Ohio University
Corporate MBA Program

TENAGA NASIONAL

CMBA 611: Management of Operations

Problem Set # 1: Economic Operation of Electric Power Systems

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Problem 1.1: Energy and Power

The purpose of this problem is to get a feel for energy and power ¾ the principle products of the electric utility industry. In answering the questions, be sure to cite your sources.

Part A: Suppose one takes a round-trip automobile excursion from Kuala Lumpur to Malacca. How much energy (in kWh) does the automobile require to make the trip? What is the average power consumption (in kW) of the automobile? How much does it cost (in $, $/h and ¢/kWh) to make the trip?

Part B: How do the automobile excursion figures compare with Tenaga Nasional Berhad's largest power plant? For example, how long would it take the plant (operating at maximum power output) to generate the same energy as the automobile consumes and at what cost (again in $, $/h and ¢/kWh)?

Part C: How quickly can a typical residential electric power customer purchase the same energy as the automobile trip consumes and at what cost (in $, $/h and ¢/kWh)? How does the automobile trip's energy consumption compare with the monthly electric energy consumption of a typical residential customer?

Part D: How many automobiles does it take to consume the same power that the power plant of Part C produces when it operates at maximum power output?

Part E: How much energy does Tenaga Nasional Berhad produce each year? Suppose all of this energy could be produced by a single fictitious (but representative) oil-fired unit. How much oil would the unit consume? If this oil could somehow be evenly distributed over the surface area of Kuala Lumpur, how deep would the oil be?

Problem 1.2: Economic Dispatch of Electric Power Plants ¾ Variable I Case

The purpose of this problem is to explore the principles of classical economic dispatch of thermal power plants. Suppose an electric utility's generating resources consist of two generating units having the following operating costs and operating ranges:

Unit 1: $C_1(P_1) = 0.1\,P_1^2 - 100P_1 + 85{,}000$ ($/h), $500\text{ MW} \le P_1 \le 1500\text{ MW}$

Unit 2: $C_2(P_2) = 160\,P_2 + 20{,}000$ ($/h), $500\text{ MW} \le P_2 \le 1000\text{ MW}$

Part A: Develop the minimum production cost strategy (i.e., specify the output power of each unit in terms of the load power $P_L = P_1 + P_2$) over the entire range of (feasible) load power.

Part B: Use your results from Part A to determine the most economical output power (in MW) of each unit, the total production cost (in both k$/h and ¢/kWh) and the system incremental cost (in ¢/kWh) all for a load of 1922 MW.

Part C: Suppose one of the utility's customers adds to the 1922 MW load of Part B by switching on a 100 Watt incandescent lamp. How much does it cost the utility to serve this additional load and how much should the customer pay for it? Give your answers in ¢/kWh.

Part D: What is the production cost (in both k$/h and ¢/kWh) of each unit at minimum output power? Repeat for maximum output power. What is the average incremental cost (in ¢/kWh) of each unit. Compare and contrast all these costs for each unit. How do the energy costs compare with those of your own (residential) electric bill? Do the quadratic cost equations resemble those of real (actual) power plants?

Part E: At what power output does each unit produce energy most economically and what is the production cost (in both k$/h and ¢/kWh) of each unit for that output?

Part F: At what power output does each unit produce energy most efficiently and what is the production cost (in both k$/h and ¢/kWh) of each unit for that output?

Part G: If the load equals the sum of the output powers calculated in Part E, what is the most economical way to operate the units and what is the total production cost (in k$/h and ¢/kWh) of the two-unit power system? How do your answers here compare with those of Part E? Repeat for Part F. How would you explain any differences to a layman?

Part H: For the load of Part B, what is the operating strategy which will maximize the total overall energy efficiency of the power system? How do your answers here compare with those of Parts B and G?

Problem 1.3: Independent Power Producers (IPP's)

For the prototype power system shown, the independent power producer charges the utility 6 ¢/KWH for the energy that it injects (at the rate of 350 MW) into it. The utility's own energy costs 10 ¢/KWH.

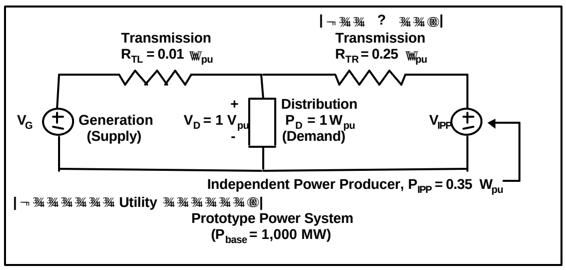
Part A: What percentage of the IPP's injected power is actually consumed by the load* and how much revenue (in k$/h) does the IPP receive from the utility?

Part B: What is the IPP's impact (in ¢/kWh) on the utility's production cost?

