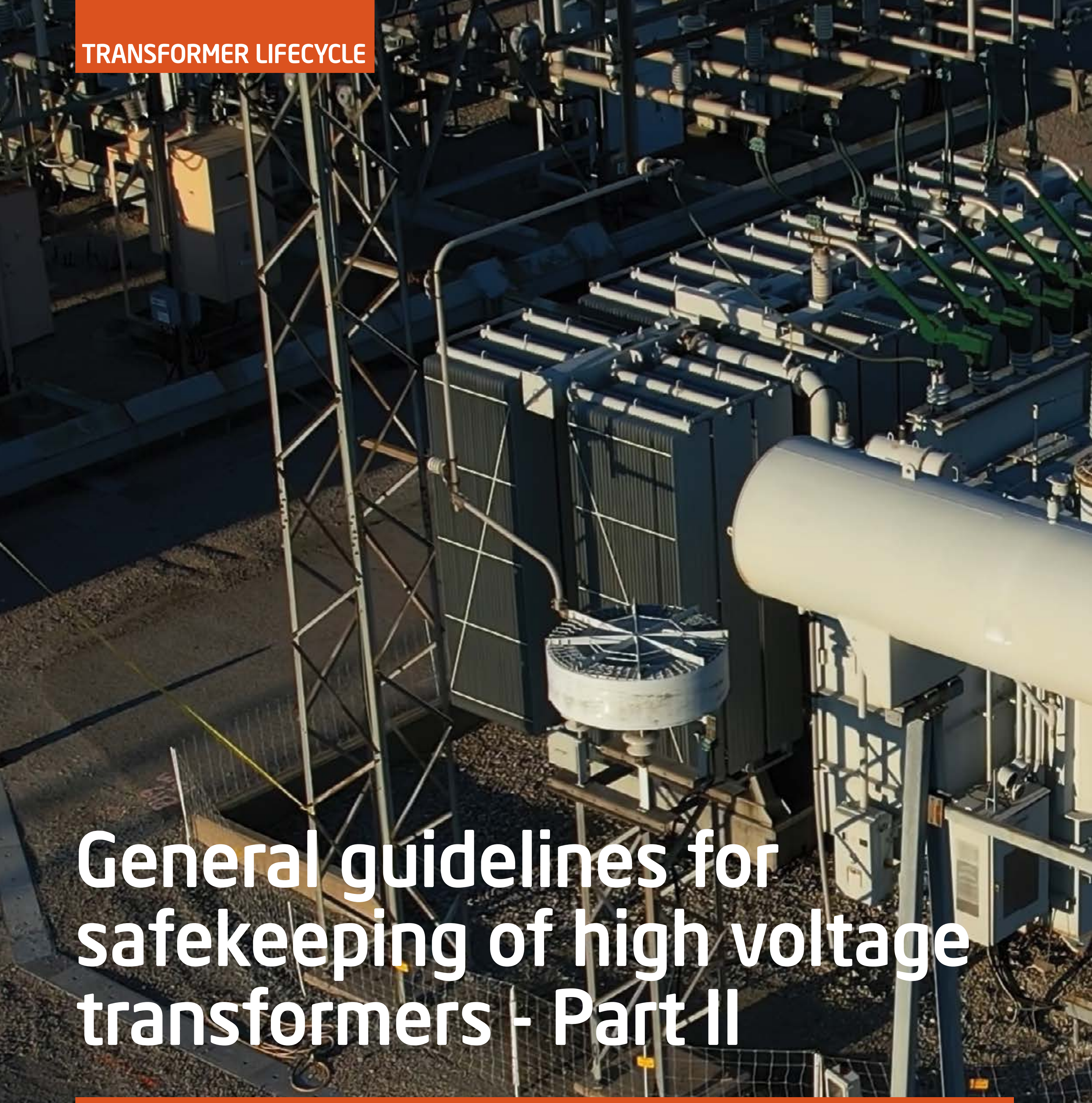

# General guidelines for safekeeping of high voltage transformers - Part II


## ABSTRACT

Transformers such as HV/EHV (132 kV and above) are the most vital and costly equipment in power systems and large Industries. It is the prime duty of HV/EHV substation managers, asset managers, and substation Operation & Maintenance (O&M) engineers to look after transformers, beginning from receipt on-site through their lifecycle scrupulously with motherly feelings.

Generally, OEM (Original Equipment Manufacturer) guidelines must be followed. This article is a significant and important contribution of experienced engineers in O&M and testing and commissioning up to 400 kV in HV/EHV substations. The authors deliberate all the aspects from receiving the consignment of an EHV Transformer on-site through its lifecycle, including O&M and life expectancy enhancement.

This article serves as a guideline for substation managers, asset managers, and substation engineers in the absence of any guidelines issued by their utilities or in the industry.



