Section A-Research paper
ISSN 2063-5346

"Analysis & Improvement in Testing of High Voltage Instrument Transformers"

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DOI: 10.48047/ecb/2023.12.13.124

Abstract: This paper discuss analyses for testing of high voltage instrument transformers. In this paper it shows performed test and analyse from it. We will try to improve that analyse problems. Instrument transformers for high-voltage applications play a key role in energy supply. Acting as the link between the primary network and the metering or protection equipment connected to the secondary side, a safe and reliable operation without failures is essential in relation to this background, this paper discusses testing for instrument transformers. And also discuss about multi stage Impulse Voltage Generator.

Introduction:-

1. Instrument Transformers

Indirect measuring devices, such as instrument transformers, are needed for the generation, transmission, and distribution of electric power in order to measure current flow and operate protective relays, maintaining system stability and, consequently, system reliability. The only interface between high power electric circuits and control electronics is provided by instrument transformers, so ensuring the functionality of the measuring device is crucial. If a current transformer provides an inaccurate reading, protection coordination cannot be done, which will result in a systematic loss of control and, if it is not corrected promptly, will eventually lead to system failure.

Transforming voltage or current from high values in transmission and distribution networks to low values that may be used by low-voltage devices is what instrument transformers (ITs) are meant to do.

There are three primary applications for which ITs are used:

- Metering (for energy billing and transaction purposes);
- Protection control (for system protection and protective relaying purposes);
- Load survey (for economic management of industrial loads).

➢ National and international standards characterise the parameters for our testing procedures. The relevant standards subdivide the instrument transformers into classes.

➢ ITs are required to accurately operate at a multiple of the nominal current while providing protective relays.

➢ It's usual to underestimate the importance of IT tests. Testing before initial usage can considerably decrease risks such as making up connections or mistaking ITs for metering and protection.

➢ Transformers are essential for the production, transmission, distribution, and use of energy. It is clear that transformers need to be tested and maintained regularly. The following are some of the main justifications for checking instrument transformers:

- To verify the proper operation of electrical transformers primary parts/components.
- To check the transformer's overall performance.
- To reduce the possibility of working failure.
- To verify the transformer's performance and specs.
- To reduce the chance of future failures caused by mechanical, thermal, or electrical problems.

Following Standards are national standard - Indian Standards (IS) and International standards - International Electrotechnical Commission (IEC) of Current Transformers & Potential Transformers testing

IS for CT		**Is for PT**		**IEC for CT**		**IEC for PT**	
NO	**YEAR**	**NO**	**YEAR**	**NO**	**YEAR**	**NO**	**YEAR**
2705-1	1992	3156-1	1992	61869-1	2007	61869-1	2007
2705-2	1992	3156-2	1992	61869-2	2012	61869-3	2011
2705-3	1992	3156-3	1992	61869-4	2013	61869-4	2013
2705-4	1992	3156-4	1992			61869-5	2011
16227-1	2016	16227-1	2016				
16227-2	2016	16227-3	2015				
16224-4	2015	16227-4	2015				
		16227-5	2011				

