

BASICS OF TRANSFORMER



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PRESENTATION OUTLINE

- ❑ TRANSFORMERS WORKING PRINCIPLE,**
- ❑ VARIOUS TYPES OF TRANSFORMERS USED IN A POWER STATION,**
- ❑ CONSTRUCTIONAL FEATURES OF MAIN TRANSFORMER AND ACCESSORIES,**
- ❑ BUCHOLTZ RELAY AND MAIN PROTECTIONS,**
- ❑ TYPES OF COOLING,**

BASICS OF TRANSFORMER AND ITS WORKING PRINCIPLE

SOME HISTORY OF TRANSFORMER

- ❑ HISTORICALLY, THE FIRST ELECTRICAL POWER DISTRIBUTION SYSTEM DEVELOPED BY EDISON IN 1880s WAS TRANSMITTING DC (DIRECT CURRENT)**
- ❑ IT WAS DESIGNED FOR LOW VOLTAGES (SAFETY AND DIFFICULTIES IN VOLTAGE CONVERSION); THEREFORE, HIGH CURRENTS WERE NEEDED TO BE GENERATED AND TRANSMITTED TO DELIVER NECESSARY POWER**
- ❑ THIS SYSTEM SUFFERED SIGNIFICANT ENERGY LOSSES!**

SOME HISTORY OF TRANSFORMER

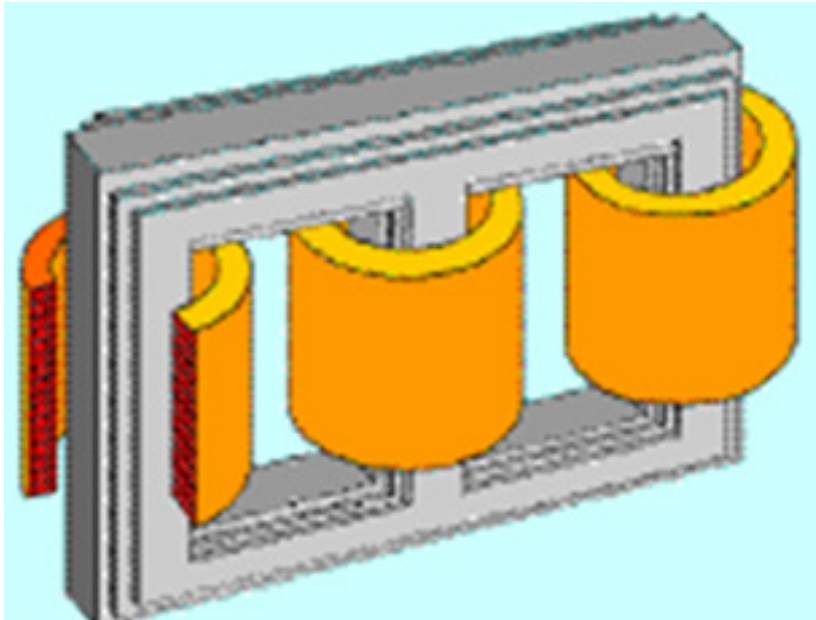
- ❑ **THE SECOND GENERATION OF POWER DISTRIBUTION SYSTEMS (WHAT WE ARE STILL USING) WAS PROPOSED BY TESLA FEW YEARS LATER.**
- ❑ **HIS IDEA WAS TO GENERATE AC POWER OF ANY CONVENIENT VOLTAGE, STEP UP THE VOLTAGE FOR TRANSMISSION (HIGHER VOLTAGE IMPLIES LOWER CURRENT AND, THUS, LOWER LOSSES),**
- ❑ **TRANSMIT AC POWER WITH SMALL LOSSES, AND FINALLY STEP DOWN ITS VOLTAGE FOR CONSUMPTION**
- ❑ **POWER LOSS IS PROPORTIONAL TO THE SQUARE OF THE CURRENT TRANSMITTED**
- ❑ **THE STEP UP AND STEP DOWN VOLTAGE CONVERSION WAS BASED ON THE USE OF TRANSFORMERS.**

PRELIMINARY CONSIDERATIONS

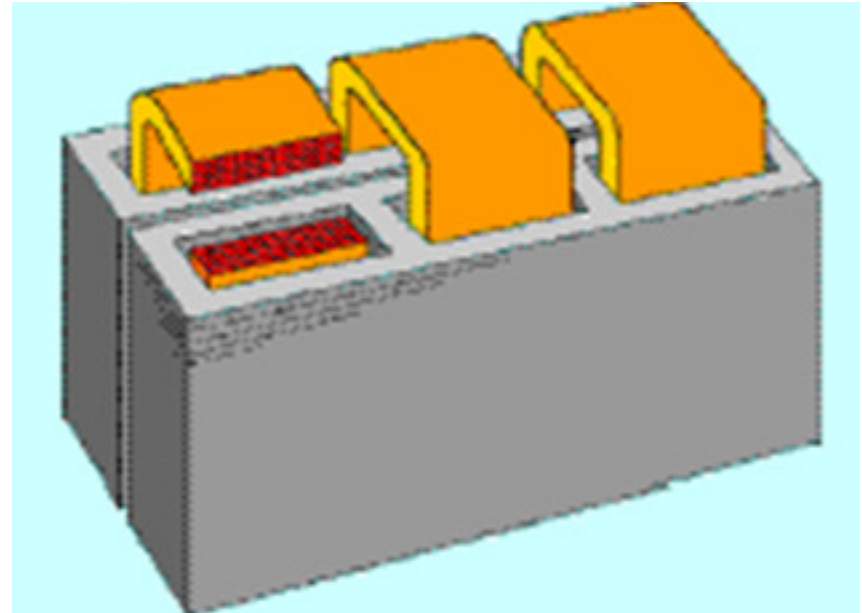
❑ A TRANSFORMER IS A DEVICE

- THAT CONVERTS ONE **AC** VOLTAGE TO ANOTHER **AC** VOLTAGE AT THE SAME FREQUENCY
- IT CONSISTS OF ONE OR MORE COIL(S) OF WIRE WRAPPED AROUND A COMMON **FERROMAGNETIC CORE**
- THESE COILS ARE USUALLY NOT CONNECTED ELECTRICALLY TOGETHER
- HOWEVER, THEY ARE CONNECTED THROUGH THE **COMMON MAGNETIC FLUX** CONFINED TO THE CORE
- ASSUMING THAT THE TRANSFORMER HAS AT LEAST TWO WINDINGS, ONE OF THEM (**PRIMARY**) IS CONNECTED TO A SOURCE OF **AC POWER**; THE OTHER (**SECONDARY**) IS CONNECTED TO THE **LOADS**.

BASIC DESIGN CONCEPT



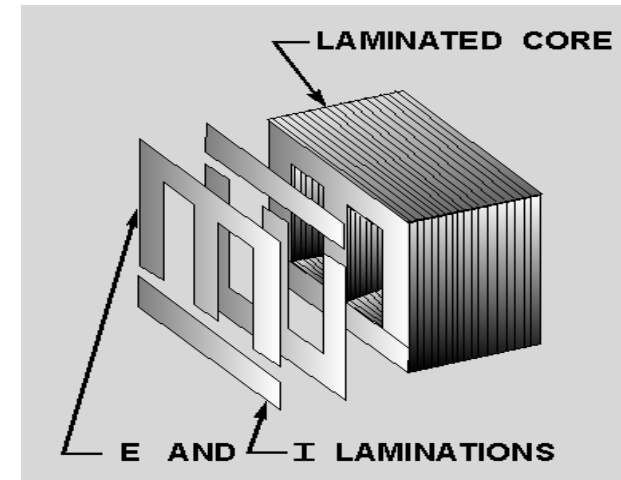
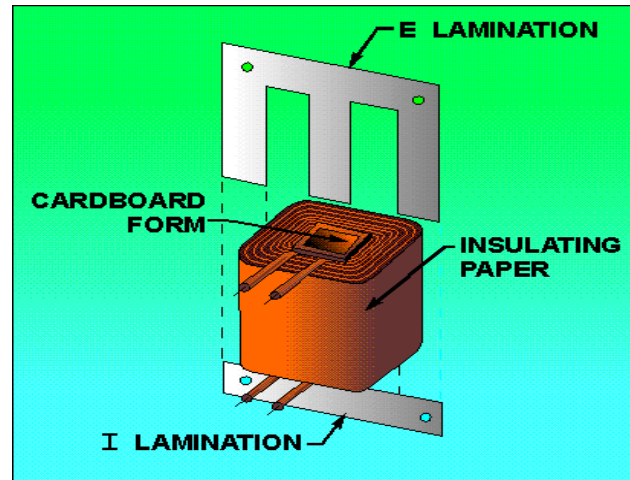
- **CORE TYPE**
- ❖ **CIRCULAR SHAPED WINDINGS**



