Operation of Single-phase Auto transformer :-

The working of an auto-transformer is similar to ~~that of~~ a two-winding transformer, A-T/F shown below.

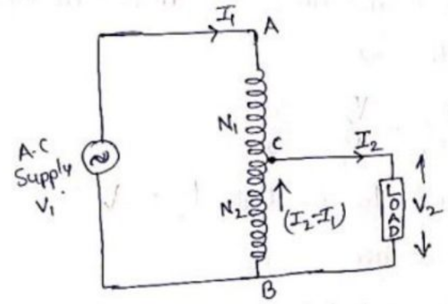


Diagram of Auto-Transformer

In above diagram, the AB is the primary winding of transformer and `CB' is secondary winding where the tapping is provided.

When a supply voltage V_1 is applied to the primary winding AB, an alternating flux set up in the core due to which an induced emf 'E_1' is devoloped.

Since the secondary winding is a ~~part of~~ the primary winding, a ~~part of~~ the induced emf E_1, is taken in to which the load is connected.

→ Let E_2 be the induced emf in the secondary winding

→ This induced emf drives the current in the secondary winding and hence the load connected to it.

→ As in an ordinary transformer, the transformation ration is turn ratio as

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

→ The power delivered to load is $P_L = V_2 I_2$

→ But in Auto transformer

$$\boxed{P_{Auto} = V_2 I_2 (1-k)}$$

→ The power conducted directly is $\boxed{P = K V_2 I_2}$

→ When $N_1 > N_2$ → is Stepdown Transformer

$N_1 < N_2$ → is Step-up Transformer.

Miniature Circuit Breaker (MCB):-

* A miniature circuit breaker is an electromechanical device which makes and breaks the circuit in normal operation and disconnects the circuit under the abnormal condition when current exceeds a preset value.

* MCB is a high fault capacity current limiting, trip free, automatic switching device with thermal and magnetic operation to provide protection against overload and short circuit.

* It is necessary to use MCB because of its following features

1) Its operation is very fast and opens in less than one milli-second.

2) No tripping circuit is necessary and the operation is automatic.

3) provides protection against overload and short circuit without noise, smoke or flame.

4) It can be reset very quickly after correcting the fault, just by switching a button. No rewiring is required.

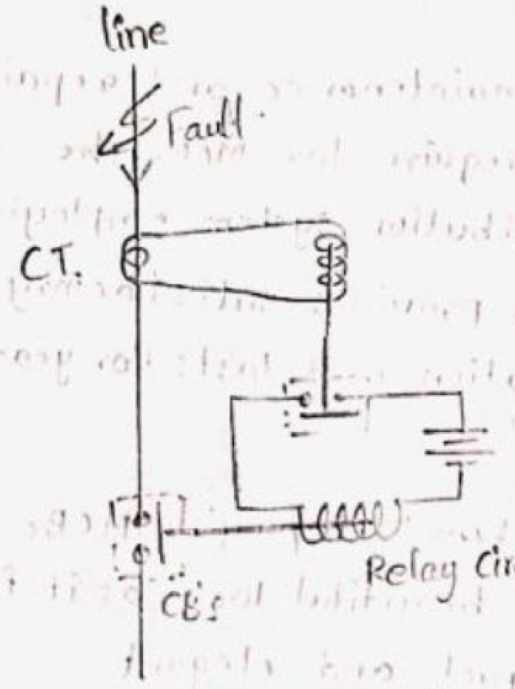
5) It can not be reclosed if fault persists.

6) The mechanical life is upto or more than one lakh operating cycle.

