Electric Power Distribution Systems II

EME410

Spring 21-22

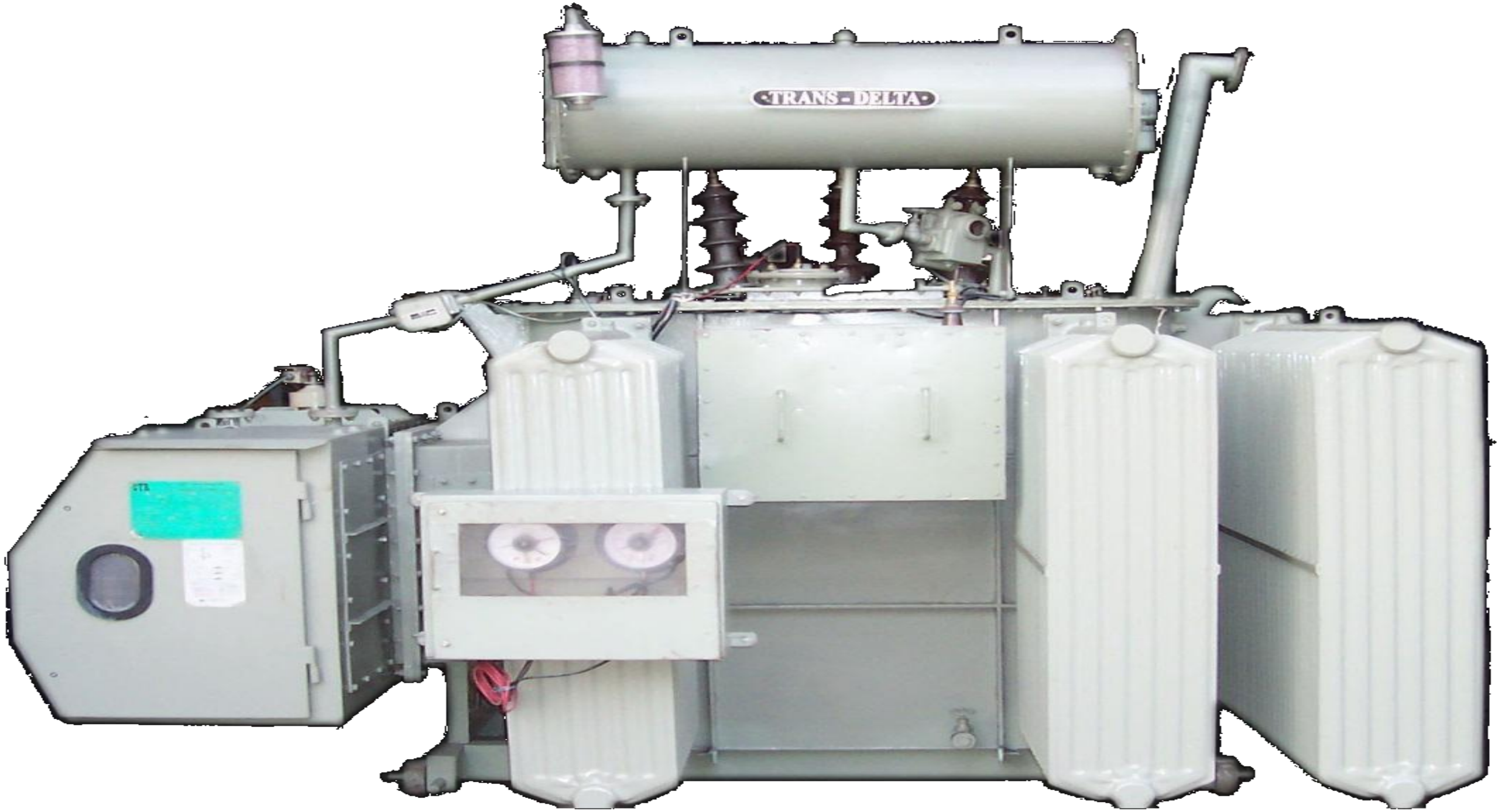
Lecture 4

Transformer sizing and Selection

INSTRUCTOR

DR / AYMAN SOLIMAN

TRANSFORMERS



What is a transformer ?

It is an electrical device that
transfers electrical power from
one circuit to another
by magnetic coupling

It does so without change of frequency
and without any moving parts.

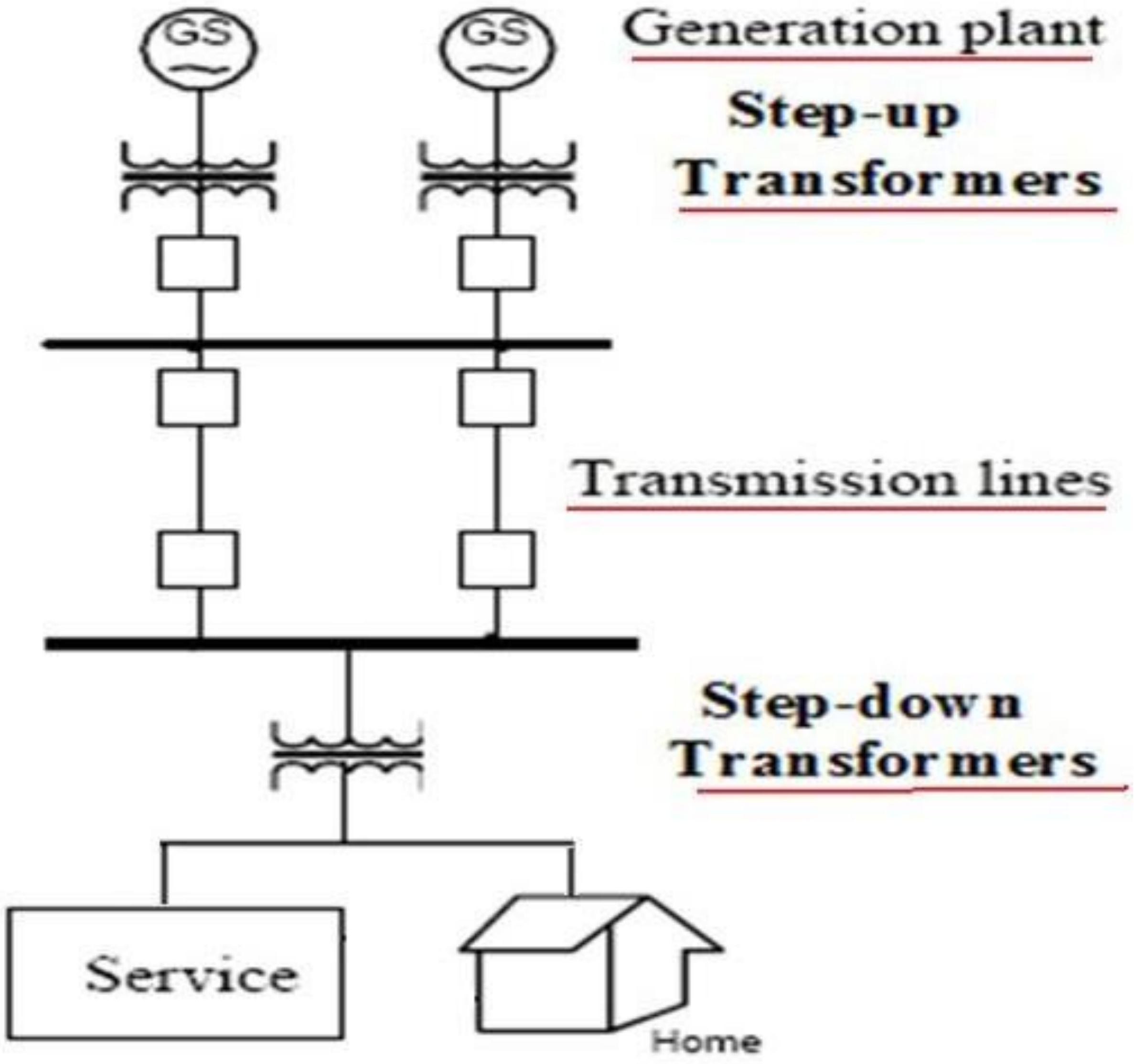
Transformer works only with AC

Why do we need transformers?

Because transformers

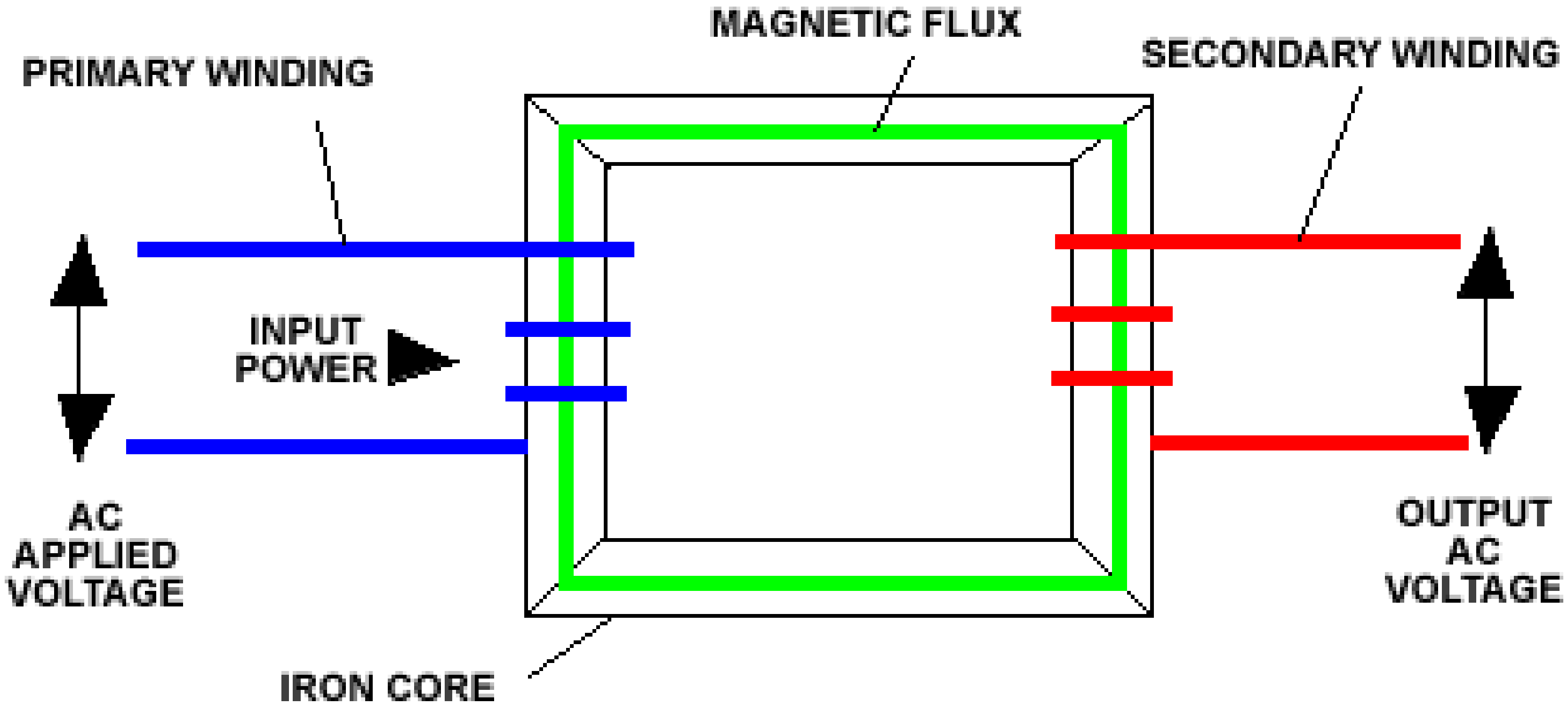
- adjust the voltage coming into the appliance to keep it operating properly
- measure high voltages and currents in a safe manner.
- help using devices in wet areas.

Why do we need transformers?



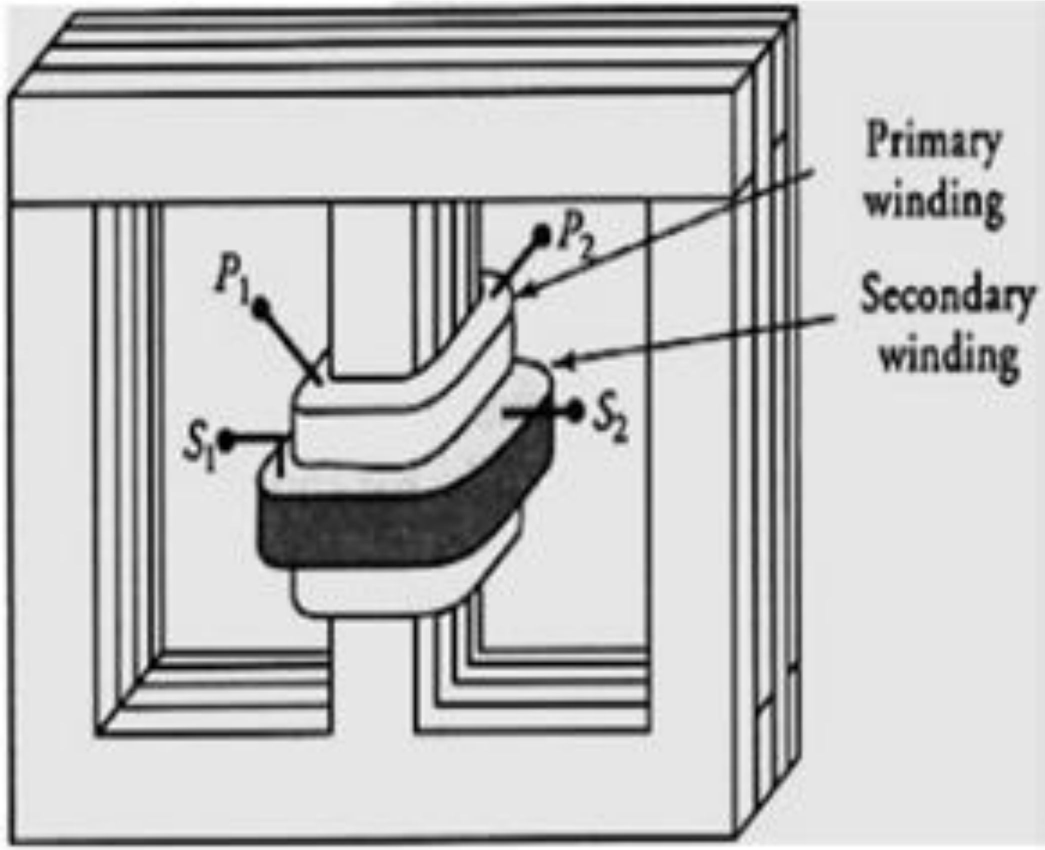
Construction of Transformer :

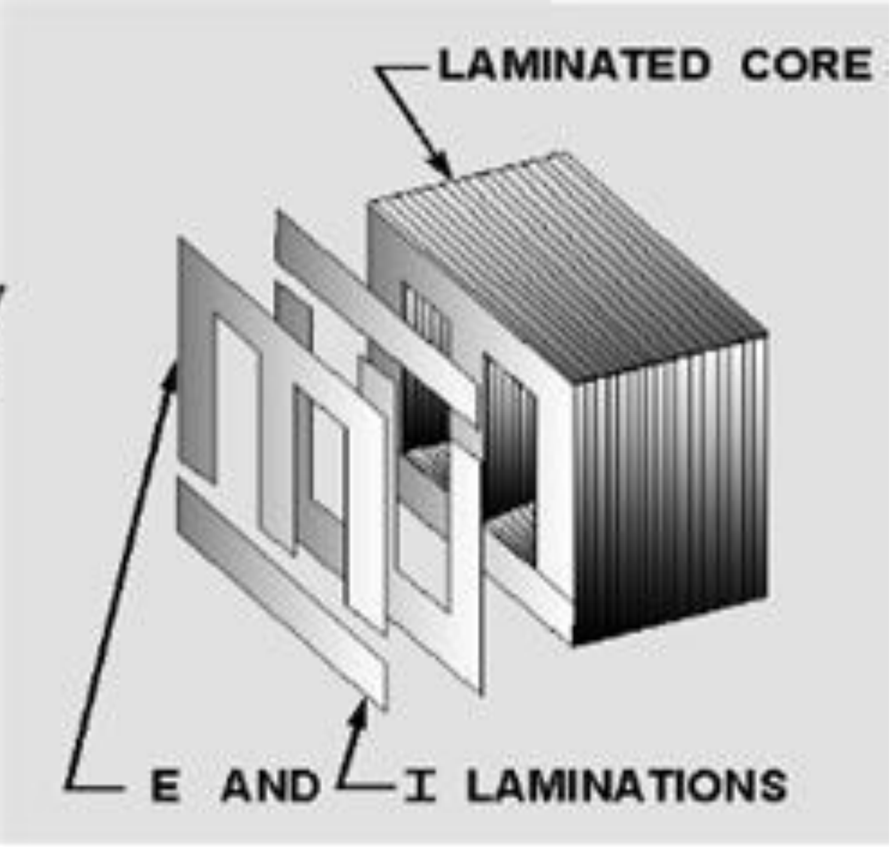
The transformer is very simple in construction It consists of magnetic circuit linking with two windings.



