सत्यमेव जयते

२२० के वी एवं उच्चतर विभव के सबस्टेशनों के क्षतिग्रस्त उपकरणों पर विशेषज्ञों की स्थायी समिति की रिपोर्ट

(अप्रैल २०१८-मार्च २०१९)

REPORT OF STANDING COMMITTEE OF EXPERTS ON FAILURE OF 220 kV & ABOVE VOLTAGE CLASS SUBSTATION EQUIPMENT

(APRIL 2018 - MARCH 2019)

केविप्रा cea

भारत सरकार

Government of India

केन्द्रीय विद्युत प्राधिकरण

Central Electricity Authority

विद्युत मंत्रालय

Ministry of Power

नई दिल्ली

New Delhi

(विद्युत अधिनियम २००३ की धारा ७३(एल) के तहत के.वि.प्रा. के दायित्व का निर्वहन करते हुए)

(In fulfillment of CEA's obligation under Section 73(1) of the Electricity Act, 2003)

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EXECUTIVE SUMMARY

1.0 INTRODUCTION

1.1 A Standing Committee comprising experts in the field of design and operation of EHV Substations from CEA, various power utilities and research/academic institutes was constituted under Section 73, Clause (l) of the Electricity Act, 2003, to investigate the failure of 220 kV and above voltage class substation/ switchyard equipment such as Power/Generator Transformer, Circuit Breaker (CB), Instrument Transformer [i.e. Current Transformer (CT), Potential Transformer (PT) & Capacitor Voltage Transformer (CVT)], Surge Arrester (SA), Isolator etc. and recommend measures to avert recurrence of such failures in future. As a part of such activity, CEA has been receiving reports of failures of various substation/ switchyard equipment from power utilities. Office order vide which Standing Committee was constituted is enclosed at Annexure- V.

1.2 The prime objective of Standing Committee is to visit site of failure, investigate the cause of failure, discuss the cause of failure of various substation/ switchyard equipment of Power utilities in the meeting, recommend remedial measures to prevent recurrence of such failures in future and prepare a compendium of all failures. In the process, the participating utilities are mutually benefitted so as to adopt best practices.

1.3 As per the requirement of the Standing Committee, all utilities are supposed to report the failure of substation/ switchyard equipment of 220 kV & above voltage class to CEA. In fact, number of failure cases remain unreported as many of power utilities [State Transmission Utilities, Private Utilities/Licensees, Central Transmission Utilities, Public Sector Power Utilities] in the Country neither report the failure of substation/ switchyard equipment nor participate in such National level meeting. This fact has been brought in the past to the notice of Central Electricity Regulatory Commission, Joint Electricity Regulatory Commission and all State Regulatory Commissions.

1.4 In most of the cases, due to delay in reporting of event, the visit to site of failure do not materialize and analysis of cause of failure is done based on information provided by utilities. The information furnished by utilities is generally found to be inadequate for analysis of cause of failure. Either many vital information is found to be missing or not available with O&M section because the O&M history of equipment/

transformer, records of all test results including tests carried out before & after failure incidences (factory tests, pre-commissioning tests, tests carried out during O&M etc.) are not properly maintained.

1.5 For the information and use of the utilities, the format for furnishing of information of failure of substation equipment is provided at Annexure III. The utilities should provide adequate information in the format and submit it to CEA along with supporting test reports, O&M history, disturbance recorder data, photographs etc. as early as possible after the occurrence of failure.

1.6 A meeting of the Standing Committee of experts was held in CEA on 05th July 2019 to discuss cause of failure of substation equipment failed between 1st April 2018 and 31st March 2019 as reported to CEA by various utilities. Minutes of the meeting are enclosed at Annexure – IV.

1.7 Previous report on failure of substation equipment was published in July 2019 which contained the information regarding failure of substation equipment reported to CEA between 1st January 2017 and 31st March 2018.

2.0 Brief details of the failure of substation equipment failed between 1st April 2018 and 31st March 2019 as reported to CEA

2.1 The Committee investigates failures of 220 kV and above voltage class equipment only. Failure of total 72 Nos. of Transformers, GTs, Reactors, Instrument Transformers, Surge Arresters, coupling capacitors, and disconnectors of 220 kV and above voltage rating failed between 1st April 2018 and 31st March 2019 was reported to CEA. The voltage wise quantity of each equipment has been indicated in the Table-1 below:

TABLE-1

Equipment	Voltage Class			Total Quantity (Nos.)
	220 kV	400 kV	765 kV	
	Quantity (Nos.)			
Interconnecting Transformers	14	10	0	24

Generator Transformers	2	1	0	3
Station Transformer	1	0	0	1
Reactors	0	1	0	1
Current Transformer	11	2	0	13
Potential Transformer/Capacitive Voltage Transformer	4	0	0	4
Surge Arrester	18	5	0	23
Coupling Capacitor	2	0	0	2
Disconnector	1	0	0	1
			Grand Total	**72**

2.2 Quantity of failed equipment and years of service put in by these equipment before failure is given in Table-2.

TABLE-2

Years of Service	**Nos. of equipment failed**						
	Transformers / GT	**Reactors**	**CC**	**Surge Arrester**	**CT**	**CVT / PT**	**Disconnector**
0-5 years	6	1	0	3	3	1	0
Over 5 years-10 years	7	0	0	7	5	1	1
Over 10years -15 years	2	0	1	5	3	0	0
Over 15 years - 20 years	1	0	1	3	1	1	0

More than 20 years	12	0	0	4	1	1	0
Total	**28**	**1**	**2**	**23**	**13**	**4**	**1**

2.3 Complete detail of all above-mentioned failures is provided at Annexure-I.

2.4 **Failure of Transformers:**

(i) Transformer, the costliest equipment in a switchyard/substation, is expected to serve the entire life of a substation which is considered to be 35 years. The expected life in other countries are 40 years in USA, 45 years in Germany and 36 years in Australia. However, it has been observed that many transformers installed in Indian utilities have failed within first few years of service which is a matter of concern.

(ii) Summary of Inter Connecting Transformers/GTs reported to CEA to have failed between April 2018 and March 2019 is detailed below (Table 3):

TABLE - 3

S. No.	Utility	Substation	Make	Rating	Year of commissioning	Date of failure	Probable Cause of failure*
1.	PGCIL	Gwalior	BHEL	315 MVA, 420/220 kV	2008	17.04.2018	Lead insulation failure
2.	PGCIL	Puducherry	TELK	315 MVA, 400/230/ 33 kV	2010	16.09.2018	Winding insulation failure
3.	MSETCL	Chinchwad	CGL	100MVA, 220/22-22kV	2013	23.04.2018	Winding insulation failure
4.	MSETCL	Chinchwad	BHEL	100MVA, 220/22-22kV	2014	16.05.2018	Winding insulation failure

5.	MSETCL	Kalwa	R-ph: BHEL	600MVA, 400/220kV	2013	01.06.2018	Bushing failure
6.	MSETCL	Kalwa	Y-ph: ALSTOM	600MVA, 400/220kV	2013	01.06.2018	Bushing failure
7.	MSETCL	Buttibori	Aditya Vidyut	50 MVA, 200/33kV	1997	12.09.2018	Winding insulation failure
8.	MSETCL	Mulund	Aditya Vidyut	100MVA, 200/22-22kV	2015	25.09.2018	Winding insulation failure
9.	MSETCL	Kamba	AVAL	100 MVA, 220/22-22 kV	2014	14.07.2018	Winding insulation failure
10.	MSETCL	Colourchem	EMCO	50 MVA, 220/22 kV	1998	01.11.2018	Winding insulation failure
11.	MSETCL	Padghe	NGEF	105 MVA	1995	15.11.2018	Ageing
12.	MSETCL	Padghe	CGL	167 MVA, 400/220/33 kV	2017	25.11.2018	Tapping winding fault
13.	RVPN	GSS Akal	SEIMENS	400/220/33 kV	2015	05.08.2018	Bushing failure
14.	RVPN	GSS Akal	AREVA	400/220/33 kV	2011	22.08.2018	Bushing failure
15.	DTL	Rajghat	EMCO	100 MVA, 220/33/11 kV	2005	03.09.2018	Winding insulation failure
16.	DTL	Rajghat	CGL	100 MVA, 220/33/11 kV	1985	12.03.2019	Winding insulation failure
17.	DTL	Okhla	BHEL	100 MVA, 220/66-33/11 kV	1998	27.09.2018	Winding insulation failure

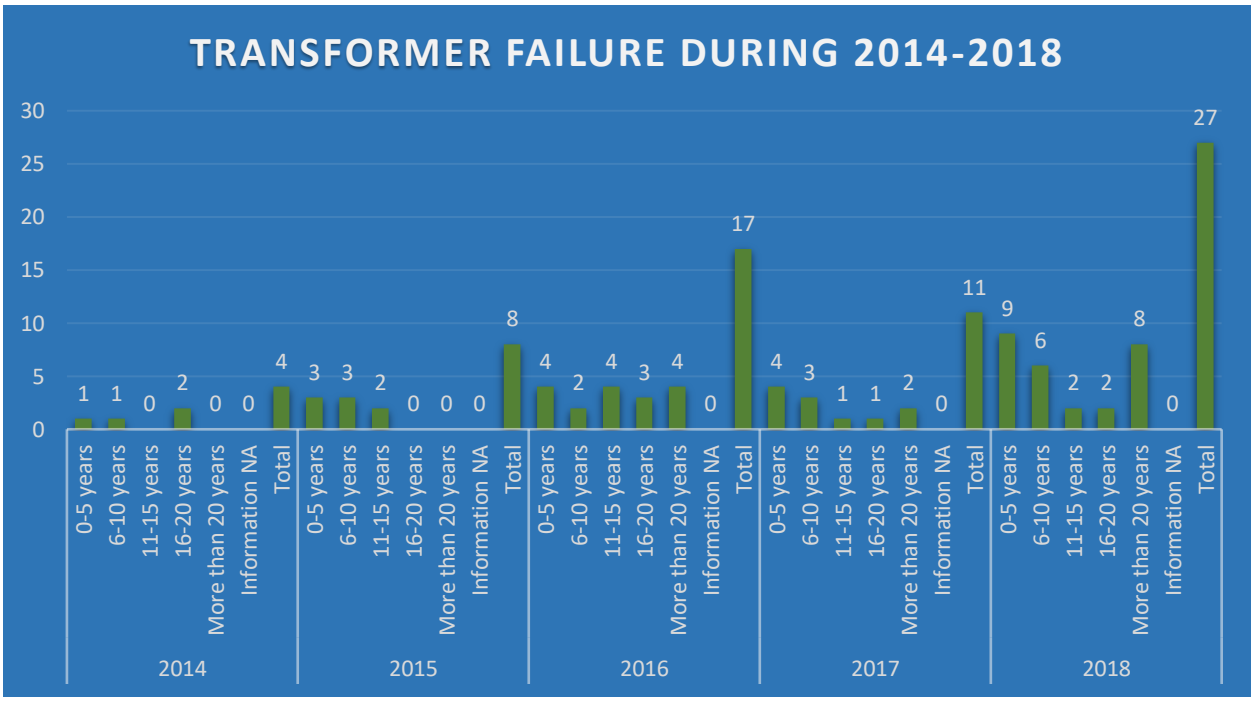
18.	DTL	Vasant Kunj	Bharat Bijlee	160 MVA, 220/66/11 kV	2010	26.04.2018	Winding insulation failure
19.	CSPTCL	Bhilai	CGL	125 MVA, 220/132kV	1980	28.09.2018	Ageing
20.	MPPTCL	Ashta	BHEL	160 MVA	2011	23.07.2018	Tapping winding fault
21.	KPCL	Raichur Thermal PS	CGL	50 MVA, 220/6.9/6.9 kV	2003	31.12.2018	Bushing failure
22.	PPCL	Bawana	BHEL	292.4 MVA,16.5 / 420 kV	2014	19.03.2019	Flashover across bushing
23.	WUPPTCL	Indirapuram	BHEL	60 MVA, 220/33kV	2016	14.02.2019	Winding insulation failure
24.	WUPPTCL	Indirapuram	BHEL	60 MVA, 220/33kV	2016	02.03.2019	Winding insulation failure
25.	WUPPTCL	Indirapuram	BHEL	60 MVA, 220/33kV	2016	02.03.2019	Winding insulation failure
26.	MSPGCL	Gas turbine power station, Uran	BHEL	146 MVA, 240/10.5 kV	1984	09.06.2018	Winding insulation failure
27.	MSPGCL	Gas turbine power station, Uran	CGL	150MVA, 230/10.5 kV	1994	27.08.2018	Tapping winding fault
28.	WBPDCL	TPS Kolaghat	BHEL	105 MVA 16.5/420 kV	1984	17.04.2018	Bushing failure

* Probable cause of failure is based on information, data and reports furnished by the utility.

(iii) As can be seen from Table 3 above, twenty-eight (28) transformer failure cases from April 2018 to March 2019 have been reported by elven (11) Utilities to CEA. It is a matter of concern that approximately 50% of the reported failed transformers were in operation/service for less than 10 years. It is highlighted that a large number of transformer failure cases remains unreported as many of power utilities [State Transmission Utilities, Private Utilities/Licensees, Central Transmission Utilities, Public Sector Power Utilities] in the Country do not report the failures.

(iv) In case of failure of Transformers in the substations of PGCIL, a team constituted by PGCIL carried out the investigation of failure of these Transformers. Reports as prepared by the team has been enclosed as Annexure-II.

(v) **Failures of transformers during 2014-2018:** The number of different transformer failures as reported in last 5 years to CEA has been shown in the graph below:



2.5 Failure of Reactor:

(i) Failure of following Reactor has been reported to CEA during the period from April 2018 and March 2019 by PGCIL which is of 400 kV class. Failure is attributed to tracking which developed from the HV lead to the

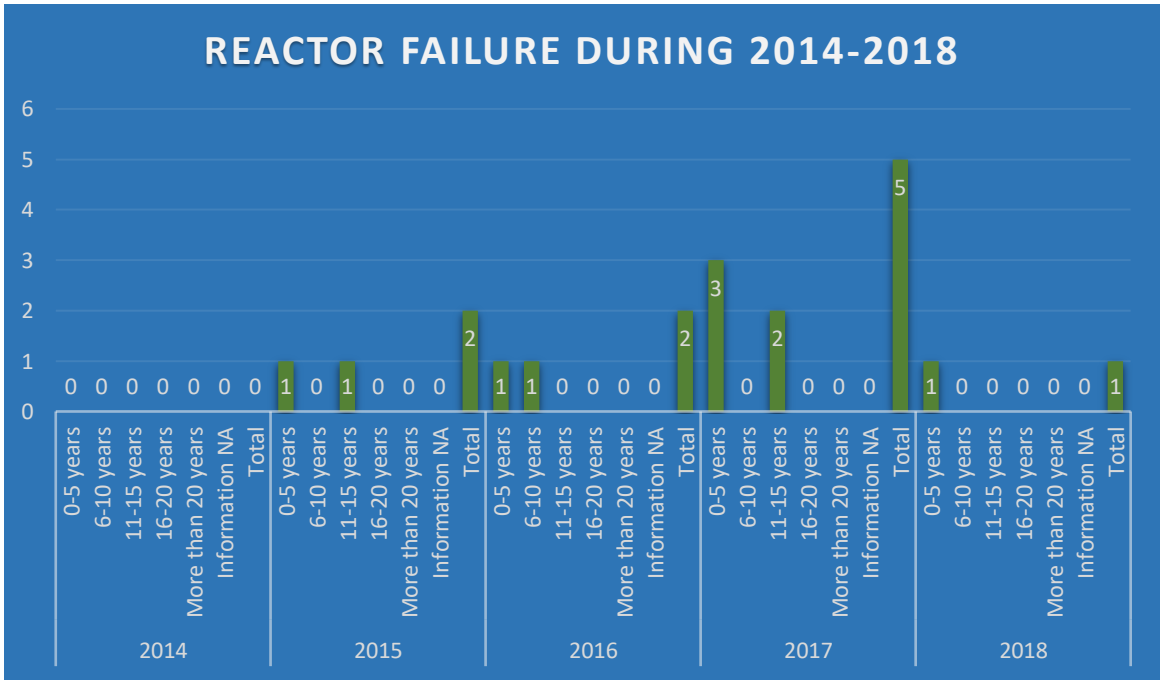
ground causing dielectric break down. Cause of failure is based on information, data & reports furnished by the utility.

TABLE - 4

S. No.	Utility	Substation	Make	Rating	Year of commissioning	Date of failure	Probable Cause of failure*
1.	PGCIL	Biswanath Chariali	BHEL	3-phase, 63MVAR, 420 kV	2017	02.05.2018	Failure of HV insulation

(ii) In case of failure of Reactor in the substations of PGCIL, a team constituted by PGCIL carried out the investigation of failure of this Reactor. Reports as prepared by the team has been enclosed as Annexure-II.

(iii) **Failures of reactors during 2014-2018:** The number of different reactor failures as reported in last 5 years to CEA has been shown in the graph below. No reactor failure was reported during 2014.



2.6 **Failure of Instrument Transformers (CT/PT/CVT), Surge Arresters (SA), Coupling Capacitors (CC) and Disconnectors:**

(i) Summary of failure of CTs, PTs, CVTs, SAs, CCs, and Disconnector occurred between April 2018 and March 2019 as reported to CEA is detailed below (Table 5):

Table-5

Equipment (Quantity)	Utility	Make	Rating	Year of commissioning	Date of failure
CT (13)	MSETCL	AREVA	400kV	2011	01.05.2018
	MSETCL	AREVA	400kV,Ratio 2000-1000-500/1A	2011	16.10.2018
	MSETCL	Universal Magnoflux Limited	800-400-200/1A	2012	06.07.2018
	MSETCL	LAMCO	220kV	2014	01.06.2018
	MSETCL	LAMCO	220kV	2012	01.06.2018
	MSETCL	MEHRU	220 kV, Ratio 800-400-200A	2009	02.11.2018
	MSETCL	MEHRU	220 KV,800-400-200/1A	2008	22.11.2018
	MSETCL	MEHRU	220kV, 1600-800/1 A	2013	13.11.2018
	MSETCL	SCT	220kV, 2400/1200/1 A	2014	08.11.2018
	APTRANSCO	WSI	220kV	1999	16.04.2018
	DVC	TELK	220kV, Ratio:800-400/1-1-1-1-1	1990	21.04.2018
	KPCL	ALSTOM	220kV	2005	04.08.2018
	TANTRANSCO	ALSTOM	400kV	2005	28.01.2019
CVT/PT (4)	BBMB	ALSTOM	220/√3 kV / 110√3 V	2004	07.05.2018
	BBMB	RadeKoncar	220/√3 kV /	1978	27.05.2018

			110√3 V		
	MSETCL	SCT	220√3 kV / 110/√3 V	2014	11.09.2018
	MSETCL	CGL	220/√3 kV / 110/√3 V	2000	09.08.2018
SA (23)	WBSETCL	CGL	198 kV	1998	30.04.2018
	WBSETCL	CGL	398kV	-	18.11.2018
	WBSETCL	CGL	360kV	2005	03.10.2018
	WBSETCL	CGL	360kV	2017	07.04.2018
	WBSETCL	OBLUM	198 kV	2012	11.05.2018
	WBSETCL	OBLUM	198 kV	2012	11.05.2018
	WBSETCL	OBLUM	198 kV	2016	11.11.2018
	WBSETCL	OBLUM	198 kV	2010	13.04.2018
	WBSETCL	OBLUM	198 kV	2016	05.05.2018
	MSTECL	CGL	398kV	2007	18.10.2018
	MSTECL	CGL	398kV	2007	08.09.2018
	MSTECL	CGL	220 kV	2002	29.10.2018
	MSTECL	CGL	198 kV	2002	15.07.2018
	MSTECL	OBLUM	198 kV	2009	16.07.2018
	MSTECL	ELPRO	198 kV	1992	17.04.2018
	MSTECL	LAMCO	200kV	2012	11.07.2018
	MSTECL	LAMCO	200kV	2011	21.07.2018
	BBMB	CGL	198kV	2010	15.05.2018
	TANTRANSCO	CGL	216 kV	2006	27.12.2018
	TANTRANSCO	CGL	216 kV	2006	18.06.2018
	TANTRANSCO	CGL	230 kV	1992	08.03.2019
	TANTRANSCO	CGL	420 kV	2004	11.03.2019
	APTRANSCO	LAMCO	220kV	1993	04.05.2018
CC (2)	CSPTCL	WSI	220 kV	1999	20.07.2018

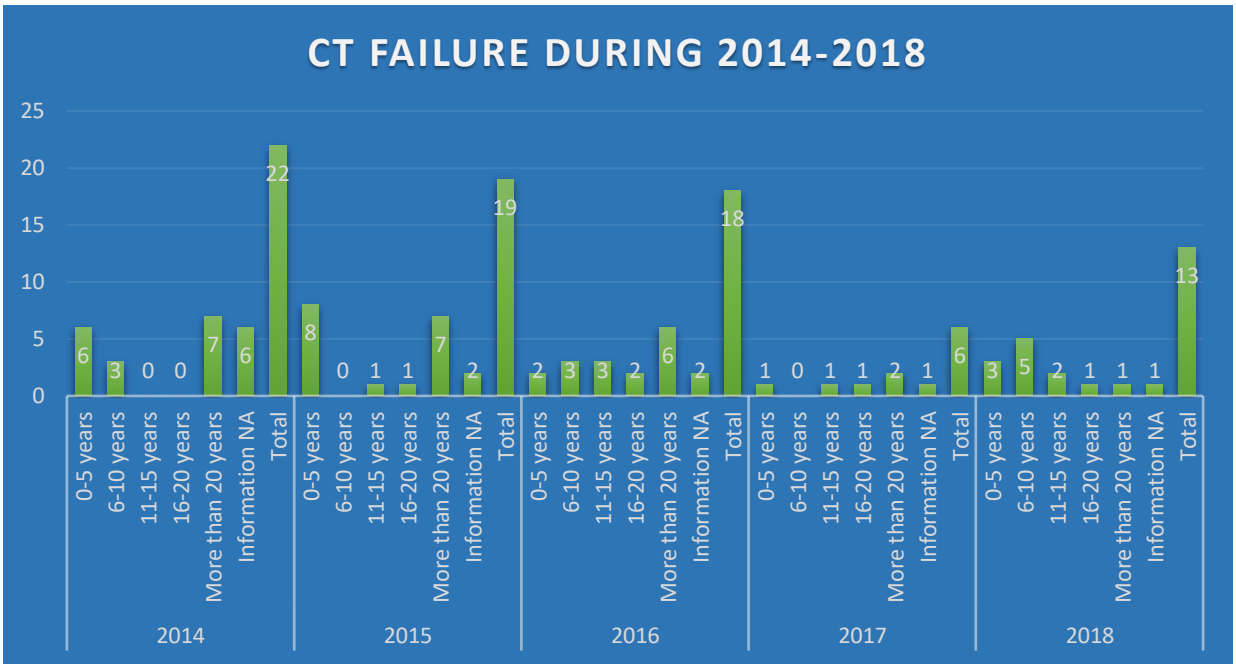
	MSETCL	ALSTOM	220 kV	2007	26.04.2018
Disconnector (1)	Reliance Infrastructure – Mumbai Transmission	ABB	220 KV	2011	27.05.2018

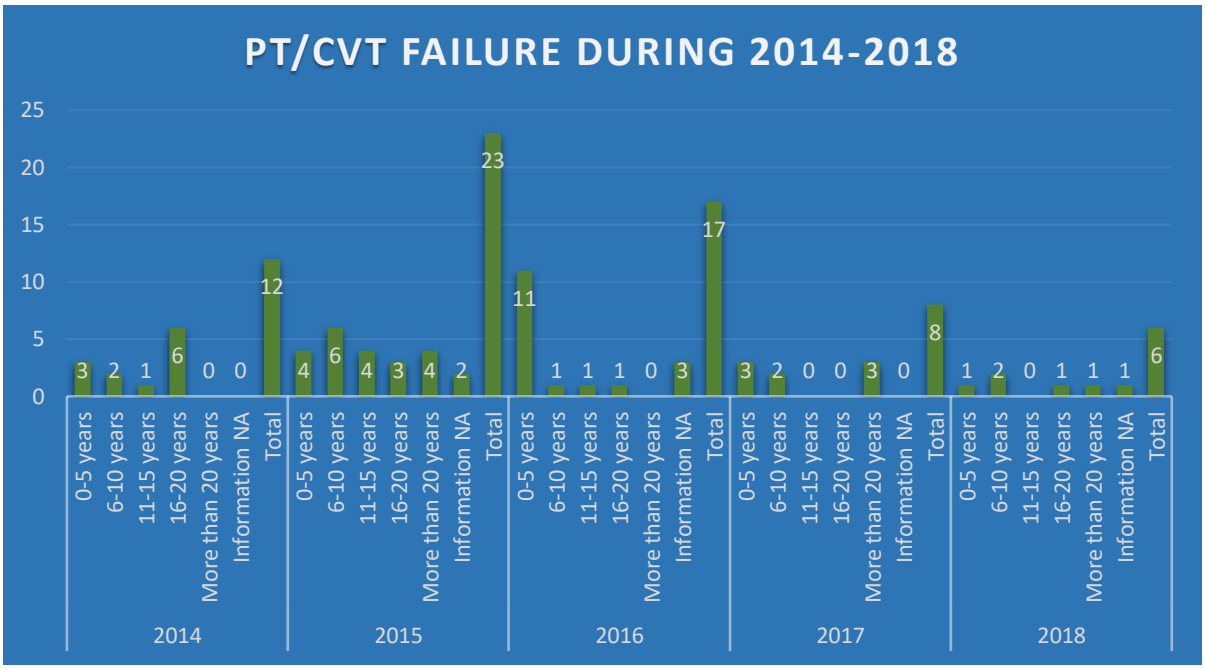
(ii) It is observed that thirteen (13) nos. of cases of CT failure occurred during the period from April 2018 to March 2019 have been reported to CEA by five (5) utilities.

(iii) In case of PT/CVT, four (4) nos. of failure occurred during the period from April 2018 to March 2019 have been reported to CEA by two (2) Utilities. However, it may be noted that due to a handful of utilities reporting the failure, it is not possible to successfully capture the statistics of service life of key electrical equipment in the substations across various utilities in India.

(iv) In most of the cases of failure of CT/ CVT/ PT/ SA, the equipment had blasted or flashed over. In such cases, it becomes difficult to pin point the cause of failure. However, such failures may be attributed to deterioration of internal insulation and moisture ingress. Some of the failures of equipment / transformers could be due to ageing.

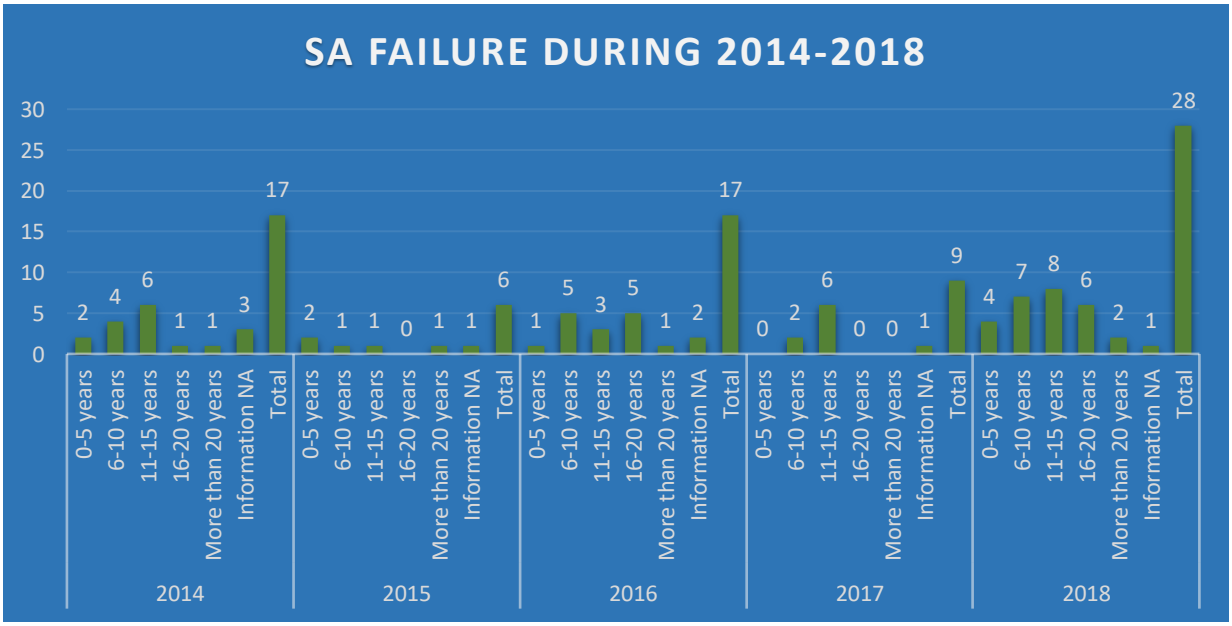
(v) **Failures of CTs/PTs/CVTs during 2014-2018:** The number of different CT/PT/CVT failures as reported in last 5 years to CEA has been shown in the graph below.





(vi) As per the reports received by CEA, twenty-three (23) nos. of cases of SA failure occurred during the period from April 2018 to March 2019 have been reported to CEA by five (5) utilities. Out of these, seventeen (17) nos. of SAs are of 220/230kV class and rest six (6) nos. of SAs are of 400kV class.

(vii) **Failures of SAs during 2014-2018:** The number of different SA failures as reported in last 5 years to CEA has been shown in the graph below.



(viii) Two (2) no. cases of failure of Coupling Capacitors and One (1) no. Disconnector failure case occurred during the period from April 2018 and March 2019 have been reported to CEA.

3.0 OBSERVATIONS:

(i) It is observed that reported failures are primarily due to following reasons:

a. Normal Ageing

b. Failure of Insulation system for CB/CT/PT/CVT/SA.

c. Failure of Insulation system & Bushing for Transformers & Reactors.

d. Lack of prudent maintenance practices

e. Frequent System Faults and transient over voltages generated by the system.

(ii) In most of the failure cases of CT/PT/CVT/SA, equipment blast or get completely damaged making it impossible to carry out any test after failure. Without tests, internal condition of the failed equipment cannot be assessed and cause of failure cannot be determined. However, in most of the cases it is assumed that degradation of insulation due to ingress of moisture and transient system voltages might be the reason of failure of these equipment.

(iii) Condition Based Maintenance (CBM) Practices using modern diagnostic tools is not being followed by most of the utilities and in general, periodic Time Based Maintenance (TBM) is still being practiced.

(iv) Adequate modern Diagnostic tools are not available with most of the State Utilities.

(v) Most of the utilities are facing problem due to shortage of technical staff for operation & maintenance of sub-station equipment. Sometimes interpretation of test results becomes difficult in absence of experts / experienced O&M staff.

(vi) Sometimes due to unavailability of shut down, maintenance of equipment is deferred which affects the efficient functioning of the equipment and further deteriorate the health of equipment.

(vii) In most of the cases of failures, utilities do not furnish factory test reports, pre-commissioning test reports, history of O&M & repairs, relay settings, environmental & system conditions at the time of failure etc. which makes it very difficult to analyze the cause of failure.

(viii) In case of failure of transformers and reactors, report of detailed internal inspection carried out by OEM at site or at its works are not provided.

(ix) In some cases, even though, there are indications of abnormalities after carrying out diagnostic tests, no corrective actions are taken.

(x) It is observed that sometimes same tests are carried out using different test methods with different kind/rating of test apparatus under different environment conditions which results in inconsistent and erroneous results.

(xi) In one of the cases, fire in one transformer led to collapse of fire wall and fire in the adjacent transformer.

4.0 RECOMMENDATIONS:

Recommended measures suggested by the Committee for the Utilities to improve the performance of the substation equipment are listed below. Some of the recommendations are being repeated from the previous report (July 2019) with the objective to remind the actions required to be taken by utilities to improve performance of equipment and to use modern diagnostic tools for condition assessment so as to keep substation equipment healthy for long trouble-free and reliable operation.

4.1 General Recommendations:

(i) All the utilities should furnish preliminary information of failure of substation equipment of 220 kV and above voltage class within 48 hours of the occurrence of the failure and detailed report within a Month in the prescribed format available at Annexure-III and also on CEA website. The report should accompany tests carried out after failure, test reports and details of previous maintenance, pre-commissioning test reports and photographs of the failed equipment.

(ii) The utilities should report to the Original Equipment Manufacturer (OEM) about the failure of equipment, even if warranty has expired, which may help the manufacturers to take corrective action for improving the product design.

(iii) The practice of Condition Based Monitoring using modern diagnostic tools should be followed instead of conventional Periodic / Time Based Maintenance. Some of the important diagnostic tools have also been suggested in Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations.

(iv) The frequency/periodicity of measurement should be changed depending on condition/healthiness of equipment in operation. The trend of the test results should be monitored rather than absolute values of test result.

(v) Utilities should follow best practices for maintenance of each equipment. All the equipment which have reached/approaching end of service life need to be monitored closely and utility should plan and take action in advance for replacement of such equipment in a phased manner.

