test results must be converted to operating conditions (e.g. measured operating burden) for the *metering installation*, which is detailed in Appendix C of this Procedure.

8.1. High Voltage Metering Installation Overall Error Estimation

High voltage metering installations have three sources of error, the *VTs*, *CTs* and *meter*. They can be found in two metering arrangements, three element (four wire) metering and two element (three wire) metering. Depending on the type of the arrangement in place, the way to calculate the Overall Error differs.

8.1.1. Three Element (Four Wire) Metering Arrangements

Step1: find the metering error of each element γ_R, γ_W and γ_B of the *instrument transformers*.

For active energy, the Element Metering Error is given by the formula:

$$\gamma_{PHASE} = \left(\frac{e_v}{100} + \frac{e_i}{100} + \tan\Phi \sin(\Phi_i - \Phi_v)\right) \times 100\%$$

For reactive energy, the Element Metering Error is given by the formula:

$$\gamma_{PHASE} = \left(\frac{e_v}{100} + \frac{e_i}{100} + \cot\Phi \sin(\Phi_v - \Phi_i)\right) \times 100\%$$

where,

e_v = the *VT* magnitude error in percent

e_i = the *CT* magnitude error in percent

Φ_v = the *VT* phase displacement in Centiradians (Crad)

Φ_i = the *CT* phase displacement in Centiradians (Crad)

Φ = the angle between the current and voltage and is positive if the current lags voltage

Step 2: for each of the active and reactive energy element metering errors, find the total metering error γ_{TOTAL} of the instrument transformers using the following formula:

$$Total\ Metering\ Error = \gamma_{TOTAL} = \frac{(\gamma_R + \gamma_W + \gamma_B)}{3}$$

Step 3: for active and reactive energy, find the overall error using the following formula:

$$Overall\ Error = \gamma_{TOTAL} + Meter\ Error\ (e_m)$$

8.1.2. Two Element (Three Wire) Metering Arrangements

Step1: find the metering error of each element γ_{RW} and γ_{BW} of the *instrument transformers* using the same formulas in step 1 of section 8.1.1 for *active energy* and *reactive energy*.

Step 2: for each of the *active energy* and *reactive energy* element metering errors, find the total metering error γ_{TOTAL} of the *instrument transformers*.

For *active energy*, the total metering error is given by the formula:

$$\gamma_{TOTAL} = \frac{\cos(\Phi_{RW})}{\cos(\Phi_{RW}) + \cos(\Phi_{BW})}(\gamma_{RW}) + \frac{\cos(\Phi_{BW})}{\cos(\Phi_{RW}) + \cos(\Phi_{BW})}(\gamma_{BW})$$

For *reactive energy*, the total metering error is given by the formula:

$$\gamma_{TOTAL} = \frac{\sin(\Phi_{RW})}{\sin(\Phi_{RW}) + \sin(\Phi_{BW})}(\gamma_{RW}) + \frac{\sin(\Phi_{BW})}{\sin(\Phi_{RW}) + \sin(\Phi_{BW})}(\gamma_{BW})$$

Step 3: for *active energy* and *reactive energy*, find the overall error using the formula in step 3 of section 8.1.1.

8.2. Low Voltage CT Metering Installation Overall Error Estimation

Low voltage *CT* connected *metering installations* have two sources of error, the *CTs* and *meter*.

Where both the LV *CTs* and *meter* at a *metering installation* have been tested, use the following method to determine the Overall Error.

Step1: find the metering error of each element γ_R, γ_W and γ_B of the *instrument transformers*.

For *active energy*, the Element Metering Error is given by the formula:

$$\gamma_{PHASE} = \left(\frac{e_i}{100} + \tan\Phi \sin(\Phi_i)\right) \times 100\%$$

For *reactive energy*, the Element Metering Error is given by the formula:

$$\gamma_{PHASE} = \left(\frac{e_i}{100} - \cot\Phi \sin(\Phi_i)\right) \times 100\%$$

where,

e_i = the *CT* magnitude error in percent

Φ_i = the *CT* phase displacement in Centiradians (Crad)

Φ = the angle between the current and voltage and is positive if the current lags voltage

Step 2: for each of the *active energy* and *reactive energy* element metering errors, find the total metering error γ_{TOTAL} of the *instrument transformers* using the following formula:

$$Total\ Metering\ Error = \gamma_{TOTAL} = \frac{(\gamma_R + \gamma_W + \gamma_B)}{3}$$

Step 3: for *active energy* and *reactive energy*, find the overall error using the following formula:

$$Overall\ Error = \gamma_{TOTAL} + Meter\ Error\ (e_m)$$

Where an LV *CT metering installation* that has an overall error calculation performed fails to meet the NER requirements, the MC must notify AEMO to aid in determining if there may be a pattern to look out for.

Where LV *CTs* and/or LV *CT meters* are sample tested, for those LV *CTs* and/or LV *CT meters* that did not get tested, provided that the family or sub-family as a sample pass testing requirements of this Procedure, then the LV *CT metering installations* will be deemed to meet the Overall Error requirements of the NER based on the sample of Overall Error calculations performed on the *metering installations* tested.

8.3. Whole Current Metering Installation Overall Error Estimation

Whole current (direct connected) *metering installations* have one source of error, the *meter*.

Provided that the *meter* tested passes testing requirements of this Procedure, the *meter* will be deemed to meet the Overall Error requirements of the NER.

Where *meters* are sample tested, for those *meters* that did not get tested, provided that the family or sub-family as a sample pass testing requirements of this Procedure, then the whole current (direct connected) *metering installations* will be deemed to meet the Overall Error requirements of the NER based on the sample of Overall Error results of the *metering installations* tested.

9. Asset Management Strategy and Test Plan Requirements

9.1. MC Asset Management Strategy

The MC *asset management strategy* is a document that details an MC's testing and inspection strategy for *metering installation* assets that the MC is responsible for (nominated MC in MSATS).

The MC *asset management strategy*, irrespective of whether the MC is testing and inspecting in accordance with the NER or this Procedure, must be submitted to AEMO for approval.

The MC must have the following information in the *asset management strategy*:

Table 12 Essential components of the MC Asset Management Strategy

Category	Details
Scope	• MC business name and participant IDs covered under the MC's *asset management strategy* • Assets covered • Summary of assets history (e.g. age profile, refurbishments etc) • Forecast of future assets to be installed • Period for which the strategy is valid • List of MPs and their participant IDs utilising the MC's *asset management strategy*
Methodology	• Method selected to test (e.g. time-based testing or sample-based testing) for each asset covered • Inspection program for each *metering installation* type • Type of test for each *instrument transformer* (e.g. primary injection or alternative method as approved by AEMO, etc) • Manifestation of the test plan (i.e., ensure MPs test plans align with MC's *asset management strategy*)
Sample Testing Details	• Family groupings / sizes and sample sizes (noting that the MC must size families in order that they can be rectified within the timeframes specified in the NER should the family be deemed to failed under section 5 of this Procedure) • Management of family failures (i.e., financial resources, personnel resources, and equipment logistics)
Delivery	• Essential contact information relating to the MC's *asset management strategy* • Sign off for the MC's *asset management strategy* by authorised level of authority

9.2. MP Test Plan

The MP test plan is a document prepared by an MP that must align with an AEMO approved MC *asset management strategy*.

