Interview Guidebook

for

Engineering Services Examination,
State Engineering Services, PSUs and
other competitive examinations

Electrical Engineering

Part-I : Theory

Interview oriented concise theory, definitions,
concepts and formulae

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Interview Guidebook

Part - I : Theory

Interview oriented concise theory, definitions, concepts and formulae

Electrical Engineering

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Important Definitions

Q.1 What is Electrical Engineering?

Ans. Electrical engineering is concerned with the basic forms of energy that run our world. Where it's gas, hydro, turbine, fuel coal, solar, geothermal or wind energy, electrical engineers deal with distributing these energies from their sources to our homes, factories, offices, hospitals and schools.

Electrical engineering also involves the exciting field of electronics and information technology.

Q.2 What is control Systems?

Ans. A control system is a device or set of devices, that manages, commands, directs or regulates the behaviour of other devices or systems.

Q.3 What is electrical measurements?

Ans. Electrical measurements are the methods, devices and calculations used to measure electrical quantities.

Q.4 What is instrumentation?

Ans. Instrumentation is the use of measuring instruments to monitor and control a process.

Q.5 What is material science and engineering?

Ans. Material science and engineering involves the characterization of the physical and chemical properties of solid materials (metals and alloys, ceramics, magnetic materials, polymers etc.) for the purpose of using, changing or enhancing inherent properties to create or improve end products.

Q.6 What is electromagnetic theory?

Ans. Electromagnetic theory is a discipline concerned with the study of charges at rest and in motion.

Q.7 What is machine?

Ans. A machine is a tool containing one or more parts that uses energy to perform an intended action.

or

Semi or fully automated device that magnifies human physical and/or mental capabilities in performing one or more operations.

Q.8 What is power systems?

Ans. A electric power system is a network of electrical components used to supply transmit and use electric power.

Q.9 What is analog electronics?

Ans. Analog electronics are electronic systems with a continuously variable signal.

or

Analog circuit, electronic circuit that operates with currents and voltages that vary continuously with time and have no abrupt transitions between levels.

Q.10 What is digital electronics?

Ans. Digital electronics, or digital (electronic) circuit, represent signals by discrete bands of analog levels, rather than by a continuous range. All levels within a band represent the same signal state.

Q.11 What is microprocessor?

Ans. The microprocessor is a multipurpose programmable device that accepts digital data as input, processes it according to instructions stored in its memory, and provides results as output, it is an example of sequential digital logic, as it has internal memory.

Q.12 What is power electronics?

Ans. Power electronics is the study of switching electronic circuits in order to control the flow of electrical energy.

or

Power electronics is the application of solid-state electronics for the control and conversion of electric power.

Q.13 What is analog communication?

Ans. A communication format in which information is transmitted by modulating a continuous signal, such as sound wave.

or

Analog communication is a data transmitting technique in a format that utilizes continuous signals to transmit data including voice, image, video etc.

Q.14 What is digital communication?

Ans. A digital communications is the physical transfer of data (a digital bit stream) over a point-to-point communication channel.

E.g. Copper wires, optical fibres, wireless communication channels.

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CHAPTER 1

Electric Machines

TRANSFORMERS

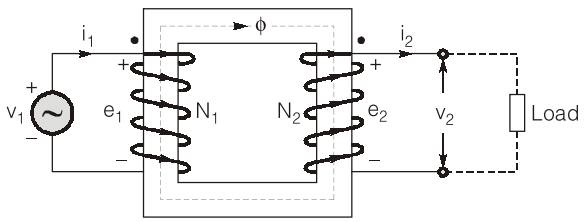
A transformer is a static device which consists of two or more stationary electric circuits interlinked by a common magnetic circuit for the purpose of transferring electrical energy between them while keeping the frequency of operation consant.

Remember

- Basic principal behind the transformer action is Faraday's law of electromagnetic induction.
- Transformer is a constant frequency and constant power device.

Induced EMF

Direction of induced emf can be found by "Lenz's law" and magnitude of induced emf can be given by "Faraday's law of electromagnetic induction".



❑ RMS value of induced Emf.

In primary winding

$$\boxed{E_1 = \sqrt{2}\,\pi N_1 f \phi_m} \text{ Volts}$$

In secondary winding

$$\boxed{E_2 = \sqrt{2}\,\pi N_2 f \phi_m} \text{ Volts}$$

where,

N_1 = Number of turns in primary winding

N_2 = Number of turns in secondary winding

ϕ_m = Maximum value of the magnetic flux, in webers

f = Supply frequency, in Hz

Remember

- Emf per turn in primary = Emf per turn in secondary
- Compensating primary mmf = Secondary mmf

$$\boxed{I_1' N_1 = I_2 N_2}$$

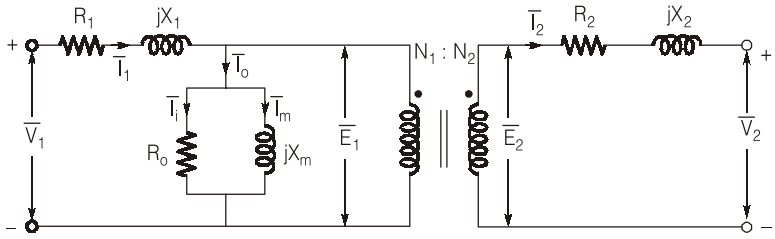
where, I_1' = Load component of primary current I_1

- Primary volt-amperes = Secondary volt-amperes.
- Instantaneous power input into primary is equal to the instantaneous power output from the secondary.
- Step up transformer : $N_1 < N_2$.
- Step down transformer : $N_1 > N_2$.

