

REPORT
ON
FAILURE OF
220 KV AND ABOVE VOLTAGE CLASS
SUBSTATION EQUIPMENT



CENTRAL ELECTRICITY AUTHORITY
MINISTRY OF POWER
GOVERNMENT OF INDIA
NEW DELHI

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1.0 Introduction

In order to investigate the failure of 220 kV and above substation equipment and recommend measures to avert recurrence, a Standing Committee under Section 73, Clause(1) of the Electricity Act, 2003, comprising experts in the field of design and operation of EHV Substations from CEA, various power utilities and research/academic institutes was constituted. As part of such activity, CEA has received reports of failures between 1st April, 2014, and 30th September, 2014, in respect of following equipments from various utilities:

- a) Failure of 390 kV, 10 kA Lightning Arrestor (B phase) at 400 kV Nelamangala Station of KPTCL
- b) Failure of 390 kV, 10 kA Surge Arrestor (Y-phase) of 400 kV Nelamangala-Hassan feeder at 400 kV Nelamangala Receiving Station of KPTCL
- c) Failure of 390 kV, 10 kA Surge Arrestor (B-phase) of 400 kV Nelamangala-Talaguppa feeder at 400 kV Nelamangala Receiving Station of KPTCL
- d) Failure of 390 kV, 10 kA Surge Arrestor (R-phase) of 400 kV Nelamangala-Hassan feeder at 400 kV Nelamangala Receiving Station of KPTCL
- e) Failure of 420 kV, 8800 pF CVT (Y-phase Bus-B) at 400 kV Nelamangala Receiving Station of KPTCL
- f) Failure of 100 MVA Power Transformer at 220 kV Honnali Receiving Station of KPTCL
- g) Failure of 220 kV CVT (B phase) at 220 kV Bidadi Receiving Station of KPTCL
- h) Failure of 420 kV, 2000 A circuit breaker (Unit-7) at Raichur Thermal Power Station of KPCL
- i) Failure of 420 kV, 2000 A circuit breaker (Unit-8) at Raichur Thermal Power Station of KPCL
- j) Failure of 400 kV LA (R phase) in 400/110 kV Auto transformer feeder at 400 kV Alamathy Sub Station of TANTRANSCO
- k) Failure of 230 kV CT (Y phase) of Sriperumbudur feeder-II at Kadapperi Sub Station of TANTRANSCO
- l) Failure of 230 kV LA (Y-phase) of Thanjavur feeder at 230 kV Thiruvarur Sub Station of TANTRANSCO
- m) Failure of 390kV, 10kAp LA (B phase) of 400/230 kV, 315 MVA Auto transformer (ICT 5) feeder at 400 kV Alamathy S/s of TANTRANSCO
- n) Failure of 230 kV CT (B phase) of 230 kV Siruseri feeder at 230 kV Kits Park S/s of TANTRANSCO
- o) Failure of 390kV, 10kAp LA (Y phase) of 400/230 kV, 315 MVA Auto transformer (ICT 5) at 400 kV Alamathy S/s of TANTRANSCO
- p) Failure of 230kV, 10kAp LA (B phase) of 230 kV Korattur feeder at 400 kV Alamathy S/s of TANTRANSCO
- q) Failure of 230kV LA of 100 MVA, 230/110 kV Auto transformer-II HV side B phase at 230 kV Korattur Sub station of TANTRANSCO
- r) Failure of CVT (B phase) in 230kV Bus 'A' at 230 kV Cuddalore sub-station of TANTRANSCO

- s) Failure of 198 kV LA (B Phase) of Narela ckt-II at 220 kV Rohtak Road Sub Station of BBMB
- t) Failure of 216 kV/10 kA, LA (R Phase) of 220 kV Samaypur Badshahpur Ckt-I at 220 kV Sub Station of BBMB
- u) Failure of 220 kV CVT (R Phase) on 220 kV Jalandhar-Pong Ckt at 220 kV Jalandhar Sub Station of BBMB
- v) Failure of 198 kV LA (Y phase) of 220/132 kV, 100 MVA transformer (T-3) at 220 kV GSS Hisar Sub station of BBMB
- w) Failure of various equipment of 220 kV Ballabgarh-Samaypur ckt-I at 220 kV Ballabgarh & Samaypur Sub stations of BBMB
- x) Failure of R phase limb/pole of 245 kV SF-6 Breaker of Unit no. 8 of 220 kV Sub station of Bhakra Right Bank Power House of BBMB
- y) Failure of 245 kV CT (B phase) of 220/132 kV, 50 MVA transformer (T-3) at 220 kV Kurukshetra sub-station of BBMB
- z) Failure of 220 kV CT at 220 kV Sabalgarh S/s of MP Power Transmission Corporation Ltd.
- aa) Failure of 220kV CT (Y phase) of 220 kV Gurur-Barsoor Ckt-II at 220 kV Barsoor sub-station of CSPTCL
- bb) Failure of 220kV LA (Y phase) of 220 kV Lower Sileru Ckt-I at 220 kV Barsoor sub-station of CSPTCL
- cc) Failure of Unit-4 CT (Y-phase) at 220 kV Switch Yard at Srisailam Right Bank Power House of Andhra Pradesh Power Generation Corporation Limited (APPGCL)
- dd) Failure of 400 kV Current Transformer (CT) at 400/230 kV Tiruvalam substation of PGCIL
- ee) Failure of 400 kV Current Transformer (CT) at 400 kV Kalivanthapattu substation of PGCIL

Salient features of each of the substations and analysis of failure of equipment are detailed in pages 5-41 and general recommendations are given in pages 42-43.

2.0 Failure of B phase of 390 kV, 10 kA Lightning Arrester of Nelamangala-Talaguppa feeder at 400 kV Nelamangala Station, Karnataka Power Transmission Corporation Ltd. (KPTCL)

- 1 Name of Substation : 400 kV Receiving Station, Nelamangala
- 2 Utility/Owner of substation : KPTCL
- 3 Faulty Equipment : Surge Arrester (B-phase)
- 4 Rating : 390 kV, 10 kA
- 5 Make : Crompton Greaves Limited
- 6 Sr. No. : Information not available
- 7 Year of manufacturing : 2000
- 8 Year of commissioning : Information not available
- 9 Date and time of occurrence/discovery of fault : 03.02.2014, 16:47
- 10 Information received in CEA : 17.04.2014
- 11 Fault discovered during : Information not available
- 12 Present condition of equipment : SA was replaced and line was taken into service on 04.02.2014.
- 13 Details of previous maintenance : 28.11.2013
- 14 Details of previous failure : Same phase Surge Arrester failed on Nov 2011
- 15 Sequence of events/ Description of fault :

On 03.02.2014, the 400 kV Nelamangala – Talaguppa line was made idle charged from Nelemangala end by opening breaker at Talaguppa end at 15:39 hrs as per the directions of SLDC. The idle charged line tripped on Distance Protection with B phase to ground fault due to flash over of B Phase Line Surge Arrester at 16:47 hrs on 03.02.2014 with fault current of 18.92 kA.
- 16 Details of Tests done after failure : NA

17 Conclusion/recommendations : Refer para 33.0.

3.0 Failure of 390 kV, 10 kA Surge Arrester (Y-phase) of 400 kV Nelamangala-Hassan feeder at 400 kV Nelamangala Receiving Station of KPTCL

- 1 Name of Substation : 400 kV Receiving Station, Nelamangala
- 2 Utility/Owner of substation : KPTCL
- 3 Faulty Equipment : 390 kV Surge Arrester (Y-phase)
- 4 Rating : 390 kV, 10 kA
- 5 Make : Crompton Greaves Limited
- 6 Sr. No. : 14220
- 7 Year of manufacturing : 2000
- 8 Year of commissioning : Information not available
- 9 Date and time of occurrence/discovery of fault : 25.04.2014 @ 23:46 hrs
- 10 Information received in CEA : 26.05.14
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced using the R-phase surge arrester of Hassan shunt reactor (as no spare one was available at the time)
- 13 Details of previous maintenance : Previous maintenance was carried out on 17.09.2013.
- 14 Details of previous failure : Surge Arrester same make and year of manufacture, provided for 400 kV Nel – Talaguppa line failed on 03.02.2014 and 17.03.2014 and was replaced with the Surge Arrester released from the Hassan Line Shunt Reactor on 04.02.2014 and 18.03.2014 respectively.
- 15 Sequence of events/ Description of fault

1. On 22.04.2014 @ 22:43 hrs Hassan Line tripped due to flash over of R phase Suspension String Insulator at location 884 near Nelamangala. Same was restored on 23.04.2014 @ 21:38 hrs.

2. After 10 minutes again line was tripped @ 21:47 hrs due to flash over of Y phase Suspension string insulator at location 888 near Nelamangala; same was attended on 25.04.2014 @ 19:14 hrs.
3. On 25.04.2014 line again tripped due to flash over of Y phase Line Surge Arrester.

