Did Imperialism Kill Micro-Grids? Is the Regulatory Mindset Preventing Electrification?

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Small Power for Providing Light

- Specialized power plant
  - BP Solar 3,000 Brazilian schools
  - California with 30 GW of small generators—1998
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- Neighbor to neighbor micro-grids

Big Power Advocate

Scale Economies

- Kentucky Power Company—Single 800 MW steam turbine for 600 MW peak
- American Electric Power Service Corporation
  - 1300 MW steam turbines
  - 765 KV transmission lines
- Rate Consultant to Reynolds Metals Company, 300 MW load, 23.9x7; 4 AP&L Cases: $4M, $5M
- Invented Committed Unit Basis (CUB)—Adopted by TxPUC, used for 3 QF PPAs totaling 1000 MW

Seams Issues

- "Electricity Is Too Chunky: The Midwest power prices were neither too high nor too low. They were too imprecise," *Public Utilities Fortnightly,* 1998 September 1.
- "Wide Open Load Following," Presentation on Loop Flow to NERC Control Area Criteria Task Force, Albuquerque, New Mexico, 2000 February 14/15

Micro-grids and Small Power Issues

- U.S. electric industry started with micro-grids
- International Paper Company (IPC) was once International Paper and Power Company (IPPC), supplying areas close to paper plants
- “Saving California With Distributed Generation: A Crash Program To Use Small, Standby Diesel Generators To Keep The Lights On,” *Public Utilities Fortnightly*, 2001 June 15

Total Numbers of Domestic Gensets

Distributions by State

Range (KW) / State	50-70	71-150	151-300	301-700	701-1200	1201-2000	2001+	Total
California	22,405	23,558	14,373	7,062	5,259	5,257	1,968	79,882
Washington	3,699	3,553	4,060	1,400	916	812	304	14,744
Arizona	2,961	1,421	2,708	1,120	220	650	230	9,310
Oregon	2,143				530	470	176	8,148
Nevada	1,072				266	236	83	4,072
Colorado	2,556	2,700	3,273	967	506	561	201	10,764
Utah	1,337	1,284	978	506	332	294	110	4,841
New Mexico	1,145	1,100	1,047	433	283	251	94	4,353
Montana	547	621	538	222	146	129	48	2,251
Wyoming	321	494	323	122	80	71	27	1,438
Total	38,186	37,818	30,240	13,049	8,538	8,731	3,241	139,803

Huge number of small generators in California

Total Capacity (MW) of Domestic Gensets

Distributions by State

Range (KW)	50-70	71-150	151-300	301-700	701-1200	1201-2000	2001+	Total
Nominal (KW)	60	110	220	500	950	1600	3000	
State								
California	1,344	2,591	3,162	3,531	4,996	8,411	5,904	29,940
Washington	222	391	893	700	870	1,299	912	5,287
Arizona	178	156	596	560	209	1,040	690	3,429
Oregon	129					752	528	2,975
Nevada	64					378	249	1,475
Colorado	153					898	603	3,635
Utah	80					470	330	1,805
New Mexico	69	121	230	217	269	402	282	1,589
Montana	33	68	118	111	139	206	144	820
Wyoming	19	54	71	61	76	114	81	476
Total	2,291	4,160	6,653	6,525	8,111	13,970	9,723	51,432

Small gen sets have capacity comparable to central station plants

The Raj Fails to Deliver

- “Free” electricity for farmers
- Load control on rural loads to keep lights on in city
- Constant shortages institutionalized: reporting on unserved
  - MW
  - MWH

