Q-1 supply system has following loads
a lighting load of 1 KVA 700 KW,
industrial load = 1200 KW at 0.907
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

Resistive

Heat by dielectric heating.
$12 \times 12 \times 3$ 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 ther
or what will be $f = ?$ to get same
loss.

Q1 Lighting load works at unity p.f.
∴ 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 $kVAR = kW \tan\phi$.

∴ Tot lagging kVAR by taken by (ii) & (iv)
$$= 400 \tan(\cos^{-1} 0.707) + 500 \tan(\cos^{-1} 0.6)$$
$$= 1200 \tan(\cos^{-1} 0.707) + 500 \tan(\cos^{-1} 0.6)$$
$$= 1200 + 666.6$$
$$= 1866.66$$

Leading kVAR taken by (iii)
$$= 600 \tan(\cos^{-1} 0.8)$$
$$= 450$$

∴ Leading kVAR to be taken by synch motor :
$$= 1866.66 - 450 = \underline{1416.66 \ kVAR}$$

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

Motor input = $\frac{output}{efficieny}$: $\frac{600}{0.95}$ = $\underline{631.5 \ kW}$

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

$$\phi = 73.32°$$

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

Ɵ2 $12 \times 12 \times 3$ dielectric   ∴ 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?

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

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

     β → ∴ $V = \sqrt{\dfrac{P}{2\pi f C \, pf}}$

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

       $= 1.832 \times 10^3$ V

       $\boxed{V = 1832 \text{ V}}$

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

     $P \propto V^2 f$ ∴ $\left(\dfrac{V_2}{V_1}\right)^2 = \left(\dfrac{f_1}{f_2}\right)$

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

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

8-∅ 50 Hz 415 V induction motor develop 100 HP power at 0.75 P.F. with the efficiency of 99 %. 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 μU capacitor, connected in series. Determine the capacitance of each capacitor.

$\cos\phi_1 = O/P_1V \times \quad = \cos\phi_2 = C_2/e_2$

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

$\rightarrow$ f = 50 Hz
$V_L = 415 V$
$\cos\phi_1 = 0.75 \ (lug)$
$\cos\phi_2 = 0.95 \ (lug)$
$P = 100 \ HP$
$\quad = 74.5 \ kW$
$\eta = 99\%$

$\phi_1 = \cos^{-1}(0.75) = 41.4°$
$\phi_2 = \cos^{-1}(0.95) = 18.19$
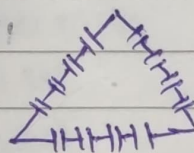
$Q_1 = P \tan\phi_1 = 74.5 \tan(41.4) = 65.66 \ KVAR$
$Q_2 = P \tan\phi_2 = 74.5 \tan(18.19) = 24.47 \ KVAR$

Capacitor projected capacitance = $65.66 - 24.47$

$= 41.19$ KVAR

Per capacitor phase projected

Capacitance $= \dfrac{41.19}{3} = 13.74$ KVAR

$\rightarrow I_{cp} = \dfrac{V_L}{X_C}$

Capacitance $= \dfrac{V_L}{1/2\pi f C}$

$= V_L \times 2\pi f C$

$= 415 \times 2 \times 3.14 \times 50 \times C$

$= \underset{130.37}{\cancel{13005}} \times 10^3 \, C \quad A \qquad \dots ①$

$\rightarrow KVAR_P = \dfrac{V_L \times I_{cp}}{1000}$

$13.73 = \dfrac{415 \times 130.37 \times 10^3 \times C}{10^3}$

$C = 253 \times 10^{-6} \, F$

$C_P = 253 \, \mu F$

each capacitor's capacitance $= 253 \times 4 \, \mu F$

$= 1012 \, \mu F$

Q)

3-∅ Induction motor 5 kw, P.F. 0.75 lagg

Bank of capacitors is connected in

delta across the supply terminal,

P.F. is raised 0.9 lagging determine

KVAR rating of capacitors bank

connected to each phase.