(vi) The utilities should make it a practice to carry out various tests on major electrical equipment at sites one or two months prior to expiry of warranty period of respective equipment so that any abnormality observed in test results can be discussed with OEM for taking up further necessary action within warranty period.

(vii) The utilities must be careful while storing the equipment as spare or keeping transformer in the yard for long time before putting in to service. The OEM's recommendation for storage should be followed strictly. Spare equipment should be periodically tested as per OEM's recommendation.

(viii) Utilities should take appropriate actions for repair/replacement of concerned equipment as soon as some abnormality is observed through visual inspection or diagnostic tests.

(ix) Frequent failures of equipment of any particular make should be thoroughly investigated in consultation with OEM and necessary action including design modification, if required, should be carried out by OEM.

(x) Most of the utilities are facing problem due to shortage of supporting staff for operation & maintenance of sub-station equipment. The manpower should be strengthened for efficient operation & maintenance.

(xi) The regular cleaning of dust deposited on the housings of major equipment and bushings of transformer in Thermal Power Plant are essential to avoid flash over across the insulators, as such frequent flashover across the bushing / housing of equipment (due to operation in such dusty environment) may lead to failure of equipment. Wherever feasible, the porcelain housings of major equipment (CB/LA/CT/CVT) and bushings of transformer may be protected by providing Room Temperature Vulcanisation (RTV) coating. RTV coating over porcelain housing of equipment (CB/LA/CT/CVT) / bushings of transformer & reactors may also be considered by utilities for substation equipment installed in pollution prone areas.

(xii) Utilities should create and maintain complete data base of equipment/transformers including previous test reports (reports of factory tests/pre-commissioning tests/tests during O&M etc.), operation & maintenance history of equipment with make, model & year of commissioning etc. for proper evaluation, interpretation of test results and for taking Run-Refurbish-Replacement decision.

(xiii) However, merely maintaining the history of O&M is not sufficient. Test results are not useful if correct method of testing is not followed. All tests and maintenance should be carried out as per best practices. The method of testing as well as the conditions while conducting the tests should be consistent / identical to previous testing condition as far as possible. For example, test voltage, tap position at which test is conducted etc. should be maintained while measuring IR or Turns Ratio, or conducting SFRA and other similar tests. Details of test kits, should be maintained so that the test results can be compared with subsequent test results. For variation in temperature, required correction factors could be incorporated. Calibration of the testing instruments should be ensured for reliability of the assessment.

(xiv) Utilities should explore the possibility of installation of CCTV cameras in the substation, covering transformer area so that transformers could be monitored from the control room and any mishap with the transformer could be recorded for further analysis. It would also help to determine the point of initiation and actual cause in case of fire in transformer.

(xv) To avoid spread of fire in cable trenches in case of oil leakages, the trenches should be filled with sand up to a certain distance starting from the equipment.

(xvi) If any damaged equipment is sent to the manufacturer's works for repair, detailed investigation report including probable causes of failure should be submitted to the Standing Committee for benefit of the other utilities.

4.2 Recommendations for Transformers (ICT & GT), Reactors and Instrument Transformers (CT/PT/CVT):

(i) The proper handling, loading, transportation, unloading, and storage at site before assembling play important role in satisfactory operation of equipment.

(ii) The erection of major equipment including transformers/reactors should always be carried out by experienced technical team under the close supervision of manufacturer.

(iii) Inordinate delay in commissioning of equipment after reaching at site should be avoided.

(iv) When there is a wide gap between the year of manufacturing and year of commissioning of the transformers/ reactors, proper care must be taken to ensure satisfactory operation of transformer/ reactor. Storage and periodic testing of transformer/ reactor should be done as per manufacturer's recommendations.

(v) Transformer/ reactors should not be kept for more than three (3) months with dry air/inert gas (Nitrogen) filling and all throughout the period, required pressure needs to be maintained in order to avoid the exposure of active part to atmosphere. After three (3) months, transformer/ reactor should be filled with oil under vacuum and it should be provided with oil conservator including oil level indicator and breather. The oil parameters need to be monitored regularly.

(vi) As far as possible the transformer/ reactor should be transported filled with dry air. Use of nitrogen for this purpose should be avoided.

(vii) The height of the fire wall between two transformers/reactors should be at least 600 mm above the highest point of the transformer and fire wall should be rated for four hour fire rating so that fire in one transformer/reactor does not affect adjacent transformers/ reactor.

(viii) Whenever there is movement of transformer either from manufacturing works or from one station to other, SFRA should be carried out before movement and after shifting to new location. SFRA signature would provide valuable information about deformation in winding /core during transportation.

(ix) OLTC is one of the contributors to the failure of transformer. Possibility of eliminating OLTC from 400kV & 765kV class transformer should be considered (based on system studies) in consultation with Regional Power Committee (RPC) and Regional Load Dispatch Centre (RLDC) / POSOCO and CEA. The reduction in number of taps/steps can also be considered in case of OLTC of 220kV and below voltage class transformers. The removal of OLTC will simplify the design and manufacturing of transformers.

(x) Tertiary winding should be avoided, wherever feasible, as it increases the probability of failure of the transformer. Tertiary terminals of transformer prone to short circuiting by external element such as bird or animal may be suitably insulated.

(xi) Transformer should be subjected to short circuit test as per CEA Regulations to verify its capability to withstand dynamic effect of short circuit. The design review of the transformers should be carried out properly before commencement of manufacturing. Stage inspection should also be carried out to check manufacturing process as well as quality of material used in subsequent transformers.

(xii) An internal inspection of the failed transformer on-site is warranted at times to locate fault inside the transformer and to assess the extent of damage. As far as possible, internal inspection should be carried out in association with OEM / in presence of representative of OEM. All safety precautions must be observed at all times. Internal inspection must be

performed by experienced staff with proper training. The internal inspection should not cause any further damage to the transformer and precaution should be taken to prevent ingress of moisture and any foreign material into the transformer and hence internal inspection should be meticulously planned.

(xiii) As far as possible, LV test and SFRA should be conducted after through fault to check the integrity of the transformer.

(xiv) The capacitance and tan delta measurement of transformer bushing at variable frequency and DGA of bushing oil should be carried out for health assessment of bushings as this has been proved to be very effective in assessing the condition of in-service bushings.

(xv) Residual Life Assessment (RLA) should be conducted for old and aged transformers (approaching end of service life) for proper planning to replace them in stages.

(xvi) Periodic oil testing including DGA (wherever feasible) in case of instrument transformers are recommended. Health of gaskets and bellows needs to be checked periodically for CTs. Thermo vision scanning of CTs, CVTs and PTs should also be carried out regularly as a good maintenance practice.

(xvii) While measuring tan delta of transformer bushing/CT/PT/CVT, apart from absolute value, rate of rise of tan delta should also be monitored and it should not be more than 0.1% per year. Frequency of measurement should be increased in case tan delta value is approaching 0.7%. Following tables can be referred while measuring tan δ and capacitance of CVTs:

Change in Tanδ	**Monitoring Frequency**
Upto +0.002	Three yearly
+0.002 to +0.003	Yearly
Above +0.003	Alarming

Change in Capacitance	**Monitoring Frequency**
upto ±2%	Three yearly

±2% to ±3%	Yearly
Above ±6%	Alarming

(Source: - CBIP Manual on EHV Substation Equipment Maintenance)

(xviii) The change in secondary voltage of CVTs is a very good indicator of the condition/health of CVTs. Following table may be referred for monitoring of secondary voltage:

Drift in secondary Voltage (to be measured by 0.2 / 0.5 class multimeter)	**Condition**	**Monitoring Frequency**
Upto ± 0.5 volts	Healthy	Six monthly
± 0.5 to ±0.8 volts	To be monitored	03monthly
+0.8 to +1.2 volts	Close monitoring	Monthly
+1.2 to +2.0 volts	Close monitoring	15 days
above +2.0 volts	Alarming	replacement
-0.8 to -4.0 volts	Close monitoring	15 days
less than -4.0 volts	Alarming	replacement

(Source: - CBIP Manual on EHV Substation Equipment Maintenance)

(xix) Following table can be referred while measuring tan δ of CTs:

Value of Tanδ	**Monitoring Frequency**
Upto 0.007 (annual rise@0.001)	Yearly
0.007 to 0.011	Half Yearly
Above 0.011	Replace the CT

(Source: - CBIP Manual on EHV Substation Equipment Maintenance

(xx) Oil level in CTs should be checked before charging. For CTs with metallic bellows, the oil should be present up to the top of the bellow for

proper functioning. The oil leakage needs to be checked periodically. Bellow level should be closely watched. The level of bellows of all CTs in one bay should be same at any point of time. Different bellow level may be an indicator of oil leakage, gassing or fault. Similarly, Capacitor units & EMU of CVTs in one bay should have same oil level indication at any point of time.

(xxi) Varistors protect the CVT from over voltage due to Ferro-resonance (FR) oscillations. They may fail in service due to sustained FR or if the energy to be handled exceeds designed limit. If a varistor fails, it should be replaced by the varistor of the same voltage rating.

(xxii) At the substations where fault level has increased beyond the design level, suitable corrective measures such as splitting of bus or employment of fault limiting devices should be adopted.

4.3 Recommendations for Surge Arrester:

(i) Measurement of the 3rd harmonic resistive component of leakage current is a very good method for assessing healthiness of SA. If 3rd harmonic component of resistive current is more than 150 µA, then Insulation Resistance (IR) value test should also be conducted and if current exceeds 350 µA, then SA should be removed from service and replaced. The measurement of leakage current before and after the monsoon should be carried out so as to ascertain the effect of moisture.

(ii) Before erection, the condition of the Arrester unit should be checked and it should be ensured that there is no damage during erection. If SA is kept on an uneven surface, it is likely to damage the pressure relief diaphragm. Any damage to this thin & sensitive material while handling & erecting will result into moisture entry into Surge Arrester, which will lead to its failure.

(iii) Thermal scanning is another simple on-line check often used on SAs to locate hot spot due to improper/defective terminations/excessive watt loss.

(iv) The specification of SA should include Dip test/Sealing Test which can be carried out at manufacturer's works to ensure proper sealing against ingress of moisture.

4.4 Recommendations for Circuit Breaker:

Dynamic Contact Resistance Measurement (DCRM) test kit is a very important tool to assess the healthiness of circuit breaker. This test may be carried out once in two years. Moreover, while formulating the specification for procurement of CB for new substation, provision for

procurement of Operational Analyzer along with Dynamic Contact Resistance Measurement (DCRM) test kit should be included for one substation or a group of nearby substations depending upon the requirement.

4.5 Recommendations for disconnectors:

(i) Disconnectors used for transferring load currents from one bus system to another should be designed and tested for bus transfer current switching duty.

(ii) Measurement of resistance of disconnector main contacts should be carried out and it should not exceed 300 micro ohms.

Annexure-I

Detailed Information of All Failed Equipment Reported to CEA between April 2018 and March 2019

Annexure-I

Detailed Information of All Failed Equipment Reported to CEA between April 2018 and March 2019

Detailed information in respect of following failures is given in subsequent pages of this annexure:

S.no	Failure report	Utility	S/S Equipment	Serial no.	Date of Failure
TRANSFORMERS					
1.	Failure of 315 MVA, 420 kV, ICT-II at Gwalior Substation	PGCIL	Transformer	6006372	17.04.2018
2.	Failure of 400/230/33kV, 3 Ph, 315 MVA ICT-II at Puducherry Substation	PGCIL	Transformer	6003978 (J-637)	16.09.2018
3.	Failure of 100MVA, 220/22-22kV Power Transformer at Chinchwad substation	MSETCL	Transformer	24767 (J-580)	23.04.2018
4.	Failure of 220/22-22kV, 100MVA, Transformer at Chinchwad substation	MSETCL	Transformer	6003978 (J-637)	16.05.2018
5.	Failure of 200 MVA, 400/220kV R-ph & Y-ph unit of 600MVA ICT-II at Kalwa Substation	MSETCL	Transformer (2 Nos.)	6003887 & 21726601	01.06.2018
6.	Failure of 50MVA, 220/33kV Transformer at Buttibori Substation	MSETCL	Transformer	HT1358/ 11662	12.09.2018
7.	Failure of 100MVA, 220/22-22kV Transformer at Mulund Substation	MSETCL	Transformer	177278	25.09.2018
8.	Failure of 100MVA,	MSETCL	Transformer	6001397	14.07.2018

	220/22kV Power Transformer at Kamba Substation				
9.	Failure of 50MVA, 220/22kV Power Transformer at Colourchem Substation	MSETCL	Transformer	HT/1359/ 11668	01.11.2018
10.	Failure of 315MVA, 400kV Power Transformer at Padghe Substation	MSETCL	Transformer	6800000116	15.11.2018
11.	Failure of 315MVA, 400kV Power Transformer at Padghe Substation	MSETCL	Transformer	T09735	25.11.2018
12.	Failure of 500 MVA, 400/220/33kV Power Transformer at GSS Akal Jaisalmer Substation	RVPN	Transformer	130111-01	05.08.2018
13.	Failure of 315 MVA, 400/200/33 kV Power Transformer at GSS Akal Jaisalmer Substation	RVPN	Transformer	B 30538	22.08.2018
14.	Failure of 100 MVA, 220/33/11 kV Power Transformer at Rajghat Substation	DTL	Transformer	HT1644/ 12426	03.09.2018
15.	Failure of 100 MVA, 220/33/11 kV Power Transformer at Rajghat Substation	DTL	Transformer	24591	12.03.2019
16.	Failure of 100 MVA, 220/66-33/11 kV Power Transformer at Okhla Substation	DTL	Transformer	2010227	27.09.2018

17.	Failure of 160 MVA, 220/66/11 kV at Vasant Kunj Substation	DTL	Transformer	5098/1	26.04.2018
18.	Failure of 125 MVA, 220/132kV Transformer at Bhilai Substation	CSPTCL	Transformer	2410884	28.09.2018
19.	Failure of 160 MVA, 400 kV Transformer at Ashta substation	MPPTCL	Transformer	-	23.07.2018
20.	Failure of 50 MVA, 220/6.9/6.9 kV Station Transformer at Raichur TPS	KPCL	Station Transformer	BH-8926/1	31.12.2018
21.	Failure of 292.4 MVA, 420/16.5kV Generator Transformer of STG-2 at CCPP, PPS-III, Bawana station	PPCL	Generator Transformer	6006757	19.03.2019
22.	Failure of 60 MVA, 220/33kV Power Transformer at Indirapuram S/s	WUPPTCL	Transformer	2038225	14.02.2019
23.	Failure of 2 nos. 60 MVA, 220/33 kV Transformer at Indirapuram S/s	WUPPTCL	Transformer (2 Nos.)	2038227 & 2038226	02.03.2019
24.	Failure of 146 MVA, 240/10.5 kV GT at Gas Turbine Power Station, Uran of MSPGCL	MSPGCL	Generator Transformer	N 406889	09.06.2018
25.	Failure of 150 MVA, 230/10.5 kV GT at Gas Turbine Power Station, Uran of MSPGCL	MSPGCL	Generator Transformer	T 8324/2	27.08.2018
26.	Failure of 105 MVA, 400/√3 / 220/√3 / 33kV ICT at KTPS substation	WBPDCL	Generator Transformer	6004571	16.04.2018

REACTORS					
27.	Failure of 420 kV, 63 MVAR reactor at Biswanath Chariali substation	PGCIL	Reactor	6007609	02.05.2018
CURRENT TRANSFORMERS					
28.	Failure of 400kV CT of 500MVA ICT-2 at Khaperkheda Substation	MSETCL	CT	20081244	01.05.2018
29.	Failure of 400kV CT of 400KV Khaperkheda-Koradi Ckt-I Substation	MSETCL	CT	200812134	16.10.2018
30.	Failure of 220kV CT at TELCO substation	MSETCL	CT	17014	06.07.2018
31.	Failure of CT of 500MVA,400/220kV ICT-III at Kalwa Substation	MSETCL	CT	CF-333	01.06.2018
32.	Failure of CT of 500MVA,400/220kV ICT-III at Kalwa Substation	MSETCL	CT	CF-323	01.06.2018
33.	Failure of 220kV CT at APTA Substation	MSETCL	CT	OC/2064/2/270/08	02.11.2018
34.	Failure of 220kV CT at Malegaon Substation	MSETCL	CT	OC-2064/2/52/07	22.11.2018
35.	Failure of 220kV CT at Kandalgaon Substation	MSETCL	CT	OC/2064/2/254/08	13.11.2018
36.	Failure of 220kV CT at SPCL Substation	MSETCL	CT	2009/09	08.11.2018
37.	Failure of 220kV Bus Coupler Bus-2 CT at Nellore Substation	APTRANSCO	CT	931129	16.04.2018

38.	Failure of 150MVA,220kV Y-ph PCT at Jamshedpur Substation	DVC	CT	230140-6	21.04.2018
39.	Failure of 245kV/220kV CT at Sharavathy generating Substation	KPCL	CT	20040119/ 2004	04.08.2018
40.	Failure 420kV CT at Sriperumpudur Substation	TANTRANSCO	CT	20030842 /2003	28.01.2019
POTENTIAL TRANSFORMERS / CAPACITOR VOLTAGE TRANSFORMERS					
41.	Failure of 220kV CVT at Panipat Substation	BBMB	CVT	88121009	07.05.2018
42.	Failure of 220kV CVT at Panipat Substation	BBMB	CVT	VCU-245	27.05.2018
43.	Failure of 220kV PT at Lonikand-II Substation of MSETCL	MSETCL	PT	2010/2024	11.09.2018
44.	Failure of 220kV PT at 220kV Bus at Satana Substation	MSETCL	PT	10248	09.08.2018
SURGE ARRESTER					
45.	Failure of 198 kV SA at Gokarna Sub-Station	WBSETCL	SA	-	30.04.2018
46.	Failure of 398 kV SA at Jeerat Sub-Station	WBSETCL	SA	-	18.11.2018
47.	Failure of 360 kV SA at Arambag Sub-Station	WBSETCL	SA	-	03.10.2018
48.	Failure of 360 kV SA at Kharagpur Sub-Station	WBSETCL	SA	91842	07.04.2018
49.	Failure of 198kV SA at Kharagpur Sub-Station	WBSETCL	SA	24	11.05.2018

50.	Failure of 198kV SA at Kharagpur Sub-Station	WBSETCL	SA	28	03.10.2018
51.	Failure of 198kV SA at Kharagpur Sub-Station	WBSETCL	SA	14	11.11.2018
52.	Failure of 198kV SA at Midnapore Sub-Station	WBSETCL	SA	04	13.04.2018
53.	Failure of 198kV SA at Midnapore Sub-Station	WBSETCL	SA	12	05.05.2018
54.	Failure of 398kV SA at PADGHE Sub-Station	MSETCL	SA	55526	18.10.2018
55.	Failure of 398kV SA at PADGHE Sub-Station	MSETCL	SA	55538	08.09.2018
56.	Failure of 220kV SA at Kathapur Sub-Station	MSETCL	SA	2182	29.10.2018
57.	Failure of 198kV SA at Kathapur Sub-Station	MSETCL	SA	12561 & 12562	15.07.2018
58.	Failure of 198kV SA at Volkswagen Sub-Station	MSETCL	SA	02	16.07.2018
59.	Failure of 200 kV SA at RS Karad Substation	MSETCL	SA	08-80-372	22.05.2018
60.	Failure of SA of 220kV Siemens Bay at Kalwa Substation	MSETCL	SA	881ABC	11.07.2018
61.	Failure of 200kV SA at Kalwa Substation	MSETCL	SA	884 ABC	21.07.2018
62.	Failure of 198kV SA at Panipat Substation	BBMB	SA	51925	15.05.2018
63.	Failure of 216kV R-Ph SA of 230kV Manali-II feeder at Alamathy Substation	TANTRANSCO	SA	27212	18.06.2018
64.	Failure of 216kV Y-Ph SA of 230kV Koyembedu bay	TANTRANSC	SA	28214	27.12.2018

	at Alamathy Substation	O			
65.	Failure of B-ph SA of 315 MVA, 400/230 kV ICT-II at Sriperumbudur Substation	TANTRANSCO	SA	4867	08.03.2019
66.	Failure of R-ph SA of 315 MVA, 400/230 kV ICT-II at Sriperumbudur Substation	TANTRANSCO	SA	24917	11.03.2019
67.	Failure of 220kV SA at Switching station, Gooty	APTRANSCO	SA	105A, 105B & 105C	04.05.2018
COUPLING CAPACITOR					
68.	Failure of 245kV Coupling Capacitor of 220 kV Urla-Siltara feeder at Urla Substation	CSPTCL	CC	8808602	20.07.2018
69.	Failure of 220kV, 6600pF Coupling Capacitor at Phursungi substation	MSETCL	CC	20020535	26.04.2018
DISCONNECTOR					
70.	Failure of 220kV Main Bus-1 Side Disconnector module of 125 MVA TR-2 bay at 220 kV Gorai EHV Substation	Reliance Infrastructure Mumbai Transmission	Disconnector	500340954/2010	27.05.2018

TRANSFORMERS

1. Failure Report of ICT-II 315 MVA, 420/220 kV at Gwalior Substation of PGCIL

A.	Name of Substation	:	Gwalior
B.	Utility/Owner of substation	:	PGCIL
C.	Faulty Equipment	:	ICT-II
D.	Rating	:	315 MVA, 420/220 kV
E.	Make	:	BHEL
F.	Sr. No.	:	6006372
G.	Year of manufacturing	:	2006
H.	Date of commissioning	:	28.02.2008
I.	Date and time of occurrence/discovery of fault	:	17.04.2018 at 12:15 hrs
J.	Information received in CEA	:	31.07.2018
K.	Fault discovered during	:	During operation
L.	Details of previous maintenance	:	Last testing was carried out on 13.07.2017 during annual maintenance and results were found to be normal. History of previous maintenance tests carried out on the transformer are listed below:

DGA History

Date	TGC (%)	N2 (%)	O_2 (%)	H_2	CH_4	C_2H_4	C_2H_6	C_2H_2	CO	CO_2
16.04.18	7.57	6.11	0.64	26	38	5	6	0	1237	6910
10.03.17	5.72	4.59	0.16	11	20	11	5	0	1371	8256
05.08.16	4.6	3.85	0.16	32	24	27	10	0	1048	4873
20.10.15	4.25	3.57	0.34	27	11	7	4	0	583	2736

Oil Parameter History

Sample Date	BDV	Water	Res (E12)	Tan D	IFT	Acidity	Flash
24.06.17	61.8	14	7	0.00023	38.3	0.0125	149
21.06.16	82.2	294	170	0.00053	43.2	0	159

Bushing DGA carried out in between 2013 to 2016 and DGA results of HV bushings were found to be normal. However, lV Bushings were found with high DGA and were replaced in Oct. 2015 with CGL make bushings.

Bushing Desc.	S. date	H_2	CH_4	C_2H_4	C_2H_6	C_2H_2	CO	CO_2
HV B-Ph , BHEL-735076	02-06-16	24	6	1	1	0	558	1455
HV R-Ph, BHEL735073	02-06-16	8	8	2	2	0	385	1926
HV Y Ph , BHEL-737048	02-06-16	15	7	1	1	0	790	2086
IV (B-Ph), BHEL-740137	11-10-15	41813	2556	1	385	0.5	234	581
IV (Y-Ph),	11-10-15	42073	1504	0	218	0.2	92	727

BHEL-730104

M.	Details of previous failure	:	Transformer was in operation without any problem till the date of failure.
N.	Sequence of events/ Description of failure	:	

On 17.04.2018 at 1215 hrs, ICT- tripped on Differential and REF protection, causing isolation of fault. Simultaneously PRD, Buchholz, OTI, WTI and Oil Surge Relay operated.

12:15:47.480	Transformer Y-Ph Instantaneous Differential Operated
12:15:47.487	Buchholz Alarm
12:15:47.488	Transformer R/Y/B Ph Percent Differential Operated
12:15:47.490	Transformer R & B Ph Instantaneous Differential Operated
12:15:47.493	REF Trip
12:15:47.495	Group A protection trip
12:15:47.505	Buchholz Trip
12:15:47.508	Group B protection trip
12:15:47.513	Main CB Open
12:15:47.513	Tie CB open
12:15:47.520	220 kV side CB open
12:15:47.693	OLTC Oil Surge Relay
12:16:21.821	WTI Alarm
12:16:26.451	WTI Trip
12:16:43.997	OTI Alarm
12:16:49.374	WTI Alarm

Heavy noise was heard in control room at the time of failure. Fire protection operated immediately after failure and fire hydrant system was used to control the fire. However, fire was so severe that fire tender was called for extinguishing the fire.

O.	Details of Tests done after failure	:	No tests were possible as the transformer had completely burnt.
P.	Observations & analysis	:	

It was observed that there was fault current of 21.4 kA in Y-ph of 400 kV side and 1.67 kA from 220 kV side. Fault of 10.7 kA was also observed in B-ph of 400 kV side

after 40 ms.

The findings of Internal Inspection as reported by PGCIL are as follows:

1. Transformer caught fire immediately after the tripping of the Transformer and fire was extinguished with the fire tender. However, the intensity of the fire was so severe that black smoke continued to come out of the tank for hours.
2. All 3 HV bushings are burnt and damaged.
3. All 220 kV & tertiary bushings found intact with the tank but due to intensity of the fire, all these bushings have also lost their property due to fire.
4. Main tank found burnt and bulged towards HV side. Rim found distorted.
5. All Turret CT of R, Y & B phase were completely burnt/ damaged in this fire incidence.
6. Due to heavy fire, all windings, insulations, cleat support and support structures were completely burnt out.
7. The marshaling box, cables, Radiator pipe line, cooler bank, Conservator was also damaged badly due to fire.
8. All 3 HV side LAs and associated structures were found to be damaged. 220 kV side LAs were intact on the structure.

Prima facie, this seems that fault was initiated in the winding end of the Y-ph HV Bushing and it further spread to B- ph as fault current of the order of 21.4 kA in Y-ph and 10.6 kA in B-ph of 400 kV side was observed. Due to fault heavy arcing took place inside the tank and pressure increased which led to damage to the turrets and hot oil came into contact with the air leading to fire.

2. Failure of 400/230/33kV, 3 Ph, 315 MVA ICT-II at Puducherry Substation of PGCIL

A.	Name of Substation	:	400/230kV Puducherry
B.	Utility/Owner of substation	:	PGCIL
C.	Faulty Equipment	:	ICT-II
D.	Rating	:	400/230/33kV, 3 Ph, 315 MVA
E.	Make	:	TELK
F.	Sr. No.	:	140131-2
G.	Year of manufacturing	:	2008

H.	Year of commissioning	:	2010
I.	Date and time of occurrence/discovery of fault	:	16.09.2018 at 23:22 Hrs.
J.	Information received in CEA	:	15.10.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	On 29.06.2018, LV Y-ph bushing replaced with spare bushing & damaged gasket of IV B-ph bushing replaced with spare gasket.

DGA HISTORY

Date	BDV	H_2	CH_4	C_2H_4	C_2H_6	C_2H_2	CO	CO_2
02.07.18	69.5	11	2	4	1	0	94	1392
05.01.18	74.8	9	7	10	3	0	416	4048
05.07.17	NT	6	9	11	3	0	895	8388
03.01.17	67.9	7	9	10	3	0.2	840	5487
15.07.16	NT	12	9	6	2	0.4	845	5560

M.	Details of previous failure	:	Nil
N.	Sequence of events/ Description of fault	:	ICT-II tripped on Diff. relay, Buchholz relay & PRD operation.
O.	Details of Tests done after failure	:	Following Tests were carried out: DGA, Magnetic Balance test, Magnetizing current, winding resistance, SFRA, winding Cap. & Tan Delta, IR of winding Violation in the results of DGA a. All test results of R-ph found violating. b. R-ph winding found damaged and deformed

Magnetic Balance Test						
Apply 1-230vAc		**Voltage Measured In Volts**				
Across (1)		**Between (2)**		**Between (3)**		**Remarks**
1U1–N:	238.87	2V1–N:	158.11	2W1–N:	78.11	Current: U: 2.48mA
1V1–N:	238..98	2U1–N:	70	2W1–N:	167.2	Current: V: 1.49mA
1W1–N:	238.9	2U1–N:	34.5	2V1–N:	203.08	Current: W: 1.74mA

Winding Resistance				
Between Windings	**Resistance**	**Resistance At 75°C (in Ohms)**		**%Deviation**
	Site Value@32°C	**Factory**	**Site**	
1U1–N	769.7	778.2	893.7	-14.8
1V1–N	684.5	778.2	794.7	-2.1
1W1–N	684.6	778.2	794.9	-2.1
2U1–N	485.2	457.6	563.3	-23.1
2V1–N	402.17	457.6	466.9	-2
2W1–N	402.3	457.6	467.1	-2.1

IR Measurement					
Main Winding	**IR in GΩ**			**Dielectric Absorption Coefficient DAI=60 Sec/ 15 Sec**	**Polarisation Index PI=600 Sec/ 60Sec**
	15 sec	**60 sec**	**600 sec**		
	GΩ	**GΩ**	**GΩ**		
Combination for Autotransformer:					
a) HV+IV/LV	1.61	4.34	11.4	2.69	2.627
b) HV+IV/E	0.171	0.167	0.143	0.933	0.856
c) LV/E	1.78	3.52	9.59	1.978	2.724

P.	Observations & Analysis	:	

The findings of Internal Inspection as reported by PGCIL are as follows:

R Phase

1. Oil seal has come out at bottom of winding and outer cylinder is seen broken at the bottom side near tap lead take out.
2. Burned paper and carbon deposits are seen spattered all over the tank as well as at coil top.
3. One of the IV side clamping ring is seen dislodged and seen shifted towards Y-ph. Lot of carbonization is seen on the ring.
4. Core clamping wedge between R & Y phases is displaced.
5. Outer winding of R-ph is found to be deformed and the top portion of outer cylinder is touching outer cylinder of Y-ph.
6. Carbon deposits are seen mainly over the R-ph IV winding indicating major failure for it.
7. HV line lead is seen to be slightly dislocated from the center of bushing shield.

Y phase

1. Carbon deposits are scattered over Y-ph also. But deposits are not seen over individual windings. Hence this seems to have come from R-ph.
2. There is no problem visible for the clamp rings/window wedge etc.
3. Y-ph OLTC is stuck at nominal position (not rotating in either direction) but there is no visual defect on the Top selector.

B phase

Even though minor carbon deposits are seen over the phase also, the winding appears to be intact.

Internal inspection, test results and fault current of 12.97 kA observed at R-ph of 230kV side reveal that there is a failure in the R-ph winding. The winding resistance measured as well as the presence of carbon deposits over the lV winding also points towards a major failure of the R-ph lV winding. Several incidents of IV line faults in feeder lines were reported. Repeated faults on 220 kV side might have resulted in deterioration of winding insulation and due to this dielectric failure of transformer might have happened.

Some mechanical deformation was also observed on the outer side of HV winding. However, the damage to the other windings and reason for OLTC stuck in Y-ph can be ascertained only through detailed inspection after disassembly of the windings and dismantling of the Diverter switch/chamber respectively.

