

2076
Chaitanya

Demand Side Management

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given,

$$35 \text{ kW IM, } pf_{PL} = 0.9, \eta_{PL} = 0.9$$

$$pf_{HL} = 0.5; \eta_{HL} = 0.8$$

At no load,

$$I_0 = I_{NL} = 0.25 I_{PL}$$

$$pf_{NL} = 0.1$$

Now,

→ Input to motor at full load,

$$P_{in, PL} = \frac{\text{Rated O/P}}{\eta_{PL}}$$

$$= \frac{35}{0.9}$$

$$= 38.89 \text{ kW}$$

kVAR (lagging) drawn by the motor at full load,

$$kVAR_{PL} = P_{in, PL} \tan \phi_{PL}$$

$$= 38.89 \tan [\cos^{-1} 0.9]$$

$$= 18.935 \text{ kVAR}$$

→ Input to motor at half load,

$$P_{in, HL} = \frac{1/2 \times 85}{0.9}$$

$$= 21.875 \text{ kW}$$

KVAR (lagging) drawn by the motor at half load,

$$KVAR_{HL} = P_{in, HL} \tan \phi_{HL}$$

$$= 21.875 \tan [\cos^{-1} 0.5]$$

$$= 37.89 \text{ kW}$$

Now,

→ Full load current,

$$I_{FL} = \frac{35 \times 10^3}{\sqrt{3} \times V_L \times 0.9 \times 0.9}$$

$$I_{FL} = \frac{24,947.23}{V_L} \text{ A}$$

→ No load current,

$$I_{NL} = 0.25 \times \frac{24,947.23}{V_L}$$

$$I_{NL} = \frac{6,236.8}{V_L} \text{ A}$$

Then,
No-load $\pm IP$,

$$P_0 = \frac{\sqrt{3} V_L I_0 \cos \phi_0}{1000}$$

$$= \frac{\sqrt{3} \times V_L \times 6.236 \times 0.1}{1000 \times V_L}$$

$$= 1.08 \text{ kW}$$

Now,

KVAR (lagging) drawn by the motor at no-load,

$$\text{KVAR}_{NL,1} = 1.08 \tan [\cos^{-1} 0.1]$$

$$= 10.75 \text{ KVAR}$$

Now,

KVAR (lagging) drawn from mains at half load with cap actors,

$$\text{KVAR}_{HL,2} = 21.875 \tan [\cos^{-1} 0.8]$$

$$= 16.406 \text{ KVAR}$$

Now,

KVAR supplied by capacitors,

$$KVAR_c = KVAR_{HL,1} - KVAR_{HL,2}$$

$$= 37.89 - 16.406$$

$$= 21.484 \text{ KVAR}$$

Now,

KVAR drawn from mains at full load with capacitors,

$$KVAR_{PL,2} = 18.895 - 21.484$$

$$= -2.649 \text{ (leading)}$$

then,

$$KVA_{PL} = \sqrt{P_{in,PL}^2 + KVAR_{PL,2}^2}$$

$$= \sqrt{38.89^2 + 2.649^2}$$

$$= 38.98 \text{ KVA}$$

then,

$$\cos \phi_{PL} = \frac{P}{S} = \frac{38.89}{38.98} = 0.998 \text{ (leading)}$$

KVAR drawn from mains at no load
with capacitors

$$\begin{aligned} KVAR_{NL,2} &= 10.75 - 21.484 \\ &= -10.734 \text{ KVAR (leading)} \end{aligned}$$

$$\begin{aligned} KVA_{NL} &= \sqrt{1.08^2 + 10.734^2} \\ &= 10.79 \text{ KVA} \end{aligned}$$

then,

$$\cos \phi_{NL} = \frac{1.08}{10.79} = 0.1 \text{ (leading)}$$

Monthly cost of electricity for No-Load Operation

Assuming 30 day month

then,

$$\text{total hours} = 30 \times 24 = 720 \text{ h}$$

$$\begin{aligned} \text{Operating time at NL} &= 0.8 \times 720 \\ &= 576 \text{ hr} \end{aligned}$$

a) Energy charge

$$\text{Energy} = P_{NL} \times 576$$

$$= 1.08 \times 576$$

$$= 622.08 \text{ kWh}$$

Then,

$$\begin{aligned} \text{Energy Cost} &= 622.08 \times 0.50 \\ &= \text{Rs. } 311.04 \end{aligned}$$

b) Max^m demand (kVA) Change

With the capacitor connected,

$$\text{kVA}_{NL} = 10.79 \text{ kVA}$$

So,

$$\begin{aligned} \text{Cost(demand)} &= 10.79 \times 200 \\ &= \text{Rs. } 2158 \end{aligned}$$

then,

$$\begin{aligned} \text{Total monthly cost} &= 2158 + 311.04 \\ &= \text{Rs. } 2469.04 \end{aligned}$$