Entrepreneurs in Iraq

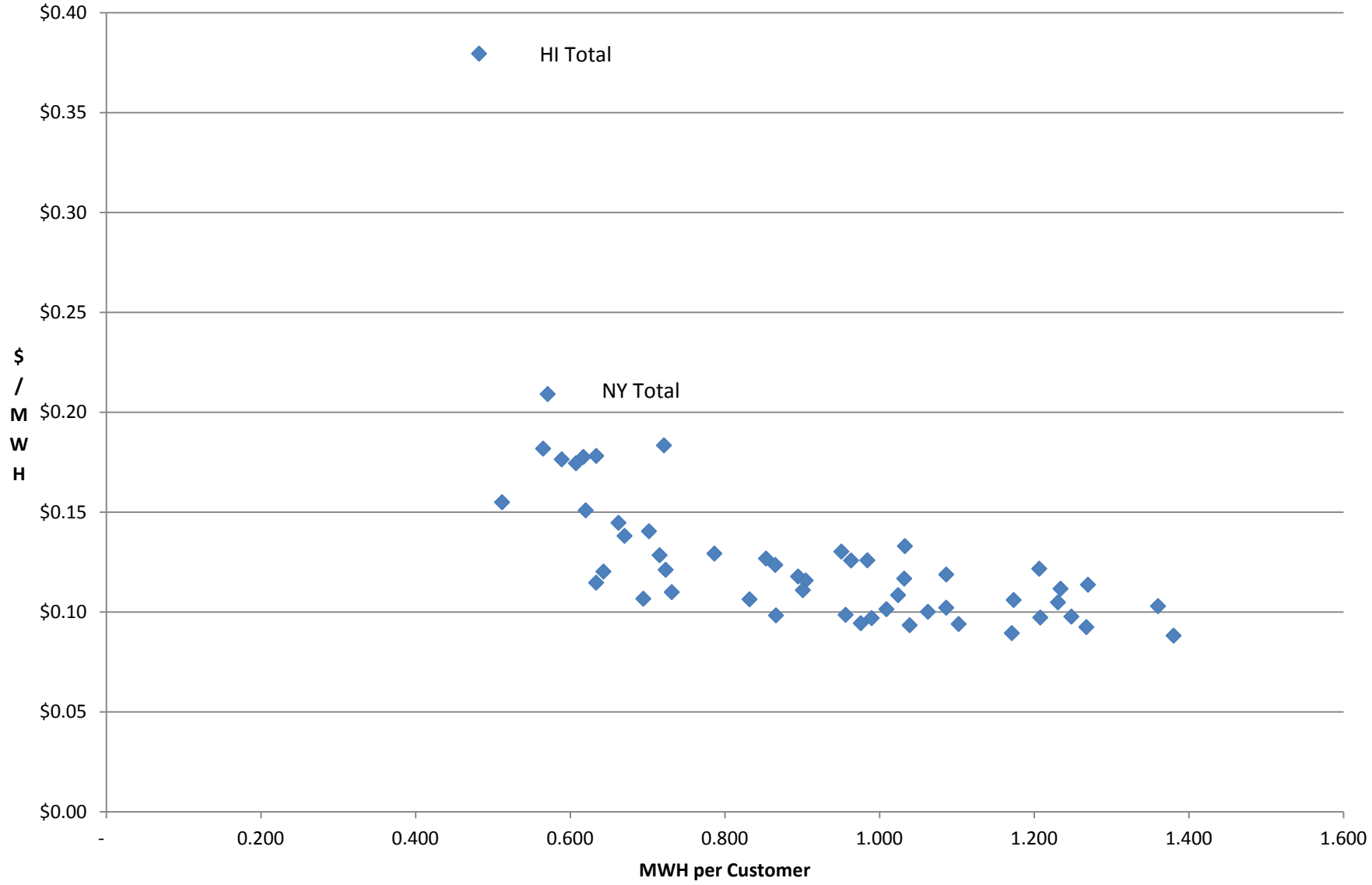
- Articles in *The Washington Post* & *Newsweek*
- Neighbors supply each other with power
- Overhead wires look like a spider's web
- Contrary to "Nation Building" to have such independent, unregulated utilities
- Kept the lights on
- At a high price

