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2-16

$$D_g = \frac{\left(\sum_{i=1}^{12} TCD_i\right) \times DF_i}{F_D} = \frac{\sum_{i=1}^{12} (20 \text{ kW} \times 0.6)}{1.15} = \frac{12 \times 20 \times 0.6}{1.15} = 125.2 \text{ kW}$$

2-17 (a)

$$\text{Annual } P_{avg} = \frac{100{,}000{,}000 \text{ kWh/yr}}{8760 \text{ h/yr}} = 11{,}415{,}5 \text{ kW}$$

or

$$\text{Monthly energy} = \frac{100{,}000{,}000 \text{ kWh/yr}}{12 \text{ mos/yr}} = 8{,}333{,}333.3 \text{ kWh}$$

$$\text{Avg. monthly demand} = \frac{8{,}333{,}333.3 \text{ kWh}}{730 \text{ h/mo}} = 11{,}415.5 \text{ kW}$$

$$F_{LD} = \frac{\text{Ann. avg. load}}{\text{Peak monthly demand}}$$

(b) $$\text{Max. monthly demand} = \frac{\text{Ann. avg. load}}{F_{LD}} = \frac{11{,}415.5 \text{ kW}}{0.6} \cong 19{,}026 \text{ kW}$$

Note that, max means peak here.

2-18 (a)

$$D_{FD} = \frac{900 + 1000 + 2100 + 2000}{D_g} = 1.25 \Rightarrow D_g = \frac{6{,}000}{1.25} = 4{,}800 \text{ kW} = P$$

$PF_1 = \cos\theta_1 = 0.85 \Rightarrow \theta_1 = 31.79^\circ$

$PF_2 = \cos\theta_2 = 0.9 \Rightarrow \theta_2 = 25.84^\circ$

$PF_3 = \cos\theta_3 = 0.95 \Rightarrow \theta_3 = 18.2^\circ$

$PF_4 = \cos\theta_4 = 0.9 \Rightarrow \theta_4 = 25.84^\circ$

$$Q = \frac{\sum_{i=1}^{4} P_i \times \tan\theta_i}{F_D} = \frac{900\tan 31.79^\circ + 1000\tan 25.84^\circ + 2100\tan 18.2^\circ + 2000\tan 25.84^\circ}{1.25}$$

$$= \frac{2{,}701.09}{1.25} \cong 2{,}160.87 \text{ kvar}$$

$$S = \left(P^2 + Q^2\right)^{1/2} = \left(4800^2 + 2{,}160.87^2\right)^{1/2} \cong 5{,}264 \text{ kVA which is also } D_g \text{ in kVA}$$

(b) $$LD = \sum_{i=1}^{4} D_i - D_g = 6000 - 4{,}800 = 1{,}200 \text{ kW}$$

(*c*) Since $(4687 \text{ kVA})1.25 = 5{,}858.75 \text{ kVA} > 5{,}264 \text{ kVA}$

choose 3750/4687 kVA transformer.

$(d)\quad (1+g)^{10} = 2 \Rightarrow (1+g) = \sqrt[10]{2} = 1.07177 \Rightarrow g = 7.177\ \%/\text{yr}$

Thus, $(1.07177)^n \times 5{,}264 = 9375\ \text{kVA} \Rightarrow 1.07177^n = 1.7810$

$$n = \frac{\ln 1.7810}{\ln 1.07177} \cong 8.33 \text{ yrs that is about 8 years and 4 months.}$$

2-19 (a) As shown in Figure 2-9,

$$F_{LD} = \frac{P_{avg}}{P_{max}} = \frac{P_{avg}}{P_2} = \frac{P_2 + P_1(T-t)}{T \times P_2} = \frac{t}{T} + \left(\frac{P_1}{P_2}\right)\left(\frac{T-t}{T}\right)$$

$$= \frac{12}{24} + \left(\frac{5\ \text{MW}}{50\ \text{MW}}\right)\left(\frac{24-12}{24}\right) = 0.55$$

(b) $$F_{LS} = \frac{Avg.\,P_{loss}}{Max\ P_{loss}} = \frac{Avg.\,P_{loss}}{P_{L2}} = \frac{(P_{L2})t + P_{L1}(T-t)}{T \times P_{L2}} = \frac{(kP_2)^2 + (kP_1)^2(T-t)}{T \times (kP_2)^2}$$

$$= \frac{t}{T} + \left(\frac{P_1}{P_2}\right)^2\left(\frac{T-t}{T}\right) = \frac{12}{24} + \left(\frac{5\ \text{MW}}{10\ \text{MW}}\right)^2\left(\frac{24-12}{24}\right) = 0.5005$$

2-20 (a) From Figure 2.13,

$$P_{avg,\max} = \begin{cases} 1.9\ \text{kW/house for dryer} \\ 0.95\ \text{kW/house for range} \\ 0.08\ \text{kW/house for refrigerator} \\ 0.65\ \text{kW/house for lighting \& misc.} \end{cases}$$

