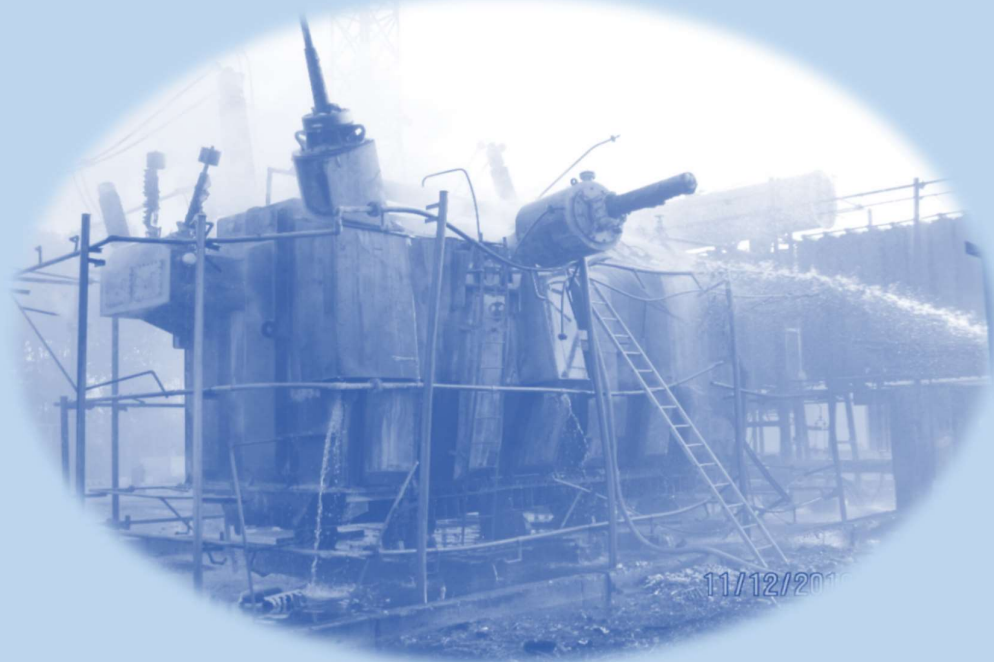




२२० के वी एवं उच्चतर विभव के सबस्टेशनों के क्षतिग्रस्त उपकरणों पर विशेषज्ञों की स्थायी  
समिति की रिपोर्ट  
(सितम्बर २०१५-दिसंबर २०१६)

**REPORT OF STANDING COMMITTEE OF EXPERTS ON FAILURE OF 220 kV &  
ABOVE VOLTAGE CLASS SUBSTATION EQUIPMENT  
(SEPTEMBER 2015-DECEMBER 2016)**



भारत सरकार  
**Government of India**  
केन्द्रीय विद्युत प्राधिकरण  
**Central Electricity Authority**  
विद्युत मंत्रालय  
**Ministry of Power**  
नई दिल्ली  
**New Delhi**

(विद्युत अधिनियम २००३ की धारा ७३(एल) के तहत के.वि.प्रा. के दायित्व का निर्वहन करते हुए)  
(In fulfillment of CEA's obligation under Section 73(1) of the Electricity Act, 2003)

**TABLE OF CONTENTS**

<b>SUBJECT</b>	<b>PAGES</b>
INTRODUCTION	2
OBSERVATIONS	13
RECOMMENDATIONS	14
ANNEXURE-I	20
INVESTIGATION REPORTS OF FAILURE OF POWER TRANSFORMERS OF DTL	
ANNEXURE-II :	48
DETAILED INFORMATION IN RESPECT OF EACH FAILED EQUIPMENT REPORTED TO CEA BETWEEN 1 <sup>ST</sup> SEPTEMBER 2015 AND 31 <sup>ST</sup> DECEMBER 2016 AND BRIEF ANALYSIS OF FAILURE OF THESE EQUIPMENT	
ANNEXURE-III :	219
MINUTES OF MEETING OF THE STANDING COMMITTEE OF EXPERTS TO INVESTIGATE THE FAILURE OF 220 KV AND ABOVE VOLTAGE CLASS SUBSTATION EQUIPMENT HELD ON 1 <sup>ST</sup> MARCH 2017 IN CEA	
ANNEXURE-IV :	226
OFFICE ORDER CONSTITUTING THE STANDING COMMITTEE	

## **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(1) 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, Wave Trap, Coupling Capacitor, XLPE Cable 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- IV.
- 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. As per the requirement of the Standing Committee, all utilities are supposed to report the failure of substation/ switchyard equipment of 220 kV and 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.
- 1.3 In most of the cases, the visit to site of failure do not materialize and analysis of cause of failure is done based on information provided by utilities in prescribed format. 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.
- 1.4 A meeting of the Standing Committee of experts was held in CEA on 1<sup>st</sup> March 2017 to discuss cause of failure of substation equipment for which information/failure report was received in CEA between 1<sup>st</sup> September 2015 and

31<sup>st</sup> December 2016 from various utilities. Minutes of the meeting are enclosed at Annexure - III.

- 1.5 In most of the cases of failure of CT / CVT / PT/ SA, the equipment had blasted. 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.
- 1.6 Quantity of failed equipment and years of service put in by these equipment before failure, reported to CEA between 1<sup>st</sup> September 2015 and 31<sup>st</sup> December 2016, is given in Table-I. Details of these failures are provided at Annexure-II.

**TABLE-1**

Years of Service	Nos. of equipment failed						
	Transformers/ GT	Reactors	CB	Surge Arrester	CT	CVT/PT	Coupling Capacitor
0-5 years	6	2	2	0	6	13	0
5-10 years	3	2	0	9	2	5	0
10-15 years	5	0	3	2	3	3	1
15-20 years	2	0	0	3	1	3	0
More than 20 years	5	0	1	2	10	4	1
<b>Total</b>	<b>21</b>	<b>4</b>	<b>6 *</b>	<b>16^</b>	<b>22 #</b>	<b>28 \$</b>	<b>2</b>

\* Total reported CB failures are 7 Nos.; information on year of commissioning for 1 No. CB is not available, hence years of service could not be determined.

^ Total reported SA failures are 17 Nos.; information on year of commissioning for 1 No. SA is not available, hence years of service could not be determined.

# Total reported CT failures are 26 Nos.; information on year of commissioning for 4 Nos. CTs is not available, hence years of service could not be determined.

\$ Total reported CVT/PT failures are 32 Nos.; information on year of commissioning for 4 Nos. CVTs/PTs is not available, hence years of service could not be determined.

1.7 Previous report was published in March 2016 which contained the information regarding failure of substation equipment reported to CEA between 1<sup>st</sup> October 2014 and 31<sup>st</sup> August 2015.

1.8 **Failure of Transformers:**

- (i) The 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. However, it has been observed that many Transformers have failed within first few years of service which is a matter of concern.
- (ii) Twenty-one (21) transformer failure cases have been reported to CEA during the period from September 2015 to December 2016 by nine (9) Utilities. Out of these twenty-one (21) transformers, one transformer is 765 kV class, seven (7) Nos. of transformers are of 400 kV class [5 Nos. ICTs and 2 Nos. GTs] and thirteen (13) Nos. of transformers are of 220kV class [one GT and 12 Nos. ICTs]. Seventeen (17) numbers of failures are due to internal insulation failure, two (2) number of failures are attributed to bushing failure, one failure on account of ageing and in case of one failure, sufficient information was not available to determine any cause of failure. It is a matter of concern that 9 Nos. of transformers have failed within 10 years of operation/service. It is highlighted that 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.
- (iii) Summary of failure of Inter Connecting Transformers (ICTs) / Generator Transformers (GTs) reported to CEA between 1<sup>st</sup> September 2015 and 31<sup>st</sup> December 2016 is detailed below (Table 2):

**TABLE - 2**

Equipment	Utility/Name of substation	Make	Rating	Year of commissioning	Date of failure	Probable Cause of failure*
Power transformer (18 Nos.)	DTL Geeta Colony	BHEL	220/33kV, 100MVA	2005	02.02.2016	Internal insulation failure
	DTL Bawana	EMCO	315 MVA, 400/220/33 kV	2010	08.03.2016	Internal insulation failure
	DTL Papankalan	EMCO	100 MVA, 220/66-33/11 kV	2006	04.09.16	Internal insulation failure

DTL Park Street	BHEL	100 MVA, 220/66-33/11 kV	1994	11.09.16	Internal insulation failure
DTL Bawana	BHEL	400/220/33 kV, 315 MVA	2000	11.12.2016	Internal insulation failure
DTL Geeta Colony	BHEL	100 MVA, 220/33/11 kV	2005	01.12.2016	Internal insulation failure
DTL Wazirpur	EMCO	220/33/11k V, 100 MVA	2014	19.10.2016	Internal insulation failure
PGCIL Bareilly	CGL	500 MVA, 765/400 kV	2016	15.11.2016	Internal insulation failure
HVPL Nawada	Areva	315 MVA, 400/220 kV	2013	22.04.2015	Internal insulation failure
HVPL Madanpur	BHEL	220/66 kV, 100 MVA	2003	13.03.2015	Internal insulation failure
APTRANSCO Pulivendula	BHEL	100 MVA, 220 kV /132 kV	2010	11.10.2015	Internal insulation failure
APTRANSCO Tadikonda	EMCO	220/132kV, 100 MVA	1999	24.08.2016	Bushing failure
APTRANSCO Gudivada	TOSHIBA	220/132 kV, 160 MVA	2015	24.09.2016	Internal insulation failure
TANTRANSCO Manali	EMCO	230/110/11 kV, 100 MVA	2008	01.12.2015	Sufficient information not available
TANTRANSCO Gummidipoon di	BHEL	100 MVA, 230/110 kV	1994	31.03.2016	Internal insulation failure
KSEB Edamon	BHEL	33.3 MVA, 220/110 kV	1978	04.05.2016	Ageing
KPTCL Hoody	CGL	1-Ph, 167 MVA, 400 /220/33 kV	2004	02.06.2016	Bushing failure

	OPTCL Meramundali	BHEL	315 MVA, 400/220/33 kV	2005	12.11.2016	Internal insulation failure
Generator Transformers (3 Nos.)	KPCL Raichur TPS	CGL	250MVA, 15.75/220kV	1991	23.05.15	Internal insulation failure
	KPCL Bellary TPS	BHEL	207 MVA, 21/400/ $\sqrt{3}$ kV	2015	28.08.2015	Internal insulation failure
	KPCL Raichur TPS	CGL	250 MVA, 15/420 kV	1994	28.02.2016	Internal insulation failure

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

- (iv) CEA Officers visited sites of Delhi Transco Ltd. (DTL) for joint investigation of following failure cases of transformers (Table-3). The Officers collected relevant data/information from site, interacted with substation staff, and carried out inspection of the transformer through inspection window, wherever feasible. Based on the information/data collected from the sites, preliminary reports were prepared. The reports of these visits are enclosed at Annexure-I.

**TABLE-3**

Utility/Name of substation	Make	Rating	Year of commissioning	Date of failure
DTL Geeta Colony	BHEL	220/33kV, 100MVA	2005	02.02.2016
DTL Bawana	EMCO	315 MVA, 400/220/33 kV	2010	08.03.2016
DTL Papankalan	EMCO	100 MVA, 220/66-33/11 kV	2006	04.09.16
DTL Park Street	BHEL	100 MVA, 220/66-33/11 kV	1994	11.09.16
DTL Bawana	BHEL	400/220/33 kV, 315 MVA	2000	11.12.2016
DTL Geeta Colony	BHEL	100 MVA, 220/33/11 kV	2005	01.12.2016

1.9 **Failure of Reactors:**

- (i) Four (4) Nos. reactor failure cases have been reported to CEA during the period from September 2015 to December 2016 by PGCIL. Out of these, one reactor is of 765 kV class and remaining three are of 400 kV class. Three Nos. failures are attributed to internal insulation failure and one number failure is due to bushing failure. Cause of failure is based on information, data & reports furnished by the utility. It is a matter of concern that all four Nos. of reactors have failed within 10 years of operation/service.
- (ii) Summary of failure of Reactors reported to CEA between 1<sup>st</sup> September 2015 and 31<sup>st</sup> December 2016 is detailed below (Table-4):

**TABLE-4**

Equipment	Utility/Name of substation	Make	Rating	Year of commissioning	Date of failure	Probable Cause of failure*
Reactor (4 Nos.)	PGCIL Kota	BHEL	420 kV, 80 MVAR	2009	28.09.2016	Bushing failure
	PGCIL Satna	BHEL	420 kV, 50 MVAR	2006	05.11.15	Internal insulation failure
	PGCIL Bina	CGL	765 kV, 80 MVAR	2012	28.11.2015	Internal insulation failure
	PGCIL Binaguri	BHEL	420 kV, 125 MVAR	2012	29.02.2016	Internal insulation failure

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

1.10 **Failure of Circuit Breakers (CBs):**

Seven (7) Nos. of cases of CB failure have been reported to CEA during the period from September 2015 to December 2016 by four (4) Utilities. Out of these seven (7) Nos. of CBs, two CBs are of 400kV class and remaining five (5) Nos. of CBs are of 220kV class. In all these cases of CB failures, failed pole or component such as Pre-Insertion Resistor (PIR), Grading Capacitor etc. had to be replaced with the new one. Repair of failed CB was not possible in any of the cases. In most of the cases, cause of failure of CB was internal insulation failure.

1.11 **Failure of Current Transformers(CTs):**

It is observed that twenty-six (26) Nos. of cases of CT failure have been reported to CEA during the period from September 2015 to December 2016 by six (6)



Utilities. All twenty- six (26) CTs are of 220kV class. It is observed that in most of the cases, the CTs have blasted and have been replaced. It is a matter of concern that twelve (12) Nos. of CTs have failed within 10 years of operation. Information on year of commissioning is not available for four (4) Nos. of CT, hence service rendered by these CTs could not be ascertained.

**1.12 Failure of Potential Transformers (PTs) / Capacitive Voltage Transformers (CVTs):**

It is observed that thirty-two (32) Nos. of cases of CVT / PT failure have been reported to CEA during the period from September 2015 to December 2016 by seven (7) Utilities. Out of these thirty-two (32) CVTs / PTs, five (5) Nos. of CVTs are of 400kV class and rest seventeen (17) Nos. of CVTs / PTs are of 220kV class. In most of the cases, the CVTs / PTs have blasted and have been replaced. It is a matter of concern that eighteen (18) Nos. of CVTs / PTs have failed within 10 years of operation. Information on year of commissioning is not available for four (4) Nos. of CVT/PT, hence service rendered by them could not be ascertained.

**1.13 Failure of Surge Arresters (SAs):**

It is observed that seventeen (17) Nos. of cases of SA failure have been reported to CEA during the period from September 2015 to December 2016 by four (4) Utilities. Out of these seventeen (17) Nos. of SAs, three Nos. of SAs are of 400kV class and rest fourteen (14) Nos. of SAs are of 220kV class. In most of the cases, the SAs have blasted and have been replaced. It is a matter of concern that nine (9) Nos. of SAs have failed within 10 years of operation. Information on year of commissioning is not available for one No. SA, hence service rendered by it could not be ascertained.

**1.14 Failure of Coupling Capacitor:**

Failure of two Nos. of Coupling Capacitors, both of 220 kV voltage class, have been reported to CEA between September 2015 to December 2016 by two Utilities. Both Coupling Capacitors have burst due to internal fault leading to operation of distance relay.

**1.15 Summary of failure of CB/CT/CVT/PT/SA/Coupling Capacitor:**

**TABLE-5**

<b>Equipment (Quantity)</b>	<b>Utility</b>	<b>Make</b>	<b>Rating</b>	<b>Year of commissioning</b>	<b>Date of failure</b>
Circuit Breaker (7)	BBMB	Siemens	220 kV	2015	31.05.15
	KPTCL	ABB	220kV	2000	20.10.2015

	KPCL	CGL	2000 A	2002	12.11.2015
	BBMB	CGL	400kV, 3150A, 40KA for 3 Sec.	2001	22.01.2016
	KPCL	BHEL	2000 A	1994	13.04.2016
	APTRANSCO	CGL	400kV, 2000 A	2012	06-09-2016
	BBMB	Siemens	220kV	NA	08.12.2016
CT (26)	BBMB	SCT	220 kV	2015	31.05.15
	TANTRANSCO	TELK	230 kV	1985	24.08.2015
	KSEB	VITRANS	220 kV	NA	19.05.2015
	TANTRANSCO	SCT	230 kV	2012	25.05.2015
	TANTRANSCO	TELK	230 kV	1986	26.09.2015
	MPPTCL	SCT	220 kV, 800- 400/1 A	2011	25.07.2015
	MPPTCL	TELK	220 kV, 800- 400/1 A	1993	18.08.2015
	KPTCL	W.S.Industries	220 kV	NA	15.10.2015
	KPTCL	Mehru	220 kV	2012	24.10.2015
	APTRANSCO	TELK	220 kV	1981	22.12.2015
	KPTCL	SCT	220 kV Class CT of Ratio 800/1-1-1-1- 1A	2007	22.02.2016
	KPTCL	Sri Venkateshwar Electicals Ltd	220 kV	2003	24.02.2016
	KPTCL	HBB	220 kV, 800- 600-400- 200/1-1-1A	1984	26.02.2016
	TANTRANSCO	Areva	220 kV, 600/1 A	2009	14.02.2016
	APTRANSCO	TELK	220 kV	1993	21.02.2016

	BBMB	NTPLC-24	220 kV	1979	17.04.2016
	APTRANSCO	BHEL	220 kV, Ratio: 800-600- 400/1-1-1-1-1	1993	06.06.2016
	KPTCL	SCT	220 kV, Ratio: 800-600-400- 300/1 Amp	2001	27.06.2016
	KPTCL (2 nos.)	SCT	3000-2000 / 1- 1-1-1-1 Amps	2016	27.05.2016
	APTRANSCO	BHEL	220 kV	NA	30.07.2016
	APTRANSCO	BHEL	220 kV	NA	10.03.2016
	APTRANSCO	TELK	400 kV	2000	04.04.2016
	KPTCL	TELK	220 kV	2005	22.08.2016
	BBMB	BHEL	220kV, 1200/800/600/ 400/300/1-1- 1A	1988	06.07.2016
	BBMB	ASEA	220 kV	1969	09.12.2016
CVT/ PT (32)	KSEB	TELK	220 kV	NA	19.05.2015
	KSEB	CGL	220 kV	1994	03.08.2015
	BBMB	WSI	220 kV	1990	10.07.2015
	TANTRANSCO	SCT	230 kV	2012	07.03.2015
	TANTRANSCO	CGL	230 kV	2007	26.04.2015
	KPTCL	CGL	220 kV	1998	22.09.2015
	KPTCL	WSI	400 kV	2005	23.09.2015
	KPTCL	WSI	220 kV	2004	24.09.2015

TANTRANSCO	HBB	230 kV	1983	13.12.2015
APTRANSCO	SCT	220 / 110 kV	2012	18.09.2015
BBMB	CGL	220 kV	2001	08.07.2015
PGCIL	CGL	400 kV	2005	05.10.2015
APTRANSCO	CGL	220 kV	1995	19.10.2015
APTRANSCO (2 nos.)	Trench Electric	220 kV	1996	24.11.2015
APTRANSCO	SCT	220kV/ $\sqrt{3}$ / 110V/ $\sqrt{3}$	2012	26.11.2015
KPTCL	ABB	400/ $\sqrt{3}$ kV / 110/ $\sqrt{3}$ V, 4400pF	NA	15.12.2015
APTRANSCO	SCT	220 kV	2011	23.02.2016
APTRANSCO	SCT	220 kV	2011	02.03.2016
APTRANSCO	Trench Electric	220 kV	1992	15.03.2016
KPTCL	SCT	220 kV	2012	07.03.2016
KPTCL	Areva	220 kV	2006	27.09.2015
KPTCL	SCT	220 kV	2011	02.04.2016
KPTCL	WSI	400kV/ $\sqrt{3}$ / 110/ $\sqrt{3}$ V, Single Phase, 8800 pF	NA	12.05.2016
KPTCL	SCT	220 kV	2011	13.10.2015
KPTCL	SCT	220 kV	2014	23.07.2016
APTRANSCO	SCT	220 kV	2011	01.08.2016

	KPTCL	SCT	220 kV	2011	12.07.2016
	KPTCL	SCT	220 kV	2010	01.07.2016
	APTRANSCO	SCT	220 kV	2011	13.05.2016
	KPTCL	SCT	220 kV	2011	30.05.2016
	NHDC	CGL	400 kV	2003	18.05.2016
SA (17)	KSEB	NA	220 kV	NA	19.05.2015
	BBMB	CGL	198 kV	2006	19.11.2015
	TANTRANSCO	CGL	400 kV	2006	11.03.15
	KPTCL	WSI	220 kV	1992	17.12.2015
	KPTCL	CGL	220 kV	2008	27.12.2015
	KPTCL	CGL	220 kV	2003	06.03.2016
	Reliance	CGL	220 kV	2005	30.11.2015
	KPTCL	CGL	216 kV, 10 kA	2001	28.12.2015
	GETCO	CGL	220 kV	1999	19.12.2015
	TANTRANSCO	CGL	390 kV	2006	13.12.2015
	TANTRANSCO	CGL	230 kV	1998	16.06.2016
	TANTRANSCO	CGL	230 kV	2000	19.06.2016
	BBMB	CGL	400 kV	2006	19.09.16
	TANTRANSCO	CGL	216 kV, 10 kA <sub>p</sub>	2006	26.05.2016
	TANTRANSCO	OBLUM	230 kV	2016	13.12.2016
	BBMB	CGL	198 kV	2006	25.04.2016

	APTRANSCO	ELPRO	220 kV	1980	18.05.2016
Isolator (1) BBMB: 01 Elektrolites : 01	BBMB	Elektrolites	220 kV	2015	31.05.15
Coupling capacitor (2)	TANTRANSCO	CGL	230 kV	2001	30.11.2015
	GETCO	WSI	220 kV	1984	11.11.2015

Note: Quantity in brackets indicates number of failed equipment.

**2.0 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/Coupling Capacitor)
  - c. Failure of Insulation system & Bushing (For Transformers & Reactors)
  - d. Lack of good maintenance practice
  - e. Frequent System Faults and transient over voltages generated by the system.
- (ii) 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.
- (iii) Adequate modern Diagnostic tools are not available with most of the State Utilities.
- (iv) In most of the failure cases 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.
- (v) Most of the utilities are facing problem due to shortage of supporting staff for operation & maintenance of sub-station equipment. Sometimes interpretation of test results becomes difficult in absence of experts / experienced O&M staffs.
- (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.

### 3.0 **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 (March 2016) 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 & reliable operation.

#### 3.1 **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, 2010.
- (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) 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.
- (ix) 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.
- (x) 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.
- (xi) 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.

### **3.2 Recommendations for Transformers (ICT & GT) and Instrument Transformers (CT/PT/CVT):**

- (i) The proper handling, loading, 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 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) 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.
- (vii) 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 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.
- (viii) 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.
- (ix) 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.
- (x) 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.
- (xi) 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  $\delta$  and capacitance of CVTs:

Change in Tan $\delta$	Monitoring Frequency
Upto +0.002	Three yearly
+0.002 to +0.003	Yearly

Above +0.003	Alarming
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Change in Capacitance	Monitoring Frequency
upto $\pm 2\%$	Three yearly
$\pm 2\%$ to $\pm 3\%$	Yearly
Above $\pm 6\%$	Alarming

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

- (xii) 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.
- (xiii) 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 $\pm 0.5$ volts	Healthy	Six monthly
$\pm 0.5$ to $\pm 0.8$ volts	To be monitored	03monthly
$\pm 0.8$ to $\pm 1.2$ volts	Close monitoring	Monthly
$\pm 1.2$ to $\pm 2.0$ 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)

- (xiv) Following table can be referred while measuring  $\tan \delta$  of CTs:

Value of $\tan \delta$	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)

- (xv) 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.
- (xvi) 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.

### 3.3 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  $\mu$ A, then Insulation Resistance (IR) value test should also be conducted and if current exceeds 350  $\mu$ A, 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.

### 3.4 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.

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## **ANNEXURE I**

### INVESTIGATION REPORTS OF FAILURE OF POWER TRANSFORMERS OF DELHI TRANSCO LTD. (DTL)

**REPORT ON INVESTIGATION OF FAILURE OF 100 MVA, 220/66-33/11 KV POWER TRANSFORMER AT 220KV GEETA COLONY SUBSTATION OF DELHI TRANSCO LTD. (DTL)**

**1.0 Introduction:**

- 1.1 DTL vide letter No. F.DTL/206/2015-16/Mgr(T)O&M-E-2/22 dated 04.02.2016 requested CEA to investigate the cause of failure of 100 MVA, 220/66-33/11 kV Power transformer (failed on 02.02.16 at 1326 hrs) in Geeta Colony sub-station of DTL.
- 1.2 A team of officers from PSE&TD Division of CEA [Sh. Y.K.Swarnkar, Director(Substation); Sh. Faraz, Assistant Director; and Ms. Bhaavya Pandey, Assistant Director] along with officers of DTL visited the site of failure on 05.02.16. The details of visit are as under.

**2.0 Background:**

- 2.1 One 220 kV double circuit line from Patparganj S/s and one 220 kV double circuit line from South of Wazirabad S/s of DTL are terminating in Geeta Colony substation of DTL. This substation feeds power at 33 kV to Geeta colony-I, Geeta colony-II, Kanti Nagar-I, Kanti Nagar-II, Kailash Nagar-I, Kailash Nagar-II and Shakarpur feeders. Two Nos. of 100 MVA, 220/66-33/11 kV power transformers are in operation on 220 kV Geeta Colony substation. Both transformers are of BHEL make and are operating in parallel.
- 2.2 BHEL make 100 MVA, 220/66-33/11 kV power transformer with serial no. 2015821 failed during operation on 02.02.16 at 1326 hrs.
- 2.3 Brief details of the failed transformer are as follows:

Capacity	100 MVA
Voltage	HV: 220 kV MV: 66-33 kV (33kV tap was in use) LV: 11 kV (Tertiary-unloaded)
Phase	3 phase
S. No.	2015821
Make	BHEL
Type of Cooling	ONAN/ONAF/OFAF
Vector group	YNyn0d11
Insulation level	1050(HV)/325(MV)/170(LV)/95 (N) kVp
Year of manufacturing	2004

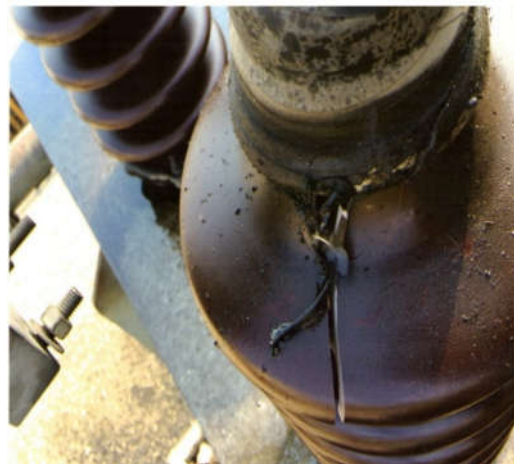
Year of commissioning	2005 (31 <sup>st</sup> August)
Impedance (%)	11.72% (HV-MV) maximum tap 15.21% (HV-MV) normal tap 21.83% (HV-MV) minimum tap
Tap range	-15% to +5% in steps of 1.25% each

**3.0 Observations:**

- 3.1 Prior to fault, load on transformer was 23 MW. Maximum loading on transformer was 32 MW on the day of fault (2<sup>nd</sup> February). Transformer was not loaded even up to 50% of its capacity for the last many days. The transformer was operating on tap 5 (Normal Tap is Tap 3) at the time of failure.
- 3.2 Tertiary of transformer is unloaded. All three terminals of tertiary winding have been brought outside the tank and terminals were not insulated.
- 3.3 During physical inspection of the failed transformer at site, it was observed that there was minor dislocation of all three HV bushings from their turrets (Exhibit-I), MV bushing flanges of Y & B phases had cracked, LV bushing of B phase had punctured (Exhibit-II) and transformer tank had cracked at a number of places (Exhibits -III&IV), although there was no visible sign of bulging of the tank.



**Exhibit-I**



**Exhibit-II**



**Exhibit-III**



**Exhibit-IV**

- 3.4 There was no damage to nearby equipment/ material of the substation.
- 3.5 Transformer was checked for internal damage through inspection window. Visible damage was observed on Y-phase winding (Exhibits- V&VI). Damage on other windings was not visible through inspection window. The extent of damage inside the transformer would be assessed only after opening of tank.



**Exhibit-V**



**Exhibit-VI**

- 3.6 As per information provided by DTL the transformer had tripped on Differential relay, Buchholz relay, OSR and PRV.



- 3.7 The event logger data indicates that the contribution of fault current from 220 kV side was 17.266 kA. 220 kV and 33 kV side breaker had opened within 69 ms of operation of differential relay.
- 3.8 There is no provision for fire protection of the transformers in the substation.
- 3.9 Time stamping of the relays/event logger/disturbance recorder at the substation was not synchronised to the Indian Standard Time.

**4.0 O &M History of failed transformer:**

It was informed by DTL that since 2011, Buchholz relay of the transformer had operated in number of occasions. Most of the times it was found that the winding resistance values were on higher side. During inspection by DTL/BHEL, most of the times it was found that either winding lead connections were loose or core-yoke was found shorted with transformer tank. In last 6 years, MV side bushings have been replaced number of times when tan delta values were found to be alarming.

**5.0 Analysis of cause of failure:**

- 5.1 Following tests were conducted on the transformer post failure:
- Magnetic balance test
  - Magnetizing current
  - Tan  $\delta$  test of HV, MV and LV windings
  - Sweep Frequency Response Analysis (SFRA)
  - DGA
  - Winding resistance measurement test
- 5.2 Magnetizing current in Y-phase was found to be 1.06 A compared to 3.6 mA in R-ph and 3.5 mA in B-ph which is very high. Also, very low voltage (0.506 V) was observed in Y-ph in magnetic balance test when 231 V was applied on R-phase which indicates problem in Y-phase winding. DGA of oil indicated high concentration of Hydrogen ( $H_2$ -2064ppm), Ethylene ( $C_2H_4$ -271 ppm), Methane ( $CH_4$ -148 ppm), Acetylene ( $C_2H_2$ -398.8). Total Dissolved Combustible Gases (TDCG) was 3064 which is higher than normal value. These high concentration of acetylene gas could be due to high energy arcing inside the tank. Significant variation was observed while comparing the pre and post fault signatures/ traces of SFRA tests carried out on transformer. The test result indicates problem in core coil assembly.

5.3 Operation of Differential, Buchholz, OSR & PRV relays indicates internal fault of the transformer. The internal winding insulation failure might have led to inter turn winding insulation failure, which is also supported by the test results and preliminary internal inspection. The fault is most likely in Y- ph of winding. The detailed investigation after opening of tank will provide the extent of damage, type of failure(s) and other valuable information.

5.4 High energy arcing inside the transformer tank might have led to sudden pressure rise and tripping of oil surge relay & PRV. Rate of rise of gas pressure might be very high (before operation of PRV), which might have resulted in cracks at weak areas of the transformer tank.

**6.0 General Remarks and Recommendations:**

6.1 The practice of Condition Based Monitoring with the use of various modern diagnostic tools as suggested in Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010, is recommended.

6.2 The frequency/periodicity of measurement should be changed depending on condition/health of transformer in operation.

6.3 Fire protection system for transformers should be installed as per Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010 so that damage due to delay in extinguishing of fires can be prevented.

6.4 Except for transformer banks formed out of single phase units and 5- limbed 3-ph units, the tertiary winding may be avoided in line with above mentioned CEA Regulations as it increases the probability of failure of the transformer. Tertiary winding terminals taken out of the tank of transformer to avoid short circuiting between terminals or terminal to ground should be kept insulated.

6.5 It was informed by DTL that second transformer commissioned at Geeta colony substation also had problems since commissioning and had tripped many times due to various reasons. It is advised that complete overhaul of this transformer should be taken up in consultation with OEM to avoid repeated failure/outage of transformer.

6.6 During visit of CEA officers, the failed transformer tank was inspected through inspection window only. Detail inspection of the transformer is required to be carried out by OEM/ expert of repairing agency after opening the tank, which may

not be possible at site. The feedback/ warnings from the investigation should be used for planning future course of action. A detailed report of the failed transformer may be provided to CEA after thorough internal inspection of the failed transformer is carried out.

- 6.7 Time stamping of all relays/DR/event loggers in all substations of DTL should be properly synchronised to Indian Standard Time through GPS so that DR & event logger information may be used for co-relating the sequence of events and operation of protection relays of transformer.

**Report on investigation of failure of 315 MVA Auto transformer at 400 kV Bawana Substation of Delhi Transco Ltd.(DTL)**

**1.0 Introduction:**

- 1.1 DTL vide letter No. F.DTL/206/F.06/2015-16/Mgr(Bawana)/353 dated 08.03.2016 requested CEA to investigate the cause of failure of 315 MVA, 400/220/33 kV Auto transformer (failed on 8<sup>th</sup> March 2016 at 1201 hrs) in Bawana sub-station of DTL.
- 1.2 A team of officers from PSE&TD Division of CEA [Sh. Y.K.Swarnkar, Director(Substation); Sh. Faraz, Assistant Director; and Ms. Bhaavya Pandey, Assistant Director] along with officers of DTL visited the site of failure on 9<sup>th</sup> March 2016. The details of visit are as under.

**2.0 About Substation:**

- 2.1 The 400/220/66 kV substation of DTL at Bawana has 6 Nos. of 315 MVA, 400/220 kV auto transformers and one no. 100 MVA, 220/66 kV power transformer. There are 6 Nos. line bays at 400 kV level (Tikrikalan-I&II, Abdullapur, Dipalpur, and Mandola-I&II) and 8 Nos. line bays & provision for 4 Nos. future bays at 220 kV level. Bawana S/s is connected at 400 kV level to adjacent switchyard of Bawana Power Plant of Pragati Power Corporation Ltd.

**3.0 Sequence of Events:**

- 3.1 On 08.03.16, at 1201 hrs., EMCO make 315 MVA auto transformer (ICT-4) tripped with heavy jerk and sound with following facia/relay indications and caught fire:
  - a. Differential protection 87 T1
  - b. Differential 3-ph trip
  - c. Differential R-ph trip
  - d. Differential Y-ph trip
  - e. Differential B-ph trip
  - f. WTI/PRV trip

- g. Overcurrent and earth fault Protection
  - h. 64 T2 REF protection
  - i. REF trip
  - j. Buchholz trip
  - k. OLTC Buchholz Y-ph trip
- 3.2 After hearing the sound, staff present at substation rushed to the switchyard and found 220 kV bushing of Y & B-phase of ICT-4 under fire. Nitrogen Injection Fire Protection System and High Velocity Water Spray System operated but fire could not be controlled. Fire tenders from nearby Bawana Power Plant of PPCL rushed to the site and quenched the fire.
- 3.3 Brief details of the failed transformer are as follows:

Capacity	315 MVA
Voltage	HV:400 kV MV:220 kV LV: 33 kV (Tertiary-unloaded)
Phase	3 phase
S. No.	HT/1798/13000
Make	EMCO Ltd.
Type of Cooling	ONAN/ONAF/OFAF
Vector group	YNa0d11
Insulation level	1300(HV)/950(MV)/250(LV)/95 (N) kVp
Year of manufacturing	2009
Year of commissioning	2010
Impedance (%)	11.88% (NT)
Tap range	-10% to +10% in steps of 1.25% each

#### 4.0 **Observations:**

- 4.1 Prior to fault, load on transformer was 121 MW. The transformer was operating on normal tap 9B at the time of failure. OLTC has not been operated since commissioning.
- 4.2 During physical inspection of the failed transformer at site, it was observed that MV Bushings of Y & B-phase had completely damaged due to fire, burnt insulation

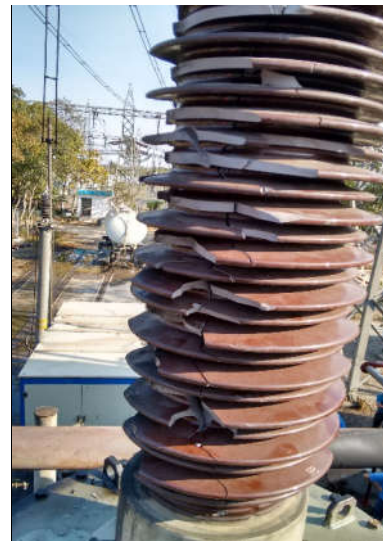
paper and connecting rods of bushings were visible, ceramic housing was found scattered around transformer and flanges had damaged (Exhibits-I & II).



**Exhibit-I**



**Exhibit-II**



**Exhibit-III**

- 4.3 MV bushing of R-phase and tertiary bushings were also found damaged (Exhibit-III & IV). Since the direction of wind was away from HV bushings, not much damage to HV bushings was observed, however some petticoats of bushings had chipped.





**Exhibit-IV**

- 4.4 Transformer tank was found bulged at MV side and it had cracked at a number of places (Exhibits-V & VI).



**Exhibit-V**



**Exhibit-VI**

- 4.5 220 kV Surge Arresters had completely damaged due to heat (Exhibit-VII), surge counters had melted and ZnO blocks & pieces of arrester housing were scattered on the ground (Exhibit-VIII).



**Exhibit-VII**



**Exhibit-VIII**

- 4.6 220 kV Bus Post Insulators, aluminium pipes, and disc insulators of jack bus on MV side were also burnt due to fire (Exhibits-IX & X).



**Exhibit-IX****Exhibit-X**

- 4.7 One of the tertiary bushings was removed in front of the CEA team and tank was inspected through that opening. No visible damage to tertiary terminals was observed.
- 4.8 Tertiary of transformer is unloaded. All three terminals of tertiary winding have been brought outside the tank and terminals were not insulated.
- 4.9 The event logger data indicates that the fault current level was 44.827 kA. 400 kV side main breaker and tie breaker had opened within 53 ms and 57 ms respectively of operation of differential relay.
- 4.10 The event logger data also indicates operation of Differential relay and PRV/Buchholz which might have led to operation of Nitrogen Injection Fire Protection System.
- 4.11 It was informed by DTL representative that High Velocity Water Spray (HVWS) System had operated, however, it could not quench the fire of bushings. It appears that water mist from water spray system could not provide sufficient cooling effect

around transformer tank & bushings due to wind and thus HVWS system was not able to extinguish fire.

- 4.12 It was informed by DTL that surge counter of 220 kV R-phase surge arrester was not functional and it was bypassed through a cable.
- 4.13 Common earthing pit was provided for all three SAs (R,Y&B phases) on 220 kV side. Earthing electrode was not visible in any of the earth pits for transformer neutral and SAs on 400 kV & 220 kV side.
- 4.14 It was observed that the high resistive gravels spread over the earthmat in the switchyard area was covered with grasses in many areas of the switchyard defeating the very purpose of spreading of gravels.



**Exhibit-X**

#### **5.0 O & M History of failed transformer:**

No major overhaul has been carried out on the transformer since its commissioning. Capacitance & tan delta measurement and DGA of oil was carried out in February 2016 and various LV tests (magnetic balance, magnetising current measurement, ratio test, vector group measurement, winding resistance measurement, PI measurement etc.) and testing of oil parameters were carried out in July 2010 and no abnormality was observed.

