



University of
Massachusetts
Amherst

Lecture 6–Power Distribution

ECE 197SA – Systems Appreciation

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



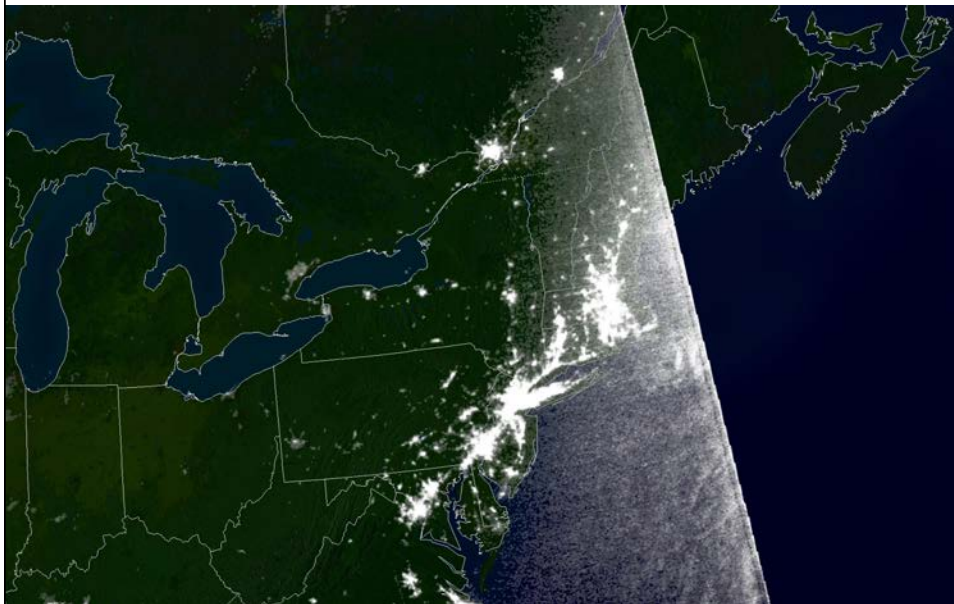
Importance of Electricity

- Northeast blackout on August 14, 2003



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Normal Night



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During Blackout



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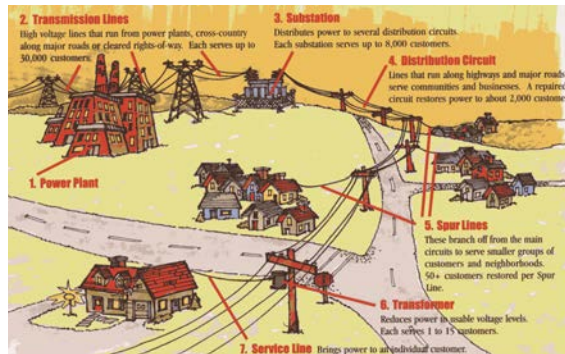
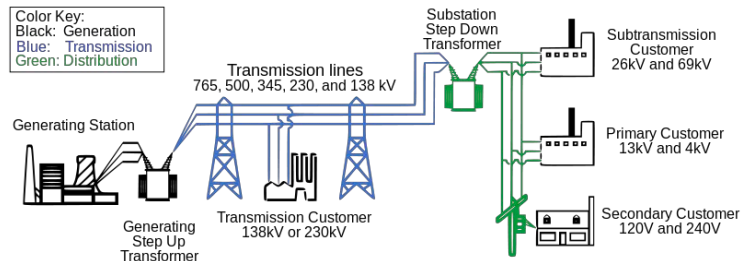
Power Distribution

- How does power get from generation point to home?