3. Failure of 100MVA, 220/22-22kV Transformer at Chinchwad substation of MSETCL (23.04.2018)

A.	Name of Substation	:	220kV Chichwad
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	Power Transformer
D.	Rating	:	100MVA, 220/22-22kV
E.	Make	:	CGL
F.	Sr. No.	:	24767(J-580)
G.	Year of manufacturing	:	2011
H.	Year of commissioning	:	2013
I.	Date and time of occurrence/discovery of fault	:	23.04.2018 at 06:20 Hrs.
J.	Information received in CEA	:	25.09.2018
K.	Fault discovered during	:	During Operation
L.	Details of previous maintenance	:	
On 21.01.2017, major overhauling was done on the OLTC. Annual maintenance work on 30.12.2017: Relay testing, Transformer auxiliary trials taken for operation of trip relay, Annunciator/HV/LV CB trip test, HV & LV CB timing test, LV CB Vacuum test, HV CT tan delta measurement etc. On 05.03.2018: HV side SA IR values measurement was taken. RET670 differential relay was replaced on16.04.2018.			
M.	Details of previous failure	:	No previous failures

N.	Sequence of events/ Description of fault	:	On 23.04.2018 at 06:20 hrs, transformer tripped along with tripping on 22kV Mahindra feeder with following indications: • Differential Protection Operated • PRV Operated • Buchholz trip • Buchholz alarm • Low oil level
O.	Details of Tests done after failure	:	

Following tests were conducted:

1) Ratio Test:

HV			LV1			LV2		
RN	YN	BN	rn	Yn	bn	Rn	Yn	bn
228.5V	225.8V	226.8V	22.25V	20.99V	22.02 V	22.55 V	22.26 V	22.39 V
		Ratio:	10.15	10.75	10.29	10.13	10.14	10.13
RY	YB	BR	ry	Yb	br	ry	yb	br
391V	393V	389V	38.4V	38.6V	36.7V	38.4V	38.5V	38.1V

2) Open circuit test: Supply to HV; LV 1/2 open

	RN	YN	BN	
Voltage applied	231.6V	228.8V	230V	
Current in mA	R	Y	B	N
1ph	2.9	154.4	3.4	-
3ph	6.4	148.6	9.6	126.2
3ph w/o N	45.4	99.6	47.9	-

Supply to LV1; HV, LV 2 open

Voltage	rn	Yn	bn	
Current in A	R	Y	B	N
1ph	0.25	9.4	0.23	-
3ph	1.04	8.69	1.04	7.28
3ph w/o N	3.04	6.17	3.12	-

Supply to LV2; HV, LV 1 open

Voltage	rn	Yn	bn	
	229V	220.1V	228.9V	

Current in A	R	Y	B	N
1ph	0.23	9.18	0.22	-
3ph	1.35	7.94	1.37	5.49
3ph w/o N	2.92	5.97	3.01	-

3) Magnetic Balance:

Voltage supply to	HV			LV1			LV2		
	RN	YN	BN	rn	yn	bn	Rn	yn	bn
R ph	230.5 V	4.15V	224.2 V	22.5V	0.36V	21.9V	22.55 V	0.41V	21.96 V
Y ph	84.6V	228.5 V	136.2 V	8.21V	21.9V	13.28 V	8.22V	22.27 V	13.31 V
B ph	222.7 V	4.7V	229.V	21.71 V	0.42V	22.41 V	21.7V	0.46V	22.44 V

LV1				LV2			
	rn	yn	bn		rn	yn	bn
R ph	229.6V	265V	226.5V	R ph	228.4V	3.64V	224.9V
Y ph	84.6V	228.5V	136.2V	Y ph	82V	218.5V	126.2V
B ph	222.7V	4.7V	229.9V	B ph	223.5V	3.8V	228.2V

4) Short circuit test: Tap 7

HV to LV1 shorted

HV				LV1			
R	Y	B	N	r	y	B	n
1.70A	1.64A	1.71A	84mA	17.62a	16.8a	17.68a	0.91A

HV to LV2 shorted

HV				LV1			
R	Y	B	N	r	y	B	n
1.70A	1.74A	1.72A	85.5mA	17.67A	16.96A	17.69A	0.69A

HV to LV1 + LV2 shorted

HV				LV1					LV2		
R	Y	B	N	r	y	b	n	r	y	b	n
3.0A	2.9A	3.0A	79 mA	17.62 A	12.25 A	16.33 A	0.6 A	16.2 1A	15.8 A	16.31 A	0.48 A

5) Winding resisting measurement (Oil temp:48°C, Tap No.7):

HV	RN	YN	BN
	828mΩ	629.7 mΩ	630 mΩ

LV1	Rn	Yn	bn
	10.386 mΩ	11.16 mΩ	10.529 mΩ
LV2	Rn	Yn	Bn
	10.39 mΩ	10.45 mΩ	10.445 mΩ

6) PI/IR values:

At 5kV

Oil temp: 50°C

IR Value		PI Value				
HV to E+ LV+LV2	12.6GΩ	15sec: 11.04GΩ	1min: 13.5GΩ	10min 19GΩ	PI 1.42	I(nA) 2.69
LV1 to E+ HV+LV1	4.45Ω	-	-	-	-	-
LV2 to E+ HV+LV1	13.94Ω	-	-	-	-	-
HV to LV1	22.3G Ω	-	-	-	-	-
HV to LV2	33.7G Ω	-	-	-	-	-
LV1 to LV2	18.3G Ω	-	-	-	-	-

P.	Observations & Analysis	:	

The open circuit test indicates high current in Y-ph for all HV, LV1, LV2. Voltage induced in Y-ph was very less when supply was given to R-ph and B-ph during magnetic balance test. During the physical observation by the utility, it was observed that transformer core test stud and grounding link had melted, displacement of LV windings was observed. The utility reported considerable amount of gases observed during DGA. Buchholz operated due to the gases generated because of high arcing fault inside. PRV operated to release extra oil pressure developed inside.

As per the information provided by the utility, faults on 22kV side are very frequent. A fault had occurred on 22 kV Mahindra feeder which was cleared in 60 ms as indicated by DR of back up relay of the feeder. DR taken from transformer differential relay indicated that 50% of 3 phase fault current of 22kV feeder was flowing through the subject transformer just after the fault on feeder and around 70ms later, only current for HV Y-ph and differential current appeared in the transformer due to fault. Because of the frequent faults on 22 kV side feeders, the transformer was subjected to forces due to short circuits current of varying

magnitude, thereby, causing physical displacement of LV windings and mechanical damage to winding leading to insulation failure of Y-phase winding of the transformer.

4. Failure of 100MVA, 220/22-22kV Power Transformer at Chinchwad substation of MSETCL (16.05.2018)

A.	Name of Substation	:	220kV Chinchwad
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	Power Transformer
D.	Rating	:	100MVA, 220/22-22kV
E.	Make	:	BHEL
F.	Sr. No.	:	6003978(J-637)
G.	Year of manufacturing	:	2011
H.	Year of commissioning	:	2014
I.	Date and time of occurrence/discovery of fault	:	16.05.2018 at 18:10 Hrs.
J.	Information received in CEA	:	25.09.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Annual maintenance (SFRA, Tan Delta, PI of Transformer was taken and nut bolt tightening, cleaning) was carried out from 01.01.2018 to 06.01.2018.
M.	Details of previous failure	:	Information not available
N.	Sequence of events/ Description of fault	:	On 16.05.2018 at 18:10 hrs, transformer tripped along with following indications: Differential protection HV & LV Master trip relay

			Buchholz trip Buchholz alarm
O.	Details of Tests done after failure	:	Information not available
P.	Observations & Analysis	:	

On date 16.05.2018, 220/22-22KV, PTR No. 2, 100MVA transformer tripped simultaniously with 22 kV Pimri feeder on differential protection. During the physical observation by the utility, displacement of LV windings was observed. The utility reported considerable amount of gases observed during DGA.

DR taken from transformer differential relay indicated flow of differential current through the transformer 45 ms after fault on feeder confirming internal fault. Buchholz operated 600ms after differential operation as seen from DR, due to high arcing fault inside.

Because of the frequent faults on 22 kV side feeders, the transformer was subjected to forces due to short circuits current of varying magnitude, thereby, causing physical displacement of LV windings and mechanical damage to winding leading to insulation failure of B-phase winding of the transformer..
MSETCL is carrying out installation of a Neutral Grounding Reactor (NGR) for TF-2 on trial basis to reduce undesirable impact of fault current (kA) on transformers.

5. Failure of 200 MVA, 400/220kV R-ph and Y-ph unit of 600MVA ICT-II at Kalwa Substation of MSETCL

A.	Name of Substation	:	400kV Kalwa
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	R-ph unit of ICT-II Y-ph unit of ICT-II
D.	Rating	:	400/220kV
E.	Make	:	R-ph: BHEL Y-ph: ALSTOM
F.	Sr. No.	:	R-ph: 6003887 Y-ph: 21726601
G.	Year of manufacturing	:	R-ph: 1975 Y-ph: 1976

H.	Year of commissioning	:	R-ph: 2013 (18.01.2013) Commissioned after refurbishment Y-ph: 2016 (07.01.2016) Commissioned after refurbishment
I.	Date and time of occurrence/discovery of fault	:	01.06.2018 at 01:02 hrs.
J.	Information received in CEA	:	25.09.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last annual maintenance done on 25.03.2018
M.	Details of previous failure	:	18.01.2013
N.	Sequence of events/ Description of fault	:	On 01.06.2018 at 01:02 hrs ICT-II tripped along with following indications: Buchholz alarm, Differential protection, PRV, Master trip relay Operated
O.	Details of Tests done after failure	:	Information not available
P.	Observations & Analysis	:	

The findings of Internal Inspection as reported by the Utility are as follows:

1. Condition prior to occurrence of fault was normal. However, Only Buchholz alarm of ICT-II Y-ph was persisting.
2. DR of differential protection & ICT-II LV backup protection indicated that pre fault condition was normal as per load.
3. Y-ph NIFPS operated but Nitrogen Injection didn't happen.
4. The non-operation of REF protection in this case might be due to damage to bushing CT during damage of bushing.

Operation of non-resettable buchholz alarm shows that there is incipient nature of fault. Fault current of around 55 kA was observed in Y-ph of 220kV side. Corresponding bus fault on Y-ph 220kV side was also recorded in DR. When fault occurred on Y-ph 220kV side, ICT-II tripped on differential protection (Y & B ph). PRV operated, however, the sudden pressure developed due to fault couldn't be released in time resulting into bursting of 220kV Y-ph bushing. It is to be noted that the capacitance & Tan delta values of failed 220kV bushing was within limit.

However, the said bushing was very old & it was in service since commissioning.

Further, as reported by the utility, there seems to be no indication of any internal fault in R-ph unit. When fault occurred on Y-Ph 220kV side, ICT-II tripped on differential protection (Y & B-Ph) and it caught fire. Hot burning part of Y-ph unit fell on cooling radiator bank of R-ph unit & subsequently R-ph unit caught fire & burnt completely.

6. Failure of 50MVA, 220/33kV Transformer at Buttibori Substation of MSETCL

A.	Name of Substation	:	220kV Buttibori
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	Power Transformer
D.	Rating	:	50 MVA, 200/33kV
E.	Make	:	EMCO
F.	Sr. No.	:	HT1358/11662
G.	Year of manufacturing	:	1997
H.	Year of commissioning	:	1997
I.	Date and time of occurrence/discovery of fault	:	12.09.2018 at 09.05 Hrs
J.	Information received in CEA	:	16.01.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	On 14.06.2018, tan delta measurement of winding & Bushings, DGA test is carried out and all results were found satisfactory.
M.	Details of previous failure	:	Information not available
N.	Sequence of events/ Description of fault	:	On 12.09.2018 at 09:05 hrs, transformer tripped on differential protection & Main buchholz along with fault on 33kV Cytech feeder.
O.	Details of Tests done after failure	:	Open circuit test, short circuit test, Magnetic balance, winding resistance, PI, SFRA, were

			carried out.

1). Open Circuit Test: - (Excited from HV)

Tap No.	HV Voltage (V)						LV Voltage (V)						3ph No load current (mA)				1ph No Load Current (mA)		
	RN	YN	BN	RY	YB	BR	rn	yn	bn	ry	yb	br	R	Y	B	N	R	Y	B
9	233	234	229	405	393	409	33	33	32	58	57	58	**74**	17	18	**46**	**88**	3.2	3.39

2). Short Circuit Test: - (3 Phase Supply given to HV & LV Shorted)

Tap No.	HV Current (A)				LV Current (A)			
	I_R	I_Y	I_B	I_N	I_R	I_Y	I_B	I_N
9	1.79	1.76	1.79	0.13	12.11	12	11.8	0.88

3). Magnetic Balance Test at Tap No. 9: -

Voltage applied on Phase	HV Voltage (V)			LV Voltage (V)		
	V_{RN}	V_{YN}	V_{BN}	V_{rn}	V_{yn}	V_{bn}
R	**232**	177	33	**31**	24	5
Y	4	233	225	**1**	32	31
B	4	223	228	4	31	32

4). Winding Resistance Test: -

Tap No.	RN (Ω)	YN (Ω)	BN (Ω)	rn (mΩ)	yn (mΩ)	bn (mΩ)
9	1.54	1.53	1.53	28.1	28.1	27.8

5). PI Test: -

IR	1 Min	10 min	PI
HV-LV	1.15 GΩ	2.14 GΩ	1.86
HV-E	1.19 GΩ	1.65 GΩ	1.39
LV-E	1.04 GΩ	1.92 GΩ	1.85

P.	Observations & Analysis	:	
Result of Open Circuit test & Magnetic balance test was found abnormal. SFRA plots found distorted. Winding resistance was drastically reduced. During internal inspection Copper granules observed below R-ph winding and was found carbonized. The fault current recorded by 33 kV Cytech feeder was 5.8KA. Results of Open Circuit test & Magnetic balance test and presence of copper granules below R-phase winding indicate fault in R-phase winding. Because of the fault, large forces were generated inside the transformer, thereby, causing physical displacement of LV windings.			

7. Failure of 100MVA, 220/22-22kV Transformer at Mulund Substation of MSETCL

A.	Name of Substation	:	220kV Mulund
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	Transformer
D.	Rating	:	100MVA, 200/22-22kV
E.	Make	:	OEM: English Electric Converted & refurbished by Aditya Vidyut Appliances Ltd(AVAL)
F.	Sr. No.	:	177278
G.	Year of manufacturing	:	2013 (Repaired by AVAL)
H.	Year of commissioning	:	2015
I.	Date and time of occurrence/discovery of fault	:	25.09.2018 at 14.40 hrs
J.	Information received in CEA	:	16.01.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	On 04.06.2018, capacitance and tan delta measurement of winding & Bushings was carried out and all results were found satisfactory. Polarization Index values was also measured and all the values were well within the limits.
M.	Details of previous	:	NA

	failure		
N.	Sequence of events/ Description of fault	:	On 25.09.2018 at 14.40 hrs, transformer tripped on Differential protection along with Main Buchholz Alarm.
O.	Details of Tests done after failure	:	a. Open circuit test from HV and LV side b. Magnetic balance test c. Short Circuit test d. Oil DGA test

DGA (oil test Sample: Top)

Sr No.	Gas Analysis	Safe Fault Gas level (in ppm) as per IEEE C57.104-2008	Results Derived (in ppm)
A	Volume of the individual component gas contained in a given volume of oil at Room Temp. & Atmospheric Pressure (in ppm)		
1	Hydrogen (H_2)	Not more than 100	**158**
2	Carbon Monoxide (CO)	Not more than 350	**518**
3	Methane (CH_4)	Not more than 120	105
4	Carbon Di-oxide (CO_2)	Not more than 2500	2372
5	Ethylene (C_2H_4)	Not more than 50	**203**
6	Ethane (C_2H_6)	Not more than 65	22
7	Acetylene (C_2H_2)	Not more than 1	**177**
B	Total Dissolved combustible Gas (in ppm) TDCG	Not more than 686	**1183**

DGA (oil test Sample: Bottom)

Sr No.	Gas Analysis	Safe Fault Gas level (in ppm) as per IEEE C57.104-2008	Results Derived (in ppm)
A	Volume of the individual component gas contained in a given volume of oil at Room Temp. & Atmospheric Pressure (in ppm)		
1	Hydrogen (H_2)	Not more than 100	**165**
2	Carbon Monoxide (CO)	Not more than 350	**521**
3	Methane (CH_4)	Not more than 120	109
4	Carbon Di-oxide (CO_2)	Not more than 2500	2389
5	Ethylene (C_2H_4)	Not more than 50	**206**
6	Ethane (C_2H_6)	Not more than 65	23

7	Acetylene (C_2H_2)	Not more than 1	**179**
B	Total Dissolved Combustible Gas (in ppm) TDCG	Not more than 686	**1203**

DGA (oil test Sample: Buchholz relay)

Sr No.	**Gas Analysis**	**Safe Fault Gas level (in ppm) as per IEEE C57.104-2008**	**Results Derived (in ppm)**
A	Volume of the individual component gas contained in a given volume of oil at Room Temp. & Atmospheric Pressure (in ppm)		
1	Hydrogen (H_2)	Not more than 100	**210**
2	Carbon Monoxide (CO)	Not more than 350	**516**
3	Methane (CH_4)	Not more than 120	116
4	Carbon Di-oxide (CO_2)	Not more than 2500	2403
5	Ethylene (C_2H_4)	Not more than 50	**214**
6	Ethane (C_2H_6)	Not more than 65	23
7	Acetylene (C_2H_2)	Not more than 1	**136**
B	Total Dissolved combustible Gas (in ppm) TDCG	Not more than 686	**1215**

Date	**Excitation Current at Tap 12 at 10 kV**			
	Phase	**Voltage**	**I (mA)**	**Inductance (kH)**
04.06.2018	R-N	10 kV	34	1.276
	Y-N	10 kV	25.4	1.717
	B-N	10 kV	34.6	1.245
25.09.2018	R-N	186 V	2.09	3.541
	Y-N	10 kV	34.7	1.310
	B-N	10 kV	34.8	1.298

P.	Observations & Analysis	:	

Disturbance recorder and sequence of events shows that 3 phase fault occurred on 22kV HariOm-3 feeder, which got cleared in 119 ms but simultaneously R phase fault developed inside the TF.

On analyzing results of tests carried out after fault, and correlating it with the DGA of the Top, Bottom and Buchholz Relay oil sample, the observations are as

below: (a) There is deviation in 10kV Excitation & Inductance of R phase Transformer. (b) DGA tests of the Bottom and Buchholz Relay oil samples indicate the presence of fault gases. Comparing with previous DGA result, it found that C2H2 (Acetylene) value increases very high. The Key Gas Analysis Method indicates "Possible Arcing" in the R-phase of the transformer. The above results clearly indicate that an internal failure of the R phase 22 kV winding had occurred due to 3-phase fault on the 22kV HariOm-3 feeder.

8. Failure of 100MVA, 220/22kV Power Transformer at Kamba Substation of MSETCL

A.	Name of Substation	:	220/22 kV Kamba
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	Power Transformer
D.	Rating	:	100 MVA, 220/22-22 kV
E.	Make	:	OEM: BHEL Converted & refurbished by AVAL (Earlier 125 MVA 220/100 kV)
F.	Sr. No.	:	BHEL 6001397
G.	Year of manufacturing	:	2013
H.	Year of commissioning	:	2014
I.	Date and time of occurrence/discovery of fault	:	14.07.2018 at 15:15 hrs
J.	Information received in CEA	:	14.06.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Repairing of LV neutral earthing, Y-Ph Bus isolator jaw palm and nut bolt breaker side replacement done along with diagnostic tests on

			09.07.2018
M.	Details of previous failure	:	NA
N.	Sequence of events/ Description of fault	:	On 14.07.2018 at 15:15 hrs, transformer tripped along with following indications: Buchholz alarm, Differential Trip, Master Trip relay
O.	Details of Tests done after failure	:	a. Open circuit test from HV and LV side b. Magnetic balance test c. Short Circuit test d. Oil DGA test
P.	Observations & Analysis	:	--

The results of tests carried out after fault are as follows:

1) **Open circuit test results:** There is increase in Y-ph current in HV, LV1 and LV2.
2) **Magnetic Balance results:** The results of the test are not satisfactory.
3) **Oil DGA test results** of Top and Bottom oil samples indicates the presence of fault gases. C_2H_2 (Acetylene) value in the DGA test was found to be on higher side.
4) **Winding resistance measurement test results:** After the test, it was found that winding resistance of Y-ph of LV1 side has changed.

The above results clearly indicate that an internal failure of the Y phase 22 kV winding had occurred due to fault on the 22kV feeder. Due to frequent tripping's on 22 kV side the transformer was subjected to numerous short circuits leading to deterioration on the insulation ultimately causing fault in the transformer Y-ph winding.

9. Failure of 50MVA, 220/22kV Power Transformer at Colourchem Substation of MSETCL

A.	Name of Substation	:	220kV Colourchem
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	Transformer - 3
D.	Rating	:	50 MVA, 220/22 kV

E.	Make	:	EMCO
F.	Sr. No.	:	HT/1359/11668
G.	Year of manufacturing	:	1996
H.	Year of commissioning	:	1998
I.	Date and time of occurrence/discovery of fault	:	01.11.2018 at 21: 18 hrs
J.	Information received in CEA	:	14.06.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Transformer main tank top plate gasket and other gasket replacing work done during overhauling from date 26.10.2018 to 01.11.2018. HV winding resistance test, ratio test, open circuit test, short circuit test, bushing tan delta test, 10 kV excitation test were conducted before charging the transformer and the results were found to be in order.
M.	Details of previous failure	:	No previous failure
N.	Sequence of events/ Description of fault	:	
On 01.11.2018, transformer was in outage for attending oil leakage of main tank and OLTC overhauling work. After completion of said work Transformer was charged from HV side and thereby after 18 min, transformer was tripped on differential protection & master trip and following indications were observed. Differential Trip, Main Buchholz alarm, Main Buchholz Trip, OLTC Buchholz Trip, operated.			
O.	Details of Tests done after failure	:	1) OC test 2) SC test 3) DGA

O/C TEST (from HV side)

Magnetizing Current

TAP NO.	Ir	Iy	Ib
8	7.57mA	226.3mA	7.93mA

O/C TEST (from LV side)-10 V

Magnetizing Current

Ir	Iy	Ib
38.1 mA	800 mA	38.6 mA

MAGNETIC BALANCE

TAP NO.	RN (V)	YN (V)	BN (V)	rn (V)	yn (V)	bn (V)
8	242.5	2.78	233.9	23.95	0.277	23.13
	77.4	242.8	149.7	7.61	24.53	15.0
	232.0	5.38	243.0	22.94	0.54	23.99

P.	Observations & Analysis	:	

From the DR and test results following observations were reported by the Utility:

1) In Differential relay DR, fault current was observed in HV R-ph and Y-ph.
2) During single phase open circuit test, magnetizing current of Y-ph was found to be on higher side.
3) R-ph and Y-ph winding found shifted and their insulation was also found damaged.
4) Bottom oil samples and Buchholz relay oil samples indicates the presence of fault gases**.** Value of C_2H_2 (129-buccolz sample; 58-bottom sample) & H_2 (652-buccolz sample; 147-bottom sample) in the DGA test was found to be on higher side.

High values of acetylene and Hydrogen indicate high energy arcing. From DR data and test results it appears that fault took place between HV side R-ph and Y-ph winding. Because of the fault, large forces were generated inside the transformer, thereby, causing the displacement of R-ph and Y-ph winding.

10. Failure of single phase, 105 MVA, 400kV Power Transformer at Padghe Substation of MSETCL (15.11.2018)

A.	Name of Substation	:	400 kV Padghe
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	Y-ph Unit of ICT-1
D.	Rating	:	single phase, 105 MVA
E.	Make	:	NGEF

F.	Sr. No.	:	6800000116
G.	Year of manufacturing	:	1994
H.	Year of commissioning	:	1995
I.	Date and time of occurrence/discovery of fault	:	15.11.2018 at 10: 07 hrs
J.	Information received in CEA	:	14.06.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	On 23.03.2018, Capacitance & Tan delta Test of Bushing & Winding, IR test were carried out and all results were found satisfactory.
M.	Details of previous failure	:	Nil
N.	Sequence of events/ Description of fault	:	On 15.11.2018 at 10: 07 hrs, ICT-1 tripped on Differential Protection with Buchholz Alarm.
O.	Details of Tests done after failure	:	Low voltage test was carried out and test results as reported by the utility are mentioned below: A) **Open circuit test:** Magnetizing current was 0.34 mA B) **Short circuit test:** Current in HV winding: 3.55 A Current in IV winding: 3.54 A C) **Winding Resistance by Mico-Ohm meter Kit:** Shows over-range D) **10 kV Excitation Test :** I = 21.5 mA, Inductance : 2023H
P.	Observations & Analysis	:	

As reported by the utility, ICT-1 might have failed due to ageing effect. Operation of differential relay and buchholz alarm indicates internal fault. However, the reason can be ascertained only after detailed inspection at after disassembly of the windings and dismantling of the core respectively.

11. Failure of single phase, 167 MVA, 400kV Power Transformer at Padghe Substation of MSETCL (25.11.2018)

A.	Name of Substation	:	400 kV Padghe
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	R-ph Unit of ICT-5
D.	Rating	:	single phase, 167 MVA, 400/220/33 kV
E.	Make	:	CGL
F.	Sr. No.	:	T09735
G.	Year of manufacturing	:	2010
H.	Year of commissioning	:	24.11.2017
I.	Date and time of occurrence/discovery of fault	:	25.11.2018 at 12:54 hrs
J.	Information received in CEA	:	14.06.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	On 24.11.2017 i.e. before commissioning Capacitance & Tan delta test of Bushing & winding, 10 k V Excitation, IR Values Test were carried out and results were found satisfactory.
M.	Details of previous failure	:	Nil
N.	Sequence of events/ Description of fault	:	On 25.11.2018 at 12:54 hrs, ICT-5 tripped on Differential Protection with Buchholz R-ph Tripped, HV REF, PRV, 86A & 86B Tripped, OSR trip, NIFPS Operated.
O.	Details of Tests done after failure	:	Information not available
P.	Observations & Analysis	:	
Blackish Colored Oil was observed to be spread out heavily through Bottom Plates of Main body. Main body was found deformed on East & North side of ICT unit. HV & IV Bushings found damaged & Cracked. OLTC Rod was found broken. Sufficient information was not available to arrive at any specific conclusion. However, operation of above mentioned protection system indicates internal fault probably in the tap winding leading to development of high pressure which damaged OLTC rod and HV & IV bushings.			

12. Failure of 500 MVA, 400/220/33kV Power Transformer at GSS Akal Jaisalmer Substation of RRVPNL

A.	Name of Substation	:	400kV GSS Akal
B.	Utility/Owner of substation	:	RRVPNL
C.	Faulty Equipment	:	Power Transformer
D.	Rating	:	400/220/33kV
E.	Make	:	SEIMENS
F.	Sr. No.	:	130111-01
G.	Year of manufacturing	:	2013
H.	Year of commissioning	:	2015
I.	Date and time of occurrence/discovery of fault	:	05.08.2018 at 15.50 hrs
J.	Information received in CEA	:	20.08.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	07.03.2018
M.	Details of previous failure	:	(a) On 28.07.2015 at 10:03, the transformer had tripped on Buchholz and over-flux protection. Trapped air was found in Buchholz pipeline. Further, DGA was carried out and no abnormal gases were observed. (b) Differential relay operated on 20.08.2015. Further, complete transformer testing was carried out and results were found in order.
N.	Sequence of events/ Description of fault	:	R-phase bushing of 400 kV side burst and transformer caught fire. Both Main-I & Main-II Hi-set Differential protection operated. Afterwards, PRV, Buchholz & oil surge relay also operated. Emulsifier system was manually operated by the staff and fire brigade was called which quenched the fire.

O.	Details of Tests done after failure	:	NA
P.	Observations & Analysis	:	

Disturbance recorder showed fault current of more than 8 kA on HV side of R-ph and more than 3 kA on 220 kV side of R-ph was observed causing the tripping of relay on Hi-set differential protection. As per DR, the fault was cleared in approx. 50 ms.

REF, high impedance differential and over current earth fault protection did not operate.

From the observations and DR data it is inferred that failure of 400 kV side R-ph bushing lead to the fire in the transformer. Due to fire in the transformer main tank oil, PRD, Buchholz and OSR operated.

13. Failure of 315 MVA, 400/200/33 kV Power Transformer at GSS Akal Jaisalmer Substation of RRVPNL

A.	Name of Substation	:	400kV GSS Akal
B.	Utility/Owner of substation	:	RRVPNL
C.	Faulty Equipment	:	Power Transformer
D.	Rating	:	400/220/33kV
E.	Make	:	AREVA
F.	Sr. No.	:	B 30538
G.	Year of manufacturing	:	2010
H.	Year of commissioning	:	2011
I.	Date and time of occurrence/discovery of fault	:	22.08.2018 at 22.54 hrs
J.	Information received in CEA	:	06.09.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Maintenance of the transformer was carried out as per maintenance schedule on Monthly, Quarterly, Half Yearly and Yearly basis. Last Yearly maintenance was done on 15.08.2018 and no abnormality was observed.

M.	Details of previous failure	:	Transformer was manually tripped on 04.08.2018 for replacement of 220 kV side Y-ph damaged bushing.
N.	Sequence of events/ Description of fault	:	Fault occurred in B-phase bushing of 400 kV side of the transformer and caught fire. The fire damaged nearby Y-phase bushing also. Both Main-I & Main-II Hi set Differential protection operated. However, after fire took place Buchholz alarm, Buchholz trip and PRV trip also operated. Fire protection system operated.
O.	Details of Tests done after failure	:	Turn ratio test, magnetizing current test, magnetic balance test, short circuit test, insulation resistance measurement test, sweep frequency response analysis.
P.	Observations & Analysis	:	

Joint inspection of the transformer was carried out by the representatives of GE (erstwhile AREVA) and RRVPNL and following was observed:

1. The bushing of HV side Y & B-phase were found completely damaged.
2. Selector switches of OLTC of all three phases (220 kV side) were found damaged.
3. Damages were observed in radiator, cables and HV& LV bushings.
4. After transformer oil was drained, pieces of bushings were found in the tank. Connecting leads (connecting bushing with winding) of the bushings were also found damaged.
5. No further major damage was observed inside the transformer and transformer windings were visibly healthy.
6. Load on the transformer at just before failure was 275 MW.
7. OTI/WTI Readings: OTI: 48 deg C, WTI-HV: 53 deg C, WTI-IV: 52 deg C, WTI-LV: 50 deg C
8. DR of Differential protection relay (Main-I) shows fault current of more than 8 kA on HV side of B-ph and more than 1.7 kA on 220 kV side of B-ph. DR of Differential protection relay (Main-II) also shows that the relay was operated on Hi-set differential protection of B-ph.
9. No other equipment/line got tripped except the transformer.

LV tests conducted after failure of the transformer indicated healthy winding. The fault current of 8 kA in B-phase and complete damage of B-phase bushing indicates that B-phase bushing of 400 kV side failed and caught fire which lead to operation of differential, PRV and Buchholz.