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given,

Factory load, $P_1 = 200 \text{ kW}$

$$\cos \phi_1 = 0.85 \quad \tan \phi_1 = 0.62$$

$$\cos \phi_2 = 0.9 \quad \tan \phi_2 = 0.4843$$

Suppose the leading kVAR taken by the capacitor is π .

$$\therefore \text{Capacitor loss} = \frac{100 \times \pi}{1000}$$

$$= 0.1 \pi \text{ kW}$$

then,

$$\text{Total power, } P_2 = (200 + 0.1 \pi) \text{ kW}$$

Now,

Leading kVAR taken by the capacitor is

$$\pi = P_1 \tan \phi_1 - P_2 \tan \phi_2$$

$$\text{or, } \pi = 200 \times 0.62 - (200 + 0.1 \pi) \times 0.4843$$

$$\text{or, } \pi = 124 - 96.86 - 0.04843 \pi$$

$$\text{or, } \pi = 27.14 - 0.04843 \pi$$

$$\text{or, } 1.04843 \pi = 27.14$$

$$\therefore \pi = 25.886 \text{ kVAR}$$

2) Annual cost before pf improvement,

$$\text{Max. kVA demand} = \frac{200}{0.85} = 235.29 \text{ kVA}$$

$$\begin{aligned} \text{kVA demand charges} &= \text{Rs. } 150 \times 235.29 \\ &= \text{Rs. } 35,293.5 \end{aligned}$$

$$\begin{aligned} \text{units consumed / year} &= 200 \times 2500 \\ &= 5,00,000 \text{ kWh} \end{aligned}$$

$$\begin{aligned} \text{Energy charges} &= 5,00,000 \times 0.05 \\ &= \text{Rs. } 25,000 \end{aligned}$$

then,

$$\begin{aligned} \text{Total annual cost} &= 35,293.5 + 25,000 \\ &= \text{Rs. } 60,293.5 \end{aligned}$$

3) Annual cost after pf improvement,

$$\text{Max kVA demand} = \frac{200}{0.9} = 222.22 \text{ kVA}$$

$$\begin{aligned} \text{kVA demand charges} &= \text{Rs. } 222.22 \times 150 \\ &= \text{Rs. } 33,330 \end{aligned}$$

$$\text{Energy charges} = \text{Rs. } 25,000$$

then,

Annual interest and depreciation,

$$= \text{Rs. } 420 \times 25.89 \times 0.1$$

$$= \text{Rs. } 1087.38$$

Annual energy loss in capacitors

$$= 0.1 \times 2500$$

$$= 0.1 \times 25.89 \times 2500$$

$$= 6472.5 \text{ kWh}$$

Annual cost of losses occurring in capacitors,

$$= \text{Rs. } 0.05 \times 6472.5$$

$$= \text{Rs. } 323.625$$

Therefore, total annual cost

$$= \text{Rs. } (33,330 + 1087.38 + 25,000 + 323)$$

$$= \text{Rs. } 59,740.38$$

Then,

$$\text{Annual saving} = 60,293.5 - 59,740.38$$

$$= \text{Rs. } 553.12$$

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Given,

Load, $S = 1200 \text{ kVA}$ @ 0.75 lagging pf

$$\begin{aligned} \text{KW} &= 1200 \times 0.75 \\ &= 900 \text{ KW} \end{aligned}$$

Annual cost before p.f. correction,

$$\begin{aligned} \text{Max}^m \text{ demand charges} &= \text{Rs. } 5000 \times 1200 \\ &= \text{Rs. } 60,00,000 \end{aligned}$$

$$\begin{aligned} \text{Energy charges / year} &= \text{Rs. } \frac{5}{0.75} \times 3000 \times 900 \\ &= \text{Rs. } \frac{20,25,000}{1,35,00,000} \end{aligned}$$

Then,

$$\begin{aligned} \text{Total annual cost} &= \text{Rs. } (60,00,000 + \frac{20,25,000}{1,35,00,000}) \\ &= \text{Rs. } \frac{80,25,000}{1,95,00,000} \end{aligned}$$

