INSTRUCTION, OPERATION AND MAINTENANCE MANUAL

DISTRIBUTION TRANSFORMER

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ANNEXURE

PREFACE

PEL Transformers are designed, manufactured and tested with care. With proper attention during installation and use, the user should receive from it the maximum expected service. Before installing the transformer, read this manual carefully. This manual has been prepared to provide information on assembly, installation, commissioning and regular maintenance of the transformers and shall form part of Instruction Manual.

This manual does not intend to cover operation and maintenance of the transformer under abnormal conditions.

Should further information be needed or any problem arises which is not covered by these instructions, please refer to the HV Transformer Division of Pak Elektron Limited (PEL) for further information.

During operating of the transformer, care should be taken that loading limits, as specified by the nameplate data, are strictly followed.

INTRODUCTION

Thank you for purchasing our transformer. This unit was manufactured using the most modern techniques available and has been fully tested in our Quality Control Division before it left the factory. It is possible, however, that during shipping, installation or operation the transformer could be damaged through improper handling or other unimpeded events. Thus, it is crucial that you read this manual carefully.

This instruction manual covers a brief description about the installation, energization, commissioning, operation, routine/preventive maintenance and precautionary activities for the oil immersed distribution transformer. In addition to that following useful data is also included to help the customer to operate the transformer trouble free.

- Purpose and functionality of the accessories explained with the help of pictures.
- Failure report form is included to help the customer to explain its problem to the manufacturer in detail, in case of a fault arises in the transformer.
- Routine and Preventive maintenance chart is available in the manual for performing the maintenance activities at the customer end.
- For on site trouble shooting a trouble-shooting chart is also included to help the customer to rectify the problems, which can easily be handled at the site.
- In addition to this guide, the manufacturer should be consulted for specific recommendations on special conditions.

General

This manual describes general operation / maintenance of 3-phase two winding oil immersed distribution transformers manufactured according to IEC / BS standards. Technical parameters of transformers are stated on the rating plate and in the factory routine test report.

Safety Instructions

All personnel involved in installation, commissioning, operation, maintenance or repair of the equipment must be suitably qualified and strictly observe these operating instructions. Improper operation or misuse can lead to reduction in the efficiency of the equipment, damage to equipment and property of the user, serious or fatal injury.

Safety instructions in this manual are presented in three different forms to emphasize important information.

WARNING!

This information indicates particular danger to life and health. Disregarding such a warning can lead to serious or fatal injury.

CAUTION!

This information indicates particular danger to the equipment or other property of the user. Serious or fatal injury cannot be excluded.

NOTE!

These notes give important information on a certain topic.

A safety checklist is incorporated in Annexure C, for the ready reference, and to be thoroughly implemented during installation and commissioning and before first energization.

NOTE!

The local management shall inform the labor, responsible for the operation of the transformer, about any hazards, which could affect the health and safety requirements.

Construction

The transformer is composed of core, coils, oil, tank, bushings, nameplate, tap changer & other accessories as required by the customer. Details are mentioned in the dimension drawings, provided with the transformer.

Tap Changer

Tapping switch mounted on tank cover or sidewall is used to adjust the voltages. Before changing the tapping switch (tap changer) ensure that transformer is completely isolated (denergized) from high & low voltage sides in case of off-load tap changer. In case of On-Load, tap changer (OLTC) the tapping can be adjusted with the transformers energized. For details, please refer to OLTC operation manual. For tap changer adjustment according to desired voltage, please refer nameplate of the transformer.

WARNING!

The transformer is fitted with off-load tap-changer. Be very sure to de-energize the transformer before step changing.

NOTE!

The tap changer must be operated to all its tappings once a year to ensure proper operation and safety.

Transportation & Lifting

Take special care in transportation, tie the transformer with proper rope in a place specified by the manufacturer, and maintain clearance between two transformers transported on one vehicle. During transportation, the road condition must also be taken into consideration & during transportation slope of the transformers should not be over 15°. Never try to lift the transformer other than the correct fittings (lifting lugs) provided for this purpose. The transformer is designed for road as well as railway transportation. It can be transported by means of trailer of adequate load carrying capacity. Main components have to be dismounted in order to decrease the size and weight of the transformer body.

WARNING!

Never stay under the lifted transformer or any of its parts.

NOTE!

All information can be found on the Outline drawing for transportation.

Check & Acceptance at purchasers' premises

After receiving the transformer verify immediately that the transformers is in conformity with the order contract & according to delivery documents. Also, check any external damages & position of the accessories. Any abnormality must be reported immediately to PEL or its authorized representative.

CAUTION!

Upon arrival of the transformer at the purchasers' premises, please make sure all the sealing points are intact and the product is free from any damage

Guarantee/Warranty

CAUTION!

If any of the sealing, points of the transformer are found damaged / tempered, that might void the warranty of the transformer. Please do consult the manufacturer before undertaking such activity.

CAUTION!

During the guarantee period, draying, treatment of oil and all operations that involve transformer opening, must be carried out by skilled personnel of Pak Elektron Limited, otherwise the guarantee may void.

Installation and Commissioning

Location

Transformers, as is the case with most electrical equipment, generate a substantial amount of heat during operation. This heat must be removed in order to allow the transformer to maintain its designed maximum temperature limits, if a transformer is located outdoors the heat will be removed by natural convection cooling unless the radiator airflow is restricted by surrounding objects.

Indoor installations require adequate ventilation to remove the heat of transformer operation. Inlet ventilation openings should be as low as possible, and outlet ventilation openings as high as possible.

Average temperature over 24 hours must not exceed 30°C and the temperature of the room should not exceed 40°C. Care should also be taken to prevent restriction of air circulation. Adequate space must be maintained between transformers, or between transformers and nearby equipment or walls. Separation is especially important near the transformer radiators, with spacing equal to the radiator panel depth being recommended. During installation, the following rules must be followed in order to ensure that the transformer operates correctly

a. The local regulations for installing liquid-filled transformer is buildings on a pole, in a cabinet or in the open air must be followed to the letter in relation to, among others, fire safety, protection against leaking (sump or oil-catchments tank), accessibility, electrical regulations.
b. The place where the transformer is set up must be adequately ventilated in order to enable dissipation of the heat given off by the transformer. We are at the disposal to do relevant calculations and to explain the precautions to be taken. For distribution transformer set up in buildings or steel sheet substations this means that there must be a regular supply of fresh air from outside, that there is adequate ventilation and enough free space above the transformer.
c. Oil sample plug, tap changer and any other operating and protection equipment must be easily accessible. Monitoring apparatus such as thermometers must be clearly visible and/or readable.
d. Setting up the transformer parallel with a wall is not advisable as this can increase the noise. Anti-vibration pads under the wheels can reduce the transfer of the noise vibrations to the ground.
e. The area in which the transformer is placed must be inaccessible to pets, birds, rodents

We once again remind you that lifting the transformer by taking it under the cooling fins is absolutely forbidden. This will create leaks

After installation & before putting into operation it is recommended to perform the following checks / tests on transformers.

- Visual Inspection
- Oil level checks
- Connections of Cables, Bus Bars or Overhead Conductors to Bushings
- Earthings
- Measurement of Insulation Resistance of the Windings (Megger Test)
- Measurement of Voltage (Turns) ratio
- Measurement of Winding Resistance
- Measurement of dielectric strength of oil
- Open Circuit Test & Short Circuit Test (If possible, to be performed)
- Functionality test and Physical check of all accessories, parts and components.

Spark Gaps of Arcing Horns

Adjust the spark gaps of the arcing horns (if available) to comply with the dimension drawing, the locally applicable regulations or the instructions of the customer. Please find below the maximum gap width.

Rated Voltage (kV)	Gap width (mm)
10	70
20	85-120
30	200
60	400
110	750
150	1000
220	1450

Energization

When a transformer is energized for the first time the tap changer position should be set at nominal voltage & transformer to be run at no-load condition for few hours, check for abnormal sound (noise) if any, if no abnormality is observed then gradually increase the load.

CAUTION!

We cannot accept any liability and cannot include any guarantees for damage to equipment, which is due to the improper operation of the transformer!

NOTE!

For any abnormality, please contact qualified service personal.

NOTE!

Repair & service of transformer is a highly skilled job and might cause damage / injury to man and equipment if not carried out by professionally skilled persons

Operation

The transformer is designed for the continuous operation at rated voltage and current assigned to each tapping position as specified in the data sheets in normal service conditions. Wave shape of the supply voltage has to be practically sinusoid, its frequency 50 Hz. The three phases has to be practically symmetrical.

Ambient conditions and temperature rise

Transformers are designed for normal operation in the following ambient conditions:

- The highest altitude for installation and operation of transformer is 1000m above sea level
- Air ambient temperature may not exceed value given in technical characteristics of transformer.

Under these conditions, guaranteed temperature rise (maximal temperature rise of oil and average temperature rise of windings) above the ambient temperature will not exceed values given in technical characteristics of transformer. If the ambient temperature exceeds value given in technical characteristics of the transformer it will endanger the life time of the transformer even if the transformer operate with rated load (IEC 354). In that case allowable temperature, rises need to be reduced to the some degree by means of reducing the transformer power.

Operation above the rated voltage

The permitted maximum continuous operation voltage is 105% of the rated voltage referring to the actual tap-position.

Operation above the rated current

The general limitations and effects of loading beyond the nameplate rating shall be considered as specified in the Loading Guide for Oil-immersed Transformers issued by IEC 60076-7.

Voltage Regulation

The voltage regulation of the transformer is realized by means of a hand-driven off-load tap changer installed in the tank. The off-load tap changer has the function to change the transformation ratio by adding the turns of the regulation winding to the turns of the high voltage winding while maintaining the load conditions of the transformer unchanged.

The hand wheel control complies with the step-by-step switching. After de-energizing the transformer, rotate the hand-wheel of the off-load tap-changer to the desired position. Then re-energize the transformer again.

Parallel Operation

Two or more transformer in case of parallel operation, each transformer has to be in equal voltage value and vector group.

The circuits of the auxiliaries (cooling, protections & CTs)

The circuits of auxiliaries and the terminal strips are shown in the Documentation. Description about the devices can be found in the coming chapters, the adjusting values are too described in detail.

Signals

Alarm and trip signals are given according to the control drawing.