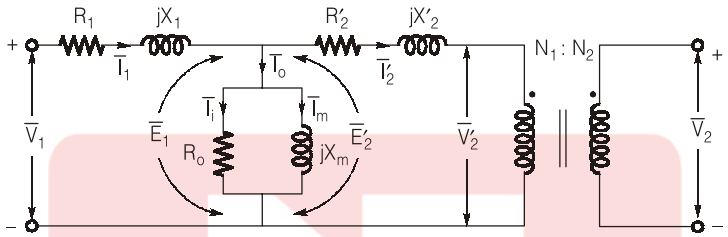
Ideal Transformer

- The transformer core has infinite permeability. So, flux established without any magnetising current.
- The primary and secondary windings have zero resistance. So, there is no ohmic power loss and no resistive voltage drop.
- There is no magnetic leakage flux.
- The core loss considered to be zero.

Equivalent Circuit



Exact equivalent circuit of transformer



Equivalent circuit referred to primary side

where, $\bar{V}_1$ = Applied voltage to primary side.

$\bar{V}_2'$ = Secondary terminal voltage referred to primary side.

$\bar{E}_1, \bar{E}_2$ = Induced emf in primary and secondary side.

$\bar{E}_2'$ = Secondary induced emf referred to primary side.

$\bar{I}_o$ = No load current.

$\bar{I}_m, \bar{I}_i$ = Magnetizing and core loss component of exciting current.

R_1, R_2 = Primary and secondary winding resistances.

X_1, X_2 = Primary and secondary winding leakage reactances.

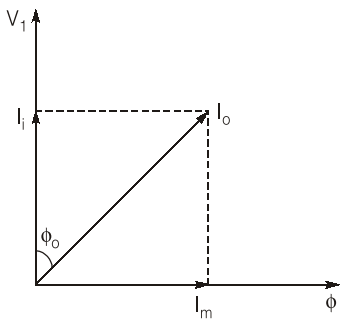
R_2', X_2' = Secondary resistance and leakage reactance referred to primary side.

R_o = Core loss equivalent resistance.

X_m = Magnetising reactance.

Note:

At no load, current drawn from the supply is I_o



$\bar{I}_o = \bar{I}_m + \bar{I}_i = (2 \text{ to } 5\% \text{ of } I_{fl})$

$\bar{I}_m = I_o \sin\phi_o$

= Magnetizing current and is responsible for the production of flux.

$\bar{I}_i = I_o \cos\phi_o$

= Core loss current responsible for the active power being drawn from the source to provide hysteresis and eddy current losses.

ϕ_0 = No load phase angle (80 to 85°)

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Basic Equations for Transformer

$$\bar{E}_1 = a\bar{E}_2$$

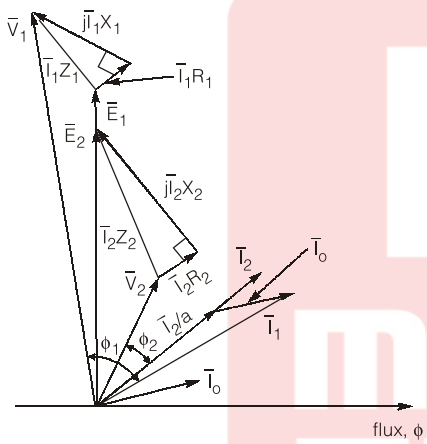
$$\bar{I}_o = \bar{I}_m + \bar{I}_i$$

$$\bar{E}_2 = \bar{V}_2 + \bar{I}_2 R_2 + j\bar{I}_2 X_2$$

$$\bar{V}_1 = \bar{E}_1 + \bar{I}_1 R_1 + j\bar{I}_1 X_1$$

$$\bar{I}_1 = \frac{\bar{I}_2}{a} + \bar{I}_o$$

Phasor Diagram



Step down transformer at lagging power factor

Note:

- $R_{01} = R_1 + R_2'$ = Equivalent resistance referred to primary side.
- $X_{01} = X_1 + X_2'$ = Equivalent reactance referred to primary side.
- $Z_{01} = \sqrt{R_{01}^2 + X_{01}^2}$ = Equivalent impedance referred to primary side.
- Core of transformer should have low reluctance and high permeability.
- It is made from CRGO (cold rolled grain oriented) material with 4% of silicon.
- It is laminated to reduce eddy current losses.

Types of Transformer Construction

1. Core type 2. Shell type

S.No.	Core type transformer	Shell type transformer
1.	Series magnetic circuit	Parallel magnetic circuit
2.	2 limb and 2 yoke	3 limb and 2 yoke
3.	Suitable for low flux density application	Suitable for high flux density application
4.	Required more amount of copper	Required less amount of copper
5.	Required less amount of insulation so suitable for high voltage and high power applications	Suitable for low voltage and lower power applications

Remember:

- Transformer windings are made up of stranded conductors instead of solid conductor.
- Low voltage windings are placed nearer to the core, for reducing insulation requirement.

Losses in Transformer

1. Copper Loss (P_{cu})

This loss is variable loss.

Total copper loss = Primary copper loss + Secondary copper loss

$$P_{cu} = I_1^2 R_1 + I_2^2 R_2$$

Resistance referred to any one side.

$$P_{cu} = I_1^2 R_{01} = I_2^2 R_{02}$$

Remember:

p.u. resistance = p.u. full load copper loss

2. Iron Loss (P_i)

This loss is constant loss.