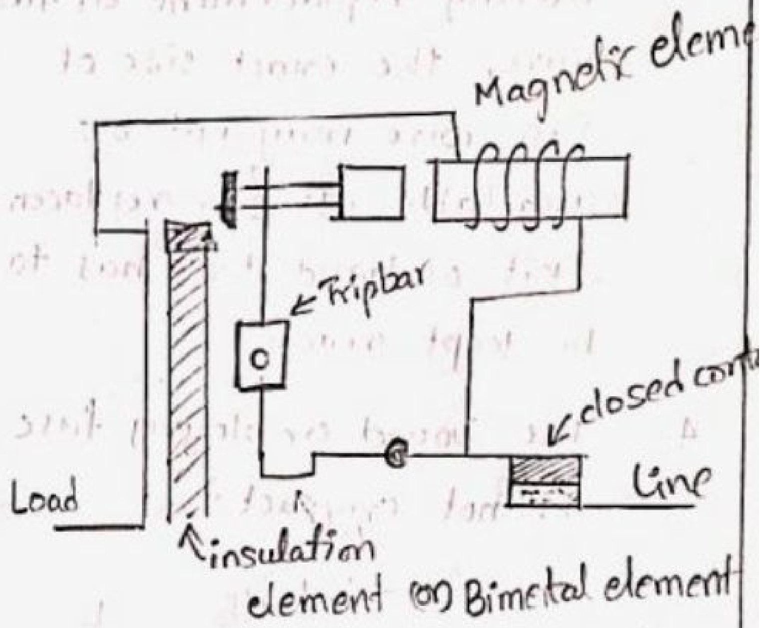
* Hence now a days MCBs are used rather than rewirable fuse.

* Generally MCBs are rated for a.c voltage of 240 V for single phase, 415 V for three phase or 220 V d.c. The current rating available is from 0.5A to 63 A. It is available as single pole (SP), Double pole (DP), Tripple pole (TP) with short circuit breaking capacity from 1kA to 10kA with a rated frequency.

* A typical view of MCB and its practical appearance is shown in Fig. below.



Equalent Circuit of CB'S



Basic diagram of MCB's

4-(1)

* The three phase induction motor consists of two main parts, namely.
1) The part carrying three phase windings, which is stationary called stator.
2) The part which rotates and is connected to the mechanical load through shaft called rotor.

1. Stator:- The stator has a laminated type of construction made up of stampings which are 0.4 to 0.5mm thick.

* The stampings are slotted on its periphery to carry the stator winding. The stampings are insulated from each other. Such a construction essentially keeps the iron losses to a minimum value.
* The number of stampings are stamped together to build the stator core.
* The slots on the periphery of the stator core carries a three phase winding, connected either in star or delta. This three phase winding is called stator winding. It is wound for definite number of poles.
* The radial duts are provided for the cooling purpose. The fig Q.35.1 shows a stator lamination.

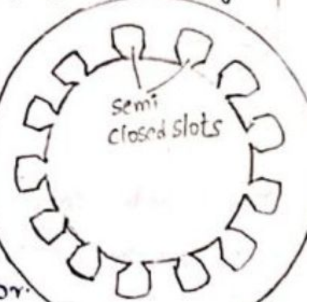
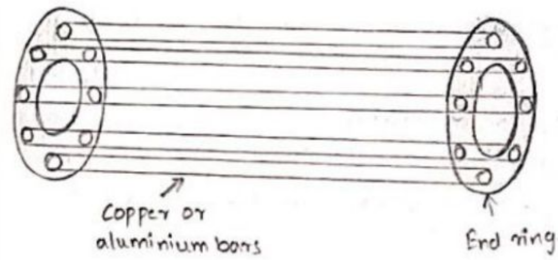


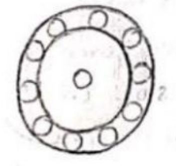
Fig. Q.35.1 stator lamination

2) Rotor:- The rotor is placed inside the stator.
* The air gap between stator and the rotor is 0.4mm to 4mm.
* The two types of rotor constructions which are used for induction motor are, a. squirrel cage rotor and b. slip ring or phase wound rotor.

a) Squirrel cage rotor:-
* The rotor core is cylindrical and slotted on its periphery.
* The rotor consists of uninsulated copper (or) aluminium bars called rotor conductors. The bars are placed in the slots.
* These bars are permanently shorted at each end with the help of conducting copper ring called end ring. The bars are usually brazed to the end rings to provide good mechanical strength.
* The entire structure looks like a cage, forming a closed electrical circuit. So the rotor is called squirrel cage rotor. The construction is shown in the fig. Q.35.2.