NOTE!

Connect the trip signal of the devices to the transformer main circuit breaker or to the protection system!

Storage

If the intention is to keep the transformer in storage for some time, prior to its energization, then make sure storage is done properly. For this purpose, the main body of the transformer must be covered, to protect it from dust. When a transformer is received from the manufacturer, it should be preferably placed (stored) at its final installation place in order to minimize handling. All the parts that are not fitted should be unharmed, too. These are to be stored on wooden pillows in covered store protected against humidity. The components can be stored in transport packing provided it is considered in good condition. Check all parts of the transformer also for mechanical damages. If the transformer is out of operation for more than a month, the heater of the marshalling kiosk / terminal box must be connected and put in service in order to prevent condensed moisture inside the cabinet. If this is not possible, bags with at least 0.6 kg silicagel must be put into the cabinet.

Storage with oil

For longer storage period, it is highly recommended to fill the transformer with oil and the conservator is fitted. In the course of longer storage, check the transformer on monthly basis, whether the oil level is corresponding to the level relating to the ambient temperature.

CAUTION!

Make sure breathing mechanism (where applicable) is intact with the transformer with the help of temporary or permanent breather provided with the transformer.

Storage without oil

For shorter storage period, the transformer can be stored without oil but filled with nitrogen. Not more than four weeks, it can be stored without any special action. Only the pressure of the nitrogen must be will be checked and maintained effectively.

Accessories (purpose and functionality)

Buchholz Relay

Purpose:

Buchholz Relay is the main protection device of the transformer. It is used to detect, Gas formation in the transformer tank up to the level 200cm^{3,} (First Alarm and then tripping (if the gas formation is continued)), sudden flow of oil @ 1 m/s from tank body towards the conservator (normally internal flashovers are the causes of oil flow) causing direct tripping.

Functional Check:

Mostly all of the Buchholz relays are equipped with two Normally Open (NO) Contacts (see Figure 1). The functional test (continuity) of these contacts can be performed via a push button available on the relay (see figure 3).

- Half press of this button will change the state of Alarm contact from Normally open (NO) to Normally Close (NC)
- Full press of this button will change the state of Trip contact from Normally open (NO) to Normally Close (NC) too

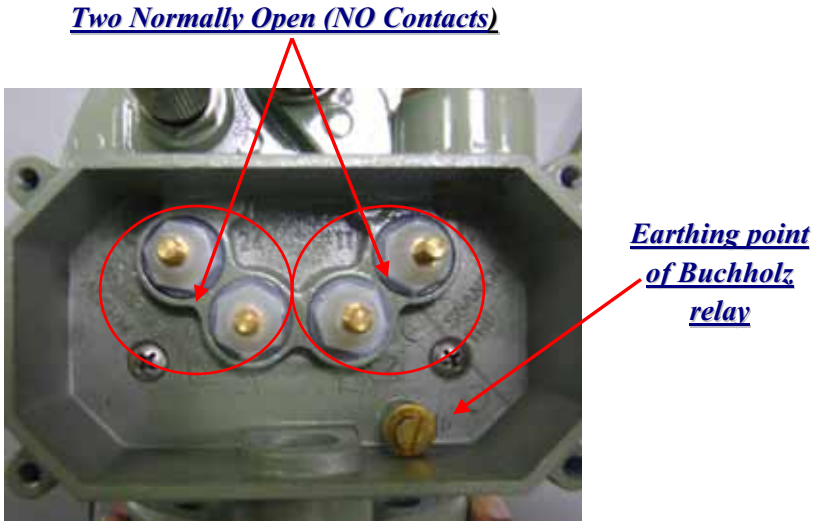


Figure 1 : Buchholz relays are equipped with two Normally Open (NO) Contacts

Before the energization of the transformer buchholz relay must be subjected to bleeding (removal of trapped air), possible via a bleeding point (see Figure 2)

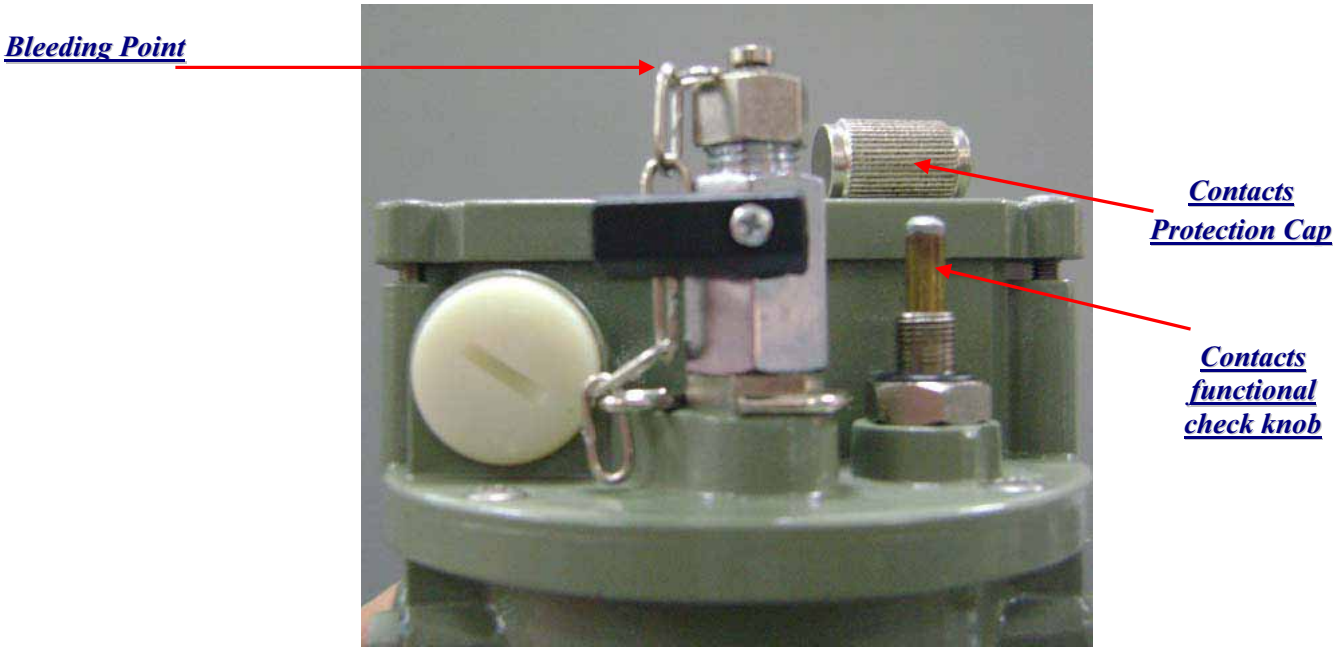


Figure 2 : Bleeding Point, Contacts Protection Cap & Contacts functional check point

Transportation and Protection of Contacts:

For the protection of contacts during transportation of the transformer, a red (or black) colored small rubber piece is provided in the cap over the functional test push button (see Figure 3). This rubber piece must be removed before energization of the transformer.

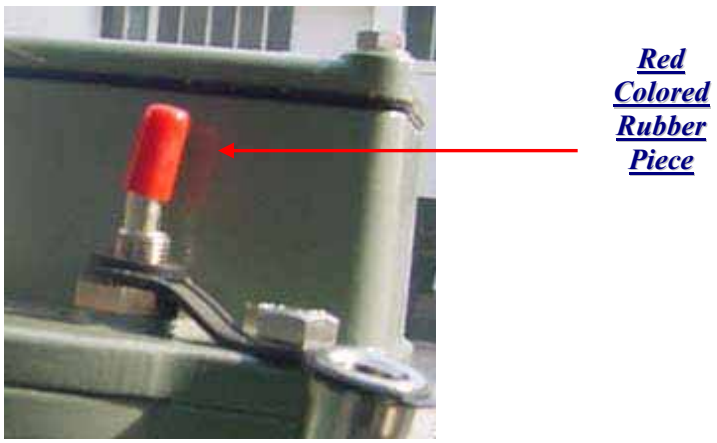


Figure 3 : Red colored rubber piece installed for the protection of contacts

Oil Temperature Indicator

Purpose:

Oil Temperature Indicator is used to monitor the top oil temperature of the transformer. Mostly all of the temperature indictors are located on the top plate. Usually three types of temperature indicators are used.

- Without contacts
- With 2 contacts (First Alarm and then tripping) (See Figure 5)
- With 4 contacts (First Fan OFF, Second Fan ON, Third Alarm & Fourth Trip)