## KEYWORDS:

$N_2$ (nitrogen gas), SFRA (Sweep Frequency Response Analysis), FAT (Factory Acceptance Test), TCIV (Transformer Conservator Isolation Valve), OEM (Original Equipment Manufacturer), DGA (Dissolved Gas Analysis), FDS (Frequency Domain Spectroscopy), furan analysis

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**Bushings should be thoroughly checked for cracks and oil leakage since even a hairline thin crack over the condenser portion of the bushing renders the bushing useless**

**Since the bushings of transformers and reactors rated 400 kV and up are physically long, utmost care should be taken when lowering the bushings into the tank through the turrets**

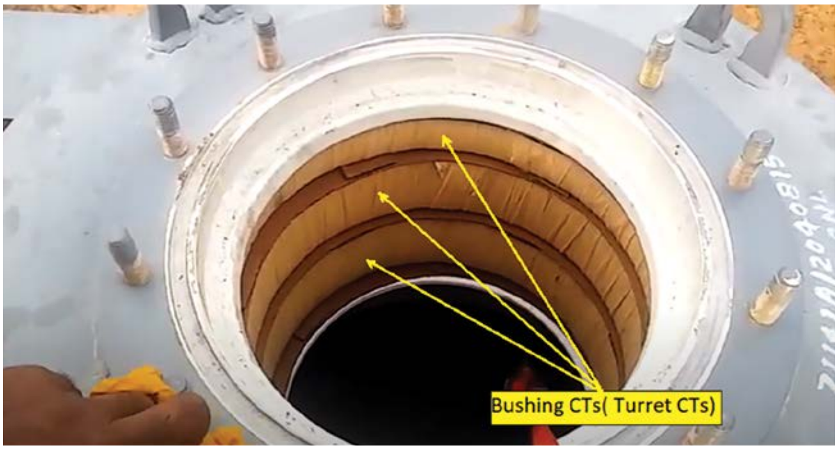


Figure 5A. Bushing CTs (Turret CTs)


Figure 5B. Hydra Long-boom crane

## 5. Erection of bushings

### 5.1 Before erection of bushings

i. Tally and confirm the number of bushings from the FAT.
ii. Bushings should be thoroughly checked for cracks and oil leakage. Even a hairline thin crack over the condenser portion of the bushing renders the bushing useless. Therefore, proper handling of bushing should be ensured.
iii. In this era, bushings are hermetically sealed. Leaky bushings should not be used as the leak is a source of moisture ingression.
iv. Before installation of the bushings, the bushing of (current transformers) CTs (turret CTs) should be tested for ratio, polarity, winding resistance, and knee point voltage using a test-kit CT analyzer conforming to IS:16227, part 2 / IEC 61869-2.

**Note:** Some OEMs dispatch turrets with BCTs fitted inside with blanking plates on either side of the turrets. In such case, remove the blanking plates


Figure 6. Lowering a 420 kV bushing by means of two Hydra long-boom cranes

and test the BCTs as described above. Also, test for the IR value of the secondary winding terminals to earth (turret body), before fitting the turrets on the ear-marked locations of the transformer body.

i. IR value of the bushings should be taken before installation.
ii. Record tan-δ measurements if available.

**Note:** The quantities tan-δ and C should be measured after holding the bushing in an up-right position on a specially fabricated structure for 24 hrs.

### 5.2 Lowering down the bushings

i. Care should be taken when lowering bushings into the tank through the turrets. Such jobs are executed with a single long-boom crane. Use nylon ropes for handling bushings and for aligning a bushing's lower portion as per the angular deviation of the turrets. Care should be taken to prevent the bushing's lower portion from fouling the bushing CTs.
ii. Since the bushings of transformers and reactors rated 400 kV and up are physically long, utmost care should be taken when lowering the bushings into the tank through the turrets. It is recommended by OEMs to use two long-boom Hydra cranes to execute such precision jobs.

**Note:** (a) As seen in Figure 6, two long-boom cranes are used. One crane lifts the bushing. The other crane is dedicated to carrying a beltman with the assigned job of lowering down and pulling up the draw lead / draw-rod and fixing the bushing terminal; (b) while lowering the bushing, care must be taken to ensure that the bushing does not foul with the bushing CTs (turret CTs).

### 5.3 Procedure

a. Pull the lead up from the winding.
b. Lower down the draw-lead / draw-rod of the bushing (see Figures 7A and 7B). Couple the half-lap joint clamp of the lead from the winding with the half-lap joint clamp of the draw-lead / draw-rod of the bushing together and tighten them (Figure 7C). Insulate them with crepe paper tape and wrap cotton tape over the same. In the case of draw-lead,