- **SHELL TYPE:**
- ❖ **RECTANGULAR SHAPED WINDINGS**

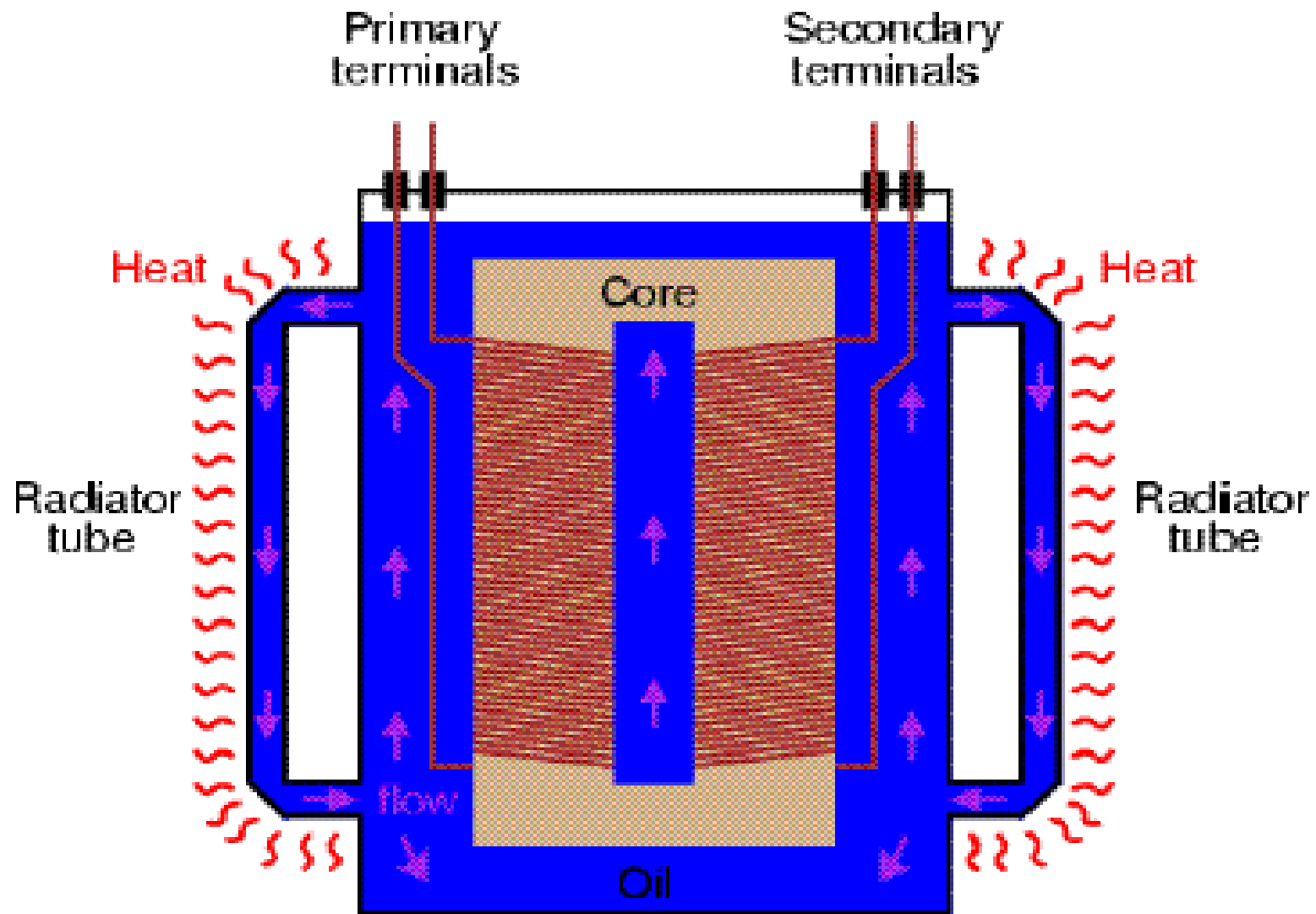
TRANSFORMER MAIN INTERNAL PART

□ CORE



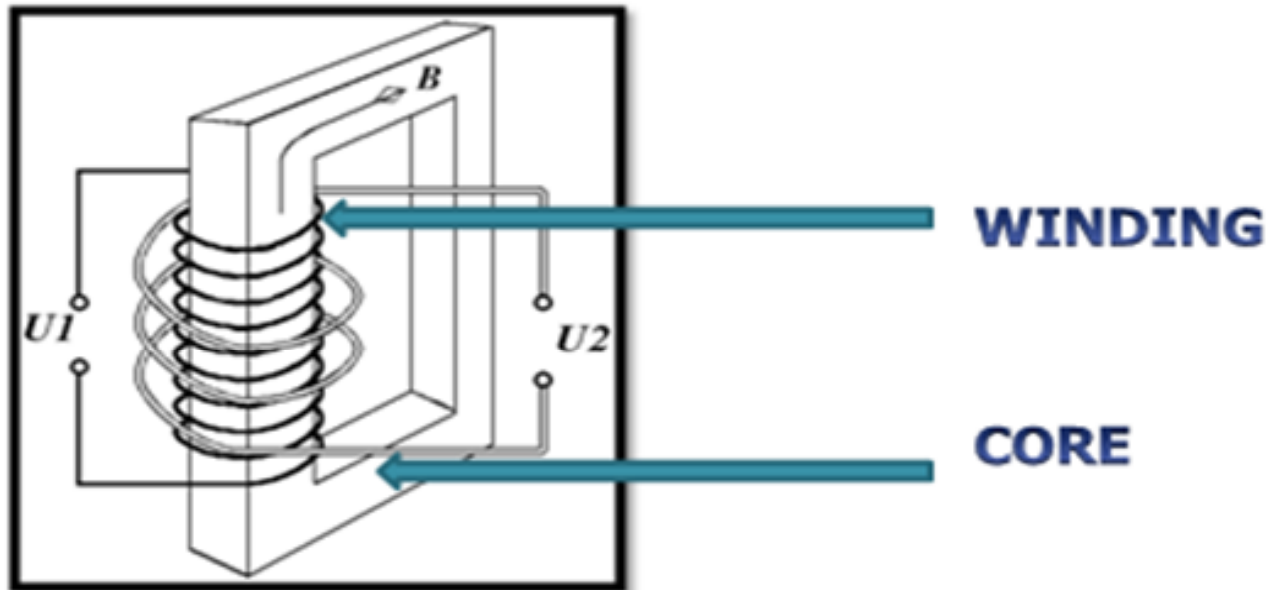
- THE CORE WILL WORK AS A **CAGE FOR THE MAGNETIC FLUX**
- MOST OF THE **FLUX** WILL BE KEPT INSIDE THE CORE
- THE CORE IS MADE WITH A **VERY SPECIAL ELECTRICAL STEEL**
- THE STEEL IS MADE AS THIN INSULATED SHEETS WHICH MUST BE **MOUNTED ONE BY ONE**
- THE FINAL GOAL IS TO **MINIMIZE THE SIZE OF THE CORE AND LOSSES.**

BASIC LAYOUT



BASIC LAYOUT

▪ CONDUCTORS FOR CURRENT AND MAGNETIC FLUX



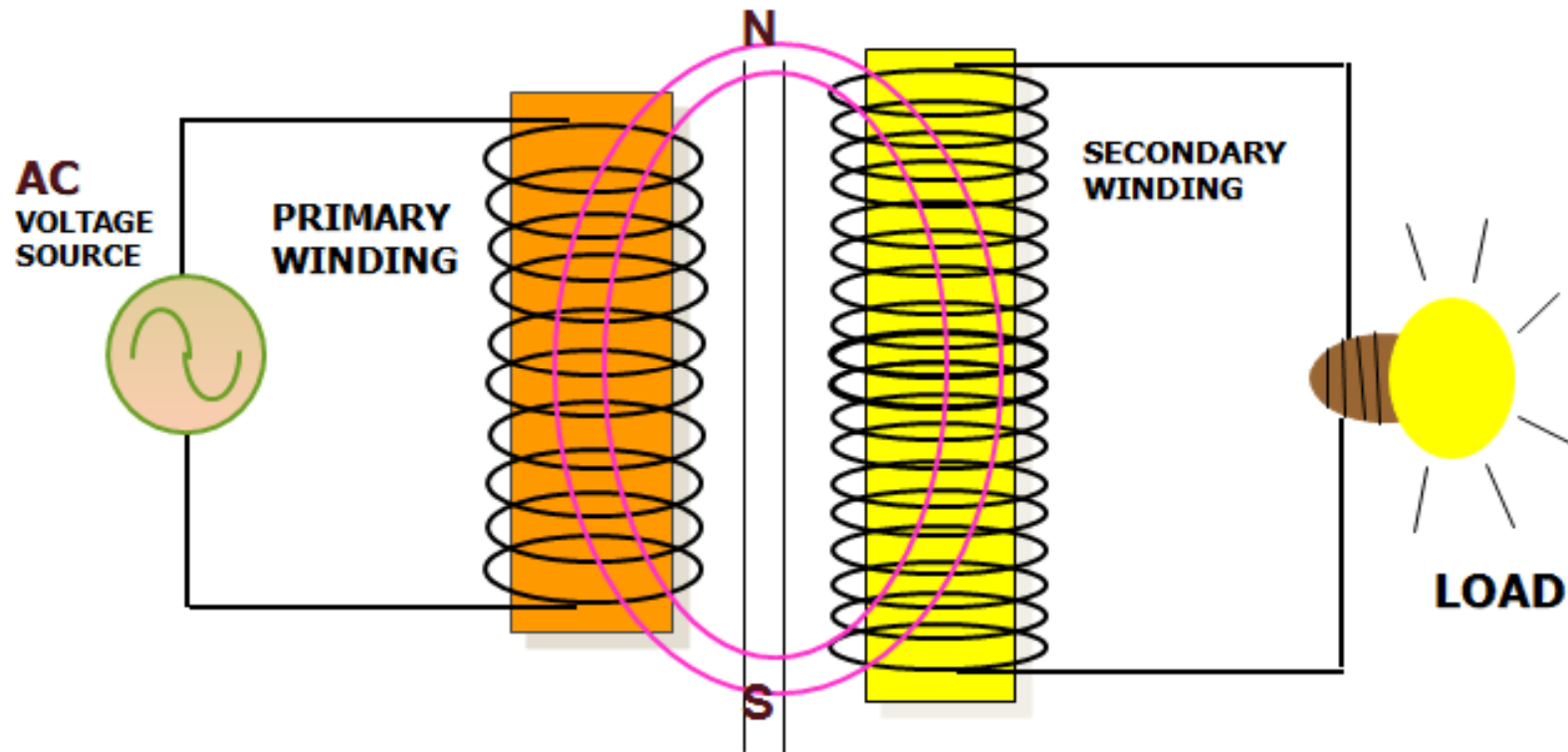
WINDING : THE CURRENT CONDUCTOR

CORE : THE FLUX CONDUCTOR, PROVIDES AN UNINTERRUPTED PATH FOR THE FLUX INVOKED BY THE COIL.

THE PRINCIPLE PARTS OF A TRANSFORMER AND THEIR FUNCTIONS ARE

- ❑ THE CORE: WHICH PROVIDES A PATH FOR THE MAGNETIC LINES OF FLUX**
- ❑ THE PRIMARY WINDING: WHICH RECEIVES ENERGY FROM THE AC SOURCE**
- ❑ THE SECONDARY WINDING: WHICH RECEIVES ENERGY FROM THE PRIMARY WINDING AND DELIVERS IT TO THE LOAD**
- ❑ THE ENCLOSURE: WHICH PROTECTS THE ABOVE COMPONENTS FROM DIRT, MOISTURE, AND MECHANICAL DAMAGE.**

TRANSFORMER ELECTROMAGNETIC DEVICE (MUTUAL INDUCTION)



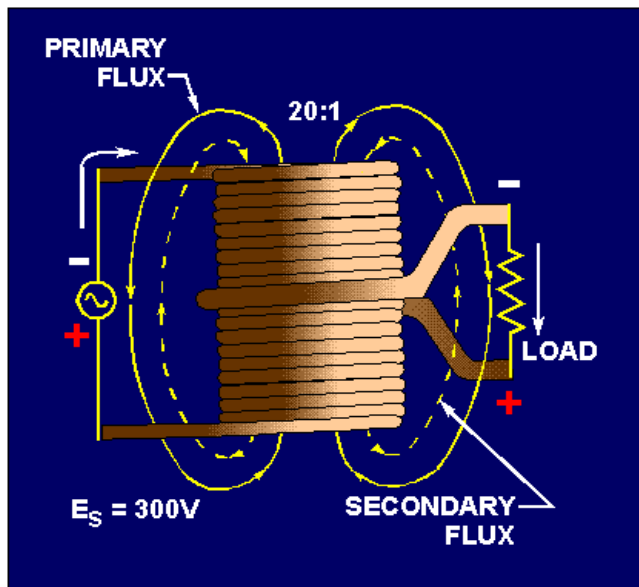
- 2 ADJACENT COILS
- COILS NOT PHYSICALLY CONNECTED TO EACH OTHER

TRANSFORMER ELECTROMAGNETIC DEVICE (MUTUAL INDUCTION)

- **THE PRIMARY WINDING IS CONNECTED TO A 50 HERTZ AC VOLTAGE SOURCE**
- **THE MAGNETIC FIELD (FLUX) BUILDS UP (EXPANDS) AND COLLAPSES (CONTRACTS) ABOUT THE PRIMARY WINDING**
- **THE EXPANDING AND CONTRACTING MAGNETIC FIELD AROUND THE PRIMARY WINDING CUTS THE SECONDARY WINDING AND INDUCES AN ALTERNATING VOLTAGE INTO THE WINDING**
- **THIS VOLTAGE CAUSES ALTERNATING CURRENT TO FLOW THROUGH THE LOAD**
- **THE VOLTAGE MAY BE STEPPED UP OR DOWN DEPENDING ON THE DESIGN OF THE PRIMARY AND SECONDARY WINDINGS.**

MUTUAL FLUX

- WHEN A LOAD DEVICE IS CONNECTED ACROSS THE SECONDARY WINDING OF A TRANSFORMER, CURRENT FLOWS THROUGH THE **SECONDARY AND THE LOAD**
- THE **MAGNETIC FIELD PRODUCED** BY THE CURRENT IN THE SECONDARY INTERACTS WITH THE MAGNETIC FIELD PRODUCED BY THE CURRENT IN THE PRIMARY
- THIS INTERACTION RESULTS FROM THE **MUTUAL INDUCTANCE** BETWEEN THE PRIMARY AND SECONDARY WINDINGS.