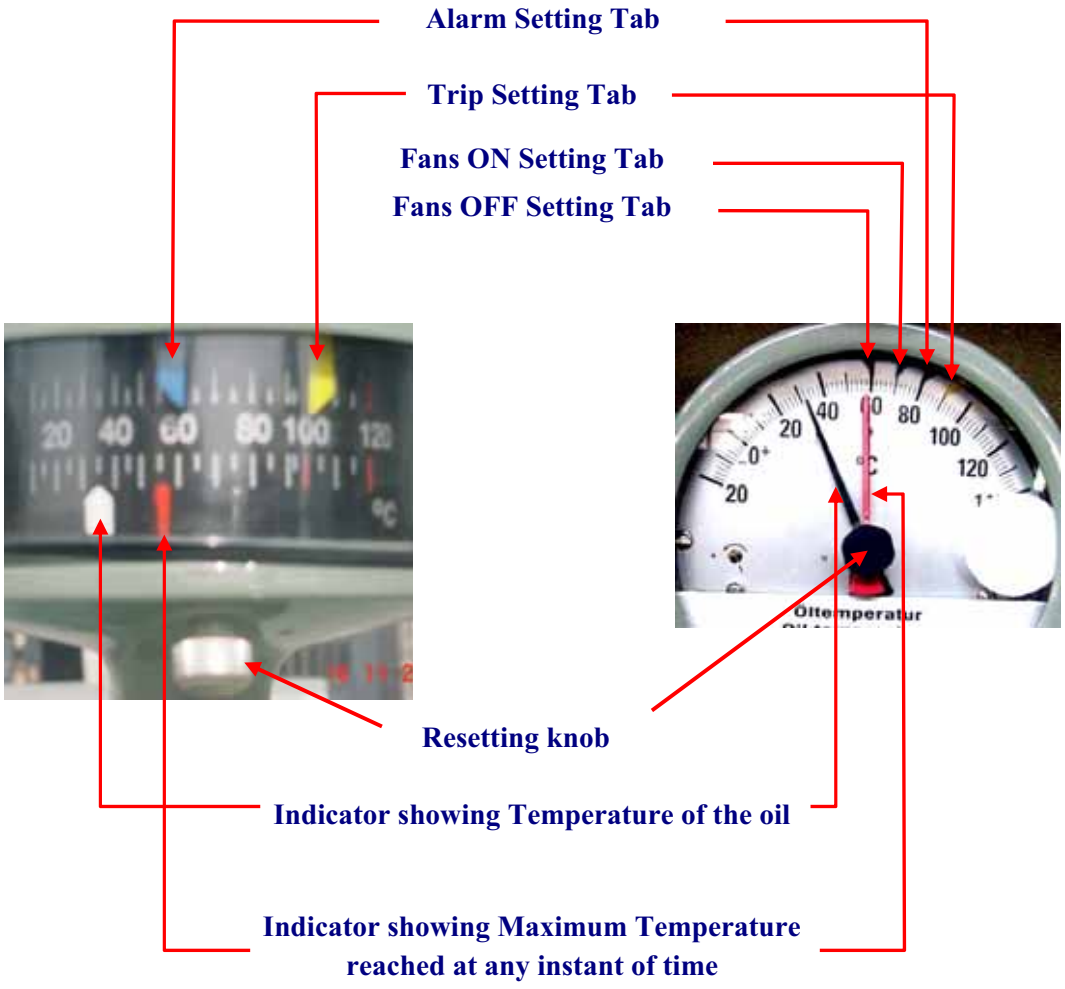


Figure 4 : Different types of Oil Temperature Indicators

Functional Check:

Temperature indicators can be checked for the proper functionality of their contacts (see Figure 4). Mostly all of the contacts are Normally Open (NO) contacts.

- Sliding the alarm tab below the oil temperature indicator will change the state of Alarm contact from Normally open (NO) to Normally Close (NC)
- Sliding the trip tab below the oil temperature indicator will change the state of Trip contact from Normally open (NO) to Normally Close (NC)
- For the settings of Alarm and Trip contacts please refer nameplate data.
- Settings of Fan OFF and Fan ON contacts are on customer's own will.

However typical settings are:

i. For Fans OFF 60 °C for hot areas and 70 ° C for cold areas

ii. For Fans ON 70 °C for hot areas and 80 ° C for cold areas

- The maximum temperature knob can be rest at any time via a knob available on the indicator (see Figure 4)

Example:

Ambient Temperature : 50 °C (From Name Plate)

Oil Temperature : 40 °C (From Name Plate)

i. Alarm Setting:

= Ambient Temperature (°C) + Oil Temperature (°C) - 10(°C)

= 50 + 40 – 10 = 80 (°C)

ii. Trip Setting:

= Ambient Temperature (°C) + Oil Temperature (°C)

= 50 + 40 = 90 (°C)

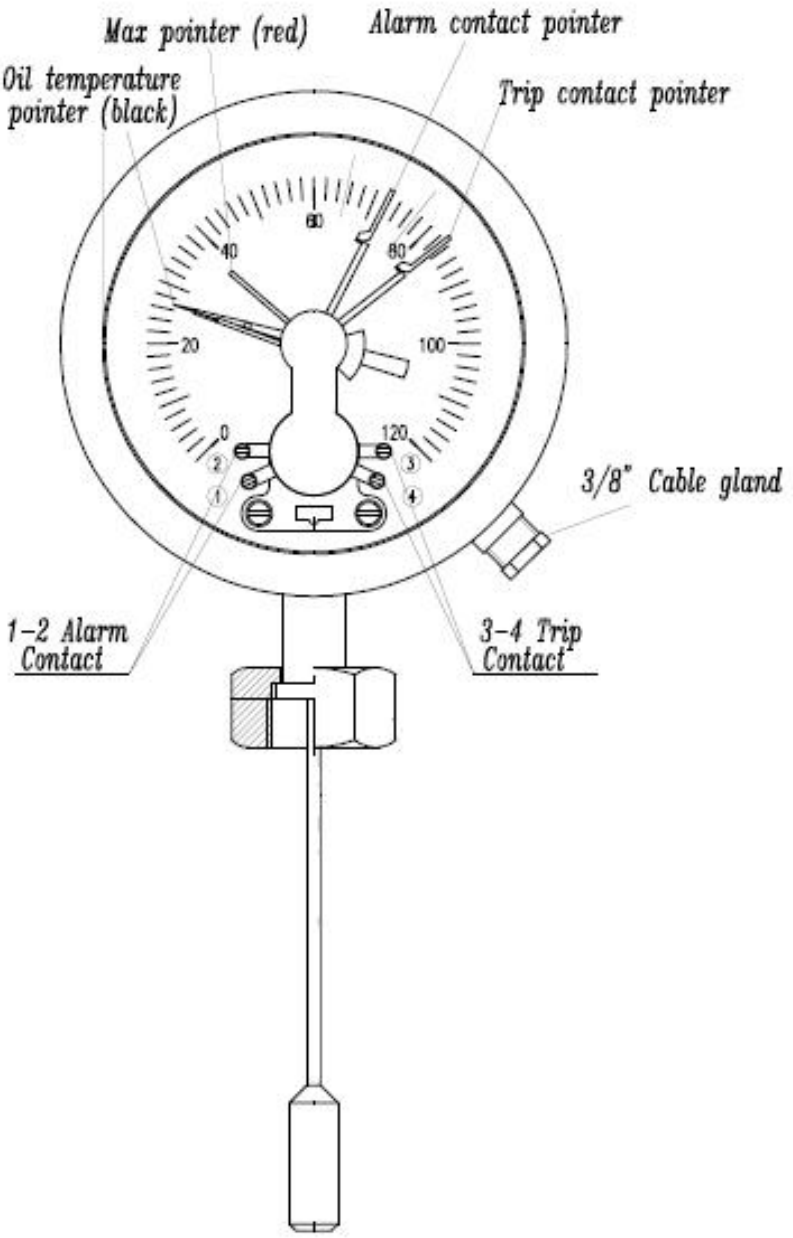


Figure 5 : Oil Temperature indicator widely used

Oil Level Indicator

Purpose:

Oil level indicator is used to monitor the oil level in the conservator. Mostly all of the oil level indicators are located on the sidewalls of the conservator. Usually two types of oil level indicators are used.

Without contacts, (see figure 6)

Figure 6 : Oil level indicators (without contacts)

- **With contacts (see Figure 7)**

  i. Maximum level (MAX) having two contacts (1 NO and 1 NC)
  ii. Minimum level (MIN) having two contacts (1 NO and 1 NC)

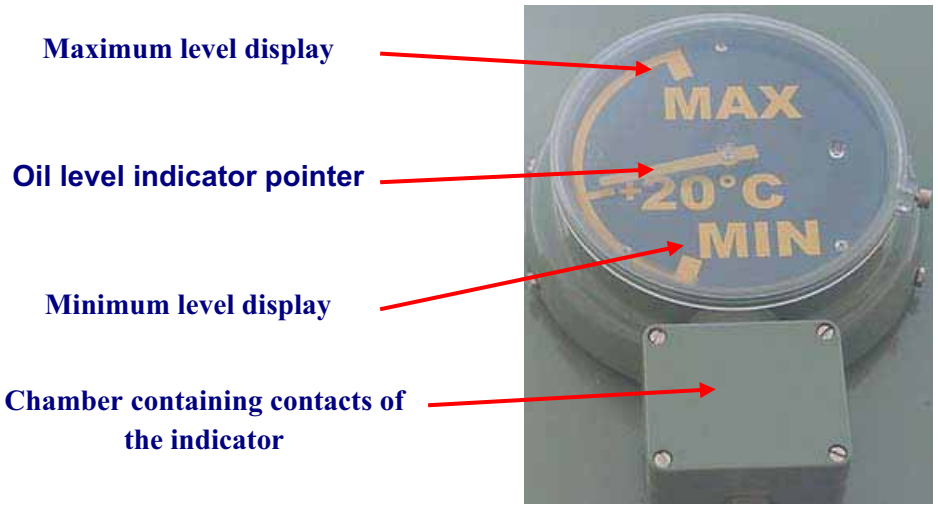


Figure 7 : Different parts of Oil Level Indicator

Functional Check:

The display is typically labeled with MAX, +20 °C & MIN values. If the oil level reaches to the maximum level the two contacts (1 NO and 1 NC) change their state. The same procedure repeats when the oil is lowered until minimum level. The functionality of the contacts can be electrically checked by checking the continuity and discontinuity of the contacts when their state changes.

The level indicator pointer could be moved manually to make/break these contacts. The display is graded in terms of temperature, because the oil expansion and contraction is the temperature dependent phenomena, since during the operation of transformer, oil quantity doesn't changes only the temperature variations changes its volume (level)

Pressure Relief Device (PRD)

Purpose:

Pressure relief device is used to give a relief to the oil pressure built up in case of a short circuit is developed inside the transformer. In the absence of this device the dangers of explosion or tank deformation exists. Mostly the pressure relief device is used on top plate. The spring type construction enables the PRD to automatically reset itself as soon as the oil pressure is released. Usually two types of PRD are used.

- Without contacts, (see Figure 8).
- With contacts (1 NO contact and 1 NC contact) (see figure9).