Thus, 1.9 + 0.95 + 0.08 + 0.65 = 3.58 kW/house

or $(3.58\ \text{kW/house}) \times 4\ \text{houses} = 14.32\ \text{kW/trf}$

(b) For 800 houses, (it's the same as for 100 houses, since that part of the curve is flat),

$$P_{avg,\max} = \begin{cases} 1.2\ \text{kW/house for dryer} \\ 0.53\ \text{kW/house for range} \\ 0.044\ \text{kW/house for refrigerator} \\ 0.52\ \text{kW/house for lighting \& misc.} \end{cases}$$

Thus, 1.2 + 0.53 + 0.044 + 0.52 = 2.294 kW/house

or $(2.294\ \text{kW/house}) \times 800\ \text{houses} = 1835.2\ \text{kW/feeder}$

But,

$(14.32\ \text{kW/trf})(200\ \text{trfs}) = 2{,}804\ \text{kW} > 1835.2\ \text{kW}$ due to the diversity of appliances.

(c) Contributions to the demand:

Time	Dryers, kW	Ranges, kW	Refrigerators, kW	Lighting & Misc., kW	Total hourly diversified demand, kW
6 AM	7.6 × 0 = 0	3.8 × 0.05 = 0.19	0.32 × 0.75 = 0.24	2.6 × 0.19 = 0.50	0.93
12 Noon	7.6 × 0.98 =7.448	3.8 × 0.33 =1.254	0.32 × 0.875 = 0.272	2.6 × 0.28 = 0.728	9.702

7 PM	7.6 × 0.26 = 1.976	3.8 × 0.30 =1.14	0.32 × 0.95 = 0.304	2.6 × 1.00 = 2.6	6.02

where 1.9 × 4 = 7.6
0.95 × 4 = 3.8
0.08 × 4 = 0.32
0.65 × 4 = 2.6

Also note that, the numbers 0, 0.98. and 0.26 in column 2 above are from Table 2.3 on the book.

2-21

(a)

For customer A: $F_{LD} = \dfrac{7000 \text{ kWh}}{40 \text{ kW} \times 730 \text{ h}} = 0.24$

For customer B: $F_{LD} = \dfrac{7000 \text{ kWh}}{40 \text{ kW} \times 730 \text{ h}} = 0.24$

(b) $S_A = \dfrac{P_A}{\text{cus}\,\theta} = \dfrac{40 \text{ kW}}{0.95} = 42.1 \text{ kVA}$

$S_B = \dfrac{P_B}{\text{cus}\,\theta} = \dfrac{40 \text{ kW}}{0.50} = 80 \text{ kVA}$

(c)

For customer A:

Monthly biling demand = $40 \text{ kW} \times \dfrac{0.85}{0.95} = 40 \text{ kW} \leftarrow$ Still 40 kW!

Monthly demand charge = 40 kW × \$15/kW = \$600

Monthly energy charge:

First 1000 kWh = \$0.12/kWh × 1000 kWh = \$120
Next 3000 kWh = \$0.10/kWh × 3000 kWh = \$300
Excess kWh = \$0.06/kWh × 3000 kWh = \$240

Monthly energy charge = \$660

Total monthly bill = monthly demand charge + monthly energy charge
= \$600 + \$660 = \$1,260

For customer B:

Monthly biling demand = $40 \text{ kW} \times \dfrac{0.85}{0.50} = 68 \text{ kW}$

Monthly demand charge = 68 kW × \$15/kW = \$1,020

Monthly energy charge:

First 1000 kWh = \$0.12/kWh × 1000 kWh = \$120
Next 3000 kWh = \$0.10/kWh × 3000 kWh = \$300
Excess kWh = \$0.06/kWh × 3000 kWh = \$240

Monthly energy charge = \$660

Total monthly bill = monthly demand charge + monthly energy charge
= \$1,020 + \$660 = \$1,680

(d) For customer B: $\dfrac{7000\text{ kWh}}{0.50}\times\sin\left(\cos^{-1}0.50\right)=12{,}124.4\text{ kvarh}$

When its PF raised to 0.85:

$\dfrac{7000\text{ kWh}}{0.85}\times\sin\left(\cos^{-1}0.85\right)$ = 4,338 kvarh

The capacitor size required: $\dfrac{12{,}124.4\text{ kvarh} - 4338\text{ kvarh}}{730\text{ h}}\cong 10.7\text{ kvar}$

(e) The new monthly bill for customer B:

Monthly biling demand = 40 kW

Monthly demand charge = 40 kW × \$15/kW = \$600

Monthly energy charge = \$660

Total monthly bill = monthly demand charge + monthly energy charge

= \$600 + \$660 = \$1,260

Savings = \$1,680 – \$1260 = \$420/month

or

Savings = \$1,020 – \$600 = \$420/month ← still!

The cost of the installed caps: \$30/kvar × 10.7kvar = \$321

Payback period $=\dfrac{\text{caps cost}}{\text{savings}}=\dfrac{\$321}{\$420/\text{mo}}$ = 0.76 < 1month

But, in practical size is 15 kvar instead of 7 kvar. Therefore,

\$30/kvar × 15kvar = \$450

Thus, payback period = $\dfrac{\$450}{\$420/\text{mo}}$ = 1.07months

2-22

(a)

(b)