The electricity grid

GEOS 24705/ENST 24705
Lecture 14

Figure: EPRI

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The electrical grid: link between generation and consumption

For most of 20th century, one entity owned all components in chain

Now typically owned by 2 or 3 diff. entities, managed by another, and market can be managed by outside broker – up to 5 players in game

- Generator
- Transmitter (long-dist. wires)
- Grid operator (wires operator)
- Utility for distribution (local wires)
- Load-serving entity (seller to consumer)
Electrical grid operation: physical infrastructure questions

- What controls how much power flows, and where?
- How much power is lost in transit?
- Why so many different voltages?
- What happens when too few people want power?
- What happens if too many people want power?
- How do blackouts happen?
- What happens if voltage or frequency is beyond specifications?
- How reliable is the grid?
- What are problems with bringing renewables online?
- How much does it cost to build a transmission line?
Electrical grid operation: management questions

• Who owns what? (generation, transmission, distribution)
• Who pays, and to who?
• Who sets the amounts that people pay?
• Who makes the rules?
• Who enforces the rules? (inspects, investigates, fines)
• Who builds the grid?
• Who plans? (if anyone...)
• Who bears liability if something goes wrong?
• How much extra capacity is there at any given time?
Electrical power transmission: why are lines in multiples of 3?

Image: PennLive.com

Image: NationalGrid
Electrical power transmitted as 3-phase power

Why 3-phase? Because voltages (and current) sum to 0 if perfectly balanced – meaning there is no need for a return wire, which saves costs.

Also power (I*V, prop. to V^2) sums to a constant – there are no fluctuations in the power transmitted.
Distribution: neutral wire is added

As power is distributed from substations to neighborhoods or households, currents may become unbalanced. Different houses (or sometimes circuits within a house) will draw on the different single-phase circuits, and if these loads are unbalanced, a net flow of current would occur. A neutral (return) wire is therefore added at some point.

The return loop of current is not all the way back to the generator but (usually) just to the substation, or sometimes even just to the local transformer.

At your house, an additional wire – a grounding wire for protection against faults – is added and wired to the actual physical ground.
Electrical grid operation: basic questions

- What controls how much power flows, and where?

Nothing except the balance of generation and demand – an entire interconnected grid is a single complex circuit. Imagine a plumbing system with interconnected pipes but no “valves” that control the flow of current. You can’t control what power flows where except by tinkering with inputs and outputs.

The U.S. grid is broken into 3 weakly connected regions, and not much power flows in between. But the regions are connected to Canada (strongly) & Mexico (weakly).

Texas is its own grid! And its own regulatory entity.

Electrical grid operation: basic questions

- Why so many different voltages?

Note also different layout in E. and W.
Electrical grid operation: basic questions

• Why so many different voltages?

To some extent is logical – don’t want to waste money building big transformers for lines running a short distance, if can get away with lower voltage.

To some extent is historical circumstance – grid arose from many independent companies and regions, all of which picked their own voltage standards.

For historical reasons, typical voltages are different in Eastern and Western U.S.
Electrical grid operation: basic questions

• How much power is lost in transit?

Total ~ 7% of power lost

Losses due to:
• Joule heating ($I^2R$) (resistive losses)
• Coronal discharge losses
• Inductance and capacitance (reactive power)

- Conductor size is large and $V$ high to minimize resistive losses
- Coronal discharge sets upper limit on $V$
- Inductance and capacitance losses are not a factor for DC

Total U.S. network: 300,000 km, > 250,000 km are > 230 kV
Individual HVDC transmission line lengths > 1000 km
(mostly in China, carrying > 3 GW each)
Suggested practical limits to transmission length:
~ 7000 km DC, 3-4000 km AC
(Paris et al., 1984). U.S. is ~ 4600 km x 2000 km

<table>
<thead>
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<th>Voltage (kV)</th>
<th>Length (miles)</th>
<th>Maximum capacity (GW)</th>
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<tr>
<td></td>
<td>400</td>
<td>0.1</td>
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</tbody>
</table>

Electrical grid operation: basic questions

• What happens when too few people want power?