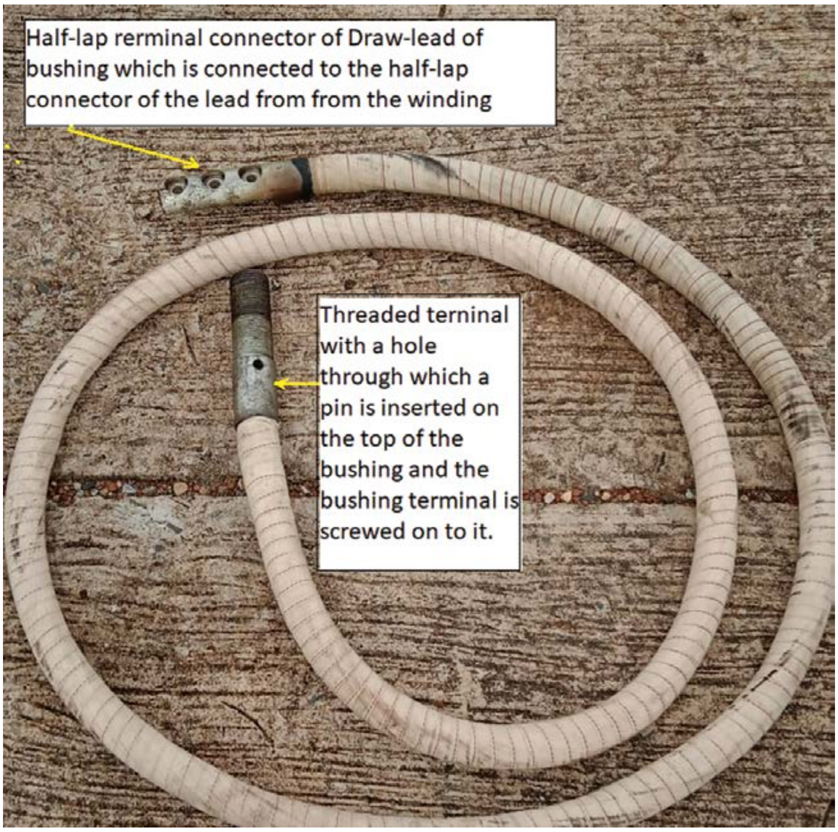


Figure 7A. Draw-lead of the draw-lead type bushing

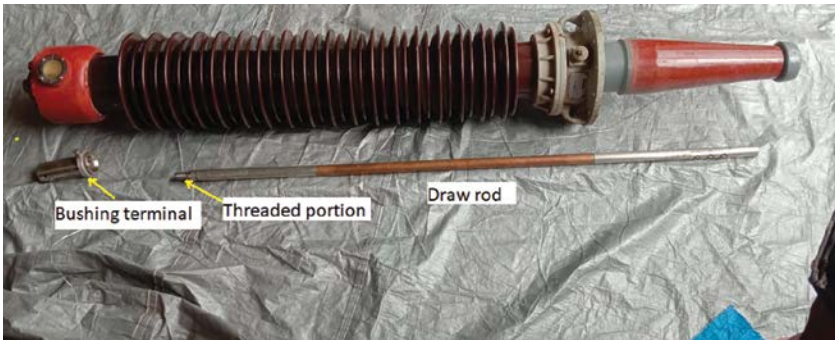


Figure 7B. Draw-rod type bushing

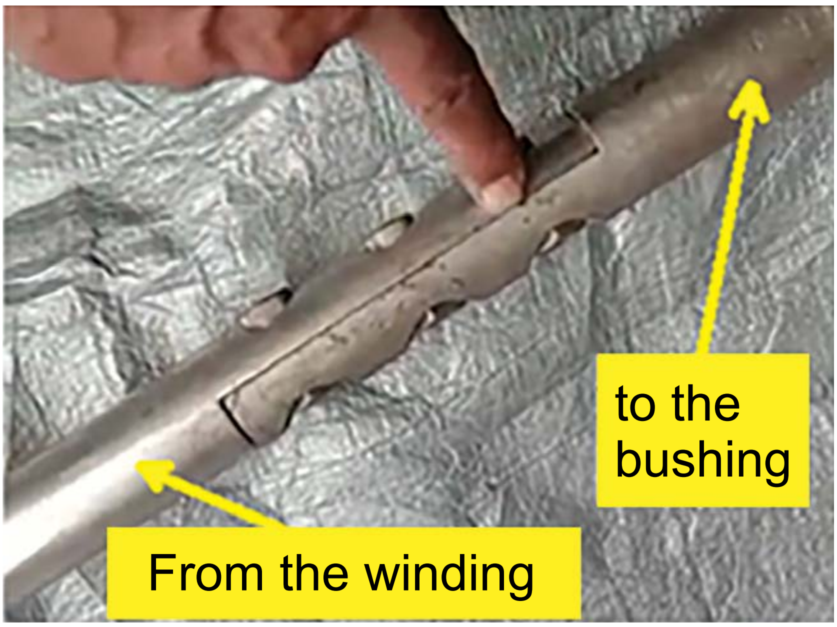


Figure 7C. The joint between the draw-rod of the bushing and the winding lead

**After the bushings are installed on the turrets, ensure that the tan-δ measuring test-tap cover provided on the bushings is properly fitted and the condenser is properly grounded on the tank cover of the transformer**

