King Fahd University of Petroleum & Minerals

Electrical Engineering Department

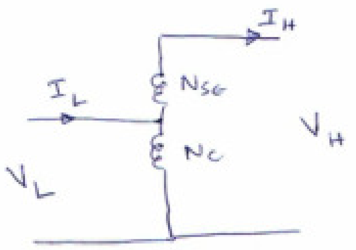
EE-360 Problem session #2, 2014, 132

Problem 1:

A 24-kVA, 60-Hz, 2400/240-V distribution transformer is to be reconnected for use as an autotransformer. Determine the following for step-up and step-down connections:

a) The primary winding voltage
b) The secondary winding voltage
c) The ratio of transformation
d) The nominal rating of the autotransformer

* Step-up autotransformer



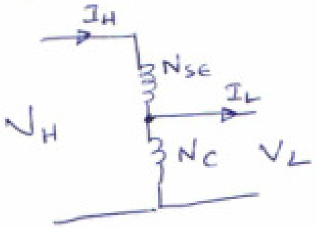
(a) $V_P = V_L = 2400\,V$

(b) $V_S = V_H = 2400 + 240 = 2640\,V$

(c) $a = \frac{2400}{2640} = 0.91$

(d) $S_{10} = V_H I_H = 2640 \times \frac{24\text{ kVA}}{240} = 2640 \times 100 = 264\text{ kVA}$

* Step-down autotransformer



(a) $V_P = V_H = 240 + 2400 = 2640\,V$

(b) $V_S = V_L = 2400\,V$

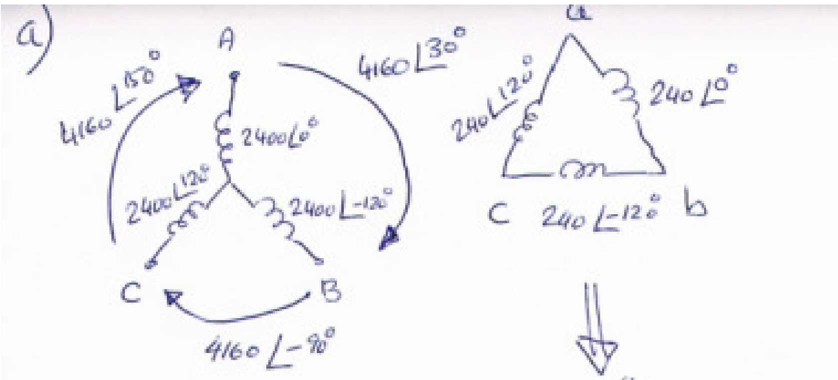
(c) $a = \frac{2640}{2400} = 1.1$

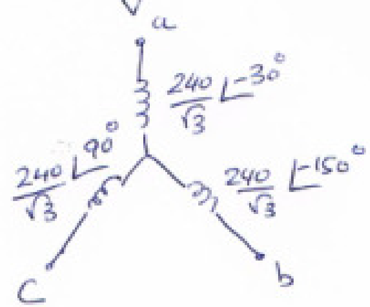
(d) $S_{10} = V_L I_L = 2400 \left(\underbrace{\frac{24\text{ kVA}}{240}}_{I_{SE}} + \underbrace{\frac{24\text{ kVA}}{2400}}_{I_C} \right) = 2400 \times 110 = 264\text{ kVA}$

Problem 2:
A 150-kVA wye-delta connected step down transformer has an input line-voltage of 4160-V and an output line voltage of 240-V

a) Draw the winding arrangements and its equivalent wye-wye representation
b) Determine the transformer ratio
c) Determine the rated line and phase currents for the high side
d) Determine the rated line and phase currents for the low side

a)





(b)

$$a = \frac{V_{\phi P}}{V_{\phi S}} = \frac{4160/\sqrt{3}}{240} = 10$$

(c)

$$S = \sqrt{3}\, V_{LP} I_{LP}$$

$$I_{LP} = \frac{150\,kVA}{\sqrt{3} \times 4160} = 20.8A$$

$$I_{\phi P} = I_{LP} = 20.8A$$

(d)

$$S = \sqrt{3}\, V_{LS} I_{LS}$$

$$I_{LS} = \frac{150\,kVA}{\sqrt{3} \times 240} = 360.8\,A$$

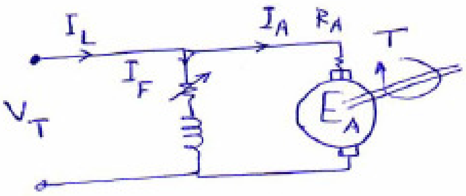
$$I_{\phi S} = \frac{I_{LS}}{\sqrt{3}} = \frac{360.8}{\sqrt{3}} = 208.3A$$

Problem 3:

