२२० के वी एवं उच्चतर विभव के सबस्टेशनों के क्षतिग्रस्त उपकरणों पर विशेषज्ञों की स्थायी समिति की रिपोर्ट
(जनवरी २०१७-मार्च २०१८)

REPORT OF STANDING COMMITTEE OF EXPERTS ON FAILURE OF 220 kV & ABOVE VOLTAGE CLASS SUBSTATION EQUIPMENT
(JANUARY 2017-MARCH 2018)

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(l) 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. Hence, the basic purpose of formation of above standing committee gets defeated. This fact has been brought to the notice of Hon'ble 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 24th September 2018 to discuss cause of failure of substation equipment for which information/failure report was received in CEA between 1st January 2017 and 31st March 2018 from various utilities. Minutes of the meeting are enclosed at Annexure – IV.

1.7 During discussion in the meeting on the failure of Surge Arresters of KPTCL, it emerged that some of the arresters were reported failed in view of leakage current in these arresters found to be more than acceptable values during leakage current measurement. The committee decided that such cases should not be treated as failures and hence has been left out from the report.

1.8 Previous report on failure of substation equipment was published in July 2017 which contained the information regarding failure of substation equipment reported to CEA between 1st September 2015 and 31st December 2016.

2.0 Brief details of the failure of substation equipment reported to CEA between 1st January 2017 and 31st March 2018

2.1 The Committee investigates failures of 220 kV and above voltage class equipment only. Failure of total 72 Nos. of Transformers, GTs, Reactors, Circuit Breakers, Instrument Transformers, Surge Arresters and XLPE

Cable of 220 kV and above voltage rating was reported to CEA between 1st January 2017 and 31st March 2018. 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	9	6	0	15
Generator Transformers	0	1	0	1
Reactors	0	3	2	5
Circuit Breaker	4	0	0	4
Current Transformer	8	0	0	8
Potential Transformer/Capacitive Voltage Transformer	11	2	0	13
Surge Arrester	19	6	0	25
XLPE Cable	1	0	0	1
			Grand Total	**72**

2.2 Quantity of failed equipment and years of service put in by these equipment before failure, reported to CEA between 1st January 2017 and 31st March 2018, is given in Table-2.

TABLE-2

Years of Service	Nos. of equipment failed						
	Transformers / GT	**Reactors**	**CB**	**Surge Arrester**	**CT**	**CVT/PT**	**XLPE Cable**
0-5 years	7	3	1	1	1	5	0
Over 5 yrs-10 years	3	0	2	3	1	2	1
Over 10yrs. -15 years	1	2	0	11	1	0	0
Over 15 yrs. -20 years	1	0	0	6	2	0	0
More than 20 years	4	0	1	1	3	3	0
Total	**16**	**5**	**4**	**22***	**8#**	**10$**	**1**

** Total reported SA failures are 25 Nos.; information on year of commissioning for 3 No. SA is not available, hence years of service could not be determined.*
 # Total reported CT failures are 08 Nos.; information on year of commissioning for 1 Nos. CT is not available, hence years of service could not be determined.
$ Total reported CVT/PT failures are 13 Nos.; information on year of commissioning for 3 Nos. CVTs/PTs is not available, hence years of service could not be determined.

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 as per CERC norm. 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 failure of Inter Connecting Transformers/GTs reported to CEA between January 2017 and March 2018 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	Raigarh	CGL	315 MVA, 400/220 kV	2008	03.09.2017	Winding insulation failure
2.	PGCIL	Jalandhar	BHEL	315 MVA, 400/220 kV	2000	13.12.2017	Winding insulation failure
3.	PGCIL	Kolar	BHEL	167 MVA, 400 kV level	2007	11.02.2017	Bushing failure
4.	PGCIL	Bidadi	Alstom	500 MVA, 420 kV level	2012	16.09.2017	Winding insulation failure
5.	DTL	Naraina	CGL	100 MVA, 220/66-33/11 kV	2002	26.07.2017	Insulation failure
6.	DTL	Lodhi Road	BHEL	100 MVA, 220/33/ 11 kV	1994	22.03.2017	Winding insulation failure
7.	DTL	Okhla	EMCO	100 MVA, 220/33 kV	2010	07.04.2017	Winding insulation failure

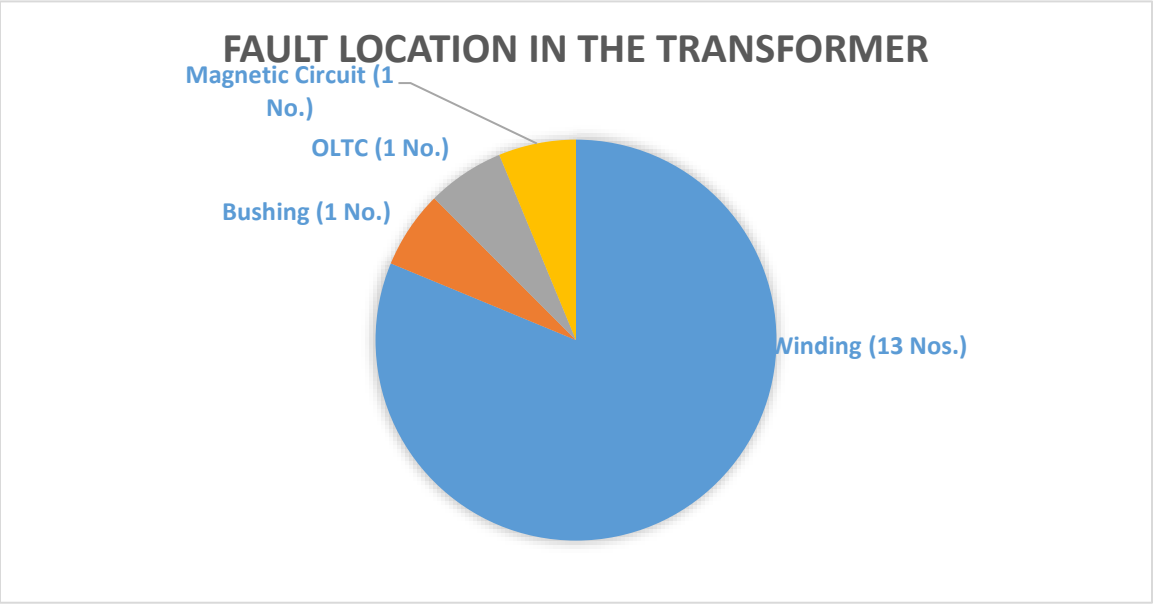
8.	DTL	Preet Vihar	BHEL	100 MVA 220/33/ 11 kV	2017	12.03.2018	Erection Deficiency
9.	DTL	Pappankala-III	BHEL	160 MVA 220/66/ 11 kV	2018	09.03.2018	Winding problem/ manufacturing defect
10.	OPTCL	Bhadrak	CGL	100 MVA, 220/132/33kV	2015	31.05.2017	Winding insulation failure
11.	OPTCL	New Bolangir	BHEL	160 MVA, 220/132/ 33 kV	2014	09.02.2017	Inter turn fault
12.	KPTCL	Sirsi	Kirloskar	50 MVA 220/110/ 11 kV	1982	15.07.2017	Ageing
13.	KPTCL	Bidnal	T&R	100 MVA, 220/110 kV	2013	15.11.2016	Probable manufacturing defect
14.	PPCL	Bawana	BHEL	292.4 MVA, 16.5/420 kV	2014	08.10.2017	Inter turn fault
15.	MPPTCL	Bina	BHEL	315 MVA, 400/220/ 33 kV	1994	15.01.2018	OLTC
16.	MPPTCL	Bina		315 MVA, 400/220/ 33 kV	1995	14.02.2018	Winding insulation failure

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

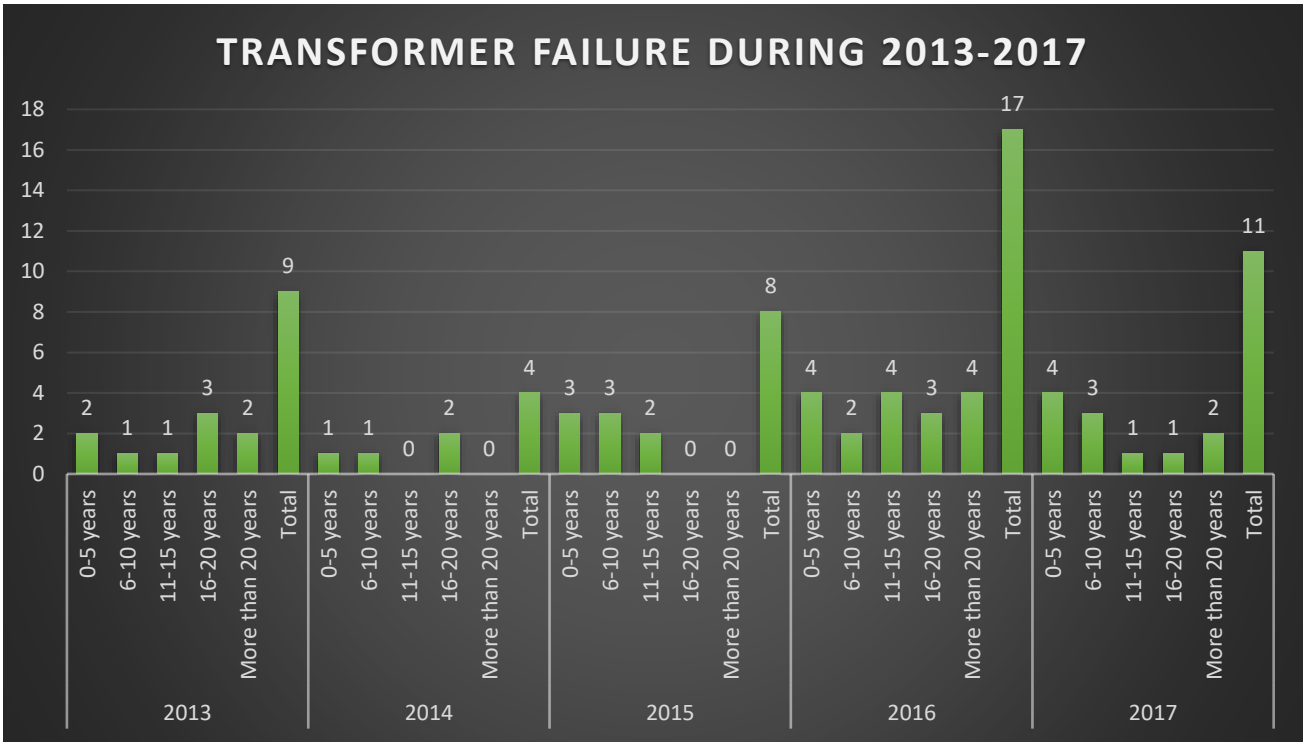
(iii) As can be seen from Table 3 above, sixteen (16) transformer failure cases have been reported to CEA during the period from January 2017 and March 2018 by six (6) Utilities. It is a matter of concern that more than 50% of the reported failed transformers were in operation/service for less than 10 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) As per the information available for reported failure, number of failures caused due to fault in the particular location/component of the transformer has been indicated in the pie chart below. As can be seen from the pie chart, 12 Nos. transformers out of 16 Nos. failed due to failure/flashover in the winding.



(vi) **Failures of transformers during 2013-2017:** 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 Reactors:**

(i) Five (5) nos. Reactor failure cases have been reported to CEA during the period from January 2017 and March 2018 by PGCIL. Out of these, two reactors are of 765 kV class and remaining three are of 400 kV class. Three nos. failures are attributed to internal insulation failure/flashover; one number failure is due to bushing failure; and one due to excessive vibration due to 2nd harmonics. Cause of failure is based on information, data & reports furnished by the utility.

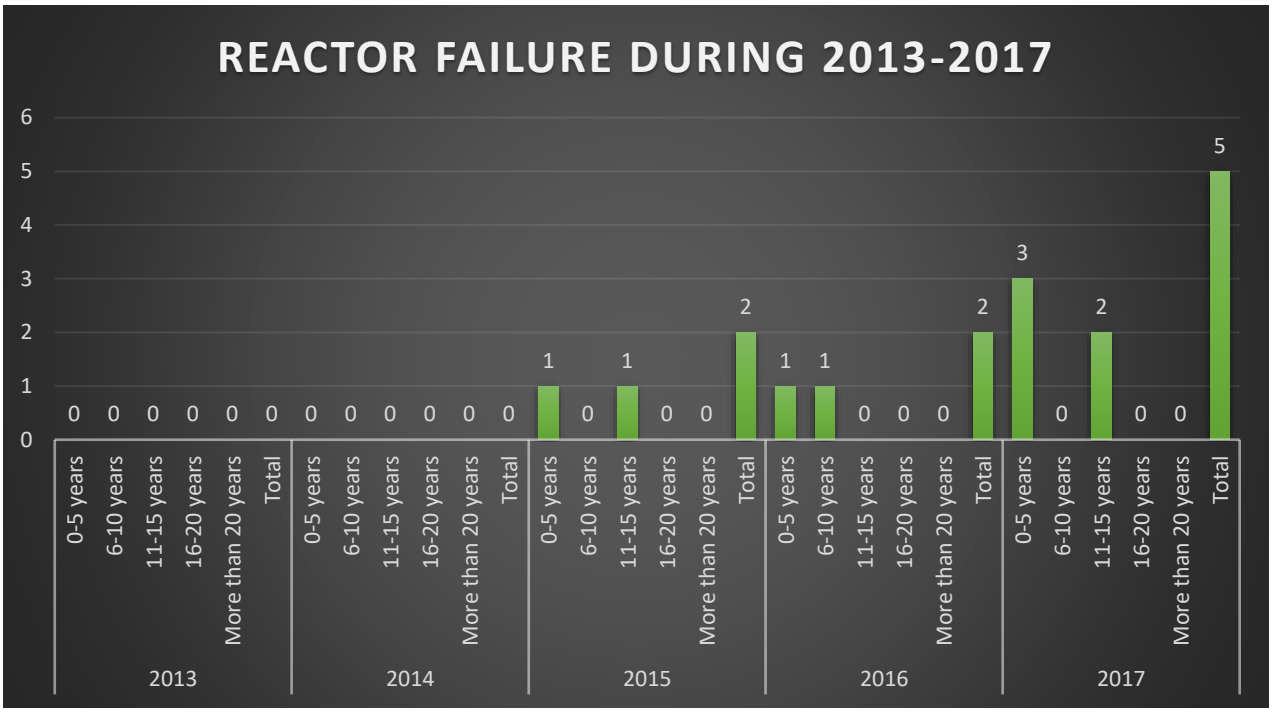
(ii) Summary of failure of Reactors reported to CEA between January 2017 and March 2018 is detailed below (Table 4):

TABLE - 4

S. No.	Utility	Substation	Make	Rating	Year of commissioning	Date of failure	Probable Cause of failure*
1.	PGCIL	Vizag	CGL	3-phase, 80 MVAR, 400 kV	2005	28.04.2017	Excessive vibration due to 2nd harmonic component
2.	PGCIL	Agra	CGL	1-phase, 16.67 MVAR, 420 kV	2005	22.05.2017	Bushing Failure
3.	PGCIL	Satna	CGL	3-phase, 80 MVAR, 765 kV	2012	01.06.2017	Internal flashover
4.	PGCIL	Kishenganj	CGL	80 MVAR, 400 kV	2016	01.09.2017	Failure of HV insulation
5.	PGCIL	Varanasi	TBEA	80 MVAR, 765 kV	2016	27.12.2017	Internal flashover

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

(iv) **Failures of reactors during 2013-2017:** 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 2013 & 2014.



2.6 **Failure of Circuit Breakers (CBs), Instrument Transformers (CT/PT/CVT) & Surge Arresters SAs):**

(i) Summary of failure of CBs, CTs., PTs, CVTs & SAs reported to CEA between January 2017 and March 2018 is detailed below (Table 5):

Table-5

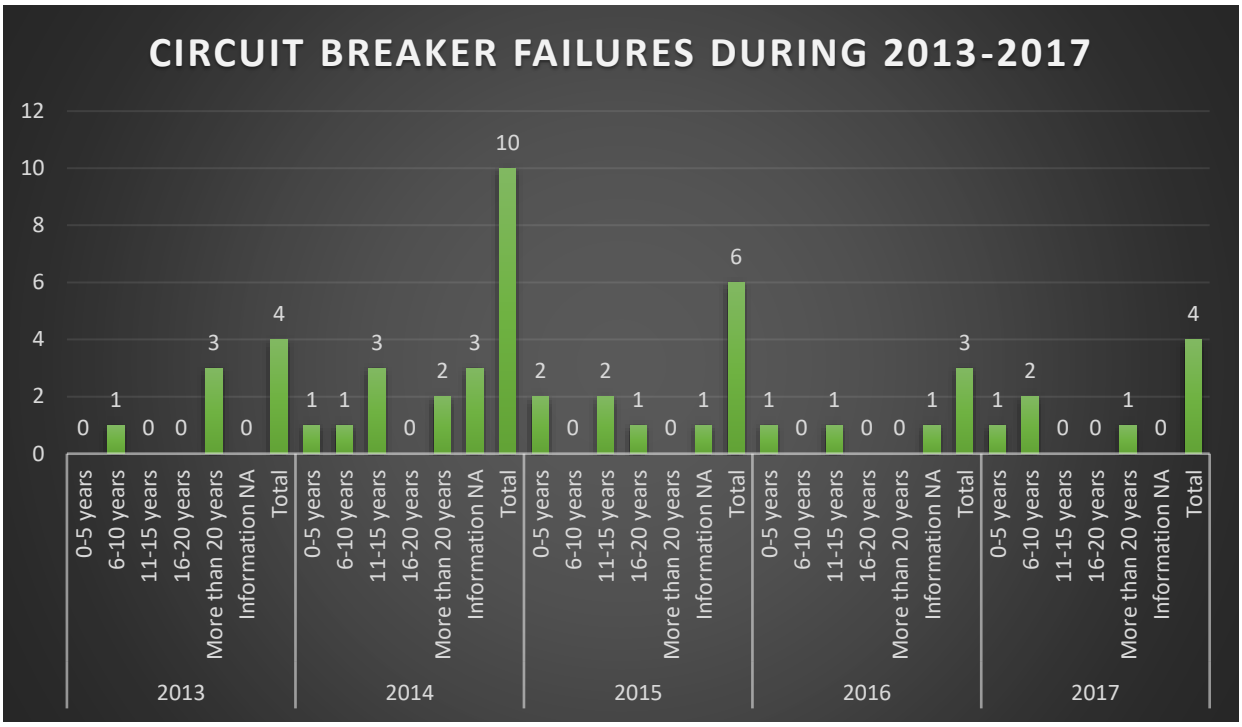
Equipment (Quantity)	Utility	Make	Rating	Year of commissioning	Date of failure
Circuit Breaker (4)	BBMB	Siemens	245 kV	2008	20.11.2017
	APTRANSCO	BHEL	245 kV	1998	22.10.2017
	KSEB	CGL	245 kV	2015	05.11.2017
	TANTRANSCO	AREVA	230 kV	2009	12.04.2017
CT (8)	TANTRANSCO	ABB	230 kV	2004	11.09.2017
	KPTCL	SVEI Pvt. Ltd	220 kV	2006	29.9.2016
	KPTCL	CGL	220 kV	1998	05.11.2016

	KPTCL	Hindustan Brown Boveri	220 kV	1995	02.04.2017
	KPTCL	SCT	220 kV	2000	05.09.2017
	APTRANSCO	WSI	220 kV	1993	17.01.2017
	APTRANSCO	BHEL	220 kV	NA	27.03.2018
	MSETCL	MEHRU	220 kV	2017	11.08.2017
CVT/PT (13)	KPTCL	WSI	420 kV	NA	26.07.2016
	KPTCL	WSI	220 kV	NA	07.09.2016
	KPTCL	WSI	220 kV	2014	28.01.2017
	KPTCL	SCT	220 kV	2011	04.07.2017
	KPTCL	SCT	220 kV	2014	13.08.2017
	BBMB	WSI	220 kV	1988	12.04.2017
	BBMB	WSI	220 kV	1989	15.04.2017
	TANTRANSCO	CGL	230 kV	1994	17.10.2016
	APTRANSCO	SCT	220 kV	2011	19.11.2016
	APTRANSCO	SCT	220 kV	2011	18.11.2016
	APTRANSCO	ABB	220 kV	2016	09.12.2016
	MSETCL	CGL	220 kV	2010	08.01.2018
	KPTCL	WSI	400 kV	NA	19.10.2017
SA (25)	BBMB	CGL	220 kV	2006	17.04.2017
	TANTRANSCO	CGL	230 kV	1988	11.11.2016
	TANTRANSCO	CGL	230 kV	2003	22.02.2017
	KPTCL	CGL	230 kV	NA	22.01.2017
	TANTRANSCO	CGL	400 kV	2006	16.02.2018
	KPTCL	CGL	220 kV	2009	15.01.2017
	KPTCL	CGL	220 kV	2003	09.01.2017
	KPTCL	CGL	400 kV	2002	12.09.2017

	KPTCL	CGL	400 kV	NA	29.10.2016
	KPTCL	CGL	220 kV	2003	06.11.2016
	KPTCL	CGL	400 kV	NA	11.11.2016
	KPTCL	CGL	220 kV	2003	18.11.2016
	KPTCL	CGL	220 kV	1999	19.11.2016
	BBMB	CGL	220 kV	2006	18.12.2016
	APTRANSCO	ELPRO	220 kV	1998	02.12.2016
	TANTRANSCO	LAMCO	220 kV	2015	07.08.2016
	TANTRANSCO	CGL	220 kV	2006	24.12.2016
	TANTRANSCO	CGL	400 kV	2006	05.02.2017
	KPTCL	CGL	220 kV	2003	11.12.2017
	KPTCL	CGL	220 kV	2003	23.02.2018
	KPTCL	CGL	220 kV	2002	07.03.2018
	KPTCL	CGL	400 kV	2002	21.01.2018
	KPTCL	CGL	220 kV	2002	07.03.2018
	MSETCL	CGL	220 kV	2008	25.07.2017
	MSETCL	CGL	400 kV	2002	30.03.2018

(ii) From January 2017 to March 2018, four (4) nos. of cases of CB failure have been reported to CEA during the period by four (4) Utilities. In three of the cases, cause of failure of CB was internal insulation failure while one no. CB failed due to ageing.

(iii) **Failures of CBs during 2013-2017:** The number of different CB failures as reported in last 5 years to CEA has been shown in the graph below.

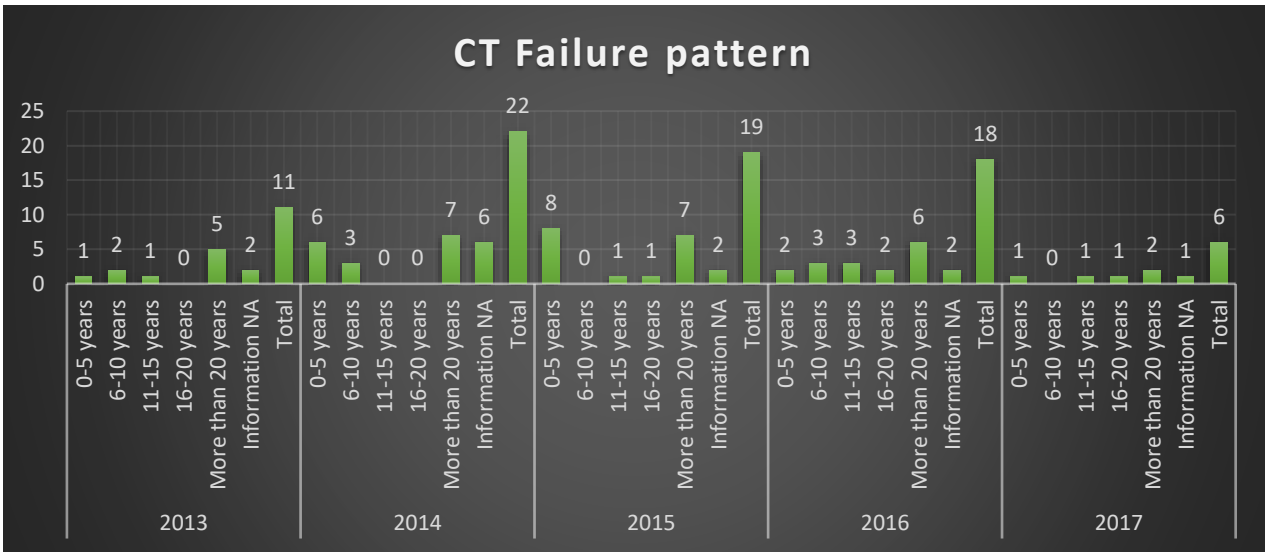


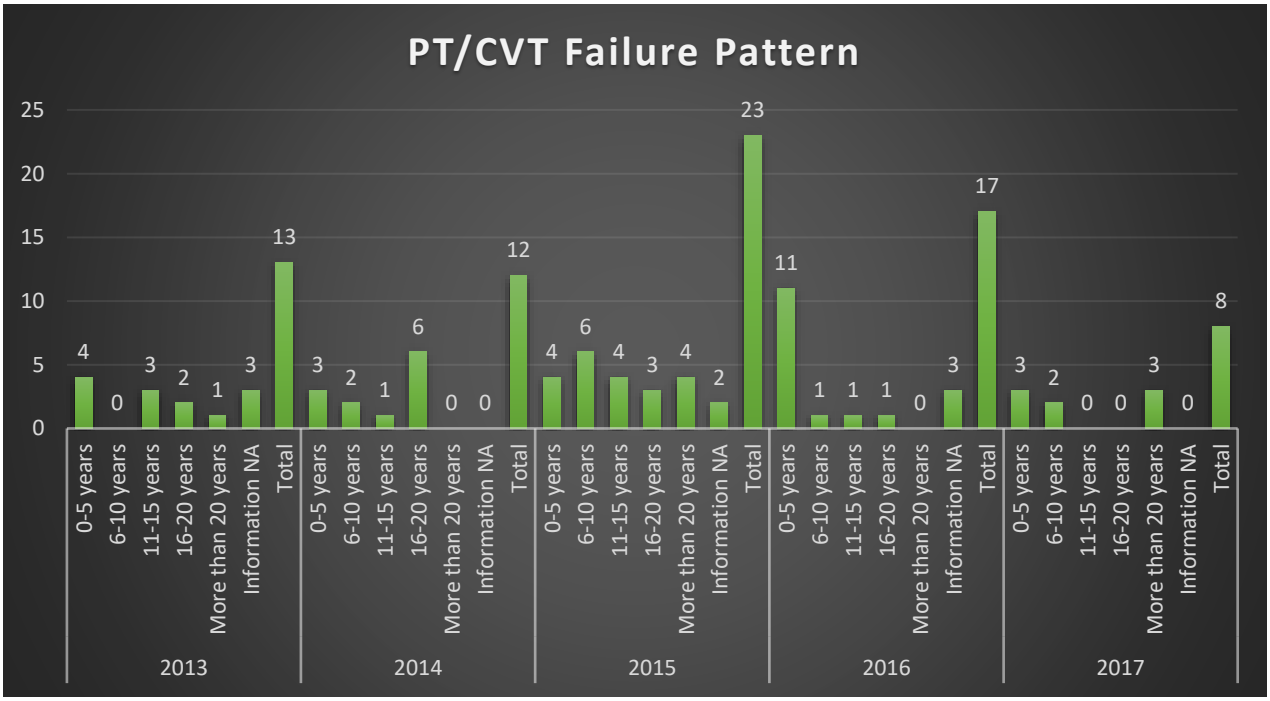
(iv) It is observed that eight (8) nos. of cases of CT failure have been reported to CEA during the period from January 2017 to March 2018 as reported by four (4) utilities.

(v) In case of PT/CVT, thirteen (13) nos. of failure have been reported to CEA during the period from January 2017 to March 2018 by five (5) 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.

(vi) In most of the cases of failure of CT / CVT / PT, the equipment had blasted or flashed over. In such cases, it becomes difficult to pin point the cause of failure. Some of the failures of equipment / transformers could be due to ageing.

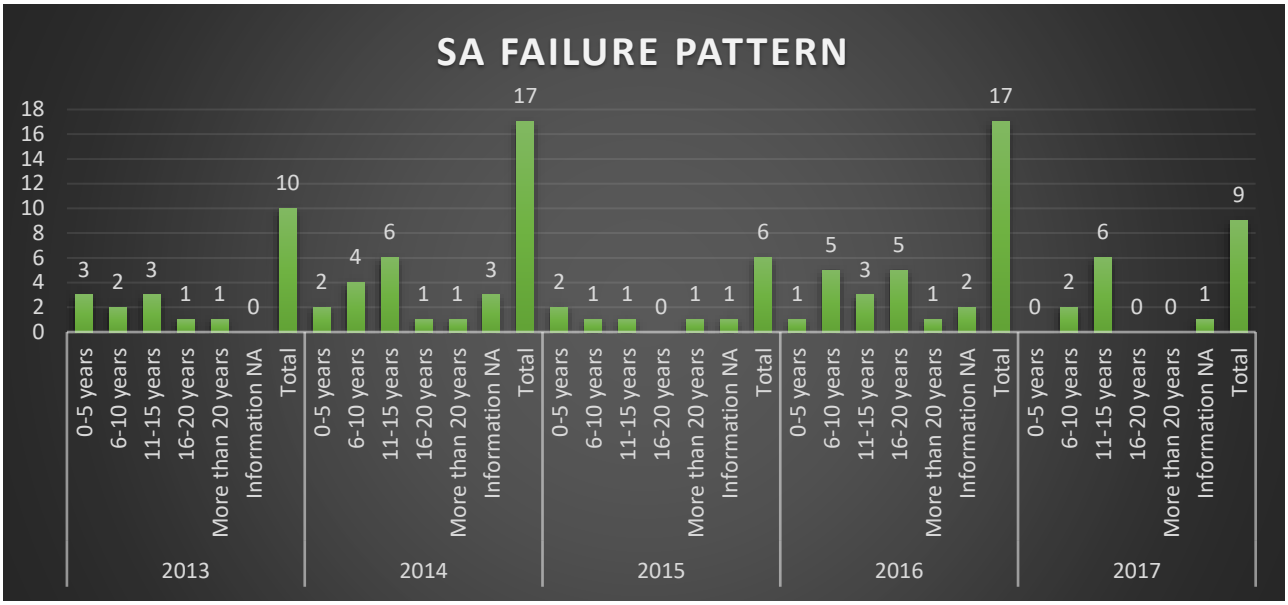
(vii) **Failures of CTs/PTs/CVTs during 2013-2017:** The number of different CT/PT/CVT failures as reported in last 5 years to CEA has been shown in the graph below.





(viii) As per the reports received by CEA, twenty five (25) nos. of cases of SA failure have occurred in 2017 and till March 2018. These reports have been furnished by five (5) utilities. Out of these, seven (7) nos. of SAs are of 400kV class and rest eighteen (18) nos. of SAs are of 220/230kV class.

(ix) **Failures of SAs during 2013-2017:** The number of different SA failures as reported in last 5 years to CEA has been shown in the graph below.



2.7 One number case of failure of 220 kV XLPE Cable of DTL was reported. The cable had failed in February 2018. The failure may be attributed to improper restoration of original installation conditions of cable during excavation for metro work.

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.

f. Improper installation (XLPE cable)

(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 analyse 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.

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 2017) 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) 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.

(ii) 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.

(iii) 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.

(iv) 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.

(v) 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.

(vi) 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 manufacturer's recommendation for storage should be followed strictly.

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

(viii) 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.

(ix) 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.

(x) 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.

(xi) 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.

(xii) 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.

4.2 Recommendations for Transformers (ICT & GT) 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 / transformer.

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

(iii) Inordinate delay in commissioning of equipment /transformer 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, proper care must be taken to ensure satisfactory operation of transformer. Storage of transformer should be done as per manufacturer's recommendations.

(v) Transformer 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 should be filled with oil under vacuum and transformer 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 should be transported filled with dry air. Use of nitrogen for this purpose should be avoided.

(vii) 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.

(viii) 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.

(ix) 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.

(x) 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.

(xi) 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.

(xii) 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.

(xiii) 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)

(xiv) 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)

(xv) 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

(xvi) Oil level should be checked before charging. For CTs with metallic bellows, the oil should be present upto 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 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 time.

(xvii) Varistors protect the CVT from over voltage due to Ferro-resonance (FR) oscillations. They may fail in service if FR is sustained or the energy to be discharged is beyond its designed capacity. Simple visual check will ensure the healthiness. A varistor should be replaced by the varistor of the same voltage rating, as secondary voltage is tuned to a varistor.

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 Sealing Test which can be carried out at manufacturer's works to ensure proper sealing against ingress of moisture.

(v) Digital surge counter's employment in substations could be explored.

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 XLPE Cable:

(i) The cable should be laid in the configuration as approved during design stage as per manufacturer's recommendations. If cable is repaired, it should be restored to its original laying condition.

(ii) The monitoring of healthiness of Sheath Voltage Limiter (SVL) and monitoring of Partial Discharge (PD) of all straight-through joints & terminations in addition to hot spot monitoring using Distributed Temperature Sensor (DTS) is essential.

ANNEXURE-I

Detailed Information of All Failed Equipment Reported To CEA between January 2017 and March 2018

Detailed Information of All Failed Equipment Reported to CEA between January 2017 and March 2018

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

S.no.	Failure report	Utility	Serial no.	Date of Failure
TRANSFORMERS				
1.	Failure of 315 MVA, 400 kV level 1-ph, ICT-II at Raigarh Substation	PGCIL	T-09096/3	03.09.2017
2.	Failure of 315 MVA, 400 kV level ICT-I at Jalandhar Station	PGCIL	T-6005782	13.12.2017
3.	Failure report single phase 167 MVA Transformer at Kolar s/s	PGCIL	6006351	11.02.2017
4.	Failure report 500 MVA ICT at Bidadi s/s	PGCIL	30575	16.09.2017
5.	Failure of 100 MVA, 220/66-33/11 kV Power Transformer at 220 kV Naraina S/s	DTL	T8423/1	26.07.2017
6.	Failure of 100 MVA, 220/33/11 kV Power Transformer at 220kV Lodhi Road Substation	DTL	2008099	22.03.2017
7.	Failure of 100 MVA, 220/33 kV, Power Transformer at Okhla Substation	DTL	HT-1824/13092	07.04.2017

8.	Failure report of 100 MVA, 220/33/11 kV Transformer at Preet Vihar	DTL	2043278	12.03.2018
9.	Failure report of 160 MVA, 220/66/11 kV Transformer at Pappankala-III s/s	DTL	2043264	09.03.2018
10.	Failure of 220/132kV, 100 MVA Auto Transformer-III at Bhadrak s/s	OPTCL	T8537/2	31.05.2017
11.	Failure of 160 MVA, 220/132/33 kV Auto transformer-2 at New Bolangir s/s	OPTCL	2035208	09.02.2017
12.	Failure of 50 MVA, 220/110/11 kV Auto-transformer at Sirsi s/s	KPTCL	77220-001/1	15.07.2017
13.	Failure of 100 MVA, 220/110 kV Power Transformer at Bidnal Substation	KPTCL	PM0100075	15.11.2016
14.	Failure report of 292.4 MVA, 16.5/420 kV StGT#2, Transformer at PPS-III, Bawana S/s	PPCL	6006757	08.10.2017
15.	Failure of 315 MVA, 400/220/33 kV auto-transformer at 400 kV SS Bina	MPPTCL	6005210	15.01.2018
16.	Failure of 315 MVA, 400/220/33 kV, – 3 Ph	MPPTCL	6005211	14.02.2018

	ICT at 400 kV S/s Bina substation			
REACTORS				
17.	Failure of 80 MVAR, 400 kV Reactor at Vizag Substation of	PGCIL	T8975/2	28.04.2017
18.	Failure of 16.67 MVAR, 400kV Line Reactor at Agra S/s	PGCIL	T8353/1	22.05.2017
19.	Failure of 80MVAR, 765 kV Bina-II R-ph Line Reactor at Satna substation	PGCIL	BH09823/01	01.06.2017
20.	Failure report 80 MVAR, 420 kV Line Reactor at Kishenganj s/s	PGCIL	T10416/1	01.09.2017
21.	Failure report 80 MVAR, 765 kV B-Phase Line Reactor at Varanasi s/s	PGCIL	14B09098	27.12.2017
CURRENT TRANSFORMERS				
22.	Failure of 230kV CT at Alundur Substation, Trichy	TANTRANSCO	2101007/2001	11.09.2017
23.	Failure of 220kV Current Transformer at Kudachi Substation	KPTCL	313/1/7	29.09.2016
24.	Failure of 245kV CT at HSR Layout, Bangalore Substation	KPTCL	9019	05.11.2016
25.	Failure of 220kV B-phase CT at KIADB Doddaballapura s/s	KPTCL	IB027/700	02.04.2017

26.	Failure of 220kV CT at Kavoor Substation	KPTCL	2000/289 2000/287	05.09.2017
27.	Failure of 220kV CT at Yerraguntla Substation	APTRANSCO	910815	17.01.2017
28.	Failure of 220 kV R-ph CT at Vishakhapatnam s/s	APTRANSCO	2241286	27.03.2018
29.	Failure of 220 kV CT at Warora s/s	MSETCL	OC2927 /1/4/10	11.08.2017
POTENTIAL TRANSFORMERS/ CAPACITIVE VOLTAGE TRANSFORMERS				
30.	Failure of 420 kV class CVT at Nelamangala substation	KPTCL	20000827	26.07.2016
31.	Failure of 220kV CVT of Anchepalya line-2 at Nelamangala Substation	KPTCL	20000837	07.09.2016
32.	Failure of 220kV PT at Anchepalya substation of.	KPTCL	2012/803	28.01.2017
33.	Failure of 220kV PT at Chikkodi Substation	KPTCL.	2010/1809	04.07.2017
34.	Failure of 220 kV PT at Anchepalya Substation	KPTCL	2012/802	13.08.2017
35.	Failure of 220kV CVT at GSS Hisar Substation	BBMB	88121019	12.04.2017
36.	Failure of 220kV CVT at Charkhi, Dadri Substation	BBMB	8707552	15.04.2017

37.	Failure of 230kV CVT at Arni Substation	TANTRANSCO	5952	17.10.2016
38.	Failure report of 220kV PT at Krishngiri Substation	APTRANSCO	2009/509	19.11.2016
39.	Failure of 220kV PT at Brahmanakotkur Substation	APTRANSCO	2009/502	18.11.2016
40.	Failure of 220kV CVT at Anantapuramu Substation	APTRANSCO	2213100	09.12.2016
41.	Failure of 220 kV R-ph PT at Gadchiroli s/s of	MSETCL	13049	08.01.2018
42.	Failure of 400 kV CVT at Nelamangala s/s	KPTCL	20000643	19.10.2017
CIRCUIT BREAKER				
43.	Failure of 245 kV CB at Right bank power house	BBMB	2007/IND /03/3378	20.11.2017
44.	Failure of 245 kV CB at Kondapalli Substation	APTRANSCO	401929	22.10.2017
45.	Failure of 220 kV CB at Kanhirode Substation	KSEB	46017C	05.11.2017
46.	Failure of 230kV CB at Manali Substation	TANTRANSCO	151136	12.04.2017
SURGE ARRESTER				
47.	Failure of 220kV SA at Jalandhar Substation	BBMB	51896	17.04.2017
48.	Failure of 230 kV SA at Mylapore Basin bridge Substation	TANTRANSCO	4864	11.11.2016

49.	Failure of 230kV SA at Korattur s/s	TANTRANSCO	4856	22.02.2017
50.	Failure of 220kV SA of Nelamangala substation	KPTCL	5123	22.01.2017
51.	Failure of 400kV SA at Alamathy Substation	TANTRANSCO	14687	16.02.2018
52.	Failure of 220 kV SA of Nelamangala substation	KPTCL	5103	15.01.2017
53.	Failure of 220kV SA of Narendra substation	KPTCL	23912	09.01.2017
54.	Failure of 400 kV SA at Nelamangala substation	KPTCL	5083	12.09.2017
55.	Failure of 400kV SA at Nelamangala Substation	KPTCL	5077	29.10.2016
56.	Failure of 220kV SA at Honnali Substation	KPTCL	15162	06.11.2016
57.	Failure of 400kV SA at Neelamangala Substation	KPTCL	5087	11.11.2016
58.	Failure of 220kV SA at Honnali Substation	KPTCL	15157	18.11.2016
59.	Failure of 220kV SA at Kemar, Karkala Substation	KPTCL	9507303	19.11.2016
60.	Failure report of 220kV SA at Sangrur Substation of	BBMB	51889	18.12.2016
61.	Failure of 220kV SA at Tallapalli Substation of	APTRANSCO	9L11LAH	02.12.2016

62.	Failure of 230kV SA at Korattur Substation of	TANTRANSCO	464A	07.08.2016
63.	Failure of 230kV SA at Almathy Substation	TANTRANSCO	27215	24.12.2016
64.	Failure of 400 kV SA at Almathy Substation	TANTRANSCO	26183	05.02.2017
65.	Failure of 220 kV R-ph SA at Honnali s/s	KPTCL	15163	11.12.2017
66.	Failure of 220 kV R-ph SA at Honnali s/s	KPTCL	15155	23.02.2018
67.	Failure of 220 kV R-ph SA at Nelamangala s/s	KPTCL	5113	07.03.2018
68.	Failure of 220 kV R-ph SA at Nelamangala s/s	KPTCL	5075	21.01.2018
69.	Failure of 220 kV Y-ph SA at Nelamangala s/s of	KPTCL	5111	07.03.2018
70.	Failure of 220 kV Y-Phase SA at Oni Substation	MSETCL	24128	25.07.2017
71.	Failure of 400 kV SA at Talandage	MSETCL	22264A	30.03.2018
XLPE Cable				
72.	Failure of 220 kV XLPE Cable of Maharani Bagh-Electric Lane (Harish Chandra Mathur Lane) circuit-I	DTL	--	22.02.2018

Transformers

1. Failure Report of ICT-II 315 MVA, 400/220/33 kV at Raigarh Substation of PGCIL

A	Name of Substation	:	Raigarh
B	Utility/Owner of substation	:	PGCIL
C	Faulty Equipment	:	ICT-II
D	Rating	:	315 MVA, 400/220 kV
E	Make	:	CGL
F	Sr. No.	:	T-09096/3
G	Year of manufacturing	:	Information not available
H	Year of commissioning	:	2008 (31.01.2008)
I	Date and time of occurrence/discovery of fault	:	03.09.2017 at 16:15 hrs.
J	Information received in CEA	:	18.01.2018
K	Fault discovered during	:	During operation
L	Details of previous maintenance	:	Transformer had a history of DGA violation (H_2 and C_2H_2 gases) since 03.12.2012. Since then internal inspection by OEM, M/s CGL has been carried out four times on 17.04.2013, 22.06.13, 18.11.2013 and 31.08.2016. Transformer was energized on 19.09.2016 after the fourth round of inspection. DGA violation (C2H2) was observed in the ICT and as per the information provided by PGCIL, the same was being monitored. The gas levels had stabilized prior to failure.

M	Details of previous failure	:	Information not available
N	Sequence of events/ Description of failure	:	

On 03.09.17 at 1615 hrs, ICT-II tripped on Y and B phase fault. Fault was sensed by differential and REF protection. Loud sound was heard by the substation personnel and upon rushing to the site, emulsifier operation was seen.

16:15:16:026	Differential protection start
16:15:16:035	REF protection operated
16:15:16:038	Instantaneous Phase Overcurrent Trip
16:15:16:038	Instantaneous Earth Fault Trip
16:15:16:042	Differential trip

Prior to failure system was in normal operation and there was a load of 141 MW on ICT-I and ICT-II.

Signal	**Pre-fault values**	**Fault values**
I_a	219 A	0.58 kA
I_b	222 A	45.44 kA
I_c	220 A	38.79 kA
V_a	239 kV	316 kV
V_b	242 kV	69.8 kV
V_c	236 kV	105.9 kV

O	Details of Tests done after failure	:	LV tests were carried out. Test results are as mentioned below: IR Value R Phase -2.78 GΩ IR Value Y Phase -3.01 G Ω IR Value B Phase -126 G Ω Magnetizing Current at 230 Volts : R phase: 1 Amp; Yph-3 mA; B ph – 2 Amp.

DGA test results:

S. No.	Date	H_2	CH_4	C_2H_6	C_2H_4	C_2H_2	CO	CO_2
1	06.09.2017 (Post Failure)	3553	2714	515	5556	4721	336	1527
2	25.07.2017	31.00	6.00	1.00	10.00	0.4	191.00	2116.00
3	27.05.2017	34	6	1	10	0.7	176	1970
4	04.05.2017	39	6	1	10	1.2	149	1754
5	04.05.2017	29	5	1	9	1.9	91	1245
6	07.02.2017	39	7	1	9	3.6	67	988
7	25.01.2017	34	8	4	9	6	49	1184
8	20.12.2016	39.80	6.50	0.80	7.9	6.8	43.60	817.98
9	21.11.2016	42.55	6.80	0.96	8.80	12.72	41.50	743.10
10	27.10.2016	59.13	6.84	0.33	7.96	14.00	36.76	1477.00
11	07.10.2016	25.0	3.5	0	4.3	9.9	11.4	305.1

P	Observations and Analysis	:	

All 400 kV and 220 kV bushing flanges had cracked, internal porcelain cones had also cracked (but not shattered). This might have happened because of the high pressure generated during the fault and shock waves generated. 33 kV bushings were healthy.

Main tank hood was bulged from the bottom on the 400 kV side and bell tank joint bolts broke off.

ICT-II tripped on operation of differential protection (Y and B Phase) and REF protection. Fault current of the order of 44 kA was seen in Y Phase and 38.5 kA in B phase. The fault was cleared within 40-50 milliseconds (2.5 cycles).

Y Phase and B Phase windings were affected in the same portion; hence there is strong possibility of Phase to Phase fault. The winding (both Y and B Phase) had bulged and deformed. The windings were also displaced (come closer to each other).

The top yoke also displaced and gap could be seen from the laminations. Charred wraps, block and spacers were found in the bottom of the tank. The tank wall shunts have detached and CRNGO strips had come out from the 400 kV side of bell tank joint which had opened.

No abnormality in the cores was observed, except mechanical displacement.

OLTC was operated manually and tap change occurred on all phases. However, due to the mechanical force, the selector switch housing detached from the diverter chamber for Y-Phase. As the transformer was running with intermittent DGA violation since December, 2012, there is a possibility of weakening of phase barrier insulation between the Y and B phase winding due to intermittent high energy discharges. It is possible that just prior to the failure, the insulation had deteriorated to an extent that it could not withstand power frequency voltage and led to phase to phase fault between Y & B phases. Operation of REF and earth fault relay indicates that phase to phase fault might have spread to earthed components+.

