17/ENG06/048
Mechanical Engineering
300 Level

Question 1
ABUAD mango juice factory is serviced by a 415V, 3-phase 4-wire, 50Hz. This supply powers the main drive motor having an output of 74.6KW and running on full load at a power factor of 0.7 Lagging with an efficiency of 85%. Identify the drive motor type and sketch the motor-supply circuit with a direct-online starter.

Determine the capacitance per phase of a mesh connected capacitor necessary to raise the power factor to i) Unity ii) 0.9 Lagging.

Solution

$V = 415V$ $P = 74.6$ $eff = 85\%$
$F = 50Hz$ $p.f = 0.7$ 3

i) unity $= 1$

$$C = \frac{KVAR}{2\pi f V^2} \quad \left(KVAR = P \times (\tan \text{actual p.f} - \tan \text{target p.f})\right)$$

$\Rightarrow$ actual $p.f = \cos\theta = 0.7$

$\theta = \cos^{-1} 0.7$

$\theta = 45.573$

$\tan(45.573) = 1.0202$

target $p.f = \cos\theta = 1$

$\theta = \cos^{-1} 1 = 0$

$\tan(0) = 0$

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Question 1

$KVAR = 74.6 \times (1.0202 - 0)$

$= 76.10692$

$\simeq 76.1$ unit.

$C = 76.1 / 2 \times \pi \times 50 \times 415^2$

$= 76.1 \times 1.405930403 \times 10^{-6}$ unit

ii) 0.9 Lagging

actual P.F = 1.0202

target P.F = $\cos\theta = -0.9$

$\theta = \cos^{-1}(-0.9)$

$= 154.16$

$\tan\theta = -0.48$

$KVAR = 74.6 \times (1.0202 - (-0.48)) = 111.91492$

$\simeq 112$ unit

$C = \frac{KVAR}{2\pi fV} = \frac{112}{2 \times \pi \times 50 \times 415^2} = 2.069174837 \times 10^{-6}$ unit

Drive motor type is

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Question 2

A 25 hp, 415 V(Line-Line), 6-pole, 50Hz, Star-Star Connected 3-phase induction motor has used in the production factory of PZ cussons stator/rotor phase voltage ratio of 6/5. The Stator and Rotor impedences per phase are $(0.25+j0.75)$ ohms and $(1.173+j0.52)$ ohms respectively. Using the approximate circuit version 2 referred to the rotor side at a slip of unity. Find the following:

i) Draw the equivalent circuit diagram referred to the rotor side (version 2)

ii) Rotor (secondary) current I_2

Solution

(i)

ii) Supply voltage per phase, $V = 415/\sqrt{3} = 239.60V$

Rotor i $R_{02} = (R_2 + k^2 R_1)$

$= (1.173 + (5/6)^2 \times 0.25)$

$= 1.347\Omega$

$X_{02} = \sqrt{(0.52 + (5/6)^2 \times 0.75)}$

$= 1.041$

$Z_{02} = R_{02} + X_{02}$

$= 1.347 + j\,1.041$

$Z_{02} = \sqrt{1.347^2 + 1.041^2}$

$= 1.7\Omega$

To find rotor current

$I_2 = E_2/Z_{02}$

Recall that $E_2 = kV_1$

$= 239.6 \times 0.85$

$= 199.67$ unit

$\therefore I_2 = \frac{199.67}{1.7} = 117.45A$

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Question 3

A 50Hz, 1/4hp motor runs at 2000rpm and takes 0.7A when connected to a 220V DC source. If the resistance and inductance of the machine are given as 15Ω and 0.25H respectively. Determine the following when the motor is connected to a 220V, 50Hz AC supply and is loaded to take 0.7A of current;

i) Speed of the motor
ii) Power factor of the motor
iii) Torque developed by the motor
iv) What type of motor could be used for this application

Solution

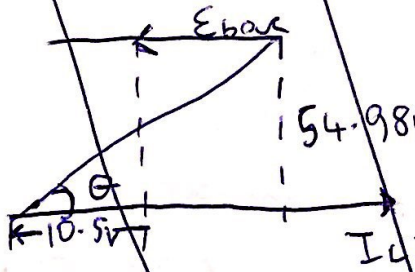
F = 50Hz V = 220
1/4 hp, 15Ω, 0.25H

On DC supply; Supply voltage = 220V
Current drawn, $I_L = 0.7A$

Reactance drop = $I_L \times R = 0.7 \times 15 = 10.5V$

Reactance voltage drop = $I_L \times X_L = 0.7 \times 2\pi FL$

where, $X_L = j\omega L = 2\pi FL$
$= 0.7 \times 2\pi \times 50 \times 0.25$
$= 54.98V$



$E_{bac} = \sqrt{V^2 - (X_L)^2} - IR$

$= \sqrt{(220)^2 - (54.98)^2}$

$= 213.019$

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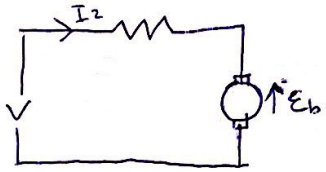
$V - \mathcal{E}_b = I_L \times R$

$V - [I_L \times R] = \mathcal{E}_b$

$\mathcal{E}_b = 220 - [0.7 \times 15]$

$= 209.5V$

Speed on DC; $N_{dc} = 2000$rpm



On AC supply

Supply voltage = 220V

current, $I_L = 0.7A$

Reactance drop = $I_L \times R = 0.7 \times 15$

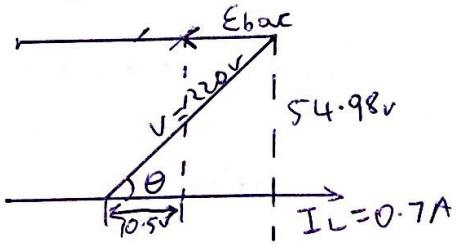
$= 10.5V$

Reactance voltage drop = $I_L \times X_L$

$= 0.7 \times 2\pi fL$

where, $X_L = 0.7 \times 2\pi \times 50 \times 0.25$

$= 54.98V$



$\mathcal{E}_{bac} = \sqrt{V^2 - (X_L)^2} - IR$

$= \sqrt{(220)^2 - (54.98)^2} - 10.5$

$= 213.019247 - 10.5$

$= 202.519247V$

$\simeq 202.52V$

i) $\frac{N_2}{N_1} = \frac{\mathcal{E}_{b2}}{\mathcal{E}_{b1}}$ so $\frac{\mathcal{E}_{bac}}{\mathcal{E}_{bdc}} = \frac{N_{ac}}{N_{dc}}$

making N_{ac} subject of formular

$N_{ac} = N_{dc} \times \frac{\mathcal{E}_{bac}}{\mathcal{E}_{bdc}} = 2000 \times \frac{202.52V}{209.5V}$

$N_{ac} = 1933.37$rpm

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ii) Power Factor, $\cos\phi = \frac{E_{bac} + IR}{V}$

$= 202.52 + 10/220$

$= 0.968$ unit

iii) Torque developed, $T_w = E_{bac} \times I$

$T_{ac} = \frac{E_{bac} \times I}{w}$

$w = 2\pi n$

$T_{ac} = \frac{E_{bac} \times I_L}{2\pi \times N_{ac}/60}$

$= \frac{202.52 \times 0.7 \times 60}{2\pi \times 1933.37}$

$= 0.700$ Nm