

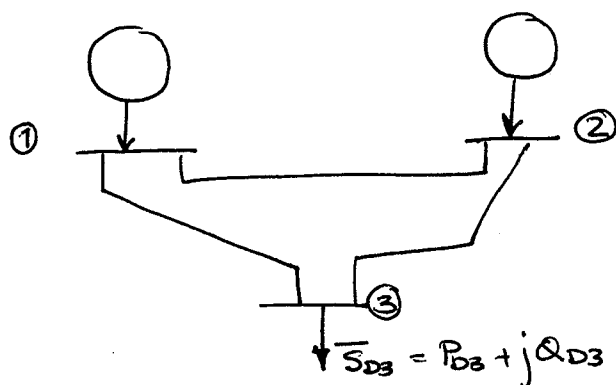
LECTURE 18

ECONOMIC DISPATCH

- MOTIVATION
- PROBLEM FORMULATION

MOTIVATION

So far, we spent time figuring out how to solve the power flow problem



- Given $V_1, \theta_1, P_2, V_2, P_{D3}, Q_{D3}$, find $P_{G1}, Q_{G1}, Q_{G2}, V_3, \theta_3$
- In other words, we were fixing the power generation except for the swing bus.
- Now, the question turns into :

What is the criteria for fixing the generation of each individual unit ?

The criteria are:

- Cost of operation (ECONOMIC DISPATCH)
- Reliability

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We focus on this one.

The total cost of operation includes:

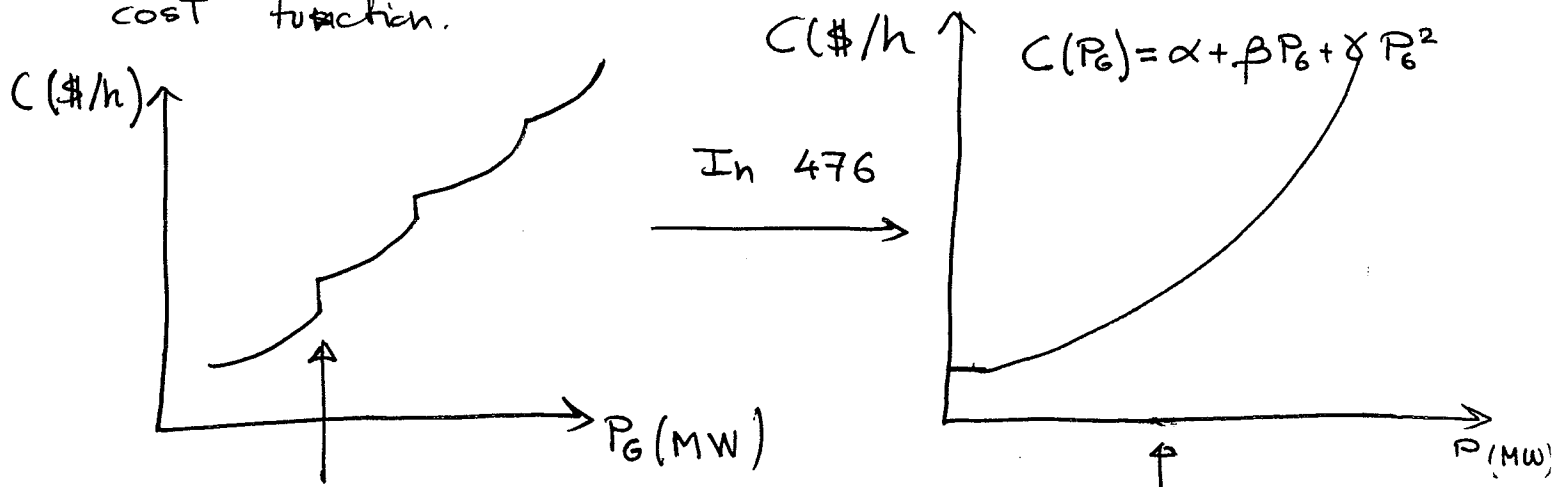
- i) fuel
- ii) labor
- iii) Maintenance

To simplify the problem, we will only focus on fuel costs.

- We will assume that fuel-cost curves for each generating unit are available.
- The cost of the fuel used per-hour is a function of the generator power output P_G

$$c(\$/h) = f(P_G)$$

- fuel-cost curves are usually not smooth functions, however a good approximation of the fuel-cost curve of a generator is a piece-wise quadratic cost function.



These discontinuities are due to the firing of equipment such as additional boilers or condensers as power output is increased

We will assume a quadratic function

In ECE 476, we will assume that the cost-fuel functions are quadratic (this is a good approximation used in practical settings)

$$C(P_G) = \alpha + \beta P_G + \gamma P_G^2$$

ECONOMIC DISPATCH PROBLEM FORMULATION

- We have a system with m generator, the cost of each generator is

$$C_i = \alpha_i + \beta_i P_{Gi} + \gamma_i P_{Gi}^2$$

- The total cost is

$$C_T = \sum_{i=1}^m C_i$$

- The economic dispatch problem is about minimize C_T subject to certain constraints. These constraints are:

i) Generator constraints

$$P_{Gi}^{\min} \leq P_{Gi} \leq P_{Gi}^{\max} \quad \forall i=1,2,\dots,m$$

ii) Network equations (power flow)

$$S_j = V_i \cdot \sum_k (Y_{ik} \cdot V_k)^* \quad \forall i=1,2,\dots,N$$

iii) Flow constraints:

$$|P_{ij}| \leq P_{ij}^{\max} \quad \text{for all lines}$$

iv) Voltage constraints:

$$V_i^{\min} \leq V_i \leq V_i^{\max}$$

A few comments are in place:

- The upper limit on P_{Gi} is set by thermal limits on the turbine generator unit.
- The lower limit on P_{Gi} is set by boiler and/or other thermodynamic consideration; i.e., a certain minimum flow of water and/or steam is required in the boiler to prevent "hot spots" from developing when the unit is on.
- The fuel burning rate must also be sufficient to keep the flame from going out.
- The constraints on voltage keep the system voltages from varying too far from their rated or nominal values, with the objective of helping to maintain the consumer's voltage.

The minimization of a ^{nonlinear} cost function subject to equality and inequality constraints is a problem in optimization treated by a branch of applied math called nonlinear programming.

CLASSICAL ECONOMIC DISPATCH

- We neglect losses
- We do not enforce any constraints (besides the obvious one that the generator ~~loss~~ must equal the demand)

$$\text{minimize } C_T = \sum_{i=1}^m C_i(P_{Gi}) = \sum_{i=1}^m (\alpha_i + \beta_i P_{Gi} + \gamma_i P_{Gi}^2)$$

$$\text{subject to } \sum_{i=1}^m P_{Gi} = P_n \triangleq \sum_{i=m+1}^n P_{Di} \leftarrow \text{these are the demands on the } \text{nodes} \text{ load buses.}$$