(a) Cage type structure of rotor



(b) Symbolic representation

) Slip Ring Rotor (or) phase wound Rotor:-

* In this type of construction, rotor winding is exactly similar to the stator.
* The rotor carries a three phase star (or) delta connected, distributed winding, wound for same number of poles as that of stator.
* The rotor construction is laminated and slotted. The slots contain the rotor winding.
* The three ends of three phase winding, available after connecting the winding in star (or) delta, are permanently connected to the slip rings.
* with the helps of slip rings, the external resistances can be added in series with each phase of the rotor winding. This

(5)

rrangement is shown in the Fig Q.35.3

4-(2)

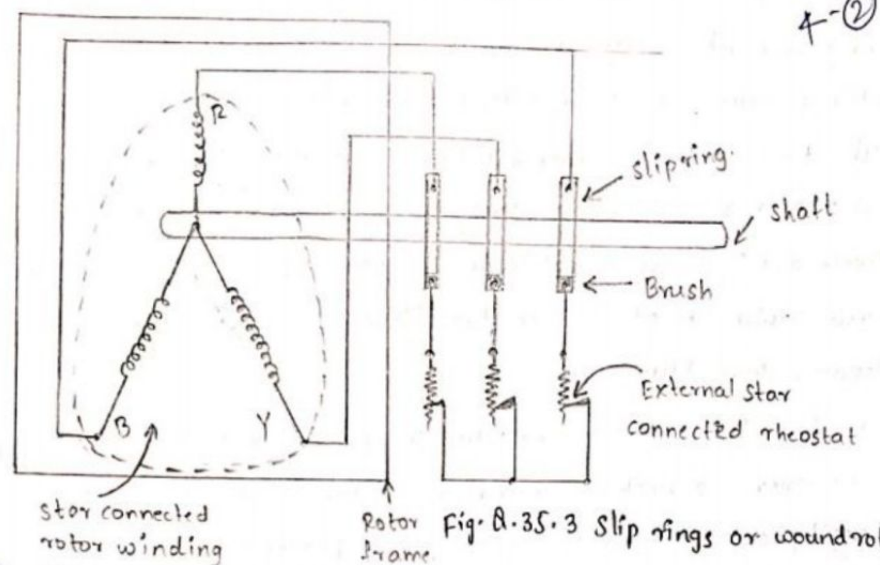


Fig. Q.35.3 Slip rings or wound rotor.

In the running condition, the slip rings are shorted.

orking principle of three phase induction motor:-

nduction motor works on the principle of electromagnetic Induction. When a three phase supply is given to the three phase stator inding, a rotating magnetic field of constant magnitude is roduced. The speed of this rotating magnetic field is synchronous speed, N_s r.p.m.

$N_s = \frac{120f}{P}$ = speed of rotating magnetic field.

This rotating field produces an effect of rotating poles around

$N_s = \frac{120f}{P}$ = speed of rotating magnetic field.

* This rotating field produces an effect of rotating poles around a rotor.
* At this instant rotor is stationary and stator flux R.M.F. is rotating. so its obvious that there exists a relative motion between the R.M.F and rotor conductors.
* Whenever conductor cuts of flux, e.m.f gets induced in it. So e.m.f gets induced in the rotor conductors called rotor induced e.m.f
* As rotor forms closed circuit, induced em.f circulates through

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rotor called rotor current

* Any current carrying conductor produces its own flux. so rotor produces its flux called rotor flux.
* The two fluxes, stator flux and the rotor flux interact with each other such that on one side of rotor conductor, two fluxes are in same direction hence add up to get high flux area while on other side, two fluxes cancel each other to produce low flux area
* As flux lines act as stretched rubber band, high flux density area exerts a push on rotor conductor toward low flux density area. So rotor conductor experiences a forces due to interaction of the two fluxes.
* As all the rotor conductors experiences a force, the overall rotor experiences a torque and starts rotating.
* According to Lenz's law the direction of induced current in the rotor is so as to oppose the cause producing it.
* The cause of rotor current is the induced e.m.f. which is induced because of relative motion present between the rotating magnetic field and the rotor conductors.
* Hence to oppose the relative motion i.e, to reduce the relative speed, the rotor experiences a torque in the same direction as that of R.M.F. and tries to catch up the speed to rotating magnetic field.

⑥

4-③

Slip of Induction motor:-

The differenkebetween the speed of rotating magnetic field and the actual rotor speed is called slip speed i.e. $N_S - N$ = slip speed of the motor.

$$\boxed{\therefore \text{ slip speed} = N_s - N}$$

* slip of the induction motor is defined as the difference between the synchronous speed (N_s) and actual speed of rotor i.e. motor (N) expressed as a fraction of the synchronous speed (N_s). This is also called absolute slip (or) fractional slip and is denoted as 's'.