Construction of Transformer :

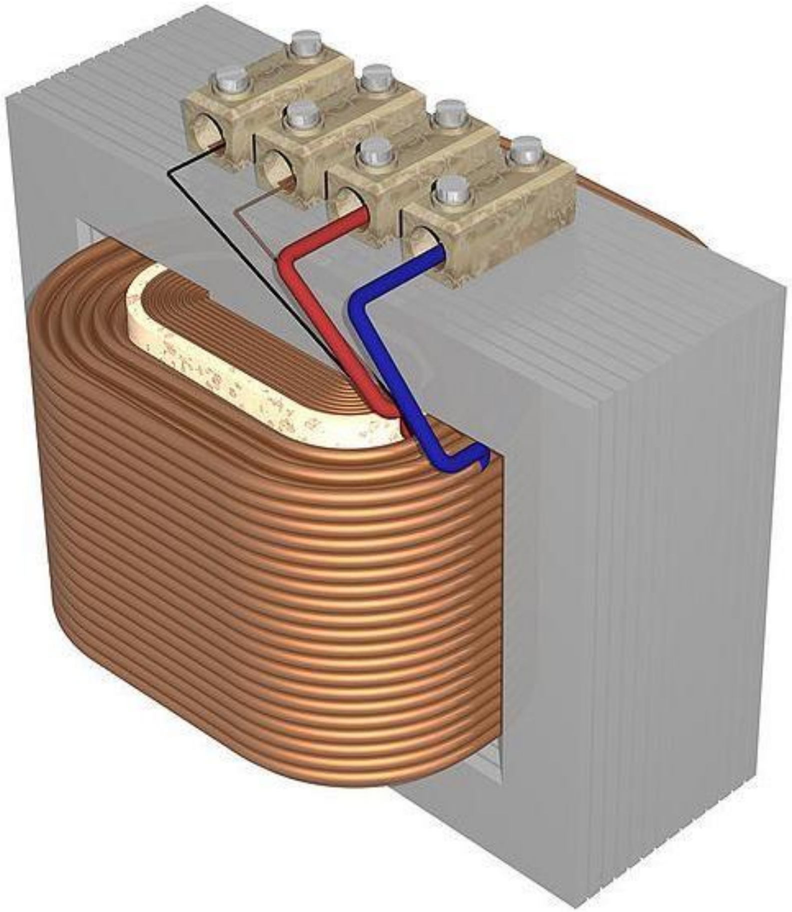
Core is made up of laminations to reduce the eddy current losses
The thickness of laminations is usually 0.4mm





Construction of Transformer

The coil windings are wound on the limbs and are insulated from each other

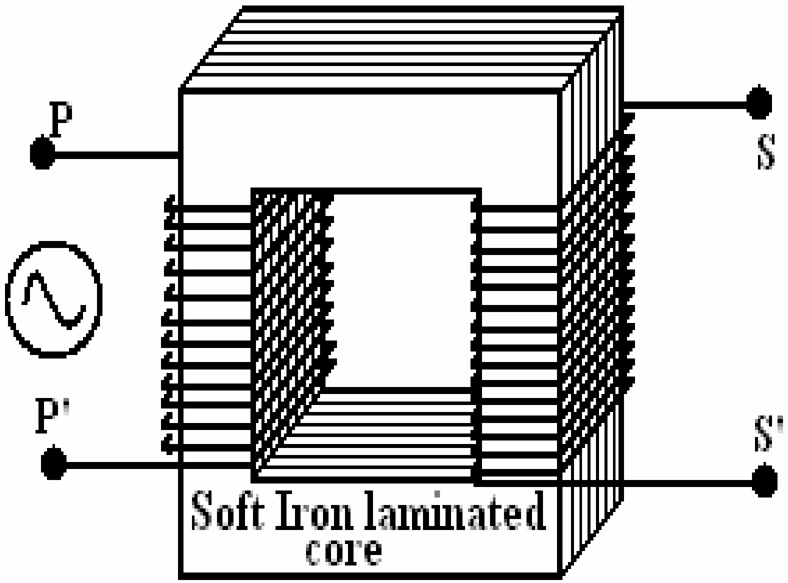


Function of Transformer Parts

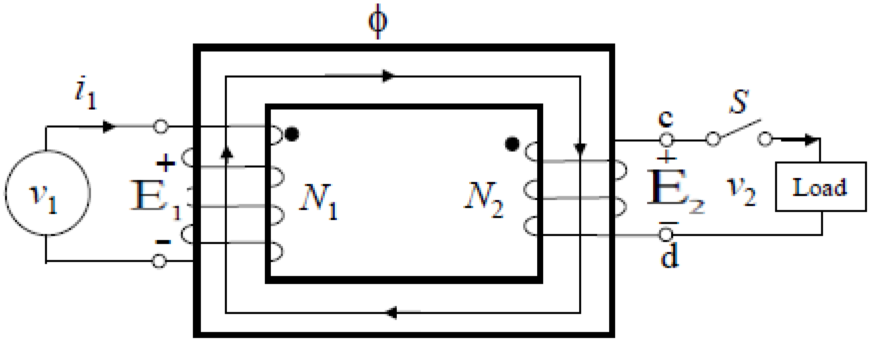
Piece	Function
Core	Provides a path for the magnetic
Primary winding	Receives the energy from the ac source
Secondary winding	Receives energy from the primary winding and delivers it to the load
Enclosure	Protects the above components from dirt, moisture, and damage

Principle of operation

1. When current in the primary coil changes being alternating in nature, a changing magnetic field is produced
2. This changing magnetic field gets associated with the secondary through the soft iron core
3. Hence magnetic flux linked with the secondary coil changes.
4. Which induces e.m.f. in the secondary.



Principle of operation



The rms value of the induced voltages are

$$E_1 = \frac{N_1 \Phi_p \omega}{\sqrt{2}} = \frac{2\pi f}{\sqrt{2}} \Phi_P N_1 = 4.44 f \Phi_P N_1$$

$$E_2 = 4.44 f \Phi_P N_2$$

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = a = turns\ ratio$$

Principle of operation

For ideal transformer E1=V1 and E2= V2

$$\frac{V_1}{V_2} = \frac{E_1}{E_2} = a$$

The power in ideal transformer

Then

$$V_1 I_1 = V_2 I_2$$

$$\frac{I_1}{I_2} = \frac{N_2}{N_1} = \frac{1}{a}$$

Transformer Rating

- It is written in terms of Apparent Power.
- Apparent power is the product of its rated current and rated voltage.

$$VA = V_1 I_1 = V_2 I_2$$

- Where,
  - I_1 and I_2 = rated current on primary and secondary winding.
  - V_1 and V_2 = rated voltage on primary and secondary winding.

  - **Rated currents are the full load currents in transformer**

Transformer Rating and Name Plate

Assume that the transformer has the following name plate ratings:

40 kVA, 11 kV/ 440 V, 50 Hz

What do these numbers imply?

Transformer Rating and Name Plate

40kVA

11000/440 Volts

The transformer has two windings one rated for 11KV

and the other one for 440V

a = 11000/440 = 25 = turns ratio

- Each winding is designed for 40 kVA
- The current rating for high-voltage winding is

40000/11000 = 3.636 A

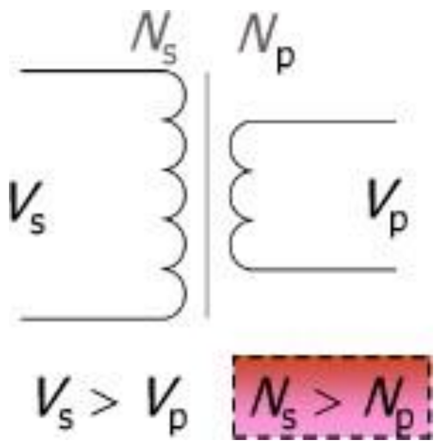
- The current rating for lower-voltage winding is

40000/440 = 90.9 A

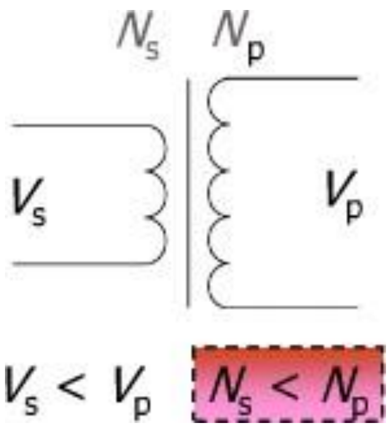
Classification of transformers:

- according to turns ratio:

- 1- step up transformer

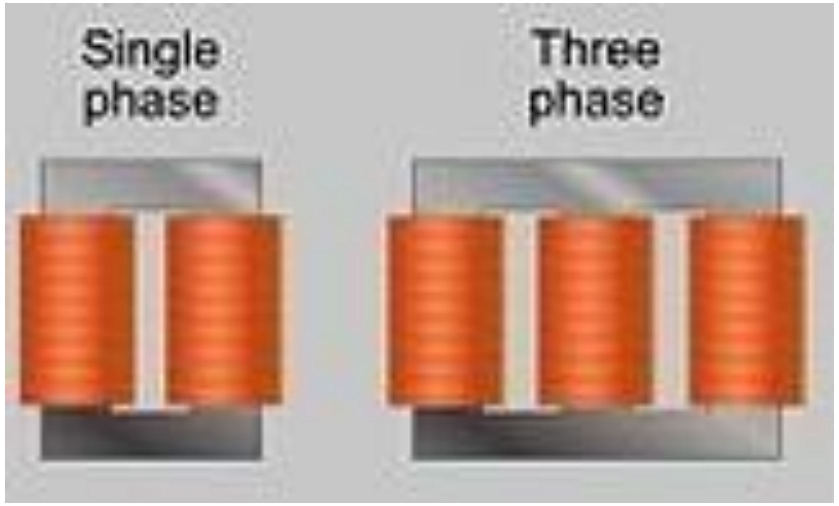


- 2- step down transformer



Classification of transformers:

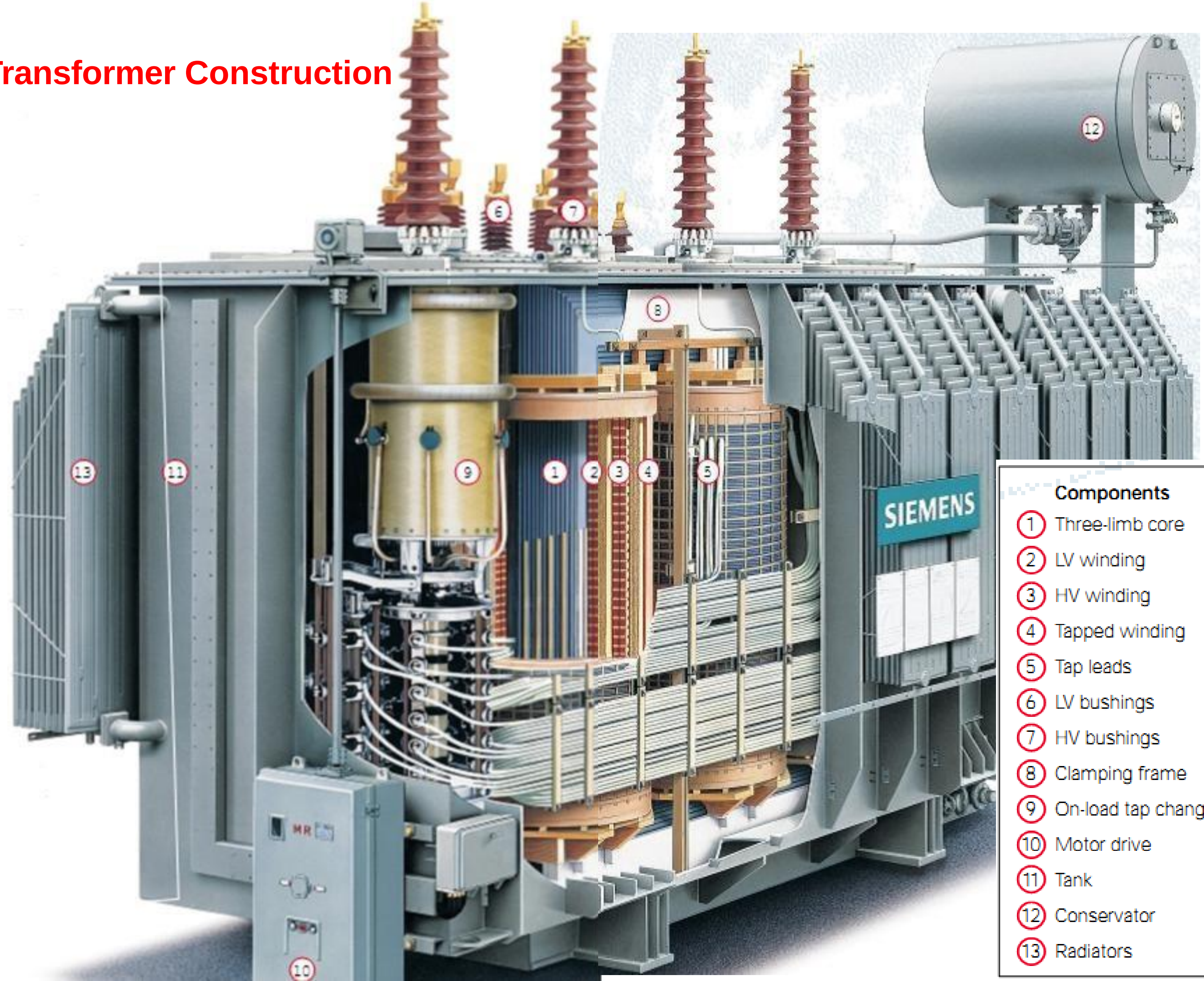
- according to number of phases
- 1- single phase transformer
- 2- poly phase transformer



Classification of transformers:

- according to their function :
- 1- power transformer
- 2- distribution transformer
- 3- measuring transformers
- A)voltage transformer
- B) current transformer
- 4-Autotransformer- Tapped autotransformer