2. Failure Report of 315 MVA, 400/220 kV ICT-I at Jalandhar Station of PGCIL

A	Name of Substation	:	Jalandhar
B	Utility/Owner of substation	:	PGCIL
C	Faulty Equipment	:	ICT-I
D	Rating	:	315 MVA, 400/220 kV
E	Make	:	BHEL
F	Sr. No.	:	T-6005782
G	Year of manufacturing	:	Information not available
H	Year of commissioning	:	2000 (31-12-2000)
I	Date and time of occurrence/discovery of fault	:	13.12.2017 at 11:03:58 Hrs.
J	Information received in CEA	:	18.01.2018
K	Fault discovered during	:	During operation
L	Details of previous maintenance	:	Due to oil leakage problem major overhauling of this ICT was carried out in November, 2015. All gaskets were replaced along with overhauling of OLTC. Increase

			in gases (H_2) was observed in February, 2017 and since then ICT was kept under 15 days DGA monitoring. Last Annual Maintenance result of said ICT was under limit and next maintenance was due in March, 2018.
M	Details of previous failure	:	Information not available
N	Sequence of events/ Description of failure	:	On 13.12.17 at 11:03 hrs , fault was sensed by following electrical and mechanical protections:

11:03:58:884	Back up E/F operated
11:03:58:885	Differential operated
11:03:58:885	86B operated
11:03:58:886	REF operated
11:03:58:886	Back up O/C operated
11:03:58:886	86A operated
11:03:58:925	400 kV Main CB open
11:03:58:927	220 kV CB open

Prior to the failure, system was in normal operation and the load was 93MW on ICT-I.

Signal	**Pre-fault values**			**Fault values_11:03:58:875**		
	Main CT	**Tie CT**	**220 kV CT**	**Main CT**	**Tie CT**	**220kV CT**
I_a	82	53	243	1567	937	27081
I_b	74	61	238	62	77	787
I_c	83	52	237	164	58	261

O	Details of Tests done after failure	:	

DGA test:

S. No.	Date	H2	CH4	C2H6	C2H4	C2H2	CO	CO2
1.	08-Aug-2017	719	39	6	3	0	197	1971
2.	22-Aug-2017	784	42	6	2	0	199	1997
3.	04-Sep-2017	870	48	7	2	0	211	2056
4.	21-Sep-2017	945	52	7	3	0	216	2125
5.	11-Oct-2017	925	52	7	2	0	197	1885
6.	27-Oct-2017	1018	58	9	2	0	198	1882
7.	17-Nov-2017	1136	66	10	3	0	200	1787
8.	06-Dec-2017	1171	70	11	3	0	193	1743
9.	13-Dec-2017 Post failure	1274	170	27	264	309	190	1534

Violation in H_2 and CH_4 was observed and was being monitored.

Following LV tests have been carried out:

a. **IR value measurement**
   HV+IV to LV – 32.3 kΩ
   HV+IV to E – 86.5 MΩ
   LV to E – 91.5 MΩ
b. **Magnetizing Current at 230 Volts** HV- R ph: 460 mA; Y ph-1.82 mA; B-ph -1.8 mA
   IV-R ph:1140 mA; Y ph -590 mA; B ph -590 mA

c. Magnetic Balance Test:
IV side

R-phase	Y-phase	B-phase
246.7 V	129.6	9.05 V
0.78 V	**247.7V**	247 V
0.5 V	247.2 V	**248.2 V**

P	Observations and Analysis	:	

Fault current of the order of 27 kA was seen in R phase IV side. The fault was cleared within 61 milliseconds. Both PRVs operated along with OLTC oil surge/Buchholz Trip & alarm relays. Terminal connectors of 400kV R&Y phase bushings were found to be broken. Cracks were observed in HV and IV bushings base flanges along with oil leakage from base. Cracks and oil leakage were found near HV side R and Y phase area. Cracks has also been observed in R & Y phase OLTC top head cover.

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

1. The CC-CL link was found to be completely burnt due to flow of fault current i.e. core – winding insulation failure. Low IR values also confirm the same.
2. IV side was not accessible hence detailed inspection could not be done. However no sign of any damage found in IV side.
3. No flashover was observed in bushing. However, all bushing flanges have been damaged due to high pressure.
4. No sign of any external flash over in the winding has been observed.
5. Insulation barriers of R-ph were found to be burnt and charred spacers & lot of insulation material were found scattered in main tank bottom.

FRA test was carried out to ascertain the location of the fault. No deviation was observed in HV-N IV shorted response. However, HV-N LV shorted response shows clear deviation of Y and B ph signatures from R-ph. Shorting of R-phase core with partial damage to R-ph winding is observed. Common part of Y-ph winding has been partially damaged. Barrier insulation and spacers between core and tertiary of R-ph have been shorted.

DGA results do not indicate presence of any incipient fault in the transformer. Partial Discharge indicated in the unit seem to be confined to oil insulation and degradation of paper insulation is not envisaged prior to failure. Further, as indicated by LV test results and FRA, the R-phase winding seems to be completely damaged with impact on other two phases.

As fault current of the order of 27 kA was detected in IV side R-phase (about 33 times rated FL current) and REF & earth fault relay had also operated, the

phase to ground fault is envisaged in R-phase of the IV side. However, same can be confirmed only through detailed inspection after dismantling of windings.

3. Failure report 167 MVA Transformer at Kolar s/s of PGCIL

A.	Name of Substation	:	Kolar
B.	Utility/Owner of substation	:	PGCIL
C.	Faulty Equipment	:	Transformer (ICT-2)
D.	Rating	:	1-ph., 420/√3 kV, 167MVA
E.	Make	:	BHEL
F.	Sr. No.	:	6006351
G.	Year of manufacturing	:	2007
H.	Year of commissioning	:	2007 (31.08.2007)
I.	Date and time of occurrence/discovery of fault	:	11.02.2017 at 1001 Hrs.
J.	Information received in CEA	:	31.07.2018
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Last AMP carried out prior to failure on 25.08.16 and results were found to be normal.
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	
On 11.02.2017 at 1001 hrs., the B-ph unit of ICT-2 at Kolar tripped on operation of Differential protection due to the blasting of BHEL make 420 kV 1250 A HV bushing. The Transformer caught fire and the emulsifier system			

operated which checked the fire from reaching the main tank. As per DR & EL, following are the sequence of different events at the time of Transformer HV Bushing failure:

10:01:58:639 - ICT-2 Differential Relay Optd

10:01:58:654 - ICT-2 HV side BU E/F & O/C Optd

10:01:58:663 - ICT-2 GR A/B Trip Optd

10:01:58:673 - 21252 Circuit Breaker open

10:01:58:676 - 40352 Circuit Breaker open

10:01:58:678 - 40252 Circuit Breaker open

O.	Details of Tests done after failure	:	LV Tests were carried out after failure found to be Normal

DGA History

Sample Date	H2	CH4	C2H4	C2H6	C2H2	CO	CO2
10.01.2017	3	23	59	7	0	253	1368
09.12.2016	4	22	59	7	0	256	1474
06.09.2016	4	6	16	2	0	214	1489
08.06.2016	2	2	1	1	0	208	1552
08.03.2016	2	2	1	0	0	204	1043
07.09.2015	4	2	1	1	0	167	1045

Bushing DGA

Sl. No.	Sample Date	H_2 (140)	CH_4 (40)	C_2H_4 (30)	C_2H_6 (70)	C_2H_2 (2)	CO (1000)	CO_2 (3400)
665094	04.09.2013	8	4	1	1	0	258	553
	02.09.2014	20	4	1	1	0	265	565
	24.03.2016	5	6	1	1	0	383	776

Oil Test Results

Date	BDV	PPM	Resistivity	Tan D	IFT	Acidity	Flash
	(50 min)	(20 Max)	(0.1 min)	(0.2 max)	(15 min)	(0.3 max)	(125 min)
13.0217 (Before failure)	71.4	6	25	0.0032	43	0.0096	150
08.03.16	73.6	5.8	20.9	0.0036	41.13	0.018	154

Bushing Capacitance & Tan Delta at 10kV

	HV		IV		LV1		LV2	
PRE COMM	451.2	0.0028	304.6	0.0047	197.281	0.003851	194.142	0.004985
07.08.08	453.635	0.0033	303.887	0.00425				
25.09.10	455.4525	0.004176	303.265	0.004641				
15.09.10	453.831	0.004881	303.632	0.0054				
24.04.12	458.125	0.004386	304.909	0.005179				
03.06.13	458.023	0.004329	302.285	0.005513				
04.09.13	454.715	0.004749	302.735	0.002783				
20.01.14	453.217	0.00512	305.058	0.005379				
					OLD Bushing replaced in 2014			
12.06.14	457.051	0.004636	305.214	0.005556	198.107	0.003747	195.137	0.004625
11.08.15	455.267	0.004877	305.072	0.005564	198.428	0.004161	195.471	0.005005
13.06.16	454.7	0.004868			197.424	0.004418	194.745	0.005266

Winding Capacitance & Tan Delta

Date	HV-IV/LV in UST Mode		HV-IV/LV+G in GST Mode		HV-IV/LV with guard GSTg Mode		LV/HV-IV in UST Mode		LV/HV-IV+G in GST Mode		LV/HV-IV with guard GSTg Mode	
11.8.15	2304.81	0.004042	5805.49	0.003651	3500.76	0.0033	2303.94	0.0044	9246.63	0.0031	6942.87	0.0027
13.6.16	2303.7	0.004045	5805.16	0.003705	3501.21	0.0035	2303.52	0.0045	9246.19	0.0031	6942.62	0.0028

The detail reading of Transformer SA is mentioned below:

Phase	Transformer SA counter		
	R-Ø (HV/IV/LV)	Y-Ø (HV/IV/LV)	BØ (HV/IV/LV)
Before Tripping	12/17/12	22/24/18	8/5/7
After Tripping	12/17/12	22/24/18	8/5/7

Post failure DGA of main tank was carried on 11.02.2017 and found to have high fault gasses. LV tests were carried out after failure are found to be normal.

The adopted settings of differential relay & Backup O/C relay and current recorded during tripping instances are detailed below;

Differential Relay Setting (7UT613)		
Setting Description	Set Value	Current value Recorded during Tripping (from DR)
1221-Pickup value of Differential Current (Diff>)	0.20I/InO	IDiff-13.11/InO, IRest-1301/InO@ 10:01:58:640
1231-Pickup value of High Set Trip (Dift>>)	9.61/InO	IDiff-9.811/InO@ 10:01:58:632

B-Ph Backup O/C Relay (2TJM12)		
Setting Description	Set Value	Current value Recorded during Tripping (from DR)
DOC_PMS	1	IB-12.7kA @ 10:01:58:659
DOC_TMS	0.175	
DOC_HS	5	

As evident in the DR, the high set Differential Trip (IDiff>>) of Differential relay had picked up @ 10:01:58:632hrs, i.e. around 12ms after differential pickup, and extended trip command to HV, IV and LV side Circuit Breakers through Group-A/B Trip relays. The fault had isolated at 10:01:58:678hrs. i.e. 58ms after differential pickup, by opening the circuit breakers from all voltage levels. Meanwhile, just before isolation of fault, at 10:01:58:654hrs the high set of ICT-2 B-Ph Backup O/C relay had also picked up and extended instantaneous trip command to the Group-A/B Trip relays. As recorded in the EL, consequent to the blasting of HV Bushing and sudden spillover/thrust of oil had caused the operation of Buchholz and PRV relays.

As such the operation of all protective relays and devices functioned in the intended manner and isolated the fault at shortest possible time.

P.	Observations & Analysis	:	

(A) following observation were made:

Transformer had failed with failure of 400kV B phase bushing and immediately caught fire. Porcelain of B phase bushing was found to be shattered.

i. No external damage has been observed in the Transformer main tank except shattering of porcelain of B phase bushing.

ii. Blasting of HV Bushing led to consequential damage of following major equipment.

a. Porcelain of IV Bushing, LV Bushing
b. 2nos. BPI for Neutral Bus bar
c. One number 390kV LA
d. ACSR Twin moose 400kV conductor clamp – 1 no.
e. Radiator Fins – 3 nos.
f. Through Clamp between BPI & Neutral

iii. A clear hole was found in the air end portion of HV phase bushing. The location of hole is approximately 1.7 mtr from bottom of bushing.

iv. Oil end side porcelain of HV bushing was found to be completely shattered and porcelain pieces and burnt paper were found laid at the bottom of the tank.

v. Some flash marks where found in the inner surface of the metallic portion meant for BCT accommodation of bushing

vi. HV winding lead take off was found to be damaged and uprooted. However, the winding lead was found to be intact and no other visible abnormalities were noticed during the internal inspection.

The blasting of HV Bushing in ICT-2 B-ph had resulted flashover between HV bushing lead & BCT metallic portion and heavy flow of fault current to the ground through transformer body. The fault current in turn activated differential relay @ 10:01:58:639 and Back-up O/C relay of HV side @ 10:01:58:654.

Prima facie, the fault seems to be initiated from HV Bushing and it is suspected that failure occurred due to failure of the bushing. As evident from the variable frequency test results and bushing DGA test results, bushing condition was normal prior to 8 months of failure. Failure of the bushing seems to be random in nature and due to explosion of the B phase bushing, air end portion porcelain got shattered leading to flashover of bushing condenser core with the flange which is evident from the punctured hole nearer to bushing flange.

4. Failure of 500 MVA, 420 kV ICT at Bidadi s/s of PGCIL

A.	Name of Substation	:	Bidadi
B.	Utility/Owner of substation	:	PGCIL
C.	Faulty Equipment	:	ICT
D.	Rating	:	500 MVA, 420 kV
E.	Make	:	ALSTOM
F.	Sr. No.	:	30575
G.	Year of manufacturing	:	2011

H	Year of commissioning	:	2012 (29.03.2012)
I	Date and time of occurrence/discovery of fault	:	16.09.2017 at 04:56:22 hrs.
J	Information received in CEA	:	31.07.18
K	Fault discovered during	:	Operation
L	Details of previous maintenance	:	On 24.09.2012, tap lead modification was carried out on the said Transformer on 11.02.2013 (Insertion of Treated PBD barrier in all phases has been provided) and re-commissioned on 10.04.2013. Further, due to tan delta test tap issues, all the 245 kV and 52 kV bushings were replaced with new bushings on 08.04.2015.

DGA History

Sample Date	H2	CH4	C2H4	C2H6	C2H2	CO	CO2
30.05.2014	7.29	0.96	0.09	0.15	0.049	85	520
01.07.2014	10	1	0.13	0.27	0.09	115	646
04.08.2014	17	2	0.13	0.35	0.05	164	821
10.10.2015	45	8	0.38	1.2	0	448	1757
01.08.2016	49	8	0	1	0	408	2433
04.01.2017	49	7	1	2	0	450	2061
10.04.2017	38	8	0	1	0	428	3183

M	Details of previous failure	:	None
N	Sequence of events/ Description of fault	:	

On 16.09.2017, said Transformer failed and fault current of 10.6 kA was observed in 220kV side.

Following indication were noted at the time of tripping:

- REF Trip
- Transformer Differential trip
- PRV Trip (Both)
- HV Back up O/C Earth fault relay operated
- Transformer Buchholz Trip
- OSR trip

Prima facie, from the DGA history and AMP test results, it may be inferred that the transformer was healthy prior to failure and had failed due to sudden fault inside the transformer.

O	Details of Tests done after failure	:	The details of tests done after failure are not available.
P	Observations & Analysis	:	

Committee visited GE, Naini works for inspection as well as for failure investigation and following observations was made:

a. Cracks were observed in tank stiffeners and severe deformation was observed on both sides of tank wall and tank cannot be reused.
b. U-phase outer wrap was found burnt at different locations in middle portion. The lead take out portion was found to be intact. V-phase and W-phase outer wrap and lead take out portion was found to be intact.
c. Flashover mark was observed between disc no.50 and 52 in outer side of U-phase HV(series) winding along with pitting (melting) of copper. Black spot was observed on tank wall just opposite to the above flashover mark.
d. Some deformation was also observed on Bottom Clamping frame near U-phase.
e. Common winding part, leads and regulating winding were found to be intact.
f. The middle part of bottom yoke clamping studs between U and V phases was found to be burnt.
g. Burn marks were also observed in outer part of V-phase winding outer wrap, no further burn mark was observed from outside on coil stacks of V and W phase windings.

Based on the internal inspection carried out on site, it was difficult to exactly establish the failure cause. Hence, it was decided to shift the Transformer to GE, Naini works for establishing cause of failure. From the inspection, it may be inferred that failure of Transformer was occurred due to failure of R phase winding. As suspected earlier, tap lead was not involved in the failure. Fault might have initiated in winding turns/inter disc in HV series winding. Considering the extent of damage, carbonization and exposure of other winding insulations, it was recommended to replace all the windings along with all insulation materials and tank.

5. Failure of 100 MVA, 220/66-33/11 kV Power Transformer at 220 kV Naraina Substation of DTL

A	Name of Substation	:	Naraina Substation
B	Utility/Owner of substation	:	Delhi Transco Ltd. (DTL)
C	Faulty Equipment	:	Power Transformer
D	Rating	:	100 MVA, 220/66-33/11kV
E	Make	:	CGL
F	Sr. No.	:	T8423/1
G	Year of manufacturing	:	1994
H	Year of commissioning	:	2002
I	Date and time of occurrence/discovery of fault	:	26.07.2017 at 2348 hrs.
J	Information received in CEA	:	27.07.2017
K	Fault discovered during	:	During running condition
L	Details of previous maintenance	:	

Major tripping and maintenance detail since commissioning as provided in DTL's preliminary report is as under:

Sr. No.	Date	Reason of outage	Action taken by DTL
1.	25.04.13	Replacement of Y-ph LV bushing	Bushing replaced as the result of tan δ test was on high side
2.	18.04.14	Replacement of R-ph LV bushing	Bushing replaced as the result of tan δ test was on higher side
3.	04.09.16	Buchholz alarm, Protection trip group 86A, Auxiliary trouble, Control cable found damaged	Replacement of damaged control cable with healthy one

i) Oil of Transformer-I was tested in CPRI on 10.03.2016 and 14.03.2017 and all properties were found to be within permissible limits as per IS-1886.
ii) DGA on 27.02.2017 indicate increased values of CO_2 (3242 ppm) and CO (457 ppm) which could be attributed to cellulose overheating. All other gases were found to be within permissible limits.
iii) LV tests were performed on the transformer on 02.12.2016 and results were found to be satisfactory.
iv) Earth resistance was measured on 01.06.2017 and its value was 0.55 ohm which is within acceptable limit.
v) As per DTL's report, last thermos-vision scanning done on 27.04.2017 did not indicate any hot-spots.

M	Details of previous failure	:	No other fault in the transformer prior to this failure.
N	Sequence of events/ Description of failure	:	On 26.7.17 at 2348 hrs, subject Power Transformer tripped on Differential (R&B ph), Buchholz, PRD, SPR, WTI and OTI trip.
O	Details of Tests done after failure	:	As the transformer had blasted, no test was possible.
P	Observations and Analysis	:	

1. DTL informed that CGL make power Transformer-I tripped on 26.07.2017 at 2348 hrs. on Differential relay (R& B ph), Buchholz relay, PRD, SPR, WTI

trip and OTI trip and caught fire. Further, power transformer-II running in parallel, tripped on overcurrent relay after the load of power Transformer-I was shifted on the former.

2. It was informed by DTL that the transformer was operating on the tap no. 5. The transformer – I was running in parallel with 100 MVA transformer – II. The load at transformer –I was 74 MW and at transformer – II was 67 MW, CB (HV side) of transformer – III was in lock – out condition
3. As per the DR data, the faulty transformer was isolated within 64 ms.
4. During physical inspection by CEA officers, it was observed that the transformer had severely damaged due to blazing fire.
5. All bushing (HV, LV & Tertiary) and three LAs (on HV side) were completely shattered. Two turrets were found open.
6. The conservator tank fell on the ground due to bending of its support; radiators and marshalling box were damaged; and all control winding were burnt.
7. Spilled transformer oil was observed around the tank.
8. Due to fire and flying debris of transformer/SA, insulator of nearby isolator and jumper conductor also got damaged.
9. No fire protection system was available for the transformer except for portable fire extinguishers. Fire tenders were called for extinguishing the fire.
10. Factory test results and pre-commissioning test result for the failed transformer were not available with DTL.
11. Year of mfg. of the Transformer is 1994 while it was commissioned in 2002. Information regarding its storage and maintenance during the period 1994-2002 was not available with DTL.
12. All relays were electromechanical type and disturbance recording facility was not available.
13. It was informed that flags of the relays were reset manually; hence, operation of the relays could not be verified through flag position.
14. Disturbance recorder data for 220 kV Bamnuali Ckt-II was provided. During its study, it was found that R- Phase voltage was recorded as 10 kV. Upon enquiry, DTL representative informed that this was due to technical problem with R- Phase CVT.
15. As the transformer had blasted, no test was possible.
16. No disturbance recorder is installed for transformer, hence, no data of fault current could be determined. DR data of 220kV Bamnauli Ckt-II was provided which indicated flow of 1300A current.
17. Since the transformer had caught fire, no oil sample for testing could be collected. In the absence of oil testing report, amount of gas generated during fault could not be determined.

18. Since the transformer could not be opened at the time of visit, internal inspection of transformer could not be carried out. Without detailed internal inspection of transformer, exact cause of failure can not be ascertained. Since the transformer had burnt for considerable period, even internal inspection might not present enough evidences to reach any conclusion.
19. Report of DTL transformer committee suggests that the external fire in the oil around the transformer or control cable due to AC/DC leakages may be the cause of failed and that the transformer got burnt due to damage of LV side R-ph bushing. However, based on available information and considering the fact that cables were FRLS type, reason claimed in DTL report does not seem satisfactory enough to accept as probable cause of failure.
20. Operation of Differential, Buchholz, PRD & SPR relays indicates internal fault of the transformer. It appears that insulation of winding might have failed causing short circuit and arcing. High energy arcing due to fault inside the transformer tank might have led to sudden pressure rise in tank, tripping of Buchholz, SPR & PRV and blasting of bushing. The flow of heavy fault current in windings might have caused rise in winding temperature and operation of OTI & WTI trip. As soon as heated oil found an opening through turrets and came in contact of oxygen, it caught fire.

6. Failure of 100 MVA, 220/33/11 kV Power Transformer at 220kV Lodhi Road Substation of Delhi Transco Ltd.

A.	Name of Substation	:	Lodhi Road
B.	Utility/Owner of substation	:	DTL
C.	Faulty Equipment	:	Power Transformer
D.	Rating	:	100 MVA, 220/33/11 kV
E.	Make	:	BHEL
F.	Sr. No.	:	2008099
G.	Year of manufacturing	:	1994
H.	Year of commissioning	:	1994
I.	Date and time of occurrence/discovery of fault	:	22.03.17 at 2230 hrs.

J.	Information received in CEA	:	30.03.17
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Information not available
M.	Details of previous failure	:	According to DTL officers, there has not been any other fault in the transformer prior to this failure.
N.	Sequence of events/ Description of failure	:	

The transformer had tripped on 22.03.2017 at 2230 hrs on differential (R & B phase), HV REF, LV REF, O/C (R & B phase), Buchholz relay, PRD and SPRV.

It was informed by DTL that the transformer was operating on tap no. 3 and the load on the transformer was 25 MW at the time of failure

It was also informed that OLTC is generally operated bi-annually, at the onset of winter and summer season.

O.	Details of Tests done after failure	:	

Following tests were conducted by DTL on the transformer post failure:

- Magnetic balance
- Magnetizing current
- Tan δ test of HV, LV and Tertiary windings
- Sweep Frequency Response Analysis (SFRA)
- DGA
- Voltage Ratio
- Insulation Resistance
- Winding resistance

P.	Observations & Analysis	:	

During physical inspection by CEA Officers, it was observed that there was no visible sign of bulging of or cracks on the tank and all HV, LV, Tertiary and

Neutral bushings were intact. Further, spilled transformer oil was observed around the tank due to PRV operation.

No fire protection system was available for the transformer except for portable fire extinguishers.

Factory test results and pre-commissioning test results for the failed transformer were not available with DTL.

DTL informed that the service engineer of OEM, M/s BHEL Ltd. visited the site on 30.03.2017 and inspected the failed transformer. DTL had drained the oil from the transformer. The transformer was physically inspected from inside by the service engineer of BHEL.

Following observations from physical inspection were made by M/s BHEL, as per MOM provided by DTL:

(a) All HV, LV, Tertiary and Neutral bushings and their leads were found intact.
(b) OLTC selector switch was found in normal position.
(c) Top core lamination stampings on R phase side was found distorted in shape and gap between them was between them was found increased & irregular during internal inspection which indicates shifting of core along with widening of air-gap.

(d) Perma-wood supports and pin pad nut bolts were found broken near R phase windings.
(e) Burnt pieces of paper insulation were found below HV windings.

DGA of oil indicates high concentration of Hydrogen (H2-2185 ppm), Ethylene (C2H4-586 ppm), Ethane (C2H6-160 ppm), Methane (CH4-413 ppm) and Acetylene (C2H2-709.5). Total Dissolved Combustible Gases (TDCG) was 3900 ppm which is higher than normal value. The high concentration of acetylene gas could be due to arcing inside the tank. Values of Roger's ratio (CO2/CO = 9.88 and C2H4/C2H6= 3.66) also suggest high energy discharge. Due to the generation of these gases, high pressure might have built up, which led to the operation of PRV and SPRV.

Operation of Differential, Buchholz, PRD & SPRV relays indicates internal fault of the transformer. Operation of REF indicates that the fault involved ground.

Magnetising current of R-phase HV winding was 760 mA which is much higher than 2.7 mA in Y-phase & B-phase of HV winding. Similarly, magnetising current of R-phase LV winding was 29.4 A which is much higher than 63.3 mA in Y-phase & 62.7 mA in B-phase of LV winding. The findings suggest fault in R-phase winding. The same is also corroborated by the abnormal results of magnetic balance test and the fault current of 15.75 kA in R-phase of the winding, as per DR data.

Tan δ value of HV-LV insulation had jumped from earlier value of 0.43%, measured on 28.03.16, to 16.38% after fault which is much higher than the permissible limits and indicates deterioration of insulation between HV and LV winding. The same is suggested by low values of insulation resistance and Polarisation Index for HV-LV insulation.

SFRA carried out on transformer after fault is found to be dissimilar, especially in low frequency zone, to SFRA recorded on same transformer on 28.03.16 which is indicative of shifting of core/winding and the same has also been verified by internal inspection carried out by BHEL Engineer.

The extent of damage to the core & winding, exact cause of failure and type of failure could be determined only after thorough internal inspection.

7. Failure of 100 MVA, 220/33 kV, Power Transformer at Okhla Substation of DTL

A.	Name of Substation	:	Okhla s/s

B.	Utility/Owner of substation	:	DTL
C.	Faulty Equipment	:	Power Transformer
D.	Rating	:	100 MVA, 220/66-33/11 kV
E.	Make	:	EMCO
F.	Sr. No.	:	HT-1824/13092
G.	Year of manufacturing	:	2010
H.	Year of commissioning	:	2010
I.	Date and time of occurrence/discovery of fault	:	07.04.17 at 1115 hrs
J.	Information received in CEA	:	13.04.17
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Maintained as per utility's O&M schedule
M.	Details of previous failure	:	
	According to DTL officers, on 05.07.2016 at 1053 hrs, the transformer had tripped with huge sound. On inspection, selection switch of OLTC and all phase HV & LV bushing were found cracked. The transformer was energised on 01.08.2016 after repairing work was carried out under supervision of OEM. OLTC was repaired and HV & LV bushings were replaced with new ones. All LV & HV tests were carried out.		
N.	Sequence of events/ Description of failure	:	
The transformer had tripped on 07.04.2017 at 1115 hrs on differential (B phase), Master Relay and both PRDs. The transformer tripped when during the shifting of 33 kV Masjid Moth feeder (on load condition) from Bus-I to Bus-II with 33 kV bus-coupler on. B phase Bus-II isolator suffered a mechanical fault and flash over occurred between equipment support structure and live jumper.			

The transformer was operating on tap no. 3 and the load on the transformer was 15 MW at the time of failure.			
O.	Details of Tests done after failure	:	Following tests were conducted by DTL on the transformer post failure: • Magnetic balance • Magnetizing current • Tan δ test of HV, LV and Tertiary windings • Sweep Frequency Response Analysis (SFRA) • DGA • Voltage Ratio • Insulation Resistance • Winding resistance
P.	Observations & Analysis	:	

All relays for the Power Transformer were electromechanical type which is obsolete. In the absence of numerical relays, disturbance recording data was not available and amount of fault current could not be determined.

During physical inspection, it was observed that there was no visible sign of bulging of or cracks on the tank and all HV, LV, Tertiary and Neutral bushings were intact.

DTL informed that the service engineer of OEM, M/s EMCO Ltd. visited the site on 08.04.2017 and inspected the failed transformer through top inspection window and side inspection window after oil was drained from the transformer.

Following observations from physical inspection were made by M/s EMCO, as per MOM provided by DTL:

(a) HV & LV winding of Y-phase were found damaged.
(b) Transformer oil was found highly carbonized and consisting of copper particles.
(c) Carbon and copper particles were ingressed in R & B phase windings too.

DGA of oil indicates high concentration of Hydrogen (H_2-1696 ppm), Ethylene (C_2H_4-1934 ppm), Ethane (C_2H_6-194 ppm), Methane (CH_4-721 ppm) and Acetylene (C_2H_2-549.5). Total Dissolved Combustible Gases (TDCG) was 6344 ppm which is higher than normal value. The high concentration of acetylene gas could be due to arcing inside the tank. Values of Roger's ratio (CH_4/H_2 = 0.43, C_2H_2/C_2H_4 = 0.28 and C_2H_4/C_2H_6= 9.97) also suggest high energy

discharge. Due to the generation of these gases, high pressure might have built up, which led to the operation of both PRDs.

Operation of Differential relay (B phase) and PRDs indicates internal fault of the transformer.

Magnetising current of Y-phase HV winding was 740 mA which is much higher than 4.4 mA in R-phase & B-phase of HV winding. Similarly, magnetising current of Y-phase LV winding was immeasurable due to very high current while it was 118 mA in R & B phases of LV winding. The findings suggest fault in Y-phase HV and LV windings.

Magnetic balance test report indicates that negligible voltage was being induced in Y phase windings upon application of 240 V to R phase and B phase windings.

Tan δ value of HV-LV insulation had increased by 0.0048 and of LV-T by 0.0027 as compared to values measured 8 months back, which exceeds permissible limits and indicates deterioration of insulation between HV and LV winding & between LV-T winding.

Y phase HV winding resistance was found to be very high while Y phase LV winding resistance was 11.2% lower than R and B phase LV winding resistance which indicates shorted turns. The same is also corroborate by higher HV to LV Y phase voltage ratios as compared to R & B phase values.

SFRA carried out on transformer after fault is found to be dissimilar (for some configurations) both at lower frequencies (< 1kHz) and at high frequencies (around 100 kHz) from the results of SFRA test conducted on 01.08.2016. The findings of SFRA are found to be inconclusive towards determination of nature of fault.

During excitation current test at 10 kV across YN of HV winding, voltage could not be injected due to fault in Y phase winding.

Disturbance Recorder data was extracted from relay of incomer at Badarpur TPD and the fault current of 3.8 kA (approx.) and 4.2 kA (approx.) in B phase and Y phase respectively was observed. Fault current appeared in B phase 80 ms (approx.) earlier than in Y phase.

Taking into consideration, a) Very high HV Y phase winding resistance, b) low LV Y phase winding resistance, c) higher Y-phase HV and LV magnetising currents, d) abnormal magnetic balance test results and e) tan δ change for HV-LV insulation, there is a higher probability of HV-LV winding insulation failure in Y phase.

8. Failure report of 100 MVA 220/33/11 kV Transformer at Preet Vihar s/s of DTL

A.	Name of Substation	:	Preet Vihar
B.	Utility/Owner of substation	:	DTL
C.	Faulty Equipment	:	Transformer
D.	Rating	:	100MVA, 220/33/11 kV
E.	Make	:	BHEL
F.	Sr. No.	:	2043278
G.	Year of manufacturing	:	2016
H.	Date of commissioning	:	22.03.2017
I.	Date and time of occurrence/discovery of fault	:	12.03.2018
J.	Information received in CEA	:	20.04.18
K.	Fault discovered during	:	operation
L.	Details of previous maintenance	:	Information not provided
M.	Details of previous failure	:	No previous failure
N.	Sequence of events/ Description of fault	:	On 12.03.18, the 100MVA, 220/33/11 kV system Transformer tripped on PRV operation and Buchholz relay while in operation. No other electrical protection operated.
O.	Details of Tests done after failure	:	All tests i.e. Turns Ratio, Resistance, magnetizing current, IR, Capacitance & Tan delta, Sweep Frequency Response Analysis were in order and does not indicate any abnormalities in active part or winding

			assembly. DGA tests were conducted which revealed high amount of hydrocarbon gases.

Oil test Report of main tank bottom after tripping

Oil Parameters Reference Standard: IS-1868-2000					Dissolved Gas Analysis Test Method: IEC 80587			Violation Limits, max as
Parameter	Unit of Measurement	Measured Value	Violation Limit	Test Method	Parameter	Unit	Measured Value	Ref. Standard IEEE-C57.104
Break down Voltage	kV	68.1	50 Min	IS-6792	Total Gas Content	%	5.72	-
Water Content	mg/kg	8	20 Max	IS-13567	Nitrogen (N2)	%	1.32	-
Resistivity @ 90^{0}C	E12 ohm-cm	NT	0.1 Min	IS-6103	Oxygen (O2)	%	0.31	-
Resistivity @ 27^{0}C	E12 ohm-cm	NT		IS-6103	Hydrogen (H2)	µL/L	5345	100
Tan Delta @90^{0}C	-	NT	0.2 Max	IS-6262	Methane (CH4)	µL/L	11855	120
InterFacia Tension@ 27^{0}C	mN/m	NT	15 Min	IS-6104	Ethylene (C2H4)	µL/L	28352	50
Total Acidity	mgKOH /g	NT	0.3 Max	IEC-62021	Ethane (C2H6)	µL/L	2586	65
Flash Point	°C	NT	125 Min	ASTMD-6450	Acetylene (C2H2)	µL/L	1555	1
Sludge Sediments	%	NT	--	IS-1866	Carbon Monoxide(CO)	µL/L	249	350
Appearance		Colorless			Carbon Dioxide (CO2)	µL/L	963	2500

Oil Test Result of OLTC after tripping

Oil Parameters Reference Standard: IS-1868-2000					Dissolved Gas Analysis Test Method: IEC 80587			Violation Limits max as
Parameter	Unit of Measurement	Measured Value	Violation Limit	Test Method	Parameter	Unit	Measured Value	Ref. Std IEEE - C57.104
Break down Voltage	kV	53.9	50 Min	IS-6792	Total Gas Content	%	7.34	-
Water Content	mg/kg	24	20 Max	IS-13567	Nitrogen (N2)	%	5.34	-
Resistivity @ 90^{0}C	E12 ohm-cm	NT	0.1 Min	IS-6103	Oxygen (O2)	%	1.83	-
Resistivity @ 27^{0}C	E12 ohm-cm	NT		IS-6103	Hydrogen (H2)	µL/L	49	100
Ten Delta@90^0 C	-	NT	0.2 Max	IS-6262	Methane (CH4)	µL/L	58	120
Inter-Facia Tension@27^{0}C	mN/m	NT	15 Min	IS-6104	Ethylene (C2H4)	µL/L	123	50
Total Acidity	mgKOH/g	NT	0.3 Max	IEC-62021	Ethane (C2H6)	µL/L	12	65
Flash Point	°C	NT	125 Min	ASTMD-6450	Acetylene (C2H2)	µL/L	7	1
Sludge Sediments	%	NT	--	IS-1866	Carbon Monoxide (CO)	µL/L	159	350
Appearance		Colorless			Carbon Dioxide	µL/L	1244	2500

					(CO2)			

Capacitance & Tan Delta of Windings

Meas.	Test kV	mA	Watts	%PF Corr	Corr. Factor	Cap(pF)
CH	10.00	15.858	0.5540	0.32	0.92	5047.8
CHL(UST)	10.00	56.323	1.379	0.22	0.92	17928.2
CL	10.00	4.407	0.2570	0.53	0.92	1402.7
CLT(UST)	10.00	2.020	0.0520	0.24	0.92	643.03
CT	10.00	47.094	1.177	0.23	0.92	14990.5
CHT(UST)	10.00	23.699	0.6160	0.24	0.92	7543.5

Capacitance & Tam Delta of HV Bushing

Specimen and Connection	Test Mode	Test KV	mA	Watts	%PF	Cap(pF)
220kV R PH Bushing	**UST R**	10.002	1.647	0.0470	0.29	524.39
220 kV Y PH BUSHING	**UST R**	10.002	1.665	0.0480	0.29	529.94
220 kV B PH BUSHING	**UST R**	10.002	1.663	0.0500	0.30	529.23

Exciting Current Tests

		R-N		Y-N		B-N	
LTC	**Test kV**	**mA**	**Watts**	**mA**	**Watts**	**mA**	**Watts**

5	10.00	22.597	185.28	15.084	132.23	22.374	180.28

Insulation Resistance Test: (At 5 kV)

Configuration	**Resistance at 15 seconds (GΩ)**	**Resistance at 60 Seconds (GΩ)**	**Resistance at 600 Seconds (GΩ)**	**PI**
HV-E	5.26	6.51	12.8	1.97
HV-MV	4.01	4.72	16.0	3.39
HV-LV	4.93	13.7	32.4	2.36
MV-LV	18.3	20.0	48.5	2.42
MV-E	5.05	12.9	21.7	1.68
LV-E	4.09	7.90	20.7	2.62

Turn Ratio (H-L) Tests:

	True cap.	**HV Winding**	**LV Winding**
	9665.8	**L-L**	**L-L**
Connections	**H1-N**	**H2-N**	**H3-N**
	L1-N	**L2-N**	**L3-N**

Np Volt	**LTC**	**Np Volt**	**Cal**	**Ratio 1**	**Ratio 2**	**Ratio 3**	**Min Lim**	**Max Lim**
231	1	33	7	7.0012	7.0128	7.1234	6.965	7.035
228.25	2	33	6.917	6.9200	6.9289	7.0373	6.882	6.951
225.50	3	33	6.833	6.8387	6.9568	6.9528	6.799	6.868
222.75	4	33	6.750	6.7565	6.8160	6.8698	6.716	6.784
220	5	33	6.667	6.6748	6.7320	6.7854	6.633	6.700
217.25	6	33	6.583	6.5924	6.5996	6.7007	6.550	6.616
214.50	7	33	6.500	6.5098	6.5655	6.6163	6.468	6.533

211.75	8	33	6.417	6.4272	6.5389	6.5327	6.385	6.449
209	9	33	6.333	6.3445	6.3991	6.4016	6.302	6.365
206.25	10	33	6.250	6.2623	6.3474	6.3624	6.219	6.281
203.50	11	33	6.167	6.1798	6.1865	6.2777	6.136	6.198
200.75	12	33	6.083	6.0971	6.1695	6.1417	6.053	6.114
198.25	13	33	6.008	6.0144	6.1130	6.0601	5.978	6.038
195.25	14	33	5.917	5.9318	5.9372	5.9358	5.887	5.946
192.50	15	33	5.833	5.8488	5.9140	5.8524	5.804	5.863
189.75	16	33	5.750	5.7662	5.8609	5.7696	5.721	5.779
187	17	33	5.667	5.6834	5.7772	5.6834	5.638	5.695

Turn Ratio (H-T) Tests

		True Cap.	**HV Winding**	**LV Winding**
		9664.0	**L-L**	**L-L**
Connections		**H1-N**	**H2-N**	**H3-N**
		TR-TB	**TY-TR**	**TB-TY**

Np volt	**Tap**	**Ns Volt**	**Cal**	**Ratio 1**	**Ratio 2**	**Ratio3**	**Min Lim**	**Max Lim**
231	1	11	12.124	12.1744	12.2345	12.1163	12.064	12.185
228.25	2	11	11.980	11.9752	11.1790	11.9797	11.920	12.040
225.50	3	11	11.836	11.8315	11.0349	11.9323	11.777	11.895
222.75	4	11	11.691	11.8679	11.8868	11.8722	11.633	11.750
220	5	11	11.547	11.7253	11.7396	11.7267	11.489	11.605
217.25	6	11	11.403	11.4016	11.5931	11.5806	11.346	11.460
214.50	7	11	11.258	11.4326	11.4462	11.3414	11.202	11.315
211.75	8	11	11.114	11.1144	11.3003	11.2897	11.058	11.170
209	9	11	10.970	10.9706	11.1529	11.1439	10.915	11.025

206.25	10	11	10.825	10.8268	11.0056	10.9943	10.771	10.879
203.5	11	11	10.681	10.6832	10.8609	10.8499	10.628	10.734
200.75	12	11	10.537	10.5399	10.7152	10.7033	10.484	10.589
198.25	13	11	10.405	10.3959	10.5675	10.5583	10.353	10.457
195.25	14	11	10.248	10.2525	10.4217	10.2590	10.197	10.299
192.5	15	11	10.104	10.1088	10.2743	10.1151	10.053	10.154
189.75	16	11	9.959	9.9639	10.1310	10.0259	9.909	10.009
187	17	11	9.815	9.8191	19.9814	9.8291	9.766	9.864

Turn Ratio (L-T) Tests

	True Cap.	**HV Winding**	**LV Winding**
	9662.6	**L-L**	**L-L**
Connections	**L1 – N**	**L2 – N**	**L3 - N**
	TR – TY	**Y – R**	**B - Y**

Np Volt	**Tap**	**Np Volt**	**Cal**	**Ratio 1**	**Ratio 2**	**Ratio 3**	**Min Lim**	**Max Lim**
33	1	11	1.732	1.7319	1.7319	1.7318	1.723	1.741

Winding Resistance Test at 34 deg. C

HV Winding:

Tap Position	**HV(R-N) (Ω)**	**HV(Y-N) (Ω)**	**HV(B-N) (Ω)**
01	0.4490	0.4509	0.4501
02	0.4435	0.4446	0.4450
03	0.4380	0.4386	0.4391
04	0.4320	0.4335	0.4333
05	0.4265	0.4268	0.4273
06	0.4208	0.4212	0.4221
07	0.4154	0.4160	0.4169

08	0.4093	0.4106	0.4107
09	0.4040	0.4035	0.4032
10	0.4103	0.4106	0.4111
11	0.4159	0.4165	0.4171
12	0.4211	0.4220	0.4227
13	0.4281	0.4275	0.4281
14	0.4327	0.4335	0.4338
15	0.4380	0.4385	0.4391
16	0.4436	0.4449	0.4446
17	0.4499	0.4505	0.4502

LV Winding Resistance (Tap 01):

LV (R – N) (m Ω)	**LV (Y – N) (m Ω)**	**LV (B – N) (m Ω)**
9.432	9.460	9.549

Tertiary Winding Resistance (Tap 01)

Tertiary (R – Y) (m Ω)	**Tertiary (Y - B) (m Ω)**	**Tertiary (B– R) (m Ω)**
5.907	5.890	6.018

P.	Observations & Analysis	:	

The transformer was at no load at the time of failure. Higher concentration of gases i.e. acetylene (1761 ppm), methane (10694 ppm), ethane (2279 ppm), ethylene (30207), hydrogen (>5000ppm) was observed in post-fault DGA, while the DGA test conducted six months prior, i.e. on 22.09.17 was found to be OK. DTL officials also reported that black spots were found inside the tank during inspection through window.

LV tests performed at site were indicative of of thermal fault of high temperature inside the transformer without indication of thermal

decomposition/involvement of cellulose insulation. fault in "U" phase. The overall results indicate possibility of fault in magnetic circuit i.e. core, end frame or core clamping structure. DGA results and LV tests rule out winding involvement and points towards a metallic fault.

The failed transformer was sent to Jhansi works of BHEL for detailed investigation and repair. The transformer was opened in presence of representatives of CEA, PGCIL & DTL in June & July 2018 and following observations were made by the team:

1. No sign of flashover/damage seen over the winding. Top portion of the top yoke was found heated at some places and heating marks observed at centre location. Heating makrs were also noticed at the same location inside the bell-cover. BHEL expressed that the same may happen due to multiple earthing of core through Core belts or core belts earthing strip.

2. Magnetizing current was taken at 220V, single phase supply from HV and LV and the results have been found in order.

	U phase	V Phase	W Phase
HV	3.62mA	2.62mA	3.20mA
LV	68.6mA	41.6mA	55.89mA

3. Top yoke was removed. Burning spots and pits were observed on the bottom side of top yoke. The laminations found damaged due to burning. Just below the burnt yoke portion severe burning were observed on the wooden ring too.

   It appeared that some metallic piece might have remained in the tank, even after commissioning of the transformer. It shorted the yoke, leading to heavy circulating currents flowing in it and the same led to its damage. Continuous local discharge caused gases to generate and subsequent operation of Buchholz and PRV.