A 20 hp, 240 V shunt DC motor has an armature resistance of 0.1 Ω. The motor's field resistance is 240 Ω. At no load, the motor draws 5 A from the source and produces a no-load speed of 1800 rpm. When delivering the rated horse power, the motor draws 69.1 A from the source.

a) Calculate the motor speed regulation.
b) Calculate the converted power and the corresponding induced torque.
c) Find the rotational losses and the motor efficiency

a)



$P_{out} = 20hp = 14.92\ KW$
$V_T = 240\ V$
$R_A = 0.1\ \Omega$
$R_F = 240\ \Omega$
$n_{nL} = 1800\ rpm$
$I_{L_{nL}} = 5\ A$
$I_{L_{fL}} = 69.1\ A$

b) $SR = \frac{n_{nL} - n_{FL}}{n_{FL}} \times 100\%$

At no load $I_{L_{nL}} = 5A$

$I_F = \frac{240}{240} = 1A$, $I_{A_{nL}} = 5 - 1 = 4A$

$E_{A_{nL}} = V_T - I_{A_{nL}} \cdot R_A = 240 - (4)(0.1) = 239.6V$

At rated Load $E_{A_{fL}} = V_T - I_{A_f} \times R_A$, $I_{A_{fL}} = 69.1 - 1 = 68.1\ A$

so $E_{A_{fL}} = 240 - (68.1)(0.1) = 240 - 6.81 = 233.19\ V$

$n_{fL} = \frac{E_{A_{fL}}}{E_{A_{nL}}} n_{nL} = \frac{233.19}{239.6} \times 1800 = 1752\ rpm$

$SR = \frac{1800 - 1752}{1752} \times 100\% = 2.74\%$

c) $P_{con} = E_{fL} \cdot I_{A_{fL}} = 233.19 \times 68.1 = 15.88\ Kw$

$T_{in} = P_{con}/\omega_{fL} = \frac{15.88 \times 10^3}{\frac{2\pi}{60}(1752)} = 86.55\ N.m$

d) $P_{rot} = P_{con} - P_{out} = 15.88 - 14.92\ KW = 960W$

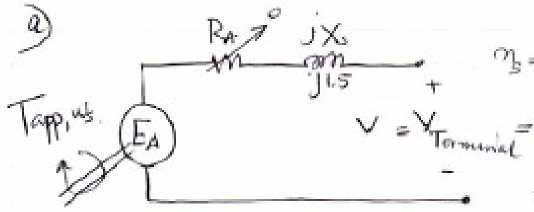
$\eta = \frac{P_{out}}{P_{in}} \times 100\% = \frac{14.92 \times 10^3}{240 \times 69.1} \times 100 = 90\%$

Problem 4:

A 25-kVA, 230-V, three-phase, 60-Hz, four-pole, Y-connected synchronous generator has a synchronous reactance of 1.5 Ω per phase and negligible armature resistance

a) Draw the single phase equivalent circuit and determine the synchronous speed
b) Find the excitation voltage (E_A) and the power angle (δ) if the generator is delivering rated kVA at 0.8 PF lagging
c) The field current is increased by 20 % without changing the input power from the prime mover. Find the armature current, the power factor, and the reactive power supplied by the machine

a)



$$n_s = \frac{120f}{P} = \frac{120 \times 60}{4} = 1800 \text{ rpm.}$$

b) $P_{o/p} = 25 * 0.8 = 20$ kW

$$I_a = \frac{P}{\sqrt{3}\, V \cos\phi} \angle -\cos^{-1} pf = \frac{20 * 10^3}{\sqrt{3} * 230 * 0.8} \angle -\cos^{-1} 0.8$$

$$= 62.76 \angle -36.9^\circ \text{ A}$$

$$E_a = V + I_a * jX_s = \frac{230}{\sqrt{3}} + 62.76\angle -36.9 * 1.5\angle 90$$

$$= 132.8 + 94.14\angle 53.1 = 189.3 + j75.28$$

$$= 203.7 \angle 21.69^\circ \text{ V}$$

$E_{aph} = 203.7$ V , $\delta = 21.69^\circ$

c) $|E_{a2}| = 1.2 * |E_a| = 244.44$ V

$$E_{a2} \sin\delta_2 = E_a \sin\delta \Rightarrow \delta_2 = 17.94^\circ$$

$$I_a = \frac{244.44\angle 17.94 - 132.8}{j1.5} = 50.2 - j66.5$$

$$= 83.3 \angle -52.95^\circ \text{ , } pf = 0.6 \text{ lagging}$$

$$Q = \sqrt{3}\, V I \sin\phi = 26.55 \text{ KVAR}$$

$$\text{or } Q = \frac{3V}{X_s}(E\cos\delta - V) = 26.5 \text{ KVAR}$$