ECEN 460, Spring 2026
Power System Operation and Control

Class 17: Economic Dispatch Examples

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Announcements

- Homework #7: 6th edition book problems 6.62, 6.63, 6.65 or 7th edition book problems 7.1, 7.2, 7.4
  - Due Tuesday, March 24th

Economic Dispatch Summary

- Minimize total generator cost, subject to serving total load
- Each generator's incremental cost curve is derivative of cost curve
- Key necessary conditions for economic dispatch solution:
  - Total generated power must equal load + losses
  - Incremental cost for each generator (times penalty factor if losses are included) must be equal to the system λ.

System Lambda and Generator Limits

- When the ED problem is solved, part of the solution is the incremental cost λ in $/MWh. This would be the cost to serve one more MW of power. Higher λ is typical for a more constrained or higher-load situation.
- Generators have limits on the minimum and maximum amount of power they can produce
  - Often times the minimum limit is not zero. This represents a limit on the generator’s operation with the desired fuel type
  - Because of varying system economics usually many generators in a system are operated at their maximum MW limits.
- Each generator has an incremental cost
  - If the generator's incremental cost is < λ, the generator should be operated at its maximum.
  - If the generator's incremental cost is > λ, it should be operated at its minimum.
  - Some generators may have their incremental cost = λ, these are the marginal units operated somewhere between minimum and maximum.

Penalty Factors

- The losses on the transmission system are a function of the generation dispatch. In general, using generators closer to the load results in lower losses
- This impact on losses should be included when doing the economic dispatch, and can be done by using what are known as penalty factors
- A penalty factor is multiplied by the generator cost to represent the effect of losses: i.e. a generator that increases the losses by operating has a penalty factor > 1.0
- For Lab 6 we are looking at the effect of penalty factors

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- Generators have limits on the minimum and maximum amount of power they can produce
  - Often times the minimum limit is not zero. This represents a limit on the generator's operation with the desired fuel type
  - Because of varying system economics usually many generators in a system are operated at their maximum MW limits.
- Each generator has an incremental cost
  - If the generator's incremental cost is $< \lambda$, the generator should be operated at its maximum.
  - If the generator's incremental cost is $> \lambda$, it should be operated at its minimum.
  - Some generators may have their incremental cost = λ, these are the marginal units operated somewhere between minimum and maximum.

Economic Dispatch Problem, Example 1

- A system has two generators with the following cost curves.
- C_1 and C_2 are the generator costs, in \$/hr
- P_1 and P_2 are the generator real power outputs, in MW

$$C_1(P_1) = 5500 + 14\,P_1 + 0.002\,P_1^2$$
$$C_2(P_2) = 2000 + 12\,P_2 + 0.004\,P_2^2$$

- Each generator must be dispatched within the following limits

$$10\text{ MW} \le P_1 \le 200\text{ MW}$$
$$50\text{ MW} \le P_2 \le 500\text{ MW}$$

- If the total system load is 325 MW, what should be P_1 and P_2 to minimize the total system cost $C_1 + C_2$?
- Also, what is the incremental cost to supply 1 more MW? How does the solution change if the load goes up to 400 MW? Down to 250 MW? Up to 570 MW? Up to 750 MW?

Economic Dispatch Problem, Example 1

- *Fundamental principle: For generators within their limits, the incremental cost should be equal to the system marginal cost λ*
- So we basically have two equations: We need to meet the load

$$P_1 + P_2 = 325$$

- And we need the incremental cost (derivatives) to be equal

$$\lambda = \frac{dC_1}{dP_1} = \frac{dC_2}{dP_2}$$

- Take the derivatives to find the incremental cost

$$\lambda = \frac{dC_1}{dP_1} = 14 + 0.004\,P_1$$

$$\lambda = \frac{dC_2}{dP_2} = 12\ + 0.008\,P_2$$

- Solving, we get $P_1 = 50\text{ MW}, P_2 = 275\text{ MW}, \lambda = 14.2\,\frac{\$}{MWh}$

Economic Dispatch Problem, Example 1

- Now try with the other values of the load
  - For load of 400 MW, you get $P_1 = 100, P_2 = 300, \lambda = 14.4\ \$/MWh$
  - For load of 250 MW, you get $P_1 = 0, P_2 = 250, \lambda = 14\ \$/MWh$
  - For load of 570 MW, you get $P_1 = 213, P_2 = 357, \lambda = 14.85\ \$/MWh$
  - For load of 750 MW, you get $P_1 = 333, P_2 = 417, \lambda = 15.33\ \$/MWh$
- But wait a minute, check the limits
  - In the first case, we are fine, no limit violations
  - In the second case, P_1 will be stuck at its min limit, $P_1 = 50,\ P_2 = 200,\ \lambda = 13.6\ \$/MWh$
  - In the third case, P_1 will be stuck at its max limit, $P_1 = 200,\ P_2 = 370,\ \lambda = 14.96\ \$/MWh$
  - In the fourth case, we have a problem!!
- Note that lambda and the incremental cost are related in this way

$$\begin{cases} IC < \lambda & if \text{ Generator at max limit} \\ IC = \lambda & if \text{ Generator not at limit} \\ IC > \lambda & if \text{ Generator at min limit} \end{cases}$$

Worksheet -- Economic Dispatch, Exercise 2

Four generators with the following cost equations and limits:

$C_1(P_1) = 0.025\ P_1^2 + 16\ P_1$ $\quad$ $15 \leq P_1 \leq 115$

$C_2(P_2) = 0.035\ P_2^2 + 9\ P_2$ $\quad$ $30 \leq P_2 \leq 185$

$C_3(P_3) = 0.004\ P_3^2 + 15\ P_3$ $\quad$ $8 \leq P_3 \leq 325$

$C_4(P_4) = 14\ P_4$ $\quad$ $0 \leq P_4 \leq 250$

Two parts to this question:

1. Make a table with five values of λ (system marginal cost): 9, 12, 15, 18, 21 \$/MWh. Calculate $P_1, P_2, P_3, P_4,$ and total system P for each of these λ's. (Remember, $\lambda = dC_i/dP_i$ for each generator *i* not at a limit.)
2. If we want to serve a total of 500 MW of load, what is the optimal dispatch (P_1, P_2, P_3, P_4), the system marginal cost λ, and total cost?

Economic Dispatch, Exercise 2

λ ($/MWh)	P_1	P_2	P_3	P_4	P_{total}
9					
12					
15					
18					
21					