Power Delivery Systems Overview

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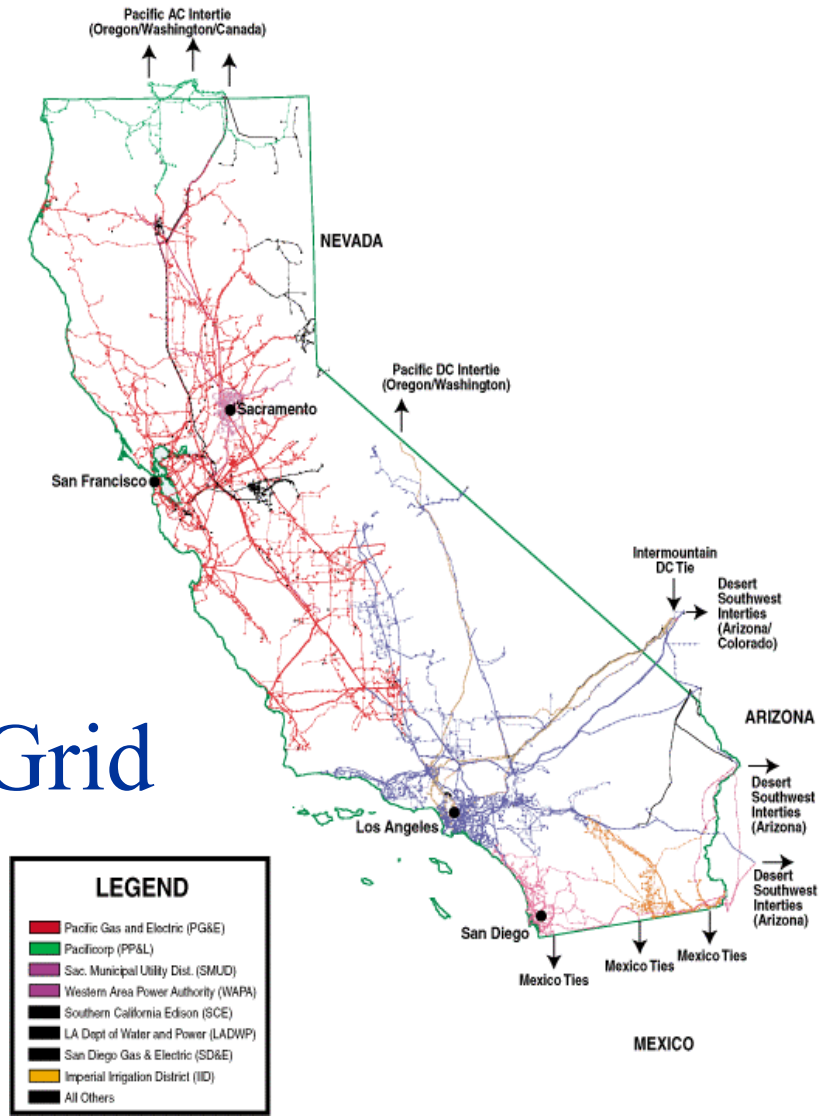
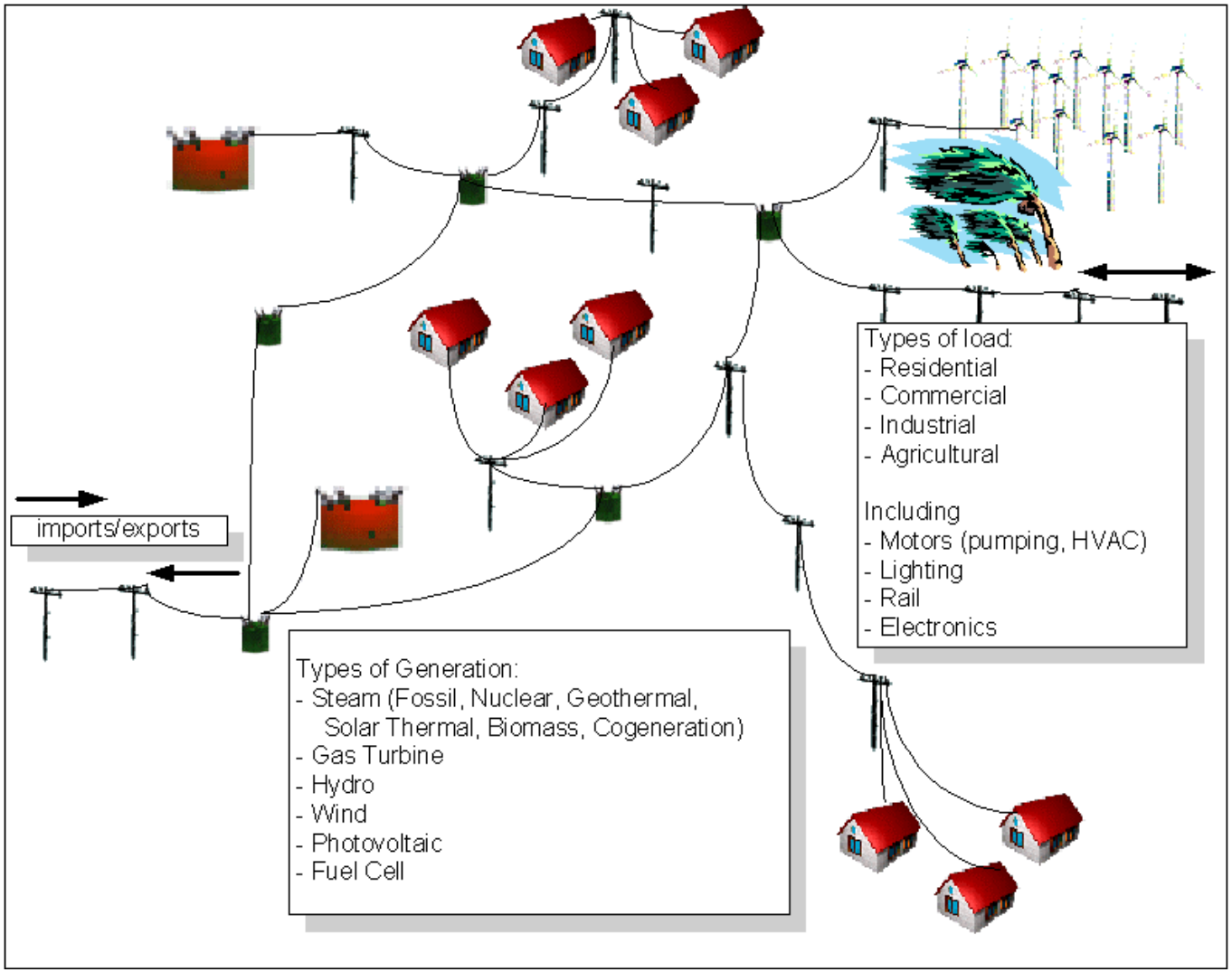
California Transmission Grid