**6.0 Probable cause of failure:**

- 6.1 The bushings were dislocated from its original position and damage to the transformer due to fire was so severe that it was not possible to carry out any test on failed transformer.
- 6.2 Operation of Differential relay along with operation of Buchholz, OSR (OLTC Buchholz) & PRV relays indicates fault inside the transformer. Operation of REF indicates that fault involves ground. The flow of heavy fault current in windings might have led to rise in winding temperature and operation of WTI Trip.
- 6.3 High energy arcing due to fault inside the transformer tank might have led to sudden pressure rise in tank and tripping of Buchholz & PRV. PRV being a slow operating device might not have been able to bring down the gas pressure inside the tank to safe value and high rate of rise of gas pressure might have resulted in cracks at weak areas of the transformer tank.
- 6.4 It was informed by DTL staff that at first fire was noticed on Y-phase MV bushing only and later on it spread to other accessories and equipment. It is possible that damage to insulation of Y-phase MV winding might have taken place. This is also supported by event logger data showing 44 kA fault current in Y-phase. The detailed investigation, after opening of tank, will provide the extent of damage, type of failure(s) and other valuable information.
- 6.5 Buchholz relay (OSR) of OLTC of Y & B-phase had operated indicating oil surge in respective OLTCs which might be due to fault in regulating (tap) windings.

**7.0 General Remarks and Recommendations:**

- 7.1 The practice of Condition Based Monitoring with the use of various modern diagnostic tools as suggested in Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010, is recommended.

- 7.2 The frequency/periodicity of measurement should be changed depending on condition/health of transformer in operation.
- 7.3 In addition to PRV which operates when static pressure inside the transformer tank crosses a pre-set pressure limit, use of Fast Depressurization System which works on first dynamic peak of pressure and is very fast should be explored for future orders of transformers.
- 7.4 Other than transformer banks formed out of single phase units and 5- limbed 3-ph units, the tertiary winding may be avoided in-line with above mentioned CEA's Regulations as it increases the probability of failure of the transformer. Tertiary winding terminals taken out of the tank of transformer should be kept insulated to avoid short circuiting between terminals or terminal to ground.
- 7.5 Separate earthing pits should be used for earthing of individual Surge Arresters.
- 7.6 Switchyard area should be properly maintained to prevent growth of grass so that benefit of spreading of the gravel is realised and safety of personnel is not compromised.
- 7.7 DR & event logger information may be used for co-relating the sequence of events and operation of protection relays of transformer.
- 7.8 After opening of the transformer tank, detail inspection of the transformer is required to be carried out by OEM/ expert of repairing agency which may not be possible at site. The feedback/ learnings from the investigation should be used for planning future course of action. The detailed findings of the failed transformer may be provided to CEA after completion of thorough internal inspection of the failed transformer.

The failure of the ICT-4 shall be discussed in the meeting of the Standing Committee of Experts to Investigate the causes of failure of 220 kV & above substation equipment and final report shall be submitted thereafter.

**Report on investigation of failure of 100 MVA, 220/66-33/11 kV power transformer at 220kV Pappankalan-I Substation of Delhi Transco Ltd.(DTL)**

**1.0 Introduction:**

- 1.1 DTL vide letter No. F.DTL/206/2015-16/Mgr(T)O&M-W-2/67 dated 07.09.2016 requested CEA to investigate the cause of failure of 100 MVA, 220/66-33/11 kV Power transformer (failed on 04.09.16 at 0635 hrs) at Pappankalan-I sub-station of DTL.
- 1.2 A team of officers from PSE&TD Division of CEA [Sh. Faraz, Assistant Director; and Ms. Bhaavya Pandey, Assistant Director] along with officers of DTL visited the site of failure on 14.09.16. The details of visit are as under.

**2.0 Background:**

- 2.1 Two nos. 220 kV double circuit lines from Bamnauli s/s of DTL are terminating in Pappankalan-I substation of DTL. This substation feeds power at 66 kV to Budhella-II, Park Street G-6 Ckt. I, Park Street G6 Ckt. II, Park Street G2 Ckt. I, Park Street G2 Ckt. II, Bindapur I, Bindapur II, Budhella-I, Rewari, DMRC I & DMRC II and at 11 kV to Palam Village, Sector-7, Evergreen, Vinodpuri, Mahavir Enclave, Local 400 kVA Transformer, Nasirpur Village, Bengali Colony, Peripheral-II, NSIT, Park Street Sector-19, Manglapuri Phase-II, Mahalaxmi S-8, Peripheral-I, O/G S-10 & Park Street S-II. Four Nos. of 100 MVA, 220/66-33/11 kV power transformers (two nos. EMCO make and two nos. BHEL make) and one no. 160 MVA 220/66-33/11 kV BHEL make are installed at 220 kV Pappankalan-I substation.
- 2.2 No major overhauling was carried out since commissioning. As informed by DTL, the transformer is under 10-year defect liability period excluding one-year normal warranty period.
- 2.3 EMCO make 100 MVA, 220/66-33/11 kV power transformer with serial no. HT/1644/12460 failed during operation on 04.09.16 at 0635 hrs. The transformer tripped on differential relay, Buchholz relay, PRD and SPRV.
- 2.4 Brief details of the failed transformer are as follows:

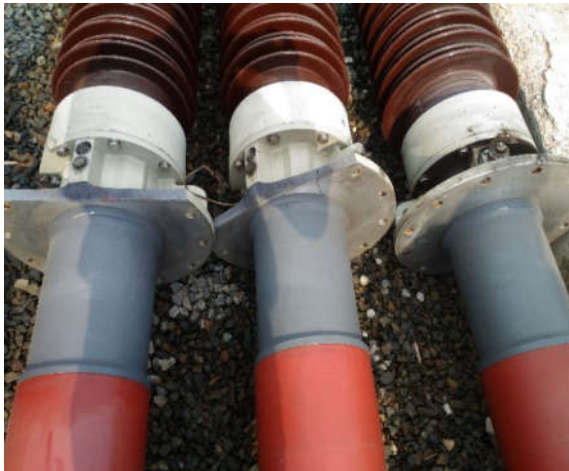
Capacity	100 MVA
Voltage	HV: 220 kV MV: 66-33 kV (66 kV tap was in use)



	LV: 11 kV (Tertiary-unloaded)
Phase	3 phase
S. No.	HT/1644/12460
Make	EMCO
Type of Cooling	ONAN/ONAF/OFAF
Vector group	YNyn0d11
Insulation level	HV : LI 1050/ AC 460 kV LV : LI 325/ AC 140 kV Tertiary: LI 170/ AC 70 kV
Year of manufacturing	2006
Year of commissioning	2006 (April 30 <sup>th</sup> )
Impedance (%)	19.9% (HV-MV) maximum tap 14.74% (HV-MV) normal tap 21.20% (HV-MV) minimum tap
Tap range	-15% to +5% in steps of 1.25% each

**3.0 Observations:**

- a) DTL informed that the transformer had tripped on differential relay, Buchholz relay, PRD and SPRV, flange plates of all three phases of HV and MV windings were found to be cracked and oil was leaking. It was informed that the transformer was operating on normal tap (tap no. 5) at the time of failure and OLTC was last operated on 18.05.16.
- b) During physical inspection of the failed transformer at site, it was observed that flange of all bushings were cracked (Exhibit-I and Exhibit-II).



**Exhibit-I** (HV bushings)



**Exhibit-II** (MV bushings)

- c) There was no visible sign of bulging of the tank or cracks on the tank (Exhibit III).



**Exhibit-III**

d) DTL informed that the service engineers of OEM, M/s EMCO Ltd. visited the site on 06.09.16 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 M/s EMCO.

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

- i. Y- ph HV winding was found damaged. Disc had collapsed.
- ii. Burnt insulating material was found inside the tank.
- iii. All bushing connections were intact.
- iv. OLTC leads were OK.
- v. All HV, LV and tertiary bushings were found damaged.

M/s EMCO also had recommended the following actions:

- i. Due to damage in HV Y-ph winding, it is not possible to rectify the fault at site. The transformer needs to be taken back to the factory for the replacement of winding.
  - ii. The healthiness of remaining windings shall be ascertained at the time of joint Physical Verification Report at works.
- e) Transformer was checked for internal damage through inspection window. As transformer was refilled with oil to prevent moisture ingress, damaged windings were not visible from the inspection window. However, following photographs of windings taken after opening of the tank were provided by DTL (Exhibits V and VI). The damage to the windings can be seen in these photographs. Some burnt material can also be observed.



**Exhibit-V**



**Exhibit-VI**

- f) There was no provision for fire protection of the transformer in the substation.
- g) Tertiary winding of the transformer was not loaded.

#### **4.0 O &M History of failed transformer:**

According to DTL officers, there has not been any other fault in the transformer prior to this failure.



## 5.0 Analysis of cause of failure:

- a) Following tests were conducted by DTL on the transformer post failure:
- Magnetic balance
  - Magnetizing current
  - Tan  $\delta$  test of HV, MV and LV windings
  - Sweep Frequency Response Analysis (SFRA)
  - DGA
  - Voltage Ratio
  - Insulation Resistance
  - Winding resistance
- b) DGA of oil indicates high concentration of Hydrogen ( $H_2$ -544ppm), Carbon dioxide ( $CO_2$ - 16459 ppm), Carbon monoxide ( $CO$ - 1613 ppm), Ethylene ( $C_2H_4$ -470 ppm), Methane ( $CH_4$ -280 ppm) and Acetylene ( $C_2H_2$ -385.7). Total Dissolved Combustible Gases (TDCG) was 3343 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 ( $CH_4/ H_2= 0.52$  and  $C_2H_2/ C_2H_4= 0.82$ ) also suggest high energy discharge. Due to the generation of these gases, high pressure might have built up, which might have led to the cracking of the flanges of the bushings.
- c) As can be observed from DR data, fault current of 2959 Amp passed through Y- ph HV side winding, which might be due to inter-turn fault in Y- ph HV winding. M/s EMCO, during physical inspection, had also observed damage to the Y- ph HV winding.
- d) Operation of Differential, Buchholz, PRD & SPRV relays indicates internal fault of the transformer. The internal winding insulation failure might have led to inter turn winding short circuit. The detailed investigation after opening of tank will provide the extent of damage, type of failure(s) and other valuable information.

- e) As the transformer did not catch fire, the temperature did not cross the flashover point of oil. It is also supported by the fact that OTI/WTI alarms did not operate. As per DTL officials, alarm/trip settings of OTI and WTI were 75<sup>0</sup>C/ 85<sup>0</sup>C and 95<sup>0</sup>C/ 105<sup>0</sup>C respectively.
- f) It was difficult to analyse the SFRA results, as the pre-commissioning SFRA results provided by DTL, had nine waveforms overlapped on the same graph, thus making it difficult to identify the deviations with reference to original signature. Moreover, details of conditions (e.g. tap position, ambient condition etc.) under which reference SFRA signature was taken and the SFRA signature taken after failure are not identical.
- g) Polarisation index, measured on 21.04.16, of HV-IV, MV-E and LV-E is found to be less than 1.5, which is less than previously measured PI values, indicating deterioration of insulation.

#### **6.0 General Remarks and Recommendations:**

- (a) During visit of CEA officers, the failed transformer tank could not be inspected through inspection window as oil was refilled to keep the other windings safe. Detail inspection of the transformer is required to be carried out by OEM/ expert of repairing agency after opening the tank, which may not be possible at site.

OEM representative who inspected the failed transformer at the site also stated (as per Minutes of Meeting held between DTL and M/s EMCO), that due to damage in the Y-ph winding, it is not possible to rectify the defect at site, and the detailed analysis will be carried out at manufacturer's works conducting various tests and physical inspection. The feedback of the investigation by OEM should be used for planning future course of action. A detailed report of the failed transformer may be provided to CEA after thorough internal inspection of the failed transformer is carried out.

- (b) As per maintenance schedule of DTL, presently Time Based Maintenance (TBM) Practice is being followed by DTL. The practice of Condition Based Monitoring with the use of various modern diagnostic tools as suggested in Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, is recommended. The frequency/periodicity of measurement should be increased depending on trend analysis of various critical parameters indicating the condition/health of transformer in operation.
- (c) Fire protection system for transformers should be installed as per Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric

Lines) Regulations so that damage due to delay in extinguishing of fires can be prevented.

- (d) Other than transformer banks formed out of single phase units and 5- limbed 3-ph units, the tertiary winding may be avoided in-line with above mentioned CEA's Regulations as it increases the probability of failure of the transformer. Elimination of tertiary winding will make the transformer design simpler and probability of failure of transformer due to tertiary winding will be zero. Tertiary winding terminals taken out of the tank of transformer should be kept insulated to avoid short circuiting between terminals or terminal to ground.
- (e) Whenever, the tank is opened after fault for internal inspection, apart from the photographs, video recording can also be made covering all the visuals of damaged sections of windings, connection etc.
- (f) The condition under which reference SFRA test was carried out (e.g. tap position, oil temperature, ambient condition etc.) should be recorded properly so that the subsequent SFRA test can be carried out under similar condition. The waveforms/ signature for different cases should be properly stored for subsequent analysis/ comparison.
- (g) DR & event logger information may be used for co-relating the sequence of events and operation of protection relays of transformer.
- (h) Device sensitive to rate of rise of pressure inside the transformer tank may be considered for installation in addition to PRD which operates only above a set pressure.
- (i) Periodic testing of earthing system should be done to ensure its efficacy.

The matter will be discussed further in the Standing Committee and the final report will be submitted to the concerned utility.

**Report on investigation of failure of 100 MVA, 220/66-33/11 kV power transformer-2  
(S. No.: 2007616) at 220kV Parkstreet Substation of Delhi Transco Ltd.(DTL)**

**1.0 Background:**

- 1.1 DTL vide letter No. F.DTL/206/2016-17/Mgr(T)O&M-E-3/01PKS dated 23.09.2016 requested CEA to investigate the cause of failure of 100 MVA, 220/66-33/11 kV Power transformer (failed on 11.09.16 at 1047 hrs) at Parkstreet sub-station of DTL.
- 1.2 A team of officers from PSE&TD Division of CEA [Sh. Faraz, Assistant Director; and Ms. Bhaavya Pandey, Assistant Director] along with officers of DTL visited the site of failure on 23.09.16.
- 1.3 220/66 kV Parkstreet substation of DTL is fed from IP Extension-I and IP Extension-II substation through two 220 kV cables. This substation feeds power at 66 kV to DMRC-I, DMRC-II, NDMC-I, NDMC-II, Shastri Park-I, Shastri Park-II, B D Marg-I, B D Marg-II, Ridge Valley-I, Ridge Valley-II.and at 33 kV to Faiz Road-I, Faiz Road-II, Motya Khan-I, Motya Khan-II, Baird Road-I, Baird Road-II, Nirman Bhawan, Hanuman Road, Shankar Road and Prasad Nagar. Two nos. of 100 MVA, 220/66 kV power transformers (one EMCO make and other BHEL make) operating in parallel supply power to 66 kV feeders & two nos. of 100 MVA, 220/33 kV power transformers both BHEL make operating in parallel supply power to 33 kV feeders. In addition, there are two parallel 30 MVA, 66/33 kV transformers.
- 1.4 BHEL make 100 MVA, 220/66-33/11 kV power transformer-2 with serial no. 2007616 failed during operation on 11.09.16 at 10:47 hrs.

**2.0 Brief details of the failed transformer:**

Capacity	100 MVA
Voltage	HV: 220 kV MV: 66 kV LV: 11 kV (Tertiary-unloaded)
Phase	3 phase
S. No.	2007616
Make	BHEL
Type of Cooling	ONAN/ONAF/ODAF
Vector group	YNyn0d11
Insulation level	HV : 1050 kVp/460 kV rms IV : 325 kVp/140 kV rms

(LIWL/Power Voltage) Frequency Withstand	LV : 170 kVp/70 kV rms
Year of manufacturing	1993
Year of commissioning	1994 (Jan 31 <sup>st</sup> )
Impedance (%)	IV – LV : 10.412 HV – LV : 26.94 (at Tap 5) HV – IV : 13.668 (at Tap 1) 15.473 (at Tap 5) 22.067 (at Tap 17)
Tap range	1-17

### 3.0 Sequence of events:

The subject transformer tripped on 11.09.2016 at 10:47 hrs on following indications:

1. Buchholz (Trip)
2. Differential (87 Ta & Tc)

Load on transformer at 10:00 hrs was 36 MW. The transformer was charged at 12:55 hrs but was switched off at 20:42 hrs due to high winding temperature. Following tests were carried out by DTL on the failed transformer.

1. Winding resistance
2. Magnetizing balance
3. Magnetizing current
4. IR value
5. Tan Delta
6. Sweep Frequency Response Analysis (SFRA)
7. Dissolved Gas Analysis (DGA)
8. Core-yoke insulation test
9. Voltage ratio

TL reports indicated that SFRA, Magnetic balance and exciting current results were abnormal. DGA of tank oil also showed Acetylene gas value of 92.8 ppm, which is abnormally high. The transformer had completed 22 years of trouble free service.

DTL requested OEM i.e. BHEL to inspect the transformer. M/s BHEL engineer visited the site on 22-23 Sept., 2016 and carried out internal inspection of the transformer after complete draining of transformer oil. No visible fault nor any pitting/burning mark was observed inside the transformer.

M/s BHEL was of the view that *“due to abnormal temperature rise and high magnetizing & exciting current, DGA (acetylene 92.8 ppm) & SFRA deviation, the transformer could not be charged and the possibility of fire and blast cannot be ruled out if charged. The transformer could not be repaired on site and was declared failed”*.

#### 4.0 **Observations:**

- a) During physical inspection of the failed transformer at site, no visible damage to bushing and transformer tank was observed; there was no leakage of oil from the transformer and no damage to nearby equipment of the substation.
- b) Tertiary of transformer was unloaded. All three terminals of tertiary winding have been brought outside and are insulated.
- c) Maximum loading on transformer was 79 MW on 08.09.2016. The transformer was operating on tap 4 at the time of failure. It was a normal day with clear sky.
- d) There was no provision for fire fighting system including soak pit/oil collecting pit.
- e) As informed by DTL, internal inspection of the transformer was carried out by the representatives of BHEL & DTL and no visible burning/pitting marks were observed.
- f) As per information provided by DTL the transformer had tripped on Buchholz relay and Differential relay.
- g) The event logger data was not available in the substation.
- h) Capacitance & tan delta tests were conducted on 26.06.2015 and 18.06.2016 and from test results, it was observed that capacitance for 33 kV Y phase bushing and 220 kV B phase bushing had changed -6.84% and 12.07% respectively, which were higher than normal variation.
- i) The DGA, magnetizing & exciting current and SFRA tests show abnormality as per OEM's (i.e. BHEL) report and there was abnormal temperature rise (20°C).
- j) DTL officials informed about unavailability of factory test results, pre-commissioning test results, past maintenance records and GA drawing of the transformer.

#### 5.0 **Analysis of cause of failure:**

- a) From the measurements of magnetizing currents, it is observed that excitation current in R phase HV and MV winding is much higher than in other two phases, which indicates that there might be inter turn fault in R phase winding; the same may also be corroborated through magnetic balance test.

Operation of Differential and Buchholz relays indicates internal fault of the transformer. It is assumed that inter-turn winding insulation failure caused flow of heavy current which triggered operation of differential relay. In the absence of

Disturbance Recorder data, it is difficult to ascertain the amount of current flow through various phases during fault. Fault current might have caused arcing inside the transformer leading to generation of gases and subsequent operation of Buchholz relay.

- b) DGA of oil sample collected after failure indicated high generation of H<sub>2</sub> (288 ppm), CO<sub>2</sub> (3300 ppm), CO (687 ppm), C<sub>2</sub>H<sub>4</sub> (332 ppm), C<sub>2</sub>H<sub>6</sub> (105 ppm), CH<sub>4</sub> (234 ppm) & C<sub>2</sub>H<sub>2</sub> (92.8 ppm). Total Dissolved Combustible Gases were found to be 1739 ppm, much higher than acceptable value of 720 ppm as per IEEE C57.104-2008 Standard. It was found that Roger's ratio for CH<sub>4</sub>/H<sub>2</sub>, C<sub>2</sub>H<sub>2</sub>/C<sub>2</sub>H<sub>4</sub> & C<sub>2</sub>H<sub>4</sub>/C<sub>2</sub>H<sub>6</sub> were 0.81, 0.28 & 3.15 respectively which indicates high energy discharge. The abnormal rise in acetylene content supported by high temperature rise indicates high energy fault.
- c) Post fault SFRA report shows deviation from previous SFRA report, especially at lower frequencies (<1 kHz), which also supports inter turn fault proposition.
- d) In the absence of factory test results, it is difficult to comprehend values of insulation resistance measurement. However, prima facie, these values appear to be on lower side indicating deterioration of insulation.
- e) Detailed investigation of core-coil assembly of the transformer would be required to ascertain the degree of damage to the winding & core and ascertain any movement of core/winding which would also help in further analysis of the cause of fault.

#### **6.0 General Remarks and Recommendations:**

- (a) The practice of Condition Based Monitoring with the use of various modern diagnostic tools as suggested in Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010, is recommended.
- (b) The frequency/periodicity of measurement should be changed depending on condition/health of transformer in operation.
- (c) Fire protection system for transformers should be installed as per Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010 so that damage due to delay in extinguishing of fires can be prevented.
- (d) Other than transformer banks formed out of single phase units and 5- limbed 3-ph units, the tertiary winding may be avoided in-line with above mentioned CEA's Regulations as it increases the probability of failure of the transformer.



- (e) Use of Fast Depressurization system which act on rate of rise of pressure inside the transformer may be considered along with PRD which operates only above a set pressure.
- (f) Disturbance Recorder & Event Logger should be provided at each substation and these equipment should be provided with time synchronization facility for global common time reference.
- (g) After fault in a transformer, for detailed investigation, magnetizing current measurement test and turns ration test should be carried out on all taps, if possible.
- (h) Factory test results, pre-commissioning test results and past maintenance records must be preserved in hard copy/soft copy for information and analysis in case of failure.
- (i) In cases of failures where transformer is found non-reparable and DTL decides to scrap the transformer, it should first carefully ascertain the extent of damage to the windings, core etc. for future record and analysis.
- (j) During visit of CEA officers, the failed transformer tank was inspected through inspection window only. Detail inspection of the transformer is required to be carried out by OEM/ expert of repairing agency after opening the tank, which may not be possible at site. The feedback/ warnings from the investigation should be used for planning future course of action. The detailed report on investigation of failure by OEM after repairing the transformer should be available in concerned substation for future reference. A detailed report of the failed transformer may be provided to CEA after thorough internal inspection of the failed transformer is carried out at manufacturer's works.
- (k) Periodic testing of earthing system should be done to ensure its efficacy.

The matter will be discussed further in the Standing Committee and the final report will be submitted to DTL..

## **ANNEXURE II**

DETAILED INFORMATION IN RESPECT OF EACH  
FAILED EQUIPMENT REPORTED TO CEA  
BETWEEN 1<sup>ST</sup> SEPTEMBER 2015 AND 31<sup>ST</sup>  
DECEMBER 2016 AND BRIEF ANALYSIS OF  
FAILURE OF THESE EQUIPMENT

**TRANSFORMERS**

- 1. Failure of 220/33 kV, 100 MVA Power Transformer at 220/33 kV Geeta Colony substation of DTL**
- A. Name of Substation : 230/33kV Substation, Geeta Colony
- B. Utility/Owner of substation : Delhi Transco Limited
- C. Faulty Equipment : Transformer
- D. Rating : 220/33kV, 100MVA
- E. Make : BHEL
- F. Sr. No. : 2015821
- G. Year of manufacturing : 2004
- H. Year of commissioning : 2005
- I. Date and time of occurrence/discovery of fault : 02.02.2016
- J. Information received in CEA : 04.02.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Transformer is under breakdown.
- M. Details of previous maintenance : On 06.11.2015, Transformer shutdown was availed for replacement of high Tan Delta Y-phase MV bushing.
- N. Details of previous failure : Nil
- O. Sequence of events/Description of fault : Transformer tripped on Differential Relay, Buchholz relay, OSR & PRV. There was minor dislocation of all three HV bushings from their turrets, MV bushing flanges of Y & B phases had cracked, LV bushing of

B- ph had punctured and transformer tank had cracked at a number of places, although no bulging of the tank was visible.

P. Details of Tests done after failure : Following tests were carried out:

1. Magnetic Flux test
2. Magnetizing current
3. TAN Delta of H.V, M.V and LV Winding.
4. SFRA
5. Dissolved Gas Analysis.
6. Winding Resistance.

Q. Probable cause of failure :

1. Magnetizing current in Y-phase was found to be 1.06 A which is very high as compared to 3.6 mA in R-ph and 3.5 mA in B-ph. Also, very low voltage (0.506 V) was observed in Y-ph in magnetic balance test when 231 V was applied on R-phase which indicates problem in Y-phase winding. DGA of oil indicated high concentration of Hydrogen (H<sub>2</sub>-2064ppm)), Ethylene (C<sub>2</sub>H<sub>4</sub>-271 ppm), Methane (CH<sub>4</sub>-148 ppm), Acetylene (C<sub>2</sub>H<sub>2</sub>-398.8). Total Dissolved Combustible Gases (TDCG) was 3064 which is higher than normal value. These high concentration of acetylene gas could be due to high energy arcing inside the tank.

2. Significant variation was observed while comparing the pre and post fault signatures/traces of SFRA tests carried out on transformer. The test result indicates problem in core coil assembly. Operation of Differential, Buchholz, OSR & PRV relays indicates internal fault of the transformer. The internal winding insulation failure might have led to inter turn winding insulation failure, which is also supported by the test results and preliminary internal inspection.

3. High energy arcing inside the transformer tank might have led to sudden pressure rise and tripping of oil surge relay & PRV. Rate of rise of gas pressure might be very high (before operation of PRV), which might have resulted in cracks at weak areas of the transformer tank.

4. The fault is most likely in Y- ph of winding. The detailed investigation after opening of tank will provide the extent of damage, type of failure(s) and other valuable information.

## 2. Failure of 315 MVA, 400/220/33 kV Auto transformer at 400 kV Bawana substation of DTL

- A. Name of Substation : 400 kV Bawana substation
- B. Utility/Owner of substation : DTL
- C. Faulty Equipment : Auto transformer

- D. Rating : 315 MVA, 400/220/33 kV
- E. Make : EMCO
- F. Sr. No. : HT-1798
- G. Year of manufacturing : 2009
- H. Year of commissioning : 2010
- I. Date and time of occurrence/discovery of fault : 08.03.2016 at 1201 hrs
- J. Information received in CEA : 08.03.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced
- M. Details of previous maintenance :

Tests carried out on 12.07.2010

Sr. No.	Test for	Permissible limits	Sample 1
1.	Water Content, ppm	10(Max)	8
2.	Breakdown Voltage, (rms), kV	60(Min)	80

Tests carried out on 19.07.2010

Sr. No.	Test for	Permissible limits	Sample 2	Sample 3	Sample 4
1.	Water Content, ppm	10(Max)	10	9	9
2.	Breakdown Voltage, (rms),kV	60(Min)	72	72	73

Sr. No.	TEST FOR	PERMISSIBLE LIMITS	SAMPLE 1
.			

1.	Appearance	Clear, free from sediment and suspended matter	Clear, free from sediment and suspended matter
2.	Density @ 29.5°C, gm/cm <sup>3</sup>	0.89(Max)	0.82
3.	Kinematic Viscosity @ 27°C, cSt	27(Max)	16
4.	Pour point, °C,	-6(Max)	Less than -6
5.	Interfacial Tension, N/m	0.035(Min)	0.039
6.	Flash Point, °C	140(Min)	153
7.	Neutralisation Value, mg/g	0.03(Max)	Nil
8.	Breakdown Voltage, (rms), kV	60(Min)	78
9.	Dielectric Dissipation Factor(Tan delta) @90°C	0.010(Max)	0.0014
10	Specific Resistance, X 10 <sup>12</sup> Ohm-cm. @90°C	6(Min)	60
11	Water Content, ppm	10(Max)	9

Tests carried out on 21.07.2010

i. PI measurement using 5 kV Megger

REF	60 sec	600 sec	PI	REMARKS
HV+IV to EARTH	199.0 G Ω	281.0 G Ω	1.412	
LV to EARTH	223.0 G Ω	260.0 G Ω	1.165	
HV+IV to LV	163.0 G Ω	179.0 G Ω	1.098	

ii. MAGNETIC BALANCE IN HV

IX - N	IY - N	IZ - N	IX - N	IY - N	IZ - N	I mag. (mA)
232.4 V	-	-	--	219.2 V	16.8 V	2.1
-	225.6 V	-	132.0 V	--	92.0	1.40
-	-	229.4 V	20.24 V	217.8	--	2.0

iii. MAGNETIC BALANCE IN IV

2X - N	2Y - N	2Z - N	2X - N	2Y - N	2Z - N	I mag. (mA)
229.1	-	-	--	223.7 V	13.10 V	3.96
-	224.4 V	-	126.7 V	--	97.8 V	3.35
-	-	228.7 V	18.6	223.0 V	--	3.47

iv. MAGNETIC BALANCE IN LV

3X - 3Y	3Y - 3Z	3Z - 3X	3X - 3Y	3Y - 3Z	3Z - 3X	I mag. (mA)

400.9V	-	-	--	197.5 V	202.2 V	42.1
-	400.7 V	-	347.0 V	--	202.9 V	49.4
-	-	399.6 V	335.6 V	206.9 V	--	55.6

v. RATIO TEST BETWEEN HV to LV

Tap No.	Theoretical Ratio	<u>1X</u> 3X	<u>1Y</u> 3Y	<u>1Z</u> 3Z
9b	12.12	12.36	12.12	12.02

vi. RATIO TEST BETWEEN IV to LV

Tap No.	Theoretical Ratio	<u>2X</u> 3X	<u>2Y</u> 3Y	<u>2Z</u> 3Z
9b	6.66	6.86	6.59	6.61

vii. RATIO TEST BETWEEN HV to IV

Tap No.	Theoretical Ratio	<u>1XN</u> 2XN	<u>1YN</u> 2YN	<u>1ZN</u> 2ZN
1	2.000	2.206	2.021	2.014
2	1.977	1.980	1.949	1.975
3	1.955	1.943	1.962	1.963
4	1.932	1.934	1.919	1.947
5	1.909	1.914	1.911	1.916
6	1.886	1.908	1.881	1.894
7	1.864	1.870	1.854	1.869
8	1.841	1.842	1.844	1.843
9	1.818	1.801	1.824	1.825
10	1.795	1.791	1.785	1.807
11	1.773	1.760	1.775	1.774
12	1.750	1.752	1.742	1.751
13	1.727	1.724	1.718	1.730
14	1.705	1.704	1.686	1.699
15	1.685	1.679	1.684	1.692
16	1.654	1.658	1.650	1.659
17	1.636	1.634	1.616	1.637

viii. VECTOR GROUP MEASUREMENT YN(a)0d 11=

$1Y-3Y=1Z-3Z=1Y-3Z-Z-3Y$

APPLIED VOLTAGE	MESURED ACROSS	MEASURED VOLTS
1X-1Y = 401	1X-3X	375
	1Y-3Y	376
	1Z-Z	388
	1Z-3Y	401



1Y-1Z = 426	1X-N	228.5
	1X-3Z	25.2
1Z-1X = 424	3Z-N	202

ix. SHORT CIRCUIT CURRENT (LV SHORT, 3X+3Y+3Z)

Tap No.	APPLIED VOLTAGE IN PRIMARY(Volts)			MEASURED AMPS IN PRIMARY(Amp.)			MEASURED AMPS IN SECONDARY(Amp.)		
	XY	YZ	ZX	1X	1Y	1Z	2X	2Y	2Z
9b	398.3	398.1	397.5	0.59	0.59	0.59	7.15	7.15	7.15

x. WINDING RESISTANCE IN HV SIDE IN (mΩ)

TAP NO.	MEASURED RESISTANCE		
	1X-N	1Y-N	1Z-N
1.	331.6	331.3	330.9
2.	325.9	324.4	324.5
3.	319.8	319.4	318.4
4.	314.7	313.7	312.9
5.	308.6	308.0	307.4
6.	301.8	300.8	301.2
7.	296.8	295.7	295.5
8	290.8	290.0	290.3
9B	284.3	283.5	283.5
10	290.7	290.2	290.3
11	297.0	296.4	295.8
12	302.4	301.5	301.1
13	308.1	307.3	307.0
14	314.1	313.3	313.6
15	320.6	319.6	319.0
16	325.9	325.9	324.7
17	332.2	330.8	332.2

xi. WINDING RESISTANCE IN IV SIDE IN (mΩ)

Tap No.	2X-N	2Y -N	2Z-N
Normal	354.8	350.7	354.8

xii. WINDING RESISTANCE IN LV SIDE IN (mΩ)

Tap No.	3X3Y	3Y3Z	3Z3X
Normal	15.4	16.4	15.3

Tests carried out on 22.12.2015

Dissolved Gas Results: (in ppm)			Key Gas Concentration Limits (As per IEEE Std. C57.104-2008) (in ppm)
	Present	1 <sup>st</sup> Prior	
Test Date	22.12.15	09.06.15	
Hydrogen H	10	14	100
Carbon Di-oxide CO	5774	5580	2500
Carbon Mono-oxide CO	274	216	350
Ethylene C <sub>2</sub> H <sub>4</sub>	7	5	50
Ethane C <sub>2</sub> H <sub>6</sub>	6	6	65
Methane CH <sub>4</sub>	12	11	120
Acetylene C <sub>2</sub> H <sub>2</sub>	0.5	<0.5	1
TDCG	309	252	720
Roger's Ratio Indicates (for Present Simple only)			
CH <sub>4</sub> / H <sub>2</sub>	1.23		
C <sub>2</sub> H <sub>2</sub> / C <sub>2</sub> H <sub>4</sub> =	0.09		
C <sub>2</sub> H <sub>4</sub> / C <sub>2</sub> H <sub>6</sub> =	1.28		
C <sub>2</sub> H <sub>6</sub> / CH <sub>4</sub> =	0.48		
CO <sub>2</sub> / CO=	21.10		
IEEE Std. C57. 104-2008 (by comparing present and previous TDCG values) suggests:			
Change in TDCG Value = 57 ppm		Rate = 0.3 ppm/day	
*sampling Interval :		6 Months	

Tests carried out on 19.02.2016

Sr. No.	Insulation Tested	Make & SI No.	Yr. of Muf & Yr. of com.	Mod e	Volt age Applied (kV)	Capacitance (pF)	Dissipation Factor (%)	
							Meas ured	CORRECT ED @ 20°C
1.	(HV - LV) - TV	--	--	UST-R	10	6471.60	0.20	0.18
2.	(HV - LV) - E	--	--	GST g-RB	10	7851.56	0.22	0.20
3.	TV - E	--	--	GST g-RB	10	15630.52	0.20	0.18

4.	400 kV R- Bushing	CGL-S70954	2009	UST- R	10	521.74	0.26	--
5.	400 kV Y- Bushing	CGL-S70972	2009	UST- R	10	529.93	0.28	--
6.	400 kV B- Bushing	CGL-S70969	2009	UST- R	10	548.14	0.29	--
7.	220 kV R- Bushing	CGLS2453002 10 8	2009	UST- R	10	373.40	0.30	--
8.	220 kV Y- Bushing	CGLS2453002 13 0	2009	UST- R	10	380.76	0.23	--
9.	220 kV B- Bushing	CGLS2453002 12 4	2009	UST- R	10	374.71	0.22	--
10	33 kV R- Bushing	CGL - 52100553	2009	UST- R	10	198.06	0.26	--
11	33 kV Y- Bushing	CGL - 52100600	2009	UST- R	10	203.47	0.27	--
12	33 kV B- Bushing	CGL - 52100604	2009	UST- R	10	204.12	0.27	--
13	220 kV I/C R- CT	BHEL- 2448925	2005	UST- R	10	783.21	0.33	--
14	220 kV I/C y- CT	BHEL- 2448924	2005	UST- R	10	817.67	0.24	--
15	220 kV I/C B- CT	BHEL- 2448923	2005	UST- R	10	817.28	0.27	--
16	Excitation Current Test							
18	10 kV					R	Y	B
						15.42	13.41	14.99

N. Details of previous failure : Nil

O. Sequence of events/ :  
Description of failure

i. On 08.03.16, at 1201 hrs., EMCO make 315 MVA auto transformer (ICT-4) tripped with heavy jerk and sound with following facia/relay indications and caught fire:

- a. Differential protection 87 T1
- b. Differential 3-ph trip
- c. Differential R-ph trip
- d. Differential Y-ph trip
- e. Differential B-ph trip
- f. WTI/PRV trip
- g. Overcurrent and earth fault Protection
- h. 64 T2 REF protection
- i. REF trip
- j. Buchholz trip
- k. OLTC Buchholz Y-ph trip

ii. After hearing the sound, staff present at substation rushed to the switchyard and found 220 kV bushing of Y & B-phase of ICT-4 under fire. Nitrogen Injection Fire Protection System and High Velocity Water Spray System operated but fire could not be controlled. Fire tenders from nearby Bawana Power Plant of PPCL rushed to the site and quenched the fire.

P. Details of Tests done after failure : The bushings were dislocated from its original position and damage to the transformer due to fire was so severe that it was not possible to carry out any test on failed transformer.

Q. Observations :

i. Prior to fault, load on transformer was 121 MW. The transformer was operating on normal tap 9B at the time of failure. OLTC had not been operated since commissioning.

ii. During physical inspection of the failed transformer at site, it was observed that MV Bushings of Y & B-phase had completely damaged due to fire, burnt insulation paper and connecting rods of bushings were visible, ceramic housing was found scattered around transformer and flanges had damaged.

iii. MV bushing of R-phase and tertiary bushings were also found damaged. Since the direction of wind was away from HV bushings, not much damage to HV bushings was observed, however some petticoats of bushings had chipped.

iv. Transformer tank was found bulged at MV side and it had cracked at a number of places.

- v. 220 kV Surge Arresters had completely damaged due to heat, surge counters had melted and ZnO blocks & pieces of arrester housing were scattered on the ground.
- vi. 220 kV Bus Post Insulators, aluminium pipes, and disc insulators of jack bus on MV side were also burnt due to fire.
- vii. One of the tertiary bushings was removed in front of the CEA team and tank was inspected through that opening. No visible damage to tertiary terminals was observed.
- viii. Tertiary of transformer is unloaded. All three terminals of tertiary winding have been brought outside the tank and terminals were not insulated.
- ix. The event logger data indicates that the fault current level was 44.827 kA. 400 kV side main breaker and tie breaker had opened within 53 ms and 57 ms respectively of operation of differential relay.
- x. The event logger data also indicates operation of Differential relay and PRV/Buchholz which might have led to operation of Nitrogen Injection Fire Protection System.
- xi. It was informed by DTL representative that High Velocity Water Spray (HVWS) System had operated, however, it could not quench the fire of bushings. It appears that water mist from water spray system could not provide sufficient cooling effect around transformer tank & bushings due to wind and thus HVWS system was not able to extinguish fire.
- xii. It was informed by DTL that surge counter of 220 kV R-phase surge arrester was not functional and it was bypassed through a cable.
- xiii. Common earthing pit was provided for all three SAs (R, Y&B phases) on 220 kV side. Earthing electrode was not visible in any of the earth pits for transformer neutral and SAs on 400 kV & 220 kV side.
- xiv. It was observed that the high resistive gravels spread over the earthmat in the switchyard area was covered with grasses in many areas of the switchyard defeating the very purpose of spreading of gravels.

