Power Apparatus and System Design

Assignment - 3

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1) The key difference between Power & distribution transformers are:

Power Transformer	Distribution Transformer
→ Rated Voltage is 33kV or more.	→ Rate Voltage is less than 33kV.
→ It cannot handle high variation in load.	→ It handles high load variation.
→ Step-up transformers to feed transmission lines from generating station.	→ Step-Down transformer to feed power to consumer units from distribution lines
→ Built to operate at full load throughout the day	→ Doesn't work at full load throughout the day and is highly dependent on workload.
→ Power rating is more than 200MVA.	→ Power rating is less than 200MVA.
→ Can be step-up ~~&~~ or step down	→ Only step-down variant available
→ Designed to operate at maximum efficiency at full load.	→ Designed to operate at max efficiency at 60-70% load.
→ It generally has one primary & one secondary winding.	→ It has one primary but several secondary windings.
→ Generally, primary is connected in Star & Secondary in delta config.	→ Generally, primary is connected in Delta but secondary in Star.
→ flux density is high.	→ Flux density is lower.

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2) (a) Energy efficiency is a measure of ratio of the instantaneous power output and input for the transformer.
All day efficiency is a measure of the ratio of total energy supplied. Note that the supplied energy is the sum of power output & losses.

(b) The power required of my houses is ~~136.905~~ 6.385 kVA.
Since, most appliances are inductive, for the sake of simplicity, let assume a reasonable power factor of 0.9.

$S = \cancel{136.905}\ 6.385\ \text{kVA}$, $PF = 0.9$

$P = S \times pf = \cancel{136.905}\ 6.385 \times 0.9 = 5.7465\ \text{kW}$

$Q = \sqrt{S^2 - P^2} = 2.7831\ \text{kVAr}$.

Let the peak load be applied for my home from 9:30 AM to 2:00 ~~AM~~.
Let the times be divided into regions, R_i three R_{vi}

→ In R_i, $PF = \cos\left(\tan^{-1}\frac{Q_i}{P_i}\right) = \cos\left(\tan^{-1}\frac{45}{65}\right) = 0.82$

$$\text{Energy Input}(I_i) = \left[S_i \times PF + P_{\text{iron-core}} + P_{\text{iron-ohmic}} \times \left(\frac{S_i}{S}\right)^2\right] \times t_i$$

$$= \left[65 + 0.04 + 1.35 \times \frac{\sqrt{65^2+45^2}}{100}\right] k$$

$$= 231.85\ \text{kWh}.$$

$$\text{Energy Output}(O_i) = P_i \times t_i = 65\ \text{kW} \times 3.5\ \text{h}$$
$$= 227.50\ \text{kWh}.$$

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→ In R_{ii}, $P_{hmm} = 5.74$ kW, $Q = 2078$ kVAr

$P_{ii} = 85.74$ kW, $Q_{ii} = 52.78$ kVAr

Energy Input (I_{ii}) $= t_{ii}\left[85.74 + 0.4 + 1.35\left(\frac{\sqrt{85.74^2+52.78^2}}{100}\right)^2\right]$

$= 306.246$ kWh

Energy Output (O_{ii}) $= t_{ii} \times P_{ii} = 300.09$ kWh

→ In R_{iii}, $P_{iii} = 55.74$ kW, $Q_{iii} = 42.78$ kVAr.

Energy Input (I_{iii}) $= t_{iii}\left[55.74 + 0.4 + 1.35\left[\frac{81}{5}\right]^2\right] t$

$= 171.265$ kWh.

Energy Output (O_{iii}) $= t_{ii} \times P_{iii}$

$= 167.22$ kWh

→ In R_{iv}, $P_{iv} = 41.74$ kW, $Q_{iv} = 2.78 + \frac{36}{0.85} \times \sqrt{1-0.85^2}$

$= 25.09$ kVAr.

Energy Input (I_{iv}) $= 288.8828$ kWhr.

Output Energy (O_{iv}) $= 281.745$ kWhr.

→ In R_v, $P_v = 30.74$ kW, $Q_v = 2.78 + \frac{25}{0.9}\sqrt{1-0.9^2}$

$= 14.888$ kW.

Energy Input (I_v) $= 102.70$ kWh

Output Energy (O_v) $= 99.905$ kWhr.

