Exercises

6.1 Consider the analysis in Example 6.1.

(a) Write all of the six independent equations that are used in this analysis.

(b) Use the measurements in (6.11) and the fact that $V_0 = 1\angle 0^\circ$ to solve the equations in Part (a). You may use `fsolve` in MATLAB [34].

6.2 Again, consider the analysis in Example 6.1. Suppose, we know that $V_{1,\text{base}} = 1$ per unit. Therefore, the only unknown parameter in this system is α.

(a) Suppose the load at bus 2 operates at full load. Estimate the unknown parameter α at bus 1 based on the following per unit measurements:

$$S_0 = 3.502596 + j1.601236, \quad S_2 = 2.5 + j0.6. \tag{6.41}$$

(b) Suppose the load at bus 2 operates at half load. Estimate the unknown parameter α at bus 1 based on the following per unit measurements:

$$S_0 = 2.250666 + j1.300281, \quad S_2 = 1.25 + j0.3. \tag{6.42}$$

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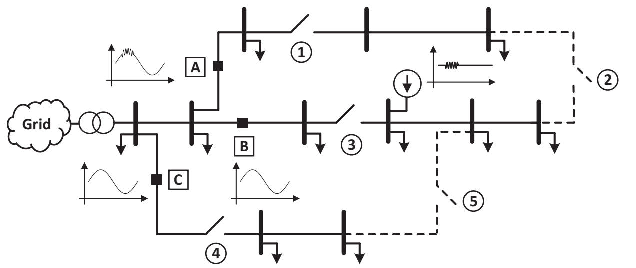

Figure 6.18 The power distribution network that is considered in Exercise 6.5.

(c) Explain how the combination of the results in Parts (a) and (b) can provide redundancy in estimating parameter α.

6.3 File `E6-3.csv` contains the current and voltage measurements corresponding to the probing experience in Figure 6.2.

(a) Calculate how much the current decreases and how much the voltage decreases every time that the generation is curtailed at the PV unit.

(b) Calculate how much the current increases and how much the voltage increases every time that the generation is resumed at the PV unit.

(c) Present the results in Parts (a) and (b) in a scatter plot where the x-axis is the change in current and the y-axis is the change in voltage.

6.4 File `E6-4.csv` contains the current waveform measurements at four signal discriminators on the same distribution feeder. A signal generator generates a probing signal at a frequency of 1.2 kHz for a short period of time.

(a) Which one of the signal discriminators detects the probing signal?

(b) What is the time duration of the probing signal?

6.5 Consider the power distribution network in Figure 6.18. The network has five switches. Switches ①, ③, and ④ are the normally closed switches. Switches ② and ⑤ are the normally open switches. One probing signal generator device is installed on this network to generate high frequency probing signals, as shown with a current source in the figure. The probing signal *is* detected by signal discriminator A. The probing signal is *not* detected by signal discriminators B and C. What are the possible radial topology configurations in this network based on the probing results?

6.6 Again, consider the probing experiment in Exercise 6.3.

(a) Use the available voltage and current measurements to obtain a first-order approximation for the relationship between voltage and current. In other words, express voltage as a linear function of current at the PV unit:

$$V = a + bI, \tag{6.43}$$

where a and b are unknown parameters that need to be estimated. Parameters a and b can be estimated by using a least square optimization based on the collection of the points that we plotted in Part (c) in Exercise 6.3.

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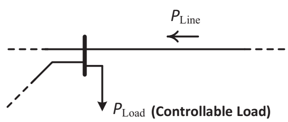

Controllable Load P_{Load} (p.u.)	Line Power Flow P_{Line} (p.u.)
3.5	1.2193
4.0	1.3491
4.5	1.4808

Figure 6.19 The partial transmission network and the measurements in Exercise 6.8.

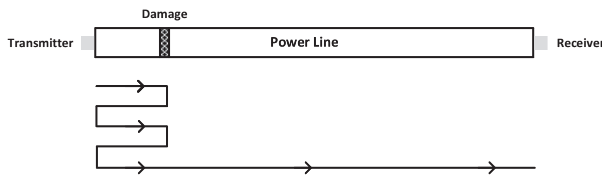

Figure 6.20 Reflections of the PLC signal in a damaged power cable in Exercise 6.9.

(b) Use the results in Part (a) to indicate the current level at the PV unit that is required in order to regulate the voltage at 290 V.

6.7 File `E6-7.csv` contains the damping oscillations in voltage measurements at a transmission line that result from two subsequent probing experiments. Obtain the dominant modes of oscillation in each case. You can use Prony analysis that we learned in Section 2.6.3 in Chapter 2. Set $m = 101$.