14. Failure Report of 100 MVA, 220/33/11 kV at Rajghat Substation of DTL

A	Name of Substation	:	220 kV Rajghat Substation
B	Utility/Owner of substation	:	DTL
C	Faulty Equipment	:	Power Transformer
D	Rating	:	100 MVA, 220/33/11 kV
E	Make	:	EMCO
F	Sr. No.	:	HT1644/12426
G	Year of manufacturing	:	2005
H	Year of commissioning	:	2005 (at Okhla Substation of DTL)
I	Date and time of occurrence/discovery of fault	:	03.09.2018 @ 12:50 hrs
J	Information received in CEA	:	13.09.2018
K	Fault discovered during	:	Operation
L	Details of previous maintenance	:	During DGA, higher values of CO and CO_2 were observed: (in ppm) | 01.09.2018 | 23.05.2018 CO_2 | 9036 | 7366 CO | 924 | 720 In Winding Resistance Test carried on 12.05.2018 at Tap 9, LV side resistance R_{YB} = 6.2 ohm (10% lower than the other two phases R_{RY} = R_{BR} = 6.9 ohm). Magnetic Balance Test conducted on 12.05.2018 and values were in order. The transformer was handed over to DTL by IPGCL in 2017 and as per DTL, previous record of the failed transformer is not available with it.
M	Details of previous failure	:	Failed in 2010. The same was repaired and diverted to Rajghat Substation (IPGCL) in 2011.
N	Sequence of events/ Description of failure	:	As per the submission of DTL, the Transformer tripped on Buchholz relay, PRV and Differential relay. The day was cloudy and there was drizzling/raining.
O	Details of Tests done after failure	:	
Dissolved Gas Result :(in ppm)			

Test Date: 04.09.2018			
	present	**I st prior**	**Key Gas Concentration Limited (As per IEEE std. C57.104-2008) (in ppm)**
Test Date	**04.09.18**	**01.09.18**	
Hydrogen H_2	190	14	100
Carbon Dioxide CO_2	7709	9036	2500
Carbon Monoxide CO	856	924	350
Ethylene C_2H_4	115	14	50
Ethane C_2H_6	19	12	65
Methane CH_4	59	20	120
Acetylene C_2H_2	193.8	0.5	1
TDCG	1432	985	720
Roger's Ratio			
C_2H_2/C_2H_4	1.69		
CH_4/H_2	0.31		
C_2H_6/CH_4	0.32		
CO_2/CO	9.01		
C_2H_4/C_2H_6	6.11		

Insulation Resistance Test

Voltage Applied : 5kV, DC					
Configuration	**Resistance at 15 second**	**Resistance at 60 seconds**	**Resistance at 600 seconds**	**PI**	**Previous Resistance at 15 second**
HV-E	3.14GΩ	5.05GΩ	7.81GΩ	1.55	9.81 GΩ
HV-MV	2.71GΩ	4.18GΩ	7.49GΩ	1.8	3.14 GΩ
HV-LV	3.28GΩ	6.98GΩ	12.37GΩ	1.77	3.74 GΩ
MV-LV	4.00GΩ	8.13GΩ	13.72GΩ	1.69	6.26 GΩ
MV-E	3.77GΩ	6.68GΩ	9.78GΩ	1.47	9.02 GΩ
LV-E	3.25GΩ	5.21GΩ	10.13GΩ	1.95	3.30 GΩ

Magnetic Balance Test				
Tap position	**Voltage Applied(Volts)**	**Voltage Induced(Volts)**		**Magnetizing current (mA)**
Lowest	V_{RN} V_{YN} V_{BN}	**V_{YN}** **N_{RN}** **V_{RY}**	**V_{BN}** **V_{BN}** **V_{YN}**	**I_{RN}** **I_{YN}** **I_{BN}**

Normal	V_{RN} 240.5 V_{YN} 240.1 V_{BN} 241.6	**V_{YN} 0 V_{RN} 238.6** **V_{RN} 11.6 V_{BN} 10.1** **V_{RN} 240.7 V_{YN} 3.1**	**I_{RN} 13.3** **I_{YN} 3210** **I_{BN} 14**
Highest	V_{RN} V_{YN} V_{BN}	**V_{YN} V_{BN}** **V_{RN} V_{BN}** **V_{RN} V_{YN}**	**I_{RM}** **I_{YN}** **I_{BN}**
MV Side:			
Tap position	**Voltage Applied(Volts)**	**Voltage Induced(Volts)**	**Magnetizing Current(mA)**
Normal	V_{RN} **240.1** V_{YN} **4.1** V_{BN} **0.8**	**V_{YN} 1.5 V_{BY} 239.6** **V_{RN} 241.8 V_{BN} 241.9** **V_{RN} 240.6 V_{YN} 3.9**	**I_{RN} 226** **I_{YN} 225** **I_{BN} 225**
LV Side			
Tap position	**Voltage Applied(Volts)**	**Voltage Induced(Volts)**	**Magnetizing Current(mA)**
Normal	V_{RY} 240.1 V_{YB} 240.5 V_{BR} 240.1	Heavy sparks so test not performed V_{RY} 7.5 V_{BR} 240.6 V_{RY} 9.6 V_{YB} 219	 I_{YB} 450 I_{BR} 450

Voltage Ratio Testing Report

Voltage Applied 415 V 3-Ø, 50 HZ

Tap position	HV Side Applied Voltage (Volts)			MV Side Induced Voltage (Volts)			LV Side Induced Voltage (Volts)		
	V_{RN}	V_{YN}	V_{BN}	V_{RN}	V_{YN}	V_{BN}	V_{RY}	V_{YB}	V_{BR}
1	240.5	240.4	238.6	30.46	0.15	30.76	2.05	17.19	16.96
2	240.6	238	235	30.3	0.149	30.3	1.94	17.37	17.17
3	240.7	240.6	238.1	31.7	0.15	31.45	1.84	17.6	17.38
4	247.7	238	235	31.1	0.151	31.4	1.75	17.82	17.62
5	240.1	238	236	31.82	0.152	31.8	1.65	18.08	17.88
6	238	238	236	31.8	0.153	32.1	1.58	18.32	18.11
7	241.8	242.3	239.1	33.5	0.252	30.6	1.44	18.57	18.34
8	238	238	236	32.6	0.155	33	1.356	18.78	18.57
9	238	238	236	33.1	0.156	33.3	1.255	19.03	18.78
10	238	241.5	236	33.83	0.157	33.7	1.15	19.26	19.04
11	238	238	236	33.8	0.157	34.1	1.043	19.52	19.3
12	241	241	238.9	34.2	0.3	34.3	19.52	19.2	19
13	240.8	240.8	238.4	34.6	0.33	34.9	19.2	19.5	19.3
14	240.6	240.8	238.1	35	0.3	35.3	19.5	19.8	19.6

15	240.7	240.7	238.1	35.6	0.4	35.8	19.8	20.1	20.4
16	241.2	240.8	238.3	36.1	0.4	36.3	20.1	20.3	20.2
17	240.4	240.3	237.9	36.6	0.4	36.7	20.3	20.6	20.5

Winding Resistance Testing Report

Temp. HV Wdg 32 C **MV Wdg.:40 C**
LV Wdg.:40 C
Current Applied : 10 A, DC

	Current result (08.09.2018)									Previous Result (12.05.2018)								
Tap	**HV side Resistance (mΩ)**			**MV side Resistance (mΩ)**			**LV side Resistance (mΩ)**			**HV side Resistance (mΩ)**			**MV side Resistance (mΩ)**			**LV side Resistance (mΩ)**		
	R_{RN}	R_{YN}	R_{BN}	R_{RN}	R_{YN}	R_{BN}	R_{RY}	R_{YB}	R_{BR}	R_{RN}	R_{YN}	R_{BN}	R_{RN}	R_{YN}	R_{BN}	R_{RY}	R_{YB}	R_{BR}
1	594	587	592	10.4	2.6	10.8	9.2	5.5	8.3	624	625	626	11	11	11	6.9	6.2	6.0
2	587	592	585							619	620	621						
3	581	581	580							614	614	615						
4	576	576	575							609	609	609						
5	570	570	570							603	603	603						
6	565	566	565							597	598	598						
7	560	560	560							592	592	592						
8	556	555	555							587	587	587						
9	549	548	550							580	580	579						
10	553	554	555							586	586	586						
11	559	560	563							590	592	592						
12	564	565	568							597	597	597						
13	570	570	575							602	603	603						
14	576	575	577							607	609	608						
15	581	580	582							613	614	614						
16	585	585	590							619	620	620						
17	590	590	595							625	626	625						

S.NO.	Insulation Tested	Make & Sl. No.	Yr. Of Mfg. & Yr. of comm.	Mode	Previous Results dtd. 08.12.2017			Current Results 05.09.2018		
					Capacitance	Dissipation Factor %		Capacitance	Dissipation Factor %	
					(pF)	Meas.	@20 °C	(pF)	Meas.	@20 °C
1	HV-LV	--	--	UST- R	25491.10	0.28	0.18	25617.66	0.29	0.19
2	HV-E	--	--	GSTg-RB	3868.41	0.28	0.18	3858.53	0.33	0.21
3	LV-T	--	--	UST-R	1087.49	0.23	015	1103.16	0.28	0.18
4	LV-E	--	--	GSTg-RB	3023.68	0.50	0.32	3061.60	0.60	0.39
5	T-HV	--	--	UST-R	14040.34	0.26	0.17	14482.21	0.28	0.18
6	T-E	--	--	GSTg-RB	20210.41	0.28	0.18	20208.73	0.29	0.19
7	220kV R-Ø Bushings	CGL/245300 157	2005/	UST-R	371.06	0.32	--	374.09	0.38	--
8	220kV Y-Ø Bushings	CGL/245300 118	2005/	UST-R	367.18	0.22	--	368.51	0.24	--
9	220kV B-Ø Bushings	CGL/245300 3336	2011/	UST-R	353.82	0.22	--	255.53	0.26	--
10	33kV R-Ø Bushings	CGL/S-72300 60254	2011/	UST-R	328.78	0.36	--	329.49	0.38	--
11	33kV Y-Ø Bushings	CGL/S-72300 60256	2011/	UST-R	328.63	0.35	--	329.28	0.38	--
12	33kV B-Ø Bushings	CGL/S-72300 60255	2011/	UST-R	327.65	0.36	--	328.38	0.38	--
13-15	Excitation current	Test at 2 kV	R-ph	50.25mA	Y-Ph	--	--	B-Ph	49.89mA	--
16-18	Excitation current	Test at 10 KV	R-ph	113.34mA	Y-Ph	--	--	B-Ph	113.40 mA	--

P Observations and Analysis :

1. Only portable fire extinguishers were available in the substation.

2. Very high concentration of C_2H_2 signifies arcing with high energy discharge inside the transformer. The same may have been due to inter-turn short in Y-phase of MV side. The same is corroborated by lower winding resistance for R_{YN} (2.6mΩ) as compared to R_{YN} (11 mΩ) measured on 12.05.2018. Internal fault is confirmed by the operation of differential, Buchholz and PRV.

High CO and CO_2 concentration in DGA results (both pre and post failure) indicate deterioration of insulation inside the transformer.

SFRA plots taken after failure on 05.09.2018 were compared with the plots taken on 8.12.17

and it also indicated problem in the Y-phase winding.

Magnetic balance test and magnetizing current measurement test also indicate problem in Y-phase winding. Voltage ratio test indicate problem in MV Y-phase winding and LV R & Y-phase winding.

Data provided by the utility for Magnetic Balance test results on MV side conducted on 04.09.2018 appear erroneous.

No DR data was provided in the absence of which fault current could not be recorded.

Report of internal inspection carried out at manufacturer's works detailing the damages inside the transformer, cause of failure,and remedial action taken by the manuctureshould be shared with the Standing Committee for the benefit of other utilities.

15. Failure Report of 100 MVA, 220/33/11 kV at Rajghat Substation of DTL

A	Name of Substation	:	220 kV Rajghat Substation
B	Utility/Owner of substation	:	DTL
C	Faulty Equipment	:	Power Transformer
D	Rating	:	100 MVA, 220/33/11 kV
E	Make	:	CGL
F	Sr. No.	:	24591
G	Year of manufacturing	:	1985
H	Year of commissioning	:	1985
I	Date and time of occurrence/discovery of fault	:	12.03.2019, 15:45 hrs
J	Information received in CEA	:	13.03.2019
K	Fault discovered during	:	Operation
L	Details of previous maintenance	:	In Magnetic Balance, Magnetizing Current Test, C & Tan delta test, voltage ratio test, Winding Resistance Test, Insulation Resistance Test, DGA & SFRA were conducted from 08.03.2019 to 11.03.2019. The results were in order.
M	Details of previous failure	:	Information not available.
N	Sequence of events/ Description of failure	:	The transformer tripped on Buchholz relay, Differential relay and PRV with spillage of oil. The sky was clear on the day of fault.

O	Details of Tests done after failure	:	

Dissolved Gas Results (in ppm)			Key Gas Concentration Limits (as per IEEE Std. (57.104+2008) (in ppm)
	1st Prior	Present	
Test date	12.03.19-I	12.03.19-II	
Hydrogen H_2	<5	1182	100
Carbon Dioxide CO_2	86	141	2500
Carbon Monoxide CO	6	144	350
Ethylene C_2H_4	2	252	50
Ethane C_2H_6	5	16	65
Methane CH_4	2	122	120
Acetylene C_2H_2	0.5	448.2	1
TDCG	15	2165	720
Roger's Ratio			
C_2H_2/C_2H_4	1.78		
CH_4/H_2	0.10		
C_2H_6/CH_4	0.13		
CO_2/CO	0.98		
C_2H_4/C_2H_6	15.75		

Voltage Ratio Testing Report						
Voltage Applied: 230V, 1-Phase, 5- Hz						
Tap	HV Side Applied		MV Side Induced		LV Side Induced	
5	V_{RN}	250	V_{RN}	8.6	V_{RY}	-
	V_{YN}	249.2	V_{YN}	37.6	V_{YB}	-
	V_{BN}	250	V_{BN}	37.5	V_{BR}	-

Winding Resistance Testing Report									
Current Applied: 10A, DC									
Tap	HV Side Resistance (milliohm)			MV Side Resistance(milliohm)			LV Side Resistance (milliohm)		
	R-N	Y-N	B-N	r-n	y-n	b-n	r'y'	y'b'	b'r'
5	687	688	*	15.04	14.89	14.91	--	--	--

*Current not rising in HV during winding resistance test.

Magnetizing Current & Magnetic Balance Test

Voltage Applied: 230V, 1-Phase, 5- Hz

High Voltage Side

Tap Position	Voltage Applied (Volts)		Voltage Induced (Volts)				Magnetizing Current (mA)	
5	V_{RN}	248.4	V_{YN}	229.6	V_{BN}	31.85	I_{RN}	2.24
	V_{YN}	249.8	V_{RN}	121.6	V_{BN}	76.9	I_{YN}	1.56
	V_{BN}	249.2	V_{RN}	12.85	V_{YN}	50.7	I_{BN}	1.6

MV Side

Tap Position	Voltage Applied (Volts)		Voltage Induced (Volts)				Magnetizing Current (mA)	
5	V_{RN}	250	V_{YN}	235	V_{BN}	43	I_{RN}	44.2
	V_{YN}	250	V_{RN}	125	V_{BN}	124	I_{YN}	28.89
	V_{BN}	250	V_{RN}	41	V_{YN}	234	I_{BN}	44.4

P Observations and Analysis :

1. Only portable fire extinguishers were available in the substation.

2. Oil spillage from the transformer was observed.

3. Very high concentration of C_2H_2 (448.2 ppm) in post failure DGA results signifies arcing with high energy discharge inside the transformer.

4. In Voltage Ratio Test, for approximately the same applied HV phase voltage (= 250 V), lower V_{RN} (= 8.6 V) voltage induced in LV phase as compared to V_{YN} (= 37.6 V) and V_{BN} (= 37.5 V) hints at inter-turn short of R phase winding of LV phase.

5. DR data indicated a current of 1280 A in B-phase and 300 A in neutral of HV side which indicates a fault in the winding portion near to the neutral.

6. In Winding Resistance Test, current did not rise in B phase in HV side after application of voltage; the same implies that there may have been a loose contact in the B-phase winding.

7. In Magnetic Balance Test on HV side, when voltage was applied on Y phase (249.8 V), lower voltage was induced in B phase (36.9 V) as compared to R phase (121.6 V). Similarly on application of 249.2 V on B phase, lower induced voltages in R phase (12.85 V) and Y phase (50.7 V) were measured. The results indicate problem in HV side B-phase, although the same are not corroborated by voltage ratio measurement.

8. Transformer had been in operation for 34 years and ageing might be one of the reasons which lead to the failure.

16. Failure Report of 100 MVA, 220/66-33/11 kV at Okhla Substation of DTL

A	Name of Substation	:	220/66 kV Okhla Substation
B	Utility/Owner of substation	:	DTL
C	Faulty Equipment	:	Power Transformer
D	Rating	:	220/66-33/11 kV, 100 MVA
E	Make	:	BHEL
F	Sr. No.	:	2010227
G	Year of manufacturing	:	1997
H	Year of commissioning	:	1998
I	Date and time of occurrence/discovery of fault	:	27.09.2018 @ 10:15 hrs
J	Information received in CEA	:	08.10.2018
K	Fault discovered during	:	Operation
L	Details of previous maintenance	:	The transformer was overhauled in Feb-2017.
M	Details of previous failure	:	NIL
N	Sequence of events/ Description of failure	:	On 27.09.18 at 10:15 hrs, the transformer was tripped off with heavy sound. Transformer tripped on Differential Relay, SPRV, PRV and Buchholz relay.
O	Details of Tests done after failure	:	Following test were conducted on the transformer after failure:

Capacitance and Tan delta Test Result										
S.NO.	Insulation Tested	Make & Sl. NO.	Yr. Of Mfg & Yr of comn.	Mode	Previous Results dt. 04.01.2018			Current Results 27.09.2018		
					Capacitance	Dissipation Factor %		Capacitance	Dissipation Factor %	
					(PF)	Meas.	@20 °C	(PF)	Meas.	@20 °C
1	HV-LV	--	--	UST- R	27796.79	0.43	0.38	28714.38	1.46	0.68
2	HV-E	--	--	GSTg-RB	5432.75	0.41	0.36	5510.07	1.50	0.70
3	LV-T	--	--	UST-R	1243.29	0.39	0.34	1276.14	1.33	0.62
4	LV-E	--	--	GSTg-RB	3457.69	0.57	0.51	3520.49	2.17	1.02
5	T-HV	--	--	UST-R	14115.05	0.47	0.41	14392.30	1.24	0.58
6	T-E	--	--	GSTg-RB	17660.71	0.47	0.42	18186.29	2.08	0.98
7	220kV R-Ø Bushings	BHEL/	--	UST-R	337.08	0.41	--	340.96	0.31	--
8	220kV Y-Ø Bushings	BHEL/	--	UST-R	382.55	0.62	--	390	0.4	--
9	220kV B-Ø Bushings	TELK/330108-87	2006/2015	UST-R	328.89	0.4	--	333.88	0.32	--
10	66kV R-Ø Bushings	CGL/	2014/2015	UST-R	340.11	0.42	--	344.53	0.3	--
11	66kV Y-Ø Bushings	BHEL/	--	UST-R	281.04	0.56	--	286.8	0.42	--
12	66kV B-Ø Bushings	TELK/	--	UST-R	365.61	0.64	--	372.73	0.76	--
22-24	Excitation current Test	At 10 kV	R-Ph	54.94mA	Y-Ph		--	B-Ph	55.47mA	--

DGA

S.NO.	Activity	Previous Result	Result
1.	Testing of oil for DGA, PPM,BDV	-	-
2.	Hydrogen H2	6	2294
3.	Carbon Di-oxide CO2	3747	6244
4.	Carbon Mono-oxide CO	278	480

5.	Ethylene C2H4	16	769
6.	Ethane C2H6	23	80
7.	Methane CH4	7	432
8.	Acetylene C2H2	0.0	718.7
9.	TDCG	328	4774

Roger's Ratio		
C_2H_2/C_2H_4	0.933	
CH_4/H_2	0.188	
C_2H_4/C_2H_6	9.6125	

Insulation Resistance Test

Voltage Applied : 5kV DC

Configuration	Resistance at 15 second	Resistance at 60 seconds	Resistance at 600 seconds	PI	Previous PI
HV-E	113MΩ	141MΩ	-	-	-
HV-MV	88MΩ	112MΩ	-	-	-
HV-LV	129MΩ	166MΩ	-	-	-
MV-LV	193MΩ	226MΩ	-	-	-
MV-E	169MΩ	187MΩ	-	-	-
LV-E	106MΩ	140MΩ	-	-	-

Magnetizing current & Magnetic Balance Test :

Voltage applied: 230 V, 1-Ø, 50 HZ

HV side:

Tap position	**Voltage Applied(Volts)**		**Voltage Induced(volts)**				**Magnetizing current**	
Tap-5	**V_{RN}**	**242**	**V_{YN}**	**0**	**V_{BN}**	**245**	**I_{RN}**	**3mA**
	V_{YN}	**247**	**V_{RN}**	**44.8**	**V_{BN}**	**28.3**	**I_{YN}**	**2.96A**
	V_{BN}	**241.1**	**V_{RN}**	**245**	**V_{YN}**	**0**	**I_{BN}**	**3.3mA**

MV Side:

Tap position	**Voltage Applied(Volts)**		**Voltage Induced(volts)**				**Magnetizing Current(mA)**	
	V_{RN}	**249.8**	**V_{YN}**	**0**	**V_{BN}**	**242**	**I_{RN}**	**28.5mA**

Tap-5	V_{YN}		V_{RN}		V_{BN}		I_{YN}	**Could not be carried out due to taking high current**
	V_{BN}	**238.2**	V_{RN}	**238**	V_{YN}	**0**	I_{BN}	**29.7mA**

Voltage ratio testing report

Voltage applied :415 V, 3-Ø, 50-HZ

Tap	HV Side Applied Voltage (Volts)			MV side Induced Voltage (Volts)			LV side Induced Voltage (Volts)		
	VRN	VYN	VBN	VRN	VYN	VBN	VRY	VYB	VBR
1	238.2	240	240	71.1	8	71.2	20	0	20
2									
3	245	242	245	71	8	71.2	20.2	0	20
4									
5	244	244	244	69	8	69.2	20	0	20

Winding Resistance Testing Report

Current Applied : 10 A, DC

	Previous result									Current Result								
Tap	HV side Resistance(mΩ)			MV side Resistance(mΩ)			LV side Resistance(mΩ)			HV side Resistance(mΩ)			MV side Resistance(mΩ)			LV side Resistance(mΩ)		
	R_{RN}	R_{YN}	R_{BN}	R_{RN}	R_{YN}	R_{BN}	R_{RY}	R_{YB}	R_{BR}	R_{RN}	R_{YN}	R_{BN}	R_{RN}	R_{YN}	R_{BN}	R_{RY}	R_{YB}	R_{BR}
1	545	542	560	39.2	39.5	39.3				604.1	604.5	618.1	47.2	40.7	47.1	12.4	7.3	6.7
2	538	540	542							601.6	597.4	607.6						
3	525	530	530							589.8	590.3	597.1						
4	538	528	529							583.0	584.1	590.4						
5	515	519	520							575.7	577.6	580.7						
6	514	515	490							567.7	572.6	575.6						
7	503	502	500							560.3	561.6	567.4						
8	497	498	496							552.6	563.1	562.6						
9	491	493	490							544.7	544.4	547.1						

10	500	498	497							557.1	556.3	572.0						
11	505	503	504							559.6	561.7	573.0						
12	510	510	515							568.7	569.5	579.5						
13	515	518	519							575.3	575.5	585.3						
14	525	522	525							582.3	587.7	595.6						
15	532	530	530							588.3	590.3	602.6						
16	539	538	537							596.2	603.2	609.2						
17	544	542	543							603.8	604.7	615.0						

P	Observations and Analysis	:	

1. Flange of R phase LV bushing was observed cracked.

2. Very high concentration of C_2H_2 (= 718.7 ppm) and H_2 (= 2294 ppm) signifies arcing with high energy discharge inside the transformer. High concentrations of CO (= 480 ppm) and CO_2 (= 6244 ppm) hints at deterioration of insulation inside the transformer.

3. Increase in tan delta of the winding without marked increase in capacitance indicates thermal deterioration of the insulation.

3. In Magnetic Balance Test, in both HV and MV side, the non-inducement of voltage in Y phase when voltage is applied to R and B phases indicates damage in the Y-phase winding. A very high Magnetizing Current in the HV side Y phase was observed while measurement of magnetizing current on LV side Y phase could not be carried out due to very high value indicates shorted turns in the winding. There might be presence of air gap in the core. Further, the Voltage Ratio Test also indicates damage to the Y-phase winding.

4. However, no conclusive inference could be drawn from the winding resistance test results although the same indicates higher resistance values from previous measurement which could be due to increased contact resistance.

5. Report of internal inspection carried out at manufacturer's works detailing the damages inside the transformer, cause of failure,and remedial action taken by the manucture should be shared with the Standing Committee for the benefit of other utilities.

17. Failure of 160 MVA, 220/66/11 kV at Vasant Kunj Substation of DTL

A.	Name of Substation	:	220 kV Substation Vasant Kunj
B.	Utility/Owner of	:	DTL

	substation		
C.	Faulty Equipment	:	Power Transformer
D.	Rating	:	160 MVA, 220/66/11 kV
E.	Make	:	Bharat Bijlee
F.	Sr. No.	:	5098/1
G.	Year of manufacturing	:	2008
H.	Year of commissioning	:	2010
I.	Date and time of occurrence/discovery of fault	:	26.04.2018, 01:48 hrs.
J.	Information received in CEA	:	26.04.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	DGA of transformer main tank oil was carried out on 09.02.2018 and Capacitance & Tan delta of winding & bushings was measured on 16.01.2018 and no abnormality was observed. Earthing resistance of transformer was measured on 11.02.2018 and values were within limits.
M.	Details of previous failure	:	NIL
N.	Sequence of events/ Description of fault	:	

On 26.04.2018 at 1:15 AM, 66kV outgoing Palam feeder (of BRPL) (carrying approx. 150A load current) got tripped with following indications:

Distance protection (0.5kM), B-phase faulty, O/C, E/F, 186, 86.

66kV bay (carrying approx. 200A load current) of 160MVA transformer also tripped on master trip relay 86 and B Phase O/C relay. Transformer 66kV bay was connected on bus-II along with faulty feeder (Palam), Vasant Kunj D-1, D-2, Ridge Valley Ckt-I&II (Vasant Kunj Institutional Area) and 20MVA, 66/11kV Transformer-2. 66kV Bus-coupler was off at the time of fault.

At 1:25AM, 66kV feeder Palam was isolated and after checking the yard & the transformer, 160MVA transformer was energized.

At 1:48AM, 160MVA transformer tripped on 295CA, 295CB, 295CC, 195CA, 195CB, 195CC, OTI alarm, Buchholz, PRV, 30ABCD, 30EFGH, over flux relay, 86 and 295B with 66kV bay tripped on inter-tripping.

Immediately operation staff rushed to the yard and noticed that 160MVA had caught fire. Transformer was then isolated from system immediately. Operation staff tried to extinguish the fire using portable extinguishers but could not succeed. Thereafter, they informed Fire department and SLDC control room. Fire tenders (10 nos.) reached at site within approx. 15 minutes.

At 02:10AM, 100MVA transformer-II (near to 160MVA transformer) tripped on 295CA,295CB,295CC, 195CC, 30D, 86 and the same was informed to SLDC control room. Further, 220kV infeed line Mehrauli Ckt-I&II and AC & DC supply was switched off for safety purpose.

At 05:30AM, Fire tenders controlled the fire.

2x100MVA transformers were on Bus-I and 160MVA transformer was on Bus-II, Bus coupler was off. Load on 66kV side of each 100MVA transformer was 375A and for 160MVA transformer was 200A.

O.	Details of Tests done after failure	:	Since the transformer had damaged in the fire, no test was possible.
P.	Observations & Analysis	:	

As informed by the utility, a spark in neutral CT led to fire in the control cable laid around the transformer and eventually the transformer caught fire. However, the Committee did not concur with the views of DTL and was of the opinion that during normal operating condition, current in neutral CT cannot be large enough to produce spark. If there is some loose contact at terminals of the neutral CT, it would melt the contacts rather than causing sufficient spark to cause fire in the cables in the vicinity. Further, control cables are generally FRLS type and should not support spreading of fire. If this is assumed that fire in the cable may cause the fire in transformer, then it may be inferred that the installation condition and maintenance of cables in the substation was not appropriate and with proper care such fires cases could be easily avoided.

It appears that the transformer insulation could not withstand the short circuit caused by fault on 66 kV feeder. Short circuit weakened the insulation which was further deteriorated after transformer was re-energised.

Although the Nitrogen injection fire protection system was installed for fire protection, however, the same did not operate automatically as differential relay had not operated. The system could not be operated manually from remote as

cables had burnt.

18. Failure of 125 MVA, 220/132kV Transformer at Bhilai Substation of CSPTCL

A.	Name of Substation	:	Bhilai Substation
B.	Utility/Owner of substation	:	Chattisgarh State Power Trans. Co. Ltd.
C.	Faulty Equipment	:	Transformer-IV
D.	Rating	:	3-Phase 125 MVA, 220/132kV
E.	Make	:	CGL
F.	Sr. No.	:	2410884
G.	Year of manufacturing	:	1978
H.	Date of commissioning	:	19.03.1980
I.	Date and time of occurrence/discovery of fault	:	28.09.2018, time of failure not available
J.	Information received in CEA	:	23.10.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Following tests were conducted on 15.03.2018. 1. Magnetizing Current Test

			2. Magnetic Balance Test 3. Voltage Ratio Test 4. Short Circuit Test 5. IR Value Test 6. Measurement of capacitance and tan delta of windings All test results were found normal.
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 28.09.18, Transformer-IV tripped with following relay operations: Main differential -I and II operation 86A, 86B, 86C,86 Buchholz alarm 30A Buchholz trip Explosion vent diaphragm was found broken and some oil had splashed out.
O.	Details of Tests done after failure	:	

Following tests were conducted after failure on 28.09.2018 & 29.09.2018 :

1. **Magnetizing Current Test (current in mA) on 28.09.2018**

Applied voltage Volts(V):V_{RN}=225V, V_{YN}=246.7 V, V_{BN}=233.7 V

HV (mA)		IV (mA)		LV	
R-Phase	2.2	r-Phase	4.6	r'y'	108.9 mA
Y-Phase	11.9	y-Phase	15.7	y'b'	3.03A
B-Phase	2.3	b-Phase	4.6	b'r'	108.7 mA

2. **Magnetic Balance Test on 28.09.2018**

RN	YN	BN	rn	yn	bn	r' y'	y'b'	b' r'
223.7	8.13	218.4	140.5	4.94	136.9	20.14	0.763	20.60
41.6	**223.7**	50.4	25.91	190.5	31.7	4.65	8.43	3.81
218	8.8	**223.9**	136.8	5.49	140.2	20.65	0.870	20.15

3. **Voltage Ratio Test on 28.09.2018:**

	RY	YB	BR	RN	YN	BN
HV	409	413	406	206.3	281.3	223.3
	ry	yb	br	rn	yn	Bn
IV	302.3	297.7	252.8	129.2	227.0	140.2
	r'y'	y'b'	b'r'			
LV	20.51	13.54	19.11			

4. **Short Circuit Test on 28.09.2018:**

Voltages applied;

V_{RN}=225, V_{YN}=246.7 V, V_{BN}=233.7 V

3-Phase LT supply applied on 220kV side (HV) with all 3-ph of 132kV side(IV) shorted with neutral open.

HV (Amp)		IV (Amp)	
R-Phase	7.65	r-Phase	13.76
Y-Phase	4.28	y-Phase	4.66
B-Phase	7.75	b-Phase	13.50

Current measured between IV shorted and neutral (r+y+b-n) = 4.10A

5. Winding Resistance Test 29.09.2018 :-

Particulars	R ph-N	Y ph-N	B ph-N
	Resistance (mΩ)	Resistance (mΩ)	Resistance (mΩ)
HV side	820.6	-	818.5
IV Side	577.3	-	575.8

Particulars	R Ph (R-r)	Y Ph (Y-y)	B Ph (B-b)
	Resistance (mΩ)	Resistance (mΩ)	Resistance (mΩ)
HV Side - IV Side	246.9	245.8	245.9

6. Magnetizing Current Test (Current in mA) 29.09.2018 :

Applied voltage volts (V): V_{RN}=227V, V_{YN}=240 V, V_{BN}=235V

HV (mA)		IV (mA)		LV	
R-Phase	5.6	r-Phase	12.7	r' y'	320.4 mA
Y-Phase	11.8	y-Phase	15.9	y'b'	3.206A
B-Phase	5.8	b-Phase	13.1	b' r'	298.7 mA

7. Magnetic Balance Test (Applied voltage underlined in Volts) on dtd. 29.09.2018

RN	YN	BN	Rn	yn	bn	r' y'	y'b'	b' r'
226.7	21.14	214.1	141.6	12.92	134.1	19.74	2.074	20.78
57.5	**226.4**	30.58	36.0	194.3	19.14	2.814	8.10	5.29
217.4	12.56	**225.8**	136.0	7.67	141.4	20.79	1.227	20.14

8. IR Value Test Result on dtd. 29.09.2018 (taken by S/S Dn.):

at oil temp. 37°C:-

Particulars	15sec	60 sec	600 sec	PI
HV TO LV	990.1 MΩ	1.6496GΩ	2.4837GΩ	1.5
HV TO EARTH	1.4031GΩ	2.1707GΩ	3.088GΩ	1.4
LV TO EARTH	1.1336GΩ	1.9042GΩ	2.8086GΩ	1.4

P.	Observations & Analysis	:	Explosion vent diaphragm was found broken and some quantity of oil had splashed out. Magnetizing current test shows high current drawn by y-ph winding. Magnetic balance test also shows that magnetic coupling with Y-ph winding is damaged. The transformer had served for 38 years. It seems that some internal fault due to ageing in Y-ph of the transformer could have led to the failure of the transformer.

19. Failure of 160 MVA, 400 kV Transformer at Ashta substation of MPPTCL

A.	Name of Substation	:	400 kV Ashta
B.	Utility/Owner of substation	:	MPPTCL
C.	Faulty Equipment	:	Transformer
D.	Rating	:	160 MVA, 220/132/33 kV
E.	Make	:	BHEL
F.	Sr. No.	:	6005209
G.	Year of manufacturing	:	1993
H.	Year of commissioning	:	First commissioning at 220 kV Julwania S/S on 14.11.1995.