- 16 Details of Tests done after : NA
failure
- 17 Conclusion/recommendations : Refer para 33.0.

4.0 Failure of 390 kV, 10 kA Surge Arrester (B-phase) of 400 kV Nelamangala-Talaguppa feeder at 400 kV Nelamangala Receiving Station of KPTCL

- 1 Name of Substation : 400 kV Receiving Station, Nelamangala
- 2 Utility/Owner of substation : KPTCL
- 3 Faulty Equipment : 390 kV Surge Arrester (B-phase)
- 4 Rating : 390 kV, 10 kA
- 5 Make : Crompton Greaves Limited
- 6 Sr. No. : 5076
- 7 Year of manufacturing : 2000
- 8 Year of commissioning : Information not available
- 9 Date and time of occurrence/discovery of fault : 17.03.2014 @ 20:49
- 10 Information received in CEA : 26.05.14
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced using the Y-phase surge arrester of Hassan shunt reactor (as no spare one was available at the time)
- 13 Details of previous maintenance : Information not available
- 14 Details of previous failure : Same surge arrester failed on 03.02.2014 and replaced with the surge arrester released from the R-phase of Hassan line shunt reactor on 04.02.2014.

- 15 Sequence of events/ :
Description of fault
- On 17.03.2014, the 400 kV Nelamangala-Talaguppa line was in charged condition. The line tripped in Distance protection with B phase to ground fault due to flash over of B-phase line surge arrester @ 20:49 hrs on 17.03.2014 with fault current of 19 kA.
- 16 Details of Tests done after : NA
failure
- 17 Conclusion/recommendations : Refer para 33.0.

5.0 Failure of 390 kV, 10 kA Surge Arrester (R-phase) of 400 kV Nelamangala-Hassan feeder at 400 kV Nelamangala Receiving Station of KPTCL

- 1 Name of Substation : 400 kV Receiving Station, Nelamangala
- 2 Utility/Owner of substation : KPTCL
- 3 Faulty Equipment : 390 kV Surge Arrester (R-phase)
- 4 Rating : 390 kV, 10 kA
- 5 Make : Crompton Greaves Limited
- 6 Sr. No. : 14219
- 7 Year of manufacturing : 2001
- 8 Year of commissioning : 2003
- 9 Date and time of occurrence/discovery of fault : 18.05.2014 @ 16:24 hrs
- 10 Information received in CEA : 12.08.2014
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced with Oblum make metal oxide SA and line was taken into service on 19.05.2014.
- 13 Details of previous maintenance : The third harmonic resistive leakage current measured on 28.11.2013 was found to be 25.8 μ A.
- 14 Details of previous failure : 1. Surge Arrestor, CGL make and YOM

2000, provided for 400 kV Nel-Talaguppa line failed on 03.02.2014. It was replaced with CGL make Surge Arrestor of Hassan line Shunt Reactor (R-phase) of Sr. No. 5076 YOM 2000 which was in service since 2003.

2. The above replaced Surge Arrestor (Sr. No. 5076) failed on 17.03.2014. Again this was replaced with CGL make Surge Arrestor of Hassan line Shunt Reactor (Y phase) of Sr. No. 5093, YOM 2000 which was in service since 2003.

3. CGL make Surge Arrestor of Sr. No. 14220, YOM 2000 provided for Y-phase of 400 kV Nelamangala-Hassan line failed on 25.04.2014 @ 21:47 hrs. This was replaced with Surge Arrestor released from Hassan Shunt Reactor (B phase) Sr. No. 5091, YOM 2000 which was in service since 2003.

15 Sequence of events/ :
Description of fault

On 18.05.2014 @ 16:24 hrs Hassan line tripped due to flash over of Y phase line Surge Arrestor.

16 Details of Tests done after : No test was conducted (LA's flashover)
failure

17 Conclusion/recommendations : Refer para 33.0.

6.0 Failure of 420 kV, 8800 pF CVT of Y-phase Bus-B at 400 kV Nelamangala Receiving Station of KPTCL

1 Name of Substation : 400 kV Receiving Station, Nelamangala

2 Utility/Owner of substation : KPTCL

3 Faulty Equipment : Single phase 8800 pF CVT

4 Rating : 420 kV Class, 8800 pF

5 Make : Alstom Instruments Transformers Private Limited, Bangalore

6 Sr. No. : 20000704

- 7 Year of manufacturing : 2004
- 8 Year of commissioning : 2012 (8th Dec.)
- 9 Date and time of occurrence/discovery of fault : 18.05.2014 @ 11:30 hrs
- 10 Information received in CEA : 12.08.2014
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced by spare ABB make CVT on 25.05.2014 and taken into service on 25.05.2014.
- 13 Details of previous maintenance : 10.12.2012
- 14 Details of previous failures :
 1. 420 kV Class, Alstom make 4400 pF CVT provided for R-phase of 400 kV Nelamangala-Hoody line 1 failed on 03.08.2006. Same was replaced by spare on 11.08.2006.
 2. 420 kV Class, Alstom make 4400 pF CVT provided for 400 kV Nelamangala-Hiriyur line 1 Y phase failed on 01.06.2009. Same was replaced by spare on 31.12.2009.
 3. 420 kV Class, Alstom make 4400 pF CVT provided for R-phase of 400 kV Nelamangala-Hassan R phase failed on 04.05.2012. Same was replaced by spare on 17.04.2012.
 4. 420 kV Class, Alstom make 4400 pF, Y phase CVT of 400 kV Bus B failed on 06.12.2012. Same was replaced with 8800 pF on 08.12.2012.
 5. 420 kV Class, Alstom make 8800 pF, Y phase CVT of 400 kV Bus B failed on 18.05.2014. Same was replaced with 8800 pF on 25.05.2014.
- 15 Sequence of events/ :
 Description of fault

On 18.05.2014 @ 11:30 hrs, it was observed in SAS that MW reading of 400 kV side of all ICT's was less than that of 220 kV side. On investigation, it was found that secondary voltage of Y phase of 400 kV bus B CVT was less i.e.

56.1 volts as against 61.6 volts in other phases. Immediately the bus CVT was taken out of service. Voltage for protection and metering of 400 kV side ICT's was extended from bus A CVT and the faulty CVT of Bus-B was replaced by spare ABB make CVT on 25.05.2014.

16 Details of Tests done after failure : Capacitance & Tan-Delta measurement and Ratio test were performed on CVT. Tan delta of bottom stack was found to be on higher side and CVT was found faulty in ratio test.

17 Conclusion/recommendations :

Tan delta of bottom stack was found to be on higher side. In ratio test, it was found that measured secondary voltage was less than normal. For recommendations refer para 33.0.

7.0 Failure of 100 MVA Power Transformer at 220 kV Honnali Receiving Station of KPTCL

1 Name of Substation : 220 kV Receiving Station, Honnali

2 Utility/Owner of substation : KPTCL

3 Faulty Equipment : Power Transformer

4 Rating : 100 MVA

5 Make : T&R

6 Sr. No. : 600048

7 Year of manufacturing : 2006

8 Year of commissioning : 2010 (24th Mar.)

9 Date and time of occurrence/discovery of fault : 31.05.2014 @ 03:10 hrs

10 Information received in CEA : 12.08.2014

11 Fault discovered during : Operation

12 Present condition of equipment : Faulty

13 Details of previous maintenance : 1. Maintenance work was carried out on 03.05.2014.

2. Tan delta & capacitance measurement tests were conducted on 31.01.2014 and results were found to be in order.
3. Periodic oil Testing of above transformer was carried out on 06.05.2014.
4. Oil leakage arrested on HV side B-phase bushing bottom on 03.05.2014.
- 14 Details of previous failure : Information not available.
- 15 Sequence of events/ :
Description of fault
- On 31.05.14 at 3:10 AM, power transformer tripped on differential; PRV, Buchholz & REF relays along with Nitrogen based fire protection system also operated.
- 16 Details of Tests done after : Tan delta testing of bushing & winding
failure & winding resistance test was performed.
The IR values measured on 31.05.2014 were found to be 6.49 MΩ (LV-Gnd) and 342 MΩ (MV-Gnd) as compared to factory test results of 27000 MΩ (LV-Gnd) and 25600 MΩ (MV-Gnd).
During LV tests, it was observed that the excitation current drawn by the MV winding was 2.36A to 3.4A when the applied voltage was 251V and excitation current drawn by the LV winding was 34A to 39A when the applied voltage was 237V. The excitation current drawn by the MV and LV winding were high, coming in the order of Amps instead of milli Amps.
- 17 Conclusion/recommendations :
- Operation of differential relay, PRV, bucholz & REF indicate towards internal fault in the transformer which is also confirmed by the abnormal test results of IR measurement and excitation current measurement test. The transformer was commissioned after four years of manufacturing. Such inordinate delay in commissioning should be avoided by utilities as manufacturers generally do not recommend keeping transformer without oil for more than three (3) months. The manufacturer's recommendation should be followed if delay is more than three (3) months.
For recommendations refer para 33.0.