Thus,

$$\boxed{\text{slip, } S = \frac{N_s - N}{N_s} \quad \text{and } \% \; S = \frac{N_s - N}{N_s} \times 100}$$

Torque equation of three phase inductor motor:-

The torque developed by the rotor is directly proportional to

i, rotor current

ii, rotor E.m.f

iii, power factor of the rotor circuit

$$T \propto E_2 I_2 \cos\phi_2$$

Rotor current $I_2 = \frac{SE_2}{Z_2} = \frac{SE_2}{\sqrt{R_2^2 + (SX_2)^2}}$

$$\cos\phi_2 = \frac{R_2}{Z_2} = \frac{R_2}{\sqrt{R_2^2 + (SX_2)^2}} \; ; \; \tau = \frac{KSE_2^2 R_2}{R_2^2 + (SX_2)^2}$$

starting Torque i.e. at $S = 1$ (slip)

$SE_2 = E_2$, $SX_2 = X_2$

So starting Torque is given by

$$T_s = KE_2 I_2 \cos\phi_2$$

$$T_s = KE_2 \times \frac{E_2}{\sqrt{R_2^2 + X_2^2}} \times \frac{R_2}{\sqrt{R_2^2 + X_2^2}}$$

$$T_s = \frac{KE_2^2 R_2}{(R_2^2 + X_2^2)}$$

$$T_S = \frac{\quad}{(R_2^2 + X_2^2)}$$

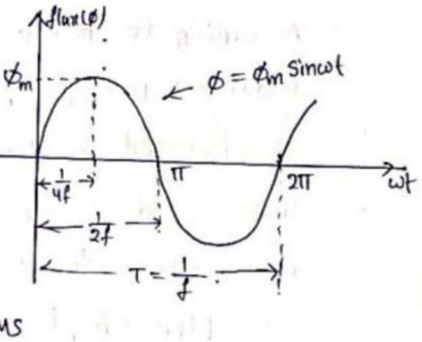
Generally, the startor supply voltage is constant (V), so that flux set up by the stator also fixed, This in turn means that the Emf induced in the Rotor will be constant, so.

$$T_S = \frac{K_1 R_2}{\quad}$$

EMF- equation of Transformer

When the primary winding is excited by an alternating voltage 'V_1', it circulates alternating current producing an alternating flux 'ϕ'.

The waveform for alternating flux 'ϕ' can drawn as for time period '2π'.



Let ϕ = alternating flux

ϕ_m = maximum flux

N_1 = No. of primary turns

N_2 = No. of secondary turns

E_1 = primary induced emf in RMS

E_2 = Secondary induced emf in RMS

f = frequency of supply.

→ According to Faraday's law of electromagnetic induction the average emf induced ~~per~~ in each turn is proportional to the average rate of change of flux.

∴ Average emf per turn = Average rate of change of flux

i.e $\dfrac{d\phi}{dt} = \dfrac{\text{change in flux}}{\text{Time required for change in flux}}$

In above ~~above~~ figure initial flux ($\phi = 0$) and

after "$1/4$th" cycle the fluxes are maximum i.e 'ϕ_m', so

i.e $\dfrac{d\phi}{dt} = \dfrac{\phi_m - 0}{(1/4f)} = 4f\phi_m$ wb/sec

So, Average emf per turn $= 4f\phi_m$ volts. i.e emf/turn $= 4f\phi_m$

→ The RMS value of induced emf per turn

$$\text{emf/turn} = 1.11 \times 4 . f\ \phi_m$$

i.e $\quad$ ~~E~~ $= 4.44\, f \phi_m$

→ If primary winding has 'N_1' of no. of turns, then RMS value of induced emf in primary

→ The RMS value of induced emf per turn

$$emf/_{turn} = 1.11 \times 4 \cdot f \, \phi_m$$

i.e $\quad = 4.44 \, f \, \phi_m$

→ If primary winding has 'N₁' of no. of turns, then RMS value of induced emf in primary

i.e $\boxed{E_1 = N_1 \times 4.44 f \, \phi_m}$ volts

Simillarly, in secondary

$$\boxed{E_2 = N_2 \times 4.44 f \, \phi_m} \text{ volts.}$$

Transformation ratio (K)

