REPORT

ON
FAILURE OF CIRCUIT BREAKER AND TRNSFORMER
AT
RANASAN AND LIMDI SUBSTATIONS
OF
GUJRAT ELECTRIC TRANSMISSION COMPANY (GETCO)

सत्यमेव जयते

CENTRAL ELECTRICITY AUTHORITY
MINISTRY OF POWER
GOVERNMENT OF INDIA
NEW DELHI

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Report on failure of 132kV Circuit Breaker (CB) at Ranasan substation and 220kV/132kV/11kV, 50 MVA Transformer at Limdi substation of GETCO on 22-07-2006 and 29-06-2006 respectively

1.0 Introduction:

The 220kV/132kV/66kV Ranasan substation and 220kV/132kV/66kVLimdi substation of GETCO, Gujrat are very old stations commissioned sometimes during 1969. The substation at Ranasan is operating with 600MVA total transformation capacity [Five transformers: with 3x150MVA, 220kV/132kV; 1x100MVA, 220kV/132kV and 1x50MVA, 132kV/66kV]. The substation at Limdi is operating with 420 MVA total transformation capacity [Eight transformers: with 2x100MVA, 220kV/132kV; 1x50MVA, 220kV/132kV; 3x50MVA, 132kV/66kV; 2x10MVA, 66kV/11kV]. The maximum load at Ranasan substation was only 274MW and 314MW during last May, 2006 and June, 2006 respectively. Maximum load at Limdi substation at 220kV bus, 132kV bus, 66kV, and 11kV level were 110MW, 168MW, 57 MW and 8.7 MW respectively during last July 2006. The transformers and the lines emanating from these stations have never been overloaded beyond their rated capacity. Most of the time transformers operate below 50% of their rated capacity.

The Ranasan substation is connected with Chiloda substation at 132kV level by S/c line of about 15km length. The 132kV CB (ABB make) at Ranasan end of Ranasan-Chiloda line failed on 22-07-2006 and the line was out of service till July 29, 2006 when the 132kV line was reenergized at 15:30 Hrs after replacement of one of the poles of the faulty breaker by a new one.

The 220kV/132kV, 50MVA transformer (BHEL make) failed on 29-06-2006 at Limdi substation. The transformer is out of service and likely to be repaired shortly.

A standing committee has been formulated at national level to assess the cause of failure and rate of failure of various substation equipment of 220kV and above voltage class and to suggest remedial measures so as to minimise / avert such failures in future. As part of such activity, S.K.Ray Mohapatra, Dy. Director and Avinash Chander, Dy. Director of SE&TD Division of CEA visited the site of failure of 132kV Circuit Breaker (SF6) at Ranasan 220kV/132kV/66kV substation and also the site of failure of 220kV/132kV, 50MVA transformer at Limdi substation of Gujrat Electric Transmission Company Ltd.(GETCO) on August 30,2006.

During the visit, the team discussed in detail with the operation and maintenance staff of both the station about the sequence of events leading to failure of Circuit breaker and transformer. Some test result and other relevant information was also collected. The analysis of failure of CB and transformer is discussed below.

2.0 FAILURE OF CIRCUIT BREAKER AT RANASAN SUBSTATION

The brief details of the failed CB are as follows:

CB Particulars	Details
Name of Substation	Ranasan
Make	ABB, Vadodara
Type of Circuit Breaker	SF6
Voltage Rating	145kV
Sr.No.	15000108
Model	LTB 145 D1/B
Year of Commissioning	08-09-2001
Last maintenance work	05-05-2006
Date of Failure	22.07.2006 at 19:23 Hrs
Normal current, short time current	2000A, 40kA for 3 Sec
Lightning Impulse withstand voltage and power frequency withstand voltage	650kVp, 275kV(rms)
Operating Mechanism	Spring charged three phase gang operated

The Y pole of 132kV ABB make SF6 Circuit Breaker of Ranasan-Chiloda line had blasted / failed on 22-07-2006 at 19:23 Hrs at Ranasan Substation. The detailed analysis of failure of Circuit Breaker is discussed below.

2.1 <u>Observations</u>

The failed 132kV CB (ABB make) is spring charged and three phase gang operated type. The interrupter Chambers of Y pole had blasted and porcelain housing had shattered into pieces. Following observations were made:

1. Interrupter chamber was completely damaged **(Exhibit-2)**. The porcelain housing of interrupter chamber had broken into pieces. The healthy CB pole along with replaced new pole after re-energisation is shown in **Exhibit-1**.