9. Failure report of 160 MVA 220/66/11 kV Transformer at Pappankalan-III of DTL

A.	Name of Substation	:	Pappankalan-III
B.	Utility/Owner of substation	:	DTL

C.	Faulty Equipment	:	Power Transformer
D.	Rating	:	160 MVA, 220/66/11 kV
E.	Make	:	BHEL
F.	Sr. No.	:	2043264
G.	Year of manufacturing	:	2016
H	Year of commissioning	:	2018
I	Date and time of occurrence/discovery of fault	:	09.03.2018
J	Information received in CEA	:	24.04.2018
K	Fault discovered during	:	Operation
L	Details of previous maintenance	:	No maintenance as the transformer failed during commissioning
M	Details of previous failure	:	No previous failure
N	Sequence of events/ Description of fault	:	The transformer was kept on no load for 24 hours after the pre-commissioning tests were conducted. After the air purging, tap position was changed off-line. On attempting to charge it again, on 09.03.18, the transformer failed with PRV, Differential and REF operation.
O	Details of Tests done after failure	:	Following tests were conducted:

a) Magnetizing Investigation and Site Results:

Supply on	Voltage	Measurement at	U Phase	V Phase	W Phase	Remarks
IV Side	430 V	Factory	13.68 milliamp	12.15 milliamp	16.4 milliamp	Shorting in U phase winding

		After Failure	65.0 Amp	31.2 milliamp	Not done	assembly/lead takeout

b. Magnetic Balance Test (Supply on HV side)

Winding	Measurement at	Supply	Measured on		Remarks
HV	Factory	1 U-N = 243 V	1V-N=198V	1W-N=46V	Shorting in U phase winding assembly / lead takeout
	After Failure	1 U-N = 241 V	1V-N=**89.2**V	1W-N=**28V**	
	Factory	1 V-N = 243 V	1U-N=143V	1W-N=100V	
	After Failure	1 V-N = 242 V	1U-N **=0V**	1W-N=**242V**	
	Factory	1W-N = 242 V	1U-N=**177V**	1U-N=**66V**	
	After Failure	1W-N = 241 V	**1V-N =241V**	**1U-N=0V**	

Test Result MAIN TANK SAMPLE

Oil Parameters Reference Standard: IS-1800-2000				Dissolved Gas Analysis Test Method: IEC 80587			Violation Limits, max as
Parameter	Unit of Measurement	Measured Value	Violation Limit	Parameter	UoM	Measured Value	Ref. Standard IEEE-C57.104
Break down Voltage	kV	NT	50 Min	Total Gas Content	%	7.85	-
Water Content	mg/kg	NT	20 Max	Nitrogen (N2)	%	5.69	-
Resistivity @ 90^{0}C	E12ohm-cm	NT	0.1 Min	Oxygen (O2)	%	1.95	-
Resistivity @ 27^{0}C	E12ohm-cm	NT		Hydrogen (H2)	µL/L	298	100
Ten Delta@90^0 C	-	NT	0.2 Max	Methane (CH4)	µL/L	248	120

interfacial Tension@ 27^{0}C	mN/m	NT	15 Min	Ethylene C2H4)	µL/L	304	50
Total Acidity	mgKOH/g	NT	0.3 Max	Ethane (C2H6)	µL/L	22	65
Flash Point	°C	NT	125 Min	Acetylene (C2H2)	µL/L	208.1	1
Studge Sediments	%	NT	--	Carbon Monoxide (CO)	µL/L	658	350
Appearance		Colorless		Carbon Dioxide (CO2)	µL/L	288	2500
BDV Not Tested							
** STL REMARKS: DGA results show abnormal amount of fault gases levels, H2-298ppm, CH4-248ppm, C2H4-304ppm, C2H6-22ppm, C2H2-208.1ppm							

Test Result OLTC SAMPLE

Oil Parameters Reference Standard: IS-1800-2000				Dissolved Gas Analysis Test Method: IEC 80587			Violation Limits, max as
Parameter	Unit of Measurement	Measured Value	Violation Limit	Parameter	UoM	Measured Value	Ref. Standard IEEE-C57.104
Break down Voltage	kV	NT	50 Min	Total Gas Content	%	7.40	-
Water Content	mg/kg	NT	20 Max	Nitrogen (N2)	%	5.29	-
Resistivity @ 90^{0}C	E12ohm-cm	NT	0.1 Min	Oxygen (O2)	%	2.01	-
Resistivity @ 27^{0}C	E12ohm-cm	NT		Hydrogen(H2)	µL/L	147	100

Tan Delta@90^0 C	-	NT	0.2 Max	Methane(CH4)	µL/L	53	120
interfacial Tension@ 27^{0}C	mN/m	NT	15 Min	Ethylene(C2 H4)	µL/L	77	50
Total Acidity	mgKOH /g	NT	0.3 Max	Ethane (C2H6)	µL/L	4	65
Flash Point	°C	NT	125 Min	Acetylene (C2H2)	µL/L	133.7	1
Sludge Sediments	%	NT	--	Carbon Monoxide (CO)	µL/L	49	350
Appearance		Colorle ss		Carbon Dioxide (CO2)	µL/L	540	2500
BDV Not Tested							
STL REMARKS: H2 and C2H2 Violating norms:DGA results shows abnormal amount of (C2H2 : 133.7 ppm, H2-147ppm) gases.							

Insulation Resistance Measurement

Across Winding	Applied Voltage	Measured Value			
		15 Sec (G Ω)	60 Sec (G Ω)	600 Sec (G Ω)	PI
HV to Earth	5 kV	1.01	1.63	3.92	2.40
IV to Earth	5 kV	1.06	1.77	2.9	1.63
HV to IV	5 kV	0 Ω			
HV to LV	5 kV	1.07	2.31	6.66	2.88
IV to LV	5 kV	1.17	2.85	5.64	1.97

Measurement of Winding Resistance (In mΩ)

A) High Voltage Side

Top position	Winding Resistance in m ohm			Resistance At 75° C		
	1R-1N	1Y-1N	1B-1N	1R-1N	1Y-1N	1B-1N
1	224.1	241.4	242.6	252.6	272.1	273.4
2	221.9	238.1	239.3	250.1	268.4	269.7
3	222	234.9	236	250.2	264.7	266.0
4	221.9	231.3	232.5	250.1	260.7	262.0
5	222	228.2	229.3	250.2	257.2	258.4
6	221.2	225	226.2	249.3	253.6	254.9
7	219.9	221.6	222.6	247.8	249.8	250.9
8	217.7	218.3	219.5	245.4	246.0	247.4
9b	214.8	214.3	215.1	242.1	241.5	242.4
10	216.3	218.3	219.3	243.8	246.0	247.2
11	217.3	221.5	222.4	244.9	249.6	250.7
12	217	224.9	226	244.6	253.5	254.7
13	218	228.3	229.1	245.7	257.3	258.2
14	218.1	231.3	232.3	245.8	260.7	261.8
15	217.5	235	235.8	245.1	264.9	265.8
16	219.4	238.1	239.1	247.3	268.4	269.5
17	222.2	241.7	242.2	250.4	272.4	273.0

B) Intermediate Voltage Side

Between Windings	Resistance	Resistance
	Site Value @ 40° C	Site Value @ 75° C
2R1-N	26.43	29.7
2Y1-N	22.83	25.7
2B1-N	23.02	25.9

C) Low Voltage Side

Between Windings	Resistance	Resistance
	Site Value@ 40°C	Site Value @ 75°C
3 R1-3B1	5.449	6.14
3 Y1-3R1	4.273	4.81
3 B1-3Y1	5.023	5.66

Q	Observations & Analysis	:	

LV tests performed at site were indicative of fault in "U" phase. The oil sample indicated presence of fault gases. Transformer was opened at site and small carbon soot were found on the top of top ring assembly. The failed transformer was sent to Jhansi works of BHEL for detailed investigation and repair. The transformer was opened in presence of representatives of CEA, PGCIL & DTL in June & July 2018 and following observations were made by the team:

1. No sign of flashover/damage could be seen. 3 tapping busbars of copper of "U" phase was found inward bent. It is apprehended that the same may be due to force of attraction between the busbar due to circulating current.

2. The tap-changer diverter was separated and magnetizing current was taken between winding ends such that tapping lead and tap-changer were not in circuit. Magnetizing current at 220V single phase supply was measured as below:-

	U phase	V Phase	W Phase
HV	2.38Amp	5.5mA	3.84mA
IV	5.03Amps(20V)	9.81mA	7.60mA

   From the above results, it is clear that "U" phase is affected which is indicative of problem inside the winding.

3. To further analyze, it was decided to take out the outer pressboard barrier covering of "U" phase to see outermost winding (HV) condition. After removal of pressboard barriers, outermost winding (HV) was visible. No sign of damage could be noticed.

4. All the coils of the "U" phase were taken out of leg. HV coil was found intact. IV coil (66 kV) was found carbonized, burnt and damaged at approximately 500 mm from bottom of coil. Tapping coil was also found damaged at same location as in case of IV.

5. Coil assemblies of other two phases were found intact.

From the LV tests conducted and internal inspection at works indicate that there was insulation failure between "U" phase IV winding and tap winding. Zero IR value between HV & IV also corroborate the same. Transformer had failed after tap changing operation, it appears that fault developed in tap changer leads of "U" phase which further spread to "U" phase IV winding. Manufacturing defect can not be ruled out in this case.

10. Failure of 220/132kV, 100MVA Auto Transformer-III of Bhadrak Substation of OPTCL

A	Name of Substation	:	Bhadrak
B	Utility/Owner of substation	:	Odisha Power Transmission Co-operation Ltd.
C	Faulty Equipment	:	Auto Transformer –III
D	Rating	:	100 MVA, 220/132/33kV
E	Make	:	CGL
F	Sr. No.	:	T8537/2
G	Year of manufacturing	:	1996
H	Year of commissioning	:	2015 (23.06.15) at Bhadrak. Originally, brought from 220/132/33 kV Grid S/S Bhanjanagar. Date of Commissioning at Bhanjanagar - 24.09.1997
I	Date and time of occurrence/discovery of fault	:	31.05.2017 at 17:45 hrs.
J	Information received in CEA	:	19.02.2018
K	Fault discovered during	:	Idle charge/ Operation
L	Present condition of equipment	:	Replaced
M	Details of previous maintenance	:	

Transformer shifted from Bhanjanagar Grid S/s during the year 2014-15. Routine maintenance activities required during installation & pre-commissioning tests were carried out. Test results were normal. The transformer was charged on 01.03.2015 but the transformer tripped on Buchholz relay. Since all test results were OK prior to charging, it necessitated

a visual inspection to find out the fault. On visual inspection it was found that, there was flashover mark and disconnection of the lead connected to the Y-phase bushing of tertiary. Necessary rectification work was done. All tests were conducted. Transformer was charged and put in to service on 23.06.2015.

220kV Y-phase bushing detected of high tan-delta value on dated 20.01.2017 during routine condition monitoring. Transformer was kept under shutdown for replacement of the bushing. One new bushing was arranged and replaced on 28.04.2017 & oil reconditioning done as usual procedure. Necessary tests on transformers were conducted again before charging of the transformer. The test results were found to be normal.

The transformer was idle charged at 1651 hrs. on 31.05.2017.

N	Details of previous failure	:	As described above
O	Sequence of events/ Description of failure	:	100 MVA Auto transformer–III was idle charged on dated 31.05.2017 at 1651 hrs. The charging parameters were normal. During idle charged condition at 1745 hrs. on dated 31.05.2017, the transformer tripped on Buchholz, PRV & high set over current & Earth fault and bushing burst. Also the transformer caught fire and was completely burnt.
P	Details of Tests done after failure	:	Tests could not be carried out as transformer had burnt.
Q	Observation and Analysis	:	From the fault data it is observed that current in Y-phase after fault was 6.5 kA. It appears that there was already some problem in Y-phase winding which could not be detected in LV tests but the winding could not withstand voltage stress developed on application of power frequency voltage and turned into a phase to earth fault. Due to this fault gases were generated into the oil and pressure of the tank rose leading to operation of buchholz and PRV. Excessive pressure caused rupture of bushing leading to fire.

11. Failure of 160 MVA 220/132/33 kV Auto Transformer-1 & 2 at New Bolangir s/s of OPTCL

A.	Name of Substation	:	New Bolangir
B.	Utility/Owner of substation	:	OPTCL
C.	Faulty Equipment	:	Auto Transformer
D	Rating	:	160 MVA, 220/132/33 kV
E.	Make	:	BHEL
F.	Serial No.	:	2035209 (AT-1) 2035208 (AT-2)
G	Year of manufacturing	:	2013
H	Year of commissioning	:	2014
I.	Date and time of occurrence/discovery of fault	:	09.02.17 at 1358 hrs
J.	Information received in CEA		07.04.2017
K.	Fault discovered during (operation/maintenance)	:	Operation
L.	Details of previous maintenance	:	AT-2:Last maintenance done on 28.12.16 with functional checks and conditional monitoring tests. Details of the tests were not furnished.
M	Details of previous failure	:	No previous failure
N.	Sequence of events/Description of fault	:	On 09.02.17 at 1358 hrs., the 160MVA, 220/132KV Auto transformer-1 tripped with differential, REF & Buchholz relay operation. Simultaneously 160MVA, 220/132KV Auto Transformer-2 tripped on Main Tank PRD. 132 kV Y-Phase bushing failure was observed in

			Autotransformer-1. The same was replaced and Autotransformer-1 was taken back to service on 20.03.2017 at 17:30hrs. Auto transformer-2 was sent to factory site for investigation and repair.
O	Details of Tests done after failure	:	

TEST REPORT OF 160MVA Auto Transformer- 02 at 220/132/33KV Grid S/S Sadeipali, Bolangir on dated 22.02.2017

1. OPEN CIRCUIT TEST

Tap No.	Voltage applied on HV side in Volts			HV Current in mA			
	rn	yn	bn	R	Y	B	N
1(Min)	122	116	125	13	67	12	77.7
9(N)	134	131	135	18.2	785	18.6	86.6
17(Max)	150	151	156	22	98.7	24	100

Remark: High and abnormal magnetising current in Y phase.

2. SHORT CIRCUIT TEST

Tap No.	**RY**	**YB**	**RB**	**HV Current measured in Amp**				**LV Current measured in Amp**			
				R	**Y**	**B**	**N**	**r**	**y**	**b**	**n**
1(Min)	382	386	388	7	6	7	0	13.1	12.4	13.1	0
9(N)	390	392	393	7.0	6.7	7.0	0	11.1	11.6	11.5	0
17(Max)	388	391	390	6.6	6.4	6.5	0	10.1	9	9	0

3. TTR TEST

TAP No.	RN-rn	YN-yn	BN-bn
1	1.8212	1.8740	1.8320
2	1.8080	1.8545	1.8105
3	1.7873	1.8329	1.7901
4	1.7665	1.8115	1.7691
5	1.7461	1.7896	1.7489
6	1.7260	1.7681	1.7285
7	1.7053	1.7470	1.7079
8	1.6847	1.7251	1.6872

9(N)	1.6642	1.7038	1.6666
10	1.6432	1.6821	1.6459
11	1.6231	1.6607	1.6255
12	1.6024	1.6390	1.6054
13	1.5821	1.6178	1.5849
14	1.5616	1.5960	1.5640
15	1.5409	1.5752	1.5434
16	1.5205	1.5534	1.5232
17	1.500	1.5320	1.5027

4. MAGNETIC BALANCE TEST

Tap no.	Applied voltage in Phase	Voltage on HV Side in Volts			Voltage Measured on LV side in Volts		
		RN	YN	BN	rn	yn	bn
1(Min)	RN	224.5	2.9	221.8	122.7	1.4	121.1
	YN	106	222.2	113.5	60.4	118.3	62.6
	BN	223	2.7	225.7	122	1.7	123.1
9(N)	RN	224.7	2.9	220.6	134	1.5	132
	YN	112.8	220	111.7	66.2	129.2	68.9
	BN	221.6	2.9	224.1	133.0	1.8	134.6
17(Max)	RN	225	2.8	221.9	150	1.6	148
	YN	113	223	114	75	145	87
	BN	224.4	2.71	227.1	149.6	1.98	151.4

5. Winding Resistance (Tap No.-15).

	LEAD	R PHASE (m ohm)	Y PHASE (m ohm)	B PHASE (m ohm)
IV Winding	NEUTRAL	315.7	371	315.6
TAPPING	4-12	41.75	41.74	41.69
HV WINDING	3-1	198.04	196.07	195.91

P. Observation & Analysis :

Findings in physical internal observation:-

1. Copper dust found inside transformer near Y-Phase winding.
2. Carbon sludge formation found at the bottom of tank.
3. Small metallic balls formation found on the bottom press of Y phase.
4. Paper insulation found burnt in lead no.12 of Y phase near to coil.

During the site visit by OEM, following points were noted:

1. Both the Transformers viz. AT-1 and AT-2 are connected in parallel for delivering load at Bolangir S/S.
2. In transformer Sl. No.2035209 (AT-1) the IV side 132kV 'Y' Phase bushing failed while in service on dated 09.02.2017 because of dielectric failure.
3. OPTCL informed that the transformers had cleared the fault with following relay operation.
   AT-1:
   (i) Numerical Differential Relay (RET-316)
   (ii) Restricted Earth Fault Relay.
   (iii) Buchholz Trip.
   AT-2:
   (i) PRV Trip.
4. The probability of feeding fault to AT-1 from the transformer AT-2 couldn't be established.
5. It is apprehended that inter turn fault of the IV winding of AT-2 has occurred after/during the failure of 'Y' Phase IV bushing of AT-1.
6. The transformer AT-2 cannot be repaired at site and needs to be sent to BHEL, Jhansi works for taking up rectification work.

Though inter turn fault in Y phase of IV winding seems to be the cause of failure of AT-2, exact cause can only be established after detailed inspection at the works.

12. Failure of 50 MVA, 220/110/11 kV Auto-transformer at Sirsi s/s of KPTCL

A	Name of Substation	:	Esale, Sirsi
B	Utility/Owner of substation	:	KPTCL
C	Faulty Equipment	:	Auto-Transformer
D	Rating	:	50 MVA, 220/110/11 kV
E	Make	:	Kirloskar
F	Sr. No.	:	77220-001/1
G	Year of manufacturing	:	1981

H	Year of commissioning	:	1982 (Belagavi s/s) 2008 (Sirsi s/s) *From 1998 to 2008 transformer was lying in 220kV Belagavi s/s, after reconditioning it was shifted to 220kV Sirsi s/s.
I	Date and time of occurrence/discovery of fault	:	15.07.2017 at 02:10 hrs.
J	Information received in CEA	:	20.11.17
K	Fault discovered during	:	Operation
L	Details of previous maintenance	:	Last maintenance was carried out on 06.06.17 (Bushings were cleaned, tightness of the clamps was checked and found OK, Associated Relays were tested and checked).
M	Details of previous failure	:	Information not available
N	Sequence of events/ Description of fault	:	Power transformer tripped on 15.07.17 at 0210 hrs. on Differential (R and B phases) and Buchholz alarm.
O	Details of Tests done after failure	:	

Following tests are carried out on 15.07.2017

1. Tertiary side resistance		
3U-3V	3V-3W	3W-3U
28 m ohms	23 m ohms	13.4 m ohms

2. Open circuit test (volts)

TAP	**1U**	**1V-N**	**1W-N**	**2u-n**	**2v-n**	**2w-n**	**3u-3v**	**3v-3w**	**3w-3u**
4	242	246	243	118	117	108	20	20	17
5	241	244	242	119	118	110	20	20	17
6	243	245	242	120	120	111	20	20	17

3. Open Circuit Current (3ph voltage applied on 220kV side)

1U	1V	1W
134 mA	130 mA	**0.24 A**

4. Short Circuit Test (Amps)

TAP	1U	1V	1W	3u	3v	3w
4	1.13	1.12	1.17	22.4	22.5	22.7
5	1.14	1.14	1.19	22.6	22.8	22.7
6	1.16	1.16	1.21	22.8	22.3	22.8

5. Magnetic Balance Test (Volts)

1U-N	1V-N	1W-N	2u-n	2v-n	2w-n	3u-3v	3v-3w	3w-3u
212	209	0.5	105	105	0.22	18	18	0.04
222	225	5.0	110	109	2.14	36	36	0.3
223	233	5.0	111	113	2.1	37	37	0.3

6. IR Values with 5kV Megger at avg 38 deg. C

Connection	
N-T	125 M- ohm
N-G	100 M - ohm
T-G	**Zero**

7. 110kV side excitation test.

2u-n	2v-n	2w-n	Current
417	420	0.9	4.9 mA
422	**419**	0.95	4.9 mA

	61	336	**423**	**2.7 Amps**

P	Observations & Analysis	:	

While carrying out tertiary excitation test, heavy arcing/ spark occurred.

Differential (R, B) and Buchholz alarm relays operated. Gas was observed in Buchholz relay

Tertiary winding was grounded.

Winding resistance and IR test indicate that tertiary is shorted. However, no pre-failure test values of the test done during maintenance are available which might have helped assess the health of the transformer prior to failure.

The transformer has already served successfully for 35 years. It is possible that ageing had led to deterioration of the insulation in the windings. Presence of gases in Buchholz could be an indication of incipient fault. These factors might have eventually led to failure.

13. Failure of 100 MVA Power Transformer at Bidnal Substation of KPTCL

A	Name of Substation	:	220kV R/S Bindal
B	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Ltd.
C	Faulty Equipment	:	Power Transformer
D	Rating	:	100MVA, 220/110kV
E	Make	:	T & R
F	Sr. No.	:	PMO 100075
G	Year of manufacturing	:	2012
H	Year of commissioning	:	2013(14.08.2013)

I	Date and time of occurrence/discovery of fault	:	15.11.2016 at 1451 hrs.
J	Information received in CEA	:	09.01.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	To be repaired by OEM
M	Details of previous maintenance	:	Last quarterly maintenance was carried out on 21.06.2016 which included the following activities: 1.Checking of transformer Alarm Circuits/Trip circuit 2. Checking of Bushing Oil Level and earthing cap of capacitor bushing for tightness 3. Air release in Main Tanks, Buchholz Relays, Bushing turret etc. 4. Pressure checked in Nitrogen Injection fire protection system.
N	Details of previous failure	:	Nil
O	Sequence of events/ Description of fault	:	On 15.11.2016 at 1451 hrs., 110kV Bidnal-PHC line tripped on distance protection relay (L-2.2km, Y-Phase). 100MVA Power transformer-2 tripped on differential protection relay(Y-Phase) and Buchholz alarm indication was observed. On detailed inspection one winding was found open.
P	Details of Tests done after failure	:	Following tests were conducted 1. Open circuit test 2. Short circuit test 3. Measuring IR values. However, no test reports were furnished to CEA.
Q	Observations & Analysis	:	In the absence of test reports, it is not possible to ascertain the cause of failure. However, as

			the winding was found open, it appears that during fault on Bidnal-PHC line, due to transient some fault developed on Y-phase winding.

14. Failure report of 292.4 MVA 16.5/420 kV Station GT#2 at PPS-III, Bawana Substation of PPCL

A.	Name of Substation	:	PPS-III, Bawana
B.	Utility/Owner of substation	:	Pragati Power Corporation Ltd.
C.	Faulty Equipment	:	Generator Transformer of Steam Turbine#2
D.	Rating	:	292.4 MVA, 16.5/420 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	:	08.10.2017 at 00.09 hrs.
J	Information received in CEA	:	September 2018
K	Fault discovered during	:	Operation
L	Details of previous maintenance	:	No information provided
M	Details of previous failure	:	
On 06.09.17 at 1530 hrs, the unit was running at about 178 MW and Buchholz relay operated. DGA suggested presence of acetylene (5ppm) in transformer oil. Subsequently, three more samples were taken and C_2H_2 was found to be increasing (23.9 ppm in last sample). Transformer was inspected internally at site by OEM, in which wall shunt assembly was found loose and insulation damage was observed on HV line lead			

insulation. No other abnormality was found during physical inspection inside the transformer.

After rectification of the problem at site, transformer was re-commissioned on 28.09.17.

N	Sequence of events/ Description of fault	:	On 08.10.2017 at 00.09 hrs, the load was increased to 220 MW, after which transformer tripped on differential, buchholz and PRV operation. No fire incident occurred.
O	Details of Tests done after failure	:	

Low voltage tests and DGA analysis carried out on 08.10.17. Result of the same indicated the probability of fault in B phase LV winding.

1. **IR Value: -**

Testing of transformer at Temp: - OTI -35^{0}C, WTI (HV) – 35^{0}C, WTI (LV) – 36^{0}C Ambient – 34^{0}C

With Megger (MIT525) at 5 kV

Winding	IR 15	IR 60	IR 600	PI
HV - E	1.79 G Ω	4.59 G Ω	13.13 G Ω	2.86
LV - E	545.00 M Ω	505.00 M Ω	448.00 M Ω	0.88
HV - LV	2.73 G Ω	6.89 G Ω	14.88 G Ω	2.16

Description	IR 15	IR 60	Absorption Coefficient
Core-Yoke	537.00 M Ω	808.00 M Ω	1.50
Core –tank	1.10 G Ω	2.9 G Ω	1.90
Yoke – tank	1.56 G Ω	3.01 G Ω	1.93

2. **Magnetizing Current: -** Three Phase 415 Volt applied at HV

Tap Position	R Phase (in mA)	Y Phase (in mA)	B Phase (in mA)
1	1.91	1.28	2.04

2	2.30	1.26	2.20
3	2.15	1.36	2.22
4	2.16	1.24	2.20
5	2.12	1.30	2.26

3. **Magnetic Balance (HV Side):** - Single phase voltage applied at R-N

RN = 251.30 V	YN = 128.70 V	BN = 7.20 V

Single phase voltage applied at Y-N

RN = 121.60 V	YN = 251.10 V	BN = 118.20 V

Single phase voltage applied at B-N

RN = 7.00 V	YN = 128.20 V	BN = 250.60 V

4. **Voltage Ratio: -**

Tap No.	Voltage Applied (HV) (in Volts)			Measured Voltage (LV) (in Volts)		
	RY	YB	BR	ry	yb	br
1	436	435	436	14.5	14.6	15.7
2	436	435	436	14.9	15.3	16.3
3	436	435	436	15.3	15.7	16.8
4	436	435	436	15.8	16.2	17.2
5	436	435	436	16.5	17.1	17.8

5. **Winding Resistance:** -

HV Side:

Tap Position	R - N (in m Ω)	Y- N (in m Ω)	B – N (in m Ω)
1	462.2	462.6	461.9
2	453.6	454.2	453.1
3	444.9	445.5	444.4
4	436.6	437.4	436.0
5	427.9	428.8	427.2

LV Side: -

r – y (in m Ω)	y – b (in m Ω)	b – r (in m Ω)
1.51	3.04	1.53

6. **Capacitance, dissipation Factor (Tan Delta) and Dielectric loss: -**

Description	Effective Capacitance Measured	Capacitance (pF)	Dissipation Factor	Dielectric Loss (W)
HV – LV (UST MODE)	C_{HL}	17438	3.22%	18.69
HV – LV (GST-G MODE)	C_H	5715	0.25%	0.58
HV – LV (GST-Y+G MODE)	$C_{HL}+C_H$	23310	2.67%	22.70
LV – HV (UST MODE)	C_{HL}	17564	3.62%	22.60
LV – HV (GST-G MODE)	C_L	26575	1.56%	14.60
LV – HV (GST-Y+G MODE)	$C_{HL}+C_L$	44125	2.43%	36.80
R-Phase (bushing)	---	543.00	0.28%	0.056
Y-Phase (bushing)	---	539.10	0.31%	0.062
B-Phase (bushing)	---	552.50	0.32%	0.064

7. **Transformer oil Test Results: -**

DGA, BVD and Moisture content result of 292.4 MVA, 16.5/420 kV Generator transformer of STG#2	
Sample taken From	Transformer Bottom Flange
Hydrogen – H_2	2811 PPM
Carbon Di-oxide-CO_2	476 PPM
Carbon Monoxide-CO	920 PPM
Ethylene-C_2H_4	1091 PPM
Ethane- C_2H_6	14 PPM
Methane-CH_4	609 PPM
Acetelene-C_2H_2	486.6 PPM
Total Dissolved combustible gases	5932
Break Down Voltage (BDV)	55.5 kV
Water Content – H_2O	6.48 ppm

Transformer was dispatched to BHEL Bhopal works for inspection, analysis and repair.			
P	Observations	:	Observations by OEM are as below:
'B' phase: carbon particle, burnt insulation debris and copper globules were observed on tank surface and over winding assembly. 'R' and 'Y' Phase: Coil assembly, tapping leads, tap changer, terminal leads, pressboards barriers/rings and other insulations were physically intact. Carbonization and traces of copper globules were found. Tap changer and Tapping leads of all phases were physically intact; however, healthiness of the tap changer is to be checked and ensured. B Phase coil barriers were removed in sequence till HV winding. HV winding was found intact. No blackening/burning marks were observed. Immediate press board barrier over LV phase winding was found to be burnt/damaged. LV winding found heavily damaged. Copper conductors found heavily melted at top 14 & bottom 14 discs from center. Copper globules were also observed in various parts of the winding. The analysis made by OEM indicates that the presence of foreign particle might have damaged the conductor insulation and resulted into inter-turn fault and further damage. Air might have ingressed at the suction point (gasket joints) of pump, which might have entered into the LV winding leading to discharges resulting into inter-turn fault and the failure of GT.			

15. Failure of 315 MVA 400/220/33 kV Transformer at Bina substation of MPPTCL

A.	Name of Substation	:	Bina
B.	Utility/Owner of substation	:	MPPTCL
C.	Faulty Equipment	:	Auto Transformer
D.	Rating	:	315 MVA, 400/220/33 kV
E.	Make	:	BHEL Bhopal

F.	Sr. No.	:	6005210
G.	Year of manufacturing	:	1993
H	Year of commissioning	:	1994 [23.03.1994 (1st comm.)] 2017 (2nd comm)
I	Date and time of occurrence/discovery of fault	:	15.01.2018 at 1329 hrs
J	Information received in CEA	:	22.02.19
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. On Dtd. 15.01.2018 at 13.29 Hrs. transformer tripped with loud sound on differential high set A-PH. REF protection operated, OSR tripped (OLTC), main Buchholz trip and PRV trip indication. Transformer NIFPS system operated but not effective due to explosion in R-ph OLTC Compartment.

2. Transformer caught fire and 1 No. 400 kV Bushings, 2 No. 220 kV Bushings and 3 Nos. 33 kV Bushings shattered one by one in fire. There was no other tripping in the event. Other element including two transmission lines at this S/S remain in service and no supply interruption took place.

3. The DR records are as under: -

HV Side R PH 2962 A Y PH-205 A B PH 583 A

MV Side R PH-24452 A Y PH-1212 A B PH 219.6 A

Fault clearing time 61 msec (13:29:07:461-13:29:07:522)

4. All protection operated in time and correctly.

5. Fire was Extinguished by foam type fire tender called from Bina oil refinery. The fire was quenched within 2 ½ Hrs.			
O	Details of Tests done after failure	:	Tests were not possible as the transformer caught fire
P	Observations & Analysis	:	
Lower portion insulation and condenser portion of 400kV R-ph and 220 kV R-ph and Y-ph bushings were intact. Upper portion porcelain found damaged/burst due to fire developed on outer periphery of transformer. The tank was bulged towards 220 kV side and tertiary side. Stiffners provided on tank between R and Y phases had cracks on joints. The R-ph OLTC top plate was found shattered and OLTC buchholz relay found blown out of tank. The barrier boards, winding tap changer, all other solid insulation also damaged. Flash over marks on bottom of the tank near R ph were observed. The cause of explosion of R ph OLTC cover was due to breaking of OLTC cylinder assembly resulting 220 kV R-ph to ground fault at the bottom of main tank. This is confirmed from magnitude of fault current i.e. approx. 30kA recorded in DR and physical observation of flash over marks inside tank with leads connected to selector switch.			

16. Failure of 315 MVA, 400/220/33 kV Auto-Transformer at Bina substation of MPPTCL.

A.	Name of Substation	:	Bina
B.	Utility/Owner of substation	:	MPPTCL
C.	Faulty Equipment	:	Auto-Transformer
D.	Rating	:	315 MVA, 400/220/33 kV

E.	Make	:	BHEL Bhopal
F.	Serial No.	:	6005211
G.	Year of manufacturing	:	1993
H.	Year of commissioning	:	1995 (25.01.1995)
I.	Date and time of occurrence/discovery of fault	:	14.02.18
J.	Information received in CEA	:	07.03.19
K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	Regular testing of oil parameters done on quarterly basis. Routine testing and maintenance done during pre-monsoon and post-monsoon maintenance.
M.	Details of previous failure	:	Details not provided
N.	Sequence of events/Description of fault	:	On dated 14.02.2018 at 0144 Hrs., 220kV Interconnector ckt. II tripped from both ends on line fault with indication at 400 kV SS Bina R-ph, Zone-1, at a distance of 7.4 km. After 346 msec. 315 MVA AT tripped on differential and Buchholz. The DR record is as under: HV side: R PH – 2146 A Y PH-177A B PH-615A N-1357A IV side: R PH – 4399A Y PH-224A BPH-614A N-3982A Fault clearing time 140 msec.

O.	Details of Tests done after failure	:	LV test results: 1. Magnetizing current values were raised 1.5 times in R-ph and 2 times in B-ph. 2. No change in IR value of winding. 3. Higher TAN delta of winding from previous value. 4. Variation in winding resistance of HV/IV. 5. Variation in magnetic balance voltage.(Imbalance) 6. High concentration of gases in DGA.
P.	Observation & Analysis	:	

R-ph winding top pressing ring/yoke shunt piece was found lying at the bottom of the tank near tertiary side.
R-ph packing of winding top pressing ring/yoke shunt packing was loose around the periphery of winding towards HV and IV side. It reflects that ICT encountered heavy jerk during fault.
Some heat marks/ discoloration patches were observed in the R-ph limb near IV side.
Few supports of Y-ph winding top pressing ring/yoke shunt packing were also found loose on HV side.
All winding supports were found perfectly intact in B ph near HV side.

No flash over marks observed in Bushing, turret and HV winding of all three phases.

Insulation failure in R-ph HV winding during interconnector line fault feeding could be the cause of failure.

Reactors

17. Failure of 80 MVAR, 400 kV Reactor at Vizag Substation of PGCIL

A.	Name of Substation	:	Vizag
B.	Utility/Owner of substation	:	Power Grid Corporation of India Ltd.
C.	Faulty Equipment	:	Shunt Reactor
D.	Rating	:	80 MVAR, 400 kV
E.	Make	:	CGL
F.	Sr. No.	:	T8975/2
G.	Year of manufacturing	:	Information not provided
H.	Year of commissioning	:	2005 (01.03.2005)
I.	Date and time of occurrence/discovery of fault	:	28.04.2017 at 0907 hrs
J.	Information received in CEA	:	2.01.2018
K.	Fault discovered during	:	Operation
L.	Present condition of equipment	:	Repaired by replacing the bushing and the bakelite sheet of turret CT connected in Y-ph.
M.	Details of previous maintenance	:	Information not provided
N.	Details of previous failure	:	Information not provided
O.	Sequence of events/ Description of failure	:	

The auxiliary supply of both Pole-1 and Pole 2 of HVDC Vizag is fed through the 400 kV, 315 MVA ICT-2. The auxiliary supply failed at 0844 hrs. Y-Ph fuse of 33 kV tertiary was found blown. Pole 2 auxiliary supply auto changeover to DG set was successful but the same was unsuccessful in Pole-1 resulting in tripping of the Pole-1 at 0844 Hrs. Meanwhile at 0907 Hrs. Pole-2 tripped on activation of Pole Y block activation –WA1 Protective Y-Block Executed. This protection gets activated in case of any major fault in AC side. It was further found that Pole 2 East Shunt Reactor (80 MVAR, CGL make) had tripped due to operation of differential and PRD protection. Further, heavy oil leakage was observed from the Y-ph bushing of the shunt reactor.

Brief Record of Events

Pole	Date	Time	Event
Pole-1	2017-04-28	08:44:21:317	Pole-1 de-energize
Pole-2	2017-04-28	09:02:17:873	W2B Overvoltage Protection WA2-W1 Over Voltage Level 1 Alarm
Pole-2	2017-04-28	09:07:30:390	P2B Block Sequences WA1 Protective Y-Block Executed
Pole-2	2017-04-28	09:07:30:411	P2B Block Sequences WA2 Protective Y-Block Executed Pole Blocked
Pole-2	2017-04-28	09:07:30:435	W2B Shunt Reactor WA2 Differential current phase L2 Trip

Pole 2 tripped on initiation of protective Y Block due to sustained voltage fluctuations which started from 0902 Hrs. as per the event longer. The Shunt Reactor tripped at 09:07:30:435 on initiation of differential protection (Y-Phase). The fault current in Y Phase as per the DR record was to the tune of

785 A and the voltage went upto 626.46 kV during the same instance. Continuous overvoltage had been observed along with dominant presence of second harmonics prior to failure.

P.	Details of Tests done after failure	:	

Magnetizing Current measurements and winding resistance measurements were carried out.

Magnetizing Current Readings			**Winding Resistance Measurement**		
R-ph	**Y-ph**	**B-ph**	**R-ph**	**Y-ph**	**B-ph**
120.7 mA	120 mA	120.3 mA	2.233 Ω	2.232 Ω	2.232 Ω

The test results were found to be normal.
Subsequently, DGA of the reactor oil sample was carried out to look for any fault generation in the reactor.

DGA:

S.no.	Date	H2	CH4	C2H6	C2H4	C2H2	CO	CO2
1	28.4.17	53	19	4	20	6.4	300	3671
2	18.4.17	27	18	5	18	0.9	375	3904
3	27.2.17	7	3	12	2	0.4	231	1911
4	06.12.16	24	7	0	7	0	315	4539

No significant gases were generated post failure. The rise in acetylene may be attributed to broken insulator from the bushing.

Also, no abnormalities were observed in core/winding during internal inspection.

Q.	Observations & Analysis	:	

(i) Porcelain Insulator was found to be detached from the middle of the Y-Phases Bushing of the reactor and scattered near the ground. Oil was also observed to be flowing out of the inspection cover at the bottom of the turret. The inspection turret was deformed and had attained concave shape facing inwards.
(ii) Cracks were observed on the metal flange joints.

(iii) No flashover marks on paper insulation
(iv) Single point flashover mark on the inside body of the turret.
(v) Corona shield also contained flashover marks and was found to be damaged with broken connecting points
(vi) Oil end porcelain dome of Y-ph bushing was broken and was found scattered on the bottom inside the Reactor main tank
(vii) REF did not operate during the tripping
(viii) Dominant 2nd harmonics were present in the system prior to fault.

Higher second harmonic component in the Eastern bus may have caused vibration in the reactor resulting in the stress in the bushing. Due to high stress, it is likely that flashover occurred between turret body and corona shield leading to shattering of oil end insulator. Consequently, high pressure developed leading to loosening of terminal connector and leakage of oil. Due to the vibrations caused by the development of high stress, cracks appeared in metal flange and insulator pieces from the middle section broke off at the joints.

18. Failure of 16.67 MVAR, 400KV Bhiwadi-I R-ph Line Reactor at Agra S/s of PGCIL

A	Name of Substation	:	Agra
B	Utility/Owner of substation	:	PGCIL
C	Faulty Equipment	:	Line Reactor
D	Rating	:	16.67 MVAR, 400 kV
E	Make	:	Crompton Greaves limited
F	Sr. No.	:	T8353/1
G	Year of manufacturing	:	Information not available
H	Year of commissioning	:	2005 (01.03.2005)
I	Date and time of occurrence/discovery of fault	:	22.05.2017 at 01:27 hrs
J	Information received in CEA	:	02.01.2018
K	Fault discovered during	:	Operation

L	Present condition of equipment	:	Repaired by replacing the bushing
M	Details of previous maintenance	:	

Tan delta and capacitance test results:

Cap (pF)	**TD (%)**	**Diff**	**Cap (pF)**	**TD (%)**	**Diff**	**Cap (pF)**	**TD (%)**	**Diff**	**Cap (pF)**	**TD (%)**	**Diff**
17.08.2016			13.07.2015			07.04.2015			05.04.2014		
500.4	0.377	0.022	502	0.355	0.022	500.6	0.333	0.017	499.4	0.316	0.071
387.7	0.371	0.026	384.2	0.345	-0.07	382.5	0.415	0.047	382.6	0.368	0.035

DGA was also carried out regularly during maintenance and results are indicated in subsequent para.

N	Details of previous failure	:	Information Not Available
O	Sequence of events/ Description of failure	:	

The Agra–Bhiwadi-I Line tripped at 01:27 Hrs. on 22.05.2017 on single phase fault on R-N at 15.7 km (Main 1) from Agra End with failure of bushing. During failure, fault current of 35.78 kA was recorded to have flown through the reactor. Following protection operated:

01:27:24.977	Main 1(D60)-gnd dist Z1 optd
01:27:24.984	Main2- zone 4 pickup
01:27:25.016	Main2- zone 1 optd
01:27:25.029	R-ph main and tie CB open
01:27:25.047	Y-ph and B ph Main and tie CB open

P	Details of Tests done after failure	:	

IR Value: 85 GΩ
Magnetizing Current: 69.6 mA
Winding Resistance: 3.63 Ω

DGA :

S.no.	Date	H2	CH4	C2H6	C2H4	C2H2	CO	CO2
1	29.5.17	643	283	290	26	327	367	2533
2	21.11.16	11	11	2	5	0	122	1157
3	31.5.16	12	8	2	4	0	109	1100
4	17.5.16	13	9	2	5	0	110	1087

No significant gases were generated post failure. The rise in acetylene may be attributed to consequential damage.

Q	Observations & Analysis	:	

The bushing of the Agra-Bhiwadi 1 LR was charred from the top and subsequently caught fire. The burning oil falling from the bushing damaged the nearby cables and Marshaling Box. However, recording instruments were found to be in working order.

Outer sheath of the cable from reactor to MB box was found burnt and MB was damaged.

No abnormalities were found in the core/ windings during internal inspection. Charred paper and broken pieces of oil end insulator were found in the bottom of the tank.

Puncture mark observed in the metal rod of the bushing above the first aluminium insulation, at a distance of 1.63 m from the bottom of the expansion chamber just beneath the first porcelain joint.

Metal flange was also found to be burnt at the bottom of the bushing with partial melting of the flange and signs of sparking present.

Bushing was 31 years old and it appears that due to ageing its insulation got weak over time. It is likely that during fault on Agra-Bhiwadi line, bushing insulation could not withstand high stress and internal flashover occurred below the top porcelain joint of the bushing (weakest mechanical part of the bushing). Fire developed in the bushing oil and the insulation paper was completely charred. The spark travelled to the bottom flange (providing ground point to the current) causing its partial melt on the sides.

19. Failure of 80 MVAR, 765 kV Bina-II R-ph Line Reactor at Satna substation of PGCIL

A	Name of Substation	:	Satna
B	Utility/Owner of substation	:	PGCIL
C	Faulty Equipment	:	Switchable Reactor (R-Phase)
D	Rating	:	80 MVAR, 765kV
E	Make	:	CGL
F	Sr. No.	:	BH09823/01
G	Year of manufacturing	:	2012
H	Year of commissioning	:	2012 (01.07.2012)
I	Date and time of occurrence/discovery of fault	:	01.06.2017 at 00:59 hrs.
J	Information received in CEA	:	02.01.2018
K	Fault discovered during	:	Operation
L	Details of previous maintenance	:	

Said reactor was commissioned on 01.07.12 and since then, increase in C_2H_4 and C_2H_2 was observed which was attended by M/s CGL in August 2015. After resolving the issue reactor was taken in service on 16.09.2015. Again, increase of C_2H_4 and C_2H_2 was observed in the reactor which was reported to CGL on 29.08.2016 and later on many occasions. DGA trend after repair is given as below.

Sample Date	H2	CH4	C2H4	C2H6	C2H2	CO	CO2
17.05.2017	34	86	188	23	3.6	373	1797
15.05.2017	32	60	137	70	4.6	301	1441
28.04.2017	35	63	125	18	2.6	290	1380
27.03.2017	40	63	122	18	2	268	1149
06.03.2017	48	70	134	19	2.1	295	1099
13.02.2017	50	68	130	18	2.7	273	975

Tan ō & Capacitance Measurement: (As per last AMP carried out).

		Pre-Commg.(27.01.2012)	**25.08.2015**
Tan δ	R	0.33%	0.30%
	N	0.44%	0.37%
Capacitance	R	586 pF	586 pF
	N	278 pF	271 pF

	Tan Data		**Capacitance**	
WINDING	Tested on 11.12.15	Factory	Tested on 11.12.15	Factory
HV/Tank+E	0.251%	0.27%	4.380 nF	4.419 nF

M	Details of previous failure	:	Information not available
N	Sequence of events/ Description of failure	:	On 01.06.17 at 0059 hrs, Bina-II-line switchable reactor (R-ph) failed on operation of REF, Differential and body protection. According to the report submitted to CEA, heavy fault current of almost 20 kA had flown from 765kV side.

Sequence of Protection Operated

S/s	Time	Protection	Fault current
Satna End	00:59:26:559 hrs.	REF Optd	482 A
	00:59:26:572 hrs.	Diff ST-2 Optd	19.9 kA
	00:59:26.594 hrs.	Reactor CB Open	
	00:59:26:599 hrs.	Flow Control Valve R Ph	
	00:59:26:610 hrs.	Bunch 1/2 Alarm R Ph	
	00:59:26:625 hrs.	Bunch 1 Trip R Ph	
	00:59:26:648 hrs.	Bunch 2 Trip R Ph	
	00:59:26:868 hrs.	PRV2 – R Ph Optd	
Bina End	00:59:26:575 hrs.	Main-1 Zone-2 & Zone-3 Start	2.3 kA
	00:59:26:579 hrs.	Main-1 Zone-2 & Zone-3 Start	

O	Details of Tests done after failure	:	LV Tests were carried out on 03.06.2017

Winding C & Tan Delta measurement:

Winding C & Tan delta in GST Mode	Factory value at 10 kV	Precomm. value at 10kV	Post tripping site value at 10 kV
10 kV	4.419 nF, 0.265%	4.375 nF, 0.231%	2.917 nF, 4.52%

It can be seen that Winding Capacitance is reduced by 33% and tan delta w.r.t. ground increased by 20 times.

Insulation resistance measurement:

Winding configuration	Pre-commissioning value	Post tripping site value at 2.5 kV
CC-G(Frame to Tank)	87.2 G Ω	2.35 G Ω
CL-G (Core Tank)	55.7 G Ω	2.33 G Ω
CC-CL (Core to Frame)	39.1 G Ω	0
Shield 1 – Shield 2	396 G Ω	950 G Ω
Shield 1 – Earth	216 G Ω	690 G Ω
Shied 2 – Earth	234 G Ω	157 G Ω
IR Value at 15/60 Sec	29.2/33.6 G Ω	1.9/2.03 G Ω

IR values of CC-CL (Core to Frame) became zero and those of winding, Core and Frame to earth reduced drastically.

No load magnetizing current at 230 Volts:

HV & Neutral	Pre-commissioning value	Post tripping site value
241 V	99.4 mA (at 240.6 Volt)	325.5 mA(at 241 Volt)

It can be seen that magnetizing current increased around 3.27 times compared to pre-commissioning value.

DC Winding Resistance at 75° C:

Pre-commissioning value	Post tripping site value
1.967Ohm	2.649 Ohm

DC winding resistance is increased 35% compared to pre-commissioning

P	Observations & Analysis	:	

On physical inspection, following observations were made :

(i) Tank was heavily bulged towards HV side damaging the MB. Stiffeners were found cracked and oil came out from the reactor.
(ii) HV Bushing flange & cement joint was found broken, oil level in bushing was below minimum
(iii) Neutral bushing porcelain found displaced at bottom side.
(iv) Reactor bottom welding at jacking pad found broken on all side which shows reactor displacement.
(v) Consequential damage was also observed in radiator.
(vi) 132 kV Neutral SA failed, Earth lead of SA got removed from its bottom stack & its counter was found blasted.

Internal Inspection:

Internal inspection was carried out jointly by CGL and PGCIL and following observations were made:

(i) Most of the pressboard barriers found badly broken and burnt.
(ii) The winding insulation components viz., washers and caps were found to be dislocated.
(iii) Winding near HV bushing lead area was damaged and the insulation over winding was also damaged badly. The bare copper was visible in the HV lead area. Similarly, copper was also visible in the top part of winding near Neutral.
(iv) Heavy charring of insulation was found inside.
(v) No oil was left inside tank.

From the DR details it was observed that heavy fault current of almost 20 kA flown from 765 kV side. The Reactor tripped on REF, differential and Body protections. Also, winding tan delta increased almost 20 times and core to frame insulation failed.

It appears that there was an internal flashover between top portions of HV side and neutral side winding, short circuiting the reactor impedance altogether. Heavy internal pressure was generated due to high fault current leading to the heavy bulging of reactor.

NGR SA failure may be due to neutral voltage rise during heavy fault current (Vn=680 kV at the time of tripping).

