The complex and heterogeneous energy system is changed by the influence of decentralized fluctuating renewable energy generation.

1) Distributed Energy Resources
2) Combined (Cooling) Heat and Power
Specific challenges for distribution grids

Physical effects

- Distributed Generation → U problem (rural area), I problem (urban areas)
- Flexible Tariffs → “synchronized” consumption behavior
- Implemented protection concepts become obsolete
- Flexibility Trading & e-mobility → load problems combined with U/I challenges
- High amount of inverters connected to the grid → Grid stability

Challenges for distribution grid operators

- Which effect causes problems where in the LV/MV Grid → Lack of information
- Passive consumers become highly dynamic & active prosumers → Grid planning rules loose their validity

Strong demand to increase efficiency

- Efficient utilization of existing infrastructure, optimized grid operation
- Demand for more information to support efficiency of 3rd parties (TSO’s, market partners, energy consumer)
<table>
<thead>
<tr>
<th>Use case</th>
<th>Description</th>
<th>Action SysDL module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptation of voltage band at coupling point</td>
<td>• Risk of violation of agreed voltage bands</td>
<td>Evaluation of temporary voltage band adaptation for period of potential voltage band violation in high voltage grid</td>
</tr>
<tr>
<td>Reactive power request by distribution grid</td>
<td>• Risk of deviation from allowed voltage band in transport grid</td>
<td>Determination of reactive power set-points for distributed power generation systems</td>
</tr>
<tr>
<td>Evaluation of re-dispatch request</td>
<td>• TSO requests allowance of preventive re-dispatch with power plant from 110 kV grid</td>
<td>Evaluation of effects of re-dispatch and – as a consequence - acceptance or denial</td>
</tr>
<tr>
<td>Local voltage control 110 kV</td>
<td>• Voltage in distribution grid approaches allowed bounds</td>
<td>Local voltage control in distribution grid by appropriate reactive power provisioning</td>
</tr>
<tr>
<td>Minimizing losses 110 kV</td>
<td>• Normal operation</td>
<td>Minimizing losses by appropriate reactive power provisioning</td>
</tr>
<tr>
<td>Local contingency management 110 kV</td>
<td>• Current contingency in 110 kV grid</td>
<td>Activation of reactive power set-points in distributed power generation systems for contingency management and for minimizing active power reduction</td>
</tr>
</tbody>
</table>
Future power system control architecture must be compatible to existing architecture and components

A self-similar control architecture guarantees scalability of coordinated distributed control
**Higher level control tasks - overview**

Some or all of these tasks can be executed on large scales down to micro-grid or even building level.

<table>
<thead>
<tr>
<th>Economic planning</th>
<th>Supervisory power control</th>
<th>Voltage and frequency control</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Matches predicted power demand and supply (e.g. on day ahead) at lowest cost</td>
<td>• Execution of economic planning on power system</td>
<td>• Implemented locally on generators and loads and coordinated by superordinate management systems</td>
</tr>
<tr>
<td>• At large scales, power is supplied by large power plants or by aggregated smaller plants and flexible loads</td>
<td>• Fast power balancing after unpredicted generation and demand variations</td>
<td>• Usually achieved by droop controllers (=proportional controllers) providing reference values for the low level controllers</td>
</tr>
<tr>
<td>• At smaller scales, distributed generation and flexible storages and loads are coordinated centrally (e.g. at building, campus or city level)</td>
<td>• Takes into account requirements concerning e.g. power-line overloading or N-1 safety</td>
<td>• Analysis and design of these controllers is quite challenging because of the complex, interconnected dynamics of the individual generators</td>
</tr>
<tr>
<td>• Market based approaches support economic unbundling of power generation and power distribution and hide sensible information</td>
<td>• Required flexibility of generation and load is achieved by ancillary service platforms, e.g. for active and reactive power reserves similar to today’s primary reserve market</td>
<td>• Voltage control in distribution grids has become an acute problem because of the strong power injection at this level</td>
</tr>
</tbody>
</table>

**Timescale:**
- Economic planning: 5-15 min
- Supervisory power control: <100s
- Voltage and frequency control: <1s
Outlook

Main trends
• Substantial progress in battery technology (e.g. longer cycle-lifetime, lower price, simple recharging)
• Electricity will have increased share in heating and mobility sector
• Digitalization will lead to reduced engineering effort and allows for new service business models

Open research issues
• How to improve estimates on attractor regions in dynamic power system models?
• How to treat uncertainties in power flow calculations and optimal control applications properly?
• How to control islanding of micro-grids?
• What is the effect of islanding of many micro-grids on the dynamics of the whole grid?
• Control solutions for multimodal energy systems
References I


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