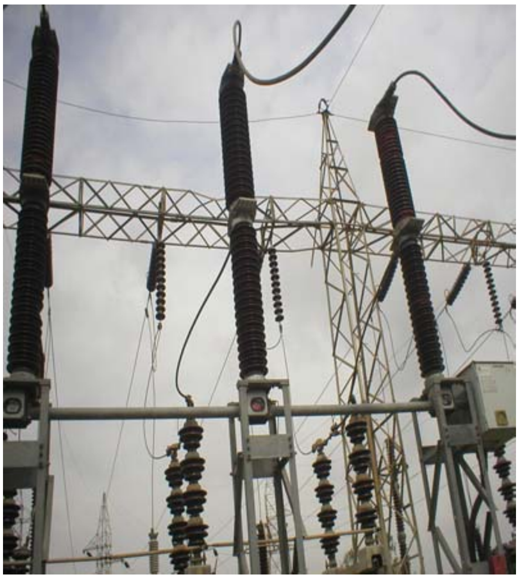	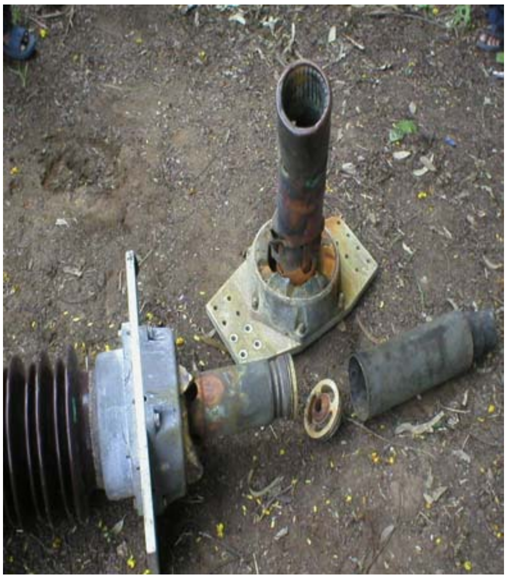
Exhibit-1 **Healthy R&B pole with replaced new**	**Exhibit-2** **Failed Y pole of CB**

Y pole of the CB and damaged petticoats of porcelain housing of R & B poles	

2. Abnormal flashover marks with holes on the metallic portion of arcing chamber are clearly visible **(Exhibit-3)**.

3. Support insulator of failed breaker pole was found to be almost healthy **(Exhibit-4)** except breakage at linkage with gang operating rod connected to the common motor.

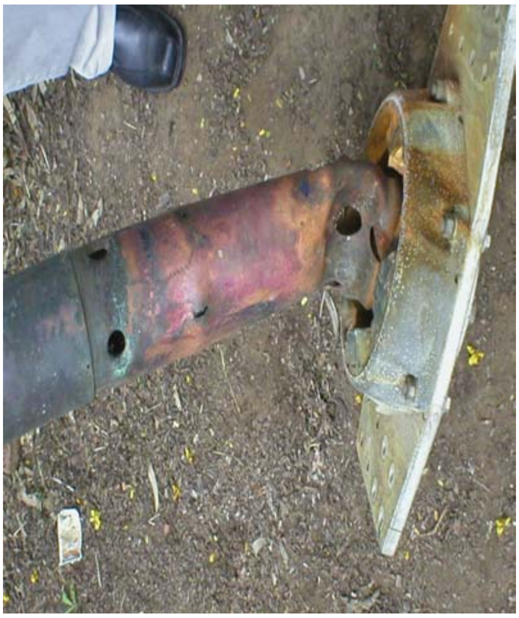	
Exhibit-3 **Abnormal Flashover mark with holes**	**Exhibit-4** **Bottom Support insulator intact**

4. Fingers of main contact are found to have no severe arcing marks **(Exhibit-5)**. However, connecting rod was found to be damaged.

5. Although the substation is operating in industrial area, there is no polluting industry in the vicinity of the substation.

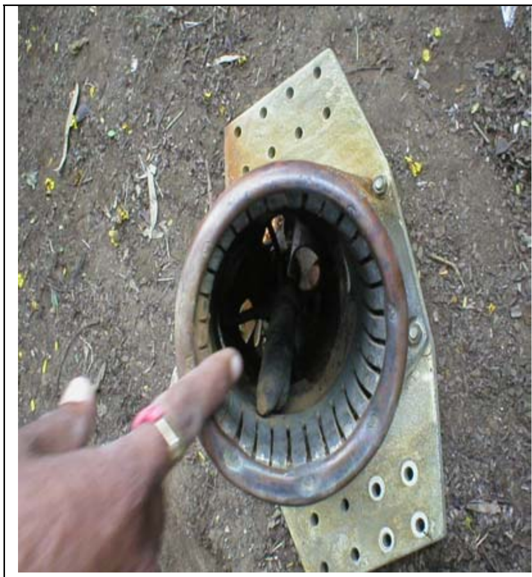	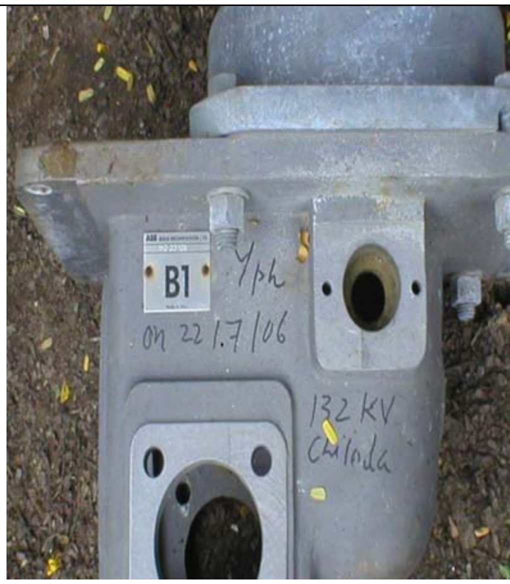
Exhibit-5 **Main arcing contact**	**Exhibit-6** **Broken metallic part disengaged from common driving rod**