20. Failure report 80 MVAR, 420 kV Patna-1 Line Reactor at Kishenganj s/s of PGCIL

A.	Name of Substation	:	Kishenganj
B.	Utility/Owner of substation	:	PGCIL
C.	Faulty Equipment	:	Patna -1 line Reactor (Switchable)
D.	Rating	:	80 MVAR, 420 kV
E.	Make	:	CGL
F.	Sr. No.	:	T10416/1
G.	Year of manufacturing	:	2014
H	Year of commissioning	:	2016 (14.03.2016)
I	Date and time of occurrence/discovery of fault	:	01.09.2017 at 11:03 hrs
J	Information received in CEA	:	31.07.18
K	Fault discovered during	:	Operation
L	Details of previous maintenance	:	Information not provided
M	Details of previous failure	:	Information not provided
N	Sequence of events/ Description of fault	:	

Prior to the failure, system was in normal condition and all lines (New Siliguri-1&2, New Purea-1&2 and patna-1&2) were in service and charged at 400 kV level. The weather was clear and there was a load of 120 MW each on Kishenganj-patna lines. The Bus voltage was 413 kV.

It was found that the reactor had tripped three times in August 2017 due to "NGR Buchholz operation". It was informed that the alarm was disregarded as maloperation and was not investigated properly. On 01.09.2017 too, there was a tripping on the same alarm at 08:19 hrs. and the reactor was taken in service

at 08:25 hrs. The reactor again tripped again at 11:02 hrs. on the same alarm and was again taken back in service at 11:03:36. Immediately after being taken in service, a loud sound was heard in the control room and surrounding area and Patna-1 Line Reactor tripped along with the line. Upon investigation by the operation staff, it was found that the line reactor had tripped on REF, Buchholz and PRD operation.

At the same time, the Main-1 protection also detected the fault in Zone-1 and extended a single phase tripping to Y phase Main & Tie CBs & sent carrier to remote end. Due to the priority scheme in the Auto Reclose, Tie CB closed after 2 seconds but the main CB did not reclose causing the remaining two poles to trip on Pole Discrepancy. However, direct trip was received immediately from remote end causing the line to trip again.

Sequence of operation of protection devices is as below:

11:03:36:950	Reactor REF protection operated
11:03:36:950	Reactor PRV operated
11:03:37:000	Tie CB (417) Y Phase opened
11:03:37:003	Reactor Switchable CB (415) opened
11:03:37:005	Reactor Buchholz protection operated
11:03:37:006	Main CB (416) Y Phase opened
11:03:39:088	Tie CB (417) Y Phase closed
11:03:39:647	Main CB (416) R&B Phase opened
11:03:40:261	Direct Trip received and Tie CB (417) tripped

The various parameters during the incidence were as shown:

Signal	Pre-fault values	Fault values
I_a	110 A	406 A
I_b	223 A	15 kA
I_c	110 A	655 A
V_{a-n}	276 kV	276 kV
V_{b-n}	272 kV	4.8 kV
V_{c-n}	274 kV	273 kV

O	Details of Tests done after failure	:	

Initial Test Results of the Reactor:

Pre-commissioning Values	**Last Testing (10.05.17)**	**After Failure (04.09.17)**
Magnetizing Current R-N: 16.22 mA Y-N: 16.33 mA B-N: 17.27 mA **IR Value** HV-E: 9.40 GΩ (600 sec) **Winding Resistance** R-N: 1.6071 Ω Y-N: 1.6118 Ω B:N 1.6025 Ω	**IR Value** HV-E:9.50 GΩ **Tan delta of Bushing** R ph: 0.3018%/533 pF Y ph: 0.2646%/533.38 pF B ph: 0.2484%/534.41 pF	**Magnetizing Current** R-N: 110.61 mA Y-N: 290.23 mA B-N: 111.10 mA **IR Value** HV-E: Zero **Winding Resistance** R-N: 1.67 Ω Y-N: 1.78 Ω B-N:1.65 Ω

DGA Result of the reactor:

Date	H2	CH4	C2H6	C2H4	C2H2	CO	CO2
02.9.17 (Post Failure)	4502	2107	206	2330	1706	968	475
20.7.17	15	13	3	21	0	202	584
20.4.17	10	4	0	0	0	101	166
9.12.16	8	3	0	0	0	68	157

4. There is a strong indication of a fault in paper, either a hot spot or electrical arcing.

P	Observations & Analysis	:	

There was no visual damage to the bushings of the reactor. The main tank was intact and there was no bulging or any physical damage. Both the PRDs had operated and oil had discharged. CC-CL Earthing link on top of the reactor was found damaged.

There was a sudden rise of gases on failure causing the PRD/Buchholz to operate. The tripping signals also indicate a rapid development of fault inside the reactor. Consequently, internal inspection was carried out of the reactor in the presence of the representative of CGL, Mumbai and the findings as shared by the utility are as follows:

1. The HV Lead exits of R&B phase were found intact but the insulation around the Y phase was found damaged.

2. Black residue was found at the bottom of the tank and at many places inside the reactor. The preliminary investigation indicates that there has been a flashover from the Y phase HV side to the core. The burn marks could not be verified in core at site however there is a strong possibility of an inter-turn fault in the reactor.

3. The Y-phase winding was subjected to fault, wherein the insulation of winding was adversely affected due to same.

4. As per DGA Report dated 26 July 2017, the ratio of CO_2/CO was less than 3.

5. The reactor was in idle condition during 26.07.2016 to 03.04.2017, while re-commissioning.

The probable reason for failure may be failure of HV insulation around Y-phase winding causing flashover to core. The exact cause could only be ascertained only after detailed internal inspection at works.

21. Failure of 80 MVAR, 765 kV B-Phase Line Reactor at Varanasi s/s of PGCIL

A.	Name of Substation	:	Varanasi
B.	Utility/Owner of substation	:	PGCIL
C.	Faulty Equipment	:	Kanpur-2 Line Reactor (B Phase)
D.	Rating	:	80 MVAR, 765 kV

E.	Make	:	TBEA
F.	Sr. No.	:	14B09098
G.	Year of manufacturing	:	2014
H	Year of commissioning	:	2016 (14.07.2016)
I	Date and time of occurrence/discovery of fault	:	27.12.2017 at 01:38 hrs.
J	Information received in CEA	:	31.07.2018
K	Fault discovered during	:	Operation
L	Details of previous maintenance	:	Information not provided
M	Details of previous failure	:	Information not provided
N	Sequence of events/ Description of fault	:	

Prior to the failure:

- System was in normal condition
- All 765 kV & 400 kV line were in service.
- Dense fog was pesent
- Load of 225 MW each on the two 765 kV Varanasi-Kanpur lines.
- Bus voltage 790/422 kV.

At 00.59 hrs., Buchholz alarm appeared in the 765 kV B phase reactor of Kanpur-2 Line Reactor. Station operator was advised by the maintenance staff to physically observe the Buchholz for presence of gas and to open the reactor in co-ordination with CPCC. The station operator checked the reactor and did not find any abnormally high OTI/WTI readings. However, as advised by the maintenance staff he was co-ordinating the outage of the reactor when at 01:38 hrs., a loud explosion was heard from the reactor side followed in quick succession by another explosion. 765 kV Varanasi-Kanpur-2 Line and the switchable line reactor had tripped. Upon investigation of the switchyard, the Kanpur -2 B phase Line Reactor was found burning and the emulsifier system had operated. On seeing the flames reaching towards the adjoining R phase line reactor of Kanpur-1, the operator hand tripped 765 kV Varanasi-Kanpur-1 and

associated line reactor. The fire was successfully extinguished in the morning around 07:00 hrs.

Sequence of events:

00:59:29.117	Buchholz 1/2 B phase Alarm
01:38:11.242	Kanpur-2 Line Reactor REF operated
01:38:11.264	Kanpur-2 Line Reactor B phase PRV operated
01:38:11.282	Kanpur-2 Line Reactor B phase Buchholz operated
01:38:11.284	Kanpur-2 Line Reactor Differential operated (High Set)
01:38:11.284	Kanpur-2 Line Reactor B phase OTI trip operated
01:38:11.878	Kanpur-2 Line Reactor B Phase Emulsifier operated
01:38:14.729	Kanpur-2 Line Reactor REF operated
01:38:14.735	Kanpur-2 Line Reactor Differential operated (High Set)

The various parameters during the incidence were as shown:

Single	Pre-fault values	Fault values
I_a	191 A	214 A
I_b	192 A	225 A
I_c	190 A	18.3 kA

O	Details of Tests done after failure	:	Since the HV bushing is completely destroyed the LV testing could not be carried out. However, oil sample from Buchholz and the main tank were sent to lab for DGA sampling.

DGA Result of the reactor:

S. No.	Date	H2	CH4	C2H6	C2H4	C2H2	CO	CO2

1	(Post Failure)	2235	2377	476	3467	2540	1180	4987
2	13.12.17	16	18	1	3	0	717	2050
3	07.11.17	21	18	1	3	0	708	2206
4	09.10.17	16	17	1	3	0	666	2151
5	09.09.17	25	16	1	3	0	629	1940
6	17.08.17	23	14	1	3	0	610	1850

Further the online DGA result were as shown:

Time stamp	H2	ROC
26/12/17 20:58	4	3.1
26/12/17 21:28	4	3.1
26/12/17 21:58	4	3.1
26/12/17 22:28	4	3.1
26/12/17 22:58	850	5.8
26/12/17 23:28	1093	20.8
26/12/17 23:58	1545	22.6
27/12/17 00:26	12271	42511.6
27/12/17 00:56	12671	44996.3
27/12/17 01:26	12608	43173

P	Observations & Analysis	:	

There was extensive damage to the reactor and bulging was seen near the HV bushing. The HV Bushing had shattered completely and insulation paper was partly burnt. The neutral bushing was also damaged due to the explosion. Both the PRDs had operated and the oil was discharged. The tan delta point of both the bushing was intact and there was no pitting/burning marks found in bushing caps. The top inspection window of the reactor was found nearly 60 feet away narrowly missing the GIB of the switchable line reactor due to the violent rise pressure during fault. Flashover marks were also seen near the base of HV turret at the top of the reactor. The neutral LA had also failed.

Internal Inspection of the Reactor:

As per the report submitted by the utility, findings of the internal inspection are as follows:

HV lead exit had violently sheared away from the HV bushing and the insulation was completely burnt. However, the HV bushing oil end corona ring seemed to be intact and there was no abnormality observed on the tan delta point. The lead of the neutral bushing was intact. The visible portion of winding also seemed to be intact except for minor fire damage. This indicates that the fault had initiated from the HV lead exit to Static end ring (SER) of the neutral end of the winding either at the top or bottom.

The second fault seems to have been caused due to burning material rising from the reactor which caused an ionized path to the bushing from the line (which was charged) above the failed reactor. The flashover then travelled through the bushing CT and then through the tank so it cannot be seen in the Neutral CT.

Current Transformer (CT)

22. Failure of Y-phase CT at 230kV Alundur Substation, Trichy of TANTRANSCO

A	Name of Substation	:	Alundur Substation
B	Utility/Owner of substation	:	TANTRANSCO
C	Faulty Equipment	:	CT (HV side of 100 MVA, 230/110 kV Auto Transformer-II)
D	Rating	:	230kV ; 1600/1200/600/800/300-1
E	Make	:	ABB
F	Sr. No.	:	2101007/2001
G	Year of manufacturing	:	2001
H	Date of commissioning	:	28.08.2004
I	Date and time of occurrence/discovery of fault	:	11.09.17 at 0107 hrs
J	Information received in CEA	:	02.02.2018
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced
M	Details of previous maintenance	:	The Tan Delta test conducted on 22.01.2015 and result were found to be satisfactory.
N	Details of previous failure	:	Information not provided
O	Sequence of events/ Description of failure	:	On 11.09.17 at 0107 hrs, Y phase CT of HV side of 100 MVA, 230/110 kV Auto Transformer-II failed and caught fire. Auto transformer –II HV & LV Master trip and Differential Relay acted. All 230 kV feeders, Auto transformer-I HV, ICT-I, II & III tripped

			by bus bar main & check zone protection. HV O/C Y Phase operated.
P	Details of Tests done after failure	:	No tests done as the CT had burnt
Q	Observations & Analysis	:	CT caught fire and huge amount of oil spread out of the CT. The bottom of oil tank was bulged. At the time of failure: Bus voltage: 245 kV Ambient temp: 36^{o}C Weather: Clear Internal fault could be the possible cause of failure. Due to fault pressure might have risen leading to bulging of tank and fire. Failure of CT might have led to appearance of a differential current, and resulted in operation of the differential protection.

23. Failure of 220kV Current Transformer at Kudachi Substation of KPTCL

A	Name of Substation	:	Kudachi Substation
B	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Ltd.
C	Faulty Equipment	:	CT(R-Phase, Mahalingpur Incoming line)
D	Rating	:	220kV
E	Make	:	Shree Venkateshwara Electrical Industries Pvt. Ltd.
F	Sr. No.	:	313/1/7
G	Year of manufacturing	:	2004
H	Date of commissioning	:	06.04.2006

I	Date and time of occurrence/discovery of fault	:	29.9.2016 at 06:35 hrs.
J	Information received in CEA	:	09.01.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced
M	Details of previous maintenance	:	
On 21.07.2015, station maintenance work was undertaken: (1) Cleaning of the porcelain portion of CTs (2) Visual inspection of CTs for any cracks. (3) Checking & tightening of the clamps of CTs. (4) Checking & tightening of the secondary wiring interconnection of CTs. (5) Checked the Oil level & oil leakage in the CTs and all the found intact. (6) IR measured by 5kV Megger was found to be 2000 Mohm.			
N	Details of previous failure	:	Nil
O	Sequence of events/ Description of failure	:	
On 29.09.2016, the following events occurred: 6:30 AM: The station was in normal condition, the 220kV Bus Coupler was connected to buses A and B. GOS was in closed condition. 6:35 AM: R-Phase CT of 220kV Mahalingpur line blasted at 06:35 AM. At the same time Bus Bar protection relay operated and all 220kV feeders tripped at Kudachi end. At the same time both 100MVA Power Transformers I & II also tripped. 6:40 AM: The Mahalingpur line GOS of 220kV line opened and CB opened. The fire was brought into control immediately.			
P	Details of Tests done after failure	:	No tests possible as the CT blasted

Q	Observations & Analysis	:	Internal fault could be the possible cause of failure. Failure of CT might have led to appearance of a differential current, and resulted in operation of the differential protection.

24. Failure of 220 kV CT at HSR Layout, Bangalore Substation of KPTCL

A.	Name of Substation	:	HSR Layout
B.	Utility/Owner of substation	:	KPTCL
C.	Faulty Equipment	:	R-ph CT for 220 kV Hoody line at 220/66/11 kV substation
D.	Rating	:	245kV
E.	Make	:	Crompton Greaves Limited
F.	Sr. No.	:	9019
G.	Year of manufacturing	:	1996
H.	Date of commissioning	:	26.01.1998
I.	Date and time of occurrence/discovery of fault	:	05.11.2016 at 13:00 hrs.
J.	Information received in CEA	:	11.08.2017
K.	Fault discovered during	:	Operation
L.	Present condition of equipment	:	Replaced by new CT
M.	Details of previous maintenance	:	Last maintenance was carried out on 16.05.2016, however, further details were not provided.
N.	Details of previous failure	:	Nil

O.	Sequence of events/ Description of fault	:	On 05.11.2016 at 13:00 hrs., CT Bellow expanded and oil leakage from top was observed.
P.	Details of Tests done after failure	:	Information not provided
Q.	Observations & Analysis	:	The CT had spent over 18 years in service. Expansion of below indicates that some gases were generated in the CT due to partial discharge in the insulation.

25. Failure of 220kV B-phase CT at KIADB Doddaballapura s/s of KPTCL

A	Name of Substation	:	220/66/11kV KIADB R/S Doddaballapura
B	Utility/Owner of substation	:	KPTCL
C	Faulty Equipment	:	CT (B-phase of 50 MVA transformer)
D	Rating	:	220 kV, 800-600-400-300/1-1-1A
E	Make	:	Hindustan Brown Boveri
F	Sr. No.	:	IB027/700
G	Year of manufacturing	:	Information not available
H	Date of commissioning	:	13.07.1995
I	Date and time of occurrence/discovery of fault	:	02.04.2017 at 2210 Hrs.
J	Information received in CEA	:	20.11.17
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced
M	Details of previous maintenance	:	Last routine maintenance done on 15.03.2017 (Tightening of Clamps Terminals, cleaning of insulators, observing oil level)

N	Details of previous failure	:	Information not available
O	Sequence of events/ Description of fault	:	
On 02.04.2017 at 2210 hrs., loud sound was heard in 220 kV Yard. Upon inspection it was found that 'B' Phase 220kV CT of 50 MVA transformer had flashed over and burnt. Tripping Details are as follows: Transformer Differential protection operated 87C Trip supervision relay 895 Tripping relay 286 V2 HV Side: Directional over current relay 67C LV Side: Directional over Current relay 167A, 167B, 167C			
P	Details of Tests done after failure	:	Not possible as CT had burnt
Q	Observations & Analysis	:	Internal fault could be the possible cause of failure. Failure of CT might have led to appearance of a differential current, and resulted in operation of the differential protection.

26. Failure of 220kV CT at Kavoor Substation of KPTCL

A	Name of Substation	:	Kavoor
B	Utility/Owner of substation	:	KPTCL
C	Faulty Equipment	:	Y and B ph Current Transformers of Bajpe-1 line
D	Rating	:	220kV
E	Make	:	SCT Ltd.

F	Sr. No.	:	1. 2000/289 (Y Phase CT) 2. 2000/287 (B Phase CT)
G	Year of manufacturing	:	1. 1999 (Y Phase CT) 2. 1999 (B Phase CT)
H	Year of commissioning	:	1. 2000 (Y Phase CT) 2. 2000 (B Phase CT)
I	Date and time of occurrence/discovery of fault	:	05.09.2017 at 18:00 hrs.
J	Information received in CEA	:	20.11.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Both CTs Irreparable
M	Details of previous maintenance	:	Carried out routine maintenance works on 29.07.2017. Details of maintenance work is not available.
N	Details of previous failure	:	No previous failures
O	Sequence of events/ Description of fault	:	On 05.09.2017 at about 18:00 hrs, 220kV Kavoor-Bajpe line -1 tripped on Distance relay due to rupturing of B Phase CT and flashover of Y-Phase Current Transformer at 220kV SRS, Kavoor. The B-Phase CT had ruptured entirely. Y-Phase CT had flashed over, deglazing of jacket insulator and mechanical damages like damages to primary stud, delink of cemented portion were observed.
P	Details of Tests done after failure	:	No test was possible as both CTs had damaged.
Q	Observations & Analysis	:	As no test values of tests conducted during previous maintenance is available, it is hard to

			ascertain the health of the CTs. Flashover of Y-phase CT could be due to internal fault. Damage of B-phase CT could be due to splinters of Y-phase CT, however, sufficient information is not available to corroborate the same.

27. Failure of 220kV CT at Yerraguntla Substation of APTRANSCO

A.	Name of Substation	:	Yerraguntla substation
B.	Utility/Owner of substation	:	APTRANSCO
C.	Faulty Equipment	:	R-Phase CT of RTPP-I
D.	Rating	:	800-600-400/1-1-1-1-1A
E.	Make	:	WS
F.	Sr. No.	:	910815
G.	Year of manufacturing	:	1991
H	Year of commissioning	:	1993
I	Date and time of occurrence/discovery of fault	:	17.01.17 at 1110 hrs
J	Information received in CEA	:	28.03.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced
M	Details of previous maintenance	:	Information not available
N	Details of previous failure	:	Information not available

O	Sequence of events/ Description of fault	:	On 17.01.17 at 1110 hrs, 220kV RTPP-I R-ph CT blasted while in operation.
P	Details of Tests done after failure	:	No test was possible as the CT had blasted.
Q	Observations & Analysis	:	Sufficient information is not available to ascertain cause of failure. However, it appears, reduction in dielectric strength of the insulation due to ageing might have led to the failure and blasting of CT.

28. Failure report of 220 kV R-ph CT at Vishakhapatnam s/s of APTRANSCO

A.	Name of Substation	:	Vishakhapatnam s/s
B.	Utility/Owner of substation	:	APTRANSCO
C.	Faulty Equipment	:	R-ph CT of Bus Coupler
D.	Rating	:	220 kV
E.	Make	:	BHEL
F.	Sr. No.	:	2241286
G.	Year of manufacturing	:	2003
H	Year of commissioning	:	Information not available
I	Date and time of occurrence/discovery of fault	:	27.03.2018 at 1610 hrs
J	Information received in CEA	:	29.06.18
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced on 28.03.2018
M	Details of previous maintenance	:	No maintenance as the CT was in store.

N	Details of previous failure	:	Earlier CT installed in R-phase of Bus-I side, replaced on 25.03.19 because oil leakage observed from stud and H2 was found in the The CT had served for 26 years.
O	Sequence of events/ Description of fault	:	On 27.03.18, the current transformer blasted.
P	Details of Tests done after failure	:	No tests could be conducted as CT had blasted
Q	Observations & Analysis	:	As reported by the utility, the subject CT was in idle condition at the Stackyard at TLC stores Gajuwaka since 2003. It appears that since CT was in store for a long time, due to moisture ingress and other environmental factors, its internal insulation might have weakened which could not sustain voltage stress when put into service.

29. Failure report of 220 kV CT at Warora s/s of MSETCL

A.	Name of Substation	:	Warora
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	Y-ph CT of Bhugaon-1 line
D.	Rating	:	220 kV
E.	Make	:	MEHRU
F.	Sr. No.	:	OC2927/1/4/10
G.	Year of manufacturing	:	2010
H	Date of commissioning	:	29.07.2017
I	Date and time of occurrence/discovery of fault	:	11.08.2017, 2323 hrs

J	Information received in CEA	:	05.07.2018
K	Fault discovered during	:	During Operation
L	Present condition of equipment	:	Replaced by new CT
M	Details of previous maintenance	:	Information not available
N	Details of previous failure	:	Information not available
O	Sequence of events/ Description of fault	:	On 11.08.2017 at 23:23 hrs, bus sectionalizer, LBB operated resulting in tripping of SWPCL line 1 & line 2 and Bhugaon ckt. 2, due to bursting of Y-Phase CT.
P	Details of Tests done after failure	:	Test could not be done as the CT was completely damaged.
Q	Observations & Analysis	:	It is highlighted that CT was manufactured in 2010 and commissioned in 2017. Information on the conditions under which CT was stored during this period is not available. Internal insulation failure due to ingress of moisture appears to be cause of failure of CT.

Capacitive Voltage Transformer (CVT)/ Potential Transformer (PT)

30. Failure of 420 kV class Bus-A CVT at Nelamangala substation of KPTCL

A	Name of Substation	:	400kV Nelamangla Substation
B	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Ltd.
C	Faulty Equipment	:	Capacitive Voltage Transformer (Bus A, Y-Phase)
D	Rating	:	400/√3/110/√3kV Class, Single Phase 8800 pF
E	Make	:	W.S. Industries
F	Sr. No.	:	20000827
G	Year of manufacturing	:	2000
H	Year of commissioning	:	Information not available
I	Date and time of occurrence/discovery of fault	:	26.07.2016 at 09.30 hrs
J	Information received in CEA	:	09.01.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Suspected Faulty, to be replaced
M	Details of previous maintenance	:	On 27.06.2016 the Voltage measured at Y-Phase CVT was 63.5 Volts.
N	Details of previous failure	:	Information not available
O	Sequence of events/ Description of failure	:	On 26.07.2016 at 09.30 hrs., it was observed that no secondary voltage was appearing in all the 3 cores of Y-Phase CVT of 400 kV Bus A, while other phases were

			recording normally. Hence, suspected fault in the CVT and to avoid further untoward incidents Bus A CVT kept open. However, no protection or metering is provided under this Bus selection.
P	Details of Tests done after failure	:	As per KPTCL's report, test will be conducted after dismantling the CVT
Q	Observations & Analysis	:	No other observation except zero reading of the secondary voltage was reported. Internal fault in or shorting of capacitor elements is suspected as cause of failure.

31. Failure of 220kV CVT at Nelamangala Substation of KPTCL

A	Name of Substation	:	Nelamangala Substation
B	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Ltd.
C	Faulty Equipment	:	Capacitive Voltage Transformer provided for Y-Phase of 220kV Nelamangala Anchepalya Line-2
D	Rating	:	220/√3/110/√3kV Class, Single Phase 4400 pF
E	Make	:	W. S. Industries
F	Sr. No.	:	20000837
G	Year of manufacturing	:	2000
H	Year of commissioning	:	Information not available
I	Date and time of occurrence/discovery of fault	:	07.09.16
J	Information received in CEA	:	09.01.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced

M	Details of previous maintenance	:	On 15.08.2016 the Voltage measured at Y-Phase CVT was 62.3 Volts.
N	Details of previous failure	:	Information not available
O	Sequence of events/ Description of failure	:	On 07.09.16, it was observed that secondary Voltage of Y-Phase CVT in all the cores was showing 78.4 volts instead of 61.6 volts in other phases. However, line was taken into service by extending the Bus B CVT Voltage for Metering & Protection.
P	Details of Tests done after failure	:	Information not available
Q	Observations	:	Information not available
R	Probable cause of failure	:	Voltage of CVT increased due to puncture of capacitor element in C1 side (upper capacitor unit).

32. Failure report of 220kV Bus-A PT at Anchepalya substation of KPTCL.

A.	Name of Substation	:	Anchepalya
B.	Utility/Owner of substation	:	KPTCL
C.	Faulty Equipment	:	PT (Bus-A; B-phase)
D.	Rating	:	220/√3 kV / 110/ √3 V
E.	Make	:	SCT Limited
F.	Sr. No.	:	2012/803
G.	Year of manufacturing	:	2012
H.	Date of commissioning	:	08.03.2014
I.	Date and time of occurrence/discovery of fault	:	28.01.2017 at 0850 hrs.
J.	Information received in CEA	:	11.08.2017

K.	Fault discovered during	:	Operation
L.	Details of previous maintenance	:	On 16.08.2016 at 1022 hrs., routine maintenance was carried out. Terminal connections of PT and isolators were checked. All the earth connections were tightened.
M.	Details of previous failure	:	No previous failures
N.	Sequence of events/ Description of fault	:	At 0848 hrs. loud sound was heard in 220kV yard. After yard inspection, it was found that B phase 220kV PT in Bus-A had flashed over and had caught fire. Tripping details are as follows: Bus Coupler: Tripped on B/B protection, 96 relay and with Zone X, Y, trip & C ph CT fault indications. Transformer 1&2(HV Side): EFR & B/U protection Nelamangala 1 : Auto reclosure, 186A & 186B Nelamangala 2: Tripped on fault without any indications.
O.	Details of Tests done after failure	:	No tests were conducted as the PT was burnt
P.	Observations & Analysis	:	Internal fault in PT caused huge pressure resulting into its blasting.

33. Failure of 220kV PT at Chikkodi Substation of KPTCL.

A	Name of Substation	:	Chikkodi substation
B	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Limited (KPTCL)
C	Faulty Equipment	:	PT (Bus-A, B-phase)
D	Rating	:	220 kV/√3/110 V/√3

E	Make	:	SCT
F	Sr. No.	:	2010/1809
G	Year of manufacturing	:	2010
H	Date of commissioning	:	17.12.2011
I	Date and time of occurrence/discovery of fault	:	04.07.2017, 02:09 hrs.
J	Information received in CEA	:	20.11.17
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced
M	Details of previous maintenance	:	Routine maintenance was done on 29.8.15 and 16.10.16. Details of activities of routine maintenance not available.
N	Details of previous failure	:	No previous failures
O	Sequence of events/ Description of fault	:	On 04.07.2017, at 0209 hrs, the B-phase PT of 220 kV Bus A blasted.
P	Details of Tests done after failure	:	No tests could be conducted as the PT blasted.
Q	Observations & Analysis	:	As no previous test values during last few maintenance activities are available, it is not possible to ascertain the health of PT. However, internal insulation failure may be a plausible reason.

34. Failure of 220 kV PT at Anchepalya Substation of KPTCL

A	Name of Substation	:	Anchepalya substation

B	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Limited (KPTCL)
C	Faulty Equipment	:	PT (Bus-A, Y-phase)
D	Rating	:	220 kV/√3/110 V/√3
E	Make	:	SCT Ltd.
F	Sr. No.	:	2012/802
G	Year of manufacturing	:	2012
H	Date of commissioning	:	08.03.2014
I	Date and time of occurrence/discovery of fault	:	13.08.2017 at 13:43 hrs.
J	Information received in CEA	:	20.11.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Irreparable
M	Details of previous maintenance	:	Last half yearly maintenance carried out on 09.08.2016, which involved meggering of 220kV PT Insulation Stack. Nuts and bolt of all the terminal connections of PTs were tightened.
N	Details of previous failure	:	Details not available
O	Sequence of events/ Description of fault	:	On 13.08.2017 at 13:43 hrs, PT flashed over and caught fire. Loud sound and smoke was observed inside station yard along with following relay indication: Transformer 1 & 2 (HV side) : EFR 51N 86BV Nelamangala Line & Magadi line : Tripped at 400kV Nelamangala Station.
P	Details of Tests done after failure	:	No tests on Y-phase PT possible as it had flashed over. However, meggering of R &

			B-phase PT was done and IR value of R-phase was found to be very low.
Q	Observations & Analysis	:	However, assuming that no abnormalities were observed in the tests done in periodic maintenance by the utility, some internal fault could be the reason of failure of PT.

35. Failure of 220kV CVT at GSS Hisar Substation of BBMB

A	Name of Substation	:	Hisar GSS
B	Utility/Owner of substation	:	BBMB
C	Faulty Equipment	:	CVT (B-phase of Hisar-Bhiwani line)
D	Rating	:	220kV/√3/ 110/√3-110/√3-110/√3-110/√3-110/√3
E	Make	:	WSI
F	Sr. No.	:	88121019
G	Year of manufacturing	:	1988
H	Year of commissioning	:	1988
I	Date and time of occurrence/discovery of fault	:	12.04.2017 at 15:01 hrs.
J	Information received in CEA	:	07.08.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Not reparable
M	Details of previous maintenance	:	Previous maintenance done on 07.11.2016. No abnormality was observed.

N	Details of previous failure	:	Nil
O	Sequence of events/ Description of fault	:	On 12.04.2017 at 15:01 hrs., VT fuse failure alarm appeared on C&R Panel. Upon inspection it was observed that oil of CVT was found spilling out breaking the Level indicator.
P	Details of Tests done after failure	:	Insulation Resistance measurement was done on CVT and its value was found to be zero. Secondary voltage was also zero.
Q	Observations & Analysis	:	VT fuse failure alarm indicates blown fuse, however whether fuse of which core was blown, is not known. The CVT had served for 29 years. Partial discharge in the internal insulation due to ageing could be the reason of failure, which caused generation of excessive gases leading to breakage of level indicator and spillage of oil. However the exact cause of failure could not be ascertained in absence of sufficient information.

36. Failure of 220kV CVT at Charkhi, Dadri Substation of BBMB

A	Name of Substation	:	Charkhi Dadri
B	Utility/Owner of substation	:	BBMB
C	Faulty Equipment	:	Blue Phase CVT of 220kV Ch. Dadri – Ballabhgarh S/C
D	Rating	:	245kV
E	Make	:	WSI
F	Sr. No.	:	8707552
G	Year of manufacturing	:	1987

H	Date of commissioning	:	10.06.1989
I	Date and time of occurrence/discovery of fault	:	15.04.2017 at 02:27 hrs.
J	Information received in CEA	:	10.07.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced with new PT
M	Details of previous maintenance	:	(i) IR Value-Primary to Earth = 35k x 5MΩ Primary to Sec = 25k x 5MΩ Sec. to Earth = 5k x 1 MΩ Secondary output voltage = 63.5volt Measured on 28.10.16 during shut down. (ii) Tan Delta – 0.4988, Cap = 2844.54 pF at 10 kV measured on 17.04.2015
N	Details of previous failure	:	Information not available
O	Sequence of events/ Description of fault	:	On 15.04.2017 at 02:27 hrs., B-Phase CVT of 220kV Ch. Dadri –Ballabgarh line burst.
P	Details of Tests done after failure	:	No test was done as CVT had burst
Q	Observations & Analysis	:	Ageing could be a reason that some internal fault developed and caused the CVT to burst. Although during maintenance test results were found normal.

37. Failure of 230kV CVT at Arni Substation of TANTRANSCO.

A	Name of Substation	:	Arni Substation Villupuram Operation Circle
B	Utility/Owner of substation	:	TANTRANSCO
C	Faulty Equipment	:	Capacitive Voltage Transformer (“B” Phase of 230kV Arni – Singarapet feeder)

D	Rating	:	230kV
E	Make	:	Crompton Greaves Limited
F	Sr. No.	:	5952
G	Year of manufacturing	:	1994
H	Year of commissioning	:	1994
I	Date and time of occurrence/discovery of fault	:	17.10.2016 at 06:35 hrs.
J	Information received in CEA	:	13.04.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Not known
M	Details of previous maintenance	:	Periodical routine maintenance was carried out including meggering, capacitance and secondary voltage measurement and results were found in order.
N	Details of previous failure	:	Nil
O	Sequence of events/ Description of fault	:	On 17.10.2016 at 06:35 hrs, the 230kV Arni – Singarapet Feeder tie was opened as per LD Centre instruction. At the time of opening, it was noticed that there is no line voltage in 230kV Arni – Singarapet Feeder. The secondary voltage of CVT had collapsed.
P	Details of Tests done after failure	:	Meggering & ratio check tests were conducted. As per the utility, test results show CVT ratio had collapsed.
Q	Observations & Analysis	:	Internal fault could be the probable cause of failure.

38. Failure report of 220kV PT at Krishnagiri Substation of APTRANSCO

A	Name of Substation	:	Krishnagiri Substation
B	Utility/Owner of substation	:	APTRANSCO
C	Faulty Equipment	:	Potential Transformer
D	Rating	:	220kV
E	Make	:	SCT Limited
F	Sr. No.	:	2009/509
G	Year of manufacturing	:	2009
H	Year of commissioning	:	2011
I	Date and time of occurrence/discovery of fault	:	19.11.2016 at 00:52 hrs.
J	Information received in CEA	:	07.02.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Not known
M	Details of previous maintenance	:	Maintained as per schedule of the utility. Details not available.
N	Details of previous failure	:	Information not available
O	Sequence of events/ Description of fault	:	On 19.11.2016 at 00:52 hrs., 220 kV PT at Krishnagiri substation failed.
P	Details of Tests done after failure	:	No tests could be conducted as the PT was completely damaged.
Q	Observations & Analysis	:	Internal insulation failure could be the cause of failure.

39. Failure of 220kV PT at Brahmanakotkur Substation of APTRANSCO

A	Name of Substation	:	Brahmanakotkur
B	Utility/Owner of substation	:	APTRANSCO
C	Faulty Equipment	:	B-ph Potential Transformer (Metering Bay)
D	Rating	:	220kV
E	Make	:	SCT Ltd.
F	Sr. No.	:	2009/502
G	Year of manufacturing	:	2009
H	Date of commissioning	:	06.01.2011
I	Date and time of occurrence/discovery of fault	:	18.11.2016 at 01:30 hrs.
J	Information received in CEA	:	09.02.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	To be replaced
M	Details of previous maintenance	:	Regularly Maintained as per schedule of the utility
N	Details of previous failure	:	Information not available
O	Sequence of events/ Description of fault	:	On 18.11.2016 at 01:30 hrs., 220 kV PT of the metering bay blasted while in operation.
P	Details of Tests done after failure	:	No tests could be conducted as PT had blasted.
Q	Observations & Analysis	:	Internal fault could be the reason of failure.

40. Failure of 220kV CVT at Anantapuramu Substation of APTRANSCO

A	Name of Substation	:	Anantapuramu
B	Utility/Owner of substation	:	APTRANSCO
C	Faulty Equipment	:	Y-ph CVT of 220 kV Ramagiri feeder
D	Rating	:	245kV
E	Make	:	ABB
F	Sr. No.	:	2213100
G	Year of manufacturing	:	2015
H	Year of commissioning	:	2016
I	Date and time of occurrence/discovery of fault	:	09.12.16 at 1601 hrs
J	Information received in CEA	:	27.02.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Sent to OEM for repairing
M	Details of previous maintenance	:	Information not available
N	Details of previous failure	:	Information not available
O	Sequence of events/ Description of fault	:	On 09.12.16 at 1601 hrs, Y-ph CVT of 220 kV Ramagiri feeder blasted while in operation. No line fault had occurred at the time of failure.

P	Details of Tests done after failure	:	Information not available
Q	Observations	:	Normal weather
R	Probable cause of failure	:	Blasting of CVT could be due to internal fault.

41. Failure report of 220 kV R-ph PT at Gadchiroli s/s of MSETCL

A.	Name of Substation	:	Gadchiroli
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	R ph PT of 220 kV Bus
D.	Rating	:	220 kV
E.	Make	:	CGL
F.	Sr. No.	:	13049
G.	Year of manufacturing	:	1999
H	Date of commissioning	:	01.09.2010
I	Date and time of occurrence/discovery of fault	:	08.01.2018 at 2135 hrs
J	Information received in CEA	:	05.07.2018
K	Fault discovered during	:	During Operation
L	Present condition of equipment	:	Replaced by new PT
M	Details of previous maintenance	:	Information not available
N	Details of previous failure	:	Information not available

O	Sequence of events/ Description of fault	:	On 08.01.2018 at 2135 hrs, Bus bar protection operated. Simultaneously all 220 kV circuit breakers Tripped. After yard inspection it was observed that, R-ph bus PT's oil was spilled on ground.
P	Details of Tests done after failure	:	Test could not be done as the PT was completely damaged.
Q	Observations & Analysis	:	No information of previous maintenance is available. It is difficult to say what the condition of PT before failure was. However, it appears that due to internal fault, gases generated in PT leading to pressure and spillage of oil.

42. Failure report of 400/√3 /110/√3 kV CVT at Nelamangala substation of KPTCL

A.	Name of Substation	:	Nelamangala s/s
B.	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Limited
C.	Faulty Equipment	:	B-ph Capacitive Voltage Transformer of Bus B
D.	Rating	:	400/√3/110/√3 kV Class , 4400 pF
E.	Make	:	W. S. Industries
F.	Sr. No.	:	20000643
G.	Year of manufacturing	:	2000
H.	Year of commissioning	:	Information not available
I.	Date and time of occurrence/discovery of fault	:	19.10.2017 at 02:59 hrs.
J.	Information received in CEA	:	11.04.18

K.	Fault discovered during	:	Operation
L.	Present condition of equipment	:	Removed from service
M.	Details of previous maintenance	:	Last Condition Monitoring done on 16.10.2017.
N.	Details of previous failure	:	Information not known
O.	Sequence of events/ Description of fault	:	ICT-1 had tripped on over flux Relay. On observation, it was found that CVT fuse had failed. There was indication in Backup Relay of ICT 1, 2 and 3. It was found that B-Phase CVT voltage was less compared to the other two Phases.
P.	Details of Tests done after failure	:	

Test result after releasing CVT from service on 27.10.2017

Test conducted on 28.10.2017

A. Capacitance Tan Delta Test

Test Carried out on			Factory Test Report at rated Voltage of 400 kV		Pre-commisioning/ Field Test Report		28.10.17	
Test specification	Mode	Volt applied in kV	Capacitance in pF	Tan Delta in %	Capacitance in PF	Tan Delta in %	Capacitance in pF	Tan Delta in %
Top Stack	UST	2	13030	0.00324	-	-	12807	0.29
		10			-	-	12810	0.31
Middle Stack	UST	2	13130	0.00312	-	-	11972	0.28
		10			-	-	11975	0.29
Bottom Stack	UST	2	13282	0.0031	-	-	13985	27.3
		10			-	-	14280	25.2
	UST	2	4381.9	0.00326	4300	0.00328	4255.6	0.27

Full Stack		10			4299	0.00314	4255.6	0.27
	GST	2	-	-	-	-	4464.6	3.07
		10			-	-	4467.6	3.04

B. Voltage Ratio Test

Test Carried out on		Factory Test Report		Pre-commissioning/ Field Test Report		28.10.2017	
1-ph AC supply applied to Primary Stud and Earth	Secondary Terminal	Voltage Applied	Measured Voltage in V	Voltage Applied	Measured Voltage in V	Voltage Applied	Measu-red Voltage in V
	1a-1n	-	-	230 Volts	0.074	236.1 Volts	0.080
	2a-2n		-		0.074		0.080
	3a-3n		-		0.074		0.081

Note: At 236.1 Volts Single Phase AC supply applied to primary Stud and earth measured voltage at Secondary terminal should be 0.0649V

C. DC IR Test

Test Carried out on	Factory Test Report		Pre-commissioning /Field Test Report		28.10.2017	
	Voltage Applied	IR value in GΩ	Voltage Applied	IR value	Voltage Applied	IR value in GΩ
HV to Grnd	5 kV	-	5 kV	>5000MΩ	5 kV	197
LV to Gnd (1a to Gnd)	500 V	-	500 Volts	>1000MΩ	500 Volts	Invalid value
LV to Gnd (2a to Gnd)		-		>1000MΩ		22
LV to Gnd (3a to Gnd)		-		>1000MΩ		24.8

D. Voltage Measured at Site on 23.10.2017

Voltage In Volts	Core 1	Core 2	Core 3
R-N	61.3	62.5	62.4
Y-N	60.1	60.2	60.1
B-N	29.29	33.63	33.87

Q.	Observations & Analysis	:	The equipment failed in ratio test, capacitance, tan delta under GST Mode and Core 1 DC insulation Resistance. This could be due to deteriorate insulation and /or damaged capacitor elements due to excessive moisture. However, operation of overflux relay could not be explained.

Circuit Breaker

43. Failure report of 220kV CB at Right Bank Power House of BBMB.

A.	Name of Substation	:	Right Bank Power House.
B.	Utility/Owner of substation	:	BBMB
C.	Faulty Equipment	:	Circuit Breaker
D.	Rating	:	245 kV, 3150 A, 40 kA
E.	Make	:	M/s Siemens Limited
F.	Sr. No.	:	2007/IND/03/3378
G.	Year of manufacturing	:	2007
H	Year of commissioning	:	2008 (12.03.2008)
I	Date and time of discovery of fault	:	20.11.2017 at 1624 hrs.
J	Information received in CEA	:	02.01.2018
K	Fault discovered during	:	Operation (At the time of Building up 11 kV voltage)
L	Present condition of equipment	:	Replaced
M	Details of previous maintenance	:	Last annual Maintenance done in January 2017 and Half yearly maintenance done in July, 2017
N	Details of previous failure	:	A similar fault had occurred on 08.08.2014 on R-Phase pole.
O	Sequence of events/ Description of fault	:	On 20.11.2017 at 16:24 hrs., unit No. 10 started and excited to build up 11 kV Voltage. Bus Coupler A-30 and Jamalpur Circuit-I Breaker A-32 tripped with the operation of LBB (CBRD) protection. On investigation, it was found that head flash over protection of unit no. 10 operated resulting in operation of

			LBB protection. SF_6 pressure of Y-phase pole was found to be increased by 0.5 kg/cm^2.
P	Details of Tests done after failure	:	Contact Resistance, IR, timing test. However, no test reports have been furnished.
Q	Observations & Analysis	:	Internal fault might have caused the flash over which in turn increased the pressure in the pole

44. Failure of 245 kV CB at Kondapalli Substation of APTRANSCO

A	Name of Substation	:	Kondapalli Substation
B	Utility/Owner of substation	:	APTRANSCO
C	Faulty Equipment	:	Circuit Breaker pertaining to 220kV VTPS-II feeder (Hydraulic mechanism)
D	Rating	:	245kV
E	Make	:	BHEL Limited
F	Sr. No.	:	401929
G	Year of manufacturing	:	1994-95
H	Date of commissioning	:	23.03.1998
I	Date and time of occurrence/discovery of fault	:	22.10.2017 at 13:38 hrs.
J	Information received in CEA	:	20.11.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced with spring charged CB
M	Details of previous maintenance	:	Information not available
N	Details of previous failure	:	Nil

O	Sequence of events/ Description of fault	:	On 22.10.2017 at 13:38 hrs, DC fuse failure was observed in DCDB pertaining to 220kV VTPS-II feeder. Upon inspection, it was found that limit switch pertaining to hydraulic pressure was burnt. Internal leakage problem was observed in hydraulic mechanism pertaining to Y-Phase Limb of 220kV VTPS-II feeder Circuit Breaker. Oil was returning back to tank without building up the pressure. The same was replaced with new limit switch and the DC failure was rectified. However, when the breaker was tried to be put in service the hydraulic pressure did not build up for closing the breaker.
P	Details of Tests done after failure	:	No tests were conducted as the problem was of mechanical nature associated with the hydraulic system.
Q	Observations & Analysis	:	It appears that due to ageing, the hydraulic mechanism might have developed some internal problem which led to the failure.

45. Failure of 220kV CB at Kanhirode Substation of KSEB

A	Name of Substation	:	220kV Substation Kanhirode
B	Utility/Owner of substation	:	KSEB Ltd.
C	Faulty Equipment	:	Circuit Breaker
D	Rating	:	245kV
E	Make	:	Crompton Greaves Ltd.
F	Sr. No.	:	46017C
G	Year of manufacturing	:	2015
H	Year of commissioning	:	2015

I	Date and time of occurrence/discovery of fault	:	05.11.2017 at 15:39 hrs.
J	Information received in CEA	:	15.11.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Irreparable
M	Details of previous maintenance	:	Last routine maintenance carried out on 15.9.2017.
N	Details of previous failure	:	Nil
O	Sequence of events/ Description of fault	:	On 05.11.2017 at 15:39 hrs, the Y-phase interrupter of CB blasted during auto reclosing on single phase fault (Y ph).
P	Details of Tests done after failure	:	No tests could be done as the CB blasted.
Q	Observations & Analysis	:	Health of CB prior to failure could not be ascertained as details of maintenance carried out on CB on 15.09.2017 are not available. It is suspected that dielectric strength of the breaker was weak and it could not withstand the voltage stress across its terminal during reclosure attempt on fault.

46. Failure of 230kV CB at Manali Substation of TANTRANSCO

A	Name of Substation	:	Manali
B	Utility/Owner of substation	:	TANTRANSCO
C	Faulty Equipment	:	Circuit Breaker of Mylapore feeder
D	Rating	:	230 kV
E	Make	:	AREVA
F	Sr. No.	:	151136

G	Year of manufacturing	:	2008
H	Year of commissioning	:	13.07.2009 (as Basin Bridge Feeder) 19.10.2013 (as Mylapore Feeder)
I	Date and time of occurrence/discovery of fault	:	12.04.2017 at 06:30 hrs.
J	Information received in CEA	:	28.06.17
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced
M	Details of previous maintenance	:	Information not available
N	Details of previous failure	:	nil
O	Sequence of events/ Description of fault	:	On 12.04.2017 at 06:30 hrs., while trying to hand trip the 230kV Mylapore feeder while issuing LC, heavy arcing /flash was noticed and breaker burst (other end already tie opened).
P	Details of Tests done after failure	:	No test could be conducted as the had CB burst.
Q	Observations & Analysis	:	Failure might be due to some internal insulation failure.