❖ **SIMPLE TRANSFORMER INDICATING
PRIMARY- AND SECONDARY-WINDING
FLUX RELATIONSHIP**

VOLTAGES IN A TRANSFORMER

- ❑ THE VOLTAGES IN THE PRIMARY & SECONDARY COILS DEPEND ON NUMBER OF TURNS IN COILS

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

- ❑ WHERE

V_p = PRIMARY VOLTAGE

V_s = SECONDARY VOLTAGE

N_p = NUMBER OF TURNS OF PRIMARY COIL

N_s = NUMBER OF TURNS OF SECONDARY COIL

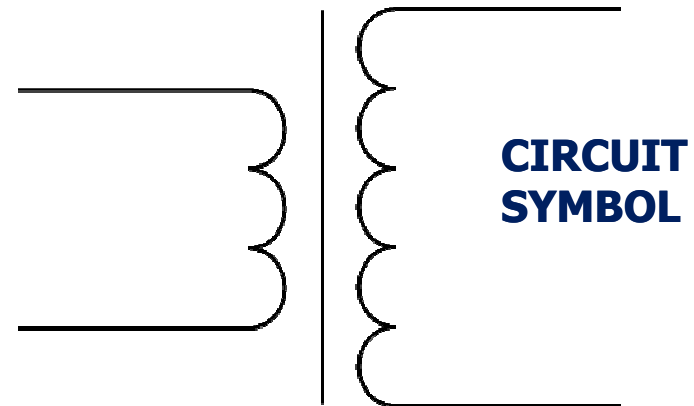
VOLTAGES IN A TRANSFORMER

□ THERE ARE 2 TYPES OF TRANSFORMERS

1 STEP-UP TRANSFORMER

$$V_s > V_p$$

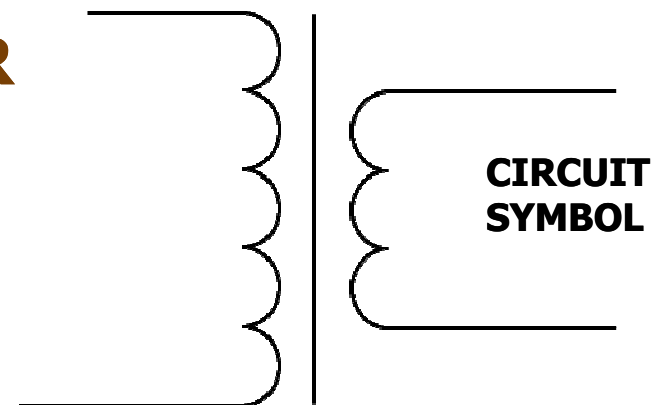
$$N_s > N_p$$



2 STEP-DOWN TRANSFORMER

$$V_s < V_p$$

$$N_s < N_p$$



CURRENTS IN A TRANSFORMER

□ IF NO POWER IS LOST IN A TRANSFORMER

POWER INPUT TO
PRIMARY COIL

=

POWER OUTPUT FROM
SECONDARY COIL

PRIMARY I $V_p \times I_p = V_s \times I_s$ SECONDARY I

PRIMARY VOLTAGE V_p SECONDARY VOLTAGE V_s

$$\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{I_p}{I_s}$$

$$\boxed{\frac{N_s}{N_p} = \frac{I_p}{I_s}}$$

(NO POWER LOSS)

URNS AND CURRENT RATIOS

- IF THE SECONDARY OF A TRANSFORMER HAS TWO TIMES AS MANY TURNS AS THE PRIMARY, THE VOLTAGE INDUCED INTO THE SECONDARY WILL BE TWO TIMES THE VOLTAGE ACROSS THE PRIMARY
- IF THE SECONDARY HAS **ONE-HALF** AS MANY TURNS AS THE PRIMARY, THE VOLTAGE ACROSS THE SECONDARY WILL BE ONE-HALF THE VOLTAGE ACROSS THE PRIMARY.
- HOWEVER, THE TURNS RATIO AND THE CURRENT RATIO OF A TRANSFORMER HAVE AN **INVERSE RELATIONSHIP**.
- THUS, A 1:2 STEP-UP TRANSFORMER WILL HAVE ONE-HALF THE CURRENT IN THE SECONDARY AS IN THE PRIMARY.
- A 2:1 STEP-DOWN TRANSFORMER WILL HAVE TWICE THE CURRENT IN THE SECONDARY AS IN THE PRIMARY.

WHAT ARE THE TYPES OF TRANSFORMERS

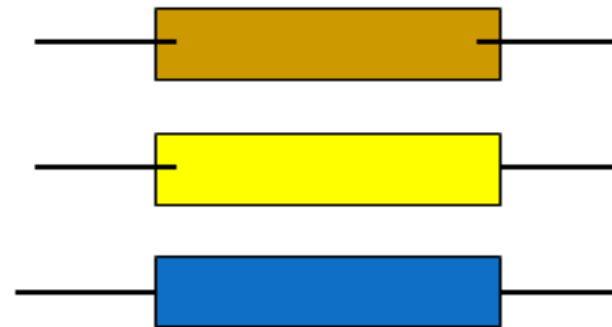
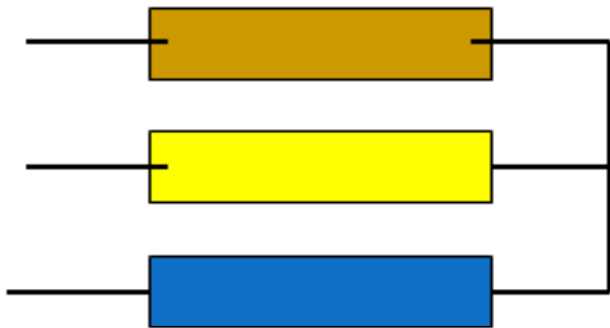
- ❑ **POWER TRANSFORMERS** : USED IN TRANSMISSION NETWORK OF HIGHER VOLTAGES, DEPLOYED FOR STEP-UP AND STEP DOWN TRANSFORMER APPLICATION (765 kV, 400 kV, 220 kV, 110 kV, 66 kV, 33kV,22kV)
- ❑ **DISTRIBUTION TRANSFORMERS:** USED FOR LOWER VOLTAGE DISTRIBUTION NETWORKS AS A MEANS TO END USER CONNECTIVITY. (11kV, 6.6 kV, 3.3 kV, 440V, 230V)

TRANSFORMER CONNECTIONS

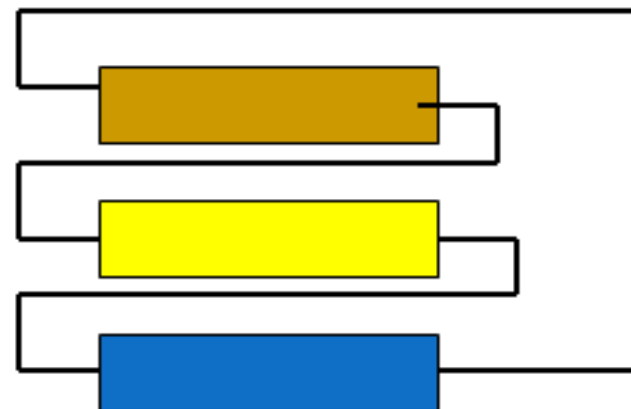
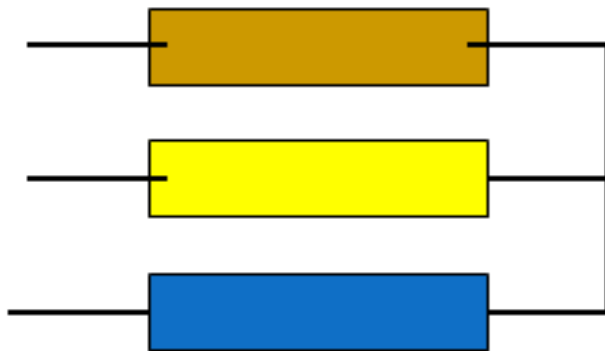
- ❑ **DELTA/STAR: USED IN GENERATING STATIONS FOR STEP-UP**
- ❑ **STAR/DELTA: USED IN RECEIVING STATIONS FOR STEP-DOWN**
- ❑ **ALL GTs ARE DELTA/STAR CONNECTED**
- ❑ **ALL TIE IN TRANSFORMERS ARE STAR/STAR CONNECTED.**

TRANSFORMER CONNECTIONS

❑ STAR / STAR CONNECTION



❑ STAR / DELTA CONNECTION



VARIOUS TYPES OF TRANSFORMERS USED IN A POWER STATION

POWER TRANSFORMER



DIFFERENT TRANSFORMERS IN A POWER PLANT

- **GENERATOR TRANSFORMER (GT)**
- **STATION TRANSFORMER (ST)**
- **UNIT AUXILIARY TRANSFORMER (UAT)**
- **EXCITATION TRANSFORMER**
- **NEUTRAL GROUNDING TRANSFORMER**
- **AUXILIARY TRANSFORMERS**

GENERATOR TRANSFORMER

- ☐ **GENERATOR TRANSFORMER: THE GENERATOR IS CONNECTED TO THIS TRANSFORMER BY MEANS OF ISOLATED BUS DUCTS.**
- ☐ **THIS TRANSFORMER IS USED TO STEP UP THE GENERATING VOLTAGE OF AROUND 15KV TO GRID VOLTAGE.**
- ☐ **THIS TRANSFORMER IS GENERALLY PROVIDED WITH OFAF COOLING.**
- ☐ **IT IS ALSO PROVIDED WITH OFF CIRCUIT/ON LOAD TAPS ON THE HIGH VOLTAGE SIDE.**
- ☐ **THIS TRANSFORMER HAS ELABORATE COOLING SYSTEM CONSISTING OF NUMBER OF OIL PUMPS AND COOLING FANS APART FROM VARIOUS ACCESSORIES.**

UNIT AUXILIARY TRANSFORMER

- ❑ THE UAT DRAWS ITS INPUT FROM THE MAIN BUS-DUCT CONNECTING GENERATOR TO THE GENERATOR TRANSFORMER.**
- ❑ THE TOTAL KVA CAPACITY OF UNIT AUXILIARY TRANSFORMER REQUIRED CAN BE DETERMINED BY ASSUMING 0.85 POWER FACTOR AND 0.9 EFFICIENCY FOR TOTAL AUXILIARY MOTOR LOAD.**
- ❑ IT IS SAFE AND DESIRABLE TO PROVIDE ABOUT 20% EXCESS CAPACITY THAN CIRCULATE SO AS TO PROVIDE FOR MISCELLANEOUS AUXILIARIES AND POSSIBLE INCREASE IN AUXILIARY LOAD.**
- ❑ WITH HIGHER UNIT RATINGS AND HIGHER STEAM CONDITIONS, THE AUXILIARY POWER REQUIRED ALSO INCREASES AND LIMITATIONS IMPOSED BY THE SWITCHGEAR VOLTAGES AVAILABLE, INDICATE THE MAXIMUM SIZE OF UNIT AUXILIARY TRANSFORMER WHICH CAN BE USED**

