What Matters for Successful Integration of Distributed Generation

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Energynautics Areas of Expertise

Grid Integration

Renewable Energies

Decentralised Power Plants

Energy Markets

SUSTAINABLE DEVELOPMENT FOR POWER AND ENERGY
Agenda

1. Definition of Distributed Generation

2. Experience with Distributed Generation

3. Future Requirement: Coordinated Control

4. Additional Success Factors
Definition Distributed Generation*

- The purpose of distributed generation is to provide a source of active electric power.
- The location of distributed generation is defined as the installation and operation of electric power generation units connected directly to the distribution network or connected to the network on the customer site of the meter.
- The rating of distributed generation of the DG power source is not relevant.
- The power delivery area is not relevant.
- The technology used for DG is not relevant.
- The environmental impact of DG is not relevant.
- The mode of operation of distributed power generation is not relevant.
- The ownership of DG is not relevant.
- The penetration of distributed generation of DG is not relevant.

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Examples of DG Penetration Levels:

> Germany PV (Total PV: 33 GW—min Demand in Germany: about 40 GW/max. 80 GW):
  > Approx. 65% (21.5 GW) at LV level (230 V/400 V)
  > Approx. 35% (11 GW) at MV level (11–60 kV)
  > Few plants (0.5 GW) at HV level (110 kV)

> Germany Wind Power (Total Wind: 32 GW):
  > Mainly (95%) connected to MW level (11–60 kV), but changing due to re-powering

> Italy Wind+PV (Enel Distribuzione):
  > Approx. 20 GW at LV+ MV level

> Spain Wind (Total: 20 GW):
  > Approx. 3% (0.6 GW) at MV level (11–45 kV)
  > Approx. 10% (2 GW) at MV level (66 kV)
  > Approx. 87% (17.4 GW) at HV level (110–400 kV)
Distribution of Production Capacity in Denmark

Interconnections:
- 400 kV: 4 primary units, 1,488 MW
- 150 kV: 5 primary units, 1,914 MW
- 60 kV: 15 local CHP units, 569 MW
- 10-20 kV: 545 local CHP units, 1,087 MW
- 400 V: 4,074 wind power units, 2,214 MW

Source: Energinet.dk
Typical Issues: Voltage Control

**Common & partly recommended concepts**

- **$P_{f_{fix}}$** constant power factor
- **$PF(P)$** power factor due to actual active power feed-in
- **$Q(V)$** reactive power depending on actual grid voltage
## Possible Voltage Control Solutions

<table>
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<tr>
<th>Conventional</th>
<th>Voltage regulation unit</th>
<th>Indirect via power management</th>
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<td>Network enhancement</td>
<td>Electronic voltage regulator vs. tap changer</td>
<td>&quot;Wide area&quot;-regulator</td>
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- Source: ABB
Cos $\varphi$ - Regulation Specification by BDEW, Germany

--- MV-Network ---

- Each dispersed generation unit must be operated with a displacement factor of $\cos \varphi = \pm 0.95$
- Reactive power determined by set-point value or by remote controlled value
- Set-point value
  - fixed displacement $\cos \varphi$,
  - $\cos \varphi (P)$ ($0 < t < 10$ sec),
  - Fixed reactive power in MVar,
  - Reactive power / voltage characteristic $Q(U)$
- Remote control value has to be realized within 1 min
Additional Issues Identified by TSOs

- Protection Coordination (bi-directional power flow) and protection relays trip local generators after distant faults on the high-voltage transmission grid (Solutions available);

- Local grids cannot maintain normal n-1 security if local generation exceeds local demand and if separation of generation and consumption is insufficient (Rather small impact on system operation);

- Traditional under-frequency load shedding schemes will disconnect both load and generation (Important);

- System operation and security analysis has become less accurate due to missing information on local generation for system operator (Very important and significant task);

- Restoration after fault has become more complicated and more time consuming (Important);
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2. Experience with Distributed Generation
3. **Future Requirement: New Control Approach**
4. Additional Success Factors
Example: The Cell Controller Concept in Denmark “The largest Smart Grid Project in Europe”