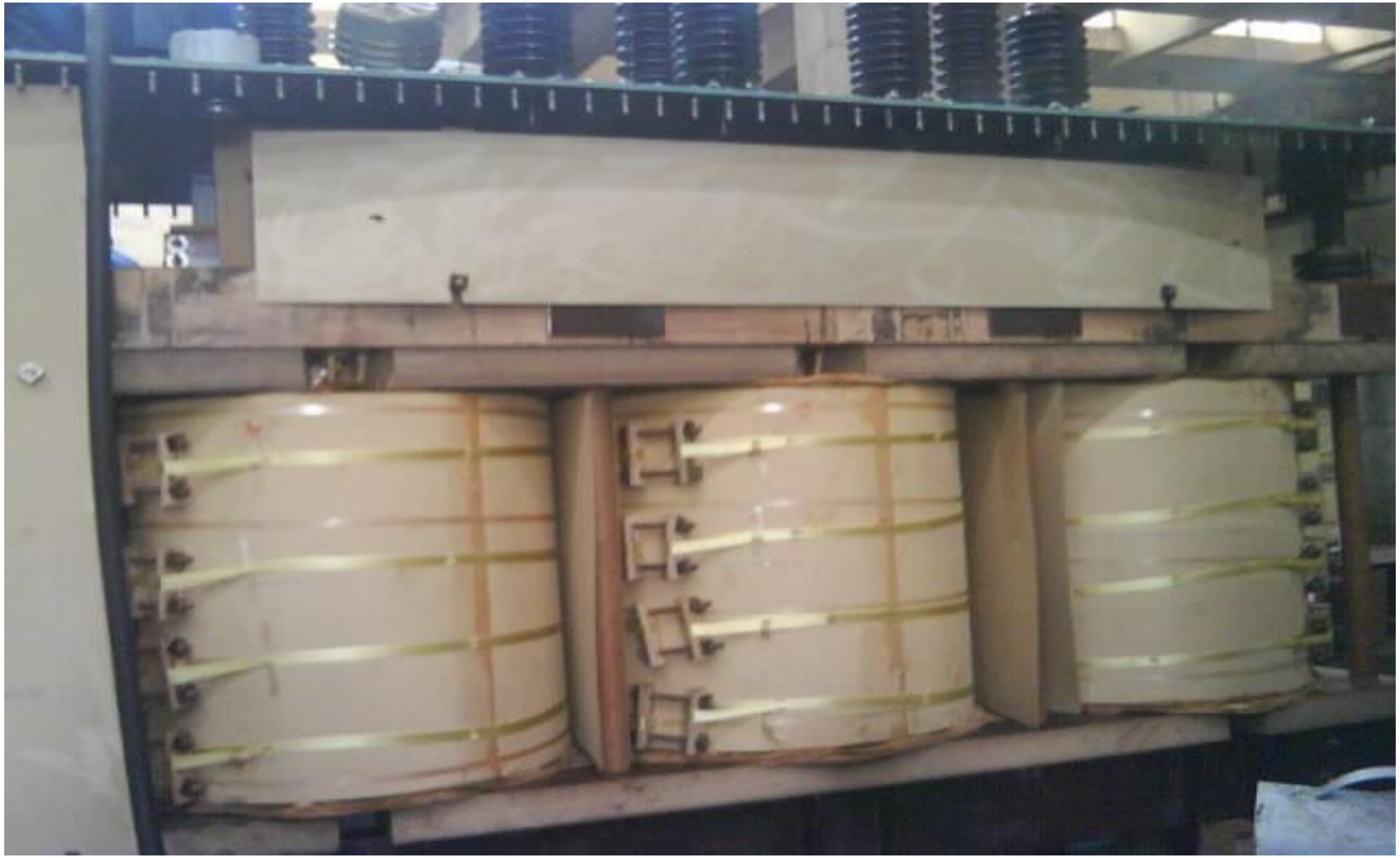
Transformer Construction



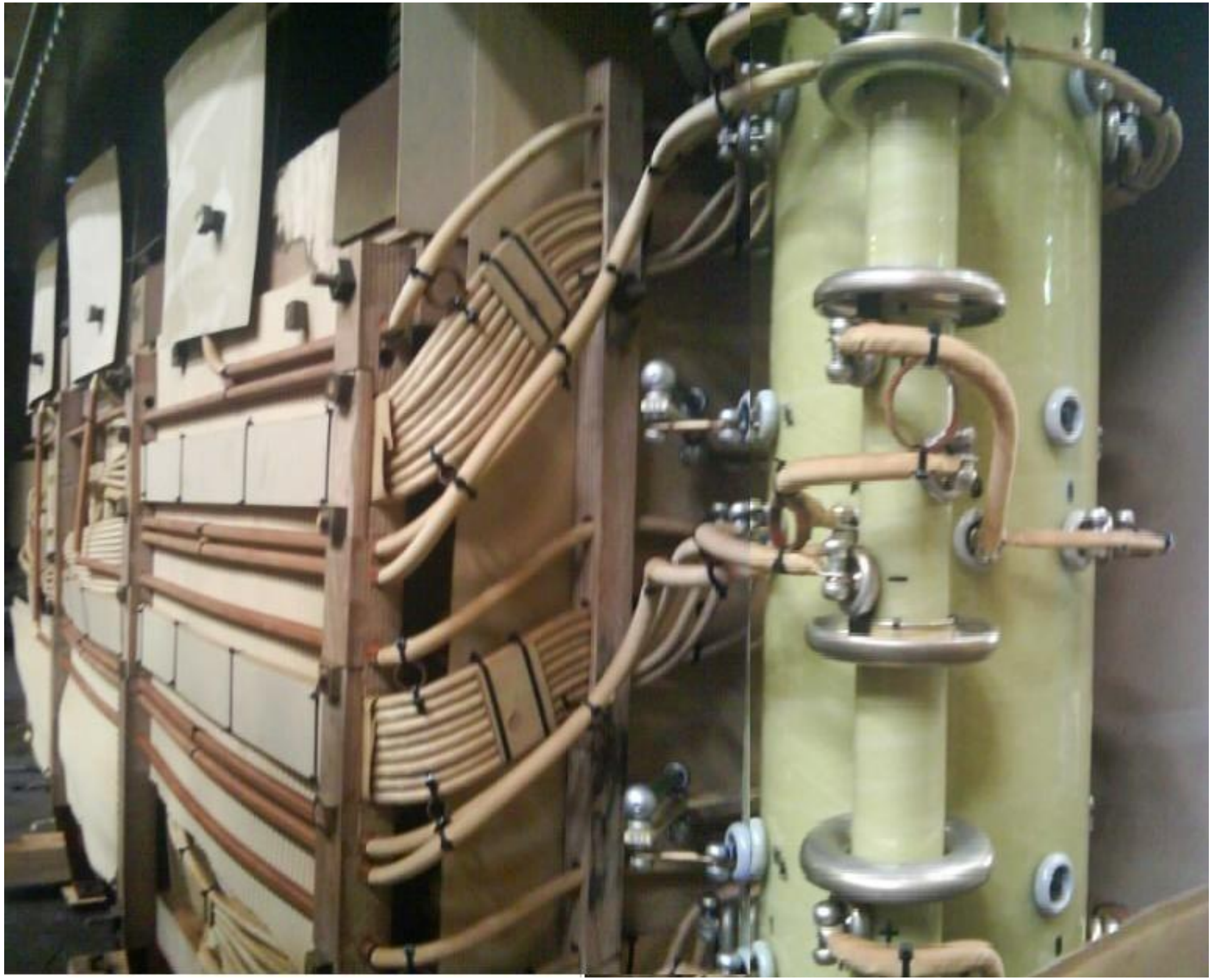
Components

1. Three-limb core
2. LV winding
3. HV winding
4. Tapped winding
5. Tap leads
6. LV bushings
7. HV bushings
8. Clamping frame
9. On-load tap changer
10. Motor drive
11. Tank
12. Conservator
13. Radiators

Core of a 40-MVA ,66/11 kV transformer



Winding of a 40-MVA ,66/11 kV transformer.



Tap changer of a 40-MVA, 66/11 kV transformer

1-Power Transformer:

- It is a power transformer connected to the output of a generator and used to step its voltage up to the transmission level .
- Power transformers are used in transmission network of higher voltages for step-up and

step down application (400 kV, 200 kV, 110 kV, 66 kV, 33kV) and are generally rated above 200MVA.

2-Distribution transformer

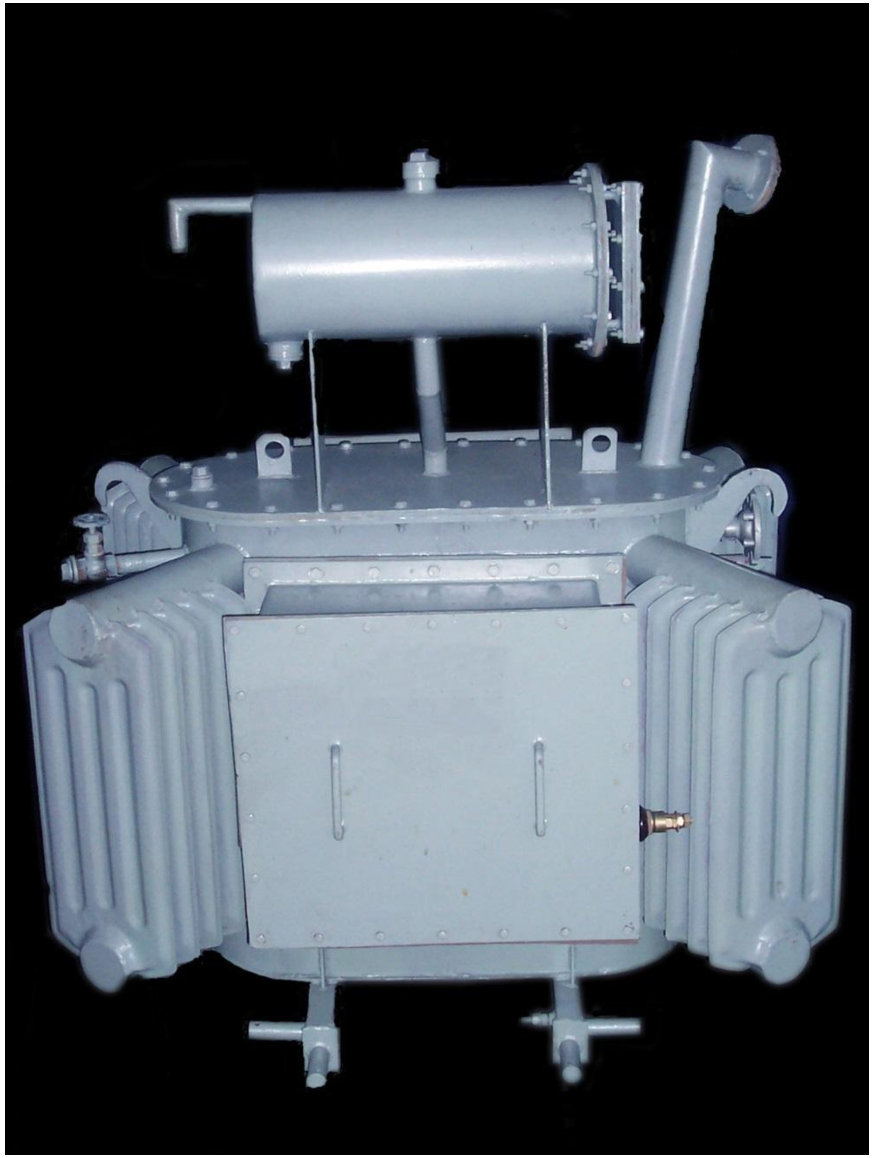
- It is a transformer converting the distribution voltage down to the final level

DISTRIBUTION TRANSFORMER

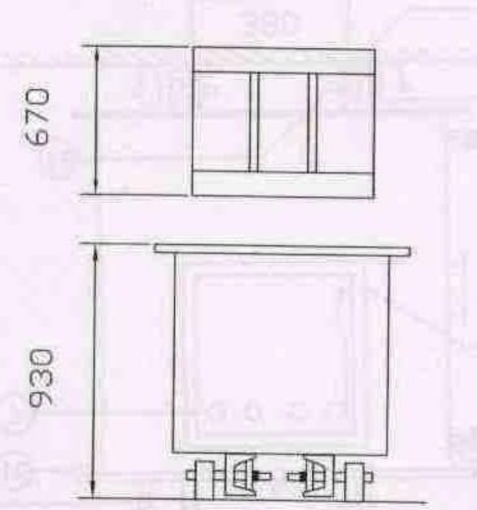
- Distribution transformers are used for lower voltage distribution networks as a means to end user connectivity. (11kV, 6.6 kV, 3.3 kV, 440V, 230V) and are generally rated less than 200 MVA.
- 11KV/400V is the standard voltage rating.
- NATURALY COOLED (ONAN TYPE).

25,63,100,160,200,250,315,400,500,630,750 , 1000 , 1250,1500,2000,2500 KVA.

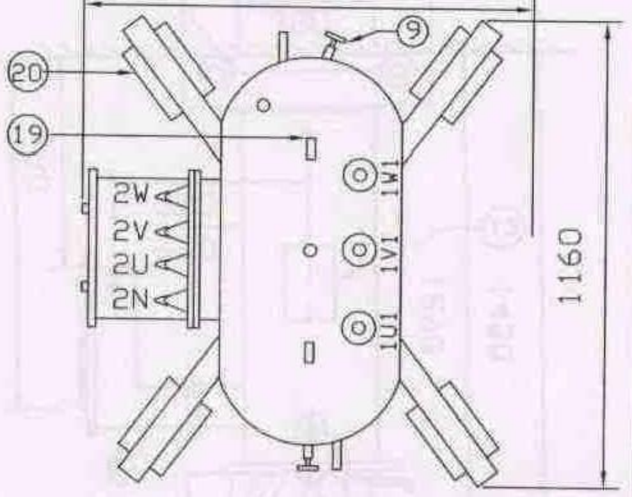
PARTS OF TRANSFORMER

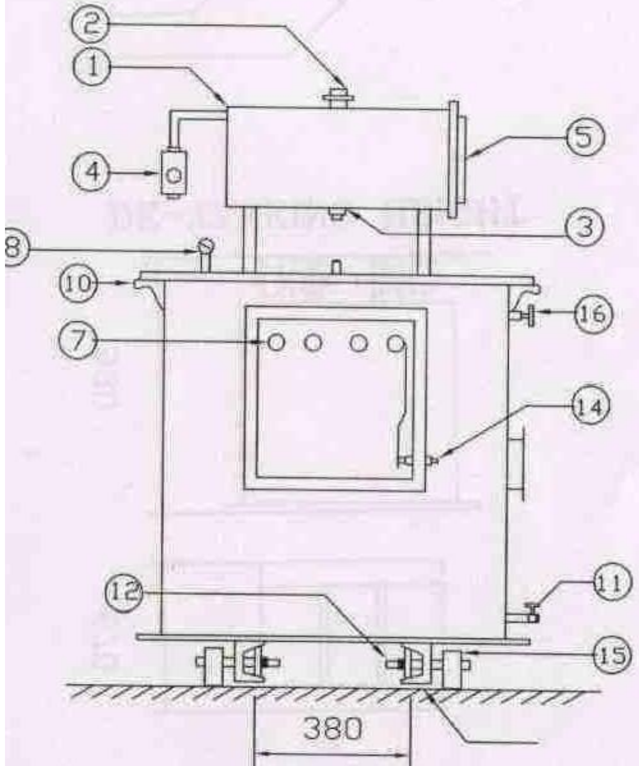


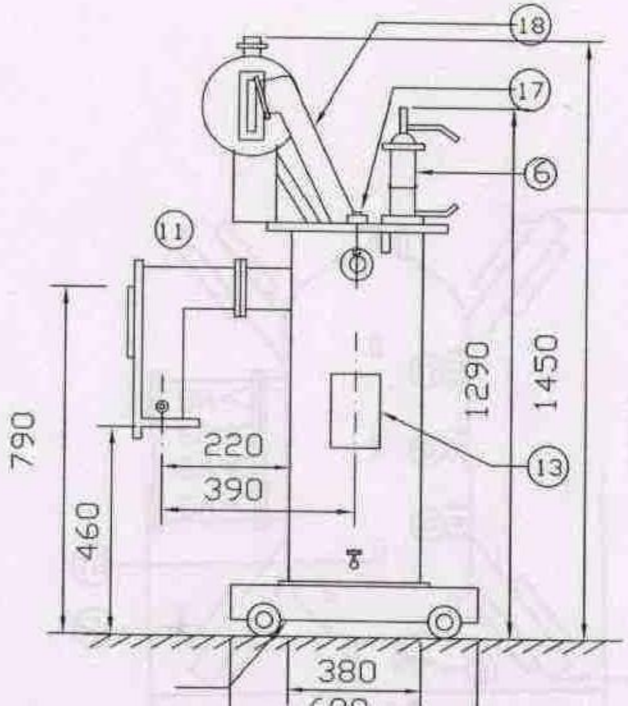
- MAIN TANK
- RADIATORS
- CONSERVATOR
- EXPLOSION VENT
- LIFTING LUGS
- AIR RELEASE PLUG
- OIL LEVEL INDICATOR
- TAP CHANGER
- WHEELS
- HV/LV BUSHINGS
- FILTER VALVES
- OIL FILLING PLUG
- DRAIN PLUG
- CABLE BOX