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Power Transmission and Distribution



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Components

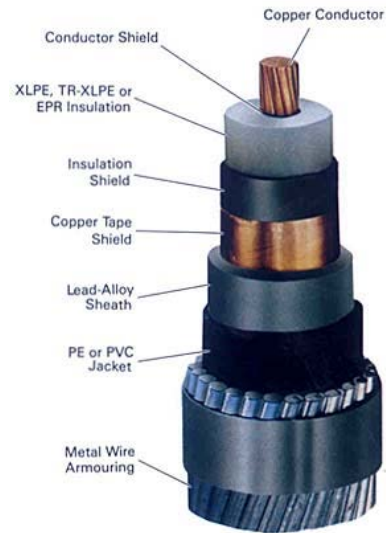
- Power plant
- High-voltage transmission line
- Substation
- Distribution line
- Transformer
- Service line

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Transmission Lines

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

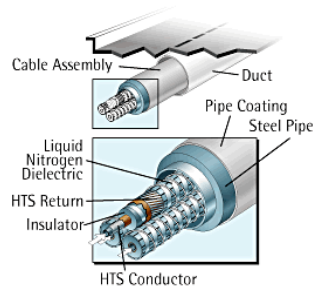


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High-Voltage Cables

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



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Substation

- Conversion from high-voltage to lower voltage

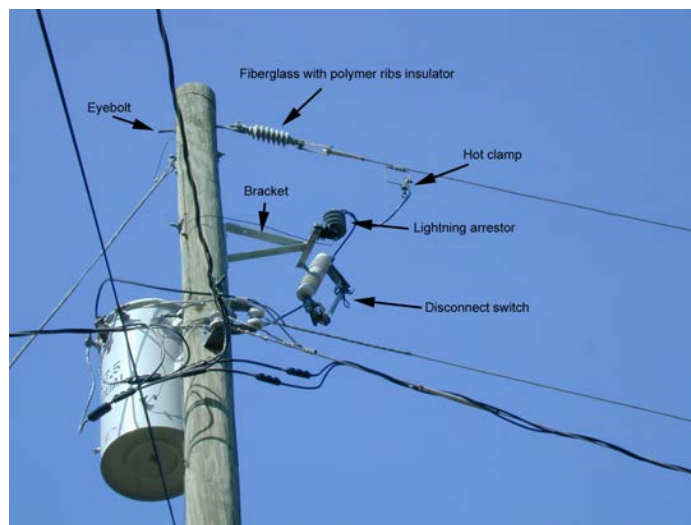


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Transformer and Service Line

- Transformer converts voltage down to 110V



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Safety

- High-voltage obviously hazardous



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Live-Line Repair

- Skilled technicians can repair powered lines



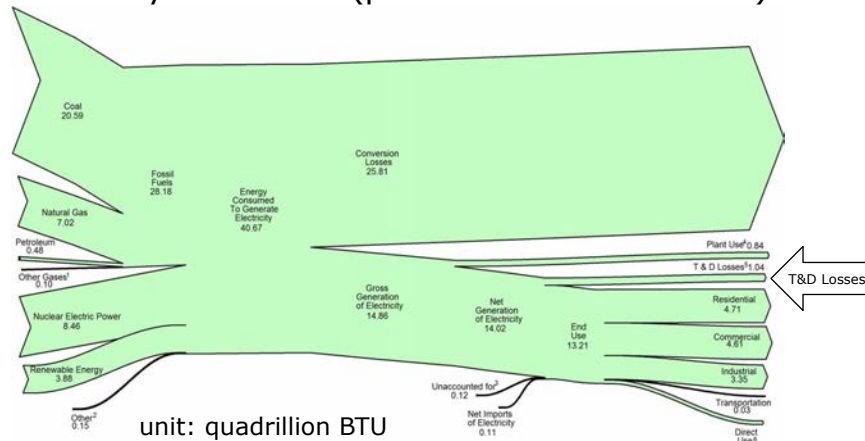
- Why is high-voltage used for transmission lines?

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Energy Losses

- Power dissipation in resistance: $P_{\text{loss}} = I^2R$
 - Power to transmit: $P_t = V \cdot I$
 - Power dissipation depending on voltage: $P_{\text{loss}} = P_t^2 R / V^2$
- Electricity flow in US (part of last week's chart):