			Second commissioning on 01.07.2011 at 400 kV Ashta S/S after being repaired from first failure at 220 kV Julwania S/S.
I.	Date and time of occurrence/discovery of fault	:	23.07.2018 at 13.36 hrs
J.	Information received in CEA	:	22.02.19
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	During the last annual maintenance, low voltage tests viz. magnetic balance, magnetizing current, ratio test, IR value test were carried out and all the values of tests were normal and well within the specified limits. Winding Resistance, Tan Delta & Capacitance of winding and condenser bushing were also checked and found normal. DGA of the transformer oil was also carried out and all the values obtained during the test were within specified limit. The earth resistance of the S/S and transformer was also measured and the value was found to be 0.5 Ohm.
M.	Details of previous failure	:	This transformer was initially commissioned on 14.11.1995 at 220 kV Julwania s/s and it was failed on 12.02.2009. The transformer was sent for repair and was re-commissioned on 01.07.2011 at 400 kV Ashta s/s. There was no problem in the transformer after repairing (no parts have been replaced or repaired such as Bushings, Oil, Diverter switch etc.). Results of Bushings, windings, low voltage test results of the repaired transformer were found to be stable and comparable. Oil parameters of the repaired transformer were also within limit.
N.	Sequence of events/ Description of fault	:	On 23.07.2018 at 13.36 hrs, transformer tripped on Differential protection, Buchholz, OSR and PRV along with tripping of 132 kV

			SEL radial feeder at 400 kV Ashta S/S on Y-ph, Zone-I (Fault distance recorded was 636.7 m). At the time of tripping there was heavy lightning and mild rain in the area. Since the feeder is a radial one and supplying to HT consumer, line tripping occurred from S/S side only. No other tripping occurred at this S/S or adjoining S/S. No interruption occurred due to above tripping as load was manageable from the other 160 MVA transformer.
O.	Details of Tests done after failure	:	Results of tests done after the failure are as follows:

Continuity of winding test

Continuity Checked Between	**Terminals**	**Continuity**	**Continuity Checked Between**	**Terminals**	**Continuity**
Phase to Phase Bushing Terminals (220 kV)	1R-1Y	X	Phase to Phase Bushing Terminals (132 kV)	2R-2Y	X
	1Y-1B	X		2Y-2B	X
	1B-1R	OK		2B-2R	OK
Phase to Neutral Bushing Terminals (220 kV)	1R-N	OK	Phase to Neutral Bushing Terminals (132 kV)	2R-N	OK
	1Y-N	X		2Y-N	X
	1B-N	OK		2B-N	OK
HV and IV Bushing Terminals	1R-2R	OK	Tertiary Bushing Terminals 33 kV	3R-3Y	OK
	1Y-2Y	OK		3Y-3B	OK

	1B-2B	OK	Winding	3B-3R	OK

MAGNETISING CURRENT TEST

Phase	HV Side (220 kV)				IV Side (132 kV)			
	1 Phase		3 Phase		1 Phase		3 Phase	
	mA	V	mA	V	mA	V	mA	V
R-ph	3.18	200	0.78	431	6.89	200	2.52	431
Y-ph	0	200	**1.02 A**	427	0	200	1.76	427
B-ph	3.06	200	1.99	423	7.42	200	4.18	423

Phase	Tertiary Winding (33 kV)			
	1 Phase		3 Phase	
	mA	Voltage	mA	Voltage
R-ph	**1.75 A**	200	**5.71 A**	431
Y-ph	28.14	200	**3.10 A**	427
B-ph	28.11	200	30.06	423

MAGNETIC BALANCE TEST

Voltage Applied	HV Side (220 kV)			IV Side (132 kV)		
	1R-N	1Y-N	1B-N	2R-N	2Y-N	2B-N

1R-N	200	74.2	197.9	121.5	74	120
1Y-N	00	200	00	0	200	0
1B-N	197.9	69.6	200	119.8	70.6	121.9

Voltage Applied	IV Winding (132 kV)		
	2R-2Y	2Y-2B	2B-2R
2R-N	200	74.1	198.2
2Y-N	00	200	00
2B-N	199	70.4	200

Voltage Applied	Tertiary Side (33 kV)		
	3R-3Y	3Y-3B	3B-3Y
3R-3Y	200	116.6	83.7
3Y-3B	1.96	200	199.9
3B-3R	1.97	200	200

DGA TEST RESULTS (in ppm)

Date of Test	**CH_4**	**C_2H_6**	**C_2H_4**	**C_2H_2**	**H_2**	**CO**	**CO_2**
11.05.18	6.8263	2.0722	6.970	0.00	69.064	526.39	2668
09.08.18	21.007	3.26040	67.304	130.37	21.001	56.066	545.96

P.	Observations & Analysis	:	

Following observations were reported by the utility:

1. When transformer tripped, oil from the transformer started coming out from the Y-ph PRV and Y-ph OLTC top cover side.
2. The Y-ph OLTC diverter switch cylinder housing ring was broken from many places and was found resting inside the transformer.
3. The Y-ph top/bottom press boards for winding were deformed and broken.
4. Many winding spacers were found displaced due to excessive pressure on the winding in the fault.
5. The end point of Y-ph tap lead to the IV winding was burnt badly due to fault with end frame and opened.
6. Heavy spark mark on the end frame near tap leads was observed.
7. All connecting leads to OLTC selector switch and OLTC for all phases were found intact.
8. All HV and IV bushings were found slightly displaced from its original position at flange level.
9. Sparking marks on the tank around core, end frame, tank plate shorting leads was observed.
10. All other windings & Tank was physically ok.

The DR records of transformer differential relay are as under :-

HV	side	299 A (R-ph)	2195 A (Y-ph)	50 A (B-ph)
IV	side	875 A (R-ph)	14177 A (Y-ph)	998 A (B-ph)

Fault clearing time was 85 msec.

Current during fault on the SEL feeder was:

R ph, 452 Amp, Y Ph 17.6 KA B Ph 315.9 Amp

Results of continuity test, magnetic balance test & magnetizing current test and indicate the fault in Y-phase IV winding which is also corroborated by operation of differential, OSR, PRV and Buchholz trip. It appears that due to heavy lightening a fault occurred on 132 kV SEL line very near to the substation. The transformer winding could not withstand the fault current and fault occurred on tap lead connection to Y-phase IV winding. Due to this fault large forces were generated inside the transformer causing physical displacement and damage of windings & pressboards.

20. Failure of 50 MVA, 220/6.9/6.9 kV Station Transformer at Raichur TPS of KPCL

A.	Name of Substation	:	Raichur Thermal PS
B.	Utility/Owner of substation	:	KPCL
C.	Faulty Equipment	:	Station transformer- I
D.	Rating	:	50 MVA, 220/6.9/6.9 kV
E.	Make	:	CGL
F.	Sr. No.	:	BH-8926/1
G.	Year of manufacturing	:	2003
H.	Date of commissioning	:	13.05.2003
I.	Date and time of occurrence/discovery of fault	:	31.12.18 at 2039 hrs
J.	Information received in CEA	:	16.01.19
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last annual overhaul done in April 2018. Oil samples were tested in CPRI. No abnormalities were observed.
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	
On 31.12.18 at 2039 hrs, CWP-1 C tripped and Unit 1 was on HG mode. An abnormal sound was heard in the transformer bay. Upon inspection, it was observed that the transformer (ST-1) had caught fire. ST-1 and its associated CBs had tripped along with following relay operation: Differential relay 87 ST REF 64 ST OC relay IDMT-T 50 A/B			

Transformer Aux. Prot. Relay 30 A/B/C
Master relay 86

Following annunciation appeared;
Buchholz/winding/Oil temp/oil level low
Transformer oil/ winding High trip
Main tank/ OLTC Buchholz stage -2 trip
PRD trip

Isolators were opened, emulsifier system operated and fire was quenched using foam and DCP.
Fault current recorded from ICT-3 at 400 kV side:
Ir- 634 A
Iy: 3.76 kA
Ib- 639.8 A

O.	Details of Tests done after failure	:	Reports not provided
P.	Observations & Analysis	:	Observations provided by the utility are as under:

1. Y-ph bushings were completely burnt and R&B phase were also heavily damaged

2. LV-1 cable-box cables were burnt

3. All bushings of LV-1 were broken

4. Neutral bushing of LV-2 were cracked

5. Buchholz, OSR, MOGs, air cell, 2 radiators , driving mechanism, marshaling box, LV-1 cable box along with disconnector chamber, all cables from the instruments to the MB, tertiary bushings, CFT terminal board, all turret CTs were completely damaged.

6. Internal support boards were intact

7. The windings seem to be intact physically, but the electrical test results were erratic.

Y-ph bushing seems to be the cause of failure which caught fire and this fire subsequently damaged the other bushings, windings and other components.

21. Failure of 292.4 MVA, 420/16.5 kV Generator Transformer of STG-2 at CCPP, PPS-III, Bawana station of PPCL

A.	Name of Substation	:	CCPP, PPS-II, Bawana
B.	Utility/Owner of substation	:	PPCL
C.	Faulty Equipment	:	Generator Transformer of STG-2
D.	Rating	:	292.4 MVA, 420/16.5 kV
E.	Make	:	BHEL, Bhopal
F.	Sr. No.	:	6006757
G.	Year of manufacturing	:	2009
H.	Year of commissioning	:	2014
I.	Date and time of occurrence/discovery of fault	:	19.03.19 at 1300 hrs
J.	Information received in CEA	:	22.04.19
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Due to operation of buccholz alarm on 06.09.2017 and increase in acetylene, the GT was inspected by BHEL. After replacement of insulation of connecting leads of HV leads and other repair works, the GT was taken back into service on 28.09.2017.
M.	Details of previous failure	:	The GT had previously failed on 08.10.2017 and was re-installed after repair at the works of BHEL.
N.	Sequence of events/ Description of fault	:	On 19.03.19 at 1300 hrs, 292.4 MVA, 16.5/420 kV GT of STG#2 was running at 197 MW when it tripped on overall Differential relay with a loud sound from the STG#2 side. On inspection, it was found that flashover had occurred on R-ph HV bushing along with snapping of one of the twin moose conductor at R-ph CT.

O.	Details of Tests done after failure	:	Following tests were conducted on 19.03.19 after flashover: IR, Magnetizing current, Magnetic balance, Voltage ratio, Winding resistance, Capacitance , tan delta and dielectric loss, Transformer oil test The results showed no abnormality.
P.	Observations & Analysis	:	No abnormality inside the transformer was found by OEM during the internal inspection and all leads and joints were intact. R-phase HV bushing was tested by OEM and results were also found to be in order. The differential relay might have operated due to flashover across R-phase HV bushing.

22. Failure of 60 MVA, 220/33kV Power Transformer at Indirapuram of WUPPTCL

A.	Name of Substation	:	Indirapuram
B.	Utility/Owner of substation	:	Western U.P. Power Transmission Co. Ltd. (WUPPTCL)
C.	Faulty Equipment	:	Transformer (ICT-5)
D.	Rating	:	60 MVA, 220/33kV
E.	Make	:	BHEL
F.	Sr. No.	:	2038225
G.	Year of manufacturing	:	2014-15
H.	Date of commissioning	:	16.10.2017
I.	Date and time of occurrence/discovery of fault	:	14.02.19, 0822 hrs.
J.	Information received in CEA	:	27.02.19
K.	Fault discovered during	:	Operation

<table>
<tr><td>L.</td><td>Details of previous failure</td><td>:</td><td>No previous failure.

Although 10 ppm acetylene was observed in DGA on 10.02.2019. The observation was sent to BHEL, however, the transformer failed on 14.02.2019 before any action could be taken.</td></tr>
<tr><td>M.</td><td>Details of previous maintenance</td><td></td><td>Periodical maintenance is carried out as per schedules. DGA is conducted once in every six months.</td></tr>
<tr><td>N.</td><td>Sequence of events/ Description of fault</td><td>:</td><td></td></tr>
<tr><td colspan="4">ICT 3, 4 and 5 were working in parallel. Altogether the load in all the 3 ICTs was 60MW only. On 33 kV side, 8 no. feeders are present in total. Each line feeder is protected with Overcurrent, earth fault (IDMT, DT) protection.

On 14.02.19 at 08:22 hrs, 2 nos. 33 kV feeders tripped on Overcurrent & earth fault protection and connected breakers cleared the fault.

398 ms later, ICT-5 tripped on PRV, differential and Buchholz. Timings of event are as under:

<table>
<tr><td>Bay 311 Line fault inception time (Nitikhand –II feeder)</td><td>08:22:50:939</td></tr>
<tr><td>Bay 312 Line fault inception time (Shaktikhand feeder)</td><td>08:22:50:977</td></tr>
<tr><td>Bay 311 Line CB</td><td>08:22:51:008</td></tr>
<tr><td>Bay 312 Line CB</td><td>08:22:51:047</td></tr>
<tr><td>Bay 210 ICT-5 HV CB</td><td>08:22:51:424</td></tr>
<tr><td>Bay 313 ICT-5 LV CB</td><td>08:22:51:445</td></tr>
</table>
</td></tr>
<tr><td>O.</td><td>Details of Tests done after failure</td><td>:</td><td></td></tr>
</table>

Magnetizing current measurement, winding resistance measurement and sweep frequency response analysis (SFRA) were carried out after fault. The results are as following:

Magnetizing Current: (HV Side)

Tap No.	1R-1N (Volts)	1Y-1N (Volts)	1B-1N (Volts)	I_R (mA)	I_Y (mA)	I_B (mA)	I_N (mA)
9	240.3	243.1	241.2	2.8	163.2	4.6	172.1

Winding Resistance Test: (LV Side)

Tap No.	2R-2N (mΩ)	2Y-2N (mΩ)	2B-2N (mΩ)
9B	20.63	Current not injected	20.42

P.	Observations & Analysis	:	

Results of magnetization current test, winding resistance test and SFRA indicate the fault in Y-ph winding. During internal inspection of the transformer at site, copper granules were found in LV side of the transformer. Further damage can only be assessed after detailed internal inspection of transformer at the works.

As reported by the utility, 33 kV feeders experience tripping. It appears that high current caused by fault on 33 kV feeder led to stress on LV winding of the transformer which the winding could not withstand. DGA in February 2019 also indicated existing problem or partial discharge activity in the transformer which aggravated due to fault on the feeder.

The utility had the apprehension about the verification of capability of the transformer to withstand dynamic effect of short circuit current during the design stage.

Similar failures were observed in other transformers on 02.03.2019 operating in parallel with the transformer under discussion. Details of those failures is provided in subsequent table. Similar nature of failure in all three transformers of the same make and probably manufactured simultaneously indicate manufacturing defect in LV winding of Y phase in the transformer. The manufacturer need to examine the design and carry out necessary modification as required. It is recommended that capability of the transformer to withstand dynamic effect of short circuit current should be verified by the manufacturer .

23. Failure of 2 nos. 60 MVA, 220/33 kV Transformer at Indirapuram S/s of WUPPTCL

A.	Name of Substation	:	Indirapuram
B.	Utility/Owner of substation	:	WUPPTCL
C.	Faulty Equipment	:	Transformer (ICT-3 and 4)
D.	Rating	:	60 MVA, 220/33kV
E.	Make	:	BHEL
F.	Sr. No.	:	2038227 (ICT-3) 2038226 (ICT-4)
G.	Year of manufacturing	:	2014-15
H.	Year of commissioning	:	16.10.2017 (ICT-3) 02.01.2018 (ICT-4)
I.	Date and time of occurrence/discovery of fault	:	02.03.19, 2026 hrs.
J.	Information received in CEA	:	05.04.19
K.	Fault discovered during	:	Operation
L.	Details of previous failure	:	No previous failure
M.	Details of previous maintenance	:	Periodical maintenance is carried out as per schedules. DGA is conducted once in every six months.
N.	Sequence of events/ Description of fault	:	

On 02.03.19 at 20:26 hrs, ICT 3 and ICT 4 at the substation tripped on PRV-1, Differential and Buchholz protection. Event timings are as under:

Bay 311 Line fault inception time	20:26:18:057
Bay 312 Line fault inception time	20:26:18:177

	Bay 311 Line CB	20:26:18:127
	Bay 312 Line CB	20:26:20:247
	Bay 209 ICT-4 HV CB	20:26:20:373
	Bay 308 ICT-4 LV CB	20:26:20:406
	Bay 208 ICT-3 HV CB	20:26:20:610
	Bay 302 ICT-3 LV CB	20:26:20:649

O.	Details of Tests done after failure	:	

Magnetizing current measurement, winding resistance measurement and sweep frequency response analysis (SFRA) were carried out after fault. The results are as following:

Test results of ICT-3

Magnetizing Current: (HV Side)

Tap No.	1R-1N (Volts)	1Y-1N (Volts)	1B-1N (Volts)	I_R (mA)	I_Y (mA)	I_B (mA)
9B	418	419	417	3.1	2.8	2.3

Winding Resistance Test: (LV Side)

Tap No.	2R-2N (mΩ)	2Y-2N (mΩ)	2B-2N (mΩ)
9B	20.1	Current not injected	20.1

Test results of ICT-4

Magnetizing Current: (HV Side)

Tap No.	1R-1N (Volts)	1Y-1N (Volts)	1B-1N (Volts)	I_R (mA)	I_Y (mA)	I_B (mA)
9	416	419	416	7.8	190	5.9

Winding Resistance Test: (LV Side)

Tap No.	2R-2N (mΩ)	2Y-2N (mΩ)	2B-2N (mΩ)
9B	20.93	22.04	21.2

P.	Observations & Analysis	:	

DGA on ICT-3 carried out Monthly since May 2019 and Ethylene was found high. Fault current observed as reported by utility based on DR was less than 25 kA and persisted for less than 1 second. Results of magnetization current test, winding resistance test and SFRA indicate the fault in Y-ph winding. During internal inspection of the transformer at site, copper granules were found in LV side of the transformer. Further damage can only be assessed after detailed internal inspection of transformer at the works. As reported by the utility, 33 kV feeders experience tripping. It appears that high current caused by fault on 33 kV feeder led to stress on LV winding of the transformer which the winding could not withstand. DGA results also indicated existing problem or partial discharge activity in the transformer which aggravated due to fault on the feeder. The utility had the apprehension about the verification of capability of the transformer to withstand dynamic effect of short circuit current during the design stage.Similar failures were observed in ICT-5 on 02.03.2019 operating in parallel with the transformer under discussion. Details of those failures is provided in previous table. Similar nature of failure in all three transformers of the same make and probably manufactured simultaneously indicate manufacturing defect in LV winding of Y phase in the transformer. The manufacturer need to examine the design and carry out necessary modification as required. It is recommended that capability of the transformer to withstand dynamic effect of short circuit current should be verified by the manufacturer .		

24. Failure of 146 MVA, 240/10.5 kV GT at Gas Turbine Power Station, Uran of MSPGCL

A.	Name of Substation	:	Gas Turbine Power Station, Uran
B.	Utility/Owner of substation	:	MSPGCL
C.	Faulty Equipment	:	Generator Transformer (Unit-6)
D.	Rating	:	146 MVA,240/10.5 kV
E.	Make	:	Trafo Union ,West Germany
F.	Sr. No.	:	N 406889
G.	Year of manufacturing	:	1984
H.	Year of commissioning	:	1984
I.	Date and time of occurrence/discovery of fault	:	09.06.2018, 11.50 Hrs

J.	Information received in CEA	:	25.09.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last periodic testing of transformer oil was carried out in November 2017. Transformer oil filtration were carried out in March 2018 and oil tested on 08.03.2018.
M.	Details of previous failure	:	N/A
N.	Sequence of events/ Description of fault	:	Differential protection of Y & B phase operated followed by Buchholz relay alarm & trip protection. PRV was not operated.
O.	Details of Tests done after failure	:	1. Entrapped gas in Buchholz relay was sampled on 10.06.2018 and tested which shows presence of acetylene, H2, and methane. 2. Transformer oil samples were taken on 09.06.2018 for DGA and tested on 10.06.2018 which shows increase in acetylene, methane. 3. Low voltage electrical test carried out on 10.06.2018, the result shows B-Phase HV winding abnormal resistance.
P.	Observations & Analysis	:	As per information provided by the utility

- In HV B-ph winding nearly 4 coils found damaged. The affected area is nearly 150*150 mm. Rest of the winding seems intact.
- Carbon deposits & melted copper particles are spread over all the windings and inside the transformer.
- All equalizing pipe lines found intact. No physical deformation found in the transformer. No significant rise in oil & winding temperature observed.

From the physical damage and LV tests cause of failure is suspected to be inter-turn fault in HV B-phase winding. The transformer had served for 35 years. Ageing might be the reason for deterioration in the insulation.

25. Failure of 150 MVA, 230/10.5 kV GT at Gas Turbine Power Station, Uran of MSPGCL

A.	Name of Substation	:	Gas Turbine Power Station, Uran
B.	Utility/Owner of	:	MSPGCL

	substation		
C.	Faulty Equipment	:	WHRP Unit-A0 Generator Transformer
D.	Rating	:	150 MVA,230/10.5 kV
E.	Make	:	CGL
F.	Sr. No.	:	T 8324/2
G.	Year of manufacturing	:	1992
H.	Year of commissioning	:	1994
I.	Date and time of occurrence/discovery of fault	:	27.08.2018, 02.06 Hrs
J.	Information received in CEA	:	25.09.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	• The transformer was overhauled. Internal inspection /Dry out done in Nov-Dec 2012 and work of tap changing contact clearing was done. • 5 nos. of radiators replacement and transformer oil filtration were carried out in March 2018 • Last periodic testing of transformer oil was carried out in 30.06.2018. • Furan analysis of insulation paper carried out on 24.07.2018 and found normal.
M.	Details of previous failure	:	• On Jan-2011, LV Y-Phase bushing cracked and hence replaced with spare bushing. • Transformer tripped on differential protection during Mar-2013. All testing done and winding resistance for Y-phase Tap changer position no.6 found open circuit. Tap changer position fixed on tap no.7 and after clearances by the agency transformer was charged again.
N.	Sequence of events/ Description of fault	:	Differential protection of R, Y & B phase operated along with Over-current pickup for all three phases, Main Tank Buchholz trip, OLTC Buchholz trip, PRV protection operated and heavy oil found spread in nearby area. No rise in oil & winding temperature observed.
O.	Details of Tests done after failure	:	• Trapped gas from Buchholz analyzed and traces of H_2, CH_4, and acetylene found. • Insulation resistance test, Voltage Ratio

			and magnetic balance test, Vector group test, winding resistance measurement, magnetizing current test were carried out on 27.08.2018. • On date 30.08.2018 after removal of transformer oil, detailed winding resistance measurement is carried out with all taps and found that some contacts of R & Y phases are open.
P.	Observations & Analysis	:	As per information provided by the utility
• Tap windings of HV side for all phases found deformed and distorted. Winding blocks, spacers are also found dislocated. Some of the blocks were found fallen inside the tank and tank shunts found damaged. • Carbon deposits are found over all three windings and inside the transformer. • OLTC found heavily carbonized and its tie resistances fallen down. • Y-ph HV bushing bottom side found cracked & oil leakage observed through it. • Form the above observations, operation of protection systems and test results, it appears that the fault was initiated in the tap winding.			

26. Failure of 105 MVA, 400/√3 / 220/√3 / 33kV Transformer at KTPS S/S of WBPDCL

A.	Name of Substation	:	Kolaghat Thermal Power Station (KTPS)
B.	Utility/Owner of substation	:	WBPDCL
C.	Faulty Equipment	:	Transformer (R-ph)
D.	Rating	:	1-phase,105 MVA, 400/√3 / 220/√3 / 33 kV
E.	Make	:	BHEL
F.	Sr. No.	:	6004571
G.	Year of manufacturing	:	1984
H.	Year of commissioning	:	1991
I.	Date and time of occurrence/discovery of fault	:	16.04.2018 at 17:38 hrs
J.	Information received in CEA	:	03.07.2019

<table>
<tr><td>K.</td><td>Fault discovered during</td><td>:</td><td>Operation</td></tr>
<tr><td>L.</td><td>Details of previous maintenance</td><td>:</td><td>Maintenance practices followed by the utility are as follows:
<table>
<tr><th>Name of the Test</th><th>Frequency of conducting the test</th></tr>
<tr><td>Thermo vision</td><td>Quarterly</td></tr>
<tr><td>3rd harmonic LA leakage current measurement</td><td>Quarterly</td></tr>
<tr><td>Transformer oil DGA</td><td>Half yearly</td></tr>
<tr><td>Transformer oil full test</td><td>Yearly</td></tr>
</table>
Tan delta and capacitance measurement of the bushings was carried out on 06.02.2015 and results were found satisfactory. Last furan test was carried out by CPRI in October 2014 and no abnormality was found in the test results.</td></tr>
<tr><td>M.</td><td>Details of previous failure</td><td>:</td><td>NIL</td></tr>
<tr><td>N.</td><td>Sequence of events/ Description of fault</td><td>:</td><td></td></tr>
</table>

On 16.04.2018 at 17:38 hrs, the transformer caught fire. Simultaneously, transformer tripped and following protection operated:

1. Transformer Differential at R & B-ph.
2. Transformer REF protection operated at R-ph only.
3. Transformer WTI/OTI/OLTC Buchholz/Transformer Buchholz/PRV operated at R-ph only.

Following data was recorded by Bus differential protection unit:

Pre-fault condition on 400 kV side:

Phase	Current
R	128 A
Y	131 A
B	120 A
Neutral	7 A

Post-fault condition on 400 kV side:

Phase	Current (values referred to primary)
R (faulty phase)	18 kA

Y	278 A
B	404.97 A
Neutral	18 kA

Pre-fault condition on 220 kV side:

Phase	Current
R	212 A
Y	217 A
B	207 A
Neutral	4 A

Post-fault condition on 220 kV side:

Phase	Current
R (faulty phase)	2493 A
Y	271 A
B	443 A
Neutral	3155 A

Pre-fault current and voltages recorded from P14 relay:

Phase	Current	Voltage
r	215 A	133 kV
y	222 A	134 kV
b	209 A	132 kV

Post-fault current and voltages recorded from P14 relay:

Phase	Current	Voltage
r	2523 A	66 kV
y	277 A	122 kV
b	449 A	125 kV

O.	Details of Tests done after failure	:	The transformer was completely damaged and therefore no test was possible.
P.	Observations & Analysis	:	

R-phase transformer was completely damaged due to fire. Cracks as well as bulging in the tank was also observed on the 400 kV bushing side.

Further, damage in the following nearby equipment was also observed:

1. The radiator zone & conservator of Y-ph transformer.
2. Cables (including cables on 33kV side) associated with both the transformer banks.
3. LA of 33kV side of R-phase transformer.
4. The overhead conductor as well as insulator.
5. Entire emulsifier system along with the fire wall is damaged.

It is observed from the report provided by the utility that only one number PRD has been provided for the transformer which is insufficient for such a large transformer. Since the tank was bulged in the area near to the 400 kV bushing and fault current was very high, the transformer failed due to bushing failure.

REACTORS

27. Failure of 420 kV, 63 MVAR reactor at Biswanath Chariali substation of PGCIL

A.	Name of Substation	:	Biswanath Chariali Substation
B.	Utility/Owner of substation	:	PGCIL
C.	Faulty Equipment	:	Bus Reactor
D.	Rating	:	63MVAR, 420 kV
E.	Make	:	BHEL
F.	Sr. No.	:	6007609
G.	Year of manufacturing	:	2017
H.	Date of commissioning	:	09.12.2017
I.	Date and time of occurrence/discovery of fault	:	02.05.2018 at 19:05 hrs.
J.	Fault discovered during	:	Operation
K.	Details of previous maintenance	:	
	Reactor was received at site in June 2017 and commissioned on 09.12.2017. The reactor was being utilized as bus reactor without NGR. The reactor was subject to frequent switching as required by NERLDC for voltage regulation and since charging there were 17 nos. of switching operations. On 27th April, 2018 at 1245 hrs, the reactor was taken out of service as per the RLDC instruction and again put back in service at 1640 hrs on same day. The said Reactor was in operation without any problem till the date of failure. Results of DGA and oil test done on 27.04.2018, revealed no abnormalities.		
L.	Details of previous failure	:	No previous failures
M.	Sequence of events/ Description of fault	:	
	The reactor tripped on Differential and REF protection on 02.05.2018 at 19:05:55 hrs. Simultaneously, PRD and Buchholz also operated. As per the information given by the utility, a fault current of 12 kA was observed in B-ph winding. Sequence of tripping event is as given below:		

	REF : 19:05:54:514 RPR : 19:05:54:538 (Rapid rise pressure relay) Diff Trip : 19:05:55:473 PRD Trip : 19:05:55:507 Buchholz Trip: 19:05:55:669
N.	Details of Tests done after failure :

A) Magnetization Current Test

Voltage Applied (Volts)		Current Measured (m Amp)		Remark
R-N	231.9	R- Ø	85.6	B Phase has less excitation current as compared to other phases
Y-N	231.5	Y- Ø	85.6	
B-N	231.0	B- Ø	63.4	

B) Tan δ & capacitance Measurement of Bushing(30ºC)

	R-Ø	Y-Ø	B-Ø	Neutral
(C1 in pf) Site Capacitance	606.935	600.511	596.250	345.541
% Tan δ at site	0.300	0.301	0.299	0.288

C) Tan δ & capacitance of Winding (30ºC)

Voltage	Winding Combination	Test Mode	Capacitance		Tan δ %	
			Site (pF)	Factory	Site	Factory
2 kV	HV/Tank+Earth	GST	9682	--	0.884	--
10 kV			9687	10140	0.655	0.25

D) Insulation Resistance in GΩ (5000 V Megger) at (30ºC)

Main Winding	IR Value (GΩ)			DAI=60/15 Sec	PI=600 Sec/60 Sec
	15 Sec	**60 Sec**	**600 Sec**		
HV to E	6.33	7.72	14.9	1.22	1.94

E) Core Insulation Test at 1000 V DC

Terminals	Value	Terminals	Value	Terminals	Value
CC-G	3.6 GΩ	CC-CL	98.2MΩ	CL-G	3.8 GΩ

F) Winding Resistance in Ω (OTI/WTI 44ºC)

Winding Resistance [HV-N]			Resistance At 75ºC			Factory Value			% Deviation		
R	Y	B	R	Y	B	R	Y	B	R	Y	B
2.509	2.512	5.035	2.787	2.791	5.594	2.978	2.982	2.979	-6.4	-6.4	87.8

O.	Observations & Analysis	:	

Following observations were made during inspection of the Reactor by the utility:

1. Twin moose connector of B-phase bushing was found broken.
2. In CC-CL epoxy terminal board, Core Clamp terminal was found melted.
3. SA of reactor was intact and no increase in readings of SA counters was observed.
4. Cracks developed in flange of R-phase and B-phase bushings.
5. Slight bulging/deformation observed in reactor tank.
6. Maximum readings of OTI & WTI went up to 75 degree centigrade.
7. Carbon particles were observed inside the reactor and also on core coil assembly as well as at the bottom of the tank.
8. B-phase winding found damaged from lead take off location.
9. During inspection it was felt that some moisture accumulation has occurred on the press board surface of B phase. However, ppm value was within the limit prior to failure (5 ppm).
10. Melting of lamination was observed at the bottom cross flux plate. Melting of lamination sheets observed in auxiliary limb of core adjacent of R-phase winding and bottom part of auxiliary limb adjacent to B-phase winding.
11. Tracking observed through outer press-board barrier surface emanating from conductor of lower half of the winding to flux plate. On further removal of the press-board barrier, tracking and treeing marks were observed on both side of the winding insulation from lead take off to the ground.
12. After removing the insulation pressboard barriers, burning of conductors was observed in lead take-off area of winding. Two conductor strip were broken/melted in the 3rd disc from the top of the lower half the winding.
    Unlike press board, no treeing/tracking is observed in the winding.
13. Due to defect in online DGA system, any development of fault gases during last two months prior to failure could not be known.
14. Equipotential lead and lead take off area was found intact.

Opening and closing voltage/current response taken at 12:45 hrs. from CSD device was found normal.

As per the information given by the utility, some moisture accumulation was observed at B-ph pressboard. Also, there was tracking from the B phase HV lead take off to bottom cross flux plate through surface of the press board barrier. Prima facie, it seems that fault was initiated from B phase HV lead. Frequent switching operations may have aided tracking which developed from the HV lead to the ground causing dielectric break down.

CURRENT TRANSFORMERS

28. Failure of 400kV B-ph CT of 500MVA ICT-2 at Khaperkheda Substation of MSETCL

A.	Name of Substation	:	400kV Khaperkheda.
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	B-ph CT of 500MVA ICT-2 TIE BAY
D.	Rating	:	400kV
E.	Make	:	AREVA
F.	Sr. No.	:	20081244
G.	Year of manufacturing	:	2008
H.	Year of commissioning	:	19.11.2011
I.	Date and time of occurrence/discovery of fault	:	01.05.18 at 20:21 hrs
J.	Information received in CEA	:	05.07.18
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last annual maintenance was done on 05.02.2018. Tan delta test was carried out and results were within limits.
M.	Details of previous failure	:	No previous failure
N.	Sequence of events/ Description of fault	:	On 01.05.18 at 20:21 hrs, B-ph CT of 500MVA ICT-2 TIE BAY burst due to which 400kV Busbar Protection Zone-I was operated. However, Station busbar tripping relay 96 did not trip, which resulted in the operation of reverse zone of all 400kV lines & backup protection of 220kV lines at 220kV Khaperkheda substation end.

O.	Details of Tests done after failure	:	B-ph CT was completely burnt and therefore, it was not possible to carry out any test after the failure.
P.	Observations & Analysis	:	The CT might have failed due to insulation failure.

29. Failure of 400kV CT of 400KV Khaperkheda-Koradi Ckt-I R ph Substation of MSETCL

A.	Name of Substation	:	400kV Khaperkheda S/s
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	400 kV Khaperkheda-Koradi Ckt-I R-ph CT
D.	Rating	:	420kV, Ratio 2000-1000-500/1A
E.	Make	:	Areva
F.	Sr. No.	:	200812134
G.	Year of manufacturing	:	2008
H.	Year of commissioning	:	14.05.2011
I.	Date and time of occurrence/discovery of fault	:	16.10.2018 at 23:26hrs
J.	Information received in CEA	:	27.02.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Tan delta was carried out on 15.11.2017, all values were within limits.
M.	Details of previous failure	:	Information not Available
N.	Sequence of events/ Description of fault	:	On 16.10.2018 at 23:26 hrs, at 400kV Khaperkheda-Koradi Ckt-I R-ph CT (Bus side) Main Bay failed, resulting in the operation of Teed & Bus bar operation of 400KV Main Bus-II. Bays connected to 400kV Main bus-2 tripped on bus bar protection scheme. 500MVA ICT-I & 500 MVA ICT-2MV CBs tripped as per the scheme (initiation from 96 busbar tripping relays).

			Further, 400kV Khaperkheda Ckt, CB was also found to be tripped on zone-2 at 400kV Koradi (Old) s/s.
O.	Details of Tests done after failure	:	B-ph CT was completely burnt and therefore, it was not possible to carry out any test after the failure.
P.	Observations & Analysis	:	Insulation failure might be the reason of failure of CT.