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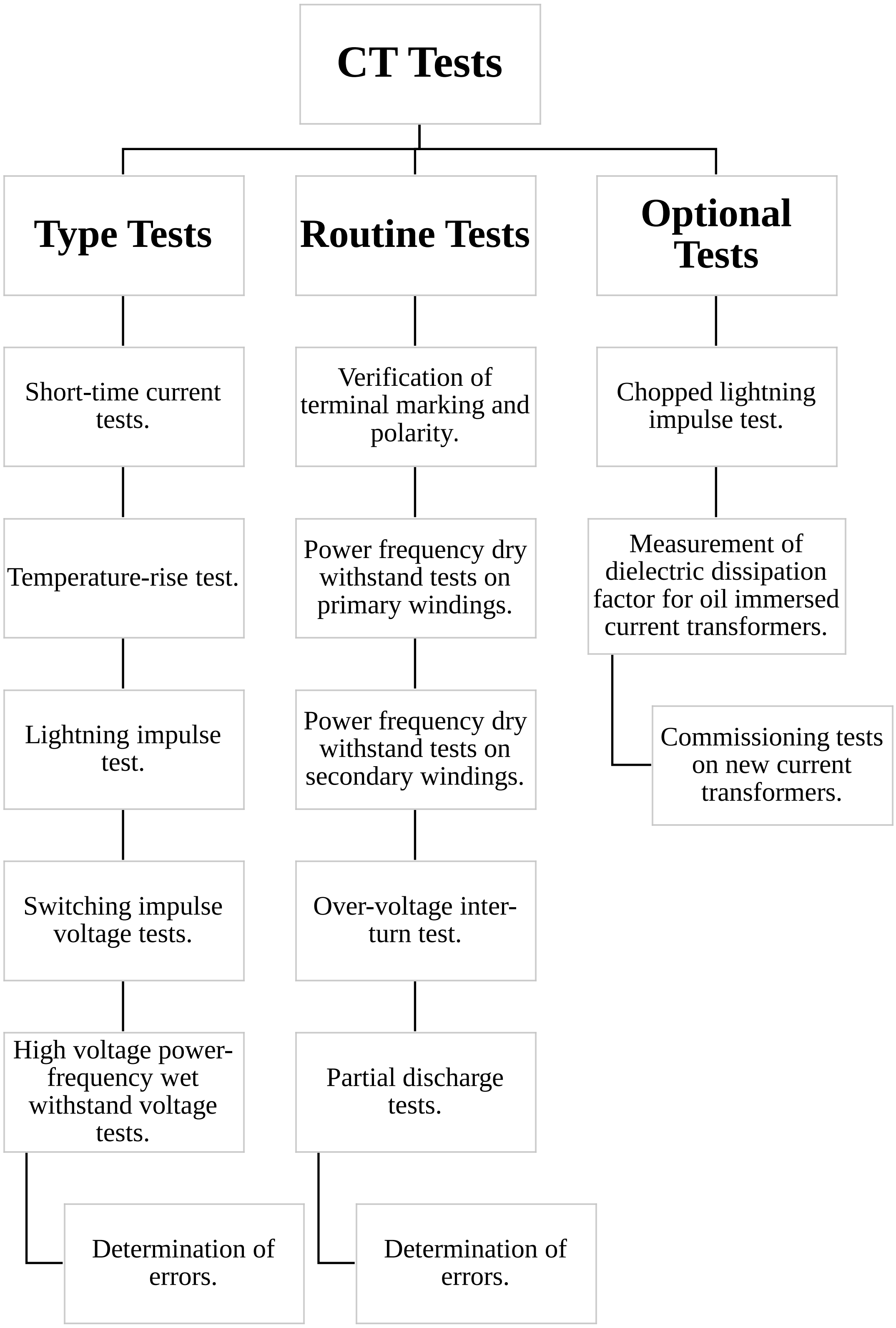
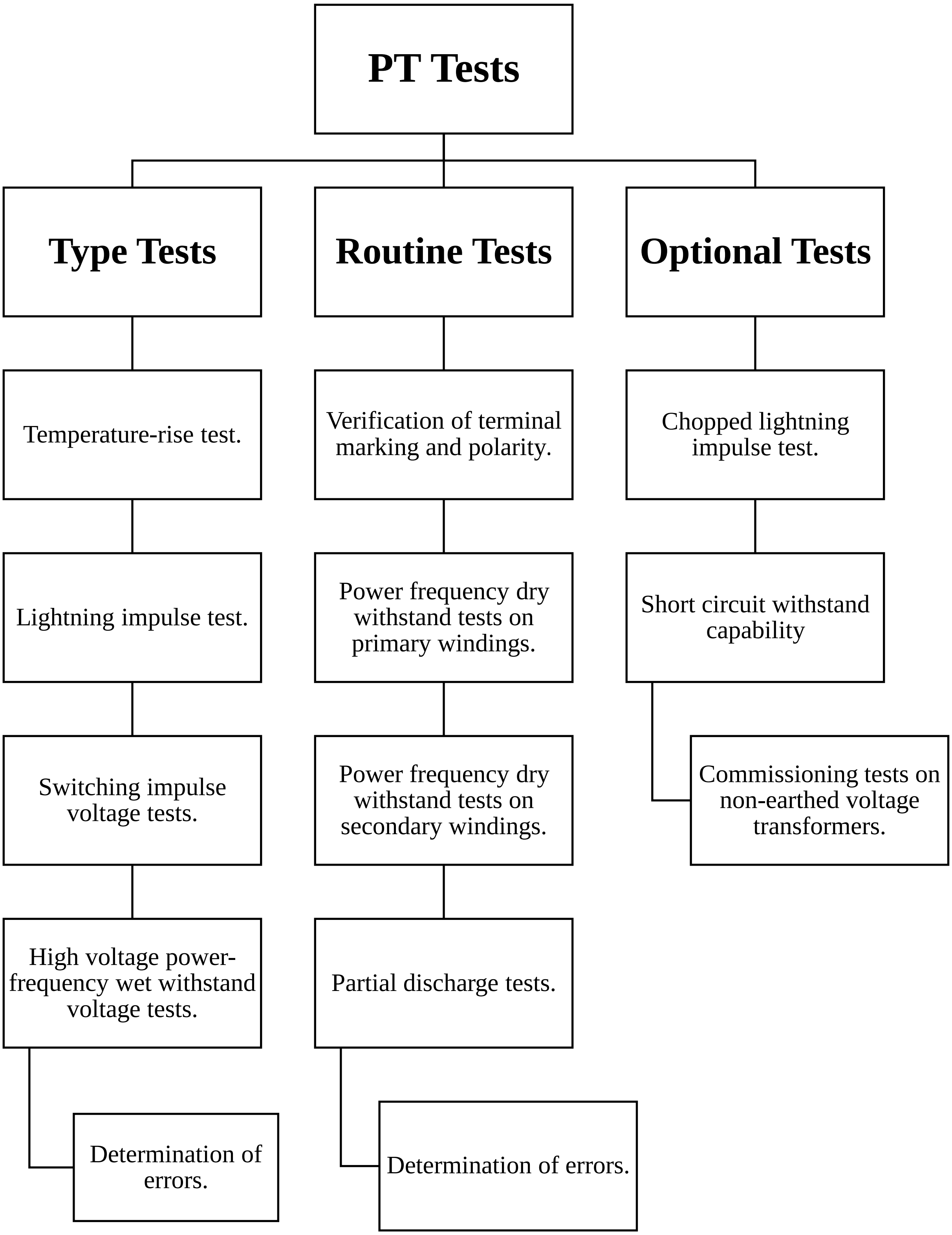
Test To Be Covered:-


CT Tests
Type Tests
Routine Tests
Optional Tests
Short-time current tests.
Temperature-rise test.
Lightning impulse test.
Switching impulse voltage tests.
High voltage power-frequency wet withstand voltage tests.
Determination of errors.
Verification of terminal marking and polarity.
Power frequency dry withstand tests on primary windings.
Power frequency dry withstand tests on secondary windings.
Over-voltage inter-turn test.
Partial discharge tests.
Determination of errors.
Chopped lightning impulse test.
Measurement of dielectric dissipation factor for oil immersed current transformers.
Commissioning tests on new current transformers.


PT Tests
Type Tests
Routine Tests
Optional Tests
Temperature-rise test.
Verification of terminal marking and polarity.
Chopped lightning impulse test.
Lightning impulse test.
Power frequency dry withstand tests on primary windings.
Short circuit withstand capability
Switching impulse voltage tests.
Power frequency dry withstand tests on secondary windings.
Commissioning tests on non-earthed voltage transformers.
High voltage power-frequency wet withstand voltage tests.
Partial discharge tests.
Determination of errors.
Determination of errors.

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Impulse Voltage Generator: -

Testing with lightning impulse voltages

Transmission line terminations caused by lightning strikes will result in steeply rising voltages, travelling waves along the line, and possible insulation damage. Depending on the insulation, the magnitude of these overvoltages could reach several thousand kilovolts. Extensive testing and years of experience have proven that lightning overvoltages are distinguished by brief front duration, which can range from a microsecond to several tens of seconds before slowly coming to an end. The accepted definition of the standard impulse voltage is an aperiodic impulse that accomplishes its peak value in 1.2 seconds and then steadily declines (in around 50 seconds) to half its peak value.

