

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)

$$\text{Annual } P_{\text{avg}} = \frac{100,000,000 \text{ kWh/yr}}{8760 \text{ h/yr}} = 11,415.5 \text{ kW}$$

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)

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

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

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

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

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

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

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

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

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

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

choose 3750/4687 kVA transformer.

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

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

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

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

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

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

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

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

2-20 (a) From Figure 2.13,

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

$$\text{Thus, } 1.9 + 0.95 + 0.08 + 0.65 = 3.58 \text{ kW/house}$$

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

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

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

$$\text{Thus, } 1.2 + 0.53 + 0.044 + 0.52 = 2.294 \text{ kW/house}$$

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

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	$7.6 \times 0 = 0$	$3.8 \times 0.05 = 0.19$	$0.32 \times 0.75 = 0.24$	$2.6 \times 0.19 = 0.50$	0.93
12 Noon	$7.6 \times 0.98 = 7.448$	$3.8 \times 0.33 = 1.254$	$0.32 \times 0.875 = 0.272$	$2.6 \times 0.28 = 0.728$	9.702

7 PM	$7.6 \times 0.26 =$ 1.976	3.8×0.30 =1.14	0.32×0.95 = 0.304	2.6×1.00 = 2.6	6.02
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where $1.9 \times 4 = 7.6$
 $0.95 \times 4 = 3.8$
 $0.08 \times 4 = 0.32$
 $0.65 \times 4 = 2.6$

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)

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

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

$$(b) \quad S_A = \frac{P_A}{\cos \theta} = \frac{40 \text{ kW}}{0.95} = 42.1 \text{ kVA}$$

$$S_B = \frac{P_B}{\cos \theta} = \frac{40 \text{ kW}}{0.50} = 80 \text{ kVA}$$

(c)

For customer A:

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

$$\text{Monthly demand charge} = 40 \text{ kW} \times \$15/\text{kW} = \$600$$

Monthly energy charge:

$$\text{First } 1000 \text{ kWh} = \$0.12/\text{kWh} \times 1000 \text{ kWh} = \$120$$

$$\text{Next } 3000 \text{ kWh} = \$0.10/\text{kWh} \times 3000 \text{ kWh} = \$300$$

$$\text{Excess kWh} = \$0.06/\text{kWh} \times 3000 \text{ kWh} = \$240$$

$$\text{Monthly energy charge} = \$660$$

$$\begin{aligned} \text{Total monthly bill} &= \text{monthly demand charge} + \text{monthly energy charge} \\ &= \$600 + \$660 = \$1,260 \end{aligned}$$

For customer B:

$$\text{Monthly billing demand} = 40 \text{ kW} \times \frac{0.85}{0.50} = 68 \text{ kW}$$

$$\text{Monthly demand charge} = 68 \text{ kW} \times \$15/\text{kW} = \$1,020$$

Monthly energy charge:

$$\text{First } 1000 \text{ kWh} = \$0.12/\text{kWh} \times 1000 \text{ kWh} = \$120$$

$$\text{Next } 3000 \text{ kWh} = \$0.10/\text{kWh} \times 3000 \text{ kWh} = \$300$$

$$\text{Excess kWh} = \$0.06/\text{kWh} \times 3000 \text{ kWh} = \$240$$

$$\text{Monthly energy charge} = \$660$$

$$\begin{aligned} \text{Total monthly bill} &= \text{monthly demand charge} + \text{monthly energy charge} \\ &= \$1,020 + \$660 = \$1,680 \end{aligned}$$

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

When its PF raised to 0.85:

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

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

(e) The new monthly bill for customer B:

Monthly billing demand = 40 kW

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

Monthly energy charge = \$660

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

Savings = \$1,680 - \$1,260 = \$420/month

or

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

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

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

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

\$30/kvar \times 15kvar = \$450

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

2-22

(a)

(b)

(c)

2-23

$$(a) \quad F_{LS} = 0.3F_{LD} + 0.7F_{LD}^2 \quad \text{where } F_{LD} = \frac{TW}{P_{\max}} = \frac{9,000 \times 10^6 \text{ Wh}}{(3,000 \times 10^3 \text{ W}) 8760} = 0.3425$$
$$= 0.3(0.3425) + 0.7(0.3425)^2 = 0.1849$$

$$(b) \quad F_{LS} = 0.16F_{LD} + 0.84F_{LD}^2 = 0.16(0.3425) + 0.84(0.3425)^2 = 0.1533$$

(c) For an urban area:

$$F_{LS} = \frac{\text{Avg. } P_{\text{loss}}}{\text{Peak } P_{\text{loss}}} \Rightarrow \text{Avg. } P_{\text{loss}} = F_{LS} \times \text{Peak } P_{\text{loss}} = (0.1849)(300 \text{ kW}) = 55.47 \text{ kW/hr}$$

$$\text{Thus, } \sum \text{Ann. Cu loss} = (55.47 \text{ kW/hr}) 8760 \text{ hr/yr} = 485,917.2 \text{ kWh}$$

$$\text{Cost of } \sum \text{Ann. Cu loss} = (485,917.2 \text{ kWh})(\$0.06/\text{kWh}) = \$29,155.03$$

EXTRA:

$$\text{Cost of } \sum \text{Monthly Cu loss} = \frac{\$29,155.03}{12} \cong \$2,429.6/\text{mo}$$

$$\text{Cost of } \sum \text{Hourly Cu loss} = \frac{\$2,429.6/\text{mo}}{(30 \text{ days/mo})(24 \text{ hrs/day})} \cong \$3.38/\text{hr}$$

(d) For a rural area,

$$\text{Avg. } P_{\text{loss}} = F_{LS} \times \text{Peak } P_{\text{loss}} = (0.1533)300 = 45.99 \text{ kW}$$

Therefore,

$$\sum \text{Ann. Cu loss} = (45.99 \text{ kW})(8760 \text{ hrs/yr}) = 402,872.4 \text{ kWh}$$

$$\text{Cost of } \sum \text{Ann. Cu loss} = (402,872.4 \text{ kWh})(\$0.06/\text{kWh}) = \$24,172.34/\text{yr}$$