PSerc and Some Grand Challenges

Sarosh Talukdar
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Power Systems Engineering Research Center (PSERC)

Universities working with industry to find innovative solutions to challenges facing a restructured electric power industry

PSERC

A Collaboration among Universities and Industry

- An NSF Industry / University Cooperative Research Center
- Eleven universities and over thirty industry members
- Multidisciplinary (engineering, economics, operations research, etc.)
- Research and education priorities

PSERC Universities

- Cornell University (lead university)
- Arizona State University
- University of California at Berkeley
- Carnegie Mellon University
- Colorado School of Mines
- Georgia Institute of Technology
- The University Of Illinois at Urbana
- Iowa State University
- Texas A&M University
- Washington State University
- University of Wisconsin-Madison

Research Program

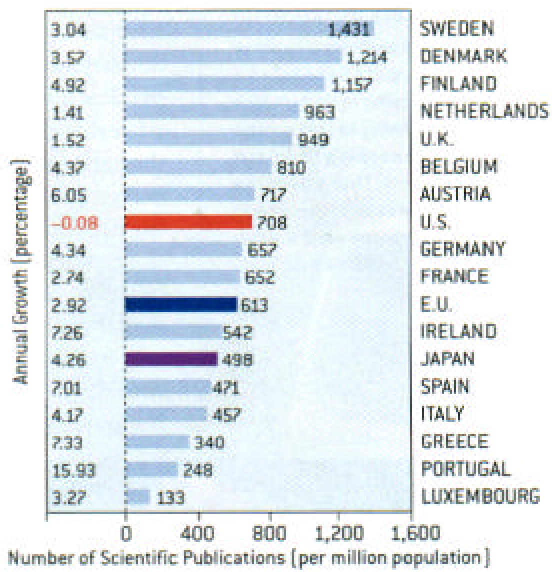
- Three research stems
  - Markets
  - Transmission and distribution technologies
  - Systems
- Leveraged research (such as Consortium for Electric Reliability Technology Solutions)
- Public documents: www.pserc.wisc.edu

Areas with open issues

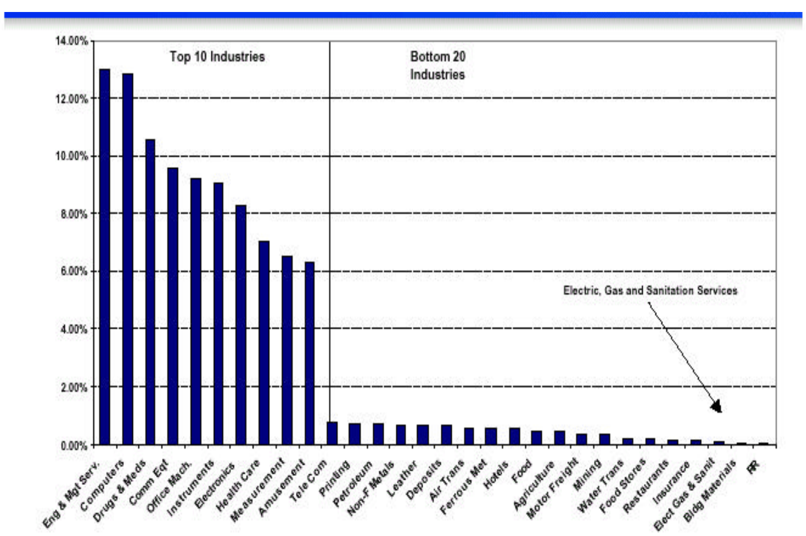
1. investments
2. reliability
3. planning
4. testing and verification
5. organization-design

Investments

- research
- networks



Source: Scientific American, April 2002



*R&D expenditures as % of net sales

EPRI

Reliability

Measures

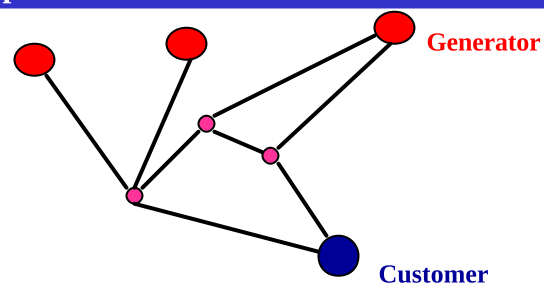
Outage Duration	Availability
≤ 1 hour/year	≥ 0.999
≤ 1 millisecond/year	≥ 0.999999999

Reliability by country

Country	Year	Outage Minutes/Year/Household
Japan	1997	10
Korea	1995	18
France	1997	58
U.K	1997	77
USA	1997	90
Philippines	1995	150

Source: IEEE Power Engineering Review, Dec. 2000

Multi-path networks:

