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

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FERC Electricity Workshop/Trans-Atlantic Infraday (TAI) 
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>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>22,405</td>
<td>23,558</td>
<td>14,373</td>
<td>7,062</td>
<td>5,259</td>
<td>5,257</td>
<td>1,968</td>
<td>79,882</td>
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<td>Washington</td>
<td>3,699</td>
<td>3,553</td>
<td>4,060</td>
<td>1,400</td>
<td>916</td>
<td>812</td>
<td>304</td>
<td>14,744</td>
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<tr>
<td>Arizona</td>
<td>2,961</td>
<td>1,421</td>
<td>2,708</td>
<td>1,120</td>
<td>220</td>
<td>650</td>
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<tr>
<td>Oregon</td>
<td>2,143</td>
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<td>4,060</td>
<td>1,400</td>
<td>916</td>
<td>812</td>
<td>304</td>
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<tr>
<td>Nevada</td>
<td>1,072</td>
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<td></td>
<td>266</td>
<td>236</td>
<td>83</td>
<td>4,072</td>
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<tr>
<td>Colorado</td>
<td>2,556</td>
<td>2,700</td>
<td>3,273</td>
<td>967</td>
<td>506</td>
<td>561</td>
<td>201</td>
<td>10,764</td>
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<tr>
<td>Utah</td>
<td>1,337</td>
<td>1,284</td>
<td>978</td>
<td>506</td>
<td>332</td>
<td>294</td>
<td>110</td>
<td>4,841</td>
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<tr>
<td>New Mexico</td>
<td>1,145</td>
<td>1,100</td>
<td>1,047</td>
<td>433</td>
<td>283</td>
<td>251</td>
<td>94</td>
<td>4,353</td>
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<tr>
<td>Montana</td>
<td>547</td>
<td>621</td>
<td>538</td>
<td>222</td>
<td>146</td>
<td>129</td>
<td>48</td>
<td>2,251</td>
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<tr>
<td>Wyoming</td>
<td>321</td>
<td>494</td>
<td>323</td>
<td>122</td>
<td>80</td>
<td>71</td>
<td>27</td>
<td>1,438</td>
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<tr>
<td>Total</td>
<td>38,186</td>
<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>
</tr>
</tbody>
</table>

### Notes:
- **Huge number of small generators in California**
- The table shows the total numbers of domestic gensets distributed by state, classified by power range (in kilowatts).
<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>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal (KW)</td>
<td>60</td>
<td>110</td>
<td>220</td>
<td>500</td>
<td>950</td>
<td>1600</td>
<td>3000</td>
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<tr>
<td>State</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>California</td>
<td>1,344</td>
<td>2,591</td>
<td>3,162</td>
<td>3,531</td>
<td>4,996</td>
<td>8,411</td>
<td>5,904</td>
<td>29,940</td>
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<tr>
<td>Washington</td>
<td>222</td>
<td>391</td>
<td>893</td>
<td>700</td>
<td>870</td>
<td>1,299</td>
<td>912</td>
<td>5,287</td>
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<tr>
<td>Arizona</td>
<td>178</td>
<td>156</td>
<td>596</td>
<td>560</td>
<td>209</td>
<td>1,040</td>
<td>690</td>
<td>3,429</td>
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<tr>
<td>Oregon</td>
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<tr>
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<td></td>
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<td>Colorado</td>
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<td>3,635</td>
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<tr>
<td>Utah</td>
<td>80</td>
<td>141</td>
<td>219</td>
<td>238</td>
<td>343</td>
<td>470</td>
<td>330</td>
<td>1,805</td>
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<tr>
<td>New Mexico</td>
<td>69</td>
<td>121</td>
<td>230</td>
<td>217</td>
<td>269</td>
<td>402</td>
<td>282</td>
<td>1,589</td>
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<tr>
<td>Montana</td>
<td>33</td>
<td>68</td>
<td>118</td>
<td>111</td>
<td>139</td>
<td>206</td>
<td>144</td>
<td>820</td>
</tr>
<tr>
<td>Wyoming</td>
<td>19</td>
<td>54</td>
<td>71</td>
<td>61</td>
<td>76</td>
<td>114</td>
<td>81</td>
<td>476</td>
</tr>
<tr>
<td>Total</td>
<td>2,291</td>
<td>4,160</td>
<td>6,653</td>
<td>6,525</td>
<td>8,111</td>
<td>13,970</td>
<td>9,723</td>
<td>51,432</td>
</tr>
</tbody>
</table>
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>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$10.10</td>
</tr>
<tr>
<td>10</td>
<td>$1.10</td>
</tr>
<tr>
<td>30</td>
<td>$0.43</td>
</tr>
<tr>
<td>100</td>
<td>$0.20</td>
</tr>
</tbody>
</table>
Average Residential Prices By State
First 6 Months 2014

- 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)

Production (MW)

Liquid
Gas
Wind

Mark B. Lively
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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