How much renewable energy can I have?
Theoretical limits to RE contribution in islanded hybrid-diesel microgrids

Marc Mueller-Stoffels, PhD
The Question and why to ask it

- **How much RE can be integrated into an isolated diesel microgrid?**
- **Integration with existing infrastructure**
  - Diesel generators
  - Life-cycle: 20+ years
- **Adding too much RE**
  - Damage to diesels
  - Power quality issues
  - Reduced/no savings
MOL & SRC conditions

• At no load level may the available RE power cause the logically online generators to be under-loaded.
  
  – *Implication*: the maximum RE power allowable is the load minus the *Minimum Optimal Loading* (MOL) of the online generators

• At any time, the generators online have to be able to meet the total unmanaged load plus the spinning reserve requirement.
  
  – *Implication*: More RE power does not mean a smaller generator set can be used due to lack of spinning reserve capacity (SRC).
<table>
<thead>
<tr>
<th>Penetration Class</th>
<th>Operating Characteristics</th>
<th>Power Penetration</th>
<th>Energy Penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low</td>
<td>No integrated control system</td>
<td>&lt;60%</td>
<td>&lt;8%</td>
</tr>
<tr>
<td>Low</td>
<td>Integrated controls curtail/dispatch RE; Simple managed loads</td>
<td>60 – 120%</td>
<td>8 – 20%</td>
</tr>
<tr>
<td>Medium</td>
<td>Sophisticated managed loads</td>
<td>120 – 300%</td>
<td>20 – 50%</td>
</tr>
<tr>
<td>High</td>
<td>Diesel-off possible; highly sophisticated controls; potentially energy storage</td>
<td>300 – 900%</td>
<td>50 – 150%</td>
</tr>
</tbody>
</table>
Case 1: No Control over RE resource

- Powerhouse knows nothing about RE resource
  - Pretend it is not there, i.e., static system
- Thus, maximum allowable RE directly determined by margin between MOL and load

**Example System:**
- Sum of diesel capacity is 1200 kW, e.g., 200 kW and 1000 kW units, or 500 kW and 700 kW units
- Load ranges from 360 kW to 1000 kW
- Spinning reserve is 75 kW
- MOL: 30%
Case 2: Still No Control over RE

- Powerhouse knows RE power output
  - Dynamic spinning reserve
- Improves maximum RE penetration somewhat in some cases
- Next step: ability to curtail

- **SRC or RE Backup:**
  - Assumes that sudden rise in load and drop in RE will not coincide
  - If RE Power < SRC, keep SRC
  - If RE Power > SRC, use RE Power as SRC
Case 3: Simple Managed Load

- One load that can be turned on or off
- Does not need diesel backing
- Control system turns load on if sufficient RE power is available
- Assume: part of general load requirements

**Examples:**
- Simple Electric Boiler
- Cooling Unit
- Pump
- Motor
Case 4: Variable Managed Load

• Single load that can receive a set point
• Or, aggregated small load
  – Much higher level of sophistication
• Does not need diesel backing

• Example:
  – Remote controlled smart metered loads
  – Distributed heat/cooling
## Summary

<table>
<thead>
<tr>
<th>Case</th>
<th>RE Power Penetration [kW]</th>
<th>Generator 1 [kW]</th>
<th>Managed Load [kW]</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.50</td>
<td>480</td>
<td>-</td>
<td>Very Low</td>
</tr>
<tr>
<td>2</td>
<td>0.54</td>
<td>440</td>
<td>-</td>
<td>Very Low/Low</td>
</tr>
<tr>
<td>3</td>
<td>1.33</td>
<td>340</td>
<td>290</td>
<td>Low/Medium</td>
</tr>
<tr>
<td>4*</td>
<td>1.55</td>
<td>340</td>
<td>270</td>
<td>Low/Medium</td>
</tr>
</tbody>
</table>

Warning! All of the above are theoretical results. Actual implementation depends on a whole lot more dynamic variables.
QUESTIONS?

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