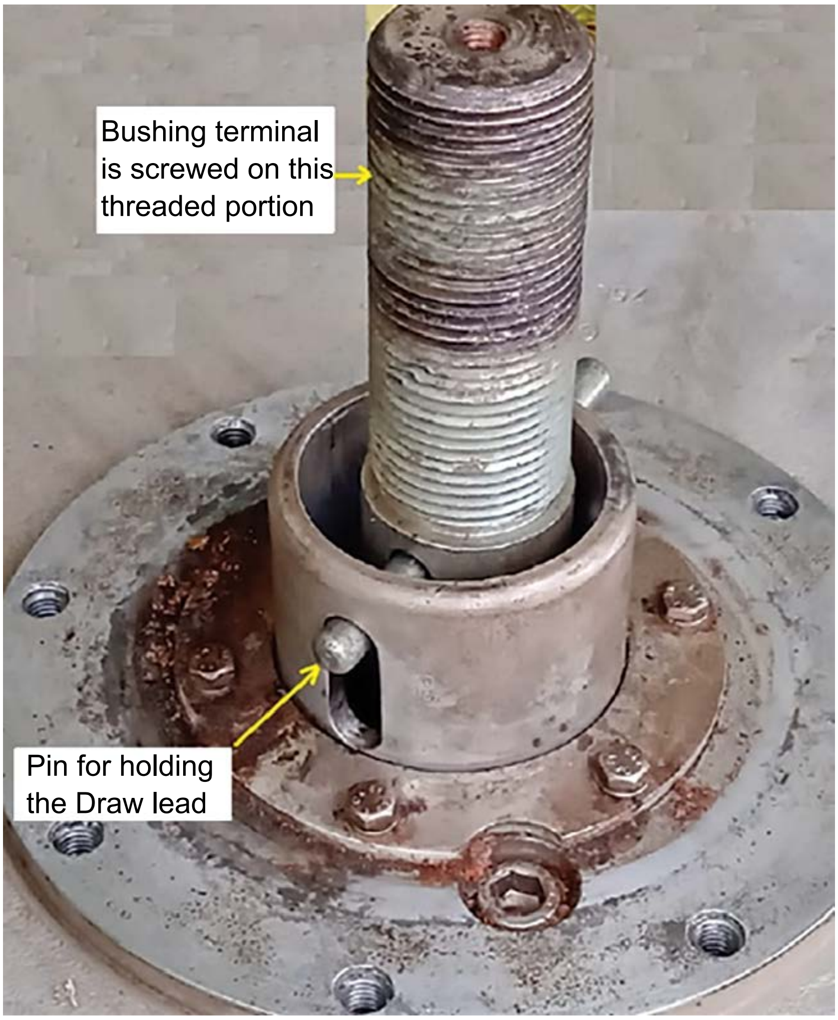


Figure 7D. Illustration of how to insert a pin through the draw lead


Figure 7E. Display of a bushing terminal

care should be taken so that the lead is not twisted. Otherwise, the lead will fall short.

c. Pull the draw-lead/draw-rod up and tighten the top terminal of the bushing.

   a) Pull the bushing up and hold it in position by inserting a pin through the draw lead (Figure 7D).
   b) Pull the draw-rod type bushing up and screw the bushing terminal over it.

d. After the bushings are installed on the turrets, ensure that the tan-δ measuring test-tap cover provided on the bushings is properly fitted and the condenser is properly grounded on the tank cover of the transformer.

## 6. Erection of radiators, thermo-siphon, PRV and pipelines from main tank to conservator, including Buchholz relay

### 6.1 Erection of NIFPS fire protection system and Buchholz relay

In case the transformer is equipped with NIFPS (Nitrogen Injection Fire Protection System):

a) Preparation of the oil sump, supply of equipment, installation, and commissioning are in the scope of the OEM of NIFPS.
b) The following components are to be fitted sequentially when assembling the pipe from the conservator to the main tank:
   (i) Buchholz relay

**Note:** (a) Arrow embossed on Buchholz relay must point towards the conservator. (b) The "Test & Service Switch" should be locked in the service position properly; otherwise, it could shift to the test position due to vibration, and the transformer will trip.

   (ii) TCIV (Transformer Conservator Isolation Valve) (Figure 8A)
   (iii) steel bellow pipe

Figure 8A. Showing a Buchholz relay (with acrylic cover to protect against rainfall) and TCIV (Transformer Conservator Isolation Valve)

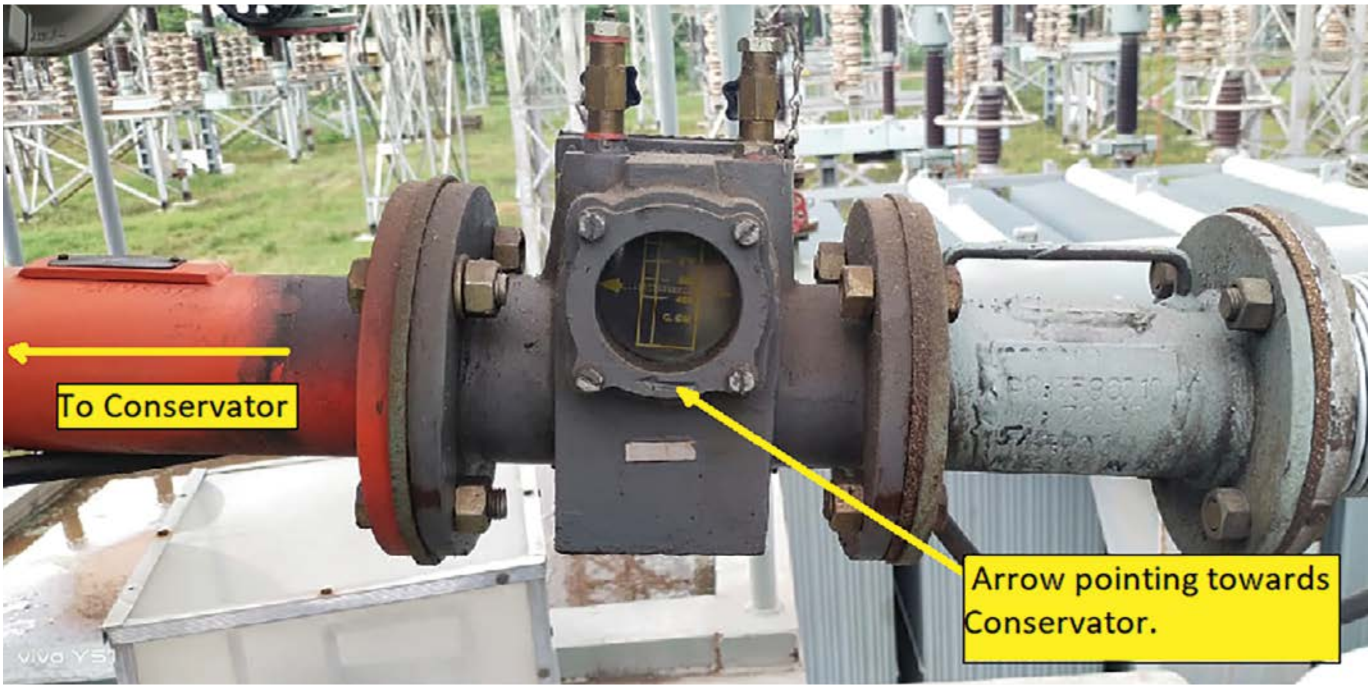

Figure 8B. Buchholz relay

**If the temperature exceeds the set value, the automatic MulsiFyre system sprays water at high pressure on the surface of the transformer to control the fire of burning spilt oil**