Iron loss = Hysteresis loss + Eddy current loss

(a) Hysteresis loss (P_h)

$$P_h = K_h f B_m^x$$

where,

K_h = Proportionality constant depends upon volume, quality of the core material and units used

B_m = Maximum flux density in the core
f = Supply frequency
x = Steinmetz exponent (value vary from 1.5 to 2.5)

But, $B_m \propto \frac{V}{f}$

(i) If $\frac{V}{f}$ = constant

$$\boxed{P_h \propto f}$$

(ii) If $\frac{V}{f} \neq$ constant

$$\boxed{P_h = A V^{1.6} f^{-0.6}}$$ [if x = 1.6 i.e. for silicon steel]

where, A = constant

(b) Eddy current loss (P_e)

$$\boxed{P_e = K_e f^2 B_m^2 t^2}$$

where, K_e = Proportionality constant depends upon volume and resistivity of the core material, thickness of laminations and units employed
f = Supply frequency
B_m = Maximum flux density
t = Thickness of lamination

But, $B_m \propto \frac{V}{f}$

(i) If $\frac{V}{f}$ = constant

$$\boxed{P_e \propto f^2}$$

(ii) If $\frac{V}{f} \neq$ constant

$$\boxed{P_e \propto V^2 \text{ or } P_e = BV^2}$$

where, B = constant

Remember:

- The iron-loss can be reduced by reducing the core flux density which means that the for same flux, the core cross-sectional area must be increased.
- Size of distribution transformer is larger as compare to similar power transformer as iron to copper ratio of distribution transformer is higher.

(c) Stray load loss

It largely results from leakage flux including eddy currents in the tank walls, conductors etc.

(d) Dielectric loss

The seat of this loss is in the insulating materials particularly in transformer oil and solid insulations of high voltage transformers.

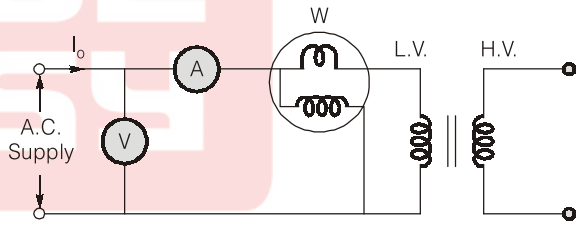
Remember:

Rating of transformer is given in kVA because constant loss is proportional to voltage and variable loss is proportional to current so total loss in transformer is proportional to volt ampere.

Open Circuit Test and Short Circuit Test

- These two tests on transformer helps to determine are:
  (a) The parameters of the equivalent circuit
  (b) Voltage regulation
  (c) Efficiency
- They help in predicting performance of transformer without actually loading it.

1. Open Circuit (OC) Test



Main objectives of this test are:

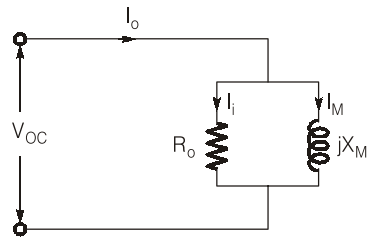
(a) To find out parameters of no load branch i.e. R_o and X_m of equivalent circuit (shunt branch parameter).
(b) To find out constant losses in the transformer (i.e. core loss).

Remember:

- This test must be conducted at rated flux condition i.e. at rated voltage and rated frequency.
- This test is performed on L.V. side while H.V. side is open circuited.

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Sequence of equations used to find different parameters



Wattmeter reading = P_i (core loss or iron loss)
Voltmeter reading = V_{oc} (Rated voltage)
Ammeter reading = I_o (No load current)
No load power factor = Cos ϕ_o

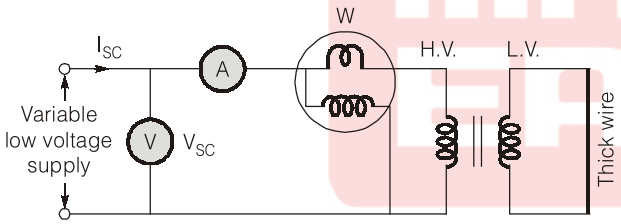
$$P_i = V_{oc} I_o \cos\phi_o$$

$$\cos\phi_0 = \frac{P_i}{V_{oc} I_o}$$

$$I_i = I_o \cos\phi_o \quad \text{and} \quad I_m = I_o \sin\phi_o$$

$$R_o = \frac{V_{oc}}{I_i}, \quad \text{and} \quad X_m = \frac{V_{oc}}{I_m}$$

2. Short-Circuit (SC) Test



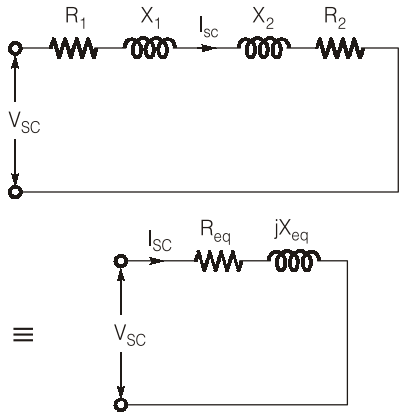
Main objectives of this test are:

(a) To find out total resistance and reactance of transformer, when referred to the winding in which the measuring instruments are placed to conduct this test.

(b) To find out variable losses in the transformer (i.e. copper loss).

Remember:

- This test should be conducted at rated current condition.
- This test is conducted at H.V. side while L.V. side is short circuited with a thick conductor.