The MP test plan can be one document that aligns with multiple MC *asset management strategies*, or can be multiple documents (i.e., one for each MC's *asset management strategy*).

The MP test plan(s) must be registered with AEMO so that AEMO can correlate against AEMO approved MC *asset management strategies*.

Table 13 Essential components of the MP Test Plan

Category	Details
Scope	• The MC *asset management strategies* that the MP test plan aligns with • List of MCs and their participant IDs covered under the MP test plan • MC's Assets covered • Period for which the test plan is valid
Testing Process	• Details of test equipment used • *NATA* traceability of test equipment used • Expected uncertainties of test results • How testing will be performed (e.g. field and laboratory testing)
Test Capabilities	• Details of internal test capabilities to perform the work • Details of external test capabilities to perform the work (Noting that for new sub-contractors, MP must ensure MP complies with accreditation general checklist items 42 to 45, before submitting test plan to AEMO)
Delivery	• Essential contact information relating to the MP test plan • Sign off for the MP test plan by authorised level of authority

9.3. Document Format Requirements

The MC *asset management strategy*, and the MP test plan must be submitted track changed against the previously submitted version in either word (*.docx) format or searchable saved PDF (*.pdf) format. This will allow AEMO to better assess the relevant sections of each.

Do not provide a scanned version as the quality of content can be pixelated and hard to read

9.4. MC Asset Management Strategy Revocation

AEMO may revoke an approval of an MC's *asset management strategy* where there is evidence that the MC is:

(a) Failing to comply with an approved asset management strategy;

(b) Found to have materially breached their obligations in the NER; or

(c) Failing to take corrective and preventative actions in response to critical performance and compliance issues identified within audit findings or AEMO performance reports.

10. Reporting Requirements

10.1. MC's Annual Summary Report

The MC must prepare an annual summary report of activities performed in the previous Australian financial year (i.e. for period of 01 July PREVIOUS YEAR to 30 June CURRENT YEAR) and submit it to AEMO within the first three months of each new Australian financial year.

The MC's annual summary report must include the following information:

(a) Where time-based testing, findings and cause of failure of each non-conforming item, list of sites tested and inspected, list of non-tested and non-inspected sites and the reason why;

(b) Where sample-based testing, family acceptance of each family and proposed extension periods in accordance with this Procedure and cause of failure of each non-conforming item;

(c) Where sample-based testing, full list of random samples selected upfront before the commencement of sample testing (attached as an appendix), and which were tested and which were not and the reason why not, this needs to be auditable with version history;

(d) Details of physical inspections conducted learnings and findings;

(e) If approved by AEMO, details of alternate inspections conducted, learnings and findings; and

(f) Details of testing and inspection programs, are they tracking on time, and if not why?

10.2. Accuracy Test Reports

As part of the MC's Annual Summary Report, where the non-confirming item has failed due to accuracy, the MC must provide AEMO with the MP's accuracy test report for that non-confirming item.

11. Approval Process of Asset Management Strategies

11.1. Queuing Policy

AEMO expects all MCs to demonstrate good faith and respond expeditiously to queries from AEMO when submitting an *asset management strategy* for review, in accordance with this Procedure. The MC's responsiveness when addressing requests for further information or resubmission of *asset management strategy* will be taken into consideration when AEMO is required to assess more than one MC *asset management strategy* at a time.

AEMO will prioritise its assessment of each *asset management strategy* on the basis of the responsiveness demonstrated by each MC in its pursuit of the *asset management strategy* approval, especially when AEMO has sought further information or required the MC to review and update their *asset management strategy*.

Upon receipt of an MC's *asset management strategy*, AEMO will assign a placement in the queue for assessment and notify the MC of their queue position.

11.2. AEMO's Assessment

AEMO will review the MC's *asset management strategy* and supporting documentation within 20 business days once it has reached the top of the queue and will notify the MC of its queries or concerns and agree on a due date with the MC by which a response is required from the MC.

Provided the MC responds to AEMO's queries or concerns by the due date, the MC will not lose its place in the queue.

An MC's *asset management strategy* will be placed at the end of the queue if the MC:

(a) Does not provide any response to AEMO's queries, or provide the requested documentation by the date agreed upon by the MC with AEMO; or

(b) Provides inadequate responses to AEMO's queries or not all the requested information by the date agreed upon by the MC with AEMO, and AEMO reasonably considered that AEMO does not have sufficient information to continue the review of the MC's *asset management strategy*.

11.3. Matters Taken into Consideration

An MC's *asset management strategy* submitted for AEMO's approval will be considered on its merits and no previous grant of an approval will be taken as creating a binding precedent on AEMO.

AEMO will make the following considerations when approving an MC's *asset management strategy*:

(a) The contents of the *asset management strategy* and it's alignment with the NER and this Procedure;

(b) Supporting evidence, procedures and processes justifying the *asset management strategy*;

(c) MC's compliance with current AEMO approved *asset management strategy*;

(d) MC's compliance with recent audit findings and AEMO's performance reports;

(e) MC's nominated MP's compliance with the registered test plan, audit findings and AEMO's performance reports;

(f) MC's nominated MDP's compliance with audit findings and AEMO's performance reports;

(g) MC's annual summary report; and

(h) The nature of any active AEMO issued Notice of Breach.

Appendix A. Terminology

A.1 Statistical Terms

The following definitions apply:

A.1.1 Limiting Quality (LQ)

The consumers risk of having a non-conforming meter.

A.1.2 Acceptable Quality Limit (AQL)

The producer's risk of manufacturing a non-conforming meter.

A.1.3 Family Characteristics

Characteristics of items (metering components) that are homogeneous which determine a family.

A.1.4 Sub-Family Characteristics

Sub characteristics of items that are homogeneous which determine a sub-family.

A.1.5 Family [Population / Inspection Lot]

Quantity of items submitted for testing or inspection.

A.1.6 Family Size [Population (p)]

Number of items in the family.

A.1.7 Sample

Number of items taken from a family for sample inspection.

A.1.8 Sample Size (n)

Number of items in the sample.

A.1.9 Cumulative Sample Size (n_K)

Cumulative sample sizes in double sampling; for the first sample, the cumulative sample size corresponds to the sample size of the first sample; for the second sample, it corresponds to the sum of the sample sizes of the first and the second samples.

A.1.10 Sampling Inspection

Inspection based on a sampling instruction in the case of which the family is assessed in accordance with the result obtained for a single sample or, if necessary, for various samples.

A.1.11 Single Sampling Inspection

The decision whether or not the criteria defined in the sampling instruction are complied with is taken on the basis of a single sample.

A.1.12 Double Sampling Inspection

The decision whether or not the criteria defined in the sampling instruction are complied with is taken on the basis of the first sample or, depending on the result of the first sample, on the basis of the combined first and second sample.

A.1.13 Sampling Instruction

Instruction for taking one or, if necessary, several samples, and for evaluating the result with regard to acceptance or rejection of a family.

