Task Force on Partial Discharge Testing of Class I Power Transformers

Monday, November 15, 2021
Online Meeting 10:50 am – 12:05 pm CDT

IEEE/PES Transformers Committee
Fall 2021 – Virtual Meeting

Agenda

1. Welcome and call to order
2. Patent announcement
3. Membership and quorum
4. Approval of agenda
5. Approval of minutes.
6. Review of scope and purpose of task force
7. Review of progress to date
8. Open items
9. Vote on proposed verbiage
10. Vote on location in standard
11. Vote to submit to TF for Continuous Revision to Low Frequency Tests
12. Last thoughts
13. Approval to adjourn

Participants have a duty to inform the IEEE of Essential Patent Claims

Participants shall inform the IEEE (or cause the IEEE to be informed) of the identity of each holder of any potential Essential Patent Claims of which they are personally aware if the claims are owned or controlled by the participant or the entity the participant is from, employed by, or otherwise represents

Participants should inform the IEEE (or cause the IEEE to be informed) of the identity of any other holders of potential Essential Patent Claims

Membership Requirements

1. **Voting membership shall be granted automatically to those participants attending the meeting of a newly chartered Task Force upon their request.**
2. **Voting membership may be requested and granted after attending two consecutive meetings. Voting membership is granted after the second consecutive meeting.**
3. **If a voting member misses two consecutive meetings, his or her voting privileges may be revoked. Notification will be sent if voting privileges are revoked.**
4. **Voting privileges may be reinstated and granted after attending two consecutive meetings.**
5. **Attendance will be taken of those that are logged into the virtual meeting.**

Voting Membership (35 – Quorum = 18)

(Based on attendance at last two meetings requesting membership)

Javier Arteaga
Onome Avanoma
Donald Ayers
Israel Barrientos
David Calitz
James Cross
Jorge Cruz
John Foschia
Jose Gamboa
Carlos Gaytan
Zoran Goncin
Detlev Gross
Said Hachichi
Sergio Hernandez Cano
Philip Hopkinson
Peter Kleine
David Larochelle
Ali Naderian
Parminder Panesar
Leopoldo Rodriguez
Pugazhenthi Selvaraj
Charles Sweetser
Janusz Szczechowski
Ajith Varghese
Pragnesh Vyas

Scope

This task force will define the partial discharge testing procedure of liquid-immersed power transformers, autotransformers and regulating transformers, classified as Class I by IEEE Std. C57.12.00, Clause 5.10

Definition of Class I Power Transformer

IEEE Std. C57.12.00, 5.10 Insulation Levels

… power transformers are separated into two different classes as follows:

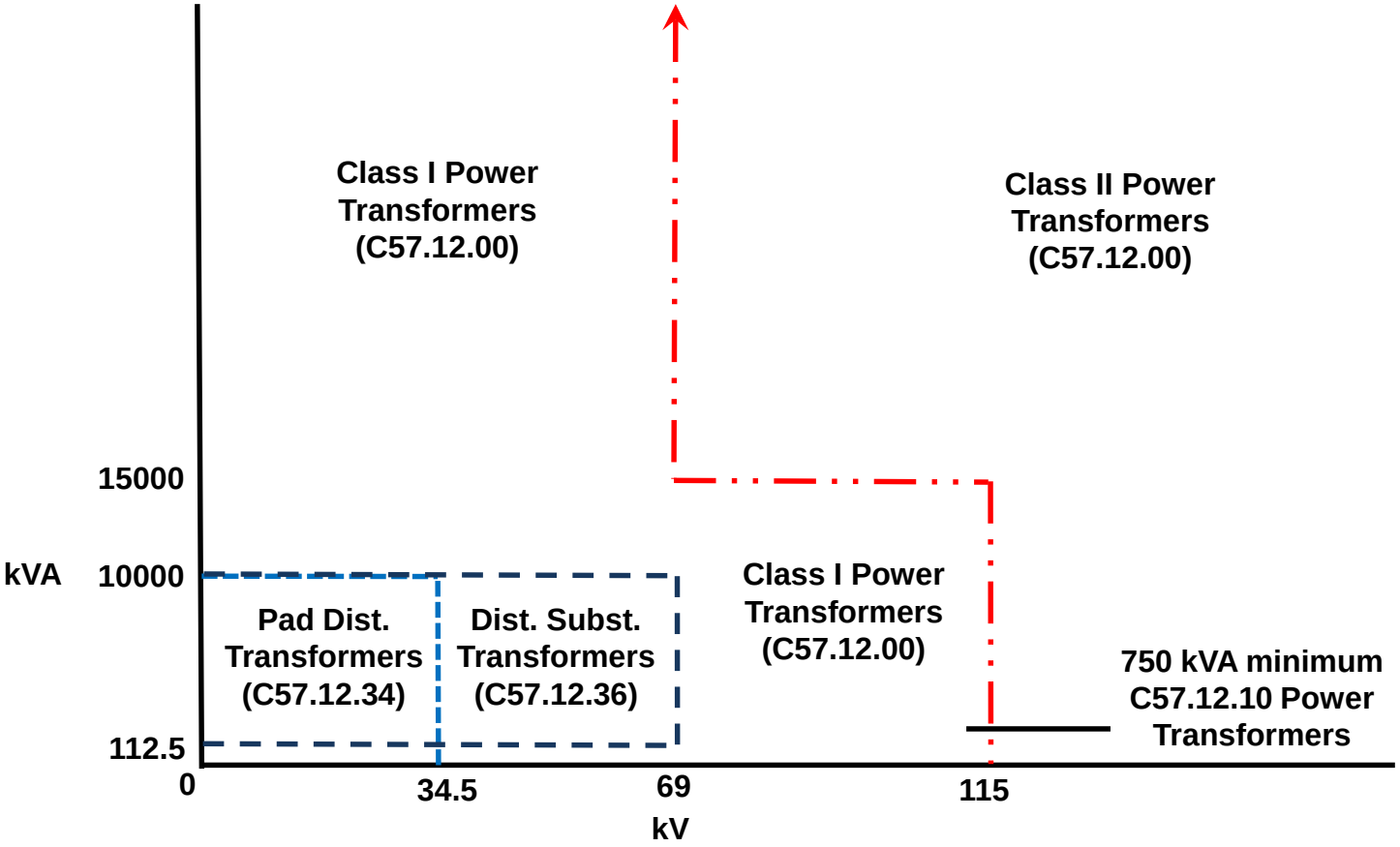
a) Class I power transformers are any that are not categorized as Class II, described in item b).

b) Class II power transformers shall include power transformers with high-voltage windings rated for 115 kV nominal system voltage and above, and also power transformers with high-voltage windings rated 69 kV through 115 kV nominal system voltage, having a top nameplate rating of at least 15 000 kVA for three-phase transformers or 10 000 kVA for single-phase transformers.

c) Scope will not include transformers designated as distribution transformers.

Definitions

(Corrected 4/28/2021)



Purpose of Task Force

The task force is to establish the methodology, procedures and performance requirements for partial discharge testing on Class I Power Transformers.

Progress to Date

Motions voted on to date

1. Enhanced voltage test to be set at 200%. Motion failed (3+/22-).
2. Enhanced voltage test to be set same as Class II level. Motion passed (All +).
3. Extended time test voltage to be set at 1.58 NSV. Motion passed (All +).
4. Extended time test length to be set at 1 hour. Motion passed (All +).
5. Level of 1st PD measurement to be at 1 hour level – 1.58 NSV (All +).
6. When PD testing is specified for Class I power transformers, this test should be carried out as defined by C57.12.00-2015, and the PD limit shall be as stated in C57.12.90-2015. Motion passed (16+, 2-, 7 abstain).
   (Note: pC57.12.90-2021 Draft 4 reduces passing criteria from maximum of 500 pC to 250 pC and the maximum increase from 150 pC to 50 pC)
6. Measure PD only on the terminals with the highest voltage rating. Motion passed (16+, 1-, 6 abstain).