Given,

$$\cos \phi_1 = 0.75$$

$$\tan \phi_1 = 0.88$$

$$\cos \phi_2 = 0.95$$

$$\tan \phi_2 = 0.33$$

Now,

Leading kVAR taken by the capacitors,

$$= P (\tan \phi_1 - \tan \phi_2)$$

$$= 900 [0.88 - 0.33] = \underline{\underline{495 \text{ kVAR}}}$$

Annual cost after pf correction,

$$\text{Max}^m \text{ kVA demand} = \frac{900}{0.95}$$

$$= 947.37 \text{ kVA}$$

Then,

$$\text{kVA demand charges} = \text{Rs. } 5000 \times 947.37$$

$$= \text{Rs. } 47,36,850$$

$$\text{Energy charges} = \text{Rs. } 20,25,000$$

$$11,35,00,000$$

$$\text{Capacitor charge} = \text{Rs. } 495 \times 8,000$$

$$= \text{Rs. } 39,60,000$$

Interest and depreciation

$$= \text{Rs. } 0.1 \times 39,60,000$$

$$= \text{Rs. } 3,96,000$$

$$\text{Total annual cost} = \text{Rs. } (11,35,00,000 + 47,36,850 + 3,96,000)$$

$$= \text{Rs. } 11,86,32,850$$

Then,

$$\text{Annual saving} = \text{Rs. } (1,86,32,850 - 1,95,00,000)$$

$$= \text{Rs. } (1,95,00,000 - 1,86,32,850)$$

$$= \text{Rs. } 8,67,150$$

2070 Asadh98

Given,

800 kW @ 0.8 lagging

Then,

$$\text{kVA} = \frac{800}{0.8}$$

$$= 1000 \text{ kVA}$$

given,

$$\cos \phi_1 = 0.8$$

$$\tan \phi_1 = \tan [\cos^{-1} 0.8]$$

$$= 0.75$$

Then,

⇒ Annual costs before pf correction,

$$\text{Max}^m \text{ demand charges} = \text{Rs. } 100 \times 1000$$

$$= \text{Rs. } 1,00,000$$

$$\text{Energy charges / year} = 0.2 \times 800 \times 3000 \\ = \text{Rs. } 4,80,000$$

$$\text{Total annual cost} = \text{Rs. } (1,00,000 + 4,80,000)$$

$$= \text{Rs. } 5,80,000$$

also,

$$\cos \phi_2 = 0.9$$

$$\tan \phi_2 = \tan [\cos^{-1} 0.9] = 0.484$$

Then,

Leading kVAR taken by capacitors,

$$= P (\tan \phi_1 - \tan \phi_2)$$

$$= 800 (0.75 - 0.484)$$

$$= 212.8 \text{ kVAR}$$

=) Annual cost after pf correction,

$$\Rightarrow \text{Max}^m \text{ kVA demand} = \frac{800}{0.9}$$

$$= 888.89 \text{ kVA}$$

$$\text{Max}^m \text{ demand charges} = 100 \times 888.89$$

$$= \text{Rs. } 88,889$$

$$\text{Energy charges} = \text{Rs. } 4,80,000$$

$$\begin{aligned} \text{Capital cost of capacitors} &= 212.9 \times 60 \\ &= \text{Rs. } 12,768 \end{aligned}$$

$$\text{Annual Interest and depreciation}$$

$$\begin{aligned} &= 0.1 \times 12,768 \\ &= 1276.8 \end{aligned}$$

$$\begin{aligned} \text{Then, Total annual cost} &= 88,889 + 4,80,000 \\ &\quad + 1,276.8 \end{aligned}$$

$$= \text{Rs. } 5,70,165.8$$

Then,

$$\begin{aligned} \text{Annual saving} &= 5,90,000 - 5,70,165.8 \\ &= \text{Rs. } 9,834.2 \text{ per annum} \end{aligned}$$