Command and control:
Operators shut down generating plants or shed power

Market response:
Cheap power induces wildcatters to buy and store

Failure mode:
If no regulation of generation/load balance, generators would start to spin too fast and both voltage and frequency of grid would rise – remember $V = B * A * N * 4 * f$
Electrical grid operation: basic questions

• What happens if too many people want power?

Command and control:
Grid operators buy more power even from high-cost generators – short-term prices spike. Also shut down demand (contracts with some industrial purchasers include provision to shut them down when demand is too high). Order rolling blackouts if desperate.

Market response:
No market-driven demand response yet – no hourly pricing on retail end

Failure mode:
Generators can’t keep up, both voltage and frequency of grid drop: get brownouts. Generators may also work too hard and overheat, or transmission lines may be overloaded.

Brownouts: because incandescent bulbs are highly voltage-dependent, get dim (brownish) with even slight voltage drops
Electrical grid operation: basic questions

- How do blackouts happen?

**Failure mode:**
Overworked generators or transmission lines are shut down, increasing the load elsewhere and overloading more generators and lines, which are in turn shut down ... get cascading failures, each of which causes more failures: a chain reaction.

**Only solution:**
Containment – isolate healthy parts of the grid from the failing parts.
Electrical grid operation: basic questions

- What happens if voltage or frequency is beyond specifications?

**Space heaters:**
Don’t care.

**AC-DC converters:**
Typically don’t care.

**Lightbulbs:**

**Electric motors:**
Spin faster or slower with frequency, can burn out.

**Electronics:**
Can be very sensitive and can die quickly. Computers especially vulnerable.
Electrical grid operation: basic questions

• How reliable is the grid?

Federal Electricity Regulation Commission (FERC) chairman Joseph Kelliher:

“The U.S. transmission system has suffered from underinvestment for a sustained period. In 2005, the expansion of the interstate transmission grid in terms of circuit miles was only 0.5 percent. At the same time, congestion has been rising steadily since 1998.”


“There is growing evidence that the U.S. transmission system is in urgent need of modernization. The system has become congested because growth in electricity demand and investment in new generation facilities have not been matched by investment in new transmission facilities. Transmission problems have been compounded by the incomplete transition to fair and efficient competitive wholesale electricity markets.”

What happened in 2003? As predicted, major blackouts over the Northeast, Midwest, and Canada, in August during peak demand, because of initial instabilities that cascaded
Electrical grid operation: basic questions - How reliable is the grid?

The Report Card for America's Infrastructure, prepared by the American Society of Civil Engineers, gives the US Electric Grid a rating of D.

“The U.S. power transmission system is in urgent need of modernization.” Growth in electricity demand and investment in new power plants has not been matched by investment in new transmission facilities. Maintenance expenditures have decreased 1% per year since 1992. Existing transmission facilities were not designed for the current level of demand, resulting in an increased number of "bottlenecks," which increase costs to consumers and elevate the risk of blackouts.”

Edwin D. Hill, president of Intnl. Brotherhood of Electrical Workers:
“The average age of power transformers in service is 40 years, which also happens to be the average lifespan of this equipment. Combine the crying need for maintenance with a shrinking workforce, and we may find that the 2005 blackout that affected parts of Canada and the northeastern United States might have been a dress rehearsal for what's to come. Deregulation and restructuring of the industry created downward pressure on recruitment, training and maintenance, and the bill is now coming due”.
Electrical grid operation: basic questions - How reliable is the grid?