R. Probable cause of failure :

Operation of Differential relay along with operation of Buchholz, OSR (OLTC Buchholz) & PRV relays indicates fault inside the transformer. Operation of REF indicates that fault involves ground. The flow of heavy fault current in windings might have led to rise in winding temperature and operation of WTI Trip.

High energy arcing due to fault inside the transformer tank might have led to sudden pressure rise in tank and tripping of Buchholz & PRV. PRV being a slow operating device might not have been able to bring down the gas pressure inside the tank to safe value and high rate of rise of gas pressure might have resulted in cracks at weak areas of the transformer tank.

It was informed by DTL staff that at first fire was noticed on Y-phase MV bushing only and later on it spread to other accessories and equipment. It is possible that damage to insulation of Y-phase MV winding might have taken place. This is also supported by event logger data showing 44 kA fault current in Y-phase.

Buchholz relay (OSR) of OLTC of Y & B-phase had operated indicating oil surge in respective OLTCs which might be due to fault in regulating (tap) windings.

### **3. Failure of 100 MVA, 220/66-33/11 kV Power Transformer at 220kV Pappankalan-I Substation of Delhi Transco Ltd.(DTL)**

- A. Name of Substation : 220kV Pappankalan-I Substation
- 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/1644/12460
- G. Year of manufacturing : 2006
- H. Year of commissioning : 2006 (30.04.06)
- I. Date and time of occurrence/discovery of fault : 04.09.16 at 0635 hrs
- J. Information received in CEA : 07.09.16
- K. Fault discovered during : Operation

- L. Present condition of equipment : EMCO recommended to send the failed transformer to their works for further assessment. The transformer is to be repaired by OEM.
- M. Details of previous maintenance :
- N. Details of previous failure : No previous failures
- O. Sequence of events/  
Description of failure : On 04.09.16 at 0635 hrs, the transformer tripped on differential relay, Buchholz relay, PRD and SPRV. On inspection it was found that flange plates of all three phases of HV and MV windings were cracked and oil was leaking.  
There was no visible sign of bulging of the tank or cracks on the tank.
- vi. Y- ph HV winding was found damaged. Disc had collapsed.
  - vii. Burnt insulating material was found inside the tank.
  - viii. All bushing connections were intact.
  - ix. OLTC leads were OK.
  - x. All HV, LV and tertiary bushings were found damaged.
- P. Details of Tests done after failure : Following tests were conducted by DTL on the transformer post failure:
- Magnetic balance
  - Magnetizing current
  - Tan  $\delta$  test of HV, MV and LV windings
  - Sweep Frequency Response Analysis (SFRA)
  - DGA (test results given below)
  - Voltage Ratio
  - Insulation Resistance
  - Winding resistance



Dissolve Gas Results:( in ppm)			Key Gas Concentration Limits (As per IEEE Std. C57.104-2008) (in ppm)
	present	1 <sup>st</sup> Prior	
Test Date	04.09.16	01.09.16	
Hydrogen H <sub>2</sub>	544	14	100
Carbon Di-oxideCO <sub>2</sub>	16459	15812	2500
Carbon Mono-oxide CO	1613	1442	350
Ethylene C <sub>2</sub> H <sub>2</sub>	470	26	50
Ethane C <sub>2</sub> H <sub>6</sub>	49	37	65
MethaneCH <sub>2</sub>	280	43	120
AcetyleneC <sub>2</sub> H <sub>2</sub>	385.7	<0.5	1
TDCG	3343	1562	720
Rogers' Ratio Indicates(for present BOTTOM sample only)			
CH <sub>4</sub> /H <sub>2</sub> =	0.52		
C <sub>2</sub> H <sub>2</sub> / C <sub>2</sub> H <sub>4</sub> =	0.82		
C <sub>2</sub> H <sub>4</sub> / C <sub>2</sub> H <sub>6</sub> =	9.64		
C <sub>2</sub> H <sub>6</sub> / CH <sub>4</sub> =	0.17		
CO <sub>2</sub> /CO =	10.20		
IEEE Std. C57.104-2008 (by comparing present and previous TDCG values) suggests:			
Change in TDCG Value = 1781 ppm		Rate = 593.63 ppm/day	

Q. Probable cause of failure: : DGA of oil indicates high concentration of Hydrogen (H<sub>2</sub>-544ppm), Carbon dioxide (CO<sub>2</sub>- 16459 ppm), Carbon monoxide (CO- 1613 ppm), Ethylene (C<sub>2</sub>H<sub>4</sub>-470 ppm), Methane (CH<sub>4</sub>-280 ppm) and Acetylene (C<sub>2</sub>H<sub>2</sub>-385.7). TDCG was 3343 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<sub>4</sub>/ H<sub>2</sub>= 0.52 and C<sub>2</sub>H<sub>2</sub>/ C<sub>2</sub>H<sub>4</sub>= 0.82) also suggest high energy discharge. Due to the generation of these gases, high pressure might have built up, which might have led to the cracking of the flanges of the bushings.

A fault current of 2959 Amp passed through Y- ph HV side winding, which might be due to inter-turn fault in Y- ph HV winding.

Operation of Differential, Buchholz, PRD & SPRV relays indicates internal fault of the transformer. The internal winding insulation failure might have led to inter turn winding short circuit.

As the transformer did not catch fire, it can be assumed that the temperature did not cross the

flashover point of oil. It is also supported by the fact that OTI/WTI alarms did not operate.

**4. Failure of 100 MVA, 220/66-33/11 kV Power Transformer-2 at 220kV Parkstreet Substation of Delhi Transco Ltd.(DTL)**

- A. Name of Substation : 220kV Parkstreet Substation
- B. Utility/Owner of substation : DTL
- C. Faulty Equipment : Power transformer
- D. Rating : 100 MVA, 220/66-33/11 kV
- E. Make : BHEL
- F. Sr. No. : 2007616
- G. Year of manufacturing : 1993
- H. Year of commissioning : 1994 (31.01.94)
- I. Date and time of occurrence/discovery of fault : 11.09.16 at 1047 hrs
- J. Information received in CEA : 23.09.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : OEM stated that the failed transformer could not be repaired on site and was declared faulty.
- M. Details of previous maintenance : Capacitance & tan delta tests were conducted on 26.06.2015 and 18.06.2016 and from test results given below, it was observed that capacitance for 33 kV Y phase bushing and 220 kV B phase bushing had changed -6.84% and 12.07% respectively, which were higher than normal variation.

S. No.	Insulation Tested	Mode	Current Results dt. 12.09.16			Current Results 18.06.16			Previous Results dt. 26.06.2015		
			Cap.		Dissipation Factor %	Cap.		Dissipation Factor %	Cap.		Dissipation Factor %
			(pF)	Meas. @20°C		(pF)	Meas. @20°C		(pF)	Meas. @20°C	
1.	HV - LV	UST-R	28533.29	0.55	0.47	28578.20	0.57	0.36	28473.27	0.57	0.47
2.	HV - E	GSTg-RB	5485.85	0.32	0.31	5495.27	0.39	0.20	5473.14	0.37	0.32

3.	LV-T	UST-R	1197.38	0.32	0.27	1195.48	0.35	0.20	1195.56	0.32	0.29
4.	LV-E	GSTg-RB	3624.65	0.43	0.63	3623.64	0.55	0.28	3580.64	0.76	0.45
5.	T-HV	UST-R	13544.80	0.39	0.32	13551.79	0.40	0.25	13502.13	0.39	0.33
6.	T-E	GSTg-RB	16648.37	0.49	0.48	16676.97	0.57	0.31	16616.75	0.58	0.48
7.	220kV R-φ Bushing	UST-R	376.58	0.41	--	378.79	0.41	--	377.77	0.41	--
8.	220kV Y-φ Bushing	UST-R	373.47	0.38	--	375.51	0.37	--	374.74	0.39	--
9.	220kV B-φ Bushing	UST-R	372.73	0.39	--	374.01	0.37	--	373.32	0.39	--
10	33kV R-φ Bushing	UST-R	367.96	0.45	--	368.85	0.45	--	368.31	0.44	--
11	33kV Y-φ Bushing	UST-R	331.63	0.34	--	332.47	0.32	--	356.87	0.32	--
12	33kV B-φ Bushing	UST-R	388.16	0.46	--	389.01	0.47	--	390.42	0.44	--
13	220kV R-φ GIS Bushing	UST-R	242.36 m A	--	--	537.91	0.32	--	537.43	0.38	--
14	220kV R-φ GIS Bushing	UST-R	31.07 m A	--	--	854.09	0.45	--	762.13	0.45	--
15-17	Excitation Current Test	35.43 m A	33.53 m A	--	--	B-ph	33.97	--	Y-ph	25.19	--

N. Details of previous failure : No previous failure

O. Sequence of events/ : The subject transformer tripped on 11.09.2016 at 10:47 hrs on following indications:  
Description of failure

1. Buchholz (Trip)
2. Differential (87 Ta & Tc)

Load on transformer at 10:00 hrs was 36 MW. The transformer was charged at 12:55 hrs but was switched off at 20:42 hrs due to high winding temperature.

During physical inspection of the failed transformer at site, no visible damage to bushing and transformer tank was observed; there was no leakage of oil from the transformer and no damage to nearby equipment of the substation.

Tertiary of transformer was unloaded. All three terminals of tertiary winding have been brought outside and are insulated.

Maximum loading on transformer was 79 MW on 08.09.2016. The transformer was operating on tap 4 at the time of failure. It was a normal day with clear sky.

P. Details of Tests done after : Following tests were carried out by DTL on the failure  
failure

1. Winding resistance
2. Magnetizing balance
3. Magnetizing current (test results given below)

4. IR value
5. Tan Delta
6. Sweep Frequency Response Analysis (SFRA)
7. Dissolved Gas Analysis (DGA) (test results given below)
8. Core-yoke insulation test
9. Voltage ratio

**1. Magnetizing Current measurement**

HV Side (1 Ph Supply)		Voltage Balance Test (TAP – 4)		
Magnetizing Current Test		V <sub>RN</sub>	V <sub>YN</sub>	V <sub>BN</sub>
I <sub>RN</sub>	9.1 m A	234	213	20
I <sub>YN</sub>	5.4 m A	96.7	234.5	145.5
I <sub>BN</sub>	6.8 m A	22	213	234

MV Side (1 Ph Supply)		Voltage Balance Test		
Magnetizing Current Test		V <sub>RN</sub>	V <sub>YN</sub>	V <sub>BN</sub>
I <sub>RN</sub>	310 m A	232.6	213.2	20.94
I <sub>YN</sub>	160 m A	101.7	233.1	144.5
I <sub>BN</sub>	190 m A	20.5	213.4	233.1

LV Side (1 Ph Supply)		Voltage Balance Test		
Magnetizing Current Test		V <sub>RN</sub>	V <sub>YN</sub>	V <sub>BN</sub>
I <sub>RN</sub>	390 m A	233.8	157.4	88.7
I <sub>YN</sub>	460 m A	218.7	234.6	17.2
I <sub>BN</sub>	910 m A	213.3	21.37	233.5

**2.. DGA results**

Dissolve Gas Results:( in ppm)			Key Gas Concentration Limits (As per IEEE Std. C57.104-2008) (in ppm)
	present	1 <sup>st</sup> Prior	
Test Date	12.09.16	19.07.16	
Hydrogen H <sub>2</sub>	288	9	100
Carbon Di-oxide CO <sub>2</sub>	3300	1788	2500
Carbon Mono-oxide CO	687	228	350
Ethylene C <sub>2</sub> H <sub>2</sub>	332	12	50
Ethane C <sub>2</sub> H <sub>6</sub>	105	79	65
Methane CH <sub>4</sub>	234	74	120
Acetylene C <sub>2</sub> H <sub>2</sub>	92.8	<0.5	1
TDCG	1739	403	720
Rogers' Ratio Indicates(for present BOTTOM sample only)			
CH <sub>4</sub> /H <sub>2</sub> =	0.81		
C <sub>2</sub> H <sub>2</sub> / C <sub>2</sub> H <sub>4</sub> =	0.28		
C <sub>2</sub> H <sub>4</sub> / C <sub>2</sub> H <sub>6</sub> =	3.15		
C <sub>2</sub> H <sub>6</sub> / CH <sub>4</sub> =	0.45		
CO <sub>2</sub> /CO =	4.80		
IEEE Std. C57.104-2008 (by comparing present and previous TDCG values) suggests:			
Change in TDCG Value = 1781 ppm		Rate = 25.2 ppm/day	

Q. Probable cause of failure: : The DGA, magnetizing current measurement and SFRA tests show abnormality as per OEM's (i.e. BHEL) report and there was abnormal temperature rise (20°C). From the measurements of magnetizing currents, it is observed that magnetizing current in R phase HV and MV winding is much higher than in other two phases, which indicates that there might be inter turn fault in R phase winding; the same may also be corroborated through magnetic balance test. Operation of Differential and Buchholz relays indicates internal fault of the transformer. It is assumed that inter-turn winding insulation failure caused flow of heavy current which triggered operation of differential relay. In the absence of Disturbance Recorder data, it is difficult to ascertain the amount of current flow through various phases during fault. Fault current might have caused arcing inside the transformer leading to generation of gases and subsequent operation of Buchholz relay. DGA of oil sample collected after failure indicated high generation of H<sub>2</sub> (288 ppm), CO<sub>2</sub> (3300 ppm), CO (687 ppm), C<sub>2</sub>H<sub>4</sub> (332 ppm), C<sub>2</sub>H<sub>6</sub> (105 ppm), CH<sub>4</sub> (234 ppm) & C<sub>2</sub>H<sub>2</sub> (92.8 ppm). Total Dissolved Combustible Gases were found to be 1739 ppm, much higher than

acceptable value of 720 ppm as per IEEE C57.104-2008 Standard. It was found that Roger’s ratio for CH<sub>4</sub>/H<sub>2</sub>, C<sub>2</sub>H<sub>2</sub>/C<sub>2</sub>H<sub>4</sub> & C<sub>2</sub>H<sub>4</sub>/C<sub>2</sub>H<sub>6</sub> were 0.81, 0.28 & 3.15 respectively which indicates high energy discharge. The abnormal rise in acetylene content supported by high temperature rise indicates high energy fault. Post fault SFRA report shows deviation from previous SFRA report, especially at lower frequencies (<1 kHz), which also supports inter turn fault proposition.

**5. Failure of 315 MVA, 400/220/33 kV ICT-I at 400 kV Bawana substation of DTL.**

- A. Name of Substation : 400 kV Bawana Substation
- B. Utility/Owner of substation : DTL
- C. Faulty Equipment : ICT-I
- D. Rating : 400/220/33 kV
- E. Make : BHEL
- F. Sr. No. : 6005263
- G. Year of manufacturing : 1994
- H. Year of commissioning : 2000 (09<sup>th</sup> June)
- I. Date and time of occurrence/discovery of fault : 11.12.2016 at 0837 hrs
- J. Information received in CEA : 12.12.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Damaged
- M. Details of previous maintenance : Following tests were conducted on 17.02.16:

**1. Capacitance & Tan delta tests**

S. No.	Insulation Tested	Make & Sl. No.	Yr. of Mfg. & Yr. of Comm.	Mode	kV	Cap. (pF)	Dissipation Factor (%)	
							Measured	Corrected @ 20°C

1.	(HV+LV) - TV	--	--	UST-R	10	4947.29	0.14	0.14
2.	(HV+LV) - E	--	--	GSTg-RB	10	7651.12	0.33	0.31
3.	TV – E	--	--	GSTg-RB	10	18165.26	0.25	0.24
4.	400kV R- $\phi$ Bushing	BHEL/9325031	1993/2000	UST-R	10	470.37	0.28	--
5.	400kV Y- $\phi$ Bushing	Areva/0705122	2007/2008	UST-R	10	395.49	0.19	--
6.	400kV B- $\phi$ Bushing	Areva/0708008	2007/	UST-R	10	403.72	0.23	--
7.	220kV R- $\phi$ Bushing	Areva/0711245	2007/	UST-R	10	323.52	0.36	--
8.	220kV Y- $\phi$ Bushing	BHEL-9314008	2008/	UST-R	10	307.50	0.15	--
9.	220kV B- $\phi$ Bushing	BHEL-9318023	2008/	UST-R	10	311.15	0.20	--
10.	33 kV R- $\phi$ Bushing	BHEL-0703092	2007/	UST-R	10	336.14	0.29	--
11.	33 kV Y- $\phi$ Bushing	BHEL-0705029	2007/	UST-R	10	337.35	0.41	--
12.	33 kV B- $\phi$ Bushing	BHEL-0705028	2007/	UST-R	10	334.04	0.42	--
13.	220kV I/C R- $\phi$ CT	WS-940369	1994	UST-R	10	840.04	0.35	--
14.	220kV I/C Y- $\phi$ CT	WS-940364	1994	UST-R	10	834.98	0.29	--
15.	220kV I/C B- $\phi$ CT	WS-940373	1994	UST-R	10	797.34	0.30	--
16.	Excitation Current Test							
17.	Voltage Applied(kV)					R- $\phi$ (mA)	R- $\phi$ (mA)	R- $\phi$ (mA)
18.	10					11.72	11.39	11.66

**2. Magnetizing Current & Magnetizing Balance Test**

Voltage Applied: 230 V, 1- $\Theta$ , 50 Hz		
HV Side:		
Tap Position	Voltage Applied (Volts)	Voltage Induced (Volts)
Normal	$V_{RN}$ 237	$V_{YN}$ 225 $V_{BN}$ 23
	$V_{YN}$ 237.4	$V_{RN}$ 120.6 $V_{BN}$ 194.1
	$V_{BN}$ 237.6	$V_{RN}$ 21.6 $V_{YN}$ 224.1
MV Side:		
Tap Position	Voltage Applied (Volts)	Voltage Induced (Volts)
Normal	$V_{RN}$ 236.1	$V_{YN}$ 219.6 $V_{BN}$ 24.26
	$V_{YN}$ 237.4	$V_{RN}$ 126.4 $V_{BN}$ 109.1
	$V_{BN}$ 237.4	$V_{RN}$ 30.3 $V_{YN}$ 213.6
LV Side:		

Tap Position	Voltage Applied (Volts)		Voltage Induced (Volts)	
Normal	V <sub>RY</sub>	237.6	V <sub>YB</sub> 119.4	V <sub>BR</sub> 47.4
	V <sub>YB</sub>	236.3	V <sub>RY</sub> 182.1	V <sub>BR</sub> 107.3
	V <sub>BR</sub>	231.4	V <sub>RY</sub> 180.1	V <sub>YB</sub> 108.1

### 3. Voltage Ratio Tests

Temp. HV Wdg.			MV Wdg.			LV Wdg.			
Voltage Applied: 415V,3- $\phi$ , 50-Hz									
Tap	HV Side Applied Voltage (Volts)			MV Side Induced Voltage (Volts)			LV Side Induced Voltage (Volts)		
	V <sub>RN</sub>	V <sub>YN</sub>	V <sub>BN</sub>	V <sub>RN</sub>	V <sub>YN</sub>	V <sub>BN</sub>	V <sub>RY</sub>	V <sub>YB</sub>	V <sub>BR</sub>
9b	237	236	236.1	106.3	107.1	107	21	20.6	20.6

### 4. IR measurement of winding of transformer

Configuration	Resistance at 15 seconds	Resistance at 60 seconds	Resistance at 600 seconds	PI
HV - E	1.5 G $\Omega$	2.05 G $\Omega$	4.02 G $\Omega$	1.97
HV - LV	1.72 G $\Omega$	2.50 G $\Omega$	8.03 G $\Omega$	3.2
MV - E	1.64 G $\Omega$	2.11 G $\Omega$	4.20 G $\Omega$	1.99
LV - E	1.G $\Omega$	1.9 G $\Omega$	3.93 G $\Omega$	2.02

### 5. Winding Resistance measurement

Tap	HV Side Resistance(m $\Omega$ )			MV Side Resistance (m $\Omega$ )			LV Side Resistance(m $\Omega$ )		
	R <sub>RN</sub>	R <sub>YN</sub>	R <sub>BN</sub>	R <sub>RN</sub>	R <sub>YN</sub>	R <sub>BN</sub>	R <sub>RY</sub>	R <sub>YB</sub>	R <sub>BR</sub>
9	608	606	602	345	346	346	27	29	26

### DGA history:

	1	2	3	4	5	6	7	8
	H <sub>2</sub>	CO <sub>2</sub>	CO	C <sub>2</sub> H <sub>4</sub>	C <sub>2</sub> H <sub>6</sub>	CH <sub>4</sub>	C <sub>2</sub> H <sub>2</sub>	TDCG
19.10.13	14	8749	716	16	7	10	0.5	764
28.02.14	13	4709	405	7	3	7	< 0.5	436
28.08.14	38	7972	759	16	12	12	<0.5	838
19.11.14	19	7726	782	15	9	14	<0.5	839
17.02.15	22	7588	858	16	7	16	<0.5	919
26.05.15	29	9269	954	17	11	14	<0.5	1025
28.08.15	24	9259	895	16	6	15	<0.5	956



22.12.15	8	9528	1148	18	5	19	0.5	1198
30.03.16	13	9669	1108	17	6	20	<0.5	1165
30.06.16	11	10937	1270	19	9	18	0.5	1327
07.10.16	5	6513	795	8	3	19	<0.5	828

N. Details of previous failure : In 2008, R phase HV bushing had blasted. The transformer was recommissioned after repairing.

O. Sequence of events/ : On 11.12.2016 at 08:37 hrs, 315 MVA, 400/220/33 kV ICT-I tripped with heavy sound and caught fire. Description of failure : 220 kV Rohini-1 Ckt-II had tripped on Y-phase zone -1 earth fault. Atmosphere was foggy at the time of fault. Details of all tripping and relay's operations/indications are given below.

Sr. No.	Equipment	Relays
1.	Rohini-I Circuit-II, CB No. 1552	Zone-1, Y Phase tripped, Earth Fault Relay Operated: 186 A & B, 195 A & B, 295 B Fault Duration: 49 ms. Fault Location: -1.17 KM $I_a = 634.6 \text{ A}$ $I_b = 20.84 \text{ kA}$ , $I_c = 286.9 \text{ A}$ .
2.	315 MVA, BHEL Make, ICT-I	Main CB of ICT- I i.e. 420- 52 & Tie CB 421-52 tripped. Relay – Over Current & Earth Fault protection 67.1 HV, Over Current (DMT-2 Tripped) Stage-2, 86A Group Operated. Differential R & Y, Differential 3 Phase, OTI Trip, WTI Trip, PRV Trip OTI Alarm, HV & LV WTI Alarm, 86A & 86B relay operated. <b>Relay on 220 kV Incomer_I</b> Facia- CB Auto Trip, Relay - 195 & 295 A, B & C

3.	315 MVA, BHEL Make, ICT- III	Facia: CB TC-I & II Faulty Group 1 & 2 Tripped Relay Circuit Faulty Relay: Tripped Circuit supervision, TC-I 195 & 295 and 86 B 167(Over Current B Phase) 197 (Fuse Fail) 86B I Group, 75D CVT Switching, 95B-1, Supervision Trip Relay CT Switching 752 X <b>Incomer Relay:</b> Facia: CB Auto Tripped Relay: 195 CB, Trip Circuit Supervision, TC-IB
4.	315 MVA, BHEL make ICT-IV (Main CB- 422-52)	86A & B operated Buchholz Alarm <b>Relay on 220 kV Incomer-IV</b> 86.1 & 86.2 Relay Operated
5.	220 kV Incomer No. V	86 A & B Operated LBB port. Relay 50Z, LBB Trip.

P. Details of Tests done after failure : Not applicable, as there was extensive damage to the windings, core and main tank due to fire.

Q. Observations :

- All HV, LV & TV bushings and all 400 kV LAs were damaged along with their display counters.
- Main tank was bulged and burst opened from HV side's top welded joint.
- 3 phase OLTC was damaged.
- Heavy carbonization had accumulated inside the tank of ICT-I due to burning of windings.
- Marshalling box and associated cables were burnt.
- Oil flow indicators were damaged.
- LV side B phase LA was also damaged.
- Heating marks observed on radiator bank.
- As per M/s BHEL opinion, transformer is beyond repair.

R. Probable cause of failure : It is clear from relay indication that Rohini-1 ckt-II tripped due to phase to earth fault in Y-phase with a fault current of 27 kA (as registered in DR). Upon inspection it was found that Y-phase insulator string on one of the towers had damaged and conductor

touched the tower leading to phase to earth fault. It appears that flow of such high current through windings of ICT-I damaged its insulation and caused fault inside the transformer resulting into operation of differential and overcurrent relay. Fault current recorded in DR was 47.85 kA. Due to high current the temperature of the oil & winding and pressure inside the tank increased causing operation of OTI, WTI, PRV, & Buchholz.

**6. Failure of 100 MVA, 220/33/11 kV Power Transformer at Geeta Colony substation of DTL**

- A. Name of Substation : 220 kV Geeta Colony Substation
- 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. : 2015820
- G. Year of manufacturing : 2004
- H. Year of commissioning : 2005
- I. Date and time of occurrence/discovery of fault : 01.12.2016 @ 08:38 hrs.
- J. Information received in CEA : 02.12.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Faulty
- M. Details of previous maintenance : Details of last periodic maintenance are as follows:

**1. Insulation Resistance (Meggar) (conducted on 20.10.2016): -**  
Applied Voltage :- 1 kV, DC

S.No.	Core To Yoke	Core To Tank
-------	--------------	--------------

	At 15 sec.	At 60 sec.	At 600 sec.	P.I	At 15 sec.	At 60 sec.	At 600 sec.	P.I
1	730 MΩ	971 MΩ	1.47 GΩ	1.52	847 MΩ	1.22 GΩ	1.69 GΩ	1.38

**2. Winding Resistance measurement** (conducted on 19.03.2016):

Current applied: 10 A, DC

Tap	HV side Resistance (mΩ)			LV side Resistance (mΩ)			TV side Resistance (mΩ)		
	R <sub>RN</sub>	R <sub>YN</sub>	R <sub>BN</sub>	R <sub>RN</sub>	R <sub>YN</sub>	R <sub>BN</sub>	R <sub>RY</sub>	R <sub>YB</sub>	R <sub>BR</sub>
5	450	450.5	455.7	10.6	10.6	10.6	6.5	6.5	6.2

**3. Voltage Ratio** (conducted on 19.03.2016):

Voltage applied: 415 V, 3 phase, 50 Hz

Tap	HV side applied voltage (V)			LV side induced voltage (V)			TV side induced voltage (V)		
	R <sub>RN</sub>	R <sub>YN</sub>	R <sub>BN</sub>	R <sub>RN</sub>	R <sub>YN</sub>	R <sub>BN</sub>	R <sub>RY</sub>	R <sub>YB</sub>	R <sub>BR</sub>
5	236.2	235.8	235.5	35.1	35.1	35	20.2	20.2	20.2

**4. Magnetizing Current** (conducted on 19.03.2016): -

Tap	HV			LV			TV		
	R- (mA)	Y- (mA)	B- (mA)	R- (mA)	Y- (mA)	B- (mA)	RY (mA)	YB (mA)	BR(mA)
5	1.9	1.6	1.7	41.0	30.0	40.2	72.5	100.6	99.4

**5. Magnetic Balance** (conducted on 19.03.2016): -

S.No	Tap	Voltage (volts)						
	HV							
1	5	V <sub>RN</sub>	<b>235.0</b>	V <sub>YN</sub>	216.6	V <sub>BN</sub>	23.7	
2	5	V <sub>RN</sub>	126.2	V <sub>YN</sub>	<b>234.8</b>	V <sub>BN</sub>	108.3	
3	5	V <sub>RN</sub>	23.7	V <sub>YN</sub>	219.0	V <sub>BN</sub>	<b>234.8</b>	
	LV							
1	5	V <sub>RN</sub>	<b>235.3</b>	V <sub>YN</sub>	199.2	V <sub>BN</sub>	38.0	
2	5	V <sub>RN</sub>	119.2	V <sub>YN</sub>	<b>235.2</b>	V <sub>BN</sub>	115.6	
3	5	V <sub>RN</sub>	38.2	V <sub>YN</sub>	198.7	V <sub>BN</sub>	<b>235.1</b>	
	TV							
1	5	V <sub>RY</sub>	<b>235.0</b>	V <sub>YB</sub>	117.1	V <sub>BR</sub>	117.5	
2	5	V <sub>RY</sub>	196.5	V <sub>YB</sub>	<b>235.2</b>	V <sub>BR</sub>	42.4	
3	5	V <sub>RY</sub>	197.5	V <sub>YB</sub>	43.3	V <sub>BR</sub>	<b>236.6</b>	

**6. Capacitance and tan delta** (conducted on 19.03.2016):

S.No.	Insulation Tested	Make & Sl. No.	Yr. of Manuf &	Mode	Capacitance (pF)	Dissipation Factor(%)

			Yr. of comm.		kV applied		Measured	Corrected @20°C
1	HV-LV	--	--	UST-R	10	20511.41	1.15	0.95
2	HV-E	--	--	GSTg-RB	10	5345.45	0.61	0.51
3	LV-T	--	--	UST-R	10	890.25	0.63	0.52
4	LV-E	---	--	GSTg-RB	10	3473.34	0.85	0.71
5	T-HV	--	--	UST-R	10	11981.27	0.85	0.71
6	T-E	--	--	GSTg-RB	10	15576.58	1.04	0.86
7	220 kV R- Bushing	BHEL 0448062	2004	UST-R	10	368.03	0.40	--
8	220 kV Y- Bushing	BHEL 0440147	2004	UST-R	10	311.04	0.20	--
9	220 kV B- Bushing	BHEL 0440146	2004	UST-R	10	301.80	0.19	--
10	33 kV R- Bushing	9708154	2000	UST-R	10	265.55	0.38	--
11	33 kV Y- Bushing	CGL/S723 0069450	2015/2015	UST-R	10	334.71	0.34	--
12	33 kV B- Bushing	CGL/S723 0069436	2015/2015	UST-R	10	339.37	0.35	--

**7. Measurement of earth resistance of transformer neutral & tank (Winter) conducted on 22.01.2016:**

S.No	Activity	Previous result	Current result
	R <sub>E</sub>		
1.	Tank	0.49 Ω	0.11 Ω
2.	Neutral	0.49 Ω	0.11 Ω

**8. DGA:** DGA of oil was conducted on 22.11.16 and values of acetylene, CO<sub>2</sub> & CO were found to be higher than permissible limits. DTL informed M/s BHEL in this regard on 24.11.16 and requested to inspect the transformer. Before BHEL could schedule a visit, transformer failed. Values of DGA are provided under item 'P'.

- N. Details of previous failure : MV side bushings have been changed previously due to high value of capacitance and tan delta. Gas formation has been observed on many occasions which reflected in DGA reports. Transformer has had trouble since commissioning.
- O. Sequence of events/ Description of failure : On 01.12.2016 at 08:38 hrs, the transformer tripped on Differential, REF, PRV, Buchholz & Sudden Pressure Relay. Transformer oil spilled around transformer. BHEL recommended to send the

transformer to BHEL works for further inspection and analysis.

P. Details of Tests done after : Post failure tests were conducted on 01.12.2016 failure and results are as follows:

**1. DGA:**

Results in ppm:			Key Gas Concentration Limits (As per IEEE Std. C57.104-2008)
	Present	1 <sup>st</sup> prior	
Test date	01.12.2016	22.11.2016	
H <sub>2</sub>	922	61	100
CO <sub>2</sub>	6035	5732	2500
CO	508	363	350
C <sub>2</sub> H <sub>4</sub>	408	16	50
C <sub>2</sub> H <sub>6</sub>	29	17	65
CH <sub>4</sub>	176	20	120
C <sub>2</sub> H <sub>2</sub>	511.2	5	1
TDCG	2554	482	720
Rogers' Ratio Indicates (for test conducted on 01.12.2016)			
CH <sub>4</sub> /H <sub>2</sub>		0.19	
C <sub>2</sub> H <sub>2</sub> /C <sub>2</sub> H <sub>4</sub>		1.25	
C <sub>2</sub> H <sub>4</sub> /C <sub>2</sub> H <sub>6</sub>		13.93	
C <sub>2</sub> H <sub>6</sub> /CH <sub>4</sub>		0.17	
CO <sub>2</sub> /CO		11.88	
Change in TDCG value = 2072 ppm			Rate = 259 ppm/day

**2. Magnetizing current:**

In mA

Tap	HV			LV			TV		
	R	Y	B	R	Y	B	RY	YB	BR
5	590	2.8	3.8	23800	43.5	44.7	106.7	107.4	47000

**3. Magnetizing Balance:**

S.No.	Tap	Voltage (Volts)					
	HV						
1	5	V <sub>RN</sub>	<b>233.1</b>	V <sub>YN</sub>	208.3	V <sub>BN</sub>	22.6
2	5	V <sub>RN</sub>	0	V <sub>YN</sub>	<b>237.7</b>	V <sub>BN</sub>	236.9
3	5	V <sub>RN</sub>	0	V <sub>YN</sub>	237.7	V <sub>BN</sub>	<b>238.9</b>

LV							
1	5	V <sub>RN</sub>	<b>218.8</b>	V <sub>YN</sub>	179.6	V <sub>BN</sub>	34.7
2	5	V <sub>RN</sub>	0	V <sub>YN</sub>	<b>233.1</b>	V <sub>BN</sub>	232.7
3	5	V <sub>RN</sub>	0	V <sub>YN</sub>	233	V <sub>BN</sub>	<b>233.0</b>
TV							
1	5	V <sub>RY</sub>	<b>234.8</b>	V <sub>YB</sub>	234.8	V <sub>BR</sub>	0
2	5	V <sub>RY</sub>	235	V <sub>YB</sub>	<b>235.6</b>	V <sub>BR</sub>	0
3	5	V <sub>RY</sub>	155.3	V <sub>YB</sub>	36.9	V <sub>BR</sub>	<b>191.3</b>

#### 4. Voltage Ratio:

In volts

Tap	HV		LV		TV	
5	V <sub>RN</sub>	233.3	V <sub>RN</sub>	32.4	V <sub>RY</sub>	17.7
5	V <sub>YN</sub>	233.8	V <sub>YN</sub>	34.7	V <sub>YB</sub>	20
5	V <sub>BN</sub>	233.5	V <sub>BN</sub>	34.7	V <sub>BR</sub>	0

#### 5. Insulation Resistance:

Voltage applied: 5 kV

In GΩ

Configuration	At 15 sec.	At 60 sec.	At 600 sec.	PI
HV-E	0.864	1.30	1.49	1.15
HV-MV	0.858	0.850	0.836	0.98
HV-LV	2.25	3.35	4.66	1.31
MV-LV	2.78	4.56	5.67	1.25
MV-E	0.913	1.28	1.37	1.07
LV-E	1.79	2.86	3.98	1.38

- Q. Observations : Internal inspection by BHEL and DTL engineers showed no visible damage. All bushings and their leads were found intact. Inspection by CEA officers was also carried out wherein no external damage was observed; however, oil spillage around the transformer tank was found.
- R. Probable cause of failure : DGA conducted on 22.11.2016 showed acetylene quantity higher than permissible limits. It appears that some arcing was taking place inside the transformer which aggravated to major fault causing transformer to trip on differential and REF protection. Operation of PVR, Buchholz and SPR indicates that due to arcing pressure inside the tank might have increased. Results of magnetizing

current measurement, magnetic balance, voltage ratio measurement and insulation resistance measurement tests carried out after the fault indicates inter-winding fault in R-phase. However, exact cause and location of fault could be ascertained after detailed internal inspection at manufacturer's works.

**7. Failure of 100MVA, 220/66-33/11 kV Transformer EMCO make installed at 220kV S/Stn. Wazirpur , DTL**

- A. Name of Substation : 220kV Substation Wazirpur
- B. Utility/Owner of substation : Delhi Transco Limited
- C. Faulty Equipment : Power transformer
- D. Rating : 220/33/11kV, 100 MVA  
Vector group: YNyn0d11
- E. Make : EMCO
- F. Sr. No. : HT1870/13208
- G. Year of manufacturing : 2010-11
- H. Year of commissioning : 2014
- I. Date and time of occurrence/discovery of fault : 19.10.2016 at 1648Hrs.
- J. Information received in CEA : 16.11.16
- K. Fault discovered during : Transformer was at no load at the time of fault
- L. Present condition of equipment : Transformer is to be repaired at OEM Works.
- M. Details of previous maintenance : Magnetic balance test, magnetizing current test, ratio test, IR test, BDV measurement of OLTC oil were carried out on 09.09.2016 along with the cleaning of bushings, checking of oil levels, contactor, gaskets etc. and electrical testing of OLTC surge relay, Buchholz etc.  
Tan delta and capacitance measurement test were carried out on 18.01.16.



DGA was carried out on 22.07.16 and CO<sub>2</sub> & CO were found to be more than permissible limit.

- N. Details of previous failure : No previous failures
- O. Sequence of events/  
Description of failure : On 19.10.16 at 1648 hrs., the transformer tripped on Buchholz Alarm and Differential relay. Transformer was on no load at the time of tripping.
- P. Details of Tests done after :  
failure :  
1. Magnetic Balance Test  
2. Magnetizing current.  
3. Tan delta of windings and bushings  
4. Dissolved Gas Analysis of transformer oil  
5. Voltage Ratio Test  
6. Insulation Resistance  
7. Winding Resistance
- Q. Observations & Probable :  
cause of failure : Voltage ratio test between HV-IV carried out after fault indicates a deviation more than 0.5% from the factory results. This could be due to shorted turns in the windings or inter turn fault.  
Tan delta of winding (IV-LV & IV-E) values as provided shows a higher annual rise than permissible which indicates considerable deterioration in insulation between IV-LV and IV-Earth, given that the transformer has only been in service for two years.  
DGA test reports high acetylene (80.6 ppm), CO<sub>2</sub> (4391 ppm), CO (589 ppm) and TDCG (816 ppm). Roger's ratio indicates high energy discharge inside the transformer.  
DR indicates a fault current of 1.6 kA in the HV side B-phase winding.
- Test data indicates that internal fault (inter-turn fault) could be a possible reason of failure.

**8. Failure of 500 MVA, 765/400 kV, Y phase ICT-1 at 765/400 kV Bareilly substation of PGCIL**

- A. Name of Substation : 765 kV Bareilly Substation

- B. Utility/Owner of substation : PGCIL
- C. Faulty Equipment : ICT-1 (Y phase)
- D. Rating : 500 MVA, 765/400 kV
- E. Make : CGL
- F. Sr. No. : BH1054-2
- G. Year of manufacturing : 2013
- H. Year of commissioning : 2016 (15<sup>th</sup> November)
- I. Date and time of occurrence/discovery of fault : 15.11.2016 at 1745 hrs
- J. Information received in CEA : 08.12.2016
- K. Fault discovered during : Commissioning
- L. Present condition of equipment : Under defect liability period, to be replaced
- M. Details of previous maintenance : No O&M history of the transformer. Transformer was previously put as cold spare at Lucknow substation.
- N. Details of previous failure : Nil
- O. Sequence of events/ Description of failure : On 15.11.2016 at 1745 Hrs., 765/400 kV, 500 MVA, Y-phase unit of ICT-1 tripped on operation of Differential, PRD and Buchholz relay, during charging for the first time.

