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

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6-7 November 2014, Washington DC
Small Power for Providing Light

• Specialized power plant
  – BP Solar 3,000 Brazilian schools
  – California with 30 GW of small generators—1998

• Transportable batteries
  – Niece Erica charging cell phone after Chile earthquake
  – Propane tanks, pickup or delivery

• 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

<table>
<thead>
<tr>
<th>Range (KW)</th>
<th>50-70</th>
<th>71-150</th>
<th>151-300</th>
<th>301-700</th>
<th>701-1200</th>
<th>1201-2000</th>
<th>2001+</th>
<th>Total</th>
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<td>146</td>
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<td>71</td>
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<td>Total</td>
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<td>37,818</td>
<td>30,240</td>
<td>13,049</td>
<td>8,538</td>
<td>8,731</td>
<td>3,241</td>
<td>139,803</td>
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</table>

Huge number of small generators in California
## Total Capacity (MW) of Domestic Gensets

### Distributions by State

<table>
<thead>
<tr>
<th>Range (KW)</th>
<th>50-70</th>
<th>71-150</th>
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<th>701-1200</th>
<th>1201-2000</th>
<th>2001+</th>
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<tr>
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<td>110</td>
<td>220</td>
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<td>950</td>
<td>1600</td>
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<tr>
<td>California</td>
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<td>217</td>
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<td>402</td>
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<tr>
<td>Montana</td>
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<td>111</td>
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<td>Wyoming</td>
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<td>81</td>
<td>476</td>
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<tr>
<td>Total</td>
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<td>6,525</td>
<td>8,111</td>
<td>13,970</td>
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<td>51,432</td>
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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)

<table>
<thead>
<tr>
<th>KWH/Mo</th>
<th>$/KWH</th>
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<tbody>
<tr>
<td>1</td>
<td>$ 10.10</td>
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<tr>
<td>10</td>
<td>$ 1.10</td>
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<td>30</td>
<td>$ 0.43</td>
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<tr>
<td>100</td>
<td>$ 0.20</td>
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</table>
Average Residential Prices By State
First 6 Months 2014

$0.00 $0.05 $0.10 $0.15 $0.20 $0.25 $0.30 $0.35 $0.40

$/MWH per Customer

- 0.200 0.400 0.600 0.800 1.000 1.200 1.400 1.600

HI Total

NY Total
Average Residential Prices By U.S. Utility
First 6 Months 2014

Alaska Village Elec Coop, Inc
Bethel Utilities Corp
Kauai Island Utility Cooperative
Micro-grids

• Need to be operated
• Need to be priced
• Do both together with WOLF
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
$30/MWH offset to hyperbolic sine of frequency error with frequency error divided by -0.005 Hertz
Marginal Operating Costs

Marginal Cost ($/MWH) vs. Production (MW)

- Liquid
- Gas
- Wind

Graph showing the marginal operating costs for different types of production, with Liquid and Gas having higher costs compared to Wind.
WOLF Pricing
Control Theory

Raise Price
Low Frequency

Lower Price
High Frequency
Monthly Distribution of Minute by Minute Frequencies

- Jan-02: 48.69 Hertz
- Jan-03: 49.91 Hertz
- Jul-04: 50.02 Hertz
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