imports/exports
Types of Generation:
- Steam (Fossil, Nuclear, Geothermal, Solar Thermal, Biomass, Cogeneration)
- Gas Turbine
- Hydro
- Wind
- Photovoltaic
- Fuel Cell
Types of load:
- Residential
- Commercial
- Industrial
- Agricultural
Including
- Motors (pumping, HVAC)
- Lighting
- Rail
- Electronics

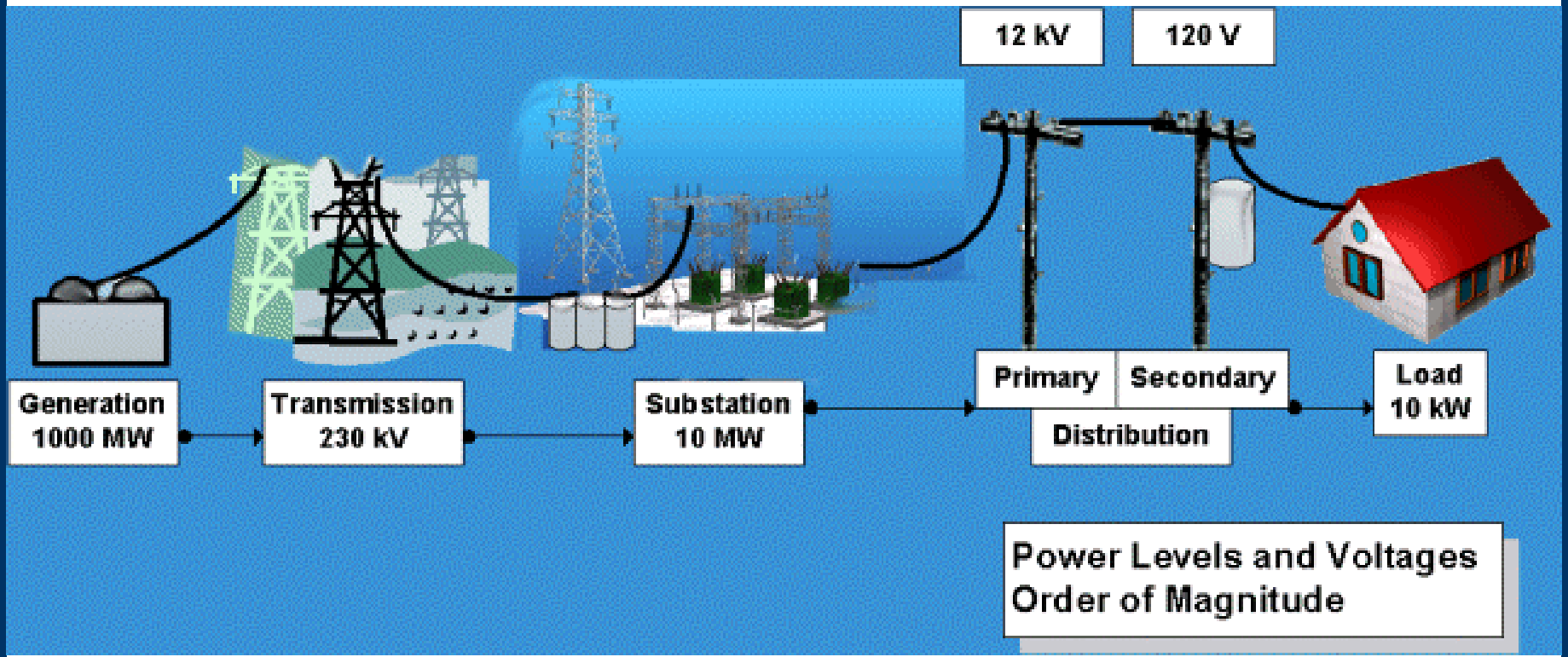
Why are power systems large and interconnected?

- Economies of scale in generation
- Load factor (load diversity)
- Pooled resources

  (reliability, access to low-cost resources)

Why do we use alternating current (a.c.)?

- Want high voltage transmission (minimize I^2R losses) but low voltage service (safety)
- Transformers are cheap & easy but work only with a.c.


12 kV
120 V
Generation
1000 MW
Transmission
230 kV
Substation
10 MW
Primary
Secondary
Distribution
Load
10 kW
Power Levels and Voltages
Order of Magnitude

Why hierarchical structure of T&D system?

- Centralized large-scale generation
- Coordination & control

Why radial structure of distribution system?

- Circuit protection
- Cost

One-way philosophy:

- **One-way flow of power**
- **One-way flow of control**
- **Demand is externally given;**
  supply is adjusted to meet demand


PG&E
Cotati
Substation

T&D Hardware:

- Typical age on the order of decades
- Key technology a century old
- Traditional design and operating philosophies consistent with hardware capabilities
- Existing infrastructure represents large investment; not simply replaced