North American Electricity Reliability Council (NERC) (2004 letter to Congress):

“Thus, the future of the U.S. transmission network is uncertain and is a continuing concern. Overall use of the transmission system is growing without significant additions of new construction or upgrades. Approval of new projects and the acquisition of new rights-of-way have been difficult. Many customers oppose having new transmission facilities built nearby. These transmission facilities support interstate commerce; but the siting and approval are generally a state and local governmental responsibility. In addition, the prelude to deregulation created and continues, to some degree, to cause limited investment in the transmission system.

The transmission grid is intended to be flexible, reliable and open to all exchanges, regardless of where the suppliers and consumers of energy are located. But neither the existing transmission grid nor its current management infrastructure can fully support this diverse and open exchange. The existing system was built for local needs, and is struggling to meet the demands of a global system brought about by deregulation. Electricity transactions that are highly desirable from a market standpoint may be quite different from the transactions for which the transmission grid was designed, and may stress the limits of safe operation.

The risks that they pose may not be recognized in time to avert major system emergencies, and, when emergencies occur, they may be of unexpected types that are difficult to manage without loss of customer load.
Electrical grid operation:

• How reliable is the grid?

Congestion increases the chances of cascading failures.

Congested corridors have been known for decades

“National Interest Transmission Corridors” have been formally designated in Mid-Atlantic and Southwest.


Few permits have been issued — finally (2010) TRAIL line is under construction (Ohio -> N Jersey)

From DOE 2006 Electricity Congestion Study
Southwest National Interest Transmission Corridor:
Continuing ... electrical grid operation: basic questions

- What controls how much power flows, and where?
- How much power is lost in transit?
- Why so many different voltages?
- What happens when too few people want power?
- What happens if too many people want power?
- How do blackouts happen?
- How do you shut off part of the grid deliberately?
- What happens if voltage or frequency is beyond specifications?
- How reliable is the grid?
- What are problems with bringing renewables online?
- How much does it cost to build a transmission line?
Electrical grid operation: basic questions

• What are problems with bringing renewables online?

**Timing:** solar isn’t on at night at all. Wind is on equally day and night

**Intermittency:** wind and sun are both erratic

**Inefficiency:** DC-AC conversion (solar or variable-speed wind); inefficiencies required to produce AC (wind)

**Scale:** distributed generation means multiple connections

**Safety:** need automatic disconnects to protect workers

**Inductive load:** wind, which uses induction generator that cause reactive loads.

\[ P = I \times V, \text{ but in AC power transmission, power can only be transmitted if } I \text{ and } V \text{ are in phase. If out of phase, that power can’t actually be used ("reactive power") .. but still creates heating in wires (which have some inductance and capacitance).} \]
Electrical grid operation: basic questions

- What are problems with bringing renewables online?

**Inductive load:** to correct, utilities must switch in capacitor banks or deliberately generate reactive power to compensate
Electrical grid operation: basic questions

- How much does it cost to build a transmission line?

... about $1M/km in practice

Arrowhead-Weston line in Minnesota cost > $1.1 M/ km in 2002
Original estimate ~ $0.7M/ km
Cost nearly doubled from original projections. Environmental safeguards and payments to landowners were large cause of overrun, plus two-year delay caused by opposition and permit issues

Permitting hassles perhaps double the cost

Australian outback: proposed 220 kV line from Southdown magnetite mine (2006) estimated at $0.6M/km, no people to complain

Projected total costs in future are high

Estimates of annual cost in U.S. that will need to be spent in next 10 years just to keep pace with electricity demand: $9-12 B/yr

(Report Card for America’s Infrastructure, ASCE, 2005)
Electrical grid operation: basic questions

• How is voltage transformed?

AC transformers work on Ampere’s and Faraday’s laws: changing AC current generates magnetic field, and changing magnetic field in turn generates current. Inside giant box is just a core with 2 wire windings.