2.2 Consequential Damages:

The blasting of CB also caused further damage to the following neighbouring equipment:

1. Support Insulators and Porcelain housing of interrupter chamber of R and B pole of the CB **(Exhibit -1)**

2. Support Insulators of isolator and CT of nearby bay **(Exhibit -7 &8)**

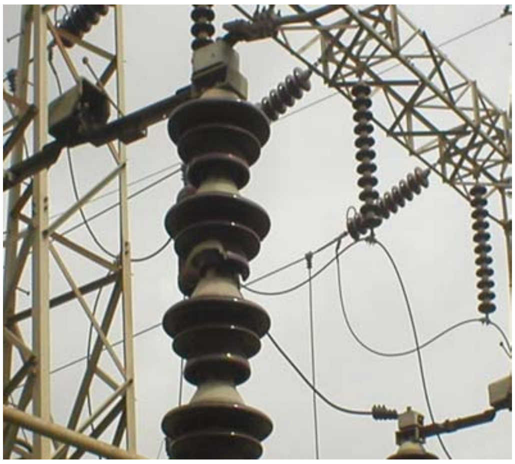	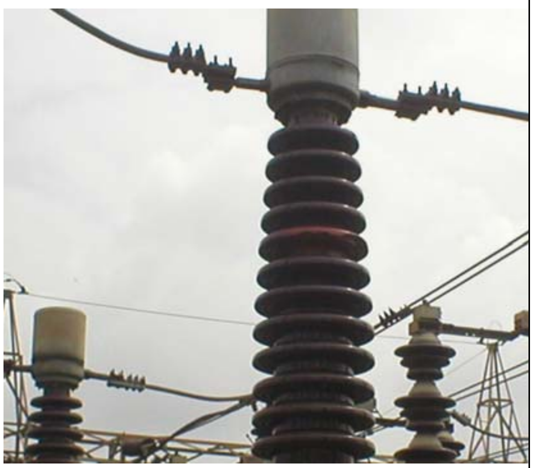
Exhibit-7 **Broken support insulator of isolator**	**Exhibit-8** **Broken petticoat of CT**

2.3 Sequence of Events

- On 22-07-2006, at 19:23 hrs, flashover of insulator string of Y phase at tower location No. 14 (about 3 km from Ranasan) of 132kV Ranasan-Chiloda line
- Tripping of Circuit Breaker at Ranasan end initiated
- During tripping operation of the circuit breaker, R & B pole opened successfully. Y pole of the breaker blasted.
- The blasted pole of breaker(Y pole) being disengaged from the common operating rod fell over the nearby isolator of the same bay causing bus fault leading to outage of all bays connected to that bus as the 132kV system is at present operating with single bus scheme without sectionalisation. There is also no provision of bus bar protection at 132kV level although it is an important station.
- Tripping of all four 220kV / 132kV transformers
- The complete outage of 132 kV system affected the 66kV system also. The tripping caused outage of both 132kV and 66kV system for about 31 minutes.
- The direct trip command initiated at Ranasan opened the breaker at the Chiloda end of the line.
- Earth fault element of distance protection operated at both Ranasan [30G, 30E(Y-N)] and Chiloda substation.

Similar type of failure of Circuit Breaker (blasting of Y pole of 132kV SF6 Circuit Breaker of M/s Siemens) had occurred on 04-02-2005 at Ranasan substation due to fault on Ranasan-Talod line.

2.4 O & M History of CB:

The CB (Sr.No. 15000108) was commissioned on 08-09-2001. On 05-05-2006, IR value was measured and relay tripping test was undertaken. From the record it is observed that Insulation Resistance measurement, checking of gas leakage, lubrication, operation of protective relays, tightness of wiring are being carried out by GETCo. as part of the routine maintenance checks. Last maintenance work was carried out on 05-05-2006.

In last one years there have been 4 tripping of this CB (14-01-2006, 05-05-2006, 24-05-2006, 03-07-2006). Last successful tripping operation of this CB was on 03.07.2005

2.5 Analysis of failure of Circuit Breaker :

The flashover of insulator string of Y phase at tower location No.14 of Ranasan – Chiloda line (about 3 km from Ranasan) caused ground fault. The flashover had taken place on a normal day without any rain. The fault on the line initiated the tripping of the three phase gang operated Circuit breaker at Ranasan end. During opening of the circuit breaker R and B pole of the breaker successfully opened. Unfortunately the Y pole of the gang operated breaker failed to break the fault current. The fault current continued to flow through the Y pole of the CB for quite some time. In absence of Disturbance recorder / modern numerical relay it is not possible to ascertain the magnitude and duration of fault current. Fault current magnitude might have exceeded rated breaking capacity (40kA for 3 sec.), which is quite high for 132kV system. The flow of high current through the breaker increased SF6 gas pressure in the interrupting chamber leading to blasting of the chamber to release excess gas pressure. Support insulator of failed breaker pole was found to be almost healthy. The power flow in the line prior to failure(at 19 hours) was only 15 MW and current was only 75 Amps. From the record it was also observed that maximum system voltage goes only upto 138kV which is well within highest system voltage of 145kV. The CB has served only for about 5 years. The visible holes on metallic part of main contact shows severe arcing marks.

