Reciprocating Engines in Support of Grid Modernization

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Feb 10, 2016

Imagination at work.
Natural Gas Reciprocating Engines

GE (Waukesha, Jenbacher), Caterpillar, Cummins, Cooper, Superior, ....

Eff ~38%, NOx <1g/hp-hr, CHP compatible

www.eren.doe.gov/deer.html

Navigant - 27 GW of NG-Generators installed by 2024
NG Recip – Rich Burn - Performance

Meets CA, TX standards w/ 3-way catalyst

Grid Independent Mode (Islanded), load ramp-up response
## Grid Services - CAISO

<table>
<thead>
<tr>
<th>Grid Service</th>
<th>Description</th>
<th>NG Recips</th>
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</thead>
<tbody>
<tr>
<td>Frequency Regulation</td>
<td>&gt;500kW, max &lt;10 min, 30~60 min commitment, &gt;25% accuracy, ramp</td>
<td>Yes</td>
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<tr>
<td>Spinning Reserves</td>
<td>&gt;500kW, AGC w/ droop, 1 sec response, if F&lt;59.92 Hz, then 10% power in 8 sec, unit at idle for long periods</td>
<td>Yes, provisions for long idle ops</td>
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<tr>
<td>Non-Spin Reserves</td>
<td>&gt;500kW, 10 min to ramp, 30 min commitment</td>
<td>Yes</td>
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<tr>
<td>Ramping Reserves</td>
<td>Award based on 5-min ramp capability</td>
<td>Yes</td>
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<tr>
<td>Demand Response</td>
<td>&gt;500kW, full capacity in 40 min, duration 1~4 hours</td>
<td>Yes</td>
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<tr>
<td>Black Start</td>
<td>Start and support local load w/o grid, Volt/VAr control May start from “cold”</td>
<td>Yes, heaters for cold start</td>
</tr>
<tr>
<td>Voltage Reg</td>
<td>0.9 lag to 0.95 lead</td>
<td>Yes</td>
</tr>
</tbody>
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What will Grid Services look like in 2020? Or 2025?
Areas for Improvement - technical

Faster response from lean-burn engines
  fuel injection (>5 psi NG feed)
  electrified turbo chargers
  air impingement techniques
  variable valve timing

More efficiency from NG Generators
  advanced lean burn technology (→ 50% eff?)
  better “bottoming” cycle CHP technology (→ 65% eff?)

Grid Operator needs
  models for smaller DER’s
  aggregation/disaggregation functions to 100’s of DER’s