8.0 Failure of B phase CVT at 220 kV Bidadi Receiving Station of KPTCL

- 1 Name of Substation : 220 kV Receiving Station, Bidadi
- 2 Utility/Owner of substation : KPTCL
- 3 Faulty Equipment : CVT
- 4 Rating : $220/\sqrt{3}$ kV/ $110/\sqrt{3}$ V
- 5 Make : CGL
- 6 Sr. No. : 9957
- 7 Year of manufacturing : 1998
- 8 Year of commissioning : 1998
- 9 Date and time of occurrence/discovery of fault : 20.04.2014 @ 11:25 hrs
- 10 Information received in CEA : 12.08.2014
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Non repairable, to be replaced.
- 13 Details of previous maintenance : Replaced jumper between CT and CVT on 04.03.2014 and measured IR values of CVT (1800 M ohm).
- 14 Details of previous failure : Nil
- 15 Sequence of events/
Description of fault

On 20.04.14 at 11:25 hrs heavy fire observed in the B phase CVT of 220 kV Somanahalli line 2 and hence the line was manually tripped for isolating the CVT.
- 16 Details of Tests done after failure : No test was possible as CVT had damaged.
- 17 Conclusion/recommendations : Refer para 33.0.

9.0 Failure of 420 kV, 2000 A circuit breaker (Unit 7) at Raichur Thermal Power Station of Karnataka Power Corporation Ltd. (KPCL)

- 1 Name of Substation : Raichur Thermal Power Station
- 2 Utility/Owner of substation : KPCL
- 3 Faulty Equipment : Unit-7, Circuit Breaker (R & B – phase pole flashed over)
- 4 Rating : 420 kV, 2000 A, 40 kA for 1 sec
- 5 Make : M/s CGL
- 6 Sr. No. : 15871C
- 7 Year of manufacturing : 2002
- 8 Year of commissioning : 2002 (10th Dec.)
- 9 Date and time of occurrence/discovery of fault : 26.01.2014, 06:58:14
- 10 Information received in CEA : 09.04.2014
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : In service (all 3 poles were replaced)
- 13 Details of previous maintenance : Annual over hauling on 05.10.2013 (Tan delta measurement, opening & closing time measurement, DCRM)
- 14 Details of previous failure : Grading Capacitor had failed in R-Ph and was replaced on 04.12.2006.
- 15 Sequence of events/ Description of fault :

On 26.01.14 just before 06:58 hrs, all the five units (Units-4 to 8), 2 ICTs and 5 lines connected to 400 kV systems at RTPS were in service. Following events occurred after that:

- 6.58.14.714 – Mehboob Nagar – 1 R-N, Y-N & B-N fault appeared.
- 6.58.14.730 – Mehboob Nagar Line Tie Breaker opened.
- 6.58.14.714 – ICT-2 Tie Breaker opened.
- 6.58.14.714 – Gooty-1 Line Breaker A/R lockout.
- 6.58.14.714 – Gooty-2 R-N, Y-N & B-N fault appeared.

6.58.14.714 – ICT-1 Tie Breaker opened.
6.58.14.714 – Gooty-2 Line Breaker opened.
6.58.14.714 – Gooty-2 Line Breaker A/R lockout.

However, the breakers at Raichur end have not tripped.

16 Details of Tests done after failure : No test could be carried out on failed poles

17 Conclusion/recommendations :

Circuit Breaker being located near cooling towers of the Thermal Power Plant, had failed due to ash and dust deposition. KPCL generally carry out hot line water washing to clean the CB housing to prevent flashover across the insulator housing. However, KPCL has now decided to use Room Temperature Vulcanizing (RTV) coating over porcelain housing of CB, which is a good move for pollution prone areas.
For recommendations refer para 33.0.

10.0 Failure of 420 kV, 2000 A circuit breaker (Unit 8) at Raichur Thermal Power Station of KPCL

1	Name of Substation	:	Raichur Thermal Power Station
2	Utility/Owner of substation	:	KPCL
3	Faulty Equipment	:	Unit-8, Tie Breaker (B phase flashed over)
4	Rating	:	420 kV, 2000 A, 40 kA for 1 sec
5	Make	:	M/s ABB Ltd
6	Sr. No.	:	47100035
7	Year of manufacturing	:	2009
8	Year of commissioning	:	2011
9	Date and time of occurrence/discovery of fault	:	02.03.2014, 07:00:17
10	Information received in CEA	:	09.04.2014
11	Fault discovered during	:	Operation
12	Present condition of equipment	:	In Service (All 3 poles were replaced)

- 13 Details of previous maintenance : Annual over hauling in April 2011(Tan delta measurement, opening & closing time measurement, DCRM)
- 14 Details of previous failure : Y-pole flashed over on 31.01.2011
- 15 Sequence of events/ Description of fault :

On 02.03.2014 at 07:00 hrs, Raichur PG -1 tripped on distance protection zone 1, three phase trip operated. The line was about to be charged after getting grid code, when at 07:17:27 hrs Unit-8 Tie Breaker pole B flashed over and jumpers got cut and touched to the ground causing tripping of Unit – 8 on operation of GT over-current relay (51GTB) and eventually leading to operation of Unit-8 LBB relay which caused the operation of Bus-2 Bus Bar trip relay.

Unit-7 tripped on operation of Back up impedance relay (21G).

- 16 Details of Tests done after failure : No test could be carried out on failed poles
- 17 Conclusion/recommendations :

Circuit Breaker being located near cooling towers of the Thermal Power Plant, had failed due to ash and dust deposition. KPCL generally carry out hot line water washing to clean the CB housing to prevent flashover across the insulator housing. However, KPCL has now decided to use Room Temperature Vulcanizing (RTV) coating over porcelain housing of CB, which is a good move for pollution prone areas.

For recommendations refer para 33.0.

11.0 Failure of 400 kV LA (R phase) of 400/110 kV Auto transformer feeder at 400 kV Alamathy Sub Station, Tamil Nadu Transmission Corporation Ltd. (TANTRANSCO)

- 1 Name of Substation : 400 kV Alamathy Sub Station
- 2 Utility/Owner of substation : TANTRANSCO
- 3 Faulty Equipment : 400 kV LA (R phase) in 400/110 kV Auto transformer (ICT-2)
- 4 Rating : 400 kV
- 5 Make : CGL

- 6 Sr. No. : 26189
- 7 Year of manufacturing : 2003
- 8 Year of commissioning : 2006 (16th Jun.)
- 9 Date and time of occurrence/discovery of fault : 16.02.14, 19:08 hrs
- 10 Information received in CEA : 15.04.2014
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced
- 13 Details of previous maintenance : Each stack IR value measured and tightness checked on 04.08.2013.
- 14 Details of previous failure : Nil
- 15 Sequence of events/ Description of fault :
- On 16.02.14 at 19:08 hrs, 400 kV LA flashed with heavy sound. HV & LV side breakers of 400/110 kV Auto transformer – II tripped with following indications:
1. Transformer protection 87 T - Hi set
 2. Back up impedance 21 T, Start C, Start N
 3. Auxillary Relay: 86A & 86B
 4. Multiplier: 86AX, 86BX
- 16 Details of Tests done after failure : Insulator flashed out, hence tests could not be carried out.
- 17 Conclusion/recommendations : Refer para 33.0.

12.0 Failure of 230 kV CT at 230 kV Kadapperi Sub Station, TANTRANSCO

- 1 Name of Substation : 230 kV Kadapperi Sub Station
- 2 Utility/Owner of substation : TANTRANSCO
- 3 Faulty Equipment : 230 kV CT in Y phase of 230 kV Kadapperi-Sriperumbudur feeder II
- 4 Rating : 230 kV, 1200-600-300/1 (adopted ratio was 600/1 A)

- 5 Make : M/s TELK
- 6 Sr. No. : 230144/21
- 7 Year of manufacturing : 1988
- 8 Year of commissioning : 1989
- 9 Date and time of occurrence/discovery of fault : 16.02.14, 22:27
- 10 Information received in CEA : 15.04.2014
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced
- 13 Details of previous maintenance : On 04.01.2014, general cleaning was done. Insulation and oil level in CT were checked and were found to be OK. IR value was found to be greater than 200 Mega ohm.
- 14 Details of previous failure : Nil
- 15 Sequence of events/ Description of fault :

On 16.02.2014 at 22:27 hrs, 230 kV bus bar protection relay acted and auto transformer I, II and III HV breaker tripped with heavy sound. On inspection of the feeder it was found that one no. 'Y' phase TELK make CT of 230 kV Kadapperi-Sriperumbudur feeder II had burst and burnt. The same was isolated and 230 kV bus was energized through 230 kV Kadapperi-Sriperumbudur feeder I.

