

Control of interconnected power system and economic dispatch

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ECE Department at USA

- Faculty: 13 members (2 in power)
- Student: 350 – 400 students
(undergraduate and graduate)
- Program: BSEE, BSCpE and MSEE
- ABET accreditation: BSEE and BSCpE
- Laboratories – Power related
 - Electromagnetic Lab
 - Energy Conversion Lab
 - Fuel Cell Operated Smart Home Lab
(Research Lab)



ECE Department at USA

■ Concentration areas:

- ☐ Control Systems
- ☐ Communications and Networks
- ☐ Digital Systems
- ☐ Electromagnetics and Optics
- ☐ Electronics
- ☐ Power Systems

ECE Department at USA

■ Power Systems Courses

- ☐ EE 381 Electromechanical Energy Conversion
- ☐ EE 385 Energy Conversion Laboratory
- ☐ EE 481 Electrical Machines*
- ☐ EE 483 Power Systems I*
- ☐ EE 484 Power Systems II*
- ☐ EE 485 Power Distribution and Utilization*
- ☐ EE 486/586 Power Electronics*
- ☐ EE 488 Illumination Engineering*
- ☐ EE 489/589 Direct Energy Conversion*
- ☐ EE 585 Advanced Power Systems
- ☐ EE 588 Power Semiconductor Drives

* EE technical electives must be selected from Electrical Engineering courses carrying a 400 number and must include a two-course concentration



Control of Interconnected Power System and Economic Dispatch

- Overview and Background
- Objectives
- Large Power System Interconnections
 - Structure
 - Elements
 - Loads
 - Generation
 - Transmission lines
 - Control
 - Power, voltage, frequency and tie-line
- Economic Dispatch