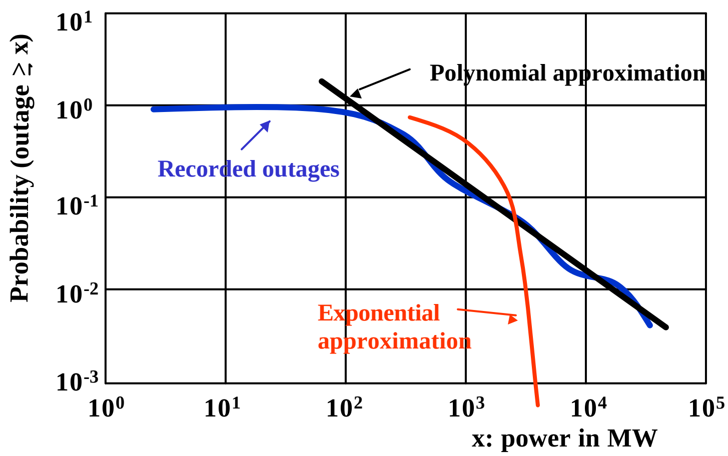


- provide ways to bypass local outages, but also
- cause outages to cascade (fatten the tails of outage distributions)

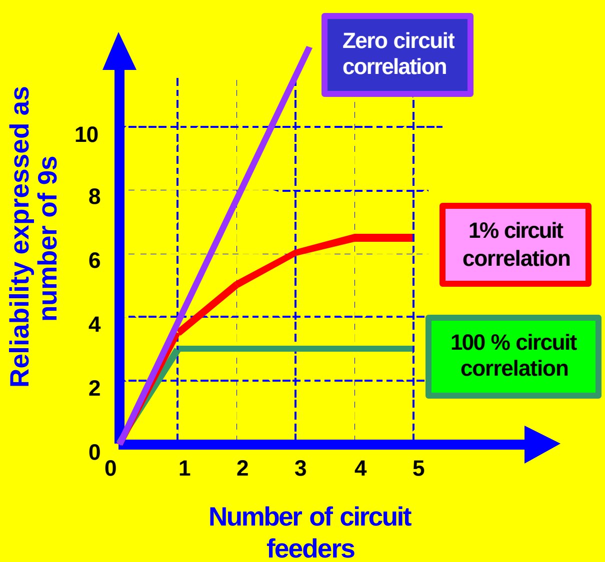
What are the trade-offs? (models are unavailable)

Major outages seem to obey a power law (a polynomial rather than an exponential relationship)

(Adapted from Chen, Thorp and Parashar, HICSS-34, Jan. 2001)



Source: Heydt, Grand Challenges, 2002



The addition of feeders to improve reliability has a diminishing effect. For practical cases, use of more than three 'independent' feeders of 100% capacity is counterproductive.

Conclusion

Remote sources and multi-path delivery networks cannot provide the reliability levels needed by many customers, even when we consider only natural disturbances, not deliberate attacks.

Other reliability questions

- How vulnerable is the grid to attack?
- Should we care?

Yes, of course. But vulnerability-to-attack is neither a critical nor an independent issue. There are other, more important issues.

Planning

Issues

Neither FERC nor anyone else has provided

a) long-term goals and

b) the means to determine if these goals are being met

The life-times of grid-subsystems far exceed our abilities to look into the future

Testing and verification

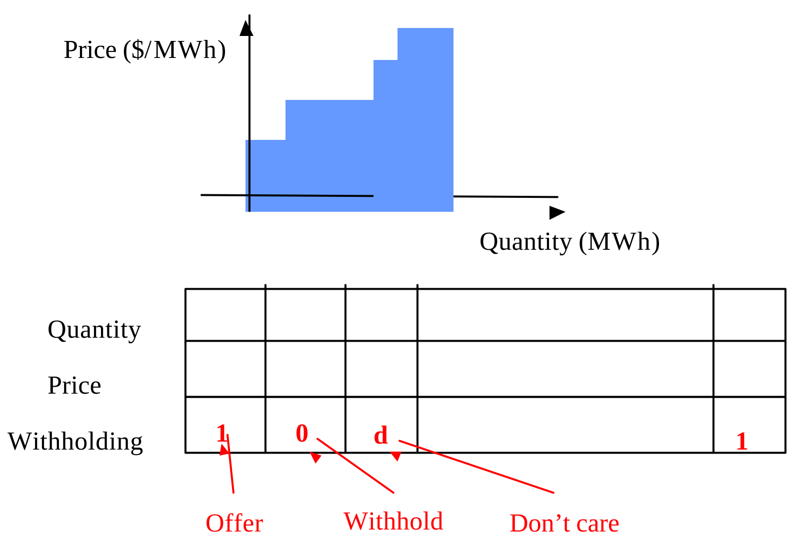
Issues

The development of markets for electric energy has proceeded without the development of the means by which to test and verify them.

