

# Report on failure of 400/220kV/33kV, 315MVA Transformer (BHEL make) at Bamnauli Substation of Delhi Transco on 11-02-2008

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## 1.0 INTRODUCTION

The 400/220kV Bamnauli substation of DTL has been commissioned sometimes during 1998. The substation is operating with 1260 MVA total transformation capacity [Three transformers: with 3x315MVA, 400/ 220kV/33kV (BHEL) plus 1x315 MVA 400/220/33 kV(TELK MAKE)]

The 400/220kV/33kV , 315MVA transformer no 1 (BHEL make) failed on 11-02-2008 at 20:40 Hrs at Bamnauli substation..

A Standing Committee has been constituted 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, Shri T.P.Singh Chief Engineer, Sh K.K. Arya, Director, Sh .M.S .Satija and Sh. Avinash Chander, Dy. Director of SE&TD Division of CEA visited the site of failure of transformer at Bamnauli on February 19, 2008..

During the visit, the team had meetings with DTL officials and discussed in detail with the operation and maintenance staff of substation about the sequence of events leading to failure of transformer. The results of various tests conducted on the transformer before and after failure including DGA and other relevant information were also collected. The assessment / analysis of failure of transformers is discussed below.

## 1.1 **FAILURE OF TRANSFORMER AT 400/220kV/33kV BAMNAULI SUBSTATION**

The brief details of the failed transformer are as follows:

<b>Transformer Particulars</b>	<b>Details</b>
Name of Substation	Bamnauli
Make	BHEL
Rating	315 MVA, 400/ 220kV/33kV/ 3phase (Transformer No. I) Vector Group – YNaoD II
Sr.No.	6005262
Type	Three winding Transformer with unloaded tertiary
Year of Commissioning	2000 (Year of manufacture 1993)
Last routine maintenance work carried out	03-11-2007 (planned)

Date of Failure	11-02-2008 at 20:40 Hrs
Insulation Level	HV(400kV): 1300 kVp, IV(220kV): 950 kVp, IV-Neutral: 95kVp LV(33kV): 250kVp,
% Impedance	HV-LV: 71.41%, HV-IV: 11.60% IV-LV: 57.04%

## 1.2 Sequence of Events

On 09.02.2008 the transformer was operating at load of 85 MW. Buchhloz Alarm appeared at 9.30 AM and at 10.30 AM the transformer was taken on shut down and all the tests such as capacitance and tan delta, insulation resistance value, DC resistance, turn ratio, magnetic balance and magnetizing current were conducted. Simultaneously oil sample was sent to CPRI for DGA Analysis. After examining the report, and the test results found to be normal, the transformer was put on no load at 5.40 PM on 11.2.2008.

At 8.40 PM, there was sudden tripping of the relays viz. Buchhloz Relay, OLTC Buchhloz, differential and REF Relays. This was followed by heavy fire in the transformer. Simultaneously, there was tripping of all the 400 kV feeders. The sprinkler system installed at the substation could not control the fire. With the explosion of main tank and spillage of transformer oil; fire spread heavily and at the same time fire tenders were called from the different fire stations of the city. Fire tenders were put in the service and the fire could be brought down only at 3.00 AM on 12.02.2208.

Photographs of the burnt transformer are shown in exhibits enclosed.

## 1.3 Consequential Damages

The blasting of the transformer caused damage to the following equipment:

(a) All the associated power and control cables

(b) Surge Arresters, 390kv -- 3nos.

(c) Surge Arrester 216 kV,-3nos

(d) Isolator 400kV –1 no

In addition to above a cooling tower of A/C plant was also got damaged.

Photographs of all the above damaged equipment are enclosed.

## 1.4 O&M History of The Transformer

The transformer was manufactured by BHEL in 1993 and was commissioned in 2000 at Bamnauli station. The transformer was kept at site in uncharged condition for seven years. No record was available with the DTL from which it could be checked whether the transformer was stored with nitrogen filled or oil filled and whether the nitrogen pressure was maintained at the pressure as per the manufacturer's recommendations.

It was observed that transformer oil test /DGA test were conducted by CPRI in 2005,2006 and 2007.Tan delta and Capacitance tests on Windings and Bushing were conducted on 10-02-08 by DTL & on 09-12-2006 & 16-12-06 by (Powergrid) and on 14-05-04 by (CPRI). Thermovision Scanning was also done on 30-10-07 and 04-02-08. As could be seen from the event of occurrence on 09-02-08, at about 9.30 AM buchholz alarm appeared in the transformer panel and transformer was on shut down on 09-02-08 and 10-02-08. All the required tests such as Tan delta and Capacitance tests on Windings and Bushing , Magnetising Voltage balance, D.C. resistance, and IR were conducted on 10-02-08 and were found to be normal. Oil sample was also sent to CPRI for DGA of oil. The DGA report was also normal . The insulation resistance (IR) measurement, magnetising current, magnetic balance test, turns ratio tests, measurement of BDV & other parameters (water content, neutralisation value, % of sediment & sludge, dielectric dissipation factor, specific resistance, interfacial tension, and flash point) of oil, cleaning of bushings, tightness of clamps, connectors, nuts and bolts, thermal scanning using infrared cameras, checking of oil leakage were being carried out by DTL as part of the routine maintenance checks.

