Electric Power Distribution

- Power generation and consumption in different places
  - Need to move electric power
- Power generation and demands change dynamically
  - Need to adapt electric power distribution
- Today’s lecture:
  - Electric power grid
  - Marketplace for electric power

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Importance of Electricity

- Northeast blackout on August 14, 2003

Normal Night
During Blackout

Power Distribution

- How does power get from generation point to home?
Components

- Power plant
- High-voltage transmission line
- Substation
- Distribution line
- Transformer
- Service line
Transmission Lines

- Voltages as high as 500 kV
- Typically three-phase AC
  - DC in some special cases

High-Voltage Cables

- Conventional cables
  - Large diameter to reduce resistance
  - Large insulation
- Superconductor cables
  - No resistance
  - Need to be cooled
Substation

- Conversion from high-voltage to lower voltage

Transformer and Service Line

- Transformer converts voltage down to 110V
Safety

- High-voltage obviously hazardous

Live-Line Repair

- Skilled technicians can repair powered lines

- Why is high-voltage used for transmission lines?
Energy Losses

- Power dissipation in resistance: \( P_{\text{loss}} = I^2R \)
  - Power to transmit: \( P_t = V \cdot I \)
  - Power dissipation depending on voltage: \( P_{\text{loss}} = \frac{P_t^2}{V^2} \)

- Electricity flow in US (part of last week’s chart):

Power Grid Challenge

- How would you design a power grid?
  - Few power sources (i.e., plants)
  - Variable consumption
  - Need for reliability
  - Etc.
Dynamics

- What are reasons for changes in demand?
  - Think short-term and long-term
- How can the grid adapt?

Adaptation

- Turn power plants on and off
  - Slow process
    - Plants take time to come online
    - Need to run for a while to make it worthwhile
- Move power around
  - Divert power from low-demand to high-demand area
  - Transmission losses limit range where this makes sense
- Control problem
  - What to do when?
Electricity Market

- Electricity can be traded as a commodity
  - Two types: power and energy
- Suppliers
  - Power companies
- Retailers
  - Utility companies selling to customers
- Market
  - Trading based on supply and demand
  - Allows for risk management
  - Market organized into regions (ISO New England)
- Big difference to other commodities
  - Electricity cannot be stored (in most cases)
  - Trading needs support from transmission system operator

Electricity Prices

- From Federal Energy Regulatory Commission (FERC)
Electricity Demand

- From Federal Energy Regulatory Commission (FERC)

Weekly Generation Output and Temperatures New England

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California Electricity Crisis

- What if electricity becomes very expensive?

The New York Times

California in State of Emergency Over Power

By JAMES EYRING and STEVE LEVIT

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Enron Involvement

- LA Times, Feb 4, 2005:
  ... According to the newly released transcript, Enron traders on Jan. 16, 2001, hatched a plan to take an Enron-controlled power plant in Las Vegas off-line the following day. In a phone call, “Bill of Enron” informed “Rich,” a Las Vegas power plant employee, that “we want you guys to get a little creative ... and come up with a reason to go down.”

The shutdown, he added, was “supposed to be, ah, you know, kinda one of those things.”

In an effort to cooperate, Rich responded: “OK, so we're just comin' down for some maintenance, like a forced outage type thing?”

”I think that's a good plan, Rich,” Bill said. “... I knew I could count on you.”

The 52-megawatt plant was out of operation for several hours the next day, when rolling blackouts plagued Northern and Central California and about half a million homes and businesses lost power. ...

Renewable Energy Sources

- Integration of new power sources into grid
  - Commercial and residential solar systems
  - Wind energy systems

- Sources of energy not co-located with demand
  - Often away from existing power grid
  - Problem of moving power into grid
Courses in ECE Curriculum

- ECE 597D – Power Systems
- ECE 580 – Feedback Control Systems
- ECE 665 – Algorithms

Upcoming...

- Next Wednesday: air traffic control
  - Radar
- Moodle quiz
Interesting Links

- Maps of power grids:
  - http://www.itoworld.com/map/4

- Maps of energy generation and use:
  - http://www.iso-ne.com/

- Grid frequency
  - http://www.dynamicdemand.co.uk/grid.htm
  - http://fnetpublic.utk.edu/gradientmap.html
  - http://powerit.utk.edu/worldmap/

- Energy prices:
  - http://www.iso-ne.com/