Y pole of the CB got disengaged from the gang / common operating rod connected to a common motor. The blasted pole of breaker(Y pole) being disengaged from the common operating rod fell over the nearby isolator of the same bay causing bus fault and outage of both 132kV and 66kV system for about 31 minutes.

From above, it may be concluded that ABB make CB installed in Ranasan substation had failed due to failure of mechanical linkage of Y pole of the breaker with common driving assembly while breaking the fault current.

2.6 Restoration of the failed CB:

Interrupting chamber of Y pole of the CB had damaged beyond repairs and was replaced by spare healthy pole. Other poles (R&B) were overhauled and CB was put back into service on 29-07-2006.

3.0 FAILURE OF TRANSFORMER AT LIMDI SUBSTATION

The brief details of the failed transformer are as follows:

Transformer Particulars	**Details**
Name of Substation	Limdi
Make	BHEL
Rating	50 MVA, 220kV/132kV/11kV (Transformer-2) Vector Group - HV-LV: Yyo, HV-TV:Yd11
Sr.No.	6004439
Type	Autotransformer
Year of Commissioning	22-01-1984 (Year of manufacture 1980)
Last routine maintenance work	04-01-2006
Date of Failure	29.06.2006 at 18:00 Hrs
Insulation level	HV: 900kVp, HV-Neutral: 38kV (rms) LV: 550kVp, TV: 28 kV (rms)
% Impedance	HV-LV: 9.89%

The 50MVA, 220kV/132kV transformer of BHEL make failed on 29-06-2006 at 18:00 Hrs at Limdi Substation. The detailed analysis of failure of Transformer is discussed below.

3.1 <u>Observations</u>

The three phase, 50MVA, 220kV/132kV/11kV autotransformer with ONAN/ ONAF cooling was in operation since 1984. The transformer had failed on 29-06-2006 with openings at welded joints on the top of tank.

Following observations were made:

1. Lower part of R-phase of HV (220kV) bushing had damaged exposing the cellulose insulation (Exhibit-1,2)

<table>
<tr><td></td><td></td></tr>
<tr><td>Exhibit-1
Damaged R-phase of HV (220kV) bushing exposing the cellulose insulation</td><td>Exhibit-2
Another view of Damaged R-phase of HV (220kV) bushing</td></tr>
</table>

2. Upper part of the R-phase bushing had popped up. **(Exhibit-3)**

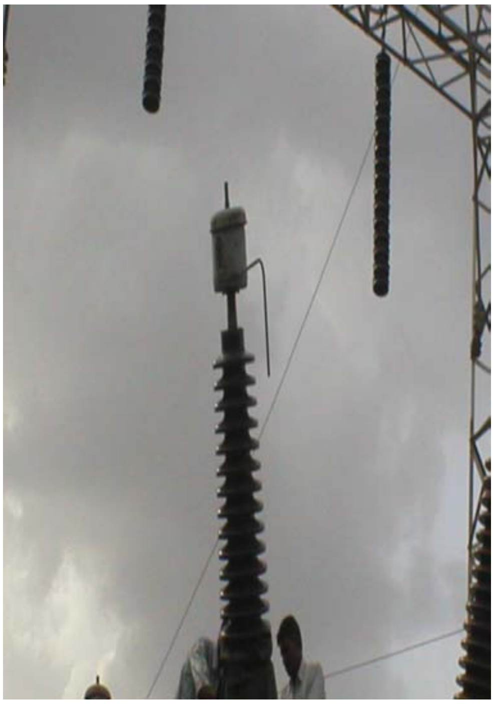	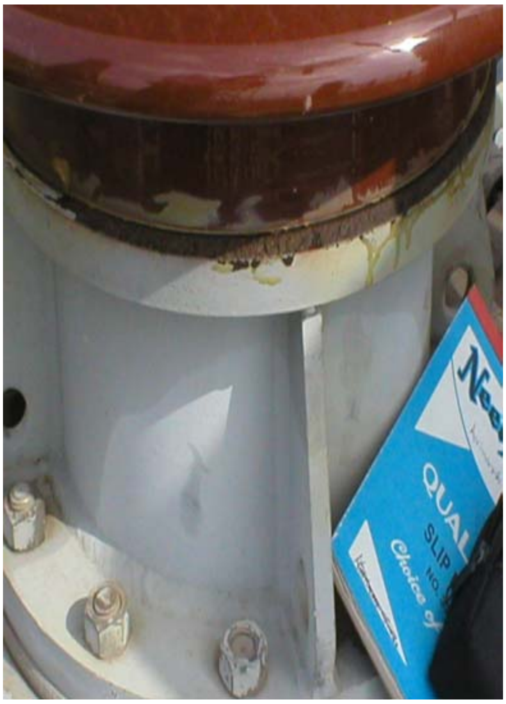
Exhibit-3 **Popped up R –phase of HV bushing**	**Exhibit-4** **Displacement of bushing from cemented portion**