for star

$V_L = \sqrt{3} V_{PL}$

$I_L = I_{P_l}$

for Delta

$V_L = V_{Ph}$

$I_L = \sqrt{3} I_{Ph}$

$\phi_2 = \cos(0.95)$

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

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

$P = 5 \text{ kW}$

$p.f_1 = 0.75 \text{ (lag)}$

$p.f_2 = 0.9 \text{ (lag)}$

Determine kVAR of capacitor bank connected
to each phase

$\phi_1 = \cos^{-1}(0.75) = 41.41°$

$\phi_2 = \cos^{-1}(0.9) = 25.84°$

$\phi = 5$ VAR rating of capacitor bank = $P(\tan\phi_1 - \tan\phi_2)$

$Q_{csh} = 5(\tan 41.41° - \tan 25.84°)$

$Q_{csh} = 1.99 \text{ kVAR}$

Rating in each phase = $\dfrac{Q_{csh}}{3}$

$= \boxed{0.663 \text{ kVAR}}$

Q:6

1-ϕ AC

i) lighting load 20 kW unit pf
ii) Induction motor ~~took W~~ 150 kW ~~o=f~~ 0.75 (lag)
iii) Synch. motor 50 kW 0.9 (lead)

Calc. kW & kVAR - Also represent phase diagram

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

$$kVA_2 = \frac{kW_2}{\cos\phi_2} = \frac{~~140~~ \; 150}{0.75} = 200 \; kVA$$

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

$$\phi_1 = P\tan\phi_1 = 0$$
$$\phi_2 = 150 \times \tan(\cos^{-1} 0.75) = 132.24 \; kVAR$$
$$\phi_3 = 50 \times \tan^{*}(\cos^{-1} 0.9) = 24.22 \; kVAR$$
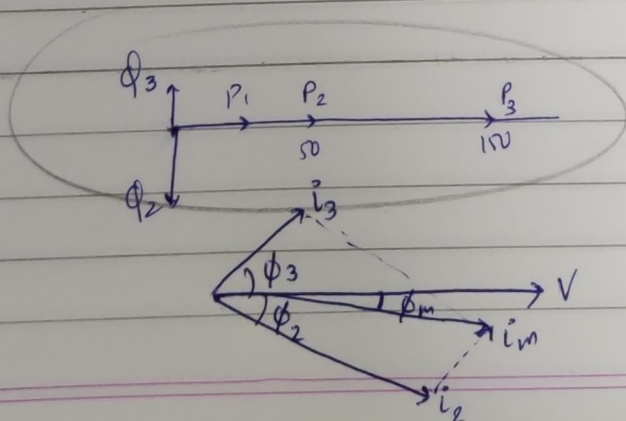
$$P = Tot \; kW = 20 + 150 + 50 = \underline{220 \; kW}$$
$$\phi = Tot \; \phi = 0 - 132.24 + 24.22 = \underline{-108.02 \; kVAR}$$

$$S = Tot \; kVA = \sqrt{(kW)^2 + (kVAR)^2} = \sqrt{(220)^2 + (-108.02)^2}$$
$$\underline{S = 245.08 \; kVA}$$

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

Bec. resultant
kVAR is lagging

As generator is
same, voltage will be
same

① Estimate efficiency = ? high efficiency furnace to melt 10 min → 1.5 kg Al. input to the furnace 5 Kw, initial Temp 15°C

specific Heat : 550 J/kg°C
latent Heat = 32 KJ/kg
melting Temp : 660°C

→ $\boxed{1 J = 2.8 \times 10^{-7} \text{ Kwh}}$

$$E = m[s(t_2 - t_1) + L]$$
$$= 1.5 \times 10^3 [550(660-15) + 32000]$$
$$= 1.5 [550(645) + 32000] J \times 10^3$$
$$= 0.195 \text{ Kwh}$$

$$\text{eff} = \frac{\text{Energy required}}{\text{kW} \times P}$$

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

$$= 23.4 \%$$

② Induction furnace. Operating at 10 V secondary 900 Kw, 0.5 PF. when hearth ps full. it secondary voltage maintain constant. estimate power absorb & PF. when the hearth is half full.
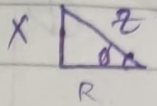
Network is full