GT AND UAT



STATION TRANSFORMERS

- ❑ THE STATION TRANSFORMER IS REQUIRED TO FEED POWER TO THE AUXILIARIES DURING START UPS.**
- ❑ THIS TRANSFORMER IS NORMALLY RATED FOR THE INITIAL AUXILIARY LOAD REQUIREMENTS OF UNIT.**
- ❑ IN TYPICAL CASES, THIS LOAD IS OF THE ORDER OF 60% OF THE LOAD AT FULL GENERATING CAPACITY.**
- ❑ BUT IN LARGE STATIONS WHERE MORE THAN ONE UNITS ARE OPERATING, THE STATION TRANSFORMERS SHOULD HAVE SUFFICIENT CAPACITY TO START TWO UNITS AT A TIME IN ADDITION TO FEEDING THE COMMON AUXILIARIES.**
- ❑ IT IS ALSO PROVIDED WITH **ON LOAD TAP CHANGER** TO CATER TO THE FLUCTUATING VOLTAGE OF THE GRID.**

AUXILIARY TRANSFORMERS

- **THESE TRANSFORMERS ARE EMPLOYED IN THE POWER PLANTS FOR DELIVERING POWER TO LOW VOLTAGE LOADS (VOLTAGE BELOW 1KV).**
- **THESE TRANSFORMERS CONNECTS BETWEEN HV DISTRIBUTION BUSES AND LV DISTRIBUTION BUSES OF THE PLANT.**
- **THEIR RATING WILL BE AROUND 1 TO 5MVA, NATURAL OIL COOLING OR AIR COOLED TRANSFORMERS ARE USED.**
- **SOME OF THE POINTS RELATED TO STATION AUXILIARY TRANSFORMERS ARE LISTED BELOW:**
 - **THESE TRANSFORMERS ARE LOCATED IN POWER PLANT TO STEP DOWN VOLTAGE FROM 6.6KV TO 415V.**
 - **THE RATING FOR THIS TRANSFORMER CORRESPONDS TO THE RATING OF THE AUXILIARY LOAD IT SHOULD BE BEARING.**
 - **THESE TRANSFORMERS ARE INDOOR TYPE AND USUALLY DRY TYPE TRANSFORMERS ARE USED.**

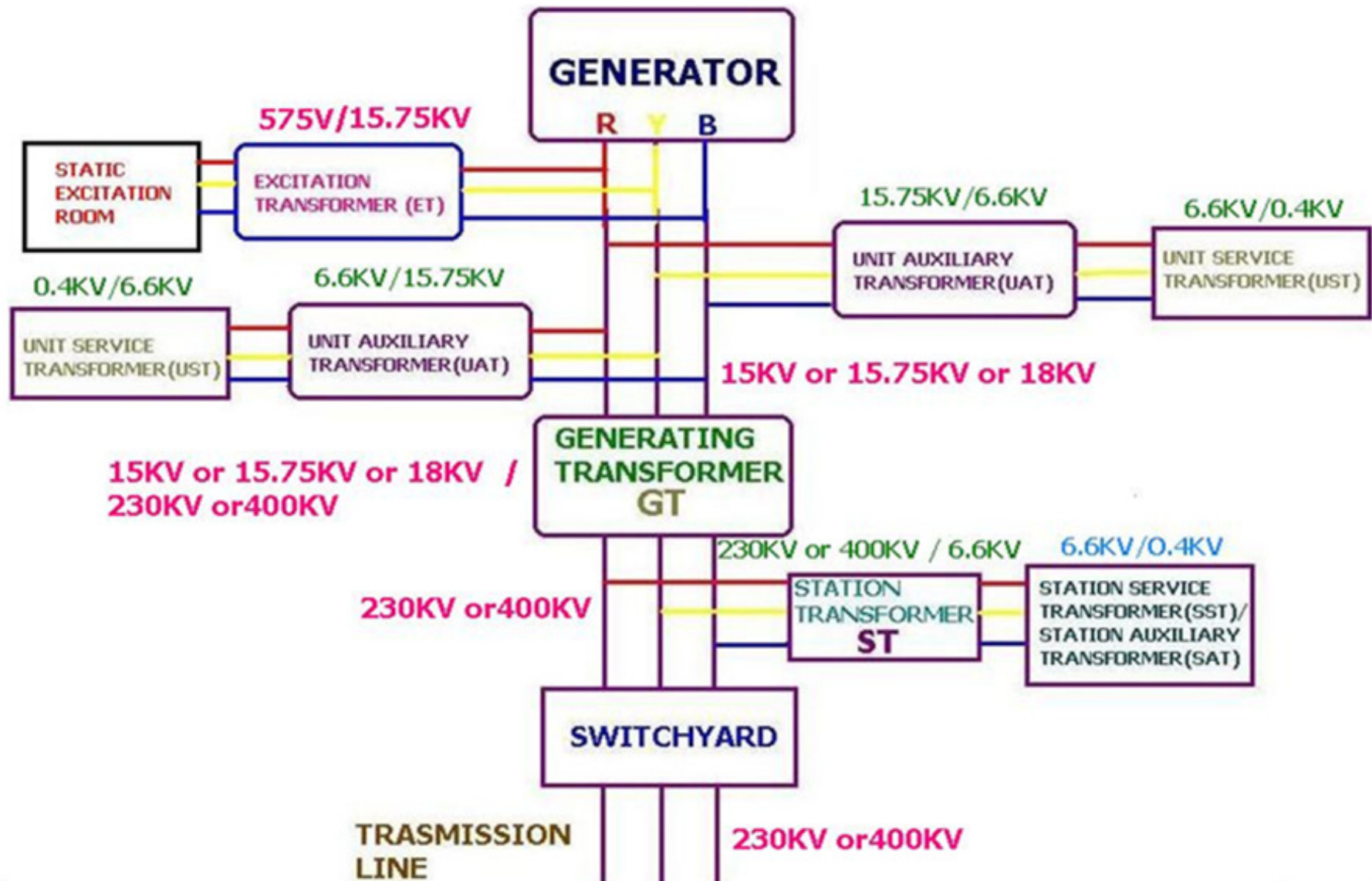
AUXILIARY TRANSFORMERS



**CUTAWAY VIEW OF OIL
IMMERSED CONSTRUCTION
TRANSFORMER**

- **THE CONSERVATOR (RESERVOIR) AT TOP PROVIDES OIL TO ATMOSPHERE ISOLATION AS COOLANT LEVEL AND TEMPERATURE CHANGES.**
- **THE WALLS AND FINS PROVIDE REQUIRED HEAT DISSIPATION BALANCE**

TYPICAL 210 MW LINE DIAGRAM



INSTRUMENT TRANSFORMERS

❑ STEP DOWN VALUES TO SAFE LEVELS FOR MEASUREMENT

➤ POTENTIAL TRANSFORMERS

- **ALSO CALLED VOLTAGE TRANSFORMERS**
- **STANDARD OUTPUT 120V**

➤ CURRENT TRANSFORMERS

- **STANDARD OUTPUT OF 1 OR 5 AMPS**
- **METERING AND RELAYING STANDARDS**
- **CAN PRODUCE HIGH VOLTAGES IF OPEN CIRCUITED**

CONSTRUCTIONAL FEATURES OF MAIN TRANSFORMER AND ACCESSORIES

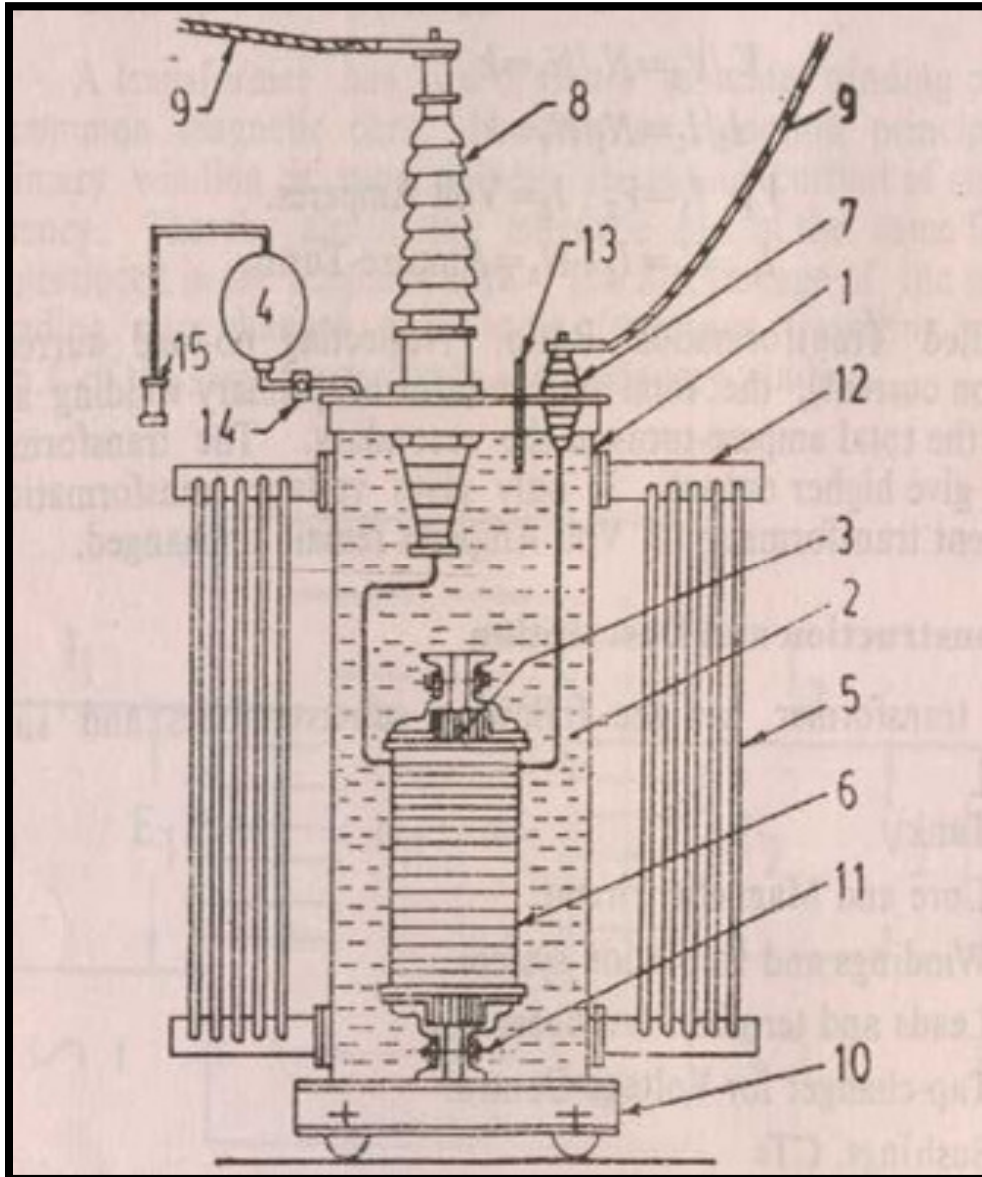
POWER TRANSFORMER



TRANSFORMER MAIN PARTS (EXTERNAL)