DE-TANKING HEIGHT







LOCATIONS OF FITTIN

S.N.	DESCRIPTION
1.	CONSERVATOR
2.	FILLING HOLE WITH CAP
3.	DRAIN PLUG FOR CONSERVATOR
4.	SILICA GEL BREATHER
5.	OIL LEVEL INDICATOR
6.	H.V. BUSHINGS 11KV OUTDOOR
7.	L.V. BUSHINGS IN CABLE BOX
8.	THERMOMETER POCKET
9.	TOP FILTER VALVE
10.	LIFTING LUGS
11.	DRAIN CUM BOTTOM FILTER VALVE
12.	EARTHING TERMINAL
13.	RATING AND TERMINAL PLATE
14.	NEUTRAL EARTHING BUSHING
15.	U-DIRECTIONAL ROLLERS
16.	TAP SWITCH HANDLE
17.	AIR RELEASE DEVICE
18.	PRESSURE RELIEF VENT
19.	COVER LIFTING LUGS
20	RADIATORS

RATING IN KVA 1

TOTAL MASS IN KG 8

DETANKING MASS IN KG 4

ALL DIMENSIONS ARE IN MM UNLESS SPEC

TOLERENCE ON DIMENSIONS ±5%

NOTE-THIS IS ONLY FOR GENERAL INFORMA

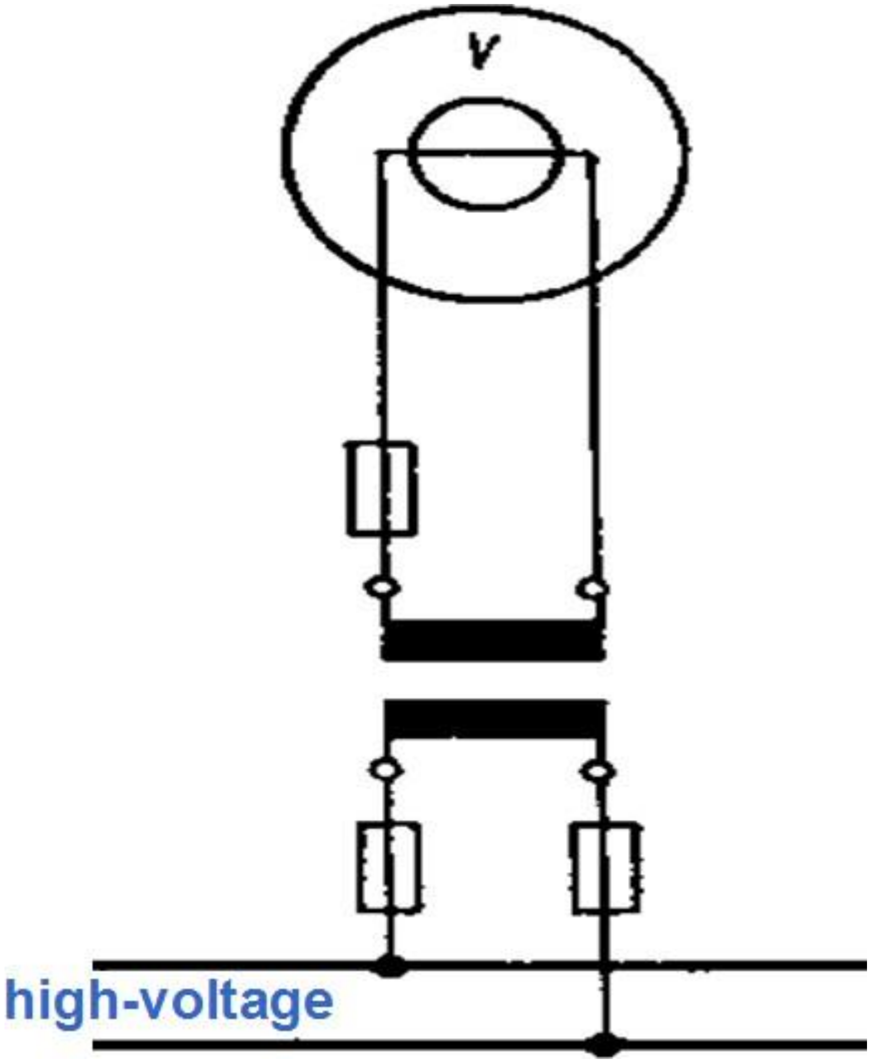
DETAILS ARE LIKELY TO CHANGE WITHOUT N

GENERAL OUTLINE OF 11KV/433V DISTRIBUTION TRANSFORMER	DRG. 1. 1. 1

TRANS-DELTA ELECTRICALS

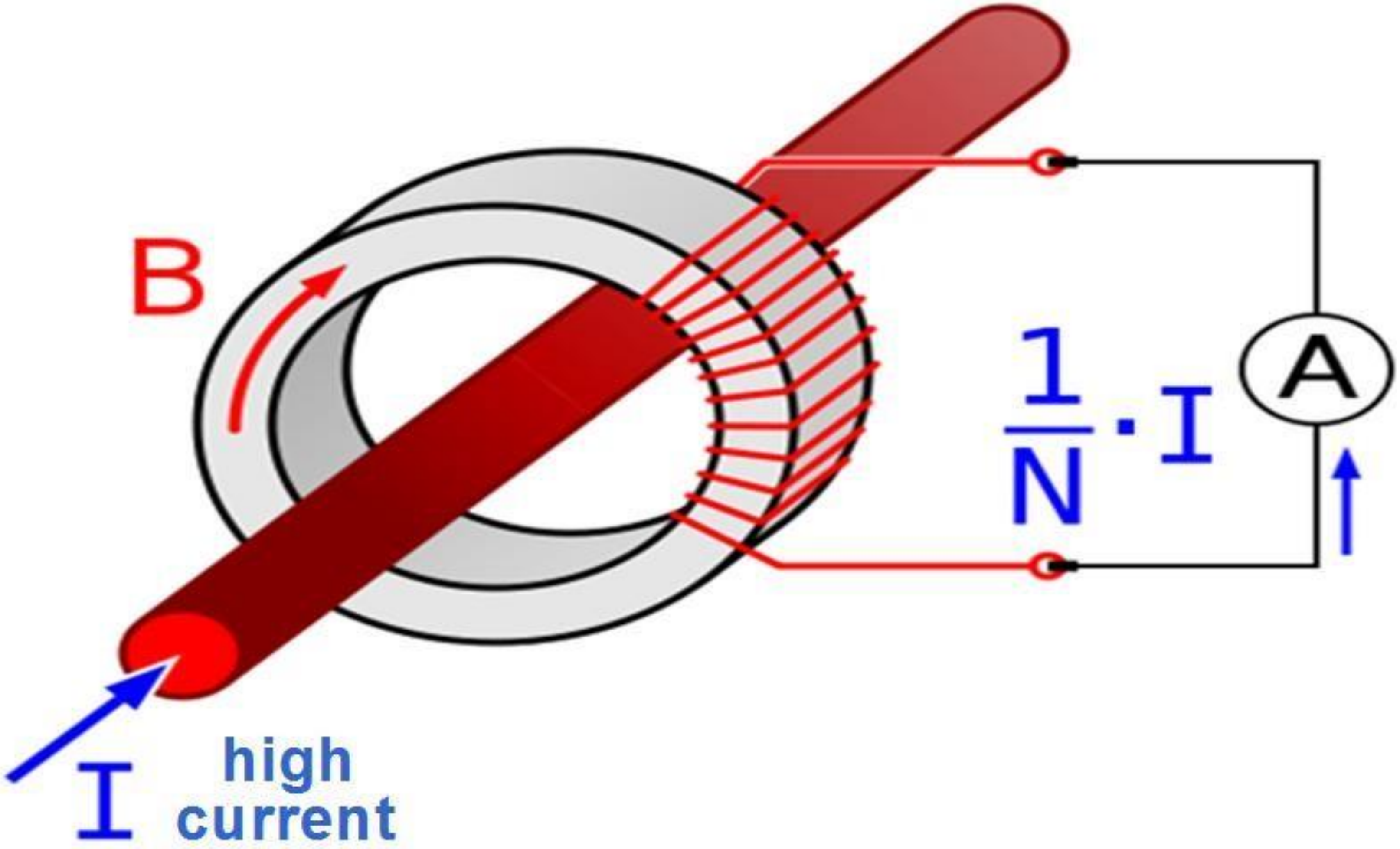
3- measuring transformers

A)Voltage Transformer



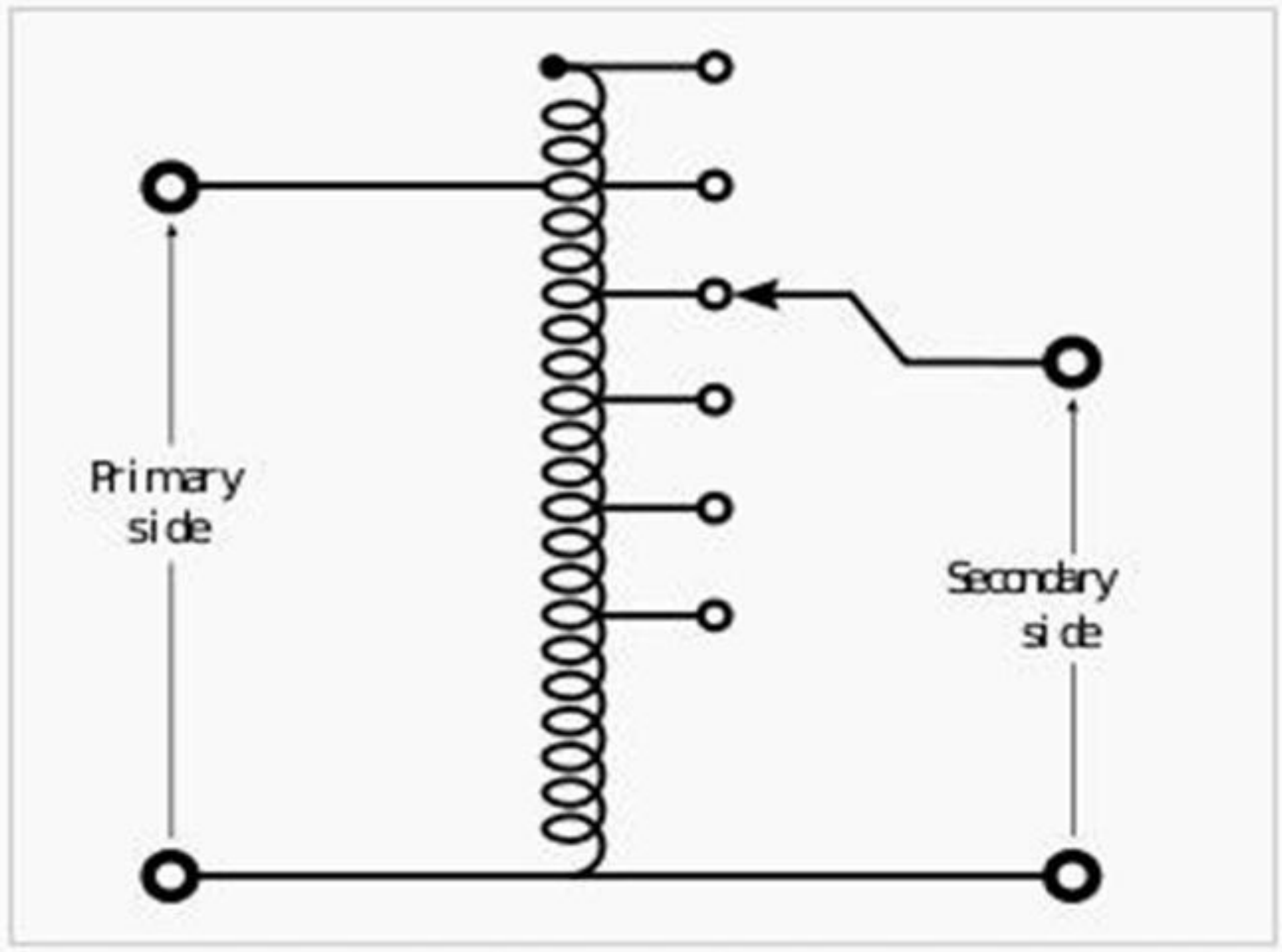
3- measuring transformers

B)Current Transformer

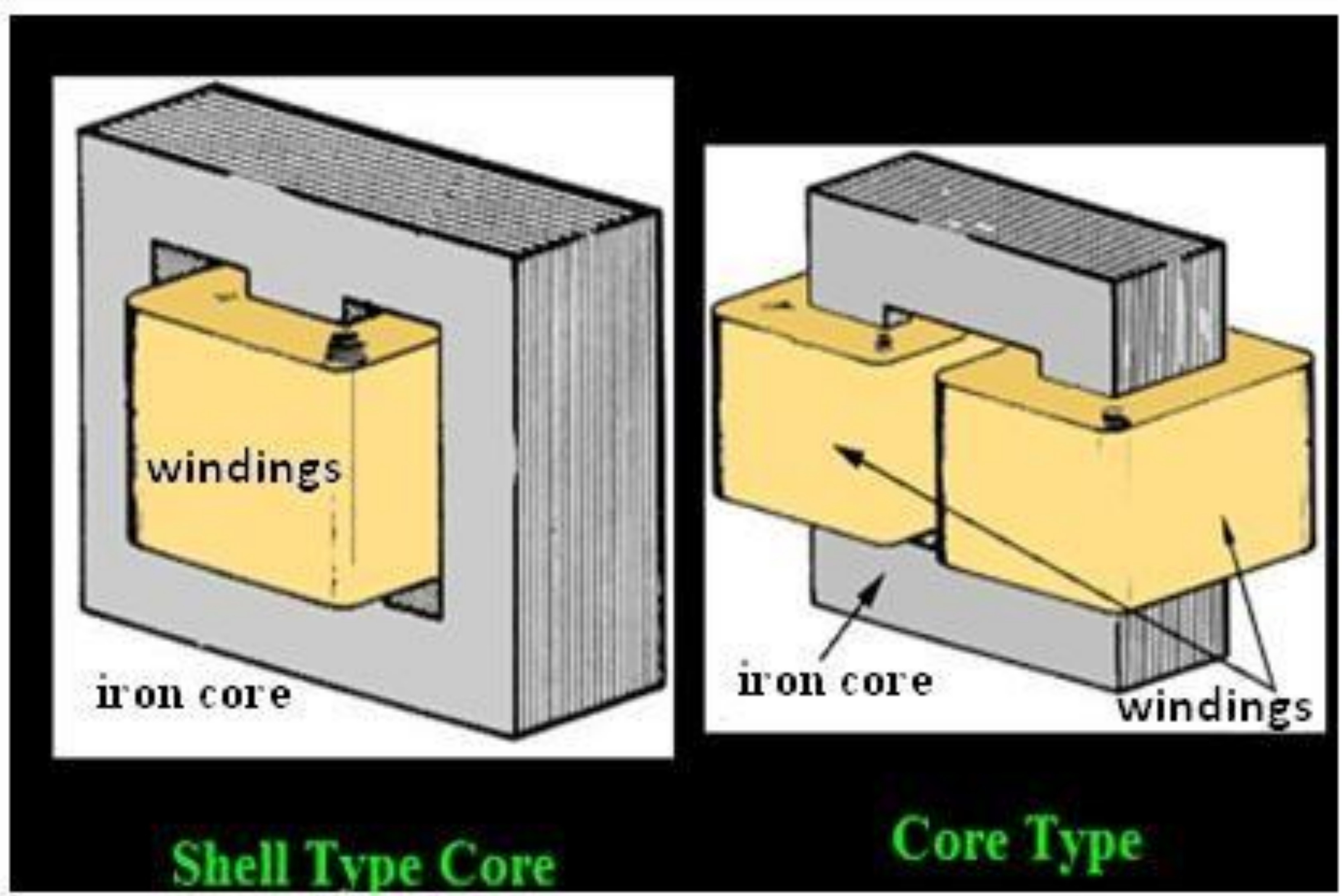


Autotransformer

Tapped autotransformer



According to transformer design



According to cooling

- **For dry type transformers**
  - Air Natural (AN)
  - Air Blast
- **For oil immersed transformers**
  - Oil Natural Air Natural (ONAN)
  - Oil Natural Air Forced (ONAF)
  - Oil Forced Air Forced (OFAF)
  - Oil Forced Water Forced (OFWF)
- **SF6 gas-insulated Transformers**

According to cooling

- **A)Air Cooling For Dry Type Transformers:**