The following indications were noted at the time of tripping:

- i) 17:45:49:549- 400 kV LV side of ICT bay was closed
- ii) 17:45:49:569- Transformer Differential Protection Operated
- iii) 17:45:49:576- PRD Tripped
- iv) 17:45:49:682- Buchholz relay Tripped
- v) 17:45:49:621- 400 kV LV side ICT bay of tripped by protection

System conditions at the time of failure of transformer were as under:

Name of element	Load in MW (1700 hrs)	Load in MW (1800 hrs)
400 kV Bareilly- Kashipur TL-1	-123	-122
400 kV Bareilly- Kashipur TL-2	-123	-122

400 kV Bareilly- Bareilly TL-1	359	309
400 kV Bareilly- Bareilly TL-2	359	309
765/400 kV ICT 2	530	372
765/400 kV ICT 1	In shut down	In shut down
765 kV Lucknow- Bareilly TL	-530	-372

Fault current of approx. 20 kA was observed from the DR of differential relay and Directional O/C. There was no advancement in reading of counter of Y Phase LA with respect to previous record.

P. Details of Tests done after :  
failure

**DGA**

S.No.	Description	Before charging (15.11.2015 at 17:42)	After tripping	Remarks
1	H <sub>2</sub>	2 ppm	0 ppm	The AC supply to the equipment was switched off immediately after tripping as a precautionary measure.
2	H <sub>2</sub> O	3 ppm	3 ppm	
3	C <sub>2</sub> H <sub>2</sub>		733 ppm	

All the pre commissioning tests were repeated after tripping of ICT. (Details not provided)

Q. Observations :

DGA test done after tripping shows very high concentration of acetylene (733 ppm) indicating high energy discharge.

External and internal inspections were carried out by PGCIL officials on 02.12.2016.

**A) External Inspection**

The physical inspection was carried out and no visual deformation in body of transformer was seen. Only marks of oil flow out of PRD were seen on the body of Transformer.

**B) Internal Inspection**

- i) HV winding insulation close to the point where HV Lead take off from the winding was burnt.
- ii) Pressboard insulation covering the HV lead take off close to winding was burnt.
- iii) Inter turn Insulation was dislodged.
- iv) Excessive burnt material was found at the bottom of the tank.

v) Carbon particles were found to be floating in oil.

R. Probable cause of failure : Very high concentration of acetylene (733 ppm) in oil and operation of differential relay, PRD and buchholz relay indicates high energy discharge inside the tank. Based on DGA result and internal inspection, prima facie the failure may be attributed to HV winding insulation failure. As the extent of winding damage can't be ascertained at site, in view of inaccessibility of complete active part, the root cause analysis of failure can be carried out at CGL factory.

**9. Failure of 315 MVA, 400/220 kV ICT-II at 400 kV Nawada substation of HVPNL**

A. Name of Substation : 400 kV Nawada substation

B. Utility/Owner of substation : HVPNL

C. Faulty Equipment : ICT-II

D. Rating : 315 MVA, 400/220 kV

E. Make : AREVA

F. Sr. No. : B-30543

G. Year of manufacturing : 2010

H. Year of commissioning : 2013

I. Date and time of occurrence/discovery of fault : 22.04.2015 @ 00:18 hrs.

J. Information received in CEA : 02.11.2015

K. Fault discovered during : Operation

L. Present condition of equipment : The damaged ICT was lying at the site. Information is not available as to whether the faulty ICT has been replaced.

M. Details of previous maintenance :

a. Tests conducted on 07.01.2015:

TESTS	TEST METHOD	REQUIREMENT IS:1866	TEST VALUE	CONFIRMITY
Electric Strength (Break Down Voltage) (kV RMS (Min.) at 50Hz	IS:6792	60	75	YES
Water Content(PPM)(Max)	IS:13567	10	4	YES

b. Tests conducted on 04.01.2015:

Sr. No.	Characteristics	CPRIRTLDDL2014 S0309	CPRIRTLLOL2014 S0310
1.	Interfacial Tension @ 27°C, mN/m	42	42
2.	Electric strength. BDV.Kv(MS)	Readings	69.5,70.5, 76.5, 79.9, 72.6, 63.0
		Average	72.1
		Reported	72
3.	Dielectric Dissipation factor(Tan Delta), @90°C	0.00020	0.00022
	Dielectric constant @ 90°C	2.05	2.04
4.	Specific Resistance (Resistivity) x 10 <sup>16</sup> Ohm@ 1) 90°C 2) 27°C	280	290
		4250	4350
5.	Water content, mg/kg(PPM)	8	7
6.	Dissolved Gas Analysis		
	Total Gas Content, ml/100ml of oil		4.70
	Methane, ppm		2
	Ethane		ND
	Ethylene, ppm		3
	Acetylene, ppm		ND
	Hydrogen, ppm		ND
	Carbon Monoxide, ppm		ND
	Carbon Dioxide, ppm		ND

c. Test conducted on 30.01.2015:

Sr. No.	Gas	Qty. Detected(in ppm)	Indication obtained from the test results/Remarks
1.	Methane(CH <sub>4</sub> )	4	

			The present gas-in-oil data, obtained after preventive maintenance followed by degassing of the oil, shall be viewed as a benchmark for future reference. The next oil sample for DGA may be sent after 3 months to monitoring the condition.
2.	Ethane(C <sub>2</sub> H <sub>6</sub> )	1	
3.	Ethylene(C <sub>2</sub> H <sub>4</sub> )	7	
4.	Acetylene(C <sub>2</sub> H <sub>2</sub> )	ND	
5.	Carbon dioxide(CO <sub>2</sub> )	187	
6.	Hydrogen( H <sub>2</sub> )	2	

d. Test conducted on 19.11.2014:

Thermovision scanning of 400 kV Nawada was carried out; the whole 400 kV substation was checked by thermal imager & following hot spots were found:

- i. AA1-1-89AY (Y phase Isolator middle point)
- ii. AA2-5-89A (Isolator R phase jaw)
- iii. 220 kV bay no. A-8 (Bay breaker) – R phase top clamp

N. Details of previous failure : Nil

O. Sequence of events/ :  
Description of failure

The sequence of events are as under:-

- On 22-4-2015, two 400/220 kV, 315 MVA ICTs were running in parallel connected on LV side through 220 KV Bus-coupler at 400 KV S/Stn Nawada.
- Two 220 KV circuits viz., A5 ckt-I and A5 ckt-II were feeding 220 KV S/Stn A-5. At 220 kV S/Stn A5, both the 220 KV ckt. were connected on separate buses and 220 kV Bus-coupler was in OFF condition.
- At 400kV S/Stn Nawada, the 220 kV A5-ckt-II tripped at 21:41 Hrs on 21-4-2015. Distance Protection Scheme relay details are as under-

Distance Protection Scheme Main -1 Operation:

1. Time: 21:41 Hrs. Dated : 21.04.2015
2. Start phase AB,
3. Tripped Phase ABC,
4. Trip Zone=1,
5. Frequency 50.04 HZ,
6. Fault Duration = 73.28 ms
7. Trip relay time=79.94ms
8. Fault Location=3.390km
9. Fault Resistance = 2.509 mΩ
10. IA=9.398 kA, IB=9.172 kA, IC=269.0 A

11.  $V_{AN}$ —64.74 kV,  $V_{BN}$ =63.29 kV,  $V_{CN}$ =127.3 kV

- The 220kV A-5 Ckt-II line was patrolled by the T/L staff and line clearance was given.
- A5 ckt-II was charged from 400 KV S/Stn Nawada at 00:18 Hrs. on 22.04.2015.
- The 220 KV A5 ckt-II did not hold and tripped showing distance relay with SOTF with following details:-

A) Distance relay Scheme Main -1 Operation as detailed below:

1. Time 00:18 Hrs      Dated : 22.04.2015
2. Start Phase ABC,
3. Tripped Phase ABC,
4. Trip Zone= 1,
5. SOTF
6. Frequency = 50.06 HZ,
7. Fault Duration = 66.59 ms,
8. Trip Relay Time = 79.90 ms
9. Fault Location 3.553 km
10. Fault resistance — 175.6 m $\Omega$
11.  $I_A$ -9.748 kA,  $I_B$ -8.953 kA,  $I_C$ =10.54 kA

12.  $V_{AN}$ = 8.865 kV,  $V_{BN}$ =6.954 kV,  $V_{CN}$  =7.604 kV

B) Distance relay Scheme Main-2 operation as below:

1. SOTF and carrier sent
- Simultaneously the 400/220 W, 315 MVA ICT-2 showing following relays:-
    1. REF
    2. Buchholz Alarm
    3. Buchholz Trip
    4. PRVT
    5. OSR
    6. O/C on HV Side & LV side
  - Site visit report on 22.4.2015 is as under:
    1. O/C on HV side:  $I_R$ = 2.927 kA,  $I_Y$ = 3.106 kA,  $I_B$ =2.933kA.
    2. O/C on LV side  $I_R$  = 5.261 kA,  $I_Y$  = 3.433 kA,  $I_B$  =5.189Kamp.
    3. The REF Relay (P632) indicates  $I_{ref}$ = 2.70 A.
    4. The Differential Relay (P633) indicated time = 00:18:30 s
  - The body of the ICT22 was found bulged and burst along with damage of 220 KV Y-Phase Bushing. The entire oil of the ICT-2 was leaked out in the pit below the ICT.

- The line was again patrolled from TL staff and Red phase jumper at tower no. 22 (no. starting from 220 KV A5 S/Stn.) was found broken.

P. Details of Tests done after failure : No tests could be carried out as the ICT was physically damaged with bulging and bursting of the body.

Q. Observations :

- DGA test results of the ICT-2 dated 21-4-2014 conducted by the CPRI were abnormal and lab’s remarks were as under:

“ DGA Indicates thermal fault of high temperature > 700 degree centigrade, over heating of copper due to eddy currents, bad connection/ joints. It is recommended for Internal inspection.”

- As per record the internal inspection of the TIF was carried out in December 2014:

"220 KV PALM Allen Screws and spring washers (inside the corona shield) were found badly carbonized and spark marks were present on both Allen screws and spring washers of Y phase busing. In R and B Phase bushing, palm screws and palm washers were found in order. However, none of the corona screws were said to be loose. In view of the transformer DGA problem due to issue of allen scew and spring washer. However, the carbonized screws and washers were replaced with new screws and spring washers along with additional plain washers.”.... “ Oil leakage/ seepage has been observed from CT epoxy terminal of HV Turrets, R and Y – ph Tap Changer top cover, PRV towards cooler side, Buchholz relay flange joint and same has been attended after tightening its fixing bolts.

- That 220 kV A-5 CKT-2 line tripped on dt 21.4.2015 at 21:41 Hrs and the maximum fault currents recorded by different relays at 21:41 Hrs on 21.4.2015 at 400 kV S/Stn Nawada per data downloaded and supplied by M&P Faridabad are as under.

Table A: Fault current data at 21:54 Hrs on 21.4.2015

Sr.No.	Name of CB	Currents (in Amp)			Relay name
		R-Phase	Y- Phase	B-Phase	



1.	A5 ckt-2	9525	9259	308	DPR P442 Main - 1
2.	ICT-2 LVL	4914	4545	261	O/C P141
3.	ICT-1 LVL	4743	4490	252	O/C P141
4.	ICT-2 LVL	2596	2511	142	O/C P141
5.	ICT-1 LVL	2600	2472	144	O/C P141

- The event waveform of the 220 kV A5 ckt-2 and both the ICTs was checked and found that the fault remained / persisted only for about 80 m sec and the fault was cleared with the tripping of A5 ckt-2 circuit breaker in 80 m sec. The fault current of the line was shared by both the ICTs i.e. ICT -1 and ICT- 2 with above details.
- The 220 kV A5 ckt -2 was being switched on at 00:18 Hrs. on 22.04.2015 but the 220 kV A-5 ckt A-5 line tripped instantaneously and the maximum fault currents recorded by different relays at 00:18 Hrs. on 22.04.2015 at 400 kV S/Stn. Nawada as per data downloaded and supplied by M&P Faridabad are as under:-

Table B Fault current data at 00:18 Hrs on 22.4.2015

Sr.No.	Name of CB	Currents (in Amp)			Relay name
		R-Phase	Y- Phase	B-Phase	
1.	A5 ckt-2	14913	17714	13623	DPR P442 Main - 1
2.	ICT-2 LV	7322	13240	6458	O/C P141
3.	ICT-1 LV	6962	7482	6564	O/C P141
4.	ICT-2 HV	33650	32858	3584	O/C P141

- The 220 kV A5 ckt-2 was switched on at 00:18 Hrs. on 22-04-2015. The same tripped by the DPR on SOTF relay. Again the fault current on 220 kV A5 ckt-2 as above (Table –B) remained for about 80 msec. The fault current of the line was shared by both the ICTs in R and B phase but in Y- phase of LV OF ICT-2 it was abnormally high (Table-B above) as this transformer developed some internal fault as is evident from the currents. The ICT – 2 could not sustain this internal fault. Due to this internal fault, an explosion took place in the ICT tank resulting in bulging of the body and opening of joint of front side sheet (LV) and bottom sheet.

- R. Probable cause of failure : The transformer was supplied to the site in Feb. 2011, and stored for 14 months in nitrogen filled state. The transformer failure could have been due to dielectric failure of the winding insulation during system short circuit which in turn could have been due to the gravitational damage of oil during storage in gas filled condition which created small cavities with trapped moisture/gases.

**10. Failure of 100 MVA, 220/66 kV Transformer at 220 kV Madanpur substation of HVPNL.**

- A. Name of Substation : 220 kV S/Station, Madanpur (Panchkula)
- B. Utility/Owner of substation : HVPNL
- C. Faulty Equipment : Transformer
- D. Rating : 220/66 kV, 100 MVA
- E. Make : BHEL, Jhansi
- F. Sr. No. : 2014333
- G. Year of manufacturing : 2002
- H. Year of commissioning : 2003 (16<sup>th</sup> January)
- I. Date and time of occurrence/discovery of fault : 13.03.2015.
- J. Information received in CEA : 2.11.2015
- K. Fault discovered during : Transformer was running on no-load after annual maintenance. The Transformer tripped off and oil spilled out from main tank of the transformer.
- L. Present condition of equipment : Damaged
- M. Details of previous maintenance : Annual periodical maintenance was done on 12.03.2015.

- N. Details of previous failure : 1.The Buchholz alarm appeared on the FACIA window on Dt. 08.07.2004. The T/F Core-Yoke clamp found short. Then, BHEL representative visited the Sub- Station on Dt. 27.07.2004 – 04.08.2004 and Bakelite insulation was provided between the Core & Yoke clamp of T/F.  
2. The Buchholz alarm appeared on the FACIA window on Dt. 01.01.2005. The T/F Core-Yoke clamp found short. Again, BHEL representative visited the Sub- Station on Dt. 06.01.2005 and Bakelite sheet of 12mm thickness inserted between the Core & Yoke clamp of T/F.
- O. Sequence of events/ Description of failure : On 13.03.2015, T/F running on No- Load after periodic maintenance, tripped off and oil comes out from the main tank of the T/F and following relays operated:  
1.Differential relay (R & Y Phase) with master trip (HV Side)  
2.Buchholz Trip & Alarm  
3.PRV of Main Tank  
4.O/C Relay (Y-Phase)  
5.REF Relay (LV Side) with master trip (LV Side)  
6.Oil & winding Temperature alarm (HV Side)
- b) The M & P team carried out the complete testing of T/F i.e. TTR, magnetizing current test, flux distribution test, winding resistance test etc. The test result of the T/F were not found satisfactory by M&P Team and recommended internal inspection by PTRW team and also for DGA test of the T/F.
- c) The PTRW team visited the S/Station on 14.03.2015 & 15.03.2015. About 100 nos. drum of oil have been drained out from T/F and on inspection from top and side inspection window it was found that small copper particle and large carbon particles have been found on Y- phase of the T/F and Y-Phase HV winding found disturbed. They recommended that T/F is not repairable at site.
- P. Details of Tests done after failure :

**DGA:**

Sr. No.	Gas	Qty. detected (in ppm)	Indication obtained from the test result
1.	Methane (CH <sub>4</sub> )	42	The key gas acetylene indicates discharges of high energy in the oil. As per Roger's Diagnostic method, the concentration of the gases in the oil is indicative of power arcing in the transformer.
2.	Ethane (C <sub>2</sub> H <sub>6</sub> )	5	
3.	Ethylene (C <sub>2</sub> H <sub>4</sub> )	47	
4.	Acetylene (C <sub>2</sub> H <sub>2</sub> )	58	
5.	Carbon dioxide (CO <sub>2</sub> )	4557	
6.	Hydrogen (H <sub>2</sub> )	134	

**Flux Distribution Test (Magnetic Balance Test):**

	Rn (V)	Yn (V)	Bn (V)
HV	260	0	258
	93	260	136
	259	0	260
LV	268	0	263
	60	250	88
	262	0	263

**Magnetizing current test:**

	R	Y	B
HV	430 mA	890 mA	430 mA
LV	4.2 A	8.5 A	4.28 A

Q. Probable cause of failure : Operation of differential relay, REF, PVR, buchholz, OTI/WTI, O/C relay indicates fault inside the transformer tank which lead to flow of high current, generation of gases and buildup of high pressure. Results of magnetic balance test, magnetizing current test and physical inspection indicates faults involving Y-phase. High value of acetylene also indicates discharges of high energy in the oil.

HVPNL in its report has suspected poor workmanship as one of the causes of failure, as problem of poor insulation between core and yoke has been observed in the past in this transformer and other transformers purchased together with this transformer.

BHEL may review its transformer design and improve workmanship quality.

**11. Failure of 220/132 kV, 100 MVA Power Transformer II at Pulivendula substation of APTRANSCO.**

- A. Name of Substation : 220 kV SS Pulivendula
- B. Utility/Owner of substation : APTRANSCO
- C. Faulty Equipment : Power Transformer- II
- D. Rating : 100 MVA, 220 kV /132 kV
- E. Make : BHEL
- F. Sr. No. : 2005071
- G. Year of manufacturing : 1989
- H. Year of commissioning : 2010 (May 26<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 11.10.2015 at 03:58 Hrs.
- J. Information received in CEA : 12.01.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : To be replaced
- M. Details of previous maintenance : Regularly maintained. (Details about maintenance are not available)
- N. Details of previous failure : Transformer tripped on E/F and differential protection. TRE wing tested and declared the transformer defective on 23.06.2006.

- O. Sequence of events/ Description of failure : On 11.10.2015 at 03:58 hrs, 132 kV Pulivendula – Lingala line tripped on Distance protection with A,B,C relay indications, distance 0.8 km. There was heavy rain and lightning at the time of failure. ‘Y’ phase LA blasted. Buchholz relay of transformer operated.
- P. Details of Tests done after failure : Turns Ratio test, Magnetic balance test, Insulation resistance test, SC test, OC test Magnetizing current test and Winding resistance test. (Details not provided by the utility)
- Q. Probable cause of failure & observations : As reported by utility, the transformer was declared faulty due to inter turn short in ‘Y’ phase winding and recommended for replacement with new 100 MVA transformer. There is a gap of 21 years between year of manufacture and commissioning at Pulivendula. Whether the transformer was installed at another substation or was kept idle during this period is not known. Also if it was kept idle, how was it stored is not known.

## **12. Failure of 100 MVA Power Transformer at Tadikonda substation of APTRANSCO**

- A. Name of Substation : 220kV/132/33kV Substation, Tadikonda
- B. Utility/Owner of substation : APTRANSCO
- C. Faulty Equipment : 100MVA PTR-II
- D. Rating : 220/132kV
- E. Make : EMCO
- F. Sr. No. : 1439/11894
- G. Year of manufacturing : 1999
- H. Year of commissioning : 1999 (27<sup>th</sup> July)
- I. Date and time of occurrence/discovery of fault : 24.08.2016 at 1810 Hrs.

- J. Information received in CEA : 17.10.16
- K. Fault discovered during : Operation
- L. Present condition of : Transformer is not reparable equipment
- M. Details of previous : Last maintenance on 20.07.2016 maintenance
- N. Details of previous failure : NA
- O. Sequence of events/ : On 24.08.16, at 1810 hrs, 220 /132 kV Power Description of failure : transformer- II failed during operation. Due to blasting of the HV side B-ph bushing, the transformer caught fire.
- P. Details of Tests done after : No tests were possible as the transformer was burnt failure
- Q. Observations : Connected BP boom, TA tower and auxiliary bus were damaged.
- R. Probable cause of failure : Sufficient information is not available to draw any conclusion. Probably failure of B ph HV bushing could be reason failure of transformer.

### **13. Failure of 160 MVA Power Transformer at Gudivada substation, APTRANSCO**

- A. Name of Substation : 220kV SS, Gudivada
- B. Utility/Owner of substation : APTRANSCO
- C. Faulty Equipment : Power Transformer
- D. Rating : 220/132 kV, 160 MVA
- E. Make : TOSHIBA
- F. Sr. No. : 90156A03
- G. Year of manufacturing : 2015
- H. Year of commissioning : 2015 (15<sup>th</sup> July)

- I. Date and time of occurrence/discovery of fault : 24.09.2016 at 0405 Hrs.
- J. Information received in CEA : 02.11.16
- K. Fault discovered during : Operation
- L. Present condition of equipment : To be replaced
- M. Details of previous maintenance : Last General Maintenance was done on 19.07.2016
- N. Details of previous failure : No previous failures
- O. Sequence of events/ Description of failure :
  - On 24.09.2016 at 0405 Hrs., transformer tripped on following indications:
    - a) HV O/L and E/F
    - b) Differential Relay
    - c) PRV Trip
    - d) Main Buchholz relay
    - e) OLTC Buchholz relay(R-Phase)
    - f) HV/LV winding temp alarm
    - g) Oil temp alarm
    - h) Low oil level alarm
  - Fault current of 11 kA was recorded during the fault.
- P. Details of Tests done after failure : Internal inspection was done. Following damages found inside the Power Transformer during internal inspection:
  - a) flashover marks were found between HV Y-Phase corona shield and core clamp bolts.
  - b) All battens of OLTC selector switch of R-Phase and few battens in OLTC selector switch of Y & B Phases were found in broken condition.
  - c) There was no dislocation of core and windings inside the Tank.
  - d) Oil was leaking from several places from Bottom tank curb due to shearing of tank cover at stiffener location due to severe pressure build up in the PTR.



- e) The oil color was found to be black.
- f) 3 nos. of HV & IV bushings found dislocated at flange and insulator joint location.

Q. Probable cause of failure : Operation of Differential relay along with operation of Buchholz, OLTC Buchholz & PRV relays indicates fault inside the transformer. Operation of E/F indicates that fault involves ground. The flow of heavy fault current (11 kA) in windings might have led to the rise in winding temperature and operation of OTI and WTI alarm.

As stated in the report submitted by the utility, the oil color had turned to black indicating deterioration of insulating property.

Heavy current due to the fault might have led to generation of gases and sudden pressure rise inside the transformer tank and tripping of Buchholz & PRV. PRV being a slow operating device might not have been able to bring down the gas pressure inside the tank to safe value and high rate of rise of gas pressure might have resulted in cracks at weak areas of the transformer tank.

**14. Failure of 230/110/11 kV, 100 MVA Auto transformer-II at 230 kV Manali substation of TANTRANSCO**

- A. Name of Substation : 230 kV Manali substation
- B. Utility/Owner of substation : TANTRANSCO
- C. Faulty Equipment : Auto transformer-II
- D. Rating : 230/110/11 kV, 100 MVA
- E. Make : EMCO (OLTC make : EASUN-MR  
HV bushing make: CGL  
IV bushing make: LTRENCH)
- F. Sr. No. : HT 1738/12847
- G. Year of manufacturing : 2007
- H. Year of commissioning : 2008 (July 7<sup>th</sup>)

- I. Date and time of occurrence/discovery of fault : 01.12.2015 at 19:51 hrs.
- J. Information received in CEA : 30.03.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced
- M. Details of previous maintenance :  
a) IV (110 kV) Y phase bushing clamps replaced on 21.9.2011  
b) Periodical Oil sample testing done on 25.3.2014  
c) Defective differential protection relay was replaced on 23.5.2014  
d) B phase LV bushing rod replaced by newly machined rod by TRB wing along with oil seals.
- N. Details of previous failure : Nil
- O. Sequence of events/ Description of failure : On 01.12.2015 at 19:51 hrs, the auto transformer failed.  
1) No oil in the Transformer as the oil drain valve had burst and opened.  
2) All Bushings (3 Nos. -230 kV, 3 Nos – 110kV, 3Nos.- 11 kV and 1 No Neutral bushing) were burst.  
3) Main tank on bottom side was slightly bulged.  
4) Inspection cover was opened and all windings were found to be physically normal.  
5) All 3 Nos. OLTCs were damaged.  
6) Transformer burnt due to fire  
Winding condition needs to be assessed and for that it has to be lifted.  
TANTRANSCO has informed that Y-phase LA and HV & LV breaker mechanism had also failed.
- P. Details of Tests done after failure : LV tan delta was measured and the values were found to be on higher side.
- Q. Probable cause of failure : Sufficient information has not been provided regarding failure of Y-phase LA and HV & LV breaker mechanism. It is difficult to comprehend the

information provided by TANTRANSCO and to reach at any conclusion.

**15. Failure of 100 MVA, 230/110 kV Auto transformer-II at 230 kV Gummidipoondi substation of TANTRANSCO**

- A. Name of Substation : 230 kV Gummidipoondi substation
- B. Utility/Owner of substation : TANTRANSCO
- C. Faulty Equipment : Auto transformer-II
- D. Rating : 100 MVA, 230/110 kV
- E. Make : BHEL
- F. Sr. No. : 2007460
- G. Year of manufacturing : 1993
- H. Year of commissioning : 1994
- I. Date and time of occurrence/discovery of fault : 31.03.2016 at 0604 hrs
- J. Information received in CEA : 23.08.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced
- M. Details of previous maintenance : Last maintenance done on 05.01.16
- N. Details of previous failure : Information not available
- O. Sequence of events/  
Description of failure : On 31.03.16, at 0604 hrs, auto transformer –II tripped with Buchholz trip indication. At the same time disc flashover on Y and B –ph 110 kV SIPCOT-II feeder at SIPCOT-II s/s was observed. Auto transformer-II was idly test charged at 1954 hrs on 01.04.16 but it tripped with differential relay indication.

- P. Details of Tests done after failure : On 31.03.16, DGA test was conducted and sharp increase in acetylene was found. On 01.04.16, DC resistance, tan delta and SFRA test were conducted.
- Q. Probable cause of failure : It appears that disc flashover in 110 kV SIPCOT-II feeder caused arcing due to loose contacts or damaged insulation inside transformer which led to generation of acetylene and operation of buchholz trip. TRB Wing examined the faulty transformer and reported that defective Y-phase winding is suspected and the same has to be ascertained only after lifting the coil which could not be carried out at site.

**16. Failure of 33.3 MVA, 220/110 kV, 1-phase transformer of 100 MVA transformer bank at 220 kV Edamon substation of KSEB**

- A. Name of Substation : 200 kV Substation, Edamon
- B. Utility/Owner of substation : KSEB Ltd.
- C. Faulty Equipment : B-phase transformer (single-phase auto transformer) of transformer bank # 1
- D. Rating : 33.33 MVA,  $\frac{220}{\sqrt{3}}/\frac{110}{\sqrt{3}}/11$  kV
- E. Make : BHEL
- F. Sr. No. : 6004019
- G. Year of manufacturing : 1977
- H. Year of commissioning : 1978
- I. Date and time of occurrence/discovery of fault : 04.05.2016 at 1711 hrs.
- J. Information received in CEA : 03.06.16
- K. Fault discovered during : Operation
- L. Present condition of equipment : Damaged
- M. Details of previous maintenance : The unit was overhauled in April 2014 and last equipment testing was conducted on 28.01.16 in

which all results were found satisfactory. Diverter switch replaced on 02.06.14, HV Bushing oil top up and OLTC Buchholz overhauled on 03.06.14. Again HV bushing oil was filled on 25.08.15. External cleaning, silica gel replacing, tightening of connections, nuts and bolts etc. were carried out on 21.03.16. HV Bushing oil leakage arrested on 20.04.16.

- N. Details of previous failure : Information not available
- O. Sequence of events/ Description of failure : On 04.05.2016, at 1711 hrs. 110 kV Edamon-Kilimanoor feeder tripped Simultaneously, 100 MVA Transformer bank #1 tripped with following relays:  
(1) Oil temp: alarm  
(2) Oil temp: trip  
(3) Tripping relay 86.2  
(4) LBB lock out relay  
After inspection the transformer was test charged and again the transformer tripped on differential protection and on Buchholz alarm on B-phase unit. Relay indication of Edamon-Kilimanoor feeder is distance protection A-C-G trip, Zone 1. There was heavy lightning and rain during the time of failure.
- P. Details of Tests done after failure : Tan  $\delta$  test - Increase in value in HV Side  
Excitation current test – HV-N exciting current is high with distorted waveform while on LV side could not be tested as the test kit was tripping on overcurrent.  
Winding resistance test – Current could not rise on HV-N & LV-N winding resistance test. It was suspected that the neutral terminal is broken.  
% Ratio error test - % Ratio error noticed in HV-LV & HV - TV with distorted current wave form and in LV - TV the test kit tripped on over current.  
DGA –Hydrogen – 2783 ppm, CO<sub>2</sub>-5063 ppm, CO-381, Ethylene – 1700, Ethane – 71, Methane – 906, Acetylene – 294.5, Water – 47, TDCG – 61340.
- Q. Observations : Upon internal inspection of the unit, spreading of pieces of wooden support and insulating material inside the transformer tank was noticed. Copper granules were found on the wall of transformer inside the transformer tank.

- R. Probable cause of failure : In the DGA, values of key gases and TDCG were found to be above permissible limit which suggests high energy discharge in the transformer. Based on the observation of test results, fault in the windings near neutral end is possible. The transformer has been in service for about 38 years. Ageing could have led to the deterioration of the winding insulations. It is very difficult, based on available information, to ascertain exact cause and location of fault.

**17. Failure of R-Phase 167 MVA single phase transformer of 500 MVA, 400/220/33 kV Bank-2 at 400 kV Hoody substation of KPTCL.**

- A. Name of Substation : 400 kV Hoody receiving station
- B. Utility/Owner of substation : KPTCL
- C. Faulty Equipment : Auto transformer (R phase) of ICT2 bank
- D. Rating : 1-Ph, 167 MVA, 400 /220/33 kV
- E. Make : CGL
- F. Sr. No. : T8907/3
- G. Year of manufacturing : 2003
- H. Year of commissioning : 2004
- I. Date and time of occurrence/discovery of fault : 02.06.2016 at 0315 hrs.
- J. Information received in CEA : 30.08.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Completely burnt.
- M. Details of previous maintenance : 1)Tan delta was carried out on 21.05.2016 and values were well within the limits  
2)Transformer mounted protection relays were tested on 21.05.2016 and found ok.

3) Transformer oil sample were sent for testing on 22.04.2015 and test results were normal.

4)Transformer bay maintenance was done on 28.02.16

- N. Details of previous failure : None
- O. Sequence of events/  
Description of failure : On 02.06.16 at 0315 hrs, 400 kV bushing of R phase auto transformer of ICT2 bank flashed over and strong fire emanated. ICT2 tripped on following relays: differential relay, buchholz relay R-ph, PRD trip R-ph, OSR R-ph, winding temp trip and oil temp trip.  
Fault current on HV side is recorded as 15352 A and LV side 2198 A.
- P. Details of Tests done after  
failure : None, as transformer is completely burnt.
- Q. Probable cause of failure : Operation of buchholz, PRD, OSR, WTI & OTI trip indicates that high energy discharge might have took place inside transformer which caused pressure rise in the tank. Failure of bushing causing arcing inside transformer followed by oil leakage from bushing might have resulted in fire. Internal inspection of transformer is required to assess the condition of the winding & the core and to ascertain the exact cause of failure.

**18. Failure of 315 MVA, 400/220/33 kV ICT- I at 400 kV Meramundali Grid substation of OPTCL.**

- A. Name of Substation : 400 kV Meramundali Grid Substation
- B. Utility/Owner of substation : Odisha Power Transmission Corporation Ltd.
- C. Faulty Equipment : Auto Transformer
- D. Rating : 315 MVA, 400/220/33 kV
- E. Make : BHEL, Bhopal
- F. Sr. No. : 6005742
- G. Year of manufacturing : 2002
- H. Year of commissioning : 2005 (May 31<sup>st</sup>)

- I. Date and time of occurrence/discovery of fault : 12.11.2016@ 23:11 hrs
- J. Information received in CEA : 13.12.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Completely damaged
- M. Details of previous maintenance : Measurement of Insulation Resistance, Capacitance & Tan delta on bushings and windings on 0.3.03.15; oil testing including DGA on 19.05.16 and leakage current measurement of LA on 31.01.15 were carried out and results were found to be in order.
- N. Details of previous failure : Nil
- O. Sequence of events/ Description of failure : On 12.11.2016 at 23:11 hrs., a loud sound was heard accompanied by tripping of both sides CBs of the ICT. with following relay indications:  
1. Differential relay  
2. High set over current & earth fault relay at LV and HV sides  
3. REF relay  
4. PRV  
5. Buchholz relay  
6. WTI  
7. OTI  
HV & LV bushings burst and all LAs on both HV & LV sides were damaged. B phase HV side caught fire, which further spread to entire ICT. Fault current of 31.251 kA in 400 kV side (B phase) and 5.35 kA in 220 kV side (B-phase) was recorded in disturbance recorder of differential relay.  
The fire was contained through water and foam tenders in six hours.  
At the time of failure, the load on the transformer was 100 MW.
- P. Details of Tests done after failure : There was extensive damage to the main tank, bushings, windings, core and other accessories; hence, no test could be done.



Q. Observations :

- a) The ICT was found with huge damage in main tank, core, winding including all its accessories like conservator, pipe work, headers, A-frame, radiator and fans which were burnt due to excessive fire.
- b) The main tank foundation was also found damaged with few cracks in the concrete and cooling bank foundation was completely damaged. The MS channel embedded with rails was found dislodged from foundation.
- c) All windings were burnt exposing bare copper shrunk towards the bottom. The core was burnt, damaged & dislodged and was found lying on the bottom in the tank.
- d) All 400 kV, 220 kV, 33kV & Neutral bushings were found completely damaged. All OLTC were damaged and burnt. One tank stiffener below the IV-B phase was dislodged from the main tank and had flown around 25 m away from ICT.
- e) All LAs of 220 kV side and 400 kV side were damaged. However, counters of only 400 kV side LAs were found burnt. The counter reading of R-phase 220 kV side LA showed one increment from pre-fault reading.
- f) The Pre-fault temperature of ICT were seen and found normal.
- g) Differential relay was not synchronized with GPS clock.
- h) Transformer was manufactured in 2002 and commissioned in 2005. During this period how transformer was stored or maintained is not known.

R. Probable cause of failure : From the operation of Differential, REF, O/C & E/F relays and flow of severe current in B phase it appears that the failure might have taken place due to failure of B-phase winding insulation or B phase HV bushing. Flow of severe current in windings might have led to rise in winding & oil temperature and operation of WTI & OTI Trip. High energy arcing due to fault might have led to sudden pressure rise in tank and tripping of Buchholz & PRV. Oil attained temperature beyond fire point and contacted fire after coming in contact with the oxygen through cracked tanks.

**GENERATOR TRANSFORMERS**

**19. Failure of 250 MVA, 15.75/220 kV GT-3 at RTPS of KPCL.**

- A. Name of Substation : Raichur Thermal Power Station.
- B. Utility/Owner of substation : KPCL
- C. Faulty Equipment : Genrator Transformer -3
- D. Rating : 250MVA, 15.75/220kV
- E. Make : CGL
- F. Sr. No. : 25009
- G. Year of manufacturing : 1990
- H. Year of commissioning : 1991
- I. Date and time of occurrence/discovery of fault : 23.05.15 at 15:48 Hrs.
- J. Information received in CEA : 03.11.2015
- K. Fault discovered during : Operation (while in Service with a load of 213 MW)
- L. Present condition of equipment : Replaced with repaired GT of Unit-I. Spare GT is being used for Unit-I.
- M. Details of previous maintenance :

During Dec. 2013, Annual Over Hauling of GT-3: Capacitance and tan delta values of HV bushing recorded are as under –

Phase	Capacitance in pF	Tan $\delta$
R	220.65	0.00355
Y	218.20	0.00338
B	225.25	0.00328

IR Value was as Follows

	15 Sec	60 Sec
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HV to Earth	200 MΩ	225 MΩ
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During April 2014, in shutdown condition tap changed from 11 to 12 as per requirement of LDC.

During Sept. 2014 AOH works, gasket of B phase LV bushing was replaced. Oil Filtration was carried out, capacitance and ten delta measurements of HV bushing were recorded.

Phase	Voltage in kV	Capacitance pF	Tan δ
R	2	222.93	0.0014
	5	224.09	0.0010
	10	224.11	0.0009
Y	2	214.34	0.0035
	5	214.26	0.0043
	10	214.11	0.0043
B	2	223.94	0.0174
	5	224.10	0.0172
	10	224.12	0.0172

IR Values was as follows

	15 Sec	60 Sec
HV to Earth	240 MΩ	260 MΩ

Transformer oil tests were carried out using CPRI mobile van during Feb-2014 and Feb. 2015 CPRI remark dated 10-02-2015 are as follows.

1. Oil parameters are within the permissible limits as per IS/1866-2000
2. DGA results indicate normal internal condition. It is recommended to monitor the transformer after one year as a routine maintenance check.

- N. Details of previous failure : No Previous Failure
- O. Sequence of events/ Description of failure : From sequence Event recorder (SER) it is found that the GT Restricted Earth Fault relay, Overall differential relay, Buchholz stage-I & II, OLTC Surge Relay, winding temp high, oil temp high etc., had operated. The GT caught fire.
- P. Details of Tests done after failure : M/s CGL representative arrived at RTPS site and inspection & testing of GT3 was carried out on 26.05.2015 & 27.05.2015
1. The LV tests on the faulty GT (Magnetic Balance, turns ratio test, magnetizing current measurement & (insulation resistance) were conducted.
  2. Y-phase of LV winding indicates shorted turns, since it was drawing more current as per LV tests.

3. Melted Copper granules/ buds was found deposit on Y-phase Compression board, yoke and it between HV winding.

Q. Probable cause of failure : During LV tests conducted on GT after failure, Y phase LV winding was found to be carrying high current which indicates fault in the Y phase winding. This fault induced gas generation & high pressure in the tank resulting in operation of PRV and Buchholz relay. Flow of high fault current increased temperature of oil and windings.