- Distributed on-line monitoring and control system
- New Control architecture integrated into power system architecture
- Efficient tool for automated DNO distribution grid management
  - VAR control
  - Voltage control
  - Constraint management
- Provides TSO services on request
  - Reactive power import/export control (Virtual Power Plant)
  - Emergency active power import/export (Virtual Power Plant)
- Shifts to intentional island operation on trigger signal
- Fully compatible with various market concepts
Layered control hierarchy using distributed agent technology and high speed fiber network

Each agent consists either of an industry CPU, a high-end RTU or an intelligent meter

New Controll Architecture for the Cell Concept
Cell test area is approx. 1000 km² and includes 28,000 customer meters

- One 150/60 kV substation with tap changer controlled transformer
- 13 substations (60/10 kV) with tap changer controlled transformers
- 5 CHP plants with a total of 11 gas engine driven synchronous generators totalling 33 MW
- 47 Danish-style wind turbines, all larger than 600 kW, with a total installed capacity of 37 MW
- One 0.8 MVA Synchronous Condenser for added voltage control
- One 1.0 MW fast reacting Secondary Load Controller (i.e. dump load) for added frequency control
- All 60 kV lines and cables within the Cell area
- 69 load feeders (10 kV) with all loads and remaining smaller wind turbines.
Cell Controller Agents – mounting and site acceptance test
Principal Controll Approach Pilot Project
Important Lessons Learned:

Software solutions can provide a lot of new functions, but it needs a long time to make the software very reliable.
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Assignment of the (full) responsibility for system stability to the TSOs is not appropriate.

DSOs shall be responsible for stability of their own system and use this as basis for defining technical requirements for all connected units.

- DSOs need to increase focus on all relevant aspects of local system aspects (system integrity)
- DSO/TSO’s should establish clear technical rules, role play and responsibilities in their common interfaces
- Example: DSOs apply ‘formal’ requirements (U/Q) without properly understanding why needed now (argument used: it may be needed in future – e.g. dynamic voltage reference)

First step: Joint reflection on the issues by TSOs and DSOs

*Source: “Success factors for high RES penetration at distribution level”, by Eckard Quitmann (Enercon), Jens Fortmann (Repower), Peter Christensen (Vestas), Bernard Ernst (SMA), Stephan Wachtel (GE), Frans Van Hulle (XP Wind), presented at: Renewable Energy Integration Symposium, Mainz, June 2013
Grid Codes are insufficient and imprecise. Justification for any performance beyond typical best practice is not given

- They do not give clear guidelines for the performance needed from DG and other connected users.
- Codes, simulation models and verification methods are developed independently in different circles
- A homogenous industry practice is missing

First step: Further develop appropriate Grid Code Requirements.
DG Capabilities

DG technologies are not fully ready to support the distribution grid in an adequate way at high penetration levels. Development and implementation of capabilities is hindered both by manufacturers and network operators.

- Some capabilities RES are well developed and poorly used
  - Reactive power
- Some other issues there is room for improvement:
  - Fast primary reserve upwards and downwards

Further development of technology required + Incentives Needed
Providing ancillary services in distribution grids is currently not economically viable for (RES) DG

- Necessity of services at D-level? Considering that TSO requirements are pushed to generators connected at D level
- To what extent is VAR provision a service? Where do minimum capabilities end and where do AS start?
- How does AS provision fit in market based approach (unbundling)?
- Which AS will exist in future grids?

Establish commercial framework to enable proper business case for RES to provide ancillary services

Or: push for good technical best practices and then ask for non-market based remuneration
Is there a limit for DG? At the moment DG level in distribution grid is often limited to x% of instantaneous load. Why?

- Relevant aspects: controllability / stability / cost-effectiveness
- Limitations arise because necessary control functionalities not yet programmed in / how realistic is it to develop/implement the relevant control changes?
- Stability: Management possible with state-of-art DG!
- EU wide (RES) DG targets often don’t consider the needs for additional control in distribution networks!

Investigate key reasons/physical obstacles for specific limit numbers

Design/test solutions - parallel solutions needed
Distributed Generation will play an important role in the future power system, but a rethinking of the overall control architecture/integration approach is required for high/very high penetration levels to be able to capture all benefits of DG.
THANK YOU FOR YOUR INTEREST!