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

1.0 Introduction:

1.1 DTL vide letter No. F.DTL/206/F.06/2015-16/Mgr(Bawana)/353 dated 08.03.2016 requested CEA to investigate the cause of failure of 315 MVA, 400/220/33 kV Auto transformer (failed on 8th March 2016 at 1201 hrs) in Bawana sub-station of DTL.

1.2 A team of officers from PSE&TD Division of CEA [Sh. Y.K.Swarnkar, Director(Substation); Sh. Faraz, Assistant Director; and Ms. Bhaavya Pandey, Assistant Director] along with officers of DTL visited the site of failure on 9th March 2016. The details of visit are as under.

2.0 About Substation:

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

3.0 Sequence of Events:

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

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

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

3.3 Brief details of the failed transformer are as follows:

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

4.0 Observations:

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

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

Exhibit-I

Exhibit-II

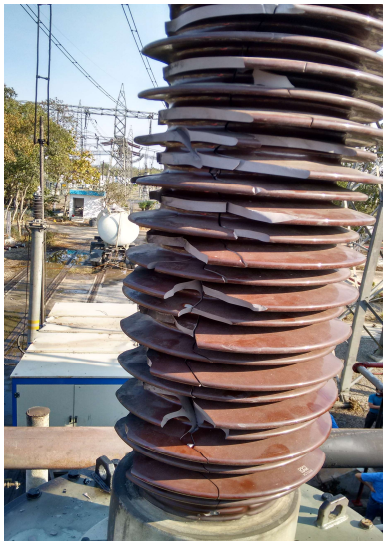

Exhibit-III

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

Exhibit-IV

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

Exhibit-V

Exhibit-VI

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

Exhibit-VII

Exhibit-VIII

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

Exhibit-IX

Exhibit-X

4.7 One of the tertiary bushings was removed in front of the CEA team and tank was inspected through that opening. No visible damage to tertiary terminals was observed.

4.8 Tertiary of transformer is unloaded. All three terminals of tertiary winding have been brought outside the tank and terminals were not insulated.

4.9 The event logger data indicates that the fault current level was 44.827 kA. 400 kV side main breaker and tie breaker had opened within 53 ms and 57 ms respectively of operation of differential relay.

4.10 The event logger data also indicates operation of Differential relay and PRV/Buchholz which might have led to operation of Nitrogen Injection Fire Protection System.

4.11 It was informed by DTL representative that High Velocity Water Spray (HVWS) System had operated, however, it could not quench the fire of bushings. It appears that water mist from water spray system could not provide sufficient cooling effect around transformer tank & bushings due to wind and thus HVWS system was not able to extinguish fire.

4.12 It was informed by DTL that surge counter of 220 kV R-phase surge arrester was not functional and it was bypassed through a cable.

4.13 Common earthing pit was provided for all three SAs (R,Y&B phases) on 220 kV side. Earthing electrode was not visible in any of the earth pits for transformer neutral and SAs on 400 kV & 220 kV side.

4.14 It was observed that the high resistive gravels spread over the earthmat in the switchyard area was covered with grasses in many areas of the switchyard defeating the very purpose of spreading of gravels.

Exhibit-X

5.0 O &M History of failed transformer:

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

6.0 Probable cause of failure:

6.1 The bushings were dislocated from its original position and damage to the transformer due to fire was so severe that it was not possible to carry out any test on failed transformer.

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

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

6.4 It was informed by DTL staff that at first fire was noticed on Y-phase MV bushing only and later on it spread to other accessories and equipment. It is possible that damage to insulation of Y-phase MV winding might have taken place. This is also supported by event logger data showing 44 kA fault current in Y-phase. The detailed investigation, after opening of tank, will provide the extent of damage, type of failure(s) and other valuable information.

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

7.0 General Remarks and Recommendations:

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

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

7.3 In addition to PRV which operates when static pressure inside the transformer tank crosses a pre-set pressure limit, use of Fast Depressurization System which works on first dynamic peak of pressure and is very fast should be explored for future orders of transformers.

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

7.5 Separate earthing pits should be used for earthing of individual Surge Arresters.

7.6 Switchyard area should be properly maintained to prevent growth of grass so that benefit of spreading of the gravel is realised and safety of personnel is not compromised.

7.7 DR & event logger information may be used for co-relating the sequence of events and operation of protection relays of transformer.

7.8 After opening of the transformer tank, detail inspection of the transformer is required to be carried out by OEM/ expert of repairing agency which may not be possible at site. The feedback/ learnings from the investigation should be used for planning future

course of action. The detailed findings of the failed transformer may be provided to CEA after completion of thorough internal inspection of the failed transformer.

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