For Impulse testing our requirement is 11kV, 22kV, and 33kv so we designed our product up to 300kV

Lighting Impulse Test: -

For 11kV product (Transformer) the output is 75kVpeak/ 95kV peak
For 22kV product (Transformer) the output is 125kVpeak
For 33kV product (Transformer) the output is 170kVpeak

Chopping Impulse test:-

Chopping Impulse Test = LI X 110%
= LI X 1.1
For 11kV = 75X1.1 = 82.5
For 22kV = 125X1.1 = 137.5
For 33kV = 170X1.1 = 187

i. Impulse Generator Circuit: -

An exact equivalent circuit of a single stage impulse generator along with a typical load are shown in Fig. 1.

The generator's C1 capacitance is what allows the sphere gap to discharge when it is charged from a d.c. source to a proper voltage. The generator may have a single capacitance, in which case it is referred to as a single stage generator, or it may have many capacitances that have been charged in parallel and discharged in series, in which case it is referred to as a multistage generator.

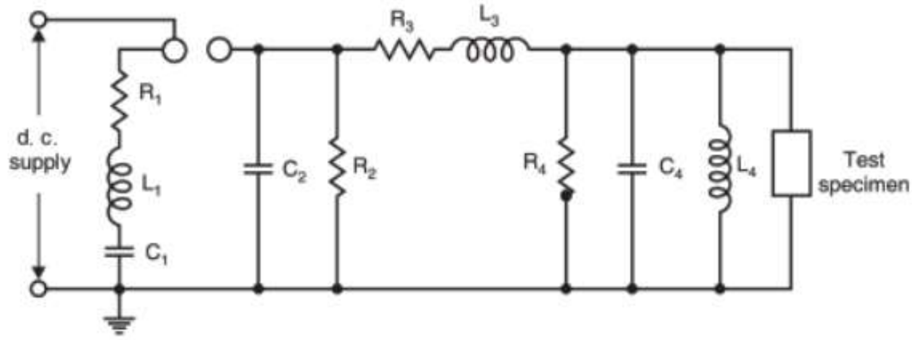


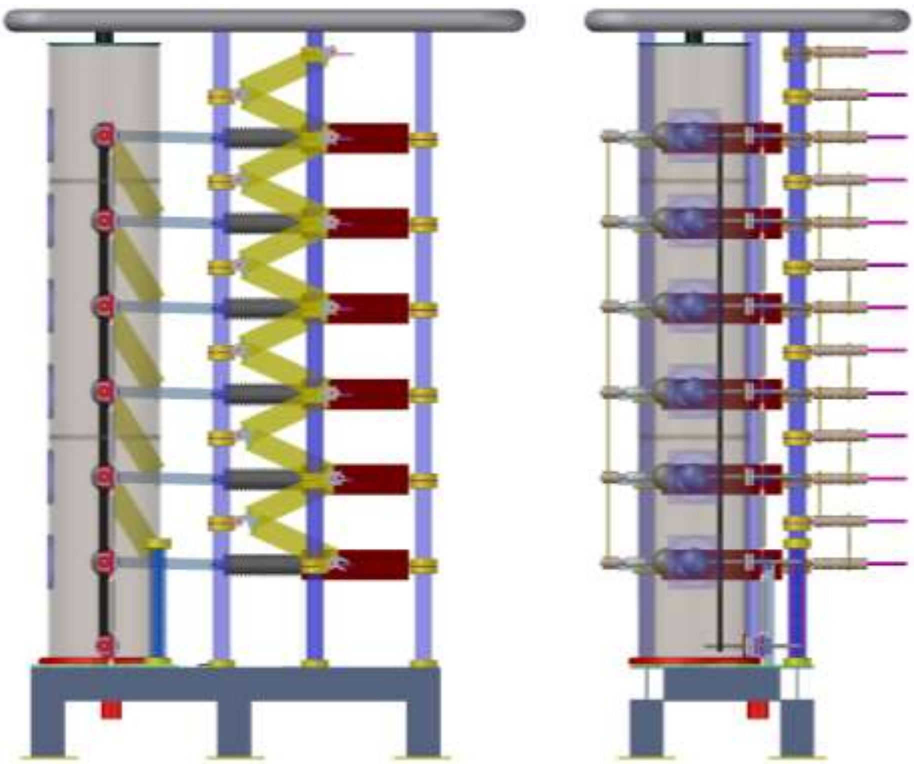
Fig. 1 Exact equivalent circuit of a single stage impulse generator with a typical load

L1, which is often kept as low as possible, is the inductance of the generator and the leads connecting the generator to the discharge circuit. the opposition In addition to the additional lumped resistance frequently introduced inside the generator for dampening purposes and to adjust the output waveform, R1 is made up of the intrinsic series resistance of the capacitances and leads. The external components L3, R3 can be connected to the generator terminal to regulate the waveform. R2 and R4 manage the wave's duration.

When a CRO is used for measurement, R4 can also act as a potential divider. The high voltage components and leads' capacitances to ground are represented by C2 and C4. C4 additionally includes any additional load capacitance necessary to provide the required wave form, as well as the capacitance of the test item. L4 represents the test object's inductance and has the potential to greatly affect the wave form.

