Electric Utility Power Systems

Generation of Electricity

Demand of an Electrical System

- The total power drawn by a customer of a large utility system fluctuates between wide limits, depending on the time, day, and season.
- **Example of demand:** 15 GW (15000 MW) in the winter and 10 GW in the summer. Both peaks at about 17:00 (5:00 pm)!
- **Base load of the system:** The minimum demand for power throughout the year. The base load demand has to be fed 100% of the time.
- **Peak load:** The annual maximum demand. This may occur for only 0.1% of the time.
- **Intermediate loads:** The demand between the two extremes. It has to be fed for less than 100% of the time.

Three Types of Generating Stations

- **Base-Power Stations:** Deliver full power at all times. Examples: Nuclear stations and coal-fired stations.

- **Intermediate-Power Stations:** They can respond relatively quickly to changes in demand by adding or removing one or more generating units. Examples hydropower stations.

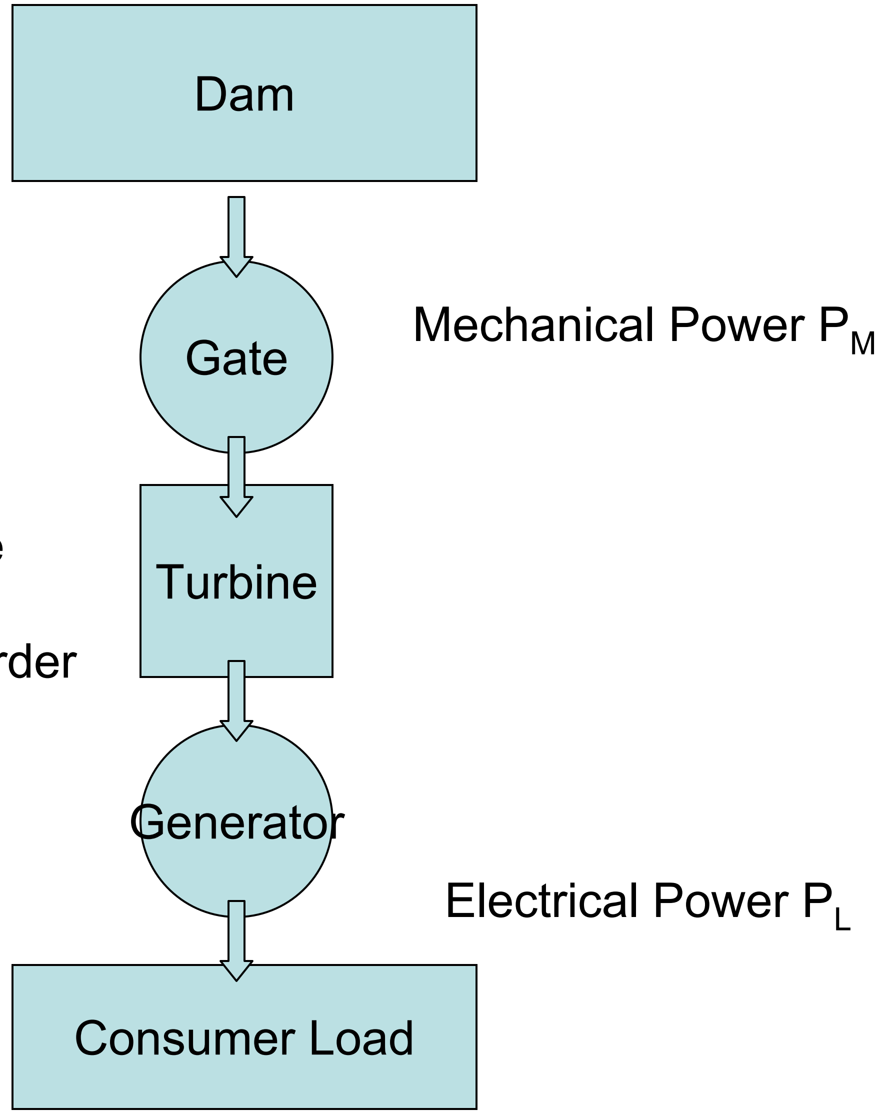
- **Peak-Generating Stations:** They deliver power for brief intervals during the day. Examples generators equipped with movers such as diesel or gas engines.

Balancing Power Between Generator and Load

If P_L is greater than P_M,
The generating unit
begins to slow down.