The Grid

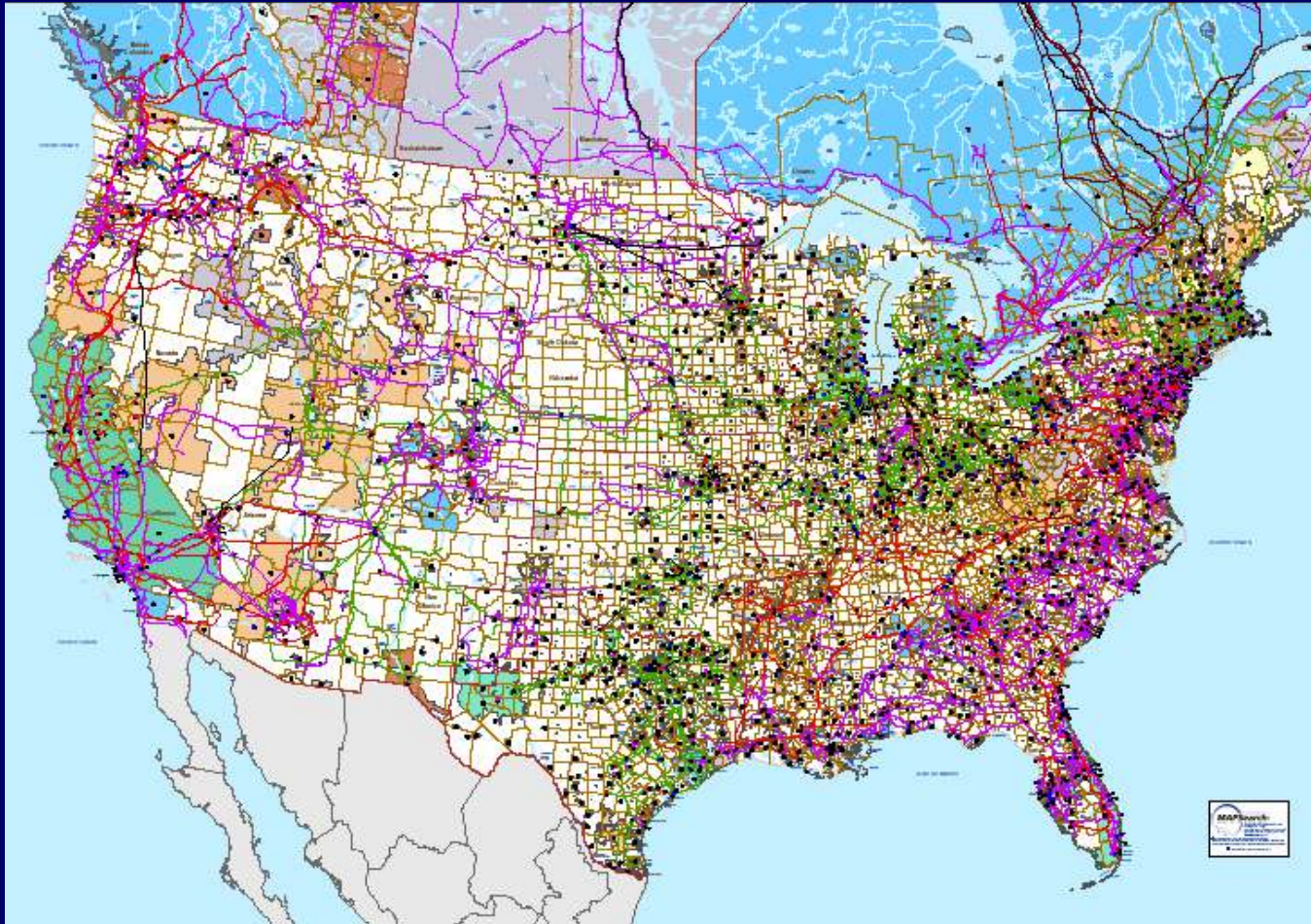


Fig. 1. Interconnected North American Power Grid [2]

Controlling the Grid



Fig. 2. Electric Control Area Operators — Continental United States, 1998
Source: http://www.eere.energy.gov/de/grid_control.html



Controlling the Grid

- Electricity is generated as it is used (there is very little ability to store electricity).
- The electric power system must constantly be adjusted to ensure that the generation of power matches the consumption of power.
- On continental U.S. power grids, more than 150 Control Area Operators serve this function by using computerized control centers to dispatch generators as needed.



Voltage Control

- Intro:

- Angle \rightarrow Active Power
 - Voltage \rightarrow Reactive Power

- Generator excitation \rightarrow Reactive power

- Overexcitation \rightarrow supply reaction power
 - Underexcitation \rightarrow absorb reactive power

- Automatic Voltage Regulation (AVR)

Automatic Voltage Regulation (AVR)

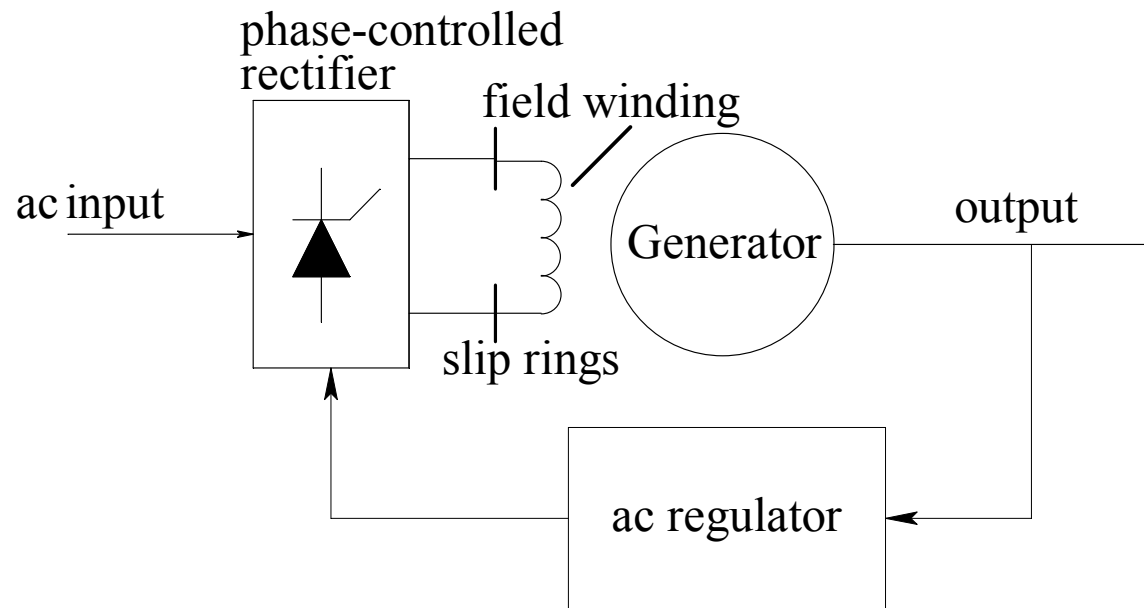


Fig. 12-1 Field exciter for automatic voltage regulation (AVR).