Surge Arrestor

47. Failure of 220kV SA at Jalandhar Substation of BBMB

A	Name of Substation	:	220kV Substation Jalandhar
B	Utility/Owner of substation	:	BBMB
C	Faulty Equipment	:	Y-Phase SA of Jalandhar- Dasuya ckt-3
D	Rating	:	220kV
E	Make	:	Crompton Greaves Ltd.
F	Sr. No.	:	51896
G	Year of manufacturing	:	2006
H	Date of commissioning	:	11.08.2006
I	Date and time of occurrence/discovery of fault	:	17.04.2017 at 16:15 hrs.
J	Information received in CEA	:	10.07.2017
K	Fault discovered during	:	During Operation
L	Present condition of equipment	:	Irreparable
M	Details of previous maintenance	:	Last scheduled Yearly maintenance was carried out on 12.10.2016. Each Stack IR value was measured and tightness checked and was found normal. The 3rd Harmonic Resistive leakage current measurement was carried out on 26.07.2016 and the value was 88 µA.
N	Details of previous failure	:	Nil
O	Sequence of events/ Description of fault	:	On 17.04.2017 at 16:15 hrs, 220 kV Jalandhar-Dasuya Ckt. No.3 tripped on Distance Protection Relay. On inspection it was found that Y-phase SA of 220 kV

			Jalandhar-Dasuya Ckt. No.3 had flashed over causing tripping of the line.
P	Details of Tests done after failure	:	Insulator flashed out on the 2 stacks, hence test could not be carried out.
Q	Observations & Analysis	:	Internal fault could be the probable cause of failure.

48. Failure of 230 kV SA at Mylapore Basin Bridge Substation of TANTRANSCO

A	Name of Substation	:	230kV Basin Bridge Mylapore
B	Utility/Owner of substation	:	TANTRANSCO
C	Faulty Equipment	:	B-ph LA of 230kV Basin bridge Mylapore feeder at Cable Termination Point
D	Rating	:	230 kV
E	Make	:	CGL
F	Sr. No.	:	4864
G	Year of manufacturing	:	Information not available
H	Year of commissioning	:	1988
I	Date and time of occurrence/discovery of fault	:	11.11.16 at 1329 hrs
J	Information received in CEA	:	01.05.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced
M	Details of previous maintenance	:	Hi-pot test conducted on 6.6.16 and SA was found to be in healthy condition.

N	Details of previous failure	:	Nil
O	Sequence of events/ Description of fault	:	On 11.11.16 at 1329 hrs, 230 kV Basin bridge feeder tripped. It was found that SA had flashed over. with B-phase 12.4 kAmps.
P	Details of Tests done after failure	:	No tests were conducted as LA had flashed over
Q	Observations & Analysis	:	Fault current of 12.4 kA was observed. Ageing might have caused deterioration in the insulation of SA and caused flashover.

49. Failure of 220 kV SA at Chennai-Korattur s/s Of TANTRANSCO

A.	Name of Substation	:	Korattur
B.	Utility/Owner of substation	:	TANTRANSCO
C.	Faulty Equipment	:	Surge Arrester of 100 MVA Auto-transformer I
D.	Rating	:	216kV, 10kA
E.	Make	:	Crompton Greaves Limited
F.	Sr. No.	:	4856
G.	Year of manufacturing	:	1999
H	Date of commissioning	:	14.06.2003
I	Date and time of occurrence/discovery of fault	:	22.02.2017 at 15:00 hrs.
J	Information received in CEA	:	18.04.17
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced

M	Details of previous maintenance	:	Hi-pot test conducted on 14.7.16 and SA was found to be in healthy condition.
N	Details of previous failure	:	Nil
O	Sequence of events/ Description of fault	:	On 22.02.2017 at 15:00 hrs., large dip in voltage and loud sound was observed from station yard. Relay panel indicated that 100MVA Auto transformer-I had tripped with differential protection. Upon yard inspection it was found that Y-Phase SA of HV side of 100 MVA Auto Transformer-I had flashed over.
P	Details of Tests done after failure	:	No tests conducted as SA had flashed over.
Q	Observations & Analysis	:	Internal fault could be the probable cause of failure.

50. Failure report of 220 kV SA of Nelamangala substation of KPTCL

A.	Name of Substation	:	Nelamangala
B.	Utility/Owner of substation	:	KPTCL
C.	Faulty Equipment	:	B-Phase Surge Arrester of 220kV Nelamangala –Dabuspet Line.
D.	Rating	:	216kV, 10kA
E.	Make	:	Crompton Greaves Limited
F.	Sr. No.	:	5123
G.	Year of manufacturing	:	2000
H.	Year of commissioning	:	Information not available

I.	Date and time of occurrence/discovery of fault	:	22.01.2017 at 16:31 hrs.
J.	Information received in CEA	:	11.08.2017
K.	Fault discovered during	:	Operation
L.	Present condition of equipment	:	Replaced
M.	Details of previous maintenance	:	During Leakage Current Measurement on 07.01.2017, the third harmonic resistive leakage current was about 838 micro amps. The SA was planned to be replaced after making suitable adjustments as the existing SA did not suit the site condition.
N.	Details of previous failure	:	Nil
O.	Sequence of events/ Description of fault	:	On 22.01.2017 at 16:31 hrs, the 220kV Nelamangala - Dabuspet line tripped with Distance protection. On inspection, it was found that B-Phase SA had failed.
P.	Details of Tests done after failure	:	No tests could be conducted
Q.	Observations & Analysis	:	The third harmonic resistive leakage current measured on 07.01.2017 was already much above the permissible limit, which was indicative of ZnO block degradation. SA was recommended for replacement but it was not done and it failed subsequently.

51. Failure of 400kV SA at Alamathy Substation of TANTRANSCO

A	Name of Substation	:	Alamathy Substation

B	Utility/Owner of substation	:	TANTRANSCO
C	Faulty Equipment	:	SA
D	Rating	:	400kV
E	Make	:	Crompton Greaves
F	Sr. No.	:	14687
G	Year of manufacturing	:	2001
H	Year of commissioning	:	2006
I	Date and time of occurrence/discovery of fault	:	16.02.2018 at 17:31 hrs
J	Information received in CEA	:	05.03.2018
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced
M	Details of previous maintenance	:	Each stack IR value was measured and tightness checked on 13.02.2018. Results were normal.
N	Details of previous failure	:	Nil
O	Sequence of events/ Description of failure	:	On 16.02.2018 at 17:31 hrs, flashover occurred in SA of 400 kV Vallure-I feeder phase B with loud noise and smoke came out of the SA.
P	Details of Tests done after failure	:	No tests carried out as SA flashed over.
Q	Observations & Analysis	:	Loud sound and smoke was observed in SA. There appears to be degradation of ZnO blocks due to moisture ingress.

52. Failure report of 220 kV SA of Nelamangala substation of KPTCL

A.	Name of Substation	:	Nelamangala
B.	Utility/Owner of substation	:	KPTCL
C.	Faulty Equipment	:	Surge Arrester in B-Phase of ICT 2
D.	Rating	:	220 kV, 10kA
E.	Make	:	Crompton Greaves Limited
F.	Sr. No.	:	5103
G.	Year of manufacturing	:	2000
H.	Year of commissioning	:	2009
I.	Date and time of occurrence/discovery of fault	:	15.01.2017 at 17:36 hrs.
J.	Information received in CEA	:	11.08.2017
K.	Fault discovered during	:	Operation
L.	Present condition of equipment	:	Replaced
M.	Details of previous maintenance	:	During Leakage Current Measurement on 07.07.2016 the third harmonic resistive leakage current was observed to be 47µA. The transformer was in open condition at the point of the measurement and was taken into service on 15.01.2017 at 12:40 hrs.
N.	Details of previous failure	:	ICT 2, B-phase transformer 216 kV class SA failed on 6.6.2009 and was replaced with spare SA on 17.7.2009.
O.	Sequence of events/ Description of fault	:	ICT 2 had tripped on Differential Protection at 17:36 hrs. on 15.01.2017. On inspection, it was found that 216kV SA of B-Phase Transformer had failed.

P.	Details of Tests done after failure	:	No tests could be conducted.
Q.	Observations & Analysis	:	Storage conditions of SA from 2000 to 2009 are not known. Internal fault is a plausible cause.

53. Failure of 220kV SA of Narendra substation of KPTCL

A.	Name of Substation	:	Narendra
B.	Utility/Owner of substation	:	KPTCL
C.	Faulty Equipment	:	Surge Arrester of Ambewadi- 2 line
D.	Rating	:	220kV
E.	Make	:	Crompton Greaves Limited
F.	Sr. No.	:	23912
G.	Year of manufacturing	:	2003
H.	Year of commissioning	:	2003
I.	Date and time of occurrence/discovery of fault	:	09.01.2017
J.	Information received in CEA	:	11.08.2017
K.	Fault discovered during	:	Operation
L.	Present condition of equipment	:	Damaged
M.	Details of previous maintenance	:	Following actions were taken during routine maintenance: i) All jumps and clamps tightened; ii) No looseness of earth connection found; iii) No cracks on insulator were found and the insulator was cleaned.
N.	Details of previous failure	:	No previous failure

O.	Sequence of events/ Description of fault	:	At the time of failure, CB tripped on fault with heavy sound (Relay NR→ B-N, 'B' phase Start, Z1 operated, Distance – 0.0 km, Fault Current N-33.9 Inom. Relay at Ambewadi s/s → DIR EFR). After yard inspection it was found that 'Y' phase surge arrester had flashed over at Narendra end (Ambewadi-2 line).
P.	Details of Tests done after failure	:	No tests were possible as SA had flashed over.
Q.	Observations & Analysis	:	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. Internal insulation failure could be the reason of flashover.

54. Failure report of 400 kV SA at Nelamangala substation of KPTCL

A	Name of Substation	:	Nelamangala
B	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Limited (KPTCL)
C	Faulty Equipment	:	R-Phase Line Surge Arrester of 400kV Nelamangala – Hiriyur Line 1.
D	Rating	:	390kV, 10kA
E	Make	:	Crompton Greaves Limited
F	Sr. No.	:	5083
G	Year of manufacturing	:	2000
H	Year of commissioning	:	2002

I	Date and time of occurrence/discovery of fault	:	12.09.2017 at 12:36 hrs.
J	Information received in CEA	:	20.11.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced
M	Details of previous maintenance	:	During Leakage Current Measurement on 26.06.2017 the third harmonic resistive leakage current was about 131 micro amps.
N	Details of previous failure	:	Nil
O	Sequence of events/ Description of fault	:	400kV Nelamangala – Hiriyur Line 1 had tripped on Distance Protection Relay at 12:36 hrs. on 12.09.2017. On inspection, it was found that 390kV R-Phase line SA had failed.
P	Details of Tests done after failure	:	No tests could be conducted.
Q	Observations & Analysis	:	It is possible that insulation failure could have caused the failure.

55. Failure of 400kV SA at Nelamangala Substation of KPTCL

A	Name of Substation	:	Nelamangala Receiving Station
B	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Ltd.
C	Faulty Equipment	:	Y-Phase Surge Arrester of 400kV Nelamangala – Talaguppa Line Shunt Reactor
D	Rating	:	390kV, 10 kA
E	Make	:	Crompton Greaves Limited
F	Sr. No.	:	5077

G	Year of manufacturing	:	2000
H	Year of commissioning	:	Information not available
I	Date and time of occurrence/discovery of fault	:	29.10.2016 at 19:33 hrs.
J	Information received in CEA	:	09.01.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced
M	Details of previous maintenance	:	On 05.07.2016, Leakage Current Measurement was done and the third harmonic resistive leakage current was found to be 110 μA.
N	Details of previous failure	:	Information not available
O	Sequence of events/ Description of fault	:	On 29.10.2016 at 19:33 hrs., 400kV Nelamangala – Talaguppa line was in closed condition at both ends while Line Shunt reactor tripped on Differential Protection. After inspection, it was found that Y-phase Surge Arrester of shunt reactor had flashed over.
P	Details of Tests done after failure	:	No tests conducted as SA had flashed over.
Q	Observations & Analysis	:	Internal fault could have led to failure.

56. Failure of 220kV SA at Honnali Substation of KPTCL

A.	Name of Substation	:	Honnali Receiving Station
B.	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Ltd.

C.	Faulty Equipment	:	Y-Phase Surge arrestor of 100MVA Power Transformer-2
D.	Rating	:	220kV
E.	Make	:	Crompton Greaves Limited
F.	Sr. No.	:	15162
G.	Year of manufacturing	:	2002
H	Date of commissioning	:	20.10.2003
I	Date and time of occurrence/discovery of fault	:	06.11.2016 at 18:30 hrs.
J	Information received in CEA	:	09.01.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	To be replaced
M	Details of previous maintenance	:	Last maintenance as following was done on 5.10.2016 : (i) LA stacks were Cleaned (ii) No cracks found on visual inspection (iii) Earth connection was Checked
N	Details of previous failure	:	Information not available
O	Sequence of events/ Description of fault	:	On 6.11.2016 at 18:30 hrs., 100MVA Power Transformer-2 tripped on following relay: (i) General trip (ii) Differential trip (iii) HVREF trip and Directional IDMT Y-Phase HV side. On inspection, it was found that HV side Y-Phase 220kV SA had flashed over.
P	Details of Tests done after failure	:	Test could not be done as SA had flashed over

Q	Observations & Analysis	:	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. Internal insulation failure could be the reason of flashover.

57. Failure of 400kV SA Substation Equipment of Receiving Station, Neelamangala of KPTCL

A	Name of Substation	:	Neelamangala Receiving Station
B	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Ltd.
C	Faulty Equipment	:	R-Phase Surge Arrestor of 400kV Nelamangla – Talaguppa line
D	Rating	:	390kV, 10 kA
E	Make	:	Crompton Greaves Limited
F	Sr. No.	:	5087
G	Year of manufacturing	:	2000
H	Year of commissioning	:	Information not available
I	Date and time of occurrence/discovery of fault	:	11.11.2016 at 21:46 hrs.
J	Information received in CEA	:	09.01.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced
M	Details of previous maintenance	:	During Leakage Current Measurement on 05.07.2016, the third harmonic resistive leakage current was 170 µA. The LA was kept under observation.

N	Details of previous failure	:	Information not available
O	Sequence of events/ Description of fault	:	On 11.11.2016 at 21:46 hrs., the R-Phase Surge Arrestor of 400kV Nelamangla – Talaguppa line flashed over. 400kV Nelamangala – Talaguppa Line Main 1 & 2 protection operated and autoreclosing was unsuccessful.
P	Details of Tests done after failure	:	No test could be conducted as SA flashed over.
Q	Observations & Analysis	:	During previous maintenance, after 3rd harmonic component of resistive current was found to be is more than 150 µA, Insulation Resistance (IR) value test should have been conducted to assess internal condition of the SA. Degradation of ZnO block seems to be cause of failure of SA.

58. Failure of 220kV SA at Honnali Substation of KPTCL

A	Name of Substation	:	Honnali Receiving Station
B	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Ltd.
C	Faulty Equipment	:	Y-Phase Surge Arrestor of 220 kV Shimoga line
D	Rating	:	220 kV
E	Make	:	Crompton Greaves Limited
F	Sr. No.	:	15157
G	Year of manufacturing	:	2002
H	Date of commissioning	:	20.10.2003

I	Date and time of occurrence/discovery of fault	:	18.11.2016 at 15:09 hrs.
J	Information received in CEA	:	09.01.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	To be replaced.
M	Details of previous maintenance	:	Last maintenance carried out on 31.08.2016 (i) SA stacks were cleaned and no cracks were found; (ii) Earth connections were checked.
N	Details of previous failure	:	Information not available
O	Sequence of events/ Description of fault	:	On 18.11.2016 at 15:09 hrs. 220kV Shimoga Line tripped on distance relay. Distance 4.1km, Y-Phase to N, Zone-1 fault current 6.43kA. On inspection, it was found that Y-Phase SA had flashed over.
P	Details of Tests done after failure	:	No test could be done as SA had flashed over.
Q	Observations & Analysis	:	Internal fault might be the probable cause of failure.

59. Failure of 220kV SA at Kemar, Karkala Substation of KPTCL

A	Name of Substation	:	Kemar Receiving Station, Karkala
B	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Ltd.
C	Faulty Equipment	:	Surge Arrestor
D	Rating	:	198kV
E	Make	:	Crompton Greaves Limited

F	Sr. No.	:	9507303
G	Year of manufacturing	:	1995
H	Year of commissioning	:	1999
I	Date and time of occurrence/discovery of fault	:	19.11.2016 at 16:53 hrs.
J	Information received in CEA	:	09.01.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced
M	Details of previous maintenance	:	During maintenance of the bay equipment on 17.09.2016, leakage current of the Surge arresters was measured and found within limits.
N	Details of previous failure	:	Information not available
O	Sequence of events/ Description of fault	:	On 19.11.2016 at 16:53 hrs., the 100MVA Power Transformer tripped with a loud sound. On Inspection/checking the yard, the burn marks were found at the bottom of the "Y" Phase Surge Arrester with smoke emanating from it.
P	Details of Tests done after failure	:	No tests could be conducted as SA had burnt.
Q	Observations & Analysis	:	Weakened insulation due to ageing could be the probable cause of failure.

60. Failure report of 220kV SA at Sangrur Substation of BBMB

A	Name of Substation	:	Sangrur
B	Utility/Owner of substation	:	BBMB

C	Faulty Equipment	:	SA (B-phase of Sangrur –Barnala line)
D	Rating	:	198kV
E	Make	:	CGL
F	Sr. No.	:	51889
G	Year of manufacturing	:	2006
H	Date of commissioning	:	04.10.2006
I	Date and time of occurrence/discovery of fault	:	18.12.2016 at 00:48 hrs.
J	Information received in CEA	:	31.01.17
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Not known
M	Details of previous maintenance	:	Last annual maintenance done on 23.11.16. Details or results of any tests done during maintenance are not available.
N	Details of previous failure	:	Nil
O	Sequence of events/ Description of fault	:	On 18.12.16 at 0048 hrs, B-ph SA of 220 kV Sangrur-Barnala S/C burst during normal operation at 220 kV GSS BBMB, Sangrur.
P	Details of Tests done after failure	:	No tests done as the SA had burst.
Q	Observations & Analysis	:	Internal fault could be the probable cause of failure.

61. Failure of 220kV SA at Tallapalli Substation of APTRANSCO

A	Name of Substation	:	Tallapalli

B	Utility/Owner of substation	:	APTRANSCO
C	Faulty Equipment	:	Surge Arrestor in 'Y' Phase of 220kV Tallapalli –NSPH Ckt.-1 feeder
D	Rating	:	220 kV
E	Make	:	ELPRO International Limited
F	Sr. No.	:	9L11LAH (001 to 002)
G	Year of manufacturing	:	1998
H	Date of commissioning	:	02.09.1998
I	Date and time of occurrence/discovery of fault	:	02.12.2016 at 15:42 hrs.
J	Information received in CEA	:	30.01.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced
M	Details of previous maintenance	:	Information not available
N	Details of previous failure	:	Information not available
O	Sequence of events/ Description of fault	:	On 02.12.2016 at 15:42 hrs., the surge arrestor in 'Y' Phase of 220kV Tallapalli –NSPH Ckt. 1 feeder flashed over and caught fire. Surge monitor was burnt.
P	Details of Tests done after failure	:	No tests could be conducted as the SA flashed over.
Q	Observations & Analysis	:	Weather was dry at the time of fault. Since details of previous maintenance are not available it is not possible to ascertain the condition of SA before fault. Insulation failure could be the reason of failure.

62. Failure of 230kV SA at Korattur Substation of TANTRANSCO

A	Name of Substation	:	Korattur
B	Utility/Owner of substation	:	TANTRANSCO
C	Faulty Equipment	:	SA in B-phase of Almathy-Korattur Feeder
D	Rating	:	230 kV
E	Make	:	LAMCO
F	Sr. No.	:	464A
G	Year of manufacturing	:	1999
H	Date of commissioning	:	03.09.2015
I	Date and time of occurrence/discovery of fault	:	07.08.2016 at 02:42 hrs.
J	Information received in CEA	:	09.05.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Damaged
M	Details of previous maintenance	:	Hi-Pot test conducted on 11.08.2016 by Hot lines and SA was reported to be in healthy condition.
N	Details of previous failure	:	Nil
O	Sequence of events/ Description of fault	:	230kV KTR –Alamathy feeder tripped on fault on 07.08.2016 at 02.40 hrs. The above feeder Line was patrolled and it was found that SA had flashed over at cable termination near police quarters, Avadi area.

P	Details of Tests done after failure	:	Tests could not be conducted as SA had flashed over.
Q	Observations & Analysis	:	It is unclear as to what were the storage condition of SA between 1999 and 2015 and whether or not it was kept charged. It is possible that the flashover had occurred due to weakened insulation of SA.

63. Failure of 230kV SA of Thiruverkadu Feeder at Almathy Substation of TANTRANSCO

A	Name of Substation	:	Alamathy
B	Utility/Owner of substation	:	TANTRANSCO
C	Faulty Equipment	:	SA (R-Phase of 230kV Thiruverkadu Feeder)
D	Rating	:	230 kV
E	Make	:	CGL
F	Sr. No.	:	27215
G	Year of manufacturing	:	2003
H	Year of commissioning	:	2006
I	Date and time of occurrence/discovery of fault	:	24.12.2016 at 10:50 hrs.
J	Information received in CEA	:	07.02.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced
M	Details of previous maintenance	:	IR value of each stack was measured and tightness was checked on 13.10.2016. No abnormality was observed.

N	Details of previous failure	:	Nil
O	Sequence of events/ Description of fault	:	On 24.12.2016 at 10:50 hrs., loud sound and smoke was observed in the SA. It was found that Insulator flashover had happened across 2 stacks.
P	Details of Tests done after failure	:	No tests were carried out as SA had flashed over.
Q	Observations & Analysis	:	Loud sound and smoke was observed. Insulation failure could be the cause of failure of SA.

64. Failure of 400 kV SA of Thiruvalam-I feeder at Alamathy Substation of TANTRANSCO

A	Name of Substation	:	Alamathy
B	Utility/Owner of substation	:	TANTRANSCO
C	Faulty Equipment	:	R-Phase SA of Thiruvalam-I feeder
D	Rating	:	390kV
E	Make	:	Crompton Greaves Limited
F	Sr. No.	:	26183
G	Year of manufacturing	:	2003
H	Year of commissioning	:	2006
I	Date and time of occurrence/discovery of fault	:	05.02.2017 at 03:56 hrs.
J	Information received in CEA	:	27.02.2017
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced

M	Details of previous maintenance	:	IR value of each stack was measured and tightness was checked on 10.08.2016. No abnormality was observed.
N	Details of previous failure	:	Nil
O	Sequence of events/ Description of fault	:	On 05.02.2017 at 03:56 hrs., loud sound and smoke was observed in the SA. It was found that Insulator flashover had occurred over 2 stacks.
P	Details of Tests done after failure	:	No tests were carried out as SA had flashed over.
Q	Observations & Analysis	:	Insulation failure may be the reason of failure of SA.

65. Failure report of 220 kV R-ph SA of Shimoga line at Honnali s/s of KPTCL

A.	Name of Substation	:	220 kV R/S Honnali
B.	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Limited
C.	Faulty Equipment	:	Surge arrester in R-Phase of 220 kV Shimoga line
D.	Rating	:	220 kV
E.	Make	:	Crompton Greaves
F.	Sr. No.	:	15163
G.	Year of manufacturing	:	2002
H	Date of commissioning	:	20.10.2003
I	Date and time of occurrence/discovery of fault	:	11.12.2017 at 16:39 Hrs.
J	Information received in CEA	:	11.04.18
K	Fault discovered during	:	Operation

L	Present condition of equipment	:	Damaged
M	Details of previous maintenance	:	On 14.09.2017, following routine maintenance was done: SA stacks were cleaned. No cracks were found. Leakage current was checked and the values were found to be within limits. Earth connection was checked. IR values were measured: Top to G - 2GΩ Middle to G-3GΩ Across stack1-800MΩ Across stack 2 -1GΩ.
N	Details of previous failure	:	Information not available
O	Sequence of events/ Description of fault	:	On 11.12.2017 at 16:39 hrs , R-ph Surge arrestor of 220 kV Shimoga line flashed over. No relay operated. Line was tripped manually.
P	Details of Tests done after Failure	:	No tests could be conducted as SA had flashed over.
Q	Observations & Analysis	:	Insulation failure could be the probable cause of failure of SA.

66. Failure report of 220 kV R-ph SA of 100 MVA Power Transformer -1 at Honnali s/s of KPTCL

A.	Name of Substation	:	220 kV Receiving s/s Honnali
B.	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Limited
C.	Faulty Equipment	:	Y-Phase SA of 100 MVA Power Transformer -1
D.	Rating	:	220 kV
E.	Make	:	CGL

F.	Sr. No.	:	15155
G.	Year of manufacturing	:	2002
H	Date of commissioning	:	20.10.2003
I	Date and time of occurrence/discovery of fault	:	23.02.2018 at 16:35 Hrs.
J	Information received in CEA	:	11.04.18
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	To be replaced
M	Details of previous maintenance	:	Following maintenance activity was carried out on 04.01.18: SA stack was cleaned. No cracks were found. Earth connection was checked and IR values were measured. Top-G-1GΩ Middle-G-2GΩ Across stack1- 500 MΩ Across stack2-800MΩ
N	Details of previous failure	:	Information not available
O	Sequence of events/ Description of fault	:	On 23.02.2018 at 16:35 hrs., 100 MVA Power transformer-I (CGL make) tripped on the REF relay MTR 86. On inspection, it was found that HV side Y-Phase 220 kV SA had flashed over.
P	Details of Tests done after failure	:	Insulation Measured : Top-G -500 MΩ Middle-G - 600 MΩ Across Stack-1- 200MΩ Across Stack-2 - 5MΩ

Q	Observations & Analysis	:	Insulation resistance measurement carried out after failure of SA indicated insulation failure of SA probably due to moisture ingress.

67. Failure report of 220 kV SA at Nelamangala s/s of KPTCL

A.	Name of Substation	:	400 kV, Nelamangala Receiving Station
B.	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Limited
C.	Faulty Equipment	:	Surge Arrester of R-ph of 220 kV Nel – Anchepalya line.
D.	Rating	:	216 kV , 10kA
E.	Make	:	CGL
F.	Sr. No.	:	5113
G.	Year of manufacturing	:	2000
H	Date of commissioning	:	10.06.2002
I	Date and time of occurrence/discovery of fault	:	07.03.2018 at 1700 hrs.
J	Information received in CEA	:	11.04.2018
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced with OBLUM make SA
M	Details of previous maintenance	:	During Leakage Current Measurement on 04.06.2017 the third harmonic resistive leakage current was about 295 micro amps which was in increasing trend. It was planned to replace the SA. However, the replacement got delayed due to some inadvertent reasons.

N	Details of previous failure	:	No previous failures
O	Sequence of events/ Description of fault	:	220 kV Nelamangala – Anchepalya Line tripped on distance protection Relays Main 1 and 2 at 17:00 hrs. on 07.03.2018. On inspection, it was found that 216 kV Surge Arrester provided for R-Phase of 220 kV Nel – Anchepalya line had failed.
P	Details of Tests done after failure	:	No tests were conducted.
Q	Observations & Analysis	:	High leakage current measured during routine maintenance was indicative of deteriorated insulation of SA. However, the same could not be replaced on time and failed subsequently.

68. Failure report of 400 kV R-ph SA of Hoody-1 line at Nelamangala s/s of KPTCL

A.	Name of Substation		400 kV Nelamangala Receiving Station
B.	Utility/Owner of substation		Karnataka Power Transmission Corporation Limited
C.	Faulty Equipment		Surge Arrester of R-ph of 400 kV Nelamangala– Hoody Line 1
D.	Rating		390 kV, 10kA
E.	Make		CGL
F.	Sr. No.		5075
G.	Year of manufacturing		2000
H.	Year of commissioning		2002
I.	Date and time of occurrence/discovery of fault		21.01.2018 at 18:35 hrs.
J.	Information received in CEA		11.04.2018

K.	Fault discovered during		Operation
L.	Present condition of equipment		Replaced with available spare of OBLUM Make bearing S. No.124.
M.	Details of previous maintenance		During Leakage Current Measurement on 04.01.2018 the third harmonic resistive leakage current was about 458 micro amps which was in increasing trend. The SA was scheduled to be replaced during the week when the failure occurred.
N.	Details of previous failure		No information available
O.	Sequence of events/ Description of fault		400 kV Nelamangala – Hoody Line 1 had tripped on Single pole. Later 3 pole trip was generated due to direct trip received from Hoody end (Distance Protection Relay) at 18:35 hrs. on 21.01.2018. On inspection, it was found that 390 kV R-Phase Line SA had failed.
P.	Details of Tests done after failure		No tests were conducted
Q.	Observations & Analysis		The third harmonic resistive leakage current value was 458 µA in January 2018, was indicative of deteriorated insulation of SA and it needed to be replaced, as was decided by the utility. However, the same could not be replaced on time and failed subsequently.

69. Failure report of 220 kV B-ph SA of Anchepalya Line at Nelamangala s/s of KPTCL

A.	Name of Substation	:	400 kV, Nelamangala Receiving Station
B.	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Limited

C.	Faulty Equipment	:	B-Phase Surge Arrester of 220 kV Nelamangala– Anchepalya Line.
D.	Rating	:	216 kV Class , 10 kA
E.	Make	:	Crompton Greaves Limited
F.	Sr. No.	:	5111
G.	Year of manufacturing	:	2000
H.	Year of commissioning	:	2002 (10.06.2002)
I.	Date and time of occurrence/discovery of fault	:	07.03.2018 at 1700 hrs
J.	Information received in CEA	:	11.04.2018
K.	Fault discovered during	:	Operation
L.	Present condition of equipment	:	Replaced with OBLUM make spare with S.No. 105.
M.	Details of previous maintenance	:	During Leakage Current Measurement on 04.01.2018, the third harmonic resistive leakage current was about 324 micro amps which was in increasing trend. The SA was scheduled to be replaced during the week when the failure occurred.
N.	Details of previous failure	:	Information not available
O.	Sequence of events/ Description of fault	:	220 kV Nelamangala –Anchepalya Line had tripped on Distance Protection Relays Main 1 and 2 at 1700 Hrs. on 07.03.2018. On inspection, it was found that 216 kV Surge Arrester provide for B-Phase had failed.
P.	Details of Tests done after failure	:	

Test conducted after releasing the faulty B Phase Line Surge Arrester provided for 220 kV Nelmangala- Anchepalya Line on 08.03.2018

DC insulation Resistance Test:

Test carried out on			Factory Test Report at rated Voltage of 400 kV	Pre-commissioning Field Test Report	08.03.2018
Test Specification	Voltage applied in kV	Duration @	Insulation Resistance		
Full stack	5	20 Sec	NA		82.9 GΩ
		1 Min.			92.4 GΩ
Top Stack	5	20 Sec			81.3 GΩ
		1 Min.			92.4 GΩ
Bottom Stack	5	20 Sec			6.18 MΩ
		1 Min.			6.52 MΩ

Q.	Observations & Analysis	:	Higher leakage current values indicated poor insulation of SA and the decision of replacement was already taken by the utility. Insulation Resistance test carried out after failure of SA was also indicative of poor insulation of the bottom stack. However, the SA could not be replaced on time and failed subsequently.

70. Failure report of 220 kV Y-Phase SA at Oni Substation of MSETCL

A.	Name of Substation	:	Oni s/s
B.	Utility/Owner of substation	:	MSETCL

C.	Faulty Equipment	:	Y-ph SA of 25 MVA T/F-1
D.	Rating	:	198 kV
E.	Make	:	CGL
F.	Sr. No.	:	24128
G.	Year of manufacturing	:	2003
H	Date of commissioning	:	19.07.2008
I	Date and time of occurrence/discovery of fault	:	25.07.2017 at 16:25 Hrs.
J	Information received in CEA	:	12.07.2018
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	Replaced by new SA on 27.12.2017
M	Details of previous maintenance	:	Cold washing of insulators for SA was carried out on 20.11.2017. LCM test was carried out on 14.03.2017 and results were found within limit (Ir_{corr} =75μA).
N	Details of previous failure	:	No previous failures
O	Sequence of events/ Description of fault	:	25 MVA BBL Transformer tripped on differential protection. Protection operation was in order. It was found that Y-phase SA had burst.
P	Details of Tests done after failure	:	No tests were possible as SA had burst.
Q	Observations & Analysis	:	Storage condition of SA during 2003 to 2008 is not known. Insulation failure might be the probable cause of failure of SA.

71. Failure report of 400 kV SA at Talandage s/s of MSETCL

A.	Name of Substation	:	Talandage (Kolhapur)
B.	Utility/Owner of substation	:	MSETCL
C.	Faulty Equipment	:	Surge Arrestor
D.	Rating	:	390 kV
E.	Make	:	CGL
F.	Sr. No.	:	22264A
G.	Year of manufacturing	:	2002
H.	Date of commissioning	:	31.03.2002
I.	Date and time of occurrence/discovery of fault	:	30.03.2018 at 1448 hrs.
J.	Information received in CEA	:	22.05.18
K.	Fault discovered during	:	Operation
L.	Present condition of equipment	:	Replaced
M.	Details of previous maintenance	:	Last maintenance was done on 23.03.2018 and LCM value was 126 µA.
N.	Details of previous failure	:	No previous failures
O.	Sequence of events/ Description of fault	:	On 30.03.2018 at 1448 hrs, the SA burst while in operation. ICT tripped on differential protection. Protection operation was in order.
P.	Details of Tests done after failure	:	SA could not be tested as it had burst.
Q.	Observations & Analysis	:	Insulation failure might be the probable cause of failure of SA.

XLPE CABLE

72. Failure of 220 kV XLPE Cable of Maharani Bagh-Electric Lane (Harish Chandra Mathur Lane) circuit-I of DTL

A.	Name of line	:	Maharani Bagh-Electric Lane circuit-I
B.	Utility/Owner	:	DTL
C.	Faulty Equipment	:	XLPE Cable (Location: DMRC construction site at Sarai-Kale Khan)
D.	Rating	:	220 kV Single core 1200 sq.mm
E.	Method of Laying	:	Directly buried in most parts and through HDPE pipes in some areas such as road crossings etc.
F.	Make	:	M/s L.S.Cable & System Ltd., Korea
G.	Year of manufacturing	:	2010
H.	Date of commissioning	:	2012
I.	Date and time of occurrence/discovery of fault	:	22.02.2018 at 1:26 AM
J.	Information received in CEA	:	08.06.2018
K.	Fault discovered during	:	Operation
L.	Details of previous failure	:	No previous failure
M.	Sequence of events/ Description of fault	:	
	On 22.05.2018 at 1:26 AM, Maharani Bagh-Electric Lane circuit-I tripped on distance protection, zone -I. Fault distance indicated by relay was 1.6 km from Maharani Bagh substation. Fault current of approx. 32 kA in B-phase cable was registered in disturbance recorder. Excavation was done to find exact location of the fault and it was traced to the portion of the cable passing through DMRC construction site at Sarai Kale Khan.		

DMRC had to carry out digging work beneath the cable for some construction activity related to metro line. During the construction period, the cables were put in hanged position on support structure as approved by DTL/LS Cable. After completion of construction work, the cable had to be restored to its original position. During restoration work, support beam & wooden plank were not removed from beneath the cable and sand was filled in the dug up area to bring it to original earth level.

N.	Details of Tests done after failure	:	Not applicable
O.	Observations & Analysis	:	

It was informed that both the circuits were covered with sand and concrete slab before fault (Exhibit-I). Soil was excavated to find faulty cable and all three single core XLPE cables of Maharani Bagh-Electric Lane circuit-I were exposed.

Exhibit-I

B-phase cable was found to be faulty and concerned part of the cable was found to be wrapped to prevent entry of water into the cable (Exhibit-II).

Exhibit-II

Some part of the exposed cable was under HDPE pipes. It was informed by DTL that at the places where excavation was not possible for laying of cable and for road crossings, the laying was done through pipes.

The cable was found to be bent at the location of the fault where it was laid on steel support and wooden plank. However, wooden plank was not in its designated place at the time of visit of the team. It was informed that the plank had fallen during wrapping of the cable. The cables were at slope beyond fault location in the direction of electric lane end.

After removing wrapping it was observed that outer jacket of the cable was damaged and corrugated metallic sheath of aluminium had melted due to heat generated during fault (Exhibit-III).

Exhibit-III

While backfilling of soil was done steel channel from beneath the cables were not removed. It appears that since enough cushion beneath the cable, it could not withstand the load of the soil and concrete slabs present over the cable and it bend at the edges of the steel channel. Due to bending, distribution of electrical stresses was not uniform across the cross section of the cable which led to increased stress at certain points of the cable. These stresses might have led to localized deterioration of the insulation resulting into short circuit in the cable which is corroborated by operation of distance relay and flow of 32 kA current as recorded in disturbance recorder. High energy arcing generated due to short circuit caused aluminium sheath to melt.

It was informed that OPGW cable had also failed few days prior to cable failure which is why differential protection did not operate.

ANNEXURE-II

Failure Report as Provided by PGCIL

Powergrid Corporation of India Ltd

Investigation Report on Failure of 315 MVA, 400/220 kV ICT-II at Raigarh Station

315 MVA, 400 kV CGL make ICT-II at Raigarh S/s on 03rd September, 2017 at 16:15 Hrs tripped on Y and B phase fault. Fault was sensed by differential and REF protections. Loud sound was heard by the SS personnel and upon rushing to the transformer, emulsifier operation was seen. The main tank hood got bulged from the bottom **(400 kV side)** and bell tank joint bolts broke away. In order to investigate the reasons for the failure and to assess extent of damage, a committee was constituted vide note DTS ref 162725 comprising of following members:

S.No.	Name	Designation	Place of Posting
1..	Sh D K Javeri	DGM	Raigarh WR 1
2.	Sh Vijay Srivastava	Manager	RHQ-AM, WR 1
3.	Sh. Deo Nath Jha	Engineer	CC-AM

The team visited Raigarh S/s for investigation of failure on 06th and 7th September, 2017.

Following are the observations:

Equipment Details:
ICT-II: Sl No.: T-09096/3 Make: CGL,
Date of Commissioning: 31.01.2008

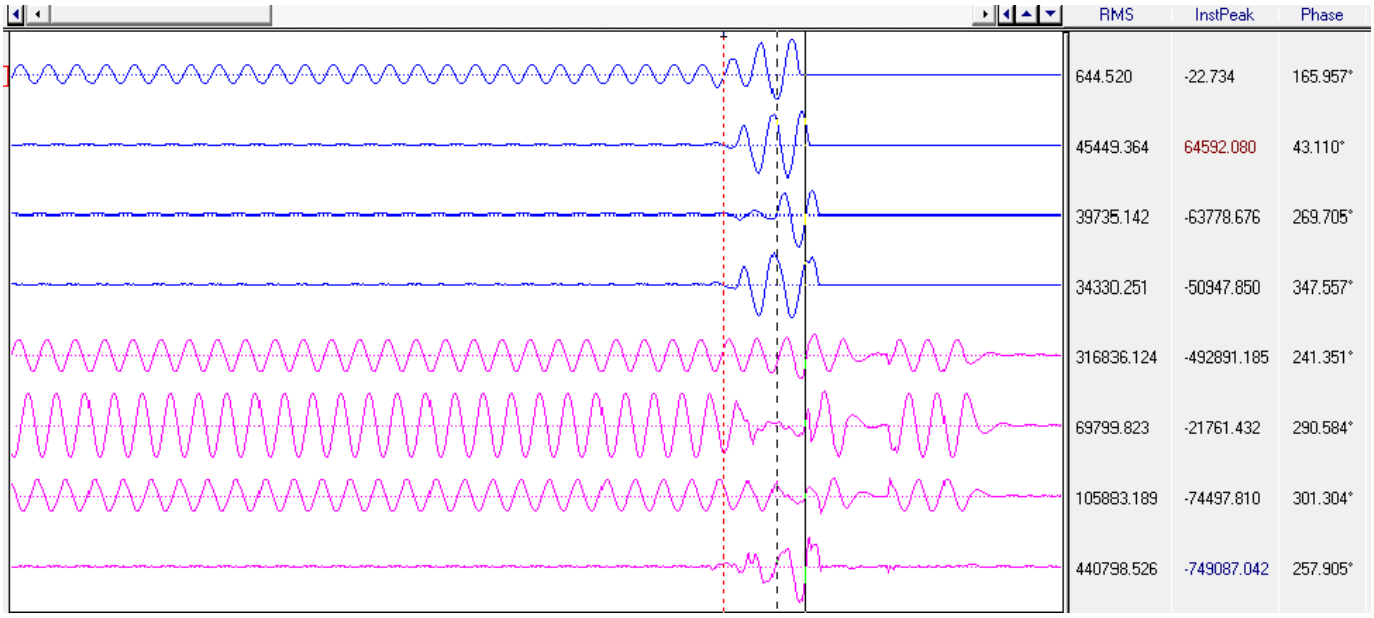
Date and Time of Failure: 03.09.2017, 16:15:15: 552

Pre-Conditions:
Prior to the failure, system was in normal operation and there was a load of 141 MW on ICT 1 and ICT 2

Sequence of Fault:

16:15:16:026	Differential protection start
16:15:16:035	REF protection operated
16:15:16:038	Instantaneous Phase Overcurrent Trip
16:15:16:038	Instantaneous Earth Fault Trip
16:15:16:042	Differential trip

Signal	Pre-fault values	Fault values
I_a	219 A	0.58 kA
I_b	222 A	45.44 kA
I_c	220 A	38.79 kA
V_a	239 kV	316 kV
V_b	242 kV	69.8 kV
V_c	236 kV	105.9 kV

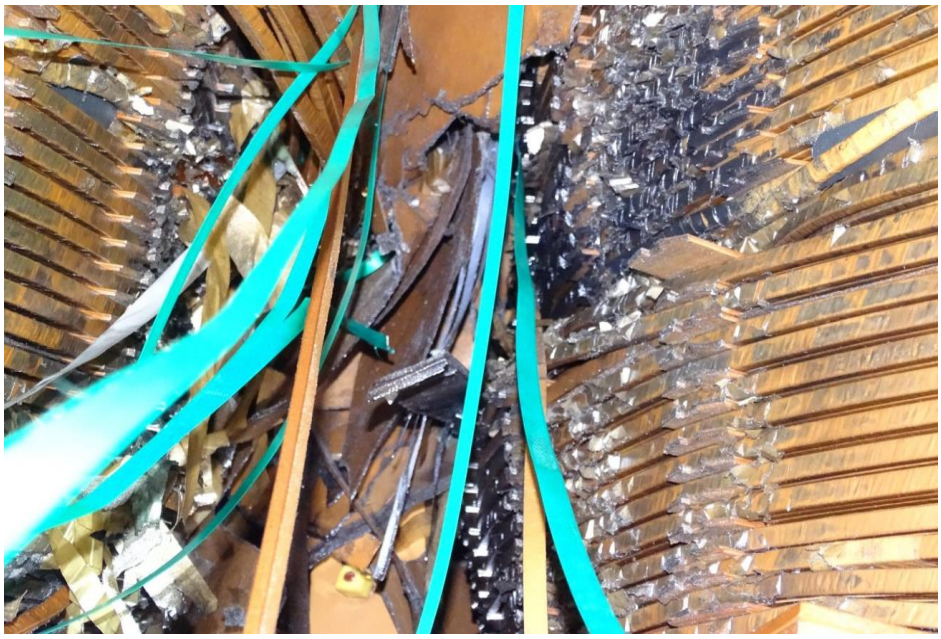


As can be seen from the DR, fault has originated in Y-phase and further spread to B-phase.

Description of Fault:

ICT 2 tripped on operation of differential protection (Y and B phases) and REF protection. Fault current of the order of 44kA was seen in Y phase and 38.5 kA in B phase. The fault was cleared within 40 - 50 milliseconds (two and a half cycles). It is observed that Y and B phase windings are affected in the same portion; hence there is strong possibility of phase to phase fault. The windings (both Y and B phase) have bulged and deformed, same are also displaced (came closer to each other). The top yoke also got displaced and gap could be seen from the laminations. Charred wraps, blocks and spacers were found in the bottom of the tank. The tank wall shunts have detached and CRNGO strips have come out from the 400 kV side of bell tank joint which has opened.

Main tank bell joint 72 bolts gave away and bell joint (400 kV) opened due to the energy of fault



Y and B phase windings after removing the wraps

Some LV tests have been carried out. Test results are as mentioned below:

IR Value R phase – 2.78 G Ohm
IR Value Y phase – 3.01 G Ohm
IR Value B phase – 126 G Ohm
Magnetizing Current @ 230 Volts - R phase : 1 Amp; Y ph – 3 m Amp; B ph – 2 Amp

Transformer had a history of DGA violation since 03.12.2012 (H2 and C2H2). Since then internal inspection by OEM, M/s CGL has been carried out four times on 17.04.2013, 22.06.13, 18.11.2013 and 31.08.2016. Transformer was energized on 19.09.2016 after the fourth round of inspection.

DGA Results of the transformer:

S.No.	Date	H2	CH4	C2H6	C2H4	C2H2	CO	CO2
1	06.09.2017 (Post Failure)	3553	2714	515	5556	4721	336	1527
2	25.07.2017	31.00	6.00	1.00	10.00	0.40	191.00	2116.00
3	27.05.2017	34	6	1	10	0.7	176	1970
4	04.05.2017	39	6	1	10	1.2	149	1754
5	04.04.2017	29	5	1	9	1.9	91	1245
6	07.02.2017	39	7	1	9	3.6	67	988
7	25.01.2017	34	8	4	9	6	49	1184
8	20.12.2016	39.80	6.50	0.80	7.90	6.80	43.60	817.98
9	21.11.2016	42.55	6.80	0.96	8.80	12.72	41.50	743.10
10	27.10.2016	59.13	6.84	0.33	7.96	14.00	36.76	1477.00
11	07.10.2016	25.00	3.50	0.00	4.30	9.90	11.40	305.10

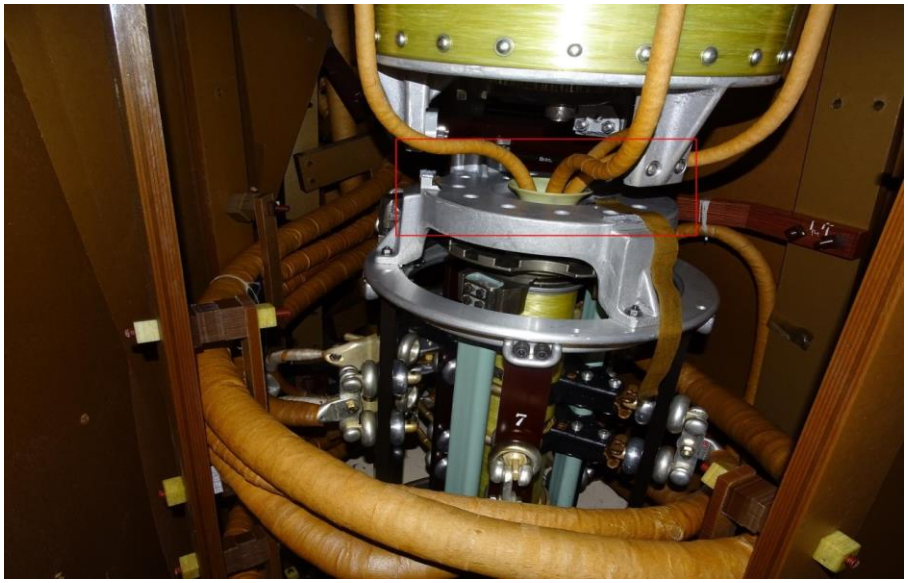
As can be observed from the DGA results, DGA violation (C2H2) was observed and same was being monitored. The gas levels had stabilized prior to failure.