30. Failure of 220kV CT at TELCO substation of MSETCL

A.	Name of Substation	:	220kV Telco
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	200 kV CT R-ph of Transformer No-03
D.	Rating	:	800-400-200/1A(5C)
E.	Make	:	Universal Magnoflux Limited
F.	Sr. No.	:	17014
G.	Year of manufacturing	:	2011
H.	Year of commissioning	:	17.09.2012
I.	Date and time of occurrence/discovery of fault	:	On 06.07.2018 at 23:28 hrs
J.	Information received in CEA	:	25.09.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	On 12.04.2018, tan delta testing was done and also maintenance work was carried out.
M.	Details of previous failure	:	No previous failure
N.	Sequence of events/ Description of fault	:	On 06.07.2018 at 23:28 hrs, R-ph CT of Transformer No-03 burst & caught heavy fire,

			which caused the operation of Transformer differential protection & REF protection (as Transformer No. 3 did not have turret CTs, HV CT cores were used for REF protection). Simultaneously with operation of ABB make RADSS bus bar protection scheme and tripping of all bus bar relays (96) resulted into the tripping of 220 kV Bhosari 2 line and consumer end Transformer No. 1,2,3 connected to 220 kV bus at 220 kV Telco substation.
O.	Details of Tests done after failure	:	Tests cannot be done as the CT was completely damaged.
P.	Observations & Analysis	:	It appears, reduction in dielectric strength of the insulation might have led to the failure and blasting of CT.

31. Failure of B-Ph CT of 500MVA,400/220kV ICT-III at Kalwa Substation of MSETCL

A.	Name of Substation	:	400kV Kalwa
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	B-ph CT of 500MVA, 400/220kV ICT-III,
D.	Rating	:	220kV
E.	Make	:	Lamco Industries
F.	Sr. No.	:	CF-333
G.	Year of manufacturing	:	2000
H.	Year of commissioning	:	12.10.2014
I.	Date and time of occurrence/discovery of fault	:	01.06.2018 at 16:00hrs.
J.	Information received in CEA	:	25.09.2018
K.	Fault discovered during	:	Operation
L.	Details of previous	:	Last Maintenance was done on 25.03.2018

	maintenance		
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	500MVA, 400/220kV ICT-3 tripped on differential protection due to failure of 220kV CT of ICT-3.
O.	Details of Tests done after failure	:	The CT was completely damaged and therefore test could not be done.
P.	Observations & Analysis	:	During internal inspection the utility found the tank of the dead tank LAMCO make CT of ICT-3 buckled and completely broken. It appears, reduction in dielectric strength of the insulation might have led to the failure and blasting of CT.

32. Failure of R-Ph CT of 500MVA, 400/220kV ICT-III at Kalwa Substation of MSETCL

A.	Name of Substation	:	400kV Kalwa
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	R-ph CT of 500MVA,400/220kV ICT-III
D.	Rating	:	220kV
E.	Make	:	Lamco Industries
F.	Sr. No.	:	CF-323
G.	Year of manufacturing	:	2011
H.	Year of commissioning	:	2012 (22.06.2012)
I.	Date and time of occurrence/discovery of fault	:	On 01.06.2018 at 18.18 hrs.
J.	Information received in CEA	:	25.09.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Maintenance done on 25.03.2018

M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 01.06.2018 at 18:18 hrs., R-ph CT of ICT-3 Burst and 500MVA, 400/220kV ICT-3 tripped on Differential Protection along with 220kV B-Bus tripping.
O.	Details of Tests done after failure	:	The CT was completely damaged and therefore test could not be done.
P.	Observations & Analysis	:	The utility found in the internal inspection that the insulation of 220kV R-ph was damaged from the center of the windings. Internal insulation failure was the cause of failure of CT.

33. Failure of 220kV CT at APTA Substation of MSETCL

A.	Name of Substation	:	220 kV APTA
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	R-ph CT of 220kV Apta-Hocl line
D.	Rating	:	245kV,800-400-200A
E.	Make	:	MEHRU
F.	Sr. No.	:	OC/2064/2/270/08
G.	Year of manufacturing	:	2008
H.	Year of commissioning	:	2009
I.	Date and time of occurrence/discovery of fault	:	02.11.2018
J.	Information received in CEA	:	14.06.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last Maintenance was done on 21.01.2018. CT tan delta value taken on 07.02.2017 is mentioned below:

Phase	(%) tan delta	Cap (pF)	Voltage (kV)
R	1.287	585	10
Y	0.128	251	10
B	0.129	582	10

M.	Details of previous failure	:	None
N.	Sequence of events/ Description of fault	:	On 02.11.2018, R-ph CT of 220kV Apta-Hocl line burst. Thus, LBB of bus sectionalizer operated
O.	Details of Tests done after failure	:	CT burnt completely therefore test could not be done.
P.	Observations & Analysis	:	It was observed that R-ph Tan delta value/di-electric loss was on higher side. The higher Tan delta value/di-electric loss means insulation degradation. Therefore, the failure of this CT may be due to insulation failure. Since, High value of Tan delta was observed on 07.02.2017, the CT should have been removed from the service.

34. Failure of 220kV CT at Malegaon Substation of MSETCL

A.	Name of Substation	:	220 kV Malegaon
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	R-ph CT of 220/33kV,50 MVA Transformer-2
D.	Rating	:	245 kV,800-400-200A
E.	Make	:	MEHRU
F.	Sr. No.	:	OC-2064/2/52/07
G.	Year of manufacturing	:	2007
H.	Year of commissioning	:	10.11.2008
I.	Date and time of occurrence/discovery of fault	:	On 22.11.2018 at 03:40 hrs
J.	Information received in CEA	:	14.06.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	On 01.06.2018, tan-delta value was measured (0.611%) & routine maintenance was carried out.

M.	Details of previous failure	:	Information not available
N.	Sequence of events/ Description of fault	:	On 22.11.2018 at 03:40 hrs, R-ph CT of 220/33kV,50 MVA Transformer-2 burst and the transformer-2 was tripped on Differential protection.
O.	Details of Tests done after failure	:	CT was damaged therefore tests could not be done.
P.	Observations & Analysis	:	CT failed due to insulation failure.

35. Failure of 220kV CT at Kandalgaon Substation of MSETCL

A.	Name of Substation	:	220/100/22kV Kandalgaon
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	220kV R-ph CT of 220kV ONGC line
D.	Rating	:	220kV, 1600-800/1 A 5C
E.	Make	:	MEHRU
F.	Sr. No.	:	OC/2064/2/254/08
G.	Year of manufacturing	:	2008
H.	Year of commissioning	:	22.10.2013
I.	Date and time of occurrence/discovery of fault	:	13.11.2018 at17:45 Hrs
J.	Information received in CEA	:	14.06.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	On 16.01.2018, Tan Delta measurement was done: Tan Delta Values was found to be 1.92 at 5kV &

			2.19 at 10Kv.
M.	Details of previous failure	:	NA
N.	Sequence of events/ Description of fault	:	220kV GIS Bus Sectionalizer No. 1 and 2 operated on LBB Protection.
O.	Details of Tests done after failure	:	CT was damaged therefore tests could not be done
P.	Observations & Analysis	:	It was observed that R-ph Tan delta value/di-electric loss was on higher side. The higher Tan delta value/di-electric loss means insulation degradation. Therefore, the failure of this CT may be due to insulation failure.

36. Failure of 220kV CT at SPCL Substation of MSETCL

A.	Name of Substation	:	220 kV SPCL
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	R-ph CT of 220kV Nagothane Line
D.	Rating	:	220kV, 2400/1200/1A 5C
E.	Make	:	SCT
F.	Sr. No.	:	2009/09
G.	Year of manufacturing	:	2009
H.	Year of commissioning	:	2014
I.	Date and time of occurrence/discovery of fault	:	08.11.2018 at 07:45 hrs
J.	Information received in CEA	:	14.06.2019

K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	On date 30.05.2018 outage was taken on line to carry out diagnostic test. Tan delta test were carried out on all CTs of 3 phases, but due to some error in the kit, R-ph result could not be taken. However, previous results of R-ph tan delta carried out on 10.02.2017 as follows:

Phase	**Voltage (kV)**	**Current (mA)**	**Measured % PF**	**Cap (pF)**
R	5	1.356	4.791	435.45
Y	5	1.354	0.235	435.24
B	5	1.318	2.105	423.76
B	10	1.1	2.160	353.55

M.	Details of previous failure	:	NA
N.	Sequence of events/ Description of fault	:	Nil
O.	De8tails of Tests done after failure	:	CT was burnt completely and hence test could not be conducted
P.	Observations & Analysis	:	As informed by the utility, the performance of SCT make PTs and CTs were found to be very poor as they have faced problems in many CTs/PTs of this make. The manufacturer need to investigate the cause of failure to improve the quality and reliability of its products. It was observed that R-ph Tan delta value/di-electric loss was on higher side which indicates insulation degradation. Therefore, the failure of this CT may be due to insulation failure. The utility should have replaced the CT when high tan delta was observed.

37. Failure of 220kV Bus Coupler Bus-2 R-Phase CT at Nellore Substation of APTRANSCO

A.	Name of Substation	:	220kV Nellore
B.	Utility/Owner of substation	:	APTRANSCO
C.	Faulty Equipment	:	R-ph CT of 220kV Bus Coupler Bus-2
D.	Rating	:	220kV
E.	Make	:	WSI
F.	Sr. No.	:	931129
G.	Year of manufacturing	:	1993
H.	Year of commissioning	:	17.12.1999
I.	Date and time of occurrence/discovery of fault	:	16.04.2018 at 11:50 hrs
J.	Information received in CEA	:	17.09.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last annual maintenance done on 01.09.2018
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 16.04.2018 at 11:50 hrs, R-ph CT of 220kV Bus Coupler Bus-2 blasted.
O.	Details of Tests done after failure	:	CT was damaged and hence test could not be conducted.
P.	Observations & Analysis	:	As no test values of tests conducted during previous maintenance is available, it is hard to ascertain the health of the CT prior to fault. However, blasting in generally caused due to generation of high pressure caused by internal fault.

38. Failure of 220kV CT at Jamshedpur Substation of DVC

A.	Name of Substation	:	200/132/33kV Jamshedpur

B.	Utility/Owner of substation	:	Damodar valley Corporation
C.	Faulty Equipment	:	220kV Y-ph CT of 150MVA Auto transformer -2
D.	Rating	:	220kV,Ratio:800-400/1-1-1-1-1
E.	Make	:	TELK
F.	Sr. No.	:	230140-6
G.	Year of manufacturing	:	1986
H.	Year of commissioning	:	1990
I.	Date and time of occurrence/discovery of fault	:	On 21.04.2018 at 17:50 hrs
J.	Information received in CEA	:	16.01.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	During previous maintenance, Insulation Resistance Test and Tan delta test was carried out. The results of the tests are mentioned below: Insulation Resistance Test: P-E=6.6 G-ohm, P1-1S1=5.9 G-ohm, P1-3S1=6.6 G-Ohm, P1-4S1=10.13 G-Ohm, P1-5S1=11.6 G-Ohm Value of Tan delta = 1.85
M.	Details of previous failure	:	NIL
N.	Sequence of events/ Description of fault	:	On 21.04.2018 at 17:50 hrs, 220kV Y-ph CT of 150MVA Auto transformer -2 busted, HT & LT CB tripped w.r.t Differential protection, REF and O/C protection operated.
O.	Details of Tests done after failure	:	No test done because CT was totally damaged at the time of failure.
P.	Observations & Analysis	:	It was observed that Y-ph Tan delta value was on higher side which indicates insulation degradation. Therefore, the failure of this CT may be due to insulation failure. The CT had served for 33 years. Ageing might be the reason

			of insulation degradation.

39. Failure of 220kV CT at Sharavathy generating Substation of KPCL

A.	Name of Substation	:	Sharavathy Generating Station
B.	Utility/Owner of substation	:	KPCL
C.	Faulty Equipment	:	R-Ph CT
D.	Rating	:	220kV, 5 core
E.	Make	:	ALSTOM
F.	Sr. No.	:	20040119/2004
G.	Year of manufacturing	:	2004
H.	Year of commissioning	:	2005
I.	Date and time of occurrence/discovery of fault	:	04.08.2018 at 09:15 Hrs.
J.	Information received in CEA	:	12.12.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Information not available
M.	Details of previous failure	:	Information not available
N.	Sequence of events/ Description of fault	:	1. CT was charged in idle condition. 2. CT flash over while opening isolator.
O.	Details of Tests done after failure	:	Information not available
P.	Observations & Analysis	:	As no test values of tests conducted during previous maintenance is available, it is hard to ascertain the health of the CT prior to the fault. Based on the available information exact cause of the failure could not be ascertained.

40. Failure 420kV CT at 400/230-110kV Sriperumbudur Substation of TANTRANSCO

A.	Name of Substation	:	400/230-110kV Sriperumbudur
B.	Utility/Owner of substation	:	TANTRANSCO
C.	Faulty Equipment	:	R-Ph CT of Auto Transformer-3
D.	Rating	:	420 kV
E.	Make	:	ALSTOM
F.	Sr. No.		20030842/2003
G.	Year of manufacturing	:	2003
H.	Year of commissioning	:	2005
I.	Date and time of occurrence/discovery of fault	:	28.01.2019 at 01.18hrs.
J.	Information received in CEA	:	05.07.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Information not available
M.	Details of previous failure	:	Information not available
N.	Sequence of events/ Description of fault	:	On 28.01.2019 at 01.18hrs, R-Ph CT of Auto Transformer-3 failed and due to which Auto Transformer-3 tripped on differential protection.
O.	Details of Tests done after failure	:	Information not available
P.	Observations & Analysis	:	As no test values of tests conducted during previous maintenance is available, it is hard to ascertain the health of the CT prior to fault. Further, detailed information regarding the failure is not available. Hence, it is difficult to ascertain the cause of the failure.

POTENTIAL TRANSFORMERS / CAPACITOR VOLTAGE TRANSFORMERS

41. Failure of 220kV CVT at Panipat Substation of BBMB

A.	Name of Substation	:	400kV BBMB Panipat
B.	Utility/Owner of substation	:	BBMB
C.	Faulty Equipment	:	B-Ph CVT of 220kV Panipat- Charkhi Dadri Ckt.
D.	Rating	:	220kV/√3 / 110/√3-110/√3-110/√3
E.	Make	:	ALSTOM
F.	Sr. No.	:	88121009
G.	Year of manufacturing	:	1998
H.	Date of commissioning	:	24.04.2004
I.	Date and time of occurrence/discovery of fault	:	07.05.18, 15:27 hrs.
J.	Information received in CEA	:	31.05.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Previous annual maintenance was done on 24.10.2017.
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 07.05.2018, 220 kV Panipat- Dadri line tripped off due to line fault in zone-II. After clearance of line it was tried to charge the line at 17:15 hrs. When the breaker was closed, the R-phase CVT busted with heavy sound and caught fire. After quenching of fire, it was observed that the complete porcelain and some lower metallic part of the CVT are completely damaged.
O.	Details of Tests done after failure	:	CVT was damaged completely and hence test could not be conducted.
P.	Observations & Analysis	:	It appears that the insulation of CVT had deteriorated and while closing circuit breaker,

			CVT could not withstand transient overvoltage conditions and developed fault inside.

42. Failure of 220kV CVT at Panipat Substation of BBMB

A.	Name of Substation	:	400kV BBMB Panipat
B.	Utility/Owner of substation	:	BBMB
C.	Faulty Equipment	:	Y-ph CVT of 220kV Panipat–Kurukshetra Ckt.
D.	Rating	:	245kV
E.	Make	:	Rade Koncar
F.	Sr. No.	:	RadeKoncar / VCU-245
G.	Year of manufacturing	:	1974
H.	Year of commissioning	:	1978
I.	Date and time of occurrence/discovery of fault	:	On 27.05.18 at 7:39 hrs
J.	Information received in CEA	:	02.07.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Previous annual maintenance was done on 24.04.18.
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 27.05.2018 at 07.39 hrs, 220 KV Panipat Kurukshetra line tripped off, Y-ph CVT busted with heavy sound and caught fire. The details of protection operated during this time is mentioned as below:

			Starting phase BCN, Trip phase ABC, Active group-1 fault in zone none, VT fail. As a result of the bursting, the flame/flash strike the live sub bus conductor (on the gantry) and this made phase to phase differential fault for the numerical bus bar protection which in turn tripped the 220kV bus-1 on which the ckt was running .
O.	Details of Tests done after failure	:	Porcelain part and some lower metallic part of the CVT was damaged completely and hence test could not be conducted.
P.	Observations & Analysis	:	The CVT had served for 40 years. Due to ageing insulation of CVT might have deteriorated and developed internal fault.

43. Failure of 220kV PT at Lonikand-II Substation of MSETCL

A.	Name of Substation	:	400kV Lonikand-II
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	Y-ph PT of 220kV Main Bus
D.	Rating	:	200√3/110/√3kV
E.	Make	:	SCT
F.	Sr. No.	:	2010/2024
G.	Year of manufacturing	:	2010
H.	Date of commissioning	:	10.05.2014
I.	Date and time of occurrence/discovery of fault	:	11.09.2018 at 02:36hrs
J.	Information received in CEA	:	16.01.2018
K.	Fault discovered during	:	Operation

L.	Details of previous maintenance	:	Previous annual maintenance was done on 10.08.2017.
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 11.09.2018 at 02:36hrs, 220kV Main bus Y-ph PT failed & burst due to which Bus bar protection operated, leading to tripping of 220kV VSNL, 220kV I/C and 400/220kV ICT-II LV.
O.	Details of Tests done after failure	:	PT was damaged completely and hence test could not be conducted.
P.	Observations & Analysis	:	As informed by the utility, the performance of SCT make PTs and CTs were found to be very poor as they have faced problems in many CTs/PTs of this make. The manufacturer need to investigate the cause of failure to improve the quality and reliability of its products. The PT had failed after being for service only for 4 years. PT had blasted due to internal insulation failure.

44. Failure of 220kV PT at 220kV Bus at Satana Substation of MSETCL

A.	Name of Substation	:	220kV Satana
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	R-ph PT of 220kV Bus
D.	Rating	:	200/√3/110/√3kV
E.	Make	:	CGL
F.	Sr. No.	:	10248

G.	Year of manufacturing	:	1997
H.	Date of commissioning	:	19.05.2000
I.	Date and time of occurrence/discovery of fault	:	09.08.2018 at 20.25 hrs
J.	Information received in CEA	:	16.01.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	On 03.06.2017, Capacitance & Tan delta test was carried out. The Value of Capacitance measured was found to be 437.4pF & the value of Tan delta obtained was 0.694%.
M.	Details of previous failure	:	Information not available
N.	Sequence of events/ Description of fault	:	PT Burst and 220kV Busbar protection Operated.
O.	Details of Tests done after failure	:	Tests cannot be done as PT was completely damaged.
P.	Observations & Analysis	:	
Before the failure of PT, on 220 kV Bus voltage side, the voltage was found to be 241 kV and at 132 kV Bus voltage side, the voltage was found to be 140 kV. As per the information given by the utility, both 200 MVA and 150 MVA 220/132 kV ICTs were running on Tap No.16 so there was no scope to control the bus voltage. The utility reported that there is daily overvoltage problem at Satana S/S. The system over-voltages cause stress on the insulation of the equipment's and ultimately deteriorates the equipment life. Therefore, the failure of this PT may be due to system over-voltages.			

SURGE ARRESTER

45. Failure of 198 kV SA at Gokarna Sub-Station of WBSETCL

A.	Name of Substation	:	220/132/33 kV Gokarna
B.	Utility/Owner of substation	:	WBSETCL
C.	Faulty Equipment	:	R-ph SA of 220kV Krishnanagar Circuit-1
D.	Rating	:	198 kV
E.	Make	:	CGL
F.	Sr. No.	:	Information not available
G.	Year of manufacturing	:	Information not available
H.	Year of commissioning	:	1998
I.	Date and time of occurrence/discovery of fault	:	30.04.2018 at 18:35
J.	Information received in CEA	:	05.02.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last annual maintenance was done on 11.07.2017 and Insulation Resistance (IR) test was carried out. The IR value during the test was found to be 22.5GΩ (for 10 kV).
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 30.04.2018 at 18:35, SA blasted.
O.	Details of Tests done after failure	:	No test was possible.
P.	Observations & Analysis	:	The insulation resistance measured on 11.07.2017 was 22.5 GΩ and SA was found to be healthy. It is not clear whether Third harmonic component of Resistive leakage Current measurement was done or not. The SA might have blasted due to dielectric breakdown, whereby the internal structure deteriorated, either due to moisture ingress or degradation of

			ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge over voltages.

46. Failure of 398 kV SA at Jeerat Sub-Station of WBSETCL

A.	Name of Substation	:	400kV Jeerat
B.	Utility/Owner of substation	:	WBSETCL
C.	Faulty Equipment	:	B-Ph SA of Line Reactor for Jeerat-BKTPP Ckt
D.	Rating	:	398kV
E.	Make	:	CGL
F.	Sr. No.	:	Information not available
G.	Year of manufacturing	:	Information not available
H.	Year of commissioning	:	Information not available
I.	Date and time of occurrence/discovery of fault	:	18.11.2018 at 00:22 hrs
J.	Information received in CEA	:	05.02.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	During the last annual maintenance, Insulation Resistance (IR) test was carried out and all the measured values were found satisfactory.
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 18.11.2018 at 00:22 hrs., SA blasted.
O.	Details of Tests done after failure	:	No test was possible.
P.	Observations & Analysis	:	Year of manufacturing or commission was not provided. Age of SA is not known. It is not clear whether Third harmonic component of Resistive leakage Current measurement was done or not. The SA might have blasted due to dielectric breakdown, whereby the internal

			structure deteriorated, either due to moisture ingress or degradation of ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages.

47. Failure of 360 kV SA at Arambag Sub-Station of WBSETCL

A.	Name of Substation	:	400/220/132/33kV Arambag Sub-Station
B.	Utility/Owner of substation	:	WBSETCL
C.	Faulty Equipment	:	R-Ph 400kV SA of Arambag-KTPP 400kV feeder bay
D.	Rating	:	360kV
E.	Make	:	CGL
F.	Sr. No.	:	Information not available
G.	Year of manufacturing	:	Information not available
H.	Year of commissioning	:	2005
I.	Date and time of occurrence/discovery of fault	:	03.10.2018 at 14:50 hrs.
J.	Information received in CEA	:	05.02.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	During the last annual maintenance, Stack Insulation Resistance (IR) test was carried out and all the measured values were found satisfactory.
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 03.10.2018 at 14:50 hrs, SA blasted.
O.	Details of Tests done after failure	:	No test was possible.
P.	Observations & Analysis	:	It is not clear whether Third harmonic component of Resistive leakage Current

			measurement was done or not. The SA might have blasted due to dielectric breakdown, whereby the internal structure deteriorated, either due to moisture ingress or degradation of ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages.

48. Failure of 360 kV SA at Kharagpur Sub-Station of WBSETCL

A.	Name of Substation	:	400kV Kharagpur
B.	Utility/Owner of substation	:	WBSETCL
C.	Faulty Equipment	:	Y-Ph SA of 400kV KGP-Chanditala Line -1
D.	Rating	:	360kV
E.	Make	:	CGL
F.	Sr. No.	:	91842
G.	Year of manufacturing	:	2014
H.	Date of commissioning	:	06.09.2017
I.	Date and time of occurrence/discovery of fault	:	07.04.2018 at 20:13 hrs.
J.	Information received in CEA	:	05.02.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last annual maintenance was done on 08.08.2017 and Insulation Resistance (IR) test was carried out. All the values measured during IR test were found satisfactory.
M.	Details of previous failure	:	No previous failures.
N.	Sequence of events/ Description of fault	:	On 07.04.2018 at 20:13 hrs, SA blasted.
O.	Details of Tests done after failure	:	No test was possible.

P.	Observations & Analysis	:	It is not clear whether Third harmonic component of Resistive leakage Current measurement was done or not. The SA might have blasted due to dielectric breakdown, whereby the internal structure deteriorated, either due to moisture ingress or degradation of ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages.

49. Failure of 198kV SA at Kharagpur Sub-Station of WBSETCL

A.	Name of Substation	:	400kV Kharagpur
B.	Utility/Owner of substation	:	WBSETCL
C.	Faulty Equipment	:	B-Ph SA of IV Side of 315 MVA Transformer (Tr-1)
D.	Rating	:	198kV
E.	Make	:	OBLUM
F.	Sr. No.	:	24
G.	Year of manufacturing	:	2009
H.	Date of commissioning	:	03.08.2012
I.	Date and time of occurrence/discovery of fault	:	11.05.2018 at 03:19 hrs.
J.	Information received in CEA	:	05.02.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	During the last annual maintenance, Insulation Resistance (IR) test was carried out and all the measured values were found satisfactory.
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 11.05.2018 at 03:19 hrs., SA Blasted.

O.	Details of Tests done after failure	:	No test was possible.
P.	Observations & Analysis	:	It is not clear whether Third harmonic component of Resistive leakage Current measurement was done or not. The SA might have blasted due to dielectric breakdown, whereby the internal structure deteriorated, either due to moisture ingress or degradation of ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages.

50. Failure of 198kV SA at Kharagpur Sub-Station of WBSETCL

A.	Name of Substation	:	400kV Kharagpur Substation
B.	Utility/Owner of substation	:	WBSETCL
C.	Faulty Equipment	:	R-Ph SA of IV side of 315 MVA Transformer (Trf-2)
D.	Rating	:	198kV
E.	Make	:	OBLUM
F.	Sr. No.	:	28
G.	Year of manufacturing	:	2009
H.	Year of commissioning	:	03.08.2012
I.	Date and time of occurrence/discovery of fault	:	03.10.2018 at 20:49 hrs.
J.	Information received in CEA	:	05.02.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Insulation Resistance Test was done and results was found satisfactory.
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 03.10.2018 at 20:49 hrs., SA blasted.

O.	Details of Tests done after failure	:	No test was possible.
P.	Observations & Analysis	:	It is not clear whether Third harmonic component of Resistive leakage Current measurement was done or not. The SA might have blasted due to dielectric breakdown, whereby the internal structure deteriorated, either due to moisture ingress or degradation of ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages.

51. Failure of 198kV SA at Kharagpur Sub-Station of WBSETCL

A.	Name of Substation	:	400kV Kharagpur
B.	Utility/Owner of substation	:	WBSETCL
C.	Faulty Equipment	:	Y-Ph SA of 400kV Kgp -Vidyasagar Park Ckt-2
D.	Rating	:	198kV
E.	Make	:	OBLUM
F.	Sr. No.	:	14
G.	Year of manufacturing	:	2009
H.	Year of commissioning	:	22.06.2016
I.	Date and time of occurrence/discovery of fault	:	11.11.2018 at 13:31 hrs
J.	Information received in CEA	:	05.02.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last annual maintenance was done on 16.08.2017 and Insulation Resistance (IR) test was carried out. As reported by the utility, all the values measured during IR test were found satisfactory.
M.	Details of previous failure	:	No previous failures

N.	Sequence of events/ Description of fault	:	On 11.11.2018 at 13:31 hrs., SA Blasted.
O.	Details of Tests done after failure	:	No test was possible.
P.	Observations & Analysis	:	It is not clear whether Third harmonic component of Resistive leakage Current measurement was done or not. The SA might have blasted due to dielectric breakdown, whereby the internal structure deteriorated, either due to moisture ingress or degradation of ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages.

52. Failure of 198kV SA at Midnapore Sub-Station of WBSETCL

A.	Name of Substation	:	220/132/33 kV Midnapore
B.	Utility/Owner of substation	:	WBSETCL
C.	Faulty Equipment	:	SA of Midnapur-KGP Ckt-2
D.	Rating	:	198kV
E.	Make	:	OBLUM
F.	Sr. No.	:	04
G.	Year of manufacturing	:	2009
H.	Year of commissioning	:	2010
I.	Date and time of occurrence/discovery of fault	:	13.04.2018 at 15:23 hrs
J.	Information received in CEA	:	05.02.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Maintenance was carried out on 28.12.2017 but details were not provided.

M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 13.04.2018 at 15:23 hrs., SA blasted.
O.	Details of Tests done after failure	:	No test was possible.
P.	Observations & Analysis	:	It is not clear whether Third harmonic component of Resistive leakage Current measurement was done or not. The SA might have blasted due to dielectric breakdown, whereby the internal structure deteriorated, either due to moisture ingress or degradation of ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages.

53. Failure of 198kV SA at Midnapore Sub-Station of WBSETCL

A.	Name of Substation	:	220/132/33 kV MIDNAPORE
B.	Utility/Owner of substation	:	WBSETCL
C.	Faulty Equipment	:	SA of 160 MVA Transformer (TR-1)
D.	Rating	:	198 kV
E.	Make	:	OBLUM
F.	Sr. No.	:	12
G.	Year of manufacturing	:	2014
H.	Year of commissioning	:	2016
I.	Date and time of occurrence/discovery of fault	:	05.05.2018 at 16:15 hrs
J.	Information received in CEA	:	05.02.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Maintenance was carried out on 12.12.2017 but details were not provided.

M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 05.05.2018 at 16:15 hrs., SA Blasted.
O.	Details of Tests done after failure	:	No test was possible.
P.	Observations & Analysis	:	It is not clear whether Third harmonic component of Resistive leakage Current measurement was done or not. The SA might have blasted due to dielectric breakdown, whereby the internal structure deteriorated, either due to moisture ingress or degradation of ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages. Since a number of failures of surge arresters of one particular make has been observed in WBSETCL, the utility may take up the issue with the OEM for investigation of cause of failure and review of the technical requirements,particularly energy handling capability of ZnO blocks, sealing arrangement, quality of pressure relief mechanism etc.. The utility may also study the overvoltage in its system and may review rating of SA accordingly equired.

54. Failure of 398kV SA at PADGHE Sub-Station of MSETCL

A.	Name of Substation	:	400/220kV PADGHE
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	Y-ph SA of 315MVA, 400/220kV ICT-2
D.	Rating	:	398kV
E.	Make	:	CGL
F.	Sr. No.	:	55526

G.	Year of manufacturing	:	2007
H.	Date of commissioning	:	06.07.2007
I.	Date and time of occurrence/discovery of fault	:	18.10.2018 at 13:20 hrs.
J.	Information received in CEA	:	27.02.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last annual maintenance was done on 11.10.2018. However, Leakage current monitor (LCM) reading was taken on 24.05.2018 and the values obtained during the test are as follows: Ir (uncorrected resistive current) =14 Micro amp Ircorrect (corrected resistive current) =10 Micro amp I_t (Peak values of the total leakage current)= 996 Micro amp
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 18.10.2018 at 13:20 hrs, ICT-2 tripped on differential protection. Consequently, it was observed that HV side Y-Ph SA was busted.
O.	Details of Tests done after failure	:	Not possible as SA burst and completely damaged.
P.	Observations & Analysis	:	The SA might have blasted due to dielectric breakdown, whereby the internal structure deteriorated, either due to moisture ingress or degradation of ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages.

55. Failure of 398kV SA at PADGHE Sub-Station of MSETCL

A.	Name of Substation	:	400/220kV PADGHE
B.	Utility/Owner of substation	:	MSETCL

C.	Faulty Equipment	:	Y-ph SA of 400kV Nagothane line-2
D.	Rating	:	398kV
E.	Make	:	CGL
F.	Sr. No.	:	55538
G.	Year of manufacturing	:	2007
H.	Year of commissioning	:	23.08.2007
I.	Date and time of occurrence/discovery of fault	:	08.09.2018 at 12:56 hrs.
J.	Information received in CEA	:	27.02.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Bay maintenance was done on 31.08.2018. However, Leakage current monitor (LCM) reading was taken on 24.05.2018 and the values obtained during the test are as follows: Ir (uncorrected resistive current) =135 Micro amp, Ircorrect (corrected resistive current) =100 Micro amp, I_t (Peak values of the total leakage current) =286 Micro amp
M.	Details of previous failure	:	Information not available
N.	Sequence of events/ Description of fault	:	On 08.09.2018 at 12:56 hrs, line tripped on transient fault and Auto-reclose operated. Subsequently, it was observed that Y-Ph SA was busted.
O.	Details of Tests done after failure	:	Not possible as SA was completely burnt.
P.	Observations & Analysis	:	The SA might have blasted due to dielectric breakdown, whereby the internal structure deteriorated, either due to moisture ingress or degradation of ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages.

56. Failure of 220kV SA at Kathapur Sub-Station of MSETCL

A.	Name of Substation	:	220/132/33kV Kathapur
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	B-ph HV side SA of 50MVA, 220/33kV transformer (TF-II)
D.	Rating	:	220 kV
E.	Make	:	CGL
F.	Sr. No.	:	2182
G.	Year of manufacturing	:	1999
H.	Year of commissioning	:	2002
I.	Date and time of occurrence/discovery of fault	:	29.10.2018 at 09:28 hrs.
J.	Information received in CEA	:	27.02.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last LCM reading was taken on dated 29.05.2018 and the values obtained during the test are as follows: Ircorrect (corrected resistive current) = 266 Micro amp, I_t (Peak values of the total leakage current) =257 Micro amp
M.	Details of previous failure	:	Information not available
N.	Sequence of events/ Description of fault	:	On 29.10.2018 at 09:28 hrs, 50MVA, 220/33kV TF-II was tripped on Differential protection. Consequently, it was observed that HV side B-ph SA had busted.
O.	Details of Tests done after failure	:	Test could not be carried out as SA was completely damaged.
P.	Observations & Analysis	:	Third harmonic component of Resistive leakage current was on slight higher side. The SA might have blasted due to dielectric breakdown, whereby the internal structure deteriorated, either due to moisture ingress or degradation of

			ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages.