**20. Failure of 207 MVA, 21/400 kV GT (Y phase) Unit # 1 at BTPS of KPCL.**

- A. Name of Substation : Bellary Thermal power Station
- B. Utility/Owner of substation : KPCL
- C. Faulty Equipment : GT (Y phase) Unit # 1
- D. Rating : 207 MVA, 21/400/ $\sqrt{3}$  kV
- E. Make : BHEL
- F. Sr. No. : 6006698
- G. Year of manufacturing : 2012
- H. Year of commissioning : 2015 (April 22<sup>nd</sup>)
- I. Date and time of occurrence/discovery of fault : 28.08.2015 at 22:52 hrs
- J. Information received in CEA : 04.11.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced

- M. Details of previous maintenance : Following works were carried out during AOH in Aug 2015:
- a. Oil Filtration
  - b. Checking of healthiness of temperature indicators
  - c. Checking of healthiness of oil level indicators
  - d. Checking of transformer protection/annunciation circuits
  - e. Checking of healthiness of radiator fans/pump circuits
  - f. Periodic oil testing by CPRI Bangalore
- N. Details of previous failure : Failed on 06.04.2015 at 14:06 hrs
- O. Sequence of events/ Description of failure : Unit-1 was under shutdown from 07.08.2015 to 28.08.2015 for annual overhauling. After the completion of overhauling activities, synchronization activity started on 28.08.2015 @ 22:15 Hrs. Unit-1 turbine speed was brought to 2957 RPM. Then excitation system was started in auto mode from HBP (Hardwired Backup Panel) in UCB room. Immediately unit-1 got tripped @ 22:15:05:946 Hrs. with the following protections & annunciations even before synchronization of the unit.
1. Unit-1 tripped on class A protection as detailed below:
    - 1.1 Gen circuit breaker was already in open condition.
    - 1.2 Group-2: Gen & GT R Phase Overall Differential protection operated 87OAR static relay.
    - 1.3 Group-2: Gen & GT Y Phase Overall Differential protection operated 87OAY static relay
    - 1.4 Group-2: Aux. to 87OA operated 87OX
    - 1.5 Group-2: GT Buch. Trip Y phase operated 30GTC.
    - 1.6 Group-2: GT PRV-B Y phase operated 30GTH.
    - 1.7 Group-2: 286A, 286X, 286AY operated.
    - 1.8 Group-1: Timer for 186A operated 2/186A.
    - 1.9 Group-1: 186A, 186AX, 186AY operated.
    - 1.10 Group-1: Timer for 2/286A operated.
    - 1.11 Group-1: GT PRV-A Y phase operated 30GTP.
    - 1.12 Group-1: 87/51NGT numerical relay: LED7: 2<sup>nd</sup> Harmonic block.

- 1.13 Group-1: 87/51NGT numerical relay: LED1: General trip.
- 1.14 Group-1: 87/51NGT numerical relay: LED3: Y phase Diff. trip.
- 1.15 Group-1: GR1 numerical relay: LED11: VT fuse failure
- 1.16 Group-1:GR1 numerical relay : LED12:CB open
- 1.17 Group-1:GR1 numerical relay : LED14: Dead machine trip.
- 1.18 Group-2:To aux.21G backup impedance R&Y flag operated. 21G2X
- 1.19 Group-2: Timer for 21 G2 operated 2/21G2A.
- 1.20 Group-2: Timer for 21G2 operated 2/21G2B
- 1.21 Group-2: 286C, 286CX operated.
- 1.22 Group-2: Timer for 186C operated 2/186C.
- 1.23 Group-1: 186C, 286CX operated.
- 1.24 Group-1: Timer for 2/286C operated.
- 1.25 Group-1: VT WDG1 fuse fail 60G 11 operated.
- 1.26 Group-2: NPS alarm 46G2.
- 1.27 286TU, 186TU operated.
- 1.28 Field CB open.
- 1.29 Turbine tripped.

A team of experts from BHEL Bhopal inspected the site and observed following points during inspection/investigation:

- 1. LV side turret got deformed & 2 nos. stiffeners got damaged at top near LV turret. Oil spilled from LV turret sealing.
- 2. HV bushing was dismantled and no physical damage was noticed.

- P. Details of Tests done after failure : 1. During testing LV side magnetizing current was found 26.5mA as against pre-commissioning value of 8mA.  
2. Continuity between HV & neutral terminal showing 9.9K $\Omega$ .  
3. IR values were more than 1.6 G $\Omega$  for all the windings.  
4. Isolation (CC-CL-E) more than 10 M $\Omega$ .
- Q. Probable cause of failure : During excitation/voltage building there appears to be failure of LV windings which resulted in operation of electrical protections, PRV & Buchholz relay. LV side turret got deformed and oil spilled

over from LV turret sealing due to excessive oil pressure in GT.

**21. Failure of 250 MVA, 15/420 kV, 3-ph Generator Transformer at Raichur Thermal Power Station of KPCL**

- A. Name of Substation : Raichur Thermal Power Station
- B. Utility/Owner of substation : Karnataka Power Corporation Ltd.
- C. Faulty Equipment : GT-4
- D. Rating : 250 MVA, 15/420 kV
- E. Make : M/s CGL
- F. Sr. No. : T-8331
- G. Year of manufacturing : 1993
- H. Year of commissioning : 1994 (Sept 28<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 28.02.2016 at 0811 hrs
- J. Information received in CEA : 22.07.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced with 3 ph 250 MVA 15.75/420 kV transformer (TELK make) (Rewound/reconditioned failed GT-7)
- M. Details of previous maintenance : Oil filtration, BDV test, capacitance and tan delta tests etc. were carried out during overhauling in August 2014 and August 2015. Annual testing of transformer oil was done by CPRI.
- N. Details of previous failure : Information not available
- O. Sequence of events/Description of failure : During the synchronization of GT-4, the unit tripped with sound. Sequence event recorder indicates that the GT PRD, Overall differential relay, Buchholz

stage-II had operated. Oil spillage was observed from PRD.

- P. Details of Tests done after failure : Following tests were carried out on failed GT on 29.02.16:
- a. IR test
  - b. Turns ratio test
  - c. Magnetic balance test
  - d. Winding resistance test

INSULATION RESISTANCE TEST:

	T1(10 secs)	T2(60 secs)	PI
HV TO LV(5KV)	530 M $\Omega$	1.36 G $\Omega$	2.58
LV TO E(1KV)	914 M $\Omega$	1.96 G $\Omega$	2.15
LV TO E(5KV)	453 M $\Omega$	8.69 M $\Omega$	1.91
HV TO E(1KV)	1.01 G $\Omega$	1.73 G $\Omega$	1.71
HV TO E(5KV)	648 M $\Omega$	1.31G $\Omega$	2.01
CORE TO E		90 K $\Omega$	

TRANSFORMER TURNS RATIO TEST:

TAP POSITION	R	Y	B
1	36.16	17.99	835.2
2	35.75	17.79	835.5
3	35.33	17.57	838.0
4	34.91	17.37	827.3
5	34.12	16.96	842.2
6	34.11	16.96	843.7
7	33.71	16.75	860.9
8	33.29	16.55	854.9
9a	32.88	16.34	862.34
9b	32.84	16.34	865.3
9c	32.84	16.32	846.3
10	32.45	16.12	847.6
11	31.90	15.88	794.7
12	31.50	15.68	812.1
13	31.09	15.48	796.7
14	30.69	15.27	817.1
15	30.30	15.08	830.2
16	29.92	14.88	843.1
17	29.52	14.70	880.1

MAGNETIC BALANCE TEST:



RN	YN	BN	ry	yb	Br
244V	244V	0V	12V	12V	0V
244V	244V	0V	12V	12V	0V
55V	63V	243V	0V	0V	0V

**MAGNETISING CURRENT TEST:**

**HV SIDE (APPLIED VOLTAGE 246.2 VOLTS)**

TAP 1	
RN	1.192 mA
YN	1.231 mA
BN	1740 mA

**LV SIDE (APPLIED VOLTAGE - 30 VOLTS)**

TAP 1	
ry	29.09 mA
yb	29.05 mA
br	12.51 mA

**WINDING RESISTANCE TEST:**

TAP NO.	RN	YN	BN	ry	yb	br
1	0.7601 $\Omega$	50.96 m $\Omega$	50.54 m $\Omega$	1.55 m $\Omega$	5.36 m $\Omega$	5.60 m $\Omega$
2	0.7544 $\Omega$	50.96 m $\Omega$	50.65 m $\Omega$			
3	0.7484 $\Omega$	50.96 m $\Omega$	50.70 m $\Omega$			
4	0.7428 $\Omega$	50.96 m $\Omega$	50.98 m $\Omega$			
5	0.7371 $\Omega$	50.96 m $\Omega$	51.00 m $\Omega$			
6	0.7313 $\Omega$	50.96 m $\Omega$	51.02 m $\Omega$			
7	0.7255 $\Omega$	50.95 m $\Omega$	51.03 m $\Omega$			
8	0.7201 $\Omega$	50.96 m $\Omega$	51.04 m $\Omega$			
9a	0.7118 $\Omega$	50.95 m $\Omega$	51.05 m $\Omega$			
9b	0.7117 $\Omega$	50.95 m $\Omega$	51.05 m $\Omega$			
9c	0.7115 $\Omega$	50.95 m $\Omega$	51.05 m $\Omega$	1.58 m $\Omega$	6.68 m $\Omega$	5.77 m $\Omega$
10	0.7196 $\Omega$	50.94 m $\Omega$	51.05 m $\Omega$			
11	0.7252 $\Omega$	50.93 m $\Omega$	51.06 m $\Omega$			
12	0.7311 $\Omega$	50.92 m $\Omega$	51.05 m $\Omega$			
13	0.7367 $\Omega$	50.88 m $\Omega$	51.04 m $\Omega$	1.58 m $\Omega$	6.83 m $\Omega$	5.92 m $\Omega$
14	0.7426 $\Omega$	50.85 m $\Omega$	50.93 m $\Omega$			
15	0.7483 $\Omega$	50.81 m $\Omega$	50.88 m $\Omega$			
16	0.7542 $\Omega$	50.78 m $\Omega$	50.89 m $\Omega$			

17	0.7601 $\Omega$	50.78 m $\Omega$	50.90 m $\Omega$	1.72 m $\Omega$	7.24 m $\Omega$	6.11 m $\Omega$
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- Q. Probable cause of failure : Operation of overall differential, PRD and buchholz indicate towards internal fault. High energy arcing due to fault inside the transformer tank might have led to sudden pressure rise in tank and tripping of Buchholz & PRV. Magnetic balance test (zero voltage across B-phase winding) and magnetizing current measurement (1740 mA in B-phase which is very high) test reports indicate that inter-turn fault might have taken place in phase B. However, Internal inspection of GT is required to assess actual cause of failure and condition of windings & core.

## REACTORS

### **22. Failure of 420 kV, 80 MVAR Bus reactor at 400 kV Kota substation of PGCIL**

- A. Name of Substation : 400 kV Kota Substation
- B. Utility/Owner of substation : PGCIL
- C. Faulty Equipment : Bus reactor
- D. Rating : 420 kV, 80 MVAR
- E. Make : BHEL
- F. Sr. No. : 6006288
- G. Year of manufacturing : 2008
- H. Year of commissioning : 2009 (25<sup>th</sup> February)
- I. Date and time of occurrence/discovery of fault : 28.09.2016 at 00:43 hrs.
- J. Information received in CEA : 08.12.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : To be replaced
- M. Details of previous maintenance :

The said Reactor was having higher levels of CO & CO<sub>2</sub> since commissioning; however, furan traces were normal. The moisture levels were high since commissioning as evident from the oil test results in Table 1. Reactor was dried out twice in April & September 2015, but moisture reappeared after recommissioning. In DGA sample dated 13.08.2016, violation of H<sub>2</sub> was observed and same was found to be in increasing trend in subsequent samples (Refer: Table 1). Busing DGA was carried out in April 2016 and increase in H<sub>2</sub> was observed in Y phase bushing DGA (Refer: Table 2).

Controlled switching device for reactor switching was commissioned on 21.09.13, and has been in successful operation since then.

Table 1

Sample Date	H <sub>2</sub>	CH <sub>4</sub>	C <sub>2</sub> H <sub>4</sub>	C <sub>2</sub> H <sub>6</sub>	C <sub>2</sub> H <sub>2</sub>	CO	CO <sub>2</sub>	Water
28-Sept-16	1518	355	447	42	365	182	3623	Failure Date
06-Sept-16	544	27	5	3	0	203	4206	17
13-Aug-16	200	14	5	2	0	208	7599	19
5-Mar-16	21	4	4	1	0	150	5548	15
6-Jan-16	57	4	3	1	0	150	4838	13
24-Oct-15	17	1	2	1	0	94	1098	19
7-Sep-15	0	0	0	0	0	1	20	4
19-Jun-15	21	3	5	1	0	112	2103	21
20-Apr-15	0	1	1	0	0	30	554	22
21-Mar-15	40	33	15	9	0	410	20159	19
29-Nov-14	75	36	17	9	0	480	20717	19
25-Oct-13	37	26	16	8	0	369	16669	14
4-Jul-12	39	22	16	6	0	275	14076	19
25-Nov-11	59	22	16	13	0	313	13536	12
7-Oct-10	32	12	12	4	0	234	8506	17
9-Oct-09	21	5	6	0	0	107	3951	10
1-May-09	0	0	0	0	0	3	244	10
1-May-09	0	0	0	0	0	3	244	7

Table 2

Bushing	Sample Date	H <sub>2</sub>	CH <sub>4</sub>	C <sub>2</sub> H <sub>4</sub>	C <sub>2</sub> H <sub>6</sub>	C <sub>2</sub> H <sub>2</sub>	CO	CO <sub>2</sub>	Water
R Phase	19.09.2014	0	13	2	42	0	73	1624	16
	28.08.2013	59	25	2	43	0	230	1541	0
Y Phase	30.04.2016	177	42	2	76	0	466	6192	0
	19.09.2014	115	44	4	77	0	637	5591	12
	28.08.2013	92	36	3	67	0	551	4149	0
B Phase	30.04.2016	91	34	2	43	0	487	9088	0
	19.09.2014	76	33	2	46	0	395	7831	15
	28.08.2013	70	29	2	41	0	308	6200	0

N. Details of previous failure : No previous failures

O. Sequence of events/ :  
Description of failure

On 28.09.2016 at 00:43 hrs., 420 kV, 80 MVAR Bus reactor tripped on operation of following relays.

SEQUENCE OF EVENTS		
28-09-16	00:39:31:542 hrs	Buchholz Alarm operated
28-09-16	00:43:12:248 hrs	Differential Operated
28-09-16	00:43:12:288 hrs	PRD relay Operated
28-09-16	00:43:31:253 hrs	TEE Differential Operated
28-09-16	00:43:12:263 hrs	REF Operated
28-09-16	00:43:12:271 hrs	Master Trip relay- 86 A Operated
28-09-16	00:43:12:272 hrs	Master Trip relay-86 B Operated
28-09-16	00:43:12:305 hrs	Buchholz Trip Operated

Reactor immediately caught fire and fire was extinguished by fire hydrant system within few minutes of occurrence of incidence. Fault current of 9.54 kA rms was observed in B-phase winding of Bus Reactor. Increment of 01 number was observed in reactor LA counter of B-phase.

P. Details of Tests done after :  
failure

**1. DGA**

Sample Date	H2	CH4	C2H4	C2H6	C2H2	CO	CO2
28-Sept-16	1518	355	447	42	365	182	3623

**2. Magnetization Current Test**

Phase	Previous value in mA	Post failure value in mA
R	110	110
Y	109	109
B	108	110

**3. Winding Resistance Measurement**

Combination	Pre Failure Results in mΩ	Post Failure Results in mΩ
R-N	2035	2044
Y-N	2048	2054
B-N	2043	2041

#### 4. Insulation Resistance Measurement

Date	Winding-Earth (60 Sec)	Winding-Earth (600 Sec)	PI
04.10.2016	1.283 G ohm	1.95	1.51
08.04.2015	1.2 G ohm	1.84 G ohm	1.53

#### 5. Core Insulation Measurement

Combination	Pre Failure Results in MΩ
CC-CL	>1000 MOhms
CC-Earth	0.4 MOhms
CL-Earth	>1000 MOhms

Q. Observations :

Following observations were made by PCGIL Officials:

- i. All 420 kV bushings were found to be damaged. B phase bushing was found to be burnt and bent from flange. Oil end side porcelain of B phase bushing was found to be completely shattered & air end porcelain was found broken from flange cementing joint.
- ii. Oil end side porcelain of R-phase bushing was found to be damaged. The porcelain part of neutral bushing was found to be slightly dislocated.
- iii. Tank top cover was found to be bulged from the tank top welded joints and cracks were observed in stiffener from tank top. Foundation bolts/nuts were also found to be damaged/dislocated from original position.
- iv. Flashover marks were found on the lower end of BCT portion and corona ring in B-phase bushing. CT terminal block of B-phase turret was found damaged.
- v. Y-phase winding was found to be damaged severely nearer to lead take off. However, no flashover/ blackening marks were found in this area.
- vi. Carbon particles and porcelain pieces were found to be accumulated at the bottom of the tank.
- vii. Entire core coil assembly was found to be shifted towards right (looking from Neutral side) and dislocated from the transportation block. Cracks have also been observed in transportation support block.
- viii. The possibility of deformation of core cannot be ruled out; detailed assessment can be made only after factory inspection.
- ix. During fire extinguishing, water was poured through hydrant point over the damaged bushing and water ingressed into the reactor. Therefore, healthiness of windings can't be assessed at site.
- x. B-phase LA and post insulator of isolator were found to be damaged.

xi. Core Insulation leads were checked and were found to be intact.

R. Probable cause of failure :

Prima facie, the fault seems to have been initiated from B phase as the fault current of 9.54 kA has flown in B phase to ground. The flashover marks were observed in lower section of Bushing CT portion and corona shield and no other flash over marks were observed inside the reactor. It is suspected that failure occurred due to shattering of oil end portion of B phase bushing. Damage to the Y phase winding and other bushing were the consequences of the B phase bushing failure according to PGCIL official report.

As envisaged from the moisture content test results, presence of moisture in the reactor was since commissioning. So atmospheric exposure of winding during manufacturing processing or during storage and commissioning of the reactor cannot be ruled out.

Further, shifting of core coil assembly was observed during inspection. It is suspected that shifting of CCA might have occurred during transportation. FRA signature was not available at site for comparative analysis.

### **23. Failure of 420 kV, 50 MVAR Vindhychal-III Line reactor at Satna substation of PGCIL**

- A. Name of Substation : 400 kV Satna S/s
- B. Utility/Owner of substation : PGCIL
- C. Faulty Equipment : Line reactor
- D. Rating : 420 kV, 50 MVAR
- E. Make : BHEL
- F. Sr. No. : 6006322
- G. Year of manufacturing : 2005
- H. Year of commissioning : 2006(Sept. 19)
- I. Date and time of occurrence/discovery of fault : 05.11.15 at 0707 hrs
- J. Information received in CEA : 05.02.16
- K. Fault discovered during : Operation

- L. Present condition of equipment : Considering the damage, failed Reactor is found to be beyond repair. Reactor including main tank, radiator pipes and accessories, Lightning arrestors, power and control cables found to be completely damaged and needs complete replacement.
- M. Details of previous maintenance : The said Reactor was operating satisfactorily till August 2015. Sudden jump in all fault gasses including  $C_2H_2$  (16 PPM) was observed on 17.09.2015 and same was confirmed in subsequent sampling on 22.09.2015. The Reactor was taken out from service on 23.09.2015 and internal inspection was carried out by PGCIL officials on 01.10.2015 & all three bushings were taken out from main tank. Hot Spot & pitting mark were found in R-phase winding lead terminal. Further, looseness in bolt between busing lead & winding lead of R phase were observed and same were attended. Also B phase bushing was replaced due to crack in flange. Tightening of bolts was carried out and CRM of R-Phase winding lead terminal were found to be 7.7 micro ohm after tightening. Insulation was provided on lead joint for all HV Bushing. Also, there was hair crack in B-phase bushing of BHEL make since commissioning and same was replaced with CGL make Busing. The 150NB connecting pipe used for main tank & Radiator bank had been replaced with 200NB pipe for better cooling and the Reactor was charged on dated 21.10.2015.
- N. Details of previous failure : None
- O. Sequence of events/ Description of failure :

Following are the events during failure of the Reactor:

- a) On 05.11.15, at 07:07:07.843, 420 kV, 50 MVAR Vindhyachal #3 Line Reactor (LR) tripped on operation of REF protection and immediately caught fire. Heavy noise was heard by the shift engineer in control room. Fire protection operated automatically immediately after failure and fire hydrant system was used to control the fire. However, fire was so severe that fire tender was called for extinguishing the fire and fire persisted till 06.11.15 evening. 400 kV line was taken into service at 12:37 hrs on 05.11.15 without line reactor. Fault occurred in B-phase of the reactor and fault Current was approx. 27kA. Other slow protection (Buchholz, PRD, WTI, and OTI) did



not operated at the time of tripping resulting in confirmation that the fault was not incipient and fault was sudden may be due to internal fault.

- b) At 07:07:07.887, the breaker opened, fault current appeared in Y phase of Vindh#3 LR may be due to re-striking voltage. Fault current – 7.09kA
- c) At 07:07:12.051hrs., 765kV ICT#2 tripped due to operation of High set element of Diff Protection caused by rise in current in R Phase probably due to dense smoke formed during failure of Reactor. R phase of 400kV Side of ICT is physically adjacent to the failed Line Reactor of 400kV Vindhychal-Satna#3.
- d) At 07:07:12.493, Vindh#4 Line auto reclosed on B – E Fault. This B phase of Vindh#4 line is adjacent to failed reactor of Vindh#3. The fault has been seen by relay in Z1 and it is also confirmed from remote end that fault seen by remote end relay in Z2.
- P. Details of Tests done after : Reactor had completely burnt and it was not failure possible to carry out any test.
- Q. Observations :
1. Reactor Tank Top welding was uprooted, and was sheared off towards B-phase side and heavy bulging of the Tank was observed towards B Phase.
  2. B-Phase Bushing was shattered. Stress shield of B-phase bushing shows no flash over marks. Y Phase Bushing flange cracked and slipped inside the Reactor Tank. Stress shield of the Y phase found with no flash over marks. R Phase Bushing flange and its air end was found damaged. Stress shield of the R Phase Bushing was completely burnt out. The Neutral Bushing was also damaged.
  3. No distortion was observed in the top yoke of the Reactor.
  4. The axial coil pressing rings of all 3 phases were completely burnt and top shunt of R and Y phase fell on the Reactor winding.
  5. Top portion of R phase and Y phase core limbs were damaged due to excessive fire inside the Tank.
  6. All Turret CT of R, Y & B phase were completely burnt in this fire incidence.
  7. Due to heavy fire inside the Reactor Tank all winding insulations completely burnt.
  8. Reactor transport support block were observed intact.

9. The marshalling box, cables, radiator pipe line were also damaged badly due to fire. Conservator tank and Radiator bank were found to be visually ok. However, healthiness of the same needs be ensured.
10. All cleat support and insulation of the Reactor Tank were completely burnt out.
11. NGR, NGR MB, Breather, Buchholz and PRD were found be visually ok and healthiness of the same needs to be ascertained.

R. Probable cause of failure :

From the DR, it was observed that fault current of 27kA passed through B phase winding. On internal inspection, end shields of B phase and Y phase bushings were found to be intact however R phase end shield was found to be completely burnt. Winding and bushing lead joints of the B phase bushing was found to be intact. There were no flashover marks on the bushing core except burning marks. In view of the above, it was suspected that fault might have been initiated from the B phase winding.

**24. Failure of 765 kV, 80 MVAR, Reactor (Y-phase) of Gwalior-II line at 765 kV Bina substation of PGCIL**

- A. Name of Substation : 765 kV Bina Substation
- B. Utility/Owner of substation : PGCIL
- C. Faulty Equipment : Line Reactor (Y-phase)
- D. Rating : 765 kV, 80 MVAR
- E. Make : CGL
- F. Sr. No. : BH09821/07
- G. Year of manufacturing : 2012
- H. Year of commissioning : 2012 (24<sup>th</sup> December)
- I. Date and time of occurrence/discovery of fault : 28.11.2015 at 22:36 hrs.
- J. Information received in CEA : 08.12.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Information not available

M. Details of previous :  
maintenance

**DGA History:**

Sampling Date	H <sub>2</sub>	CH <sub>4</sub>	C <sub>2</sub> H <sub>4</sub>	C <sub>2</sub> H <sub>6</sub>	C <sub>2</sub> H <sub>2</sub>	CO	CO <sub>2</sub>
04/06/2015	24	33	2	6	0	280	620
09/07/2015	28	38	2	6	0	347	570
14/08/2015	25	36	2	6	0	324	557
16/09/2015	28	39	2	7	0	362	648
15/10/2015	25	37	2	7	0	338	657
19/09/2015	24	37	2	7	0	338	605

**Tan δ & Capacitance Measurement:**

		Pre-Commissioning (24.12.2012)	25.08.2015	
Tan δ	R	0.30%	0.30%	
	N	0.38%	0.37%	
Capacitance	R	587 pF	586 pF	
	N	270 pF	271 pF	
		Capacitance	Tan Delta	
WINDING	Tested on 17.02.2014	Factory result	Tested on 17.02.2014	Factory result
HV/Tank-E	4.385 nF	4.394 nF	0.232%	0.197%

N. Details of previous failure : Nil

O. Sequence of events/ : On 28.11.2015 at 22:36 hrs. 765 kV, 80 MVAR CGL  
Description of failure make Gwalior-II Line Y- Phase Reactor installed at Bina s/s tripped & failed on operation of REF protection along with initiation of Differential/Back up impedance/Body protections. Sequence of events are as follows:

S/s	Time	Protection	Fault current
Bina End	22:36:36.679 hrs.	REF Optd	496 A
	22:36:36.693 hrs.	Diff Optd	12.8 kA
	22:36:36.701 hrs.	DT Send Ch 1 & 2	
	22:36:36.707 hrs.	Main 2 Zone 1 optd	21.8 kA
	22:36:36.718 hrs.	Main 1 Zone 1 optd	
	22:36:36.722 hrs.	Main CB Open	
	22:36:36.723 hrs.	Tie CB Open	

	22:36:36.746 hrs.	Buch 1/2 Alarm Y-Ph	
	22:36:36.824 hrs.	Buch 1 Trip Y-Ph	
	22:36:36.886 hrs.	Buch 2 Trip Y-Ph	
	22:36:37.121 hrs.	PRV 2 Y-Ph optd	
	22:36:37.474 hrs.	PRV 1 Y-Ph optd	
Gwalior End	22:36:36.735 hrs.	DT Receive	3.33 kA
	22:36:36.749 hrs.	Main 1 ZCOM Optd	
	22:36:36.746 hrs.	Main 2 ZCOM Optd	
	22:36:36.774 hrs.	Main & Tie CB Open	

P. Details of Tests done after : LV test were carried out on 01.12.2015.  
failure

**1. Winding C & Tan Delta measurement:**

Winding C & Tan delta in GST mode	Factory value at 10 kV	Post tripping site value at 10 kV
10 kV	4.3943 nF, 0.197%	3.0875 nF, 24.4362%

It is observed that winding Capacitance post failure reduced by 30%, whereas tan delta w.r.t ground increased many times.

**2. Insulation resistance measurement:**

Winding configuration	Pre- commissioning	Post tripping site value at 2.5 kV
CC-G(Frame to tank)	>20 G OHMS	0

CL-G(Core to Tank)	>20 G OHMS	121 MOHMS
CC-CL (Core to Frame)	>20 G OHMS	120 MOHMS
IR Value at 15 sec	29.8 G OHMS	15.0 MOHMS

IR values of CC-G became zero in Y-Phase.

**3. No Load magnetizing current at 230 Volts:**

HV - Neutral	Pre-commissioning value	Post tripping site value
234 V	97.169 mA (at 234 Volt)	94.8 mA (at 240 Volts)

It can be observed that LV magnetizing current post failure reduced around 2.4% compared to pre-commissioning.

**4. DC Winding Resistance at 75 degrees C:**

Pre-commissioning value	Post tripping site value
1.9373 Ohm	4.13 Ohm

The DC Winding resistance post failure is increased by 114% compared to pre-commissioning.

Q. Observations :

On physical inspection, following observations were made:

- i) Tank got severely bulged. Stiffeners were found cracked and oil oozed out of the reactor.
- ii) The reactor tank was bulged towards neutral side damaging the fire-fighting pipe line. The expansion bellow of bottom header to radiator was found distorted.
- iii) Neutral bushing porcelain was found cracked at bottom side.

(B) Internal Inspection:

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

- iv) Most of the pressboard barriers were found broken and burnt.
- v) The winding including insulation components viz., washers and caps were found to be dislocated.
- vi) Winding near HV bushing lead area was dislocated/deformed and the insulation over winding was also damaged badly. Bare copper was visible in the HV lead area. Similarly, copper was also visible in the bottom part of winding. HV bushing bottom end lead connected with corona shield was found to have burn marks.
- vii) Bottom SER (Static End Ring) was found burnt completely. Bottom end Yoke shunt was found dislocated.
- viii) Heavy charring of insulation was found inside the tank.

R. Probable cause of failure :

From the DR details, it is observed that heavy fault current of almost 21 kA passed through the winding during the failure. The Reactor tripped on REF protection and subsequently Differential/Backup impedance/Body protection also operated. From the LV tests done after failure, it can be observed that winding tan delta increased many times and IR values for CC-G is zero which indicates failure of insulation.

From the internal inspection, LV test result and DR details, it is suspected that there was an inter-turn fault in the winding near HV bushing termination and may be an internal flashover in the winding from HV bushing termination to the bottom portion of winding as copper was visible at these points. Failure of SER resulted in involvement of ground during failure causing initiation of REF protection.

**25. Failure of 420 kV, 125 MVAR Bus reactor-II at 400 kV Binaguri substation of PGCIL**

- A. Name of Substation : 400 kV Binaguri Substation
- B. Utility/Owner of substation : PGCIL
- C. Faulty Equipment : Bus Reactor-II
- D. Rating : 420 kV, 125 MVAR
- E. Make : BHEL
- F. Sr. No. : 6006854
- G. Year of manufacturing : 2009
- H. Year of commissioning : 2012 (28<sup>th</sup> March)
- I. Date and time of occurrence/discovery of fault : 29.02.2016 at 03:55 hrs.
- J. Information received in CEA : 08.12.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Repair at manufacturer's works was recommended.
- M. Details of previous maintenance :

**1. DGA & Oil Parameter History**

Fault gases especially H<sub>2</sub>, CH<sub>4</sub> and C<sub>2</sub>H<sub>4</sub> were showing increasing trend within a year of commissioning. C<sub>2</sub>H<sub>4</sub> and CO<sub>2</sub> violation in Reactor observed on 30.09.2013 and same was in rising trend till April 2015. C<sub>2</sub>H<sub>2</sub> of 1 ppm appeared on 24.03.2014 and same was stable thereafter.

BDV and moisture (ppm) were found to be normal prior to failure.

Sampling Date	H <sub>2</sub>	CH <sub>4</sub>	C <sub>2</sub> H <sub>4</sub>	C <sub>2</sub> H <sub>6</sub>	C <sub>2</sub> H <sub>2</sub>	CO	CO <sub>2</sub>
30.09.2013	43	16	70	8	0	163	4094
02.07.14	85	60	143	9	0	262	4614
26.09.14	74	53	123	15	0	161	4550
16.12.14	107	63	142	9	0	301	5343
12.02.15	120	69	168	20	0	323	5750
08.05.15	120	74	179	22	1.41	341	6016

07.01.16	118	98	211	22	0.6	397	7385
29.02.16(Pos t Failure	4344	703	919	82	645	503	6738
	BDV (kV)	Moisture (ppm)	Resistivity(F12 $\Omega$ -cm)	Tan $\delta$	IFT (mN/m )	Acidity (mgKOH/g )	Flash Point <sup>o</sup> C
05.08.2015	73.4	9	282.5	0.00 098	40.76	0.01315	148

Last bushing sampling was carried out in July 2014 and results were found to be normal. Variable frequency tan delta of bushings was carried out on 22.07.15 and values of all HV bushings were found to be normal.

## 2. Bushing DGA History

	Sampling Date	H <sub>2</sub>	CH <sub>4</sub>	C <sub>2</sub> H <sub>4</sub>	C <sub>2</sub> H <sub>6</sub>	C <sub>2</sub> H <sub>2</sub>	CO	CO <sub>2</sub>
Y- $\phi$ 1146053	07.07.2014	47	2	0	0	0	257	856
	02.08.2013	21	1	0	0	0	128	475
R- $\phi$ 1146057	07.07.2014	36	3	0	0	0	425	1077
	02.08.2013	18	2	0	0	0	228	618
B- $\phi$ 1144075	07.07.2014	32	2	0	0	0	220	795
	02.08.2013	15	2	0	0	0	122	402
Neutral 1160575	02.11.2015	91	19	0	6	0	531	1357
	07.07.2014	79	18	0	6	0	449	1008
	02.08.2013	48	10	0	3	0	266	584

N. Details of previous failure : Nil

O. Sequence of events/ : On 29.02.2016 at 03:55hrs., heavy noise was heard and 420 kV, 125 MVAR Binaguri Bus Reactor-II tripped on operation of following protection:  
Description of failure

Sequence of event as per SER	Description
03:55:39:086	Differential Protection (Micom-643)
03:55:39:121	REF Protection (CAG-14)
03:55:39:122	Main CB Y phase open
03:55:39:123	Main CB B phase open
03:55:39:124	Main CB R phase open
03:55:39:131	Tie CB B Phase open
03:55:39:132	Tie CB R& Y Phase open

03:55:39:143	PRV trip
03:55:39:162	WTI Trip
03:55:39:179	OTI Trip
03:55:39:266	Buchholz Trip

From the DR, it was observed that fault current of 14.4 kA rms passed through Y phase during fault condition. Fault was cleared within 46 msec.

P. Details of Tests done after :  
failure

DGA result post failure:

Sampling Date	H <sub>2</sub>	CH <sub>4</sub>	C <sub>2</sub> H <sub>4</sub>	C <sub>2</sub> H <sub>6</sub>	C <sub>2</sub> H <sub>2</sub>	CO	CO <sub>2</sub>
29.02.16(Post Failure)	4344	703	919	82	645	503	6738

Q. Observations :

Following observation were made by PGCIL officials:

1. Reactor tank top cover welding was uprooted and bulging of the tank was observed towards HV side.
2. Porcelain of B-Phase Bushing air end was shattered from the mid-section porcelain joint portion. Flanges of R & Y phase were found to be intact. Stress shields of all bushings were found intact. Porcelain of oil end portion of the bushing found to be normal in R & B phase bushings. However, same got detached/separated from the metallic joints. Porcelain of oil end portion of the Y-phase bushing was found to be shattered.
3. Heavy carbonization, porcelain pieces and burnt paper/ press board were found accumulated at the top of the core and at the bottom of the tank.
4. Burning and damage of outer press board cylinder insulation was observed in Y phase winding.
5. Guide Aluminum pipe for lead of Y phase was found to be displaced from its position. Heavy carbonization observed in Y phase winding nearer to lead take off point. Snout of Y phase was found to be burnt and winding lead take-off came out from its position. Melting of laminations in bottom yoke shield were observed in Y phase limb at three locations. Surface discharge over press board cylinder was observed from lead take-off to bottom yoke shunt. However, no flash over / burning marks were observed in other press board barrier layer in Y phase winding.
6. Melting of Aluminium lead guide tube of Y phase winding and pitting & burning of paper insulation were observed. Connecting lead between Aluminium lead guide tube and lead



take-off point was found to be detached. Further, pitting mark was also observed in connecting lead between winding take off and bushing lead.

7. Snout of Y phase winding was found completely burnt. Burning of paper insulation & flash over marks on the surface of Y- $\phi$  winding near to lead take-off along with carbon deposition were found in the same location.

8. Turret CTs of all three phase were found to be damaged and cannot be reused.

9. Prima facie, R and B phase winding were found to be visually OK from outside.

10. No distortion was observed in the top yoke of the Reactor.

11. Inspection of Neutral side of the Reactor could not be possible due to less access area. Porcelain of neutral bushing was found to be displace from its position; however, oil level was found to be normal in the bushing.

12. Minor cracks were observed in equalizing connecting pipes. Marshalling box, cables, conservator-reactor tank pipe line and other accessories seemed to be visually OK.

13. Any leakage in Conservator, radiator bank and air cell has to be assessed during recommissioning of Reactor.

14. Due to opening of welded joints, nearly 5 kL, oil spilled out from Reactor during failure and completely wasted.

15. LV tests like magnetizing current & winding resistance test result after failure were found to be comparable with pre-commissioning results and last maintenance results.

R. Probable cause of failure :

From the DR, it was observed that fault current of 14.4 kA passed through Y phase during fault condition. On internal inspection, no flash over mark was observed inside the tank nearer to the bushing end shield. Also end shield of Y phase bushing was found to be intact and no burning and flash over mark was observed in the shattered porcelain area of Y phase bushing oil end portion. In view of the above, failure on account of bushing may be ruled out. Further as evident from the inspection, surface discharge was observed on press board cylinder of Y Phase winding. Tracking in between Aluminium lead guide tube and bottom yoke shunt of Y- phase was observed. As the connecting lead between winding take-off and Aluminium lead guide tube found detached, voltage stress on the lead guide tube may lead to DGA violation as indicated in post failure oil sampling test results. Duval triangle DGA analysis indicates thermal fault. Reason of conduction and tracking between lead guide tube and bottom yoke shunt could not be found out during inspection. Reactor was recommended for repair at manufacturer's works.

**CIRCUIT BREAKERS****26. Failure of SF-6 circuit Breaker (R-phase limb), CT (R phase) & Line Isolator controlling 220 kV Chajipur ckt-I at 400 kV Panipat substation of BBMB.**

- A. Name of Substation : 400 kV s/stn. Panipat
- B. Utility/Owner of substation : BBMB
- C. Faulty Equipment : SF-6 Circuit Breaker (R-phase Limb), CT (R phase) & Line Isolator controlling of 220 kV Chajipur ckt-I
- D. Rating : 220 kV (CB, CT & Line Isolator)
- E. Make : 1. Siemens (R phase CB)  
2. SCT (R phase CT)  
3. Elektrolites (Power) Pvt. Ltd. (Line Isolator)
- F. Sr. No. : 1. IND/02/3182 (R phase CB)  
2. 2011/47 (R phase CT)  
3. Information not available for Line Isolator
- G. Year of manufacturing : 1. 2007 (R phase CB)  
2. 2014 (R phase CT)  
3. 2011 (Line Isolator)
- H. Year of commissioning : 2015 (May 29<sup>th</sup>) for R phase CB, R phase CT & Line Isolator
- I. Date and time of occurrence/discovery of fault : 31.05.15 at 21:13 hrs.
- J. Information received in CEA : 21.10.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Damaged
- M. Details of previous maintenance : Nil (Commissioned on 29.05.2015)
- N. Details of previous failure : Nil

- O. Sequence of events/ Description of failure : On 31.05.2015 at 21:13 hrs, a loud bursting sound was heard and the equipment were found damaged.
- P. Details of Tests done after failure : As the equipment burst, the tests after failure were not possible.
- Q. Probable cause of failure: : Sufficient information is not available to draw any conclusion. It might be possible that one of the equipment burst and its debris damaged other two equipment. Detail about operation of any protection is also not available.

**27. Failure of 220 kV Circuit Breaker of Varahi line- 2 at 220 kV Kemar substation of KPTCL.**

- A. Name of Substation : 220 kV Receiving Station, Kemar, Karkala
- B. Utility/Owner of substation : KPTCL
- C. Faulty Equipment : Circuit Breaker
- D. Rating : 245 kV
- E. Make : ABB
- F. Sr. No. : SB 98006DD019
- G. Year of manufacturing : 1998
- H. Year of commissioning : 2000
- I. Date and time of occurrence/discovery of fault : 20.10.2015 at 15:50 Hrs.
- J. Information received in CEA : 12.12.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced
- M. Details of previous maintenance : The SF6 gas leakage in the said breaker drive mechanism was attended by the ABB service engineer on 14.07.2010.
- N. Details of previous failure : Nil

- O. Sequence of events/ Description of failure : The 'Y' Phase Limb of 220 kV Kemar- Varahi line- 2 flashed over on 20.10.2015 at 15:50 Hrs. with a heavy sound. While flashing over it damaged the other two breaker limbs of the 'R' and 'B' phase of the same breaker. The insulator was flashed over and contacts were burned. During this time heavy lightning was observed. The line was charged on 22.10.2015 at 14:10 Hrs. by using 220 kV Bus coupler breaker as controlling breaker. The faulty breaker limb is to be replaced by the breaker limb available in the spare bay of this station.
- P. Details of Tests done after failure : Nil
- Q. Probable cause of failure : Heavy current due to lightning might have damaged internal insulation of the breaker.