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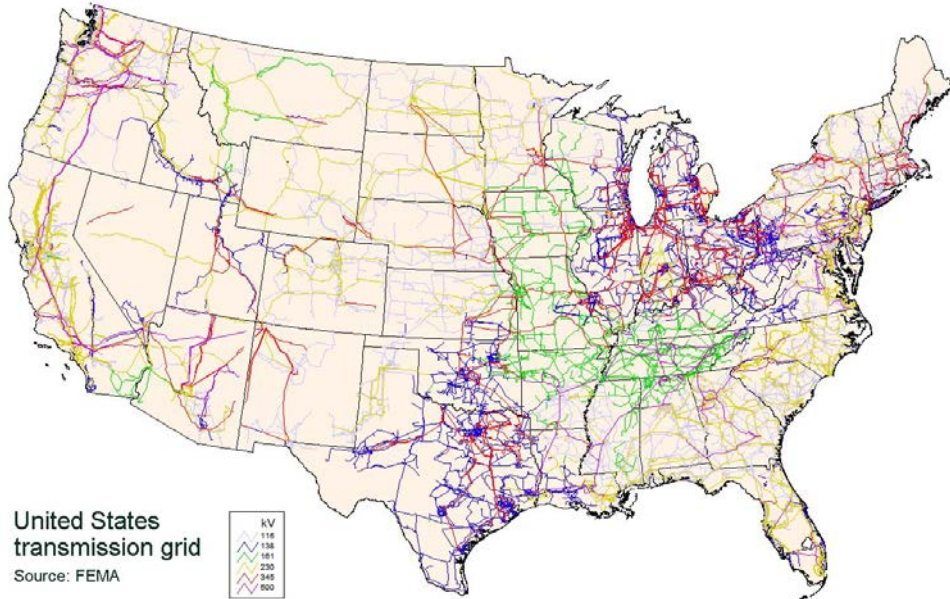
Power Grid Challenge