- It is used for transformers that use voltages below 25KV
- **1)Air natural Type (A.N.)**
- **This type of Transformer Cooling method applies to dry type transformer of small rating.**
- **As power ratings increase, transformers are often cooled by forced-air cooling**

According to cooling

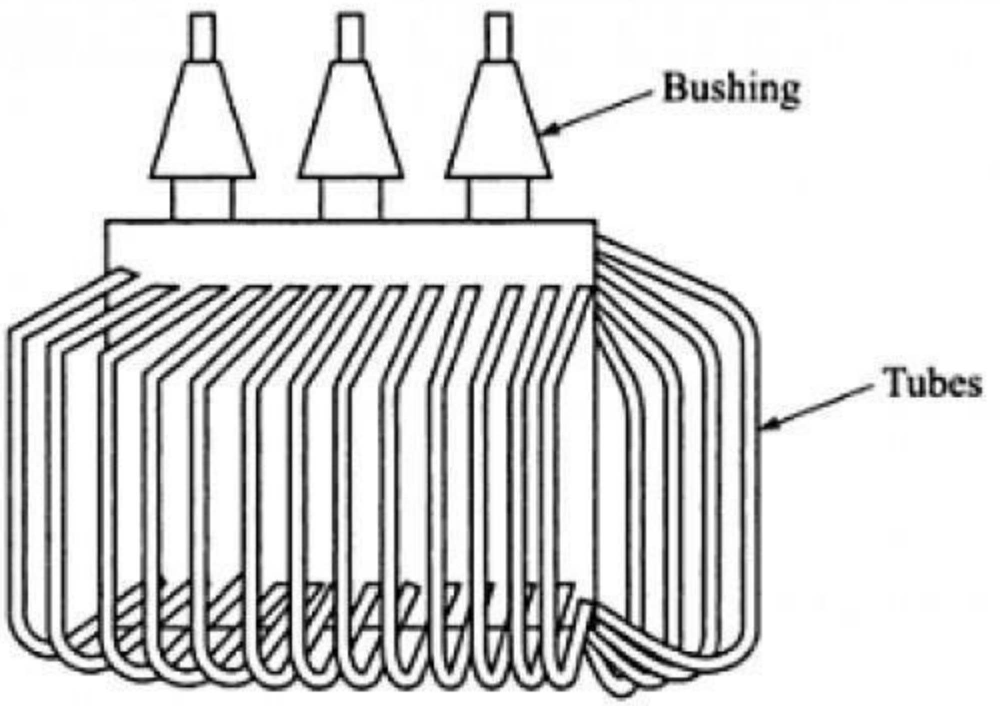
- 2)Air Forced type (A.F.)
- The air is forced on to the tank surface to increase the rate of heat dissipation.
- The fans are switched on when the temperature of the winding increases above permissible level.

According to cooling

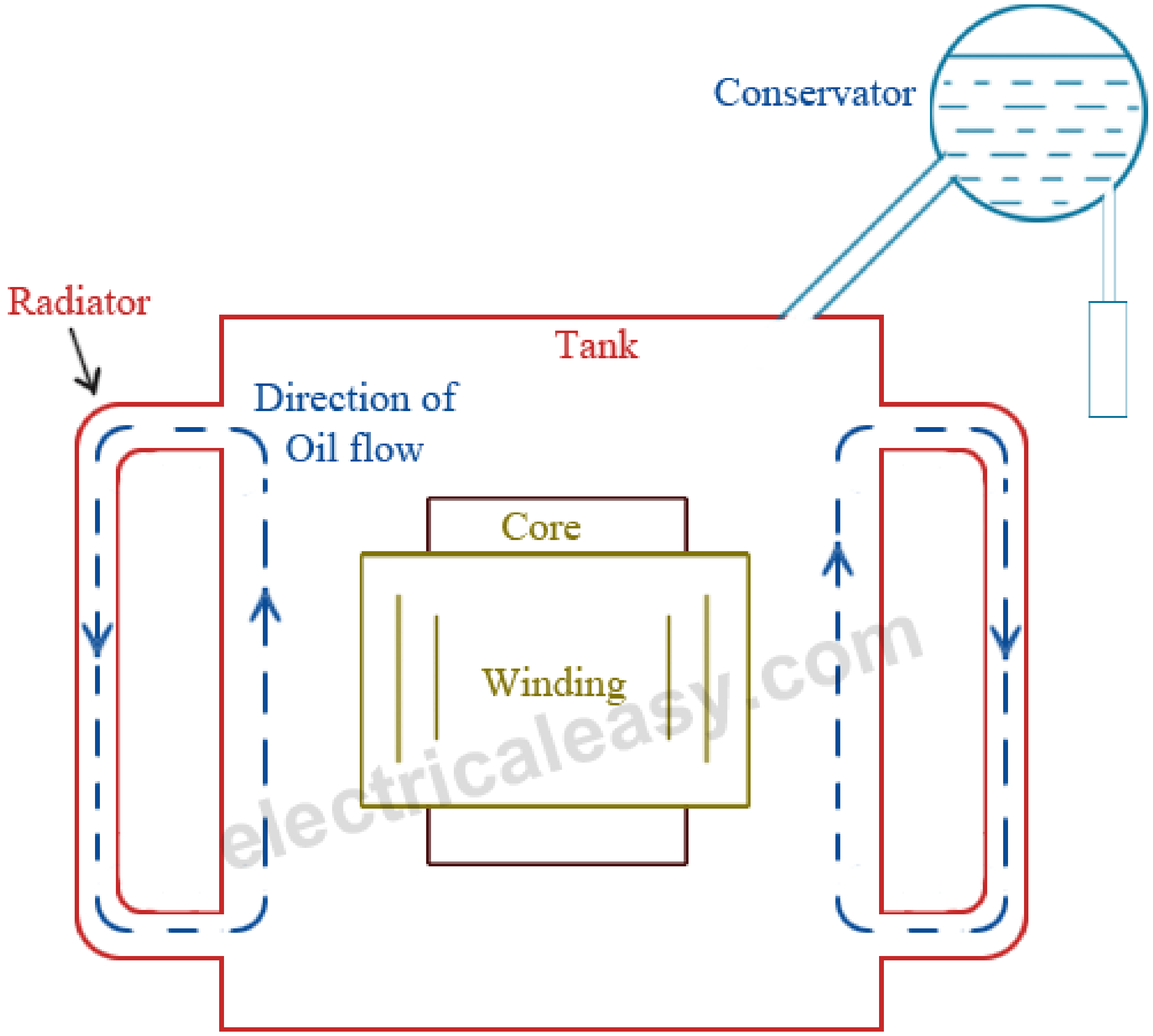
- <u>**B)Cooling For Oil Immersed Transformers:**</u>
- **1)Oil Natural Air Natural Type (O.N.A.N.)**
- **This type of Transformer cooling is widely used for oil filled transformers up to about 30MVA.**
- **Heat is transferred from transformer windings and core to the oil and**
- **the heated oil is cooled by the natural air.**
- **Cooling area is increased by providing the cooling tubes.**

According to cooling

- **B)Cooling For Oil Immersed Transformers:**



Oil Natural Air Natural Transformer Cooling



Oil Natural Air Natural (ONAN) - Cooling of Transformer

According to cooling

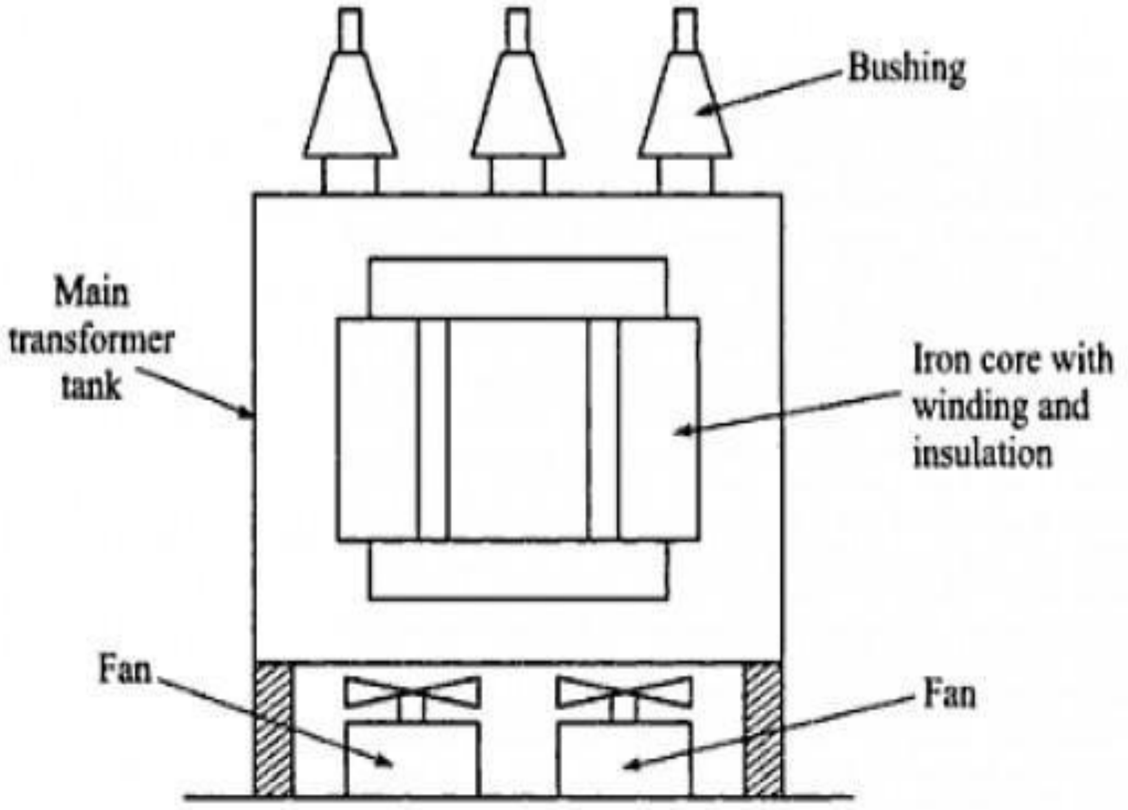
- **B)Cooling For Oil Immersed Transformers:**

- 2)Oil Natural Air Forced Type (O.N.A.F.)

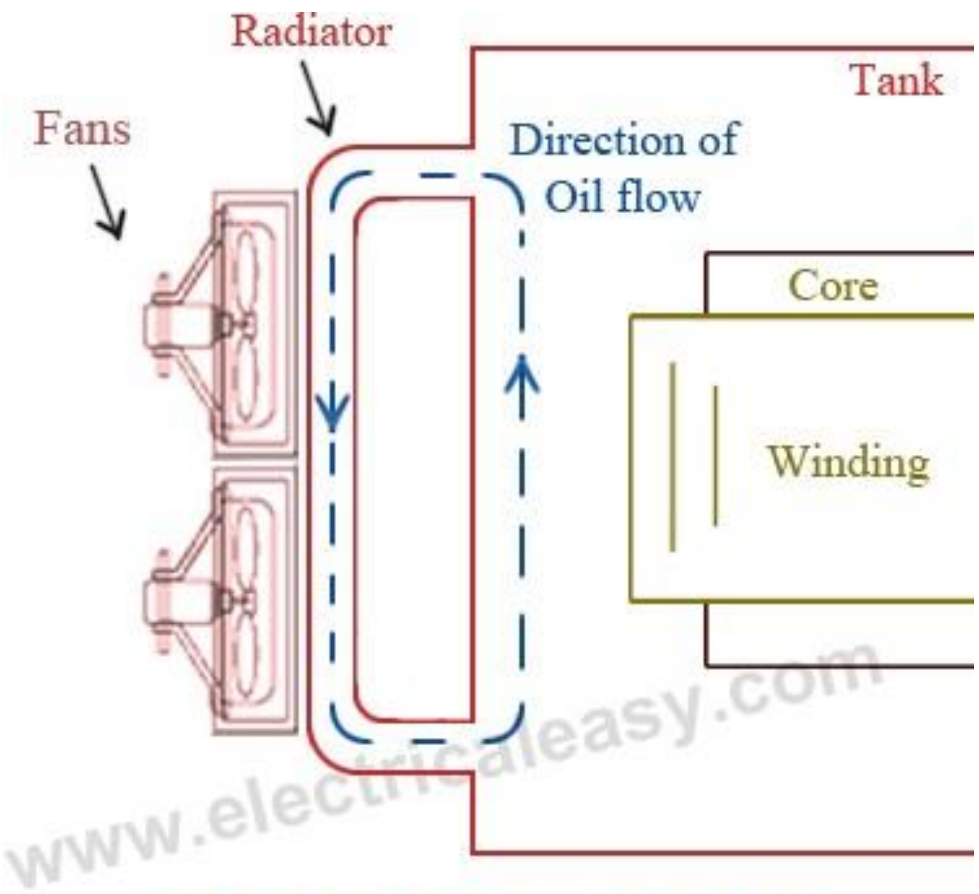
- **In higher rating transformers where the heat dissipation is difficult**
- **this type of cooling is used.**
- **Fans are used to forced and air blast on radiators.**