Subjects to Consider
(**Red** indicates agreed to actions)

- ✓ Enhanced Voltage Level (**1.8 x NSV**)
- ✓ Voltage Level of Extended Time test (**1.58 x NSV**)
- ✓ Length of Extended Time test (**1 hour**)
- ✓ Voltage Level of first reading (**1.58 x NSV**)
- ✓ Special Considerations? Bushings? (**Measure HV Bushings only**)
- ✓ Test all bushings or only highest voltage (**Highest only**)
- ✓ Acceptance levels (pC and/or μV) (**Same as Class II**)
- ❖ Required test or optional? (**Outside of stated scope**)
- Verbiage and location in standards (**Task Team Recommendation**)
- Other thoughts

Acceptance Levels

Present Standard for Class II Power Transformers
voted to be the same for Class I Power Transformers

a) The **magnitude** of the partial discharge level **does not exceed 500 pC (250 pc)** during the **1-h test period**.

b) The **increase** in partial discharge levels **during the 1-h period does not exceed 150 pC (50 pC)**.

c) The partial discharge levels during the 1-h period **do not exhibit any steadily rising trend**, and **no sudden sustained increase** in the levels occurs **during the last 20 min** of the test.

Blue notation are proposed limits in pC57.12.90-2021 Draft 4

Comparison of Test Voltages

IEEE C57.12.00-2015		Table 3	-------- Table 4 --------	
		Col 6	Col 6	Col 7
Maximum System Voltage kV	Nominal System Voltage kV	Class I Induced Test	Class II Induced Test	Class II One-Hour Test
		---------- Phase to Ground kV ----------		
		2.0 x NSV	1.8 x NSV	1.58 x NSV
1.5	1.2	1.5	**1.3**	**1.1**
3.5	2.5	2.9	**2.6**	**2.3**
6.9	5	5.8	**5.2**	**4.6**
11	8.7	10	**9**	**7.9**
17	15	17	16	14
26	25	29	26	23
36	34.5	40	36	32
48	46	53	48	42
73	69	80	72	63
121	115	**133**	120	105

*** **Figures do not presently exist in the tables**

Discussion Items

1. Discuss and vote on proposed verbiage for both:
    1. IEEE C57.12.00
    2. IEEE C57.12.90

2. Agree to send to TF for Continuous Revision of Low Frequency Tests

Task Team on Verbiage

Met on October 22, 2021, 2:00 p.m. EDT

- Pugal Selvaraj – Leader
- Daniel Sauer
- Sheldon Kennedy
- Kris Neild
- Suresh Babanna
- Kyhle Heiden
- Rodrigo Ocon Valsez
- Larry Dix
- Suresh
- Mark
- Tony Franchitti

Suggested Amended Wording of IEEE C57.12.00

(**Red** are suggested changes)

5.10.5.1 General

Low-frequency test requirements for distribution and power transformers shall be applied-voltage tests and induced-voltage tests. Table 3 specifies test levels for distribution and Class I power transformers; Table 4 specifies test levels for Class II transformers.

For Class I power transformers, when specified, partial discharge test shall be conducted as per section 5.10.5.5.

5.10.5.3 Induced-voltage test requirements for distribution and Class I power transformers without partial discharge testing

A voltage shall be developed in each winding in accordance with the levels specified in Table 3. Induced voltage tests shall be conducted at 2.0 × nominal voltage for 7200 cycles.

5.10.5.5 Induced-voltage test for Class II and, when specified Class I, power transformers

With the transformer connected and excited as it will be in service, an induced-voltage test shall be performed as indicated in Figure 2, at voltage levels indicated in Columns 6 and 7 of Table 4. Minimum line-to-ground induced test levels for Class II power transformers shall be a multiple of corresponding line-to-ground nominal system voltage as follows: 1.58 times for one hour tests and 1.8 times for 7200 cycles enhancement level tests.

Suggested Amended Wording of IEEE C57.12.00

(**Red** are suggested changes)