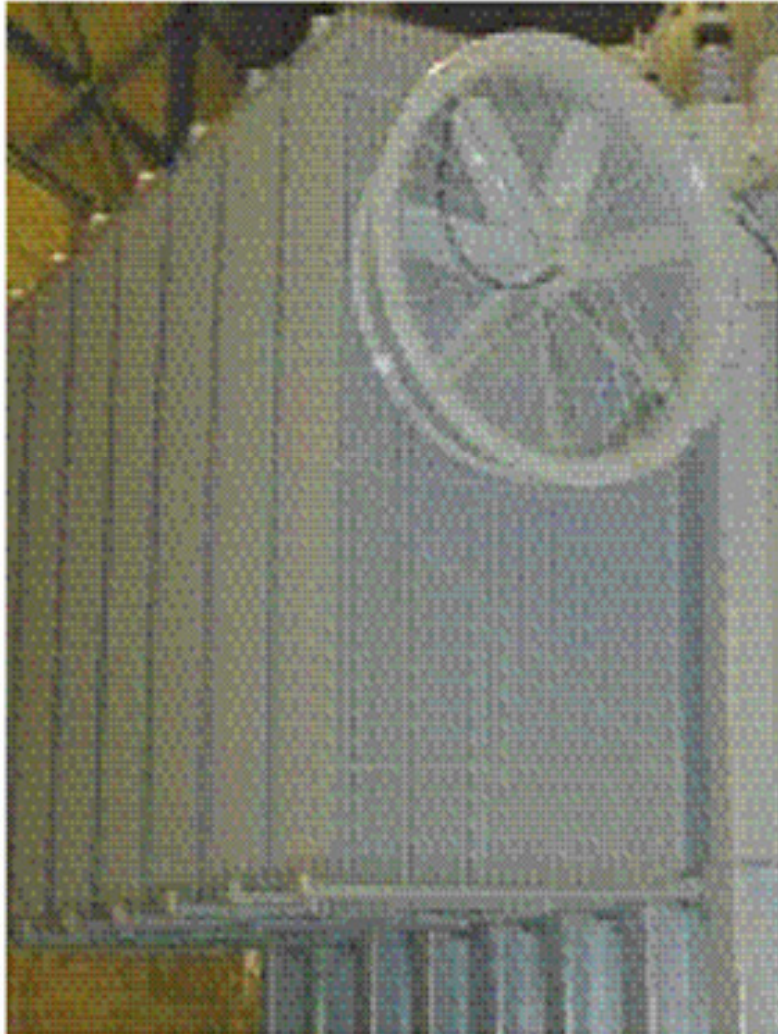
- 1. TANK**
- 2. RADIATOR/ FAN/PUMP**
- 3. BUSHINGS**
- 4. TAP CHANGER**
- 5. CONSERVATOR**
- 6. BREATHER**
- 7. TEMPERATURE INDICATORS**
- 8. BUCHHOLZ RELAY/OIL SURGE RELAY**
- 9. OIL LEVEL GAUGE**
- 10. PRESSURE RELIEF DEVICE (PRD)**
- 11. VALVES**
- 12. ROLLER**
- 13. COOLER CONTROL CUBICLE (MARSHALLING BOX)**
- 14. REMOTE TAP CHANGER CONTROL CUBICLE (RTCC)**

PARTS OF A DISTRIBUTION TRANSFORMER



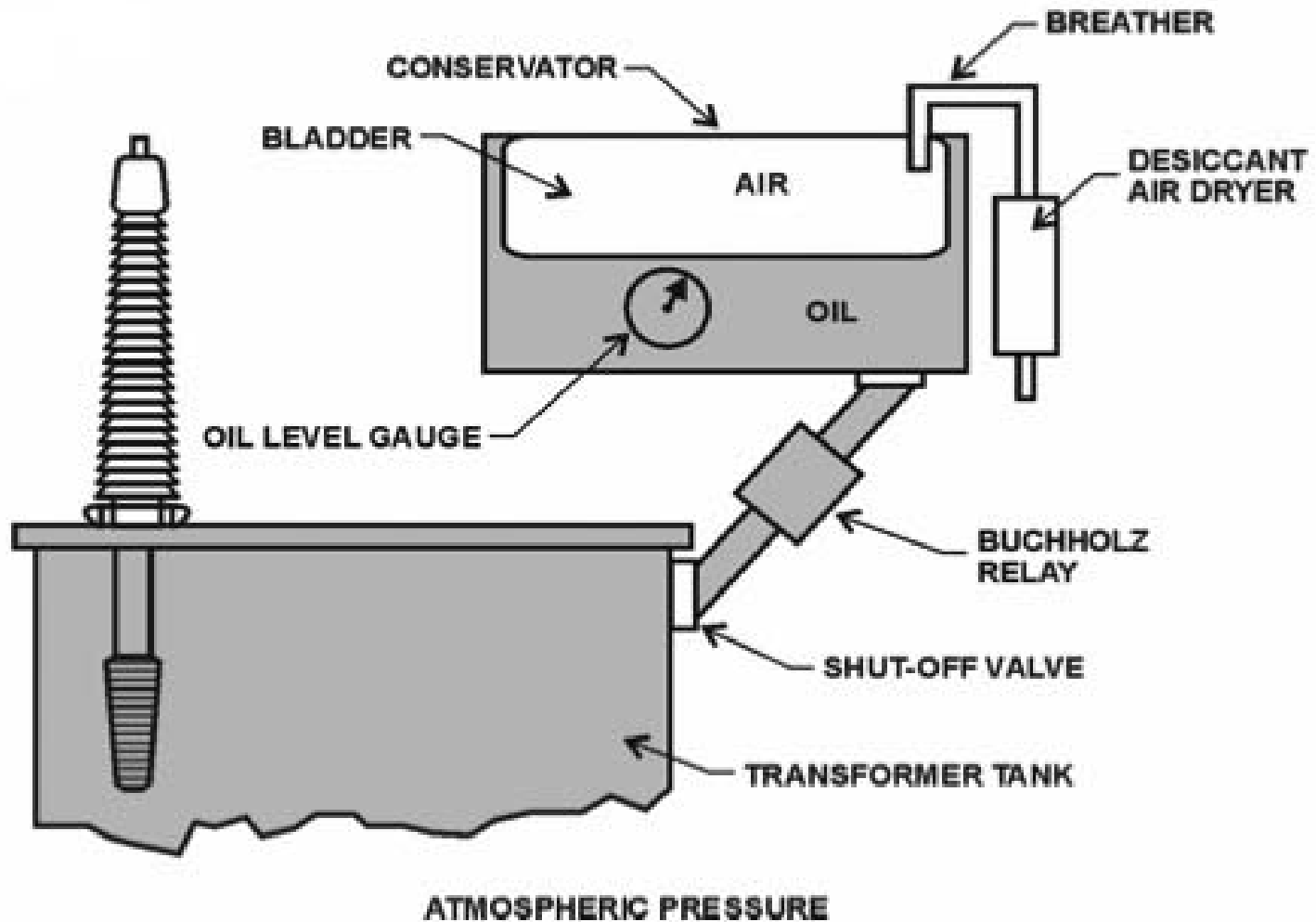
1. FLANGE FOR MOUNTING.
2. TANK, TANK COVER.
3. CORE.
4. CONSERVATOR.
5. COOLER (RADIATOR).
6. WINDINGS
7. LV BUSHING.
8. HV BUSHING.
9. TERMINALS CONNECTIONS.
10. CARRIAGE.
11. CORE-BOLTS.
12. HEADER.
13. THERMOMETER.
14. BUCHHOLZ RELAY.
15. BREATHER.

RADIATORS



- **RADIATORS ARE USED TO INCREASE THE COOLING AREA**
- **DUE TO TRANSFORMER OIL GETS HEATED UP, HOT OIL RISES TO TOP & FLOW TO RADIATOR**
- **IN RADIATOR WHILE FLOWING DOWN, OIL DISSIPATES HEAT TO COOLING MEDIUM**
- **COLD OIL AGAIN ENTERS TRANSFORMER AT BOTTOM OF RADIATOR**

CONSERVATOR



CONSERVATOR

- WITH THE VARIATION OF TEMPERATURE THERE IS CORRESPONDING VARIATION IN THE OIL VOLUME
- TO ACCOUNT FOR THIS, AN EXPANSION VESSEL CALLED **CONSERVATOR** IS ADDED TO THE TRANSFORMER WITH A CONNECTING PIPE TO THE **MAIN TANK**
- IN SMALLER TRANSFORMERS THIS VESSEL IS OPEN TO ATMOSPHERE THROUGH **DEHYDRATING BREATHERS** (TO KEEP THE AIR DRY)
- IN LARGER TRANSFORMERS, AN **AIR BAG IS MOUNTED INSIDE THE CONSERVATOR** WITH THE INSIDE OF BAG OPEN TO ATMOSPHERE THROUGH THE **BREATHERS** AND THE OUTSIDE SURFACE OF THE BAG IN CONTACT WITH THE OIL SURFACE.

SILICA GEL BREATHER

CONSERVATOR

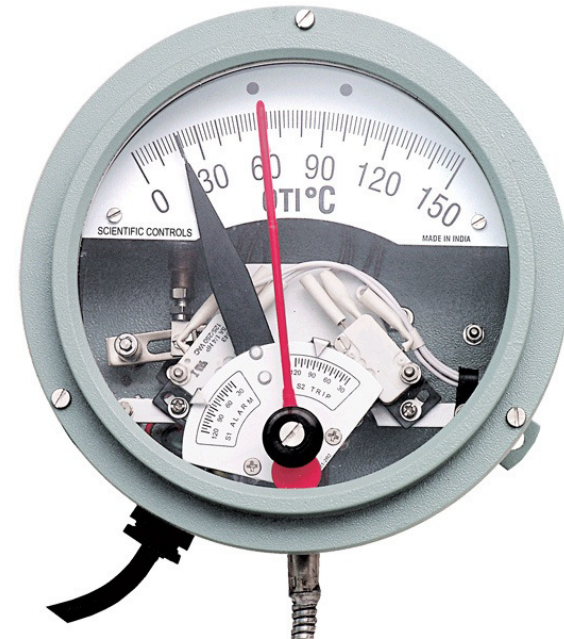
SILICA GEL BREATHER



SILICA GEL BREATHER

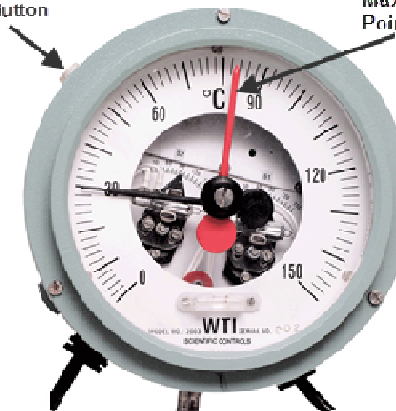
- **BOTH TRANSFORMER OIL AND CELLULOSIC PAPER ARE HIGHLY HYGROSCOPIC**
- **PAPER BEING MORE HYGROSCOPIC THAN THE MINERAL OIL TO THE MOISTURE, IF NOT EXCLUDED FROM THE OIL SURFACE IN CONSERVATOR, THIS WILL FIND ITS WAY FINALLY INTO THE PAPER INSULATION AND CAUSES REDUCTION INSULATION STRENGTH OF TRANSFORMER.**
- **TO MINIMISE THIS THE CONSERVATOR IS ALLOWED TO BREATHE ONLY THROUGH THE SILICAGEL COLUMN, WHICH ABSORBS THE MOISTURE IN AIR BEFORE IT ENTERS THE-CONSERVATOR AIR SURFACE.**