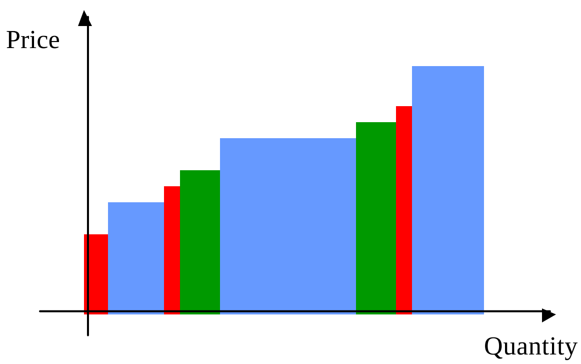
Organization design

- what role should each participant play?
  - problem decomposition
  - information use
- how much autonomy should each participant have?
  - learning
  - customer participation

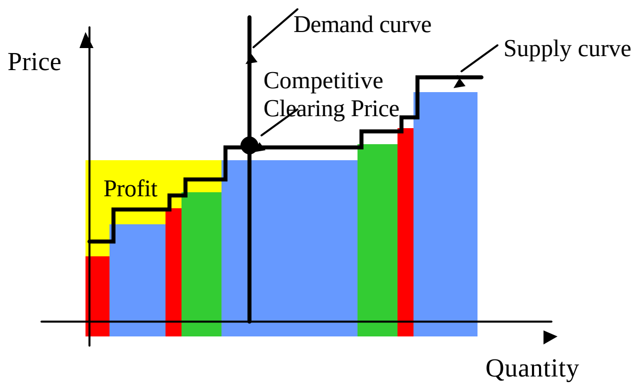
An offer by a generating company



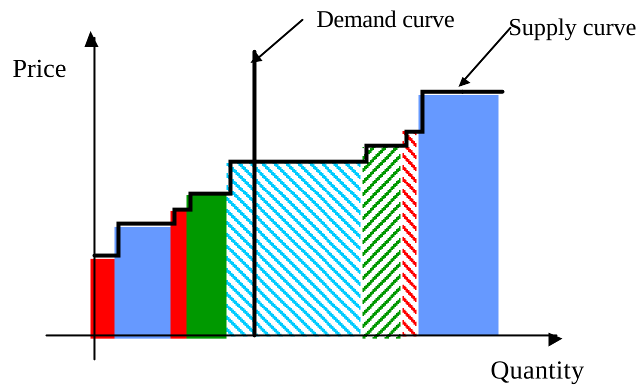
Supply curve: aggregate of the generating companies' offers

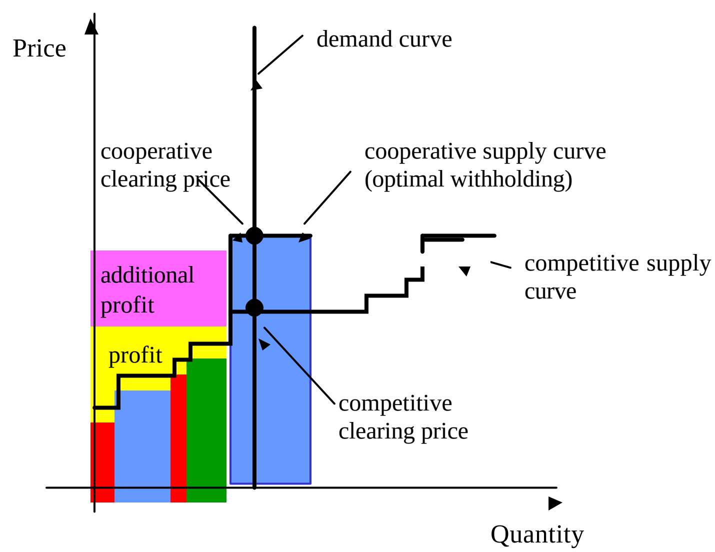


If a) total demand is fixed
b) offers by generating companies are at cost
c) a uniform auction determines the clearing price
Then:



If a) total demand is fixed
b) offers by the generating companies are at cost
c) the companies cooperate to determine withholdings
Then the optimal withholdings are:





Conclusion: cooperative profits are greater than competitive profits. But cooperation (collusion) among sellers is illegal

Question: can automatic learning do as well as cooperation?

A very simple learning algorithm for a seller in a quasi-repetitive system

To determine the binary withholding vector (BWV) for the current period:

1. Check the seller's history. Find the N previous periods with the greatest profits
2. Apply crossover and mutation operators to the seller's BWVs for these periods, to obtain a new BWV
3. Use this new BWV for the current period.

Experiment-1 by Haoyu Zhou

Demand = 50 MWh

10 suppliers, identical in all respects except their withholding strategies. Each supplier has 10 blocks of energy to sell:

Quantity (MWh)	1	1	1	1	1	1	1	1	1	1
Price ($/MWh)	1	2	3	4	5	6	7	8	9	10
Withholding	?	?	?	?	?	?	?	?	?	?