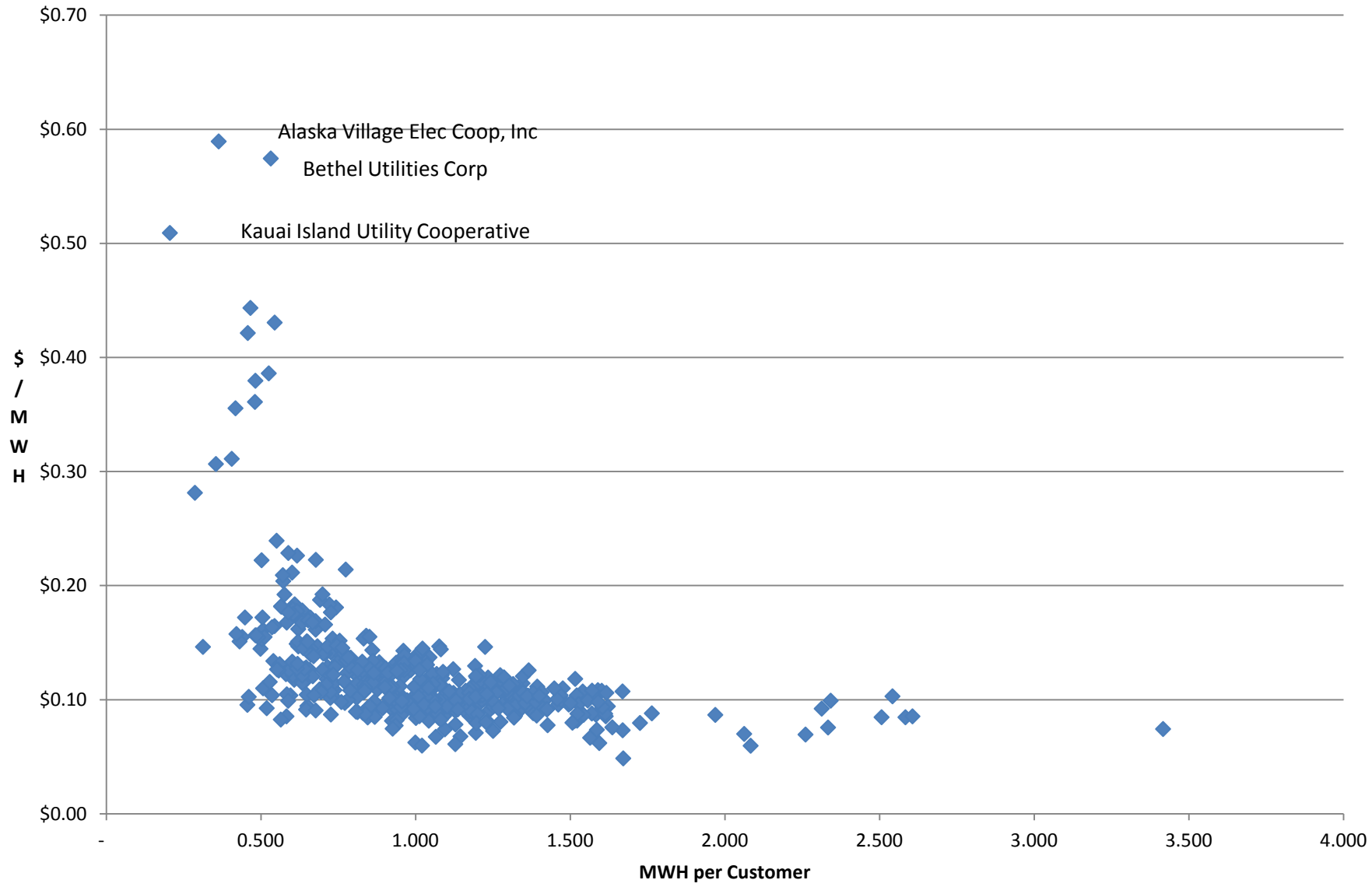
Costly Distribution System

- Assume $10/mo distribution costs/charge
- $0.10 Central Station costs (includes fuel)