DC transformer must operate via power electronics

*Images from ATSI Engineering Services (L) and The Electricity Forum (R)*
Electrical grid organization and management: basic questions

• Who owns what? (generation, transmission, distribution)
• Who pays, and to who?
• Who sets the amounts that people pay?
• Who makes the rules?
• Who enforces the rules? (inspects, investigates, fines)
• Who builds the grid?
• Who plans? (if anyone...)
• Who bears liability if something goes wrong?
• How much extra capacity is there at any given time?
Electrical grid: major regulatory shifts

1. **UNIFYING AND CENTRALIZING GRID:** shift from disconnected organizations and transmission to unified transmission (3 grid regions)
   - Federal Power Act (1920, 1935, etc. amended), led to FERC in 1977 to regulate rates (+ license hydro)
   - post 1964 blackout – more communication between utilities
   - voluntary reliability council (NERC) replaced by “Electric Reliability Organization” with actual enforcement authority in 2005

2. **MARKET FORCES:** Transition from vertically integrated regional monopolies (one utility owns generation, transmission, distribution) to competitive systems
   - 1993: FERC can order a company to carry power for someone else
   - formation of Regional Transmission Organizations (RTOs)
   - in most places now: utility buys from multiple independent generators, market for power, hourly pricing
   - proposals for market system on retail side too (req. hourly pricing)
   - no one has figured out competitive distribution yet
3. **DECENTRALIZING GENERATION: Encouragement of distributed power:**
   - small (2-10 MW) operators can sell at market rate by Fed. law
   - demand-side management, or DSM (pay for “negawatt” generation) now an option in some markets, some areas
Electrical grid organization and management: basic questions

• Who owns what? (generation, transmission, distribution)
Electrical grid organization and management: basic questions

- Who owns what? (generation, transmission, distribution)

**High-voltage transmission**: generally owned by utilities, managed by RTOs (regional transmission organizations), themselves owned by groups of utilities.

**Definition: Regional Transmission Organization** - an entity created to balance generation across a regional footprint regardless of ownership of generation. Invented to promote competition and hopefully efficiency.

RTO’s eliminate the need for generators to contract with separate utilities to sell and transmit power, and prevent integrated utilities to favor their own generation and block transmission of competitors. The goal is to create a transparent market to incentivize more optimal building and dispatching of generation.
Electrical grid organization and management: basic questions

- **Who owns what?** (generation, transmission, distribution)

### RTOs as of 2000 (EIA, DOE)

#### Updates:
- Alliance never happened, all went to MISO, now part of Ohio -> PJM, LA+ AR are their own RTO
- **Texas is unique**
  - chose to remain entirely intra-state system, never subject to Federal Regulation

#### RTO Exceptions:
- SE U.S. is traditional utility ownership and operation on big scales (e.g. TVA, The Southern Company) so no need for RTOs
- Rocky Mtn. corridor doesn’t have much transmission
- AZ doesn’t have central market but sells to California
Electrical grid organization and management: basic questions

- Who owns what? (generation, transmission, distribution)

*RTOs as of 2010 (ISO/RTO Council)*

*Note: Chicago area is part of PJM, not of MISO*
Electrical grid organization and management: basic questions

- Who owns what? (generation, transmission, distribution)

*RTO oddities:*

**Arizona:** from electricity standpoint is essentially a colony of California – its generation not managed by RTO, but independent generators make long-term contracts with California, sell into California markets.

**Texas:** The only state where a single agency regulates both the generation/transmission side (wholesale prices) and demand side (retail rates). Texas is its own RTO, full state-wide authority. Makes planning much easier to have one central power.
Electrical grid organization and management: basic questions

- Who owns what? (generation, transmission, distribution)

**Distribution:** owned by utilities: 3170 total in U.S. (75% of customers served by 239 investor-owned; remainder public, coop, Federal)

*The primary job of utilities (like ComEd) is to maintain a distribution network and to sell power to residential, commercial, and industrial customers. Many utilities still generate much of the power they carry, but some generate none. The businesses of generating and selling are becoming decoupled. You can even bypass the utility for your electricity purchase and ONLY pay them for the distribution service.*
Electrical grid organization and management: basic questions

