Impact of Microgrids concept on low voltage network reliability

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## Reliability indices for stochastic outages

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Name</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>F&lt;sub&gt;i&lt;/sub&gt;</td>
<td>Frequency of supply interruption</td>
<td>1/a</td>
</tr>
<tr>
<td>D&lt;sub&gt;i&lt;/sub&gt;</td>
<td>Mean duration of supply interruption</td>
<td>h or min</td>
</tr>
<tr>
<td>Q&lt;sub&gt;i&lt;/sub&gt;</td>
<td>Unavailability</td>
<td>min/a</td>
</tr>
<tr>
<td>P&lt;sub&gt;i&lt;/sub&gt;</td>
<td>(Cumulated) Interrupted power</td>
<td>MVA/a</td>
</tr>
<tr>
<td>E&lt;sub&gt;i&lt;/sub&gt;</td>
<td>(Cumulated) Energy not supplied</td>
<td>MVAh/a</td>
</tr>
<tr>
<td>C&lt;sub&gt;i&lt;/sub&gt;</td>
<td>(Cumulated) Interruption cost</td>
<td>€/a</td>
</tr>
</tbody>
</table>
Test network to demonstrate effects of DG reliability impacts

- 20 kV Infeed
- 0.4 kV Network
- 2 MVA transformer
- K1, K2, K3, K4 locations
- 30 m, 50 m, 80 m, 100 m distances

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Comparison of reliability improvements by different DG types

- Reliability improvement increases with increasing full load generation hours of DG (highest for CHP, lowest for PV)

- Intermittency needs to be considered -> otherwise results are too good

Assumption for figures:
Installed DER capacity equals total network load (100 % DG penetration)

Schwaegerl, Tao, Herrmann- Germany-Paper 027
Comparison of reliability impacts of DG connection and Demand Side Management

- Demand Side Management yields better Pi and Ei compared to intermittent DG
- DG units improve Fi and Qi while Demand Side Management fails to do so
MVV, Mannheim, residential LV study network

\[ P_{\text{tot}} = 1.1MW; \cos \varphi = 0.95 \]
Assumptions:
DG unavailability = 20%  
DG penetration level = 80%

Reliability evaluation results are consistent with those of simple test network:

PV < WT < CHP < Controlled DG
A minimum total reliability cost exists when interruption cost and investment cost arrive at an optimized reliability index.
Economic benefits are achieved when:

- Installation and operation cost of protection and control devices + DG operation cost during outage < savings in interruption costs

Maximum outage costs (5 €/kWh):
 Nearly all Microgrid installations are economically beneficial

Minimum outage costs (0.5 €/kWh):
 Microgrid operation is not economical from reliability point of view
Conclusions

- Renewable and non-controllable generation units contribute to reliability only if their intermittent output power is higher than simultaneous demand.

- CHP plants contribute more to reliability improvement in comparison with intermittent PV or wind turbine units; conversion from heat-driven to electricity-driven mode enables island operation.

- Economic benefits of the Microgrids approach concerning reliability rise with increasing outage costs, especially for commercial and industrial consumer segments.
Thanks for your attention !