Q-1) Supply system has following loads
a lighting load of 700 KW,
industrial load = 1200 KW at 0.707
P.F = 0.707 (lag)

→ A load of 600 KW @ 0.8 leading
P.F.

→ 500 KW @ 0.6 lagging.

→ A synchronous motor 600 KW
having overall efficiency $\eta = 95\%$.
calculate P.F. of motor so that
distribution station is operating at
Unity P.F.

Q-2

1) Enristics
Heat by dielectric heating.
12 x 12 x 3 cm. f = 20 MHz,
Power absorb = 450 W
Relative permittivity $\varepsilon_r = 5$
P.F = 0.05
Calculate Voltage & current.
→ If voltage is limited to 1700 V
What will be f = ? to get same
loss.

Q1 Lighting load works at unity p.f.
$\therefore$ its lagging kVAR = 0 .

Lagging kVAR are taken by (ii) & (iv)
(iii) & (v) take leading kVAR

For station p.f to be unity, tot lagging kVAR must be neutralised by tot. leading kVAR.
We know kVAR = kW $\tan\phi$.

$\therefore$ Tot lagging kVAR ~~by~~ taken by (ii) & (iv)
$= \cancel{400 \tan(\cos^{-1} 0.707)} + 500 \tan (\cos^{-1} 0.6)$

$= 1200 \tan(\cos^{-1} 0.707) + 500 \tan(\cos^{-1} 0.6)$

$= 1200 + 666.6$

$= 1866.66$

Leading kVAR taken by (iii)

$= 600 \tan(\cos^{-1} 0.8)$

$= 450$

$\therefore$ Leading kVAR to be taken by synch motor:
$= 1866.66 - 450 = 1416.66$ kVAR

$\cancel{\tan\phi = \frac{kVAR}{kW}}$

Motor input $= \frac{\text{output}}{\text{efficiency}} = \frac{600}{0.95} = 631.5$ kW

If ϕ is phase angle of synch. motor, then
$\tan\phi = \frac{kVAR}{kW} = \frac{1416.66}{631} = 2.245$

$\phi = 73.32°$

p.f of synch. motor $= \cos\phi = \boxed{0.406}$ leading

Q2 $12 \times 12 \times 3$ dielectric $\therefore A = 144\ cm^2$, $d = 3\ cm^2$

$f = 20$ MHz.

$P = 450$ W

$\varepsilon_r = 5$ p.f $= 0.05$

Cal. voltage & current.

If voltage is limited to 1700 V, what will be freq. to get same loss?

→ $P = 2\pi f C \times V^2 \times pf$ $\varepsilon_0 = 8.89 \times 10^{-12}$

$C = \frac{A}{d} \times \varepsilon_0 \varepsilon_r = 21.33 \times 10^{-12}$

$\therefore V = \sqrt{\frac{P}{2\pi f C\ pf}}$

$= \sqrt{\frac{450}{2 \times 3.14 \times 20 \times 10^6 \times 21.33 \times 10^{-12} \times 0.05}}$

$= 1.832 \times 10^3$ V

$\boxed{V = 1832\ V}$

$I = \frac{P}{V \times pf} = \frac{450}{1832 \times 0.05} = \boxed{4.91\ A}$

$H \propto V^2 f$ $\therefore \left(\frac{V_2}{V_1}\right)^2 = \left(\frac{f_1}{f_2}\right)$

$\therefore f_2 = f_1 \left(\frac{V_1}{V_2}\right)^2 = 20 \left(\frac{1832}{1700}\right)^2 = \boxed{23.22\ MHz}$

Specific heat of water C_{pw} 4.19 kJ/kg K.

C_{ice} = 2.1 kJ/kg K

latent heat of ice = 336 kJ/kg.

↳ Energy required to convert 1 ton of water ↓ 1 ton of ice.

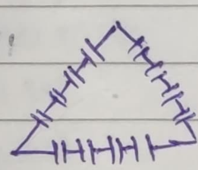
Q-4

Q. 3-Φ 50 Hz 415 V induction motor develop 100 HP power at 0.75 P.F. with the efficiency of 93 %. A capacitor bank is connected in delta across the supply to raise the P.F. 0.95 lagging. each capacitor unit is built up of 4 similar 100 V capacitors, connected in series. Determine the capacitance of each capacitor.