#### **28. Failure of B phase Tie Circuit Breaker at RTPS of KPCL**

- A. Name of Substation : Raichur Thermal Power Station
- B. Utility/Owner of substation : KPCL
- C. Faulty Equipment : Tie Circuit Breaker of Unit 7 (B- Phase)
- D. Rating : 2000 A
- E. Make : CGL
- F. Sr. No. : 15869 C
- G. Year of manufacturing : 2002
- H. Year of commissioning : 2002
- I. Date and time of occurrence/discovery of fault : 12.11.2015 at 00:30 hrs
- J. Information received in CEA : 22.12.2015
- K. Fault discovered during : During starting and excitation of the Unit after minor maintenance works in turbine.

- L. Present condition of equipment : Replaced
- M. Details of previous maintenance : AOH works carried out in Nov- 2014
- N. Details of previous failure : All the three interrupters had been replaced on 23.06.2010.
- O. Sequence of events/  
Description of failure : On 12.11.2015, after minor maintenance works in turbine, starting and excitation of the Unit was under process. The insulator of the breaker interrupter failed during Generator Voltage build-up.
- P. Details of Tests done after failure : Slow opening and slow closing of the newly erected B Phase interrupter and CRM, DCRM & Breaker timings of all the three phases were checked and found to be OK. M/s CGL (OEM) have inspected and cleared for charging.
- Q. Probable cause of failure : The insulator of the breaker interrupter might have failed due to Surface conduction during Generator Voltage build-up.

**29. Failure of 400 kV SF<sub>6</sub> CB (Y phase limb) at Bhiwani Substation of BBMB**

- A. Name of Substation : 400 kV Substation, Bhiwani
- B. Utility/Owner of substation : BBMB
- C. Faulty Equipment : 400kV SF-6 CB/X-2, (Yellow Phase)
- D. Rating : 420kV, 3150A, 40KA for 3 Sec.
- E. Make : CGL
- F. Sr. No. : 14263-C
- G. Year of manufacturing : 2001
- H. Year of commissioning : 2001 (May 19<sup>th</sup>)

- I. Date and time of occurrence/discovery of fault : 22.01.2016 at 21:18 Hrs.
- J. Information received in CEA : 17.02.2016
- K. Fault discovered during : Opening of 400 kV Bhiwani-Dehar Line (Through Direct Trip from Dehar end)
- L. Present condition of equipment : Yellow phase interrupter chamber including PIR and 1 No. Grading capacitor of this phase were damaged. Chipping on interrupter chamber of blue phase and chipping on 1No. Red Phase grading capacitor was also observed. The clamp of 400 kV yellow Phase CT was also damaged causing leakage of oil from primary terminal of CT.
- M. Details of previous maintenance : On 10.11.2015, during maintenance the results of breaker timings & Contact Resistance were found ok.
- N. Details of previous failure : On 24.12.2014 at 21:22 hrs, Y phase of 400 kV Bus-2 Graded Capacitor of CB/X-2 had failed.
- O. Sequence of events/ Description of failure : Tripping detail pertaining to the failure is as under:

Sr. No	Name of Equipment	Date & Time of Tripping & Restoration		Indication & Relays	Remarks
		Tripping	Restoration		
				This End	
1.	400 kV Dehar-Bhiwani Line with 400 kV Line reactor	22.1.2016 at 21:18 Hrs.	23.01.2016 at 11:45 Hrs.	<u>400 kv Dehar- Bhiwani Line</u> Facia:- 1) AR Lock out (CB- 5) 2) Main –II (MicomP442) Prot. Optd. 3) CB Trouble Alarm (CB X-2) 4) MCB-5 Tripped (CBX-2) <u>Main- II (MicomP442):</u> Started Phase BCN, Tripped Phase ABC, Over	Tripping occurred while opening due to high voltage yellow phase limb of 400 kV X2 found damaged.

				current start>123, Trip I > I, Fault in Zone-4 Relay: - 67NX, 85 LO Group 400 kv Bus- Bar: -87 BB, 87 B, B/B Prot. 400 KV Line- Reactor: - Facia- 3 Phase Trip Relay optd.,86 Trip Relay, REL-670 Trip, RET- 670 Trip	
2.	400 kV PGCIL Hisar & Bhiwani Line & Bus Reactor	-	22.01.2016 at 23.:27 Hrs.	Line opened on protection from other end	Opened manually at 21:30 Hrs. dt. 22.01.2016 ( As 400 kV System total supply failure)
3.	400 kV Bus Reactor	-	22.01.2016 at 23.:27 Hrs.	-	Opened manually at 21:30 Hrs. dt. 22.01.2016 ( As 400 kV System total supply failure)
4.	400/200 kV , 500 MVA, ICT Bank	22.01.2016 21:18 Hrs.	22.01.2016 at 23:33 Hrs.	Facia- O/C Prot. Optd., Bus 1&2 U/V optd. Micomp141: - LED- High set, Earth Fault Started phase ABC, Trip phase A,B,C, O/C Start I > I, Trip I > I	Tripping accrued while opening due to high voltage yellow phase limb of 400 kV X2 found damaged

**Report on the incident Damage of Yellow Phase limb of 400 kV CB/X-2**

1. On 22.01.2016 at 21:18 Hrs. 400 kV Dehar Bhiwani Line was opened manually from Dehar end due to over voltage.
2. Direct Trip command received through carrier channel at Bhiwani end thereby tripping both the circuit breakers i.e. X-5 & X-2. During opening of breaker arc appeared on the Yellow phase of the C B X-2 followed by a heavy blast.
3. These circuit Breakers are of double break type. On physical inspection line side main contact grading capacitor & PIR of yellow phase limb was found completely damaged.

4. Circuit Breaker X-2 is connected to Bus-2 and fault on this breaker was a Bus-2 fault. Accordingly, Main zone-2 Bus Differential relay has operated but unexpectedly Check Zone Bus bar relay has not operated due to which Bus Bar tripping circuit couldn't energize and the feeder connected to Bus-2 did not trip.
5. Consequently 400/220 kV ICT Bank tripped on the E/F (High-Set) relay. 400 kV PGCIL Hisar line tripped from Hisar end (Zone-2) and 400 kV PGCIL Bhiwani line tripped from PGCIL Bhiwani end (Zone-2).
6. Thus there was a complete 400 kV failure at the sub-station.
7. After isolating the damaged portion 400 kV PGCIL Bhiwani line was charged at 23:27 Hrs. 400 kV PGCIL Hisar line was charged at 23:28 Hrs and 400/220 kV ICT Bank was charged at 23:33 Hrs.

P. Details of Tests done after failure : Nil

Q. Probable cause of failure : Since the length of Dehar-Bhiwani line is 312 km, there is probability of high restriking voltage being developed due to opening of circuit breakers of these lines, which might have caused the failure of grading capacitor and PIR of subject CB. LILO of this line at PSTCL's Rajpura s/s is under process to tackle this problem.

### 30. Failure of Unit 4 Y phase Tie Breaker at Raichur TPS of KPCL

- A. Name of Substation : Raichur Thermal Power Station
- B. Utility/Owner of substation : Raichur Thermal Power Station, Karnataka Power Corporation Limited
- C. Faulty Equipment : Unit 4 Tie Breaker Y- Phase
- D. Rating : 2000 A
- E. Make : M/s BHEL
- F. Sr. No. : 401378
- G. Year of manufacturing : 1992
- H. Year of commissioning : 1994 (Sept. 28<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 13.04.2016 at 21:12 hrs



- J. Information received in CEA : 27.04.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Breaker to be replaced by a spare BHEL make breaker.
- M. Details of previous maintenance : On 30.03.2016, general maintenance works were carried out and measurement of C.B. timings, DCRM, CRM, measurement of Tan delta and capacitance of grading capacitor were carried out.
- N. Details of previous failure : B-phase interrupter had failed on 28.02.2016 and the same was replaced.
- O. Sequence of events/  
Description of failure : On 13.04.2016, Generator Transformer-4 was replaced and Voltage was build up gradually to 15 kV on LV side and was under observation. After about 25 minutes, at 21:12 hrs, PIR and interrupter of Unit-4 Y phase tie breaker failed.
- P. Details of Tests done after failure : Information not available
- Q. Probable cause of failure : Ageing and surface conduction could be reasons of failure.

**31. Failure of 420 kV CB at Kalapaka substation, APTRANSCO**

- A. Name of Substation : 400kV Substation, Kalapaka, Visakhapatnam
- B. Utility/Owner of substation : APTRANSCO
- C. Faulty Equipment : Circuit Breaker
- D. Rating : 420kV, 2000 A
- E. Make : CGL
- F. Sr. No. : 30560C
- G. Year of manufacturing : 2010

- H. Year of commissioning : 2012 (24<sup>th</sup> April)
- I. Date and time of occurrence/discovery of fault : 06-09-2016
- J. Information received in CEA : 27.10.16
- K. Fault discovered during : Operation
- L. Present condition of equipment : Not reparable
- M. Details of previous maintenance : Last maintenance done on 28.04.2016
- N. Details of previous failure : No previous failures
- O. Sequence of events/Description of failure : On 06.09.2016 the breaker was closed at 1635 hrs. An abnormal sound from the breaker chamber was heard and at 1643 hrs., the Y-Phase T Chamber blasted.
- P. Details of Tests done after failure : No test was possible as the Breaker had blasted.
- Q. Probable cause of failure : Internal fault could be the probable cause

**32. Failure of Y phase limb of 245 kV SF<sub>6</sub> CB of unit 8 at Bhakra Right Bank Power House of BBMB.**

- A. Name of Substation : 220 kV Bhakra Right Bank Power House Switchyard
- B. Utility/Owner of substation : BBMB
- C. Faulty Equipment : SF<sub>6</sub> Breaker (Y phase pole, unit 8)
- D. Rating : 245 kV
- E. Make : Siemens
- F. Sr. No. : 2007/IND/03/3375
- G. Year of manufacturing : Information not available
- H. Year of commissioning : Information not available

- I. Date and time of occurrence/discovery of fault : 08.12.2016 @ 14:25 hrs
- J. Information received in CEA : 23.12.2016
- 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 failure : On 08.12.2016 at 14:25 hrs, in order to synchronize the Unit #8, the machine was started and excited. While building up 11 kV, LBB protection (CBRD) operated resulting in the tripping of all the breakers of Bus-Section II along with the breakers of Bus Coupler bays of Section I & III.  
On observation, the SF<sub>6</sub> gas pressure of Y phase pole was found to be risen from 6.1 bar to 6.6 bar; while the SF<sub>6</sub> pressure values of R & B phase poles were found unaltered.
- P. Details of Tests done after failure : The contact resistance was found to be risen from its previous value of 39  $\mu\Omega$  to 48  $\mu\Omega$ . IR value was also found to be on the lower side.
- Q. Probable cause of failure : Sufficient information such as IR value, open/close indication of CB etc not available to pin point exact cause of failure. Operation of LBB suggests that contacts of CB might have stuck up. Dynamic Contact Resistance Measurement should be carried out periodically to assess condition and alignment of the contacts.

### CURRENT TRANSFORMERS

**33. Failure of CT in Y phase of 230 kV Perambalur-Trichy feeder at 230 kV Perambalur substation of TANTRANSCO**

- A. Name of Substation : 230kV Perambalur Substation
- B. Utility/Owner of substation : Tamil Nadu Transmission Corporation Limited
- C. Faulty Equipment : CT (Y-phase of Perambalur – Trichy feeder)
- D. Rating : 230 kV
- E. Make : TELK
- F. Sr. No. : 230116-17
- G. Year of manufacturing : Information not available
- H. Year of commissioning : 1985 (March 28<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 24.08.2015 @ 16:52 Hrs.
- J. Information received in CEA : 22.09.2015
- 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 failure : On 24.08.2015 at 16:52 hrs, CT of Perambalur-Trichy feeder suddenly burst and oil spurt out with fire surrounding it and the porcelain petty coats were broken into pieces.  
Bus bar protection operated; 230 kV TAQA feeder tripped at both ends; HV-I, LV-I, HV-II, LV-II breakers tripped; HV-III, LV-III, Auto-III were under LC

condition. No interruption to any other SS/EHT service.

Indication of relays: 230 kV Trichy feeder: Main-I : B, N; Main-II 'Y' Phase, Earth

230 kV TAQA feeder: Main-I: B, N; Main – II: Nil.

Auto-I: Voltage, frequency, over flux alarm, over flux trip. Bus bar protection: Main Y phase, check Y phase

P. Details of Tests done after failure : Information not available

Q. Probable cause of failure: : CT had served for 30 years. Internal insulation failure due to ageing might be a reason of failure of CT.

**34. Failure of CT, PT and LA of 220 kV Cochin-Kalamassery II feeder at 220 kV Kalamassery substation of KESB**

A. Name of Substation : 220kV Kalamassery Substation

B. Utility/Owner of substation : KSEB

C. Faulty Equipment : CT, PT & LA of Cochin-Kalamassery II feeder

D. Rating : 220 kV

E. Make : 1. VITRANS (CT)  
2. TELK (PT)  
3. Information not available for LA

F. Sr. No. : Information not available

G. Year of manufacturing : Information not available

H. Year of commissioning : Information not available

I. Date and time of occurrence/discovery of fault : 19.05.2015 at 20:26 hrs

J. Information received in CEA : 14.10.2015

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 19.05.2015 at 20:26 hrs, 220 kV CT on COKL # II feeder flashed leading to the total shutdown of 220 kV Kalamassery substation. After clearing the yard, bay supply was resumed by 21:42 hrs. On inspection, it was found that the Y phase LA had failed, PT had low capacitance value, CT had flashed over and pole of Y phase breaker was slightly damaged. The LAs of 220 kV Kalamassery substation were very old and steps were taken to replace the same. LAs of all three phases, Y phase PT & Y phase CT on COKL # II were replaced. The feeder was put in service on 22.05.2015 at 22:51 hrs.
- P. Details of Tests done after failure : Capacitance of PT was measured after the failure and was found to be low.
- Q. Probable cause of failure : Sufficient information is not available to draw any conclusion.
- 35. Failure of 230 kV Current Transformer in Manali-I feeder (R phase) at 400 kV Alamathy SubStation of TANTRANSCO.**
- A. Name of Substation : 400 kV Alamathy SS
- B. Utility/Owner of substation : TANTRANSCO
- C. Faulty Equipment : CT (R phase) of Manali-I feeder
- D. Rating : 230 kV
- E. Make : SCT
- F. Sr. No. : 263
- G. Year of manufacturing : 2012
- H. Year of commissioning : 2012 (15.08.2012)

- I. Date and time of occurrence/discovery of fault : 25.05.2015 at 09:09 Hrs.
- J. Information received in CEA : 04.11.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Damaged
- M. Details of previous maintenance : CT Cleaned and Tightness Checked on 08.02.2015
- N. Details of previous failure : No Previous failure
- O. Sequence of events/  
Description of failure : On 25.05.2015 @ 09.09 hrs. heavy sound and fire was observed in CT. All 230 kV feeder tripped on Bus Bar Protection and ICT-4 & 5 tripped, Buchholz relay acted.
- P. Details of Tests done after failure : CT burst, hence test could not be carried out.
- Q. Probable cause of failure : Internal fault could be the reason of failure.
- 36. Failure of R phase CT in 230 kV Trichy-Alundur II feeder at Trichy Substaion of TANTRANSCO**
- A. Name of Substation : 230 kV Trichy Substation
- B. Utility/Owner of substation : TANTRANSCO
- C. Faulty Equipment : CT (R phase) of Trichy-Alundur II feeder
- D. Rating : 230 kV
- E. Make : TELK
- F. Sr. No. : B-230116-24
- G. Year of manufacturing : Information not available
- H. Year of commissioning : 1986 (March 29<sup>th</sup>)

- I. Date and time of occurrence/discovery of fault : 26.09.2015 at 15.53 Hrs.
- J. Information received in CEA : 09.11.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced with new CT
- M. Details of previous maintenance : Information not available
- N. Details of previous failure : Information not available
- O. Sequence of events/  
Description of failure : On 26.09.2015 at 15:53 hrs, R phase CT of Trichy-Alundur II feeder suddenly burst and oil spurt out with fire surrounding it and the porcelain petty coats broken into pieces.  
1. 230kV Bus bar protection operated  
2. Master relay of Auto Tr-I & II operated  
3. 230kV Trichy-Alundur I & II feeder tripped at both end.  
4. 230kV Trichy-Samayapuram feeder and 230kV Trichy-Perambalur feeders tripped at Trichy SS only.  
5. 230kV HV 1 & HV 2 Breakers and 110 kV LV 1, 2 and LV 3 breakers tripped
- P. Details of Tests done after failure : Since CT had burst, no test was possible.
- Q. Probable cause of failure: : CT had served for 29 years. Ageing of the equipment might be a reason of failure.

**37. Failure of 220 kV R phase CT at 220 kV Mehgaon Substation of MPPTCL**

- A. Name of Substation : 220 kV Substation, Mehgaon
- B. Utility/Owner of substation : MPPTCL
- C. Faulty Equipment : CT (R phase) of Auraiya feeder
- D. Rating : 220 kV, 800-400/1 A
- E. Make : SCT
- F. Sr. No. : 2010/1921



- G. Year of manufacturing : 2010
- H. Year of commissioning : 2011 (March 16<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 25.07.2015 at 18.25 Hrs.
- J. Information received in CEA : 16.11.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Unserviceable
- M. Details of previous maintenance : Megger & Tan-delta done on 26.03.2012. Cleaning, tightening done on 25.05.2015.
- N. Details of previous failure : Nil
- O. Sequence of events/Description of failure : On 25.07.2015 at 18.25 Hrs., CT burst.
- P. Details of Tests done after failure : Megger done, results were not satisfactory.
- Q. Probable cause of failure : CT might have burst due to internal insulation failure

**38. Failure of 220 kV B phase CT at Malanpur Substation of MPPTCL**

- A. Name of Substation : 220 kV Substation, Malanpur
- B. Utility/Owner of substation : MPPTCL
- C. Faulty Equipment : CT (B phase) of PGCIL-II feeder
- D. Rating : 220 kV, 800-400/1 A
- E. Make : TELK
- F. Sr. No. : B230171/12
- G. Year of manufacturing : 1991

- H. Year of commissioning : 1993 (Sept. 9<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 18.08.2015 @ 17.25 Hrs.
- J. Information received in CEA : 16.11.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced
- M. Details of previous maintenance : Maintenance done on 12.05.2015. General cleaning, tightening & meggering carried out
- N. Details of previous failure : Nil
- O. Sequence of events/Description of fault : CT burst due to internal insulation failure. The failure occurred during heavy rain fall.
- P. Details of Tests done after failure : Tests after failure were not feasible as CT failed completely.
- Q. Probable cause of failure : CT had served for 22 years. Internal insulation failure due to ageing might be a reason of failure.
- 39. Failure of R phase 220 kV CT of Sindhanur line at 220 kV Lingapura substation of KPTCL.**
- A. Name of Substation : 220 kV Lingapura s/s
- B. Utility/Owner of substation : KPTCL
- C. Faulty Equipment : Current Transformer (R phase of Sindhanur line)
- D. Rating : 245 kV
- E. Make : W.S.Industries (India) Ltd., Bangalore
- F. Sr. No. : 881028 – ‘R’ Phase
- G. Year of manufacturing : 1988

- H. Year of commissioning : Information not available
- I. Date and time of occurrence/discovery of fault : 15.10.2015, 17:35 Hrs.
- J. Information received in CEA : 22.12.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Damaged
- M. Details of previous maintenance : On 21.08.2015, tightening of all clamps, tightening of CT, Marshalling box wiring connection, checking of oil level, greasing, lubrication etc.
- N. Details of previous failure : NA
- O. Sequence of events/  
Description of failure : Protection operated: General trip, R & Y phase trip, Distance – 54.13 km, R phase – 102 A, Y phase -3772 A, B phase- 281 A; 51AX, OCR, 86X, 30G.  
  
Due to flashover of R ph. CT, Y ph. CT also got damaged.
- P. Details of Tests done after failure : Since CT was damaged, no test was possible.
- Q. Probable cause of failure : CT was manufactured in 1988. Internal insulation failure due to ageing could be the reason of failure of CT.

**40. Failure of 220 kV R-phase metering CT of Hirebendegeri- I line at 220 kV Bidnal substation of KPTCL.**

- A. Name of Substation : 220 kV R/S Bidnal
- B. Utility/Owner of substation : KPTCL
- C. Faulty Equipment : 220 kV Current Transformer (R-phase of Hirebendegeri- I line)
- D. Rating : 245 kV  
Rated STC:40.5 KA for 3sec  
Insulation level: 460/1050 kV

CTR:300/1-1A, Acc Class:0.2S/0.2S,  
Burden: 5/5 ALF/ISF:<5/<5

- E. Make : Mehru Electrical & Mechanical Engineers Pvt. Ltd., Bhiwadi, Rajasthan
- F. Sr. No. : OC4073/1/1/12
- G. Year of manufacturing : 2012
- H. Year of commissioning : 2012 (May 3<sup>rd</sup>)
- I. Date and time of occurrence/discovery of fault : 24.10.2015 at 14:28 Hrs.
- J. Information received in CEA : 22.12.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Faulty, yet to be replaced
- M. Details of previous maintenance : Last maintenance was carried on 16-10-2014  
1.Checked for oil leaks and oil level  
2.Cleaning done.  
3.Checked and tightened the Jumpers & Clamps.
- N. Details of previous failure : Nil
- O. Sequence of events/Description of failure : 220 kV Bidnal- Hirbendegeri- I & II lines tripped on DPR & 96 relay with loud sound in the yard. On inspection it was found that, R-phase metering CT of 220 kV Bidnal-Hirebendegeri – I had flashed over causing tripping of all 220 kV lines and 100 MVA power transformers of 1 & 2 on bus bar protection relay.
- P. Details of Tests done after failure : CT was completely burnt, hence tests could not be done.
- Q. Probable cause of failure : Internal insulation failure could be the reason of failure of CT. Since CT had failed within 3 years of commissioning, OEM must be consulted for analysis of fault and to rectify any design issues.

**41. Failure of 220 kV CT connected to 100 MVA power transformer at Ongole substation of APTRANSCO.**

- A. Name of Substation : 220 kV /132/ 33 kV Ongole substation
- B. Utility/Owner of substation : APTRANSCO
- C. Faulty Equipment : Current Transformer (R – Phase) (HV CT of 100 MVA PTR- 1)
- D. Rating : 220 kV
- E. Make : TELK
- F. Sr. No. : 230076-7
- G. Year of manufacturing : 1980
- H. Year of commissioning : 1981 (August 10<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 22.12.2015
- J. Information received in CEA : 27.01.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced failed CT with new CT
- M. Details of previous maintenance : On 07.04.2015, all connections were tightened and petty coats were cleaned. IR value primary to Earth 3.0 GΩ when tested with 5.0 kV Megger.
- N. Details of previous failure : Nil
- O. Sequence of events/ Description of failure : On 22.12.2015, oil gushed out from CT.
- P. Details of Tests done after failure : IR primary to earth value found zero with 5.0 kV Megger.

Q. Probable cause of failure : CT had served for more than 35 years. Internal insulation failure due to ageing could be the reason of failure. Since the CT did not have test tap, it was not possible to carry out tan delta test on CT.

**42. Failure of R-phase CT of 220 kV Davanagere-2 line at 220 kV MRS Shivamogga substation of KPTCL.**

- A. Name of Substation : 220 kV MRS, Shivamogga
- B. Utility/Owner of substation : Karnataka Power Transmission Corporation Limited
- C. Faulty Equipment : 220 kV Class Current Transformer (R phase of Devanargrere-2 line)
- D. Rating : 220 kV Class CT of Ratio 800/1-1-1-1A
- E. Make : SCT Ltd., Ghaziabad
- F. Sr. No. : 2007/1279
- G. Year of manufacturing : 2007
- H. Year of commissioning : 2007
- I. Date and time of occurrence/discovery of fault : 22.02.2016 at 15:00 Hrs.
- J. Information received in CEA : 18.04.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced with new CT
- M. Details of previous maintenance : Last maintenance was carried out on 03.12.2015.
- N. Details of previous failure : Nil
- O. Sequence of events/Description of failure : On 22.02.2016 at 15:00 hrs, Current Transformer in R phase of Davanagere-2 line flashed over.

P. Details of Tests done after failure : Tests not done as C.T. had completely flashed over.

Q. Probable cause of failure : Internal fault could be a reason of failure.

**43. Failure of B-phase CT of 220 kV Shahabad line at 220 kV Kapnoor substation of KPTCL.**

A. Name of Substation : 220 kV Receiving Station, Kapnoor

B. Utility/Owner of substation : KPTCL

C. Faulty Equipment : CT (B phase of Shahabad Kapnoor line)

D. Rating : 220 kV

E. Make : Sri Venkateshwar Electicals Ltd.

F. Sr. No. : 280/1/8

G. Year of manufacturing : 2002

H. Year of commissioning : 2003

I. Date and time of occurrence/discovery of fault : 24.02.2016 at 01:20 hrs

J. Information received in CEA : 18.04.2016

K. Fault discovered during : Operation

L. Present condition of equipment : Replaced on 24.02.2016

M. Details of previous maintenance : Regular maintenance involved cleaning of bushing, checking oil level etc.  
On 11.12.2015, measured IR value was 8000 M $\Omega$ .

N. Details of previous failure : Nil

O. Sequence of events/Description of fault : On 24.02.2016 at 01:20 hrs, Shahabad line tripped on non-Directional earth fault relay with high set 50/51 N.

P. Details of Tests done after : As CT flashed over, tests could not be carried out.  
failure

Q. Probable cause of failure : Internal fault could be a reason of failure.

**44. Failure of R phase CT of 220 kV Kapanoor line at 220 kV Shahabad substation of KPTCL.**

A. Name of Substation : 220 kV Receiving Station, Shahabad

B. Utility/Owner of substation : KPTCL

C. Faulty Equipment : CT (R phase of Kapanoor line)

D. Rating : 220 kV, 800-600-400-200/1-1-1A

E. Make : HBB

F. Sr. No. : IB-027691

G. Year of manufacturing : 1983

H. Year of commissioning : 1984

I. Date and time of : 26.02.2016 at 01:05 Hrs.  
occurrence/discovery of  
fault

J. Information received in : 18.04.2016  
CEA

K. Fault discovered during : Operation

L. Present condition of : Burnt completely  
equipment

M. Details of previous : Tightening of nuts & bolts was done; oil level was  
maintenance checked and found OK.

N. Details of previous failure : Nil

O. Sequence of events/ : On 26.02.2016 at 01:05 hrs, CT flashed. Consequent  
Description of failure to this, HV & LV CBs of 100MVA transformer-II  
tripped; CBs of both I/C 220 kV lines tripped at  
source end i.e. at Kapnoor & Halti Gudur.



- P. Details of Tests done after failure : Since CT had burnt completely, no test was possible.
- Q. Probable cause of failure : CT had served for 32 years. Insulation failure due to ageing might be the reason of failure of CT.

**45. Failure of B phase CT of 230 kV Tondiarpet feeder at 230 kV Manali substation of TANTRANSCO.**

- A. Name of Substation : 230 kV Manali SubStation
- B. Utility/Owner of substation : TANTRANSCO
- C. Faulty Equipment : CT (B Phase)
- D. Rating : 220 kV, 1600-1200-800-600-300/1 A  
Adopted: 220 kV, 600/1 A
- E. Make : Areva
- F. Sr. No. : 200807105/2008
- G. Year of manufacturing : 2008
- H. Year of commissioning : 2009 (April 8<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 14.02.2016 at 21.06 Hrs.
- J. Information received in CEA : 28.04.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced
- M. Details of previous maintenance : In the last scheduled maintenance:  
a) CT Junction box checked  
b) CT Terminal connector checked

- N. Details of previous failure : Nil
- O. Sequence of events/  
Description of failure : On 14.02.16 at 21:06 hrs, heavy blast sound was observed from 230 kV yard. 230 kV busbar protection had acted with following indications:  
Main: C ph protection operated and  
Check: A- ph, C phase protection operated. On inspecting the yard, it was observed that B ph CT had burst and was emanating fire, damaging the petticoats of adjacent Y ph CT as well.  
The 110 kV Avadi and Metro water feeders were hand tripped immediately to restrict load in 110 kV bus.
- P. Details of Tests done after  
failure : As CT burst, tests could not be carried out.
- Q. Probable cause of failure : Internal fault in CT could be the reason of failure.

**46. Failure of B phase CT on 220/132 kV, 100 MVA Power Transformer – 1 HV side at Yerraguntla Substation of APTRANSCO.**

- A. Name of Substation : 220 kV Substation, Yerraguntla
- B. Utility/Owner of substation : APTRANSCO
- C. Faulty Equipment : CT (B phase) at 220/132 kV 100 MVA Transformer-I HV side
- D. Rating : 220 kV
- E. Make : TELK
- F. Sr. No. : 230194-6
- G. Year of manufacturing : 1993
- H. Year of commissioning : 1993 (Oct. 24<sup>th</sup>)
- I. Date and time of  
occurrence/discovery of  
fault : 21.02.2016 at 10:30 Hrs.
- J. Information received in CEA : 3.5.2016

- K. Fault discovered during : Operation
- L. Present condition of : Replaced with new CT equipment
- M. Details of previous : Information not available maintenance
- N. Details of previous failure : Information not available
- O. Sequence of events/ : On 21.02.2016 at 10:30 hrs, CT blasted.  
Description of failure
- P. Details of Tests done after : No tests were possible as the CT had blasted.  
failure
- Q. Probable cause of failure : Internal fault could be the reason of failure.

**47. Failure of 220 kV Y phase CT of Sewah Panipat-Thermal Ckt-I at 400 kV Panipat substation of BBMB**

- A. Name of Substation : 400 kV Panipat substation
- B. Utility/Owner of substation : BBMB
- C. Faulty Equipment : CT (Y phase of Sewah-Thermal Ckt. I)
- D. Rating : 220 kV
- E. Make : NTPLC-24
- F. Sr. No. : C-1036-9/1976
- G. Year of manufacturing : 1976
- H. Year of commissioning : 1979 (April 20<sup>th</sup>)
- I. Date and time of : 17.04.2016 at 18:25 hrs  
occurrence/discovery of  
fault
- J. Information received in CEA : 16.05.2016

- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced with Heptacare make CT having ratio 1200-800-400/1-1-1-1 A
- M. Details of previous maintenance : Last maintenance was carried out on 26.10.2015
- N. Details of previous failure : Nil
- O. Sequence of events/  
Description of failure : On 17.04.2016 at 18:25 hrs, heavy sound was heard. Upon checking it was found that CT had caught fire and had got damaged.
- P. Details of Tests done after failure : Since CT had got damaged, no test was possible.
- Q. Probable cause of failure : CT had served for 40 years, insulation degradation due to ageing might be the reason of failure.

**48. Failure of Y-Phase CT of 220 kV VVS-1 feeder at Pendurthi S/s of APTRANSCO**

- A Name of Substation : 220/132 kV Pendurthi SS
- B Utility/Owner of substation : APTRANSCO
- C Faulty Equipment : CT of Y-phase 220 kV VVS-1 feeder
- D Rating : 220 kV, Ratio: 800-600-400/1-1-1-1-1
- E Make : BHEL
- F Sr. No. : 2221486
- G Year of manufacturing : 1991
- H Year of commissioning : 1993
- I Date and time of occurrence/discovery of fault : 06.06.2016
- J Information received in CEA : 30.08.2016

- K Fault discovered during : Operation
- L Present condition of equipment : Replaced with CT of similar rating of SCT make
- M Details of previous maintenance : Tan delta test, cleaning of bushings and checking of oil were done periodically.
- N Details of previous failure : Nil
- R. Sequence of events/  
Description of failure : On 6.6.2016, chattering sound and oil leakage from the Y-phase CT of 220 kV VSS-I feeder was observed.
- P Details of Tests done after failure : LC was taken and tests were conducted on CT by MRT wing. Based on high tan delta value and HV-body Megger value of 1.87 Mega-ohms, CT was declared faulty.
- Q Probable cause of failure : Tan delta value was found to be higher than permissible limit. Meggar value of HV-body was found to be 1.87 Mega-ohms which is very low. Internal fault due to ingress of moisture could be the reason of failure.

**49. Failure of Y Phase CT of 100 MVA transformer- 2 bay at 220 kV Tubinakere substation of KPTCL.**

- A Name of Substation : 220/66/11 kV Tubinakere
- B Utility/Owner of substation : KPTCL
- C Faulty Equipment : Current Transformer of Y- ph of 100 MVA transformer-2 bay
- D Rating : 220 kV, Ratio: 800-600-400-300/1 Amp
- E Make : SCT
- F Sr. No. : 2000/297
- G Year of manufacturing : 1999
- H Year of commissioning : 2001 (11<sup>th</sup> July)

- I Date and time of occurrence/discovery of fault : 27.06.2016 at 0455 hrs.
- J Information received in CEA : 30.08.2016
- K Fault discovered during : Operation
- L Present condition of equipment : Faulty
- M Details of previous maintenance : 23.06.2016
- N Details of previous failure : No previous failure
- S. Sequence of events/ Description of failure : On 27.06.16, at 0455 hrs, CT flashed over during operation
- P Details of Tests done after failure : No test on Y-phase CT was possible as the CT had damaged. During testing on R-phase CT, its core-III was found saturated.
- Q Probable cause of failure : Insulation failure could be the reason of failure of Y-phase CT.
- 50. Failure of R & Y Phase CT of North Bus sectionaliser at 220 kV Hoody substation of KPTCL.**
- A Name of Substation : 220 kV Hoody substation.
- B Utility/Owner of substation : KPTCL
- C Faulty Equipment : Current Transformers (R & Y-phase)
- D Rating : 3000-2000 / 1-1-1-1-1 Amps
- E Make : SCT Limited
- F Sr. No. : 1. 2014/1809 (R-ph)  
2. 2014/1810 (Y-ph)
- G Year of manufacturing : 2014
- H Year of commissioning : 2016 (April 2<sup>nd</sup>)

- I Date and time of occurrence/discovery of fault : 27.05.2016 at 0810 hrs.
- J Information received in CEA : 30.08.2016
- K Fault discovered during : Operation
- L Present condition of equipment : All three CTs (R,Y&B phase) replaced
- M Details of previous maintenance : Nil
- N Details of previous failure : Nil
- T. Sequence of events/Description of failure : On 27.05.2016 at 0810 hrs, CTs in R and Y phase flashed over.
- P Details of Tests done after failure : Information not available
- Q Probable cause of failure : Internal fault due to insulation failure could be the reason of failure.

**51. Failure of Y-phase 220 kV CT at 220 kV Chinnakampalli substation of APTRANSCO**

- A Name of Substation : 220kV Chinnakampalli substation
- B Utility/Owner of substation : APTRANSCO
- C Faulty Equipment : CT of Y-phase Kalikiri feeder
- D Rating : 220 kV Class
- E Make : M/s BHEL
- F Sr. No. : Information not available
- G Year of manufacturing : Information not available
- H Year of commissioning : Information not available

- I Date and time of occurrence/discovery of fault : 30.07.2016 at 1400 hrs.
- J Information received in CEA : 23.09.2016
- 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 failure : On 30.07.2016 at 1400 hrs., CT of 220 kV Y-phase Kalikiri feeder failed.
- P Details of Tests done after failure : Meggering was done by MRT Wing and value of 7 M ohm was found. CT was declared faulty.
- Q Probable cause of failure : Internal fault could be the reason of failure.

**52. Failure of R-phase 220 kV CT at 220 kV Malyalapally substation of APTRANSCO.**

- A Name of Substation : 220kV Malyalapally substation
- B Utility/Owner of substation : APTRANSCO
- C Faulty Equipment : CT of R-phase NTPC-I feeder
- D Rating : 220 kV Class
- E Make : M/s BHEL
- F Sr. No. : 2212251
- G Year of manufacturing : 1985
- H Year of commissioning : Information not available
- I Date and time of occurrence/discovery of fault : 10.03.2016 at 1845 hrs.



- J Information received in CEA : 26.09.2016
- K Fault discovered during : Operation
- L Present condition of : Damaged  
equipment
- M Details of previous : Capacitance and tan delta test were done on  
maintenance 05.06.16 and values of 828.19 pF and 2.61%  
respectively were found.
- N Details of previous failure : Nil
- O Sequence of events/ : On 10.03.2016 at 1845 hrs., CT of 220 kV NTPS-I  
Description of failure feeder failed.
- P Details of Tests done after : CT had damaged, no test was possible.  
failure
- Q Probable cause of failure : CT was manufactured 31 years ago. Internal fault  
due to ageing could be the reason of failure.

**53. Failure of Y-phase 400 kV CT at 400 kV Mamidipally substation of APTRANSCO.**

- A Name of Substation : 220kV Mamidipally substation
- B Utility/Owner of substation : APTRANSCO
- C Faulty Equipment : CT of Y-phase Shankarpally feeder
- D Rating : 400 kV; 2000-1000-500/1-1-1-1-1 A
- E Make : M/s TELK
- F Sr. No. : 24004030
- G Year of manufacturing : 1998
- H Year of commissioning : 2000
- I Date and time of : 04.04.2016 at 0003 hrs.  
occurrence/discovery of  
fault
- J Information received in CEA : 26.09.2016

- K Fault discovered during : Operation
- L Present condition of : Replaced with new CT equipment
- M Details of previous : Information not available maintenance
- N Details of previous failure : Information not available
- O Sequence of events/ : On 04.04.2016 at 0003 hrs., CT of Y-phase  
Description of failure Shankarpally feeder failed.
- P Details of Tests done after : Information not available failure
- Q Probable cause of failure :

**54. Failure of R ph 220 kV CTs at Hootagalli substation of KPTCL.**

- A. Name of Substation : 220kV Hootagalli substation
- B. Utility/Owner of substation : KPTCL
- C. Faulty Equipment : Current Transformer (R Phase)
- D. Rating : 220 kV,1200/800/600/400/300/1-1-1A
- E. Make : TELK, Kerala
- F. Sr. No. : R - Ph - 230039/14-1974,
- G. Year of manufacturing : 1974
- H. Year of commissioning : 2005 (14<sup>th</sup> June) (Brought from MRS, Shimoga)
- I. Date and time of : 22.08.2016 at 0650 hrs  
occurrence/discovery of  
fault
- J. Information received in CEA : 24.10.16
- K. Fault discovered during : Operation

- L. Present condition of equipment : Not reparable
- M. Details of previous maintenance : Last maintenance done on 23.03.2016. Tightening of earthing connection, clamps and joints etc. and checking of oil level, etc. was done.
- N. Details of previous failure : Information not available
- O. Sequence of events/Description of failure : On 22.08.2016 at 0650 hrs, 220kV Bus coupler and 220kV Basthipura No.2 lines tripped on EFR. Upon inspection it was found that the R Phase CT of 220kV Vajamangala line got flashed over and had caused damage to the Y Phase CT as well.
- P. Details of Tests done after failure : Not possible as the CT had damaged
- Q. Observations : NA
- R. Probable cause of failure : The CT was commissioned after 31 years of manufacture and has been in service for another 11 years. Internal fault due to ageing could be a cause of failure.