According to cooling

- **B)Cooling For Oil Immersed Transformers:**



Oil Natural Air Forced Transformer Cooling



Oil Natural Air Forced (ONAF)
Cooling of Transformer

According to cooling

- **B)Cooling For Oil Immersed Transformers:**

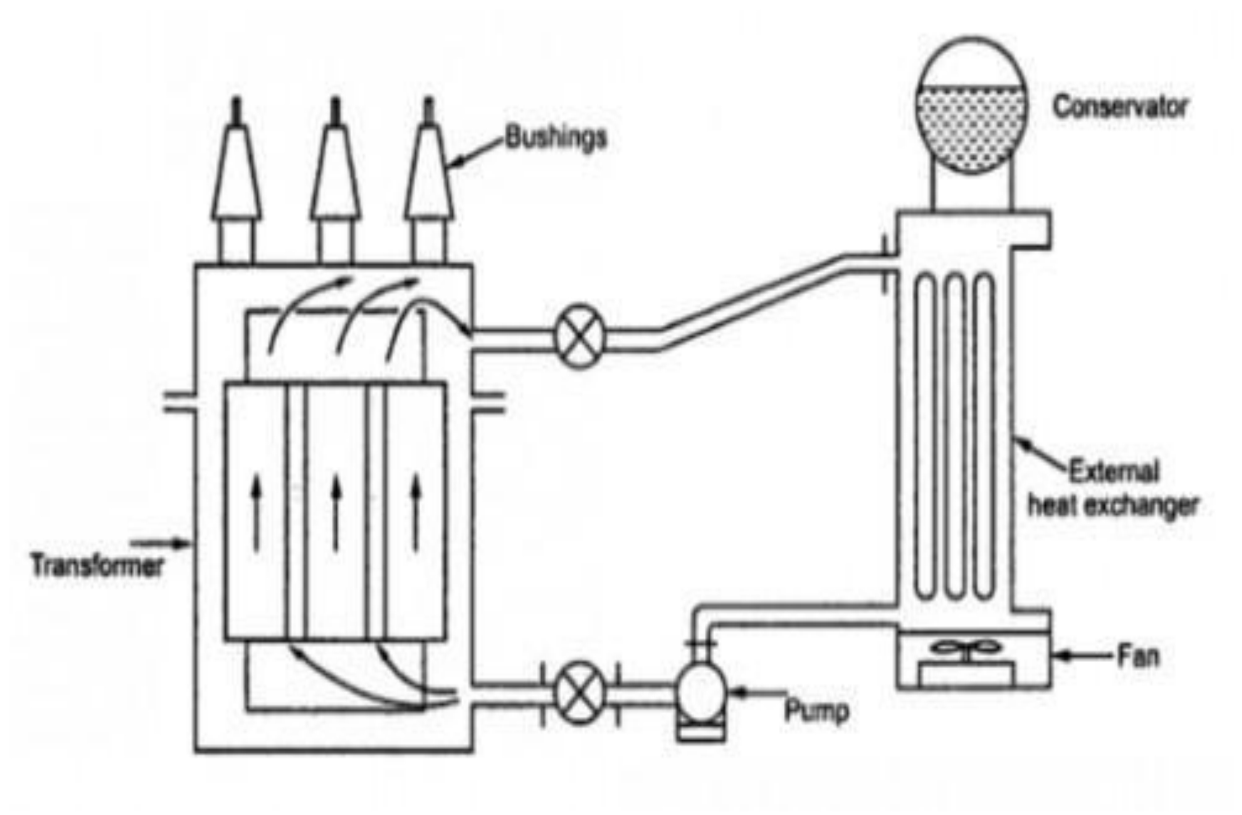
3)Oil Forced Air Forced Type (O.F.A.F.)

Oil Natural Air Forced type of cooling is not adequate to remove the heat caused by the losses.

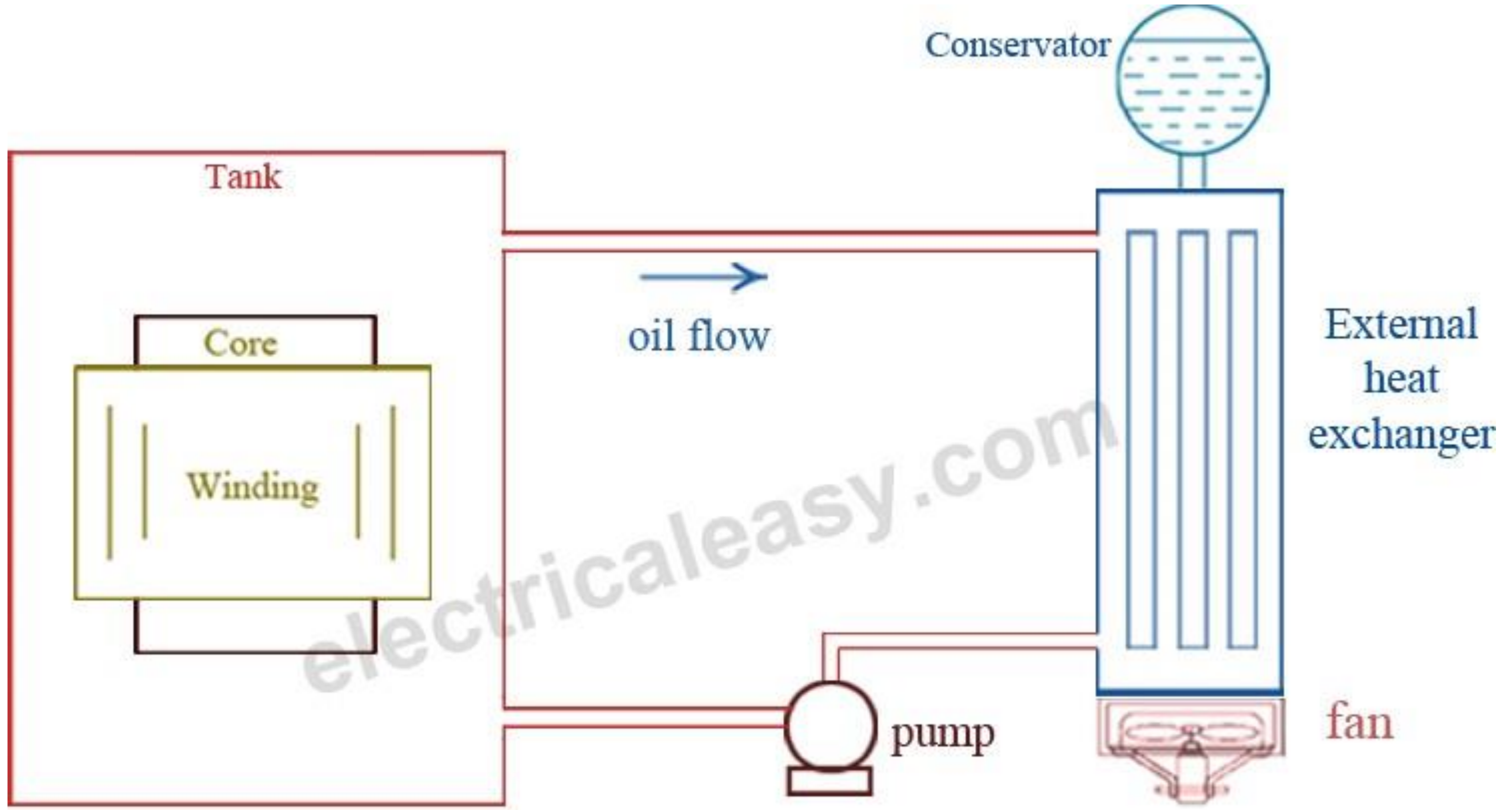
Transformers above 60 MVA employ a combination of Forced Oil and Forced Air Cooling.

According to cooling

- **B)Cooling For Oil Immersed Transformers:**



Oil Forced Air Forced Transformer Cooling



Oil Forced Air Forced (OFAF) - Cooling of Transformer

According to cooling

- **B)Cooling For Oil Immersed Transformers:**

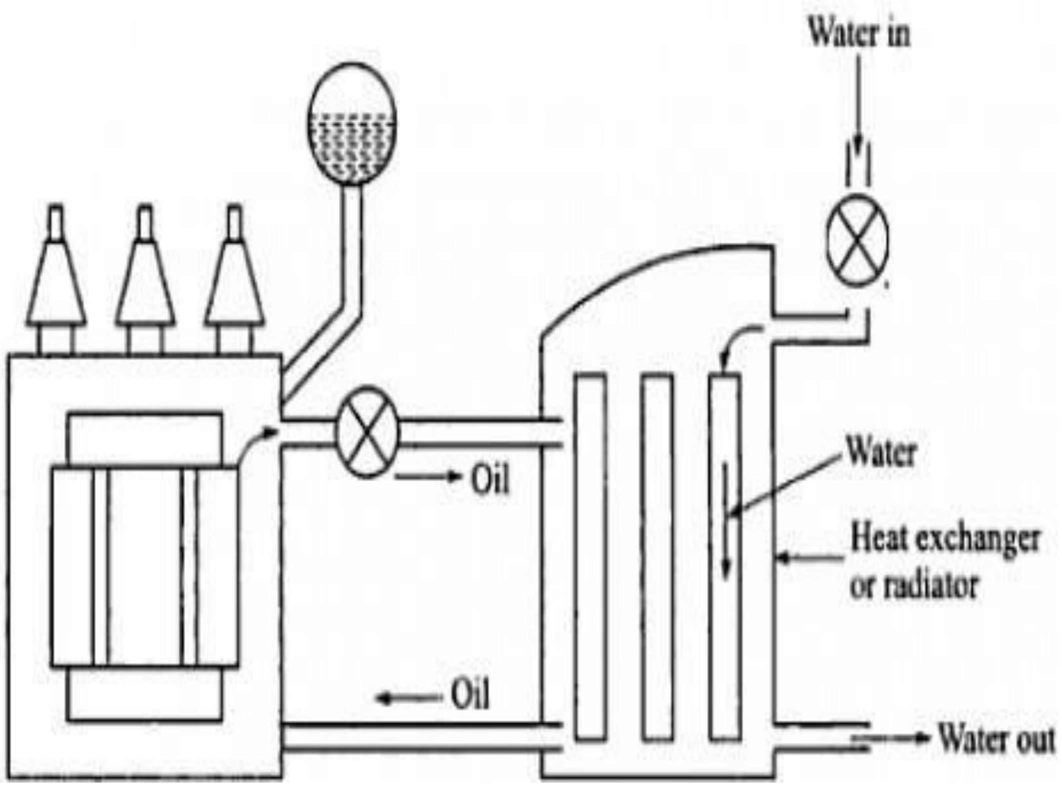
4)Oil Forced Water Forced (O.F.W.F.)

This type of cooling Is provided for very large transformers which have ratings of some hundreds of MVA

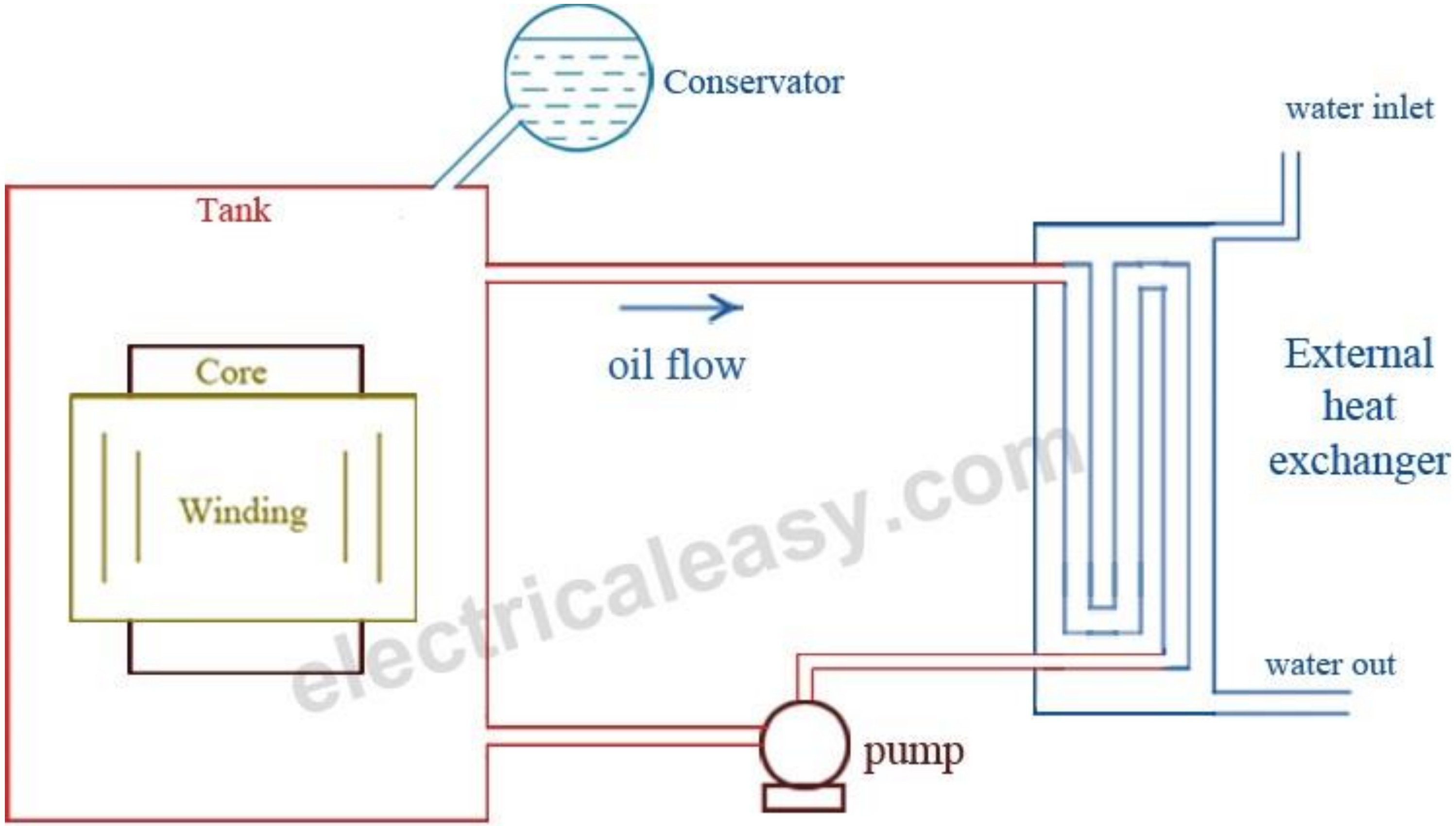
This type of transformers is used in large substations and power plants.