- 16 Details of Tests done after failure : Since CT had damaged no test was possible.
- 17 Conclusion/recommendations :

CT had served for 25 years and ageing might be the reason of failure. For recommendations refer para 33.0.

13.0 Failure of 230 kV Y-phase LA at 230 kV Thiruvarur Sub Station, TANTRANSCO

- 1 Name of Substation : 230 kV Thiruvarur substation

- | | | | |
|----|------------------------------------------------|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2 | Utility/Owner of substation | : | TANTRANSCO |
| 3 | Faulty Equipment | : | Y phase LA of Thanjavur feeder line |
| 4 | Rating | : | 230 KV |
| 5 | Make | : | M/s CGL |
| 6 | Sr. No. | : | 4886 |
| 7 | Year of manufacturing | : | 1999 |
| 8 | Year of commissioning | : | 2003 (21 st Dec.) |
| 9 | Date and time of occurrence/discovery of fault | : | 24.03.2014, 17:46 |
| 10 | Information received in CEA | : | 24.04.14 |
| 11 | Fault discovered during | : | Operation |
| 12 | Present condition of equipment | : | Pending |
| 13 | Details of previous maintenance | : | On 27.01.2014 –
1. Cleaning and crack checking of the insulators.
2. Surge monitor, milli ammeter and earth connections were checked. |
| 14 | Details of previous failure | : | Nil |
| 15 | Sequence of events/
Description of fault | : | On 24.03.2014 at 17:46 hrs 230 kV Thanjavur feeder line Y-phase LA burst out and caught fire. The 230 kV Thanjavur feeder was isolated from service. Y-phase-N protection operated. |
| 16 | Details of Tests done after failure | : | Since LA had damaged no test was possible. |
| 17 | Conclusion/recommendations | : | Refer para 33.0. |

14.0 Failure of 390kV, 10kAp LA (B phase) in 400 kV side of 400/230 kV, 315 MVA Auto transformer (ICT 5) at 400/230-110 kV Alamathy S/s of TANTRANSCO

- | | | | |
|---|--------------------|---|--------------------------------------|
| 1 | Name of Substation | : | 400/230-110 kV Sub station, Alamathy |
|---|--------------------|---|--------------------------------------|

- | | | | |
|----|------------------------------------------------|---|--------------------------------------------------------------------------------------------------------------------------------------------|
| 2 | Utility/Owner of substation | : | TANTRANSCO |
| 3 | Faulty Equipment | : | LA in 400 kV side in 'B' phase of 400/230 kV, 315 MVA Auto transformer (ICT 5) |
| 4 | Rating | : | 390 kV, 10 kAp |
| 5 | Make | : | CGL |
| 6 | Sr. No. | : | 26197 |
| 7 | Year of manufacturing | : | 2003 |
| 8 | Year of commissioning | : | 2006 (8 th Dec.) |
| 9 | Date and time of occurrence/discovery of fault | : | 05.02.2014 @ 19:56 hrs |
| 10 | Information received in CEA | : | 16.06.2014 |
| 11 | Fault discovered during | : | Operation |
| 12 | Present condition of equipment | : | Faulty LA removed from service; whether new LA has been installed or not is not known. |
| 13 | Details of previous maintenance | : | Each stack IR value measured and tightness checked on 27.10.2013 |
| 14 | Details of previous failure | : | Nil |
| 15 | Sequence of events/
Description of fault | : | Heavy sound and smoke was observed in LA and differential relay 87T1, 21Y, 86A and 86B relay acted in 400/230 kV Auto transformer (ICT 5). |
| 16 | Details of Tests done after failure | : | Insulator flashed out; hence tests were not able to be carried out. |
| 17 | Conclusion/recommendations | : | Refer para 33.0. |

15.0 Failure of 230 kV CT (B phase) of 230 kV Siruseri feeder at 230 kV Kits Park S/s of TANTRANSCO

- | | | | |
|---|--------------------|---|----------------------------------------------|
| 1 | Name of Substation | : | 230 kV Sub station, Kits Park (Sholingallur) |
|---|--------------------|---|----------------------------------------------|

- 2 Utility/Owner of substation : TANTRANSCO
- 3 Faulty Equipment : CT (B phase of Siruseri feeder)
- 4 Rating : 230 kV
- 5 Make : LAMCO
- 6 Sr. No. : CF034
- 7 Year of manufacturing : Information not available
- 8 Year of commissioning : 2010 (12th Aug)
- 9 Date and time of occurrence/discovery of fault : 02.04.2014 @ 08:58 hrs
- 10 Information received in CEA : May 2014
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced by new CT
- 13 Details of previous maintenance : Maintenance carried out on 16.02.2013, 16.07.2013, 03.01.2014, 12.02.2014
- 14 Details of previous failure : Nil
- 15 Sequence of events/ Description of fault :

On 02.04.2014 at 08:58 hrs, 230 kV B-phase CT of Siruseri feeder burst out and caught fire. This CT in turn also damaged nearby Y-phase CT of same feeder. The fire was put off immediately with the help of fire extinguisher and fire service. 230 kV Bus Bar protection acted, Bus differential R ph, Y ph, B ph bus bar protection operated, auto transformer I & II in 230 kV Tharamani feeder got tripped. All 230 kV CTs of Siruseri feeder were replaced with new CTs.

- 16 Details of Tests done after failure : As the CT had damaged, no test could be carried out.
- 17 Conclusion/recommendations :

Internal fault is suspected in B-phase CT. For recommendations refer para 33.0.

16.0 Failure of 390kV, 10kAp LA (Y phase) in 400 kV side of 400/230 kV, 315 MVA Auto transformer (ICT 5) at 400/230-110 kV Alamathy S/s of TANTRANSCO

- 1 Name of Substation : 400/230-110 kV Sub station, Alamathy
- 2 Utility/Owner of substation : TANTRANSCO
- 3 Faulty Equipment : LA in 400 kV side in 'Y' phase of 400/230 kV, 315 MVA Auto transformer (ICT 5)
- 4 Rating : 390 kV, 10 kAp
- 5 Make : CGL
- 6 Sr. No. : 26196
- 7 Year of manufacturing : 2003
- 8 Year of commissioning : 2006 (8th Dec.)
- 9 Date and time of occurrence/discovery of fault : 12.03.2014 @ 15:40 hrs
- 10 Information received in CEA : 16.06.2014
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Faulty LA removed from service; whether new LA has been installed or not is not known.
- 13 Details of previous maintenance : Each stack IR value measured and tightness checked on 27.10.2013
- 14 Details of previous failure : Nil
- 15 Sequence of events/ Description of fault :

Heavy sound and smoke was observed in LA and differential relay 87T1, 21Y, 86A and 86B relay acted in 400/230 kV Auto transformer (ICT 5).
- 16 Details of Tests done after failure : Insulator flashed out; hence tests were not able to be carried out.
- 17 Conclusion/recommendations : Refer para 33.0.

17.0 Failure of 230kV, 10kAp LA in 'B' phase of 230 kV Korattur feeder at 400/230-110 kV Alamathy S/s of TANTRANSCO

- 1 Name of Substation : 400/230-110 kV Sub station, Alamathy
- 2 Utility/Owner of substation : TANTRANSCO
- 3 Faulty Equipment : LA in 'B' phase of 230 kV Korattur feeder
- 4 Rating : 230 kV, 10 kAp
- 5 Make : LAMCO
- 6 Sr. No. : 264 A,B,C
- 7 Year of manufacturing : 2011
- 8 Year of commissioning : 2012 (3rd Sept.)
- 9 Date and time of occurrence/discovery of fault : 30.03.2014 @ 19:55 hrs
- 10 Information received in CEA : 16.06.2014
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Faulty LA removed from service; whether new LA has been installed or not is not known.
- 13 Details of previous maintenance : HiPOT test conducted on 16.12.13
- 14 Details of previous failure : Nil
- 15 Sequence of events/
Description of fault :

Heavy sound and smoke was observed in LA and Zone-I relay acted in 230 kV Korattur feeder.
- 16 Details of Tests done after failure : Insulator flashed out; hence tests were not able to be carried out.
- 17 Conclusion/recommendations : Refer para 33.0.

18.0 Failure of 230kV LA of 100 MVA, 230/110 kV Auto transformer-II HV side B phase at 230 kV Korattur Sub station of TANTRANSCO

- 1 Name of Substation : 230 kV Sub station, Korattur
- 2 Utility/Owner of substation : TANTRANSCO
- 3 Faulty Equipment : LA of 100 MVA, 230/110 kV Auto transformer II HV side B phase
- 4 Rating : 230 kV
- 5 Make : CGL
- 6 Sr. No. : 4866
- 7 Year of manufacturing : 1999
- 8 Year of commissioning : 2000
- 9 Date and time of occurrence/discovery of fault : 31.08.2014 @ 17:38 hrs
- 10 Information received in CEA : October 2014
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced by new LA
- 13 Details of previous maintenance : HiPot test was conducted on 09.12.2013 and results were in order.
- 14 Details of previous failure : Nil
- 15 Sequence of events/ Description of fault :

Heavy dip in voltage and sound was observed. Upon inspection of relay panel, it was noticed that 100 MVA Auto transformer No. II had tripped with differential protection and it was found that 'B' phase HV LAS of 100 MVA Auto transformer No. II got flashed over.
- 16 Details of Tests done after failure : Tests could not be performed due to LA flash over.
- 17 Conclusion/recommendations : Refer para 33.0.