Figure 9. Automatic MulsiFyre system

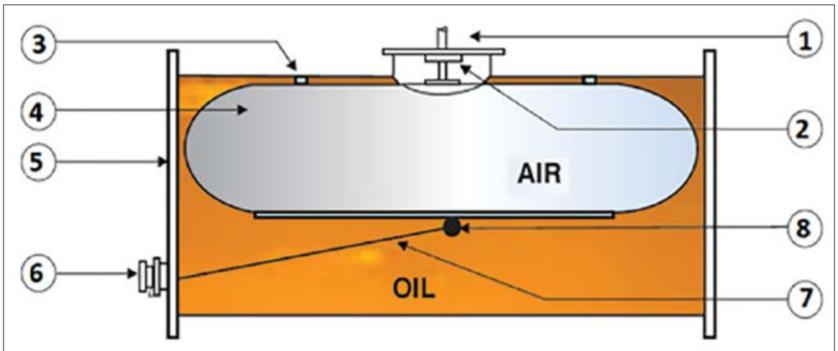


Figure 10A. The main component of the conservator is an air cell

### 6.2 Fire protection system option – automatic MulsiFyre system [2]

The MulsiFyre system is widely used for firefighting outdoor transformer fires. Fire detectors located at various strategic points sense high temperatures near the transformer. If the temperature exceeds the set value, the automatic MulsiFyre system sprays water at high pressure on the surface of the transformer to control the fire of burning spilt oil.

Primary components:

a. Main hydrant: carries water as the fire extinguisher.
b. Fire detectors are generally thermocouples.
c. Ring mains and nozzles: ring mains surround the transformer and feed water at high pressure to nozzles at different levels.
d. Pumps: feed water to the main hydrant.

**Note:** The supply of equipment, erection, and maintenance are generally the responsibility of OEMs.

### 6.3 Conservator erection

a. Before erecting the conservator, check for leakage of the air cell (Fig 10B).

**Note:** (i) $N_2$-filled conservator: this system has an $N_2$ gas replenishment attachment which continuously maintains $N_2$ pressure above the oil; (ii) air cell system.

b. Install the air-cell according to instructions from the OEM. The procedure is described in sub-chapters 6.4.1 and 6.4.2.

#### 6.3.1 Installation of air cell

**Steps to be taken chronologically**:

a. Insert the air cell into the conservator through the open end.

b. Suspend the air cell from the hooks (2) in the ceiling of the conservator using loops.
c. Close the open end of the conservator.
d. Fill the air cell to a pressure of 10 kPa (0.1 bar). Close the filling valve (3) while leaving the system pressurized. A relief hole (4) must be placed on the oil-filled side of the conservator so that the air cell may expand freely.
e. The air cell will gradually stabilize. After six hours, adjust the air pressure again to 10 kPa (0.1 bar). After 24 hours, check the pressure reading again. If the pressure has not dropped significantly, it passes the test. Temperature should be as stable as possible during the leakage testing period.

### 6.3.2 Filling the conservator

Sequential steps**:**

a. Before filling the oil, turn the TCIV to filtration mode.
b. The pressure of air in the air cell should be 10 kPa (0.1 bar). If not, then increase pressure to the correct level and close the air-fill valve.
c. Confirm that air vent valves (4) are open at both ends of the conservator.
d. Open valve (6) between the conservator and transformer tank. Pump in more oil so that the oil rises to the conservator. Limit pump speed so that pressure within the air cell does not exceed 13 kPa (0.13 bar). Stop pumping when oil comes out of the vent valves and close the vent screws.
e. Regulate air cell pressure by opening the plug in the flange or air fill valve from which the pressure hose was removed.
f. Reopen valve (6) between the conservator and the transformer tank. Continue to fill with oil until the oil level indicator gives the correct reading according to the temperature of the transformer.

**Note**: Instructions for inflating the air cell and filling oil are generally affixed to the transformer body by OEMs.

### 6.3.3 Magnetic oil level gauge (MOG)

A float senses the oil level inside the conservator tank. This information is transmitted to a switch mechanism by means of magnetic coupling. The float and the magnetic mechanism are sealed. The pointer connected to the magnetic