Wattmeter reading= P_{sc} (rated copper loss)
Voltmeter reading = V_{sc}
Ammeter reading = I_{sc} (rated current)

Note:

- R_{eq}, X_{eq} and Z_{eq} are referred to high voltage side
- Power factor on short circuit $\cos\phi_{sc} = \frac{R_{eq}}{Z_{eq}}$
- Back to back or Sumpner's test is used to determine maximum temperature rise of transformer

Efficiency

Efficiency (η)

$$= \frac{\text{Output power}}{\text{Input power}} = \frac{\text{Output}}{\text{Output} + \text{losses}}$$

$$(\eta)_{\text{Full load}} = \frac{(\text{kVA})_{f/} \cos\phi}{(\text{kVA})_{f/} \cos\phi + P_i + (P_{cu})_{f/}}$$

where, P_i = Core loss or iron loss
$(P_{cu})_{f/}$ = Full load copper loss

Note:

Efficiency at any fraction 'x' of full load

$$(\eta)_{x\cdot\text{Full load}} = \frac{x(\text{kVA})_{f/} \cos\phi}{x(\text{kVA})_{f/} \cos\phi + P_i + x^2(P_{cu})_{f/}}$$

Condition for Maximum Efficiency

Copper loss = Iron loss

$$I_{\eta max} = \sqrt{\frac{P_i}{R_{eq}}}$$

KVA load for Maximum Efficiency

$$S_{\eta_{max}} = S_{(known\ load)} \cdot \sqrt{\frac{P_i}{P_{cu(known\ load)}}}$$

where,

$S_{\eta_{max}}$ = KVA rating at maximum efficiency

$S_{(known\ load)}$ = KVA rating at known load

$P_{cu(known\ load)}$ = Copper loss at known load

For full load

$$S_{\eta_{max}} = S_{full\ load} \cdot \sqrt{\frac{P_i}{P_{cu(full\ load)}}}$$

All day efficiency

$$\eta_{all\ day} = \frac{\text{Output energy (kWh) in 24 hrs.}}{\text{Input energy (kWh) in 24 hrs.}}$$

Remember:

- The maximum efficiency for a constant load current occurs at unity power factor.
- Efficiency is independent of type of power factor.

Voltage Regulation

Voltage regulation of transformer is defined as the rise in output (secondary) voltage express as the fraction of full load rated voltage when full load (at specified pf) is reduced to zero keeping the primary impressed terminal voltage constant.

$$\text{Voltage regulation} = \frac{\text{No load voltage} - \text{Full load voltage}}{\text{Full load voltage}}$$

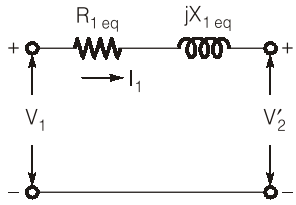
where, full load voltage = Rated voltage

Remember:

- Regulation is always calculated on full load and should be as low as possible.

Approximated Equivalent Circuit Referred to Secondary

- Voltage regulation



$$V.R = \frac{I_1 R_{1eq}}{V_{rated}}\cos\phi + \frac{I_1 X_{1eq}}{V_{rated}}\sin\phi$$

$$V.R = R_{p.u.}\cos\phi + X_{p.u.}\sin\phi$$

where, ϕ = angle between V_2' and I_1

$R_{p.u.}$ = p.u. equivalent resistance

$X_{p.u.}$ = p.u. equivalent reactance

- ϕ is positive for lagging power factor and negative for leading power factor.
- Condition for maximum voltage regulation

$$\cos\phi = \frac{|R_{p.u.}|}{|Z_{p.u.}|} = \frac{R_{1eq}}{Z_{1eq}} \text{ lagging}$$

- Maximum voltage regulation

$$(V.R)_{max} = Z_{p.u.}$$

- Condition for zero voltage regulation

$$\cos\phi = \frac{X_{p.u.}}{Z_{p.u.}} = \frac{X_{1eq}}{Z_{1eq}} \text{ Leading}$$

Remember:

- For leading p.f., greater than $\frac{X_{p.u.}}{Z_{p.u.}}$, the voltage regulation will be negative
- Regulation is always positive at all lagging p.f. loads and also at unity p.f. load.
- Regulation may be positive at large leading power factor, near to unity and regulation is negative at low leading power factor, away from unity.

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Electrical Engineering

Part-II

Topicwise Bifurcated
Previous Interview Questions
and Practice Questions

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Part-II

Topicwise Bifurcated

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CHAPTER 1

Electrical Machines

1. Magnetic Circuits

1.1 What is MMF? [ESE-2013]

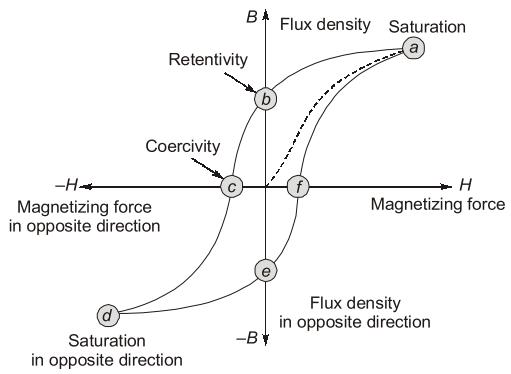
Ans. Magnetomotive force, also known as the magnetic potential, is the property of certain substances or phenomena that gives rise to magnetic flux.

1.2 What is a hysteresis curve loss and its applications? [ESE : 2013, 2014]

Ans. If an alternating magnetic field is applied to the material, its magnetization will trace out a loop called a hysteresis loop. Hysteresis means to lag behind. It is due to intermolecular friction. Common applications include magnetic tape, hard disks, credit cards etc.

1.3 Draw Hysteresis loop. [ESE-2017]

Ans.



