Lecture 10

Saturday, 10 February 2024 10:13 AM

EE114 - Power Engineering 1

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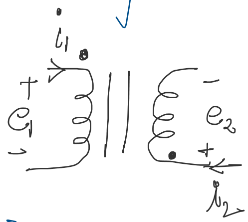
Consider the following coupled coil



What is e_2 as a function of i_1 & i_2 ?

$$e_2 = f(i_1, i_2)$$

If $i_1 = 0 \Rightarrow$ Case of self inductance

$$e_2 = L_2 \frac{di_2}{dt}$$

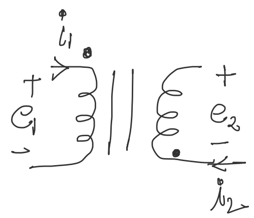
If $i_2 = 0 \Rightarrow$ Case of mutual inductance

$$e_2 = M \frac{di_1}{dt}$$

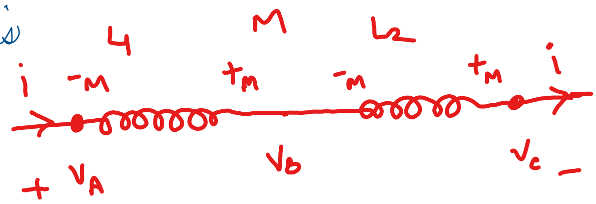
If $i_2 \neq 0$ & $i_1 \neq 0$

Applying superposition principle

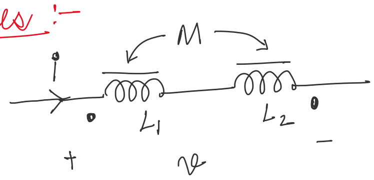
$$e_2 = L_2 \frac{di_2}{dt} + M \frac{di_1}{dt}$$



For this case the polarity of e_2 is flipped $e_2 = -L_2 \frac{di_2}{dt} - M \frac{di_1}{dt}$



Ques :-



Find v as a function of L_1, L_2, M & i.

$$V_A - L_1 \frac{di}{dt} + M\frac{di}{dt} = V_B$$

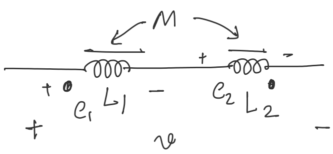
$$V_B - L_2 \frac{di}{dt} + M\frac{di}{dt} = V_C$$

$$V = V_A - V_C$$

Sol

$$v_1 = L_1 \frac{di}{dt} - M \frac{di}{dt}$$

$$v_2 = L_2 \frac{di}{dt} - M \frac{di}{dt}$$



$$v = e_1 + e_2$$

$$= (L_1+L_2)\frac{di}{dt} - 2M\frac{di}{dt}$$

Leakage flux :- When a coil produces a flux & it doesn't link the other coil, then that flux is called leakage flux.

In that case mutual inductance

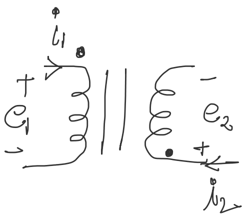
$$M = k\sqrt{L_1 L_2}$$

k → coupling coefficient

If $k=1$ → perfect coupling

$k=0$ → no coupling at all

Ques. Find the total energy absorbed by the mutually coupled coil.



$$e_1 = L_1\frac{di_1}{dt} + M\frac{di_2}{dt}$$

$$e_2 = L_2\frac{di_2}{dt} + M\frac{di_1}{dt}$$

Energy stored in the coupled coil

$$= \int (e_1 i_1 + e_2 i_2)\, dt$$

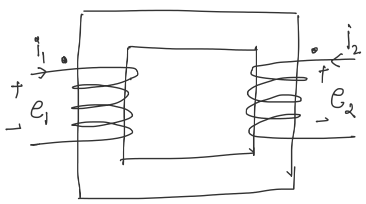
$$= \int \left(L_1 i_1 \frac{di_1}{dt} + M i_1 \frac{di_2}{dt} + L_2 i_2 \frac{di_2}{dt} + M i_2 \frac{di_1}{dt}\right) dt$$

$$= \int \left(L_1 i_1 \frac{di_1}{dt} + L_2 i_2 \frac{di_2}{dt} + M\frac{d(i_1 i_2)}{dt}\right) dt$$

$$= \int L_1 i_1\, di_1 + \int L_2 i_2\, di_2 + M\int d(i_1 i_2)$$

$$= \frac{1}{2}L_1 i_1^2 + \frac{1}{2}L_2 i_2^2 + M i_1 i_2$$

* Transformer :-



$$e_2 = N_2\frac{d\phi}{dt}$$

$$e_1 = N_1\frac{d\phi}{dt}$$

Using the definition of Dot Convention that if current is entering the dot on one side, then the dot of the other side will be positive.
The fact that coils can be coupled in different orientations makes it hard to tell where the dot will come and so if you are getting either of dot or positive terminal, mark the other.

Ideal transformer

(i) Assume $\mu \to \infty$

$$\frac{e_2}{e_1} = \frac{N_2}{N_1}$$

↳ Zero no load current

(ii) No leakage flux

(iii) No losses

$$P_{in} = P_{out}$$
$$e_1 i_1 = -e_2 i_2$$
$$N_1 i_1 = -N_2 i_2$$

Transformer nameplate :-

Have information about

	Primary	Secondary
Nominal voltage →	400V	11 kV
Rated current →	100A	
Rated Power →	40 kVA	common entries for both side.
Nominal frequency →	50 Hz	
1φ/3φ →	3φ	

can't be exceeded

Nominal / Rated

↳ Usual value → can be exceeded

$\boxed{\text{Rated power} \Rightarrow \text{o/p power}}$

$$v = V_p \cos\omega t$$
$$e = N \frac{d\phi}{dt}$$
$$\phi = \frac{V_p}{N\omega} \sin\omega t$$

$$\phi_{rms} = \frac{V_p}{N 2\pi f \sqrt{2}} = \frac{V_{rms}}{2\pi f N}$$

$$E_{rms} = 2\pi N f \frac{\phi_{peak}}{\sqrt{2}}$$

$$\boxed{E_{rms} = 4.44 N f \phi_{peak}}$$

$$e_1 = L_1 \frac{di_1}{dt} + M\frac{di_2}{dt} \quad ; \quad e_2 = L_2 \frac{di_2}{dt} + M\frac{di_1}{dt}$$

$$\frac{e_2}{e_1} = \frac{\frac{N_2^2}{R}\frac{di_2}{dt} + \frac{N_1 N_2}{R}\frac{di_1}{dt}}{\frac{N_1^2}{R}\frac{di_1}{dt} + \frac{N_1 N_2}{R}\frac{di_2}{dt}}$$

$$= \frac{N_2}{N_1}\left[\frac{\frac{N_1}{R}\frac{di_1}{dt} + \frac{N_2}{R}\frac{di_2}{dt}}{\frac{N_1}{R}\frac{di_1}{dt} + \frac{N_2}{R}\frac{di_2}{dt}}\right]$$

$$\frac{e_2}{e_1} = \frac{N_2}{N_1}$$