If transformer having primary induced emf (E_1) and secondary induced emf (E_2), then

i.e $K = \frac{E_2}{E_1}$ $\quad \because E_2 \propto N_2 \ \& \ E_1 \propto N_1$

and $K = \frac{N_2}{N_1}$ $\quad \because E_2 = V_2 \ \& \ E_1 = V_1$

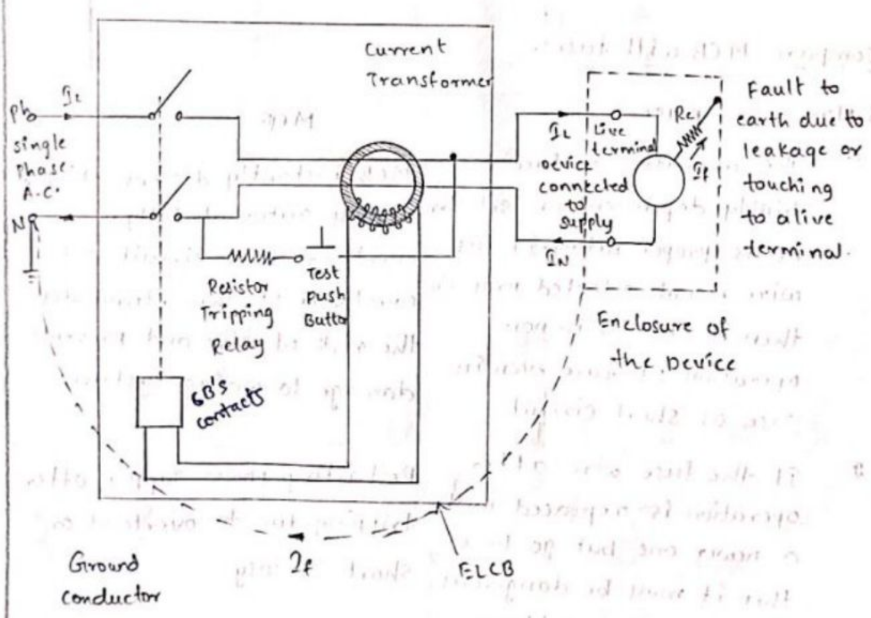
and $K = \frac{V_2}{V_1}$ i.e * $\boxed{\frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{V_2}{V_1} = K = \frac{I_1}{I_2}}$

problems:- ① The maximum flux density in the core of

5:50 PM | 0.2KB/s 86%

—* **Earth Leakage circuit Breaker (ELCB):-**

* The schematic of ELCB is as shown in the fig Q.5.1



As shown in the Fig. Q.51 ELCB consists of a small current transformer surrounding live and neutral wire. The seconda-ry winding of current transformer is connected to relay circuit which can trip the circuit breaker which is connected in the circuit.

under normal conditions, the current in line and neutral conductor is same so the net current ($I_L - I_N$) flowing through the core is zero. Eventually there will not be any production of flux in the core and no induced e.m.f. so the breaker does not trip.

* If there is a fault due to leakage from live wire to earth or a person by mistake touching to the live terminal then the net current through to the core will no longer remain as zero but equal to $I_L - I_N$ or I_f which will set up flux and emf in C.T. As per the present value, the unbalance in current is detected by C.T. and relay coil is energized which will give tripping signal for the circuit breaker. As C.T. operates with low value of current, the core must be very permeable at low flux densities.

* Thus ELCB provides protection against electric shock when

* Thus ELCB provides protection against electric shock when a person comes in contact with live parts. resulting in flow of current from body to earth.

* A properly connected ELCB detects such small currents in milliamperes flowing to earth through human body or earth wire and breaks the circuit to reduce the risk of electrocution to humans.

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* There are certain situations where leakge current can flow through the metal bodies of appliances, when person touches to Such appliances. Thus person can get a shock.
* Similarly there is risk of fire due to such earth leakage Currents.
* Thus a protective device is necessary which ~~say~~ can sense small leakage current and disconnect the circuit from supply. Such a device is called earth leakage circuit breakers (ELCB).

1) Provides protection to a human against the electric shock.
2) Detects very small leakage currents.
3) Reduces the Risk of fire due to hot Spots.
4) Saves electrical energy due to leakage.
5) Energy conservation can be achieved.