KWH/Mo	$/KWH
1	$ 10.10
10	$ 1.10
30	$ 0.43
100	$ 0.20

Average Residential Prices By State
First 6 Months 2014




Average Residential Prices By U.S. Utility
First 6 Months 2014
$0.70
$0.60
$0.50
$0.40
$0.30
$0.20
$0.10
$0.00
$ / MWH
Alaska Village Elec Coop, Inc
Bethel Utilities Corp
Kauai Island Utility Cooperative
-
0.500
1.000
1.500
2.000
2.500
3.000
3.500
4.000
MWH per Customer

Micro-grids

- Need to be operated
- Need to be priced
- Do both together with WOLF
  - “Microgrids And Financial Affairs - Creating A Value-Based Real-Time Price For Electricity,” *Cogeneration and On-Site Power Production,* September, 2007
  - "Creating a MicroGrid Market: Using a Frequency Driven Pricing Curve To Dispatch Load and Embedded Distributed Generation And To Charge and Pay for Participation," *Energy Pulse*, 2013 July 3

Most Micro-grids “Cheat”

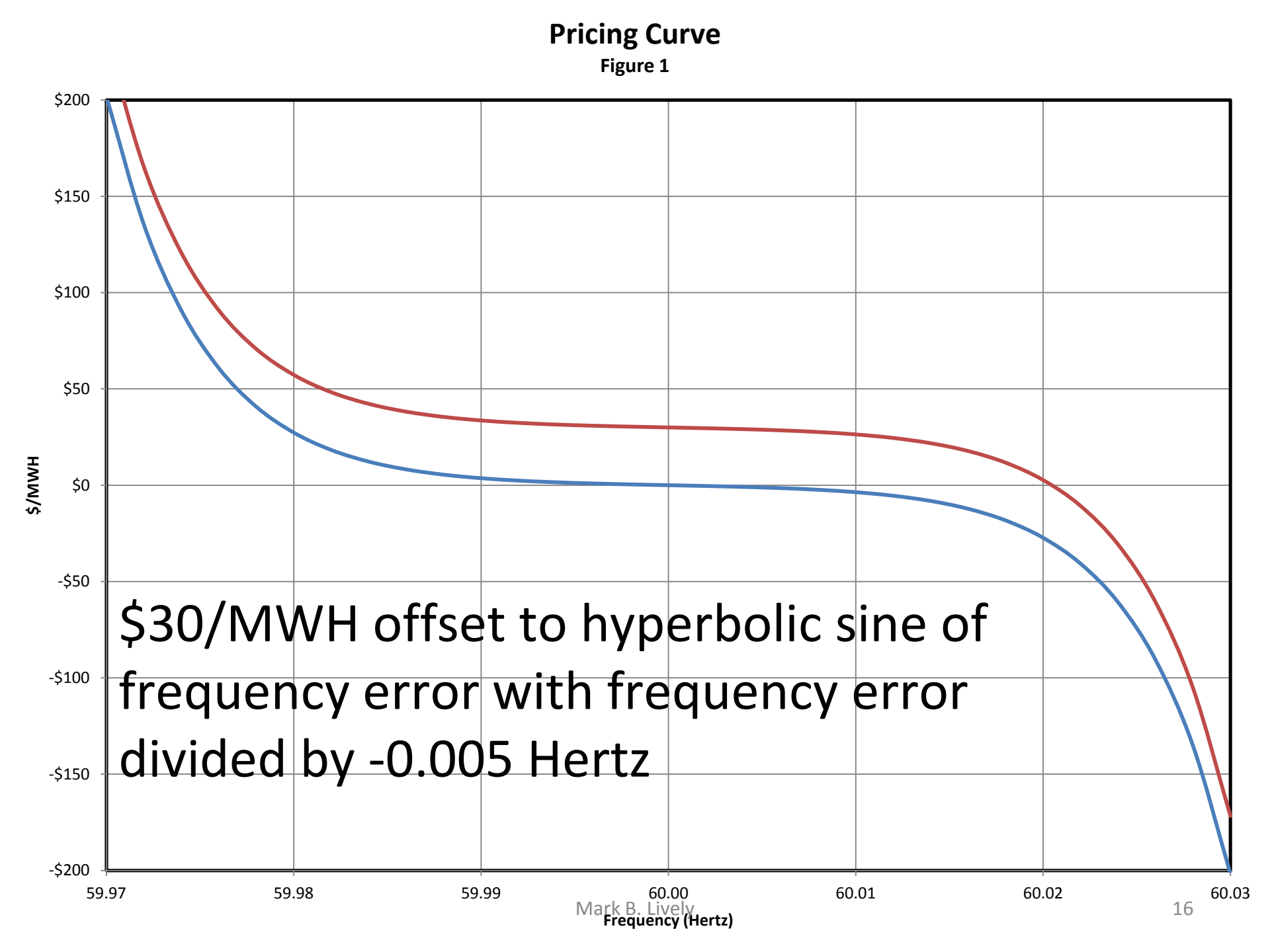
- Don’t accept QF power or any power
- Avoid FERC regulation associated with selling electricity for resale in interstate commerce
- Essentially unregulated
- I’m jealous