19.0 Failure of B phase CVT in 230kV Bus 'A' at 230 kV Cuddalore sub-station of TANTRANSCO

- 1 Name of Substation : 230 kV Sub station, Cuddalore
- 2 Utility/Owner of substation : TANTRANSCO
- 3 Faulty Equipment : B phase CVT in 230 kV bus 'A'
- 4 Rating : 230 kV
- 5 Make : M/s Crompton Greaves
- 6 Sr. No. : 8481
- 7 Year of manufacturing : 1995
- 8 Year of commissioning : 1998 (28th Feb.)
- 9 Date and time of occurrence/discovery of fault : 23.06.2014 @ 13:27 hrs
- 10 Information received in CEA : 15.07.2014
- 11 Fault discovered during : Maintenance
- 12 Present condition of equipment : Replaced on 30.06.2014
- 13 Details of previous maintenance : Periodical maintenance works of thorough cleaning, tightness checking and measuring IR value were carried out on 20.01.2014
- 14 Details of previous failure : Nil
- 15 Sequence of events/
Description of fault

At 13:27 hrs on 23.06.2014, heavy sound and arc was noticed in 230 kV B-phase CVT of bus A. On inspection of the CVT, it was noticed that oil had spurt out.
- 16 Details of Tests done after failure : Not done since the entire unit got damaged during failure.
- 17 Conclusion/recommendations : Refer para 33.0.

20.0 Failure of 198 kV B Phase LA at 220 kV Rohtak Road Sub Station of Bhakra Beas Management Board (BBMB)

- 1 Name of Substation : 220 kV Sub Station, BBMB, Rohtak Road
- 2 Utility/Owner of substation : BBMB
- 3 Faulty Equipment : LA of Narela Ckt-2
- 4 Rating : 198 kV, 10 kA
- 5 Make : Crompton Greaves Ltd.
- 6 Sr. No. : Information not available
- 7 Year of manufacturing : 2006
- 8 Year of commissioning : 2006 (13th Dec.)
- 9 Date and time of occurrence/discovery of fault : 09.04.14 at 15:46 hrs
- 10 Information received in CEA : 15.05.14
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced with LAMCO make LA on 09.04.2014.
- 13 Details of previous maintenance : Scheduled maintenance was carried out on 19.03.2014 and LA was found healthy.
- 14 Details of previous failure : Nil
- 15 Sequence of events/
Description of fault

On 09.04.2014 at 15:46 hrs, LA damaged due to B phase to earth fault on the line. LA short circuited and its surge counter burnt.
Protection operated:
M-I & M-II Micom distance protection.
Start phase: C-N, Tripped phase: ABC, Fault Length: 1.65 km (Z-1)
- 16 Details of Tests done after failure : Information not available
- 17 Conclusion/recommendations : Refer para 33.0.

21.0 Failure of 216 kV/10 kA, R Phase LA of 220 kV Samaypur Badshahpur Ckt-I at 220 kV Sub Station of BBMB

- 1 Name of Substation : 220 kV Sub Station, BBMB, Samaypur
- 2 Utility/Owner of substation : BBMB
- 3 Faulty Equipment : LA
- 4 Rating : 216 kV/10 kA
- 5 Make : CGL
- 6 Sr. No. : 9802620
- 7 Year of manufacturing : 1998
- 8 Year of commissioning : 2000 (15th Nov.)
- 9 Date and time of occurrence/discovery of fault : 09.04.2014 at 17:14 hrs
- 10 Information received in CEA : 15.05.14
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced
- 13 Details of previous maintenance : Quarterly maintenance carried out on 10.03.2014. MOSA testing by P&T Cell was carried out on 25.10.2013. Leakage current was found on higher side i.e. 304 micro Amp. Kept under observation and was to be tested after every six months but it damaged before the next date of MOSA testing due on 15.04.2014
- 14 Details of previous failure : Nil
- 15 Sequence of events/
Description of fault :

On 09.04.2014 at 17:14 hrs, LA fused/damaged with heavy sound and ckt tripped.
- 16 Details of Tests done after failure : NA

17 Conclusion/recommendations : Refer para 33.0.

22.0 Failure of 220 kV CVT (R Phase) on 220 kV Jalandhar-Pong Ckt at 220 kV Jalandhar Sub Station of BBMB

- 1 Name of Substation : 220 kV Sub Station, BBMB, Jalandhar
- 2 Utility/Owner of substation : BBMB
- 3 Faulty Equipment : CVT (R Phase) of Jalandhar-Pong circuit.
- 4 Rating : 220 kV
- 5 Make : WSI
- 6 Sr. No. : 8809652
- 7 Year of manufacturing : 1988
- 8 Year of commissioning : 2006 (24th April) (Received from Sangrur S/Stn in old and used condition)
- 9 Date and time of occurrence/discovery of fault : 22.04.14 @ 09:56 hrs
- 10 Information received in CEA : 20.05.14
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced on 22.04.2014.
- 13 Details of previous maintenance : Last scheduled maintenance was carried out on 14.10.13. The working of CVT was satisfactory. The IR values taken were as under:
P-E : 80000 M ohm
P-S : 60000 M ohm
S-E : 750 M ohm
- 14 Details of previous failure : Nil
- 15 Sequence of events/ Description of fault :

On 22.04.2014 at 09:56 hrs, the CVT was damaged due to low secondary output voltage. VT fuse fail alarm operated. On checking the IR value of the

secondary winding of the CVT, it was found negligible which indicated shorting of secondary cores.

16 Details of Tests done after failure : On checking the IR value of the secondary winding of CVT, it has been found negligible. The secondary output voltage of all the 3 No. cores was observed on the lower side during the detailed testing.

17 Conclusion/recommendations :

The probable cause of damage of CVT is failure of insulation of the secondary winding. The CVT had served for more than 25 years. For recommendations refer para 33.0.

23.0 Failure of 198 kV Y phase LA of 220/132 kV, 100 MVA transformer (T-3) feeder at 220 kV GSS Hisar Sub station of BBMB

1 Name of Substation : 220 kV Sub station, BBMB, Hisar

2 Utility/Owner of substation : BBMB

3 Faulty Equipment : 198 kV Y-Phase Lightning Arrestor of 220/132 kV, 100 MVA transformer T-3

4 Rating : 198 kV

5 Make : CGL

6 Sr. No. : 9611021

7 Year of manufacturing : 1997

8 Year of commissioning : 2000 (18th Feb.)

9 Date and time of occurrence/discovery of fault : 13.05.2014 @ 02:58 hrs

10 Information received in CEA : 11.06.2014

11 Fault discovered during : Operation

12 Present condition of equipment : Replaced with new one

13 Details of previous maintenance : During general maintenance (IR measurement, LCM, cleaning & bolt tightening) dated 19.03.2014,

equipment's condition was found normal and satisfactory.

- 14 Details of previous failure : Nil.
- 15 Sequence of events/ :
Description of fault

LA damaged on 13.05.2014 at 02:58 hrs due to lightening during rain.
- 16 Details of Tests done after : No test was done as LA was flashed
failure over due to lightening (Testing of T/F was done and test results were found satisfactory. T/F was energized at 17:17 hrs dated 13:05:2014).
- 17 Conclusion/recommendations :

LA damaged due to lightening during rain. For recommendations refer para 33.0.

