EEE-2427
MID Note?!

Transformer

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→ Transformer is an electrical devices that changes the magnitude of altering voltage or current from one value to another.

→ It has no moving parts, so it is a static device
→ Same power level
→ Change voltage / current level
→ have 3 parts
Core, Primary and Secondary winding

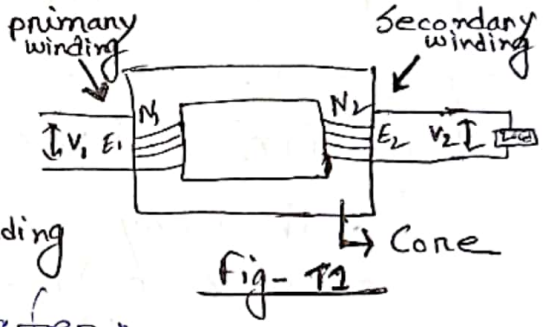

Fig- T1

Losses in [practical] Transfer:

(01) Copper Loss: The resistive heating losses in the primary and secondary windings of transformer is called copper loss.

→ This loss is proportional to the square of the current in the windings.

→ Total copper losses ⇒ $I_1^2 R_1 + I_2^2 R_2$

→ Short Circuit Test is performed to determine the copper loss.

(02) Iron / Core Loss: The power losses that take place in its iron core are known as the Iron losses

→ These losses occur due to alternating flux set up in the core.

→ Open Circuit Test is performed to determine.

→ 2 types of Iron loss are -
Eddy Current Losses (a), Hysteresis Losses (b)

(03) Leakage Flux: The flux which escape the core and pass through only one of the transformer windings are leakage fluxes

Eddy Current Losses: Because of time variation of flux in the magnetic material, Current is induced in the magnetic material is called Eddy Current.

→ They are proportional to the square of the voltage applied to the transformer.

Hysteresis Losses: It occurs due to magnetization saturation in the core of the transformer.

→ The eddy current and hysteresis loss both occurs in the core of the transformer

We can't Remove the hysteresis and eddy current losses. but we can reduce eddy current losses making the core by stacking thin sheets together. and reduce the hysteresis loss that the less area of the h. loop.

Working Principle of Transformer:

Trans-former works on the principle of faraday's Electromagnetic Mutual Induction between two coils which are magnetic copled.

fig-T1 (previous page)

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According to the principle of mutual inductance, when an alternating voltage is applied to the primary winding of the transformer, an alternating flux ϕ_m which is called as the mutual flux is produced in the core. This alternating flux links both the winding magnetically and induces EMFs E_1 in the primary winding and

E_2 in the secondary winding of the transformer according to Fanaday's Law of electromagnetic induction. The EMF (E_1) is called as primary EMF and the EMF (E_2) is known as Secondary EMF and beging given as -

$$E_1 = -N\frac{d\varphi_m}{dt} \quad \text{and} \quad E_2 = -N_2\frac{d\varphi_m}{dt}$$

Therefore, $\frac{E_2}{E_1} = \frac{N_2}{N_1}$

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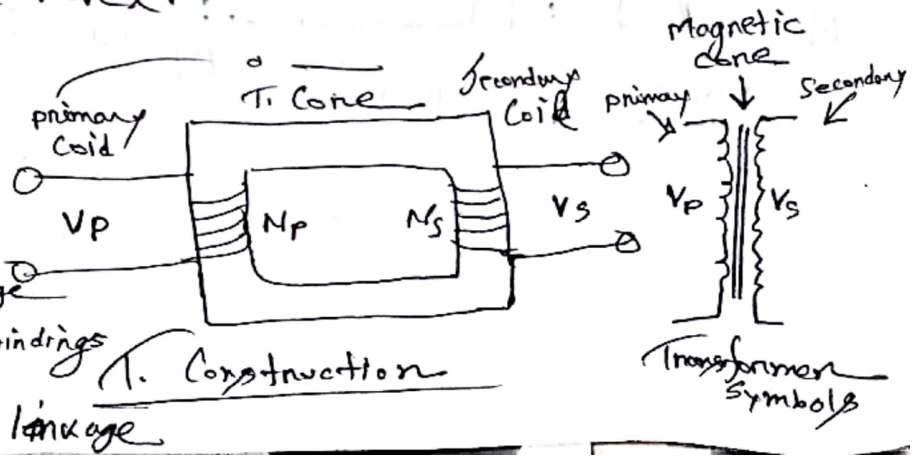
From the given expression, it can be seen that the magnitude of EMFs E_1 and E_2 depend upon the number of turns in the primary and secondary winding of the transformers respectively, i.e., if $N_2 > N_1$, then $E_2 > E_1$, thus the transformer will be Step-up and if $N_2 < N_1$, then $E_2 < E_1$, thus the transformer will be a Step-down transformer.