But what if generators aren't owned by the utility?

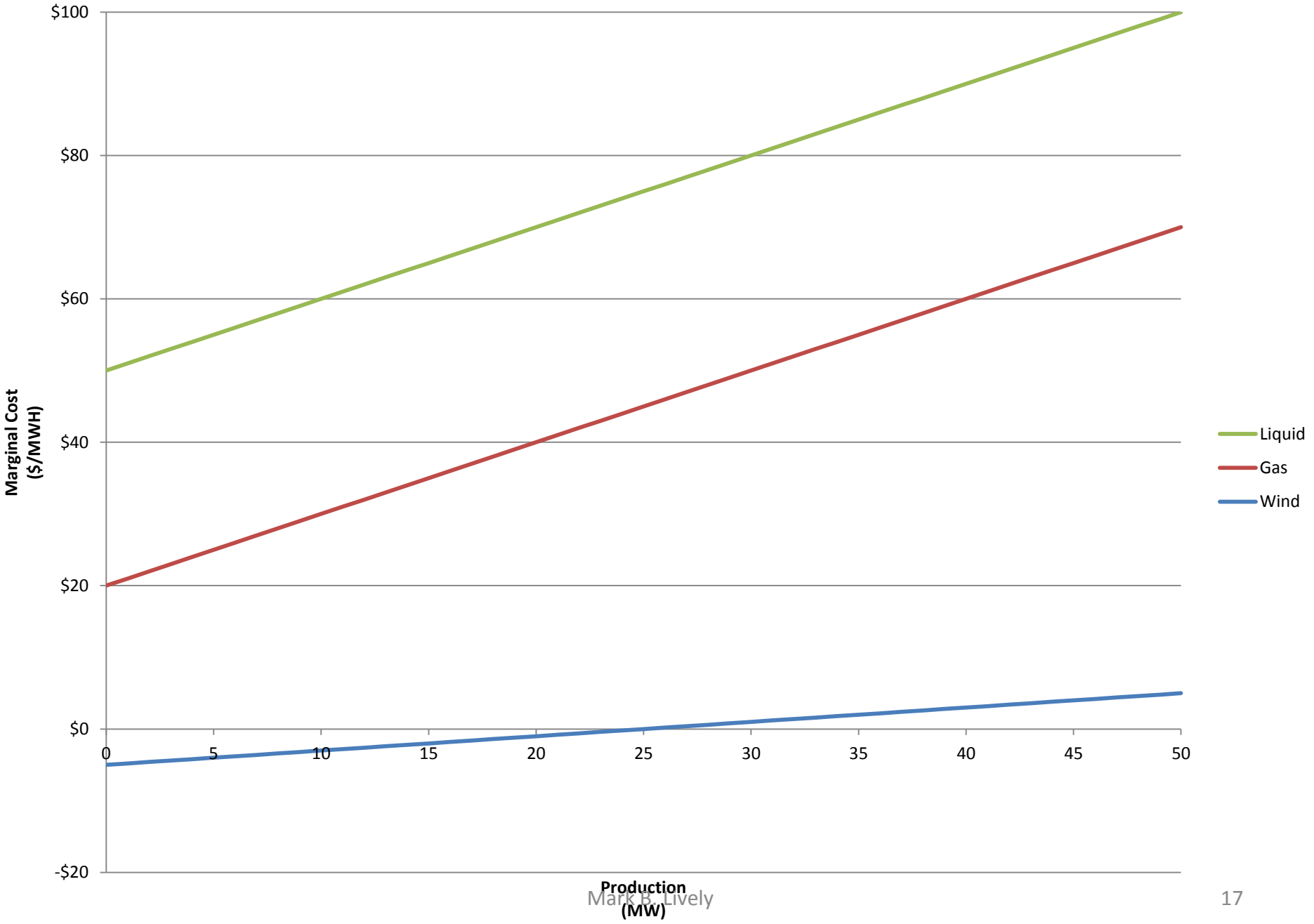
Combine two system operator functions

- Generally try to eliminate frequency error
- Also try to minimize operating cost

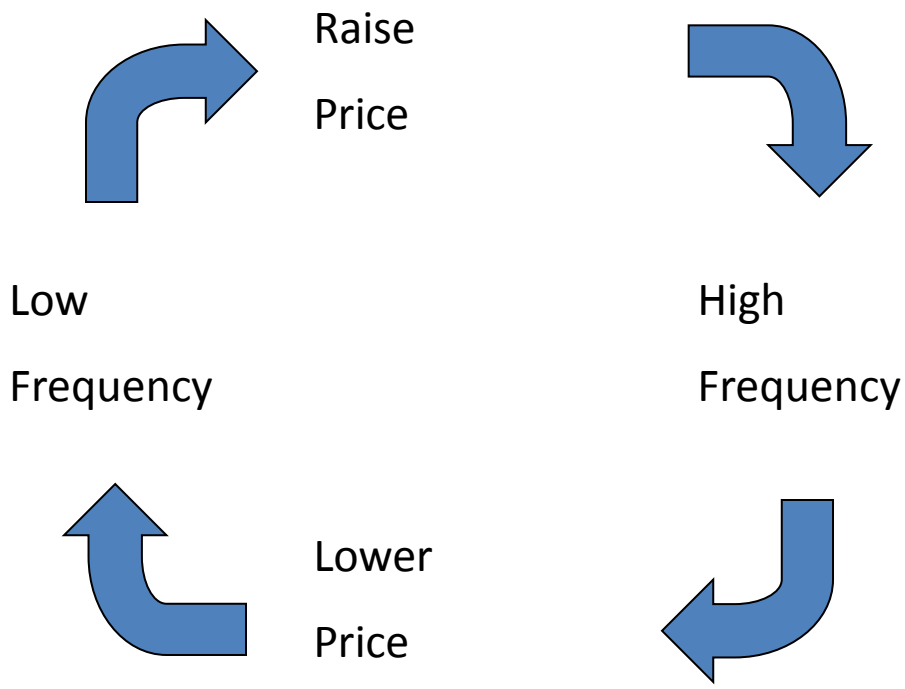
Use frequency error to set system lambda or short run marginal cost


Pricing Curve
Figure 1
$200
$150
$100
$50
$0
-$50
-$100
-$150
-$200
$/MWH
59.97
59.98
59.99
60.00
60.01
60.02
60.03
Frequency (Hertz)
$30/MWH offset to hyperbolic sine of frequency error with frequency error divided by -0.005 Hertz