All offers are at cost.

All suppliers are allowed to learn.

The "competitive solution"

Clearing Price: 5 $/MWh

Supplier	Withholding										Profit
1	1	1	1	1	1	1	1	1	1	1	10
2	1	1	1	1	1	1	1	1	1	1	10
3	1	1	1	1	1	1	1	1	1	1	10
4	1	1	1	1	1	1	1	1	1	1	10
5	1	1	1	1	1	1	1	1	1	1	10
6	1	1	1	1	1	1	1	1	1	1	10
7	1	1	1	1	1	1	1	1	1	1	10
8	1	1	1	1	1	1	1	1	1	1	10
9	1	1	1	1	1	1	1	1	1	1	10
10	1	1	1	1	1	1	1	1	1	1	10
										Total:	100

Note: this is not an equilibrium solution

A cooperative solution

Clearing Price: 10 $/MWh

Supplier	Withholding										Profit
1	1	1	1	1	1	0	0	0	0	1	35
2	1	1	1	1	1	0	0	0	0	d	35
3	1	1	1	1	1	0	0	0	0	d	35
4	1	1	1	1	1	0	0	0	0	d	35
5	1	1	1	1	1	0	0	0	0	d	35
6	1	1	1	1	1	0	0	0	0	d	35
7	1	1	1	1	0	0	0	0	0	d	30
8	1	1	1	1	1	0	0	0	0	d	35
9	1	1	1	1	1	0	0	0	0	d	35
10	1	1	1	1	1	0	0	0	0	d	35
										Total:	345

Note: this solution is a Nash equilibrium

A solution by individual learning (no cooperation)

Clearing Price: 10 $/MWh

Supplier	Withholding										Profit
1	1	1	1	1	0	0	0	0	0	1	30
2	1	1	1	1	1	0	0	0	0	1	35
3	1	1	1	1	1	0	0	0	0	1	35
4	1	1	1	1	1	0	0	0	0	0	35
5	1	1	1	1	1	0	0	0	0	0	35
6	1	1	1	1	1	0	0	0	0	1	35
7	1	1	1	1	0	0	0	0	0	0	30
8	1	1	1	1	1	0	0	0	0	1	35
9	1	1	1	1	1	0	0	0	0	1	35
10	1	1	1	1	1	1	0	0	0	0	39
										Total:	344

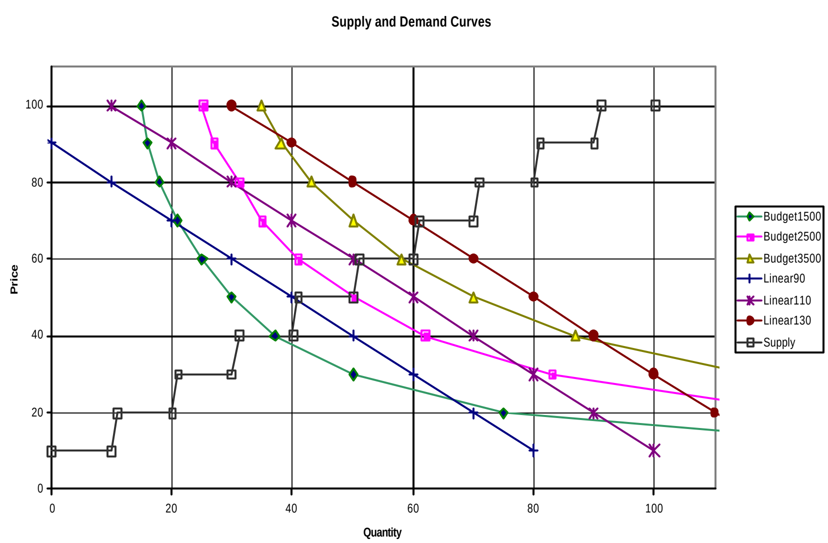
Note: this solution is a Nash equilibrium

Experiment-2 by K. C. Marshall

10 sellers, as in experiment-1

Variables:

- The number of sellers allowed to learn
- The shape of the demand curve



Clearing price / competitive price

	Constant Demand	Linear Demand	Nonlinear demand
All 10 sellers learn			
	6/2	5/5	4/4
	10/5	6/6	6/5
	10/7	7/7	7/6
7 of the 10 sellers learn			
	3/2	5/5	4/4
	5/5	6/6	5/5
	10/7	7/7	6/6
4 of the 10 sellers learn			
	3/2	5/5	4/4
	6/2	7/6	5/5
	9/7	7/7	6/6

Conclusions

Learning can be as effective as cooperation

Customers should be given the means to participate to a much greater extent than they can now