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2081 Baisakh
2080 Baisakh

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given,

Energy consumed / year = 50,000 kWh

Max^m kVA demand = 400 kVAAnnual cost of supply = Max^m demand charges
+ Energy charges

$$= \text{Rs} (120 \times 400 + 50,000 \times 5.50)$$

$$= \text{Rs. } 3,23,000$$

$$\cos \phi_1 = 0.7 \quad \phi_1 = \cos^{-1} 0.7 = 45.573^\circ$$

$$\cos \phi_2 = 0.9 \quad \phi_2 = \cos^{-1} 0.9 = 25.842^\circ$$

Now,

Max. kW demand at 0.7 p.f.,

$$P = 0.7 \times 400 \\ = 280 \text{ kW}$$

then,

Leading kVAR taken by phase advancing
equipment,

$$= P (\tan \phi_1 - \tan \phi_2)$$

$$= 280 (\tan 45.573 - \tan 25.842)$$

$$= 150.047 \text{ kVA}$$

Annual cost of phase advancing equipment

$$= 0.1 \times 150.047 \times 1000$$

$$= \text{Rs. } 15,004.7$$

2) After pf improvement,

$$\text{New max}^m \text{ kVA demand} = \frac{280}{0.9}$$

$$= 311.11 \text{ kVA}$$

Now,

$$\begin{aligned} \text{2) Reduction in Max}^m \text{ demand} &= 400 - 311.11 \\ &= 88.89 \text{ kVA} \end{aligned}$$

$$\text{Annual saving in kVA} = 88.89 \times 120$$

$$= \text{Rs. } 10,666.8$$

As the units consumed remain the same, therefore, saving will be equal to saving in MD charges minus annual cost of phase advancing plant.

Then,

$$\begin{aligned} \text{Net annual saving} &= \text{Saving in demand charges} \\ &\quad - \text{Annual additional cost of device} \end{aligned}$$

$$= 10,668.8 - 15,004.7$$

$$= -4,337.9$$

thus, instead of saving, there is an annual loss of,

approx. Rs. 4,338 per annum

2019 Bhadra

2019 given,

IM of 35 kW

Motor A

Motor B

$$\eta = 85\%$$

$$\eta = 90\%$$

$$pf = 0.9$$

$$pf = 0.8$$

pf of motor B $\Rightarrow$ 0.85 (using condensers)

motor

A

motor

B

$$= Rs. 1500$$

$$\text{condenser} = Rs. 400 / \text{kVAR}$$

interest and depreciation = 10%

working hours per annum = 3000 hrs

Now,

⇒ For Motor A,

$$P_{in, A} = 35 \text{ kW}$$

$$0.85$$

$$= 41.176 \text{ kW}$$

then,

$$\text{Max}^m \text{ KVA of motor A} = \frac{41.176}{0.9}$$

$$= 45.751 \text{ KVA}$$

$$\text{Annual energy consumption} = P_{in, A} \times \text{working hours}$$

$$= 41.176 \times 3000$$

$$= 123,528 \text{ kWh}$$

Annual energy charge

$$= 1,23,528 \times 8$$

$$= \text{Rs. } 9,88,224$$

Annual max^m demand charge

$$= 45.751 \times 250$$

$$= \text{Rs. } 11,437.75$$

Hence,
annual
total cost of running motor A,

$$C_A = 9,88,224 + 11,437.75$$

$$= \text{Rs. } 9,99,661.75 / \text{year}$$

→ For Motor B,

$$P_{in, B} = \frac{35}{0.9}$$

$$= 38.89 \text{ kW}$$

Then,

Max^m KVA demand,

$$KVA_B = \frac{38.89}{0.8}$$

$$= 48.613 \text{ KVA}$$

$$\text{Annual energy consmp}^n = P_{in, B} \times \text{Working hours}$$

We have,

$$\cos \phi_1 = 0.8, \tan \phi_1 = 0.75$$

$$\cos \phi_2 = 0.85, \tan \phi_2 = 0.6197$$

Then,

$$\begin{aligned} Q_c &= P [\tan \phi_1 - \tan \phi_2] \\ &= 98.89 [0.75 - 0.6197] \\ &= 5.07 \text{ KVAR} \end{aligned}$$

Now,

$$\begin{aligned} \text{Condenser cost} &= 5.07 \times 400 \\ &= \text{Rs. } 2028 \end{aligned}$$

$$\begin{aligned} \text{Annual interest and} \\ \text{depreciation} &= 0.1 \times 2028 \\ &= \text{Rs. } 202.8/\text{year} \end{aligned}$$

Now, After pf improvement

$$\begin{aligned} \text{KVA}_B &= \frac{98.89}{0.85} \\ &= 45.753 \text{ KVA} \end{aligned}$$

Then,

$$\begin{aligned} \text{Annual Max}^m \text{ demand} \\ \text{Charge} &= 45.753 \times 250 \\ &= \text{Rs. } 11,438.25 \end{aligned}$$