Part C: Assuming the utility breaks even, how much does the load's electricity cost decrease (in ¢/kWh) as a result of the IPP's generation? In other words, how do utility customers benefit from allowing the IPP to interlope in the electric utility's marketplace?

Part D: Suppose the IPP is located in a geographically remote area where the electric utility has very few customers. Furthermore, suppose that (since there are so few customers there) there is not enough transmission capacity between the IPP and the utility to support the IPP's power injection. This means that in order for the IPP to sell power to the utility, the capacity of the transmission system between the two parties must be increased. Who should pay for this capacity increase (e.g., new transmission line(s)) and who should pay for its maintenance after construction?

*N.B.: The terms load, demand and customer(s) are used interchangeably here.



Problem 1.4: Electricity Tariffs & Load Management

Suppose a utility's production cost is given by: $C(P) = 0.1P^2 - 100p + 85{,}000$ \$/h, where P is the utility's load power ($P \geq 500$ MW). Suppose the utility's load consists of four 500 MW customers having the following power usage requirements: One customer operates around-the-clock while the other three each require their power for one eight-hour shift. Currently, the three one-shift customers are all operating during the same eight-hour shift. Therefore the utility's load profile has an eight-hour 2000 MW peak-load period with the remaining sixteen off-peak hours 500 MW.

Part A: What is the utility's daily production cost?

Part B: Suppose the utility is somehow able to convey incremental price signals to the customers and charge them accordingly. In other words, suppose the utility is able to charge its customers whatever it costs the utility to serve them. Furthermore, suppose the customers are willing to respond to any opportunity to cut their costs. What will happen to the load profile under these conditions?

Part C: What is the utility's production cost for part B? If the utility's energy is sold at cost, how much should each customer pay (in ¢/kWh) for their energy?

Part D: Design a tariff scheme based on time-of-day rates and/or demand charges which produces the same savings as Part B. Be sure to consider carefully the customer's point of view, i.e.; be sure to carefully consider whether or not the customer is able to respond appropriately to your tariff.

Part E: For the incremental cost driven tariff of part B, how can the utility tell which customer is which? How important is the answer to this question to the feasibility and success of Part B's tariff?

Problem 1.5: Economy Interchange and Wheeling Electric Power

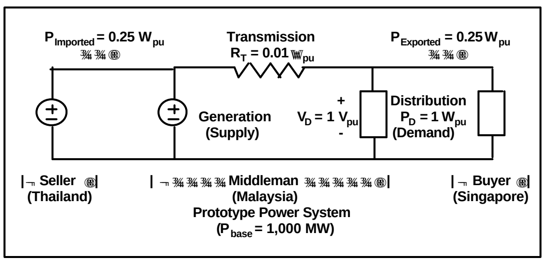
Suppose Thailand and Singapore propose to enter into a 250 MW split-savings economy-interchange agreement in order to reduce their production costs. Obviously, in order to carry this out, the power will have to be wheeled (sold) across Malaysia's transmission system (grid). Engineering studies indicate that Malaysia's transmission losses will increase 56.25% from 10 MW to 15.625 MW as a result of the proposed power transfer and that the incremental costs will be 6 ¢/kWh, 9 ¢/kWh and 10 ¢/kWh for Thailand, Malaysia and Singapore respectively during the course of the transaction.

Part A: How much rent (in ¢/kWh sold) should Malaysia charge Thailand and Singapore for the use of its transmission system in order for it to just recover the cost of its increased transmission losses (i.e., in order for it to break even)?

Part B: For the break-even case of Part A, at what price (in ¢/kWh sold) should Thailand sell energy to Malaysia? At what price (in ¢/kWh sold) should Malaysia sell energy to Singapore? How much (in ¢/kWh sold) does each country benefit?

Part C: Suppose Malaysia offers a counterproposal for which its transmission rental fee is such that all three countries benefit equally. What are the answers to Part B in this case?

Part D: Is Part C's counterproposal fair? Compare it to the hypothetical case where Thailand and Singapore trade directly by way of a fictitious lossless interconnection (rather than using Malaysia's grid). Is Malaysia taking unfair advantage of its geographical position as the hypothetical analysis might suggest? Finally, how can Malaysia justify the profit it makes by simultaneously importing and exporting energy at prices lower than its own incremental cost? How would you explain this to a layman?



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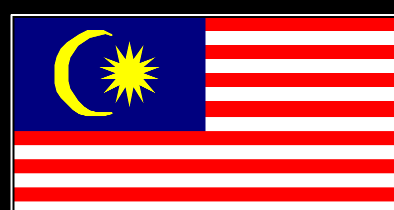

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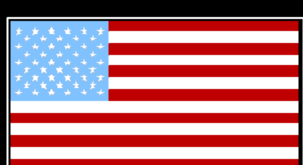

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