**Before putting the breather into service, silica gel granules are filled in from the top and blanked with a plug**

Figure 10B. Air-cell

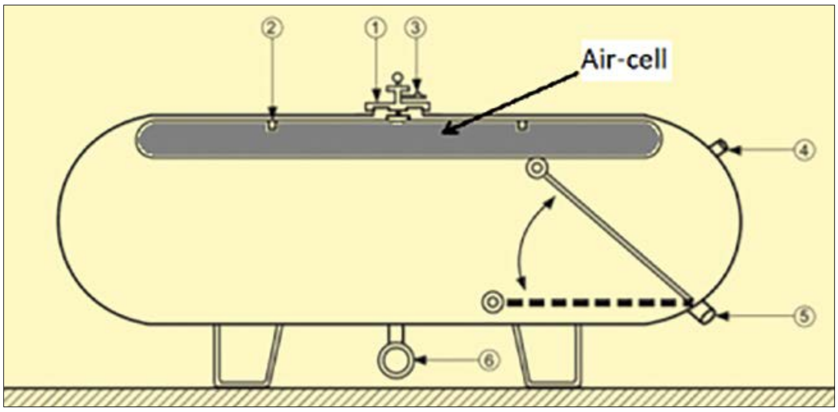


Figure10C. Installation of an air cell

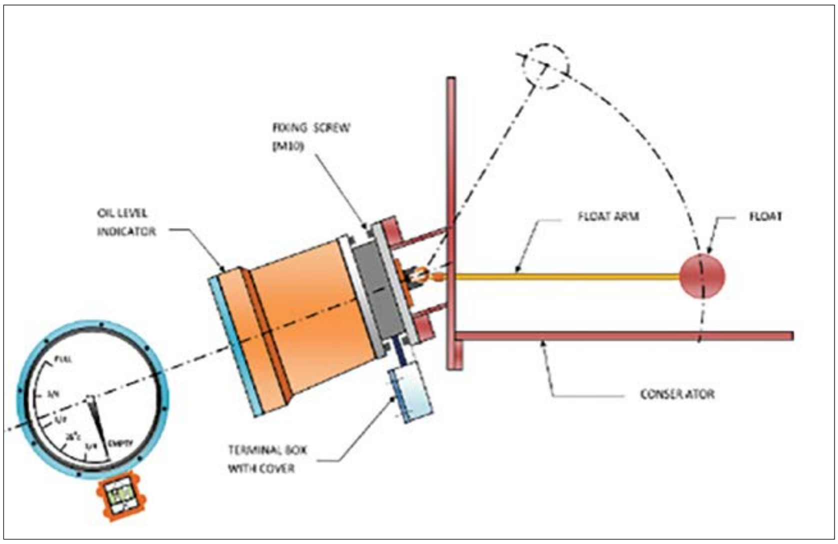


Figure 10D: Conceptual figure of MOG.

Figure 11A. Silica gel breather


Figure 11B. Twin-silica gel breather in service

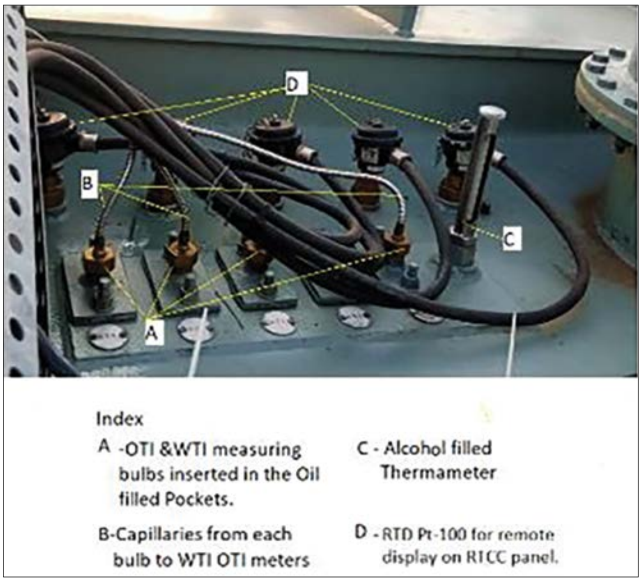


Figure 12A. WTI and OTI bulbs and RTD Pt-100 units are shown in the respective pockets on the top of the transformer

Figure 12 B. WTI meters

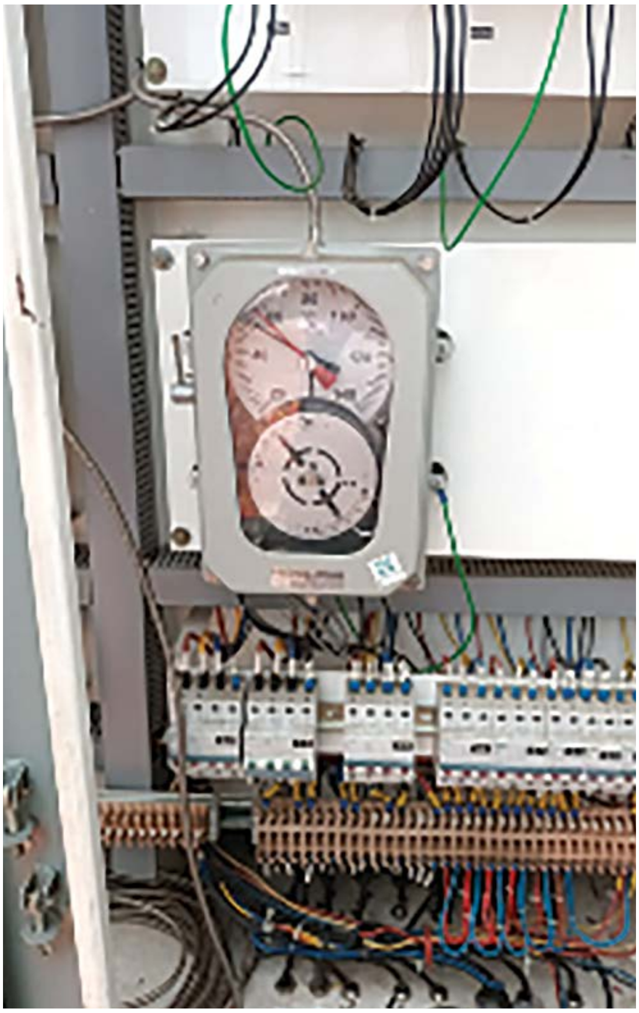

Figure 12C. OTI meter

**Steel capillary tubes are normally quite flexible, but they should not be bent sharply, and they should be supported with clips to prevent sagging**

mechanism indicates the correct oil level. It should be ensured that the oil level is indicated by the MOG dial at 35 °C. A micro-switch signals an alarm when the oil level is low.