3. Y-phase and B-phase of HV (220kV) bushing were found to be displaced from at bottom part. The gaskets were in very bad condition and continuous oil leakage found from bottom of Y-phase of HV bushing **(Exhibit-4,5).**

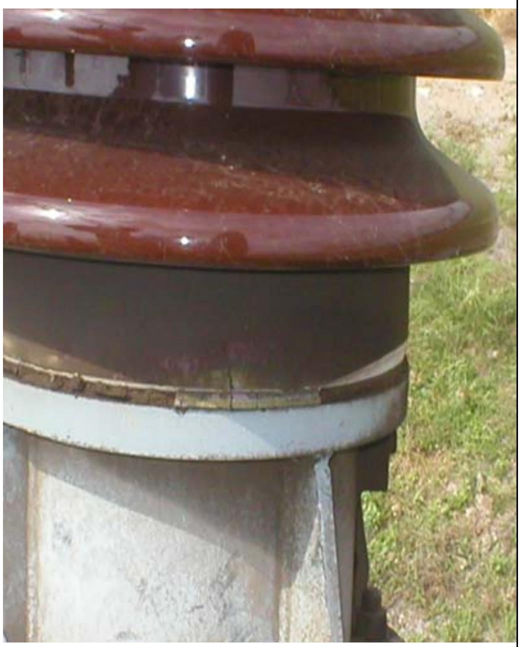	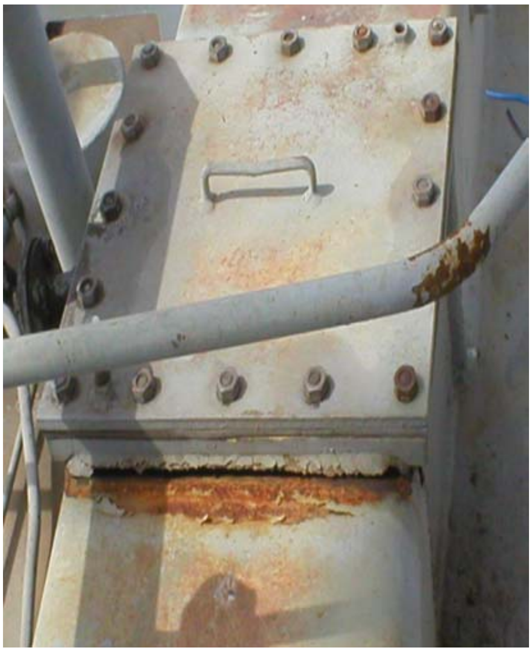
Exhibit-5 **Displacement of bushing from cemented portion**	**Exhibit-6** **Lifted inspection window**

4. Both inspection window and main tank of transformer was found lifted up from welded joint portion under pressure **(Exhibit-6,7)**.

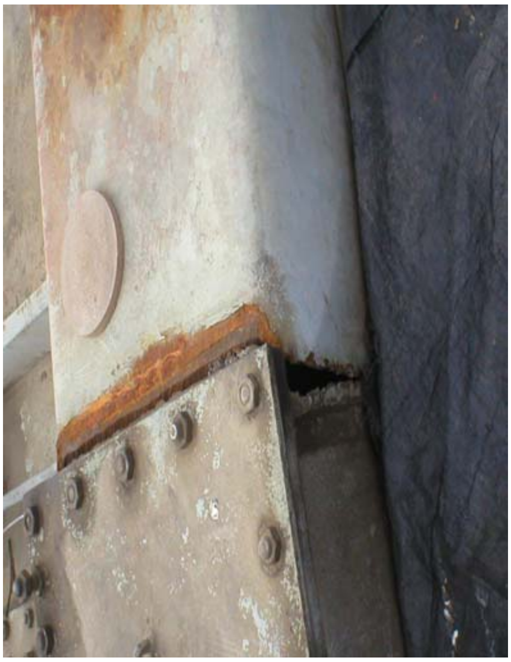	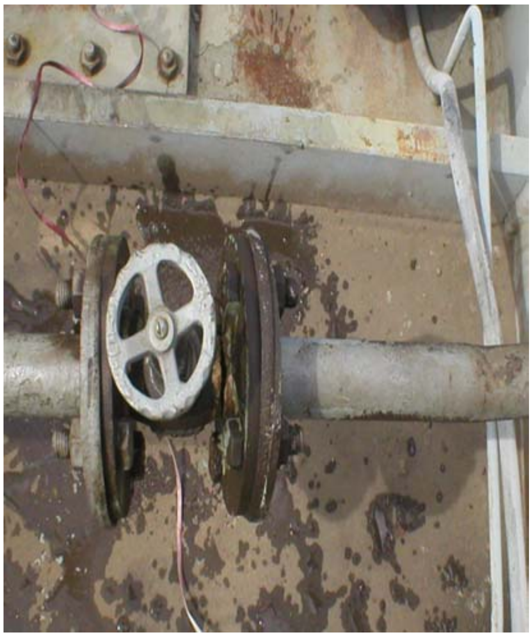
Exhibit-7 **Lifted inspection window**	**Exhibit-8** **Broken pipes**