One terminal of the impulse generator is often grounded solidly for practical reasons. By modifying the polarity of the d.c. charging voltage, the output voltage can also be polarised.

ii. 6-Stage Impulse Voltage Generator



(a) (b)

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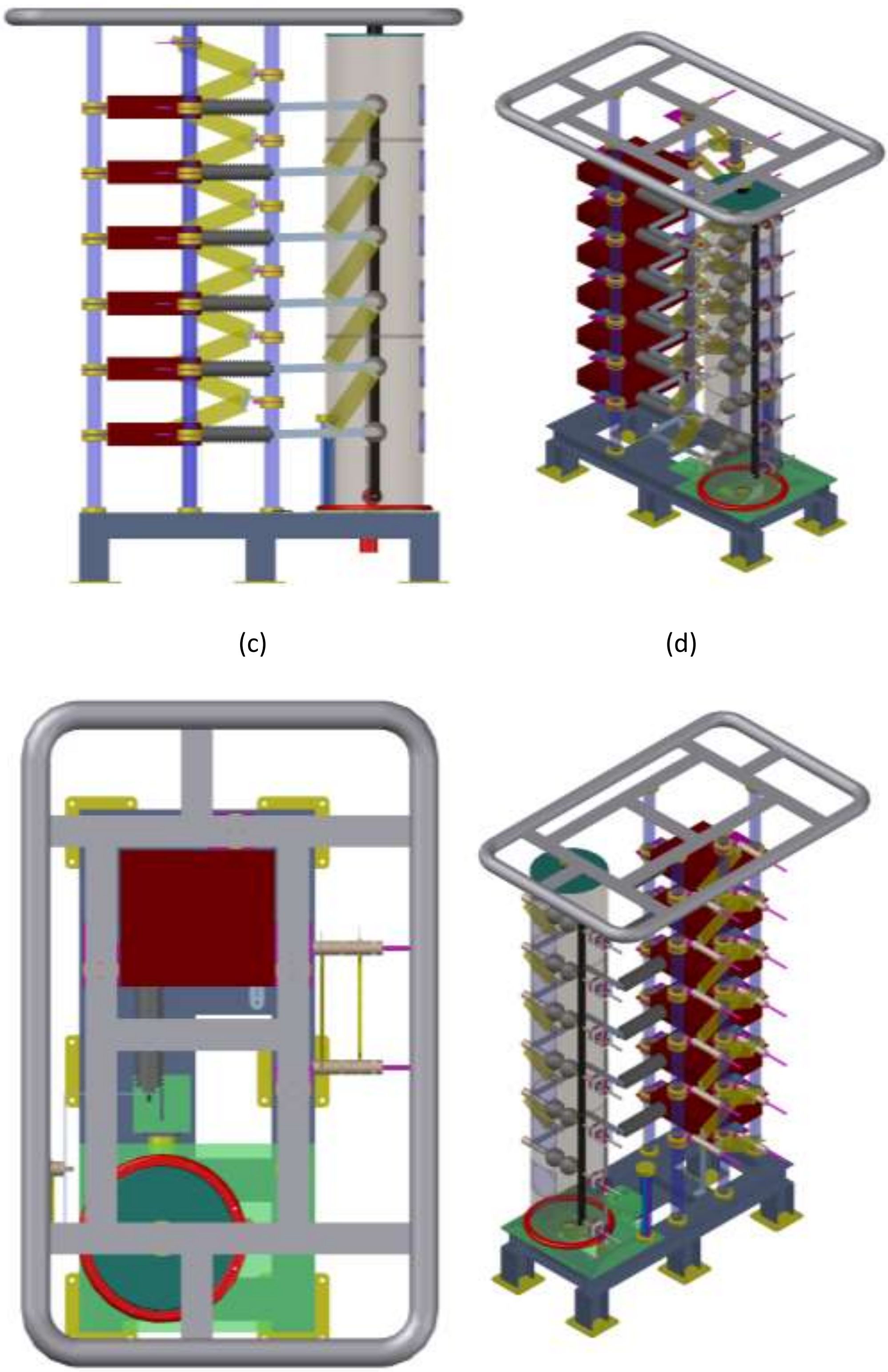

(c) (d)

(e) (f)

Fig.2 Impulse Voltage Generator

Results and Discussion: -

Test results of 66kV CT

Technical Specification of Test Sample

1.	Test sample	: **OIL COOLED CURRENT TRANSFORMER (WITH S.S. BELLOWS) (DEAD TANK) (1 Ø EARTHED)**
2.	Year of Manufacture	: 2022
3.	Ratio	: 350/1 A
4.	Accuracy class	: 0.2s
5.	Burden	: 5 VA
6.	ISF	: ≤ 5
7.	Nominal System Voltage	: 66 kV
8.	Highest System Voltage	: 72.5 kV
9.	Insulation Level	: 72.5 / 140 / 350 kVp
10.	Insulation Class	: A
11.	Rated S.T.C	: 31.5 kA for 3 Second
12.	Indoor or Outdoor	: Outdoor
13.	Type	: OCT – 66
14.	Primary terminals	: P1 - P2
15.	Secondary terminals	: 1S1 - 1S2
16.	Made to Standard	: IS 16227(Part-1):2016,IS 16227(Part-2):2016
17.	Frequency	: 50 Hz

Test Results

1. **<u>Verification of markings</u>** (Cl No. 7.3.6 of IS: 16227, Part 2 :2016)

Primary winding terminals : P1-P2

Secondary winding terminals : 1S1-1S2

Terminal marking and polarity was verified and found OK.

<u>Remarks</u>: - Confirm verification of marking after testing as mentioned in Indian standards.

2. **Power-frequency voltage withstand tests on primary terminals**

   (Cl No. 7.3.1 of IS: 16227, Part 2 :2016)

   The power frequency test voltage of **140kV (rms)** was applied between shorted primary winding terminals **(P1-P2)** and **Earth**. Body, secondary winding terminals and special terminal (suitable for dielectric dissipation factor) were shorted together and earthed. The test voltage was applied for **60 seconds**.

   There was no disruptive discharge observed. The sample withstood the test voltage satisfactorily.

   Remarks: - Confirm Power-frequency voltage withstand tests on primary terminals after testing as mentioned in Indian standards.

3. **Partial Discharge measurement** (Cl No. 7.3.2 of IS: 16227, Part 2 :2016)

   Network : Effectively Earthed Neutral System

   Procedure : - A

   The partial discharge test was performed while decreasing the voltage after power frequency withstand voltage. The voltage was reduced to partial discharge measuring level maintained without interruption to partial discharge test voltage level of **72.5kV (i.e.Um)** & **50.22kV (i.e.1.2*Um / sqrt3**) within 30 seconds.