## 6.4 Erection of breather

Assemble a pipeline from the conservator to the breather mount (Figures 11A and 11B). The breather is connected to the transformer by either a threaded or flanged joint (after removing the seal). Before putting the breather into service, silica gel granules are filled in from the top and blanked with a plug. Silica gel is blue when dry and pink when moist. Remove the oil cup and fill it with fresh transformer oil up to the line marked on the cup. Remove the seals on the air holes of the cup and fit the cup to the breather.

## 6.6 Installation of OTI and WTI system

Thermometer bulbs at the end of capillary pipes and RTD Pt-100 sensor units (Figure 12 A) are inserted in earmarked pockets (filled with transformer oil) on the top of the transformer for OTI and WTI. Both oil temperature and winding temperature meters (Figures 12B and 12C) are provided with maximum pointers and mercury switches. Precaution: steel capillary tubes are normally quite flexible, but they should not be bent sharply. They should be supported with clips to prevent sagging. Temperature measured through RTD Pt-100 is compensated with WTI CT current in the CCU (Figure 12D), and its output is displayed remotely (Figure 12E).

## 6.7 Cooling system

### 6.7.1 Radiators

The basic function of radiators is to improve transformer cooling. Thus, they play a vital role in increasing transformer load capacity. The working principle of radiators is very simple: they increase surface area for dissipating heat from oil.

### 6.7.2 Cleaning and checking

i. Radiators must be cleaned externally. They are also required to be cleaned internally by flashing with transformer-insulating oil.
ii. Before internal cleaning, it is necessary to check for radiator leakage: one side of the radiator is blanked with a blanking plate fitted with a pressure gauge, and the other side is fitted with an NRV. Air is injected through the NRV with a

**The basic function of radiators is to improve transformer cooling, and they play a vital role in increasing transformer load capacity**

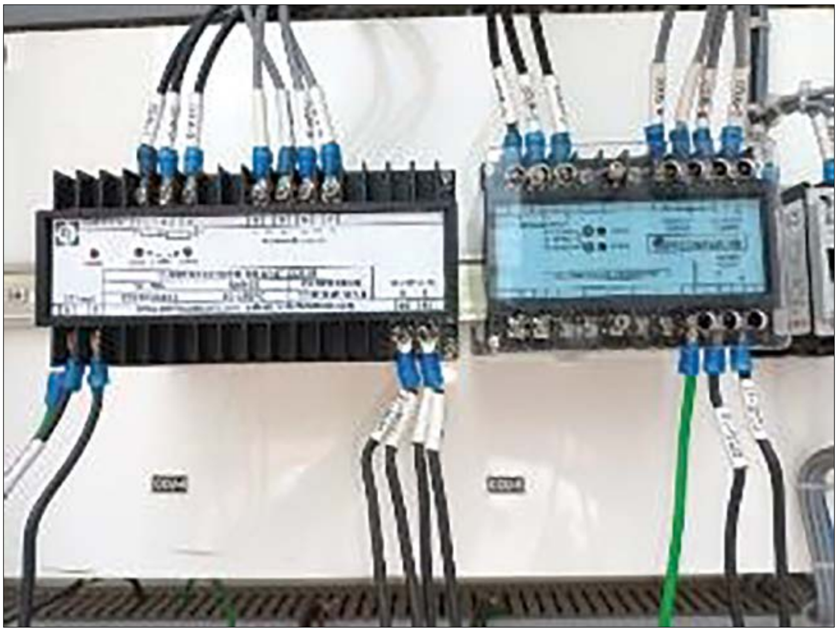

Figure 12D. Winding current compensation unit (CCU)

Figure 12E. Remote display meters of WTI and OTI on RTCC pane


Figure 13A. Body mounted radiators

Figure 13B. Externally mounted radiators

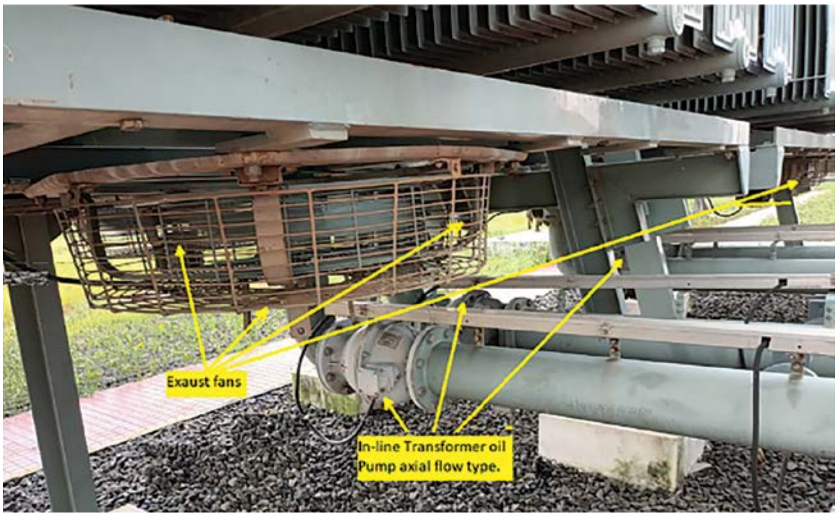


Figure 13C. Exhaust fans and inline axial flow oil pumps/motor

**Radiators may be mounted on separate frames for large transformers and flanges are provided on these headers for fixing the radiators**