Load-Frequency Control

AGC – Automatic Generation Control

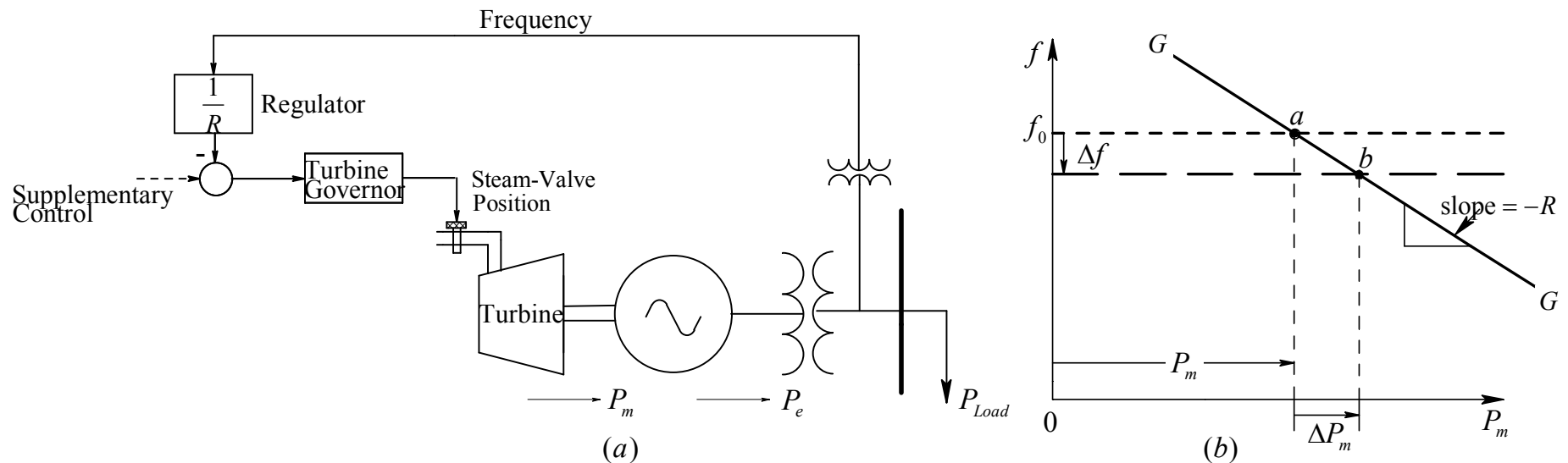


Fig. 12-3 Load-Frequency Control (ignore the supplementary control at present).