The failed autotransformer is of BHEL make with unloaded tertiary winding and was commissioned in October 2000 and after 4 years of commissioning i.e on 14.05.2004 tan delta & capacitance of 220 kV and 400 kV bushing were measured by M/s CPRI. The measurement of capacitance and tan delta of bushings and windings was again carried out on 09.12.2006. One 52 kV bushing of B phase was replaced on 14-12-2006 No other major repair work of transformer was carried out since commissioning.

#### **1.5 Analysis of Failure of Transformer:-**

It is observed that the transformer was stored at site for seven years from 1993 to October 2000. Since no record was available with the DTL regarding proper storage of the transformer as explained above, the ingress of moisture might have damaged the insulation of the winding. The transformer after receiving at site is generally kept Nitrogen filled under prescribed pressure for a maximum period of 5-6 months and it is not advisable to store the transformer beyond such a long period. In such case, it is recommended that transformer should be filled with oil and oil to be filtered at regular interval. During that period regular testing like Capacitance and Tan Delta, Break Down value of oil, DGA of oil, Furan test and degree of polymerisation should have been conducted. This is the only reason which possibly attributed to the failure of the transformer due to insulation failure. The transformer has served useful life for 8 years only i.e. from the year 2000 to 2008.

The **315 MVA 400/220/33 kV transformer** burst into flames and was totally damaged.

#### **1.6 Observations**

(a) It is observed that the periodicity of the following tests conducted by DTL for this transformer are not in accordance with the recommendations made in the CBIP Manual on EHV sub-station Equipment Maintenance

(i) **DGA test**

The CBIP manual on recommends that this test should be conducted on half yearly basis but the DTL has conducted this test on yearly basis.

**(ii) Capacitors and Tan Delta test for bushing and winding**

As per CBIP manual this test should be conducted on yearly basis but from the record made available the DTL has conducted the test only once in two years. In this connection it is added that the committee has already recommended in the earlier report to DTL that this test to be conducted twice in a year keeping in view the higher rate of failure of bushings in DTL.

- (b) From the available records, it has been observed that the data relating to testing is available since 14.05.2005 whereas the transformer was commissioning in October, 2000.
- (c) During 2006 capacitance & tan delta and capacitance measurement of bushing was done by M/s Power Grid. On 10.02.2008 capacitance & tan delta test of bushing and winding was conducted by DTL.
- (d) In 2005 SFRA test was conducted by power grid. IR measurement of winding/ testing PRV, Buchholz and OLTC surge relay were tested. In addition to this test BDV, PPM, DGA of oil of main tank and OLTC tank, by M/s CPRI were carried out.
- (e) The thermo scanning was also conducted on 4/2/2008 and no abnormalities were found.
- (f) The tripping of differential protection further supports internal fault. Therefore, the failure of transformer could be due to failure of winding insulation.
- (g) As per site inspection it was observed that the transformer got damaged completely and was beyond repair. This damage might have been caused due to the sudden jerk on the winding/core. This is evident from the photographs attached.
- (h) Possibility of transient surge from the grid cannot be ruled out which damaged the winding insulation leading to bursting and fire in the transformer.
- (i) From the DGA results conducted on the transformer from 2005 to 2008, it appears that the results of the DGA are not consistent and indicates increasing trend. Specially, there is variation of results conducted by CPRI on 09.02.2008 and previous test conducted by CPRI on 23.08.2007. The test reports of DGA conducted on 23.08.2007 indicated that Acetylene (PPM) in the range of 6 was present whereas the DGA report of 09.02.2008 indicated as not detected. This requires reconciliation.

**1.7 Restoration of the failed transformer**

As explained above the transformer got burnt completely and got burst and it is beyond repair and has to be replaced.

As such there is no question of restoration of the transformer.

**2.0 RECOMMENDATIONS**

**2.1** The transformer should not be stored at site for more than 5 to 6 months that too with nitrogen filled at a prescribed pressure with proper monitoring. In case it becomes unavoidable to store the transformer for a year or so, in that case the transformer should be oil filled and all the routine tests should be conducted at regular intervals.

**2.2** Factory test report and pre-commissioning test reports of each transformer, 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 values 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.