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

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US Power Grid

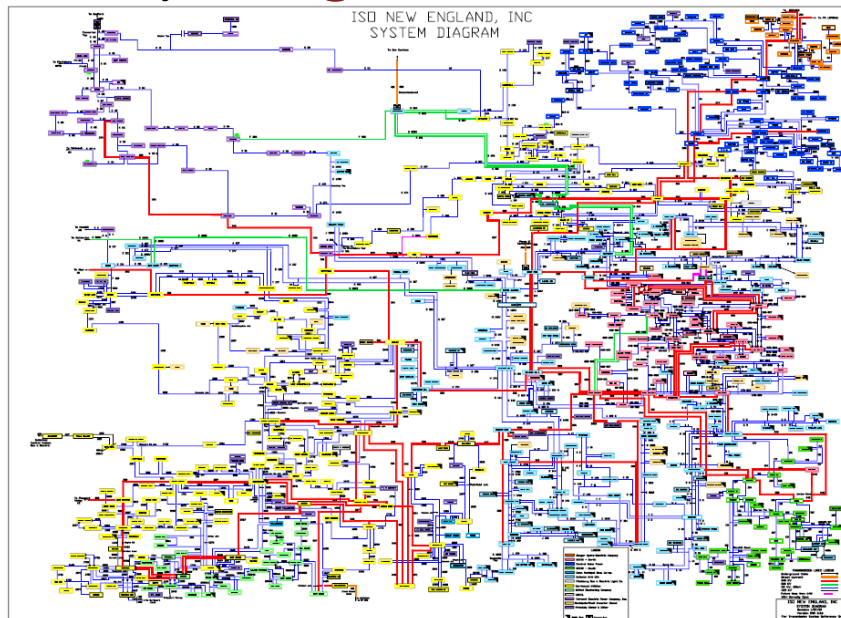


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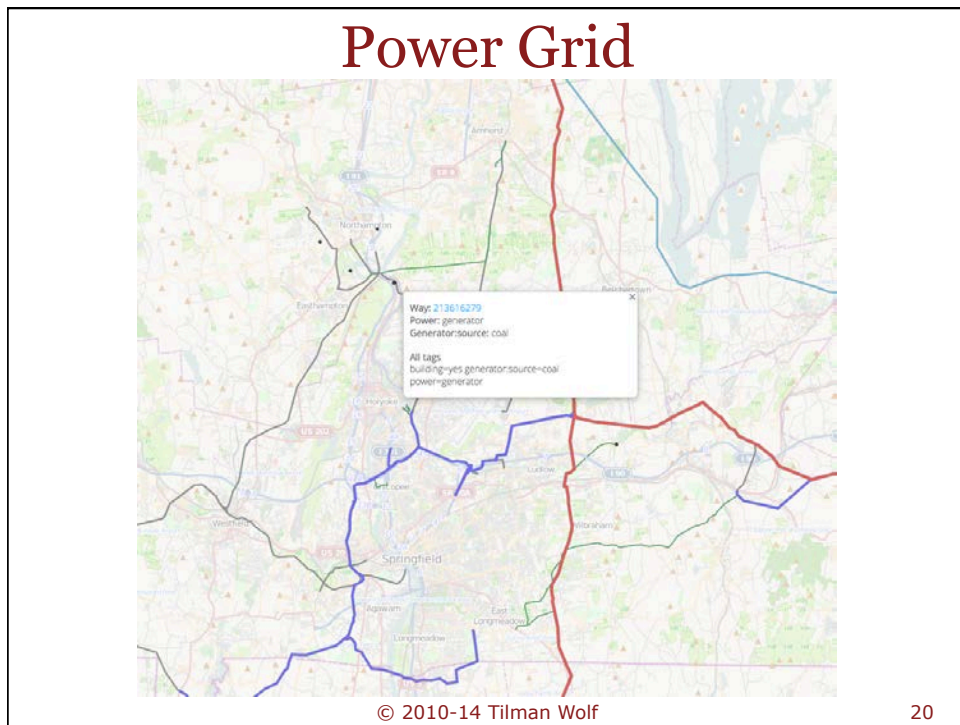
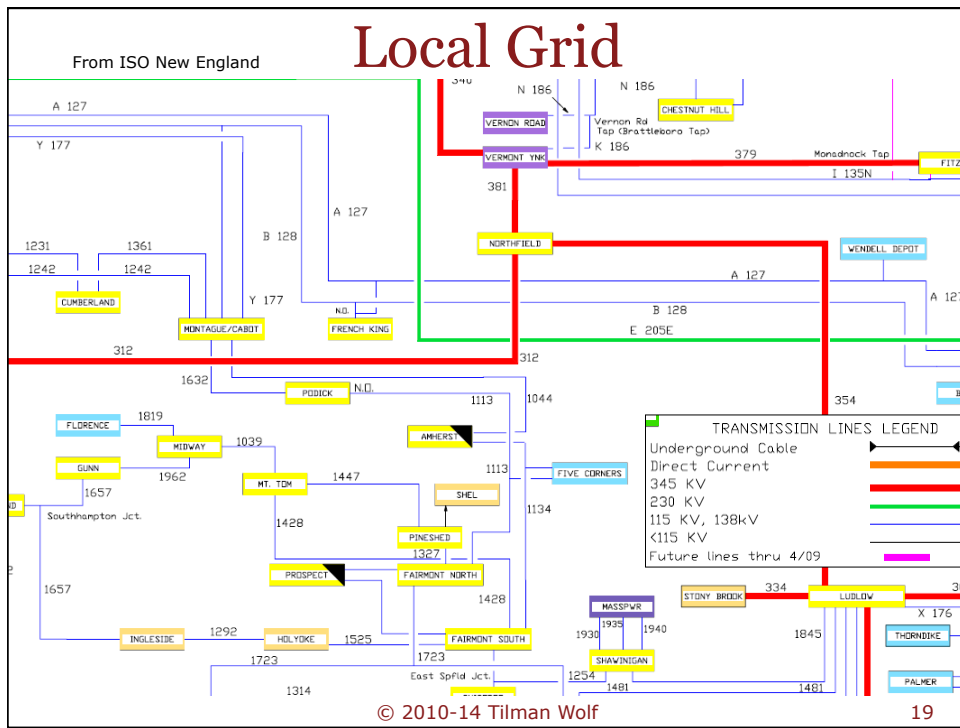
Regional Grid

From ISO New England



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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