All 400 kV and 220 kV bushings flanges have cracked, internal porcelain cones have also cracked (but not shattered). This happened because of the high pressure generated during the fault and shock waves generated. Otherwise, the 400 kV and 220 kV bushings are OK. 33 kV bushings are also healthy.

Accordingly internal inspection was carried out and no abnormality to the Cores was observed, except mechanical displacement as a consequence of winding displacement.

Top yoke displacement

OLTC was operated manually and tap change occurred on all phases, indications also confirmed on the OLTC MB. However, due to the mechanical force the selector switch housing got detached from the diverter chamber for Y and B phases.



Detached selector switch housing

Conclusion:

The likely reasons for failures were analyzed. As the transformer was running with intermittent DGA violation since December, 2012, there is a possibility of weakening of phase barrier insulation between the Y and B phase windings due to intermittent high energy discharges. Just prior to the failure, the insulation has deteriorated to an extent that it could not withstand power frequency voltage. As also can be seen from the DGA, the energy discharges were external to the active part.

Based, on the above, the committee opines that the transformer can be repaired at transformer factory by replacing the Y and B phase windings (R phase winding to be assessed upon removal of the hood and inspection of CCA), replacing all 400kV and 220kV bushings, replacing the oil, replacing affected OLTC selector switch housings of Y and B phases and repair of main tank. Complete replacement of core is not envisaged.

However, detailed joint inspection of CCA is necessary for verifying the healthiness of R phase winding and finalizing the repair procedure.

Powergrid Corporation of India Ltd

Substation: Jalandhar **Region: NR 2**

Date: 16-12-2017

Investigation Report on Failure of 315 MVA, 400/220 kV ICT-1 at Jalandhar Station

315 MVA, 400 kV BHEL make ICT-1 at Jalandhar S/s tripped on R phase fault on 13th December, 2017 at 11:03:58 Hrs. Fault was sensed by all electrical and mechanical protections. Cracks were observed in the main tank near R &Y-phases of HV side. All the bushing flanges were also found to be cracked and oil leakage was observed from bushings and various points in Main tank. In order to investigate the reasons for the failure and to assess extent of damage, a committee was constituted vide note Ref. N2JAL/SS_ Dated 14.12.2017 comprising of following members:

S.No.	Name	Designation	Place of Posting
1..	Sh S K Chowan	Asst. GM	RHQ-AM, Jammu, NR-II
2.	Sh Sukhdev Singh	Deputy Manager	Moga, NR-II
3.	Sh. Balwinder Kumar	Deputy Manager	Jalandhar, NR-II
4.	Sh. Deo Nath Jha	Engineer	CC-AM

The team visited Jalandhar S/s for investigation of failure on 14th - 16th December' 2017.

Following are the observations:

Equipment Details:

ICT-1: Sr. No.: T-6005782 Make: BHEL,

Date of Commissioning: 31.12.2000

Date and Time of Failure: 13.12.2017, 11:03:58: 884

Major Maintenance history: Due to oil leakage problem major overhauling of this ICT was carried out in November 2015, all gaskets were replaced along with overhauling of OLTC. Increase in gases (H2) was observed in February 2017 and since then ICT was kept under 15 days DGA monitoring. Last AMP result of said ICT was under limit and next AMP was due in March 2018.

Pre-Conditions:

Prior to the failure, system was in normal operation and there was a load of 93 MW on ICT 1

Sequence of Event:

11:03:58:884	Back up E/F operated
11:03:58:885	Differential Operated
11:03:58:885	86B operated
11:03:58:886	REF Operated
11:03:58:886	Back up O/C operated
11:03:58:886	86A operated
11:03:58:925	40152 Main CB open
11:03:58:927	20552 CB open

Signal	Pre-fault values			Fault Values_ 11:03:58:875		
	Main CT	Tie CT	220 kV CT	Main CT	Tie CT	220 kV CT
I_a	82	53	243	**1567**	**937**	**27081**
I_b	74	61	238	62	77	787
I_c	83	52	237	164	58	261

DR and Event Logger (SOE) are attached at Annexure-1.

Description of Fault:

Fault current of the order of 27kA was seen in R phase IV side. The fault was cleared within 61 milliseconds. Both PRVs operated along with OLTC oil surge/Bucholz Trip & alarm relays. Terminal connectors of 400kV R & Y phase bushings were found to be broken. Cracks were observed in HV & IV bushings base flanges along with oil leakage from base. Cracks and oil leakage were found near HV side R & Y phase area. Cracks has also been observed in R & Y phase OLTC top head cover.

(220 KV Y PH BUSHING)

(LEAKAGE FROM BELL JOINT)

(CRACKS IN TANK)

(DAMAGED CC-CL BLOCK)

Following LV tests have been carried out. Test results are as below:

a. **IR Value measurement**
   HV+IV to LV – 32.3 KΩ
   HV+IV to E - 86.5 MΩ
   LV to E – 91.5 MΩ

b. **Magnetizing Current @ 230 Volts** HV- R ph: 460 mA; Y ph – 1.82 m A; B ph – 1.8 mA
   IV- R ph: 1140 m A; Y ph – 590 mA; B ph – 590 mA

c. **Magnetic Balance Test:**

IV side

R-phase	Y-phase	B-phase
246.7 V	129.6	9.05 V
0.78 V	**247.7V**	247 V
0.5 V	247.2V	**248.2V**

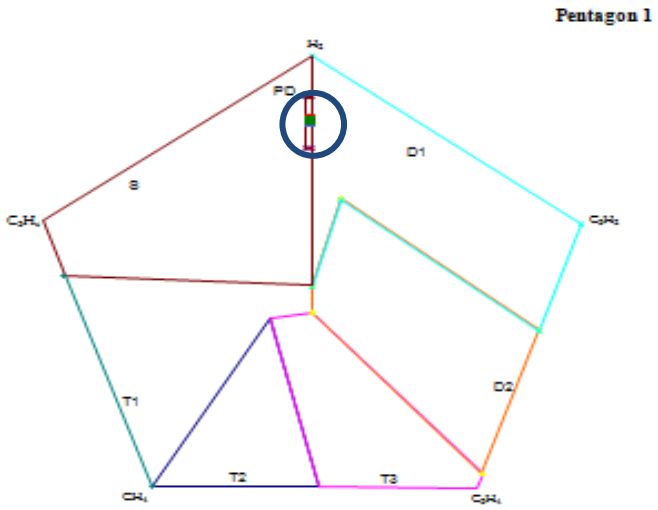
As can be seen from the LV test results, R-phase winding seems to be short circuited.

DGA Results of the transformer:

Transformer had a history of DGA violation since February 2017. DGA results of last 9 samples are as follows:

S.No.	Date	H2	CH4	C2H6	C2H4	C2H2	CO	CO2
1	08-Aug-2017	**719**	39	6	3	0	197	1971
2	22-Aug-2017	**784**	42	6	2	0	199	1967
3	04-Sep-2017	**870**	48	7	2	0	211	2056
4	21-Sep-2017	**945**	52	7	3	0	216	2125
5	11-Oct-2017	**925**	52	7	2	0	197	1885
6	27-Oct-2017	**1018**	58	9	2	0	198	1882
7	17-Nov-2017	**1136**	66	10	3	0	200	1787
8	06-Dec-2017	**1171**	70	11	3	0	193	1743
9	**13-Dec-2017 Post failure**	**1274**	**170**	**27**	**264**	**309**	**190**	**1534**

As can be observed from the DGA results, DGA violation (H2) was observed and same was being monitored. Continuous rise was also being observed in CH4.



As can be seen from Duval's Pentagon 1, DGA results indicate continuous Partial Discharge inside the transformer. However, CO and CO2 seem to be stable over the period of measurement which indicates that no discharge is present in the insulation paper/ pressboards and the partial discharge

indicated by hydrogen rise is due to voids in oil insulation. As only H2 has crossed the fault limit and other gases are stable, no incipient fault can be deduced prior to failure.

All 400 kV and 220 kV bushings flanges have cracked. This happened because of the high pressure generated during the fault and shock waves generated. Otherwise, the 400 kV and 220 kV bushings are OK. 33KV Bushing physically found ok.

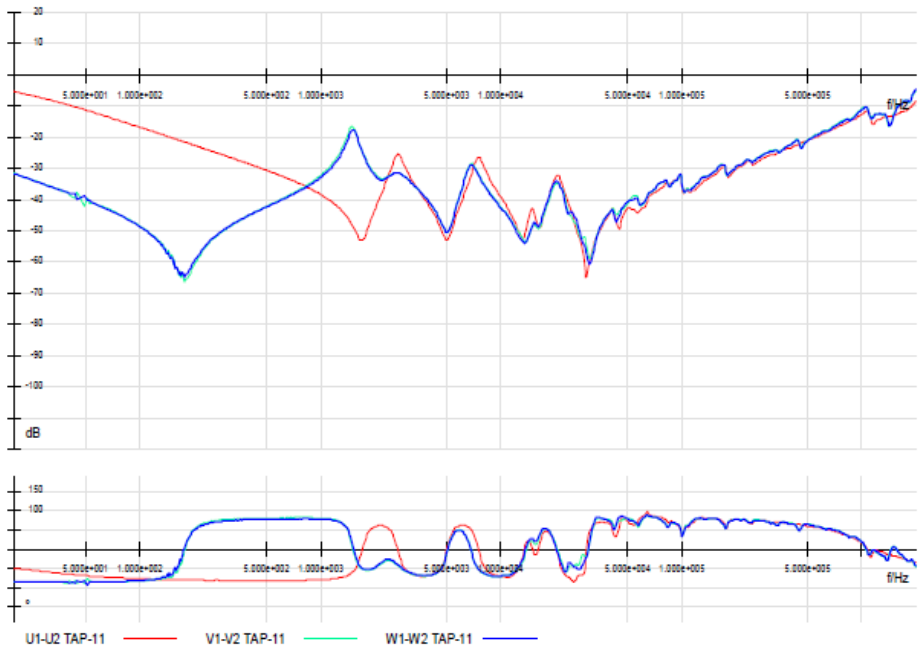
FINDINGS OF INTERNAL INSPECTION:

The findings of Internal Inspection are as follows:

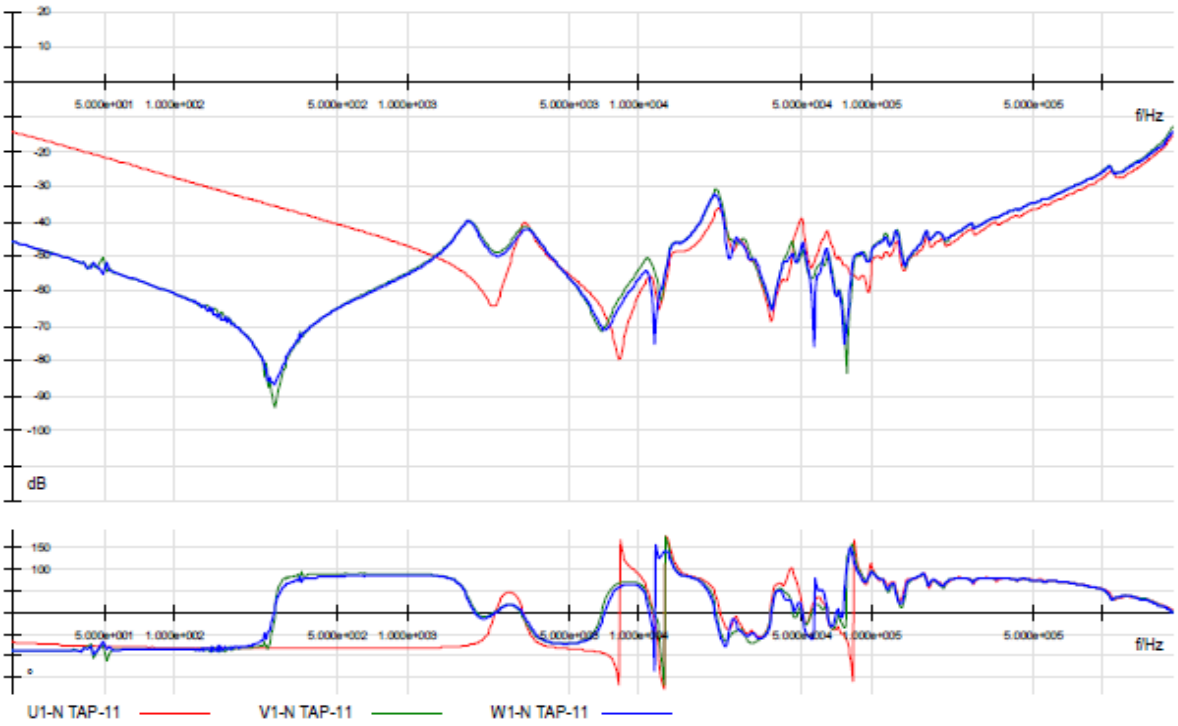
1. *The CC-CL link was found to be completely burnt due to flow of fault current i.e core- winding insulation failure. Low IR values also confirm the same.*
2. *IV side was not accessible hence detail inspection could not be done however no sign of any damage found in IV side.*
3. *No flashover was observed in bushing however all bushing flanges have been damaged due to high pressure.*
4. *No sign of any external flash over in the winding has been observed.*
5. *Insulation barriers of R-ph were found to be burnt and charred spacers and lot of insulation material were found scattered in main tank bottom.*

FRA test was carried out to ascertain the location of the fault using Omicron make “FRAnalyzer” SFRA Test Kit at Tap Position-11 and plots of the adjacent phases of transformer were compared.

Comparison of Three phase Open Circuit SFRA plot for 1U TO 2U, 1VTO 2V & 1W TO 2W at TAP- 11

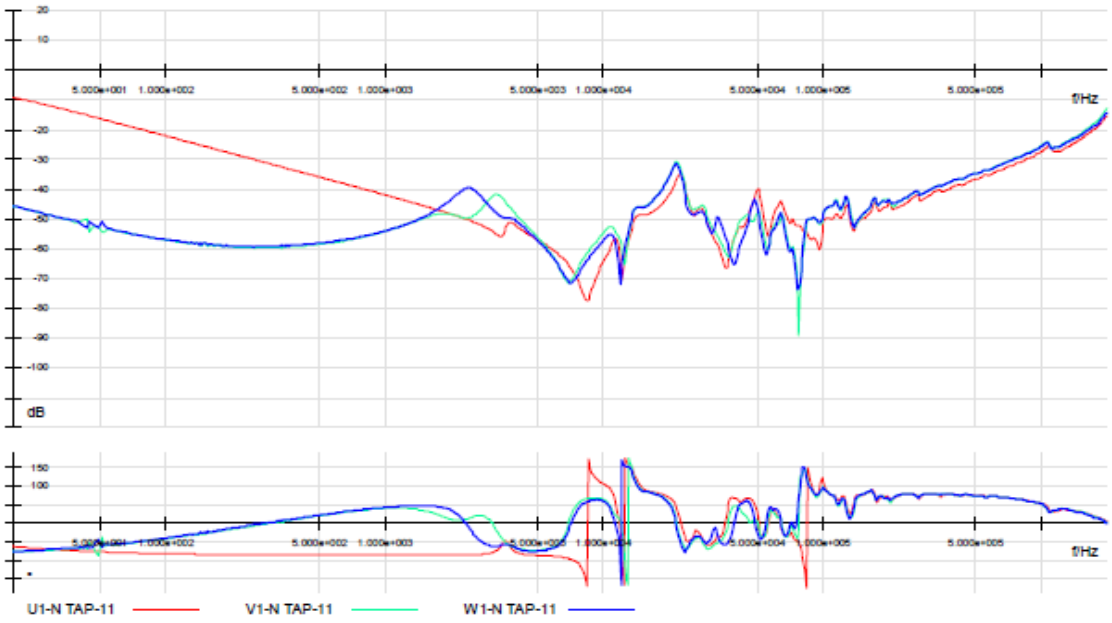


Comparison of Three phase Open Circuit SFRA plot for 1U TO N, 1V TON & 1W TO N at TAP- 11



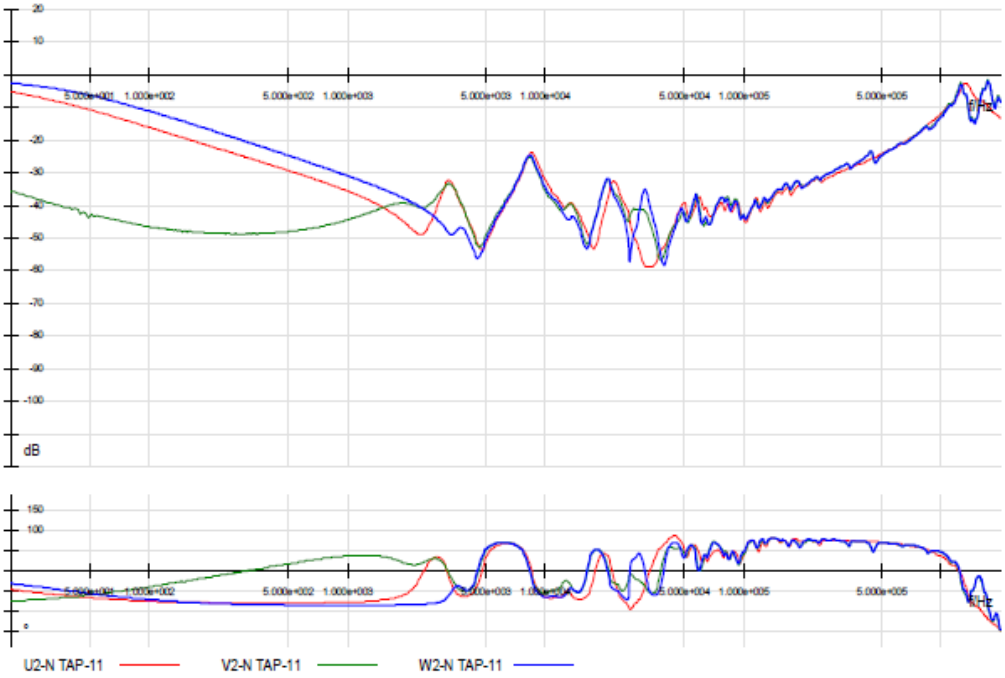
Above two plots clearly indicate the shorting of R-phase core with partial damage of R-ph windings.

Comparison of 3-ph Short Circuit SFRA plot for 1U TO N, 1V TO N & 1W TO N at TAP- 11 with LV short



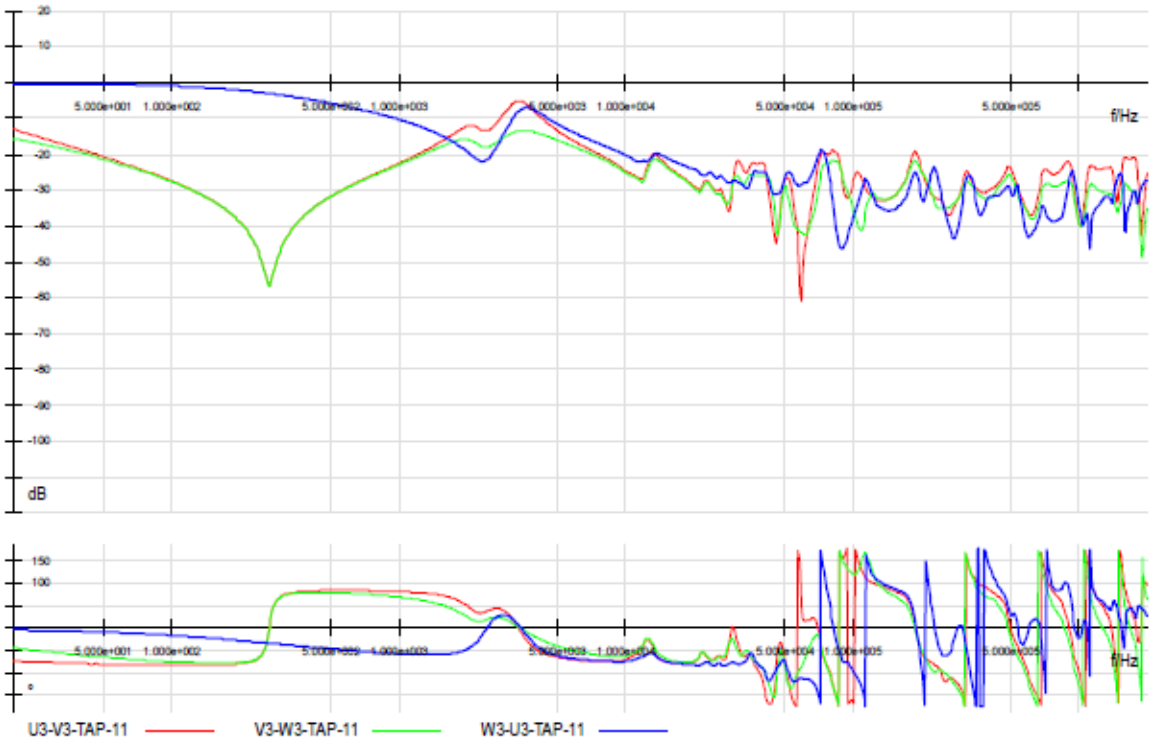
No deviation was observed was observed in HV-N IV shorted response, however, HV-N LV short response show clear deviation of Y and B phase signatures from R-phase. This might be caused due to improper elector switch contacts of OLTC or impact on series windings of Y and B phases

Comparison of 3-ph Short Circuit SFRA plot for 2U TO N, 2V TON & 2W TO N at TAP- 11 (LV short)



From the above signature, it can be inferred that the common winding part of Y-phase has been partially damaged.

Comparison of 3-ph Open Circuit SFRA plot for 3U TO 3V, 3V TO 3W & 3W TO 3U at TAP- 11



As can be seen, the response of interphase R-B tertiary connection is in deviation from other two responses in the low frequency (core) region. It can be inferred that the barrier insulation and spacers between core and tertiary of R-phase have been shorted.

Conclusion:

The likely reasons for failures were analyzed. DGA results do not indicate presence of any incipient fault in the transformer. Partial Discharge indicated in the unit seems to be confined to oil insulation and degradation of paper insulation is not envisaged prior to failure. Further, as indicated by LV test results and FRA, the R-phase winding seems to be completely damaged with impact on other other two phases.

As fault current of the order of 27kA was detected in IV side R phase (about 33 times rated FL current), hence the fault location is envisaged to be near the IV tapping point. However, same can be confirmed only through detailed inspection after dismantling of windings.

Recommendation:

The inspection results clearly indicate that the repair would involve replacement of all three windings, R-phase core and repairing of main tank. The transformer has already been in service for 17 years. As decided during 15th O&M conference at Jaipur in November, 2017, it was decided to scrap the failed transformers which had failed after 15 years of service and involving winding repair/ replacement. Hence, it is proposed to scrap the failed ICT-1 at Jalandhar (BHEL make sl. No. 6005782). Region has already initiated the replacement of the failed unit with 1 no. 315 MVA, 400/220 kV spare ICT available at Moga (ALSTOM make) which was available as SIS spare.

Hence, to replenish the spare ICT, region to take further action for procurement of a new 315 MVA, 400/220 kV ICT under SIS scheme.

Preliminary Investigation Report of failed 420kV 167 MVA Transformer at Kolar S/S (BHEL: 6006351) on 11.02.2017

1. INTRODUCTION:

On 11.02.2017 at 10:01:58hrs 500 MVA ICT-2 B phase unit at Kolar tripped on operation of differential protection due to the blasting of BHEL make 420kV,1250A HV Bushing. Transformer immediately caught fire and the emulsifier system operated automatically and extinguished the fire from spreading to the main tank. The ICT-2 was normalised on 11.02.2017 at 11:16 hrs after isolating ICT-2 B-Ph unit and by taking Spare ICT unit in place of ICT-2 B-Ph.

In order to investigate the reasons for the failure and to assess extent of damage, a committee was constituted vide note: SR-II/AM/23.32/2016-17 dated 13-02-2017 comprising the following members:

1. **Sh. K .S.Namboothiri, Asst GM(SR-II,AM)**
2. **Sh. Avinash K T , Chief Manager(Kolar HVDC station)**
3. **Sh. Sumit S H Ray, Dy. Manger(CC-AM)**

The Committee visited Kolar S/s on 16.02.2017 and inspected the failed Transformer. The brief particulars of failed Transformer are given below:

Transformer Particulars	**Details**
Make	BHEL
Voltage rating	420kV. 1∅
MVAR rating	167 MVA
Sr.No.	6006351
Year of Manufacture	2007
Date of Commissioning at Kolar	31.08.2007
Last Testing carried out prior to failure	13-06-2016
Date of Failure	11-02-2017

System Condition Just Before Tripping of ICT-2

Bus Voltage: 399kV
Bus Frequency: 50.12Hz
Load in ICT-1 : 184MW/35MVAR
Load in ICT-2: 198MW/46MVAR

2. O&M HISTORY OF FAILED TRANSFORMER

The said Transformer had not exhibitted any problem since its commissioning was kept under normal montoring. There was increase in C2H4 and CH4 gas observed in sample dated 09.12.2016 and subsequently found stable in sample dated 10.01.2017 as shown in Table-I. All other oil parameters were also normal. DGA of the bushings carried out in March 2016 was also found to be normal. Variable frequency Tanδ of bushings were carried out on 13.06.2016 and

graphs were found to be in order. Last AMP carried out on dated 25.08.2016 and results were found to be normal.

Table-I: DGA History

Sample Date	H2	CH4	C2H4	C2H6	C2H2	CO	CO2
10.01.2017	3	23	59	7	0	253	1368
09.12.2016	4	22	59	7	0	256	1474
06.09.2016	4	6	16	2	0	214	1489
08.06.2016	2	2	1	1	0	208	1552
08.03.2016	2	2	1	0	0	204	1043
07.09.2015	4	2	1	1	0	167	1045

Table-II: Bushing DGA

Sl.No	Sample Date	H2 (140)	CH4 (40)	C2H4 (30)	C2H6 (70)	C2H2 (2)	CO (1000)	CO2 (3400)
665094	04.09.2013	8	4	1	1	0	258	553
	02.09.2014	20	4	1	1	0	265	565
	24.03.2016	5	6	1	1	0	383	776

Table-III: Oil Test Results

Date	BDV (50 min)	PPM (20 max)	Resistivity (0.1 min)	TanD (0.2max)	IFT (15 min)	Acidty (0.3 max)	Flash (125 min)
13.02.2017 (Before failure)	71.4	6	25	0.0032	43	0.0096	150
08.03.2016	73.6	5.8	20.9	0.0036	41.13	0.018	154

*Oil parameter data dtd 13.02.2017, is after bushing blasting. So may be replaced with the reading dtd 08.03.2016.

Graph-I Variable frequency Tan delta Measurement (16.07.2016)

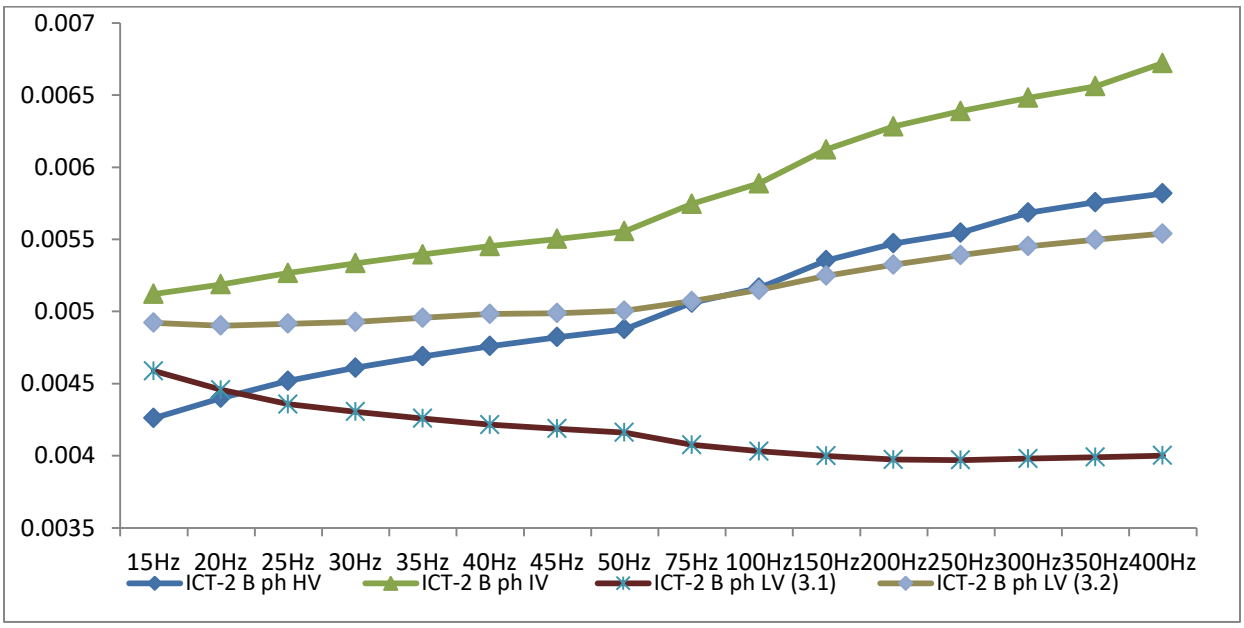


Table-IV: Bushing Capacitance & Tan Delta at 10kV

	HV		IV		LV1		LV2	
PRE COMM	451.2	0.0028	304.6	0.0047	197.281	0.003851	194.142	0.004985
07.08.08	453.635	0.0033	303.887	0.00425				
25.09.09	455.4525	0.004176	303.265	0.004841				
15.09.10	453.831	0.004881	303.632	0.0054				
24.04.12	458.125	0.004386	304.909	0.005179				
03.06.13	458.023	0.004329	302.285	0.005513				
04.09.13	454.715	0.004749	302.735	0.005783				
20.01.14	453.217	0.00512	305.058	0.005379	OLD Bushing replaced in 2014			
12.06.14	457.051	0.004636	305.214	0.005556	198.107	0.003747	195.137	0.004625
11.08.15	455.267	0.004877	305.072	0.005564	198.428	0.004161	195.471	0.005005
13.06.16	454.7	0.004868			197.424	0.004418	194.745	0.005266

Table-V: Winding Capacitance & Tan Delta

Date	HV-IV/LV in UST Mode		HV-IV/LV+G in GST Mode		HV-IV/LVwith gaurd GSTg Mode		LV / HV-IV in UST Mode		LV/ HV-IV +G in GST Mode		LV/ HV-IV with gaurd GSTg Mode	
11.08.15	2304.81	0.004042	5805.49	0.003651	3500.76	0.00338	2303.94	0.00404	9246.63	0.00311	6942.87	0.00271
13.06.16	2303.7	0.004045	5805.16	0.003705	3501.21	0.0035	2303.52	0.00405	9246.19	0.00313	6942.62	0.00282

3. FAILURE INVESTIGATION:

Transformer had failed with failure of 400kV B phase bushing and immediately caught fire. Porcelain of B phase bushing was found to be shattered. The detail reading of Transformer LA is mentioned below:

Phase	**Transformer LA counter**		
	R Ø (HV/IV/LV)	**Y Ø (HV/IV/LV)**	**B Ø (HV/IV/LV)**
Before tripping	12/17/12	22/24/18	8 / 5 / 7
After Tripping	12/17/12	22/24/18	8 / 5 / 7

Post failure DGA of main tank was carried on 11.02.2017 and found to have high fault gasses. LV tests were carried out after failure are found to be normal as per the following:

4. OBSERVATIONS

(A) **Following observations were made**:

i. No external damage has been observed in the Transformer main tank as shown in Exhibit-I except shattering of porcelain of B phase bushing.

Exhibit-I: Damaged HV B Bushings

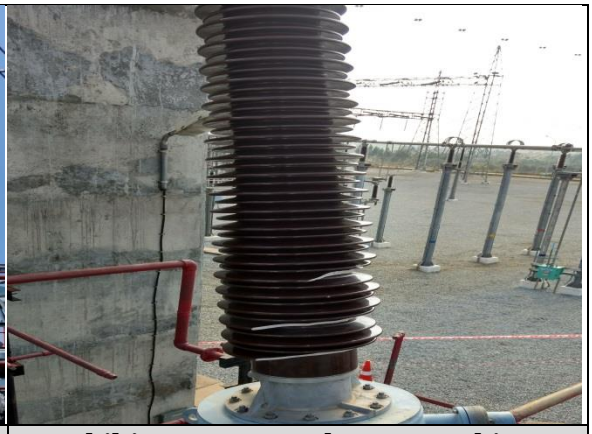


Exhibit-II: Damaged IV B Bushings

ii. Blasting of HV Bushing led to consequential damage of following major equipments;

a. Porcelain of IV Bushing(Exhibit-II) , LV II(Exhibit-III) Bushings
b. 2nos BPI for Neutral Bus bar
c. One number 390kV LA
d. ACSR Twin moose 400kV conductor clamp – 1no
e. Radiator Fins – 3 nos
f. Through Clamp between BPI & Neutral

Exhibit-III: LV bushing

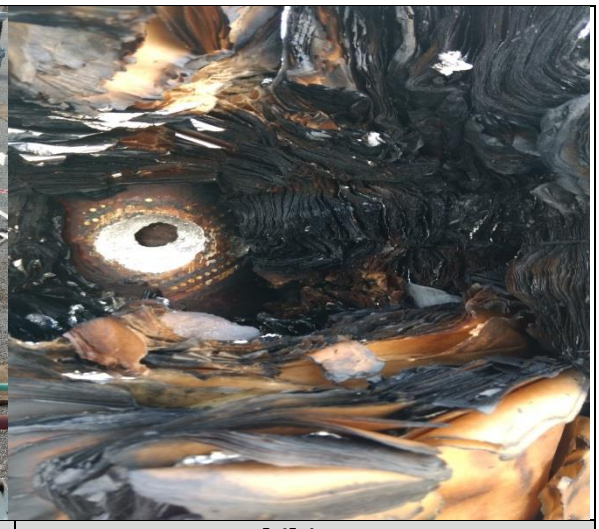


Exhibit-IV:

iii. A clear hole was found in the air end portion of HV phase bushing **(Exhibit IV)**. The location of hole is approximately 1.7 mtr from bottom of bushing.

iv. Oil end side porcelain of HV bushing was found to be completely shattered and porcelain pieces and burnt paper were found laid at the bottom of the tank at the bottom of the tank**(Exhibit V)**.

v. Some flash marks where found in the inner surface of the metalic portion meant for BCT accomodation of bushing **(Exhibit VI)**

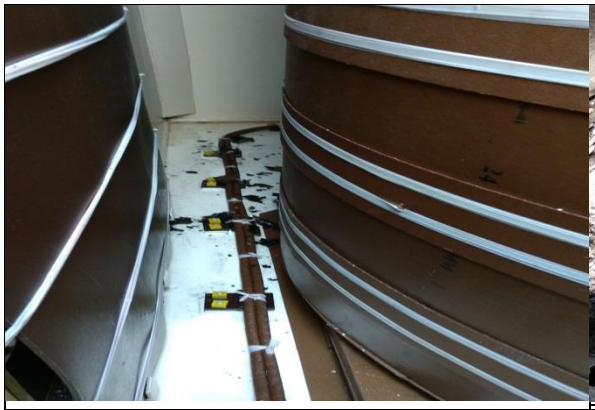


Exhibit-V	**Exhibit-VI**

vi. HV winding lead take off was found to be damaged and uprooted. However, the winding lead was found to be intact as shown in Exhibit VII & Exhibit-VIII and no other visible abnormalities were noticed during the internal inspection.

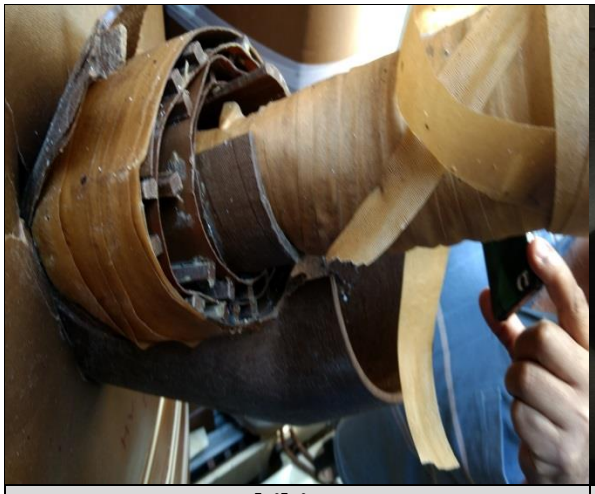
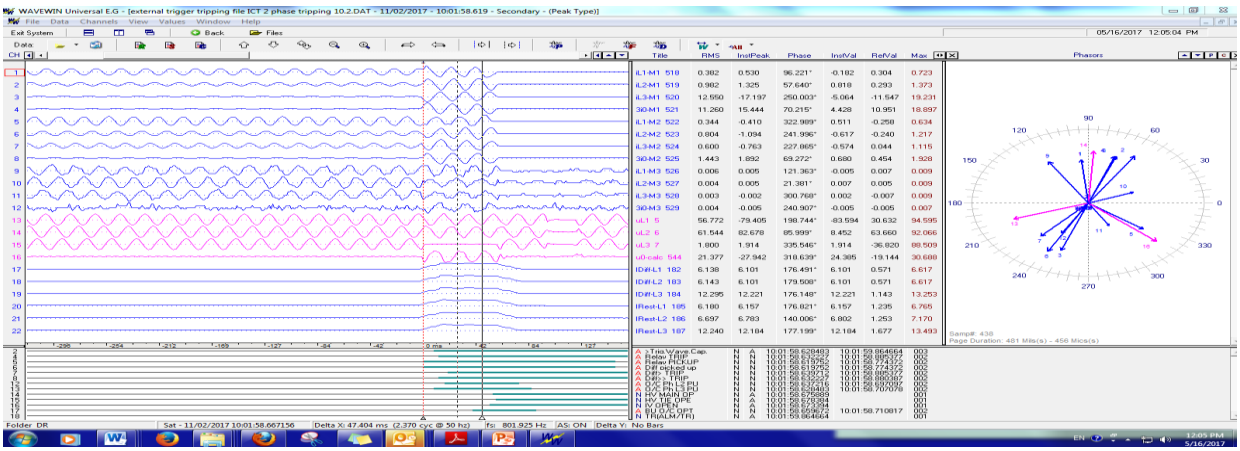


Exhibit-VII	**Exhibit-VIII**

5. SEQUENCE OF EVENTS & PROTECTION

As per DR & EL, following are the sequence of different events at the time of Transformer HV Bushing failure:

10:01:58:639 - ICT-2 Differential Relay Optd
10:01:58:654 - ICT-2 HV side BU E/F & O/C Optd
10:01:58:663 - ICT-2 GR A/B Trip Optd
10:01:58:673 - 21252 CB Open
10:01:58:676 - 40352 CB Open
10:01:58:678 - 40252 CB Open



Following protection philosophies were adopted for ICTs at Kolar in addition to the unit protection devices like PRV, Buccholz relay, OSR, OTI and WTI.

Sl.No	Protection Relay	Location of Instrument Transformers
1	Differential Relay (SIPROTEC 7UT613)	a) 402 CT (Tie Bay – M1) b) 403 CT (Main Bay CT – M1) c) 212 CT (Main Bay CT – M2) d) L04A1 CT (Tertiary CT – M3)
2	REF (RADHD) for individual 1-Ph ICT units	a) HV Bushing Turret CT b) IV Bushing Turret CT c) Neutral Bushing CT
3	HV Side Over-flux Relay (MBT191)	a) Selected 400kV Bus CVT
4	HV Side Backup O/C and Earth Fault Relay (2TJM12)	a) 402 CT (Tie Bay) b) 403 CT (Main Bay CT) c) Selected 400kV Bus CVT
5	IV Side Over-flux Relay (MBT191)	a) Selected 220kV Bus CVT
6	IV Side Backup O/C and Earth Fault Relay (2TJM12)	a) 212 CT (Main Bay) b) Selected 220kV Bus CVT

The blasting of HV Bushing in ICT-2 B-Ph had resulted flashover between HV bushing lead & BCT metallic portion, as evident in Exhibit VI, and heavy flow of fault current to the ground through transformer body. The fault current in turn activated Differential Relay @ 10:01:58:639 and Back-up O/C relay of HV side @ 10:01:58:654.
The adopted settings of differential relay & Backup O/C relay and current recorded during tripping instances are detailed below;

Differential Relay Setting (7UT613)		
Setting Description	**Set Value**	**Current value Recorded during Tripping (from DR)**
1221 – Pickup Value of Differential Current (Diff>)	0.20I/InO	IDiff-13.1I/InO, IRest- 13.0I/InO @ 10:01:58:640
1231 – Pickup value of High Set Trip (Diff>>)	9.6I/InO	IDiff – 9.81I/InO @ 10:01:58:632

B-Ph Backup O/C Relay (2TJM12)		
Setting Description	**Set Value**	**Current value Recorded during Tripping (from DR)**
DOC_PMS	1	IB - 12.7kA @ 10:01:58:659
DOC_TMS	0.175	
DOC_HS	5	

As evident in the DR, the high set Differential Trip (IDiff>>) of Differential relay had picked up @ 10:01:58:632hrs, ie around 12ms after differential pickup, and extended trip command to HV, IV and LV side Circuit Breakers through Group-A/B Trip relays. The fault had isolated at 10:01:58:678hrs, ie 58ms after differential pickup, by opening the circuit Breakers from all voltage levels. Meanwhile, ie just before isolation of fault, at 10:01:58:654hrs the high set of ICT-2 B-Ph Backup O/C relay had also picked up and extended instantaneous trip command to the Group-A/B Trip relays. As recorded in the EL, consequent to the blasting of HV Bushing and sudden spillover/thrust of oil had caused the operation of Buchholz and PRV relays.

As such the operation of all protective relays and devices functioned in the intended manner and isolated the fault at shortest possible time.

6. FAILURE CAUSE:

Prima facie, the fault seems to be initiated from HV bushing and it is suspected that failure occurred due to failure of the bushing. As evident from the variable frequency test results and bushing DGA test results, bushing condition was normal prior to 8 months of failure. Failure of the bushing seems to be random in nature and due to explosion of the B phase bushing, air end portion porcelain got shattered leading to flashover of bushing conndensor core with the flange which is evident from the punctured hole nearer to bushing flange.

7. RESTORATION & REPAIR PLAN:

From internal inspection no abnormality was observed inside the Transformer after failure of bushing. Prima facie, core coil assembly seems to be healthy. Based on the inspection, it is recommended to repair the Transformer at site through OEM as no major repair is envisaged and for expediting the restoration of the Transformer.

Committee Report on failure of 500 MVA , ALSTOM make ICT at Bidadi Sub- Station under SR-II Region

1. 500 MVA, 400 kV GE make ICT-1 at Bidadi S/s tripped on R phase fault on 16th September, 2017 at 04:56:22 Hrs. Fault was sensed by REF, Differential, Back-up Earth Fault, OSR, Buchholz and PRD protections. Severe bulging was observed in tank in 400 kV and 220 kV sides with oil drained out in sump pit. The transformer was shifted to GE factory in Naini, Allahabad for further assessment of damage. In order to investigate the reasons for the failure and to assess extent of damage, a committee was constituted comprising of following members:

S.No.	Name	Designation	Place of Posting
1.	Sh. K S Namboothiri	Asst. GM	RHQ-AM, Bengaluru, SR-II
2.	Sh. D P Singh	Ch. Manager	QA&I, Allahabad
3.	Sh. Richik Manas Das	Deputy Manager	CC-Engg. SS
4.	Sh. Deo Nath Jha	Engineer	CC-AM

The Committee visited GE works on 18th May 2018 and inspected the failed Transformer and details of the finding are brought out in this report.

Transformer Particulars	Details
Make	ALSTOM
Voltage rating	400kV
MVA rating	500 MVA
Sr.No.	30575
Year of Manufacture	2011
Date of Commissioning at	29-Mar-2012
Date of Failure	16-Sep-2017 at 04:56:22 hrs.

System conditions at the time of Transformer failure were

Name of element	Load in MW (03:00 am)	Load in MW (04:00 am)
400 kV ICT-01	128 MW	127 MW
400 kV Somanahalli-02	87 MW	65 MW
400 kV Somanahalli-01	85 MW	66 MW
400 kV ICT-02	130 MW	130 MW
400 kV Nelamangala-01	37 MW	28 MW
400 kV Nelamangala-02	37 MW	28 MW
400 KV Bus Reactor	65 MVAR	65 MVAR
400 KV Tumkur-01	-256 MW	-225 MW
400 KV Tumkur-02	-256 MW	-223

2. **O&M History of failed Transformer**

Transformer commissioned on 29-03-2012 and was in successful operation till the time of failure. In view of the failure of 500 MVA Transformer on account Tap leads as supplied by GE of the said lot, matter was taken up with M/s GE for strengthening the Tap lead insulation. In line with the discussion of 24.09.2012, tap lead modification was carried out on the said Transformer on 11.02.2013 (Insertion of Treated PBD barrier in all phases has been provided) and re-commissioned on

10.04.2013. Further, due to tan delta test tap issues, all the 245 kV and 52 kV bushings were replaced with new bushings on 08.04.2015. As per MOM date 24.09.2012, if any problem/ failure on account of Tap leads occur within 5 year from the date of lead modification, then M/s GE shall carry out repair free of cost.

DGA data prior to failure:

Sample Date	H2	CH4	C2H4	C2H6	C2H2	CO	CO2
30.05.2014	7.29	0.96	0.09	0.15	0.049	85	520
01.07.2014	10	1	0.13	0.27	0.09	115	646
04.08.2014	17	2	0.13	0.35	0.05	164	821
10.10.2015	45	8	0.38	1.2	0	448	1757
01.08.2016	49	8	0	1	0	408	2433
04.01.2017	49	7	1	2	0	450	2061
10.04.2017	38	8	0	1	0	428	3183

On 16.09.2017, said Transformer failed and fault current of 10.6 kA was observed in 220kV side. As the fault current is high, POWERGRID suspected that there may be failure in tap lead and asked GE to for free repair. Based on the internal inspection it was difficult to exactly establish the failure cause. Hence it was decided to shift the Transformer to GE, Naini works for establishing cause of failure.