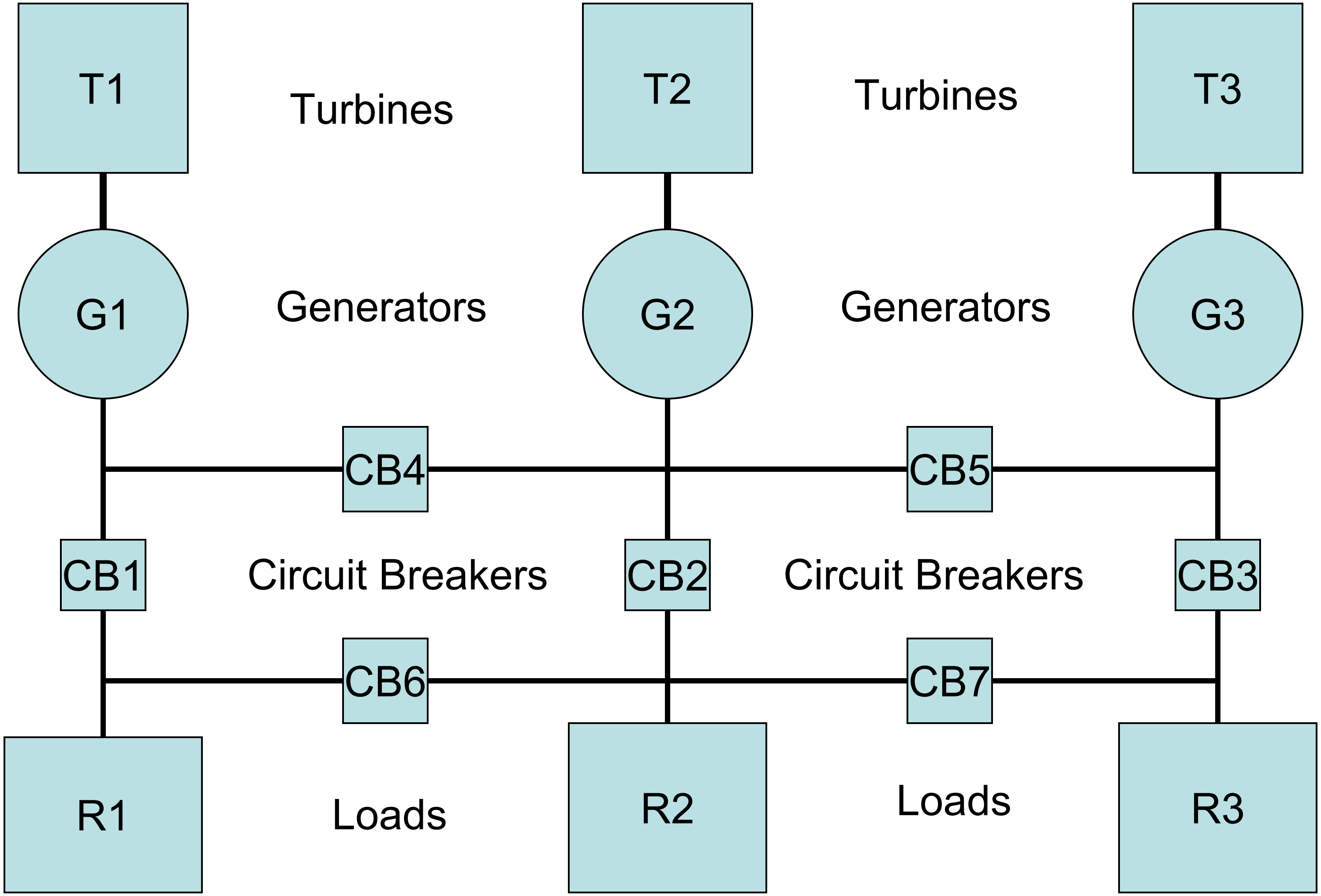
If P_L is less than P_M,
The generating unit
begins to speed up.

If the speed falls the gate
Must open and if it rises
The gate must close in order
To maintain equilibrium
Between P_L and P_M.