$$I_L \cdot \frac{P}{V\cos\phi} = \frac{500 \times 10^3}{10 \times 5} = 105$$

$Z = V/I = \frac{10}{10^5} = 10^{-4}$

$R = Z\cos\phi = 10^{-4} \times 0.5 = 5 \times 10^{-5}$

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

Network is half built

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

$X' = X$

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

$\frac{R'}{Z'} = 1 = \frac{10^{-4}}{10^{-4}\sqrt{1.86}}$ $I' = V/Z'$

$P = I'^2 R'$

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 boram sance KVA loading
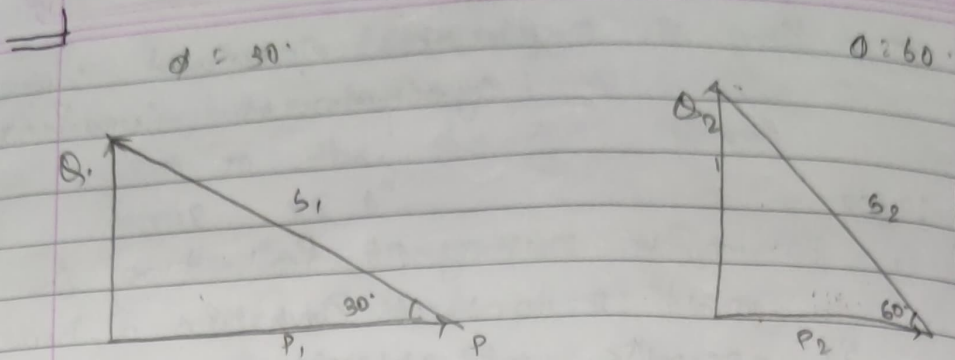
$\cos\phi = P/g$

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

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

$P_2 = S \times \cos\phi$
$= 714.29 \times 1$
$= 714.29$ kw

more Kw formed = 214.29 kw.

$\phi = 30°$ $\theta = 60°$

$$\cos \theta = \frac{P = 5\,kw}{S_1}$$ $$\cos \theta_2 = \frac{P_2}{S_2}$$

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

$$= 5.81\,KVA$$ $$= 10\,KVA$$

→ Advantage of good P.F.

→ Reactive power ↓   → Reduce bill

→ I^2R losses ↓   → stability of
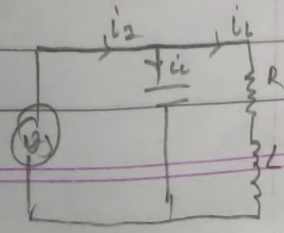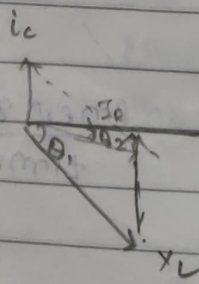   grid ↑

→ overall cost ↓

→ temp rise ↓

→ Life cycle Equipment ↑

→ False trigger ↓

→ Disadvantage of bad P.F.

Q How to improve P.F. ?

→ By adding Cupacitor bank

$Q_2 < Q_1$

$\cos \theta_2 > \cos \theta_1$

Ø How to measure required capacitor
              L synchronous capacitor.

29/09

Ex. Estimate rating of production furnace
to melt 2 tons of zinc in a hour it
it operate at efficiency of 80%.
    specific heat of Zn = 0.1 kcal/kg
    latent heat of fusion of Zm = 26.67 kcal/kg
    Melting point of Zn = 555°C
    starting temp. = 35°C
         power rating = ? w/h

    Heat energy = m[s(t₂-t₁) + L]
              = 2×10³ [0.1(555-35) + 26.67]×10³
                                                    ↓
                                                   kcal
                                                    to
                                                   cal

              = 2×10³ (52 + 26.67)10³
              = 2×78.67×10⁶ cal
              = 157.34 × 10⁶ cal
              = 157340 kcal = $\frac{157340}{860}$
    Energy ip = $\frac{\text{Energy required}}{\text{effi.}}$ = kwh

              = $\frac{157.34 \times 10^6 \text{ cal}}{0.80 \times 860}$

              = 228.69 kwh

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

                                        = 228.69 kw

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

$$V_r = I \times R_s = 4500 \times 0.002 = \underline{9V}$$

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

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

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

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

Supply p.f → $pf = \dfrac{(V + V_s)}{V_t} = \dfrac{59}{62} = \underline{0.95}$

Tot pow drawn

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

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

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

$$\frac{k\,cal}{860} = kWh$$
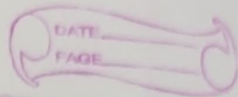
$m = 3000 \, kg = 3 \, tonnes$

$c_{steel} = 0.12$

$L_{steel} = 8.89 \, kcal/kg$

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

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

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

$= \boxed{596 \, kWh}$

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

$= \underline{\underline{477 \, kW}}$

Time req. for melting

$T = \dfrac{Energy}{Power} = \dfrac{596}{477}$

$= \underline{\underline{1.25 \, h}}$

$= \boxed{75 \, mins}$