According to cooling

- **B)Cooling For Oil Immersed Transformers:**



Oil Forced Water Forced Transformer Cooling



Oil Forced Water Forced (OFWF) - Cooling of Transformer

According to cooling

SF6 Gas Insulated Transformers

- **Features**
- The SF6 gas-insulated Transformers offer excellent insulation and cooling characteristics and thermal stability. Additionally, these Transformers possess the following features:
- 1. High-level stability
- 2. Compactness of substation
- By directly coupling with gas-insulated Switchgear, substation space can be minimized
  as the result of compact facilities.
- 3. Simplified maintenance and long service life
- Because the Transformers are completely sealed in housing cases, no contact exists
- with exterior atmospheric air, thereby eliminating problems of degradation or contamination
- triggered by moisture or dust accumulation.
- 4. Easy, clean installation
- SF6 gas can be quickly sealed into the Transformer tank from a cylinder.
  5. Ideal for high voltage systems

Applications

The SF6 gas-insulated Transformers are suitable for the following applications:

•Locations where safety against fire is essential Buildings such as hotels, department stores, schools, and hospitals Underground shopping areas, underground substations Sites close to residential areas, factories, chemical plants

•Locations where prevention of environment pollution is specifically demanded Water supply source zones, seaside areas Water treatment stations

•Locations where exposure exists to high-level moisture or dust accumulation ,industrial zones

TESTING OF TRANSFORMER

- TESTING IS CARRIED OUT AS PER IS-2026.
- ROUTINE , TYPE TESTS & SPECIAL TESTS

- ROUTINE TESTS (TO BE CARRIED OUT ON EACH JOB)
- 1.Measurement of winding resistance
- 2.Measurement of insulation resistance
- 3.Seperate source voltage withstand test (High Voltage tests on HV & LV)
- 4.Induced Over voltage Withstand test (DVDF test)
- 5.Measurement of voltage ratio
- 6.Measurement of NO LOAD LOSS & current.
- 7.Measurement of LOAD LOSS & IMPEDENCE.(EFFICIENCY & REGULATION)
- 8.Oil BDV test.

TYPE TESTS

THESE TESTS ARE CARRIED OUT ONLY ON ONE TRANSFORMER OF THE LOT.

- All routine tests
- Additionally following tests are included in type tests

1. Lightening Impulse test.
2. Temperature rise test

SPECIAL TESTS

- Additional Impulse test
- Short circuit test
- Measurement of zero Phase sequence Impedance test.
- Measurement of acoustic noise level.
- Measurement of harmonics of the no load current.
- Magnetic balance test.

ROUTINE TESTS

- 1.Measurement of winding resistance

This test measures the resistance of the HV & LV winding. The values of resistance should be balance for all three phases and should match the designed values.

Equipment used : Digital resistance meter.

ROUTINE TESTS

- 2.Measurement of insulation resistance

  Measures the insulation resistance of HV & LV windings with respect to earth (body) and between LV & HV winding.

  INSULATION TESTER OR MEGGER IS USED.

  Recommended Values are

  2000Mohms for HV & 500 Mohms for LV.

ROUTINE TESTS

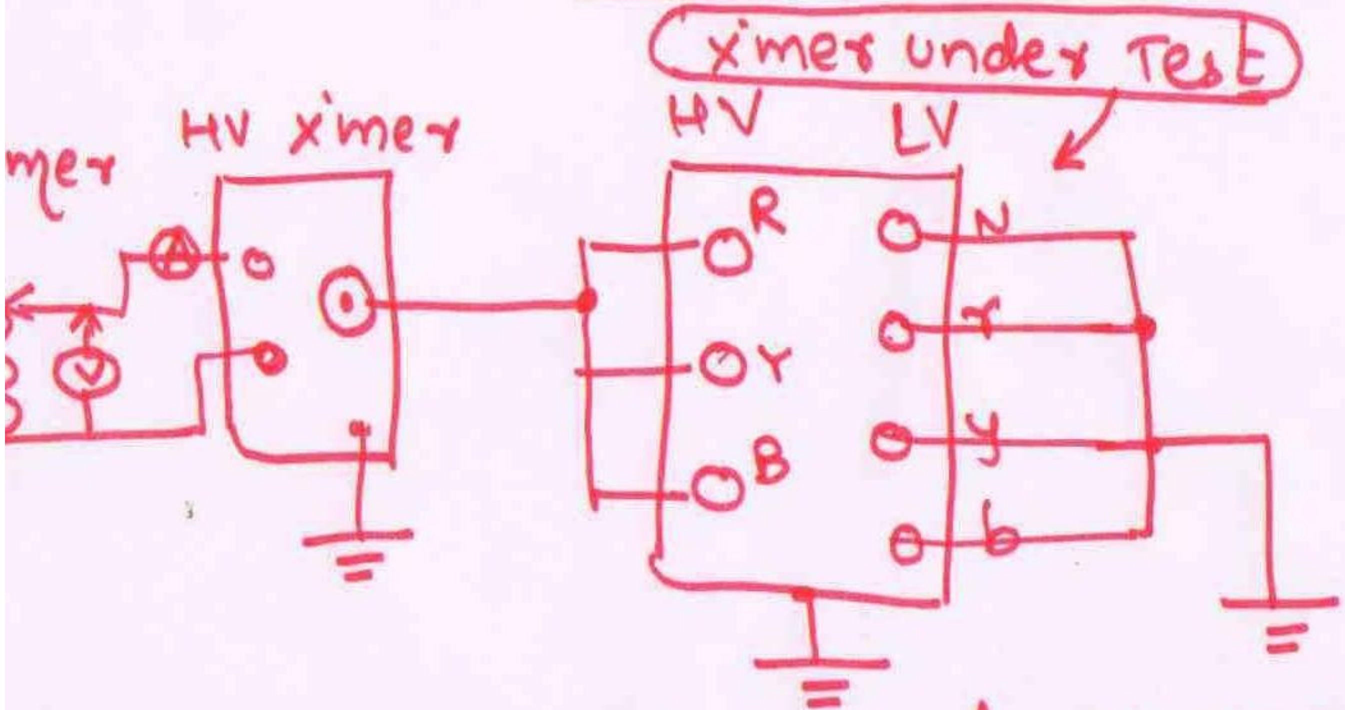
- 3.Seperate source voltage withstand test (High Voltage tests on HV & LV)- This test checks the insulation property between Primary to earth, Secondary to earth and between Primary & Secondary.

HV high voltage test : LV winding connected together and earthed. HV winding connected together and given 28 KV (for 11KV transformer) for 1 minute.

LV high Voltage test : HV winding connected together and earthed. LV winding connected together and given 3 KV for 1 minute.

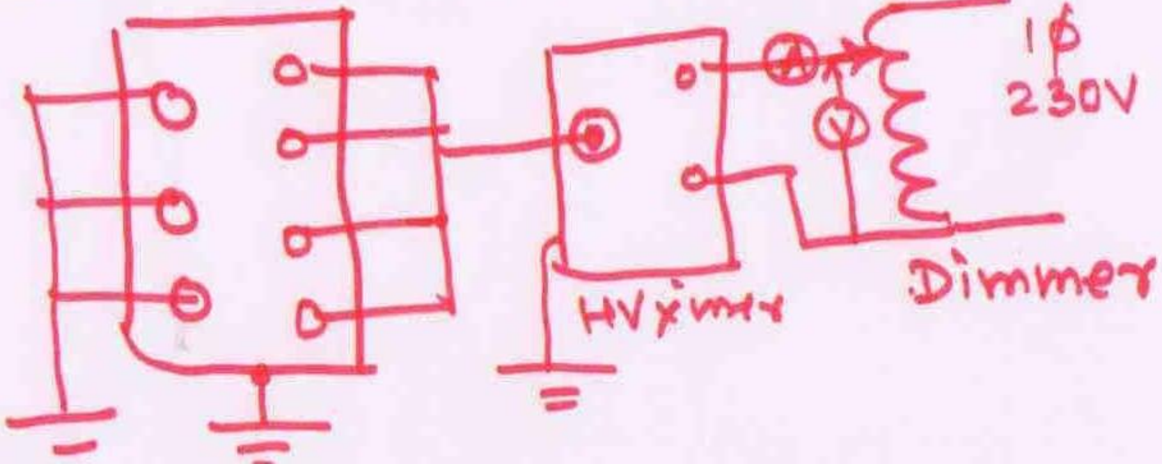
Equipment used : High Voltage tester (100KV & 3KV)

HV High Voltage Test



For	High
11KV →	28 K
22KV →	50 K
33 KV →	70 K
433V →	3 K

LV High Voltage Test



ROUTINE TESTS

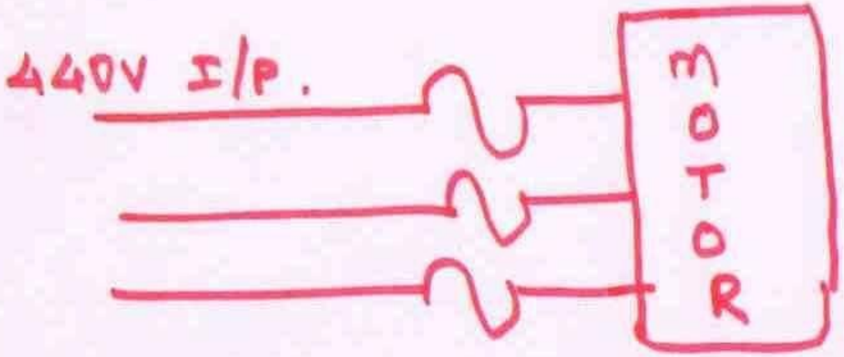
- 4.Induced Over voltage Withstand test (DVDF test)- This test checks the inter turn insulation.

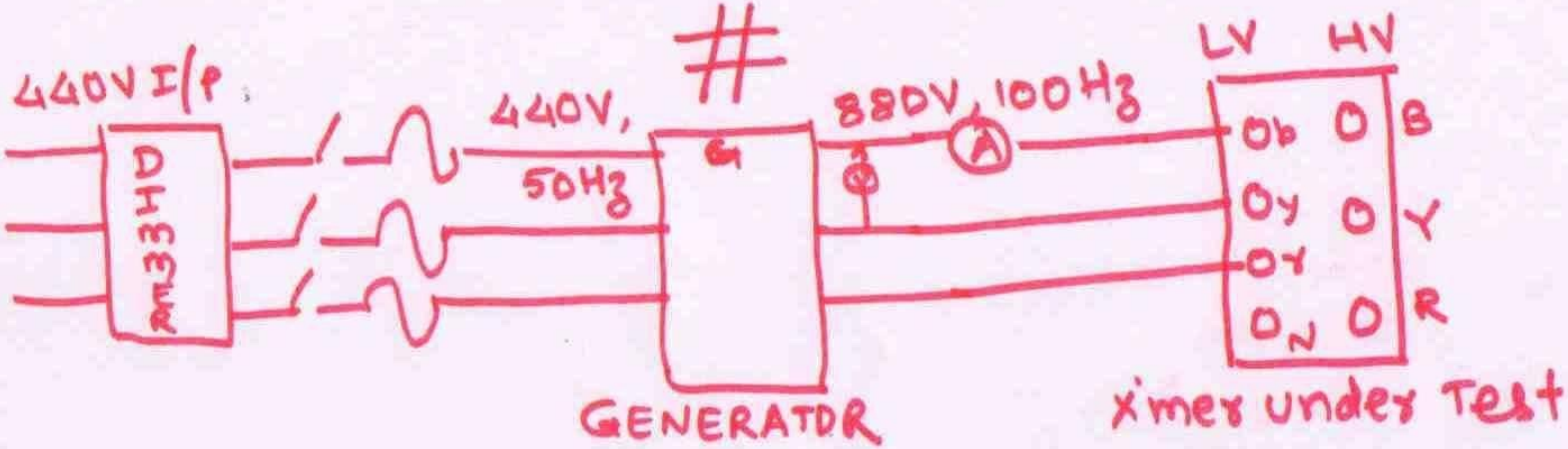
  For a 11KV/433V transformer,866 Volts are applied at the 433V winding with the help of a Generator for 1 minute. This induces 22KV on 11KV side. The frequency of the 866V supply is also increased to 100HZ.

  Equipment used : MOTOR GENERATOR SET

Double voltage Double Frequency Test

INDUCED Overvoltage Test





ROUTINE TESTS

- 5.Measurement of voltage ratio

This test measures the voltage ratio as per the customer's requirement.

$V1/V2 = N1/N2$

The voltage ratio is equal to the turns ratio in a transformer. Using this principle, the turns ratio is measured with the help of a turns ratio meter. If it is correct , then the voltage ratio is assumed to be correct.

Equipment used : Turns Ratiometer

ROUTINE TESTS

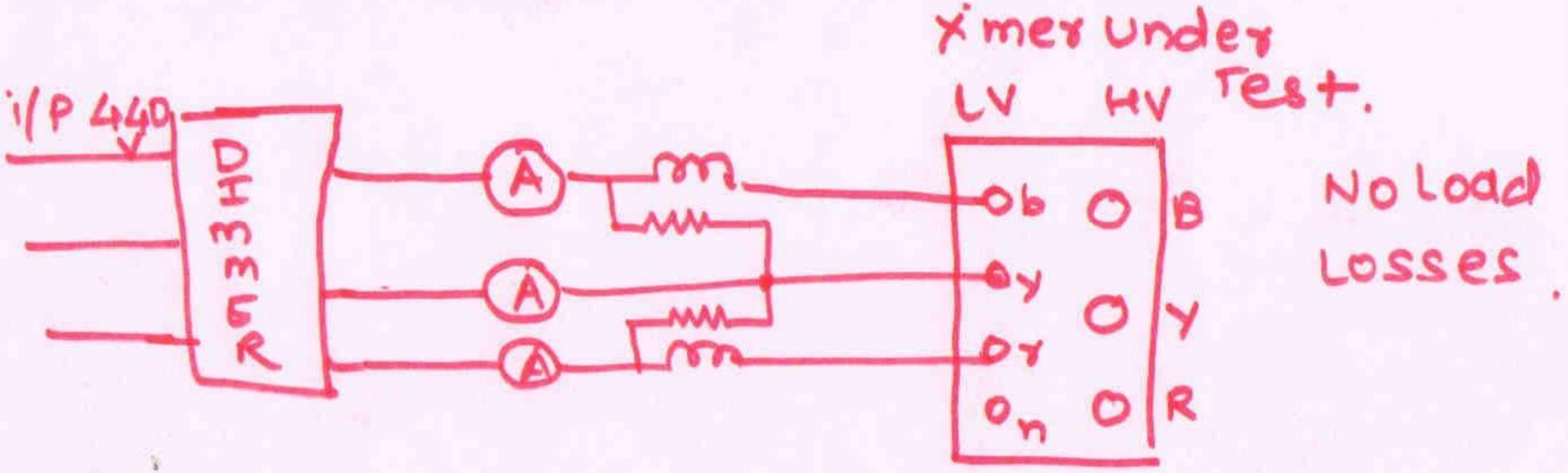
- 6.Measurement of NO LOAD LOSS & current.