**55. Failure of 220 kV B- ph CT at 220 kV Jalandhar S/s, BBMB**

- A. Name of Substation : 220kV SRS Substation, Jalandhar
- B. Utility/Owner of substation : Bhakra Beas Management Board
- C. Faulty Equipment : Current Transformer (B-phase of Jamsher feeder)
- D. Rating : 220kV,1200/800/600/400/300/1-1-1A
- E. Make : BHEL
- F. Sr. No. : 2206896
- G. Year of manufacturing : Not available
- H. Year of commissioning : 1988 (2<sup>nd</sup> August)
- I. Date and time of occurrence/discovery of fault : 06.07.2016 at 1443 Hrs.

- J. Information received in CEA : 25.10.16
- K. Fault discovered during : Operation
- L. Present condition of equipment : Damaged
- M. Details of previous maintenance : Last quarterly and half yearly maintenance carried out on 09.04.2016 and the results were satisfactory
- N. Details of previous failure : No previous failure
- O. Sequence of events/Description of failure : On 06.07.2016 at 1443hrs, B-phase 220kV CT caught fire at the upper head terminal during normal working condition. The breaker controlling 220kV Jalandhar-Jamsher Ckt. No.1 was opened manually to disconnect it.
- P. Details of Tests done after failure : Not possible as the CT was completely in burnt condition
- Q. Probable cause of failure : CT had served for 28 years. Internal fault due to ageing could be a probable cause.

**56. Failure of 245 kV R phase CT of Bus Coupler at 220 kV Sangrur substation of BBMB**

- A. Name of Substation : 220 kV Sangrur Substation
- B. Utility/Owner of substation : BBMB
- C. Faulty Equipment : CT (R phase)
- D. Rating : 245 kV
- E. Make : ASEA
- F. Sr. No. : R-5974965
- G. Year of manufacturing : Information not available
- H. Year of commissioning : 1969
- I. Date and time of occurrence/discovery of fault : 09.12.2016 @ 11:05 hrs
- J. Information received in CEA : 30.12.2016
- K. Fault discovered during : Operation

- L. Present condition of : Out of circuit equipment
- M. Details of previous : Last annual maintenance was carried out on maintenance 23.11.2016.
- N. Details of previous failure : Nil
- O. Sequence of events/ : On 09.12.2016 at 11:05 hrs, 245 kV R phase CT of Description of failure 220 kV Bus Coupler caught fire during operation.
- P. Details of Tests done after : Not applicable, as CT was damaged. failure
- Q. Observations : None.
- R. Probable cause of failure : The CT has been in operation for 47 years. Insulation failure due to ageing might be a reason for its failure.

**CAPACITOR VOLTAGE TRANSFORMERS/  
POTENTIAL TRANSFORMERS**

- 57. Failure of 220 kV R phase CVT at 220 kV Kaniyambetta substation of KSEB**
- A. Name of Substation : 220 kV Substation, Kaniyambetta
- B. Utility/Owner of substation : KSEB Ltd.
- C. Faulty Equipment : CVT (R Phase of Kaniyambetta-Areakode feeder)
- D. Rating : 220 kV
- E. Make : CROMPTON GREAVES LTD
- F. Sr. No. : 4547
- G. Year of manufacturing : 1992
- H. Year of commissioning : 1994
- I. Date and time of occurrence/discovery of fault : 03.08.2015 at 04:11 Hrs.
- J. Information received in CEA : 14.10.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced
- M. Details of previous maintenance : Preventive maintenance work carried out on 27.07.15.
- N. Details of previous failure : Nil
- O. Sequence of events/Description of failure : **03.08.15, 04.11 HRS.**  
The 220kV Kaniyambetta- Areakode feeder tripped at Kaniyambetta end with the following:
- Relay indications:**  
Main I: V fail  
Main II: AB trip Zone 1

Location – 10.7 Km  
Auto reclose relay 186A and 186B

**Annunciations:**

VT fuse fail  
Distance Protection inoperative  
Auto reclose Lockout  
Main II relay Operated  
CB reclosed

- P. Details of Tests done after failure : Since CVT had flashed, it was not possible to carry out any test on it after failure.
- Q. Observations : On yard Inspection it was found that the R Phase CVT of Kaniyambetta-Areakode feeder had flashed. The flashed CVT was dismantled and new Siemens make 220 kV CVT was lifted from 220kV Areakode Substation and the same was erected and commissioned on 03.08.15 at 21.41 Hrs. CVT had served for 21 years.
- R. Probable cause of failure : Based on the limited information provided by KSEB it is difficult to comprehend how distance relay operated with failed CVT. The meaning of 'flashed' is need to be elaborated by KSEB. In the absence of sufficient information, it is difficult to pin point exact cause of failure.

**58. Failure of 220 kV B phase CVT of Sangrur-Hisar-I at 220 kV Sangrur substation of BBMB**

- A. Name of Substation : 220 kV Substation, BBMB Sangrur
- B. Utility/Owner of substation : BBMB
- C. Faulty Equipment : CVT (B phase of Sangrur-Hisar ckt-I)
- D. Rating : 220 kV
- E. Make : WSI
- F. Sr. No. : B-8809790
- G. Year of manufacturing : 1988

- H. Year of commissioning : 1990
- I. Date and time of occurrence/discovery of fault : 10.07.2015 at 12:15 Hrs.
- J. Information received in CEA : 19.10.2015
- K. Fault discovered during : Operation.
- L. Present condition of equipment : Out of circuit (Not replaced)
- M. Details of previous maintenance : Last scheduled maintenance was carried out on 15.04.2015 and no abnormality was found.
- N. Details of previous failure : Nil
- O. Sequence of events/  
Description of failure : On 10.07.2015 at 12.15 hrs, during routine checking of the yard it was noticed that oil was oozing out with heavy pressure from oil level indicator glass seal of CVT. Oil tank was over heated & CVT was also giving low output voltage; the CVT was taken out of circuit. The defective CVT shall be replaced with a healthy CVT or PT.
- P. Details of Tests done after failure : Nil
- Q. Probable cause of failure : The damage seems to have been occurred due to some internal fault of the CVT. The CVT had served for 26 years.

**59. Failure of 230 kV B phase PT at 230 kV Athipattu substation of TANTRANSCO.**

- A. Name of Substation : 230 kV Athipattu Substation
- B. Utility/Owner of substation : TANTRANSCO
- C. Faulty Equipment : PT (B Phase – Main Bus I)
- D. Rating : 230 kV
- E. Make : SCT.



- F. Sr. No. : 2010/2250
- G. Year of manufacturing : 2010
- H. Year of commissioning : 2012 (Oct. 9<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 07.03.2015 at 21:08 Hrs.
- J. Information received in CEA : 04.11.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Recommended for replacement
- M. Details of previous maintenance : On 30.12.2014, secondary terminal and oil level of 230 kV Bus Coupler Breaker and Bus-I & Bus II PTs were checked and found ok.
- N. Details of previous failure : No Previous Failure
- O. Sequence of events/Description of failure : On 07.03.2015 at 21:08 Hrs. 230 kV Bus bar protection and Distance Protection acted. 110 kV and 33 kV feeders were hand Tripped. 230 kV PT Selector Switch of 230 kV Mosur, 230 kV NCTPS and Auto Transformer Control Panels were switched to standby bus PT. All 230 kV, 110 kV & 33 kV feeders charged one by one.
- P. Details of Tests done after failure : Tan delta test conducted and values were found to be greater than 2%. Immediate replacement was recommended.
- Q. Probable cause of failure : Operation of distance protection, busbar protection and high value of tan delta suggest internal insulation failure of PT.
- 60. Failure of 230 kV Potential Transformer of B Phase of Northern Bus at 230 kV Tondiarpet substation of TANTRANSCO.**
- A. Name of Substation : 230 kV Tondiarpet SS
- B. Utility/Owner of substation : TANTRANSCO

- C. Faulty Equipment : PT (B Phase) of Northern Bus
- D. Rating : 230 kV
- E. Make : CGL
- F. Sr. No. : 20606
- G. Year of manufacturing : 2003
- H. Year of commissioning : 2007 (29.07.2007)
- I. Date and time of occurrence/discovery of fault : 26.04.2015 at 16:42 Hrs.
- J. Information received in CEA : 04.11.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Damaged
- M. Details of previous maintenance : Periodic maintenance such as checking of oil leakage, checking of cracks of insulators and cleaning of insulators was carried out.
- N. Details of previous failure : No previous Failure.
- O. Sequence of events/Description of failure : On 26.04.2015 @ 16.42 Hrs. B Phase PT burst with heavy noise, caught fire and completely burnt. Severe petticoat damage found in Y phase PT.
- P. Details of Tests done after failure : No test was possible as both Y and B phase PTs were completely damaged.
- Q. Probable cause of failure : Internal failure in B phase PT might have increased the pressure inside PT resulting in its bursting. Flying pieces of housing of this PT damaged nearby Y phase PT.

**61. Failure of B- Phase CVT of 220 kV Bus-B at 220 kV Kadakola substation of KPTCL.**

- A. Name of Substation : 220 kV Kadakola Receiving Station
- B. Utility/Owner of substation : KPTCL

- C. Faulty Equipment : CVT of 220 kV Bus- B (B- Phase)
- D. Rating :  
a) Highest system voltage: 245 kV  
b) Ratio:  $220 \text{ kV}/\sqrt{3} / 110\text{V}/\sqrt{3} / 110\text{V}/\sqrt{3} / 110\text{V}/\sqrt{3}$   
c) Equivalent Capacitance:  $4400 + 10\%/-5\% \text{ pF}$   
d) BIL: 460/1050 kV<sub>p</sub>
- E. Make : Crompton Greaves Ltd.
- F. Sr. No. : 8138
- G. Year of manufacturing : 1995
- H. Year of commissioning : 1998
- I. Date and time of occurrence/discovery of fault : 22.09.2015
- J. Information received in CEA : 22.12.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Faulty CVT was replaced with new PT of BHEL make.
- M. Details of previous maintenance : Maintenance works carried out on 10.05.2013. (2-core PT of R phase replaced by 3- Core PT). IR Value & Ratio tests were conducted. Routine maintenance works carried out on 13.06.2015 and 09.01.2015
- N. Details of previous failure : Nil
- O. Sequence of events/ Description of failure : 220 kV Bus B was provided with PT for R phase and CVTs for Y & B phases. On 22.09.2015, there was tripping of 220 kV Kanniyambetta and C.R. Nagara line-1 due to loss of potential. On verification, it was found that there was no voltage in B phase. Loads were transferred to the other bus (Bus A). Ratio test was conducted and core-I was found faulty.
- P. Details of Tests done after failure : IR Value test and ratio tests were conducted on 23.09.2015 & it was found that secondary voltage

for all cores of CVT much less than rated value of 63.5 V.

Q. Probable cause of failure : Ratio error in CVT indicated failure of capacitor elements.

**62. Failure of Y Phase CVT of 220 kV Bus-I at 400 kV Guttur substation of KPTCL.**

- A. Name of Substation : 400/220 kV Receiving Station, Guttur
- B. Utility/Owner of substation : KPTCL
- C. Faulty Equipment : Capacitive Voltage Transformer (CVT) 400 kV Bus- I Y-ph.
- D. Rating : 400 kV
- E. Make : WSI
- F. Sr. No. : 94030146
- G. Year of manufacturing : 1994
- H. Year of commissioning : 2005 (June 11<sup>th</sup>) (This CVT was released from 400 kV Hoody substation)
- I. Date and time of occurrence/discovery of fault : 23.09.2015 at 10.28 Hrs.
- J. Information received in CEA : 22.12.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Faulty
- M. Details of previous maintenance : Measurement of Tan delta & capacitance measurement was carried out on 30.07.15 and results were found to be within permissible limits.
- N. Details of previous failure : 11-06-2005

- O. Sequence of events/ Description of failure : When, 400 kV Beeranahalli- I & 400 kV side of ICT – II tripped, it was found that oil had completely oozed out from CVT.
- P. Details of Tests done after failure : Meggered on 25.09.2015: IR value Phase to Ground- 0
- Q. Probable cause of failure : Due to failure of CVT, 400 kV Beeranahalli-I line tripped; then due to overflux, 400 kV side of ICT-II also tripped. It seems there was internal fault in CVT which caused high pressure inside the tank and leakage of oil.

**63. Failure of Y Phase CVT of 220 kV Haveri-II line at 400 kV Guttur substation of KPTCL.**

- A. Name of Substation : 400/220 kV Receiving Station, Guttur
- B. Utility/Owner of substation : KPTCL
- C. Faulty Equipment : Capacitive Voltage Transformer (CVT) 220 kV Guttur- Haveri- II Line Y-ph.
- D. Rating : 245 kV
- E. Make : WSI
- F. Sr. No. : 97111060
- G. Year of manufacturing : 1993
- H. Year of commissioning : 2004
- I. Date and time of occurrence/discovery of fault : 24.09.2015 at 04.40 Hrs.
- J. Information received in CEA : 22.12.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Damaged
- M. Details of previous maintenance : August 2015 (Details not available)
- N. Details of previous failure : Nil

- O. Sequence of events/ Description of fault : On 24.09.15, CVT had burst and upon inspection it was found that Oil had completely drained out from CVT and insulator stack was completely damaged.
- P. Details of Tests done after failure : Tests after failure not possible as the CVT had burst.
- Q. Probable cause of failure : It seems there was internal fault in CVT resulting in high pressure inside the tank which lead to bursting of CVT and spillage of oil. There is a gap of 11 years between manufacturing and commissioning. Information about condition of CVT during these 11 years is not known.

**64. Failure of Capacitor Voltage Transformer (B-phase) of 230 kV Arni - Sriperumbudur feeder at 230 kV Arni substation of TANTRANSCO**

- A. Name of Substation : 230 kV Arni Substation
- B. Utility/Owner of substation : TANTRANSCO
- C. Faulty Equipment : CVT (B-phase of 230 kV Arni- Sriperumbudur feeder)
- D. Rating : 230 kV
- E. Make : HBB
- F. Sr. No. : 1B 048269
- G. Year of manufacturing : 1981
- H. Year of commissioning : 1983
- I. Date and time of occurrence/discovery of fault : 13.12.2015 at 04:17 Hrs.
- J. Information received in CEA : 04.01.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Damaged

- M. Details of previous maintenance : Periodical tests like meggering, measurement of capacitance & secondary voltage were carried out and results were found in order.
- N. Details of previous failure : Nil
- O. Sequence of events/ Description of failure : On 13.12.2015 at 04:17, the line side CVT was completely damaged due to bursting.
- P. Details of Tests done after failure : Since CVT had burst, no tests could be carried out.
- Q. Probable cause of failure : The CVT has served more than 32 years. It might have failed due to ageing.

**65. Failure of 220 kV Bus PT R phase at 220 kV Kondapuram substation of APTRANSCO.**

- A. Name of Substation : 220 kV Kondapuram substation
- B. Utility/Owner of substation : APTRANSCO
- C. Faulty Equipment : 220 kV Bus Potential Transformer (R- Phase)
- D. Rating :  $220 \text{ kV}/\sqrt{3} / 110/\sqrt{3}$
- E. Make : SCT
- F. Sr. No. : 2413
- G. Year of manufacturing : 2009
- H. Year of commissioning : 2012
- I. Date and time of occurrence/discovery of fault : 18.09.2015 at 11:03 Hrs.
- J. Information received in CEA : 12.01.2016
- K. Fault discovered during : Operation

- L. Present condition of equipment : Blasted 220 kV PT removed from service
- M. Details of previous maintenance : As per APTRANSCO schedule, detailed information is not available
- N. Details of previous failure : Nil
- O. Sequence of events/  
Description of failure : i) R-Phase 220 kV Bus PT blasted with heavy sound at 11:03 Hrs. and 220 kV Thimmapuram Circuit I & II tripped.  
ii) 220 kV Bus PT isolated from 220 kV bus by opening bus isolator at 11:15 Hrs.
- P. Details of Tests done after failure : Since PT had blasted, no tests could be carried out.
- Q. Probable cause of failure : Internal insulation failure could be the cause of failure.
- 66. Failure of 220 kV CVT on R phase of 220/66 kV, 45/60 MVA Transformer T- 2 at Jagadhri substation of BBMB**
- A. Name of Substation : 220 kV GSS, Jagadhri.
- B. Utility/Owner of substation : BBMB
- C. Faulty Equipment : CVT Installed on R- Phase of 220/ 66 kV, 45/60 MVA, Transformer T-2
- D. Rating : 245 kV
- E. Make : CGL, Nasik
- F. Sr. No. : 15497
- G. Year of manufacturing : 2001
- H. Year of commissioning : 2001 (April 9<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 08.07.2015 at 04:01 hrs



- J. Information received in CEA : 12.01.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Totally Damaged
- M. Details of previous maintenance : Last annual maintenance done on dated 26.02.2015
- N. Details of previous failure : Nil
- O. Sequence of events/  
Description of failure : The CVT was exposed to fire with heavy blast and it was burnt to pieces. Fire was extinguished using CO<sub>2</sub> gas fire extinguishers and water.
- Following protections operated:  
MICOM- P632- DIFF, TRIP- I, II, III  
MICOM- P141- HS O/C, HS E/F, A-PH  
LBB, Tripping Relay- 86  
Facia: T/F DIFF Operated, Back protection operated.  
P&T cell, BBMB Chandigarh visited Jagadhari substation and declared the CVT damaged.
- P. Details of Tests done after failure : Tests could not be carried out as the CVT had blasted.
- Q. Probable cause of failure : It seems CVT burst due to some internal fault in capacitor unit.

**67. Failure of 400 kV B phase CVT of Nunna-Vemagiri II (APTRANSCO bay) at Nunna Substation of PGCIL**

- A. Name of Substation : 400 kV Nunna s/s
- B. Utility/Owner of substation : APTRANSCO bays in PGCIL switchyard.
- C. Faulty Equipment : CVT (B phase) in Nunna – Vemagiri –II feeder
- D. Rating : 400 kV
- E. Make : CGL
- F. Sr. No. : 20324

- G. Year of manufacturing : 2003
- H. Year of commissioning : 2005
- I. Date and time of occurrence/discovery of fault : 05.10.2015
- J. Information received in CEA : 3.5.2016
- 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 failure : On 05.10.2015, drift in secondary voltage of CVT was observed and CVT was replaced with new one.
- P. Details of Tests done after failure : Information not available
- Q. Probable cause of failure : Internal fault in capacitors could be the reason of failure.
- 68. Failure of 220 kV Y phase CVT of Somayajulapalli-Dhone feeder-2 at 220 kV Somayajulapalli Switching Station of APTRANSCO.**
- A. Name of Substation : 220 kV Switching Station, Somayajulapalli.
- B. Utility/Owner of substation : APTRANSCO
- C. Faulty Equipment : CVT (Y-Phase) of 220 kV Somayajulapalli-Dhone feeder-2
- D. Rating : 220 kV
- E. Make : CGL

- F. Sr. No. : 4167
- G. Year of manufacturing : 1991
- H. Year of commissioning : 1995 (Aug. 3<sup>rd</sup>)
- I. Date and time of occurrence/discovery of fault : 19.10.2015 at 11:10 Hrs.
- J. Information received in CEA : 3.5.2016
- K. Fault discovered during : Maintenance (While carrying out quarterly maintenance of CVTs)
- L. Present condition of equipment : Information not available
- M. Details of previous maintenance : On 27.07.2015, Secondary voltages were: Y- 81.23 V (Core – 1) & 81.03 V (Core – 2) were beyond the permissible limits. Proposal for procurement of new CVT was moved.
- N. Details of previous failure : Nil
- O. Sequence of events/Description of failure : On 19.10.2015 at 11:10 hrs., during maintenance activity secondary voltages of CVT were measured and found to be low: Core- 1:19.2 V & Core- 2: 19.3 V. The CVT was declared faulty.
- P. Details of Tests done after failure : Not applicable
- Q. Probable cause of failure : Internal fault in capacitors could be the reason of failure.
- 69. Failure of 220 kV Y & B phase CVT at 220 kV Kodur Substation of APTRANSCO**
- A. Name of Substation : 220 kV Substation, Kodur
- B. Utility/Owner of substation : APTRANSCO
- C. Faulty Equipment : 220 kV Kodur- Reniguta feeder 220 kV Capacitive Voltage Transformer-02 Nos(Y-ph & B-ph)

- D. Rating : 220 kV
- E. Make : Trench Electric
- F. Sr. No. : Y-ph:947108547  
B-ph:947108551
- G. Year of manufacturing : 1994
- H. Year of commissioning : 1996 (June 19<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 24.11.2015 at 20:10 Hrs.
- J. Information received in CEA : 15.02.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Information not available
- M. Details of previous maintenance : Information not available
- N. Details of previous failure : Information not available
- O. Sequence of events/Description of failure : Information not available
- P. Details of Tests done after failure : Checked the Voltage Between Terminal; found zero failure
- Q. Probable cause of failure : CVT had served for more than 29 years. Internal failure due to ageing could be a reason of failure.
- 70. Failure of 220 kV PT (B phase of Bus II) at Thimmapuram substation of APTRANSCO**
- A. Name of Substation : 220 kV Substation, Thimmapuram
- B. Utility/Owner of substation : APTRANSCO
- C. Faulty Equipment : PT (Bus- II B-phase)

- D. Rating : 220kV/ $\sqrt{3}$  / 110V/ $\sqrt{3}$
- E. Make : SCT
- F. Sr. No. : 2009/2421
- G. Year of manufacturing : 2009
- H. Year of commissioning : 2012
- I. Date and time of occurrence/discovery of fault : 26.11.2015
- J. Information received in CEA : 15.02.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced with new CGL make PT
- M. Details of previous maintenance : Information not available
- N. Details of previous failure : Nil
- O. Sequence of events/  
Description of failure : On 26.11.2015, the PT blasted and also damaged Y phase solid core support insulators.
- P. Details of Tests done after failure : Test could not be carried out as PT had blasted.
- Q. Probable cause of failure : Internal fault could be the cause of failure.
- 71. Failure of R phase CVT of 400 kV Shantigrama line at 400 kV Nelamangala substation of KPTCL**
- A. Name of Substation : 400 kV receiving station, Nelamangala
- B. Utility/Owner of substation : KPTCL
- C. Faulty Equipment : Capacitor Voltage Transformer (R phase of 400 kV Nelamangala-Shantigrama Line)
- D. Rating : 400/ $\sqrt{3}$ kV / 110/ $\sqrt{3}$ V class, 4400pF

- E. Make : ABB limited
- F. Sr. No. : 4212032
- G. Year of manufacturing : 2012 (Feb)
- H. Year of commissioning : Information not available
- I. Date and time of occurrence/discovery of fault : 15.12.2015 at 10:30 hrs
- J. Information received in CEA : 15.02.2016
- K. Fault discovered during : Monitoring
- L. Present condition of equipment : Replaced with spare CVT
- M. Details of previous maintenance : 17.05.2012
- N. Details of previous failure : Nil
- O. Sequence of events/Description of failure : On 15.12.2015 at 10:30 hrs., during monitoring the secondary voltage of R phase of Hassan line CVT was recording 58.4 volts in place of 63.5V.
- P. Details of Tests done after failure : Result of tests carried out after failure and their comparison with result of tests carried out previously on 19.05.12 are given below:

(a) Capacitance Tan Delta test

Test Carried out on			19.05.2012		21.12.2015 (after failure)	
Test Specimen	mode	Volt applied in kV	Capacitance in pF	Tan Delta in %	Capacitance in pF	Tan Delta in %
Top Stack	UST	2	12999	0.17	13001	0.03
		10	12997	0.09	13007	0.07
	GST	2	-	-	13044	0.03
		10	-	-	13049	0.06
Middle Stack	UST	2	13040	0.19	13033	0.03
		10	13033	0.10	13041	0.08
	GST	2	-	-	13129	0.04
		10	-	-	13137	0.08
Bottom Stack	UST	Could not carry out the test in UST mode as the HF terminal is earthed inside the tank				
	GST	2	13062	0.49	13245	0.34
		10	13068	0.37	13263	0.35
Full Stack	UST	Could not Carry out the test in UST mode as the HF Terminal is Earthed inside the Tank				
	GST	2	4386.6	0.3	4419.4	0.17
		10	4389.8	0.29	4423.8	0.17

(b) Voltage Ratio Test

Test Carried out on	19.05.2012			21.12.2015 (after failure)		
	Voltage Applied	Secondary terminal	Measured Voltage in V	Voltage Applied	Secondary terminal	Measured Voltage in V
Single phase AC supply applied to Primary Stud and earth	226 V	1a – 1n	0.063	235 V	1a – 1n	0.060
		2a – 2n	0.063		2a – 2n	0.060
		3a -3n	0.063		3a – 3n	0.060

Note: a) At 226 Volts Single phase AC Supply Applied to primary Stud and earth measured voltage at secondary terminal should be 0.062 V

b) At 235 Volts Single phase AC Supply Applied to primary stud and earth, measured voltage at secondary terminal should be 0.0644 V

c) DC insulation resistance test

Applied voltage: 5 kV

Insulation Resistance: Ok

Q. Probable cause of failure : Drift in secondary voltage indicates shorting in capacitor elements. CVT was replaced with spare CVT.

**72. Failure of 220 kV PT at 220/11 kV Nansuralla substation of APTRANSCO.**

- A. Name of Substation : 220/11kV Nansuralla Substation
- B. Utility/Owner of substation : APTRANSCO.
- C. Faulty Equipment : Potential Transformer
- D. Rating : 220kV
- E. Make : SCT
- F. Sr. No. : 2009/220
- G. Year of manufacturing : 2009
- H. Year of commissioning : 2011
- I. Date and time of occurrence/discovery of fault : 23.02.2016, 05:55 hrs.
- J. Information received in CEA : 24.05.2016
- K. Fault discovered during : Operation.
- L. Present condition of equipment : Information not available
- M. Details of previous maintenance : Maintenance was carried out as per Schedule
- N. Details of previous failure : Nil



- O. Sequence of events/ : On 23.02.2016 at 05:55 hrs, PT got damaged.  
Description of failure
- P. Details of Tests done after : Nil  
failure
- Q. Probable cause of failure : Internal fault could be the reason of failure.

**73. Failure of 220 kV R phase PT at 220/11 kV Ragulapadu substation of APTRANSCO**

- A. Name of Substation : 220/11kV SS, Ragulapadu
- B. Utility/Owner of substation : APTRANSCO
- C. Faulty Equipment : PT in R phase of Metering bay for LIS pump house
- D. Rating : 220 kV
- E. Make : SCT
- F. Sr. No. : 2009/228
- G. Year of manufacturing : 2009
- H. Year of commissioning : 2011 (06.06.2011)
- I. Date and time of : 02.03.2016 @ 14:25 hrs  
occurrence/discovery of  
fault
- J. Information received in CEA : 24.05.2016
- K. Fault discovered during : Operation
- L. Present condition of : Replaced  
equipment
- M. Details of previous : Information not available  
maintenance
- N. Details of previous failure : Information not available
- O. Sequence of events/ : On 02.03.2016 at 14:25 hrs, R- ph metering PT for  
Description of failure LIS pump house blasted.

- P. Details of Tests done after failure : As the PT had blasted, the tests could not be carried out.
- Q. Probable cause of failure : Internal fault in capacitors could be the reason of failure.

**74. Failure of 220 kV Y phase CVT connected to Gooty RS feeder at 220 kV Gooty Switching Station of APTRANSCO**

- A. Name of Substation : 220 kV Gooty RS
- B. Utility/Owner of substation : APTRANSCO
- C. Faulty Equipment : CVT (Y phase in Gooty RS feeder)
- D. Rating : 220 kV
- E. Make : Trench Electric
- F. Sr. No. : 947108541
- G. Year of manufacturing : 1992
- H. Year of commissioning : 1992 (June 10<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 15.03.2016 at 08:00 hrs
- J. Information received in CEA : 24.05.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Information not available
- M. Details of previous maintenance : Information not available
- N. Details of previous failure : Information not available
- O. Sequence of events/ Description of failure : On 15.03.2016 at 08:00 hrs, PT/CVT fail alarm and annunciation was observed; CVT indication bulb in Y phase was not glowing. After switching off the

MCB, the voltages in 3 cores were found low i.e. 15V, 30V & 5V.

P. Details of Tests done after failure : Information not available

Q. Probable cause of failure : Internal fault could be the reason of failure.

**75. Failure of Y Phase PT of 220 kV Main Bus at 220kV Lingapura substation of KPTCL.**

A. Name of Substation : 220 kV SRS Lingapura

B. Utility/Owner of substation : KPTCL

C. Faulty Equipment : Potential Transformer ('Y'ph of 220 kV main bus)

D. Rating :  $(220 \text{ kV}/\sqrt{3}) / (110 \text{ V}/\sqrt{3})$

E. Make : SCT Ltd., Ghaziabad

F. Sr. No. : 2010/1789 ('Y'ph)

G. Year of manufacturing : 2010

H. Year of commissioning : 2012 (June 28<sup>th</sup>)

I. Date and time of occurrence/discovery of fault : 07.03.2016 at 05:20 Hrs.

J. Information received in CEA : 18.04.2016

K. Fault discovered during : Operation

L. Present condition of equipment : To be replaced

M. Details of previous maintenance : Last Maintenance was carried out on 12.01.2015

N. Details of previous failure : Nil

- O. Sequence of events/ : On 07.03.2016 at 05:20 hrs, PT flashed over.  
Description of failure
- P. Details of Tests done after : Due to Flashover, the tests could not be carried  
failure out.
- Q. Probable cause of failure : Internal fault could be a reason of failure.

**76. Failure of 220 kV Y Phase CVT of 150 MVA Transformer at 220 kV Peenya substation of KPTCL.**

- A. Name of Substation : 220 kV SRS Peenya.
- B. Utility/Owner of substation : KPTCL
- C. Faulty Equipment : Capacitor Voltage Transformer (CVT)
- D. Rating : 220 kV
- E. Make : Areva T & D Instrument T/F India Pvt. Ltd.
- F. Sr. No. : 20051133/2005
- G. Year of manufacturing : 2005
- H. Year of commissioning : 2006
- I. Date and time of : 27.09.2015 at 04.22 Hrs.  
occurrence/discovery of  
fault
- J. Information received in : 22.12.2015  
CEA
- K. Fault discovered during : Operation
- L. Present condition of : Replaced  
equipment
- M. Details of previous : 19.07.2015  
maintenance
- N. Details of previous failure : Nil

- O. Sequence of events/ Description of failure : At 04:22 Hrs. 220 kV “Y” ph. CT of 150 MVA Power Transformer No-3 flashed over with heavy sound and fire, power transformer tripped on Differential, HV REF.
- P. Details of Tests done after failure : Tests after failure not possible as the CT had burst.
- Q. Probable cause of failure : Internal fault could be the cause of failure.

**77. Failure of Y Phase PT of 220 KV BUS –A at 220 kV Haveri substation of KPTCL.**

- A Name of Substation : 220kV R/s, Haveri
- B Utility/Owner of substation : KPTCL
- C Faulty Equipment : PT of Bus ‘A’
- D Rating : 220 kV Class
- E Make : SCT
- F Sr. No. : 2010/1780
- G Year of manufacturing : 2010
- H Year of commissioning : 2011 (6<sup>th</sup> April)
- I Date and time of occurrence/discovery of fault : 02.04.2016 at 1812 hrs.
- J Information received in CEA : 30.08.2016
- K Fault discovered during : Operation
- L Present condition of equipment : Damaged
- M Details of previous maintenance : Last maintenance carried out on 20.10.2015
- N Details of previous failure : None

- O Sequence of events/ Description of failure : On 02.04.2016 at 1812 hrs., PT of 220 kV Bus 'B' failed & flashed over. The windings were completely burnt out.
- P Details of Tests done after failure : No tests could be conducted as PT had damaged.
- Q Probable cause of failure : Internal fault due to insulation failure could be the reason of failure.

**78. Failure of B Phase CVT of 400 KV Talaguppa line at 400 kV Nelamangala substation of KPTCL.**

- A Name of Substation : Nelamangala
- B Utility/Owner of substation : KPTCL
- C Faulty Equipment : CVT for 'B' phase of Nelamangala- Talaguppa Line
- D Rating : 400kV/ $\sqrt{3}$  / 110/ $\sqrt{3}$  V, Single Phase, 8800 pF
- E Make : M/s W.S.Industries
- F Sr. No. : 20000707
- G Year of manufacturing : 2000
- H Year of commissioning : Information not available
- I Date and time of occurrence/discovery of fault : 12.05.2016 at 0622 hrs.
- J Information received in CEA : 30.08.2016
- K Fault discovered during : Operation
- L Present condition of equipment : Replaced with spare CVT on 17.05.16
- M Details of previous maintenance : On 03.05.2016, CVT secondary voltage was measured and found within limit.
- N Details of previous failure : None

- O Sequence of events/ : On 12.05.2016 at 0621 hrs 400 kV Nelamangala-Talaguppa line tripped on fault with overvoltage relay indication and Direct Trip sent to Talaguppa end. Overvoltage relay recording was observed. Value was 126 V secondary for Ux measurement. However, bus voltage was 390 kV. On field inspection, it was found that oil was spilling from 'B'ph CVT. Later the faulty CVT was disconnected from the power circuit and Bus A CVT secondary voltage was extended for protection and metering of Nelamangala-Talaguppa line and line was taken into service on 12.05.2016 at 1519 hrs.
- P Description of failure : Carried out Capacitance, tan delta and Ratio test. Results are as follows:

Capacitance and Tan delta test:

Test Carried out on			18.5.2016	
Test Specimen	Mode	Volt applied in kV	Capacitance in pF	Tan Delta in %
Top Stack	UST	2	26045	0.35
		10	26046	0.37
	GST	2	-	-
		10	-	-
Middle Stack	UST	2	26117	0.31
		10	26119	0.32
	GST	2	-	-
		10	-	-
Bottom Stack	UST	2	90000	76
		10	The kit could not measure the values at 10 kV as the kit was tripping	
	GST	2	90851	69.6
		10	The kit could not measure the values at 10 kV as the kit was tripping	
Full Stack	UST	2	11859	7.54
		10	11884	7.26
	GST	2	11733	7.02
		10	11759	6.72

Voltage ratio test:

Test Carried out on	18.05.2016		
	Voltage Applied	Secondary Terminal	Measured Voltage in V

Single Phase AC supply applied to Primary Stud and earth	240.9	1a – 1n	0.094
		2a – 2n	0.094
		3a – 3n	0.094

**Note:** At 240.9 Volts Single Phase AC supply applied to Primary Stud and earth measured voltage at secondary terminal should be 0.066 V

DC insulation resistance test:

Applied voltage: 5 kV

Insulation resistance : OK

Q Probable cause of failure : High values of tan delta indicates deteriorated insulation and high secondary voltage indicates failure of capacitive elements. Higher voltage on CVT secondary caused the operation of overvoltage relay resulting in tripping of the line.

**79. Failure of 220 kV R Phase PT of 220 kV Bus –A at 220 kV Chikkodi substation of KPTCL.**

- A. Name of Substation : 220 kV R/S Chikkodi
- B. Utility/Owner of substation : KPTCL
- C. Faulty Equipment : PT (Bus- A, R-phase)
- D. Rating :  $220\text{ kV}/\sqrt{3} / 110\text{V} / \sqrt{3}$
- E. Make : SCT
- F. Sr. No. : 2010/1810
- G. Year of manufacturing : 2010
- H. Year of commissioning : 2011 (December 17<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 13.10.2015 at 00:35 Hrs.
- J. Information received in CEA : 22.12.2015
- K. Fault discovered during : Operation



- L. Present condition of equipment : Not replaced
- M. Details of previous maintenance : On 29.08.2015, cleaning, greasing & nut bolt tightening of all GOS coming under Bus A&B cleaning & tightening of PT connection was carried out. Oil level & leakage in PTs of Bus A&B was checked and found OK.
- N. Details of previous failure : Nil
- O. Sequence of events/ Description of failure : On 13.10.2015, the following events occurred.
- 00:30hrs- The station was in normal condition, the 220 kV BUS PT-1 & II were connected to parallel buses A & B. Both bus PT were in closed condition. Both Bus A & B were charged by MSETCL supply when bus coupler was closed.
- 00:35 hrs- The R phase PT of 220 kV BUS A blasted & also burnt the joint of 220 kV bus coupler GOS at 00:35 hrs. No relay operated & CBs of interstate lines at 220 kV R/S Chikkodi end did not trip, but CB tripped at both 400 kV Talandagi station & 220 kV Mudashinge station end.
- 220 kV Mudashinge: Distance relay operated, dist.: 73 kms, Fault loop: R ph. pickup, Tr- Z2, & fault current: I1-2.2 kA, I2-0.42 kA & I3-0.73 kA.
- 400 kV Talandagi stn.: Distance relay operated, dist.: nil, Fault loop: L1, Tr- Z2, & fault current: I1-3.067 kA, I2-0.404 kA & I3-0.869 kA. At the same time, the R ph. 220 kV line wave trap joint burnt at 400 kV Talandagi stn.
- 00:37hrs - The both CB of 220 kV Talandagi & Mudashinge hand tripped at 220 kV Chikkodi end.
- 00:37 hrs- The both CB of 220 kV Belgaum I & II lines were hand tripped at 220 kV Chikkodi end. The relays & CBs are not operated at 220 kV Begaum end due to source of power supply at Chikodi end.

00:38 hrs- The HV & LV CB of both 100 MVA Power transformer – I&II Hand Tripped.

01:10 hrs- Isolated the Blasted PT by Opening PT BUS A GOS.

- P. Details of Tests done after failure : Tests after failure were not possible as PT had blasted.
- Q. Probable cause of failure : Internal insulation failure could be the reason of failure of PT.

#### **80. Failure of 220 kV PT in 220kV Narendra substation of KPTCL**

- A. Name of Substation : 220kV Narendra
- B. Utility/Owner of substation : KPTCL
- C. Faulty Equipment : Potential Transformer (R-Phase, Bus-A)
- D. Rating : 220kV voltage class
- E. Make : SCT
- F. Sr. No. : 2012/789
- G. Year of manufacturing : 2012
- H. Year of commissioning : 2014
- I. Date and time of occurrence/discovery of fault : 23.07.2016 at 1250Hrs.
- J. Information received in CEA : 28.11.16
- K. Fault discovered during : Operation
- L. Present condition of equipment : PT is to be replaced
- M. Details of previous maintenance : 1. All jumps and Clamps tightened  
2. No looseness of earth connection was found.

3. No cracks on insulator was found & the insulator was cleaned.

- N. Details of previous failure : No previous failures
- O. Sequence of events/  
Description of failure : On 23.07.16, at 1250 hrs, fire and smoke was observed in the PT. Oil was oozing out.
- PT Selector switch was changed to Bus-B for all 220kV Lines and Transformers.
- P. Details of Tests done after failure : Megger test was done between primary and ground. IR value was found to be zero.
- Q. Probable cause of failure : Internal fault due to insulation failure could be the reason of failure of PT.