   Where Um is **72.5 kV.**

   Measured partial discharge value at 72.5 kV = 2.00 pC

   Measured partial discharge value at 50.22 kV = 1.85 pC

   Requirement: Measure partial discharge should not exceed the 10 pC at 72.5 kV, 5 pC at 50.22 kV.

   Remarks: - Confirm partial discharge test after testing as mentioned in Indian standards.

4. **Power-frequency voltage withstand tests on secondary terminals**

   (Cl No. 7.3.4 of IS: 16227, Part 2 :2016)

   The power frequency test voltage of **3kV (rms)** was applied between shorted secondary winding terminals **(1S1-1S2)** and **Earth**. Body, primary winding terminals and special terminal (suitable for dielectric dissipation factor) were shorted together and earthed. The test voltage was applied for **60 seconds**.

There was no disruptive discharge observed. The sample withstood the test voltage satisfactorily,

<u>Remarks</u>: - Confirm power - frequency voltage withstand test on secondary terminals after testing as mentioned in Indian Standard.

5. **<u>Inter-turn overvoltage test</u>** (Cl No. 7.3.204 of IS: 16227, Part 2 :2016)

With the primary winding open circuited, voltage at rated frequency was applied to the secondary winding terminal **(1S1-1S2)** such as to produce secondry current of rms value equals to **Rated secondary current (i.e. 1 amp.)** for **1 minute**.

The sample withstood the applied voltage satisfactorily for one minute.

<u>Remarks</u>: - Confirm Inter-turn overvoltage test after testing as mentioned in Indian Standards.

6. **<u>Determination of the instrument security factor (FS) of measuring current transformers</u>**

(Cl No. 7.5.2 of IS: 16227, Part 2 :2016)

Core	**1S1-1S2**	**<u>Remarks</u>:- Confirm Test**
Ratio	350/1 A	
Resistance at 75 ^{o} C (Ω)	1.2333	
Calculated SLV (Volts)	31.16	
Excitation current (A)	0.5	
Measured Voltage at excitation current (Volts)	26.7	
Calculated value of ISF	**4.28**	

7. **<u>Test for accuracy</u>** (Cl No. 7.3.5 of IS: 16227, Part 2 :2016)

PHASE DISPLACEMENT IN MIN.	RATIO ERROR IN %	% OF RATED CURRENT	RATIO ERROR IN %	PHASE DISPLACEMENT IN MIN.
RATIO: 350/1A, RATED BURDEN: 5 VA, CLASS: 0.2s, 1S1-1S2.				
BURDEN : 100 % (0.8 p.f lag.)			BURDEN : 25 % (Unity p.f)	
0.75	0.0366	120	0.0984	0.47
0.65	0.0446	100	0.0998	0.81

2.70	0.0133	20	0.102	2.11
5.40	0.0025	5	0.116	3.04
7.11	0.0005	1	0.125	3.70

Remarks: - Confirm test for accuracy after testing as mentioned in Indian Standards.

PT Test Results

Technical Specification of Test Sample

1. Test sample : **OIL COOLED VOLTAGE TRANSFORMER (WITH S.S. BELLOW) (1 Ø EARTHED) (DEAD TANK)**
2. Year of Manufacture : 2022
3. Ratio : 66000/√3 V // 110/√3 V
4. Accuracy class : 0.2
5. Burden : 10 VA
6. Insulation Level : 72.5 / 140 / 350 KVp
7. Nominal System Voltage : 66 kV
8. Highest System Voltage : 72.5 kV
9. Voltage Factor : 1.2 Conti. & 1.5 for 30 sec.
10. Indoor or Outdoor : Outdoor
11. Type : OPT – 66
12. Primary terminals : A – N
13. Secondary terminals : 1a - 1n
14. Made to Standard : IS 16227 (Part 1):2016 & IS 16227 (Part 3):2015
15. Insulation Class : A
16. Frequency : 50 Hz

Test Results

1. **Verification of markings**(Cl No. 7.3.6 of IS: 16227- 3 : 2015)

   Ratio: **66000/√3 V // 110/√3 V**

   Primary winding terminals : A - N

   Secondary winding terminals : 1a - 1n

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Terminal marking and polarity was verified and found OK.

<u>Remarks</u>:- Confirm verification of marking after testing as mentioned in Indian standards.

2. **<u>Differential mode (Induced) AC voltage test</u>**(Cl No. 7.3.1.303 of IS: 16227- 3 : 2015)

The test was performed by exciting the primary winding with a voltage **140 kVrms,** at that time The **N** terminal connected to the ground. The body, secondary winding terminal (1n) and special terminal (suitable for dielectric dissipation factor) were shorted together and earthed. The test voltage at H.V. side was measured and recorded. The test was performed at **100 Hz** for **60 seconds** duration.

The sample withstood the test voltage satisfactorily.

<u>Remarks</u>:- Confirm induced ac voltage tests as mentioned in Indian Standards.

3. **<u>Partial Discharge measurement</u>**(Cl No. 7.3.2 of IS: 16227- 3 : 2015)

Network: Effectively Earthed Neutral System

Procedure: - A

The partial discharge test was performed while decreasing the voltage after the power frequency withstand voltage**.** The voltage was then reduced to partial discharge test voltage level of **72.5kV (i.e. Um)** &**50.22kV (i.e. 1.2*Um / sqrt3**) within 30 seconds. Where Um is **72.5 kV.**

Measured partial discharge value at 72.5 kV = 2.80 pC

Measured partial discharge value at 50.22kV = 2.00 pC

Requirement: Measure partial discharge should not exceed the 10 pC at 72.5 kV, 5 pC at 50.22kV

<u>Remarks</u>:- Confirm partial discharge test after testing as mentioned in Indian standards.

4. **<u>Common mode (separate source) power frequency withstand test</u>**

(Cl No. 7.3.1.302 of IS: 16227- 3: 2015)

The power frequency test voltage of **3kV (rms)** was applied between the primary winding terminal **(N – which is intended to be earthed)** and **Earth**. Body, secondary winding terminals and special terminal (suitable for dielectric dissipation factor) were shorted together and earthed. Test voltage was applied for **60 seconds.**

There was no disruptive discharge observed. The sample withstood the test voltage satisfactorily.