Load-Frequency Control

Two generators – Load sharing

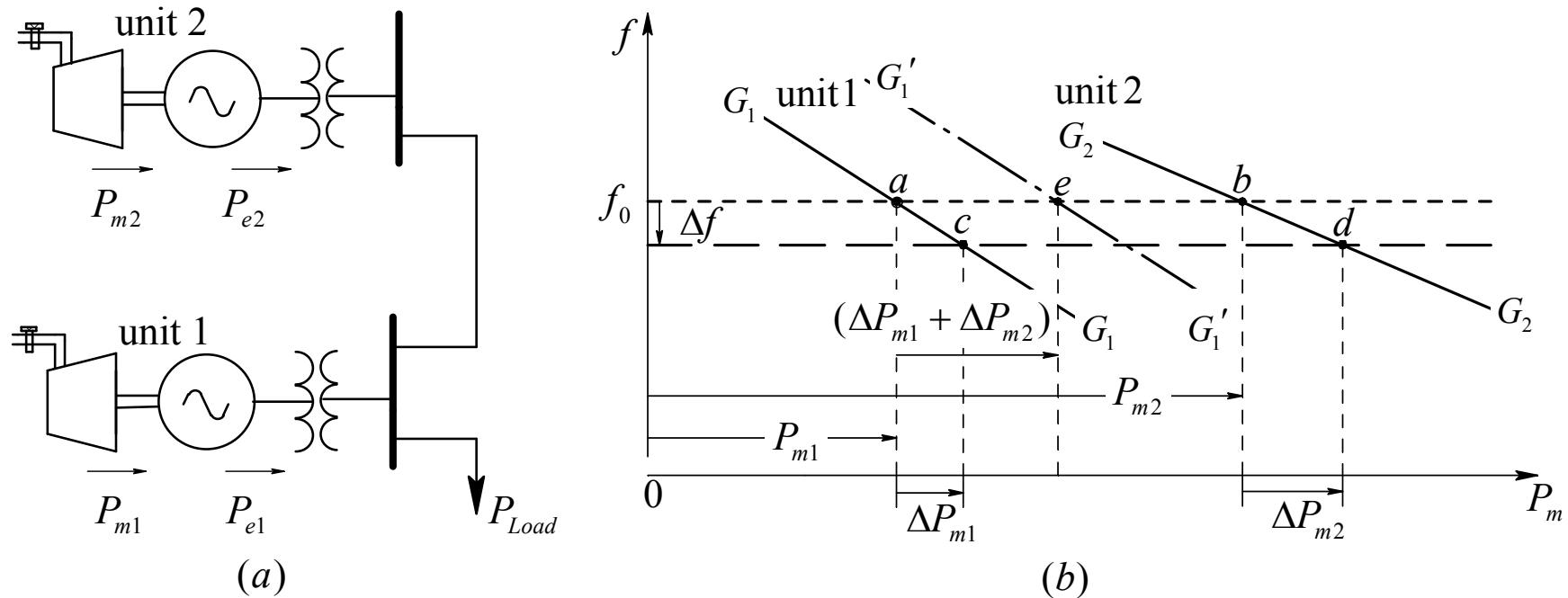


Fig. 12-4 Response of two generators to load-frequency control.

Two Control Areas

- Unit 1 and 2 represent two control areas.
- Each area has Area Control Error (ACE)

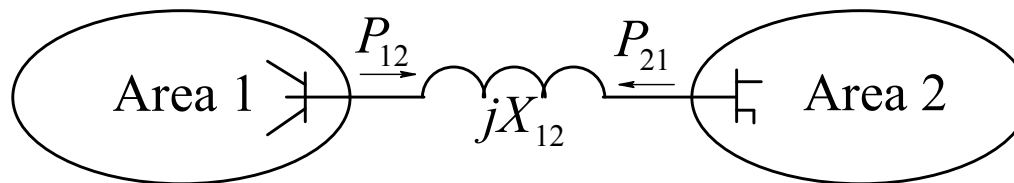


Fig. 12-5 Two control areas.

$$ACE_1 = \Delta P_{12} + B_1 \Delta f \quad \text{and} \quad ACE_2 = \Delta P_{21} + B_2 \Delta f$$

Automatic Generation Control (AGC) with Area Control Error (ACE)