Interconnected Systems

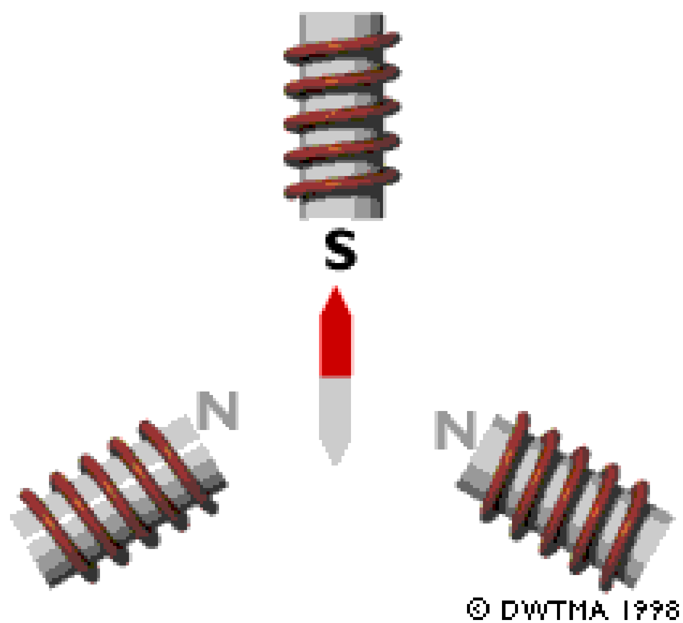
Stability: Continuity of Service; Economy



3-Phase Generator (or Motor) Principles

All 3-phase generators (or motors) use a rotating magnetic field. In the picture we have three electromagnets around a circle. Each of the three magnets is connected to its own phase in the three phase electric grid.

http://www.windpower.org/en/tour/wtrb/syncgen.htm



Outage or Contingency

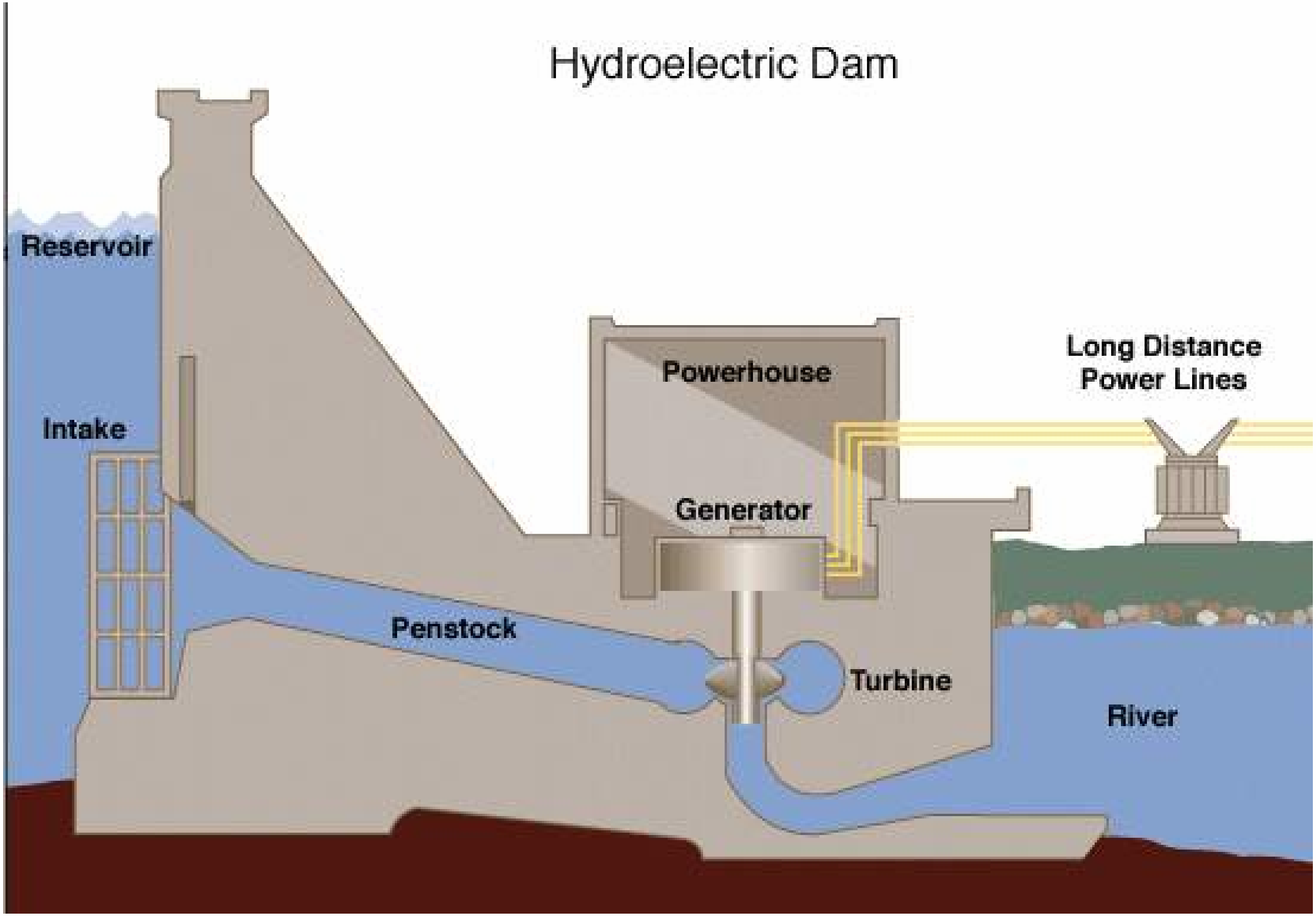
- A major disturbance of system creates a state of emergency. The sudden loss of an important load or a permanent short-circuit on a transmission line makes a major outage.
- If a big load is suddenly lost, all the turbines begin to speed up and the frequency increases everywhere in the system.
- However, if a generator is disconnected, the speed of the remaining generators decreases because they suddenly have to carry the entire load. The frequency will decrease (sometimes it reaches 5 Hz). In such case, one or more load should be shut down. Such load shedding is done by frequency-sensitive relays that open selected circuit breakers as the frequency falls. For example, on a 60-Hz system the circuit breakers shed 15% of the system when the frequency drops to 59.3 Hz. Another 15% when the frequency drops to 58.9 Hz. Load shedding must be done in less than one second to save loads.