<u>Remarks</u>:- Confirm Power-frequency voltage withstand tests on primary terminals after testing as mentioned in Indian standards.

5. **<u>Power frequency voltage withstand test on secondary terminals</u>**

(Cl No. 7.3.4 of IS: 16227- 3 : 2015)

The power frequency test voltage of **3kV (rms)** was applied between shorted secondary winding terminals **(1a-1n)** and **Earth.** Body, primary winding terminals and special terminal (suitable for dielectric dissipation factor) were shorted together and earthed. Test voltage was applied for **60 seconds.**

There was no disruptive discharge observed. The sample withstood the test voltage
satisfactorily.

<u>Remarks</u>:- Confirm power - frequency voltage withstand test on secondary terminals after testing as mentioned in Indian Standards.

6. **<u>Test for Accuracy</u>**(Cl No. 7.3.5 of IS: 16227- 3 : 2015)

PHASE DISPLACEMENT IN MIN.	RATIO ERROR IN %	% OF RATED VOLTAGE	RATIO ERROR IN %	PHASE DISPLACEMENT IN MIN.

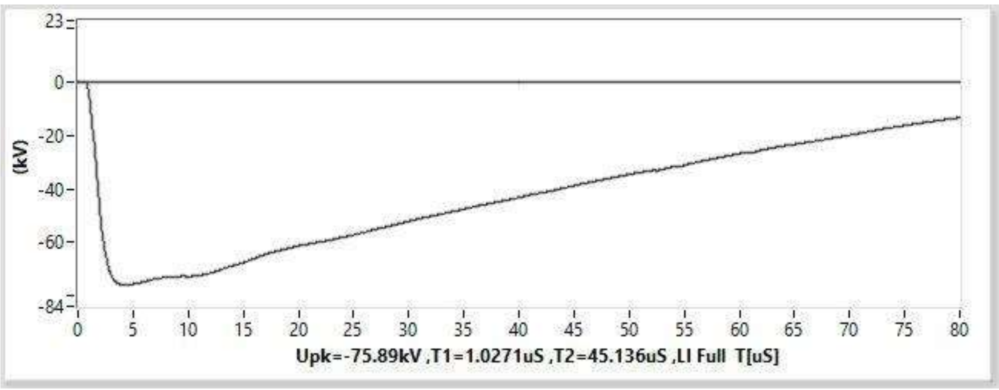
RATIO: 66000/√3 V / 110/√3 V, RATED BURDEN: 10 VA, CLASS: 0.2, 1a-1n.

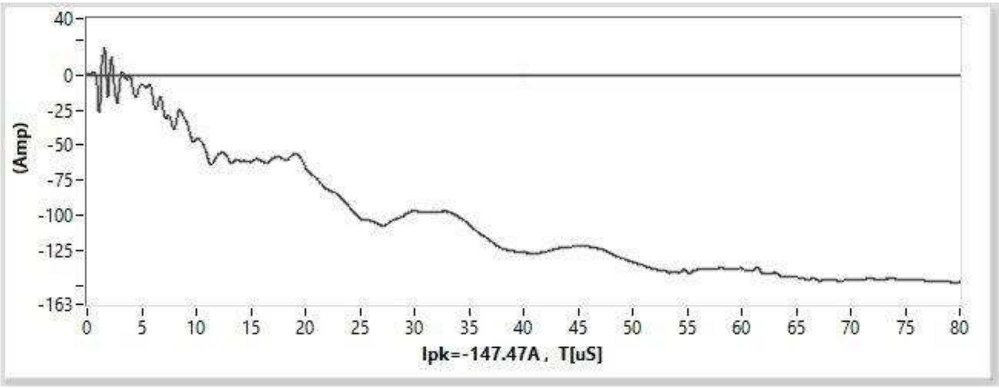
BURDEN: 100 % (0.8 p.f lag.)			BURDEN: 25 % (0.8 p.f lag.)	
0.13	0.0460	120	0.0712	0.08
0.03	0.0522	100	0.0777	0.01
-0.01	0.0541	80	0.0800	-0.04

<u>Remarks:-</u> Confirm test for accuracy after testing as mentioned in Indian Standards.

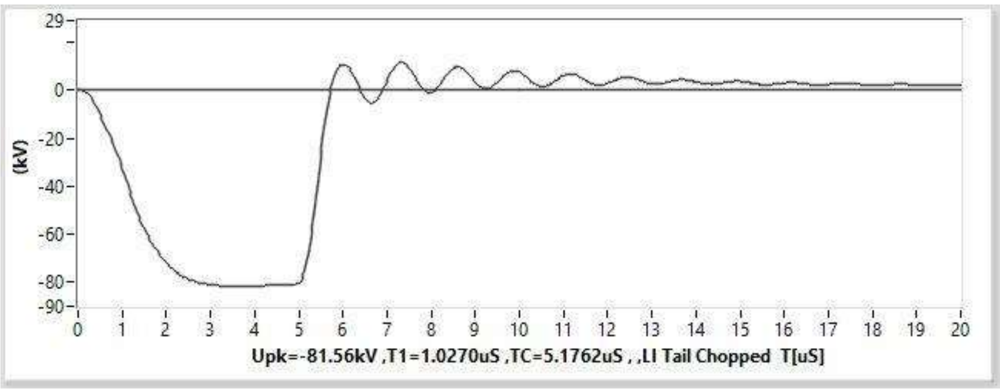
Impulse Voltage Generator Test Results: -