$\cos \phi_1 = Q/P_1$ $\cos\phi_2 = Q_2/P_2$

$\dfrac{0.75 = \dfrac{Q_1}{P}}{0.95 \quad \dfrac{Q_2}{P}}$

→ $f = 50$ Hz
$V_L = 415$ V
$\cos\phi_1 = 0.75$ (lag)
$\cos\phi_2 = 0.95$ (lag)
$P = 100$ HP
$= 74.5$ kW
$\eta = 93$ %



$\phi_1 = \cos^{-1}(0.75) = 41.4$
$\phi_2 = \cos^{-1}(0.95) = 18.19$

$Q_1 = P\tan\phi_1 = 74.5 \tan(41.4) = 65.66$ KVAR
$Q_2 = P\tan\phi_2 = 74.5 \tan(18.19) = 24.47$ KVAR

3-ϕ Induction motor 5 Kw, P.F. 0.75 lagg. Bank of capacitor is connected in delta across the supply terminal, P.F is raised 0.9 lagging determine KVAR rating of capacitor bank connected to each phase.

for star
$V_L = \sqrt{3} V_{PL}$
$I_L = I_{PL}$

for Delta
$V_L = V_{Ph}$
$I_L = \sqrt{3} I_{Ph}$

$\phi_2 = \cos^{-1}(0.95)$

$Q_1 = P \tan\phi_1 = 74.5 \tan(46.01) = \boxed{65.70 \text{ kVAR}}$
$Q_2 = P \tan\phi_2 = 74.5 \tan(20.21) = \boxed{24.47 \text{ kVAR}}$

$P = 5$ kW
$pf_1 = 0.75$ (lag)
$pf_2 = 0.9$ (lag)
Determine kVAR of capacitor bank connected to each phase.

$\phi_1 = \cos^{-1}(0.75) = 41.41^\circ$
$\phi_2 = \cos^{-1}(0.9) = 25.84^\circ$

VAR rating of capacitor bank $= P(\tan\phi_1 - \tan$
Q_{csh}

$Q_{csh} = 5(\tan 41.41^\circ - \tan 25.84^\circ)$
$Q_{csh} = 1.99$ kVAR

Rating in each phase $= \frac{Q_{csh}}{3}$
$= \boxed{0.663 \text{ kVAR}}$

Q-6

1-ϕ AC

i) lighting load 20 kW unit pf

ii) Induction motor ~~100~~ 150 kW ~~0.7~~ 0.75 (lag)

iii) Synch. motor 50 kW 0.9 (lead)

Calc. kW & kVAR - Also represent phase diagram

$$kVA_1 = \frac{kW_1}{\cos\phi_1} = 20\ kVA$$

$$kVA_2 = \frac{kW_2}{\cos\phi_2} = \frac{\cancel{100}\ 150}{0.75} = 200\ kVA$$

$$kVA_3 = \frac{50}{0.9} = 55.55\ kVA$$

$$Q_1 = P\tan\phi_1 = 0$$

$$Q_2 = 150 \times \tan(\cos^{-1} 0.75) = \underline{132.24\ kVAR}$$

$$Q_3 = 50 \times \tan(\cos^{-1} 0.9) = \underline{24.22\ kVAR}$$

$$P = \text{Tot kW} = 20 + 150 + 50 = \underline{\underline{220\ kW}}$$

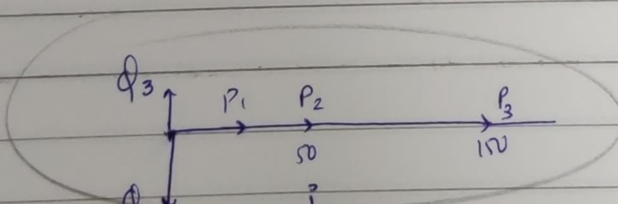
$$Q = \text{Tot } Q = 0 - 132.24 + 24.22 = \underline{\underline{-108.02\ kVAR}}$$

