ASSESSMENT OF ACTIVE POWER CURTAILMENT METHODS IN LOW VOLTAGE GRIDS WITH REGARD TO THE GERMAN REGULATORY CONTEXT

Solar Integration Workshop, October 25th, 2017

Friederike Meier
AGENDA

- German regulation 2017: Active Power Curtailment
- Active power curtailment methods
  - Static active power curtailment
  - Dynamic active power curtailment
  - P(V) droop control
- Assessment
  - Hosting capacity
  - Time series simulation
  - Comparison
- Conclusion & Recommendations
German regulation 2017: Active Power Curtailment

- German Energy Act 2017: Strategic curtailment of 3% of the annual energy of renewables in order to increase the efficiency of future grid extension

→ Dimensioning the grid not for the full installed PV capacity $P_n$ but for $P_{3\%}$

![Schematic duration curve of a PV plant](image)

3 % of the annual energy
ACTIVE POWER CURTAILMENT METHODS

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Static active power curtailment

- Static active power curtailment (SAPC): Curtailment of all active power above $P_{3\%}$
- Ex post determination of threshold value $P_{3\%}$ → uncertainty for future years

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy implementation directly in the inverter</td>
<td>Curtailment even without present violations</td>
</tr>
<tr>
<td>Predictable Behavior</td>
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</tbody>
</table>

- Compliant to German regulatory for plants smaller than 30 kWp
Dynamic active power curtailment

- Using an optimal power flow to find the optimal curtailment
  - Minimizing the curtailed energy
  - Connection to control center

- Compliant to German regulatory in terms of the feed in management

<table>
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<td>No curtailment without present violations</td>
<td>High need for Information and Communication Infrastructure (ICT)</td>
</tr>
<tr>
<td>Lowest energy losses</td>
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</tbody>
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### P(V) droop control

- **P(V) droop control configuration with** $P_{\text{max}} = P_n$ and $P_{\text{min}} = P_{3\%}$

- **Here:**
  - $V_1 = 1.05$ p.u.
  - $V_2 = 1.06$ p.u.

#### P(V) droop characteristic curve

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- Compliance to German regulatory depending on parametrization
- Billing of curtailed energy not regulated in Germany
ASSESSMENT

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Hosting capacity

- Amount of maximum installable PV capacity in a grid before operational limits are violated.
- Probabilistic determination using varying generator positions and sizes.
- Indicator for the impact of an operation method on the grid extension costs.
- Classification into voltage constrained grids and loading constrained grids.
Hosting capacity for real low voltage grids for three active power curtailment methods

\[ HC_{increase} = \frac{HC_{controlled}}{HC_{uncontrolled}} \]
Time series simulation

- Determination of annual curtailed energy of the curtailment methods
- Operational expenses of the curtailment methods
  - Reimbursement of curtailed energy to the PV plant owner (DAPC)
  - Loss in revenue for the PV plant owner (SAPC)
- Benchmark loadcase derived from maximum hosting capacity using SAPC → Grids with significant lower hosting capacity with P(V) not considered
Time series simulation

- Curtailed energy with P(V) droop control is lower than with SAPC.
- Grids 3, 10, 14: significantly less curtailment with DAPC than with P(V).

Curtailed annual energy of the low voltage grids for the respective curtailment method.
Comparison

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<th>Dynamic active power curtailment</th>
<th>P(V) droop control</th>
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<tbody>
<tr>
<td>Hosting capacity increase</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Low curtailed energy</td>
<td>0</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Low Installation costs</td>
<td>+</td>
<td>--</td>
<td>+</td>
</tr>
<tr>
<td>Compliance</td>
<td>(+)</td>
<td>+</td>
<td>(+)</td>
</tr>
</tbody>
</table>

- Compliance of P(V) depending on parametrization,
  - Billing/reimbursement not regulated
- SAPC currently only allowed for PV plants smaller than 30 kWp
  - No reimbursement
CONCLUSION & RECOMMENDATIONS

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Conclusion: Options for P(V) droop control

- Loading constrained grids: P(V) droop control is not suitable. A curtailment could only be conducted using SAPC and DAPC
- Voltage constrained low voltage grids: P(V) droop control is activated in case of violations in the grid and successfully avoids overvoltage and overloading.
- P(V): Trade-off between low curtailed energy and low installation expense
- Further investigations necessary on the combination of active power curtailment and reactive power control (At the moment, reactive power provision by distributed generators is not reimbursed) and transformer tap control
RECOMMENDATIONS

- P(V) droop control needs to be considered in future case studies on active power curtailment and its impact on grid expansion costs.

- SAPC and P(V) droop control should be respected in the revision and modification of future technical regulation.

Thank you very much for your attention!

Contact: Friederike Meier, friederike.meier@iwes.fraunhofer.de