**81. Failure of 220 kV PT at 220 kV Settypalli substation of APTRANSCO.**

- A Name of Substation : 220kV Settypalli substation
- B Utility/Owner of substation : APTRANSCO
- C Faulty Equipment : PT
- D Rating : 220 kV Class
- E Make : SCT
- F Sr. No. : 2009/493
- G Year of manufacturing : 2009
- H Year of commissioning : 2011 (18<sup>th</sup> November)
- I Date and time of occurrence/discovery of fault : 01.08.2016 at 1018 hrs.
- J Information received in CEA : 23.09.2016
- K Fault discovered during : Operation
- L Present condition of equipment : Damaged

- M Details of previous maintenance : Regularly maintained as per schedule, detailed information not available.
- N Details of previous failure : None
- O Sequence of events/Description of failure : On 01.08.2016 at 1018 hrs., 220 kV class PT failed.
- P Details of Tests done after failure : None
- Q Probable cause of failure : Internal fault could be the reason of failure.

**82. Failure of R Phase PT of 220 kV Bus-1 at 220 kV Karwar substation of KPTCL.**

- A Name of Substation : 220 kV Karwar S/s
- B Utility/Owner of substation : KPTCL
- C Faulty Equipment : PT of 220 kV Bus 1
- D Rating : 220 kV
- E Make : SCT Limited
- F Sr. No. : 2010/1774
- G Year of manufacturing : 2010
- H Year of commissioning : 2011 (18<sup>th</sup> June)
- I Date and time of occurrence/discovery of fault : 12.07.2016 at 1140 Hrs.
- J Information received in CEA : 30.08.2016
- K Fault discovered during : Operation
- L Present condition of equipment : Damaged
- M Details of previous maintenance : Last maintenance was carried out on 04.08.2016

N	Details of previous failure	:	(PT bushing was cleaned; tightness of the clamp was checked and found OK; oil level was checked and found OK; no leakages were found) Nil
U.	Sequence of events/ Description of failure	:	On 12.07.16 at 1140 hrs, 220 kV Bus-1 'R' Phase PT flashed over and failed causing dead bus at Karwar, Kadra and Kodasalli substations.
P	Details of Tests done after failure	:	As PT had flashed over and windings were completely burnt out, no tests could be conducted.
Q	Probable cause of failure	:	Insulation failure might be the reason.

**83. Failure of B Phase PT of 220 kV Bus- B at 220 kV Chikkodi substation of KPTCL.**

A	Name of Substation	:	220 kV Chikkodi substation
B	Utility/Owner of substation	:	Karnataka Power Transmission Corporation Ltd.(KPTCL)
C	Faulty Equipment	:	220 kV PT (Bus-B, B- phase)
D	Rating	:	220 kV/ $\sqrt{3}$ / 110 V/ $\sqrt{3}$
E	Make	:	SCT Ltd.
F	Sr. No.	:	2010/1811
G	Year of manufacturing	:	2010
H	Year of commissioning	:	2010 (16 <sup>th</sup> June)
I	Date and time of occurrence/discovery of fault	:	01.07.2016 at 0306 hrs
J	Information received in CEA	:	30.08.2016
K	Fault discovered during	:	Operation
L	Present condition of equipment	:	All three nos. SCT make PTs were replaced by 220 kV PTs of CGL make
M	Details of previous maintenance	:	On 21.01.2016, shutdown of both 220 kV Bus A & B was taken. Cleaning, greasing & nut bolt tightening

of PT connections was done. Oil level was checked and no leakage was found in PTs of either bus.

- N Details of previous failure : None
- V. Sequence of events/  
Description of failure : Bus A & B are connected separately to KPTCL & MSETCL supply respectively. Prior to fault, both PT bus GOS were in closed condition. The B phase PT of 220 kV BUS B blasted at 0306 hrs while in operation.
- P Details of Tests done after failure : As PT blasted, no tests could be conducted
- Q Probable cause of failure : Insulation failure might be the reason.

**84. Failure of 220 kV PT at 220/11 kV Lakkasagaram substation of APTRANCO**

- A. Name of Substation : 220 kV Lakkasagaram substation
- B. Utility/Owner of substation : APTRANSCO
- C. Faulty Equipment : Potential Transformer
- D. Rating : 220 kV
- E. Make : SCT
- F. Sr. No. : 2009/217
- G. Year of manufacturing : 2009
- H. Year of commissioning : 2011
- I. Date and time of occurrence/discovery of fault : 13.05.2016 at 08:50 hrs
- J. Information received in CEA : 25.07.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Totally damaged

- M. Details of previous maintenance : Regular maintenance carried out as per schedule
- N. Details of previous failure : Nil
- O. Sequence of events/Description of failure : On 13.05.2016 at 08:50 hrs, PT burst.
- P. Details of Tests done after failure : None as PT had damaged completely
- Q. Probable cause of failure : PT might have failed due to internal fault

**85. Failure of B Phase PT of 220 KV BUS –B at 220 kV Haveri substation of KPTCL.**

- A Name of Substation : 220 kV Haveri substation
- B Utility/Owner of substation : KPTCL
- C Faulty Equipment : PT of Bus 'B'
- D Rating : 220 kV Class
- E Make : SCT
- F Sr. No. : 2010/1782
- G Year of manufacturing : 2010
- H Year of commissioning : 2011 (6<sup>th</sup> April)
- I Date and time of occurrence/discovery of fault : 30.05.2016 at 2335 hrs.
- J Information received in CEA : 30.08.2016
- K Fault discovered during : Operation
- L Present condition of equipment : Damaged

- M Details of previous maintenance : Last maintenance carried out on 20.02.2016
- N Details of previous failure : None
- W. Sequence of events/ Description of failure : On 30.05.2016 at 2335 hrs, PT of 220 kV Bus 'B' failed & flashed over. The windings were completely burnt out.
- P Details of Tests done after failure : No tests could be conducted as PT was damaged.
- Q Probable cause of failure : Internal fault due to insulation failure could be the reason of failure.

**86. Failure of R-ph CVT at 400 kV Indira Sagar power station of NHDC Ltd.**

- A. Name of Substation : 400 kV Indira Sagar Power Station
- B. Utility/Owner of substation : NHDC Limited
- C. Faulty Equipment : CVT(R-phase) of Bus B
- D. Rating : 400 kV
- E. Make : CGL
- F. Sr. No. : 19452
- G. Year of manufacturing : 2003
- H. Year of commissioning : 2003
- I. Date and time of occurrence/discovery of fault : 18.05.2016 at 0219 Hrs.
- J. Information received in CEA : 20.06.16
- K. Fault discovered during : Operation
- L. Present condition of equipment : Damaged



- M. Details of previous maintenance : Last capacitance test & ten delta test was carried out on 16.01.11.
- N. Details of previous failure : Information not available
- O. Sequence of events/  
Description of failure : On 18.05.2016 at 0219 hrs., CVT (R-phase) of Bus # B blasted and all 4 feeders and 2 running units got tripped.
- P. Details of Tests done after failure : No test was possible as CVT had blasted.
- Q. Probable cause of failure : Internal fault could be the probable cause of failure. However, since last testing for evaluation of the health of CVT was done in 2011 as per the information provided by NHDC, it is difficult to ascertain the cause of failure.

**SURGE ARRESTERS / LIGHTNING ARRESTERS****87. Failure of 198 kV Y- Phase L.A. of 220 kV Ch. Dadri- Panipat (S/C) at 220 kV Ch. Dadri substation of BBMB.**

- A. Name of Substation : 220 kV GSS, Ch. Dadri.
- B. Utility/Owner of substation : BBMB
- C. Faulty Equipment : L.A. (Y- Phase of 220 kV Ch. Dadri- Panipat)
- D. Rating : 198 kV
- E. Make : CGL
- F. Sr. No. : 51911
- G. Year of manufacturing : 2006
- H. Year of commissioning : 2006 (Sept. 20<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 19.11.2015 at 18:05 Hrs.
- J. Information received in CEA : 03.02.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced with New One
- M. Details of previous maintenance : IR value- Top to Earth = 13Kx5M $\Omega$  measured on 19.11.2015 during S/Down. Leakage current = 591 micro Amp. measured on 29.10.2015.
- N. Details of previous failure : Nil
- O. Sequence of events/Description of failure : Equipment damaged on 19.11.2015 at 18:05 Hrs. due to line fault.
- P. Details of Tests done after failure : No test was done as LA was flashed.
- Q. Observations : No information has been provided regarding what kind of line fault had occurred. Values of IR

measured on 19.11.2015 are difficult to comprehend and it is also not clear whether value of leakage current (591 micro Amp) is total current or resistive current. If 591 micro amp measured on 29.10.15 is resistive current then LA should have been replaced immediately.

**88. Failure of 230 kV LA (R phase) at 400 kV Alamathy substation of TANTRANSCO.**

- A. Name of Substation : 400 kV Alamathy substation
- B. Utility/Owner of substation : TANTRANSCO
- C. Faulty Equipment : LA (R Phase) of 400/230 kV Auto Transformer ICT-4
- D. Rating : 230 kV
- E. Make : M/s. CGL
- F. Sr. No. : 27203
- G. Year of manufacturing : 2003
- H. Year of commissioning : 2006 (July 28<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 11.03.15 at 13:58 Hrs.
- J. Information received in CEA : 04.11.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Damaged
- M. Details of previous maintenance : Each Stack IR value measured and tightness checked on 10.03.2015 and found normal.
- N. Details of previous failure : No Previous Failure
- O. Sequence of events/Description of failure : On 11.03.2015 at 13.58 hrs., heavy smoke and sound was observed in LA and Differential relay 87T1, Distance relay 21Y, Master Trip relay 86A & 86B of 400/230kV Auto transformer (ICT#4) acted.

P. Details of Tests done after failure : Insulator flashed out on the 2 stacks, hence test could not be carried out.

Q. Probable cause of failure : LA might have failed due to internal fault.

**89. Failure of B Phase LA of 220kV Ponda-1 line at 220kV Ambewadi substation of KPTCL.**

A. Name of Substation : 220 kV R/S, Ambewadi

B. Utility/Owner of substation : KPTCL

C. Faulty Equipment : LA (B phase) of Ponda-1 line

D. Rating : 220 kV

E. Make : WS Industries Ltd.

F. Sr. No. : A-90351, B-90352, C-90353 (Top, Middle, Bottom stack)

G. Year of manufacturing : 1990

H. Year of commissioning : 1992

I. Date and time of occurrence/discovery of fault : 17.12.2015 at 18:20 Hrs.

J. Information received in CEA : 18.04.2016

K. Fault discovered during : Operation

L. Present condition of equipment : Replaced by new LA on 18.12.2015

M. Details of previous maintenance : Last quarterly maintenance was carried out on 31.05.2015.

N. Details of previous failure : Nil

O. Sequence of events/Description of failure : On 17.12.2015 at 18:20 hrs, 220 kV Ponda-1 line tripped on Distance protection relay.

- P. Details of Tests done after failure : LA broken into pieces; hence test was not possible.
- Q. Probable cause of failure : LA had served for more than 33 years. Insulation failure due to ageing could be a reason of failure.

**90. Failure of B-phase LA of 220 kV Harthi line at 220 kV Bidnal substation of KPTCL.**

- A. Name of Substation : 220 kV Receiving Station, Bidnal
- B. Utility/Owner of substation : KPTCL
- C. Faulty Equipment : 220 kV LA (B phase) of Harthi-1 line
- D. Rating : Voltage class: 198 kV, Type: Zinc oxide, Normal Discharge current: 10kA, LD class 3, Pr Relief current: 40 kA, MCOV:168 kV (rms)
- E. Make : CGL
- F. Sr. No. : 55972
- G. Year of manufacturing : 2006
- H. Year of commissioning : 2008 (March 12<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 27.12.2015 at 23:47 Hrs.
- J. Information received in CEA : 18.04.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Damaged
- M. Details of previous maintenance : Quarterly maintenance was carried out on 21.05.2015; LA stacks were cleaned, no cracks were found, earth connections were checked at LA. Electrode and line jump connections were checked for leakage current; surge counter was checked and found normal.

- N. Details of previous failure : Nil
- O. Sequence of events/  
Description of failure : On 27.12.2015 at 23:47 hrs, 220 kV Bidnal- Harthi 1 line tripped on Distance Protection Relay. On inspection it was found that B-phase LA of 220kV Bidnal- Harthi 1 had flashed over causing tripping of the line.
- P. Details of Tests done after  
failure : LA was damaged and hence no tests could be carried out.
- Q. Probable cause of failure: : Insulation failure could be a reason of failure of LA.

**91. Failure of B Phase LA of 220 kV Shimoga line at 220 kV Honnali substation of KPTCL.**

- A. Name of Substation : 220 kV R/S Honnali
- B. Utility/Owner of  
substation : KPTCL
- C. Faulty Equipment : LA (B Phase of 220 kV Shimoga line)
- D. Rating : 220 kV
- E. Make : Crompton Greaves Limited
- F. Sr. No. : 15157
- G. Year of manufacturing : 2002
- H. Year of commissioning : 2003 (20<sup>th</sup> October)
- I. Date and time of  
occurrence/discovery of  
fault : 06.03.2016 at 17:05 Hrs.
- J. Information received in  
CEA : 18.04.2016
- K. Fault discovered during : Operation

- L. Present condition of equipment : To be replaced
- M. Details of previous maintenance : On 19.01.2016, scheduled maintenance was carried out:  
1.Cleaned LA Stacks & no cracks were found  
2.Checked earth connections.
- N. Details of previous failure : Nil
- O. Sequence of events/ Description of failure : On 06.03.2015 at 17:05 Hrs. 220kV Shimoga line tripped on distance relay: distance 2.7 km, B-Ph. to N, IL1=1.06kA, IL2=0.70kA, IL3=5.13kA. On inspection, it was found that B-Phase LA had flashed over.
- P. Details of Tests done after failure : LCM test on 220 kV Shimoga line LA on 28.08.2015 and values of leakage current were found to be within limits.
- Q. Probable cause of failure : Internal fault could be a reason of failure.
- 92. Failure of 220 kV Class Y-phase LA of 220 kV, 100 MVA transformer -4 at 220 kV Versova substation of Reliance Infrastructure- Mumbai Transmission.**
- A. Name of Substation : 220 kV Versova substation
- B. Utility/Owner of substation : Reliance Infrastructure – Mumbai Transmission
- C. Faulty Equipment : Lightning Arrester (Y-phase)
- D. Rating : 220 kV Class
- E. Make : CGL
- F. Sr. No. : 35971
- G. Year of manufacturing : 2004
- H. Year of commissioning : 2005 (June 30<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 30.11.2015 at 13:22 Hrs.

- J. Information received in CEA : 09.12.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Y phase LA disconnected & the transformer was taken in service after isolating failed LA.
- M. Details of previous maintenance : Last Annual Maintenance done on 18/03/2015.  
THRC results  
16.01.2015 37 Micro Amps  
08.01.2014 53 Micro Amps
- N. Details of previous failure : Nil
- O. Sequence of events/ Description of failure : 220/33 kV 100 MVA TR- 4 tripped on Y Phase Differential Protection & Directional OC and E/F at 13:22 hrs on 30/11/2015 due to 220 kV Y Phase LA failure.
- P. Details of Tests done after failure : Visual & Physical Inspection Done during which Lightning Arrester was found to be damaged.
- Q. Probable cause of failure : Internal insulation failure.

**93. Failure of 216 kV, 10 kA R Phase Surge Arrester of 220 kV Dabespel line at 400kV Nelamanagla Substation of KPTCL**

- A. Name of Substation : 400kV Receiving Station, Nelamangala
- B. Utility/Owner of substation : KPTCL
- C. Faulty Equipment : 216 kV Surge Arrester (220 kV Dabespel line)
- D. Rating : 216 kV, 10 kA
- E. Make : CGL
- F. Sr. No. : 5129
- G. Year of manufacturing : 2000
- H. Year of commissioning : 2001



- I. Date and time of occurrence/discovery of fault : 28.12.2015 at 12.18 hrs.
- J. Information received in CEA : 15.02.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced
- M. Details of previous maintenance : Carried out 3<sup>rd</sup> Harmonic Resistive leakage current on 06.08.2015 and value was 13.2 Micro Amps.
- N. Details of previous failure : Nil
- O. Sequence of events/ Description of failure : Line tripped on Fault with big sound in the yard. On Inspection, it was found that the 220 kV Dabespet line R-Phase Surge Arrester had flashed over.
- P. Details of Tests done after failure : As SA had flashed over, the tests could not be carried out.
- Q. Probable cause of failure : Internal fault could be the cause of failure.
- 94. Failure of 220 kV R phase LA of 220/66 kV, 100 MVA Transformer I at 220 kV Sagapara substation of GETCO**
- A. Name of Substation : 220 kV Sagapara s/s
- B. Utility/Owner of substation : GETCO
- C. Faulty Equipment : LA (R-ph) of 220/66 kV, 100 MVA Transformer-I
- D. Rating : 220 kV
- E. Make : CGL
- F. Sr. No. : 9706046
- G. Year of manufacturing : 1997

- H. Year of commissioning : 1999 (Sept. 13<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 19.12.2015 at 19:15 hrs
- J. Information received in CEA : 04.01.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced
- M. Details of previous maintenance : 1. LCM value

Date	I <sub>leakage</sub> ( $\mu$ A)	I <sub>total</sub> ( $\mu$ A)
28.03.13	36	890
13.03.14	148	1860

2. On 19.12.2015, porcelain was cleaned by cloth & clamp connector tightening work was carried out. Earthing connection were also checked and found ok.

- N. Details of previous failure : Nil
- O. Sequence of events/Description of failure : On 19.12.2015 at 19:15 hrs, 220 kV class R phase LA of 220/66 kV, 100 MVA transformer no. 1 failed with blast and smoke. 100 MVA trf.-I tripped on differential only. After physical observation, it was found that 220 kV R phase LA flashed and its bottom, middle and top part had carbonized and its cable connection to surge counter opened out from LA bottom.
- P. Details of Tests done after failure : Tests after failure were not possible as the LA had blasted.
- Q. Probable cause of failure : Internal insulation failure could be the cause of failure.

**95. Failure of 390 kV LA of 400 kV Thiruvalem-I feeder (Y phase) at Alamathy substation of TANTRANSCO**

- A. Name of Substation : 400/230-110 kV ALAMATHY SS

- B. Utility/Owner of substation : TANTRANSCO
- C. Faulty Equipment : LA in Y phase of Thiruvallam-I Feeder
- D. Rating : 390kV
- E. Make : CGL
- F. Sr. No. : 26184
- G. Year of manufacturing : 2003
- H. Year of commissioning : 2006
- I. Date and time of occurrence/discovery of fault : 13.12.2015 at 22:42 Hrs.
- J. Information received in CEA : 11.01.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced
- M. Details of previous maintenance : Leaking Current Monitoring for third harmonic Current measurement was conducted on 05.06.2015 by M/s. PGCIL and results were found normal.
- N. Details of previous failure : Nil
- O. Sequence of events/  
Description of failure : 13.12.2015 at 22:42 Hrs , heavy sound and fire was observed in LA. ARC operated, I > 1 trip, SOTF, ABC phase TRIP acted in 400 kV Thiruvallam-I feeder and 400 kV Thiruvallam tie breaker also tripped.
- P. Details of Tests done after failure : LA flashed over and burst, hence no test not could be carried out.
- Q. Probable cause of failure : Internal insulation failure could be cause of failure.

**96. Failure of 230 kV 'B' phase Lightning Arrestor at 230 kV Cuddalore substation of TANTRANSCO**

- A. Name of Substation : Cuddalore substation
- B. Utility/Owner of substation : TANTRANSCO
- C. Faulty Equipment : LA (B-ph, HV side of 100 MVA Auto Transformer-I)
- D. Rating : 230 kV
- E. Make : CGL
- F. Sr. No. : 9509115
- G. Year of manufacturing : 1996
- H. Year of commissioning : 1998
- I. Date and time of occurrence/discovery of fault : 16.06.2016 at 17:37 hrs
- J. Information received in CEA : 06.07.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Not repairable
- M. Details of previous maintenance : Routine maintenance was done periodically
- N. Details of previous failure : No previous failures
- O. Sequence of events/Description of failure : On 16.06.2016, at 17:37 hrs, the 230 kV LA burst while in service
- P. Details of Tests done after failure : Not possible as LA was burst
- Q. Probable cause of failure : LA might have failed due to internal fault.

**97. Failure of 230 kV LA at 230 kV Korattur substation of TANTRANSCO**

- A. Name of Substation : 230 kV Korattur substation
- B. Utility/Owner of substation : TANTRANSCO
- C. Faulty Equipment : Lightning Arrestor
- D. Rating : LA (Y-ph HV side of 100 MVA Auto transformer-II)
- E. Make : CGL
- F. Sr. No. : 4865
- G. Year of manufacturing : 1999
- H. Year of commissioning : 2000
- I. Date and time of occurrence/discovery of fault : 19.06.2016 at 15:33 hrs
- J. Information received in CEA : 16.08.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Not repairable
- M. Details of previous maintenance : On 19.06.2016 general maintenance work was carried out. Hipot test was conducted on 10.07.2015 by Hot Lines and LA was reported healthy.
- N. Details of previous failure : None
- O. Sequence of events/  
Description of failure : On 19.06.2016 at 15:33 hrs, heavy dip in voltage was observed and sound was heard in the yard. Upon inspecting the relay panel, it was observed that 100 MVA Auto. Tr. No. II had tripped in the differential protection. Upon inspecting the yard condition it was found that 'Y' phase H.V side LA of 100 MVA Auto Tr. No. II had flashed over.
- P. Details of Tests done after failure : Test could not be conducted as LA had flashed over.

Q. Probable cause of failure : Internal fault might have damaged the LA.

**98. Failure of 400 kV LA at 400 kV Panipat substation of BBMB.**

- A. Name of Substation : 400kV GSS PANIPAT
- B. Utility/Owner of substation : BBMB
- C. Faulty Equipment : LA
- D. Rating : 400kV voltage class
- E. Make : CGL
- F. Sr. No. : 28554
- G. Year of manufacturing : 2004
- H. Year of commissioning : 2006 (30<sup>th</sup> March)
- I. Date and time of occurrence/discovery of fault : 19-09-2016 at 1406 hrs.
- J. Information received in CEA : 13.10.16
- K. Fault discovered during : During operation
- L. Present condition of equipment : Replaced with new LA (LAMCO make, Sr. No.112, year of mfg.2005 and commissioned on 20-09-2016 at 0010 Hrs.)
- M. Details of previous maintenance : Regularly maintained as per schedule
- N. Details of previous failure : Nil
- O. Sequence of events/Description of failure : On 19.09.2016 at about 1406 hrs , 400kV PANIPAT – DADRI-II line tripped off. After inspection of switch yard, the B- phase LA of said line was found to be burst.

- P. Details of Tests done after failure : No test possible as LA had burst failure
- Q. Observations : NA
- R. Probable cause of failure : Internal fault could be the probable cause of failure.

**99. Failure of R-ph LA at 400 kV Alamathy substation of TANTRANSCO**

- A Name of Substation : 400 kV Alamathy substation
- B Utility/Owner of substation : TANTRANSCO
- C Faulty Equipment : R-Phase LA of 230 kV Mosur Feeder
- D Rating : 216 kV, 10 kA<sub>p</sub>
- E Make : Crompton Greaves Ltd
- F Sr. No. : 218206
- G Year of manufacturing : 2003
- H Year of commissioning : 2006
- I Date and time of occurrence/discovery of fault : 26.05.2016 at 1650 Hrs.
- J Information received in CEA : 20.06.16
- 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 checked on 26.05.2016.
- N Details of previous failure : Nil
- O Sequence of events/Description of failure : On 26.05.2016 at 1650 hrs., heavy sound and smoke was observed in LA and following relays operated in 230 kV Mosur feeder:

- Aux. relay: 27 R, Y, B  
86 M1A, B, C  
86 M2 A, B, C  
79X. back up imp. Relay: 30 D, 30 F.
- P Details of Tests done after failure : Insulator flashed out on the 2 stacks over, hence tests could not be carried out.
- Q Observations :
- R Probable cause of failure : Internal fault could be the cause of failure. No information is available about periodic monitoring of leakage current and insulation resistance.

**100. Failure of 230 kV B phase LA of 230 kV Echur-Arni feeder at 230 kV Echur substation of TANTRANSCO**

- A. Name of Substation : 230 kV Echur Substation
- B. Utility/Owner of substation : TANTRANSCO
- C. Faulty Equipment : LA (B phase of Echur-Arni feeder)
- D. Rating : 230 kV
- E. Make : OBLUM
- F. Sr. No. : 01
- G. Year of manufacturing : Information not available
- H. Year of commissioning : 2016 (August 8<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 13.12.2016 @ 01:44 hrs
- J. Information received in CEA : 04.01.2017
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced
- M. Details of previous maintenance : Periodical maintenance was carried out.
- N. Details of previous failure : Nil



- O. Sequence of events/ Description of failure : On 13.12.2016 at 01:44 hrs, heavy bursting sound was heard at 230 kV Arni feeder side. The jumpers of 230 kV LA with surge monitor snapped from the equipment.
- P. Details of Tests done after failure : Not applicable, as LA burst.
- Q. Probable cause of failure : LA burst due to Vardha Cyclone.

**101. Failure of 198 kV R phase LA of Jamalpur-Sangrur I at 220 kV Jamalpur substation of BBMB**

- A. Name of Substation : 220kV Sub Station, Jamalpur
- B. Utility/Owner of substation : BBMB
- C. Faulty Equipment : 198 kV R phase LA of 220 kV Jamalpur-Sangrur-I feeder
- D. Rating : 198 kV
- E. Make : CGL
- F. Sr. No. : 51884
- G. Year of manufacturing : 2006
- H. Year of commissioning : 2006 (Oct. 18<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 25.04.2016 At 1804 Hrs.
- J. Information received in CEA : 25.05.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced with new LAMCO make LA
- M. Details of previous maintenance : Last maintenance was carried out on 25.04.2016. Maintenance activities need to be elaborated.

- N. Details of previous failure : Nil
- O. Sequence of events/  
Description of failure : On 25.04.2016 at 1804 hrs., 198 kV R Phase LA of Jamalpur-Sangrur Ckt I got damaged with huge sound & smoke while closing the circuit breaker from Sangrur end.
- P. Details of Tests done after  
failure : As the LA had burst, the tests could not be carried out.
- Q. Probable cause of failure : It appears that switching operation might have stressed already weekend insulation beyond its withstand capacity. failure might be the reason of failure.

**102. Failure of R-ph LA of Ongole feeder at 220 kV Nellore substation of APTRANSCO**

- A Name of Substation : 220 kV Nellore substation
- B Utility/Owner of substation : APTRANSCO
- C Faulty Equipment : R-phase LA of Nellore-Ongole feeder
- D Rating : 220kV
- E Make : ELPRO
- F Sr. No. : Information not available
- G Year of manufacturing : 1972
- H Year of commissioning : 1980 (31<sup>st</sup> March)
- I Date and time of  
occurrence/discovery of  
fault : 18.05.2016 (time of failure is not available)
- J Information received in CEA : 28.06.16
- K Fault discovered during : Operation
- L Present condition of  
equipment : To be replaced

- M Details of previous maintenance : Last Quarterly maintenance done on 14.03.2016
- N Details of previous failure : Information not available
- O Sequence of events/  
Description of failure : On 18.05.16, R-ph LA of Nellore- Ongole feeder flashed over while in operation.
- P Details of Tests done after failure : No tests could be conducted as LA flashed over
- Q Observations : Lightning was observed during failure
- R Probable cause of failure : The LA had served for 36 years. Weakening of insulation due to lightning and ageing could have caused the flashover in the LA.

**COUPLING CAPACITORS****103. Failure of B phase Coupling Capacitor of 230 kV NCTPS feeder at 230 kV Gummidipoondi substation of TANTRANSCO**

- A. Name of Substation : 230 kV Gummidipoondi substation
- B. Utility/Owner of substation : TANTRANSCO
- C. Faulty Equipment : Coupling capacitor (B phase of NCTPS feeder)
- D. Rating : 230 kV
- E. Make : CGL
- F. Sr. No. : 8817
- G. Year of manufacturing : 1996
- H. Year of commissioning : 2001
- I. Date and time of occurrence/discovery of fault : 30.11.2015 at 14:35 hrs
- J. Information received in CEA : 03.03.2016
- K. Fault discovered during : Operation
- L. Present condition of equipment : Damaged
- M. Details of previous maintenance : Last scheduled maintenance was carried out on 01.10.2015.
- N. Details of previous failure : Nil
- O. Sequence of events/Description of failure : On 30.11.2015 at 14:35 hrs, B phase Coupling Capacitor burst and heavy smoke was formed. Distance protection had operated. There was heavy rain and lightning at the time of failure. After isolating the B- phase coupling capacitor, 230 kV

NCPTS feeder was put back in service on 01.12.2015.

- P. Details of Tests done after failure : Not possible as the coupling capacitor was burst.
- Q. Probable cause of failure: : Internal fault could be the reason of failure.

**104. Failure of R-ph Coupling Capacitor of 220kV Dhuvaran Line at 220 kV Vartej substation of GETCO**

- A. Name of Substation : 220 kV Vartej Substation
- B. Utility/Owner of substation : GETCO
- C. Faulty Equipment : Coupling Capacitor (R phase of Dhuvaran line)
- D. Rating : 220 kV
- E. Make : WS Insulators
- F. Sr. No. : 801021
- G. Year of manufacturing : 1980
- H. Year of commissioning : 1984 (Nov. 7<sup>th</sup>)
- I. Date and time of occurrence/discovery of fault : 11.11.2015 at 19:53 Hrs.
- J. Information received in CEA : 8.12.2015
- K. Fault discovered during : Operation
- L. Present condition of equipment : Replaced
- M. Details of previous maintenance : On date 01.11.2015, porcelain was cleaned by cloth, clamp connector tightening work carried out. Earthing connection also checked and found OK. HF terminal also checked.
- N. Details of previous failure : Information not available

- O. Sequence of events/ Description of failure : On 11.11.2015, R-phase coupling capacitor failed/ blasted with fire. Porcelain burst into many pieces & spread all over the switchyard. The 220 kV Vartej-Dhuvaran line tripped from both ends.
- Vartej end relay: R-Y-B to Earth, zone 1 distance – 0 km.  
Dhuvaran end relay: R-Y-B to earth, distance – 164.1 km
- P. Details of Tests done after failure : As the equipment burst, post failure tests were not possible.
- Q. Probable cause of failure : The Coupling capacitor had served for 31 years. Ageing might be a reason of failure.

## **ANNEXURE III**

MINUTES OF MEETING OF THE STANDING  
COMMITTEE OF EXPERTS TO INVESTIGATE THE  
FAILURE OF 220 KV AND ABOVE VOLTAGE CLASS  
SUBSTATION EQUIPMENT HELD ON 1<sup>ST</sup> MARCH  
2017 IN CEA

**MINUTES OF MEETING OF THE STANDING COMMITTEE OF EXPERTS TO INVESTIGATE THE FAILURE OF 220 KV AND ABOVE VOLTAGE CLASS SUBSTATION EQUIPMENT HELD ON 01.03.2017 IN CEA, NEW DELHI, IN CONNECTION WITH REPORTED FAILURES FROM SEPTEMBER 2015 TO DECEMBER 2016 AT VARIOUS SUBSTATIONS IN THE COUNTRY**

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The list of participants is enclosed as **Annexure-A**.

- (1) Chief Engineer (PSE&TD) & Chairman of the subject Standing Committee welcomed the participants and highlighted the importance of timely reporting of failures to the Committee. He stated that discussing the failures and sharing of operating experiences and maintenance practices of utilities will help in adopting best practices of maintenance and thereby reducing the failures. He further informed that during the period from 1<sup>st</sup> September 2015 to 31<sup>st</sup> December 2016, 110 Nos. equipment failures (21 Nos. transformers, 4 Nos. Reactors, 7 Nos. CBs, 26 Nos. CTs, 32 Nos. CVTs/PTs, 17 Nos. LAs, 2 Nos. Coupling Capacitors, one No. Line Isolator) were reported to CEA by Fourteen (14) utilities. He further highlighted that only one incidence of failure has been reported from the Eastern Region that is from OPTCL.
- (2) Chairman informed that owing to a large number of failures of CGL make Instrument Transformers (IT) and Surge Arresters (SA), CGL was requested to depute concerned expert for discussion and deliberation. Mr. Yesuraj, GM (R&D), was deputed by CGL to make a presentation before the Committee and for a healthy interaction between manufacturer and utilities for discussing about causes of failure and best maintenance practices required to be adopted to minimize the failures.
- (3) Member Secretary informed about the absence of the representatives from KPCL, MPPTCL and GETCO. He further stated that a draft report prepared based on information provided by utilities between September 2015 and December 2016, was uploaded on CEA's website and the same was also communicated to the concerned utilities prior to meeting. He stated that the utilities submit incomplete information about the failure because of which it becomes difficult to analyze the failure cases. He requested to provide adequate information available with them along with test reports and photographs of failed equipment. He informed that in most of the failure reports of CT/CVT/PT/SA, failure type is mentioned as 'Equipment Flashed' which do not convey the actual description of failure. Utilities were requested to describe the failure properly in future reports so that misinterpretation of failure type is avoided.
- (4) Mr. Yesuraj gave a presentation pertaining to failures of Instrument Transformers and SA. Some of the significant points/issues highlighted in CGL's presentation are as follows:



- (a) At the outset, Mr. Yesuraj informed that most of failures listed in CEA's draft failure report have not been reported to CGL by the utilities, specially by the utilities in the Northern region. Moreover, details of the failure provided by the utilities to CGL are not adequate to pin point the cause of failures. If detailed information about failure is provided, it helps manufacturers to take corrective action for improving the quality of product as well as would help the manufacturer to suggest corrective action to be taken by user to avoid repetition of such failures in future.
  - (b) He intimated that based on failure of CGL make CVTs, reported by utilities, certain design changes were made in CVT model in 2007. After carrying out modification, not a single incident of CVT failure has been reported to CGL. Hence, intimation of failure to the manufacturer brings positive results.
  - (c) He also cautioned against use of N<sub>2</sub> gas cushion in CT as the gas is absorbed by oil as temperature rises; the same is released as bubbles when oil cools down leading to partial discharge, which sometimes result in blasting of CT.
  - (d) Various queries raised by different utilities were discussed during interaction with CGL representatives. CGL presentation included various suggestions to improve reliability and availability of Instrument Transformers & Surge Arresters.
- (5) After CGL's presentation, PGCIL's representative made a brief presentation on failure of transformer & reactors in PGCIL substations.
- (a) Presentation included the technical details of failed equipment, observations made during internal inspection & various tests carried out after failure, and conclusion derived based on the observations and tests. PGCIL representative presented about the pre-commissioning procedures and condition based monitoring procedures followed in PGCIL including various offline condition assessment & diagnostic techniques. He also informed about standard proforma of PGCIL for reporting of failure of substation equipment which can be filled up easily by a junior level officer without making mistakes to avoid misreporting.
  - (b) The Chairman requested PGCIL to report all failures of equipment of 220 kV and above voltage class to CEA's Standing Committee, participate regularly in the meeting and share their experiences highlighting the remedial action taken, which will benefit other participating utilities.

During presentation it was informed that the problems in bushing & winding (for both transformers & reactors) and OLTC (in transformers) leads to failure of transformers & reactors.

- (6) Due to paucity of time, it was not possible to discuss each & every case of failure. However, during the course of presentations by CGL & PGCIL representatives, various critical issues relating to failure of Transformers, Reactors, Instrument Transformers and Surge Arresters were discussed and following points emerged:
- (a) 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.
  - (b) The utilities should report OEMs about the failure of equipment even after expiry of warranty period, which may help the manufacturers to take corrective action for improving the product design.
  - (c) Utilities should make it a practice to carry out various tests on major electrical equipment at sites one or two months before the expiry of warranty period of respective equipment.
  - (d) Shortage of operation and maintenance personnel and lack of proper training are matter of concern. Utilities should look into such issues with seriousness.

**Instrument Transformers:**

- (e) 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.
- (f) 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.
- (g) The secondary voltage of CVT is an indicator of health of CVT and drifting of secondary voltage beyond a certain limit is a clear indication of problem in CVT.

**Surge Arresters:**

- (h) 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.

- (i) Thermal scanning is another simple on-line check often used on SAs to locate hot spot due to improper/defective terminations/excessive watt loss.
- (j) Monitoring of Leakage Current and IR value are essential for accessing the healthiness of Surge Arrestors (SAs). Measurement of the 3<sup>rd</sup> harmonic resistive component of leakage current is a very good method for assessing healthiness of SA which can be done on-line. If 3<sup>rd</sup> harmonic component of resistive current is more than 150  $\mu\text{A}$  then Insulation Resistance (IR) value test should also be conducted and if current exceeds 350  $\mu\text{A}$  then LA 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.
- (k) 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.
- (l) Digital surge counter's employment in substations could be explored.

The meeting ended with vote of thanks to the Chair.

**Annexure - A**

**LIST OF PARTICIPANTS**

**Central Electricity Authority, New Delhi**

1. Shri S.K.Ray Mohapatra, Chief Engineer, PSETD .....in the Chair
2. Shri Y.K.Swarnkar, Director, PSETD
3. Shri Faraz, Assistant Director, PSETD
4. Ms. Bhaavya Pandey, Assistant Director, PSETD
5. Shri. Santosh Kumar, Dy. Director, CEI
6. Shri. Krishnanand Pal, Assistant Director R&D
7. Shri. Deepak Sharma, Assistant Director, R&D

**Central Power Research Institute**

1. Shri. B.M. Mehra, Joint Director
2. Shri. S. Bhattacharyya, Joint Director

**Bhakra Beas Management Board**

1. Shri Sanjeev Kumar Saini, SSE
2. Shri. Harpreet Singh, SSE
3. Shri. Shiv Ram Agarwal, SSE
4. Shri. Harish Garg, SSE
5. Shri. Bhoop Singh Gulia SSE
6. Shri. Parveen K. Dhiman, AEE/ MTC
7. Shri. Vishal Dahiya Dy. Director- P&T Cell
8. Shri. Sunil Siwach, Dy.Director- P&T
9. Shri. Rakesh Singla
10. Shri. Ashok Gahlawat
11. Shri. R.K.Gupta, Sr. XEN

**TANTRANSCO**

Shri. T. Sakthivel

**Kerala State Electricity Board**

Shri. James. M. David, Chief Engineer (Tr. North)

**Transmission Corporation of Andhra Pradesh Ltd.**

Shri. T. Udhaya Kumar ADE/MRT/

**Karnataka Power Transmission Corporation Ltd.**

Shri. B.V. Girish, E.E.

**CGL**

1. Sh. John Yesuraj, GM- R&D
2. Gautam Tewari, AGM- NR

**Delhi Transmission Corporation Ltd.**

1. Sh. S.K. Sharma, GM (O&M)-II
2. Sh. Loveleen Singh, GM (O&M)-I
3. Sh. Roop Singh, DGM (O&M)- W
4. Sh. L.P.Kushwaha, DGM (O&M)- S

**HVPN**

1. Sh. Ashok Singla, SE
2. Sh. A.P.Singh, XEN TS

**POWERGRID**

1. Sh. Jiten Dan DGM/AM
2. Sh. Amandeep Singh DY. MANAGERCC-AM

**OPTCL**

Sh. Swarup Ku. Harichandan G.M.Maintenance

**NHDC Ltd.**

Sh. Ashok Kumar Singh, Sr. Manager (E)

**RELIANCE**

Sh. Atul Sanghrajka, GM (O&M)

## **ANNEXURE IV**

### 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/2012/1-80

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:

- To investigate the causes of failure of substation equipment in service
- 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.

o/c

  
(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.