1.4 What are eddy currents, and how do you reduce hysteresis losses? [ESE : 2025]

Ans. Eddy currents are localized loops of electrical current induced within conductors by a changing magnetic field, causing resistive heat losses. Hysteresis losses are reduced by constructing the core out of materials with a narrow B-H curve (small hysteresis loop area), such as CRGO (Cold Rolled Grain Oriented) Silicon Steel.

2. Transformer

2.1 If the thickness of laminations is reduced in a transformer, what will be the effect on core loss? [ESE : 2022]

Ans. Core loss is made of

(a) Hysteresis loss

(b) Eddy current loss

Hysteresis loss doesn't depend upon lamination thickness. Eddy current loss depends upon the square of lamination thickness.

$$P_e = K_e f^2 B_m^2$$

$$K_e = K_e' \frac{d^2}{\rho}$$

$d \rightarrow$ lamination thickness

$\rho \rightarrow$ resistivity of material

So if lamination thickness is reduced, eddy current loss will decrease.

2.2 A transformer designed to operate at 50 Hz is operated at rated voltage and 60 Hz. How will it change the core loss of the transformer?

Ans. $V = 4.44\, fN\phi_{max}$

If V is the same and f is increased then flux will decrease in the same proportion.

Eddy current loss = $K_e f^2 B_m^2$

f is increased but B_m decreases in the same proportion so eddy current loss does not change.

Hysteresis loss = $K_h f B_m^n$

n may vary from 1.5 to 2.5.

f increases, but B_m decreases so hysteresis loss will decrease.

2.3 Under which condition is the voltage regulation of a transformer zero?

Ans. Voltage regulation = $IR\cos\phi - IX\sin\phi = 0$

$\tan\phi = \dfrac{R}{X}$; leading power factor.

2.4 Why are distribution transformers are designed to attain maximum efficiency at 70% of full load?

Ans. The load at a distribution transformer varies widely during the day and night. If maximum efficiency occurs at 70% of full load, then the probability is high that most of the time the transformer operates around maximum efficiency. Due to this, the all-day efficiency of the transformer is high.

All day efficiency

$$= \frac{\text{Total energy output in 24 hours}}{\text{Total energy input in 24 hours}}$$

It is dependent on load cycle.

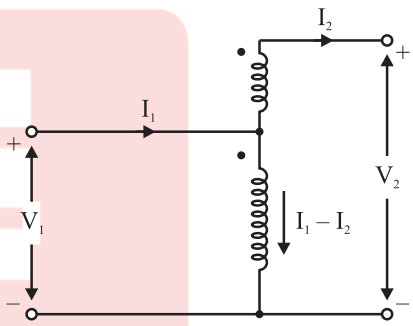
2.5 Why is the excitation current is non-sinusoidal in the case of transformers? Which harmonic is predominant?

Ans. Due to saturation of the core, magnetising current is peaky and non-sinusoidal if flux is sinusoidal. But if magnetising current is sinusoidal, then flux is flat-topped and induced emf is peaky and non-sinusoidal. In both cases, the third harmonic is predominant.

2.6 Why does inrush current flow in a transformer? [ESE-2019, 2021]

Ans. When voltage is switched ON to the transformer, flux and magnetising current undergo a transient before reaching the steady-state value. This transient current is called inrush current. The severity of the switching transient is dependent upon the instant when the voltage wave is switched on. The worst condition occurs when applied voltage has zero value at the instant of switching.

2.7 A 2000/200 V 20 kVA transformer is connected as step up autotransformer as shown in figure. What are kVA transferred inductively and kVA transferred conductively?



Ans. $V_1 = 2000$ V

$V_2 = 2000 + 200 = 2200$ V

$I_2 = \dfrac{20 \times 1000}{200} = 100$ A

$I_1 - I_2 = 10$ A ; $I_1 = 110$ A

kVA transferred inductively

$$= \frac{V_1(I_1 - I_2)}{1000} = \frac{2000 \times 10}{1000}$$

$= 20$ kVA

kVA transferred conductively = $V_1 I_1 - 20$

[$V_1 I_1$ = Total kVA]

$= 2000 \times 110 - 20$

$= 200$ kVA

2.8 For extra high voltage requirements, core type construction is preferred over shell-type. Why?

Ans. The core type construction has a longer mean length of core and a shorter mean length of coil turn. This type is better suited for EHV requirement since there is better scope for

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insulation. The core type offers the additional advantage of permitting visual inspection of coils in the case of fault and ease of repair at substation site.

2.9 In an open circuit test, the power supply is connected to the low-voltage side but in short circuit test power supply is connected to the high voltage side of the transformer. Why?

Ans. In an O.C. test rated supply voltage is applied to transformer. If power supply is connected to H.V. side then we need to make arrangement for H.V. supply. But if we connect power supply to L.V. side then we need not make such arrangement. While in short circuit test we need to short circuit H.V. side if we connect power supply to L.V. side. Also it will draw heavy current from supply line. Due to this reason we connect power supply to H.V. side. In S.C. test rated voltage is not applied so no requirement of High voltage.

2.10 Why are three single phase transformers are used in underground mines instead of one three phase transformer?

Ans. A three-phase transformer costs less than a three single-phase transformer bank. But due to easy transportation and installation single phase transformer bank is preferred in underground mines. Also this transformer bank can operate in open delta in case one unit is removed for maintenance.

2.11 What are the necessary conditions for parallel operation of transformers?

[ESE-2016, 2021]

Ans. For 1-phase and 3-phase transformers:

(i) Transformers must be properly connected with the same polarity (necessary).

(ii) Same voltage ratio and same voltage rating on primary and secondary (necessary).

(iii) Same p.u. impedances for proportional load sharing (desirable).

(iv) Same X/R ratio for the same power factor operation (desirable).