Figure 8 : Pressure Relief Device (PRD) without contacts

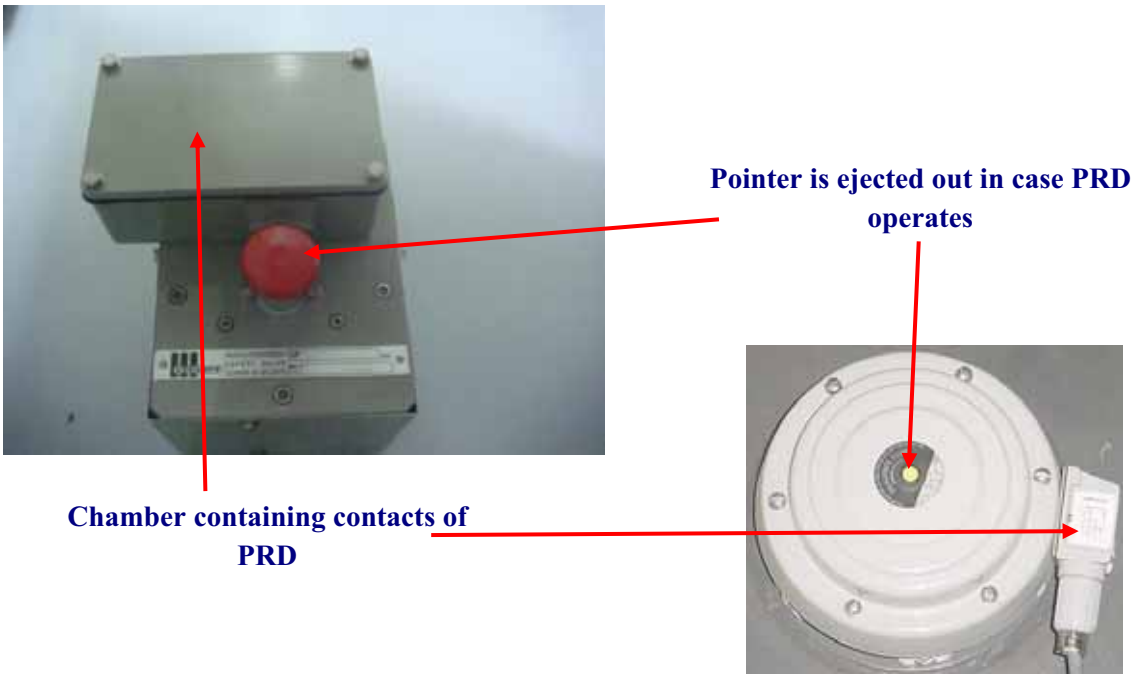


Figure 9 : Different parts of PRD

The yellow pointer as shown in the picture needs to be reset manually.

Functional Check:

The functionality of the contacts can be electrically checked by checking the continuity and discontinuity of the contacts when their state changes. A lever as shown in the picture sets the PRD and another lever resets its contacts to their initial state (see Figure 10).

Figure 10 : Set and Reset levers of PRD

Tap Changer

Purpose:

Voltage variations occurred at high voltage side is regulated by the tap changer and a constant output voltage is available at the output of the transformer. There are mainly two types of tap changers.

- OFF Load tap changers
- ON Load tap changers

OPERATION OF TAPCHANGER:

For OFF-Load tap changers, proper placement and tap selection is very important for trouble free operation of the transformer. For the tap selection, first check the incoming voltage to the transformer and then for exact matching with transformer tapping refer nameplate of the transformer. Before tap changing activity, it must be insured that the transformer is isolated (denergized) from both incoming and outgoing sides.

Almost all of the tap changers are operated in the same manner (see Figure 11)

Figure 11 : Different parts of tap changer

See Figure 12 & Figure for pictorial demonstration of different types of tap changers

- First rotate the lever clockwise / anticlockwise,
- Second rotate it to the desired tap position,
- Third place (push) the lever downwards to its final resting position

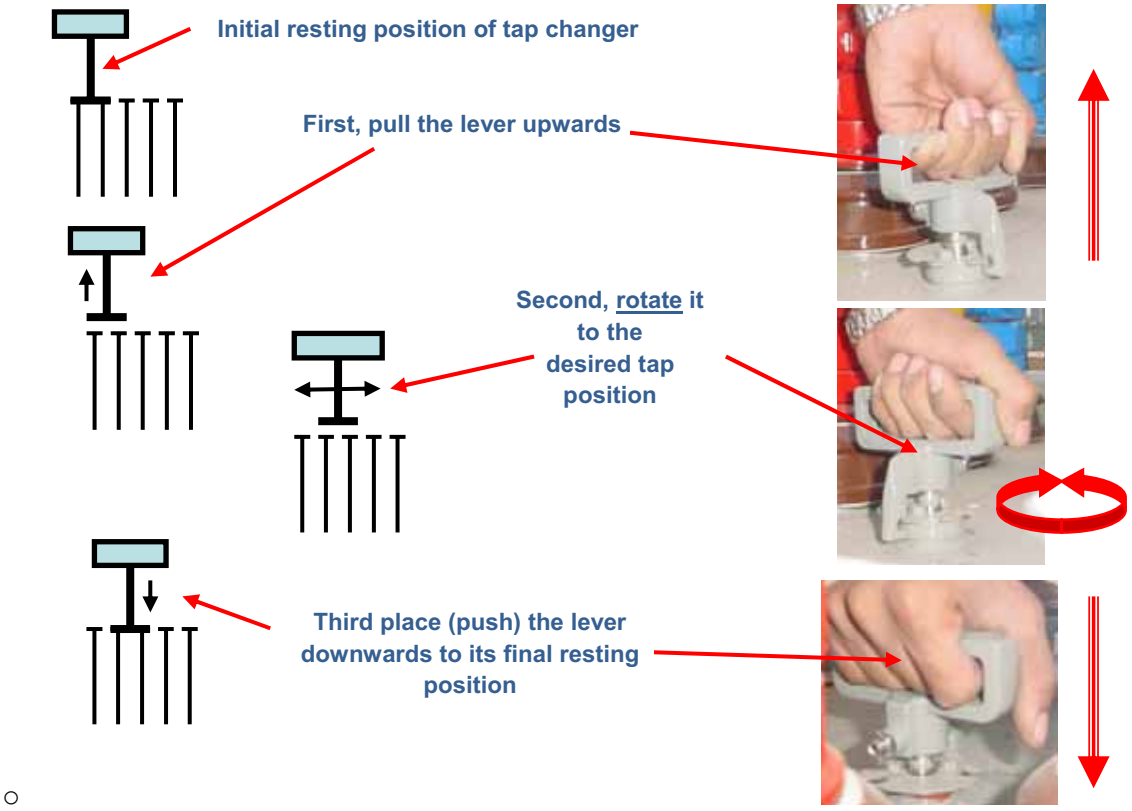


Figure 12 : Proper operation of Tap Changer (large transformers)

First rotate the lever clockwise / anticlockwise,

- Second rotate it to the desired tap position,
- Third place (push) the lever downwards to its final resting position

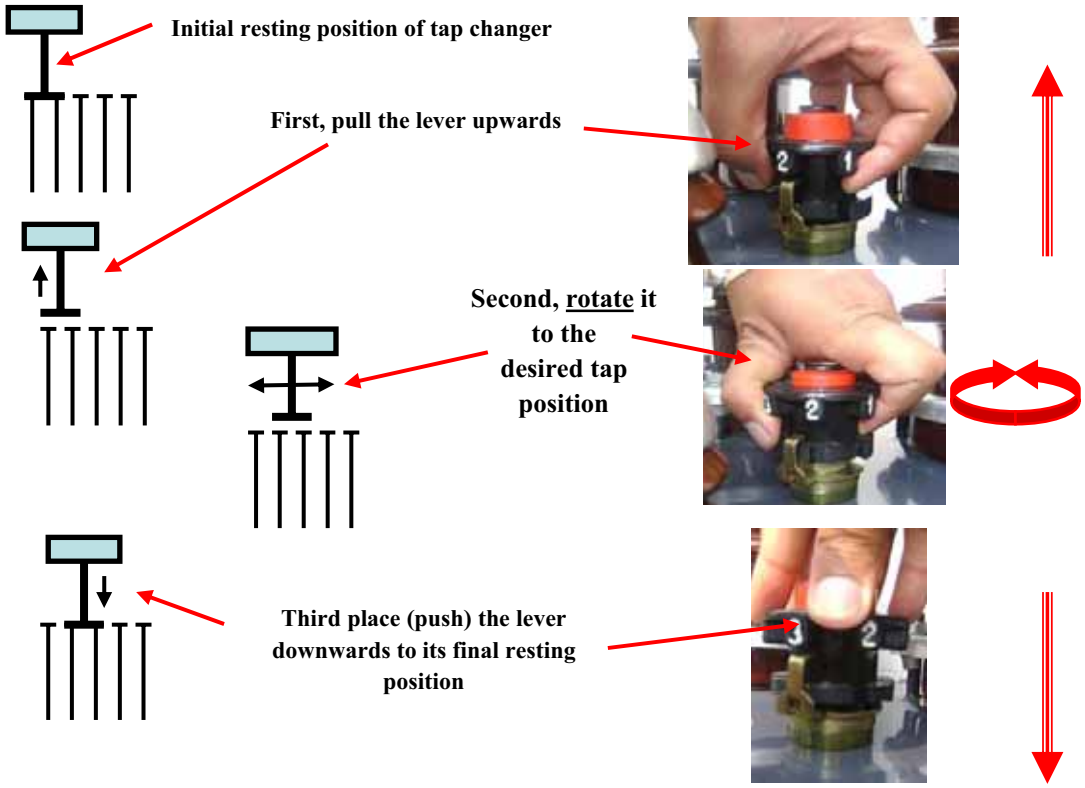


Figure 12: Proper operation of Tap Changer (small transformers)

NOTE!

For proper operation of ON-load Tap changer, please refer operating manual of the tap changer

SAFETY OF TAP CHANGER:

To keep the contacts of the tap changer in healthy condition it is recommended to operate the tap changer on all of its tap positions at least once a year. Any prolonged operation on a particular tap may cause carbonization or hot spot formation at the contact.

For ON load tap changers before energization, bleeding of tap changer is must (see Figure 13). Secondly On load tap changers need preventive maintenance after a certain number of operations or after a certain length of time depending upon the manufacturer and type of the tap changer (please refer ON load tap changer manual for the details of preventive maintenance of the tap changer)

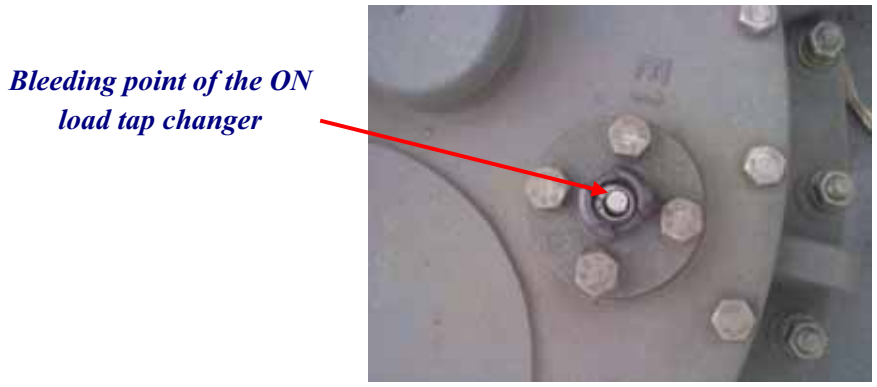


Figure 13 : Bleeding Point of ON load Tap changer

Current Transformer (CT) and Bushings

Purpose:

For some particular application, for example transformers with Automatic Voltage Regulators (AVR) or Winding Temperature Indicator (WTI), current transformers are installed in distribution transformers.