57. Failure of 198kV SA at Kathapur Sub-Station of MSETCL

A.	Name of Substation	:	220kV Kathapur
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	Y-Ph SA of 50MVA, 220/33kV Transformer
D.	Rating	:	198kV
E.	Make	:	Crompton Greaves
F.	Sr. No.	:	TOP-12561,Bottom-12562
G.	Year of manufacturing	:	2001
H.	Year of commissioning	:	2002
I.	Date and time of occurrence/discovery of fault	:	15.07.2018 at 12:45 hrs
J.	Information received in CEA	:	25.09.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last LCM reading was taken on dated 29.05.2018 and the values obtained during the test are as follows: I_t (Peak values of the total leakage current) =251 Micro amp
M.	Details of previous failure	:	No previous failures.
N.	Sequence of events/ Description of fault	:	On 15.07.2018 at 12:45 hrs, 50MVA, 220/33kV transformer (TF-II) tripped on Differential Protection.
O.	Details of Tests done after failure	:	Test could not be done, as SA was completely damaged
P.	Observations & Analysis	:	The SA might have blasted due to dielectric breakdown, whereby the internal structure deteriorated, either due to moisture ingress or

			degradation of ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages.

58. Failure of 198kV SA at Volkswagen Sub-Station of MSETCL

A.	Name of Substation	:	220kV Volkswagen
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	Y-Ph SA of 220 kV Chakan-Chakan Phase-II line
D.	Rating	:	198kV
E.	Make	:	Oblum Elect
F.	Sr. No.	:	-
G.	Year of manufacturing	:	2009
H.	Year of commissioning	:	31.12.2009
I.	Date and time of occurrence/discovery of fault	:	16.07.2018
J.	Information received in CEA	:	25.09.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last LCM reading was taken on dated 28.05.2018 and the value of leakage current obtained during the test was 183 Micro amp. Insulation Resistance (IR) test was carried out on 20.01.2018. The IR value of Y-ph obtained during the test was 1.73GΩ.
M.	Details of previous failure	:	Information not available
N.	Sequence of events/ Description of fault	:	On 16.07.2018 at 04.24 hrs, 220kV Chakan-Chakan Phase-II line tripped on distance protection. Subsequently, it was observed that Y-Ph SA was busted.
O.	Details of Tests done after failure	:	Test could not be done as LA was completely damaged

P.	Observations & Analysis	:	The SA might have blasted due to dielectric breakdown, whereby the internal structure deteriorated, either due to moisture ingress or degradation of ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages.

59. Failure of 200 kV SA at RS Karad Substation of MSETCL

A.	Name of Substation	:	400kV RS Karad
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	R-ph 200 kV SA of line
D.	Rating	:	198kV
E.	Make	:	ELPRO
F.	Sr. No.	:	08-80-372
G.	Year of manufacturing	:	1991
H.	Year of commissioning	:	1992
I.	Date and time of occurrence/discovery of fault	:	17.04.2018 at 17:25 hrs
J.	Information received in CEA	:	22.05.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	

Leakage current measurement of SA are as follows:

S.No.	Date of testing	Ir (µA)	Ir Corr. (µA)	It (µA)
1.	09.05.2017	27	27	354

2.	24.11.2017	25	24	651	
3.	05.04.2018	23	26	455	

M.	Details of previous failure	:	Information not available
N.	Sequence of events/ Description of fault	:	On 17.04.2018 at 17:25 hrs, Y-ph SA failed due to heavy lightening & busted. Due to which Line tripped on distance protection.
O.	Details of Tests done after failure	:	It was observed that all insulator stacks are damaged & thus could not be tested.
P.	Observations & Analysis	:	The equipment due to ageing could not handle the energy of heavy lightning surge and failed.

60. Failure of SA of 220kV Siemens Bay at Kalwa Substation of MSETCL

A.	Name of Substation	:	400/220kV Kalwa
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	B-Ph SA of 220kV Siemens Bay
D.	Rating	:	220kV
E.	Make	:	LAMCO
F.	Sr. No.	:	881ABC
G.	Year of manufacturing	:	2009
H.	Date of commissioning	:	07.06.2012
I.	Date and time of occurrence/discovery of fault	:	11.07.2018
J.	Information received in CEA	:	16.01.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	
Last annual maintenance was done on 26.05.18 and IR test was carried out. Following results of the IR test were provided by the utility, however, results of IR			

of Top-Bottom stack seems inappropriate in view of results for individual stacks:

Date	IR of Top-Bottom (kΩ.)	IR of Top (MΩ)	IR of Middle (MΩ)	IR of Bottom (MΩ)
10.02.2017	32.2	204	672	44.2
26.05.2018	26.1	142	129	62.5

M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 11.07.2018, SA was failed due to lightning. Due to which, it busted and got shattered.
O.	Details of Tests done after failure	:	SA could not be tested as SA burst and was completely damaged.
P.	Observations & Analysis	:	At the time of failure, rain and lightning has been reported by the utility. Reduction in insulation resistance of top and middle stack can be observed from the test results. The equipment could not handle the energy of lightning surge and failed.

61. Failure of 220kV SA at Kalwa Substation of MSETCL

A.	Name of Substation	:	400/220kV Kalwa
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	B-Ph SA of 220kV Borivali Bay
D.	Rating	:	220kV
E.	Make	:	LAMCO
F.	Sr. No.	:	884 ABC
G.	Year of manufacturing	:	2008-09
H.	Year of commissioning	:	25.12.2011
I.	Date and time of occurrence/discovery of fault	:	21.07.2018
J.	Information received in CEA	:	16.01.2019
K.	Fault discovered during	:	Operation

L.	Details of previous maintenance	:	

Last annual maintenance was done on 29.04.18 and Insulation Resistance (IR) test was carried out. The values obtained during the test are as follows:

Date	**IR of Top-Bottom (kΩ.)**	**IR of Top (MΩ)**	**IR of Middle (MΩ)**	**IR of Bottom (MΩ)**
December, 2017	110 GΩ	1.6 TΩ	1.7 TΩ	1.5 TΩ
29 April, 2018	15 MΩ	3 GΩ	8.2 GΩ	9.1 GΩ

M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 21.07.2018, SA failed due to lightning. Due to which Zone-2 operation might have been operated at Borivali end. However, Zone-1 overreach resulted in AR operation..
O.	Details of Tests done after failure	:	Tests cannot be done as SA burst and was completely damaged.
P.	Observations & Analysis	:	Significant deviations in the IR values obtained during last annual maintenance as compared to the values obtained during maintenance done on December, 2017 was observed. Further, it is not known whether third harmonic resistive current measurement, which is a good indicator of internal condition of SA, was carried out or not during previous maintenance activities. As reported by the utility, heavy lightning resulted in failure of SA.

62. Failure of 198kV SA at Panipat Substation of BBMB

A.	Name of Substation	:	400kV Panipat
B.	Utility/Owner of substation	:	BBMB
C.	Faulty Equipment	:	R-Ph SA of 220kV Panipat- Kurukshetra Ckt
D.	Rating	:	198kV

E.	Make	:	CGL
F.	Sr. No.	:	51925
G.	Year of manufacturing	:	2006
H.	Year of commissioning	:	2010
I.	Date and time of occurrence/discovery of fault	:	15.05.2018 at 16:38 hrs.
J.	Information received in CEA	:	31.05.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	24.04.18
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 15.05.2018 at 16:38 hrs., SA got busted and due to which heavy sound was observed in yard. At the time of failure, the weather was clear and atmosphere temperature was on higher side (about 42degree). Further, the behaviour of the protection schemes was in order.
O.	Details of Tests done after failure	:	Tests cannot be done as SA burst and was completely damaged.
P.	Observations & Analysis	:	Details of tests carried out during maintenance activity on 24.04.18 has not been provided by the utility. It is not known whether third harmonic resistive current measurement or insulation resistance test, which are a good indicator of internal condition of SA, were carried out or not. The SA might have blasted due to dielectric breakdown, whereby the internal structure deteriorates either due to moisture ingress or degradation of ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages.

63. Failure of 216kV R-Ph SA of 230kV Manali-II feeder at Alamathy Substation of TANTRANSCO

A.	Name of Substation	:	400/230 kV Alamathy
B.	Utility/Owner of substation	:	TANTRANSCO
C.	Faulty Equipment	:	R-Ph SA of 230kV Manali-II feeder
D.	Rating	:	216kV
E.	Make	:	Crompton Greaves
F.	Sr. No.	:	27212
G.	Year of manufacturing	:	2003
H.	Year of commissioning	:	2006
I.	Date and time of occurrence/discovery of fault	:	18.06.2018, 17.01 hrs.
J.	Information received in CEA	:	11.07.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	High Pot Test conducted on 08.06.2018. The results of test obtained were found satisfactory.
M.	Details of previous failure	:	No previous failures.
N.	Sequence of events/ Description of fault	:	On 18.06.2018 at 17.01 hrs., heavy sound and smoke was observed in SA. It is to be noted that at the time of failure, the weather was clear.
O.	Details of Tests done after failure	:	Tests cannot be done as SA was completely damaged.
P.	Observations & Analysis	:	As reported by the utility, earthing connections of SA were intact. The values of current and voltages of the feeder at Alamathy end (zone-1) were as follows: I_R = 27.79 kA

			I_Y = 816.5 A I_Y = 295.2 A V_{RN} = 7.35 kV V_{YN} = 7.35 kV V_{BN} = 7.35 kV and the value of current of R-ph at the other end (zone-2, distance 23.3 km) was I_R = 3.683 kA It is not clear whether third harmonic component of resistive leakage current measurement or insulation resistance test, which are a good indicator of internal condition of SA, were carried out or not. The SA might have blasted due to dielectric breakdown, whereby the internal structure deteriorates either due to moisture ingress or degradation of ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages.

64. Failure of 216kV Y-Ph SA of 230kV Koyembedu bay at Alamathy Substation of TANTRANSCO

A.	Name of Substation	:	400/230 kV Alamathy
B.	Utility/Owner of substation	:	TANTRANSCO
C.	Faulty Equipment	:	Y-Ph SA of 230kV Koyembedu bay
D.	Rating	:	216kV
E.	Make	:	Crompton Greaves
F.	Sr. No.	:	28214
G.	Year of manufacturing	:	2003
H.	Year of commissioning	:	2006
I.	Date and time of occurrence/discovery of fault	:	27.12.2018 at 15.17 hrs.
J.	Information received in	:	05.07.2019

	CEA		
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	High Pot Test conducted on 08.06.2018. The results of test obtained were found satisfactory.
M.	Details of previous failure	:	No previous failures.
N.	Sequence of events/ Description of fault	:	On 27.12.2018 at 15.17 hrs., heavy sound and smoke was observed in SA. It is to be noted that at the time of failure, the weather was clear.
O.	Details of Tests done after failure	:	Tests cannot be done as SA was completely damaged.
P.	Observations & Analysis	:	As reported by the utility, earthing connections of SA were intact. The values of current and voltages of the feeder at Alamathy end (zone-1, distance 53.26 m) were as follows: I_R = 205.8 A I_Y = 26.81 kA I_Y = 727.2 A V_{RN} = 126.8 kV V_{YN} = 5.346 kV V_{BN} = 128.41 kV and the value of current & voltage of Y-ph at the other end (zone-2, distance 39.4 km) was I_Y = 2.862 kA and V_{YN} = 58.10 kV It is not clear whether third harmonic resistive current measurement or insulation resistance test, which are a good indicator of internal condition of SA, were carried out or not. The SA might have blasted due to dielectric breakdown, whereby the internal structure deteriorated, either due to moisture ingress or degradation of ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages.

65. Failure of 420kV B-ph SA of 315 MVA, 400/230 kV ICT-II at Sriperumbudur Substation of TANTRANSCO

A.	Name of Substation	:	400/230-110kV Sriperumbudur
B.	Utility/Owner of substation	:	TANTRANSCO
C.	Faulty Equipment	:	230 kV B-ph SA of 315 MVA, 400/230 KV ICT-II
D.	Rating	:	230kV
E.	Make	:	CGL
F.	Sr. No.	:	4867
G.	Year of manufacturing	:	-
H.	Date of commissioning	:	07.01.1992
I.	Date and time of occurrence/discovery of fault	:	08.03.2019, 18:01 hrs.
J.	Information received in CEA	:	04.06.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last annual maintenance was done on 04.02.2019.
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 08.03.2019 at 18:01 hrs, SA failed and busted causing heavy sound in the substation. A grey smoky layer was formed on the porcelain portion of the failed SA. The glazing of the porcelain portion was also found peeled off from the stacks of SA. Simultaneously, the 400 kV HV-II and 230 kV LV-II breakers of 315 MVA ICT-II were tripped on differential protection.
O.	Details of Tests done after failure	:	Tests cannot be done as SA was completely damaged.
P.	Observations & Analysis	:	Details of tests carried out during maintenance activity on 04.02.2019 has not been provided by the utility. It is not known whether third harmonic resistive current measurement or insulation resistance test, which are a good indicator of internal condition of SA, were carried out or not. The SA had served for 27 years. Ageing might be the reason of failure of SA.

66. Failure of 420kV R-ph SA of 315 MVA, 400/230 kV ICT-II at Sriperumbudur Substation of TANTRANSCO

A.	Name of Substation	:	400/230-110kV Sriperumbudur
B.	Utility/Owner of substation	:	TANTRANSCO
C.	Faulty Equipment	:	400 KV R-ph SA of 315 MVA, 400/230 KV ICT-III
D.	Rating	:	420kV
E.	Make	:	CGL
F.	Sr. No.	:	24917
G.	Year of manufacturing	:	-
H.	Date of commissioning	:	28.07.2004
I.	Date and time of occurrence/discovery of fault	:	11.03.2019 at 00:40 hrs.
J.	Information received in CEA	:	04.06.2019
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last annual maintenance was done on 30.12.2018.
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 11.03.2019 at 00:40 hrs., SA failed and busted causing heavy sound in the substation. A grey smoky layer was formed on the porcelain portion of the failed SA. The glazing of the porcelain portion was also found peeled off from the stacks of SA. Simultaneously, the 400 kV HV-III and 230 kV LV-III breakers of 315 MVA ICT-III were tripped on differential protection.
O.	Details of Tests done after failure	:	Tests cannot be done as SA was completely damaged.
P.	Observations & Analysis	:	Details of tests carried out during maintenance activity on 30.12.18 are not known. It is not known whether third harmonic resistive current measurement or insulation resistance test, which are a good indicator of internal condition of SA, were carried out or not. The SA might have blasted due to dielectric breakdown,

			whereby the internal structure deteriorated, either due to moisture ingress or degradation of ZnO blocks, to the point where the arrester is unable to withstand applied voltage, whether normal system voltage, temporary power frequency overvoltage or lightning or switching surge overvoltages.

67. Failure of 220kV SA at Switching station, Gooty of APTRANSCO

A.	Name of Substation	:	220kV Gooty
B.	Utility/Owner of substation	:	APTRANSCO
C.	Faulty Equipment	:	R-ph SA of 220kV Anantapur feeder line
D.	Rating	:	220kV
E.	Make	:	LAMCO
F.	Sr. No.	:	105A(TOP), 105B(Middle),105C(Bottom)
G.	Year of manufacturing	:	1990
H.	Date of commissioning	:	08.04.1993
I.	Date and time of occurrence/discovery of fault	:	04.05.2018 at 12:45 hrs
J.	Information received in CEA	:	17.09.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Information not available
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	At 220kV Switching Station, Gooty on date 04.05.2018 at 12:45hrs R-ph SA of 220kV Anantapur feeder found dislodged from the base and was hanging in the air without any relay indications. As reported by the utility, load on the SA when it was in service on 04.05.2018 at 12:00 hrs. was 105 A.
O.	Details of Tests done after failure	:	Information not available
P.	Observations & Analysis	:	It appears that due to excessive heat, pressure

			inside the SA increased leading to dislodging of SA housing. The SA was in service for more than 25 years. Ageing might be the cause of failure of SA.

COUPLING CAPACITOR

68. Failure of 245kV Coupling Capacitor of 220 kV Urla-Siltara feeder at Urla Substation of CSPTCL

A.	Name of Substation	:	220 kV Urla
B.	Utility/Owner of substation	:	CSPTCL
C.	Faulty Equipment	:	R-ph Coupling Capacitor of 220 kV Urla-Siltara feeder
D.	Rating	:	245 kV
E.	Make	:	WS Industries (India) Ltd.
F.	Sr. No.	:	8808602
G.	Year of manufacturing	:	1999
H.	Year of commissioning	:	1999
I.	Date and time of occurrence/discovery of fault	:	20.07.2018, 12:26 Hrs.
J.	Information received in CEA	:	23.10.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last annual maintenance was done on 21.09.2017 and Insulation Resistance (IR) test was carried out. The IR value between R-ph & earth obtained during the test was 20 G ohm.
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	On 20.07.2018 at 12:26 hrs, 220kV Urla-Siltara feeder tripped from both end & feeder was isolated.
O.	Details of Tests done after failure	:	No further testing was done as CC was completely damaged.
P.	Observations & Analysis	:	Internal fault could be the reason of failure.

69. Failure of 220kV, 6600pF Coupling Capacitor at Phursungi substation of MSETCL

A.	Name of Substation	:	220 kV Phursungi
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	Coupling capacitor
D.	Rating	:	220kV, 6600pF
E.	Make	:	ALSTOM
F.	Sr. No.	:	20020535
G.	Year of manufacturing	:	2000
H.	Date of commissioning	:	31.03.2007
I.	Date and time of occurrence/discovery of fault	:	26.04.2018, 11:10 Hrs.
J.	Information received in CEA	:	25.09.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	27.07.2017
M.	Details of previous failure	:	Information not available
N.	Sequence of events/ Description of fault	:	On 26.04.2018 at 11:10 Hrs., B-ph CC failed at Phursungi S/S. Simultaneously, Line got tripped on distance protection.
O.	Details of Tests done after failure	:	No further testing done as CC was completely damaged.
P.	Observations & Analysis	:	Details of tests carried out during maintenance activity on 27.07.2017 are not known. Internal fault could be the reason of failure.

DISCONNECTOR

70. Failure of 220kV Main Bus-1 Side Disconnector module at 220 kV Gorai EHV Substation of Reliance Infrastructure – Mumbai Transmission

A.	Name of Substation	:	220kV Gorai
B.	Utility/Owner of substation	:	Reliance Infrastructure – Mumbai transmission
C.	Faulty Equipment	:	220 kV main Bus-1 Side Disconnector module of 125 MVA Transformer (TR-2) bay (GIS)
D.	Rating	:	252kV
E.	Make	:	ABB, China
F.	Sr. No.	:	500340954/2010
G.	Year of manufacturing	:	2010
H.	Date of commissioning	:	24.07.2011
I.	Date and time of occurrence/discovery of fault	:	27.05.2018 at 09:03 hrs.
J.	Information received in CEA	:	12.07.2018
K.	Fault discovered during	:	Operation (while shifting of 125 MVA TR-2 from Main Bus-2 to Main Bus-1 for scheduled outage of Main Bus-2)
L.	Details of previous maintenance	:	Last Annual Maintenance done on 25.10.2016.
M.	Details of previous failure	:	Information not available
N.	Sequence of events/ Description of fault	:	220kV Main Bus-1 & Main Bus-2 tripped on Busbar Protection at 09:03 hrs on 27.05.2018 while shifting of 125MVA TR-2 from Main Bus-2 to Main Bus-1 for scheduled outage of Main Bus -2.

O.	Details of Tests done after failure	:	No test was done.
P.	Observations & Analysis	:	Internal inspection done by the utility observed flashover mark on the conductors of all the 3-phases in 220kV Main Bus-1 side Disconnector (789 A) module of 125 MVA TR-2 bay (GIS). Generally, disconnectors used for transferring load currents from one bus system to another are tested for bus transfer current switching duty. Sufficient information is not available to ascertain whether failed disconnector was tested for such duty or not. Electric spark during shifting of 125MVA TR-2 from Main Bus-2 to Main Bus-1 might have caused failure of the disconnector.

Annexure-II:

Failure Report As Provided by PGCIL

Preliminary Investigation Report of failed 420kV 315 MVA ICT-2 at Gwalior S/S (BHEL: 6006372) on 17.04.2018

1. INTRODUCTION:

On 17.04.2018, 12:15:47.480 hrs, 420 kV 315 MVA ICT-2 tripped on operation of differential protection and immediately caught fire. Heavy noise was heard by the shift engineer in control room at the time of failure. As reported by site, fire protection operated automatically immediately after failure and fire hydrant system was used to control the fire. However, fire was so severe that fire tender was called for extinguishing the fire.

In order to investigate the reason for the failure and to assess extent of damage, a committee was constituted vide note ref: WRTS-II/AM/SK/186 dated 19-04-2018 comprising the following executive:

1. **Sh. Arvind Khare, Asst. GM (Gwalior S/S)**
2. **Sh. Sumit S H Ray, Dy. Manager (CC-AM)**
3. **Sh. Md. Meraj Siddiqui, Dy. Manager (RHQ-AM, Vadodara)**

The brief particulars of failed ICT are given below:

ICT Particulars	Details
Make	BHEL
Voltage rating	420 kV
MVA rating	315 MVA
Sr.No.	6006372
Year of Manufacture	2006
Date of Commissioning at Satna	28.02.2008
Last Testing carried out prior to failure	13.07.2017
Date of Failure	17.04.2018

2. O&M HISTORY OF FAILED ICT

The said transformer was in operation without any problem till the date of failure. As illustrated in Table I & II, DGA and oil results revealed no abnormalities. Last testing carried out on 13.07.2017 during annual maintenance and results were found to be normal as mentioned at Annexure-I.

.

Table-I: DGA History

Date	TGC (%)	N_2(%)	O_2 %)	H_2	CH_4	C_2H_4	C_2H_6	C_2H_2	CO	CO_2
16.04.2018	7.57	6.11	0.64	26	38	5	6	0	1237	6910
10.03.2017	5.72	4.59	0.16	11	20	11	5	0	1371	8256
05.08.2016	4.6	3.85	0.16	32	24	27	10	0	1048	4873
20.10.2015	4.25	3.57	0.34	27	11	7	4	0	583	2736

Table-II: Oil Parameter History

Sample Date	BDV	Water	Res(E12)	Tan δ	IFT	Acidity	Flash
24.06.2017	61.8	14	294	0.00023	38.3	0.0125	149
21.06.2016	82.2	7	170	0.00053	43.2	0	159

Bushing DGA carried out in between 2013 to 2016 and DGA results of HV bushings were found to be normal. However, IV bushings were found with high DGA and were replaced in October 2015 with CGL make bushings.

Bushing Desc.	S.date	H2	CH4	C2H4	C2H6	C2H2	CO	CO2
HV-B ,BHEL-735076	02-06-16	24	6	1	1	0	558	1455
HV R-Ph ,BHEL-735073	02-06-16	8	8	2	2	0	385	1926
HV Y Ph , BHEL - 737048	02-06-16	15	7	1	1	0	790	2086
IV (B-Ph), BHEL-740137	11-10-15	41813	2556	1	385	0.5	234	581
IV (Y-Ph), BHEL-730104	11-10-15	42073	1504	0	218	0.2	92	727

3. OBSERVATIONS

I. Transformer caught fire immediately after the tripping of the Transformer and fire was extinguished with the fire tender. However, the intensity of the fire was so severe that black smoke continued to come out of the tank for hours(Exhibit-I &II).

Exhibit-I

Exhibit-II

II. All 3 HV bushings are burnt and damage busing parts are lying on the ground(Exhibit-III). All 220 kV & tertiary bushings found intact with the tank but due to intensity of the fire, all these bushings have also lost their property due to heat.

III. Main tank found burnt and bulged towards HV side. Rim found distorted.

IV. All Turret CT of R, Y & B phase were completely burnt/ damaged in this fire incidence.

V. Due to heavy fire, all windings, insulations, cleat support and support structures were completely burnt out.

VI. The marshaling box (Exhibit-IV), cables, Radiator pipe line, cooler bank, Conservator was also damaged badly due to fire.

VII. All 3 HV side LAs and associated structures (Exhibit-VI) were found to be damaged and lying on the ground. 220 kV side LAs were intact on the structure however, cannot be reused.

Exhibit-III

Exhibit-IV

Exhibit-V

Exhibit-VI

4. SEQUENCE OF EVENTS & PROTECTION

400 kV ICT-1 at Gwalior tripped on Differential and REF protection at 12:15:47.480 causing isolation of fault. Simultaneously PRD, Bucholz, OTI, WTI and Oil Surge relay also operated. Following are the sequence of events at the time of failure: -

Sr.No.	Time	Event
1.	12:15:47.480	Transformer Y Ph Inst. Diff. Operated
2.	12:15:47.488	Transformer R/Y/B Ph Pcnt. Diff. Operated
3.	12:15:47.490	Transformer R & B Ph Inst. Diff. Operated
4.	12:15:47.487	Buchholz Alarm
5.	12:15:47.493	REF Trip
6.	12:15:47.495	Group A protection trip
7.	12:15:47.502	PRV-1 Trip
8.	12:15:47.505	Buchholz Trip
9.	12:15:47.508	Group B protection trip
10.	12:15:47.513	Main CB Open
11.	12:15:47.513	Tie CB Open
12.	12:15:47.520	220kV Side CB Open
13.	12:15:47.693	OLTC Oil Surge Relay Trip
14.	12:16:21.821	WTI Alarm
15.	12:16:26.451	WTI Trip
16.	12:16:43.997	OTI Alarm
17.	12:16:49.374	OTI Trip

It was observed that there was fault current of 21.4 kA in Y ph of 400 kV side and 1.67 kA from 220 kV side. Fault current of 10.7 kA was also observed in B ph of 400 kV side after 40 ms.

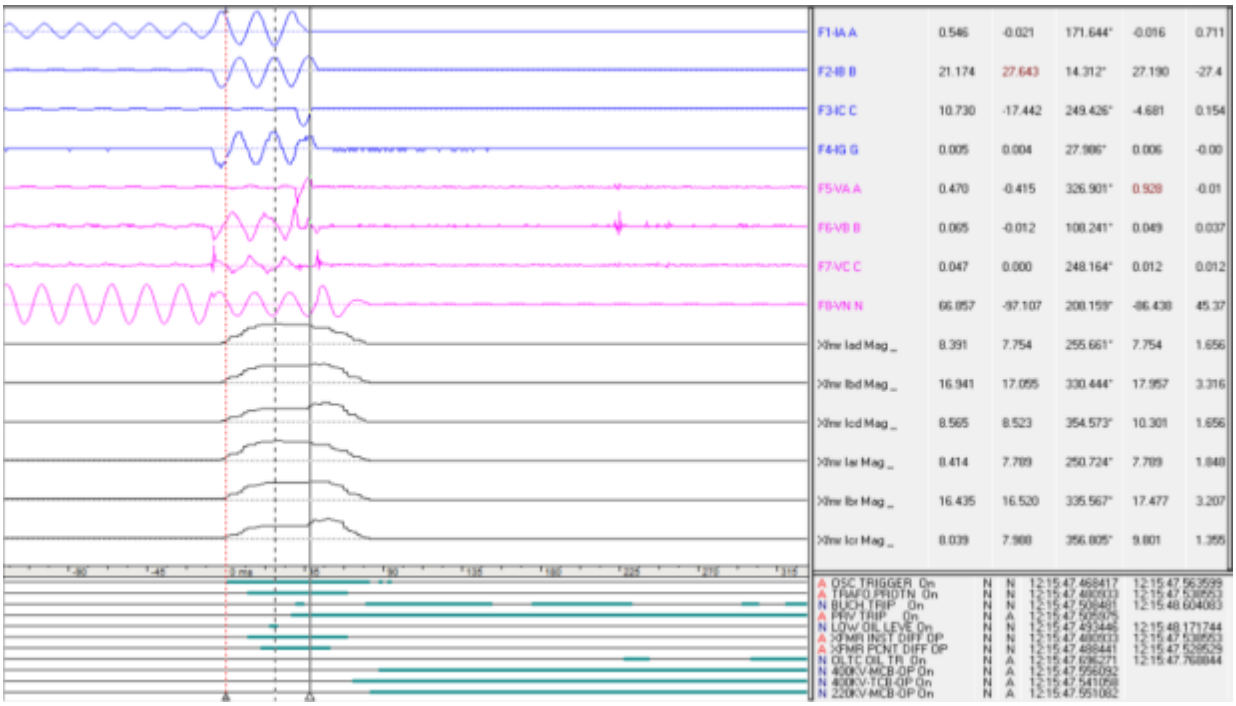


Figure: DR of Differential relay of 400kV ICT-I Gwalior

As seen from Back O/C DR, Voltage of B ph bus reduced up to 8.6 kV. From DR and EL records, fault current got cleared in around 73 ms. Prima facie, it seems that fault was initiated from Y phase. It was suspected that faults may be initiated from the Y phase.

5. RESTORATION & REPAIR PLAN:

a) Inspection was carried out in association with M/s BHEL and as recommended by M/s BHEL (MOM attached), repair of failed Transformer is not advisable. In view of extent of damages, Transformer including, radiator pipes and accessories, all lightning arrestors, power and control cables need to be replaced.

b) For immediate restoration, spare Transformer available at Satna S/s has been diverted to Gwalior.

Preliminary Investigation Report of failed 420kV 63 MVAR Reactor at Biswanath Chariali S/s on 02.05.2018

1. INTRODUCTION:

On 02.05.2018, 19:05 hrs. 420 kV 63 MVAR Reactor tripped on operation of REF, differential protection, PRD and Buchholz operations. Heavy noise was heard by the shift engineer in control room at the time of failure. In order to investigate the reason for the failure and to assess extent of damage, a committee was constituted comprising the following executive:

i. Sh. S. K. Patel, DGM (Biswanath Chariali S/S)
ii. Sh. S. K. Singh, Manager(RHQ, Shilong)
iii. Sh. Sumit S H Ray, Dy. Manager (CC-AM)

The brief particulars of failed Reactor are given below:

Reactor Particulars	Details
Make	BHEL
Voltage rating	420 kV
MVA rating	63 MVAR
Sr.No.	6007609
Year of Manufacture	2017
Date of Commissioning	09-12-2017

2. O & M HISTORY OF FAILED REACTOR

Reactor was received at site in June-2017 and commissioned on 09-12-2017. Since Line (Lower Subansiri-3) was not ready this reactor was being utilized as bus reactor without NGR. The Reactor was subject to frequent switching as required by NERLDC for voltage regulation and since charging there were 17 (Seventeen) nos. of switching operations. On 27th April 2018 at 12:45 Hrs, Reactor was taken out of service as per the RLDC instruction and again put back in service at 16.40 Hr on same day. The said Reactor was in operation without any problem till the date of failure. As illustrated in Table I & II, DGA and oil results revealed no abnormalities.

