Power System Testing

Verification of Aggregated Services

"Testing and Research Infrastructure for Future Power Grids”

Pre-Conference Workshop,
7th International Conference on Integration of Renewable and Distributed Energy Resources, Niagara Falls, October 24-28, 2016

Presenter: Wolfram Heckmann, Fraunhofer IWES, Kassel, Germany
Power System Testing – Verification of Aggregated Services

- Challenges in Future Power System Operation
- Aggregated Services
  - Project Example INEES, Fraunhofer IWES, Germany
- Validation Methods for Power System Operation
- SIRFN Approach
  - Microgrid Example, RSE, Italy
Security of supply – aspects and time scales

- Frequency management
- Turbine control
- Voltage control
- Protection

- Day-ahead
- Intra-day

- Secured power
- Fuel availability
- Climate change

- Technology
- Market
- Society

- 0,1
- seconds
- 1
- minutes
- 10
- hours
- 1
- days
- 10
- years
- 100
Less bulk power plants in future grids

<table>
<thead>
<tr>
<th>Energieträger</th>
<th>25% EE-Szenario</th>
<th>50% EE-Szenario</th>
<th>80+% EE-Szenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steinkohle</td>
<td>25,3</td>
<td>13,8</td>
<td>18,4</td>
</tr>
<tr>
<td>Braunkohle</td>
<td>18,8</td>
<td>10,2</td>
<td>11,3</td>
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<tr>
<td>Kernenergie</td>
<td>12,1</td>
<td>6,6</td>
<td>0</td>
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<tr>
<td>Pumpspeicher</td>
<td>9</td>
<td>4,9</td>
<td>10,7</td>
</tr>
<tr>
<td>Großbatteriespeicher</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Gaskraftwerke</td>
<td>23,8</td>
<td>12,9</td>
<td>37,5</td>
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<tr>
<td>Wind onshore</td>
<td>37,5</td>
<td>20,4</td>
<td>72</td>
</tr>
<tr>
<td>Wind offshore</td>
<td>0,5</td>
<td>0,3</td>
<td>25,3</td>
</tr>
<tr>
<td>Photovoltaik</td>
<td>37</td>
<td>19,1</td>
<td>56,5</td>
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<tr>
<td>Biomasse</td>
<td>7</td>
<td>3,8</td>
<td>9,2</td>
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<tr>
<td>Laufwasser</td>
<td>4,1</td>
<td>2,2</td>
<td>3,7</td>
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<tr>
<td>Speicherwasser</td>
<td>1,5</td>
<td>0,8</td>
<td>1,3</td>
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<tr>
<td>Sonstige Erzeuger</td>
<td>7,4</td>
<td>4,0</td>
<td>5</td>
</tr>
<tr>
<td>SUMME</td>
<td>184,0</td>
<td></td>
<td>253,9</td>
</tr>
</tbody>
</table>

Increasing share of distributed generation

Possible distribution of generating units in the scenarios of 25%, 50%, and 80+% renewable energy in Germany taken from the project NETZ:KRAFT
Growing Complexity

<table>
<thead>
<tr>
<th>Type</th>
<th>Number of units</th>
<th>Installed power</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV in Germany</td>
<td>More than 1 million</td>
<td>About 40 GW</td>
</tr>
<tr>
<td>Wind in Germany</td>
<td>More than 20 thousand</td>
<td>About 40 GW</td>
</tr>
</tbody>
</table>

- Growing number of generators
- Growing variability of power production
- Growing number of actors
  - Grid operator, energy supplier, ESCOs (metering service, load aggregators, generation aggregators, …)
  - Prosumers, demand-side-management
- Growing number of storage systems (large scale and household scale, electric vehicles)
- Growing number of automatic control strategies and functionalities
- Bi-directional power flow
More interdependencies in power system control

System control by
- Market mechanisms
- Interaction between market and direct actions
- Emergency actions

(German „BdEW-Ampel“)
Tasks, Functionalities and Tools in a Smart Distribution Grid

Tasks
- Voltage stability
- Contingency management
- Fault tracing and treatment
- Supply restoration/intentional islanding
- System stability support
- Loss reduction
- Reserve power provision
- Balancing group management

Functionailities
- Reactive power control
- Voltage control
- Flexible grid topology
- State Estimation
- Component monitoring
- Real power control

Tools
- Switching/isolation
- Adaptive protection
- Load/generation control
- Measurements/voltage quality
- Grid planning/asset management
- Reactive power provision
- Generation/load shifting
- Generation/load reduction
- Generation/load monitoring
- Generation/load forecast
- Power market

Tasks and services of the distribution system operator (DSO)

Possible tasks and tools of third parties

Design: Fraunhofer IWES on the basis of VDE-Positionspapier „Energieinformationsnetze und -systeme“
Example: Possible conflict between congestion management and frequency support

Fictitious, but possible grid situation

Possible conflict

1) Line congestion
2) WP2, 20 MW curtailed by DSO
3) WP1, 20 MW negative reserve requested by TSO
4) Line congestion removed
5) WP2, curtailment released by DSO

⇒ Reserve provided, but no effect for the system
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System operation – characteristics and services