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$$\text{All day efficiency} = \frac{\sum_{k=1}^{6} O_k}{\sum_{k=1}^{6} I_k} = 0.9777 \simeq \underline{97.8\%}$$

Q3) (a) Load sharing in transformers is on the basis of Zeq. It is very similar to current sharing in parallel resistor branch.

Let S_n be load taken by branch n, & S_{Rn} be its rated load. Z_{eqn}. its Zeq.

$$S_A = \frac{(Z_{eqB} \parallel Z_{eqC} \parallel Z_{eqD}) \times S}{(Z_{eqB} \parallel Z_{eqC} \parallel Z_{eqD}) + Z_{eqA}} = 115.7\ kVA.$$

$$S_B = \frac{(Z_{eqA} \parallel Z_{eqC} \parallel Z_{eqD}) \times S}{(Z_{eqA} \parallel Z_{eqC} \parallel Z_{eqD}) + Z_{eqB}} = 231.6\ kVA$$

S_C = 286.494 kVA { Similarly calculated as above }

S_D = 366.406 kVA.

Clearly, A & B are overloaded. since $S_A > S_{RA}$, $S_B > S_{RB}$

(b) $0.3914/(0.3914+1.3) \times S_{new} < 200$ (for B) & $0.12577 \times S_{new} < 100$ (for A)

$S_{new} < 844.28$ & $S_{new} < 795.23$ kVA

∴ S_{new} must be 795.23 kVA for no overloading

∴ B, C & D would be underloaded.

(c) It is not possible for B, C & D to operate at their rated kVA as doing so would overload A & B as shown in (b).

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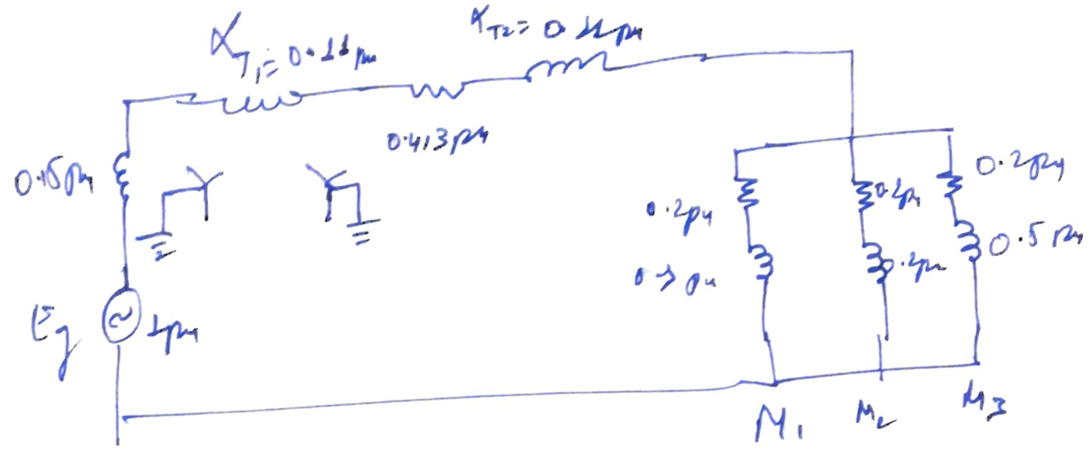
4) (a)



Net efficiency $(E) = E_{T_1} \times E_{T_1}$

$= 0.97 \times 0.97 = 0.941$

$\therefore$ Total losses $=$ Full load Power $\times (1-E)$

$= 100\,MVA \times (1-0.941)$

$= 5.91$ MW

(b) At 70% full load Power $= 70$ MVA.

So losses $= 70 \cdot (1-0.941)$

$= 4.13$ MVA $=$ const loss

$$So, \; \eta = \frac{70}{70 + 0.7^2 \times 4.13 + 4.13} \simeq 91.9\%$$

(c) Another for 97% efficiency

At full load, losses $= 100 \times (1-0.97^3) = 8.7329$ kW

At 70% load, losses $= 0.7 \times 8.7329 = 6.1129$ kW

for full load efficiency $= 0.97^3 = 0.9126$ i.e, 91.26%

$$\text{for } 70\% \text{ load} = \frac{3 \times 70}{3\times70 + 3\times0.7^2 \times 4.13 + 3 \times 4.13} = 91.9\%$$

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(d) We see the transformers when operated at 60-70% load give maximum efficiency and then distribution transformer is preferred also the demand is not all throughout the day. In 6 lc the situation relates with distribution transfer charaltristics.