HOMEWORK 3 (27 Points Total) **Leigh Tesfatsion**
DATE: Friday, September 16, 11:00am **EE/Econ 458, Fall 2011**

HW3: Cost Functions for Power Systems (WITH REVISED Q4)

Caution: Exercises should be turned in at the beginning of class on the due date. Late exercises (i.e., exercises turned in after answer keys are distributed) will not be accepted – no exceptions.

NOTE: HW3 Consists of **FOUR** questions. Please answer all parts of all four questions. General instructions for this homework are as follows:

(a) Use this packet for all of your answers.

(b) Be sure to show all your work so that partial credit can be given for answers even if some type of error occurs along the way.

(c) Read each question part carefully before you begin your answer.

(d) Define terms and concepts clearly and carefully.

(e) Carefully label all graphs. This includes labels for axis variables as well as labels that carefully identify what is being graphed.

(f) Be sure to make an extra copy of your answer packet for use in class discussion on the due date. Individuals will be called upon to report their findings.

(i) Make sure your exercise is turned in to the instructor or TA at the *beginning* of class on the due date.

Question 1 (12 Points Total, 2 Points Each part)

Assume that the fuel inputs R_1 and R_2, in MBTU/hour for generating units 1 and 2, respectively, are a function of unit MW output powers P_1 and P_2, respectively, and are given as

$$R_1 = 8P_1 + 0.024P_1^2 + 80$$

$$R_2 = 6P_2 + 0.044P_2^2 + 120$$

The minimum and maximum loadings for both units are 20 MW and 100 MW, respectively. All of the following plots a. through f. should be given as a function of unit output power in MW. To do these plots, refer to Dr. McCalley's required reading "Costs of Generating Electrical Energy" posted at his syllabus and directly accessible here: http://home.eng.iastate.edu/~JDM/ee458_2011/CostCurves.pdf

a. Plot the input-output curve for each unit.

b. Plot the heat rate curves for each unit.

c. Plot efficiency for each unit.

d. Plot the incremental heat rate curves for each unit.

e. Assume the cost of fuel is $2/MBTU. Plot the cost-rate curves for each unit.

f. Plot the incremental cost-rate curves for each unit.

QUESTION 2: [**3 Points Total**] General Terms from Microeconomics

Using required course materials for reference, explain carefully (in words) the general meaning of each of the following terms for a firm that is trying to determine at a current time t1 an optimal production level y for some future time period T:

Q2.1 (1 Point) *sunk costs of production at time t1*

Q2.2 (1 Point) *avoidable costs of production for time period T*

Q2.3 (1 Point) *net earnings from production for time period T*

QUESTION 3: [**6 Points Total**] determination of an Optimal Production Plan

Definitions: The *no-load cost* for a generating unit G is the actual or estimated (extrapolated) cost for fuel and other inputs that would have to be paid by the owner of G in order to keep G running (i.e., keep G connected to the power grid) without actually producing any power for injection into the grid; see Kirschen/Strbac, p. 84. Also, the *start-up cost* of a generating unit G is the cost required to bring G into a running and ready-to-produce state starting from a shut-down state; see Kirschen/Strbac, P. 85.

Consider a generation company (GenCo) that owns a generating unit G and that is trying to determine at 10:00am on day D an optimal energy production level for G during the noon hour of day D+1.

Q3.1 (2 Points) Express carefully (in words) the general rule that this GenCo should use at 10:00am on day D to determine its optimal energy production level for G during the noon hour of day D+1.

Q3.2 (2 Point) Suppose the generating unit G is in a shut-down state at 10:00am on day D. In what way (if any) should start-up costs for G affect the GenCo's choice at 10:00am on day D of an optimal energy production level for G during the noon hour of day D+1? What about no-load costs for G? Justify your answer.

Q3.3 (2 Point) Suppose the GenCo started up its generating unit G on day D-1, and suppose G is in a running and ready-to-produce state at 10:00am on day D. In what way (if any) should start-up costs for G affect the GenCo's choice at 10:00am on day D of an optimal energy production level for G during the noon hour of day D+1? What about no-load costs for G? Justify your answer.

QUESTION 4: [6 Points Total]

Consider a generation company (GenCo) on the morning of December 31, 2011, that has just finished the installation of a Small Generating Unit (SGU) and is trying to decide on an optimal energy production plan for this SGU for the next year (2012). To finance this installation (including land purchase, construction costs, and interconnection fees), the GenCo signed a 15 year mortgage with a one-time collateral payment of \$300,000, with monthly payments of \$28,000, and with no pre-payment option (i.e., the mortgage cannot be paid off early). The SGU is now in a running and ready-to-produce state. Suppose for simplicity that the current resale value of the SGU installation is \$0.

The GenCo has just discovered that its SGU is not currently in compliance with environmental regulations because it is not equipped with suitable emission control equipment. This equipment must be purchased and installed prior to any use of the SGU for the production of energy for market sale in 2012. The GenCo is considering purchasing this equipment during the afternoon of December 31, 2011, for a purchase price of \$35,000 that includes immediate installation. The equipment has a useful life of one year (that is, after one year its resale value declines to zero).

Given an energy production level $y \geq 0$ (MWh) for the SGU during any hour of 2012, the variable cost of production (\$) for this hour (consisting primarily of fuel and labor costs) is as follows:

$$\text{VarCost}(y) \;=\; 5y^2 \;+\; 20y \quad (\$) \tag{1}$$

The market price that the GenCo expects to receive for each MWh of energy produced by its SGU during 2012 is π (\$/MWh).

Assume for simplicity that the SGU is the GenCo's only generating unit, that the SGU must either be shut down on the morning of January 1, 2012, or kept running throughout each hour of 2012, and that the SGU must maintain a constant energy production level $y \geq 0$ for each hour of 2012. Also assume that start-up, shut-down, and no-load costs for the SGU are zero. Finally, recall that each year consists of 8760 hours.

Q4.1 (3 Points) Calculate and report a specific expression for each of the following:

(a) *sunk costs of production for the GenCo on the morning of December 31, 2011;*

(b) *avoidable costs of production for the GenCo on the morning of December 31, 2011;*

(c) *expected total net earnings of the GenCo in 2012 attained from the use of its SGU to produce a constant energy production level y during each hour of 2012, where $y > 0$.*

Q4.2 (1 Points) Express carefully, in concrete terms, the specific criterion that this GenCo should use on the morning of December 31, 2011, to determine its optimal production plan for its SGU during 2012.

Q4.3 (2 Points) Using your answers in Q4.1 and Q4.2, determine the *lowest* nonnegative expected hourly energy sale price π^* (\$/MWh) for 2012 that would lead the GenCo to conclude it is optimal to plan on using its SGU to produce at least 1 MWH of energy during each hour of 2012. Show your derivation of π^* and justify your answer.