pump or compressor up to a pressure of 0.2 kg/cm2 for 2 to 3 hours. Reduce the pressure if air leaks.

iii. Repair leakage if necessary and check again.

iv. The valve blanking plate is to be removed only when the radiator is ready to mount on flanges.

#### 6.7.3 Procedure for erection of radiators

i. Lift the radiator vertically. Bring the radiator near to the valve. Remove the blanking plates from the valve. Slide the radiator on the bolt from the pipe flange for the radiator valve and tighten using plain washers, spring washers, and nuts. Tighten nuts in sequence, applying uniform pressure on the gasket to make a proper leakproof fitting. Assemble all radiators in the same manner.

ii. Radiators must be clamped properly at the ends to minimize vibration.

iii. Fill transformer oil through the main conservator. It is recommended to use hot filtered oil directly from a filter.

iv. Fill only one radiator at a time. Open the bottom valve. Slowly unscrew the air release plug on the top of the radiators until air starts inflowing. Oil from the main tank will now flow into the radiator. Start adding fresh oil to the conservator.

v. After filling, open the valve at the top to equalize with the main tank.

vi. Fill the remaining radiators in the same manner.

vii. After filling oil in radiators and venting air from the top radiator, valves at the top and bottom must be kept in the OPEN position and sealed.

#### 6.7.4 Separately mounted radiators

Radiators may be mounted on separate frames for large transformers. Flanges are provided on these headers for fixing the radiators.

### 6.7.5 Specification of motors and fans

i. Cooling fans and oil pump motors (Figure 13C) are suitable for operation with 415 V, three-phase 50 Hz power. They shall be of premium efficiency class IE 3, conforming to IS:12615/ IEC 60034-1.
ii. Each cooling fan and oil pump motor shall be provided with a starter, thermal overload, and short circuit protection.
iii. Motor winding insulation shall be the conventional class 'B' or better. Motors shall have hose-proof enclosure equivalent to IP55 as per IS: IEC 60034-5.
iv. Temperature rise of the motor shall be limited to 70 °C above an ambient of 40 °C and shall comply with IS:12615/ IEC 60034-1.

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**J. J. L. Kapil** is a retired Assistant Engineer, 220 kV S/S, Jabalpur in June 2017. Holds a Diploma in Electrical Engineering. Among his commendations, MD, MP Power Transmission Co. Ltd. has felicitated Mr. Kapil in recognition of his hard and sincere work and for preventing many incidences. He was responsible for the upkeep of 3x40 MVA 220/132/33 kV Mitsubishi transformer bank (1-Ph. units), which are still in service after 53 years.

**Santosh Dubey** holds a Diploma in Electrical Engineering. Currently retired, he was the Assistant Engineer of 220 kV Substation at Nayagaon and at Sukha, Jabalpur, a prestigious EHV substation in the State of Madhya Pradesh. He looks after Operation & Maintenance and Erection of EHV equipment very efficiently and successfully. Down time of any equipment is minimal due to his sincerity, devotion and relentless efforts. He is an asset to the M.P. Power Transmission Co. Ltd. Jabalpur (India). He has been felicitated and awarded for his exemplary work by the M.D., M.P. Power Transmission Co. Ltd. Jabalpur. Due to his strict execution and monitoring of their maintenance practice, a 55 year-old 3x40 MVA, 220/132/33 kV transformer is still in service. He obtained the ISO-9001-2015 certificate for 220 kV S/S Nayagaon, Jabalpur which is 55 years old. He also removed and cleaned debris of bursted 72.5 kV bushing from the body of a 132/33 kV, 63 MVA Transformer and re-energised it in minimal time by replacing the failed bushing at 132 kV substation at Mansakara.

**S. K. Chaturvedi** holds a diploma in Electrical Engineering. He presently works as Assistant Engineer (maintenance) 400 kV S/s Katni, since October 2013 in a 950 MVA, 400/220/132 kV /33 kV AIS he is managing the maintenance and erection / installation jobs independently and successfully of EHV equipment up to 400 kV level. He was felicitated by MD MPPTCL for on spot repairing and installation of EMR make diverter switch on a 24-year-old 160 MVA, 220/132 kV TELK make transformer at 400 kV S/s Katni. He successfully assembled a 400 kV, 125 MVAR bus reactor and all associated equipment for the bay at 400 kV S/s Katni, within minimal time. He obtained ISO 9001-2008 certificate in 2015, for 50-year-old 132/33 kV AIS Kymore, for complete renovation. He successfully performed retrofitting and replacement of 220 kV, 132 kV, 33 kV, 22 old pneumatic circuit breakers / VCBs within minimal time and reconditioning of two 40-year-old 132/33 kV transformers.


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