Sequence of Events

Following indication were noted at the time of tripping:

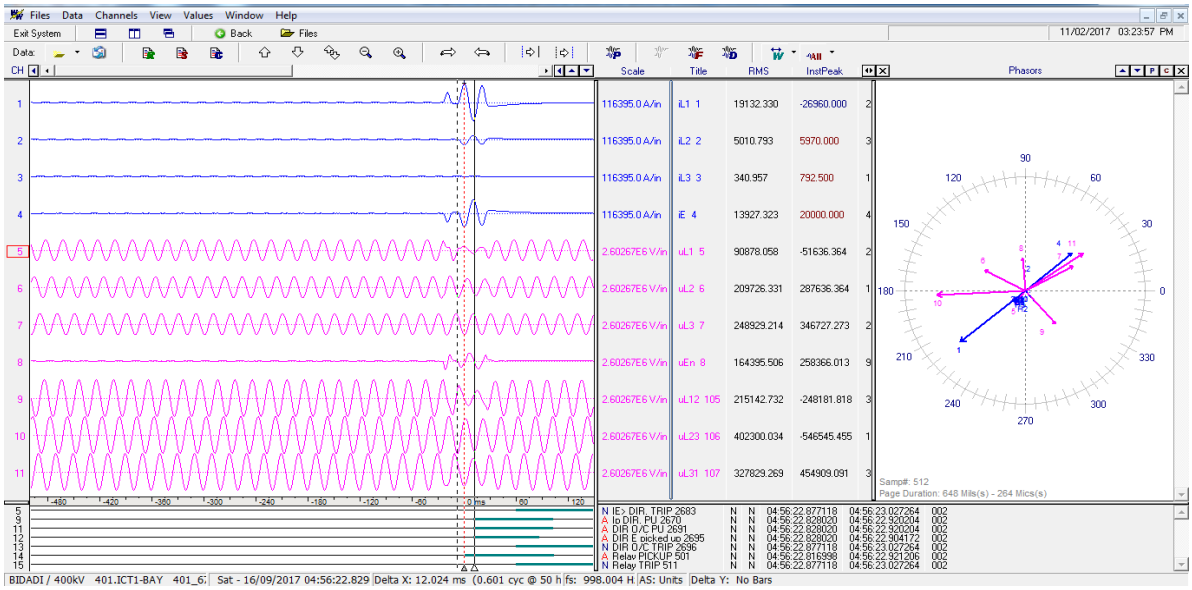
- REF Trip
- Transformer differential trip
- PRV Trip (Both)
- HV Back up O/C Earth Fault relay operated
- Transformer Bucholz Trip
- OSR trip

The sequence of event logger is as under:

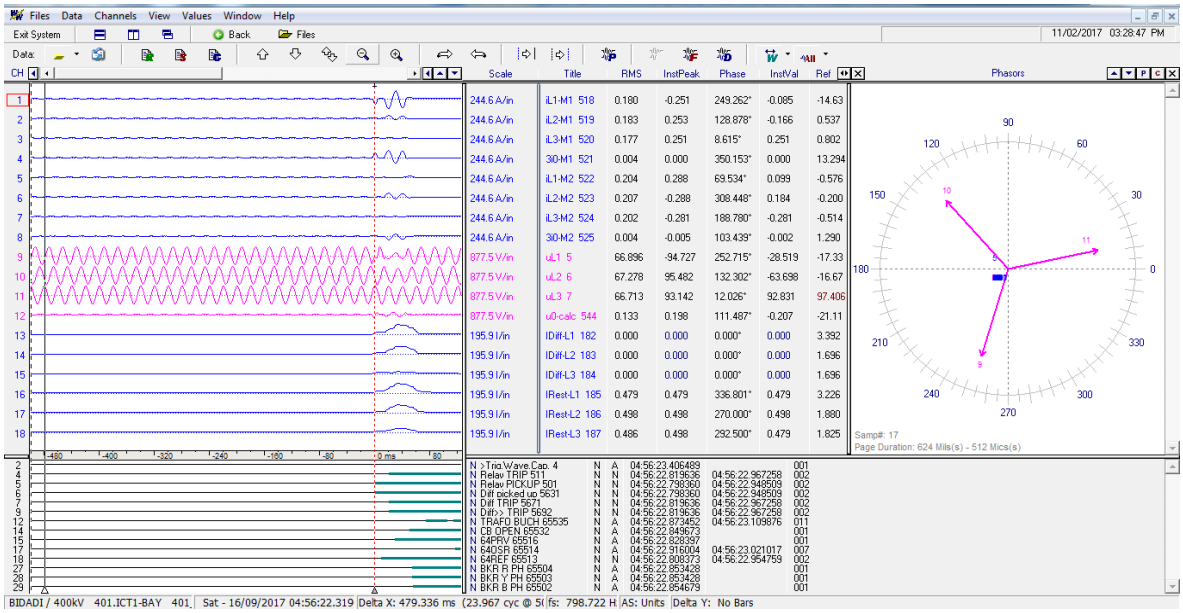
	Date	Time	Message Group	Number	ALARMS/EVENTS	Value	Cause	Status
1	16/09/201	04:56:22.804	401\64R_7UT	1003053	REF TRIP	RAISED	spontaneous	valid
2	16/09/201	04:56:22.804	401\ICT1\64R_7UT	1003053	DIFFERENTIAL PROTECTION OPERATED	RAISED	spontaneous	valid
3	16/09/201	04:56:22.818	BIDADI\401_87	1005215	SECOND HARMONIC BLOCK L1	RAISED	spontaneous	valid
4	16/09/201	04:56:22.818	BIDADI\401_87	1005215	SECOND HARMONIC BLOCK L2	RAISED	spontaneous	valid
5	16/09/201	04:56:22.818	BIDADI\401_87	1005215	SECOND HARMONIC BLOCK L3	RAISED	spontaneous	valid
6	16/09/201	04:56:22.818	BIDADI\401_87	1005216	FIFTH HARMONIC BLOCK L2	RAISED	spontaneous	valid
7	16/09/201	04:56:22.819	408\21_7SA	1007268	BUS REACTOR_21.2 VT Fuse Failure (alarm instantan	RAISED	spontaneous	valid
8	16/09/201	04:56:22.820	401\ICT1\87R_7UT	1003623	ICT-1 87R GENERAL TRIP	RAISED	spontaneous	valid
9	16/09/201	04:56:22.820	401\ICT1\87R_7UT	1003623	ICT-1 87R DIFFERENTIAL TRIP	RAISED	spontaneous	valid
10	16/09/201	04:56:22.820	401\ICT1\87R_7UT	1003624	ICT-1 87R DIFFERENTIAL TRIP R-PHASE	RAISED	spontaneous	valid
11	16/09/201	04:56:22.820	401\ICT1\87R_7UT	1003624	ICT-1 87R DIFFERENTIAL TRIP Y-PHASE	RAISED	spontaneous	valid
12	16/09/201	04:56:22.826	401\ICT1\64R_7UT	1003502	PRV TRIP	RAISED	spontaneous	valid
13	16/09/201	04:56:22.828	BIDADI\401_67HV	1006353	DIRECTIONAL EARTH FAULT PICKUP	RAISED	spontaneous	valid
14	16/09/201	04:56:22.832	BIDADI\401_BCU2	1006173	ICT-1 86.1 RELAY OPERATED	RAISED	spontaneous	valid
15	16/09/201	04:56:22.833	401\ICT1\BCU1_6MD66	1003117	86.2 TRIP RELAY OPERATED	RAISED	spontaneous	valid
16	16/09/201	04:56:22.834	408\RECTR\21_7SA	1003433	DISTANCE ZONE 1 TRIP	CLEARED	spontaneous	last topical v
17	16/09/201	04:56:22.834	408\RECTR\21_7SA	1003433	DISTANCE ZONE 1 TRIP PHASE R	CLEARED	spontaneous	last topical v
18	16/09/201	04:56:22.834	408\RECTR\21_7SA	1003434	DISTANCE ZONE 1 TRIP PHASE Y	CLEARED	spontaneous	last topical v
19	16/09/201	04:56:22.834	408\RECTR\21_7SA	1003434	DISTANCE ZONE 1 TRIP PHASE B	CLEARED	spontaneous	last topical v
20	16/09/201	04:56:22.837	401\67HV_7SJ	1003068	HV DIR HV E/F OVERCURRENT R-PH TRIP	RAISED	spontaneous	valid
21	16/09/201	04:56:22.837	401\67HV_7SJ	1003068	HV DIR HV E/F OVERCURRENT Y-PH TRIP	RAISED	spontaneous	valid
22	16/09/201	04:56:22.838	401\BCU1_6MD66	1005401	CB R PHASE POSITION	interm. state	spontaneous	valid
23	16/09/201	04:56:22.839	401\BCU1_6MD66	1005402	CB Y PHASE POSITION	interm. state	spontaneous	valid
24	16/09/201	04:56:22.840	BIDADI\401_87	1005215	SECOND HARMONIC BLOCK L1	CLEARED	spontaneous	valid
25	16/09/201	04:56:22.840	BIDADI\401_87	1005216	FIFTH HARMONIC BLOCK L2	CLEARED	spontaneous	valid
26	16/09/201	04:56:22.840	408\21_7SA	1007268	BUS REACTOR_21.2 VT Fuse Failure (alarm instantan	CLEARED	spontaneous	valid
27	16/09/201	04:56:22.841	401\BCU1_6MD66	1005401	CB B PHASE POSITION	interm. state	spontaneous	valid
28	16/09/201	04:56:22.842	BIDADI\401_87	1005215	SECOND HARMONIC BLOCK L2	CLEARED	spontaneous	valid
29	16/09/201	04:56:22.848	401\BCU1_6MD66	1005401	CB R PHASE POSITION	OFF	spontaneous	valid

During tripping back up O/C & Earth fault has been extracted and following fault current were observed: As per the DR of IV Back up Over current Relay:

Back Up O/C- HV



Differential Protection



There was no advancement in reading of counter of LAs w.r.t previous record.

LA	16-Sep-2017 Before tripping	16-Sep-2017 After Tripping
400 KV R Phase	11	11
400 KV Y Phase	11	11
400 KV B Phase	12	12
220 KV R Phase	10	10
220 KV Y Phase	12	12
220 KV B Phase	12	12

Prima facie, from the DGA history and AMP test results, it may be inferred that the transformer was healthy prior to failure and had failed due to sudden fault inside the Transformer.

3. **Factory Inspection observation**: Committee visited GE, Naini works for inspection as well as for failure investigation and following observations was made:

   a. Cracks were observed in tank stiffeners and severe deformation was observed on both sides of tank wall and tank cannot be reused.
   b. U-phase outer wrap was found burnt at different locations in middle portion. The lead take out portion was found to be intact. V-phase and W-phase outer wrap and lead take out portion was found to be intact.
   c. Flashover mark was observed between disc no. 50 and 52 in outer side of U-phase HV (series) winding along with pitting (melting) of copper. Black spot was observed on tank wall just opposite to the above flashover mark.
   d. Some deformation was also observed on Bottom Clamping frame near U-phase.
   e. Common winding part, leads and regulating winding were found to be intact.
   f. The middle part of bottom yoke clamping studs between U and V phases was found to be burnt.
   g. Burn marks were also observed in outer part of V-phase winding outer wrap. No further burn mark was observed from outside on coil stacks of V and W phase windings.

   The photographs of internal inspection are given below.

	
Flashover mark observed between disc no. 50-52 in outer side of U-phase HV winding	Burnt middle portion of U-phase outer wrap
	
Burnt Middle portion of Bottom Clamping Studs between U-V phase	Burn marks observed on outer part of V-phase winding

	
Damaged Bottom Clamping Frame near U-phase	No damage observed in Regulating winding and tap leads

Failure Cause:

From the inspection, it may be inferred that failure of Transformer was occurred due to failure of R phase winding. As suspected earlier, tap lead was not involved in the failure. Faults may be initiated due to inter turn of windings/ inter disc in HV series winding. Considering the extent of damage, carbonization and exposure of other winding insulations, it is recommended to replace all the windings along with all insulation materials and tank. Old windings shall be made scrapped.

Powergrid Corporation of India Ltd
Corporate Asset Management

Investigation Report on Failure of pole II East reactor at Vizag Station

There has been a failure of 80 MVAR, 400 kV CGL make Shunt Reactor at Vizag S/s on 28th April, 2017 at 09:07 Hrs. Subsequent to failure, a failure investigation committee was constituted comprising of following members:

S.No.	Name	Designation	Place of Posting
1.	K Srihari	Chief Manager	Vizag, SR-1
2.	V K Chandrasen	Chief Manager	CIOTL, Hyderabad, SR-1
3.	Deo Nath Jha	Engineer	CC-AM

The team visited Vizag S/s for investigation of failure causes on 3rd and 4th May, 2017. Following are the observations

Equipment Details:
Pole 2 East Reactor: Sl No.: T8975/2 Make: CGL,
Date of Commissioning: 01.03.2005

Date and Time of Failure: 28.04.2017 09:07:30:435.

Pre-Conditions:
System was in normal operation with both Jeypore- Gazuwaka Line – 1 & 2 in service in Eastern Bus and Gazuwaka -Vemagiri, Gazuwaka -Simhadri Line- 1& 2 and Gazuwaka – Kalpaka Line - 1& 2 in service in Southern Bus.
Total Power Flow: 650 MW East to South
Pole - 1: 300 MW E→S
Pole - 2: 350 MW E→S

Description of Fault:
The auxiliary supply of both Pole 1 and Pole 2 of HVDC Vizag is fed through the 400 KV, 315 MVA ICT#2. The auxiliary supply failed at 08:44 Hrs (Y phase fuse of tertiary -33 KV was found blown). Pole 2 auxiliary supply auto changeover to DG set was successful but the same was unsuccessful in Pole 1 resulting in tripping of the Pole 1 at 08:44 Hrs. Meanwhile at 09:07 hrs Pole 2 tripped on activation of Pole Y block activation-WA1 Protective Y-Block Executed. This protection gets activated in case of any major fault in ac side. It was further found that Pole 2 East Shunt Reactor (80 MVAR, CGL make) had tripped sue to operation of differential and PRD protection. Further, heavy oil leakage was observed from the Y-ph bushing of the shunt reactor.

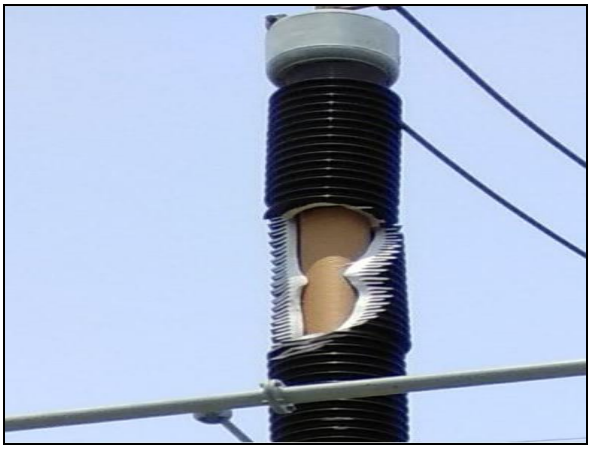
Brief Record of Events:

Pole	Date	Time	Event
Pole 1	2017-04-28	08:44:21.317	POLE-1 DE ENERGISE
Pole 2	2017-04-28	09:02:17:873	W2B Overvoltage Protection WA2-W1 Over Voltage Level 1 Alarm
Pole 2	2017-04-28	09:07:30:390	P2B Block Sequences WA1 Protective Y-Block Executed
Pole 2	2017-04-28	09:07:30:411	P2B Block Sequences WA2 Pole Blocked
Pole 2	2017-04-28	09:07:30:435	W2B Shunt Reactor WA2 Differential current phase L2 Trip

Pole 2 tripped on initiation of Protective Y Block due to sustained voltage fluctuations which started from 09:02 Hrs as per the event logger. The Shunt Reactor tripped at 09:07:30:435 on initiation of differential protection (Y phase). The fault current in Y Phase as per the DR record is to the tune of 785A. The Voltage went upto 626.46 KV during the same instance. Continuous overvoltage has been observed along with dominant presence of second harmonics prior to failure.

On physical examination of the shunt reactor following observations were made::

- Porcelain Insulator was found to be detached from the Middle of the Y-Phase Bushing and scattered near the ground. Oil was also observed to be flowing out from the inspection cover at the bottom of the turret. The inspection turret was deformed and had attained concave shape facing inwards.



- Cracks were observed on the metal flange joints.

To ascertain the healthiness of the winding, Magnetizing Current of Winding and winding resistance measurements were carried out. The readings of the test are as mentioned below.

Magnetizing Current Readings			**Winding Resistance Measurement**		
R-ph	**Y-ph**	**B-ph**	**R-ph**	**Y-ph**	**B-ph**
120.7 mA	120 mA	120.3 mA	2.233 Ω	2.232 Ω	2.232 Ω

The test results were found to be normal.

Subsequently, DGA of the reactor oil sample was carried out to look for any fault generation in the reactor.

DGA Results of the reactor:

S.No.	**Date**	**H2**	**CH4**	**C2H6**	**C2H4**	**C2H2**	**CO**	**CO2**
1	28.04.17 (Post Failure)	53	19	4	20	6.4	300	3671
2	18.04.17	27	18	5	18	0.9	375	3904
3	27.02.17	7	3	12	2	0.4	231	1911
4	06.12.16	24	7	0	7	0	315	4539

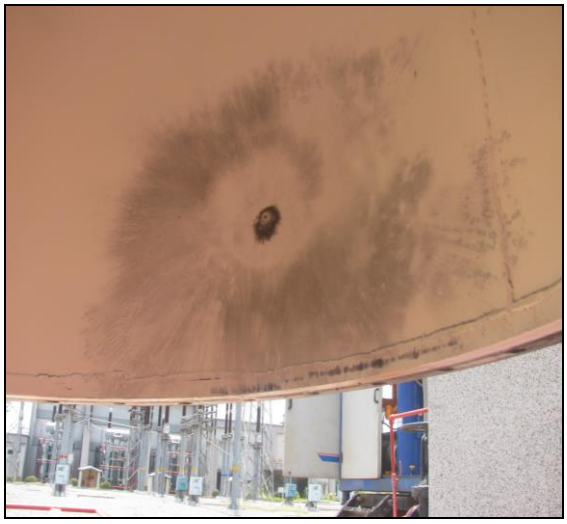
As can be observed from the DGA results, no significant fault gases have been generated post failure. The rise in C2H2 can be attributed to the consequential damage caused by broken insulator from the bushing. Hence, the fault can be assumed to be localized within bushing part only and it can be assumed that no significant damage has been caused to the core and winding of the reactor.

Consequent to the failure of the Y phase bushing, internal inspection was carried out on 03.05.17 to 04.05.17 to inspect the physical damages to the Cores/Windings, if any, before replacement of the failed Bushing.

Accordingly internal inspection was carried out and no abnormalities to the Cores/Windings were observed.

- No burn/ flashover marks observed on paper insulation. This confirmed absence of any partial discharge in the bushing.

- It was observed that the inside body of the turret was having single point flashover mark. The Corona shield also contained flashover marks and was found to be damaged with broken connecting points.



- It was found that the oil end (bottom) porcelain dome of Y-Phase Bushing was broken and lying on the bottom and scattered inside the Reactor Main Tank.

- Further, it was observed that REF relay did not operate during the tripping.

While analyzing the system conditions from the DR, it was observed that dominant second harmonics were present in the system prior to the fault. Some of the values of harmonics have been tabulated below. The harmonics have been presented as percent of True RMS value. The voltage was also observed to be above 600 kV for about 50 ms duration prior to failure.

Time before fault	Fundamental	2nd harmonics	3rd harmonics	4th harmonics	5th harmonics
0 ms	41.62%	65.06%	55.59%	22.38%	14.87%
60 ms	52.54%	73.15%	22.4%	11.68%	9.13%
120 ms	41.04%	80.91%	29.36%	17.40%	16.13%
180 ms	65.87%	65.63%	14.66%	5.53%	4.9%
240 ms	40.04%	80.79%	30.28%	16.84%	14.35%
300 ms	60.34%	70.74%	11.56%	9.32%	5.75%

The higher second harmonic content in the Eastern Bus may have been the cause of the failure of the shunt reactor.

Conclusion:

The likely reasons for failures were analyzed. The higher second harmonic component in the Eastern Bus may have caused vibration in the reactor resulting in the stress in the bushing. Due to high stress, it is likely that flashover occurred between turret body and corona shield leading to shattering of oil end insulator. Consequently, high pressure developed leading to loosening of terminal connector and leakage of oil. Due to the vibrations caused by the development of high stress, cracks appeared in metal flange and insulator pieces from the middle section broke off at the joints.

Based, on the above, the committee opines that the reactor can be repaired at site by replacing the bushing and bakelite sheet of turret CT connected in the Y-phase.

Recommendations:

- It is suggested to thoroughly clean the bell tank through hot oil circulation and any remaining insulator pieces should be flushed out.
- It is further suggested to carry out all pre-commissioning tests as per norms.
- Variable Tan delta testing of all the bushings and frequency response analysis may be carried out prior to taking the Shunt Reactor into service.
- Failure of auto changeover of Pole-1 needs to be investigated and relevant circuitry need to be checked for possible errors.
- REF Relay setting needs to be rechecked for proper operation.
- CC-CTU to investigate the possible sources and reasons for overvoltage and generation of second harmonics and suggest remedial measures.

Powergrid Corporation of India Ltd
Corporate Asset Management

Investigation Report on Failure of Bhiwadi-1 Line Reactor R-phase at Agra Station

There has been a failure of 63 MVAR, 400 kV CGL make Shunt Reactor at Vizag S/s on 22nd May, 2017 at 01:27 Hrs. Subsequent to failure, a failure investigation committee was constituted comprising of following members:

S.No.	Name	Designation	Place of Posting
1.	Pankaj Sharma	DGM	Agra, NR3
2.	D Kushwaha	Asst. GM	RHQ-AM, NR3
3.	Deo Nath Jha	Engineer	CC-AM

The team visited Agra S/s for investigation of failure causes on 1st and 2nd June, 2017. Following are the observations

Equipment Details:
Bhiwadi-1 Line Reactor R-phase: Sl No.: T8353/1 Make: CGL,
Date of Commissioning: 01.03.2005

Date and Time of Failure: 22.05.2017 01:27:25:055.

Pre-Conditions:
System was in normal operation with both Agra-Bhiwadi Line, Agra-Sikar and Agra-Auraiya lines in service.

Sequence of Fault:

01:27:24.977	Main1 (D60) - GND DIST Z1 OPTD
01:27:24.984	Main2 – Zone 4 Pick Up
01:27:25.016	Main 2 – Zone 1 Operated
01:27:25.029	R ph Main and Tie CB Open
01:27:25.047	Y ph and B ph Main and Tie CB open

Description of Fault:
The Agra-Bhiwadi-1 Line tripped at 01:27 Hrs on 22.05.2017 on single phase fault on R-N at 15.7 km (Main 1) from Agra End with failure of bushing. During failure, fault current of 35.78 kA was recorder to have flown through the reactor. The bushing of the Agra- Bhiwadi1 LR was charred from the top and subsequently caught fire. The burning oil falling from the bushing damaged the nearby cables and Marshaling Box. However, recording instruments were found to be in working order.

The outer sheath of the cable from reactor to MB box was found to be burnt and MB was found to be damaged.

To ascertain the healthiness of the winding, Magnetizing Current of Winding and winding resistance measurements were carried out. The readings of the test are as mentioned below.

IR Value: 85 GΩ
Magnetizing Current: 69.6 mA
Winding Resistance: 3.63 Ω

The test results were found to be normal.

Subsequently, DGA of the reactor oil sample was carried out to look for any fault generation in the reactor.

DGA Results of the reactor:

S.No.	Date	H2	CH4	C2H6	C2H4	C2H2	CO	CO2
1	29.05.2017 (Post Failure)	643	283	290	26	327	367	2533
2	21.11.2016	11	11	2	5	0	122	1157
3	31.05.2016	12	8	2	4	0	109	1100
4	17.05.2016	13	9	2	5	0	110	1087

As can be observed from the DGA results, no significant fault gases have been generated post failure. The rise in C2H2 and other hydrocarbons can be attributed to the consequential damage caused by broken insulator from the bushing and presence of charred paper in the oil. Hence, the fault can be assumed to be localized within bushing part only and it can be assumed that no significant damage has been caused to the core and winding of the reactor.

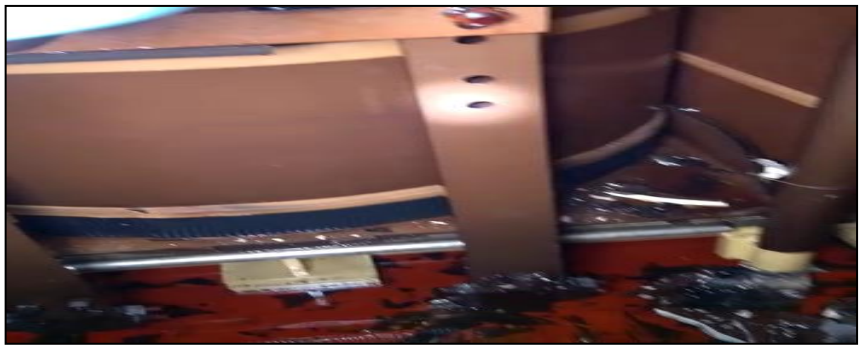
The tan delta and capacitance results of the bushings also indicated no incipient fault in bushing.

Cap (pF)	TD (%)	Diff	Cap (pF)	TD (%)	Diff	Cap (pF)	TD (%)	Diff	Cap (pF)	TD (%)	Diff
17.08.2016			13.07.2015			07.04.2015			05.04.2014		
500.4	0.377	0.022	502	0.355	0.022	500.6	0.333	0.017	499.4	0.316	0.071
387.7	0.371	0.026	384.2	0.345	-0.07	382.5	0.415	0.047	382.6	0.368	0.035

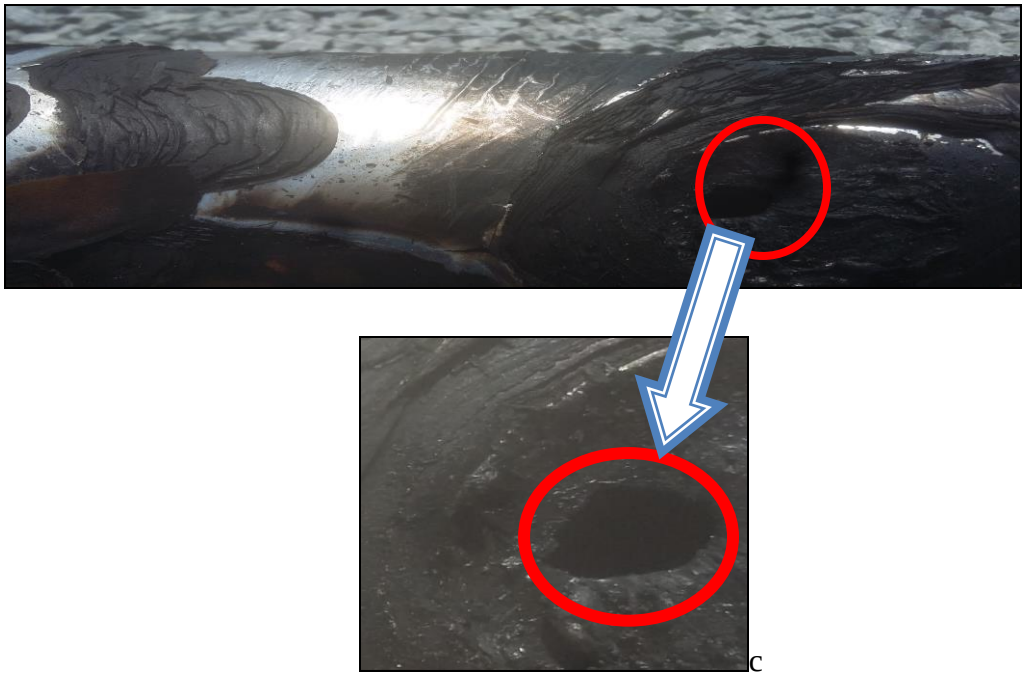
Consequent to the failure of the R phase bushing, internal inspection was carried out on 01.06.17 to 02.06.17 to inspect the physical damages to the Cores/Windings, if any, before replacement of the failed Bushing.

Accordingly internal inspection was carried out and no abnormalities to the Cores/Windings were observed.

- Charred paper and broken pieces of oil end insulator were found in the bottom of the tank



- Puncture mark (hole) was observed in the metal rod of the bushing below the first aluminum insulation.



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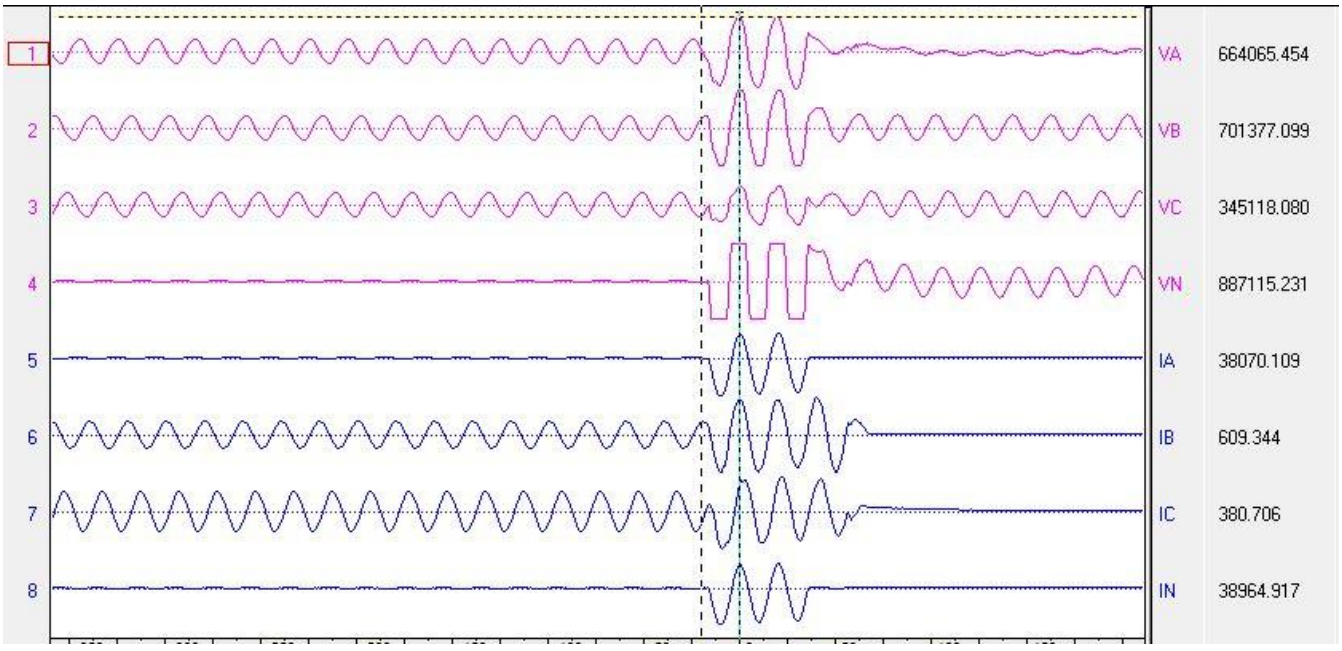
The hole was observed at a distance of 1.63 m from the bottom of the expansion chamber just beneath the first porcelain joint.

- The metal flange was also found to be burnt at the bottom of the bushing with partial melting of the flange and signs of sparking present.

While analyzing the system conditions from the DR, it was observed that high transient voltage was present in the system at the fault instance.

Signal	Pre-fault values	Fault values
I_a	238.38A	35.67 kA
I_b	240.12A	0.68 kA
I_c	240.97A	0.41 kA
V_a	237.71 kV	778.5 kV
V_b	239.91 kV	826.23 kV
V_c	242.03 kV	426.36 kV



As can be seen from the DR, distortion has been observed in the voltage waveform about 20ms prior to fault. Complete phase shift has been observed in the B-phase and partial phase shift in the Y-phase and R-phase. The bushing being aged (about 31 years old) had weaker insulation and thus could not sustain this high voltage. Spark developed in the bushings causing its failure.

Conclusion:

The likely reasons for failures were analyzed. The higher transient voltage may have caused spark generation in the bushing causing high stress. Due to high stress, it is likely that internal flashover occurred below the top porcelain joint of the bushing (weakest mechanical part of the bushing). Consequently, high leakage current caused melting of the rod below the joint. Fire developed in the bushing oil and the insulation paper was completely charred. The spark travelled to the bottom flange (providing ground point to the current) causing its partial melt on the sides. The insulation was completely charred. Any other significant damage was not found.

Based, on the above, the committee opines that the reactor can be repaired at site by replacing the bushing. CC-TD and CC-HVDC is also requested to investigate the possible causes for generation of high transient voltage and suggest remedial measures.

Failure investigation report of CGL make 765kV 80MVAR Bina-II Line reactor (R phase) at Satna (Sr.No. BH09823/01)

1. INTRODUCTION:

On 01.06.2017 at 00:59 hrs, 765kV 80MVAR CGL make BINA-II Line Switchable Reactor (R-Phase) installed at Satna s/s failed on operation of REF operation along with Differential/Body protections. The said Reactor was charged on 01.07.2012 and since then increasing in C2H4 & C2H2 was observed in the reactor, which was attended by M/s CGL during Aug-2015. After attending the issue and degassing reactor was taken back in service on 16.09.2015. Again increase of C2H4 & C2H2 was observed in reactor which was reported to M/s CGL on 29.08.2016 and later on many occasions.

In order to investigate the reasons for the failure and to assess the extent of damage, a committee comprising the following members visited the Satna s/s on 03.06.2017 & 04.06.2017 and inspected the failed reactor.

1. **Sh. Mukesh Mathur, AGM (QA&I), CC**
2. **Sh. C. Sunil Kumar, DGM(AM),Vadodra**
3. **Sh. P. R. S. Yadav, Asst. GM (AM), CC**
4. **Sh. Lalan Kumar, Manager (AM), Satna**
5. **Sh. Amit Kumar, Engineer(AM), CC**

The brief particulars of failed Reactor are given as below:

Particulars	**Details**
Make	CGL
Voltage rating	765kV
MVA rating	80 MVAR
Sr.No.	BH09823/01
Year of Manufacture	2012
Date of Commissioning	1/07/2012
Date of Failure	01/06/2017

System conditions before & at the time of failure of Reactor were as mentioned below:

Parameters	**Before**	**At the time of failure**
HV Voltage	764 kV	52kV
Neutral Voltage	3.9kV	682kV
HV Current	Ir=179A Iy=187A Ib=182A	Ir=19.9kA Iy=228A Ib=232A
Frequency	49.9 Hz	49.9 Hz

2. SEQUENCE OF PROTECTION OPERATED:

S/s	**Time**	**Protection**	**Fault current**
Satna End	00:59:26.559 hrs	REF Optd	482 A
	00:59:26.572 hrs	Diff ST-2 Optd	19.9 kA
	00:59:26.594 hrs	Reactor CB Open	
	00:59:26.599 hrs	Flow Control Valve R Ph	

	00:59:26.610 hrs	Buch 1/2 Alarm R Ph	
	00:59:26.625 hrs	Buch 1 Trip R Ph	
	00:59:26.648 hrs	Buch 2 Trip R Ph	
	00:59:26.868 hrs	PRV 2 –R Ph optd	
Bina End	00:59:26.575 hrs	Main-1 Zone-2 & Zone-3 Start	2.3kA
	00:59:26.579 hrs	Main-1 Zone-2 & Zone-3 Start	

3. O&M HISTORY OF FAILED REACTOR

A) This Switchable Reactor was commissioned on 01/07/2012. It was taken out for investigating rise in C2H2 and C2H4 gas on 29.08.2015.The same was in continuous service after attending C2H4 & C2H2 issue since 16.09.2015. DGA trend after repair is given as below.

Sample Date	H2	CH4	C2H4	C2H6	C2H2	CO	CO2
17.05.2017	34	86	188	23	3.6	373	1797
15.05.2017	32	60	137	70	4.6	301	1441
28.04.2017	35	63	125	18	2.6	290	1380
27.03.2017	40	63	122	18	2	268	1149
06.03.2017	48	70	134	19	2.1	295	1099
13.02.2017	50	68	130	18	2.7	273	975

B) **Tan δ & Capacitance Measurement:** (As per last AMP carried out).

		Pre-Commg. (27.01.2012)		**25.08.2015**	
Tanδ	R	0.33%		0.30%	
	N	0.44%		0.37%	
Capacitance	R	586 pF		586 pF	
	N	278 pF		271 pF	
		Tan Delta		**Capacitance**	
WINDING		Tested on 11.12.15	Factory	Tested on 11.12.15	Factory
HV/Tank+E		0.251%	0.27%	4.380 nF	4.419 nF

3.0 Inspection of failed reactor

(A) **Damages :** On physical inspection, following observations were made (photos of failures are attached as Annexure-I) :-

i) Tank got bulged heavily & Stiffeners were found cracked and oil came out from the reactor.

ii) The reactor tank got bulged towards HV side damaging the MB.

iii) HV Bushing flange & cement joint was found broken, oil level in bushing is also below minimum.

iv) Neutral bushing porcelain found displaced at bottom side.

v) Reactor bottom welding at jacking pad found broken on all side which shows reactor displacement.

vi) Consequential damage was also observed in Radiator.

vii) 132KV Neutral LA got failed, Earth lead of LA got removed from LA bottom stack & LA counter got blasted.

(B) Internal Inspection:

Internal inspection was carried out jointly by CGL and POWERGRID. Following are the observations after internal inspection.

i. Most of the pressboard barriers found broken badly and burnt.

ii. The winding insulation components viz: washers and caps found to be dislocated.

iii. Winding near HV bushing lead area was damaged and the Insulation over winding was also damaged badly. The bare Copper was visible in the HV lead area. Similarly, copper is also visible in the top part of winding near Neutral.

iv. Heavy charring of insulation was found inside.

v. No oil is left inside tank.

4.0 DETAILS OF TESTING AFTER FAILURE OF REACTOR

LV tests were carried out on 03/06/2017 and the following discrepancies are observed:

4.1 Winding C & Tan Delta measurement:

Winding C & Tan delta in GST mode	Factory value at 10 kV	Precomm value at 10 kV	Post tripping site value at 10 kV
10KV	4.419 nF, 0.265%	4.375 nF, 0.231%	2.917nF, 4.52%

It can be seen from the above results that Winding Capacitance is reduced by 33% and tan delta w.r.t ground increased 20 times.

4.2 Insulation resistance measurement:

Winding configuration	Pre-commissioning value	Post tripping site value at 2.5 kV
CC-G (Frame to Tank)	87.2 G OHMS	2.35 G OHMS
CL-G (Core to Tank)	55.7 G OHMS	2.33 G OHMS

CC-CL (Core to Frame)	39.1 G OHMS	0
Shield1-Shield2	396 G OHMS	950 G OHMS
Shield1-Earth	216 G OHMS	690 G OHMS
Shield2-Earth	234 G OHMS	157 G OHMS
IR Value at 15/60 Sec	29.2/33.6 G OHMS	1.9/2.03 G OHMS

It can be seen from the above results that IR values of CC-CL became zero in R-phase. IR values of Winding, Core and Frame to earth has reduced drastically.

4.3 No load magnetizing current at 230 Volts:

HV & Neutral	Pre-commissioning value	Post tripping site value
241 V	99.4 mA (at 240.6 Volt)	325.5 mA (at 241 Volt)

It can be seen from the above results that LV magnetizing current increased around 3.27 times compared to pre-commissioning.

4.4 DC Winding Resistance at 75 C:

Pre-commissioning value	Post tripping site value
1.967Ohm	2.649 Ohm

It can be seen from the above results that DC Winding resistance is increased 35% compared to pre-commissioning.

5.0 FAILURE INVESTIGATION

From the DR details available, it is observed that heavy fault current of almost 20kA has flown from 765kV side. The Reactor tripped on REF, Differential and Body protections. From the LV tests done after failure, it can be observed that winding tan delta increased almost 20 times and IR values of core to frame is zero which indicated failure of insulation.

From the internal inspection, LV test results and DR details, it is suspected that there might be an internal flashover in the winding portion between HV side to the top portion of winding on neutral side, short circuiting the reactor impedance altogether. Heavy internal pressure was generated due to high fault leading to the heavy bulging of reactor.

NGR LA failure may be due to neutral voltage rise during heavy fault current (Vn= 680kV at the time of tripping).

Failure investigation report of CGL make 765kV 80MVAR Bina-II Line reactor (R phase) at Satna (Sr.No. BH09823/01)

6. CONCLUSION:

In the joint inspection with CGL it was found that failed Reactor is damaged badly and is found beyond repair at site. The Reactor needs to be shifted CGL works to find out the cause of the failure and for necessary repair / replacement by CGL.

As seen from damages to the bushings, HV and neutral bushing can't be used as it is without any repair.

Presently reactor bank is charged with spare reactor. However immediate repair/ replacement is required. The same has been communicated to CGL in joint MOM signed after internal inspection.

The delayed operation of PRV needs to be investigated.

(Mukesh Mathur)	**(C Sunil Kumar)**	**(P R S Yadav)**	**(Lalan Kumar)**	**(Amit Kumar)**
AGM	**DGM**	**Asst GM**	**Manager**	**Engr**
(CC-QA&I)	**(RHQ-AM)**	**(CC-AM)**	**Satna**	**(CC-AM)**

Failure investigation report of CGL make 765kV 80MVAR Bina-II Line reactor (R phase) at Satna (Sr.No. BH09823/01)

Photos of Failures of 765kV 80MVAr Bina-II reactor

Fig-I (Tank Bulging & Broken stiffeners)

FIG-II (Tank Bulging & Crack from HV Side)

FIG-III (Crack in HV Bushing Flange & Cement Joint)

FIG-IV (Displacement in Neutral Bushing)

FIG-V (Displacement of Reactor tank)

Failure investigation report of CGL make 765kV 80MVAR Bina-II Line reactor (R phase) at Satna (Sr.No. BH09823/01)

FIG-VI (Damaged winding near HV terminal)

FIG-VII (Damages in top winding near Neutral terminal)

Failure investigation report of CGL make 765kV 80MVAR Bina-II Line reactor (R phase) at Satna (Sr.No. BH09823/01)

FIG-VIII (Failure of insulation near bottom neutral lead)

Failure of NGR LA

(118)

पावर ग्रिड कार्पोरेशन ऑफ इंडिया लिमिटेड

एसेट मैनेजमेंट विभाग

संदर्भ: CC/AM/TRF/118 **दिनांक** : 04/10/2017

विषय: **Preliminary investigation report of failed CGL make, 420kV, 80 MVAR Patna-1 Line reactor at Kishenganj S/S on 01.09.2017**

1. On 1st September, 2017 at 11:03 Hrs, CGL make, 420kV, 80 MVAR Line Reactor (T10416/1) tripped on REF protection and a loud explosion was heard in the vicinity. On investigation it was found by site that PRD and Buchholz had also operated.

2. Competent Authority constituted the following committee for investigation of the failure of the Reactor:

    a. Hans Raj, Manager, Banka, ER1
    b. Amandeep Singh, Manager, CC-AM
    c. Abhay Kumar, DGM, CC-Engg-S/S
    d. Rohit K. Srivastava, Dy. Manager, Kishenganj, ER1

    The committee visited Kishenganj S/S for investigation of failure causes on 7th and 8th September, 2017. The probable reason of failure may be due to failure of HV insulation around Y phase causing flashover to core. The observations and recommendations of the committee are as attached at Annexure-I.

3. Based on the physical verifications and LV test results, committee opined that the reactor cannot be repaired at site and has to be shifted to has to CGL factory for further investigation and repair.

Put up for approval please.

4/10/17
(अमनदीप सिंह)
प्रबन्धक (ए.म)

उप महा प्रबंधक (एसेट मैनेजमेंट) 4/10/17

महाप्रबंधक (एसेट मैनेजमेंट) 9.10.2017

कार्यपालक निर्देशक (एसेट मैनेजमेंट) 10/10/17

निदेशक (प्रचालन)

Findings of the teeleine may be circulated to all RHQ & ERI may be requested to resolve all the issues highlighted in the committee report.

(CAM)

POWERGRID CORPORATION OF INDIA LTD

CC – Asset Management

Investigation Report on Failure of Patna-1 Line Reactor at Kishenganj Station

On 01st September 2017, 80 MVAR, 400 kV CGL make Patna-1 Line Reactor at Kishenganj S/S tripped on REF protection and loud explosion was heard in the vicinity. On investigation it was found by site that PRD and Buchholz had also operated. In order to investigate the reasons of the failure and to assess extent of damage, a committee was constituted comprising of following members:

S.No.	Name	Designation	Place of Posting
1.	Hans Raj	Manager	Banka, ER1
2.	Amandeep Singh	Manager	CC-AM
3.	Abhay Kumar	DGM	CC-Engg-S/S
4.	Rohit K. Srivastava	Dy. Manager	Kishenganj, ER1

The team visited Kishenganj S/S for investigation of failure causes on 7th and 8th September, 2017. Following are the observations made by the committee during the visit:

Equipment Details:
Name: Patna-1 Line Reactor (Switchable)
Sl No.: T10416/1
Make: CGL
Rating: 80 MVAR
Year of Manufacture: 2014
Date of Commissioning: 14.03.2016

Date and Time of Failure: 01.09.2017 11:03:36:950.

Pre-Conditions:
Prior to the failure, system was in normal condition and all lines (New Siliguri-1&2, New Purnea-1&2 and Patna-1&2) were in service and charged at 400 kV level. The weather was clear and there was a loading of 120 MW each on the Kishenganj-Patna lines. The Bus voltages were 413/229 kV.