Connection and Safety of CT:

Either the secondary circuit of CT, in every case, in use or when not in use, must be complete. Opening the CT secondary circuit, during operation of the transformer, is hazardous to the person operating the device and might damage the CT as well.

When intended to use, the CT secondary circuit must be thoroughly checked and verified by electrical testing, recommended is to check the CT circuit by secondary current injection sets. For the secondary circuit one terminal of the CT must be earthed for the safety of the CT.

In case when the CT is not used, all the terminals of the CT must be shorted together and earthed. The same practice should be adopted for the CT in case of transportation of the transformer (see Figure 14).

There are few types of Bushings, which are provided with the bleeding point. Such bushings must be subject to bleeding prior to the energization of the transformer (see Figure 14).

CAUTION!

Make sure that the bushings are not in tension due to its termination

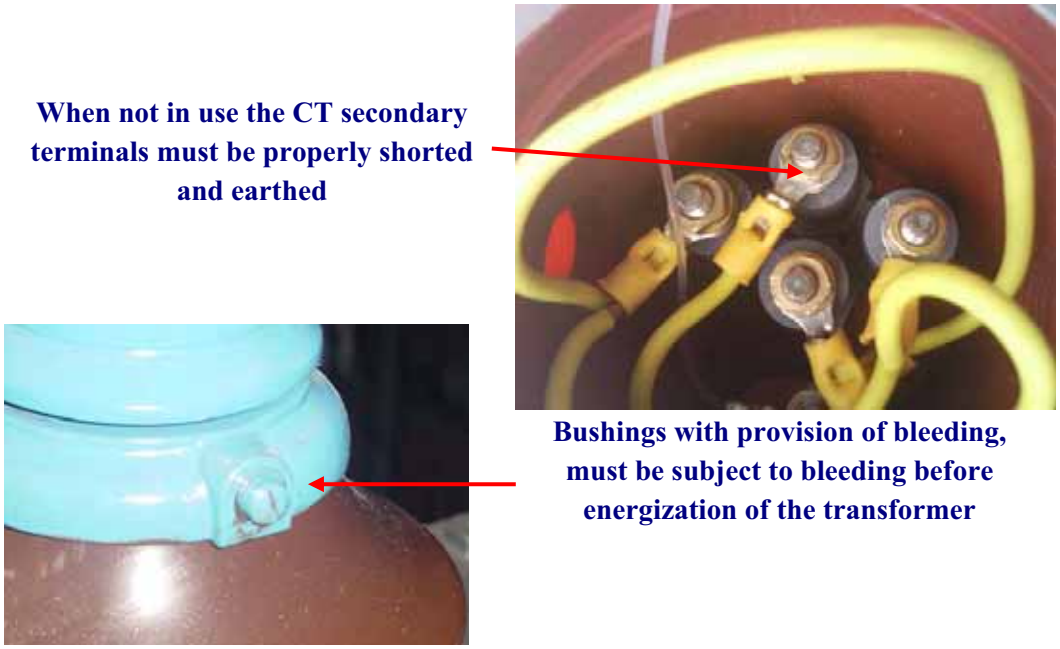


Figure 14 : CT termination and bleeding point of Bushing

Silicagel Breather

Purpose:

The purpose of silicagel is to absorb the moisture during the contraction of the oil in the transformer. During this process, transformers inhales air from the atmosphere. The air intake must be moisture free. Absorption of moisture by the oil will affect (decrease) the dielectric strength, will increase the moisture content in oil and will ultimately cause flashover in the transformer. Majority of the breathers are without any contact. See Figure 15 for example.

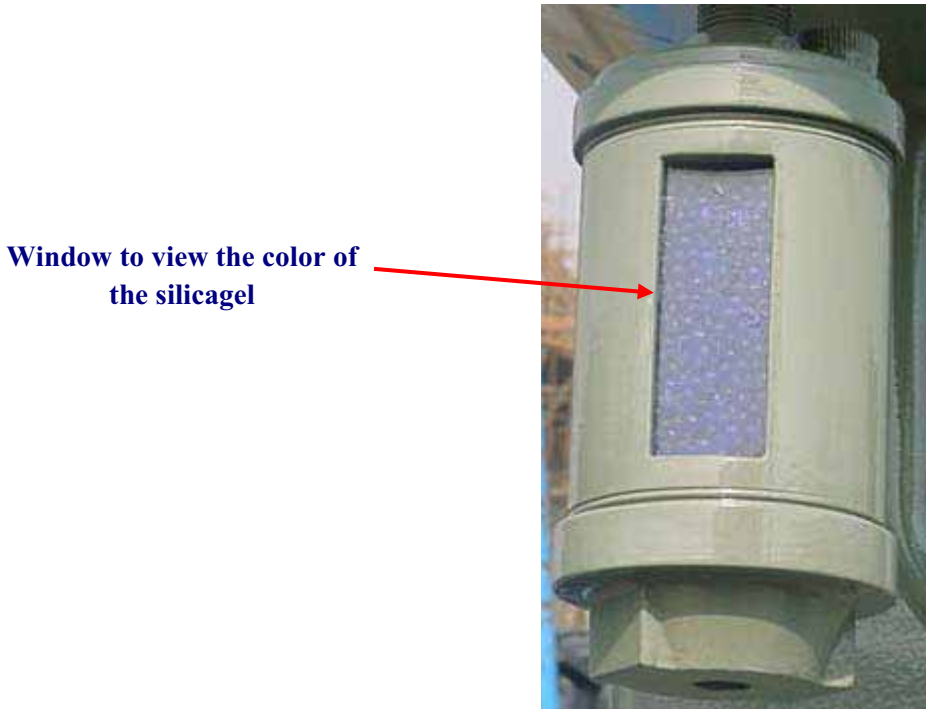


Figure 15 : Silicagel breather

Condition of Silicagel:

Usually blue color shows the healthiness of the silicagel (see Figure 15Figure 15 : Silicagel breather). With the passage of time, after moisture absorption, the color of the silicagel will turn to pink. This shows that the silicagel is exhausted, either it has to be regenerated or should be replaced.

Thermometers

Purpose:

The purpose of this instrument is to measure the temperature in oil filled transformers and is suitable for indoor installations. Temperature sensing system is of expansion type. See Figure 16 of typical thermometers used in transformers.

Figure 16 : Thermometers

Bushing Termination, Earthing and Ventilation

Bushing Termination:

Termination of HV terminals (bushings) is very important and if proper and suitable procedures are not adopted then it causes oil leakages from bushings gasket / sealing. Normally either cable terminations are used or for heavy currents bus bar arrangements are implied. For both arrangements, no tension whatsoever (axial or radial) should affect the bushings. The bushings must be absolutely tension free. For bus bars arrangements one additional care must be taken regarding thermal expansion of the bus bars. AT the time of energization, the temperature of the bus bars coincides with the ambient temperature. However, when the transformer is loaded and temperature of its oil increases so the bus bar temperature normally rises too. This causes thermal expansion of the bus bars and ultimately exerts tension on the bushings gasket.

Suitable measures should be taken to avoid the effects of thermal expansion. For that reason, usually bus bar is cut into two halves and in-between flexible conducting joints are provided. Sometimes depending on the weight, length and size (area) of the bus bar additional insulators are also provided along the length to support the bus bars so that weight and thermal expansion effects do not travel to wards the bushings.

Earthing:

For the safety of equipment itself, the load connected to the transformer and the personnel, earthing is very important. The transformer must be earthed at the point where the manufacturer has provided the earthing termination. Earth resistance must be checked periodically for the healthiness of the earthing. Except live parts, no other part of the transformer should be at any floating potential.

Ventilation:

Provide suitable ventilation system for the heat exhaust of the transformers, installed indoor.

Transformer Maintenance

The scope of routine and preventive maintenance covers following activities,

- Routine Inspection and Maintenance
- Preventive Maintenance & Chart
- Trouble Shooting

NOTE!

During operation, transformer is exposed to atmospheric conditions and electrical and mechanical stresses. In order to ensure uninterrupted operation, it is necessary to inspect and maintain the transformer carefully. Inspection and maintenance can be categorized into routine and periodic inspection and maintenance.

Routine Inspection and Maintenance

Routine inspection and maintenance can be carried out while the transformer is On-line. Pay attention to the following parameters:

- Abnormal noises, irregular vibrations, external damages, silicagel condition and deterioration of paint
- A record of the readings/recordings, from the meters/gauges provided on the transformer, should be maintained and compared with the past values. In case of abnormalities suitable measures should be taken

Routine inspection and maintenance should include, but not limited to the followings:

Transformer Temperature	:	Take and record the reading of oil/winding temperature indicator
Oil Level	:	Take and record the reading of oil level indicator
Noise	:	Check for abnormal sound/noise
Oil Leakages	:	Check oil leaks especially on location of valves, Indicators, packing and welded parts
Breather	:	Pay attention to the color of silicagel. Regenerate or replace if color has changed, (from healthy condition to the exhausted condition, the color change depends on the type of the silicagel being used)
Bushings	:	Check for excessive bushing contamination

Preventive Inspection and Maintenance

The period for the inspection is not absolute and is dependent on atmospheric and operating conditions of each transformer. The recommended period under normal conditions is one year.

Preventive maintenance and inspection should include but not limited to the following (Many of these require the transformer to be shut down).