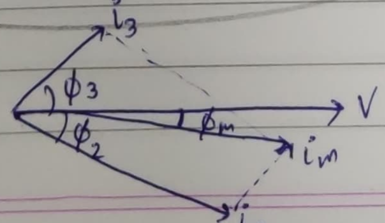
$$S = \text{Tot kVA} = \sqrt{(kW)^2 + (kVAR)^2} = \sqrt{(220)^2 + (-108.02)^2}$$

$$\underline{S = 245.08\ kVA}$$

$$\text{Net p.f} = P/S = \frac{220}{245.08} = 0.897 \approx \underline{\underline{0.9}}\ (\text{lag}).$$

Bec. resultant kVAR is lagging





As generator is same, voltage will be same

Page No.
Date / /

(1) Estimate efficiency of high frequency furnace to melt 10 min → 1.8 kg Al. input to the furnace 5 kW. initial Temp 15 °C

Specific Heat = 550 J/kg K
latent Heat = 32 KJ/kg.
melting Temp: 660 °C

$$\boxed{\rightarrow \quad 1\,J = 28 \times 10^{-7}\ kWh}$$

$$\mathcal{E} = m[s(t_2 - t_1) + L]$$
$$= 1.8 \times 10^3 [550(660-15) + 32000]$$
$$= 1.8[550(645) + 320000] \times 10^3$$
$$= 0.195\ kWh$$
$$=$$

$$Eff = \frac{\text{Energy require}}{\text{w/IP}}$$

$$= \frac{0.195 \times 6}{5}$$

$$= 23.4\ \%$$

(1) Induction furnace. operating at 10 V secondary 500 kW, 0.5 PF. when hearth is full. if secondary Voltage maintain constant. estimate power absorb & pf. when the hearth is half full!

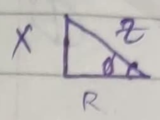
$500\ A/cm^2$

Page No

Date / /

Hearth is full

$I = \frac{P}{V\cos\phi} = \frac{500\times10^3}{10\times.5} = 10^5$ $Z = V/I = 10/10^5 = 10^{-4}$



$R = Z\cos\phi = 10^{-4}\times0.5 = 5\times10^{-5}$

$X = Z\sin\phi = 10^{-4}\times\sqrt{3}/2 = 8.6\times10^{-5}$

Hearth is half empty

$R' = 2R\ \Omega$ $= 10^{-4}$

$X' = X$ $Z' = \sqrt{R^2 + X'}$ $\sqrt{10^{-4} + 0.86\times10^{-4}}$

$PF = R'/Z' = \frac{10^{-4}}{10^{-4}\sqrt{1.86}}$ $I' = V/Z'$

$P = I'^2 R'$

26/09/22

Load of 500 kW at P.F. 0.7 lagging, if P.F is raised to unity how many kW can alternate supply from same KVA loading

$\cos\phi = P/S$

$0.7 = \frac{500}{S}$

$S = \frac{P_1}{0.7} = 714.29$ KVA

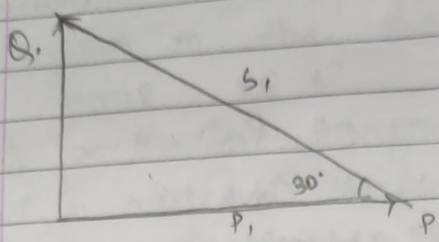
$P_2 = S\times\cos\phi$

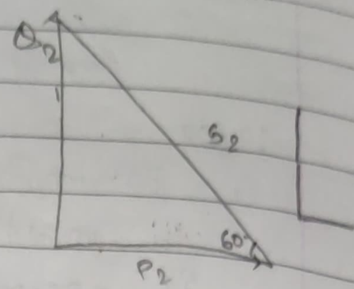
$= 714.29\times1$

$= 714.29$ kW

more kW Formed $= 214.29$ kW.