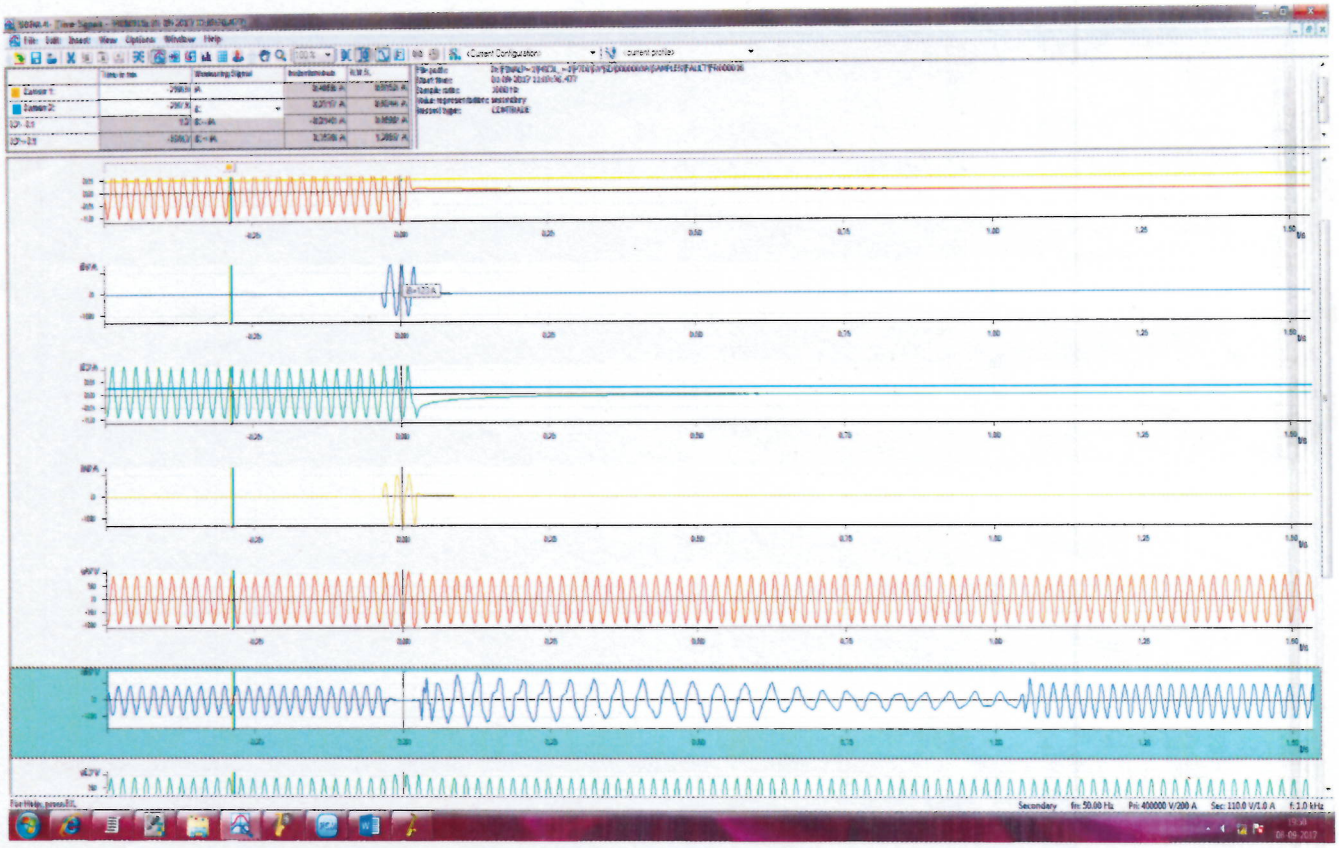
It was found that the reactor had tripped three times in the last month due to "NGR Buchholz operation". On enquiry, site revealed that the alarm was disregarded as mal-operation and was not investigated

Sd/- Sd/-

Hans Raj Prasad	Amandeep Singh	Rohit K. Srivastava	Abhay Kumar
(Manager, Banka, ER-I)	(Manager, CC-AM)	(DM, Kishanganj, ER-I)	(DGM, CC-Engg.)

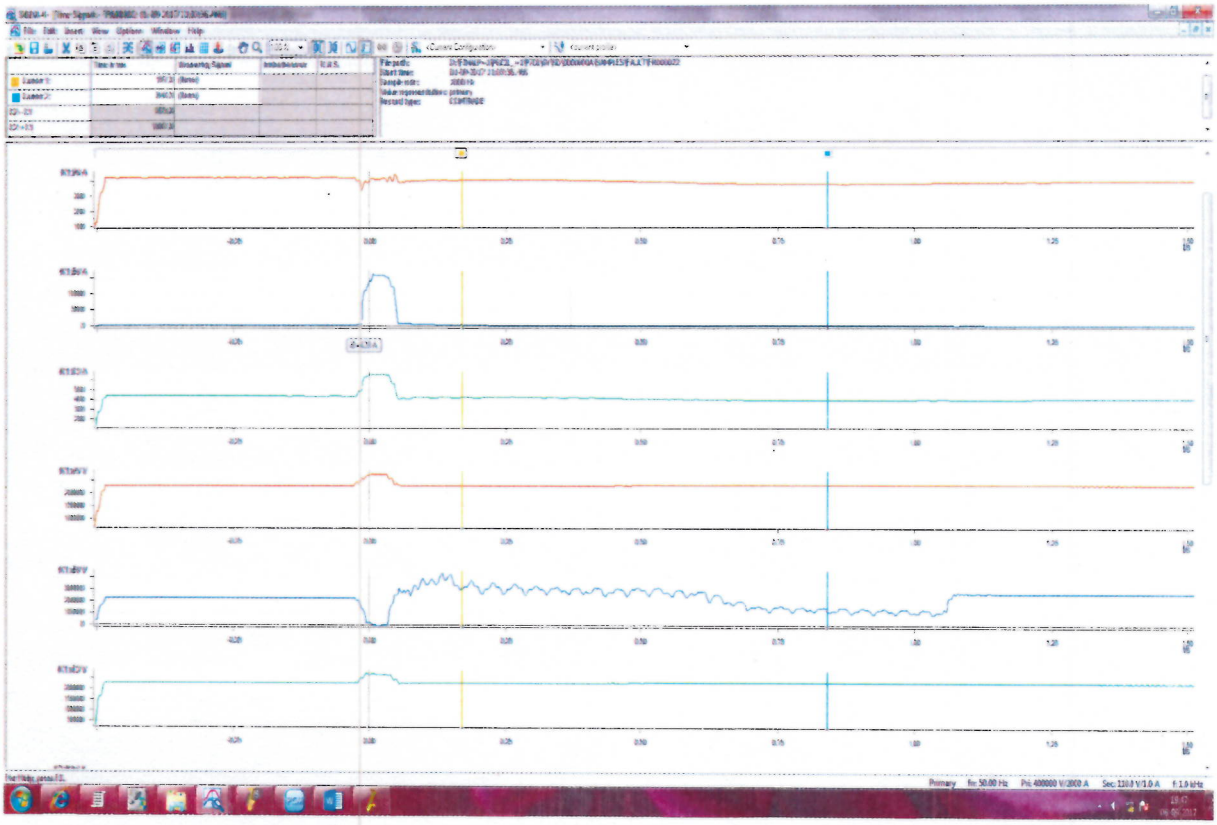
properly. On the day of tripping too there was a tripping on the same alarm at 08:19 hrs and the reactor was taken in service at 08:25 hrs. The reactor again tripped at 11:02 hrs on the same alarm and was again taken back in service at 11:03:36. Immediately after being taken in service (at 11:03:36 hrs), a loud sound was heard in the control room & surrounding area and Patna-1 Line Reactor tripped along with the line. Upon investigation by the operation staff it was found that the line reactor has tripped on REF, Buchholz and PRD operation. The initial visual investigation by the site revealed that both PRDs installed in the reactor had operated.

The DR of the REF during the tripping is as shown:



At the same time, the Main-1 protection (Siprotec 7SA522) also detected the fault in Zone-1 and extended a single phase tripping to Y phase Main & Tie CBs & sent carrier to Remote end. Due to the priority scheme in the Auto Reclose Tie CB closed after 2 seconds but the Main CB did not reclose causing the remaining two poles to trip on Pole Discrepancy. However DT was received immediately from remote end causing the line to again trip.

Hans Raj Prasad	Amandeep Singh	Rohit K. Srivastava	Abhay Kumar
(Manager, Banka, ER-I)	(Manager, CC-AM)	(DM, Kishanganj, ER-I)	(DGM, CC-Engg.)



The various parameters during the incidence were as shown:

Signal	Pre-fault values	Fault values
I_a	110 A	406 A
I_b	223 A	15 kA
I_c	110 A	655 A
V_{a-n}	276 kV	276 kV
V_{b-n}	272 kV	4.8 kV
V_{c-n}	274 kV	273 kV

The last reactor closing operation could not be retrieved since software for downloading the CSD relay was not available with site.

Sequence of Fault:

As per the Event Logger the sequence of fault was as shown:

11:03:36.950	Reactor REF Protection Optd.
11:03:36.967	Reactor PRV Optd.
11:03:37.000	Tie CB (417) Y phase opened
11:03:37.003	Reactor Switchable CB (415) opened

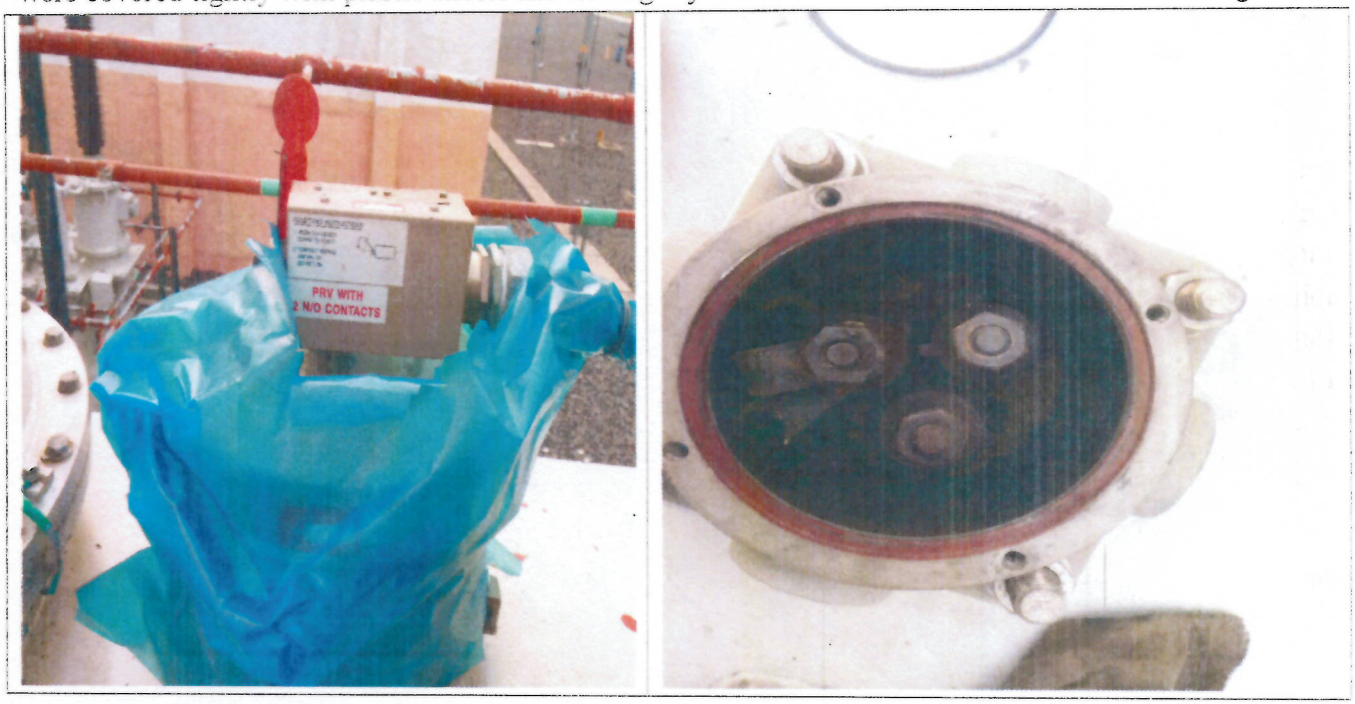
Sd/- Sd/-

Hans Raj Prasad	Amandeep Singh	Rohit K. Srivastava	Abhay Kumar
(Manager, Banka, ER-I)	(Manager, CC-A/M)	(DM, Kishanganj, ER-I)	(DGM, CC-Engg.)

11:03:37.005	Reactor Buchholz Protection Optd.
11:03:37.006	Main CB (416) Y phase opened
11:03:39.088	Tie CB (417) Y phase closed
11:03:39.647	Main CB (416) R&B phase opened
11:03:40.261	DT received and Tie CB (417) tripped

Description of Fault:

There is no visual damage to the bushings of the reactor. The main tank is also intact and there is no bulging or any physical damage. Both the PRDs have operated and oil has been discharged. CC-CL Earthing link on top of the reactor was found damaged. The PRD and Buchholz of main tank and the NGR were covered tightly with plastic sheets and tied tightly and there was no indication of moisture ingress.



Initial Test Results of the Reactor:

Pre-commissioning Values	*During Last Testing (10.05.17)*	*After Failure (04.09.17)*
Magnetizing Current	**IR Value**	**Magnetizing Current**
R-N: 16.22 mA	HV-E: 9.50 Gohms	R-N: 110.61 mA
Y-N: 16.33 mA	**Tan delta of Bushing**	Y-N: 290.23 mA
B-N: 17.27 mA	R phase: 0.3018%/533pF	B-N: 111.10 mA
IR Value	Y phase: 0.2646%/533.38pF	**IR Value**
HV-E: 9.40 Gohm(600 seconds)	B phase: 0.2484%/534.41 pF	HV-E: Zero
Winding Resistance		**Winding Resistance**
R-N: 1.6071 ohms		R-N: 1.67 ohms
Y-N: 1.6118 ohm		Y-N: 1.78 ohm

Sd/-		Sd/-	
Hans Raj Prasad	Amandeep Singh	Rohit K. Srivastava	Abhay Kumar
(Manager, Banka, ER-I)	(Manager, CC-AM)	(DM, Kishanganj, ER-I)	(DGM, CC-Engg.)

B-N: 1.6025 ohms		B-N: 1.65 ohms

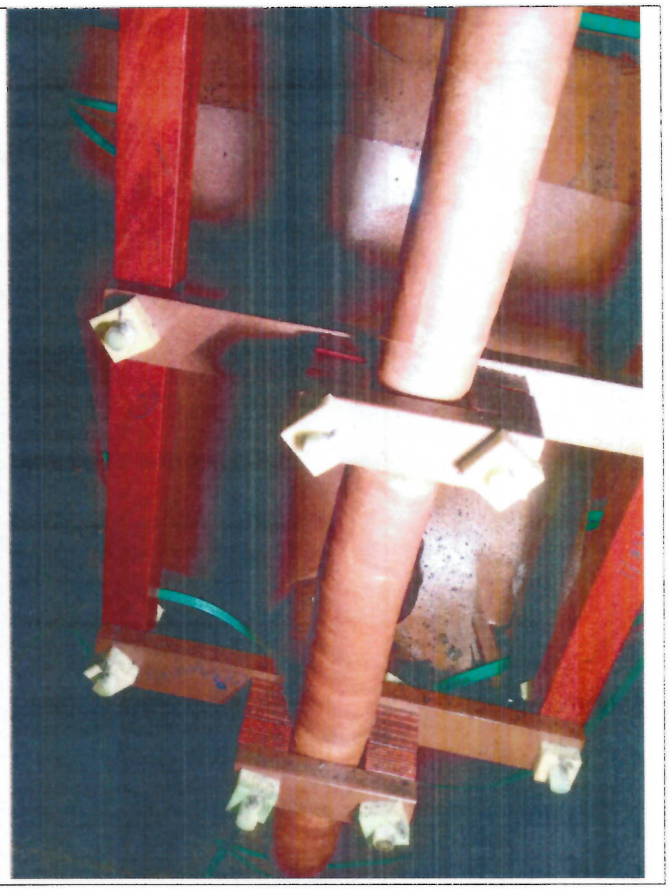
DGA Results of the reactor:

S.No.	Date	H2	CH4	C2H6	C2H4	C2H2	CO	CO2
1	02.09.2017 (Post Failure)	4502	2107	206	2330	1706	968	475
2	20.07.2017	15	13	3	21	0	202	584
3	20.04.2017	10	4	0	0	0	101	166
4	09.12.2016	08	3	0	0	0	68	157

The online-DGA was faulty since 13.08.17. There is a sudden rise of gases on failure causing the PRD/Buchholz to operate. The tripping indications also a rapid development of fault inside the reactor. Consequently an internal inspection was carried out to assess the damage inside.

Internal Inspection of the Reactor:

Accordingly internal inspection was carried out of the reactor in the presence of the representative of CGL, Mumbai. The HV Lead exits of R & B phase were found intact but the insulation around the Y phase was found damaged.



Hans Raj Prasad	Amandeep Singh	Rohit K. Srivastava	Abhay Kumar
(Manager, Banka, ER-I)	(Manager, CC-AM)	(DM, Kishanganj, ER-I)	(DGM, CC-Engg.)

Black residue was found at the bottom of the tank and at many places inside the reactor. The preliminary investigation indicates that there has been a flashover from the Y phase HV side to the core. The burn marks could not be verified in core at site however there is a strong possibility of an inter-turn fault in the reactor. The same will have to be checked after un-tanking of the reactor at factory.

The comments of the CGL representative are as shown:
"The findings are:

1. The V-winding is subjected to fault, wherein the insulation of winding is adversely affected due to same.
2. As per DGA report dated 26 July 2017, the ratio of C02/CO <3, which was not shared with us.
3. The reactor was in idle condition during 26.07.2016 to 03.04.2017, while re-commissioning, we were not involved in clearance.
4. This is a strong indication of a fault in paper, either a hot spot or electrical arcing.
5. Under such situation, we recommend to discontinue the services of reactor.
6. Detailed RCA can only be possible after dismantling the job in our plant."

The approach road to the station was also found damaged due to recent floods and the transportation of the reactor to factory will not be possible in its present condition.

Hans Raj Prasad	Amandeep Singh	Rohit K. Srivastava	Abhay Kumar
(Manager, Banka, ER-I)	(Manager, CC-AM)	(DM, Kishanganj, ER-I)	(DGM, CC-Engg.)

Conclusion

Based, on the above, the committee makes the following recommendations:

1. The reactor cannot be repaired at site and will have to be shifted to CGL, Mumbai for repair and region to take up the matter for timely repair of the same with M/s CGL.
2. The Buchholz relay of both NGR and the Main tank may be tested for healthiness. Additionally, the oil sampling of NGR needs to be carried out on an urgent basis.
3. The last closing operation of the reactor to be analyzed to gather further clues into the cause of the failure of the reactor.
4. The Differential relay did not operate during the incidence so the installed relay is to be tested by simulating the fault through secondary injection of current.
5. During the site visit it was found that the site is not maintaining the tripping records & Equipment Failure Records in ERP. Further critical evaluation parameters like PLCC counter reading, LA counter readings, etc were also not available for analysis. Site to start faithfully recording/ updating of information in ERP.
6. The site has closed the reactor on tripping on (mal)operation of NGR Buchholz seeing that no gas is accumulated in NGR Buchholz and it is getting reset automatically, such approach needs to be discouraged and root cause of the repeated tripping should be done. Region to advise all sites to report all tripping to RHQ irrespective of the nature of tripping.
7. The approach roads to the station were seriously damaged due to the recent floods and the transportation of the reactor from and to the site will not be possible in present condition. The repair work of the approach road is to be expedited in line with the engineering committee recommendations for flood affected stations.

20.09.17

Hans Raj Prasad	Amandeep Singh	Rohit K. Srivastava	Abhay Kumar
(Manager, Banka, ER-I)	(Manager, CC-AM)	(DM, Kishanganj, ER-I)	(DGM, CC-Engg.)

POWERGRID CORPORATION OF INDIA LTD
CC – Asset Management

Committee Report on Failure of Kanpur-2 Line Reactor B phase at Varanasi Station

On 27th December 2017, 80 MVAR, 765 kV TBEA make Kanpur-2 Line Reactor (B phase) at Varanasi S/S tripped on REF indication. In order to investigate the reasons of the failure and to assess extent of damage, a committee was constituted comprising of following members:

S.No.	Name	Designation	Place of Posting
1.	Amandeep Singh	Manager	CC-AM
2.	Richik Manas Das	Dy. Manager	CC-Engg
3.	Raghavendra Verma	Manager	RHQ-AM, NR3
4.	J.V. Singh	Chief Manager	Varanasi, NR3

The team visited Varanasi S/S for investigation of probable failure causes on 29th December, 2017.

Following are the observations

Equipment Details:
Name: Kanpur-2 Line Reactor (B phase)
Sl No.: 14B09098
Make: TBEA
Rating: 80 MVAR, 765kV
Year of Manufacture: 2014
Date of Commissioning: 14.07.2016

Date and Time of Failure: 27.12.2017 01:38:11 hrs

Pre-Conditions:
Prior to the failure, system was in normal condition and all 765 kV & 400 kV lines were in service. The weather was dense foggy and there was a loading of 225 MW each on the two 765 kV Varanasi-Kanpur lines. The Bus voltages were 790/422 kV.

At 00:59 hrs, Buchholz alarm appeared in the 765 kV B phase reactor of Kanpur-2 Line Reactor. Upon observing the same the station operator alerted the maintenance staff regarding it. The operator was advised by the maintenance staff to physically observe the Buchholz GCD for presence of gas and to open the reactor in co-ordination with CPCC. The station operator checked the reactor and did not find any

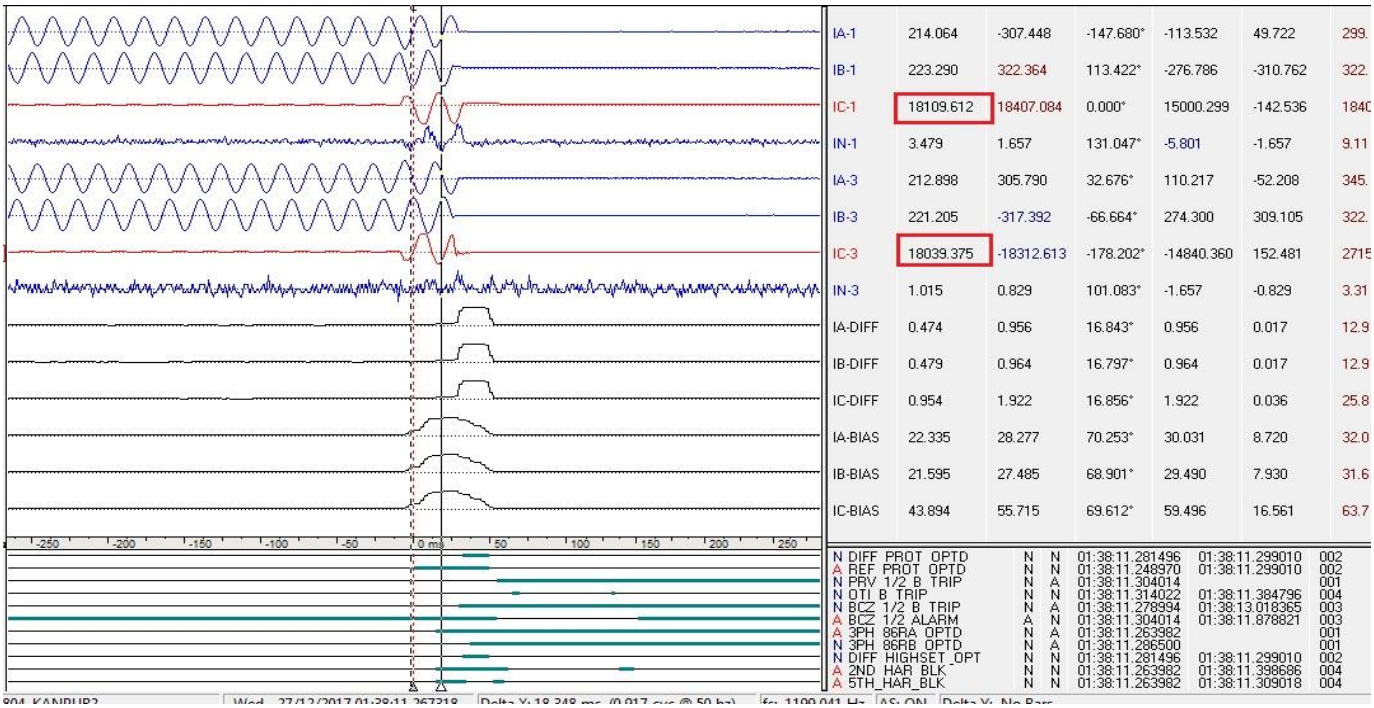
Raghavendra Verma	Amandeep Singh	J.V. Singh	Richik Manas Das
(Manager, RHQ-AM)	(Manager, CC-AM)	(Chief Manager, Varanasi)	(Dy. Manager, CC-Engg)

abnormally high OTI/WTI readings. However as advised by the maintenance staff he was coordinating the outage of the reactor when, at 01:38 hrs, a loud explosion was heard from the reactor side followed in quick succession by another explosion. 765 kV Varanasi-Kanpur-2 Line and the switchable line reactor had tripped. The operator rushed to the switchyard and found the Kanpur-2 B phase Line Reactor burning and the emulsifier system operated. On seeing the flames reaching towards the adjoining R phase Line Reactor of Kanpur-1, the operator hand tripped 765 kV Varanasi-Kanpur-I and the associated line reactor too. The operator also informed the maintenance staff who rushed to the station and started the fire-fighting process using the hydrant pipes. The fire was finally extinguished in the morning around 07:00 hrs.

Sequence of Fault:

00:59:29.117	Buchholz 1/2 B phase Alarm
01:38:11.242	Kanpur-2 Line Reactor REF optd
01:38:11.264	Kanpur-2 Line Reactor B phase PRV optd
01:38:11.282	Kanpur-2 Line Reactor B phase Buchholz optd
01:38:11.284	Kanpur-2 Line Reactor Differential optd (High SET)
01:38:11.284	Kanpur-2 Line Reactor B phase OTI trip optd
01:38:11.878	Kanpur-2 Line Reactor B phase Emulsifier optd
01:38:14.729	Kanpur-2 Line Reactor REF optd
01:38:14.735	Kanpur-2 Line Reactor Differential optd (High SET)

The DR record of the initial Buchholz alarm does not indicate any problem like imbalance of current and the same can also be seen in the differential DR (at the instance of failure of reactor). The DR is as shown:



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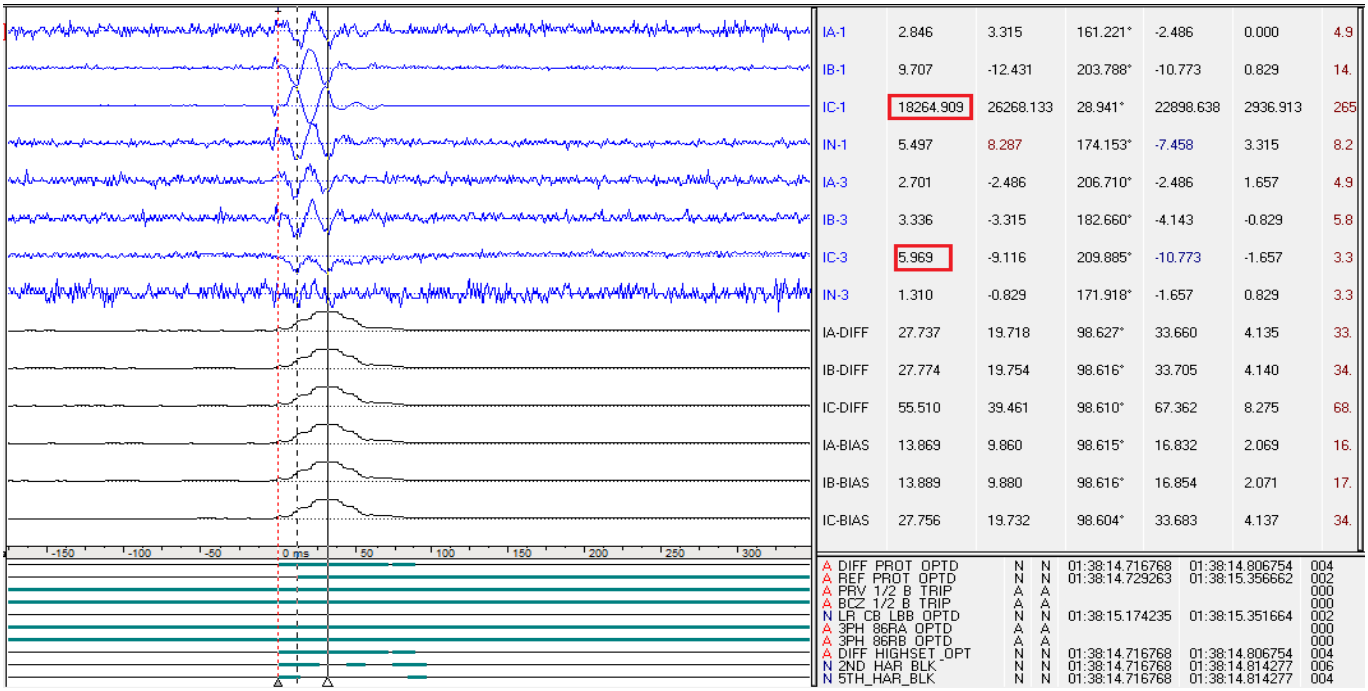
As observed from DR, HV and Neutral currents are equal. It appears that internal flash has occurred between HV and neural terminal leading to flow of high fault current and damages to bushing. However in the second instance (i.e. at 01:38:14), Fault current appeared in HV side only after 3.5s of first fault. Reactor CB was already open at that instant. Flashover might have occurred between line and reactor bushing leading to tripping of line and further damage to bushing and Reactor.



At the same time (i.e. at 01:38:14), the Main-1(P444) and Main-II (REL670) also detected the fault in Zone-1 and extended a single phase tripping to B phase Main & Tie CBs. LBB of Knp-II Reactor bay initiated & issued trip command to own CB (which is already tripped at 01:38:11 Hrs.) and also Main & Tie bay of Knp-II through its MTR 86A&86B and subsequently send DT to remote end. Finally line tripped at 01:38:14 Hrs. due to LBB operation of Reactor Bay.

The various parameters during the incidence were as shown:

Signal	Pre-fault values	Fault values
I_a	191 A	214 A
I_b	192 A	225 A
I_c	190 A	18.3 kA

Description of Fault:

There is extensive damage to the reactor and bulging is seen near the HV bushing. The HV bushing has shattered completely and the insulation paper is also partly burnt. The neutral bushing is also damaged due to the explosion. Both the PRDs have operated and the oil has been discharged. The tan delta point of both the bushings is intact and there is no pitting/burning marks found in the bushing caps. The top Inspection

window of the reactor found nearly 60 feet narrowly missing the GIB of the switchable line reactor due to the violent rise of pressure during fault. Flashover marks are also seen near the base of HV turret at the top of the reactor. The neutral LA has also failed.

Test Results of the Reactor after failure:

Since the HV bushing is completely destroyed the LV testing could not be carried out. However oil sample from Buchholz and the main tank have been sent to lab for DGA sampling.

DGA Results of the reactor:

S.No.	Date	H2	CH4	C2H6	C2H4	C2H2	CO	CO2
1	(Post Failure)	2235	2377	476	3467	2540	1180	4987
2	13.12.17	16	18	1	3	0	717	2050
3	07.11.17	21	18	1	3	0	708	2206
4	09.10.17	16	17	1	3	0	666	2151
5	09.09.17	25	16	1	3	0	629	1940
6	17.08.17	23	14	1	3	0	610	1850

Further the online DGA results were as shown:

Timestamp	H2	ROC
26/12/17 20:58	4	3.1
26/12/17 21:28	4	3.1
26/12/17 21:58	4	3.1
26/12/17 22:28	4	3.1
26/12/17 22:58	850	5.8
26/12/17 23:28	1093	20.8
26/12/17 23:58	1545	22.6
26/12/17 00:26	12271	42511.6
26/12/17 00:56	12671	44996.3
27/12/17 01:26	12608	43173

It appears that the fault has initiated from inside the reactor and has evolved rapidly between 26.12.17 22:30 hrs & 27.12.17 01:38 hrs. Consequently an internal inspection was carried out to assess the damage inside.

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<u>Internal Inspection of the Reactor</u>:

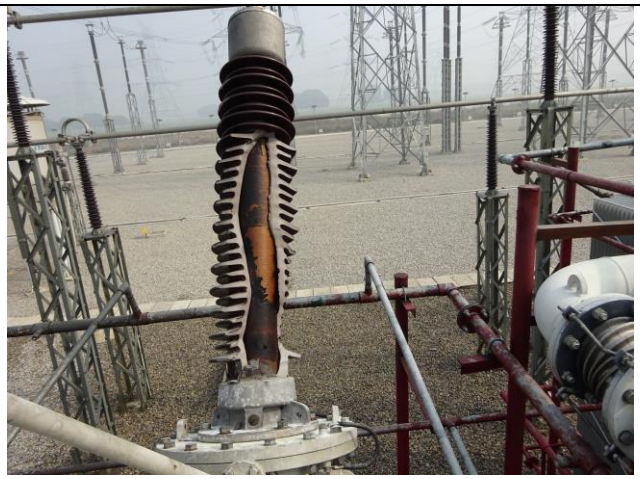
Internal inspection at site indicates that the HV lead exit has violently sheared away from the HV bushing and the insulation is completely burnt. However the HV bushing oil end corona ring seems to be intact and there was no abnormality observed on the tan delta point. The neutral lead is intact in the neutral bushing. The portion of winding visible also seems to be intact except for minor fire damage. This indicates that the fault has initiated from the HV lead exit to Static end ring (SER) of the neutral end of the winding either at the top or bottom. However the end point of the flash over or the route taken by the flashover can only be clear during the factory inspection.

The second fault seems to have been caused due to burning material rising from the reactor which caused an ionized path to the HV bushing from the line (which was charged) above the failed reactor. The flashover then travelled through the bushing CT and then through the tank so it cannot be seen in the Neutral CT.

Overall View of the reactor

Suspected flashover point during the second incidence

HV lead connection



Neutral Bushing (Mechanical damage)

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Conclusion:

Based on the inspection and discussion with representatives from M/s TBEA at site the following are the conclusions:

1. The nature of fault seems to be similar in nature to previous failures of CGL/ZTR make reactors. Further Root Cause Analysis shall only be possible in the factory.
2. The failed reactor cannot be repaired at site so the same is to be shifted to TBEA works for further inspection and repair. The said reactor is under warranty.
3. A communication was issued from CC-AM for extending of trip command the reactors in case of Buchholz alarm and the same was under implementation. Site explained that the implementation of the same is being done by using CMR (so as to retain the distinction between Buchholz Alarm & Trip, in case of any tripping). Site to expedite the process to prevent such future re-occurrence.

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ANNEXURE-III

Format for reporting of failure of the substation equipment

Format 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 equipment is properly earthed	:	
xxxii.	Earth Resistance of Substation and date of its measurement	:	
xxxiii.	Surge arrestor: (a) Is SA provided for protection (b) Whether healthiness of SA is monitored (c) Whether reading of SA counter changed during failure	:	
xxxiv.	Lightning Impulse and Switching Impulse Withstand Voltage of the bushings of all voltage level	:	
xxxv.	Lightning Impulse and Switching Impulse Withstand Voltage of the winding of all voltage level	:	
xxxvi.	Type of Fire protection provided (Emulsifier system/ N_2 Injection based fire protection system/ foam based protection etc.)	:	
xxxvii.	Weather conditions at the time of failure (clear sky/rainy/thunderstorm etc.)	:	

xxxviii.	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	:	
xxxix.	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?	:	
xl.	Number of through faults the equipment was subjected to before failure	:	
xli.	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	:	

Format 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 the Meeting of the Standing Committee of Experts to Investigate the Failure of 220 kV and above Voltage Class Substation Equipment held on 24th September 2018 in CEA

Minutes of the Meeting of Standing Committee of Experts to investigate the failure of equipment at 220 kV and above substation (January 2017 to March 2018) on 24th Sept. 2018 in CEA, New Delhi

List of participants is attached in Annexure-I

1. Chief Engineer(PSE&TD) welcomed all the representatives of CPSUs and State Utilities and various OEMs present and gave background and purpose of the Committee. He informed that total 79 nos. of failures has been reported during January 2017 and March 2018 by PGCIL, DTL, OPTCL, KPTCL, TANTRANSCO, APTRANSCO, BBMB, MSETCL & KSEB. Out of these, there have been failures of 12 nos. of transformers, 5 nos. reactors, 4 nos. CB, 28 nos. CT/PT/CVT and 30 nos. SA 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. Director (PSE&TD) requested all the utilities to furnish their failure reports indiscriminately and not selectively, so that realistic assessment of failures in the country could be made. The failure report should be complete in all regards along with test reports, O&M reports and photographs. He informed that the proforma for reporting of failure is available on CEA website.
3. Presentations, on the various failures that had occurred between January 2017 to March 2018 and were reported to CEA (Annexure-II), were given by PGCIL, DTL, BBMB, KPTCL, OPTCL, TANTRANSCO, MSETCL, MPTCL and KSEB 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.
4. Member Secretary, WRPC, suggested to include 66kV Generators failures in the purview of the Standing Committee as well, as it impacts the entire plant. He also said that the state utilities are not well aware of the Regulations and they also have problems on the fronts of workmanship and maintenance. He also commented that the inspection done in state owned substations are not upto the standard. In this regard, it was observed that the CPSUs are generally following the standard practices, but some state utilities fall short and needs updation.
5. Member Secretary, NRPC, suggested the utilities to avoid unnecessary delay in the reporting in the event of equipment failure and take necessary measures to communicate the same promptly so that inspection, if necessary, could be made possible. He further suggested

that in case of any equipment failure, photographic and video graphic documentation shall also be done in addition to the written failure report, so that the failure incident could be properly analysed by the Committee. NRPC suggested that Electrical Inspectorate should also share their findings with CEA in the event of discovering any abnormalities during their field inspections. Utilities were also advised to take necessary measures to ensure proper maintenance of their substations and to adhere to the Regulations/Guidelines provided by CEA. Care must be taken while placing the cables in the switchyard and they should be properly laid in the trenches or ducts and should be properly isolated. He suggested that Standard Operating Procedure (SOP) for storage of equipment at site may be specified for the utilities. Director (PSE&TD) suggested that BHEL, being a major OEM, may provide necessary input for SOP for storage.

6. Chief Engineer (PSE&TD) suggested that spillage of oils from transformers should be checked regularly, only trained operators should be appointed and CCTV cameras should be installed at substations so that in the event of any failure/accident/sabotaging, complete sequence could be made available to investigator.
7. Chief Engineer (PSPA-II) said that many utilities tend to report failures of only transformers and reactors, and the failures of other equipment are not reported. He suggested to practice condition-based maintenance instead of time-based maintenance. The utilities should maintain the record of all the relevant test results including the factory test reports, pre-commissioning test reports and the same should be available at substations. While determining the health of the equipment, the trend of the values of the test results should be analyzed instead of the absolute values alone. He also recommended use of modern diagnostic tools for tests so that minimum human interference and inadvertent tampering occurs.
8. OPTCL informed that watt loss test is carried out by them to check healthiness of Surge Arresters (SA) and if it is found to be more than 150 mW, the arrester is replaced. During discussion on failure of transformer of OPTCL it was informed that no fire fighting system was installed for protection of the transformer. It was also noticed by the committee that since the transformer failed immediately after replacement of bushing, poor storage condition of bushings may also be a cause of failure.
9. PGCIL said that proper care should be taken in cases where bushing is stored for long duration at the site and its condition should be checked before commissioning. It is not enough to merely have the tan Rδ value under 0.7%, but it should also be ensured that the increase in tan δ value of stored bushing from the factory result is not more than 0.1% which is indicative of moisture ingress. It was suggested that the tan δ value should be measured at different frequencies, and that in healthy condition, the value should increase with the increase in frequency. In case of SAs trend of the values of leakage current should be observed and if the variation in two subsequent readings, taken six months apart, is more than 20μA, Insulation Resistance (IR) should be

conducted to assess the health of SA. BBMB also stated that the rate of change of tan δ is indicative of the health of SA. WRPC suggested thermal scanning as a good indicator of the condition of SA and its connectors.

10. NRPC stated that many substations of various utilities are found lacking in the areas like fire fighting system, proper storage of equipment, proper testing before installation, and even the reliability of the test kits. PGCIL recommended that demo of test kits should be conducted to ensure its reliability and repeatability of measurement.
11. Regarding transformer failures, BHEL proposed that the utilities may consider making an assessment of the health of all of its transformers based on the diagnostic tests and consider overhauling of transformers wherever deemed necessary. It was also suggested that tertiary windings should be avoided as far as possible.
12. WRPC stated that after few years when short circuit fault level of the substation goes up the transformer will be at risk despite proper testing and maintenance. To which CE(PSPA-II) informed that fault current limiters or bus splitting should be adopted to take care of increased fault level.
13. CE (PSETD) suggested that the utilities have every right to repeat any of the type tests including short circuit test at their own cost and the bidder may be asked to quote price for the same at the time of bidding. He said that this will help improve the quality of the product and act as an additional quality assurance from the manufacturer's side.
14. PGCIL shared with the Committee that it has over 2400 in-service transformers and reactors of 220 kV and above level, and has a annual failure rate of 0.5% for reactors and 0.6% for transformers, which is well below the international annual rate of failure of 1% -1.5%. PGCIL informed that they had recently faced problems in the particular make bushings and had the cases of bursting of bushings. After this, they carried out DGA & variable frequency tan δ of all the bushings of the same make in all their stations and many bushings were found faulty. Variable frequency tan δ test is a very good indicator of moisture content in bushings. Every year 40-50 bushings in PGCIL substations are replaced based on variable frequency tan δ test. PGCIL also stated that if the bushing is of good quality and proper care is taken by the OEM during the manufacturing process, there shall not be any need of correction factor for tan δ tests. The faulty bushings are, in general, replaced by RIP bushings.
15. WRPC recommended to introduce RIP bushings in Make in India program. He highlighted that even if a RIP bushing will fail, it will not lead to any fire in the transformer. NRPC said that care should be taken while taking the oil sample for DGA and standard procedure should be followed. BHEL informed that as a corrective measure to address the cases of failures of bushings they have renovated the entire plant of bushings at Bhopal and assured that proper care is being taken so that such incidences could be minimised.
16. PGCIL also reported that they were facing problems with some reactors. After consultation with OEM, they had decided to get some

design modification in the windings of the reactors. It was said that the process of replacement with modified deign reactors is ongoing. The reactors were reportedly working satisfactorily after the replacement. NRPC suggested PGCIL to replace the remaining reactors as soon as possible, so that any untoward incident may be avoided.

17. BBMB suggested faster methods for detection of earth faults in circuit breakers, which they claimed had successfully prevented many cases of pole bursting. They also informed about breaker head flashover problem wherein insufficient gap after opening of the breaker was observed. This happened while synchronizing or immediately after desynchronizing and resulted in the bursting of the pole of CB. The internal chamber of the pole, in such cases, was found to be carbonised rendering the SF6 in the chamber useless. WRPC suggested that after 4-5 fault current trippings, full maintenance of the contacts of CB should be carried out. PGCIL suggested that if the CB has tripped the rated breaking current three times, the entire contact mechanism should be replaced. However, if the interrupted current is lesser, accordingly the permissible increased number of interruptions before the replacement of contact mechanism, may be allowed. CE (PSETD) suggested that only Circuit Breaker capable of breaking higher time constant currents should be used in switchyards associated with generating plants. BBMB was requested to submit the detailed failure reports of all the failures in the subject period in their stations to CEA & NRPC.
18. KPTCL told the Committee that 12 out of 17 cases of failures of SA were discovered during leakage current measurement. The Committee decided that these cases will not be treated as failures and as such will not be included in the report of the Committee.
19. WRPC highlighted that TANTRANSCO does not connect shield wire between gantry and the dead-end tower leaving the portion unprotected from lightning. TANTRANSCO confirmed the same. The committee suggested that if substation is protected from lightning through shield wire, it should be connected to cover all areas of the substation including area between dead end tower and gantry.
20. BHEL recommended the use of Controlled Switching Devices (CSD) for switching of transformers and reactors as it will reduce the stress on the equipment, especially GTs, thus improving its life. It was suggested that the operation of fire-fighting system should be linked to SCADA and the same shall be communicated to the OEM, as it will help in assessing its condition and performance pattern.
21. The Committee opined that erection & commissioning of all major equipment should be done by OEM so that problems arising due to ignorance and lack of attentiveness by inexperienced personnel may be curtailed.
22. MSETCL said that the connection between bus and transformer at substations through overhead conductor should be avoided as far as possible; instead single-core cable should be used for such connection.
23. RRVNL said that the neutral of the transformer should be connected to the earthing mat through a separate electrode. PGCIL suggested

that the neutral of transformers should be connected to earth through two conductors to avoid any problems of hotspot in the neutral. CE (PSETD) said that the neutral of 1-ph hot spare transformer should also be connected to ground to avoid any fault in the event of any surge current.

24. 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 -I

List of Participants:

CEA:

1. Shri Sanjay Srivastava, Chief Engineer and Chairman of the Committee (PSE&TD)
2. Shri Y. K. Swarnkar, Director (PSE&TD)
3. Shri R. K. Meena, Deputy Director (CEI)
4. Smt. Kavita Jha, Deputy Director (PSE&TD)
5. Shri Faraz, Deputy. Director (PSE&TD)
6. Ms. Bhaavya Pandey, Assistant Director (PSE&TD)
7. Shri Karan Sareen Assistant Director (PSE&TD)
8. Shri Mohit Mudgal, Assistant Director (PSE&TD)
9. Ms. Sippy Srivastava, Engineer (WAPCOS, Deputed in PSE&TD)

NRPC:

1. Shri M.A. K. P. Singh , Member Secretary
2. Shri Upendra Kumar, Senior Engineer

WRPC:

1. Shri A. Balan, Member Secretary

Powergrid Corporation of India Ltd.:

1. Shri R. K. Tyagi, General Manager
2. Shri Sumit S. Harichandanray, Deputy Manager
3. Shri Richik Manas Das, Deputy Manger

BHEL:

1. Shri Rajeev Sharma, General Manager
2. Shri Vivek Goel, Sr. Engg.
3. Shri Horam Singh
4. Shri Harish Kumar Sharma
5. Shri Vivek Kapil, Director General Manger

MPPTCL:

1. Shri R. K. Malviya
2. Shri P. K. Gargava

MPPGCL:

1. Shri P. K. Khare

KPTCL:

1. Shri B. V. Girish

TANTRANSCO:

1. Shri R. Regunarayanan, Executive Engineer

OPTCL:

1. Shri Sudhansu Sekhar Nanda, Director General Manger (Elect.)

MSETCL:

1. Shri Sanjeev G. Bhole, Senior Engineer

KSEBL:

1. Shri Rajan Joseph, Chief Engineer (TN)

GET & D India Ltd.:

1. Shri Santosh Kumar K.
2. Ms. Sandhya Lakhera
3. Shri Atul Rastogi

BBMB:

1. Shri Brajesh Kr. Yadav
2. Shri Rakesh Kumar Sharma, Addl. Senior Engineer

CGPISL (CGL):

1. Shri Naveen Bhatia, Senior Manger

DTL:

1. Shri Shyamal Sutradhar, Director General Manger
2. Shri S. K. Sinha, Director General Manger
3. Shri Kamal Gandhi, Assistant Manager (T)
4. Shri Loveleen Singh

RVPN:

1. Shri Mukesh Singhal
2. Shri A. K. Gupta

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.