For 3-phase transformers:

(i) Same phase sequence (necessary).

(ii) Zero relative phase difference (necessary).

2.12 What functions does a tertiary winding perform in three-winding transformers?

Ans. (a) It permits the third harmonic current to flow, thereby reducing third harmonic voltages.

(b) A delta-connected tertiary reduces the impedance offered to the zero sequence currents there by allowing a larger earth fault current to flow for proper operation of protective equipment.

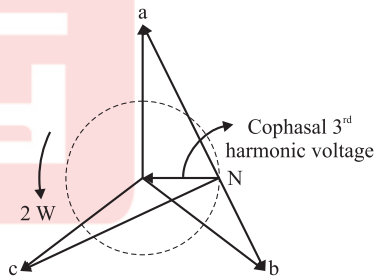
(c) Static capacitors and synchronous condensers may be connected to the tertiary winding for reactive power injection into the system for voltage control.

(d) To supply substation auxiliaries at a voltage different from those of the primary and secondary windings.

2.13 What is oscillating neutral in case of star-star connected transformers?

[ESE-2021]

Ans.



In the case of isolated neutrals, 3rd harmonic voltages are present in each phase. Since these voltages are cophasal, no 3rd harmonic voltages are present between lines. The voltage of phase 'a' to neutral can now be expressed as,

$$e_{aN} = e_a \sin\omega t + e_{a3} \sin 3\omega t$$

Third harmonic voltages are cophasal but this phase changes at a rate of 2ω with respect to fundamental frequency. Due to this voltage of neutral point oscillates at frequency 2ω. It is called oscillating neutral.

2.14 Two 3-phase transformers are to be connected in parallel on the both primary and secondary side. Why is the following arrangement not possible?
Transformer A : Primary Δ; Secondary Y.
Transformer B : Primary Δ; Secondary Δ.

Ans. In Y-Y and Δ-Δ connection phase shift possible is 180° and 0°. While in Y-Δ or Δ-Y connection phase shift possible is ±30°. Phase shift in case of transformer A will be ±30° but for transformer B will be either 0° or 180°. So phase displacement will not match on secondary side. Due to this parallel operation is not possible.

2.15 If the height-to-width ratio of the window of a core-type transformer is increased, then what will be the change in leakage reactance and voltage regulation?

Ans. Its leakage reactance and percentage voltage regulation will increase.

2.16 The rating of a transformer is expressed in kVA/MVA. Explain.

[ESE-2023, 2025]

Ans. Copper loss of a transformer depends on current and iron loss depends on voltage. Hence, total transformer loss depends on volt-ampere (VA) and not on phase angle between voltage and current i.e. it is independent of load power factor. Hence, the rating of the transformer is expressed in kVA and not in kW..

2.17 What do you understand by 'Vector Groups' of a transformer?

[ESE-2021]

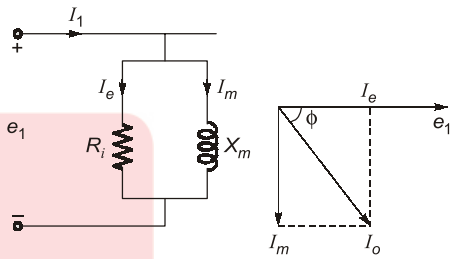
Ans. A vector group is the International Electrotechnical Commission (IEC) method of categorizing the HV winding and LV winding configurations of a three-phase transformer. The vector group designation indicates the winding configurations and the difference in phase angle between them. For example, a wye HV winding and delta LV winding with a 30-degree lead is denoted as Yd11.

2.18 Explain excitation phenomenon in a transformer.

Ans. The primary winding draws a small amount of current known as exciting current which establishes flux ϕ_m in the core which produces emf given by Faraday's law,

$$e_1 = -\frac{d\lambda_1}{dt} = -\frac{N_1\, d\phi}{dt}$$

As per Lenz's law, this emf opposes the induced current.



To keep ϕ_m constant, the primary produces an additional flux ϕ_2, so it takes additional current known as counterbalancing current. This phenomenon continues so that the total flux, ϕ_m remains constant from no-load to full-load.

2.19 Explain 'Tap-Changing' in a transformer.

[ESE-2019]

Ans. Tap-changing in transformers serves the following purposes:

1. Adjustment of consumers' terminal voltage within prescribed limits.
2. Control of real and reactive power flow in the network.
3. Periodical adjustment (1-10%) to check offset load variations.

Adjustment is normally carried out by off-circuit tap changing in 2.5-5% steps. Daily and short-time control or adjustment is carried out by means of on-load tap-changing gear.

2.20 What is an amorphous transformer?

Ans. Amorphous-core transformers use an amorphous alloy in their iron core, for example, a ribbon of steel which has a lower hysteresis loss and thus reduces the no-load or core losses of the transformer by 20-30%. Overload capacity is

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better as heat generation is less and CO_2 and SO_2 emissions are reduced (more energy efficient) due to lesser generation, compared to the conventional transformer.

2.21 What tests will you perform after the erection of a power transformer?

[ESE-2006]

Ans. 1. Polarity test
2. Open circuit and short circuit tests
3. Heat run test

2.22 What are multiple winding transformers?

[ESE-2012]

Ans. We know of transformers that have a one single primary winding and a single secondary winding. But the beauty of transformers is that they allow us to have more than just one winding in either the primary or secondary side. Transformers which have more than one winding are known commonly as Multiple Winding Transformers.