WINDING / OIL TEMPERATURE INDICATOR



Maximum Indicator
Reset Button

Maximum Indicator
Pointer (Red)



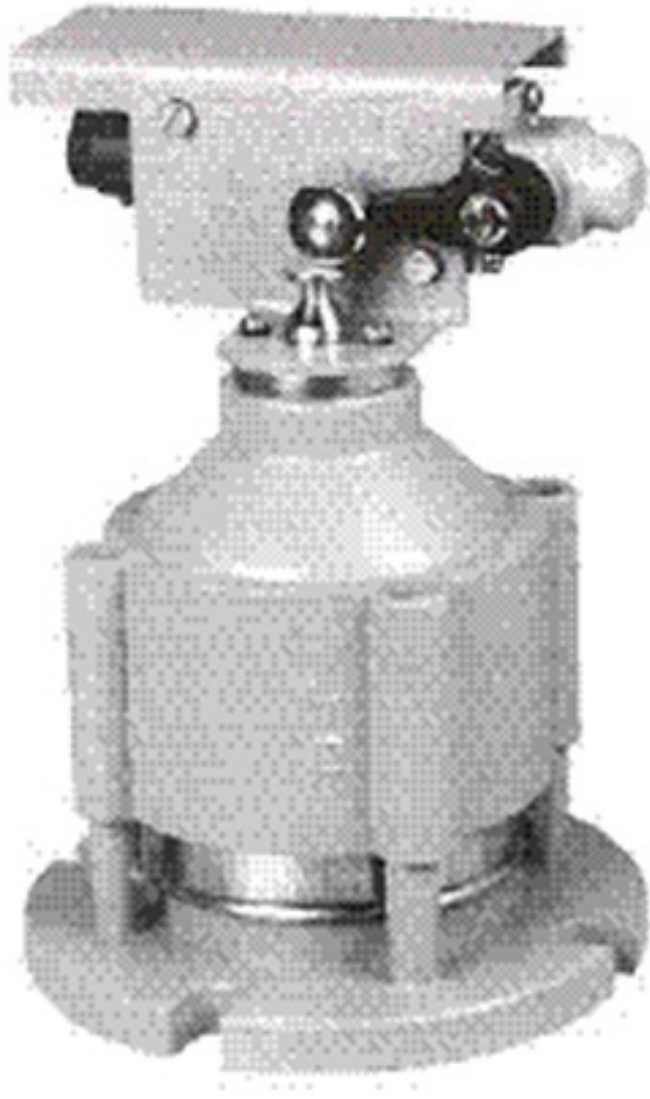
TEMPERATURE INDICATORS

- **MOST OF THE TRANSFORMER (SMALL TRANSFORMERS HAVE ONLY OTI) ARE PROVIDED WITH INDICATORS THAT DISPLACE OIL TEMPERATURE AND WINDING TEMPERATURE**
- **THERE ARE THERMOMETERS POCKETS PROVIDED IN THE TANK TOP COVER**
- **OIL TEMPERATURE MEASURED IS THAT OF THE TOP OIL, WHERE AS THE WINDING TEMPERATURE MEASUREMENT IS INDIRECT, THIS IS DONE BY ADDING THE TEMPERATURE RISE**
- **FOR PROPER FUNCTIONING OR OTI & WTI IT IS ESSENTIAL TO KEEP THE THERMOMETERS POCKET CLEAN AND FILLED WITH OIL.**

PRESSURE RELIEF DEVICE/EXPANSION VENT

- **TRANSFORMERS TANK IS A PRESSURE VESSEL AS THE INSIDE PRESSURE CAN GROUP STEEPLY WHENEVER THERE IS A FAULT IN THE WINDINGS AND THE SURROUNDING OIL IS SUDDENLY VAPORIZED**
- **TANKS ARE TESTED FOR A PRESSURE WITHSTAND CAPACITY OF 0.35 kg/ cm² TO PREVENT BURSTING OF THE TANK, THESE TANKS ARE IN ADDITION PROVIDED WITH EXPANSION VENTS WITH A THIN DIAPHRAGM MADE OF BAKELITE/COPPER/GLASS AT THE END**
- **IN PRESENT DAY TRANSFORMERS, PRESSURE RELIEF DEVICES ARE REPLACING THE EXPANSION VENTS, THESE ARE SIMILAR TO SAFETY VALVES ON BOILERS (SPRING LOADED).**

PRESSURE RELIEF DEVICE (PRD)



- **WORKS AS A PRESSURE RELEASING VALVE**
- **EQUIPPED WITH ALARM/TRIP CONTACT**
- **OPERATING PRESSURE: 8 kg/ cm²**

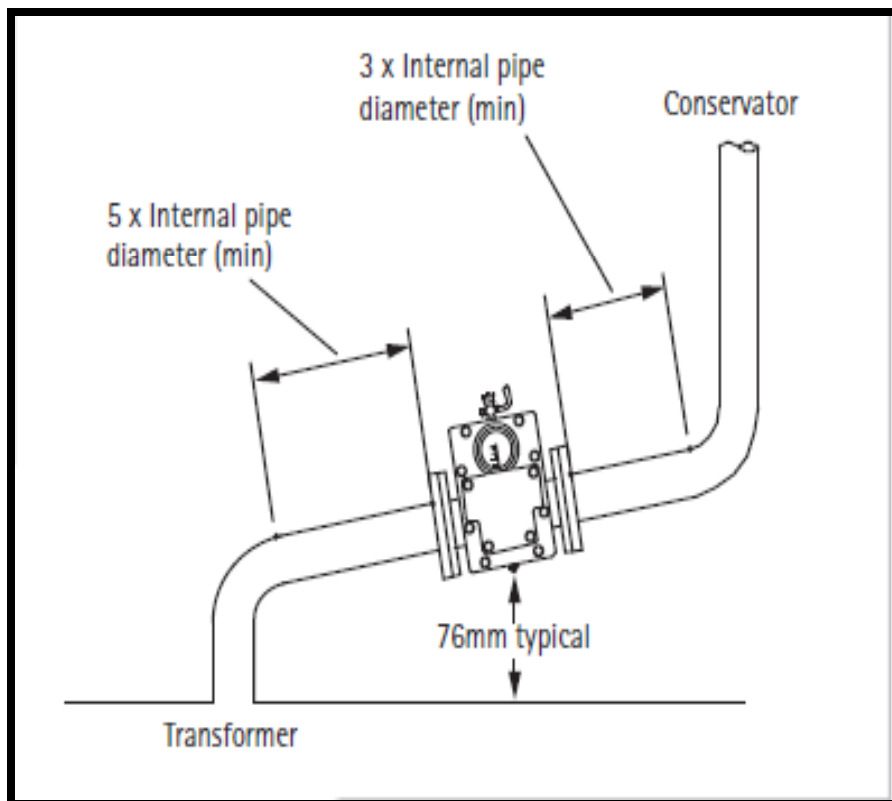
BUCHOLTZ RELAY AND MAIN PROTECTIONS

BUCHHOLZ RELAY

- **BUCHHOLZ RELAY** IS A GAS- ACTUATED RELAY INSTALLED IN OIL-IMMERSED TRANSFORMERS FOR PROTECTION AGAINST ALL KIND OF FAULTS.
- IT IS USED TO GIVES AN ALARM IN CASE OF SLOW DEVELOPING FAULTS OR INCIPIENT FAULTS IN THE TRANSFORMER AND TO **DISCONNECT THE TRANSFORMER FROM THE SUPPLY IN THE EVENT OF SEVERE INTERNAL FAULTS.**
- IT IS INSTALLED IN THE **PIPE BETWEEN THE CONSERVATOR AND MAIN TANK** AS SHOWN IN FIG ON NEXT SLIDE. THIS RELAY IS USED IN OIL-IMMERSED TRANSFORMERS OF RATING ABOVE 750 kVA.

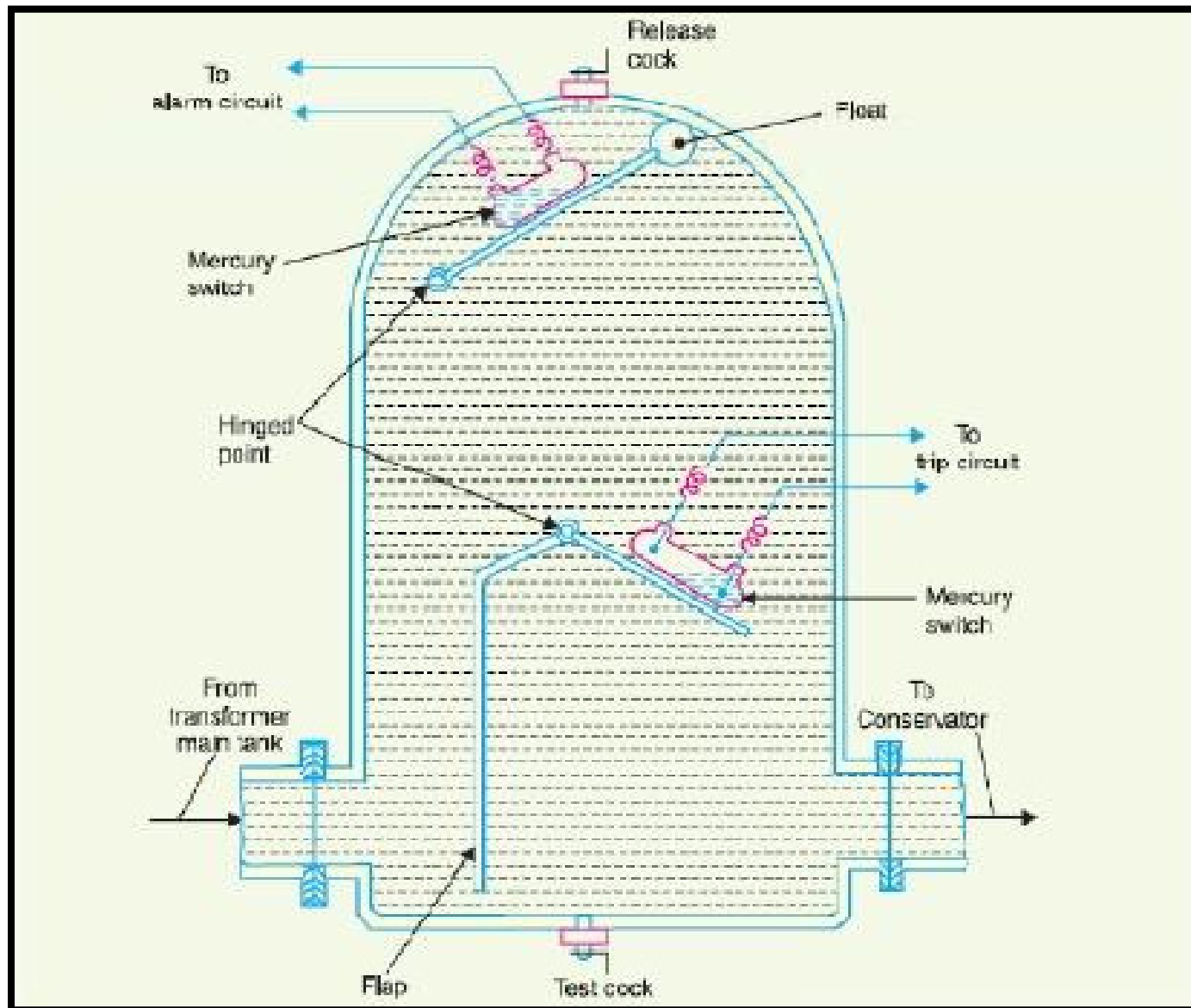
BUCHHOLZ PROTECTION

- **BUCHHOLZ PROTECTION IS NORMALLY PROVIDED ON ALL TRANSFORMERS FITTED WITH A CONSERVATOR. THE BUCHHOLZ RELAY IS CONTAINED IN A CAST HOUSING WHICH IS CONNECTED IN THE PIPE TO THE CONSERVATOR, AS IN FIGURE BELOW**