A.1.14 Sampling Plan

Compilation of sampling instructions according to general aspects in order to limit the risk of non-conforming items being tested.

A.1.15 Acceptance

Conclusion that a family satisfies the requirement criteria defined in the sampling instruction.

A.1.16 Acceptance Number (Ac)

Highest number of non-conforming items specified in the sampling instructions, or the specified highest number of non-conformities in the individual samples that permits acceptance of the family.

A.1.17 Rejection

Conclusion that the family does not satisfy the requirement criteria stated in the sampling instruction.

A.1.18 Rejection Number (Re)

Lowest number of non-conforming items or lowest number of non-conformities in the individual samples specified in the sampling instructions in the case of which the family is rejected.

A.1.19 2^{nd} Sample Number

Lowest number of non-conforming items or lowest number of non-conformities in the individual samples specified in the sampling instructions in the case of which the family is permitted to select a second sample for a double sampling inspection.

A.1.20 Non-Conforming Items

Item, one or more characteristics of which do not meet the requirements criteria stated in the sampling instruction.

A.2 Metrological Terms

The following terms apply:

A.2.1 current (I)

Value of the electrical current flowing through the meter

Note: The term 'current' in this Procedure indicates r.m.s. (root mean square) values unless otherwise specified.

A.2.2 base current (I_b)

Value of current in accordance with which the relevant performance of a direct connected meter are fixed.

A.2.3 rated current (I_n)

Value of current in accordance with which the relevant performance of a transformer operated meter are fixed.

A.2.4 starting current (I_{st})

Lowest value of current specified by the manufacturer at which the meter should register electrical energy at unity power factor and, for poly-phase meters, with balanced load.

A.2.5 minimum current (I_{min})

Lowest value of current at which the meter is specified by the manufacturer to meet the accuracy requirements.

A.2.6 transitional current (I_{tr})

Value of current at and above which the meter is specified by the manufacturer to lie within the smallest maximum permissible error corresponding to the accuracy class of the meter.

A.2.7 maximum current (I_{max})

Highest value of current at which the meter is specified by the manufacturer to meet the accuracy requirements.

A.2.8 instrument transformer

A transformer intended to supply measuring instruments, meters, relays and other similar apparatus.

A.2.9 current transformer

An instrument transformer in which the secondary current, in normal conditions of use, is substantially proportional to the primary current and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections.

A.2.10 current error (ratio error)

The error which a transformer introduced into the measurement of a current and which arises from the fact that the actual transformation ratio is not equal to the rated transformation ratio.

The current error expressed in per cent is given by the formula:

$$Current\ error\ \% = \frac{K_n I_s - I_p \times 100}{I_p}$$

where,

Kn = the rated transformer ratio

I_p = the actual primary current

I_s = the actual secondary current when I_p is flowing, under the conditions of measurement.

A.2.11 phase displacement

The difference in phase between primary and secondary current vectors, the direction of the vectors being so chosen that the angle is zero for a perfect transformer.

The phase displacement is said to be positive when the secondary current vector leads the primary current vector. It is usually expressed in minutes or centiradians (crad).

Note: The definition is strictly correct for sinusoidal currents only.

Appendix B.Annual Average Drift of Family

B.1 Definition of Drift

The Vocabulary in Metrology (VIM) defines drift as:

'Continuous or incremental change over time in indication, due to changes in metrological properties of a measuring instrument' (4.21).

B.2 Methodology

The reason for an MC to determine the annual average drift of a family is to verify whether the next test sample should be retested at the maximum compliance period as specified in section 4.9.1 of this Procedure, or if a reduced period is required where there is evidence that the family will drift out of compliance sooner than the maximum compliance period.

As an MC will use a sample testing approach, there is a limitation in how the value of drift can be represented. Under sample-based testing not every *meter* installed will have its own drift value calculated. An assumption must be made that all *meters* from the same family manufactured at the same time, under the same conditions and using the same electronic components, will be susceptible to a similar drift rate. Therefore, by finding the annual average drift of a family, it will account for any uncertainties between various test equipment used and the periods between last two test dates.

The annual average drift of a family needs to be calculated for each test point to check if there is any correlation between the different test points.

B.3 How to calculate drift of a family

B.3.1 Example test data for one test point

The following data is a small sample that is used to demonstrate how drift is calculated for Test Point 1.

Table 14 Example test data for Test Point 1

Sample No	Meter ID/Serial	Most Recent Test Date (t_2)	Most Recent Test Result (y_2)	Previous Test Date (t_1)	Previous Test Result (y_1)
1	Meter 1	1/01/2023	1.253	1/01/2018	1.023
2	Meter 2	28/02/2023	-1.222	26/02/2013	-0.688
3	Meter 3	1/01/2023	1.049	1/01/2022	0.999
4	Meter 4	9/11/2023	0.102	9/11/2021	-0.011
5	Meter 5	5/06/2023	-0.823	5/06/2021	-0.925

B.3.2 Drift since Last Test Report

The following formula is used to calculate the total drift for the *meter* between the last two test reports.

$$Meter_{Drift} = \delta y = y_2 - y_1$$

where,

$Meter_{Drift}$ = total drift between two test results of *meter*

y_2 = most recent test result

y_1 = previous test result

Excel Example:

DRIFT CALCULATOR									
		C	D	E	F	G	H	I	J
TEST POINT ID	Test Point 1								
Sample No	Meter ID/Serial	Most Recent Test Date (t_2)	Most Recent Test Result (y_2)	Previous Test Date (t_1)	Previous Test Result (y_1)	Days Between Test ($\delta t = t_2 - t_1$)	$Meter_{Drift}$ ($\delta y = y_2 - y_1$)	$\lvert Meter_{Drift}\rvert$ Per Day	$Meter_{Drift}$ Per Annum
1	Meter 1	1/01/2023	1.253	1/01/2018	1.023	1826	=D8-F8	0.0001259584	0.04563

B.3.3 Convert Drift to Drift per Annum

As *meters* may be tested on different days and therefore have varying dates between most recent test result and previous test result, the total drift of each *meter* needs to be converted to something that can be comparable between each *meter*. In order to convert the value, an assumption is made that the drift is linear with time (t_n) as the *meter* ages.