5. Equalising pipe connected with R-phase bushing turret was disengaged from main pipe of main conservator tank. **(Exhibit-8)**

6. Connecting pipe between main conservator pipe and surrounding area of B-phase OLTC pipe found damaged.

7. The oil level is observed to be low in R-phase and B-phase LV bushings

8. The test taps were checked and no sign of arcing mark was observed.

9. It was reported that On Load Tap Changer has never been called for operation since its commissioning.

10. Reading(s) of OTI was 56 deg. and that of WTI were 68, 59, 56 deg. at 15:00 hours

11. As reported there was no external fire although oil spillage was there.

12. No proper soak pit has been provided for the transformer

13. Fire Fighting wall has been provided between transformers

14. At the time of failure the OLTC was at normal tap (No.9)

15. The 220kV and 132kV system are operating with single bus scheme.

3.2 Consequential Damages:

Two(2) petticoats of porcelain housing of arcing chamber Y-phase of 220kV ABCB (HBB make type DLF) found damaged . This may be due to spreading out of broken insulator of R-phase bushing. No other damage to the neighbouring equipment was reported due to the failure of transformer.

3.3 Sequence of Events

1. Heavy rain in surrounding area at 17:15 Hrs on the day of failure

2. Transformer failed at 18:00 Hrs without any abnormal noise.

3. No system fault was reported at the time of failure.

4. Following protection provided for the transformer had operated
    - Transformer Differential relay (87)
    - Buchholz, Pressure Relive Device(PRD)
    - It was observed that physically PRV has not operated. Due to vibration or jerk, electrical signal communicated to the control room.

5. No mal operation of relays was reported

3.4 O & M History of Transformer:

The transformer was commissioned on 22-01-1984 after about four years of manufacture (1980). The overhauling of transformer was carried out from 16-05-1999 to 05-06-1999 and the transformer was put back into service. The IR measurement, magnetising current, magnetic balance test, SC test, voltage ratio test, continuity of OLTC, measurement of BDV of oil were conducted during overhauling of transformer. Routine maintenance was carried out on 18-01-2003, 31-03-2004 and 07-07-2004. The IR measurement, cleaning of all bushings, operation of Buchholz, remote tripping, oil level in main conservator tank, OLTC tank and bushing; BDV of oil, condition of Silicagel, checking of OTI & WTI, manual and electrical operation of OLTC, checking of neutral earth connection are being carried out by GETCo. as part of the routine maintenance checks.

The measurement of capacitance and tandelta of bushings and windings were carried out only once on 04-01-2006 since its commissioning. The sample of oil was last tested on 19-07-2005 for BDV, water content, neutralisation value, % of sediment & sludge, dielectric dissipation factor, specific resistance, interfacial tension, and flash point. The last Dissolve Gas analysis (DGA) was carried out on 25-06-2005. Prior to this date, no DGA was carried out.

On an average 5 trippings per month are encountered at 132kV level and most of them are due to birdage. But due to short length of line, trippings at 220kV level are much less compared to 132kV level.

No previous failure or major repair of transformer was reported.

3.5 **Analysis of Failure of Transformer** :

(a) The transformer is an autotransformer of BHEL make with unloaded tertiary winding and was commissioned on 22-01-1984 after about four (4) years from date of manufacture (1980). The tertiary is being protected by combination of surge arrester and surge capacitors. The transformer had failed on 28-06-2006 after serving for about twenty two (22) years. Openings at welded joints on the top of tank were clearly visible.

(b) The transformer is quite old and was in operation for more than two decades. The average loading on the transformer has rarely exceeded 50% of its rated capacity and has never been overloaded beyond its maximum capacity during its service life. Even on the day of failure loading on the transformer was only 18 MW. Therefore, the cellulose insulation of transformer is most likely to have passed through the normal ageing process and fast ageing due to overloading is not expected.

(c) The test conducted on 19-07-2005 shows that measured parameters of oil are well within the desired limits. But the DGA conducted on 25-06-2005 shows that content of Oxygen (O2) and Nitrogen (N2) are 6640ppm and 36426 ppm respectively. The CO2/CO ratio of 7.8 (=1577/203) is considered to be normal. But oxygen of 6640 ppm is considered dangerous for transformer. The Roger's ratio (C2H2/C2H4 <0.1, CH4/H <0.1, and C2H4/C2H6 < 0.1) indicates low density energy arcing (Partial Discharge).