- **A TYPICAL BUCHHOLZ RELAY WILL HAVE TWO SETS OF CONTACTS.**
- **ONE IS ARRANGED TO OPERATE FOR SLOW ACCUMULATIONS OF GAS, THE OTHER FOR BULK DISPLACEMENT OF OIL IN THE EVENT OF A **HEAVY INTERNAL FAULT**.**
- **AN ALARM IS GENERATED FOR THE FORMER, BUT THE LATTER IS USUALLY DIRECT-WIRED TO THE **CB TRIP RELAY**.**

BUCHHOLZ RELAY



THE OPERATION OF BUCHHOLZ RELAY

- **IN CASE OF SLOW DEVELOPING FAULTS WITHIN THE TRANSFORMER, THE HEAT DUE TO THE FAULT CAUSES DECOMPOSITION OF SOME TRANSFORMER OIL IN THE MAIN TANK.**
- **THE PRODUCTS OF DECOMPOSITION MAINLY CONTAIN 70% OF HYDROGEN GAS. THE HYDROGEN GAS BEING LIGHT TRIES TO GO INTO THE CONSERVATOR AND IN THE PROCESS GETS TRAPPED IN THE UPPER PART OF THE RELAY CHAMBER.**
- **WHEN A PREDETERMINED AMOUNT OF GAS GETS ACCUMULATED, IT EXERTS SUFFICIENT PRESSURE ON THE FLOAT TO CAUSE IT TO TILT AND CLOSE THE CONTACTS OF MERCURY SWITCH ATTACHED TO IT. THIS COMPLETES THE ALARM CIRCUIT TO SOUND AN ALARM.**

THE OPERATION OF BUCHHOLZ RELAY

- **IF SERIOUS FAULT OCCUR IN THE TRANSFORMER, AN ENORMOUS AMOUNT OF GAS IS GENERATED IN THE MAIN TANK. THE OIL IN THE MAIN TANK RUSHES TOWARDS THE CONSERVATOR VIA THE BUCHHOLZ RELAY AND IN DOING SO IT TILTS THE FLAP TO CLOSE THE CONTACTS OF MERCURY SWITCH. THIS COMPLETES THE TRIP CIRCUIT TO OPEN THE CIRCUIT BREAKER CONTROLLING THE TRANSFORMER.**

BUCHHOLZ PROTECTION

- **THE BUCHHOLZ PROTECTION DEVICE WILL GIVE AN ALARM FOR THE FOLLOWING FAULT CONDITIONS, ALL OF WHICH ARE OF A LOW ORDER OF URGENCY.**
 - a. **HOT SPOTS ON THE CORE DUE TO SHORT CIRCUIT OF LAMINATION INSULATION**
 - b. **CORE BOLT INSULATION FAILURE**
 - c. **FAULTY JOINTS**
 - d. **INTERTURN FAULTS OR OTHER WINDING FAULTS INVOLVING ONLY LOWER POWER INFEDS**
 - e. **LOSS OF OIL DUE TO LEAKAGE**
- **WHEN A MAJOR WINDING FAULT OCCURS, THIS CAUSES A SURGE OF OIL, WHICH DISPLACES THE LOWER FLOAT AND THUS CAUSES ISOLATION OF THE TRANSFORMER. THIS ACTION WILL TAKE PLACE FOR:**
 - i. **ALL SEVERE WINDING FAULTS, EITHER TO EARTH OR INTERPHASE**
 - ii. **LOSS OF OIL IF ALLOWED TO CONTINUE TO A DANGEROUS DEGREE**

BUCHHOLZ PROTECTION

- **AN INSPECTION WINDOW IS USUALLY PROVIDED ON EITHER SIDE OF THE GAS COLLECTION SPACE. VISIBLE WHITE OR YELLOW GAS INDICATES THAT INSULATION HAS BEEN BURNT, WHILE BLACK OR GREY GAS INDICATES THE PRESENCE OF, DISSOCIATED OIL.**
- **IN THESE CASES THE GAS WILL PROBABLY BE INFLAMMABLE, WHEREAS RELEASED AIR WILL NOT. A VENT VALVE IS PROVIDED ON THE TOP OF THE HOUSING FOR THE GAS TO BE RELEASED OR COLLECTED FOR ANALYSIS.**
- **TRANSFORMERS WITH FORCED OIL CIRCULATION MAY EXPERIENCE OIL FLOW TO/FROM THE CONSERVATOR ON STARTING/STOPPING OF THE PUMPS. THE BUCHHOLZ RELAY MUST NOT OPERATE IN THIS CIRCUMSTANCE.**

TYPES OF TRANSFORMER COOLING

TRANSFORMER COOLING METHODS

- **LOSSES IN THE TRANSFORMER ARE OF THE ORDER OF 1% OF ITS FULL LOAD KW RATING**
- **THESE LOSSES GET CONVERTED IN THE HEAT THEREBY THE TEMPERATURE OF THE WINDINGS, CORE, OIL AND THE TANK RISES**
- **THE HEAT IS DISSIPATED FROM THE TRANSFORMER TANK AND THE RADIATOR IN TO THE ATMOSPHERE**
- **TRANSFORMER COOLING HELPS IN MAINTAINING THE TEMPERATURE RISE OF VARIOUS PARTS WITHIN PERMISSIBLE LIMITS**
- **IN CASE OF TRANSFORMER, COOLING IS PROVIDED BY THE CIRCULATION OF THE OIL**
- **TRANSFORMER OIL ACTS AS BOTH INSULATING MATERIAL AND ALSO COOLING MEDIUM IN THE TRANSFORMER**
- **FOR SMALL RATING TRANSFORMERS HEAT IS REMOVED FROM THE TRANSFORMER BY NATURAL THERMAL CONVECTION**
- **FOR LARGE RATING TRANSFORMERS THIS TYPE OF COOLING IS NOT SUFFICIENT, FOR SUCH APPLICATIONS FORCED COOLING IS USED.**

TRANSFORMER COOLING METHODS

❑ DIFFERENT TRANSFORMER COOLING METHODS ARE:

➤ AIR COOLING FOR DRY TYPE TRANSFORMERS:

- ❖ AIR NATURAL TYPE (A.N.)
- ❖ AIR FORCED TYPE (A.F.)

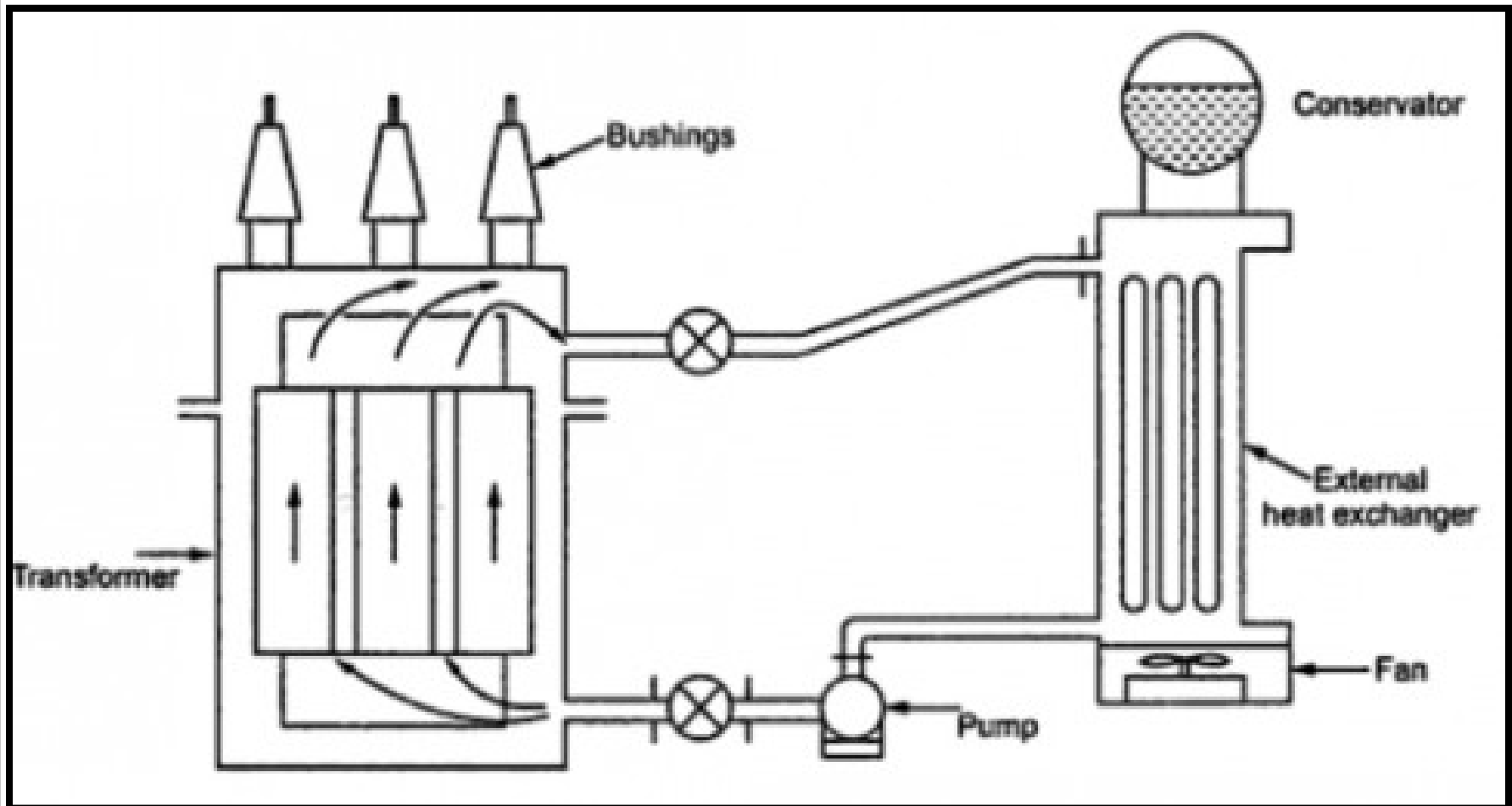
➤ COOLING FOR OIL IMMERSED TRANSFORMERS:

- ❖ OIL NATURAL AIR NATURAL TYPE (O.N.A.N.)
- ❖ OIL NATURAL AIR FORCED TYPE (O.N.A.F.)
- ❖ OIL FORCED AIR NATURAL TYPE (O.F.A.N.)
- ❖ OIL FORCED AIR FORCED TYPE (O.F.A.F.)