• Who owns what? (generation, transmission, distribution)

**Generation:** can be owned by utilities but also by independent power producers who sell on the open market

*Exelon, whose nuclear plant we’ll visit, is not a utility (despite sharing ownership with ComEd). It is a power company that owns power plants and sells their output to utilities or RTOs. No guy in an Exelon hardhat is going to come fix your utility pole when the lights go out. The hardhat guys are utility employees.*
Electrical grid organization and management: basic questions

• Who owns what? (generation, transmission, distribution)

Summary of ownership

Utilities are “wires” companies. They own the lines, repair the lines, process the billing, take payment from retail customers.

RTOs are managers: (for most people, though not everywhere): manage the market (buy and sell, set clearing prices), exercise minute-by-minute control of generation and congestion management (call to get plants turned on or off)

Anyone can be a generator: in market system power production is open to all
Electrical grid organization and management: basic questions

• Who pays, and to who?

**RTO:** Every day the RTO buys all the power that will be used and sells all that power.

Each day the RTO forecasts power demand for next day. Each day the generators all send in “bids” stating how much they’ll be willing to sell their power for. The RTO then buys all the power it thinks will be needed, at the *marginal price*. I.e. everyone gets the price of the highest-priced seller whose power is bought.

But, he RTO doesn’t actually write a check to those generators til the power is used. If power isn’t needed after all, no $ change hands. If needed the RTO writes a check to generators.

The RTO then turns around and sells all that power to utilities, who then sell it to their customers. The utilities write a check to the RTO.
Electrical grid organization and management: basic questions

• **Who pays, and to who?**

  **RTO:** Every day the RTO buys all the power that will be used and sells all that power.

  **Utilities:** The utilities pay the RTO. They can also make “bilateral contracts” with particular generators, to lock in that power for the utility at a given price. If so, the utility then pays the generator just the difference between the market price and the contract price. Hedging strategy to minimize risk.
Electrical grid organization and management: basic questions

- **Who pays, and to who?**

  **RTO:** Every day the RTO buys all the power that will be used and sells all that power.

  **Utilities:** The utilities pay the RTO. They can also make “bilateral contracts” with particular generators.

  **Generators:** Sell to RTOs. Also get $ from contracts with utilities. Generators can also be paid not for power but simply for existing, to provide power if necessary. Very expensive generators can make a living by simply existing, being standby power in case of need.

  Generators can also sell directly to customers IF on private land and if the distribution network can be bypassed.
Electrical grid organization and management: basic questions

• Who pays, and to who?

**RTO:** Every day the RTO buys all the power that will be used and sells all that power.

**Utilities:** The utilities pay the RTO. They can also make “bilateral contracts” with particular generators.

**Generators:** Sell to RTOs. Also get $ from contracts with utilities.

**Power customers:** pay $ to the utilities

Note: the new market system does not guarantee that the user will get a lower price than in the old monopoly system. He now pays the marginal cost of electricity generation rather than the average cost. And the marginal cost is always higher than the average cost...

But the theory is, the average cost will drop as the system becomes more efficient.
Electrical grid organization and management: basic questions

- Who pays, and to who?

**RTO:** Every day the RTO buys all the power that will be used and sells all that power.

**Utilities:** The utilities pay the RTO. They can also make “bilateral contracts” with particular generators.

**Generators:** Sell to RTOs. Also get $ from contracts with utilities.

**Power customers:** pay $ to the utilities

**Transmission owners:** receive payment from the RTO, including special congestion payments for lines that are heavily used

*Note: congestion payments may be counterproductive. If you get an extra payment for a heavily-used line, what incentive would you have for building another line to cut that usage?*

*Scarcity premiums cause, well, scarcity. If someone can make more money providing a scarce resource at high cost, he will...*
Diurnal cycle of demand for electricity is standard.
Diurnal cycle of demand for electricity is standard

(Figure: Climate Progress)