If a load is now connected across the secondary winding, the EMF E_2 will cause a load current I_2 to flow through the load. Therefore the transformer enables the transfer of power from one electric circuit to another electric circuit with a change in voltage level.

⇒ Construction:



T. Construction

Transformer Symbols

where,
V_P = is the primary voltage
V_S =
N_P = is the number of P. windings
N_S =
Φ (Phi) = is the flux in linkage

Transformer Rating in VA, But Why?

Ans: We know, the copper loss depends on Current and Core loss depends on voltage. And also we do not know the value or nature of load, so, we do not know the power factor. Thus, transformer rated in VA, KVA, MVA instead of KW, MW.

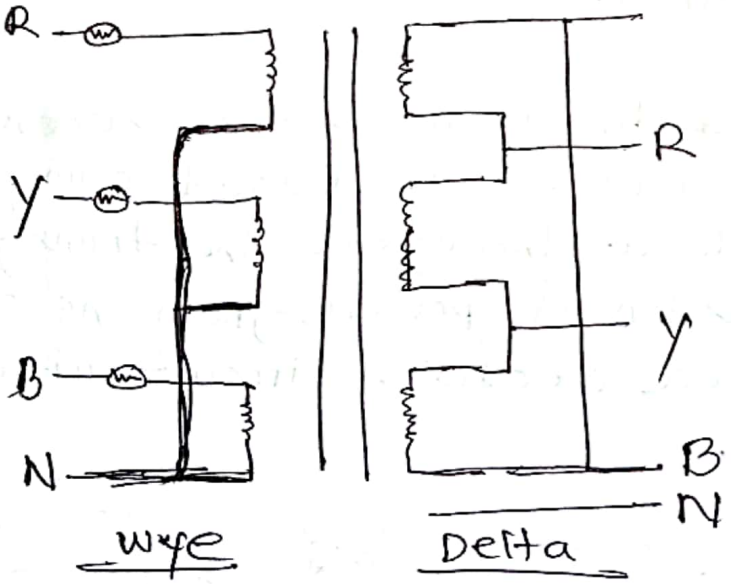
$$\text{Turn Ratio} = K = \frac{E_2}{E_1} = \frac{N_2}{N_1}$$

Transformer Do not Operate in DC, Why?

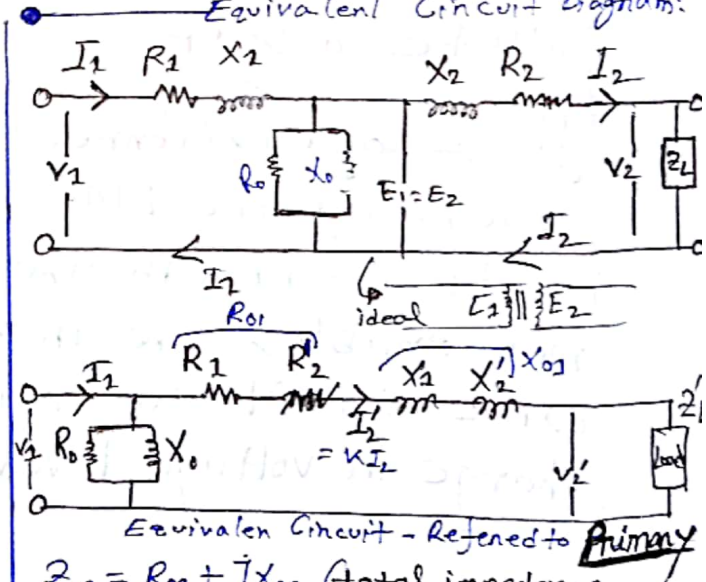
Ans: As we need alternating flux for generating electromotive force at both winding for that reason we need alternating current which is come from A.C source But in DC source, we can't have alternate of current so it can't generate alternate flux and transformer can't have emf. That's why on DC, transformer doesn't operate.