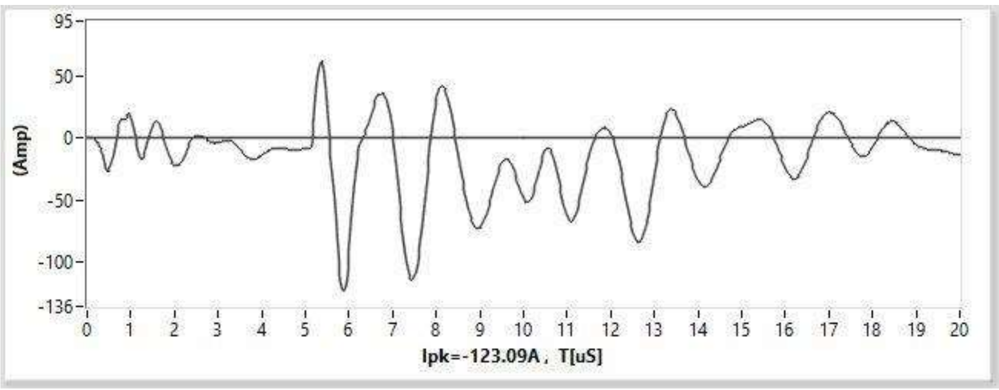
11kV Lighting Impulse



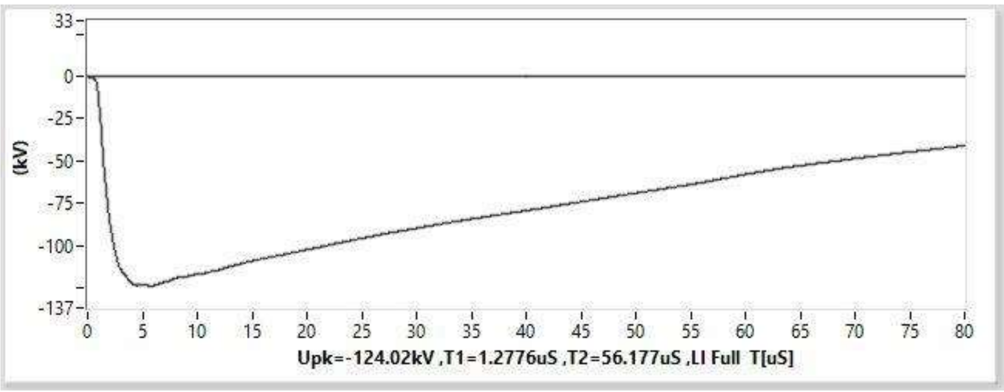


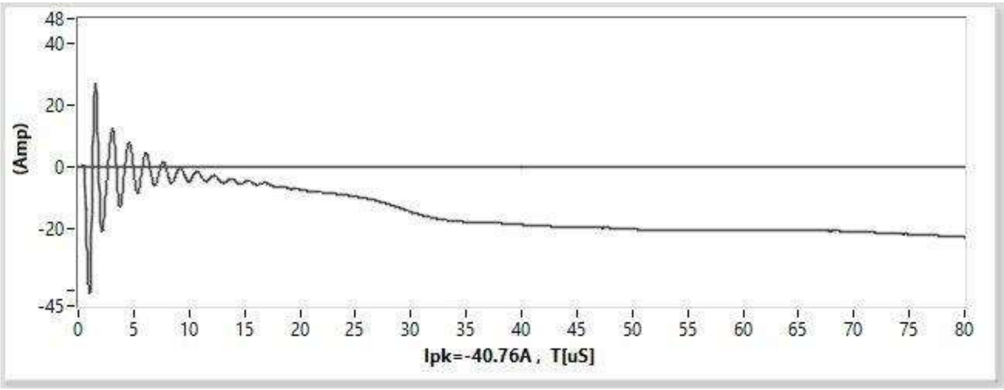
11kV Chopping Impulse



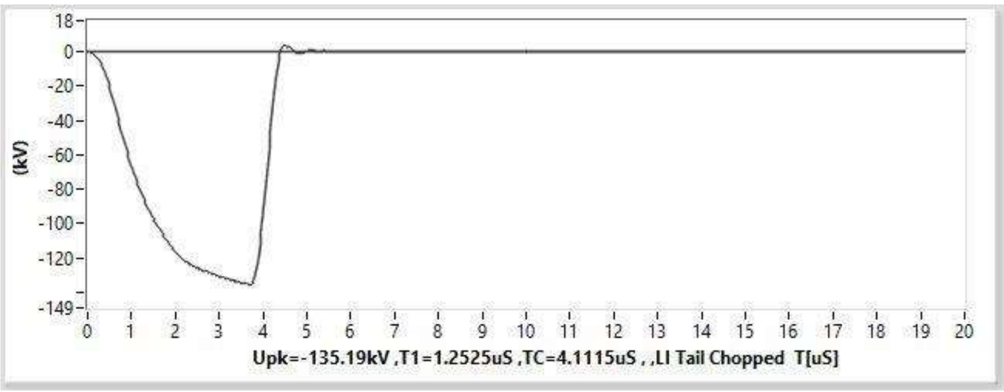


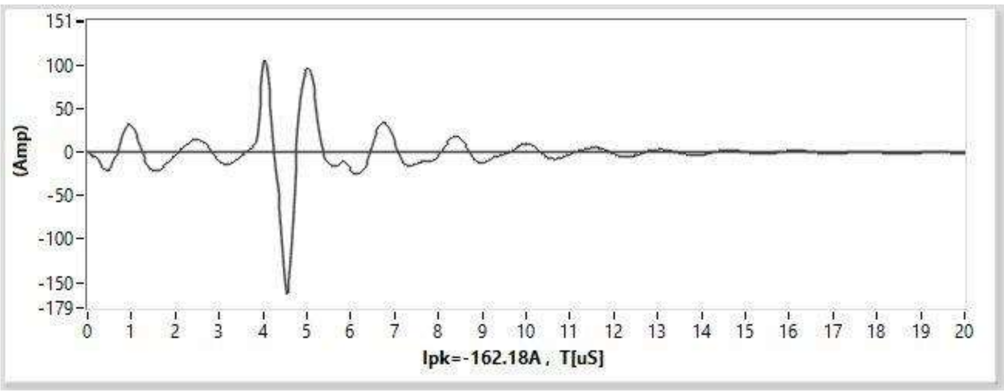
22kV Lighting Impulse



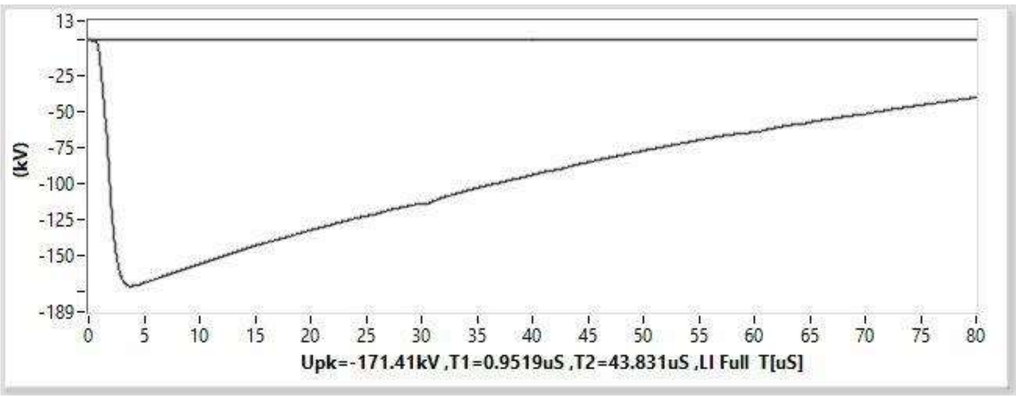


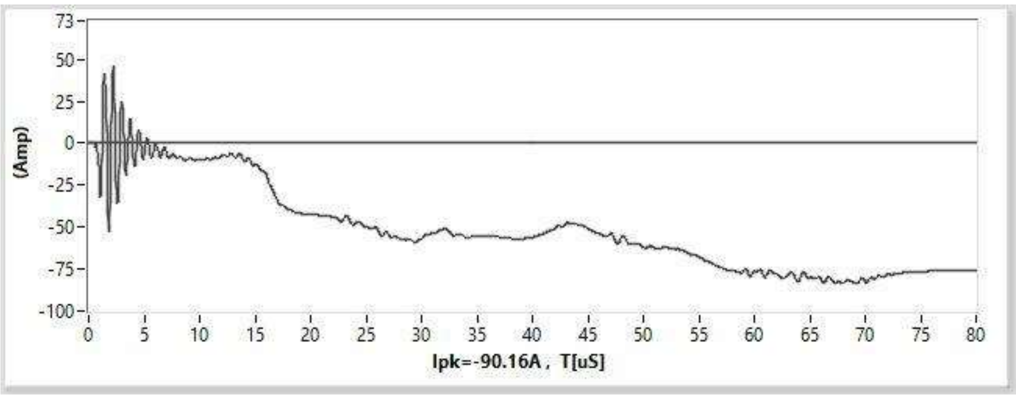
22kV Chopping Impulse



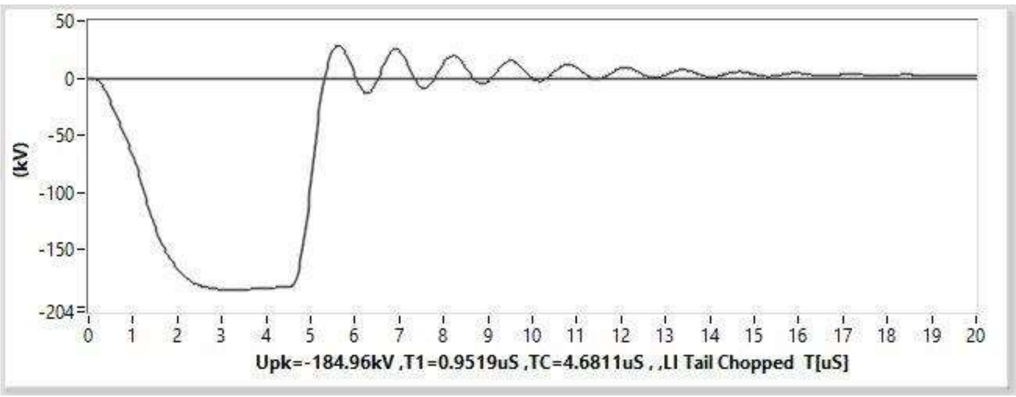


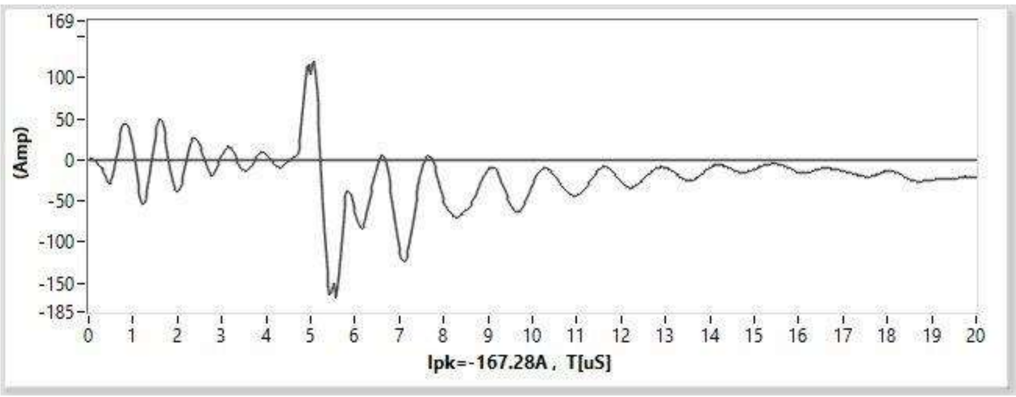
33kV Lighting Impulse





33kV Chopping Impulse





Conclusion: -

Finally, high voltage transformers are essential components of power systems, and their accuracy and reliability are critical to safe and efficient operation. Regular testing is necessary to ensure proper operation of transformers, but testing these devices presents several challenges, including capacitive and inductive effects, electromagnetic interference, temperature effects, aging, and wear.

Several approaches can be taken to overcome these challenges and improve the testing of high voltage transformers, including the use of specialized test equipment, the performance of advanced data analysis, the implementation of voltage monitoring status and improvement of test standards. These methods can quickly detect potential problems with transformers and operate them safely and efficiently.

In general, testing of high voltage transformers must be performed regularly and accurately, and industry standards are constantly being improved to keep up with technological advances and changing industry requirements.

By doing so, we can ensure the reliability and safety of the electrical system, which is essential to our modern way of life.

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