Note: This figure considers use of plug-in hybrid electric vehicles, which plug in at night, to reduce difference between daytime and nighttime demand.
Electricity strategies driven by the diurnal cycle

**Peakers:** buy high cost but fast turn-on generation that can come on just for the peak energy demand period

**Peak-shaving:** buy electricity when it’s cheap and store it, then sell it back to the grid when it’s expensive

**Demand-side management:** sign contracts with customers forcing them to turn off if demand is too high

**Demand-side management:** introduce time-variable pricing for customers to incentivize less use at peak periods, more off-peak

**Load-dumping:** since baseload power can’t turn off, sometimes just have to dump it if have too much
Peakers vs. baseload: different operating cost for different generation technologies

Market clearing means that everyone receives the price bid by the last (most expensive) generator whose bid is accepted. (Hourly bids).

Nuclear will bid zero because it wants to be on always and its operating costs are tiny. Oil is expensive so will bid high – will only turn on if price > operating costs.
Peakers vs. baseload:
Conveniently, the expensive marginal cost generation is fast to turn on and off, so these can be used as peakers

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<th>Response time</th>
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<tr>
<td>Pumped Storage</td>
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<tr>
<td>Gas Turbines</td>
<td>2 minutes</td>
</tr>
<tr>
<td>Combined Cycle Gas Turbine</td>
<td>6 hours</td>
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</tr>
<tr>
<td>Large Coal</td>
<td>24 hours</td>
</tr>
<tr>
<td>Nuclear</td>
<td>48 hours</td>
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</table>

Table 4: Typical Response Times of various forms of Power Generation
(National Grid Company, 2007).
Expensive peakers are turned on only during max load

Baseload power stays on all the time. High-marginal-cost power is purchased only during times of day when demand is highest.

During those times, the baseload providers also get peak prices – so some gaming of the system is possible (e.g. Enron)

Figure 11: Generation source for a typical daily demand profile. Courtesy of NGC 2007 (CCGT: Combined Cycle Gas Turbines). (figure from the U.K.?)
Market for generation
Generators are turned on when their bid is below market-clearing price

Each generator receives the market-clearing price when it is turned on. When no gaming occurs, should In theory result in incentives for more efficient construction of generating capacity, also for clever peak-shaving strategies (demand reduction, storage, etc.)

(Figure: Marson Energy)
Electricity storage strategies
Storage incentive is peak-shaving the diurnal cycle. What can you do with electricity during cheap times that can store energy and produce electricity again during expensive times?

• **Gravitational potential**: pumped hydro
• **Elastic (pressure)**: compressed air storage
• **Electrical**: batteries
• **Chemical**: hydrogen manufacture
• **Thermal**: stored heat (e.g. molten salt)
• **Mechanical**: flywheels
Electricity storage strategies

*Flywheels – storing mechanical motions*

Brochure from Beacon Power. Notes their advertisement of flywheels for peak shaving.

**Smart Energy 25 kWh**

The Smart Energy 25 is Beacon’s design for an advanced energy storage solution that could provide unique power quality benefits for demanding utility applications. The system would be a larger-scale version of Beacon’s field-proven and environmentally friendly patented Co-mingled Rim Technology® (PCRT). Its long-life, low-maintenance design and highly cyclic capability could outlast and outperform battery systems in the harshest environments.

And thanks to innovative modular design, a series of Smart Energy units could be configured in a Smart Energy Matrix™ to provide megawatts of reliable and responsive stored energy for minutes or even hours.

Typical single-unit applications:

- Remote back-up power
- Battery for central office power
- Peak shaving
- Bridge to generator start
- Load following

Every Smart Energy flywheel from Beacon is designed to offer many technical and performance advantages, including:

- **20-year Design Life**
  Designed for 20 years of virtually maintenance-free operation.

- **Real-time Monitoring**
  Many parameters of flywheel and system performance can be monitored remotely.