Hydropower Generating Stations

- The power that can be extracted from a waterfall depends upon its height and rate of flow: $P = 9.8\ qh$, where P is the available power in kW, q is the water rate of flow in m^3/s, h is the head of water (m).

- Hydropower stations are divided into three groups:
  - **High-Head Development:** in excess of 300 m.
  - **Medium-Head Development:** Between 30 and 300 m.
  - **Low-Head Development:** Less than 30 m.

- A hydropower installation consists of:
  - Dam: Made of earth or concrete and built across river beds or reservoirs.
  - Waterways: Conduits that lead water from dam to the generating plant.
  - Draft Tube: Carefully designed vertical channels.8
  - Power House: Synchronous generators; transformers; circuit breakers.



http://www.tva.com/power/hydroart.htm

The Generating Plant

1 Water flows through the dam and turns a large wheel called a turbine. The turbine turns a shaft which rotates a series of magnets past copper coils and a generator to produce electricity. The process produces clean renewable energy.

2 The Kaplan Head is the hydraulic associated with adjustable blades on the turbine.

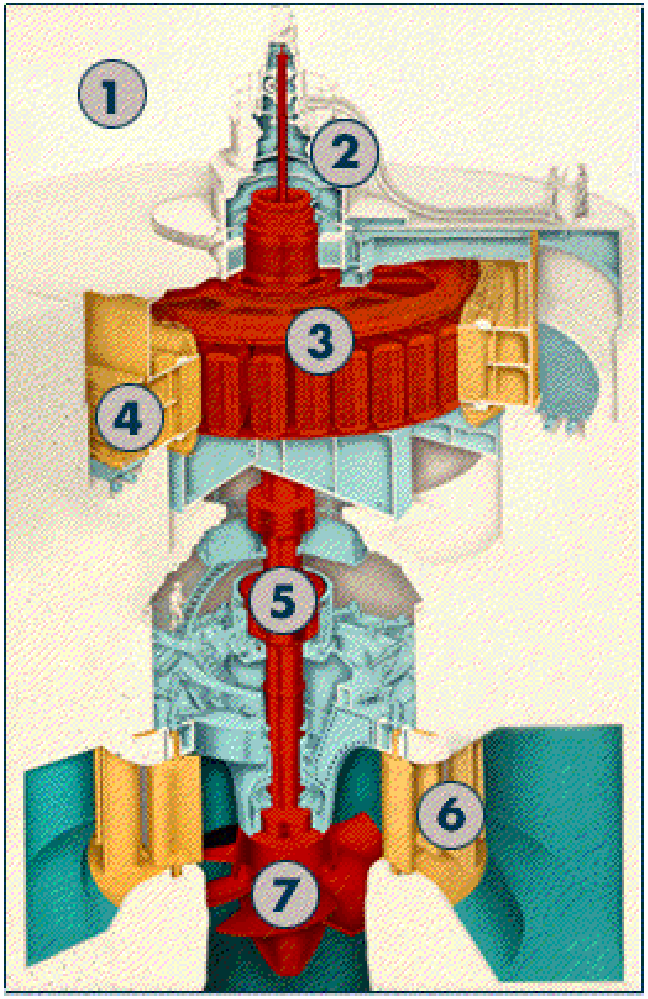
3 The rotor.

4 The stator

5 The shaft connects the turbine to the rotor section of the generator.

6 Wicket gate.

7 Turbine.



Power House and Turbine