$\phi = 30^\circ$ $\qquad\qquad$ $\phi = 60^\circ$





$\cos\phi = \frac{P = 5\,kW}{S_1}$ $\qquad$ $\cos\phi_2 = \frac{P_2}{S_2}$

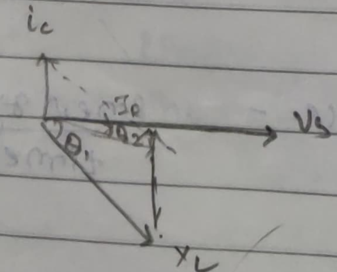
$S_1 = \frac{5\,kW}{0.866}$ $\qquad$ $S_2 = \frac{5\,kW}{0.5}$

$= 5.81\,kVA$ $\qquad$ $= 10\,kVA$

→ Advantage of good P.F.
- → Reactive power ↓ → Reduce bill
- → I^2R losses ↓ → Stability of grid ↑
- → overall cost ↓
- → temp rise ↓
- → Life cycle Equipment ↑
- → False trigger ↓

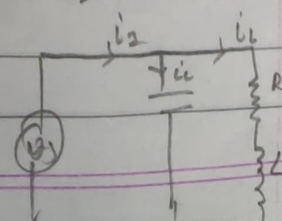
→ Disadvantage of bad P.F.

Q How to improve P.F. ?
→ By adding capacitor bank



$Q_2 < Q_1$

$\cos\phi_2 > \cos\phi_1$



Page No
Date / /

Q How to measure required capacitor & synchronous capacitor.

29/09

Ex. Estimate rating of induction furnace to melt 2 tons of Zinc in 1 hour if it operate at efficiency of 80%.
Specific heat of Zn = 0.1 kcal/kg
Latent heat of fusion of Zn = 26.67 kcal/kg
Melting point of Zn = 555°C
Starting temp. = 35°C
Power rating = ? w/h

Heat energy = $m[s(t_2-t_1)+L]$

$= 2\times10^3\,[0.1(555-35)+26.67]\times10^3$ kcal to cal

$= 2\times10^3(52+26.67)10^3$

$= 2\times78.67\times10^6$ cal

$= 157.34\times10^6$ cal

$= 157340$ Kcal $= \frac{157340}{860}$ = kwh

Energy ip = $\frac{\text{Energy require}}{\text{effi.}}$

$= \frac{157.34\times10^6 \text{ cal}}{0.80\times860}$

= 228.69 kwh

Rating of furnace = $\frac{\text{energy ip}}{\text{time}} = \frac{228.69}{1\text{ h}}$

= 228.69 kW

C = specific heat
L = Latent heat

Q. Calc. kVA & kW run from supply 3ϕ elec. arc. furnace

$I = 4500\ A$

$V_{arc} = 50\ V$

$R = 0.002\ \Omega$

$X_{02} = 0.004$

efficiency $= \eta = 60\%$

Calc. time req. to melt 3 tons of steel when $C_{steel} = 0.12$, $L_{steel} = 8.89$ kcal/kg, $\theta_{melt\ steel} = 1370°C$, $\theta_{initial} = 20°C$

(i) Volt drop due to resistance

$$V_r = I \times R_s = 4500 \times 0.002 = 9V$$

Due to reactance $V_x = I \times X_s = 4500 \times 0.004 = 18V$

Tot volt $= V_t = \cancel{\sqrt{V_r^2 + V_x^2}} = \cancel{\sqrt{9^2+18^2}}$

$$= \sqrt{(V_{arc} + V_r)^2 + V_x^2}$$

$$= \sqrt{(50+9)^2 + 18^2} = 62V$$

Supply p.f → $pf = \frac{(V + V_r)}{V_t} = \frac{59}{62} = 0.95$

Tot pow drawn

$$P = 3 \times V_t I \times pf$$

$$= 3 \times 62 \times 4500 \times 0.95\ W$$

$$\boxed{P = 795.15\ kW}$$

$$\frac{k\,cal}{860} = kWh$$

DATE
PAGE

$m = 3000\ kg = 3$ tonnes
$C_{steel} = 0.12$
$L_{steel} = 8.89\ kcal/kg$

$$\text{Energy} = m \cdot C_{steel}(t_2 - t_1) + mL$$

$$= 3000 \times 0.12\,(1350) + 3000 \times 8.89$$

$$= 512.66 \times 10^3\ kcal$$

$$= \boxed{596\ kWh}$$

Actual power utilised $= P_a = 0.60 \times P$
$= 477\ kW$

Time req. for melting

$$T = \frac{\text{Energy}}{\text{Power}} = \frac{596}{477}$$

$$= 1.25\ h$$

$$= \boxed{75\ mins}$$