- **Sustainable Technology**
  Flywheels eliminate the hazards of batteries, are emissions-free, and do not require fuel, simplifying permitting and avoiding potential ground contamination and safety issues.

- **Temperature Tolerance**
  Unlike batteries that degrade in performance at temperature extremes, flywheels exhibit no change in output or life span based on climate. In fact, a flywheel is often the only viable solution for harsh remote applications.
Electrical grid organization and management: basic questions

• Who sets the amounts that people pay?

In the old days
The utilities owned everything, and would charge customers enough to recover their costs. The state utilities commission would approve the rates.

Nowadays
Generator price set by the market: Sets the hour by hour price that generators receive for power or for capacity.

Wholesale price set by FERC: Sets the markup that the RTO can charge over market. Sets the transmission rates.

Retail price set by state utilities commissions: Determines the rates that the utilities can charge their customers. Flat rates – no hourly changes.
Electrical grid organization and management: basic questions

• Who makes the rules?

On transmission permits: the states (unless FERC declares a corridor critical and invokes its Federal authority), and some component of local authorities. No one has eminent domain rights to purchase land.

On reliability and quality standards: the EOR (a role played by the National Energy Reliability Council, now North American Electric Reliability Corp, i.e. NERC).

On zoning and permits for individual power plants: local municipalities and agencies.

On renewables portfolios standards, DSM, etc.: the states, via their utility commissions

Electrical grid organization and management: basic questions

• Who enforces the rules? (inspects, investigates, fines)

On competitiveness and the market: FERC (Federal Energy Regulatory Commission)

On reliability and quality standards: The EOR (a role played by the National Energy Reliability Council, now North American Electric Reliability Corp, i.e. NERC).

On certification of grid connections: the local utility

Utility actions: For every house that wants to put power on the grid, someone has to inspect your inverter... ComEd’s expedited review takes 4 weeks (!)
Electrical grid organization and management: basic questions

• Who builds the grid?

*Private investors .... in theory...In practice very little new build of transmission is happening.*
Electrical grid organization and management: basic questions

• Who plans? (if anyone...)

• NERC writes annual reports on reliability and can levy fines for failures but can’t force actions.

• FERC can plan transmission and can force states to comply.... but in practice they aren’t implementing.

• Federal laws e.g. subsidizing renewables are a form of planning to diversity energy generation.

• State renewable portfolio standards are a form of planning – different subsidies in different states, some requiring interstate purchase.

• States generally hinder planning by refusing to cooperate with e.g. transmission that just benefit out-of-state consumers (or even raise local rates)
Electrical grid organization and management: basic questions

- Who bears liability if something goes wrong?

Local utility bears liability for providing you with power that meets standards.

Companies like Google want higher standards though… drives business of ultra-reliable electricity on mini-grids. Or relocation to Iceland.
Electrical grid organization and management: basic questions

- How much extra capacity is there at any given time?

U.S. total capacity margin, 2007:
  - summertime 15% (down from 22% in 1990)
  - wintertime 30%

*might be as low as 10% in summer if auxiliary and parasitic loads are included*

NERC minimum mandates: 13% thermal, 9% hydro

Forecast growth rate: 1%/yr  
(U.S. EIA, 2008 Energy Outlook)

*We are awfully close to hitting a capacity limit...or already past that limit.*

*Capacity data from NERC*
When resources drop below target, capacity reserve margins will hit threshold soon.

Key:

- 2007 NERC Reliability Study
- New England capacity projected hit in 2009, Midwest in 2010

- New York 2011/2016+
- RFC 2012/2013
- SPP 2015/2016+
- ERCOT 2009/2016+

Slide: EPRI
Conclusions

• U.S. electricity system has crisis of distribution
• Also has crisis of generation (insufficient capacity)
• Demand reduction can help with short-term crisis
• Long term will require building
• Regulatory infrastructure is not well-designed to cope with either projected growth or with long-term energy policy
• No agency is in charge of energy policy