Then,

Annual energy consumption,

$$E_B = 38.89 \times 3000 \\ = 116670 \text{ kWh}$$

Annual energy charge

$$= 116670 \times 8 \\ = \text{Rs. } 9,33,360$$

Then,

Total annual operating cost of motor B

$$= \text{Rs. } [9,33,360 + 15,438.25 + 202.8]$$

$$\therefore C_B = \text{Rs. } 9,48,001.05 / \text{year}$$

We have,

$$C_A = 9,99,661.75$$

$$C_B = 9,48,001.05$$

Annual saving in motor B,

$$= \text{Rs. } [9,99,661.75 - 9,48,001.05]$$

$$= \text{Rs. } 51,660.7 / \text{year}$$

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given,

600 kW, 50 Hz, 400 V
3 ϕ

$\text{pf}_1 = 0.8$ (Initial)

$\text{pf}_2 = 0.95$ (Targeted)

using delta connected bank of 2200 V capacitors

i) capacitance of each capacitor = ?

ii) KVA rating of capacitor bank and transformer = ?

iii) Percentage reduction in the line losses = ?

We have,

To improve the pf, we have,

$$\cos \phi_1 = 0.8 \quad \tan \phi_1 = \tan [\cos^{-1} 0.8] = 0.75$$

$$\cos \phi_2 = 0.95 \quad \tan \phi_2 = \tan [\cos^{-1} 0.95] = 0.3287$$

then,

$$Q_c = P [\tan \phi_1 - \tan \phi_2]$$

$$= 600 [0.75 - 0.3287]$$

$$= 252.78 \text{ KVAR}$$

then,

Since, the capacitors are delta connected,
there are three identical capacitors.

Therefore,

$$Q_{\text{each}} = \frac{Q_c}{3}$$

$$= \frac{252.8}{3}$$

$$= 84.267 \text{ KVAR}$$

Now,

For a capacitor,

$$Q = \frac{V^2}{X_c}$$

$$= \frac{V^2}{\frac{1}{\omega C}}$$

$$\text{or, } Q = V^2 \omega C$$

$$\text{or, } C = \frac{Q}{V^2 \times 2\pi f}$$

Since,

capacitors are specified as 2200 V
capacitors,

$$V = 2200V$$

and,

$$f = 50 \text{ Hz}$$

then,

$$C = \frac{84.267 \times 10^3}{2200^2 \times 2\pi \times 50}$$

$$\therefore C = 55.419 \mu F$$

ii) kVAR rating of capacitor bank and transformer,

here,

$$Q_c = 252.8 \text{ kVAR}$$

so,

$$\text{Capacitor bank rating} \approx 253 \text{ kVAR}$$

Transformer kVA rating before improvement,

$$S_1 = \frac{P}{\cos \phi_1}$$

$$= \frac{600}{0.8}$$

$$\therefore S_1 = 750 \text{ kVA}$$

Transformer KVA after improvement,

$$S_2 = \frac{P}{\cos \phi_2}$$

$$= \frac{600}{0.95}$$

$$= 631.58 \text{ KVA}$$

Hence, the transformer loading requirement is reduced from,

$$750 \text{ KVA to } 631.58 \text{ KVA}$$

The reduction in transformer KVA demand is,

$$750 - 631.58 = 118.42 \text{ KVA}$$

$$\therefore \text{Reduction} = 118.42 \text{ KVA}$$

8.50) Percentage reduction in line losses

Here,

Line losses $\propto$ square of line current

$$\text{or } P_L \propto I^2$$

For a constant real power and constant supply voltage,

$$I = \frac{P}{\sqrt{3} V_L \cos \phi}$$

Therefore,

$$I \propto \frac{1}{\cos \phi}$$

Hence,

$$\frac{I_2}{I_1} = \frac{\cos \phi_1}{\cos \phi_2}$$

$$\text{or, } \frac{I_2}{I_1} = \frac{0.8}{0.95}$$

$$\frac{I_2}{I_1} = 0.8421$$

Since,

$$P_L \propto I^2$$

$$\text{or, } \frac{P_{L2}}{P_{L1}} = \left(\frac{I_2}{I_1} \right)^2 = 0.8421^2 = 0.7091$$

Thus, the new line losses are 70.91% of the original losses.