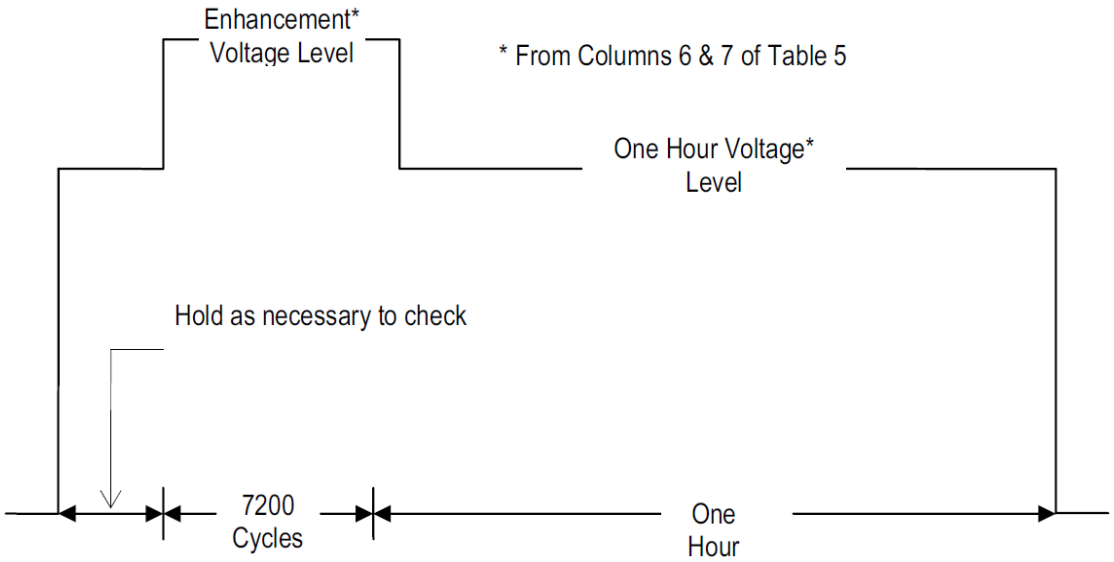


Figure 2 —Induced voltage test for Class II and, when specified Class I, power transformers

Table 4—Dielectric insulation levels for all windings of Class II power transformers, voltages in kV

Maximum system voltage (kV rms)	Nominal system voltage[a] (kV rms)	Applied voltage test[g] (kV rms)			Induced voltage test[b,c] (phase to ground) (kV rms)		Winding line-end BIL[d] (kV crest)				Neutral BIL[e,g] (kV crest)	
		Delta and fully insulated wye	Grounded wye	Impedance grounded wye or grounded wye with higher BIL	Enhanced 7200 cycle	One hour	Mini-mum	Alternates			Grounded wye	Impedance grounded wye or grounded wye with higher BIL
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11	Col 12	Col 13
1.5	1.2	10	10	10	1.3	1.1	30	45			45	45
3.5	2.5	15	15	15	2.6	2.3	45	60			60	60
6.9	5	19	19	19	5.2	4.6	60	75			75	75
11	8.7	26	26	26	9	7.9	75	95			95	95
<= 17	<= 15	34	34	34	16	14	**110**				110	110
26	25	50	34	40	26	23	**150**				110	125
36	34.5	70	34	50	36	32	**200**				110	150
48	46	95	34	70	48	42	200	**250**			110	200
73	69	140	34	95	72	63	250	**350**			110	250
121	115	173	34	95	120	105	350	**450**	550		110	250
145	138	207	34	95	145	125	450	**550**	650		110	250
169	161	242	34	140	170	145	550	**650**	750	825	110	350
242	230	345	34	140	240	210	650	**750**	**825**	**900**	110	350
362	345	518	34	140	360	315	900	1050	1175		110	350
550	500	N/A	34	140	550[f]	475[f]	1425	1550	1675		110	350
765	735	N/A	34	140	880[f]	750[f]	1950[f]	2050			110	350
800	765	N/A	34	140	885[f]	795[f]	1950[f]	2050			110	350

[a]For nominal system voltage greater than maximum system voltage, use the next higher voltage class for applied test levels.

[b]Induced voltage tests shall be conducted at 1.58 × nominal system voltage for one hour and 1.80 × nominal system voltage for enhanced 7200 cycle test.

[c]Column 6 and Column 7 provide phase-to-ground test levels that would normally be applicable to wye windings. When the test voltage level is to be measured phase-to-phase (as is normally the case with delta windings), the levels in Column 6 and Column 7 must be multiplied by 1.732 to obtain the required phase-to-phase induced-voltage test level.

[d]Bold typeface BILs are the most commonly used standard levels.

[e]Y-Y connected transformers using a common solidly grounded neutral may use neutral BIL selected in accordance with the low-voltage winding rating.

