6.

VKSU SELF INDUCTANCE

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Whenever the electric current flowing through a circuit changes, the magnetic flux liked with that circuit also changes. As a result an induced e.m.f. is set up in the circuit. According to Lenz's law the direction of induced e.m.f. is such as to oppose the change in the current. Thus the e.m.f. is against the current when the current in the circuit is increasing and along the direction of the current when the current is decreasing. The phenomenon of the production of an induced e.m.f. in a circuit itself due to the change in current through it is called self induction and the induced e.m.f. is called back e.m.f.

Let C be a circuit in which the current I is flowing. The current will set up a magnetic field and hence a magnetic flux Φ is linked with the circuit. As the magnetic field strength at any point is proportional to the current I flowing through a circuit, so that the magnetic flux ϕ linked with the circuit at any

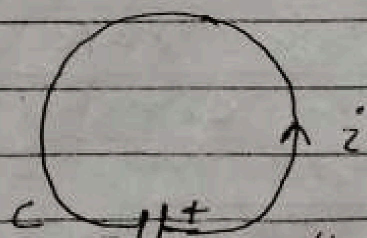

fig. (1)

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instant is proportional to the current I flowing through the same circuit at the instant i.e.

$$\phi \propto I$$

or $\phi = LI$ —— (1)

where L is a constant of proportionality called the coefficient of self ~~inductance~~ induction or self inductance of the coil. The practical unit of self inductance is henry.

When the current ~~of~~ I flowing through a circuit is changed, the magnetic flux linked with the circuit also changes and an induced e.m.f is set up in the circuit.

The rate of change of flux linked with the circuit is given by

$$\frac{d\phi}{dt} = L\frac{dI}{dt}$$

Therefore, from Faraday's law the e.m.f. induced in the circuit is

$$e = -\frac{d\phi}{dt}$$

i.e. $e = -L.\frac{dI}{dt}$ —— (2)

Now, when the current in the circuit is first switched on, the back e.m.f. opposes the growth of current, so that the current flows against the back e.m.f and does work against it. If the growing current at any instant be I. Then work done against back e.m.f. in a short time dt will be.

$$dW = -eIdt = +L\frac{dI}{dt} \cdot Idt$$

(using equ^n 2)

Hence the total work done in bringing the current from zero to a steady maximum value I_0 is

$$W = +L\int_0^{I_0} I\frac{dI}{dt}dt = L\int_0^{I_0} IdI$$

$$= \frac{1}{2}LI_0^2 \quad \text{—— (3)}$$

This work is stored as the energy of the magnetic field.

equ^n (1), (2) & (3) enable us to define the self-inductance L of a circuit in the following three ways:

(1) From equ^n (1) $\phi = LI$

$L = \phi/I$

If $I = 1$ amp., $L = \phi$ henry.

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Thus the self inductance of a circuit (in henry) is defined as the magnetic flux (in webers) linked with the circuit when 1 ampere current flows through it.

(2) From equ^n (2), $e = -L \frac{dI}{dt}$

or $L = \frac{e}{-dI/dt}$

if $-\frac{dI}{dt} = 1 A/S$, $L = e$

Thus the self inductance of a circuit is defined as the e.m.f. induced in the circuit when the rate of decay of current in the circuit is unity.

Here e.m.f. is in volts, current amp. and L in henries.

(3) From equ^n (3) $W = \frac{1}{2} L I_0^2$

or $L = \frac{2W}{I_0^2}$

if $I_0 = 1A$; $L = 2W$

Thus the self inductance of a circuit is defined as twice the work done against the induced e.m.f. in establishing unit current in the coil.

Here work is in Joule, current in ampere and L in henry.

These Three definitions are ~~indt~~ identical only when the Permeability of the medium round which the coil is wound remains constant. The role of self inductance in an electrical circuit is same as that of inertia in mechanical motion. Thus the self inductance of a coil is a measure of its ability to oppose the change in current through it.