LOSSES IN TRANSFORMER AND LC OSCILLATIONS

Losses of transformer

(a) Copper or joule heating losses

Where: There losses occurs in both coils of shell part

Reason : Due to heating effect of current ($H = I^2 Rt$)

Remedy: To minimize these losses, high current coil always made up with thick wire and for removal of produced heat circulation of mineral oil should be used.

(b) Flux leakage losses

Where: There losses occurs in between both the coil of shell part.

Cause : Due to air gap between both the coils.

Remedy: To minimize their losses both coils are tightly wound over a common soft iron core (high magnetic permeability) so a closed path of magnetic field lines formed itself within the core and tries to makes coupling factor $K \to 1$

(c) Iron losses

Where: There losses occurs in core part.

Types : (i) Hysteresis losses (ii) Eddy currents losses

i. Hysteresis losses

Cause : Transformer core always present in the effect of alternating magnetic field ($B = B_0 \sin\omega t$) so it will magnetized & demagnetized with very high frequency ($f = 50$ Hz).During its demagnetization a part of magnetic energy left inside core part in form of residual magnetic field. Finally this residual energy waste as heat.

Remedy: To minimize these losses material of transformer core should be such that it can be easily magnetized & demagnetized. For this purpose soft ferromagnetic material should be used. For Ex. soft iron (low retentivity and low coercivity)

ii. Eddy currents losses

Cause : Transformer core is always present in the effect of alternating magnetic field ($B = B_0 \sin\omega t$). Due to this eddy currents are produced in its volume, so a part of magnetic energy of core is wasted as heat.

Remedy: To minimize these losses transformer core should be laminated. with the help of lamination process, circulation path of eddy current is greatly reduced & net resistance of system is greatly increased. So these currents become

Efficiency:

The efficiency of a transformer is defined as

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

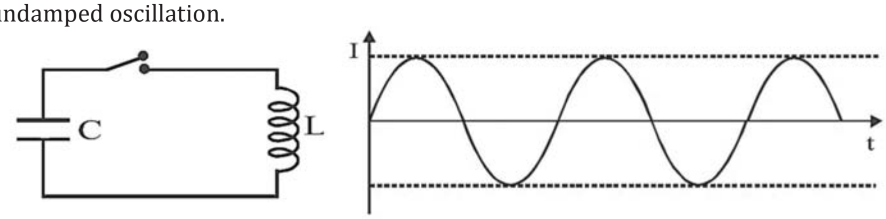
In actual transformers, their efficiency is relatively high, typically ranging from 90% to 98%, but it's not 100%.

LC Oscillations

When energy bounces back and forth between a capacitor (electric field energy) and an inductor (magnetic field energy), it's known as LC oscillation.

Undamped Oscillation

If there's no resistance in the circuit, and the energy taken from the source keeps bouncing between the capacitor and inductor without losing any, it creates constant, steady bouncing called undamped oscillation.



After switch is closed

$$\frac{Q}{C} + L\frac{di}{dt} = 0 \Rightarrow \frac{Q}{C} + L\frac{d^2Q}{dt^2} = 0 \Rightarrow \frac{d^2Q}{dt^2} + \frac{1}{LC}Q = 0$$

By comparing with standard equation of free oscillation

$$\left[\frac{d^2x}{dt^2} + \omega^2 x = 0\right]$$

$\omega^2 = \frac{1}{LC}$ Frequency of oscillation $f = \frac{1}{2\pi\sqrt{IC}}$

Charge varies sinusoidally with time $q = q_m \cos \omega t$

current also varies periodically with $I = \frac{dq}{dt} = q_m \omega \cos\left(\omega t + \frac{\pi}{2}\right)t$

If initial charge on capacitor is qm then electrical energy strored in capacitor is $U_E = \frac{1}{2}\frac{q_m^2}{C}$

At t = 0 switch is closed, capacitor is starts to discharge.

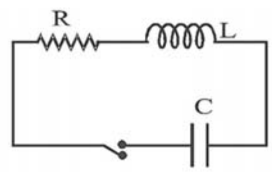
As the capacitor is fully discharged, the total electrical energy is stored in the inductor in the form of magnetic energy.

$$U_B = \frac{1}{2}LI_m^2 \text{ where } I_m = \text{max. current}$$

$$(U_{max})_{EPE} = (U_{max})_{MPE} \Rightarrow \frac{1}{2}\frac{q_{me}^2}{C} = \frac{1}{2}LI_m^2$$

Damped Oscillation

In reality, circuits always have some resistance, so a bit of energy gets lost due to resistance, causing the bouncing energy's amplitude to gradually decrease. This is known as damped oscillation.



Angular frequency of oscillation $\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$

frequency of oscillation $f = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$

oscillation to be real if $\frac{1}{LC} - \frac{R^2}{4\ L^2} > 0$

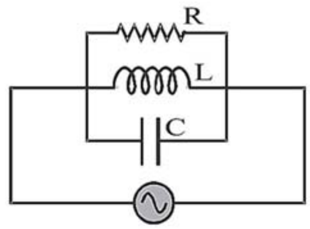
In damped oscillation amplitude of oscillation decreases exponentially with time.

At $t = \frac{T}{4}, \frac{3\ T}{4}, \frac{5\ T}{4} \ldots$ energy stored is completely magnetic

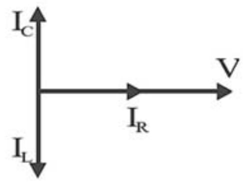
At $t = \frac{T}{8}, \frac{3\ T}{8}, \frac{5\ T}{8} \ldots\ldots$ energy is shared equally between L and C

Phase difference between charge and current is $\frac{\pi}{2}$ [when charge is maximum, current minimum / when charge is minimum, current maximum]

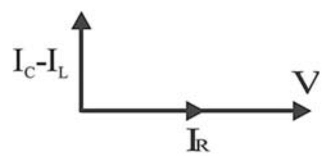
Parallel connection in AC



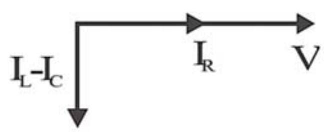
V same for R,L and C



i. if $I_C > I_L$ then



ii. if $I > I_C$ then

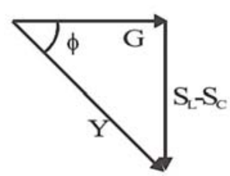


iii. $I = \sqrt{I_R^2 + (I_L - I_C)^2}$

Admittance $Y = \sqrt{G^2 + (S_L - S_C)}$

$\tan\phi = \frac{S_L - S_C}{G} = \frac{I_L - I_C}{I_B}$

iv. Admittance triangle



- if $S_L > S_C(X_L < X_C$ then V leads I, ϕ circuit nature inductive
- if $S_C > S_L(X_C < X_L)$ then V lags I, ϕ (negative) circuit nature capacitive
- In A.C. circuit voltage for L or C may be greater than source voltage or current but it happens only when circuit contains L and C both and on R it never greater than source voltage or current.
- In parallel A.C.circuit phase difference between I_L and I_C is π