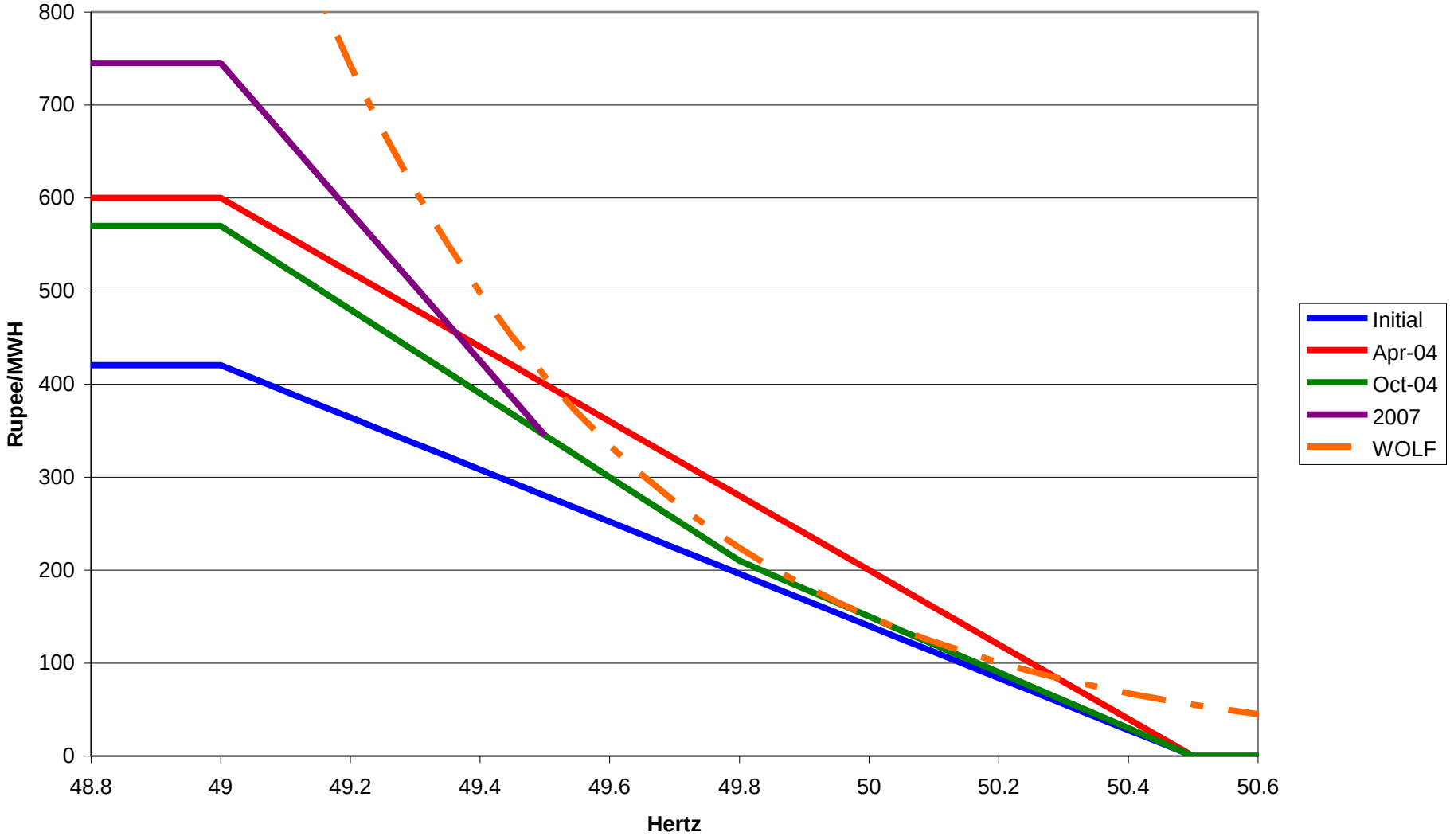
Marginal Operating Costs



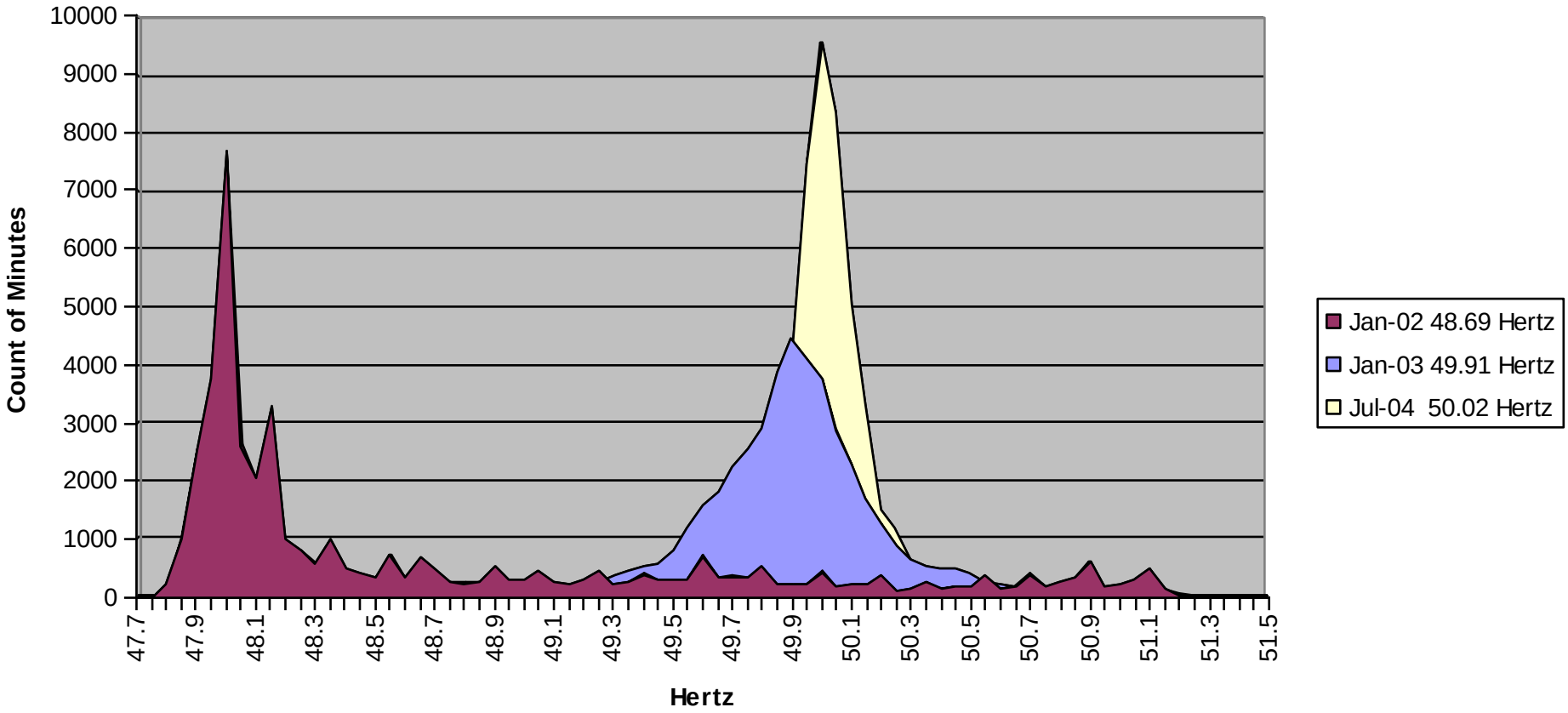
WOLF Pricing
Control Theory



ABT UI Pricing Chart
Figure 7



Monthly Distribution of Minute by Minute Frequencies



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