INTERCONNECTED MICROGRIDS THROUGH MULTIPOWER CONVERTER

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Evolution of Distribution Grid

- Distribution grid
  - + WT and PV
- Distribution grid with DGs
  - + Ancillary services
    - + Flexibility
- Active distribution grid
  - + Grid forming unit
- Operate active distribution grid in island
  - Interconnection of microgrids
### Reliability Requirement - Sweden

<table>
<thead>
<tr>
<th>Load interval (MW)</th>
<th>Interruption time under normal recovery conditions (hour)</th>
<th>Interruption time under abnormal recovery conditions (hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2 &lt; P \leq 5$</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>$5 &lt; P \leq 20$</td>
<td>8</td>
<td>24</td>
</tr>
<tr>
<td>$20 &lt; P \leq 50$</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>$P &gt; 50$</td>
<td>2</td>
<td>12</td>
</tr>
</tbody>
</table>

The delivery of electricity is **not considered as of good quality**, if the number of unplanned long interruption (>3 min) year $> 11$ times/year at the connection point.

[https://ei.se/sv/for-energiforetag/el/Leveranssakerhet-och-spanningskvalitet/](https://ei.se/sv/for-energiforetag/el/Leveranssakerhet-och-spanningskvalitet/)
## Interruption Statistics 2019: by local grid company

The number (percentage) of customers within each evaluated unit (redovisningsenherterna)

<table>
<thead>
<tr>
<th>REL</th>
<th>&gt;24 h</th>
<th>&gt;24 h &amp; &gt;11 interruptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>REL00909</td>
<td>34,896 (4.49%)</td>
<td>1,710 (0.22%)</td>
</tr>
<tr>
<td>REL00008</td>
<td>7,538 (94.20%)</td>
<td>0</td>
</tr>
<tr>
<td>REL03018</td>
<td>6,412 (4.89%)</td>
<td>2,250 (1.72%)</td>
</tr>
<tr>
<td>REL03008</td>
<td>2,505 (0.30%)</td>
<td>51 (0.01%)</td>
</tr>
<tr>
<td>REL00133</td>
<td>489 (2.92%)</td>
<td>0</td>
</tr>
<tr>
<td>REL00572</td>
<td>303 (0.26%)</td>
<td>8 (0.01%)</td>
</tr>
</tbody>
</table>
SAIFI & SAIDI 2018 & 2019 in Sweden

Ei, Supply Safety in Sweden, 2019
Other Distribution Grid Issues

- Local grid capacity congestion
- Reduced voltage quality
- Grid Losses
- Environmental aspects
Solutions to Reliability & Congestion

Reliability

- Conventional solutions
  - Build a parallel line
  - Burry down cables
  - Clean the corridor
  - Ring connection

- Modern solutions
  - Microgrid operation through interconnection by back-back converter
  - Microgrid operation through ESS

Congestion

- Conventional solutions
  - Build a parallel transformer
  - Build a new line
Barriers for Microgrid Solution in Sweden

• Island mode not allowed

• Ownership of Energy Storage
  • by DSO: limitation of functions
  • by third party: lack of financial incentives

• New knowledge & experience needed takes time
A Case Study for Interconnected Microgrid

MG-Hydro

MG-Wind

About 2 km away

Hydro Turbines

Industrial loads

Residential loads

Wind turbines
Supply Interruption in MG-Hydro

MG-Hydro

40 kV Grid

A1

T_A1

A2

A2_hydro

A2_ind

Hydro Turbines

Industrial loads

About 2 km away

MG-Wind

T_A2

T_B1

B2

B2_Res

B2_wind

Residential loads

Wind turbines
Supply Interruption in MG-Hydro

MG-Hydro

Hydro Turbines
A2_hydro
A2

Industrial loads
A2_ind

Energy Storage
A2_ESS

MG-Wind

Residential loads
B2

Wind turbines
B2_Ind

A2

About 2 km away

40 kV Grid

B2

A2_hydro
P_{net}

A2_ind

A2_ESS

100/0.4 kV

A1

A1

40/10 kV

B1

B1

40/10 kV

T_{B1}

T_{B2}

T_{A2}

T_{A1}

P_{net}

P_{wd}

P_{wd}

P_{wd}

P_{wd}

P_{wd}
Supply Interruption in MG-Wind

MG-Hydro

About 2 km away

MG-Wind
Supply Interruption in MG-Wind

 MG-Hydro

- Hydro Turbines
- Industrial loads

MG-Wind

- Residential loads
- Wind turbines
- Energy Storage

About 2 km away

40 kV Grid

B1

T

B2

B2_ESS

B2_Res

B2_wind

A1

A2

A2_hydro

P_{hyd}

P_{wd}

T_{A1}

T_{A2}

T_{B1}

T_{B2}

40/10 kV

A1

A2

T

10/0.69 kV

PMSG
Resulting Energy Storage for Each Microgrid

MG-Hydro

MG-Wind

About 2 km away

Hydro Turbines

Industrial loads

Energy Storage

Residential loads

Wind turbines

Energy Storage

A2_hydro

A2_Ind

A2_ESS

B2_hydro

B2_ind

B2_ESS

B2_Res

B2_wind

P_{hyd}

P_{wind}

P_{sad}

10/0.69 kV

10/0.4 kV

40/10 kV

40/0.69 kV

10/0.69 kV

10/0.4 kV

40/10 kV

40/0.69 kV

Energy Storage

Energy Storage
Interconnected Microgrid

MG-Hydro

MG-Wind

E.g. Cars, Trucks

Energy storage

Hydro Turbines
Industrial loads

A2_hydro

B2
B2_Ind

P_{conv,A}

P_{conv,B}

P_{inv}

Residential loads

Wind turbines

About 2 km away

Hydr. Turbines
Residential loads

PMSG
Hourly Balancing Power - 1 h Island Operation in 2018

22% – 27% of power reduction for ESS with interconnected operation @ interruption of both MGs


22% – 46% of power reduction for ESS with interconnected operation @ interruption of both MGs

M. Arvidsson, M. Hessman, K. Koit, T. Lindberg and O. N. Hurtig, On drivers, barriers and design parameters for implementation of microgrids in the Swedish power grid, Bachelor thesis, Chalmers University of Technology, May 2021
Functions Split of Multiport Converter
Without Energy Storage
Functions Split of Multiport Converter With Energy Storage

MultiportGrid project, WP1 led by Lisa Göransson, Chalmers University of Technology, Sweden
MultiportGrid project, WP2 led by Oriol Gomis, UPC, Spain
WP5, field data collection, led by Mattias Persson, RISE

WP6, Lab and field test, All
ERA-Net Smart Energy Systems

Multiportgrid Team
2020-2023