2.23 What are the Characteristics of Ideal Transformers?

[ESE-2012]

Ans. Characteristics of Ideal Transformer

- Zero winding resistance: It is assumed that the resistance of the primary as well as the secondary winding of an ideal transformer is zero. That is, both the coils are purely inductive in nature.
- Infinite permeability of the core: Higher the permeability, lesser the mmf required for flux establishment. That means, if the permeability is high, less magnetizing current is required to magnetize the transformer core.
- No leakage flux: Leakage flux is a part of magnetic flux which does not get linked with the secondary winding. In an ideal transformer, it is assumed that the entire amount of flux gets linked with the secondary winding (that is, no leakage flux).
- 100% efficiency: An ideal transformer does not have any losses like hysteresis loss, eddy current loss etc. So, the output power of an ideal transformer is exactly equal to the input power. Hence, 100% efficiency.

2.24 What are eddy current losses?

[ESE-2013, 2023]

Ans. **Eddy current:** A localized electric current induced in a conductor by a varying magnetic field.
Eddy currents generate resistive losses that transform some forms of energy, such as kinetic energy, into heat. This Joule heating reduces efficiency of iron-core transformers and electric motors and other devices that use changing magnetic fields.

2.25 What is the cooling medium in a distribution transformer?

[ESE-2014, 2022]

Ans. Cooling medium in a DT is transformer oil. This oil is generally silicon-based or fluorinated hydrocarbons, pentaerythritol tetra fatty acid, PCBs (poly chlorinated biphenyls), etc.

2.26 For a single phase transformer, if the frequency is increased from 50 Hz to 400 Hz by keeping the same voltage as 230 V, what will be the effect on core losses?

[ESE-2014]

Ans. For constant voltage,

$$P_{eddy} \propto B_m^2 f^2 \qquad \left(B_m = \frac{V}{f}\right)$$

So, P_{eddy} = Constant ...(1)

and $P_{hys} \propto B_m^{1.6} f$

$$P_{hys} \propto f^{-0.6} \quad ...(2)$$

So, the hysteresis loss will decrease while the eddy current loss will remain the same. So, the core loss is decreased.

2.27 How does a transformer breathe?

[ESE-2014, 2022]

Ans. A transformer is provided with a conservator through which it breathes into the atmosphere.

The conservator is a small-sized tank placed on top of the main tank. To prevent moisture entry into transformer, Silica gel breather is used. The cooling oil in transformer expands or contracts with temperature changes. Therefore this arrangement is provided to allow oil to expand or contract. This is called transformer breathing.

2.28 What will happen if a small air gap is introduced in transformer core? [ESE-2015]

Ans. It will increase the reluctance of the magnetic path due to which more magnetising current will flow for generating the same amount of flux in the core. If air gap is more then current rating of primary winding will impose a limit on magnetising current and desired flux can't be generated in core. Although if gap is small it will remove saturation of magnetic field in core and it is used in current transformers.

2.29 Why do we calculate the all-day efficiency of a transformer? [ESE-2015, 2020]

Ans. A distribution transformer cannot be run with constant load throughout 24 hours. At day peak time its loading is high, whereas in the night time its loading may be negligible.. So, the ratio of total energy delivered by the transformer to the total energy fed to the transformer, during a 24 hours span of time instead of ratio of power output and input of the transformer is used to calculate the efficiency of the transformer, known as all day efficiency. The efficiency of the transformer is maximum at 50% of full load.

2.30 Out of power transformer and distribution transformer, which one has more per unit reactance? [ESE-2015]

Ans. Voltage regulation for a power transformer is low as compared to a distribution transformer due to the larger comparative size of the distribution transformer, and hence the per-unit reactance of the distribution transformer is more.

2.31 What is the difference between current transformer and potential transformer? [ESE-2015, 2021]

Ans. The difference is in method of operation. Current transformers measure current in AC equipment of high rating generally, and potential transformers measure voltage by stepping the voltage down to a lower value. They differ in construction as well. Current transformer has one primary and many secondary turn of thick wire, whereas voltage transformer has many number of primary turns and few number of secondary turns.

2.32 Explain the working principle of transformer? [ESE : 2013, 2015]

Ans. Transformer works on the principle of mutual induction between two coils. When current in the primary coil changes, flux linking both coils change and consequently an EMF is induced in the secondary coil.

2.33 How can we reduce core losses in transformer? [ESE-2015, 2023]

Ans. The core losses are actually hysteresis loss and Eddy current loss together. Hysteresis loss can be reduced by using materials with less hysteresis loop area as core material of transformer for eg: soft magnetic materials, such as silicon steel, steel alloys, Mn-Zn ferrite.
Eddy current losses occur throughout the body (core) of the transformer, so in place of a solid shape, we use a stack of thin laminations, which reduces the eddy current loops in the core body and hence reduces eddy current loss. By adding silicon the resistivity is increased (4% to 5%) and hence this reduces eddy current losses.

2.34 Why are core losses higher in a DC machine as compared to transformers? [ESE-2015]

Ans. In the case of DC machines, as the iron core of the armature is rotating in a magnetic field, some losses (hysteresis and eddy current losses) occur in the core, called core losses. In transformers which are static devices, core losses are lesser due to high quality core materials (decreased

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hysteresis losses) and thinner laminations (decreased eddy current losses) used.
Also, in transformers power transformation takes place through a high quality core (to concentrate magnetic flux) but not through air gap like in motors or generators. So air gap reluctance and leakage losses are negligible.

2.35 In a transformer if we cut down the current to half, what will be the effect on core losses and copper losses?

[ESE-2015]

Ans. When the transformer is operated on full load it means maximum rated current is flowing through the secondary winding of the transformer. When load is reduced to half, it reduces copper loss which is proportional to square of current, to one fourth of full load copper loss. Core losses are not affected.