(d) The quantum of oxygen might have increased further over a period of about one year i.e till the date of failure on 28-06-2006. Moisture, especially in the presence of oxygen, is extremely hazardous to transformer insulation. This might have accelerated the ageing process of paper insulation. Low energy arcing and aged paper insulation might have resulted in insulation failure.

(e) The test conducted on 04-01-2006 shows that measured values of tandelta of HV, LV bushings are quite high (HV bushing: R-phase-0.57, Y-phase-1.26, B-phase-0.67; LV bushing: R-phase-0.60, Y-phase-52, B-phase-69). Since there was no previous / subsequent test result to compare, the change in tandelta & capacitance value can not be known. Although Tandelta value of Y-phase of HV bushing is quite high (1.26), porcelain housing of R-phase HV bushing has blasted. Similar things could have happened to other bushings also. Such situation in general calls for immediate action to avert failure of bushing.

(f) Although there was some oil spillage through opening in the damaged welding areas, no external fire had taken place as the temperature of oil was not high at the time of failure which can be noted from WTI and OTI prior to failure.

(g) No DGA test has been conducted after failure of transformer. Presence of acetylene could not be confirmed. High energy arcing can not be ruled out. Arcing might have taken place inside transformer due to either failure of winding insulation / HV bushing and / or bad contact in tap changer which has resulted in formation of gases and development of gas pressure.

(h) Continuous increase in content of oxygen and Nitrogen and insulation failure might have led to high energy arcing, accumulation of other fault gases and rise in gas pressure ultimately resulted in operation of gas operated Buchholz relay. The high gas pressure development inside the transformer and non operation of PRD possibly due to blockage **(clearly visible from Exhibit-9)** have resulted in creating openings at vulnerable regions / weak points of transformer tank and some welded junctions to vent out the gases.

Exhibit-9
Clearly visible non operation of PRD

(i) On the day of failure, it was raining and loading on the transformer was only 18 MW. As the transformer is well protected by overhead shielding wires and surge arresters, probability of failure of transformer due to lightning is very less. However, healthiness of surge arrester provided for protection of transformer is to be checked / ensured from time to time using proper diagnostic tools (such as on line leakage current monitor).

(j) The test conducted after failure shows isolation of Y-phase from neutral which is confirmed from the test result indicating zero current between Y-phase (LV winding) & neutral and infinite insulation resistance across Y-n (LV winding).

(k) The sudden pressure rise indicated by operation of buchholz relay, physical non operation of PRD (electrical operation may be due to vibration) and openings on transformer tank at welded joints might have caused displacement of winding and / core. Therefore, Frequency Response Analysis (FRA) test may be conducted along with impedance measurement to find out any displacement in winding and / core and remedial action may be carried out accordingly.

(l) Since transformer is quite old, the Degree of Polymerisation (DP) of insulating material of the winding (cellulose insulation) may be conducted to assess the remaining structural strength of the paper insulation and would give an excellent indication of remaining life of paper as well as transformer itself.

(m) In view of above observations, internal inspection is required. Internal inspection including the OLTC chamber may provide some valuable information about the transformer which could help in taking early action to avert such failure in future. Before going ahead with repairing of the transformer, thorough investigation of condition of various windings, OLTC and healthiness of bushings would be desirable as it may require replacement of some or all of the old windings and bushings of the transformer. The repair work calls for replacement of damaged bushings. In addition to that the repair works also involve welding works on the transformer tank. As the transformer is likely to be repaired, facilities for carrying out welding of tank and for conducting various tests including high voltage tests should be available at the repairing shop.

(n) **The tripping of differential protection further supports internal fault. Therefore, the failure of transformer could be due to failure of winding insulation and / bushing.**

3.6 Restoration of the failed Transformer:

The failed transformer is out of service and likely to be repaired shortly

4.0 <u>Recommendations:</u>

1. The premature failure of circuit breaker and problem with operating mechanism are matter of serious concern. It raises question about the quality of product. Problem with common driving assemblies could also be the cause of failure of similar make breaker in future. As six(6) numbers of breakers of similar model are also in the operation in the substation at Ranasan, the matter may be discussed with the manufacturer (M/s ABB), so that remedial measures, if required, could be taken by the manufacturer in advance to avert repetition of such failure in future.

2. Factory test report and pre-commissioning test reports of each equipment, which are considered to be the base results, should be made available to the operation and maintenance staff of the substation so that subsequent measured results can be compared with the base value to find out any abnormal change. The trend analysis (relative change in test result and rate of change) will provide valuable information to O&M staff for taking early action so that any major failure can be avoided.

3. From the record it is observed that Insulation Resistance measurement, checking of gas leakage, lubrication, operation of protective relays, tightness of wiring are the routine maintenance checks being carried out by GETCo. for circuit breakers which is considered not adequate to assess the health of Circuit breaker. The static contact resistance, capacitance and tandelta measurement for grading capacitor(wherever applicable), dew point measurement of SF6 gas / operating air for CBs, operating times of circuit breaker, checking of pole discrepancy relays and timer for CBs and Dynamic Contact Resistance Measurement (DCRM) should be conducted at regular interval in addition the other routine tests being conducted. Abnormality in value of static resistance as well as DCRM signature would provide valuable information about erosion / misalignment of Contact assemblies. It is recommended to conduct DCRM test and Static Contact Resistance Tests for all CBs at various substations for assessing their condition to decide on major overhauling of CBs.