$$\% \text{ reduction} = (1 - 0.7091) \times 100$$

$$= 0.2909$$

$$= 29.09\%$$

$$\therefore \% \text{ red}^n \text{ in line losses} = 29.09\%$$

2019 Barjakh

212 given,

16 hours a day for 300 days

High voltage

Rs. 1 / unit

Rs. 50 / month / KVA_{max}

Low voltage

Rs. 1 / unit

Rs. 60 / month / KVA_{max}

Avg load = 250 kW @ 0.8 pf

Max demand = 300 kW

High voltage equipment cost = Rs. 500 / KVA

losses = 5%

interest and depreciation = 12%

Here,

Annual energy consumption

$$= P_{avg} \times \text{annual operating hours}$$

$$= 250 \times 16 \times 300$$

$$= 12,00,000 \text{ kWh/year}$$

$$\text{Max}^m \text{ kVA demand} = \frac{\text{Max}^m \text{ demand (kW)}}{\text{pf}}$$

$$= \frac{900}{0.8}$$

$$= 375 \text{ kVA}$$

=) For high voltage supply

$$\text{Annual}^{\text{max}^m} \text{ demand charge} = 375 \times 12 \times 50$$

$$= \text{Rs. } 2,25,000$$

Since, the equipment rating is based on max^m demand,

$$\text{Equipment cost} = 375 \times 500$$

$$= \text{Rs. } 1,87,500$$

Annual interest and depreciation

$$= 12\% \times 1,87,500$$

$$= \text{Rs. } 22,500/\text{year}$$

Now,

Energy loss in HV equipment

Useful energy required by the factory:

$$= 12,00,000 \text{ units}$$

Losses = 5% of 12,00,000

$$= 0.05 \times 12,00,000$$

$$= 60,000 \text{ units}$$

Therefore,

energy purchased under HV supply is,

$$E_{HV} = 12,00,000 + 60,000$$

$$= 12,60,000 \text{ units}$$

then,

$$\text{Energy Charge} = 12,60,000 \times 1$$

$$= \text{Rs. } 12,60,000$$

total annual cost for high voltage supply,

$$C_{HV} = \text{Energy charges} + \text{Demand Charges} + \text{Annual equipment charges}$$

$$= 12,80,000 + 2,25,000 + 22,500$$

$$\therefore C_{HV} = \text{Rs. } 15,07,500 / \text{year}$$

⇒ For low voltage supply,

$$\begin{aligned} \text{Annual max}^m \text{ demand charge} &= 375 \times 12 \times 60 \\ &= \text{Rs. } 2,70,000 \end{aligned}$$

~~$$\text{then, Equipment cost} = \text{Rs. } 1,87,500$$~~

Annual energy charges for LV supply

$$= 12,00,000 \times 1.1$$

$$= \text{Rs. } 13,20,000$$

Then, total annual cost for Low Voltage Supply

$$C_{LV} = 13,20,000 + 2,70,000$$

$$= \text{Rs. } 15,90,000 / \text{year}$$

Then, Difference in annual cost,

$$= C_{LV} - C_{HV}$$

$$= 15,90,000 - 15,07,500$$

$$= \text{Rs. } 82,500 / \text{year}$$

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2028 Bhadra

given,

$$850 \text{ kW}, 50 \text{ Hz}$$

$$\cos \phi_1 = 0.8$$

$$\cos \phi_2 = 0.95$$

then,

$$Q_c = P [\tan \phi_1 - \tan \phi_2]$$

$$= 850 \left[\tan [\cos^{-1} 0.8] - \right.$$

$$\left. \tan [\cos^{-1} 0.95] \right]$$

$$= 358.1185 \text{ KVAR}$$

i.e. KVAR rating of capacitor = 358.1185 KVAR

Now,

$$Q_c = \frac{V^2}{X_c} = V^2 \omega C$$

$$\text{or, } C = \frac{V^2}{Q_c \times \omega}$$

$$\text{or, } C = \frac{Q_c}{V^2 \times 2\pi f}$$

$$= \frac{358.1185 \times 10^3}{2200^2 \times 2\pi \times 50}$$

$$= 2.35 \mu F \quad 235.5 \mu F$$

then, since the capacitors are delta connected,

$$\text{Capacitance of each capacitor} = \frac{2.35}{3} = \frac{235.5}{3}$$

$$= 78.5 \mu F$$

$$= 78.5 \mu F$$

then,

Transformer KVA rating before improvement,

$$S_1 = \frac{850}{0.8} = 1062.5 \text{ KVA}$$

Transformer KVA rating after improvement,

$$S_2 = \frac{850}{0.95} = 894.737 \text{ KVA}$$

Hence, the transformer loading requirement is improved from,

$$1062.5 \text{ KVA to } 894.737 \text{ KVA}$$

Reduction in KVA demand

$$\begin{aligned} &= 1062.5 - 894.737 \\ &= 167.763 \text{ KVA} \end{aligned}$$

For the same power factor improvement, the capacitor bank must supply the same reactive power Q_c .