2.36 In general, what is the efficiency of transformer?

[ESE-2015]

Ans. Transformer in general has a very high efficiency because it does not have rotating parts. The power transformers have efficiencies ranging near to 95% as they are always working at full load but in a distribution transformer efficiency is less due to variable loading conditions causing variable copper loss.
For power transformer,

$$\text{Efficiency} = \frac{\text{kVA output}}{\text{kVA output + losses}}$$

$$\text{Losses} = P_i + P_{Cu} = P_i + I^2 R_{eq}$$

maximum efficiency occurs when,

$$P_i = P_{cu}$$

2.37 What are the structural differences between a Power Transformer and a Distribution Transformer?

[ESE-2015, 2019]

Ans. As the ratio of iron to copper is high in case of distribution transformer in comparison to power transformer hence size of distribution transformer is more than power transformer for the same rating value.

2.38 With the variation in voltage. How are the losses in the transformer affected?

[ESE-2015, 2021]

Ans. Transformer emf is given by E

$$E = 4.44\, f\phi N$$

$$\therefore \quad E \propto \phi \text{ and } \frac{\phi}{A} = B$$

where, B = Magnetic flux density
A = Area of cross-section

Hysteresis loss $\propto f B_m^n$ per unit volume where,

n = Steinmetz exponent
= 1.5 to 2.5 generally taken 2.

Hence hysteresis loss $\propto E^n$
where $(1.5 < n < 2.0)$
Eddy current loss $\propto f^2 B_m^2 t^2 \propto f^2 V^2 t^2$
Hence, eddy current loss $\propto E^2$
Copper loss also vary with square of voltage proportionality as shown below

$$P_{Cu} \propto V^2$$

2.39 Explain Lenz's law? [ESE : 2013, 2016]

Ans. Lenz's law states that the direction of an induced current is always such as to oppose the change in the circuit or the magnetic field that produces it. The emf induced in a circuit due to change in flux linkages will be such that it opposes its cause of production.

2.40 How to reduce hysteresis loss? [ESE-2016]

Ans. Hysteresis loss is directly proportional to area of hysteresis loop. Hence to minimize it, silicon steel or high grade steel is used for manufacturing of core as it has small hysteresis loop area.

2.41 What is transformer efficiency?

[ESE-2016, 2019]

Ans. $$\eta = \frac{\text{Output}}{\text{Input}} = \frac{\text{Output}}{\text{Output + losses}} = \frac{\text{Input} - \text{losses}}{\text{Input}}$$

2.42 What is on load tap changing? [ESE-2016]

Ans. Tap changer is a mechanism in transformer which allows variable turn ratios to be selected in discrete steps. On load tap changers adjust their

turn ratio during operation without the need of de-energising of transformer.

2.43 What is the new type of oil to replace the older one?

[ESE-2016]

Ans. In the 1970s, Polychlorinated Biphenyls (PCBs) were often used as a dielectric fluid since they were non-flammable. It included Askarels, Inerteen, Arocor and many others. Now it is replaced by Hydrocarbon mineral oil. It consists of aromatics, paraffins, napthenes and olefins in definite proportions.

2.44 What type of insulation is used in transformer?

[ESE-2016, 2019]

Ans. (i) Main insulation consists of transformer oil which also acts as cooling medium.

(ii) Winding insulation: usually used materials are Kraft, Nomax, Enamel.

(iii) Solid insulation: Mainly made of press board, transformer wood etc.

2.45 What are the differences between the power transformer and current transformer in the context of their construction?

[ESE-2016]

Ans. (i) The main difference lies in designing of the cores. The metering core of CT has to bear heavy fault current in its primary therefore core is designed to saturate at about five times of rated current. This provides safety to the instruments whereas power transformers operates near to their rated load conditions at all times. Therefore, their core is designed to saturate at nearly 1.2-1.5 times the rated current.

(ii) CT's primary consists of a single turn compared to multi-turn primary of power transformer.

2.46 How the testing of transformer oil is carried out?

[ESE-2016]

Ans. 1. To assess the insulating property of dielectric transformer oil, a sample of the transformer oil is taken and its breakdown voltage is measured.

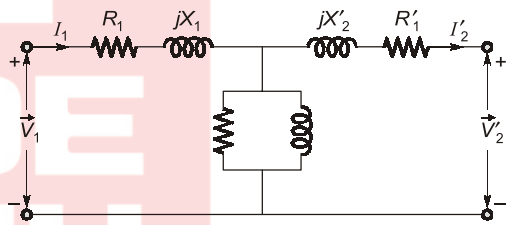
2. A test voltage is applied across circuit and is continuously increased with a constant standard compliant slew rate of 2 kV/sec. At a certain voltage level breakdown occurs in an electric arc, leading to collapse of test voltage.

Other tests are:

1. Color
2. Dissolved gas analysis
3. Dissolved metals
4. Flash point/Fire point
5. Furanic compounds
6. Neutralization number
7. Relative density
8. Resistivity

2.47 Draw the equivalent circuit of single phase transformer? [ESE-2016]

Ans.



Exact equivalent circuit

2.48 What is Conservator tank? [ESE-2016, 2022]

Ans. Conservator is a cylindrical tank mounted on supporting structure on the roof of the main transformer tank. Its main purpose is to provide adequate space for expansion of oil inside the transformer.

2.49 Which transformer will have a larger size for the same rating?

[ESE-2016]

Ans. Distribution transformer is designed for maximum efficiency at its average load. Therefore at the time of design iron losses of a distribution transformer are kept low,

$$P_i \propto B_m \propto \frac{\phi}{A}$$

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