6.5 Problems

6.1 Consider the power system shown in Figure P6.1. Assuming that the only limitations imposed by the network are imposed by the thermal capacity of the transmission lines and that the reactive power flows are negligible, check that the following sets of transactions are simultaneously feasible.

	Seller	Buyer	Amount
Set 1	B	X	200
	A	Z	400
	C	Y	300
Set 2	B	Z	600
	A	X	300
	A	Y	200
	A	Z	200
Set 3	C	X	1000
	X	Y	400
	B	C	300
	A	C	200
	A	Z	100

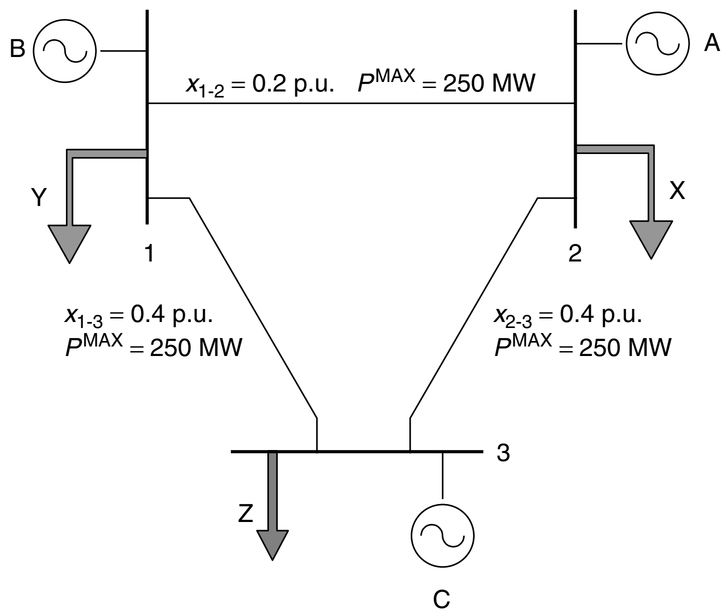

Figure P6.1 Three-bus power system for Problem 6.1

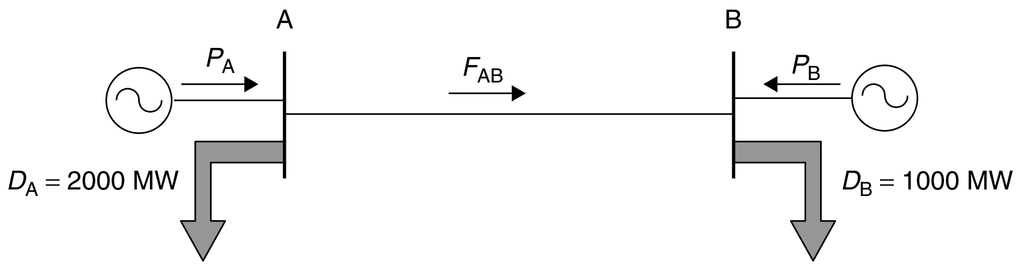

Figure P6.2 Two-bus power system for Problems 6.2, 6.3, 6.4, 6.10 and 6.11

6.2 Consider the two-bus power system shown in Figure P6.2. The marginal cost of production of the generators connected to buses A and B are given respectively by the following expressions:

$$MC_A = 20 + 0.03P_A \text{ \$/MWh}$$
$$MC_B = 15 + 0.02P_B \text{ \$/MWh}$$

Assume that the demand is constant and insensitive to price, that energy is sold at its marginal cost of production and that there are no limits on the output of the generators. Calculate the price of electricity at each bus, the production of each generator and the flow on the line for the following cases:

a. The line between buses A and B is disconnected

b. The line between buses A and B is in service and has an unlimited capacity

c. The line between buses A and B is in service and has an unlimited capacity, but the maximum output of Generator B is 1500 MW

d. The line between buses A and B is in service and has an unlimited capacity, but the maximum output of Generator A is 900 MW. The output of Generator B is unlimited.

e. The line between buses A and B is in service but its capacity is limited to 600 MW. The output of the generators is unlimited.

6.3 Calculate the generator revenues and the consumer payments for all the cases considered in Problem 6.2. Who benefits from the line connecting these two buses?

6.4 Calculate the congestion surplus for case (e) of Problem 6.2. Check your answer using the results of Problem 6.3. For what values of the flow on the line between buses A and B is the congestion surplus equal to zero?

6.5 Consider the three-bus power system shown in Figure P6.5 The table below shows the data about the generators connected to this system. Calculate the unconstrained economic dispatch and the nodal prices for the loading conditions shown in Figure P6.5.

