ELEMENTS OF ELECTRICAL ENGINEERING
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ELEMENTS OF ELECTRICAL ENGINEERING

EMF EQUATIONS OF A SINGLE PHASE TRANSFORMER

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EMF Equations of a Transformer

Let N_1 = Number of turns in the primary winding

N_2 = Number of turns in the secondary winding

Let the primary winding current be sinusoidal current given by

$I_0 = I_m\sin(\omega t)$ Amperes

This sets up a magnetic flux in the transformer core which is given by

Flux, $\Phi = \dfrac{MMF}{Reluctance}$

Flux will also be sinusoidal in nature of the form

$\Phi = \Phi_m\sin(\omega t)$ where Φ_m represents maximum value of flux.

This time varying flux linking with the primary winding induces a self-induced EMF in itself given by,

$$e_1 = N_1 \frac{d\Phi}{dt} \qquad \text{----------(1)} \qquad \text{as per Faraday's Law}$$

substituting for Φ in equation (1),

$$e_1 = N_1 \Phi_m \omega \cos(\omega t) \qquad\qquad \text{Volts}$$

RMS Value of primary induced EMF,

$E_1 = e_1/\sqrt{2} = 4.44 f \Phi_m N_1$ Volts --- (2)

Similarly, there will be a mutually induced EMF in the secondary coil given by

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

Hence,

RMS Value of secondary induced EMF,

$E_2 = 4.44f\Phi_m N_2$ Volts -------(3)

Equations (2) & (3) above represent EMF equations of a Transformer.

A 250KVA, 11000V/415V, 50Hz 1ɸ transformer with 80 turns on secondary. Calculate i) the rated primary and secondary currents ii) the number of primary turns iii) the maximum value of flux iv) voltage induced per turn.

Soln :   Given, S_{rated} =   250 KVA   ; f = 50 Hz

$\qquad\qquad\qquad E_1$ =   11000 V

$\qquad\qquad\qquad E_2$ =   415 V

$\qquad\qquad\qquad N_2$ =   80

i) Rated condition $\Rightarrow$ Full load $\Rightarrow$ $S = S_{rated}$

$\qquad \therefore \; S \; = \; 250 KVA \;\; = \; E_1 I_1 \; = \; E_2 I_2$

$$\Rightarrow \quad I_1 = \frac{S}{E_1} = 22 \cdot 73 A; \quad I_2 = \frac{S}{E_2} = 602 \cdot 41 A$$

ii) $\quad \dfrac{E_1}{E_2} = \dfrac{N_1}{N_2} \quad \Rightarrow \quad N_1 = 2120 \text{ turns}$

iii) $\quad E_2 = 4 \cdot 44 f \phi_m N_2 \quad \Rightarrow \quad \phi_m = 23 \cdot 36 \, mWb$

iv) $\quad \text{Voltage induced per turn} = \dfrac{E_1}{N_1} = \dfrac{E_2}{N_2} = 5 \cdot 19 \, V/_{turn}$

A 50KVA transformer has $N_1:N_2$ =300:20. The primary winding is connected to 2200V, 50Hz supply & maximum flux density in the core is 1.2 T.
Calculate i) Secondary voltage on No load ii) Approximate value of I_1 & I_2 under Half load iii) Net cross sectional area of the core

The primary winding of transformer is connected to a 240V, 50Hz supply. The secondary winding has 1500 turns. If the maximum value of core flux is 2.07mWb. Determine i)the secondary induced EMF ii) the number of primary turns iii) core area of cross section, if the flux density has a maximum value of 0.465 Tesla.

$E_1 = 240V$; $f = 50 Hz$ $N_2 = 1500$ turns ; $\phi_m = 2.07 mwb$

i)

$$E_1 = 4.44 \, \phi_m \, f \, N_1$$

$$N_1 = \frac{240}{4.44 \times 2.07 \times 10^{-3} \times 50} = 523 \text{ turns}$$

ii)

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} \Rightarrow E_2 = \frac{N_2 E_1}{N_1} = 688.33V$$

iii)

$$B_m = \frac{\phi_m}{a} \Rightarrow a = \frac{2.07 \times 10^{-3}}{0.465} = 44.5 \text{ cm}^2$$

A 1φ, 20KVA transformer has 1000 primary turns and 2500 secondary turns. The net cross sectional area of the core is 100cm². when the primary winding is connected to 500V, 50Hz supply. Calculate i) the maximum value of flux density in the core ii)voltage induced in the secondary winding iii) the primary and secondary full load current.

$P = 20k$ $N_1 = 1000$, $N_2 = 2500$; $a = 100\,Cm^2$, $V_1 = 500V$; $f = 50Hz$

i) $E_1 = 4.44\, \phi_m\, N_1\, f$

$\phi_m = 2.25\, m\, Wb$

$\therefore B_m = \dfrac{\phi_m}{a} = 0.22\, Wb/m^2$

ii) $\dfrac{V_2}{V_1} = \dfrac{N_2}{N_1}$ $\Rightarrow$ $V_2 = \dfrac{2500 \times 500}{1000} = 1250V$

iii) $P = V_1 I_1 = V_2 I_2$

$I_1 = \dfrac{20 \times 10^3}{500} = 40A$

$I_2 = \dfrac{20 \times 10^3}{1250} = 16A$

Text Book:

1. "Basic Electrical Engineering" S.K Bhattacharya, 1stEdition Pearson India Education Services Pvt. Ltd., 2017

2. "Basic Electrical Engineering", D. C. Kulshreshta, 2ndEdition, McGraw-Hill. 2019

3. "Special Electrical Machines" E G Janardanan, PHI Learning Pvt. Ltd., 2014

Reference Books:

1. "Engineering Circuit Analysis" William Hayt, Jack Kemmerly, Jamie Phillips and Steven Durbin, 10th Edition McGraw Hill, 2023

2. "Electrical and Electronic Technology" E. Hughes (Revised by J. Hiley, K. Brown & I.M Smith), 12th Edition, Pearson Education, 2016.

THANK YOU

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