Step 1: Convert the $Meter_{Drift}$ value from B.3.2 to $Meter_{Drift\ Per\ Day}$ value using the following formula:

$$Meter_{Drift\ Per\ Day} = \left|\frac{\delta y}{\delta t}\right| = \left|\frac{y_2 - y_1}{t_2 - t_1}\right| = \left|\frac{Meter_{Drift}}{Number\ of\ days\ between\ two\ Tests}\right|$$

where,

$Meter_{Drift\ Per\ Day}$ = linear drift rate per day of *meter*

| | = absolute value so that all values can be averaged irrespective of the direction *meter* drifts

t_2 = most recent test date

t_1 = previous test date

Excel Example:

DRIFT CALCULATOR									
		C	D	E	F	G	H	I	J
TEST POINT ID	Test Point 1								
Sample No	Meter ID/Serial	Most Recent Test Date (t_2)	Most Recent Test Result (y_2)	Previous Test Date (t_1)	Previous Test Result (y_1)	Days Between Test ($\delta t = t_2 - t_1$)	$Meter_{Drift}$ ($\delta y = y_2 - y_1$)	$\lvert Meter_{Drift}\rvert$ Per Day	$Meter_{Drift}$ Per Annum
1	Meter 1	1/01/2023	1.253	1/01/2018	1.023	1826	0.23000	=ABS(H8/G8)	0.04563

Step 2: Convert the $Meter_{Drift\ Per\ Day}$ value to $Meter_{Drift\ Per\ Annum}$ value using the following formula:

$$Meter_{Drift\ Per\ Annum} = Meter_{Drift\ Per\ Day} \times 365.25\ days$$

Excel Example:

DRIFT CALCULATOR

		C	D	E	F	G	H	I	J
TEST POINT ID	Test Point 1								
Sample No	Meter ID/Serial	Most Recent Test Date (t_2)	Most Recent Test Result (y_2)	Previous Test Date (t_1)	Previous Test Result (y_1)	Days Between Test ($\delta t = t_2 - t_1$)	$Meter_{Drift}$ ($\delta y = y_2 - y_1$)	$\lvert Meter_{Drift} \rvert$ Per Day	$Meter_{Drift}$ Per Annum
1	Meter 1	1/01/2023	1.253	1/01/2018	1.023	1826	0.23000	0.0001259584	=I8*362.25

B.3.4 Average Drift of Family

Once the $Meter_{Drift\ Per\ Annum}$ value has been calculated for each *meter*, these need to be averaged to determine the average drift of family, using the following formula:

$$Family\ Average\ Meter_{Drift\ Per\ Annum} = \overline{\delta y} = \frac{1}{n}\sum_{i=1}^{n}\frac{\delta y}{\delta t} = \frac{\sum Meter_{Drift\ Per\ Annum}\ Values}{Number\ of\ Samples}$$

where,

$Family\ Average\ Meter_{Drift\ Per\ Annum}$ = average of all *meter* annual drift values in sample

Number of Samples = number of samples test for the family.

Excel Example:

DRIFT CALCULATOR

Family Average $Meter_{Drift\ Per\ Annum}$	=AVERAGE(J8:J207)		
Standard Deviation Most Recent Sample:	1.098368		
Mean Most Recent Sample:	0.071800		

		G	H	I	J
TEST POINT ID	Test Point 1				
Sample No	Meter ID/Serial	Days Between Test ($\delta t = t_2 - t_1$)	$Meter_{Drift}$ ($\delta y = y_2 - y_1$)	$\lvert Meter_{Drift} \rvert$ Per Day	$Meter_{Drift}$ Per Annum
1	Meter 1	1826	0.23000	0.0001259584	0.04563
2	Meter 2	3654	-0.53400	0.0001461412	0.05294
3	Meter 3	365	0.05000	0.0001369863	0.04962
4	Meter 4	730	0.11300	0.0001547945	0.05607
5	Meter 5	730	0.10200	0.0001397260	0.05062
6					
7					

Appendix C. Conversion Equations

This appendix is provided for information purposes only. Where the MC is already performing overall error calculations using results converted to measured operating burden using their own method, that is also acceptable to AEMO.

Where the MC is using their own method, the MC should confirm that the results are similar to the results using the formulae in this appendix if calculated conversions are involved.

This appendix provides useful formulae that will assist MC's meet their compliance with overall error requirements of the NER at measured operating burden, should an MC choose to adopt this appendix.

These formulae are from Australian Standards and AEMO's Metrology for the NEM training course, which provides a detailed understanding of the practical use and can be adopted easily in Excel.

C.1 Converting Minutes to Centiradians

To calculate the Overall Error, the phase error needs to be in Centiradians. Some test equipment records the phase error in minutes, which needs to be converted to radians to calculate the Overall Error of the *metering installation*.

Φ_{rad} is given by the formula:

$$\Phi_{Crad} = \left(\frac{\Phi_{min}}{60}\right) \times \left(\frac{\pi}{180}\right) \times 100$$

where,

Φ_{min} = the *VT* or *CT* phase error minutes (min)

Φ_{Crad} = the *VT* or *CT* phase error Centiradians (Crad)

π = 3.14159

1 minute of arc = 0.0291 Centiradians

Example: $\Phi_{min} = 20$

$$\Phi_{Crad} = \left(\frac{\Phi_{min}}{60}\right) \times \left(\frac{\pi}{180}\right) \times 100$$

$$\Phi_{Crad} = \left(\frac{20}{60}\right) \times \left(\frac{3.14159}{180}\right)$$

$$\Phi_{Crad} = 0.582\ Crad$$

C.2 Converting Current Transformers Test Results

C.2.1 Non-Compensated Current Transformers (PF 1.0 to PF 0.8)

For non-compensated (i.e. no turns compensation) current transformers, to calculate the ratio error and phase displacement at power factor 0.8 based on a measurement performed with power factor 1.0 for a given test burden, use the formulae from *Australian Standard AS* 61869.2.

This method operates on the basis that the errors at zero total burden may be assumed to be zero, hence a simplified formula and is ideal where the testing is performed at only one burden (e.g. 25% burden), like for sample testing of low voltage current transformers.

Do not use this method if there is any doubt that the current transformer has been manufactured without any turns compensation, otherwise the converted results will not be accurate. Instead use the method detailed in section C.2.3 of this Procedure.

Ratio Error ($\varepsilon_{0.8}$) Formula:

$$\varepsilon_{0.8} = \frac{\left((R + 0.8B)\varepsilon_{1.0} - 0.6B\Delta\Phi_{1.0}\right)}{(R + B)}$$

Phase Displacement ($\Delta\Phi_{0.8}$) Formula:

$$\Delta\Phi_{0.8} = \frac{\left((R + 0.8B)\Delta\Phi_{1.0} + 0.6B\Delta\varepsilon_{1.0}\right)}{(R + B)}$$

where,

$\varepsilon_{0.8}$ = calculated ratio error (in percent) at test burden with power factor 0.8

$\Delta\Phi_{0.8}$ = calculated phase displacement (in Centiradians) at test burden with power factor 0.8

$\varepsilon_{1.0}$ = measured ratio error (in percent) at test burden with power factor 1.0

$\Delta\Phi_{1.0}$ = measured phase displacement (in Centiradians) at test burden with power factor 1.0

R = secondary winding resistance (in ohms Ω) at ambient temperature

B = test burden (in ohms Ω) with power factor 1.0

C.2.2 Non-Compensated Current Transformers (PF 0.8 to PF 1.0)

For non-compensated (i.e. no turns compensation) current transformers, to calculate the ratio error and phase displacement at power factor 1.0 based on a measurement performed with power factor 0.8 for a given test burden, using the formulae from section C.2.1 of this Procedure, the following formulae have been derived.

This method operates on the basis that the errors at zero total burden may be assumed to be zero, hence a simplified formula and is ideal where the testing is performed at only one burden (e.g. 25% burden), like for sample testing of low voltage current transformers.

Do not use this method if there is any doubt that the current transformer has been manufactured without any turns compensation, otherwise the converted results will not be accurate. Instead use the method detailed in section C.2.4 of this Procedure.