Tank	:	Check for oil leaks and paint finish
Radiators	:	Check for oil leaks, paint finish and contaminations
Bushing	:	Check for local heating, damages, contamination and oil leaks
Insulating oil	:	Check for dielectric strength, carbon sludge, offensive odor and discoloration
Dehydrating breather	:	Check for discoloration of silicagel breather
Indicators[1]	:	Check for proper functioning
Physical Checks	:	Visual Inspection of complete transformer, Oil level checks, Connections of Cables, Bus Bars or Overhead Conductors to Bushings & Earthings
Recommended Electrical Tests	:	

- Measurement of Insulation Resistance of the Windings (Megger Test)
- Measurement of Voltage (Turns) ratio (TTR)
- Measurement of Winding Resistance
- Measurement of dielectric strength of oil
- Open Circuit Test & Short Circuit Test (If possible, to be performed)
- Functionality test and physical check of all accessories, parts and components
- Complete Chemical Analysis of Transformer Oil (once after every five years, please consult PEL for the details regarding the chemical analysis of the oil)
- Measurement of capacitance and dissipation factor of insulation system of bushings (if applicable) and transformer.

NOTE!

Any Abnormality / Malfunctioning / Deterioration, if noticed should be rectified immediately. Do not delay in any corrective action

[1] *meters, gauges, relays and other devices*

Preventive Maintenance Chart

S. No.	Work to be carried out	Duration of work	Time Interval			
		hour	w[2]	m[3]	y[4]	v[5]
1-	**Tank and conservator**					
1.1	Checking the oil temperature	<1	1			
1.2	Checking the dehydrating breather	<1	1[6]			
1.3	Checking the oil levels	<1	1			
1.4	Checking the flanged joints and welds for oil leakage	<1		1		
1.5	Checking the paint finish and declining the surface	3		6		
1.6	Checking the earthing systems (protective earthing)	2			1	
1.7	Oil sampling (for oil analysis)	<1			4	
3-	**Cooling system**					
3.1	Checking the oil temperature	<1	1			
3.2	Checking the butterfly valves	<1		6		
3.4	Checking the oil sight pot	<1		6		
3.5	Checking the fans	2		1		
3.6	Checking the coolers (radiators)	8			1	
4-	**Control cubicle and terminal box**					
4.1	Checking the heating of the control cubicle.	<1		6		
4.2	Checking the enclosure for water tightness	<1			1	
5-	**Bushing**					
5.1	Checking for oil leaks	<1		1		
5.2	Checking the porcelain	8		6		
5.3	Cleaning the protective spark gaps.	<1			2	
6-	**Current Transformers**					
6.1	Checking the terminal connections	<1			1	
6.2	Cleaning the terminal earthing	<1			1	
7-	**Monitoring devices**					
7.1	Checking the Buchholz Relay	<1		6		
7.2	Checking the diverter switch relay and Pressure relief diaphragm/device	<1		6		
7.3	Checking the thermometers	<1			1	
7.4	Checking the temperature monitors	<1			1	
7.7	Checking the oil level indicators	<1			1	
7.8	Checking the pressure relief device on the transformer tank	<1			1	
7.9	Checking for gas in the Buchholz relay	~1		6		

[2] *w= week*
[3] *m= month*
[4] *y= year*
[5] *v= variable*
[6] *Maximum 2 hours, if the desiccant is to be replaced*

Trouble Shooting

Protective, monitoring devices and various components	*Fault*	*Possible Cause*	*Remedial Measures*
Buchholz relay	Buchholz relay-alarm	○ Oil loss. ○ Accumulation of air. ○ Gas generation due to inside failure. ○ Violent vibration ○ False tripping.	Operation can be continued. However, following tests and examination for fault analysis should be made as soon as possible. 1- Check oil level, pipes, position of valves 2- Check the electrical connections 3- Check the tripping mechanism of the Buchholz relay 4- Pass part of the gas through the gas analyzer 5- Take oil sample (1liter) from tank bottom and check for dielectric strength 6- Undo all bushing connections and make the following measurements 6.1.Measure the insulation resistance between the winding and tank wall and between the winding themselves. *(Rough guide value: 1 M ohm per kV rated voltage)* 6.2.Ratio measurement either by Ratio meter or by applying low voltage to the HV side 6.3.Measure the DC winding resistance DC 6.4.Measure the no-load current by applying low voltage 6.5.Compare the result with the factory test results of transformer 7- Vent the transformer and put it back into operation when it is a false tripping (confirmed) or faults have been eliminated
Buchholz relay	Buchholz relay-tripping	○ Oil loss. ○ Violent oil surge due to inside flasher. ○ Violent gas generation due to inside failure. ○ Violent vibration. ○ False tripping.	○ Maintain shutdown status. ○ Carry out tests and measurements described under point (1-) to (7-) ○ Vent the transformer and put it back into operation when it is a false tripping (confirmed) or faults have been eliminated
Thermal Replica	Winding or oil temperature too high.	○ Transformer overload or inadequate cooling. ○ Incorrect temperature adjustment. Faulty temperature gauge	○ Reduce load of the transformer. ○ Put fans or cooling equipment in service. ○ Clean the cooling equipment. ○ Check position of butterfly valves. ○ Adjust incorrect temperature setting ○ Check the proper functioning of thermometer, do comparative measurement. ○ Check the electrical connection and the tripping mechanism. ○ Check control device for cooling equipment. Check the current transformer and thermal replica calibration

Thermal Replica	Winding or oil temperature too high.	○ Transformer overload or inadequate cooling. ○ Incorrect temperature adjustment. Faulty temperature gauge	○ Reduce load of the transformer. ○ Put fans or cooling equipment in service. ○ Clean the cooling equipment. ○ Check position of butterfly valves. ○ Adjust incorrect temperature setting ○ Check the proper functioning of thermometer, do comparative measurement. ○ Check the electrical connection and the tripping mechanism. ○ Check control device for cooling equipment. Check the current transformer and thermal replica calibration
Magnetic oil level Indicator	Oil level too low.	Not enough oil. (low temperature or oil loss)	○ Check for tightness, leaks and oil level ○ Top up oil.
Dehydrating breather	The drying crystals turn from blue to pink (depending on the type of the silicagel being used. From below towards the top	○ High atmospheric humidity ○ Moisture penetrating in transformer through other parts (usually leaks or gasket failures) rather through breather ○ Damaged breather (usually glass of the breather	○ Replacement of dehydrating agent (silicagel) ○ Seal leaks and gasket failures; check the oil for moisture content ○ Flush the conservator with dry air or nitrogen.
Electrical break-down of voltage in oil	Usually in the form of earth fault or short circuit	○ Breather inoperable or transformer in service since very long and silicagel exhausted ○ Moisture contents in oil too high and weak dielectric strength of oil	○ Put breather into operation ○ Seal or repair leaks and gaskets ○ Centrifuging/dehydration of oil to be performed till the required dielectric strength of oil is reached and moisture contents are reduced to the required levels (refer IEC 60422 for details)
Protective spark gap on bushing	Frequent operation	○ Electric arcing distance no longer correct Incoming voltage at the terminals of the transformer is far greater than the rated terminal voltage	○ Adjust the clearance between the arcing horns and screw them tight ○ Check the incoming voltage and compare with the rated terminal voltage, try to adjust with the help of tap changer (if possible), if not then get the adjustment at the incoming from the source (usually grid station)

Terminal/cable lugs on bushings	Discoloration of connecting parts	Poor contact making causing hot spot formation	○ Clear and clean, the contact faces. ○ Tighten the screws.
Control cabinet	○ Electrical Apparatus does not operate properly. ○ Contacts corroded or contaminated ○ Apparatus housing bent.	○ Excessive humidity in control cabinet ○ Water or dust inside the cabinet ○ Excessive high temperature in the cabinet.	○ Set the cabinet heater to a higher temperature to eliminated the moisture ○ Seal the cabinet door; fit a dust filter if necessary ○ Protect the cabinet against solar irradiation, provide for better ventilation and check whether the thermostat settings are too high
Earthing connection	Earthing line interrupted	○ Excessive currents due to external flashovers ○ Impermissible current loops through multiple earthing.	○ Clean the contacts tighten the screws and check the electrical distances ○ Open up close current loops. Provide adequate earthings at specified paths with a sufficient cross section. ○ Check earth resistance with the help of earth tester, earth resistance should be within the specified limits
Dial Type thermometer	Oil temperature too high	○ Transformer overload or inadequate cooling. ○ Incorrect temperature adjustment. ○ Faulty temperature gauge	○ Reduce load of the transformer. ○ Put fans or cooling equipment in service. ○ Clean the cooling equipment. ○ Check position of butterfly valves. ○ Adjust incorrect temperature setting ○ Check the proper functioning of thermometer, do comparative measurement. ○ Check the electrical connection and the tripping mechanism. ○ Check control device for cooling equipment. ○ Check the current transformer and thermal replica calibration

Annexure A Transformer Failure Report Form

Customer Information:

Company :

Site/Location :

Contact Person :

Department :

Address :

Phone : **Fax :** **E-Mail :**

Test Object Information:

Manufacturer: ☐ PEL ☐ **Non** PEL **(If Yes, then specify)**

☐ **Generator transformer** ☐ **Network transformer** ☐ **Other (Specify Type)**

☐ **Distribution Transformer** ☐ **Indoor Installation** ☐ **Outdoor Installation**

☐ **Auto Transformer** ☐ **Two Winding Transformer** ☐ **Three Winding Transformer**

☐ **1 - phase** ☐ **3 - phase**

☐ **Step-up Transformer** ☐ **Step-down Transformer**

Serial / LPK No.: **Year of Manufacturer:**

Rated Power (ONAN/ONAF): / **(kVA / MVA)**

Voltage Ratio: **Vector Group:**

A) Fault Description:

B) Fault Details:

1- ALARM :

☐ Oil level Indicator (Tank) ☐ Oil level Indicator (OLTC)

☐ Oil Temp Indicator ☐ Buchholz Relay (Tank)

2- TRIPPING :

☐ Buchholz Relay (Tank) ☐ Protective Relay (OLTC)

☐ Oil level Indicator (Tank) ☐ Oil level Indicator (OLTC)

