(7) The maximum efficiency of a 500 KVA, 3300V./500V., 50-Hz. single phase transformer is 97%. and occurs at $\frac{3}{4}$ full-load, unity power factor. If the impedance is 10%, calculate the regulation at full-load, power factor 0.8 lagging.

Soln.:- Full-load current referred to primary,

$$I_1 = \frac{500 \times 1000}{3300} = 151.5\,A.$$

$$\text{Efficiency} = \frac{500 \times 0.75 \times 1}{500 \times 0.75 \times 1 + \left(\frac{9}{16} \times P_c + P_i\right)} = 0.97$$

Here $P_i = \frac{9}{16} P_c$

$$\therefore \frac{375}{375 + \frac{18}{16} P_c} = 0.97$$

$$\Rightarrow P_c = 10.31\ kW.$$

$$\therefore R_1 = \frac{10.31 \times 1000}{(151.5)^2} = 0.449\,\Omega.$$

% impedance = 10%

$$\therefore Z_1 = \frac{3300}{151.5} \times 0.1 = 2.178\,\Omega$$

$$\therefore X_1 = \sqrt{(2.178)^2 - (0.449)^2} = 2.13\,\Omega.$$

$\therefore$ Regulation at full load 0.8 p.f. lagging

$$= \frac{I_1 R_1 \cos\theta + I_1 X_1 \sin\theta}{3,300} \times 100\%$$

$$= \frac{151.5 \times 0.449 \times 0.8 + 151.5 \times 2.13 \times 0.6}{3,300} \times 100\%$$

$$= \frac{54.419 + 193.617}{3,300} \times 100\% = 7.52\%$$

(8) A 100-KVA transformer has its maximum efficiency of 0.98 at full-load at unity power factor. During the day, it is loaded as follows—

12-hours — 20 KW. at power factor 0.5
6-hours — 45 KW at power factor 0.9
6-hours — 80 KW. at power factor 0.8.

Calculate all-day efficiency of the transformer.

Soln:– At maximum efficiency, Core loss P_i = Copper loss P_c at full-load.

$$\therefore 0.98 = \frac{100 \times 1}{100 \times 1 + 2P_c} \Rightarrow P_c = 1.02 \text{ kW}$$

For 12-hours—

Energy out put $= 20 \times 12 = 240$ kWh.

Copper loss at $\frac{20}{0.5} = 40$ kVA. is $\left(\frac{40}{100}\right)^2 \times 1.02 = 0.1632$ kW.

Energy input $= (20 + 0.1632 + 1.02) \times 12 = 254.2$ kWh.

For next 6 hours —

Energy out put $= 45 \times 6 = 270$ kWh.

Copper loss at $\frac{45}{0.9} = 50$ KVA. is $\left(\frac{50}{100}\right)^2 \times 1.02 = 0.255$ kW.

Energy input $= (45 + 0.255 + 1.02) \times 6 = 277.65$ kWh.

For last 6-hours —

Energy out put $= 80 \times 6 = 480$ kWh.

Copper loss at $\frac{80}{0.8} = 100$ KVA (full-load) is 1.02 kW.

$\therefore$ Energy input $= (80 + 1.02 + 1.02) \times 6 = 492.24$ kWh.

$$\therefore \text{All-day efficiency} = \frac{240 + 270 + 480}{254.2 + 277.65 + 492.24} = 0.967 = 96.7\%$$

Separation of hysteresis and eddy current losses:—

For a sine flux wave,

Core loss, $P_c = K_h f B_m^n + K_e f^2 B_m^2$.

$\therefore \quad \frac{P_c}{f} = K_h B_m^n + K_e f B_m^2$ —— (1)

Now, $V \simeq E_1 = \sqrt{2}\pi f N \phi_{max}$. or, $\frac{V}{f} = \sqrt{2}\pi N \phi_{max} = \sqrt{2}\pi N B_m A_i$

$\cancel{\sqrt{2}\pi f N \phi_{max} = \sqrt{2}\pi N B_m A_i}$

For any transformer, ~~B_m~~ N and A_i are constants.

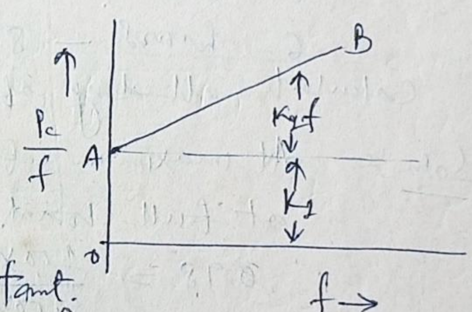
$$B_m \propto \frac{V}{f}.$$

For a particular value of $\frac{V}{f}$ or of maximum flux-density B_m, equation (1) can be written as,

$$\frac{P_c}{f} = K_1 + K_2 f \quad \text{—— (2)}$$

where, $K_1 = K_h B_m^n$ and $K_2 = K_e B_m^2$.

Values of K_1 and K_2 can be determined by performing open circuit test on the transformer. During this test V and f are varied together so as to keep $\frac{V}{f}$ (and therefore B_m) almost constant.



A wattmeter during the o.c. open circuit test, registers the core loss. After P_c, V and f are recorded, $\frac{P_c}{f}$ is plotted against f.

So, $K_1 = OA$ and slope of $AB = K_2$.

From (2), $P_c = K_1 f + K_2 f^2 = P_h + P_e$.

$\therefore \quad P_h = K_1 f$ and $P_e = K_2 f^2$.

Problem:— A transformer has the no-load loss of 55 W when the primary voltage is 250 V of frequency 50 Hz, and the no-load loss of 41 W when the primary voltage is 200 V of frequency 40 Hz. Determine the hysteresis and eddy current loss at the above conditions.

Soln.:— At no-load, induced voltage = applied voltage.

Here, the ratio $\frac{E_1}{f}$ is identical in the two cases.

$\therefore$ Hysteresis loss, $P_h = K_1 f$

Eddy current loss, $P_e = K_2 f^2$.

Now $\frac{P_c}{f} = K_1 + K_2 f.$

$\therefore \frac{55}{50} = K_1 + K_2 . 50 \Rightarrow K_1 + 50 K_2 = 1.1$

and $\frac{41}{40} = K_1 + K_2 . 40 \Rightarrow K_1 + 40 K_2 = 1.025$

$\therefore K_1 = 0.725$ and $K_2 = 0.0075.$

$\therefore$ At 50 Hz., $P_h = 0.725 \times 50 = 36.25$ W.

$P_e = \cancel{0.0075 \times 50} \; 55 - 36.25 = 18.75$ W

At 40 Hz., $P_h = 0.725 \times 40 = 29$ W.

$P_e = 41 - 29 = 12$ W.