Ratio Error ($\varepsilon_{1.0}$) Formula:

$$\varepsilon_{1.0} = \frac{\big((R+B)(R+0.8B)\varepsilon_{0.8} + 0.6B\Delta\Phi_{0.8}(R+B)\big)}{((R+0.8B)^2 + (0.6B)^2)}$$

Phase Displacement ($\Delta\Phi_{1.0}$) Formula:

$$\Delta\Phi_{1.0} = \frac{\big((R+B)(R+0.8B)\Delta\Phi_{0.8} - 0.6B\varepsilon_{0.8}(R+B)\big)}{((R+0.8B)^2 + (0.6B)^2)}$$

where,

$\varepsilon_{1.0}$ = calculated ratio error (in percent) at test burden with power factor 1.0

$\Delta\Phi_{1.0}$ = calculated phase displacement (in Centiradians) at test burden with power factor 1.0

$\varepsilon_{0.8}$ = measured ratio error (in percent) at test burden with power factor 0.8

$\Delta\Phi_{0.8}$ = measured phase displacement (in Centiradians) at test burden with power factor 0.8

R = secondary winding resistance (in ohms Ω) at ambient temperature

B = test burden (in ohms Ω) with power factor 1.0

C.2.3 Current Transformers (PF 1.0 to PF 0.8)

This method can be used for all current transformers and provides a good approximation, which can be set up in excel. This method operates on the basis of linear error lines that intersect at a zero burden point that correspond to a CT with zero winding resistance. It requires magnitude and phase errors at two test points,25% and 100% of the applied burden at a specified current both measured at power factor 1.0, in addition to the CT's winding resistance. It also allows you to convert the results to operating burden.

Step 1: Calculate the $\text{Total Burden}_{100\%}$ and $\text{Total Burden}_{25\%}$ using the following Formulae:

$$Total\ Burden_{100\%}\ (TB_{100\%})\ =\ \sqrt{(Z_b + R)^2}$$

$$Total\ Burden_{25\%}\ (TB_{25\%})\ =\ \sqrt{((Z_b \times 0.25 + R)^2)}$$

Step 2: Calculate the Line Length Factor using the following Formula:

$$Line\ Length\ Factor\ (LLF) = \frac{1}{1 - \left(\frac{TB_{25\%}}{TB_{100\%}}\right)}$$

Step 3: Calculate the Slope Error Line at power factor 1.0 using the following Formula:

$$Slope_{1.0}\ (m_1) = \frac{\Delta\Phi_{1.0(100\%)} - \Delta\Phi_{1.0(25\%)}}{\varepsilon_{1.0(100\%)} - \varepsilon_{1.0(25\%)}}$$

Step 4: Calculate the Slope Error Line at power factor 0.8 using the following Formula:

$$Slope_{0.8}\ (m_2) = \frac{m_1 + 0.75}{1 - (0.75 \times m_1)}$$

Step 5: Calculate the delta (δ) between the two Slopes, m_1 and m_2 using the following Formula:

$$\delta = \sqrt{\frac{1 + (m_1)^2}{1 + (m_2)^2}}$$

Step 6: Calculate the ratio error $\varepsilon_{(0\%)}$ and then the phase displacement $\Delta\Phi_{(0\%)}$ with no applied burden or winding resistance using the following Formulae:

$$\varepsilon_{(0\%)} = \left(LLF \times \varepsilon_{1.0(25\%)}\right) + \varepsilon_{1.0(100\%)}(1 - LLF)$$

$$\Delta\Phi_{(0\%)}\ = m_1\left(\varepsilon_{(0\%)} - \varepsilon_{1.0(100\%)}\right) + \Delta\Phi_{1.0(100\%)}$$

Step 7: Calculate the ratio errors $\varepsilon_{0.8(100\%)}$ and $\varepsilon_{0.8(25\%)}$ using the following Formulae:

$$\varepsilon_{0.8(100\%)} = \delta\left(\varepsilon_{1.0(100\%)} - \varepsilon_{(0\%)}\right) + \varepsilon_{(0\%)}$$

$$\varepsilon_{0.8(25\%)} = \delta\left(\varepsilon_{1.0(25\%)} - \varepsilon_{(0\%)}\right) + \varepsilon_{(0\%)}$$

Step 8: Calculate the phase displacements $\Delta\Phi_{0.8(100\%)}$ and $\Delta\Phi_{0.8(25\%)}$ using the following Formulae:

$$\Delta\Phi_{0.8(100\%)} = m_2(\varepsilon_{0.8(100\%)} - \varepsilon_{(0\%)}) + \Delta\Phi_{(0\%)}$$

$$\Delta\Phi_{0.8(25\%)} = m_2(\varepsilon_{0.8(25\%)} - \varepsilon_{(0\%)}) + \Delta\Phi_{(0\%)}$$

where,

pf = power factor

$\varepsilon_{1.0(100\%)}$ = measured ratio error (in percent) at 100% burden with pf 1.0

$\Delta\Phi_{1.0(100\%)}$ = measured phase displacement (in Centiradians) at 100% burden with pf 1.0

$\varepsilon_{1.0(25\%)}$ = measured ratio error (in percent) at 25% burden with pf 1.0

$\Delta\Phi_{1.0(25\%)}$ = measured phase displacement (in Centiradians) at 25% burden with pf 1.0

$\varepsilon_{(0\%)}$ = calculated ratio error (in percent) with no applied burden or winding resistance

$\Delta\Phi_{(0\%)}$ = calculated phase displacement (in Centiradians) with no applied burden or winding resistance

$\varepsilon_{0.8(100\%)}$ = calculated ratio error (in percent) at 100% burden with pf 0.8

$\Delta\Phi_{0.8(100\%)}$ = calculated phase displacement (in Centiradians) at 100% burden with pf 0.8

$\varepsilon_{0.8(25\%)}$ = calculated ratio error (in percent) at 100% burden with pf 0.8

$\Delta\Phi_{0.8(25\%)}$ = calculated phase displacement (in Centiradians) at 100% burden with pf 0.8

B_{op} = measured operating burden (in ohms Ω)

Z_b = rated burden impedance (in ohms Ω)

R = secondary winding resistance (in ohms Ω) at ambient temperature

m_1 = slope error line at pf 1.0

m_2 = slope error line at pf 0.8

C.2.4 Current Transformers (PF 0.8 to PF 1.0)

This method can be used for all current transformers and provides a good approximation, which can be set up in excel. This method operates on the basis of linear error lines that intersect at a zero burden point that correspond to a CT with zero winding resistance. It requires magnitude and phase errors at two test points, 25% and 100% of the applied burden at a specified current both measured at power factor of 0.8, in addition to the CT's winding resistance. It also allows you to convert the results to operating burden.