System Operation

- System Characteristics
  - Inertia
  - Self-regulation Effects
  - Short Circuit Capacity

- Ancillary Services
  - Frequency Control
    - Frequency Containment
    - Frequency Restoration
    - Reserve Replacement
  - Voltage Control
    - Dynamic (Fault-ride-trough)
    - Steady-state
  - System Restoration
    - Black Start Capability
    - House Load Operation
    - Grid Energizing Capability

- Operational Services
  - System Coordination/Dispatch
  - System Control
  - Data Acquisition
  - Compensation of Grid Losses

Source: Fraunhofer IWES
Aggregated services – options from DER and microgrids

- **Frequency control**
  - Global service
  - Market can be created
  - Provided by freely distributed units

- **Voltage control & system restoration**
  - Nodal service
  - Bilateral agreements or grid code requirements
  - Provided by single units or units concentrated in grid areas (e.g. microgrids)
Project example – INEES concept

- Smart interconnection of e-cars for the provision of ancillary services
  - [http://www.erneuerbar-mobil.de/projekte/inees](http://www.erneuerbar-mobil.de/projekte/inees) (unfortunately German only)
Project example – INEES field test result

- Smart interconnection of e-cars for the provision of ancillary services
- Field test with a pool of 20 cars
- Limitations because of user behavior and technical availability

Exemplary week with theoretical and actual available pool capacity

Heckmann, 2016-10-24
IRED 2016, Joint SIRFN-Electra Pre-Conference Workshop
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## Verification methods

<table>
<thead>
<tr>
<th>Type</th>
<th>Computer Simulations</th>
<th>Laboratory Tests</th>
<th>Hybrid System Tests</th>
<th>Training simulator</th>
<th>Field Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Models</td>
<td>Component</td>
<td>Interface</td>
<td>Control or Power HIL</td>
<td>Interoperability</td>
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<tr>
<td>Feature 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Feature 2</td>
<td></td>
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<td>…</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
What can we verify with what (-/0/+) score?

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<th>Hybrid System Tests</th>
<th>Training simulator</th>
<th>Field Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>+</td>
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<tr>
<td>Requirements acceptance</td>
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<td>-</td>
<td>0</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>System</td>
<td>0</td>
<td>O</td>
<td>+</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Interfaces</td>
<td>-</td>
<td>O</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Components</td>
<td>-</td>
<td>+</td>
<td>O</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Customer behaviour</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>O</td>
<td>+</td>
</tr>
<tr>
<td>Resilience &amp; recovery</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

...
System testing defines component testing

- System needs
- System services
- Product requirements
- Products
  - Hardware
  - Control
  - Communication
- Device testing specification
- System tests
- System service testing specification/grid codes
- Device tests
- System needs
- Functionality
- Interoperability
- Reliability
- Efficiency

Products:
- Hardware
- Control
- Communication

System services:
- System tests
- System needs
- Functionality
- Interoperability
- Reliability
- Efficiency

Product requirements:
- Hardware
- Control
- Communication
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Power system testing – SIRFN objectives and approach

Objectives
- Categorize testing tasks in future power systems
- Map testing tasks to existing testing capabilities and facilities
- Define the needs for development

Approach
- Select a set of relevant use cases
- Specify the testing needs
- Describe the testing activities/procedures
- Derive the necessary testing capabilities
- Map the capabilities to state-of-the-art testing facilities
- Describe possible gaps

Aggregated services
SIRFN - power system testing, knowledge sharing

- Presentation of project results related to aggregated services
  - Web conferences organized by DERlab

- DTU, Denmark
  - Global aggregated ancillary services
  - Frequency support by aggregation of huge numbers of small units
  - Performance assessment of aggregation control services for demand response

- RSE, Italy
  - Nodal aggregated ancillary services
  - Grid parallel microgrid operation
  - Intended islanding and resynchronization
**Microgrid islanded operation**

- **Objectives**: develop and test systems controls to manage islanded operation and grid re-synchronization
- **Results**: Islanded operation tested successfully; re-synchronization control under development

**Island management with systems adopting «droop controls»**

Local control algorithm that modifies generator working point in order to maintain voltage and frequency according to defined limits

- Mainly Resistive Grid Droop curves:
  - P-V
  - Q-F

**Connected Systems**

- Lithium storage (droop)
- Lead Storage
- CHP synchronous generator
- R/L Load
- PV Fields
Microgrid remote Control

Implemented Functions

- Remote disconnection and selective protections control
- Active User remote management (P/Q control) for grid balancing and voltage control

Prosumer benefits:
- disconnections reduction and grid services valorization

Grid Benefits:
- grid balancing and voltage control

TF: Sources MgM from SP GEN&LOAD

Ricerca sul Sistema Energetico - RSE S.p.A.

RSE TF Active User in Lambrate Project: part of the main Smart Grid project launched by AEEGSI (Italian Energy Authority)
SIRFN - power system testing, next web conference

- 24 November 2016, 4 p.m. German time
- Balancing energy from wind and PV farms (ReWP)
- Precise knowledge of possible in-feeds
- Risk-based bidding strategies in the balancing power market
Keep in touch!

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Operating Agent of SIRFN
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THANK YOU