6.8 Figure 6.19 shows a portion of a power transmission network. It contains a bus and three transmission lines. The load at this bus is controllable; thus, it can serve as a probing device. The controllable load is set to three different levels; and at each level the power flow on one of the transmission lines is measured accordingly. The measurements are shown in the figure.

(a) Express P_{Line} as a linear function of P_{Load}.

(b) Use the results in Part (a) to set P_{Load} such that $P_{\text{Line}} = 1.3$ per unit.

6.9 Consider the damaged power line cable in Figure 6.20.

(a) Explain the reflections of the PLC signal that are shown in this figure.

(b) What is the distance traveled by the PLC signal? Is it a multiple of L plus a positive or a negative multiple of $2l$? Elaborate your answer.

6.10 Consider the damaged power line cable in Figure 6.21. The length of the cable is 1000 m. The location of the damage is 150 m from the PLC modem on the *receiver* side. Thus, the damage is closer to the *receiver* side.

(a) Repeat the analysis in Example 6.6 and draw the signal path for five different examples of the reflected PLC signals, in a way similar to Figure 6.14.

(b) Indicate the distance that the communication wave travels in each case in Part (a). Compare the results with the distances that are listed in (6.32).

(c) What conclusions can you make about the possible location of the fault? Express your conclusions in comparison with the results in Example 6.6.

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Figure 6.21 The damaged power cable in Exercise 6.10.

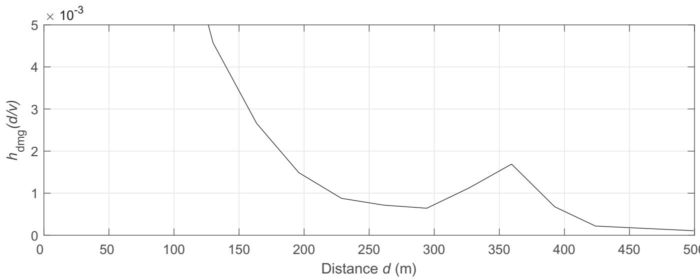

Figure 6.22 The damage impulse response of the power line cable in Exercise 6.11.

6.11 Figure 6.22 shows the damage impulse response of a damaged power line cable that is estimated by the PLC modem on the receiver side. The length of the cable is 1000 m. What is the distance of the location of the damage on the cable from the PLC modem on the *transmitter* side?

6.12 Consider a power distribution system with six buses. Bus 1 is the substation. The network topology is unknown but radial. There is one PLC device at each bus. The network is fully connected, and all PLC devices can talk to each other. The symmetric matrix of the TOF measurements is obtained as

$$\tau = \begin{bmatrix} 0 & 13.30 & 13.24 & 4.55 & 10.19 & 7.94 \\ 13.30 & 0 & 10.66 & 8.75 & 7.61 & 5.36 \\ 13.24 & 10.66 & 0 & 8.69 & 3.05 & 5.30 \\ 4.55 & 8.75 & 8.69 & 0 & 5.64 & 3.39 \\ 10.19 & 7.61 & 3.05 & 5.64 & 0 & 2.25 \\ 7.94 & 5.36 & 5.30 & 3.39 & 2.25 & 0 \end{bmatrix}. \tag{6.44}$$

Identify the topology of this power distribution network.

6.13 Repeat Exercise 6.12 for the matrix of TOF measurements that is provided in file `E6-13.csv`. The network has 10 buses. Bus 1 is the substation.

6.14 Suppose the TOF measurements are obtained separately on each phase of a three-phase power distribution system as follows:

$$\tau^{\text{Phase A}} = \begin{bmatrix} 0 & 13.30 & 0 & 4.55 & 0 & 7.94 \\ 13.30 & 0 & 0 & 8.76 & 0 & 5.36 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 4.55 & 8.76 & 0 & 0 & 0 & 3.39 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 7.94 & 5.36 & 0 & 3.39 & 0 & 0 \end{bmatrix}, \tag{6.45}$$

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$$\tau^{\text{Phase B}} = \begin{bmatrix} 0 & 0 & 13.24 & 4.55 & 10.19 & 7.94 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 13.24 & 0 & 0 & 8.69 & 3.05 & 5.30 \\ 4.55 & 0 & 8.69 & 0 & 5.64 & 3.39 \\ 10.19 & 0 & 3.05 & 5.64 & 0 & 2.24 \\ 7.94 & 0 & 5.30 & 3.39 & 2.24 & 0 \end{bmatrix}, \tag{6.46}$$

$$\tau^{\text{Phase C}} = \begin{bmatrix} 0 & 0 & 0 & 4.55 & 0 & 7.94 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 4.55 & 0 & 0 & 0 & 0 & 3.39 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 7.94 & 0 & 0 & 3.39 & 0 & 0 \end{bmatrix}. \tag{6.47}$$

Identify which buses are on Phase A, Phase B, and Phase C.

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