☐ Oil Temperature Indicator ☐ Differential

☐ Pressure Relief Device ☐ Earth fault

☐ Over load ☐ Short circuit

3- CONDITIONS OF ACCESSORIES & COMPONENTS AT THE TIME OF FAULT:

a) Silica gel (Tank & OLTC) : ☐ Pink, ☐ Blue, ☐

b) Oil Temp (°C) :

c) Tap changer Tap Position / No. of operations : /

d) Gas found : ☐ NO ☐ YES (state the details below)

- ☐ Buchholz : ☐ YES ☐ NO
- ☐ LV Bushings : ☐ YES ☐ NO
- ☐ HV Bushings : ☐ YES ☐ NO

e) Gas color : ☐ Combustable ☐ Non-combustable

f) Oil colour / Appearence :

*C) On Site Tests details (if performed):**

S. No.	Test Description	Test Performed		Test Results	
1	Megger (Insulation Resistance)	☐ YES ☐ NO		☐ PASS	☐ FAIL
2	Ratio (TTR) & vector group confirmation	☐ YES ☐ NO		☐ PASS	☐ FAIL
3	Winding Resistance	☐ YES ☐ NO		☐ PASS	☐ FAIL
4	No Load Test (Open circuit test) low voltage	☐ YES ☐ NO		☐ PASS	☐ FAIL
5	Load Test (Short circuit test) low voltage	☐ YES ☐ NO		☐ PASS	☐ FAIL
6	Dielectric Strength of oil	☐ YES ☐ NO		☐ PASS	☐ FAIL
7	Other	☐ YES ☐ NO		☐ PASS	☐ FAIL

** **Note:** Reference for the post fault test results are manufacturer's factory test results and pre-commissioning test results of the transformer. Please provide a copy of the performed test results separately for the fault analysis of the transformer*

D) Additional Information:

1- Tap Changer & Motor Drive :

Make (OLTC) : Type :

Make (MDU) : Type :

OLTC (Sr. No.) : MDU (Sr. No.) :

Tap Changer operations :

Tap Changer Servicing History (please specify details) :

2- Fans :

Quantity :

Operational Details		OFF (°C)	ON (°C)
1	Oil Temperature Indicator Settings		

3- CT Connection Details :

HV CTs :
- ☐ Connected to external circuit
- ☐ Short circuited
- ☐ Terminal grounded : ☐ S1 ☐ S2

LV CTs :
- ☐ Connected to external circuit
- ☐ Short circuited
- ☐ Terminal grounded : ☐ S1 ☐ S2

4- Neutral Grounding Details :

- ☐ Solidly grounded
- ☐ Grounded by earth-fault neutralizer ☐ HV ☐ LV
- ☐ Neutral ungrounded

5- Over Voltage Protection :

- ☐ Spark Gaps ☐ Surge Arresters
- ☐ Both ☐ None

6- Oil Conservator System :

- ☐ Free Breathing via silica gel breather
- ☐ Other (to be specified) _____

E) Operational History:

1- Service age to failure :

- ☐ < 1 year ☐ 1 - 5 years
- ☐ 5 - 10 years ☐ 10 - 25 years
- ☐ 25 - 40 years ☐ > 40 years

2- Typical loading :

- ☐ < 0.5 pu ☐ 0.5 - 0.8 pu
- ☐ > 0.8 pu ☐ Variable
- ☐ Not Known

3- Loading immediately prior to failure :

- ☐ < 0.5 pu ☐ 0.5 - 0.8 pu
- ☐ > 0.8 pu ☐ Variable
- ☐ Not Known

F) Remarks (If any):

_____

_____

Stamp (Name / Designation / Department) Signature / Date

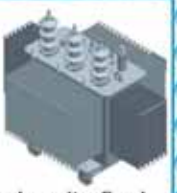
Thank you for completing this form. It will assist us in specifying the most appropriate solution/recommendation for your problem. If any additional information is available please send in with this form.

Annexure B Test Reports

Enclosed please find test report of the transformer

Annexure C Safety Checklist before Commissioning

SAFETY CHECK LIST BEFORE COMMISSIONING



DEAR CUSTOMER,

In order to operate the supplied equipment properly,
Please make sure the compliance of the below menfioned points.

- Please make sure all the sealing points are sealed and intact, when the transformer reaches its final installation site.
- Energization should be carried out by authorized personal and the locally applicable safety instructions must be followed strictly.
- During installation operators should be careful that oil sample plug, tap changer and any other operating and protection equipments are easily accessible. Monitoring equipments such as thermometer must be clearly visible and readable.
- Setting up the transformer completely parallel with a wall is not advisable as this will increase the noise. Suitable provision for natural air circulation must be provided in order to avoid overheating of transformer.
- The area in which the transformer is placed must be inaccessible to pets.
- The first energization of the transformer should be done without load.
- Before applying any supply voltage (for power, motor control & auxiliaries etc.) check whether the voltage and the output of the supply are in accordance with the required values.
- For the parallel operations of two Transformers, the parallel operation requirements must be met strictly.
- Check the Rating Plate before HT/LT connection.
- Keep the connection surface clean. A flexible connection is recommended in all cases. In this way the expansion of the conductors due to temperature can't lead to leak or cracks. Make sure that all the Bushings are not in tension due to their cable / busbar terminations.
- For tap changer adjustment according to the desired voltage, please refer Rating Plate or Guide Ring. Secondly make sure that the tap changer is placed properly on the required tapping, and locked as well.
- Before operating the tap changer, ensure that the transformer is completely switched off from high and low voltage sides. In case of an ON-Load tap changer, please refer its operating manual.
- Transformer must be operated at all taps at least once a year.
- Check the earthing terminals, before making earthing connections, make sure that the earthing points are free from rust, paint and grease. Transformer should be earthed from its specified earthing points. Secondly earth resistance must be checked periodically for the healthiness of the earthing.
- Install the original breather before energization by replacing the temporary transport breather.
- Check the color of silicagel, incase it is exhausted, replace it.
- All the bleeding points must be subjected to bleeding before first energization.
- Functionality of all the accessories must be ensured before energization.
- CT should be either shorted & grounded (if intent not to be put in to operation), if intent to use then CT circuit should be complete and grounded either through S1 or S2 terminals.
- In order to ensure uninterrupted operation, transformer routine, periodic and preventive maintenance must be thoroughly under taken.
- Valves should be in correct operating positions.
- Thermometer pockets should be filled with Oil.
- Oil should be at the correct level in the conservator, check oil level gauges,
- Arcing horn gaps should be properly adjusted, as per their corresponding voltage rating requirements,
- There should be no leakage or seepage of oil from any part of the transformer including gaskets, joints and terminals.
- Regarding explosion vent (where applicable), for the safety of Diaphragm (Aluminum Foil), during transportation a piece of M.S. sheet is provided for the safety of Diaphragm at the end of explosion vent. Please remove this M.S. sheet and keep Diaphragm in place before energization.
- In case of any abnormality, please inform Pak Elektron Limited (PEL) instead of taking any further actions.
- Damaging of the Transformer due to violation / ignorance of the above mention safety points may void the warranty of Transformer.

معزز کسٹمرز

برائے مہربانی فراہم کردہ ٹرانسفارمر کو صحیح طور پر کام میں لانے کیلئے مندرجہ ذیل ہدایات کی تکمیل کی یقین دھانی ضرور کر لیں

1- جب ٹرانسفارمر نصب کرنیوالی جگہ پر پہنچ جائے تو اس کے سارے سیل بند حصے اچھی طرح سیل بند اور محفوظ ہونے چاہیں۔

2- صرف متعلقہ شخص ہی عملی اقدام (Energization) انرجائزیشن کے عمل کو سرانجام دے۔ اور مقامی حفاظتی ہدایات کو مدنظر رکھے۔

3- نصب کرنے کے عمل کے دوران کارکن اس بات کا خیال رکھے کہ تیل کی جانچ کرنے والا کاک ٹیپ چینجر اور دوسرے عملی اور حفاظتی آلات آسانی سے قابل رسائی ہوں۔ آلات مشاہدہ جیسا کہ تھرمامیٹر وغیرہ واضح اور صاف نظر آ رہے ہوں۔

4- ٹرانسفارمر کو بالکل دیوار کے متوازی رکھنا موزوں نہیں ہے۔ کیونکہ اس سے آواز میں اضافہ ہوتا ہے۔ ٹرانسفارمر کو بالائی حرارت سے بچانے کے لیے قدرتی ہوا کی آمدورفت کیلئے مناسب جگہ فراہم کی جائے۔

5- جس جگہ ٹرانسفارمر رکھا جائے وہاں جانوروں کی رسائی نہ ہو۔

6- ٹرانسفارمر کو پہلی بار عمل میں لانے کے لیے اسے بغیر لوڈ کے چلایا جانا چاہیے۔

7- پہلی دفعہ وولٹیج سپلائی دینے سے پہلے (Power) پاور (Motor Control) موٹر کنٹرول اور (Auxiliaries) اوگزلریز وغیرہ کے لیے چیک کر لیں کہ آیا یہ وولٹیج اور سپلائی ان آلات کی حاصل مطلوبہ وولٹیج کے مطابق ہے یا نہیں۔

8- 2 ٹرانسفارمرز کے متوازی عمل کیلئے متوازی عمل کے اصولوں کو سختی سے پورا کیا جائے۔

9- ہائی اور لو وولٹیج کے (Connection) کنکشن سے پہلے (Rating Plate) ریٹنگ پلیٹ کو چیک کر لیں۔

10- (Connections) کنکشنز کی سطح کو صاف رکھیں تمام صورتوں میں لچکدار کنکشن کو موزوں قرار دیا جاتا ہے۔ کیونکہ حرارت کی وجہ سے کنڈکٹر کا پھیلاؤ، ٹیکاؤ، یا شگاف کا سبب بن سکتا ہے۔ اس بات کا یقین کر لیں کہ (Bushing) بشنگ، کیبلز اور (Busbar) بس بار کی حد بندی کسی وجہ سے کھچاؤ، یا تناؤ میں تو نہیں ہیں۔

11- (Tap Changer) ٹیپ چینجر کی ترتیب کو مطلوبہ وولٹیج کے مطابق کرنے کیلئے براہ کرم ریٹنگ پلیٹ یا گائیڈ رنگ سے رہنمائی حاصل کریں۔ نیز یہ یقین کر لیں کہ ٹیپ چینجر مطلوبہ ٹیپنگ پر صحیح طریقے سے بیٹھا ہوا ہے۔ اور (Lock) بند بھی ہو چکا ہے۔