Step 1: Calculate the Burden Resistance and Burden Reactance using the following Formulae:

$$Burden\ Resistance\ (B_{resist}) = Z_b \times 0.8$$

$$Burden\ Reactance(B_{react}) \ = Z_b \times 0.6$$

Step 2: Calculate the $\text{Total Burden}_{100\%}$ and $\text{Total Burden}_{25\%}$ using the following Formulae:

$$Total\ Burden_{100\%}\ (TB_{100\%}) \ = \sqrt{((B_{resist} + R)^2 + (B_{react})^2)}$$

$$Total\ Burden_{25\%}\ (TB_{25\%}) \ = \sqrt{((B_{resist} \times 0.25 + R)^2 + (B_{react} \times 0.25)^2)}$$

Step 3: Calculate the Line Length Factor using the following Formula:

$$Line\ Length\ Factor\ (LLF) = \frac{1}{1 - \left(\frac{TB_{25\%}}{TB_{100\%}}\right)}$$

Step 4: Calculate the Slope Error Line at power factor 0.8 using the following Formula:

$$Slope_{0.8}\ (m_1) = \frac{\Delta\Phi_{0.8(100\%)} - \Delta\Phi_{0.8(25\%)}}{\varepsilon_{0.8(100\%)} - \varepsilon_{0.8(25\%)}}$$

Step 5: Calculate the Slope Error Line at power factor 1.0 using the following Formula:

$$Slope_{1.0}\ (m_2) = \frac{m_1 - 0.75}{1 + (0.75 \times m_1)}$$

Step 6: Calculate the delta (δ) between the two Slopes, m_1 and m_2 using the following Formula:

$$\delta = \sqrt{\frac{1 + (m_1)^2}{1 + (m_2)^2}}$$

Step 7: Calculate the ratio error $\varepsilon_{(0\%)}$ and then the phase displacement $\Delta\Phi_{(0\%)}$ with no applied burden or winding resistance using the following Formulae:

$$\varepsilon_{(0\%)} = \left(LLF \times \varepsilon_{0.8(25\%)}\right) + \varepsilon_{0.8(100\%)}(1 - LLF)$$

$$\Delta\Phi_{(0\%)} \ = m_1\left(\varepsilon_{(0\%)} - \varepsilon_{0.8(100\%)}\right) + \Delta\Phi_{0.8(100\%)}$$

Step 8: Calculate the ratio errors $\varepsilon_{1.0(100\%)}$ and $\varepsilon_{1.0(25\%)}$ using the following Formulae:

$$\varepsilon_{1.0(100\%)} = \delta\left(\varepsilon_{0.8(100\%)} - \varepsilon_{(0\%)}\right) + \varepsilon_{(0\%)}$$

$$\varepsilon_{1.0(25\%)} = \delta\left(\varepsilon_{0.8(25\%)} - \varepsilon_{(0\%)}\right) + \varepsilon_{(0\%)}$$

Step 9: Calculate the phase displacements $\Delta\Phi_{1.0(100\%)}$ and $\Delta\Phi_{1.0(25\%)}$ using the following Formulae:

$$\Delta\Phi_{1.0(100\%)} = m_2\left(\varepsilon_{1.0(100\%)} - \varepsilon_{(0\%)}\right) + \Delta\Phi_{(0\%)}$$

$$\Delta\Phi_{1.0(25\%)} = m_2\left(\varepsilon_{1.0(25\%)} - \varepsilon_{(0\%)}\right) + \Delta\Phi_{(0\%)}$$

where,

pf = power factor

$\varepsilon_{0.8(100\%)}$ = measured ratio error (in percent) at 100% burden with pf 0.8

$\Delta\Phi_{0.8(100\%)}$ = measured phase displacement (in Centiradians) at 100% burden with pf 0.8

$\varepsilon_{0.8(25\%)}$ = measured ratio error (in percent) at 25% burden with pf 0.8

$\Delta\Phi_{0.8(25\%)}$ = measured phase displacement (in Centiradians) at 25% burden with pf 0.8

$\varepsilon_{(0\%)}$ = calculated ratio error (in percent) with no applied burden or winding resistance

$\Delta\Phi_{(0\%)}$ = calculated phase displacement (in Centiradians) with no applied burden or winding resistance

$\varepsilon_{1.0(100\%)}$ = calculated ratio error (in percent) at 100% burden with pf 1.0

$\Delta\Phi_{1.0(100\%)}$ = calculated phase displacement (in Centiradians) at 100% burden with pf 1.0

$\varepsilon_{1.0(25\%)}$ = calculated ratio error (in percent) at 100% burden with pf 1.0

$\Delta\Phi_{1.0(25\%)}$ = calculated phase displacement (in Centiradians) at 100% burden with pf 1.0

B_{resist} = resistive component burden (in ohms Ω) with pf 0.8

B_{react} = reactive component burden (in ohms Ω) with pf 0.8

B_{op} = measured operating burden (in ohms Ω)

Z_b = rated burden impedance (in ohms Ω)

R = secondary winding resistance (in ohms Ω) at ambient temperature

m_1 = slope error line at pf 0.8

m_2 = slope error line at pf 1.0

C.2.5 Current Transformers (PF 0.8 100% Burden to PF 1.0 100% Burden)

This method can be used for all current transformers that have two test results at different power factors in accordance with *AS* 61869.2. It requires magnitude and phase errors at two test points, one at 25% of the applied burden at a specified current measured at power factor of 1.0, and the other at 100% of the applied burden at a specified current measured at power factor of 0.8, in addition to the CT's winding resistance. It also allows you to convert the results to operating burden.

Step 1: Calculate ρ ratio using the following Formula:

$$\rho = \frac{R}{Z_b}$$

Step 2: Calculate geometric scaling factor G using the following Formula:

$$G = \sqrt{0.4\rho^2 + 0.5\rho + 0.6625}$$

Step 3: Calculate the ratio errors $\varepsilon_{1.0(100\%)}$ using the following Formula:

$$\varepsilon_{1.0(100\%)} = \varepsilon_{1.0(25\%)} + \left(\frac{0.75}{G}\right)\left[\left(\frac{0.6(1+\rho)}{G}\right)\left(\varepsilon_{0.8(100\%)} - \varepsilon_{1.0(25\%)}\right) + \sqrt{1-\left(\frac{0.6(1+\rho)}{G}\right)^2}\left(\Delta\Phi_{0.8(100\%)} - \Delta\Phi_{1.0(25\%)}\right)\right]$$

Step 4: Calculate the phase displacements $\Delta\Phi_{1.0(100\%)}$ using the following Formula:

$$\Delta\Phi_{1.0(100\%)} = \Delta\Phi_{1.0(25\%)} + \left(\frac{0.75}{G}\right)\left[\sqrt{1-\left(\frac{0.6(1+\rho)}{G}\right)^2}\left(\Delta\Phi_{0.8(100\%)} - \Delta\Phi_{1.0(25\%)}\right) - \left(\frac{0.6(1+\rho)}{G}\right)\left(\varepsilon_{0.8(100\%)} - \varepsilon_{1.0(25\%)}\right)\right]$$

where,

pf = power factor

$\varepsilon_{0.8(100\%)}$ = measured ratio error (in percent) at 100% burden with pf 0.8

$\Delta\Phi_{0.8(100\%)}$ = measured phase displacement (in Centiradians) at 100% burden with pf 0.8

$\varepsilon_{1.0(25\%)}$ = measured ratio error (in percent) at 25% burden with pf 1.0

$\Delta\Phi_{1.0(25\%)}$ = measured phase displacement (in Centiradians) at 25% burden with pf 1.0

$\varepsilon_{1.0(100\%)}$ = calculated ratio error (in percent) at 100% burden with pf 1.0

$\Delta\Phi_{1.0(100\%)}$ = calculated phase displacement (in Centiradians) at 100% burden with pf 1.0

Z_b = rated burden impedance (in ohms Ω)

R = secondary winding resistance (in ohms Ω) at ambient temperature

ρ = ratio of the total burden that is consumed internally by the CT's winding resistance

G = geometric scaling factor used to normalise and rotate the error triangle formed between measured test points in magnitude-phase error space

C.3 Converting Voltage Transformers Test Results

C.3.1 Voltage Transformers (PF 0.8 to PF 1.0)

This method can be used for all voltage transformers and provides a good approximation, which can be set up in excel. It requires magnitude and phase errors at 25% and 100% of the rated burden. It also allows you to convert the results to operating burden.