24.0 Failure of various equipment of 220 kV Ballabgarh-Samaypur ckt-I at 220 kV Ballabgarh & Samaypur Sub stations of BBMB

- 1 Name of Substations : 220 kV Sub station, Ballabgarh and 220 kV Sub station, Samaypur
- 2 Utility/Owner of substation : BBMB
- 3 Faulty Equipments : All in Ballabgarh-Samaypur Ckt-I (equipment at a to f failed at Ballabgarh S/s & equipment at g & h failed at Samaypur S/s at the same time on the same day):
a. 245 kV PT (Y phase)
b. 245 kV CVT (R phase)
c. 245 kV CVT (B phase)
d. 245 kV CT (B phase)
e. 198 kV R and Y phase LA
f. 245 kV Breaker Pole (Y phase)
g. 245 kV Breaker Pole (Y phase)
h. Wave Trap (R phase)
- 4 Ratings : a. 245 kV for CBs, CTs, PTs & CVTs
b. 198 kV for LA
c. 1250 A, 1.0 mH for Wave Trap
- 5 Makes : a. Telk make (for PT (Y phase))
b. WSI (for CVT (R phase))

- c. CGL (for CVT (B phase))
 - d. HBB (for CT (B Phase))
 - e. LAMCO (for R & Y phase LA)
 - f. CGL (for Breaker Pole (Y phase))
 - g. ABB (for Breaker Pole (Y phase))
 - h. WSI (for Wave Trap)
- 6 Sr. Nos. : a. 730136-3 (for PT (Y phase))
b. 8709643 (for CVT (R phase))
c. 28186 (for CVT (B phase))
d. 71742 (for CT (B Phase))
e. Information not available (for R & Y phase LA)
f. 1347C (for Breaker Pole (Y phase))
g. IB/105563 (for Breaker Pole (Y phase))
h. L3936(for Wave Trap)
- 7 Years of manufacturing : a. 2013 (for PT (Y phase))
b. 1987 (for CVT (R phase))
c. 2001 (for CVT (B phase))
d. 1988 (for CT (B Phase))
e. 2007 (for R & Y phase LA)
f. 1985 (for Breaker Pole (Y phase))
g. 1989 (for Breaker Pole (Y phase))
h. 1988 (for Wave Trap)
- 8 Years of commissioning : a. 2013 (for PT (Y phase))
b. 1993 (for CVT (R phase))
c. 2007 (for CVT (B phase))
d. 1989 (for CT (B Phase))
e. 2011 (for R & Y phase LA)
f. 1988 (for Breaker Pole (Y phase))
g. 1989 (for Breaker Pole (Y phase))
h. 2013 (for Wave Trap)
- 9 Date and time of occurrence/discovery of fault : 03.05.2014 @ 17:38 hrs
- 10 Information received in CEA : 11.06.2014
- 11 Fault discovered during : Operation
- 12 Present conditions of equipments : a. Replaced with new PT (for PT (Y phase))
b. Replaced with new CVT (for CVT (R phase))
c. Replaced with new CVT (for CVT (B phase))

- d. Replaced with new CT (for CT (B Phase))
 - e. Replaced with new LA (for R & Y phase LA)
 - f. Replaced with old and used breaker pole (for Breaker Pole (Y phase))
 - g. Replaced with new breaker (for Breaker Pole (Y phase))
 - h. Replacement pending (for Wave Trap)
- 13 Details of previous maintenance : a. Quarterly maintenance of CT, PT, CVTs & LAs were carried out on 18.04.2014
- b. Half yearly maintenance of Y phase Breaker Pole at Ballabgarh S/s was carried out on 15.04.2014.
- g. Quarterly maintenance of Y phase Breaker Pole at Samaypur S/s was carried out on 01.02.2014 and 28.04.14. Checked air/gas pressure, tripping/closing coil, aux. contacts, compressor, post insulators and tightened nuts and bolts of structure and jumper, operation from local and remote. Previous maintenances were carried out on 12.03.2013, 16.05.2013 and 18.10.2013. IR values, contact resistances and timings of breaker found within the limits.
- h. Carried out on 19.04.2014 and was found OK. (for Wave Trap)
- 14 Details of previous failure : Nil for all equipments.
- 15 Sequence of events/ Description of fault :
- 220 kV Ballabgarh-Samaypur Ckt-I at Ballabgarh S/s was under shut down from 30.04.2014 to 03.05.2014 for over hauling of R phase pole of ABB make SF6 Circuit Breaker under supervision of ABB Service Engineer. At 17:38 hrs on 03.05.14, on charging of 220 kV Samaypur-Ballabgarh Ckt-I from Samaypur end, Y phase PT at Ballabgarh end burst and caught fire. Circuit Breaker was in open position at Ballabgarh end. 220 kV Ballabgarh-Samaypur ckt-I tripped at Samaypur end. Porcelain pieces of burst Y phase PT hit R & B-phase CVTs, B-phase CT, R&Y Phase Las, Y-phase breaker pole and damaged these equipment.
- Wave Trap was damaged due to flow of heavy fault current during fault caused by bursting of Y-phase PT at Ballabgarh end and Y-phase circuit

breaker at Samaypur station. Tuning device, lightening arrester damaged and coil opened.

- 16 Details of Tests done after : Nil, as equipments damaged completely failure
- 17 Conclusion/recommendations : Refer para 33.0.

25.0 Failure of R phase limb/pole of 245 kV SF-6 Breaker of Unit no. 8 of 220 kV Sub station of Bhakra Right Bank Power House of BBMB

- 1 Name of Substation : 220 kV Sub station, BBMB, Bhakra Right Bank Power House
- 2 Utility/Owner of substation : BBMB
- 3 Faulty Equipment : R phase pole of 245 kV SF-6 Breaker
- 4 Rating : 245 kV
- 5 Make : M/s Siemens Limited
- 6 Sr. No. : 2007/IND/03/3375
- 7 Year of manufacturing : Information not available
- 8 Year of commissioning : Information not available
- 9 Date and time of occurrence/discovery of fault : 26.06.2014 @ 08:50 hrs
- 10 Information received in CEA : 07.07.2014
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced
- 13 Details of previous maintenance : Information not available
- 14 Details of previous failure : Information not available
- 15 Sequence of events/ Description of fault :

In order to stop unit No. 8, its breaker was opened manually at 08:50 hrs of 26.06.2014. As soon as the breaker was opened, LBB protection (CBRD)

operated resulting in tripping of all the breakers of Bus Section II i.e. Bhakra-Gwl-4 ckt., Bhakra-JML-2 ckt., Bhakra-MHL-1 ckt and Bus Coupler A-25 & A-30. Abnormal sound was observed from ckt breaker of unit no. 8 by O&M staff present over there. On inspection it was found that the gas pressure of SF6 breaker R phase limb of unit no 8 was 7.4 bar against 6.4 bar. Indications and mechanism were showing its open position but the IR value between the fixed and moving contacts was found very much of the lower side than that of the normal value. It is evident that limb contacts were not fully opened and got stuck-up.

- 16 Details of Tests done after : Information not available failure
- 17 Conclusion/recommendations : Refer para 33.0.

26.0 Failure of B phase 245 kV CT of 220/132 kV, 50 MVA transformer (T-3) feeder at 220 kV Kurukshetra sub-station of BBMB

- 1 Name of Substation : 220 kV Sub station, Kurukshetra
- 2 Utility/Owner of substation : BBMB
- 3 Faulty Equipment : B phase 245 kV CT of 220/132 kV, 50 MVA transformer T-3
- 4 Rating : 245 kV
- 5 Make : WSI
- 6 Sr. No. : 860604
- 7 Year of manufacturing : 1986
- 8 Year of commissioning : 1988 (Aug.)
- 9 Date and time of occurrence/discovery of fault : 08.06.2014 @ 18:35 hrs
- 10 Information received in CEA : 24.07.2014
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced
- 13 Details of previous maintenance : Last scheduled maintenance was carried out on 29.04.2014 and no abnormality was found. Annual Maintenance on

06.05.2014.

- 14 Details of previous failure : Nil
- 15 Sequence of events/ :
Description of fault
- On 08.06.2014 at 18:35 hrs, B-phase 245 kV CT of 220/132 kV, 50 MVA transformer (T-3) feeder burst and caught fire and simultaneously transformer tripped off. Details of protection operated:
220 kV side:
Facia: Differential protection operated
- Micom P-122:
IA – 190 A
IB – 248 A
IC – 4183 A
- KBCH-120:
IAHV – 194.5 A
IBHV – 273.9 A
ICHV – 4738 A
- 132 kV side:
Relay-86 operated.
- 16 Details of Tests done after : No tests carried out as the equipment
failure burst.
- 17 Conclusion/recommendations :

As per the report furnished by BBMB officials, CT damaged due to higher tan-delta and ageing effect. For recommendations refer para 33.0.

27.0 Failure of 220 kV CT (B-phase) at 220 kV Sabalgarh S/s of MP Power Transmission Corporation Ltd

- 1 Name of Substation : 220 kV Sub station, Sabalgarh
- 2 Utility/Owner of substation : MP Power Transmission Corporation Ltd
- 3 Faulty Equipment : CT (B-phase)
- 4 Rating : 220 kV, 800-400/1-1-1-1-1 A
- 5 Make : SCT
- 6 Sr. No. : 2011/197

- 7 Year of manufacturing : 2011
- 8 Year of commissioning : 2012 (3rd Jul.)
- 9 Date and time of occurrence/discovery of fault : 30.04.2014 @ 12:56 PM
- 10 Information received in CEA : 04.06.2014
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced
- 13 Details of previous maintenance : IR value measurement on 23.04.2014 were: P-E, P-S and S-E more than 6 G ohm
- 14 Details of previous failure : Nil
- 15 Sequence of events/ Description of fault :

On 30.04.2014 at 12:56 hrs, 160 MVA transformer-I of Areva make tripped on Differential with Diff 87R, Diff 87B relay indications. During inspection B phase 220 kV CT was found failed.

