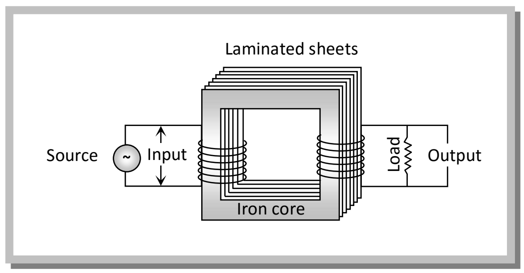
Transformer.

It is a device which raises or lowers the voltage in ac circuits through mutual induction. It consists of two coils wound on the same core. The coil which is connected to the source (i.e., to which input is applied) is called primary while the other which is connected to the load (i.e., from which output is taken) is called secondary. The alternating current passing through the primary creates a continuously changing flux through the core. This changing flux induces an alternating emf in the secondary. As magnetic lines of force are closed curves, the flux per turn of the primary must be equal to the flux per turn of the secondary, i.e.,



(i) Transformer works on ac only and never on dc.

(ii) It can increase or decrease either voltage or current but not both simultaneously.

(iii) Transformer does not change the frequency of input ac.

(iv) There is no electrical connection between the winding but they are linked magnetically.

(v) Effective resistance between primary and secondary winding is infinite.

(vi) The flux per turn of each coil must be same i.e. $\phi_S = \phi_S$; $-\frac{d\phi_S}{dt} = -\frac{d\phi_P}{dt}$

(vii) If suppose for a transformer –

NP = number of turns in primary; NS = number of turns in secondary

VP = applied (input) voltage to primary; VS = Voltage across secondary (load voltage or output)

eP = induced emf in primary ; eS = induced emf in secondary

ϕ = flux linked with primary as well as secondary

iP = current in primary; iS = current in secondary (or load current)

RP = resistance of primary; RS = resistance of secondary

tP = thickness of turn in primary; tS = thickness of turn in secondary

As in an ideal transformer there is no loss of power i.e. $P_{out} = P_{in}$ and e = V

So $V_S i_S = V_P i_P$ and $V_P \approx e_P$, $V_S \approx e_S$

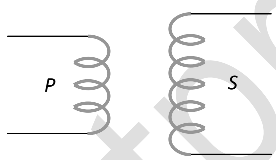
According to Faraday's law $e_S = -N_S \dfrac{d\phi}{dt}, e_P = -N_P \dfrac{d\phi}{dt}$

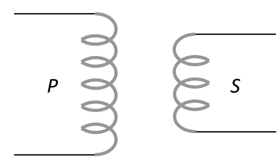
Hence $\dfrac{\boldsymbol{e_S}}{\boldsymbol{e_P}} = \dfrac{\boldsymbol{N_S}}{\boldsymbol{N_P}} = \dfrac{\boldsymbol{V_S}}{\boldsymbol{V_P}} = \dfrac{\boldsymbol{i_P}}{\boldsymbol{i_S}} = \boldsymbol{k}$; k = Transformation ratio (or turn ratio)

From above discussions, it is clear that in transformers the side having greater number of turns will have greater voltage and lesser current. Since in increasing the voltage level, the current level decreases, therefore it can be concluded that voltage increases at the cost of current.

(viii) Types of transformer: Transformer is of two type

Step up transformer	Step down transformer
It increases voltage and decreases current	It decreases voltage and increases current
VS > VP	VS < VP
NS > NP	NS < NP
ES > EP	ES < EP
iS < iP	iS > iP
RS > RP	RS < RP
tS > tP	tS > tP
k > 1	k < 1





(ix) Efficiency of transformer (η) : Efficiency is defined as the ratio of output power and input power

i.e. $\eta\% = \dfrac{P_{out}}{P_{in}} \times 100 = \dfrac{V_S i_S}{V_P i_P} \times 100$

For an ideal transformer Pout = Pin so $\eta = 100\,\%$ (But efficiency of practical transformer lies between 70% – 90%)

For practical transformer $P_{in} = P_{out} + P_{losses}$ so $\eta = \dfrac{P_{out}}{P_{in}} \times 100 = \dfrac{P_{out}}{(P_{out} + P_L)} \times 100 = \dfrac{(P_{in} - P_L)}{P_{in}} \times 100$

(x) Losses in transformer: In transformers some power is always lost due to, heating effect, flux leakage eddy currents, hysteresis and humming.