12- (Tap Canger) ٹیپ چینجر کو اپریٹ کرنے سے پہلے اس بات کی تصدیق کر لیں کہ ٹرانسفارمر ہائی اور لو وولٹیج کی طرف سے مکمل طور پر بند ہو چکا ہے۔

13- ٹرانسفارمر کو سال میں ایک دفعہ ہر (Tapping) ٹیپنگ پر استعمال کرنا چاہیے۔

14- (Earthing) ارتھنگ کنکشن کرنے سے پہلے (Earthing Terminals) ارتھنگ ٹرمینلز کو چیک کر لیں اس بات کا بھی یقین کر لیں کہ ارتھنگ کے مقامات زنگ، گریس اور رنگ سے محفوظ ہیں۔ ٹرانسفارمر کو صرف اس کے مخصوص ارتھنگ مقامات سے (Earth) ارتھ کیا جائے۔ وقتاً فوقتاً ارتھنگ (Earthing Resistance) ارتھنگ ریزسٹنس کو ارتھنگ کی موزوں حالت کیلئے معیاری طور پر چیک کیا جائے۔

-15 عملی حالت سے پہلے عارضی (Transport Breather) ٹرانسپورٹ بریدر کو نئے (Breather) بریدر سے تبدیل کریں۔

-16 (Silicagel) سلیکا جیل کے رنگ کو جانچ لیں اور پھیکا پڑنے کی صورت میں تبدیل کریں۔

-17 پہلی دفعہ ٹرانسفارمر کو آن کرنے سے پہلے تمام (Bleeding) بلیڈنگ کے مقامات کو بلیڈ کر لیا جائے۔

-18 عملی حالت سے پہلے تمام آلات کی عملی کارکردگی کی تصدیق کر لی جائے۔

-19 کرنٹ ٹرانسفارمر کو یا تو شارٹ کر کے گراونڈ کیا جائے (اگر عمل میں لانے کا ارادہ نہ ہو تو) اگر عمل میں لانے کا ارادہ ہو تو کرنٹ ٹرانسفارمر کے سرکٹ کو مکمل کر کے S1 یا S2 ٹرمینل سے گراؤنڈ کیا جائے۔

-20 بلا توقف آپریشن کیلئے ٹرانسفارمر کی معمول کے مطابق دیکھ بھال کی جانی چاہیے۔

-21 (Valves) والوا پنے صحیح عملی مقامات پر ہونے چاہیں۔

-22 تھرمامیٹر کا خانہ تیل سے بھرا ہونا چاہیے۔

-23 تیل (Conservation) کنزرویٹر کے موزوں درجے پر ہونا چاہیے۔ تیل کے آلات پیائش کو جانچ لیں۔

-24 ٹرانسفارمر کے کسی بھی حصے (Gasket) گیسکٹ کنکشنز یا اور ٹرمینلز وغیرہ سے تیل کا ٹپکاؤ یا رساؤ نہیں ہونا چاہیے۔

-25 (Explosion Vent) ایکسپلوزن وینٹ کے متعلق (جہاں موجود ہو) ڈایافرام کے بچاؤ، کیلئے (Transportation) ٹرانسپورٹیشن کے دوران (M.S.Sheet) ایم۔ایس۔شیٹ کا ٹکراؤ ایکسپوزن وینٹ کے ساتھ فراہم کیا گیا ہے۔ ٹرانسپورٹ کو ان کرنے سے پہلے اس ایم۔ایس۔شیٹ کو الگ کر لیں اور ڈایافرام کو اس کی جگہ پر واپس رکھ دیں۔

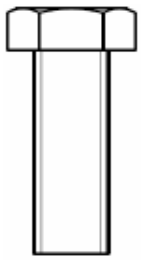
26 (Arching Horns) آرکنگ ہورن کے درمیان کا فاصلہ ان کے مطلوبہ وولٹیج کے مطابق رکھا جانا چاہیے۔

-27 کسی قسم کی خرابی کی صورت میں مزید کاروائی سے پہلے (PEL) پاک الیکٹرون لمیٹڈ کو مطلع کریں۔

-28 مندرجہ بالا حفاظتی ہدایات کو نظر انداز کرنے کی صورت میں ٹرانسفارمر کو نقصان ہو سکتا ہے جو ٹرانسفارمر کی وارنٹی کو تنسیخ کرنے کا باعث بن سکتا ہے۔

www.pel.com.pk
PEL
Factory and Main Offices:
14 K.M. Ferozepur Road, Lahore 54760, Pakistan
Tel : +92-42-5811951 Fax : +92-42-5826656, 5823030
Email: infopd-lhr@pelgroup.com.pk

Annexure D Recommended Torque Chart



	Bolt Tensile Strength as per DIN 267						
	4.6	5.6	6.9	8.8	10.9	12.9	mm
	Recommended Torque Setting (Nm)						
M 4	1.0	1.3	2.6	3.0	4.3	5.1	7
M 5	2.0	2.6	5.1	6.0	8.5	10.2	8
M 6	3.4	4.5	8.7	10.3	14.7	17.6	10
(M 7)	5.6	7.4	14.2	17.1	24.5	28.4	11
M 8	8.2	10.8	21.6	25.5	35.3	42.2	13
M 10	16.7	21.6	42.2	50.0	10.6	85.3	15
M 12	28.4	38.2	73.5	87.3	122	147	18
(M 14)	45.1	60.8	116	138	194	235	22
M 16	69.6	93.2	178	211	299	358	24
(M 18)	95.1	127	245	289	412	490	27
M 20	135	180	384	412	579	696	30
(M 22)	182	245	471	559	784	941	32
M 24	230	309	598	711	1000	1196	36
(M 27)	343	461	887	1049	1481	1775	41
M 30	466	623	1206	1422	2010	2403	46
(M 33)	632	848	1628	1932	2716	3266	50

Annexure E Standards

For more information on transformers, in general you can have a look at the following IEC and CENELEC standards:

- IEC 60076 : Power Transformers
- IEC 60076-1 : General
- IEC 60076-2 : Temperature rise
- IEC 60076-3 : Insulation levels, dielectric tests and external clearances in air
- IEC 60076-5 : Ability to withstand short-circuit
- IEC 60076-8 : Application guide (used to be IEC 606)
- IEC 60076-10 : Determination of sound levels (used to be IEC 551)
- IEC 60076-7 : Loading guide for oil-immersed power transformers
- IEC 60616 : Terminal & tapping markings for power transformers
- IEC 60296 : Specification for unused mineral insulating oils for transformers and switchgear
- IEC 60422 : Supervision and maintenance guide for mineral insulating oils in electrical equipment
- IEC 60475 : Method of sampling liquid dielectrics
- IEC 60567 : Guide for the sampling of gases and of oil from oil-filled electrical equipment and for the analysis of free and dissolved gases
- IEC 60599 : Mineral oil-impregnated electrical equipment in service–Guide to the interpretation of dissolved and free gases analysis
- EN 50180 : Bushings above 1kV up to 36kV and from 250A to 3150A for liquid-filled transformers
- HD 428 : Three-phase oil-immersed distribution transformers 50Hz, from 50 to 2500kVA with highest voltage for equipment not exceeding 36kV
- HD 596 : Bushings up to 1kV and from 250A to 5kA for liquid-filled transformers

Annexure F
Recommended torque values in Nm for various connections

Thread size	M6	M8	M10	M12	M16	M20	M30	M42	M48
Spanner size	**10**	**13**	**17**	**19**	**24**	**30**	**46**	**65**	**75**
A) Bushing Insulators									
Low voltage (LV) DIN 42530				**250A**		**630A**	**1000A**	**2000A**	**3150A**
1. Fixing of bushing terminal stud: ○ Cork gasket (Nm) ○ Buna gasket (Nm)				10-15 7-10		25-55 17-37	65-150 44-100	100-150 100-150	100-150 100-150
2. Connection between Nuts (Nm)				15-20		70-100	250-350		
3. Fixing of flag connector to terminal stud (bolt in stainless steel) (Nm)			25-35	40-60					
4. Bolts to flag connector surface (Nm)			25-35	40-70	100-150				
5. Fixing monobloc on flange: cork and Buna gasket (Nm)				20-30					
High Voltage (HV) DIN 42531									
1. Fixing of top of terminal stud (terminal stud and nuts in brass) (Nm)				10-15					
2. Connection to terminal stud (terminal stud and nuts in brass) (Nm)				15-20					
3. Fixing of base (stud and nut in stainless steel) Cork and Buna gasket (Nm)			10-20	20-35					
Plug-in bushing									
Cork and Buna gasket (Nm)			10-20						
B) LV connecting busbar									
Interconnection (pin and nut in 8.8 steel) (Nm)			45-60	65-85	95-130				
C) Cover / frame									
Bolt and nut in stainless steel (pitch = 60mm) = cork gasket (pitch = 90mm) = Buna gasket (Nm)		20-25 20-25		40-60 40-60					
D) Busbar bushings									
Fixing on cover (Nm)		8-15							
Top piece onto bottom piece (Nm)	5.4-6								

Max. Value: applied torque, Min. Value: checking torque. (If the torque, that you measure, is lower than Min. Value --> re-apply Max. torque Value). Checking recommended torque values is required:

- When setting up/installing the transformer.
- When connecting the transformer to the HV / LV connectors, and
- When carrying out maintenance work.
- We recommend re-applying Max. Torque Value 4 weeks after replacement of the seals.

www.pel.com.pk

PEL

Factory and Main Office
14-km Ferozepur Road
Lahore, Pakistan
Tel: +924235811951-9
Fax: +9242 35826656, 358230330
Email: infopd-lhr@pelgroup.com.pk

Branch Office- Karachi
Kohinoor Building, 25 west wharf Road,
karachi-74000, Pakistan
Tel: +922142200951-4, 2200134, 2312988
Fax: +9221 42310330
Email: infopd-khi@pelgroup.com.pk

Branch Office- Islamabad
1404, 14th floor Green Trust Tower,
Blue Area, Islamabad, Pakistan
Tel: +9251282941, 2824543
Fax: +9251 2273858
Email: infopd-isd@pelgroup.com.pk