- 16 Details of Tests done after failure : Failure confirmed with IR value measurement of CT which is P-E = 0. After replacement of failed CT, the transformer charged on 01.05.14 at 12:50 PM.
- 17 Conclusion/recommendations :

IR value between P-E of CT was found to be zero which indicates insulation failure. For recommendations refer para 33.0.

28.0 Failure of 220kV Y phase CT of 220 kV Gurur-Barsoor Ckt-II at 220 kV Barsoor sub-station of Chhattisgarh State Power Transmission Company Limited (CSPTCL)

- 1 Name of Substation : 220 kV Sub station, Barsoor
- 2 Utility/Owner of substation : CSPTCL
- 3 Faulty Equipment : 220 kV CT (Y phase of Gurur-Barsoor II ckt)

- 4 Rating : 220 kV
- 5 Make : Nagpur Transformers Limited, Nagpur
- 6 Sr. No. : C-1131/29
- 7 Year of manufacturing : 1979
- 8 Year of commissioning : 1980
- 9 Date and time of occurrence/discovery of fault : 13.05.2014 @ 00:03 hrs
- 10 Information received in CEA : 02.07.2014
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced
- 13 Details of previous maintenance : Megger, tightening of bolts
- 14 Details of previous failure : Nil
- 15 Sequence of events/ Description of fault :

On 13.05.2014 ay 00:03 hrs, 220 kV CT got burst, oil spilled out and porcelain got damaged. Due to CT failure both 220 kV Gurur-Barsoor Ckt. I & II tripped from Gurur end causing total interruption of 15 min in Jagadalpur and Kirandul area.

- 16 Details of Tests done after failure : Nil, as CT had damaged
- 17 Conclusion/recommendations :

CT had served for 34 years. Ageing might be one of the reasons for failure. For recommendations refer para 33.0.

29.0 Failure of 220kV Y phase LA of 220 kV Lower Sileru Ckt-I at 220 kV Barsoor sub-station of Chhattisgarh State Power Transmission Corporation Limited

- 1 Name of Substation : 220 kV Sub station, Barsoor
- 2 Utility/Owner of substation : CSPTCL

- | | | | |
|----|------------------------------------------------|---|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3 | Faulty Equipment | : | 220 kV LA Y phase |
| 4 | Rating | : | 220 kV |
| 5 | Make | : | W S Insulators India Limited, Chennai |
| 6 | Sr. No. | : | 107947 (A/B/C Unit) & 107949 (D unit)
(may be clarified by utility) |
| 7 | Year of manufacturing | : | 1979 |
| 8 | Year of commissioning | : | 1981 |
| 9 | Date and time of occurrence/discovery of fault | : | 28.05.2014 @ 00:50 hrs |
| 10 | Information received in CEA | : | 02.07.2014 |
| 11 | Fault discovered during | : | Operation |
| 12 | Present condition of equipment | : | Replaced |
| 13 | Details of previous maintenance | : | Megger, tightening of bolts |
| 14 | Details of previous failure | : | Nil |
| 15 | Sequence of events/
Description of fault | : | |
| | | | On 28.05.2014 at 00:50 hrs, 220 kV LA burst & porcelain got damaged. Due to LA failure, 220 kV lower Sileru ckt I tripped from 220 kV Barsoor sub-station. |
| 16 | Details of Tests done after failure | : | Nil, as LA had damaged |
| 17 | Conclusion/recommendations | : | Refer para 33.0. |

30.0 Failure of Unit 4 Y-phase CT at 220 kV Switch Yard at Srisailam Right Bank Power House of Andhra Pradesh Power Generation Company Limited (APPGCL)

- | | | | |
|---|-----------------------------|---|------------------------------------------------------|
| 1 | Name of Substation | : | 220 kV Switch Yard, Srisailam Right Bank Power House |
| 2 | Utility/Owner of substation | : | APPGCL |

- | | | | |
|----|------------------------------------------------|---|---------------------------|
| 3 | Faulty Equipment | : | Unit 4 Y-phase CT |
| 4 | Rating | : | 245 kV |
| 5 | Make | : | TELK, Kerala |
| 6 | Sr. No. | : | 230057-13 |
| 7 | Year of manufacturing | : | 1978 |
| 8 | Year of commissioning | : | Information not available |
| 9 | Date and time of occurrence/discovery of fault | : | 10.08.2014 @ 14:31 hrs |
| 10 | Information received in CEA | : | 25.08.2014 |
| 11 | Fault discovered during | : | Operation |
| 12 | Present condition of equipment | : | Replaced |
| 13 | Details of previous maintenance | : | Information not available |
| 14 | Details of previous failure | : | Information not available |
| 15 | Sequence of events/
Description of fault | : | |

At 14:31 hrs the internal insulation of a post mounted 245 kV hermetically sealed oil filled dead tank CT failed. Bus bar protection operated and Bus II was dead. As a result of fault, the oil container in CT caught fire. The shift staff and maintenance staff reached the location immediately and extinguished the fire to a major extent with the help of fire extinguishers. The local fire service was called and after ensuring the area was safe, the fire safety personnel entered the site and extinguished the fire completely. The fire damage was restricted to a 5 m radius.

Unit 4 Y-phase CT failed and Bus bar protection operated, Bus II was dead. At the time of tripping, Generating Units 1, 2, 4, 6 which were in service and 220 kV feeders Bilakalaguduru, Markapuram, Dindi-2 tripped at Srisailam end and Tallapalli-1 feeder was tripped at both ends which are connected to Bus-II followed by tripping of the bus coupler.

- | | | | |
|----|-------------------------------------|---|---------------------------|
| 16 | Details of Tests done after failure | : | Information not available |
| 17 | Conclusion/recommendations | : | |

CT had served for more than 35 years. Ageing might be the reason of failure.
For recommendations refer para 33.0.

31.0 Failure of 400 kV Current Transformer (CT) at 400/230 kV Tiruvalam substation, Power Grid Corporation of India Ltd. (PGCIL)

- 1 Name of Substation : 400/230 kV Tiruvalam substation
- 2 Utility/Owner of substation : PGCIL
- 3 Faulty Equipment : CT
- 4 Rating : 420 kV, 3000/1A
- 5 Make : Siemens
- 6 Sr. No. : 4CT-1457
- 7 Year of manufacturing : Information not available
- 8 Year of commissioning : Information not available
- 9 Date and time of occurrence/discovery of fault : 11.04.14, 20:08
- 10 Information received in CEA : 25.04.14
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced
- 13 Details of previous maintenance : Information not available
- 14 Details of previous failure : Nil
- 15 Sequence of events/ Description of fault :

On 11.04.2014 at 20:08 hrs, Busbar Protection of Bus-1 operated and found that Siemens make 420 kV, 3000A/1A CT bearing SI No 4CT-1457 erected in Sriperumbudur Main Bay (404CT-B) failed due to low IR value (Primary Earth).
- 16 Details of Tests done after failure : NA

17 Conclusion/recommendations : For recommendations refer para 33.0.

32.0 Failure of 400 kV Current Transformer (CT) at 400 kV Kalivanthapattu substation, PGCIL

- 1 Name of Substation : 400 kV Kalivanthapattu substation
- 2 Utility/Owner of substation : PGCIL
- 3 Faulty Equipment : CT
- 4 Rating : 400 kV
- 5 Make : Alstom
- 6 Sr. No. : 200703127
- 7 Year of manufacturing : Information not available
- 8 Year of commissioning : Information not available
- 9 Date and time of occurrence/discovery of fault : 13.04.14, 21:06
- 10 Information received in CEA : 25.04.2014
- 11 Fault discovered during : Operation
- 12 Present condition of equipment : Replaced
- 13 Details of previous maintenance : Information not available
- 14 Details of previous failure : Nil
- 15 Sequence of events/
Description of fault :

On 13.04.2014 at 21:06 hrs, CT blasted.
- 16 Details of Tests done after failure : NA
- 17 Conclusion/recommendations :

Sufficient information has not been provided. For recommendations refer para 33.0.

33.0 General Recommendations:

- The practice of condition based monitoring with the use of various diagnostic tools as suggested in Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010, is recommended for all substation equipment.
- The frequency/periodicity of measurement should be changed depending on condition/healthiness of equipment in operation.
- Periodic oil testing including DGA (wherever feasible) in case of instrument transformers in addition to power transformers are recommended.
- Utilities should follow best practices for maintenance of each equipment. All the equipment which have reached/approaching their 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.
- The manufacturer's recommendation for storage should be followed strictly in case of inordinate delay in commissioning of equipment as well as for long storage of equipment as spares.
- Measurement of the 3rd harmonic resistive component of leakage current is a very good method for assessing healthiness of SA which can be done on-line. If 3rd harmonic component of resistive current is more than 150 μA then Insulation Resistance (IR) value test should also be conducted and if current exceeds 350 μA then SA should be removed from service and replaced.
- 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%.
- 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.
- 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.
- 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.