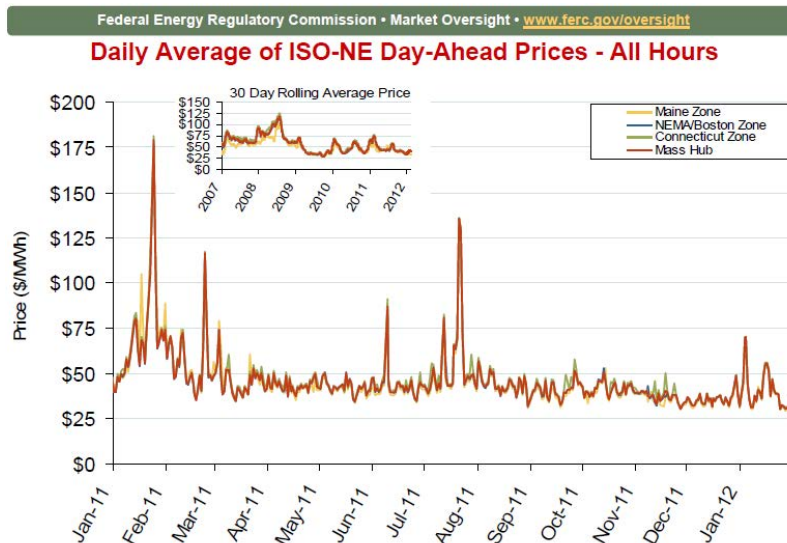
- Electricity can be traded as a commodity
 - Two types: power and energy
- Suppliers
 - Power companies
- Retailers
 - Utility companies selling to customers
- Market
 - Trading based on supply and demand
 - Allows for risk management
 - Market organized into regions (ISO New England)
- Big difference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

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Electricity Prices

- From Federal Energy Regulatory Commission (FERC)



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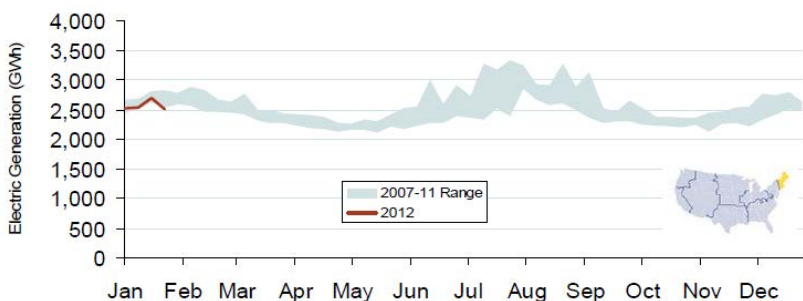
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Electricity Demand

- From Federal Energy Regulatory Commission (FERC)

Federal Energy Regulatory Commission • Market Oversight • www.ferc.gov/oversight

Weekly Generation Output and Temperatures New England



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California Electricity Crisis

- What if electricity becomes very expensive?

"All the News That's Fit to Print"

The New York Times

Late Edition
New York: Today, cloudy, a few sprinkles late, high 38. Tonight, light rain or snow, low 35. Tomorrow, periods of rain arrive, high 41. Yesterday, high 42, low 38. Details, Page B11

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of interim leader of Congo's wobbly government, which has been opposed by three rebel groups and two outside nations since Mr. Kabila took over in 1997.

These enemies, aware that the uncertainty could explode into greater violence, called for a renewed commitment to a peace accord that was signed in mid-1999 — though not respected by any side.

"He has been a difficult man, but it is not in our tradition to derive pleasure from people dying," said Joseph Bideri, spokesman for the Rwandan government. "However, it is important to point out that President Kabila was an obstacle" to honoring the peace accord. Rwanda and Uganda have backed rebel groups opposed to Mr. Kabila and stationed their own troops in Congo.

Early today Mr. Kabila, alive or dead, was flown to Zimbabwe, which has been an ally since August 1998 in emergency actions.

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California in State of Emergency Over Power

By JAMES STERNGOLD

LOS ANGELES, Jan. 17 — Gov. Gray Davis of California declared a state of emergency late this evening after the state was forced to cut power temporarily for hundreds of thousands of people on a swath from Oregon to Bakersfield.

While planned, controlled blackouts have occurred before in the state on a modest scale, this was the first time that they were carried out over such a large area. And despite frantic efforts by utilities and state officials to keep up enough power for later in the week, the prospect of continuing blackouts put pressure on the governor to step in and take emergency actions.

Governor Davis provided few specifics in his announcement, other than saying that the state's two largest utilities, Pacific Gas and Electric and Southern California Edison, were on the verge of being forced into bankruptcy and that he was ordering a state agency, the Department of Water Resources, to become the principal purchaser of electricity from the big generating companies that supply the state. The state would then sell the power to the financially strapped private utilities.