[f]For 500 kV to 765 kV nominal system voltages, induced voltage test levels do not follow rules in footnote b, and 1950 kV BIL is not a standard IEEE level.

[g]If user specifies a different BIL for the neutral than indicated above, the applied test voltage shall also be specified.

Suggested Amended Wording of IEEE C57.12.90 (1)

(**Red** are suggested changes)

10.7 Induced-voltage tests for distribution and Class I power transformers without partial discharge testing

10.8 Induced-voltage test for Class II, **and when specified Class I,** power transformers

10.8.1 General

Each Class II**, and when specified each Class I,** power transformer shall receive an induced-voltage test with the required test levels induced in the high-voltage winding. The tap connections shall be chosen, when possible, so that test levels developed in the other windings during the 1 h test are x times their maximum operating voltages, as specified in ANSI C84.1, where x is the ratio of the test voltage on the high-voltage winding to the maximum operating voltage.

10.8.2 Test procedure

The voltage shall first be raised to the 1 h level and held for a minimum of 1 min or until a stable partial discharge level is obtained to verify that there are no partial discharge problems. The level of partial discharges shall be recorded just before raising the voltage to the enhancement level. The voltage shall then be raised to the enhancement level and held for 7200 cycles. The voltage shall then be reduced directly to the 1 h level and held for 1 h.

Suggested Wording to IEEE C57.12.90 (2)

During this 1 h period, partial discharge measurements shall be made at 5 min intervals. For Class II power transformers partial discharge acceptance criteria shall be based on each line terminal rated 115 kV and above. For Class I power transformers the partial discharge acceptance criteria shall be based on the terminals with the highest rated voltage. These measurements shall be made in accordance with 10.9.

10.8.3 Connections

The transformer shall be excited exactly as it will be in service. The voltage may be induced from any winding or from special windings or taps provided for test purposes. Single-phase transformers shall be excited from single-phase sources. Three-phase transformers shall be excited from three-phase sources. The neutral terminals and other terminals that are normally grounded in service shall be solidly grounded. This will stress all of the insulation at the same per unit of overstress.

10.8.4 Frequency

The test frequency shall be increased, relative to operating frequency, as required to avoid core saturation. The requirements in 10.7.2 are also applicable in the case of this induced test.

Suggested Wording to IEEE C57.12.90 (3)

10.8.5 Failure detection

Failure may be indicated by the presence of smoke and bubbles rising in the insulating liquid, an audible sound such as a thump, or a sudden increase in the test current. Any such indication shall be carefully investigated by observation, by repeating the test, and by other diagnostic tests to determine whether a failure has occurred. In terms of interpretation of partial discharge measurements, the results shall be considered acceptable and no further partial discharge tests required under the following conditions:

10.8.5.1 Class II Power Transformer

a) The magnitude of the partial discharge level does not exceed 500 pC during the 1-h test period.

a) The increase in partial discharge levels during the 1-h period does not exceed 150 pC.

a) The partial discharge levels during the 1-h period do not exhibit any steadily rising trend, and no sudden sustained increase in the levels occurs during the last 20 min of the test.

Suggested Wording to IEEE C57.12.90 (4)

10.8.5.1 Class II Power Transformer

a) The magnitude of the partial discharge level does not exceed 500 pC during the 1-h test period.

a) The increase in partial discharge levels during the 1-h period does not exceed 150 pC.

a) The partial discharge levels during the 1-h period do not exhibit any steadily rising trend, and no sudden sustained increase in the levels occurs during the last 20 min of the test.

10.8.5.3 General

Judgment should be used on the 5-min readings so that momentary excursions of the partial discharge readings caused by cranes or other ambient sources are not recorded. Also, the test may be extended or repeated until acceptable results are obtained.

A failure to meet the partial discharge acceptance criterion shall not warrant immediate rejection, but it shall lead to consultation between purchaser and manufacturer about further investigations.

Voting

1. Agreement on verbiage for IEEE C57.12.00?
2. Agreement on verbiage for IEEE C57.12.90
3. Agreement to forward recommendation on to TF for Continuous Revision of Low Frequency Tests

Final Thoughts

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Thank you for your participation in this Task Force. Your contributions were much needed and appreciated.