Step 1: Calculate the Slope Error Line at power factor 0.8 using the following Formula:

$$Slope_{0.8}\ (m_1) = \frac{\Delta\Phi_{0.8(100\%)} - \Delta\Phi_{0.8(25\%)}}{\varepsilon_{0.8(100\%)} - \varepsilon_{0.8(25\%)}}$$

Step 2: Calculate the Slope Error Line at power factor 1.0 using the following Formula:

$$Slope_{1.0}\ (m_2) = \frac{m_1 + 0.75}{1 - (0.75 \times m_1)}$$

Step 3: Calculate the delta (δ) between the two Slopes, m_1 and m_2 using the following Formula:

$$\delta = \sqrt{\frac{1 + (m_1)^2}{1 + (m_2)^2}}$$

Step 4: Calculate the ratio error $\varepsilon_{(0\%)}$ and then the phase displacement $\Delta\Phi_{(0\%)}$ with no applied burden or winding resistance using the following Formulae:

$$\varepsilon_{(0\%)} = \left(1.333 \times \varepsilon_{0.8(25\%)}\right) - \left(0.333 \times \varepsilon_{0.8(100\%)}\right)$$

$$\Delta\Phi_{(0\%)} = m_1\left(\varepsilon_{(0\%)} - \varepsilon_{0.8(100\%)}\right) + \Delta\Phi_{0.8(100\%)}$$

Step 5: Calculate the ratio errors $\varepsilon_{1.0(100\%)}$ and $\varepsilon_{1.0(25\%)}$ using the following Formulae:

$$\varepsilon_{1.0(100\%)} = \delta\left(\varepsilon_{0.8(100\%)} - \varepsilon_{(0\%)}\right) + \varepsilon_{(0\%)}$$

$$\varepsilon_{1.0(25\%)} = \delta\left(\varepsilon_{0.8(25\%)} - \varepsilon_{(0\%)}\right) + \varepsilon_{(0\%)}$$

Step 6: Calculate the phase displacements $\Delta\Phi_{1.0(100\%)}$ and $\Delta\Phi_{1.0(25\%)}$ using the following Formulae:

$$\Delta\Phi_{1.0(100\%)} = m_2\left(\varepsilon_{1.0(100\%)} - \varepsilon_{(0\%)}\right) + \Delta\Phi_{(0\%)}$$

$$\Delta\Phi_{1.0(25\%)} = m_2\left(\varepsilon_{1.0(25\%)} - \varepsilon_{(0\%)}\right) + \Delta\Phi_{(0\%)}$$

where,

pf = power factor

$\varepsilon_{0.8(100\%)}$ = measured ratio error (in percent) at 100% burden with pf 0.8

$\Delta\Phi_{0.8(100\%)}$ = measured phase displacement (in Centiradians) at 100% burden with pf 0.8

$\varepsilon_{0.8(25\%)}$ = measured ratio error (in percent) at 25% burden with pf 0.8

$\Delta\Phi_{0.8(25\%)}$ = measured phase displacement (in Centiradians) at 25% burden with pf 0.8

$\varepsilon_{(0\%)}$ = calculated ratio error (in percent) with no applied burden

$\Delta\Phi_{(0\%)}$ = calculated phase displacement (in Centiradians) with no applied burden

$\varepsilon_{1.0(100\%)}$ = calculated ratio error (in percent) at 100% burden with pf 1.0

$\Delta\Phi_{1.0(100\%)}$ = calculated phase displacement (in Centiradians) at 100% burden with pf 1.0

$\varepsilon_{1.0(25\%)}$ = calculated ratio error (in percent) at 100% burden with pf 1.0

$\Delta\Phi_{1.0(25\%)}$ = calculated phase displacement (in Centiradians) at 100% burden with pf 1.0

B_{op} = measured operating burden (in VA)

Z_b = rated burden impedance (in VA)

m_1 = slope error line at pf 0.8

m_2 = slope error line at pf 1.0

C.3.2 Voltage Transformers (PF 1.0 to PF 0.8)

This method can be used for all voltage transformers and provides a good approximation, which can be set up in excel. It requires magnitude and phase errors at 25% and 100% of the rated burden. It also allows you to convert the results to operating burden.

Step 1: Calculate the Slope Error Line at power factor 1.0 using the following Formula:

$$Slope_{1.0}\ (m_1) = \frac{\Delta\Phi_{1.0(100\%)} - \Delta\Phi_{1.0(25\%)}}{\varepsilon_{1.0(100\%)} - \varepsilon_{1.0(25\%)}}$$

Step 2: Calculate the Slope Error Line at power factor 0.8 using the following Formula:

$$Slope_{0.8}\ (m_2) = \frac{m_1 - 0.75}{1 + (0.75 \times m_1)}$$

Step 3: Calculate the delta (δ) between the two Slopes, m_1 and m_2 using the following Formula:

$$\delta = \sqrt{\frac{1 + (m_1)^2}{1 + (m_2)^2}}$$

Step 4: Calculate the ratio error $\varepsilon_{(0\%)}$ and then the phase displacement $\Delta\Phi_{(0\%)}$ with no applied burden or winding resistance using the following Formulae:

$$\varepsilon_{(0\%)} = \left(1.333 \times \varepsilon_{1.0(25\%)}\right) - \left(0.333 \times \varepsilon_{1.0(100\%)}\right)$$

$$\Delta\Phi_{(0\%)} = m_1\left(\varepsilon_{(0\%)} - \varepsilon_{1.0(100\%)}\right) + \Delta\Phi_{1.0(100\%)}$$

Step 5: Calculate the ratio errors $\varepsilon_{0.8(100\%)}$ and $\varepsilon_{0.8(25\%)}$ using the following Formulae:

$$\varepsilon_{0.8(100\%)} = \delta\left(\varepsilon_{1.0(100\%)} - \varepsilon_{(0\%)}\right) + \varepsilon_{(0\%)}$$

$$\varepsilon_{0.8(25\%)} = \delta\left(\varepsilon_{1.0(25\%)} - \varepsilon_{(0\%)}\right) + \varepsilon_{(0\%)}$$