"The imminent threat of widespread and prolonged disruption of electrical power to California's emergency services, law enforcement, schools, hospitals, homes, businesses and agriculture constitutes a condition of extreme peril to the safety of persons and property within the state which, by reason of its magnitude, is likely to be beyond the control of the services, personnel, equipment, and facilities of any single county or city," Governor Davis said in his declaration.

The emergency declaration recognized that one of the factors that caused the blackouts and threatened more in the days ahead was the fact that the big generating companies were refusing selling their power to utilities that might never be able to pay for it.

The governor said four of these generators, the Duke Energy Corporation, the Southern Company, Reliant Energy Inc. and Dynegy Inc., were prepared to finally put the utilities into bankruptcy court, but had agreed to wait now that the state,

led by Dr. Lene Vestergaard Haas of Harvard University and the Rowland Institute for Science in Cambridge, Mass., and the other by Dr. Ronald L. Walsworth and Dr. Mikhail D. Lukin of the Harvard-Smithsonian Center for Astrophysics, also in Cambridge.

Light normally moves through space at 186,000 miles a second. Ordinary transparent media like water, glass and crystal slow light slightly, an effect that causes the bending of light rays that allows lenses to focus images and prisms to produce spectra.

Using a distantly related but much more powerful effect, the Walsworth-Lukin team first slowed and then stopped the light in a medium that consisted of specially prepared containers of gas. In this medium, the light became faster and faster as it slowed and then stopped. By flashing a second light through the gas, the team could essentially revive the original beam.

The beam then left the chamber carrying exactly the same shape, intensity and other properties it had when it entered. The experiments led by Dr. Haas achieved similar results with close y related techniques.

"Essentially, the light becomes

rely heavily on the ability of light to carry so-called quantum information, involving particles that can ex-

Continued on Page A21

INSIDE

Iraq a Puzzle in Oil Cuts
AS OPEC reduced oil production by 5 percent, Iraq loomed as a threat to the group's efforts to balance supply and demand. PAGE C1

Camby Banned for 5 Games
The N.B.A. gave a five-game suspension to Marcus Camby, who accidentally injured his coach while trying to punch an opponent. PAGE 10

Leonard Woodcock Dies
The leader of the United Auto Workers and later the United States envoy to China during the Carter administration, he was 89. PAGE 8A

\$7 Million for the Neediest
The New York Times Neediest Cases Fund has received more than \$7 million in donations for the first time in its 89-year history. PAGE 8E

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Enron Involvement

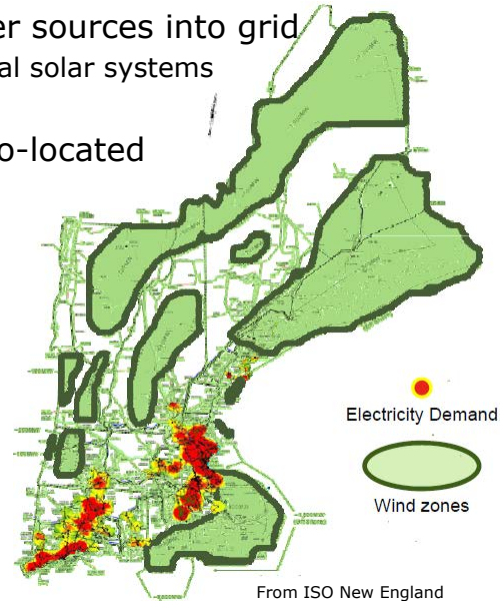
- LA Times, Feb 4, 2005:
... According to the newly released transcript, Enron traders on Jan. 16, 2001, hatched a plan to take an Enron-controlled power plant in Las Vegas off-line the following day. In a phone call, "Bill of Enron" informed "Rich," a Las Vegas power plant employee, that **"we want 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. ...

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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



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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.geni.org/globalenergy/library/national_energy_grid/
 - <http://www.itoworld.com/map/4>
- Maps of energy generation and use:
 - <http://www.npr.org/templates/story/story.php?storyId=110997398>
 - <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/>
 - <http://www.pjm.com/pub/account/lmpgen/lmppost.html>