⇒ See different kind of Transformer types form any source.

Single Phase: Single phase power is a two-wire ac power circuit. **Three phase:** Three phase powe is a three-wire ac (alternating current) with each phase ac signal 120 electrical degrees apart.



Equivalent Circuit Diagram:



$Z_{01} = R_{01} + jX_{01}$ (total impedence

$R_{01} = R_1 + R_2'$

$X_{01} = X_1 + X_2'$

$Z_{02} = R_{02} + jX_{02}$

$R_{02} = R_2 + R_1'$

$X_{02} = X_2 + X_1'$

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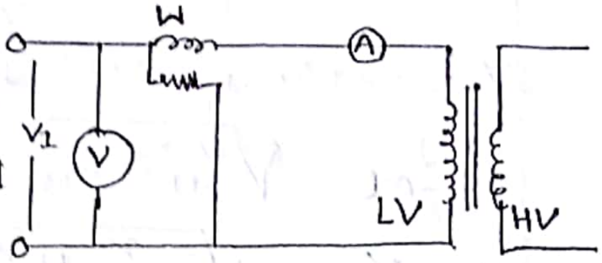
Open Circuit Test:

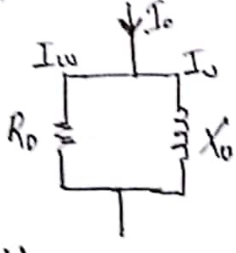
Open circuit test or no load test is performed to determine core losses of the transformer.

Usually High Voltage (HV) winding is kept open and the low voltage (LV) winding is connected to its normal supply. A



Wattmeter (W), ammeter (A) and voltmeter (V) are connected to the LV winding as shown in the figure. Now applied voltage is slowly increased from zero to normal rated value of the LV side with the help of a variac.

→ The wattmeter measures the iron loss of the transformer.
→ The ammeter measures the no load current, I_0 (is very small)
→ The voltmeter measures the applied voltage in the LV winding



$W = V_1 I_0 \cos\phi_0$

power factor, P.F, $\cos\phi = \frac{W}{V_0 I_0}$

$X_0 = \frac{V_1}{I_\mu}$, $R_0 = \frac{V_1}{I_w}$, $Z_0 = \sqrt{R_0^2 + X_0^2}$

Core loss

$I_w = I_0 \cos\phi_0$

$I_\mu = I \sin\phi_0$

Where,

W = Wattmeter Reading
V_1 = Applied Voltage
I_0 = Ammeter Reading

I_w = Core-loss component of no-load current
I_μ = Magnetizing " " " "

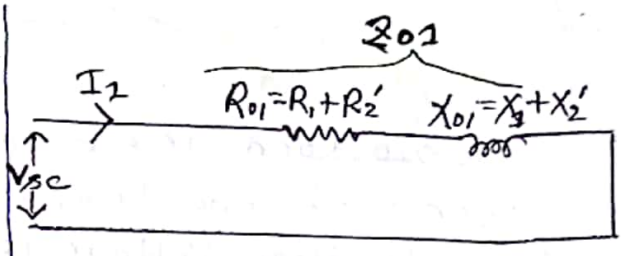
Short Circuit Test:

Short circuit test or impedence test is performed to determine R_{01} (or, R_{02}), X_{01} (or, X_{02}) and full load copper losses of the transformer. The LV side of transformer is short circuited and wattmeter (W), voltmeter (V) and ammeter (A) are connected on the HV side of the transformer. Voltage is applied to the HV side and increased from the zero until the ammeter reading equals rated current. All the readings are taken at this rated current.

$W_s = P_c = I_1^2 R_1 + I_1 R_2' = I_1^2 R_{01}$

$R_{01} = \frac{W_s}{I_1^2}$ ---①

$V_{sc} = I_1 \times Z_{01} \Rightarrow Z_{01} = \frac{V_{sc}}{I_1}$ ---②



$Z_{01} = \sqrt{X_{01}^2 + R_{01}^2}$

or, $X_{01} = \sqrt{Z_{01}^2 - R_{01}^2}$ (using ① and ②)

W_s = wattmeter reading = full load copper loss (P_c)

Short Circuit P.F $= \cos\phi_2 = \frac{W_s}{V_{sc} \times I_1}$

V_{sc} = Applied Voltage

I_1 = Ammeter reading

Transformer's Math Eqn

(01) EMF eqn of Transformer:

$E_1 = -N_1 \frac{d\phi}{dt}$

$E_2 = -N_2 \frac{d\phi}{dt}$

$E_1/E_P \rightarrow$ EMF of primary winding

$N_1/N_P \rightarrow$ Number of turns in primary

$\phi \rightarrow$ Maximum Flux

$\frac{E_2}{E_1} = \frac{N_2}{N_1}$ $\frac{V_2}{V_1} = \frac{N_2}{N_1}$ $\frac{I_2}{I_1} = \frac{N_2}{N_1}$

(02) Turns Ratio:

Turns ratio, $a = \frac{N_1}{N_2}$

Transformer Ratio, $K = \frac{N_2}{N_1} = \frac{E_2}{E_1}$

$\therefore a = \frac{1}{K}$

$K = \frac{1}{a}$

(03) Voltage Regulation:

$= \frac{oV_2 - V_2}{oV_2} \times 100$

(or) $\Rightarrow \frac{V_{No\text{-}Load} - V_{on\ load}}{V_{no\text{-}load}} \times 100$

oV_2 = No-Load Secondary Voltage

V_2 = Secondary Voltage on load

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Motor Sizing

Motor: Converts electrical energy into mechanical energy. Conversation factor: 1HP = 746 Watts

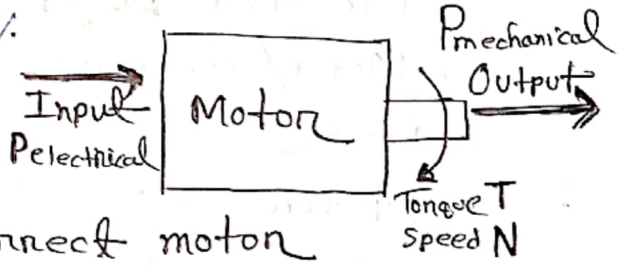
Speed (N): The number of revolutions per minute of the motor. $n = \frac{N}{60}$ revs per second $\quad \omega = 2\pi N 60$ radians per second

Torque: The force with which a motor turns is called Torque. measured in Nm.

Relation bet^n Power, Speed, Torque: $P = \frac{2\pi \times T \times N}{60}$

RMS power $= \sqrt{\frac{P_1^2 t_1 + P_2^2 t_2 + P_3^2 t_3 \cdots P_n^2 t_n}{t_1 + t_2 + t_3 + \cdots t_n}}$

Efficiency: $\eta = \frac{\text{output}}{\text{input}} \times 100\%$



⇒ Motor sizing refers to the process of picking the correct motor for a given load.

⟶ For load torque is constant then choosing a motor whose rated torque is slightly above the torque required by the load. The load ~~at~~ torque should be bet^n 75% – 100% for the rated motor torque with 95% being an ideal choice.

⇒ Motor Torque > Load Torque, the Load will Accelerate

Accelerating Torque = $T_{motor} - T_{load}$

⟶ Just go through the pdf named "Motor Duty" and Read ☺

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DC Machines

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⇒ DC machines DC outputs just because they have a mechanism converting AC voltages to DC voltages. This converting mechanism is called commutation.

→ DC machines are also called Commutating Machines.

Magnetic field: the portion of space near a magnetic body or a current carrying body in which the magnetic forces due to the body or current can be detected.

* Fleming Right Hand Rule for → Generator
* Fleming Left Hand Rule for → Motor

→ Motor/Generator have 2 parts are -

ⓐ Rador (যা ঘুরতে থাকবে।)

ⓑ Stator (যা স্থির থাকবে।)

↳ creates flux

→ Both DC and AC Generator convert mechanical power to electrical power. Both of these produce electrical power based on the principle of Faraday's law of electromagnetic induction.

Faraday's 1st Law: Whenever a conductor is moted in magnetic field emf is induced in it. If the conductor is closed, current will flow through it which is know as induced current.

The induced emf in a coil is equal to the rate of change of flux linkage. (Faraday's 2nd Law)

$$E = -N\frac{d\phi}{dt}$$

Right Hand Rule: Thumbs (বৃদ্ধাঙ্গুলি) → indicates Motion
→ Index finger indicates → the Magnetic field
→ Middle finger indicates the direction of Current.

Left Hand Rule: F → Force, B → Flux Density, I → Current