Step 6: Calculate the phase displacements $\Delta\Phi_{0.8(100\%)}$ and $\Delta\Phi_{0.8(25\%)}$ using the following Formulae:

$$\Delta\Phi_{0.8(100\%)} = m_2\left(\varepsilon_{0.8(100\%)} - \varepsilon_{(0\%)}\right) + \Delta\Phi_{(0\%)}$$

$$\Delta\Phi_{0.8(25\%)} = m_2\left(\varepsilon_{0.8(25\%)} - \varepsilon_{(0\%)}\right) + \Delta\Phi_{(0\%)}$$

where,

pf = power factor

$\varepsilon_{1.0(100\%)}$ = measured ratio error (in percent) at 100% burden with pf 1.0

$\Delta\Phi_{1.0(100\%)}$ = measured phase displacement (in Centiradians) at 100% burden with pf 1.0

$\varepsilon_{1.0(25\%)}$ = measured ratio error (in percent) at 25% burden with pf 1.0

$\Delta\Phi_{1.0(25\%)}$ = measured phase displacement (in Centiradians) at 25% burden with pf 1.0

$\varepsilon_{(0\%)}$ = calculated ratio error (in percent) with no applied burden

$\Delta\Phi_{(0\%)}$ = calculated phase displacement (in Centiradians) with no applied burden

$\varepsilon_{0.8(100\%)}$ = calculated ratio error (in percent) at 100% burden with pf 0.8

$\Delta\Phi_{0.8(100\%)}$ = calculated phase displacement (in Centiradians) at 100% burden with pf 0.8

$\varepsilon_{0.8(25\%)}$ = calculated ratio error (in percent) at 100% burden with pf 0.8

$\Delta\Phi_{0.8(25\%)}$ = calculated phase displacement (in Centiradians) at 100% burden with pf 0.8

m_1 = slope error line at pf 1.0

m_2 = slope error line at pf 0.8

C.4 Converting Test Results to Operating Burden

C.4.1 Current Transformers Test Results at Operating Burden

The current transformer test results that were converted from power factor of 0.8 to power factor of 1.0 based on C.2 of this Procedure, can be used to calculate approximate accuracy results at operating burden,

Step 1: Calculate the ratio error $\varepsilon *_{(0\%)}$ and then the phase displacement $\Delta\Phi *_{(0\%)}$ with no applied burden with power factor 1.0 using the following Formulae:

$$\varepsilon *_{(0\%)} = \left(1.333 \times \varepsilon_{1.0(25\%)}\right) - \left(0.333 \times \varepsilon_{1.0(100\%)}\right)$$

$$\Delta\Phi *_{(0\%)} = m_1\left(\varepsilon_{(0\%)} - \varepsilon_{0.8(100\%)}\right) + \Delta\Phi_{0.8(100\%)}$$

Step 2: Calculate the current transformer accuracy results at operating burden at a power factor of 1.0 using the following Formulae:

$$\varepsilon_{1.0(OP)} = \varepsilon *_{(0\%)}\left(1 - \frac{B_{op}}{Z_b}\right) + \varepsilon_{1.0(100\%)}\left(\frac{B_{op}}{Z_b}\right)$$

$$\Delta\Phi_{1.0(OP)} = m_2\left(\varepsilon_{1.0(OP)} - \varepsilon *_{(0\%)}\right) + \Delta\Phi *_{(0\%)}$$

where,

pf = power factor

$\varepsilon_{(0\%)}$ = calculated ratio error (in percent) with no applied burden or winding resistance

$\Delta\Phi_{(0\%)}$ = calculated phase displacement (in Centiradians) with no applied burden or winding resistance

$\varepsilon *_{(0\%)}$ = calculated ratio error (in percent) with no applied burden with pf 1.0

$\Delta\Phi *_{(0\%)}$ = calculated phase displacement (in Centiradians) with no applied burden with pf 1.0

$\varepsilon_{1.0(100\%)}$ = calculated ratio error (in percent) at 100% burden with pf 1.0

$\Delta\Phi_{1.0(100\%)}$ = calculated phase displacement (in Centiradians) at 100% burden with pf 1.0

$\varepsilon_{1.0(OP)}$ = calculated ratio error (in percent) at operating burden with pf 1.0

$\Delta\Phi_{1.0(OP)}$ = calculated phase displacement (in Centiradians) at operating burden with pf 1.0

B_{op} = measured operating burden (in ohms Ω)

Z_b = rated burden impedance (in ohms Ω)

m_1 = slope error line at pf 0.8

m_2 = slope error line at pf 1.0

C.4.2 Voltage Transformers at Operating Burden

The voltage transformer test results that were converted from power factor of 0.8 to power factor of 1.0 and vice versa based on 0 of this Procedure, can be used to calculate approximate accuracy results at operating burden.

Calculate the voltage transformer accuracy results at operating burden using the following Formulae:

For power factor of 1.0:

$$\varepsilon_{1.0(OP)} = \varepsilon_{(0\%)}\left(1 - \frac{B_{op}}{Z_b}\right) + \varepsilon_{1.0(100\%)}\left(\frac{B_{op}}{Z_b}\right)$$

$$\Delta\Phi_{1.0(OP)} = \Delta\Phi_{(0\%)}\left(1 - \frac{B_{op}}{Z_b}\right) + \Delta\Phi_{1.0(100\%)}\left(\frac{B_{op}}{Z_b}\right)$$

For power factor of 0.8:

$$\varepsilon_{0.8(OP)} = \varepsilon_{(0\%)}\left(1 - \frac{B_{op}}{Z_b}\right) + \varepsilon_{0.8(100\%)}\left(\frac{B_{op}}{Z_b}\right)$$

$$\Delta\Phi_{0.8(OP)} = \Delta\Phi_{(0\%)}\left(1 - \frac{B_{op}}{Z_b}\right) + \Delta\Phi_{0.8(100\%)}\left(\frac{B_{op}}{Z_b}\right)$$

where,

pf = power factor

$\varepsilon_{(0\%)}$ = calculated ratio error (in percent) with no applied burden

$\Delta\Phi_{(0\%)}$ = calculated phase displacement (in Centiradians) with no applied burden

$\varepsilon_{1.0(100\%)}$ = calculated ratio error (in percent) at 100% burden with pf 1.0

$\Delta\Phi_{1.0(100\%)}$ = calculated phase displacement (in Centiradians) at 100% burden with pf 1.0

$\varepsilon_{0.8(100\%)}$ = calculated ratio error (in percent) at 100% burden with pf 0.8

$\Delta\Phi_{0.8(100\%)}$ = calculated phase displacement (in Centiradians) at 100% burden with pf 0.8

$\varepsilon_{1.0(OP)}$ = calculated ratio error (in percent) at operating burden with pf 1.0

$\Delta\Phi_{1.0(OP)}$ = calculated phase displacement (in Centiradians) at operating burden with pf 1.0

$\varepsilon_{1.0(OP)}$ = calculated ratio error (in percent) at operating burden with pf 0.8

$\Delta\Phi_{1.0(OP)}$ = calculated phase displacement (in Centiradians) at operating burden with pf 0.8

B_{op} = measured operating burden (in VA)

Z_b = rated burden impedance (in VA)

Version release history

Version	Effective Date	Summary of Changes
1.0	01 December 2025	Initial Release