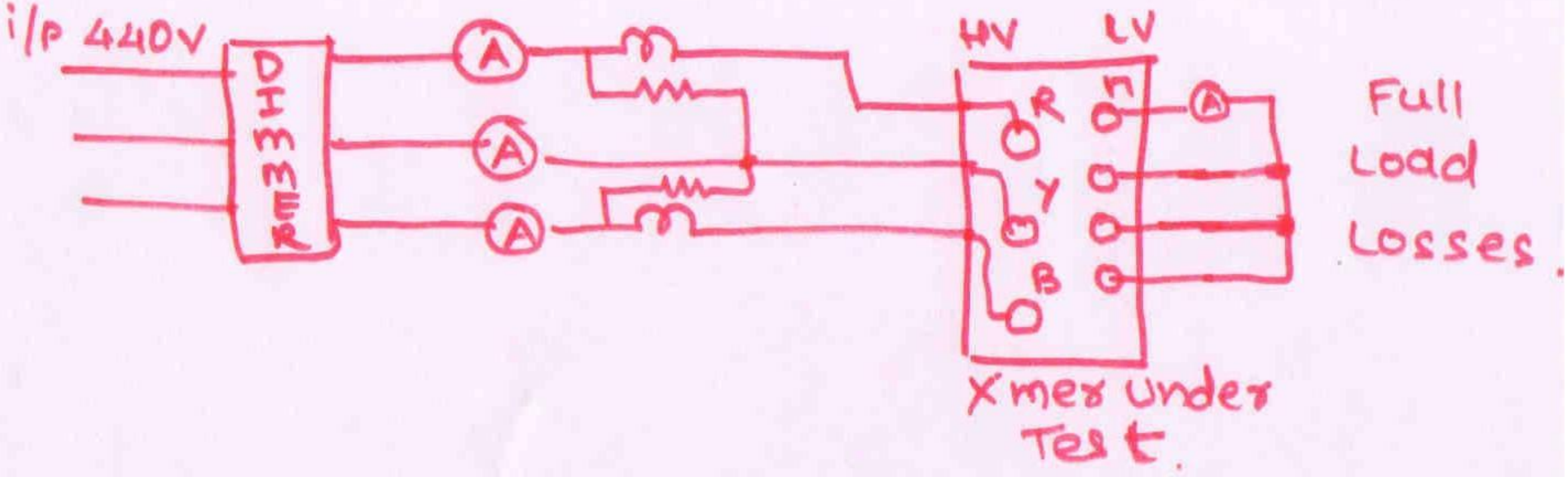
  The iron losses and no load current are measured in this test. The 433V winding is charged at 433V supply & the 11KV winding is left open .The power consumed by the transformer at no load is the no load loss in the transformer.

  Effect of actual frequency must be taken into account.

Equipment used : Wattmeters or power analyser.

LOSSES MEASUREMENT





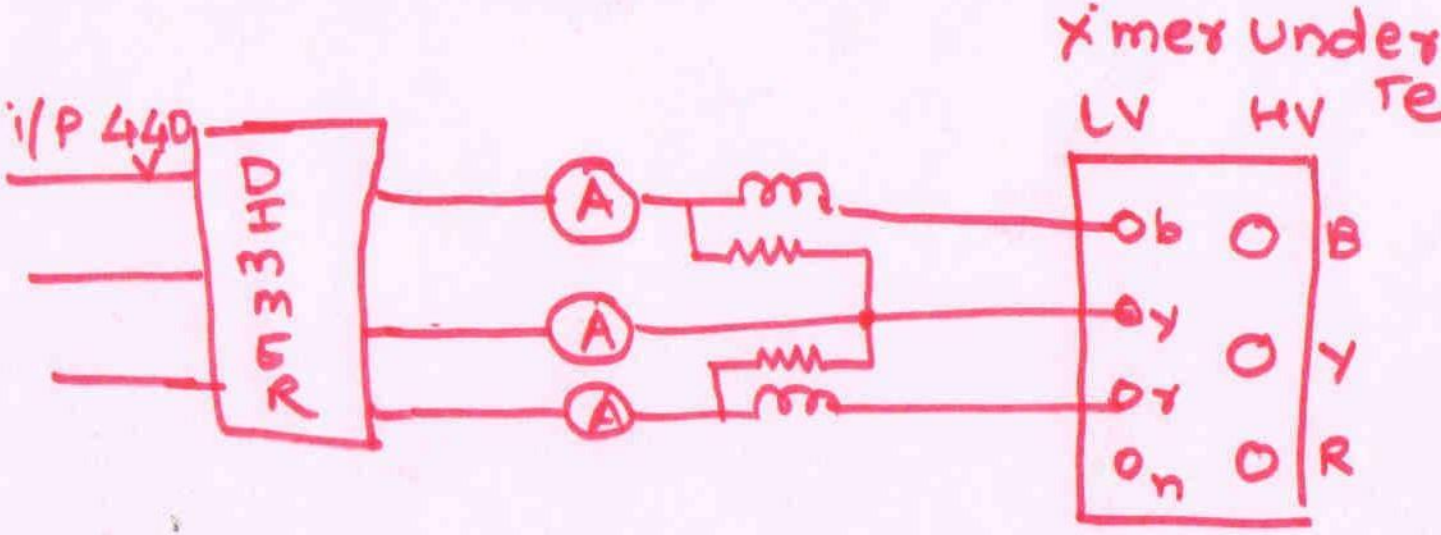
ROUTINE TESTS

- 7.Measurement of LOAD LOSS & IMPEDENCE.(EFFICIENCY & REGULATION)

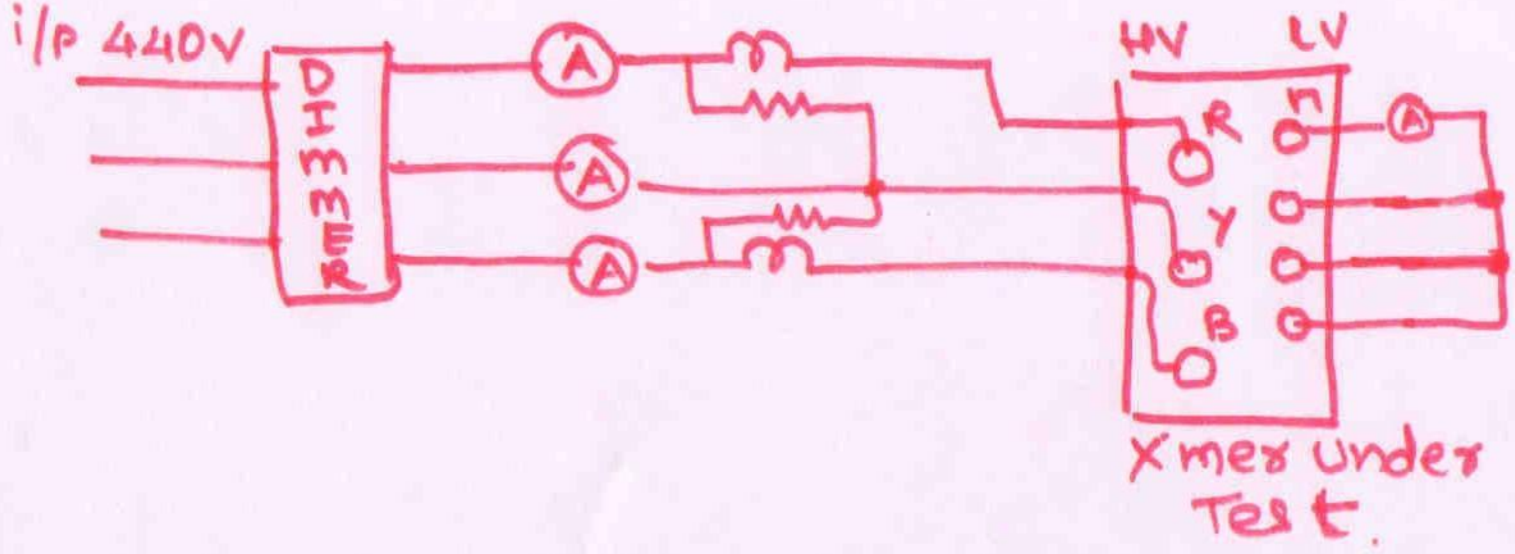
This test measures the power consumed by the transformer when the 433V winding is short circuited and The rated current is passed through the 11KV winding.

Equipment used : Wattmeters or power analyser.

LOSSES MEASUREMENT



No Load Losses.



Full Load Losses.

ROUTINE TESTS

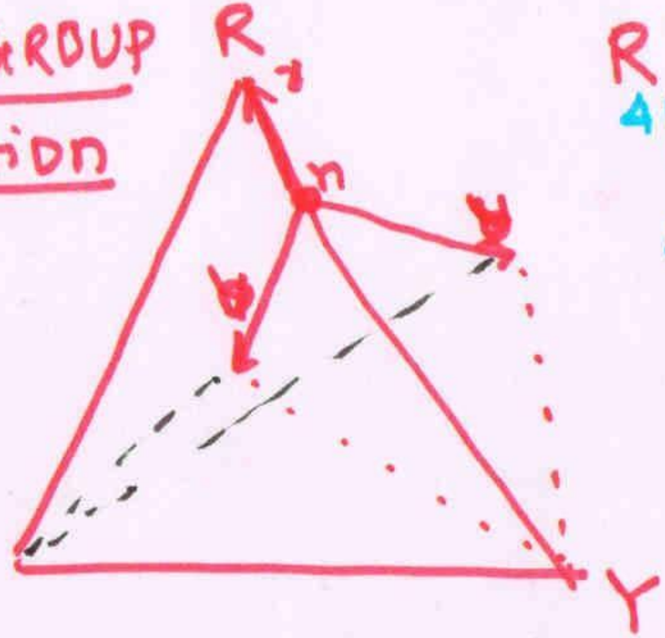
- 8.Vector Group Verification test

This test verifies the Dyn-11 vector group of a distribution transformer.

Equipment used : voltmeter.

VECTOR GROUP Verification

DYn11



$RY = Rn + Yn$

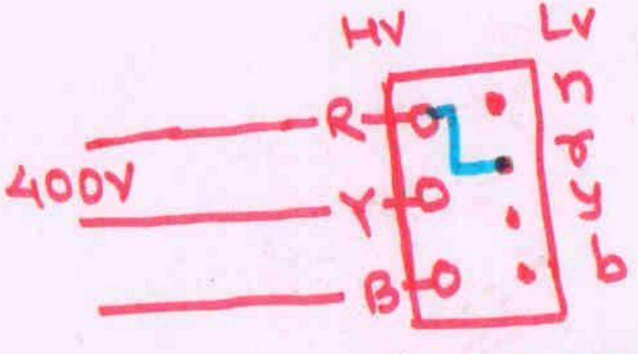
$400V = 7V + 393V$

$Yy = Yb$

$389V = 389V$

$By > Bb$

$399V > 389V$



Xmer under Test

ROUTINE TESTS

- Oil BDV TEST.

Oil breakdown voltage is checked as per IS-335.

100 mm L X 70 mm B X 80 mm Ht. glass pot.

500ml Oil sample.

Spherical electrodes with gap of 2.5 mm

Recommended value : 60KV

Equipment used : OIL BDV TEST SET.

TYPE TESTS

- LIGHTENING IMPULSE TEST

All the dielectric tests check the insulation level of the job.

Impulse generator is used to produce the specified voltage impulse wave of 1.2/50 micro seconds wave

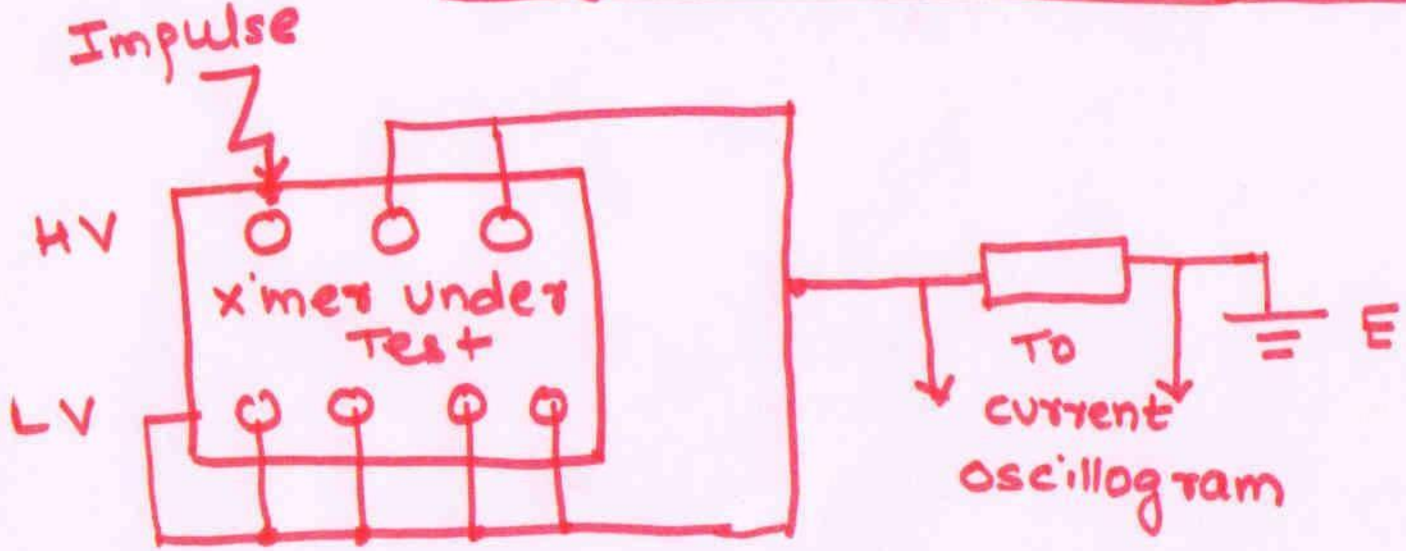
One impulse of a reduced voltage between 50 to 75% of the full test voltage and subsequent three impulses at full voltage.

For a three phase transformer, impulse is carried out on all three phases in succession.

The voltage is applied on each of the line terminal in succession, keeping the other terminals earthed.

The current and voltage wave shapes are recorded on the oscilloscope and any distortion in the wave shape is the criteria for failure.

Lightening Impulse Test



For 11KV → 75 KVP
22KV → 125 KVP
33KV → 170 KVP.

MAINTENANCE PROCEDURE

- OIL :

1. Oil level checking. Leakages to be attended.
2. Oil BDV & acidity checking at regular intervals. If acidity is between 0.5 to 1mg KOH, oil should be kept under observation.
3. BDV, Color and smell of oil are indicative.

MAINTENANCE PROCEDURE

1. Sludge, dust, dirt ,moisture can be removed by filtration.
2. Oil when topped up shall be of the same make. It may lead to sludge formation and acidic contents.

- Insulation resistance of the transformer should be checked once in 6 months.
- Megger values along with oil values indicate the condition of transformer.
- Periodic Dissolved Gas Analysis can be carried out.

MAINTENANCE

- BUSHINGS

Bushings should be cleaned and inspected for any cracks.

Dust & dirt deposition, Salt or chemical deposition, cement or acid fumes depositions should be carefully noted and rectified.

MAINTENANCE

- Periodic checking of any loose connections of the terminations of HV & LV side.
- Breather examination. Dehydration of Silica gel if necessary.
- Explosion vent diaphragm examination.
- Conservator to be cleaned from inside after every three years.
- Regular inspection of OIL & WINDING TEMPERATURE METER readings.
- Cleanliness in the Substation yard with all nets, vines, shrubs removed.

PROTECTION OF TRANSFORMERS

- The best way of protecting a transformer is to have good preventive maintenance schedule.
- Oil Temperature Indicators.
- Winding Temperature indicators.
- Buchholz Relay.
- Magnetic Oil level Gauge.
- Explosion Vent.

PROTECTION OF TRANSFORMERS

- HT fuse & D.O. fuse.
- LT circuit breaker.
- HT Circuit breaker with Over load, Earth Fault relay tripping.
- Oil Surge Relay for OLTC.
- PRV for OLTC.
- HORN GAPS & Lightening Arrestor.
- Breather.

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.

FAILURES & CAUSES

- Faulty design

•Poor Workmanship
Improper formation of core.
Improper core bolt insulation.
Burr to the lamination blades
Improper brazing of joints.
Burr /sharp edges to the winding conductor.
Incomplete drying.
Bad insulation covering.
Insufficient cooling ducts in the winding.


Thank you