- Room Temperature Vulcanizing (RTV) coating over porcelain housing of CB/LA/CT/CVT may also be considered by utilities for substation equipment installed in pollution prone areas as an alternative to Polymer housed equipment.
- When an equipment fails, Original Equipment Manufacturer (OEM) should also be consulted.

Submitted by:

**(K.K. Arya)
Chief Engineer (SETD) &
Chairman, Standing Committee to
investigate the failure of 220 kV & above
substation equipment**

**(S.K.Ray Mohapatra)
Director &
Member Secretary, Standing Committee to
investigate the failure of 220 kV & above
substation equipment**

MINUTES OF MEETING OF THE STANDING COMMITTEE OF EXPERTS TO INVESTIGATE THE FAILURE OF 220 KV AND ABOVE VOLTAGE CLASS SUBSTATION EQUIPMENT HELD ON 09.01.15 IN CEA, NEW DELHI, IN CONNECTION WITH REPORTED FAILURES FROM APRIL 2014 TO SEPTEMBER 2014 AT VARIOUS SUBSTATIONS IN THE COUNTRY

The list of participants is enclosed as **Annexure-1**.

Chief Engineer (SETD) & Chairman of the subject Standing Committee (Substation) welcomed the participants and highlighted the importance of timely reporting of failures to the Committee. He also stated that discussing the failures and sharing of experiences and maintenance practices of utilities will help in adopting best practices of maintenance and thereby reducing the failures. The representatives from PGCIL, KPTCL, and APPGCL had not attended the meeting. A draft report, prepared based on information provided by utilities between April 2014 and September 2014, was sent by post to concerned utilities prior to meeting and matter was discussed in detail with representatives of utilities present in the meeting.

Director (SETD) & Member Secretary of the Standing Committee informed that during above period 39 nos. equipment failures (16 nos. of LAs, 9 nos. of CTs, 6 nos. CVTs, 5 nos. of CBs, transformer, wave trap & PT one each) were reported by eight (8) utilities. He also highlighted that number of utilities do not report the failure of equipment and prime objective of formation of above committee is getting defeated due to non-participation of utilities and non-reporting of failures. The failure of 100MVA transformer could not be discussed in detail due to absence of representative of KPTCL. The committee observed that the transformer was commissioned after four years of manufacturing and suggested that such inordinate delay in commissioning should be avoided by utilities as manufacturers generally do not recommend for keeping transformer without oil for more than three (3) months. The manufacturer's recommendation should be followed if delay is more than three (3) months. It was also observed that most of the utility do not indicate the type of Surge Arrester (SA), which has failed. Utilities were requested to indicate the type of Surge Arrester (Metal oxide gapless type / SiC gapped type).

Failures of equipment of BBMB were discussed in detail as follow:

1. BBMB informed that at present in BBMB substations, 66 kV & 132 kV CTs with tan delta value of 1.5% and 1.1% respectively are allowed to be in service. The Committee suggested that general practice of 0.7% $\tan\delta$ limit should be followed.
2. The rate of rise of tan delta should not be more than 0.1% per year. Also the practice of $\tan\delta$ measurement should be annual as against the current practice of once in two years.
3. It was also intimated by BBMB that CVTs are being replaced by PT in BBMB as PTs are less prone to failure.
4. The Committee suggested that 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, which are very useful tool to assess healthiness of CB, should be included for one substation or a group of nearby substations depending upon the requirement.

5. BBMB informed that it is a general practice to replace the Surge Arrestor of transformer if 3rd harmonic resistive component of leakage current exceeds 100µA considering the importance and safety of transformers.
6. BBMB also informed that leakage current monitoring is being done once in two years. The committee suggested for reducing the periodicity of measurement and the measurement of 3rd harmonic resistive component of leakage current should be carried out. If harmonic current is found to be more than 150 µA, measurement of insulation resistance should also be carried out and for leakage current value exceeding 350 µA, SA should be replaced.

Representatives of Tamil Nadu Transmission Corporation Ltd., Chhattisgarh State Power Transmission Corporation Ltd. (CSPTCL), KPCL and Madhya Pradesh Transmission Corporation Ltd. (MPPTCL) furnished the missing information in draft report in respect of previously reported failures.

Regarding failures of CBs in Raichur Thermal Power Station, KPCL informed that both CBs, located near cooling towers of the Thermal Power Plant, had failed due to ash and dust deposition. KPCL generally carry out hot line water washing to clean the CB housing to prevent flashover across the insulator housing. However, KPCL has now decided to use Room Temperature Vulcanizing (RTV) coating over porcelain housing of CB. The members of the Committee also supported the action taken by KPCL and committee suggested that similar initiatives should be taken by other utilities for substation equipment installed in pollution prone areas. On enquiry about the cost, KPCL informed that about Rs 2.35 lakhs would be required for RTV coating of one CB (i.e 3 poles).

MPPTCL submitted additional reports of failures of equipment occurred during last three years in Sabalgarh sub-station. MPPTCL informed that all failed CTs were of SCT make. It was reported that Tan delta value of failed CTs as well CTs which are in service are found to be quite high. The Committee suggested that these equipment need to be replaced at the earliest.

After detail discussion, the committee felt to highlight some of the important maintenance practices for various equipment as indicated below.

CVT

- Only top and middle stacks are tested for tan delta.
- Capacitance variation of -5% to +5% of pre-commissioning value is allowed.
- Secondary voltage measurement : half yearly
- If secondary voltage changes then measurement of capacitance should be done. CVT needs to be replaced for variation in secondary voltage by more than 2.0 Volts.

CT

- Pre-commissioning test: tan delta, Insulation Resistance
- After one month of charging and within one year: DGA
- Tan delta test is repeated every year.
- For higher failure rate of CTs of a particular make, DGA is conducted.

PT

- Tan delta, DGA: every year
- Tan delta on PT is carried out in GST mode after removing jumper.

CB

- DCRM - once in two(2) years.
- CB operating timings – Once in a year
- Tan delta of grading capacitors should be < 0.007
[The rate of rise of tan delta should not be more than 0.001 per year]
- The capacitance of grading capacitors should be within $\pm 5\%$ of rated value / pre-commissioning test value

Oil Impregnated Paper (OIP) Bushing

- Bushing oil DGA and Capacitance & Tandelta at variable frequency & temperature should be carried out for health assessment which has proved to be very effective in detecting the deteriorated condition of many in-service bushings.

The Committee observed that maximum number of SA failure was reported during this six month period and most of the SAs were of CGL make. Representatives of various utilities wanted that the matter should be brought to the notice of M/s CGL and requested to take up the matter with M/s CGL and to invite M/s CGL for discussion in order to reduce the failure rate of such vital equipment in substation.

Director (SETD) enquired about fire fighting arrangements in the switchyard and for transformer / reactors. Some of the utilities did not have any fire fighting arrangement except portable fire extinguishers.

Fire fighting provision should be made available in line with the requirement of Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010. Various diagnostic tools as suggested in above Regulations should be used regularly for periodic maintenance / Condition Based Maintenance (CBM) of substation equipment and every utility should adopt best practices for maintenance of equipment in the substation / switchyard. CBIP Manual on Substation Equipment Maintenance (Publication no. 294), which provides valuable guidance for maintenance of various equipment / material, may also be referred. Utilities should follow CBM practice and periodicity of maintenance need to be modified from time to time depending on condition of equipment and trend analysis.

The meeting ended with vote of thanks to the Chair.

LIST OF PARTICIPANTS

Central Electricity Authority, New Delhi

1. Shri K.K.Arya, Chief Engineer, SETDin the Chair
2. Shri S.K.Ray Mohapatra, Director, SETD
3. Shri Y.K.Swarnkar, Deputy Director, SETD
4. Shri Faraz, Assistant Director, SETD

Bhakra Beas Management Board

1. Shri N.K.Goel, Dy. CE
2. Shri Vivek Mahajan, Addl. SE

TANTRANSCO

1. Shri S.Rajendiran, S.E.(Operation)

Chhattisgarh State Power Transmission Corporation Ltd. (CSPTCL)

1. Shri D.K.Dewangan, Executive Engineer (Jagdalpur S/s)

Karnataka Power Corporation Ltd. (KPCL)

1. Shri M.Shivamallu, Chief Engineer
2. Shri Chandrakant D., Chief Engineer
3. Shri S.R.Prakash, Superintending Engineer(Ele.), RTPS

Kerala State Electricity Board

1. Shri Jayarajan C.N., Executive Engineer

Madhya Pradesh Power Transmission Corporation Ltd.

1. Shri Pawan Shakya, A.E. (Testing)



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(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:

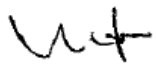
- To investigate the causes of failure of substation equipment in service
- To recommend remedial measures to avert recurrences of such failures in future.

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.


(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.