For a delta-connected capacitor bank,

$$\Phi_c = 3\omega CV^2$$

Since Φ_c , frequency and number of phases are the same,

$$CV^2 = \text{constant}$$

Therefore,

$$C \propto \frac{1}{V^2}$$

Hence,

$$\frac{C_{2200}}{C_{400}} = \left(\frac{400}{2200} \right)^2$$

$$\text{or, } \frac{C_{2200}}{C_{400}} = \left(\frac{2}{11} \right)^2$$

$\therefore$

$$\frac{C_{2200}}{C_{400}} = \frac{4}{121}$$

~~$$\begin{aligned} \text{Then, } C_{400} &= \frac{121}{4} \times C_{2200} \\ &= \frac{121}{4} \times \end{aligned}$$~~

$$\therefore C_{2200} : C_{400} = 4 : 121$$

given formula,

$$\text{Annual op-working cost} = \text{Rs} \left(a + b \times \text{kwh} + c \times \text{kwh} \right)$$

$$a = ? ; b = ? ; c = ?$$

We have,

60 MW station,

annual load factor = 50%

Capital cost of building and equipment = Rs. 5×10^6

Annual cost of fuel, oil, taxation and wages of operating staff = Rs. 9,00,000

Interest and depreciation = 10% p.a

Annual cost of organization and interest on cost of site

= Rs. 5,00,000

Determine a
given,

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Annual cost of organization and
interest on cost of site = Rs. 5,00,000

So, $a = \text{Rs. } 5,00,000 \text{ / year}$

Here,

Annual interest and depreciation = $10\% \times 50,00,000$

Determine b

= Rs. 5,00,000

This cost corresponds to,

$b \times 60 \text{ MW} = 5,00,000$

or, $b \times 60,000 = 5,00,000$

or, $b = \frac{5,00,000}{60,000}$

$\therefore b = \text{Rs. } 8.33 \text{ per kW per year}$

Now,

The annual load factor is:

$$LF = \frac{\text{Avg. load}}{\text{Max}^m \text{ load}}$$

Assuming,

max^m load equals the station capacity,

$$\text{Max}^m \text{ load} = 60,000 \text{ kW}$$

Hence,

$$\text{Avg. load} = \text{LP} \times \text{Max}^m \text{ load}$$

$$= 0.5 \times 60,000$$

$$= 30,000 \text{ kW}$$

The number of hours in one year is,

$$= 365 \times 24$$

$$= 8,760 \text{ hours}$$

Therefore,

annual energy generated,

$$E = 30,000 \times 8,760$$

$$= 26,28,00,000 \text{ kWh}$$

Determine c

given,

the annual cost of fuel, oil, taxation and operating wages = Rs. 9,00,000

This is considered as the energy dependent or running cost, represented by,

$$c \times \text{kWh}$$

thus,

$$c \times 26,28,00,000 = 9,00,000$$

Hence, $\therefore c = 0.00342 \text{ per kWh}$

We have

$$\text{Annual working cost} = a + b(\text{kW}) + c(\text{kWh})$$

where,

$$a = \text{Rs. } 5,00,000 \text{ per annum}$$

$$b = \text{Rs. } 8.33 \text{ per kW per annum}$$

$$c = \text{Rs. } 0.00342 \text{ per kWh}$$

So, the annual working cost

$$= 5,00,000 + 8.33(\text{kW}) + 0.00342(\text{kWh})$$

(in rupees)

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given,

2 shifts (8 hours/shift)

$$= 2 \times 8$$

$$= 16 \text{ hours/day}$$

$$\begin{aligned} \text{Total hours in a year} &= 16 \times 285 \\ &= 4,560 \text{ hours} \end{aligned}$$