4. Surge Arresters are generally provided at line ends and near the transformer for protection against lightning and switching over voltages. In some of the bays, it is observed that combination of gapless metal oxide and gapped type arresters are operating in different phases which is not a healthy practice. All gapped type arresters may be replaced by gapless metal oxide arresters having better protection level, higher energy handling capability etc. Healthiness of such vital equipment needs to be ensured using proper diagnostic tools (e.g Leakage current monitor) for safety of

transformers / other equipment for which resistive component of leakage current measurement may be carried out from time to time for condition assessment.

5. The moisture and oxygen content of the insulation system has a decisive influence on the ageing rate of power transformer. Moisture, especially in the presence of oxygen, is extremely hazardous to transformer insulation. Oxygen together with a water content of 2% in paper insulation can raise the rate of ageing by a factor of 20. Oxygen above 2000ppm dissolved in transformer oil is extremely destructive and accelerate deterioration of paper insulation. Generally transformer oil becomes saturated with oxygen through contact with the air in the conservator. So oxygen level must be watched closely. Transformers should be made free of oxygen as far as possible. In such situation there is need for close inspection of silicagel filled air breather.

6. Bushing failure has become a major cause of failure of transformers. Therefore, as a general practice, periodicity of measurement of capacitance and tan delta of bushings be decided based on condition assessment. In general the value of tan delta for bushings or windings should not exceed 0.5% at 20 deg. C and 0.7% in worst case and the rate of rise of tandelta per year should not exceed 0.1%. Based on the trend / relative change in measured value, remedial action, even the replacement of bushing (if required), should be taken urgently so as to avoid catastrophic failure of bushings and transformers

7. It is observed that number of important tests are still not being covered under routine maintenance. In addition to other tests being conducted by GETCO like DC resistance, turns ratio, capacitance and tan delta measurement for winding and bushings, magnetizing current, etc., it is recommended to conduct core to ground insulation resistance measurement and determination of Polarization Index (PI) corresponding to 60secs. and 600 secs., Frequency Response Analysis(FRA), Recovery Voltage measurement, impedance measurement etc.,which should form part of maintenance activity. The periodicity of the tests are to be decided.

8. Due to some reasons if a very old transformer is required to be opened for internal inspection, then the opportunity should be utilized also for conducting the Degree of Polymerisation(DP) test of insulating material of the winding (cellulose insulation) to assess the deterioration of paper and remaining life of cellulose insulation. This would require analyzing sample of paper insulation in laboratory to determine the deterioration of the molecular bonds of the paper. This would be a good indicator for remaining life of transformer.

9. Partial discharge sometimes occur in transformer at any moment of time due to ingress of moisture, trapped air due to improper oil filling, long time degradation of insulation. Acoustic partial discharge measurement may be done at different locations on four sides of transformer to detect discharge. It is recommended to corroborate the readings with DGA measurement to avoid catastrophic failure.

10. Earthing system in substation of GETCo. needs to be reviewed

11. It seems that at present no standard maintenance practice is being followed by GETCO. GETCO may follow condition based maintenance practice using modern diagnostic tools to assess health of various substation equipment including

transformers instead of following the conventional Time Based Maintenance (TBM) practices. In the process catastrophic failures can be averted, maintenance cost can be reduced, reliability & availability can be increased and ultimately life of equipment would be extended. Reliable diagnostic tools, suitable for on site measurement with EMI compliance, should be used to minimize human error involved during testing and to provide reliable, error free observations / test results while measurement is done in a charged switchyard. The operation and maintenance staffs are not well equipped with adequate modern Diagnostic tools for assessment of healthiness of substation equipment. It seems that availability of suitable testing equipment for maintenance purpose is the major constraint of the utility.

12. It is recommended that each testing group should have following major testing tools:

- Automatic Capacitance and tandelta measuring instrument
- Leakage current monitor for surge arrester
- Static contact resistance meter
- Circuit breaker operational analyser and Dynamic Contact Resistance Meter(DCRM)
- Automatic relay test kit suitable for testing elctromechanical / static / numerical relays
- Frequency Response Analyser (FRA) test set
- Earth tester for measurement of soil resistivity and ground resistance
- Thermovision camera
- Portable Dissolve Gas analyser
- Transformer winding resistance meter and turn ratio meter

FRA test set and thermovision camera can cater to number of testing groups operating under GETCO.

13. Complete data base of previous test results and history of the equipment may be maintained for proper evaluation of results. Periodicity of tests to be conducted on various equipment needs to be decided based on condition assessment and relative change in test results (trend analysis) with respect to time.

14. It is recommended to train and develop strong testing group within GETCO to monitor the healthiness of various substation equipment. Operating and maintenance staff may be trained properly to handle various modern diagnostic tools and to interpret the test results, which is a difficult task, for taking remedial action.

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