- 2.3** In addition to other tests being conducted by DTL, it is recommended to conduct core to ground insulation resistance measurement, DC resistance measurement and determination of Polarization Index (PI) corresponding to 60secs. and 600 secs., Recovery Voltage measurement, SFRA etc. may also form part of maintenance activity.
- 2.4** Complete data base of previous test results starting from factory test, pre-commissioning tests etc. and history of the transformer may be maintained properly which would help in proper evaluation of results. Periodicity of tests to be conducted on transformer needs to be decided based on condition assessment and relative change in test results with respect to time (trend analysis).
- 2.5** DGA is being carried out by DTL since 2005. But the rising trend of various fault gases need to be monitored to plan future action. It is suggested that DTL may procure on line portable DGA equipment which can cater to number of substations for condition monitoring of transformers. DGA based on the results of same equipment used at different times would provide better information for analysis / interpretation.
- 2.6** Non-operation of Pressure Relieve Device (PRD) has caused serious damages to transformers in number of cases as in recent past in DTL's system also. So far no site tests are being conducted to assess healthiness of PRD whose operation is very much required to save transformer from serious damages. Therefore, it is required to check healthiness of PRD at site at regular interval of time. The manufacturer may be consulted to find out the method of checking healthiness of PRD of transformer at site.
- 2.7** Considering the failure rate of transformers due to bushing failure as reported elsewhere in the country, it is recommended to conduct capacitance and Tan delta measurement for bushings as well as winding twice in a year to have fairly close monitoring of bushings.
- 2.8** Field test results (conducted after failure) may be verified during major repair work at manufacturer works / at site for which the concerned person associated with operation & maintenance activities may be deputed to manufacturer's works for the purpose to have better insight and understanding of cause of failure which would help in future.
- 2.9** In the above case, failure of transformer is attributed to insulation failure (inter-turn insulation failure) and / deformation in windings. The deformation in winding indicates flow of high short circuit current for longer duration. There is no Disturbance Recorder at 400kV substations to record such system faults and its duration. The replacement of conventional Electro-mechanical / static relay by modern numerical relay could help in getting such valuable information. As such the short circuit withstand level of transformer is being verified by empirical calculations. No short circuit test has been conducted on the transformer due to non-availability of indigenous testing facility. Therefore, such failures raise doubts about the short circuit withstand capability of transformers being manufactured in the country. The fault clearing time of protective system needs to be reviewed. Adequate measures need to be taken to protect the transformer from severe short circuit condition.

- 2.10** It is advisable to conduct SFRA for healthy transformers also as and when required, may be at least once in two years.
- 2.11** Following tests should be conducted strictly as per recommendation of CBIP Manual on EHV Substation Equipment Maintenance.
- a) Capacitors and Tan Delta
  - b) DGA
  - c) In addition to above Furan and Degree of Polymerisation tests should also be conducted to know the healthiness of the winding and insulation of various 400 kV, 315 MVA Power Transformers installed in DTL.
- 2.12** It was observed that there was no oil collecting pit, it is recommended that oil collecting pit of adequate size should be provided to minimise the oil spillage and fire hazard.
- 2.13** Nitrogen Injection Fire Prevention and Extinguishing System is also available today and be suitably considered by DTL over conventional fire protection systems.

**Submitted by  
Sd/-**

**Chief Engineer (SE&TD) and  
Chairman, Standing Committee to investigate  
the failure of equipment at 220kV & above  
substation**



Damaged Transformer



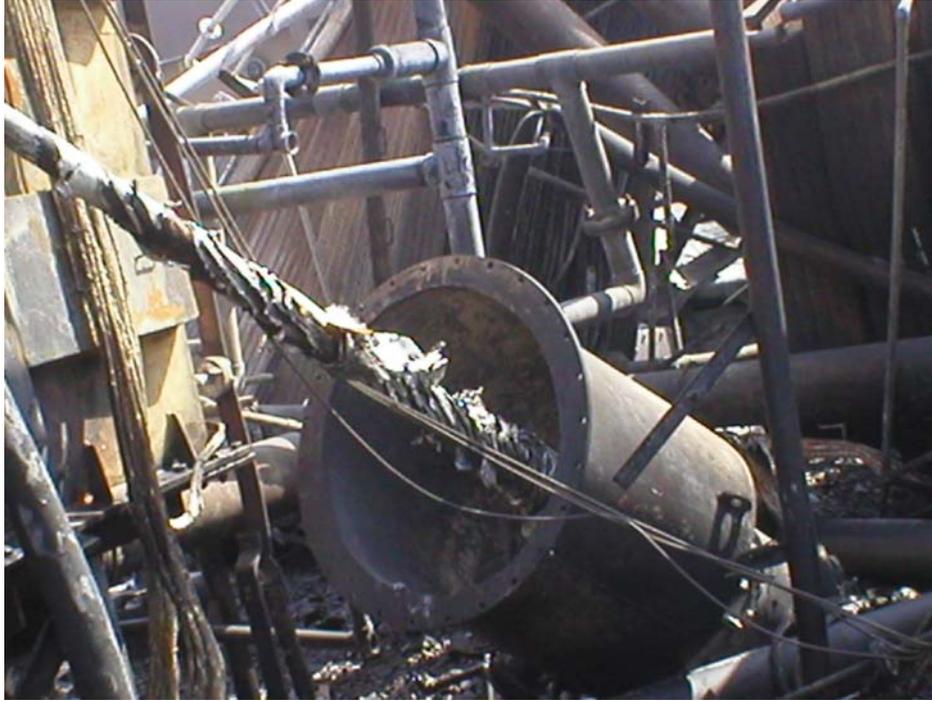
Damaged Bushing



Damaged Radiator Bank



Damaged Lightning Arrester



Damaged Bushing



Damaged Lightning Arrester



Damaged Cooling Tower



Damaged Cables



Damaged 220 kV Site Bushing