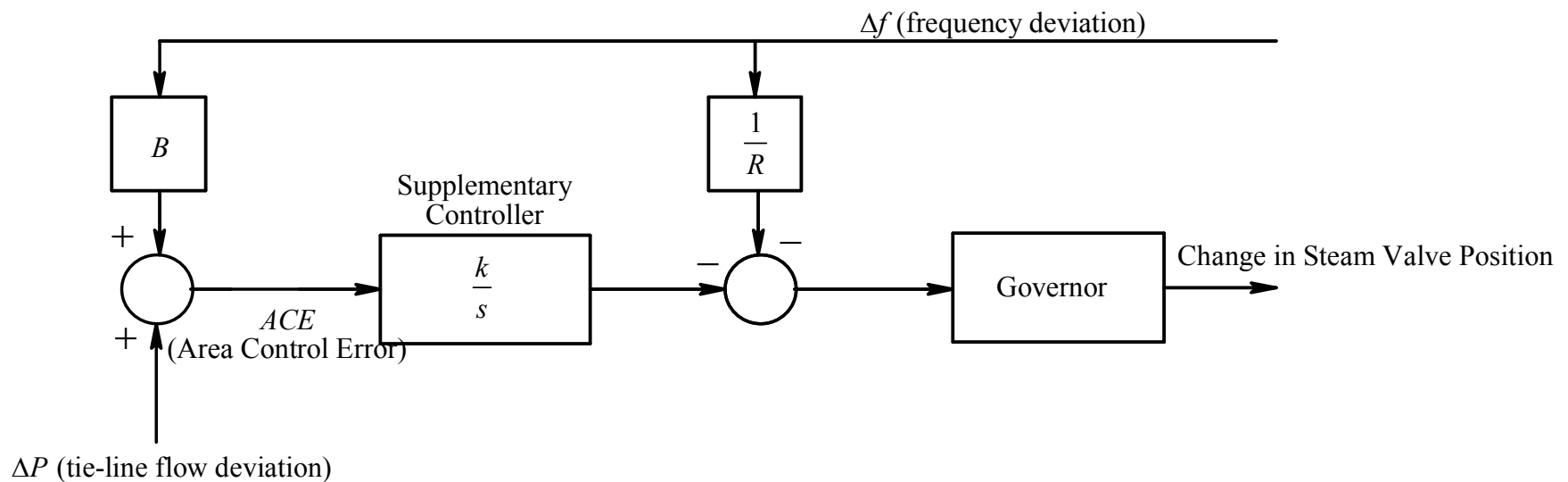


Fig. 12-6 Area Control Error (ACE) for Automatic Generation Control (AGC).

Modeling of Two Control Areas with AGC and ACE

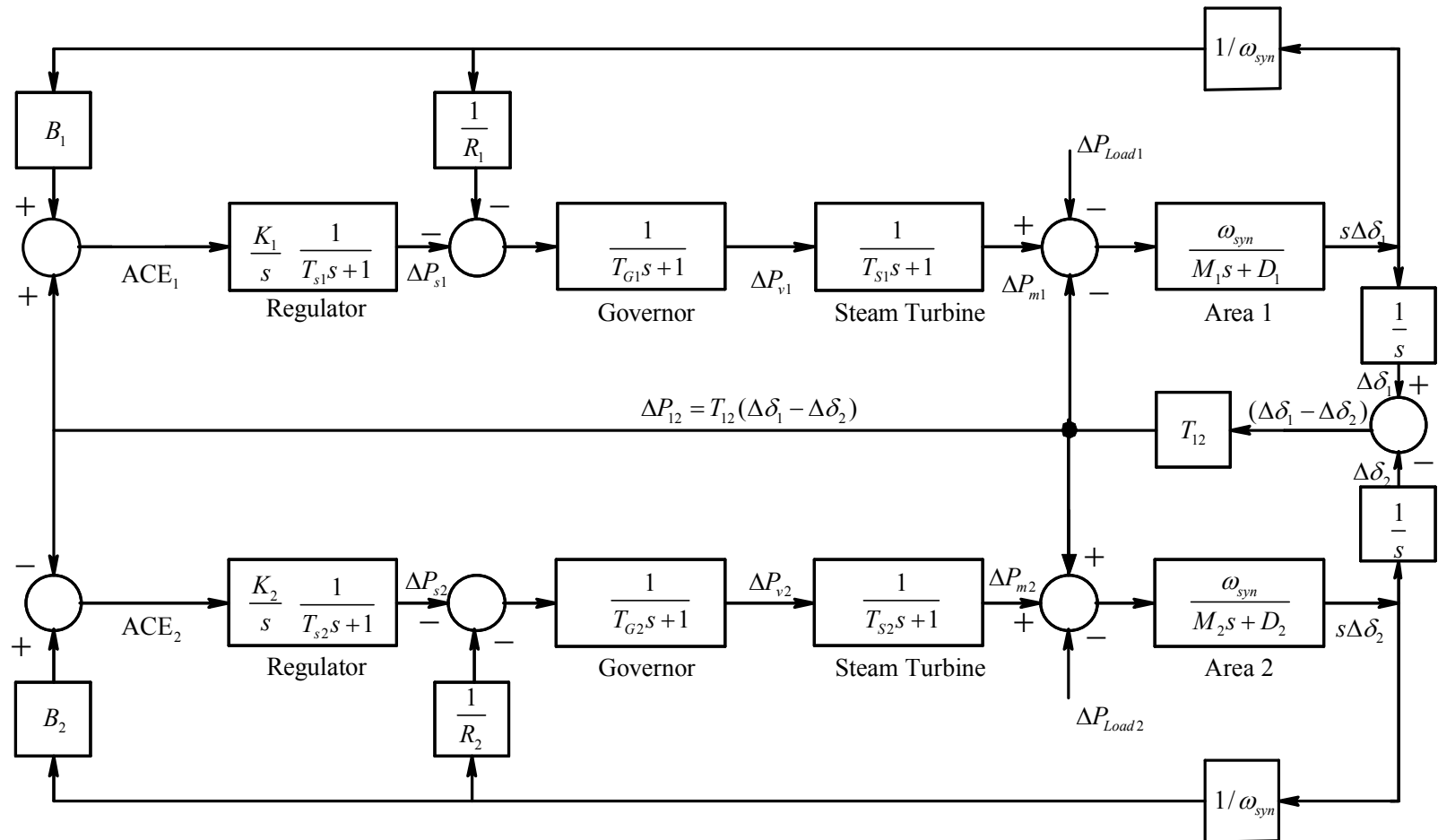


Fig. 12-10 Two-area system with AGC. Source: adapted from [6].