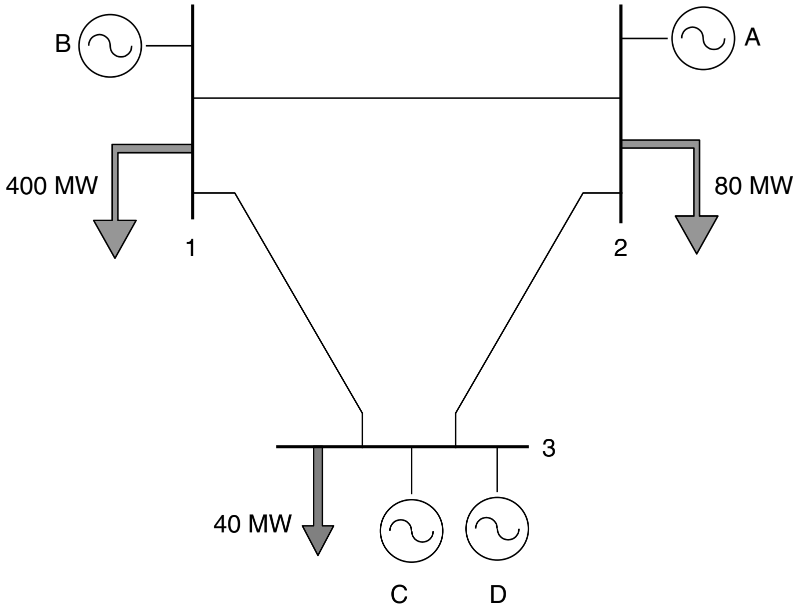

Figure P6.5 Three-bus power system for Problems 6.5 to 6.9 and 6.12 to 6.17

Generator	Capacity (MW)	Marginal cost ($/MWh)
A	150	12
B	200	15
C	150	10
D	400	8

6.6 The table below gives the branch data for the three-bus power system of Problem 6.5. Using the superposition principle, calculate the flow that would result if the generating units were dispatched as calculated in Problem 6.5. Identify all the violations of security constraints.

Branch	Reactance (p.u.)	Capacity (MW)
1-2	0.2	250
1-3	0.3	250
2-3	0.3	250

6.7 Determine two ways of removing the constraint violations that you identified in Problem 6.6 by redispatching generating units. Which redispatch is preferable?

6.8 Calculate the nodal prices for the three-bus power system of Problems 6.5 and 6.6 when the generating units have been optimally redispatched to relieve the constraint violations identified in Problem 6.7. Calculate the merchandising surplus and show that it is equal to the sum of the surpluses of each line.

6.9 Consider the three-bus power system described in Problems 6.5 and 6.6. Suppose that the capacity of branch 1-2 is reduced to 140 MW while the capacity of the other lines remains unchanged. Calculate the optimal dispatch and the nodal prices for these conditions. [Hint: the optimal solution involves a redispatch of generating units at all three buses]

6.10 Consider the two-bus power system of Problem 6.2. Given that $K = R/V^2 = 0.0001\,\text{MW}^{-1}$ for the line connecting buses A and B and that there is no limit on the capacity of this line, calculate the value of the flow that minimizes the total variable cost of production. Assuming that a competitive electricity market operates at both buses, calculate the nodal marginal prices and the merchandising surplus. [Hint: use a spreadsheet].

6.11 Repeat Problem 6.10 for several values of K ranging from 0 to 0.0005. Plot the optimal flow and the losses in the line, as well as the marginal cost of electrical energy at both buses. Discuss your results.

6.12 Using the linearized mathematical formulation (dc power flow approximation), calculate the nodal prices and the marginal cost of the inequality constraint for the optimal redispatch that you obtained in Problem 6.7. Check that your results are identical to those that you obtained in Problem 6.8. Use bus 3 as the slack bus.

6.13 Show that the choice of slack bus does not influence the nodal prices for the dc power flow approximation by repeating Problem 6.12 using bus 1 and then bus 2 as the slack bus.

6.14 Using the linearized mathematical formulation (dc power flow approximation), calculate the marginal costs of the inequality constraints for the conditions of Problem 6.9.

6.15 Consider the three-bus system shown in Figure P6.5. Suppose that Generator D and a consumer located at bus 1 have entered into a contract for difference for the delivery of 100 MW at a strike price of 11.00 \$/MWh with reference to the nodal price at bus 1, Show that purchasing 100 MW of point-to-point financial rights between buses 3 and 1 provides a perfect hedge to Generator D for the conditions of Problem 6.8.

6.16 What FGRs should Generator D purchase to achieve the same perfect hedge as in Problem 6.15?

6.17 Repeat Problems 6.15 and 6.16 for the conditions of Problem 6.9.

6.18 Determine whether trading is centralized or decentralized in your region or country or in another area for which you have access to sufficient information. Determine also the type(s) of transmission rights that are used to hedge against the risks associated with network congestion.

6.19 Determine how the cost of losses is allocated in your region or country or in another area for which you have access to sufficient information.