Medium voltage supply

$$\text{Rs. } 12 / \text{unit}$$

$$\text{Rs. } 1300 / \text{month} / \text{kVA}_{\text{max}}$$

Low voltage supply

$$\text{Rs. } 13 / \text{unit}$$

$$\text{Rs. } 650 / \text{month} / \text{kVA}_{\text{max}}$$

$$\text{Avg load} = 250 \text{ kW @ } 0.8 \text{ pf}$$

$$\text{Maximum demand} = 300 \text{ kW @ } 0.8 \text{ pf}$$

$$\text{High voltage equipment costs} = \text{Rs. } 700 / \text{kVA}$$

$$\text{Losses} = 5\%$$

$$\text{Interest and depreciation} = 10\%$$

Then,

$$\begin{aligned}\text{Total Energy Consumption} &= 250 \times 4,560 \\ &= 11,40,000 \text{ units}\end{aligned}$$

$$\text{KVA}_{\text{max}} = \frac{300}{0.8}$$

$$= 375 \text{ KVA}$$

=) For medium voltage supply

$$\begin{aligned}\text{Annual max}^m \text{ demand charge} &= 375 \times 12 \times 1300 \\ &= \text{Rs. } 58,50,000\end{aligned}$$

$$\begin{aligned}\text{Equipment cost} &= 375 \times 700 \\ &= \text{Rs. } 2,62,500\end{aligned}$$

$$\begin{aligned}\text{Annual interest} &= 10\% \text{ of } 2,62,500 \\ &= 0.1 \times 2,62,500 \\ &= \text{Rs. } 26,250 / \text{year}\end{aligned}$$

$$\text{Useful energy required} = 11,40,000 \text{ units}$$

$$\begin{aligned}\text{Losses} &= 0.05 \times 11,40,000 \\ &= 5,70,000 \text{ units}\end{aligned}$$

Now,

Energy purchased under high voltage supply,

$$E_{HV} = 11,40,000 + 5,70,000 - 57,000$$

$$= 11,97,000 \text{ units}$$

then,

$$\text{Energy charge} = 11,97,000 \times 12$$

$$= \text{Rs. } 1,43,64,000$$

So,

Total annual charge for high voltage supply,

$$C_{HV} = 1,43,64,000 + 26,250 + 58,50,000$$

$$= \text{Rs. } 20,34,9250$$

⇒ For low voltage supply,

$$\text{Annual max}^m \text{ demand charge} = 375 \times 12 \times 650$$

$$= \text{Rs. } 29,25,000$$

Annual energy charge for LV supply

$$= 11,40,000 \times 13$$

$$= \text{Rs. } 1,48,20,000$$

Then,

$$C_{LV} = \text{Rs. } (29,25,000 + 1,48,20,000)$$

$$= \text{Rs. } 1,77,45,000$$

Then,

Difference in annual cost

$$= \text{Rs. } (2,02,40,250 - 1,77,45,000)$$

$$= \text{Rs. } \cancel{2,49,} 24,95,250$$

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given,

340 kW, 50 Hz, 3 ϕ star connected IM

$$\eta = 85\%$$

$$pf_1 = 0.84$$

$$pf_2 = 0.96$$

Here,

$$P_{in} = \frac{P_{out}}{\eta}$$

$$= \frac{340}{0.85}$$

$$= 400 \text{ kW}$$

Here,

$$\cos \phi_1 = 0.85, \quad \tan \phi_1 = \tan [\cos^{-1} 0.85]$$

$$\cos \phi_2 = 0.96$$

$$= \cancel{0.6197} 0.2917$$

$$\tan \phi_2 = \tan [\cos^{-1} 0.96]$$

$$= 0.2917$$

ii)

Then,

$$Q_c = P [\tan \phi_1 - \tan \phi_2]$$

$$= 400 [\cancel{0.6197} - 0.2917]$$

iii)

$$= 183.32 \text{ KVAR}$$

We have,

For a three phase delta connected capacitor bank,

$$Q_c = 3 V_L^2 \omega C$$

where,

$$\omega = 2\pi f$$

then,

$$C = \frac{Q_c}{3V_L^2 \omega}$$

given,

$$V_L = 3300 \text{ V}$$

so,

$$C = \frac{189.32 \times 10^3}{3 \times 3300^2 \times 2\pi \times 50}$$

$$= 17.86 \times 10^{-6} \text{ F}$$

$$\therefore C = 17.86 \mu\text{F}$$

thus, the capacitance required in each limb of the delta connected capacitor bank is,

$$17.86 \mu\text{F}$$

000)
000)

We have,

$$C_{\text{limb}} = 17.86 \mu\text{F}$$

since, six capacitors are used to form one limb,

for six similar capacitors connected in parallel,

$$C_{\text{limb}} = 6 C_{\text{each}}$$

therefore,

$$C_{\text{each}} = \frac{C_{\text{limb}}}{6}$$

$$C_{\text{each}} = \frac{17.86}{6}$$

$$\therefore C_{\text{each}} = 2.9774\text{P}$$