Economic Dispatch

Cost Curve and Marginal Cost

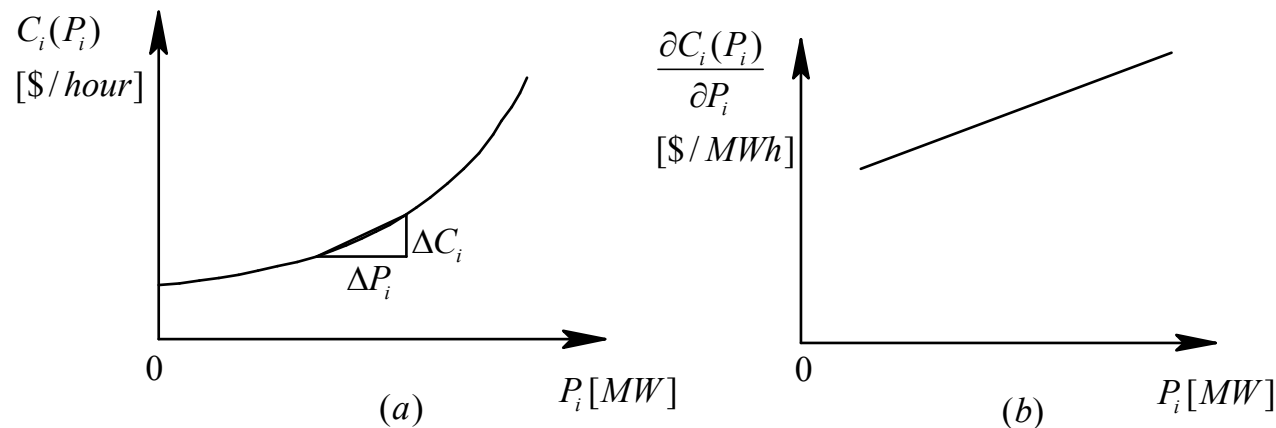


Fig. 12-13 (a) Fuel cost and (b) Marginal cost, as functions of the power output.

Economic Dispatch

Load Sharing between Three Power Plants

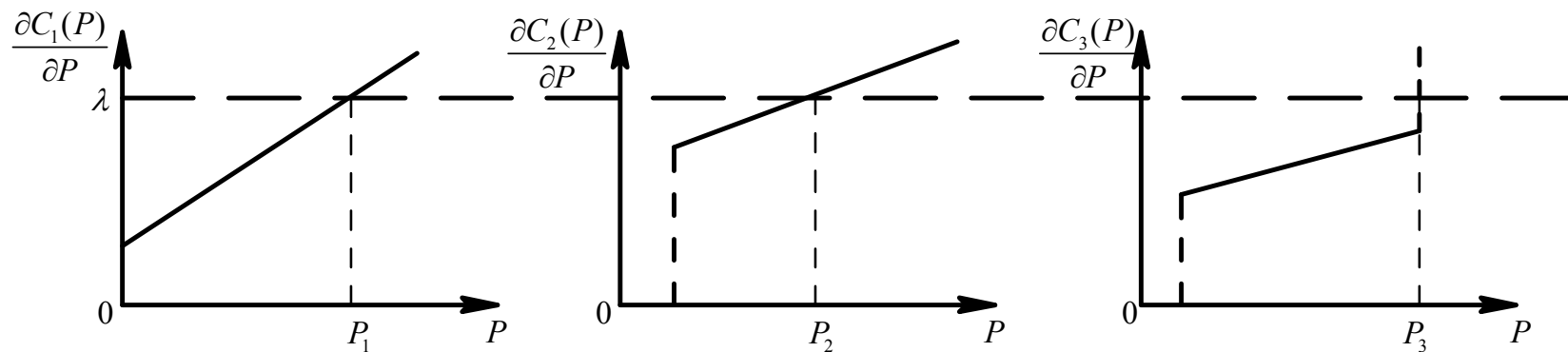


Fig. 12-14 Marginal costs for the three generators.