Date	H_2	CH_4	C_2H_4	C_2H_6	C_2H_2	CO	CO_2
11.12.2017	8	0	0	0	,0	10	105
09.01.2018	10	1	1	0	0.1	30	140
27.04.2018	3604	1024	995	87	765	264	184
Date	**PPM**	**BDV**	**Res(E12)**	**TanD**	**IFT**	**Acidity**	**Flash**
27.04.2018	5	26	24.710	0.0018	39.7		142.4

3. LV test results after tripping

A) Magnetization Current Test

Voltage Applied (Volts)		Current Measured (m Amp)		Remark
R – N	231.9	R - PH	85.6	B Phase has less excitation current as compared to other phases
Y – N	231.5	Y - PH	85.6	
B – N	231.0	B - PH	63.4	

B) Tan δ & Capacitance Measurement of Bushing(30 ºC)

	R - Ø	Y - Ø	B - Ø	Neutral
Make	TRENCH	TRENCH	TRENCH	ABB AB
Sl.No	1616740	1616741	1616737	1ZSCT21004638/05
(C1 in pf) Site Capacitance	606.935	600.511	596.250	345.541
% Tan δ at Site	0.300	0.301	0.299	0.288

C) Tan δ & Capacitance of Winding (30 ºC)

Voltage	Winding Combination	Test Mode	Capacitance		Tan δ %	
			Site (pF)	Factory	Site	Factory
2 KV	HV/ Tank+Earh	GST	9682	--	0.884	--
10 KV			9687	10140	0.655	0.25

D) Insulation Resistance in GΩ (5000 V Megger) at 30 ºC

Main Winding	IR Value (GΩ)			DAI = 60 / 15 Sec	PI = 600 Sec / 60 Sec
	15 Sec	60 Sec	600 Sec		
HV to E	6.33	7.72	14.9	1.22	1.94

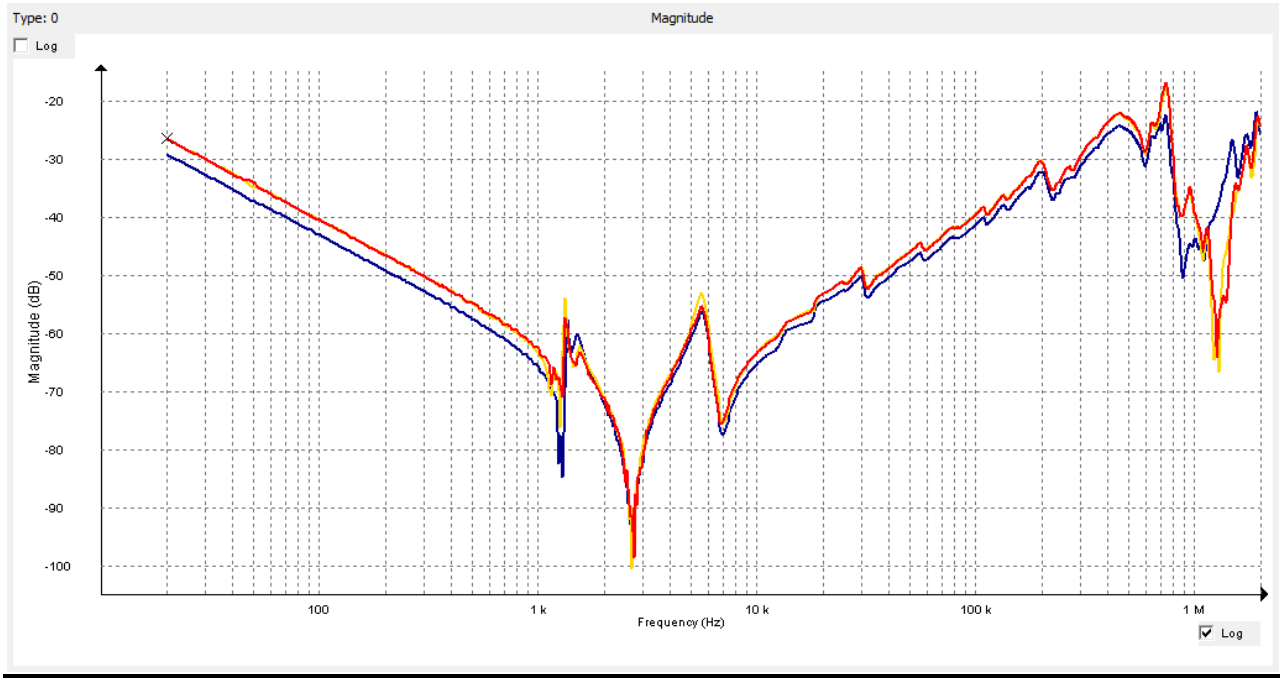
E) Core Insulation Test at 1000 V DC

Terminals	Value	Terminals	Value	Terminals	Value
CC-G	3.6 GΩ	CC-CL	98.2 MΩ	CL-G	3.8 GΩ

F) Winding Resistance in Ω (OTI/ WTI 44º C)

Winding Resistance [HV-N]			Resistance At 75º C			Factory Value At 75º C			% Deviation		
R	Y	B	R	Y	B	R	Y	B	R	Y	B
2.509	2.512	5.035	2.787	2.791	5.594	2.978	2.982	2.979	-6.4	-6.4	87.8

G) Comparision of Frequency Response of the windings



All LV test results indicate probable fault in B phase winding

4. OBSERVATIONS

Following observations were made during inspection of the Reactor:

I. Twin moose connector of B-phase bushing found broken apart as shown in Exhibit-I.

Exhibit-I

Exhibit-II

II. In CC-CL epoxy terminal board Core Clamp terminal was found melted as shown in Exhibit-II.

III. LA of reactor is intact and no advances of LA counters were observed. LA counter are read as 7 for B-Phase, 4 for Y- phase & 6 for R- phase as shown in Exhibit-II.

IV. Cracks developed in flange of R-phase (Sr.No: 1616740) & B-phase (Sr.No: 1616737) bushings as shown in Exhibit-III.

Exhibit-III

Exhibit-IV

V. Very slight bulging /deformation observed in reactor tank as shown in Exhibit-IV.

VI. OTI & WTI reading went up to 75 centigrade max

VII. Carbon particles were observed inside the Reactor and same were spread on core coil assembly as well as at the bottom of the tank as shown in Exhibit-V

Exhibit-V

Exhibit-VI

VIII. B-phase winding found damaged from lead take off location as shown in Exhibit-VI.

IX. Melting of lamination was observed at the bottom cross flux plate as shown in Exhibit-VII. Melting of lamination sheets observed in auxiliary limb of core adjacent to R-Phase winding and bottom part of auxiliary limb adjacent to B-Phase winding.

X. Tracking observed through outer press board barrier surface emanating from conductor of lower half of the winding to flux plate as shown in Exhibit-VIII. On further removal of the press board barrier, tracking and treeing marks resembling the

branches of a tree were observed on both side of the winding insulation from lead take off to the ground.

Exhibit-VII

Exhibit-VIII

XI. All the insulation pressboard barriers were removed and burning of Conductors is observed in lead take of area of winding. Two conductor strip were broken / melted in the 3rd disc from the top of the lower half the winding as shown in Exhibit-IX.

Exhibit-IX

Exhibit-X

XII. Unlike press board, no treeing/ tracking is observed in the winding as shown in Exhibit-IX.

"***Electrical treeing generally occur when a dry dielectric material is subjected to high and divergent electrical field stress over a period of time and it generally originates at points where impurities, gas voids, mechanical defects, or conducting projections cause excessive electrical field stress within small regions of the dielectric. This can ionize gases within voids inside the bulk dielectric, creating small electrical discharges between the walls of the void. Gases are often liberated as the dielectric degrades, creating new voids and cracks. These defects further weaken the dielectric strength of the material, enhance the electrical stress, and accelerate the PD process***."

XIII. As the on line DGA system was defective, any development of fault gasses during last two month prior to failure could not be known.

XIV. Equi-potential lead was checked and was found to be intact as shown in Exhibit-X. Also, no such mechanical defect was observed in the lead take off area.

XV. Opening and closing voltage/current response taken at 12:45 hrs from CSD device was found to be normal as shown in Fig-I.

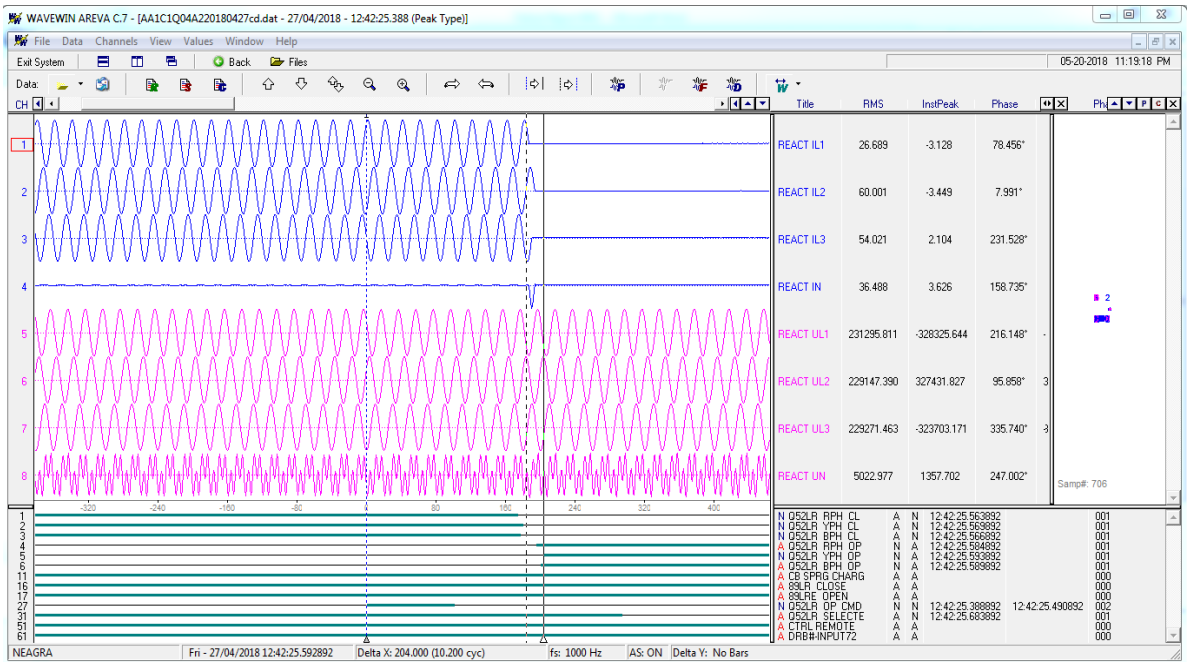


Fig-I

5. SEQUENCE OF EVENTS & PROTECTION

400 kV LSR-3 at BNC tripped on Differential and REF protection at 19:05:55 hours. Simultaneously PRD, and Buchholz, also operated. As seen from DR, it was observed that there was fault current of 12 kA flown in B ph winding.

Sequence of tripping event is as given below

REF: 19:05:54:514

RPR : 19:05:54:538 (Rapid rise pressure relay)

Diff Trip : 19:05:55:473

PRD Trip : 19:05:55:507

Buchholz Trip : 19:05:55:669

6. FAILURE CAUSE:

Prima facie, it seems that fault was initiated from B phase HV Lead. As evident from the internal inspection, there was tracking from the B phase HV lead take off to bottom cross flux plate through surface of the press board barrier. Switching is frequent in the said Reactor as per the instruction of RLDC and there were 17 nos. switching operations since the commissioning of the Reactor. CSD response taken during the hand tripping of the Reactor on 27-04-2018 at 12:42:55 hrs was also normal. Though PPM value was within the limit prior to failure (5 PPM), during inspection it was felt that as if moisture accumulation on the press board surface of B phase. During switching operations, tracking might have developed from the HV lead to the ground causing dielectric break down. Similar type of failure has already been encountered in BHEL make 125 MVAR Reactor at Binaguri.

7. RESTORATION & REPAIR PLAN:

I. Considering the damage, it is advisable to repair the failed Reactor at factory.

II. For immediate restoration and considering the repair time, available 63 MVAR Reactor in lower Subansiri-2 LR at BNC or any spare 63 MVAR Reactor may be diverted for commissioning in place of the failed Reactor.

Sh. S.K.Patelr ,	**Sh. S.K.Singh**	**Sh Sumit S H Ray**
DGM(BNC HVDC)	**Manager(RHQ-AM,Shilong)**	**Deputy Manager (CC-AM)**

Annexure-III

Format for report of failure of the Transformer/ Reactors or other substation equipment

Proforma for reporting of failure of Transformer/Reactor

i.	Name of Substation	:	
ii.	Utility	:	
iii.	Faulty Equipment (ICT/Auto-transformer/GT/Reactor etc.)	:	
iv.	Rating (MVA/MVAR, Voltage ratio, 1-phase/3-phase)	:	
v.	Make (Original equipment manufacturer)	:	
vi.	Serial No.	:	
vii.	Date and time of occurrence of fault	:	
viii.	Fault discovered during (Operation or periodic testing/ maintenance)	:	
ix.	Year of Manufacturing	:	
x.	Date of Commissioning	:	
xi.	Sequence of events/Description of fault (SOE with time stamp, Protection operated during fault)	:	
xii.	Details of Tests done after failure (What tests were conducted after the discovery of failure. If no tests were conducted, reasons for the same may be stated.)	:	
xiii.	Observations (Visual observations e.g. bulging of tank, fire, any leakage of oil, damage to various components of transformer and	:	

	nearby equipment / material etc.)		
xiv.	Probable cause of failure	:	
xv.	If OEM representative had inspected the equipment or visited the site after failure, their remarks, MoM etc. may be attached.	:	
xvi.	Present condition of equipment (Whether repairable or beyond repair)	:	
xvii.	(a) Details of previous maintenance (Activities carried out in previous maintenance including the tests conducted, periodicity of the maintenance activities) (b) Whether any abnormality observed in these tests. If yes, attach the test reports. (c) What steps were taken to address the abnormality?	:	
xviii.	Details of any previous failure on the same unit	:	
xix.	Is tertiary winding provided (Yes/No)	:	
xx.	Tertiary loaded (Yes/No) If yes, specify load on tertiary	:	
xxi.	Whether tertiary terminals are bare/ insulated		
xxii.	Details of protection for Tertiary	:	
xxiii.	Whether relay time is synchronized with UTC	:	
xxiv.	Bushing details (OIP/RIP/RIS, Porcelain / polymer housing)	:	
xxv.	On Load Tap Changer or Off Circuit Tap Changer	:	

xxvi.	Tap position of OLTC at the time of failure	:	
xxvii.	Past record of Operation of OLTC	:	
xxviii.	Tap Range	:	
xxix.	Details of Protection provided for ICT/GT/Reactor	:	
xxx.	Details of Protection operated	:	
xxxi.	Whether current input for differential protection and REF protection has been taken from bushing CT or bay CT?	:	
xxxii.	Whether equipment is properly earthed	:	
xxxiii.	Earth Resistance of Substation and date of its measurement	:	
xxxiv.	Surge arrestor: (a) Is SA provided for protection (b) Whether healthiness of SA is monitored (c) Whether reading of SA counter changed during failure	:	
xxxv.	Lightning Impulse and Switching Impulse Withstand Voltage of the bushings of all voltage level	:	
xxxvi.	Lightning Impulse and Switching Impulse Withstand Voltage of the winding of all voltage level	:	
xxvii.	Type of Fire protection provided (Emulsifier system/ N_2 Injection based fire protection system/ foam based protection etc.)	:	
xxviii.	Weather conditions at the time of failure (clear sky/rainy/thunderstorm etc.)	:	

xxxix.	Was there any lightning surge recorded by surge arrester at the time of failure	:	
xl.	Storage condition of equipment at site before commissioning: (a) Period of storage (b) Idle charged or uncharged (c) Dry air filled/Nitrogen filled/ Oil filled	:	
xli.	Whether short circuit test was carried out on this transformer or same design transformer or short circuit withstand capability was verified on the basis of calculation?	:	
xlii.	Number of through faults the equipment was subjected to before failure	:	
xliii.	Attach the following: (a) Single Line Diagram of the substation (b) Photographs of the failed equipment (c) Disturbance Recorder/Even Logger Data (d) Reports of tests conducted after failure (e) Factory test results (f) Pre-commissioning test results (g) Protection schematic diagram	:	

Proforma for failure report of other substation equipment

[Circuit Breaker, Instrument Transformers (CT/PT/CVT), Wave Trap, Isolator, Surge Arrester, Coupling Capacitor, Cable]

i.	Name of Substation	:	
ii.	Utility	:	
iii.	Faulty Equipment and the associated feeder	:	
iv.	Rating (Voltage/ current/ current ratio/ capacitance/ MCOV etc., as applicable)	:	
v.	Short circuit withstand current and duration	:	
vi.	Make (Original equipment manufacturer)	:	
vii.	Serial No.	:	
viii.	Date and time of occurrence of fault	:	
ix.	Fault discovered during (Operation or periodic testing/ maintenance)	:	
x.	Weather conditions at the time of failure (clear sky/ rainy / thunderstorm etc.)		
xi.	Year of manufacturing	:	
xii.	Date of commissioning	:	
xiii.	Storage condition of equipment if the gap between delivery at site and commissioning is over 6 months	:	
xiv.	If OEM was contacted after failure, its recommendation/remark/ report/ MoM	:	
xv.	Present condition of equipment (Repaired/ To be repaired / beyond repair)	:	

xvi.	(a) Details of previous maintenance (Activities carried out in previous maintenance including the tests conducted, periodicity of the maintenance activities) (b) Whether any abnormality observed in these tests. If yes, attach the test reports. (c) What steps were taken to address the abnormality?	:	
xvii.	Details of previous failure (Any failure which has led to a major repair of the equipment in the past since its commissioning)	:	
xviii.	Sequence of events/Description of fault (SOE with time stamp)	:	
xix.	Details of protection operated	:	
xx.	Details of tests done after failure	:	
xxi.	Observations (Any relevant observation made by the field staff or during visual inspection)	:	
xxii.	Probable cause of failure	:	
xxiii.	Attach reports of tests during pre-commissioning, periodic maintenance and after failure; Photographs of the failed equipment etc.	:	

Annexure-IV

Minutes of Meeting of the Standing Committee of Experts to Investigate the Failure of 220 kV and Above Voltage Class Substation Equipment Held on 5th JULY 2019 in CEA

Minutes of the Meeting of Standing Committee of Experts to Investigate the failure of substation equipment at 220 kV & above voltage class (April 2018 to March 2019) on 5th July 2019 in CEA, New Delhi

List of participants is attached in Annexure.

1. Chief Engineer (PSE&TD) welcomed all the participants and gave the brief background and purpose of the Committee. It was noted that no representative from APTRANSCO, WBSETCL, WBPDCL, PPCL, MSPGCL and Reliance attended the meeting. CE (PSE&TD) informed that total 72 nos. of failures have been reported between April 2018 and March 2019 by 17 utilities, viz. PGCIL, DVC, DTL, RVPNL, MPPTCL, KPTCL, TANTRANSCO, APTRANSCO, BBMB, MSETCL, CSPTCL, WBSETCL, PPCL, WUPPTCL, MSPGCL, WBPDCL & Reliance. Out of these, there have been failures of 30 nos. of transformers, 1 no. reactor, 2 nos. coupling capacitors, 12 nos. CT, 5 nos. PT/CVT, 1 no. disconnector and 21 nos. surge arrestor during this period. He urged all participants to participate actively and express their views on the failures and suggest measures to prevent such failures.

2. CE (PSE&TD) further informed that all the utilities have been requested to provide details of transformers of 66kV and above voltage class installed at their substations with age so that data of total number of installed transformers could be compiled which will help in establishing failure rate and assess the requirement of replacement of ageing transformers. He informed that so far, only 12 utilities have furnished the details and requested representatives of utilities to furnish the details at the earliest. He again emphasised the importance of reporting of equipment failure and its analysis in order to maintain the database, failure rate and corrective measures.

3. Director (PSE&TD) presented before the Committee the details of reported failures by the utilities, failure trend since 2013 and frequently observed causes of failures. He highlighted that since some of the utilities do not report the failures of equipment in their substations, the number of failures reported in a year is only 72. It is feared that the actual number of failures might be more seeing the geographical area of the country. He requested all the utilities to furnish preliminary information within 48 hours of the occurrence of the failure and detailed report within a Month. He also informed that Central and State Electricity Regulatory Commissions have been requested to advise respective utilities to report the failures in time to CEA.

4. Presentations, on the various failures that had occurred between April 2018 to March 2019 and were reported to CEA, were given by PGCIL, DTL, RRVPNL, WUPPTCL, BBMB, TANTRANSCO, MSETCL,

MPPTCL, DVC, CSPTCL and WUPPTCL on their respective equipment failures. The failure incidents and the subsequent findings were deliberated upon in the meeting by the experts in the Committee. The problem areas in the subject matter at hand were brought to the fore and various helpful suggestions from the participating members were made to address the prevalent issues that the utilities are facing regarding the failures of the substation equipment. Based on the deliberations made in the meeting, the recommendations will be appropriated in the final report of the Standing Committee.

5. PGCIL informed that acceptable CO_2 level in the transformer oil is generally taken as 2500 ppm. However, IEC is in the process of raising this value as apart from insulating paper, rubber and other material also contribute towards generation of CO_2 and as such value of 2500 ppm does not indicate the actual degradation of paper. Furan analysis should be conducted for an estimation of quality of paper insulation. As per PGCIL's practice, value of CO_2/CO lower than 3 indicates a healthy paper insulation while over 5 indicates poor paper insulation. DGA of oil in bushing may also be included in maintenance practices as generation of H_2 and other gases may lead to shattering of bushing and may even seep into the main tank oil.

6. PGCIL, along with several other utilities, also expressed the need to freeze the transformer design after short circuit and suggested that design review of other transformers of same design should be carried out. It was also suggested that stage inspection should also be carried out to ensure that same process as well as same material is used in subsequent transformers, as was used in the short-circuit tested transformer.

7. M/s Siemens suggested that when a transformer is subjected to short circuit it should be checked through inspection window for any physical change. LV test and SFRA should be conducted after through fault to check the integrity of the transformer.

8. M/s BHEL recommended Residual Life Assessment (RLA) to be conducted on transformers after 10 years of service. Use of Controlled Switching Devices (CSD) for switching operation was also suggested to avoid stresses on the equipment due to transients.

9. M/s CGL stated that a proper assessment is not possible solely based on number of faults as condition of transformer is not linearly related to the severity of failures. Maintenance practices and condition of transformer also play a huge role. Even less severe faults on ageing or poorly maintained transformers may be dangerous. Due to huge size of the electricity grid, transients are invariably present in the system which impact the health of the system. As such, transients may be monitored. In addition, while conducting RLA on the transformers,

operating condition should also be factored into along with age, maintenance practices etc.

10. CE (PSPM), CEA suggested that CSD is used for switching only and will not help to protect transformer/ reactor against short circuits. He endorsed the suggestions made by M/s Siemens in regard to tests to be carried out on transformer after through fault. It is difficult to determine whether the failure is due to short circuit, as many faults are at a much lower value than the short circuit rating of the transformer. Also, it is difficult to conclude as to the number of times the transformer is subjected to the rated fault level current. He also stated that OIP bushings are being replaced by RIP bushings as these are less prone to fire. RIS bushings are also available and are being used worldwide as their performance is considered to be even better than RIP bushings. The utilities may explore the possibility of use of RIP/RIS bushings.

11. M/s PGCIL also mentioned that overvoltage is a frequent problem in some parts of the grid and many a times they are directed by RLDC to operate equipment on higher than rated voltage levels e.g. 400 kV voltage class equipment are rated for highest system voltage of 420 kV, but are required to be operated at around 440 kV which causes undue stress on the equipment and also nullifies the warranty in case of failure. PGCIL suggested that grid operator should not allow operation of the system at voltages more than the highest system voltage.

12. CE(PSE&TD), CEA suggested the manufacturers to look into the possibility of designing the equipment, e.g. 400 kV class equipment for 440 kV voltage or at one step higher BIL than existing level. He also mention that possibility of 400kV voltage variation of (+)10% & (-)5% may also be explored to mitigate the damage of equipment.

13. M/s CGL indicated that designing the equipment for a higher voltage level than specified for a particular nominal voltage is possible, however, existing standards does not specify values for such higher voltage and this may create difficulties in its testing. Use of variable shunt reactor may also be an option to address the problem of over voltage.

14. While discussing a case of CT failure of DVC in the meeting, DVC informed that before 2015, it used to conduct only tanδ measurement test on CTs. However, after 2015, apart from tanδ measurement test, capacitance measurement test and thermography is also carried out.

15. PGCIL mentioned that if a rising trend in tanδ value is observed, DGA of CT oil should also be conducted. If high concentration of

hydrogen is observed in DGA, CT may be replaced as this indicates partial discharge or moisture ingress. PGCIL suggested that variable frequency tanδ test is also a good tool to assess the healthiness of CT. It is a common practice in PGCIL to replace the CT if tanδ value is found to exceed by more than 0.1% from its pre-commissioning value, even if its value is within permissible range.

16. During discussion on one of the failures of CT, it was observed that although tanδ value of CT was found to be more than acceptable limit, no action was taken by the utility in time, and before it could be replaced, the CT failed. CE (PSE&TD) explained to all utilities that tanδ and capacitance measurement test must be conducted periodically on all equipment of 66 kV and above voltage level. Director (PSE&TD) also endorsed the point and said that all these tests that need to be conducted, are listed in the Standing Committee's report as part of recommendations as well and should be brought into practice. Negligence in this regard may lead to damage of equipment which could otherwise have been avoided and in some cases may prove fatal to operators/workers on site as well.

17. WUPPTCL, in their presentation, explained the 3 nos. transformer failure in their Indirapuram substation. It was brought to notice that all three transformers were of same design and were manufactured by M/s BHEL simultaneously. All three transformers had failed in similar manner and fault was traced to LV side Y-ph winding. M/s BHEL said that while the transformers given to WUPPTCL were not short-circuit tested, the design was successfully tested on short circuit. Director (PSE&TD) opined that looking at the nature of similarity of failure in these transformers, it appears to be a case of design/manufacturing defect and requested M/s BHEL to conduct internal inspection on these transformers and send the report to CEA. It was also suggested by PGCIL that since faulty transformers have already been sent to the manufacturer's works for repair, one of these transformers after repair may be tested for short circuit withstand capacity.

18. While discussing the case of failure of CVT in BBMB, wherein the CVT had blasted, the Committee members opined that if proper maintenance and regular testing is carried out and due diligence is paid, the cases of bursting/ shattering of CT/CVT may be avoided. PGCIL stated that generally in a 220 kV CVT, a rise of 0.28 Volts while a rise of 0.36 volts in 400 kV CVT is observed if one capacitor element burns. If secondary voltage of 220 kV CVT increases by more than 1.5 volts or by more than 2 volts in 400 kV CVT, it is an indicator of poor health and is unsafe for continued operation. PGCIL stated that such CVTs are removed from service, as part of their practice, and that they have never experienced the cases of blasting/ bursting of CVT in their substations.

19. RRVNL, during the course of discussion stated that in case of failure in dead tank CT peripheral damage is much more, hence, they have switched to live tank CTs.

20. Many times, it was observed that due to oil spilled near the control cables, in case of a spark/fire, fire spreads to the equipment installed in the yard. It was suggested that to avoid spread of fire in trenches in case of oil leakages, the trenches should be filled with sand up to a certain distance starting from the equipment.

21. In several cases of failures, it was observed that in cases where the spare equipment after prolonged storage were commissioned, had failed. Equipment stored as spare for later use should be periodically tested to check for any deterioration in the health/quality e.g. as suggested by PGCIL, stored CTs should be tested every two years.
Similarly, if the gap between arrival of equipment at site and its commissioning is over six months, proper procedure as suggested by OEM should be followed.

22. MSETCL informed that in some of their substations, the fault levels have increased and as a measure to reduce the fault current level, they are resorting to bus splitting and installation of Neutral Grounding Reactor (NGR). MSETCL informed that in one of the cases, fire in one transformer led to collapse of fire wall and fire in the adjacent transformer. The Committee suggested that height of fire wall should be at least 600 mm above the highest point of the transformer and fire wall should be rated for four-hour fire rating so that fire in one transformer does not affect adjacent transformers.

23. Four nos. of transformers of DTL had failed between April 2018 and March 2019. DTL, in its presentation, informed the Committee that the failure of transformer at Vasant Kunj substation had been caused by fire in control cables. DTL is of view that a spark in neutral CT led to fire in cable. In the past also, DTL had attributed several failures in transformers to fire in control cables. DTL also informed that in many relays, the status of the flags was changed by the operator after the fault. During discussion, it was also observed that the relays installed at the substation are of electromechanical type.

24. However, the Committee did not concur with the views of DTL and was of the opinion that during normal operating condition, current in neutral CT cannot be large enough to produce spark. If there is some loose contact at terminals of the neutral CT, it would melt the contacts rather than causing sufficient spark to cause fire in the cables in the vicinity. Further, control cables are generally FRLS

type and should not support spreading of fire. If it is assumed that fire in cable may cause the fire in transformer, it may be inferred that the installation condition and maintenance of cables in DTL's substations is not appropriate and with proper care such fire cases could be easily avoided. DTL should take necessary actions to avoid such failures. Manual intervention by operators should also be avoided so that actual state of the relays could be recorded. It was suggested that the operators at yard should be adequately trained not to manipulate the settings/ readings. The Committee also suggested DTL to replace all electromechanical relays with numerical relays.

25. It was also suggested by the Committee that utilities should explore the possibility of installation of CCTV cameras in the substation, covering transformer area so that transformers could be monitored from the control room and any mishap with the transformer could be recorded for further analysis. It would also help to determine the point of initiation and actual cause in case of fire in transformer.

Based on data & information provided by the utilities and deliberations held during the meeting a final report incorporating recommendations made during the meeting shall be prepared and shall be circulated to all stakeholders.

The meeting ended with a vote of thanks to the Chair.

ANNEXURE

LIST OF PARTICIPANTS

CENTRAL ELECTRICITY AUTHORITY

1. Sh. Sanjay Srivastava	Chairman Standing Committee
2. Sh. S.K. Ray Mohapatra	Chief Engineer(PSPM)
3. Sh. Y.K. Swarnkar	Member Secretary of Standing Committee
4. Smt. Kavita Jha	Dy.Director(PSETD)
5. Sh. Bhanwar Singh Meena	Dy.Director(PSETD)
6. Sh. Santosh Kumar	Dy.Director(CEI)
7. Sh. Mohit Mudgal	Asstt. Director
8. Sh. Karan Sareen	Asstt. Director
9. Ms.Bhaavya Pandey	Asstt. Director
10. Sh.Anand Kumar	Sr. Manager
11. Ms. Sippy Srivastava	Engineer

NRPC

12. Sh. Kaushik Pauditrao	Asstt. Engg.

POWERGRID

13. Sh. R.K. Tyagi	CGM
14. Sh. Gunjan Agrawal	DGM
15. Sh. Rohit Kumar Jain	Chief Manager

DTL

16. Sh. K K Verma	GM (O&M)
17. Sh. Kamalesh Das	DGM (T) O&M
18. Sh. Hitesh kumar	
19. Sh.Arun kumar	Manager (T)

Damodar Valley Corp.

20. Sh. Abhijit Chakraborty	Dy. Chief Engineer (Trans.)

BHEL

21. Sh. A. K. Gautam	DGM (Marketing)
22. Sh. Vivek Goel	Sr. Engineer
23. Sh. Avinash Chandra	AGM (TCB)
24. Sh. Rahul Dixit	SDGM

MPPTCL

25. Smt. Anju Neekhre	Asstt. Engineer

WUPPTCL

26. Sh. Satya

BBMB

27. Sh. Satish Pahal	Executive Engineer
28. Sh. Vishal Mohan Dahiya	Dy. Director

CPRI Bhopal

29. Sh. B.M. Mehra	Additional Director

IIT Delhi

30. Sh. Sukumar Mishra	Professor

SIEMENS Ltd.

31. Sh. Shashank Kulkarni	Elec. Design Team Lead
32. Sh. Sunil Das	

CSPTCL

33. Sh. D.K.Chawda	Additional Chief Engineer

RVPNL

34. Sh. Mukesh Kr. Singhal	SE (Prot. Engg.)

TANTRANSCO

35. Sh. R.Regunarayanan	Executive Engineer

GET&D INDIA Ltd.

36. Sh. Kumar Gaurav	Lead Sales & Proposal Manager
37. Sh. Kapil Jetly	Lead Account Manager

CGPISL

38. Sh. Gautam Mazumder	AGM
39. Sh. Suchint Thareja	Regional Product Head Transformers

MSETCL

40. Sh. R.H. Satpute	Sr.Engineer

Annexure-V:

Office Order Constituting the Standing Committee

Government of India
Central Electricity Authority
Office of Secretary
Sewa Bhawan, R.K. Puram
New Delhi- 110 066
Fax No. 011-26108476
Tel.No. 011-26105619

(ISO :9001-2008)

No. CEA/SETD/220-O/2012/ /-80

01.01.2013

Subject:- Constitution of a Standing Committee of Experts to investigate the failure of equipment at 220 kV & above sub-stations.

In order to investigate the failure of equipment at 220 kV & above sub-stations, it has been decided to constitute a Standing Committee comprising experts in the field of design and operation of EHV substation from Central Electricity Authority(CEA), various power utilities and research/academic institutes under section 73, clause(1) of the Electricity Act, 2003.

2. The Committee shall consist of the following members:

(i)	Chief Engineer (SETD), CEA	-Chairperson
(ii)	A representative from CPRI, Bangalore	-Member
(iii)	A representative from IIT, Hauz Khas, New Delhi	-Member
(iv)	A representatives from concerned State Utility/Generating Companies/Transmission Companies where Substation Equipment failure has taken place	-Member
(v)	Member Secretary of concerned RPC	-Member
(vi)	Director (SETD), CEA	-Member Secretary

3. The terms of reference of the Committee shall be as follows:

(a) To investigate the causes of failure of substation equipment in service
(b) To recommend remedial measures to avert recurrences of such failures in future.

4. Every incident of substation equipment failure needs to be immediately reported to Chairperson of the Standing Committee by a designated officer of the concerned organization.

5. The Power Utility where failure of substation equipment has taken place will provide all assistance required by the Committee in carrying out the investigations.

6. The TA/DA and other expenses shall be borne by the respective organizations of the members of the Committee.

The Chairperson of the Committee will prepare compendium of the analysis of the failures and recommendations every six months and submit the same to the Authority and MoP.

(M.S. Puri)
Secretary, CEA

To:

1. Director General, Central Power Research Institute, Professor Sir C.V. Raman Road, P.O. Box- 8066, Bangalore- 560080.
2. Director, Indian Institute of Technology, Hauz Khas, New Delhi- 110016.
3. Chairman/CMDs of State Utility/ Generating Companies and Transmission Companies.

With a request to nominate their representative as member of the Committee along with an alternative member.

4. Member Secretaries, Regional Power Committees:
   a) NRPC, New Delhi
   b) WRPC, Mumbai
   c) SRPC, Bangalore
   d) ERPC, Kolkata
   e) NERPC, Shillong
5. Chief Engineer (SETD), CEA
6. Director (SETD), CEA.