➤ OIL IMMERSED WATER COOLING:

- ❖ OIL NATURAL WATER FORCED (O.N.W.F.)
- ❖ OIL FORCED WATER FORCED (O.F.W.F.)

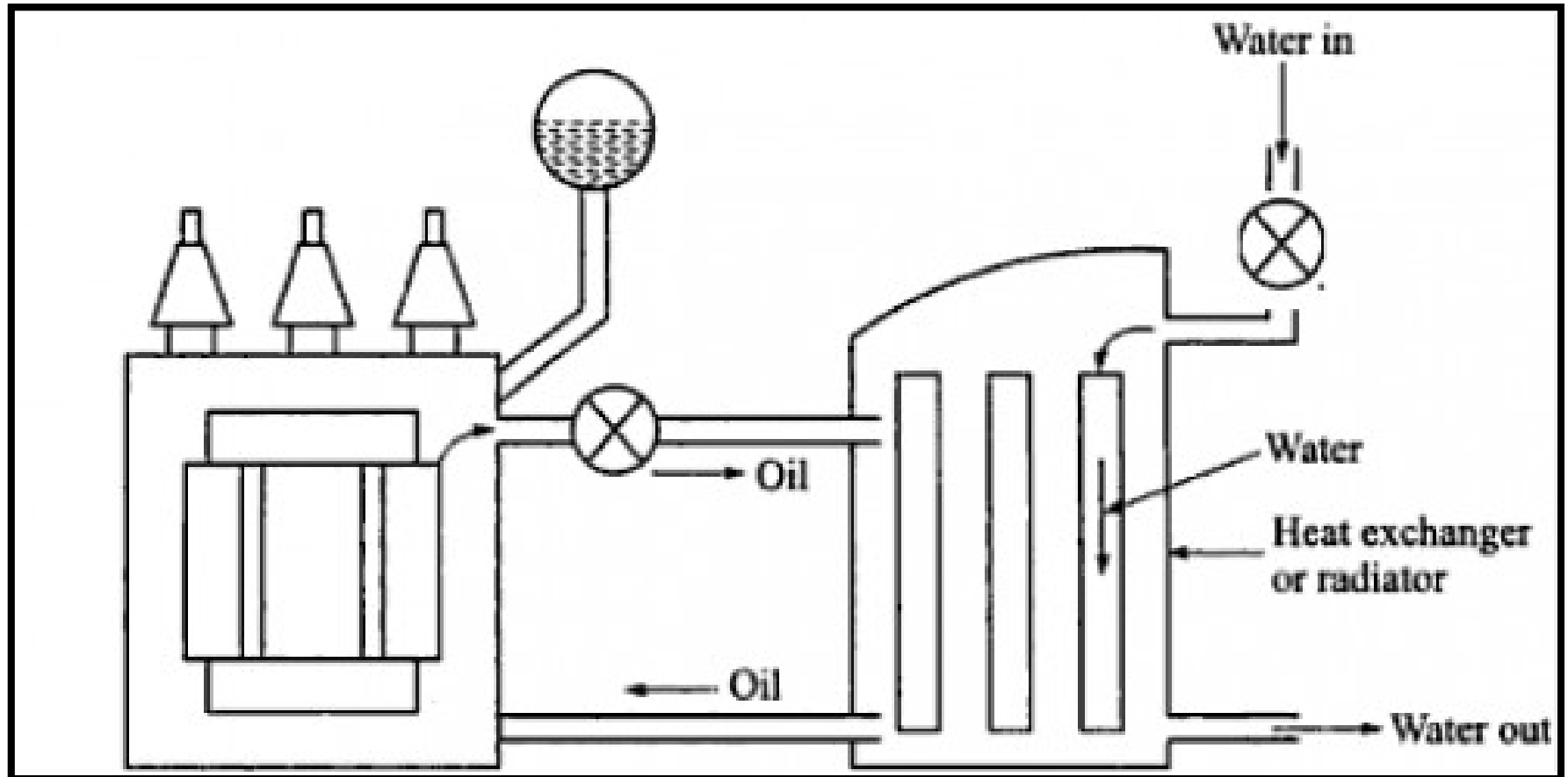
OIL FORCED AIR FORCED TRANSFORMER COOLING



OIL FORCED AIR FORCED TRANSFORMER COOLING

- **TRANSFORMERS ABOVE 60 MVA EMPLOY A COMBINATION OF FORCED OIL AND FORCED AIR COOLING**
- **OIL NATURAL AIR FORCED TYPE OF COOLING IS NOT ADEQUATE TO REMOVE THE HEAT CAUSED BY THE LOSSES WHICH IS APPROXIMATELY EQUAL TO 1% OF THE TRANSFORMER RATING (0.6MW)**
- **IN CASE OF FORCED OIL AND FORCED AIR COOLING SYSTEM A SEPARATE COOLER IS MOUNTED AWAY FROM THE TRANSFORMER TANK**
- **THIS COOLER IS CONNECTED TO THE TRANSFORMER WITH PIPES AT THE BOTTOM AND THE TOP**
- **THE OIL IS CIRCULATED FROM THE TRANSFORMER TO THE COOLER THROUGH THE PUMP**
- **THE COOLER IS PROVIDED WITH THE FANS WHICH BLAST AIR ON THE COOLING TUBES**
- **THIS TYPE OF COOLING IS PROVIDED FOR THE HIGHER RATING TRANSFORMERS AVAILABLE AT THE SUBSTATIONS AND POWER STATIONS.**

OIL FORCED WATER FORCED TRANSFORMER COOLING



OIL FORCED WATER FORCED TRANSFORMER COOLING

- **THIS TYPE OF COOLING SYSTEM NEEDS A HEAT EXCHANGER IN WHICH THE HEAT OF THE TRANSFORMER OIL IS GIVEN TO THE COOLING WATER**
- **THE COOLING WATER IS TAKEN AWAY AND COOLED IN SEPARATE COOLERS**
- **THE OIL IS FORCED THROUGH THE HEAT EXCHANGER**
- **THE OIL PUMP PUMPS THE OIL FROM TRANSFORMER TO THE HEAT EXCHANGER THROUGH THE TOP PIPES**
- **OIL FROM THE HEAT EXCHANGER IS PUMPED BACK TO THE TRANSFORMER THROUGH THE BOTTOM PIPE**
- **THIS TYPE OF COOLING IS PROVIDED FOR VERY LARGE TRANSFORMERS WHICH HAVE RATINGS OF SOME HUNDREDS OF MVA (GENERATING TRANSFORMER WILL HAVE VERY HIGH RATING AND RATING EQUAL TO THE RATING OF THE GENERATOR)**
- **THIS TYPE OF TRANSFORMERS IS USED IN LARGE SUBSTATIONS AND POWER PLANTS.**

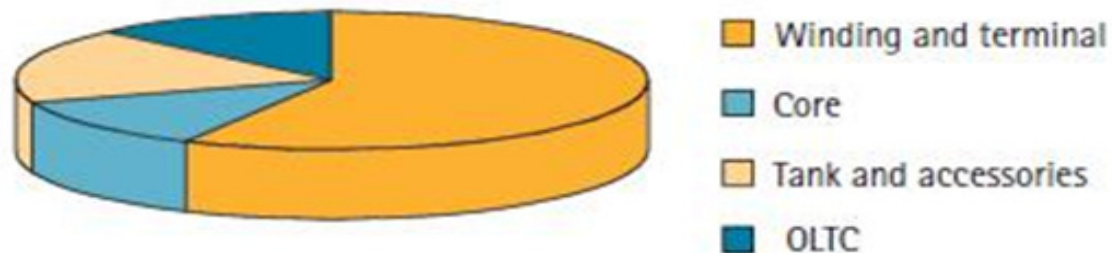
TRANSFORMER FAULTS

POWER TRANSFORMER



TRANSFORMER FAULTS ARE GENERALLY CLASSIFIED INTO SIX CATEGORIES

1. WINDING AND TERMINAL FAULTS
2. CORE FAULTS
3. TANK AND TRANSFORMER ACCESSORY FAULTS
4. ON-LOAD TAP CHANGER FAULTS
5. ABNORMAL OPERATING CONDITIONS
6. SUSTAINED OR UNCLEARED EXTERNAL FAULTS



▪ THE APPROXIMATE PROPORTION OF FAULTS DUE TO EACH OF THE CAUSES LISTED ABOVE IS SHOWN IN FIGURE

EXTERNALLY APPLIED CONDITIONS

❑ SOURCES OF ABNORMAL STRESS IN A TRANSFORMER ARE:

- ❖ OVERLOAD**
- ❖ SYSTEM FAULTS**
- ❖ OVERVOLTAGE**
- ❖ REDUCED SYSTEM FREQUENCY**

FAILURES & CAUSES

- **INSUFFICIENT OIL LEVEL**
- **SEEPAGE OF WATER IN OIL**
- **PROLONGED OVER LOADING**
- **SINGLE PHASE LOADING**
- **UNBALANCED LOADING**
- **FAULTY TERMINATION (IMPROPER SIZED LUGS ETC)**
- **POWER THEFT**
- **PROLONGED SHORT CIRCUIT**
- **FAULTY OPERATION OF TAP CHANGER SWITCH**
- **LACK OF INSTALLATION CHECKS**

MAINTENANCE SCHEDULES

HOURLY

- ❑ **THE FOLLOWING PARAMETERS ARE TO BE CHECKED EVERY HOUR AND RECORDED, IF THE OBSERVED VALUE EXCEEDS THE VALUE GIVEN BY THE SUPPLIER, IMMEDIATE REMEDIAL ACTION SHOULD BE TAKEN.**
 - 1. WINDING TEMPERATURE**
 - 2. OIL TEMPERATURE**
 - 3. LOAD CURRENT**
 - 4. TERMINAL VOLTAGE**
- ❑ **NORMALLY, MAXIMUM ALLOWED WINDING TEMPERATURE IS 55°C ABOVE AMBIENT AND OIL TEMPERATURE IS 45°C ABOVE AMBIENT (ACTUAL ALLOWED VALUE MAY VARY FROM SUPPLIER TO SUPPLIER).**

MAINTENANCE SCHEDULES

DAILY

- 1. OIL LEVEL IN MAIN CONSERVATOR**
- 2. OIL LEVEL IN OLTC**
- 3. OIL LEVEL IN BUSHING**
- 4. LEAKAGE OF WATER INTO COOLER (OFWF)**
- 5. WATER TEMPERATURE (OFWF)**
- 6. WATER FLOW (OFWF)**
- 7. COLOUR OF SILICA GEL**

MAINTENANCE SCHEDULES

QUARTERLY CHECKING/ REPLACEMENT

- RECONDITIONING OF SILICA GEL BREATHER
- CHECKING OF WATER COOLER FUNCTIONING
- CHECKING OF COOLING FANS FUNCTIONING
- GEAR OIL FOR TAP CHANGER MECHANISM
- CHECKING OF COOLING PUMPS AND MOTOR FUNCTIONING

HALF YEARLY

- ❑ INSPECTION OF ALL GASKETS AND JOINTS

THANK YOU!

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