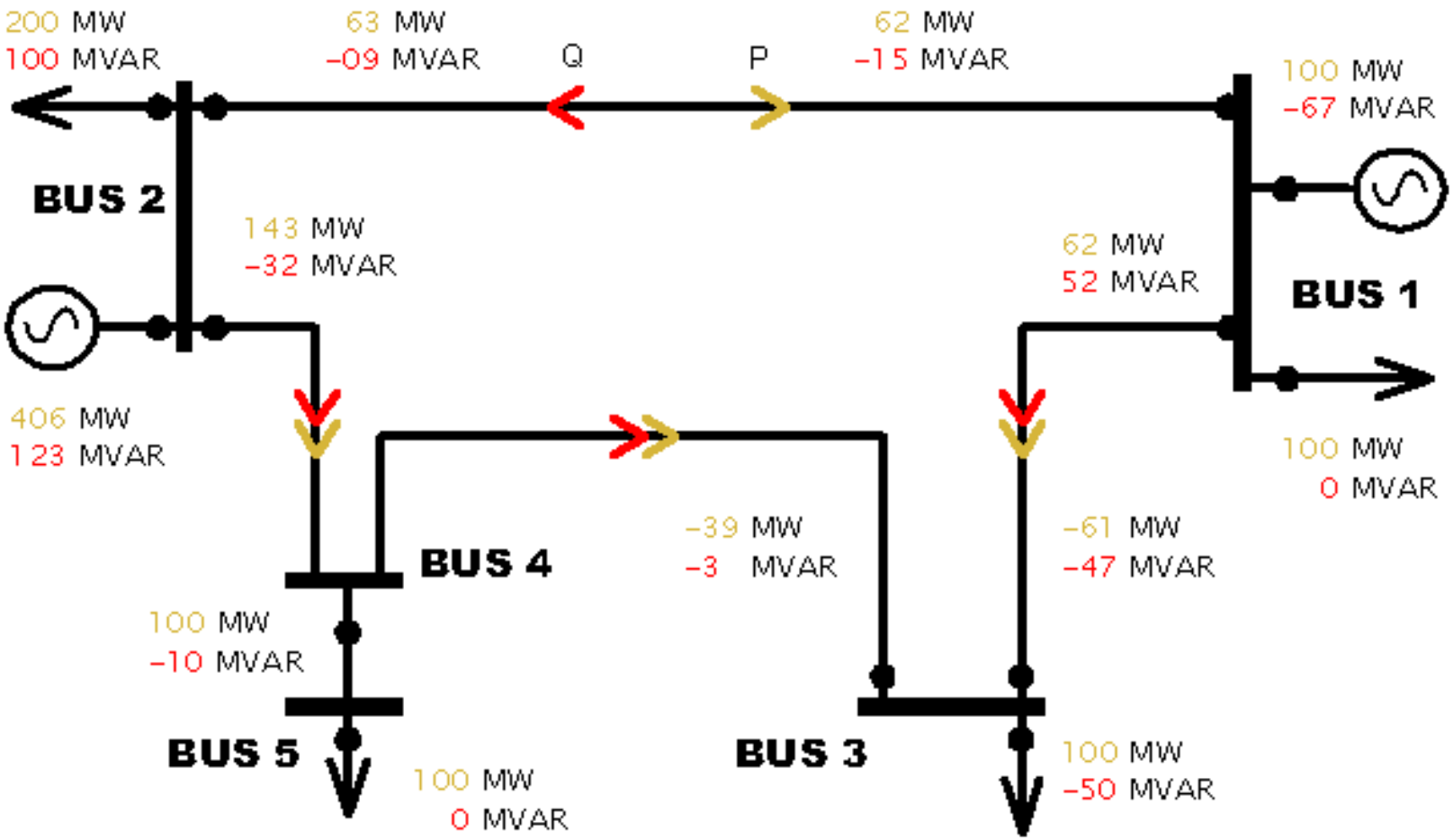
Culture clash?

- **Newer information technologies may be overlaid and integrated with existing power hardware, but may conflict with traditional operating philosophies.**

Why is industry attached to traditional philosophies?

- Cultivated risk averse attitude
- High stakes; real danger
- Complexity and challenge of operation task calls for minimizing uncertainty (of which there is a lot)

Power Flow Example



How can such old technology be so complicated?

- Complexity = no single individual can comprehend entire system at once
- Large number of buses, all interdependent
- Strict real-time operating constraints
  (power in = power out; capacities)
- Power flow problem has no closed-form solution; solved approximately by iteration
- Predicting effects of change in one variable requires simulating entire system
- Disturbances propagate (e.g. the Oregon tree)

How does this research fit in?

- Proposing to turn traditional one-way philosophy upside down by considering demand as controllable
- Small change in hardware may represent major conceptual change
- Location & function of prospective DR technology within system (e.g. meters, thermostats)

New Technologies in Context