(a) Cu loss (i2R): When current flows through the transformer windings some power is wasted in the form of heat $(H = i^2 Rt)$. To minimize this loss windings are made of thick Cu wires (To reduce resistance)

(b) Iron loss: If is further divided in two types

Eddy current loss: Some electrical power is wasted in the form of heat due to eddy currents, induced in core, to minimize this loss transformers core are laminated and silicon is added to the core material as it increases the resistivity. The material of the core is then called silicon-iron (steel).

Hystersisloss: The alternating current flowing through the coils magnetises and demagnetises the iron core again and again. Therefore, during each cycle of magnetisation, some energy is lost due to hysteresis. However, the loss of energy can be minimised by selecting the material of core, which has a narrow hysterisis loop. Therefore core of transformer is made of soft iron. Now a days it is made of "Permalloy" (Fe-22%, Ni-78%).

(c) Magnetic flux leakage: Magnetic flux produced in the primary winding is not completely linked with secondary because few magnetic lines of force complete their path in air only. To minimize this loss secondary winding is kept inside the primary winding.

(d) Humming losses: Due to the passage of alternating current, the core of the transformer starts vibrating and produces humming sound. Thus, some part (may be very small) of the electrical energy is wasted in the form of humming sounds produced by the vibrating core of the transformer.

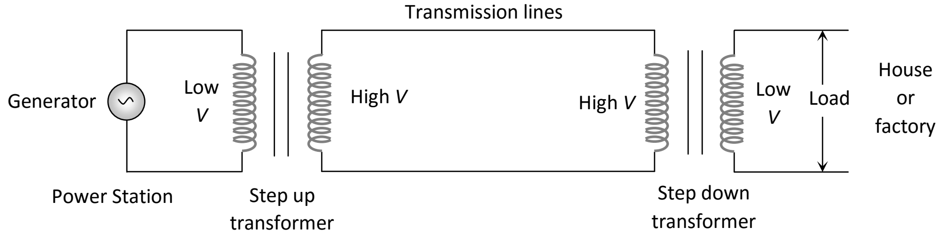
(xi) Uses of transformer: A transformer is used in almost all ac operations e.g.

(a) In voltage regulators for TV, refrigerator, computer, air conditioner etc.

(b) In the induction furnaces.

(c) Step down transformer is used for welding purposes.

(d) In the transmission of ac over long distance.



(e) Step down and step up transformers are used in electrical power distribution.

(f) Audio frequency transformers are used in radiography, television, radio, telephone etc.

(g) Radio frequency transformers are used in radio communication.

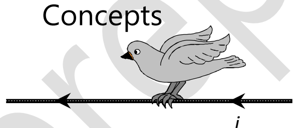
(h) Transformers are also used in impedance matching.

(xii) Relation between primary and secondary resistances: However if one end of primary and one end of secondary are connected together and a source of emf is connected across the two remaining ends, ohm's law can still be applied. Thus if voltage across primary winding alone is increased, the primary current will increase. Similarly if voltage across the secondary winding alone is increased, the secondary current will increases. But interestingly in transformers the side having greater voltage has lesser current. We know that if voltage in high voltage (H.V.) winding is k times greater the current in it is k times smaller. It is possible only when the resistance of the H.V. winding is k2 times the resistance of the low voltage (L.V.) winding. Thus, $R_{H.V.} = k^2 R_{L.V.}$ (where, k > 1)

Thus purposely the H.V. turns are kept thinner and larger in number.

Similarly the L.V. turns are kept thicker and lesser in number. This may be remembered by the fact that amount of copper used in making both H.V. and L.V. windings is same.

Concepts



When a source of emf is connected across the two ends of the primary winding alone or across the two ends of secondary winding alone, ohm's law can be applied. But in the transformer as a whole, ohm's law should not be applied because primary winding and secondary winding are not connected electrically.

Even when secondary circuit of the transformer is open it also draws some current called no load primary current for supplying no load Cu and iron loses.

Transformer has highest possible efficiency out of all the electrical machines.

When current is passing through a high voltage transmission line, the wings of a bird sitting on it are repelled due to induction which makes it fly away.