What Matters for Successful Integration of Distributed Generation

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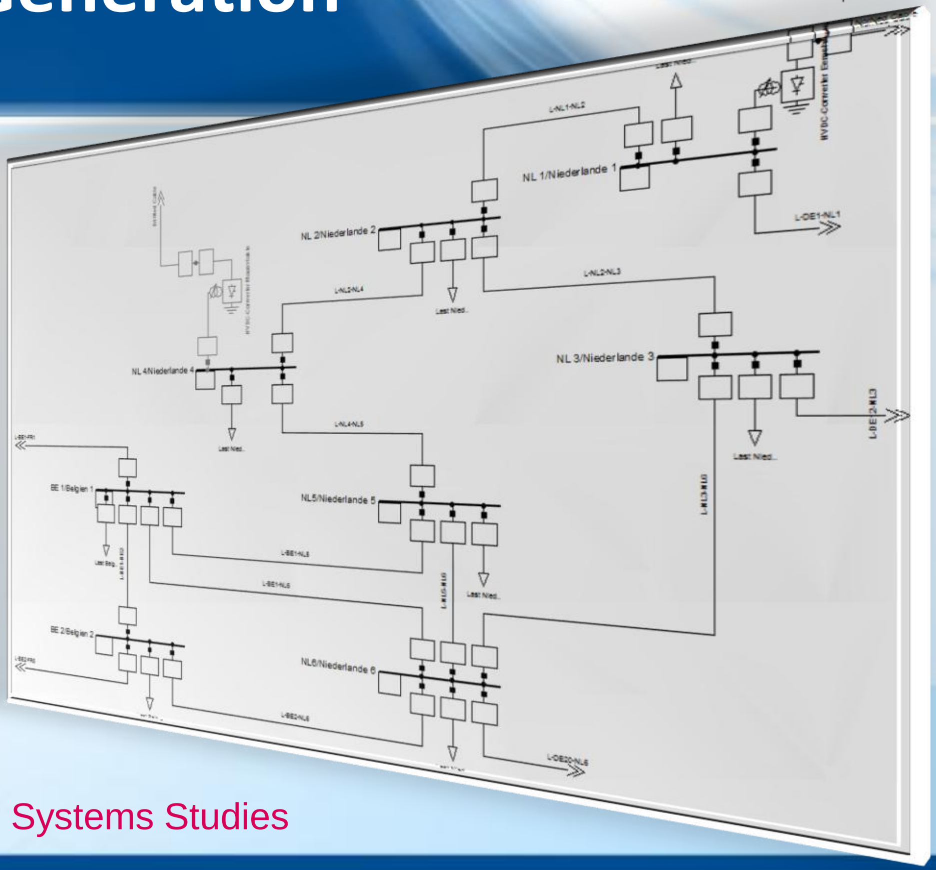

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Energynautics Areas of Expertise

Grid Integration

Renewable Energies

SUSTAINABLE DEVELOPMENT FOR POWER AND ENERGY

Decentralised Power Plants

Energy Markets

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***

*Source: Distributed Generation: A Definition, Ackermann et.al., Electric Power System Research, Vol. 57 (2001), pp. 195-204

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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 Distribuzion):
  - 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

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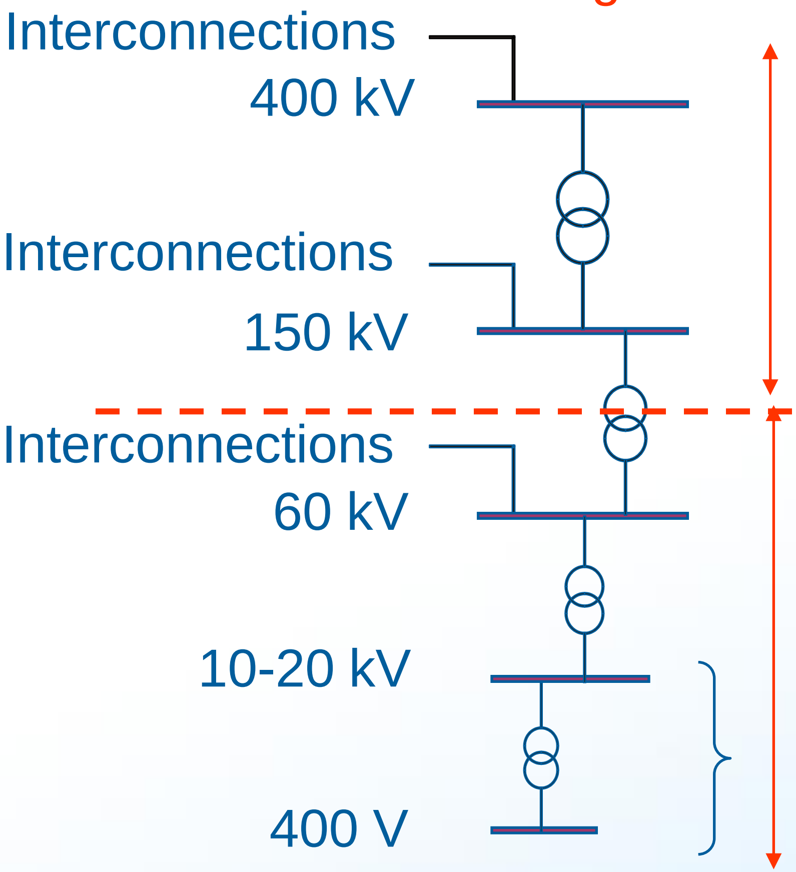
Range of central control

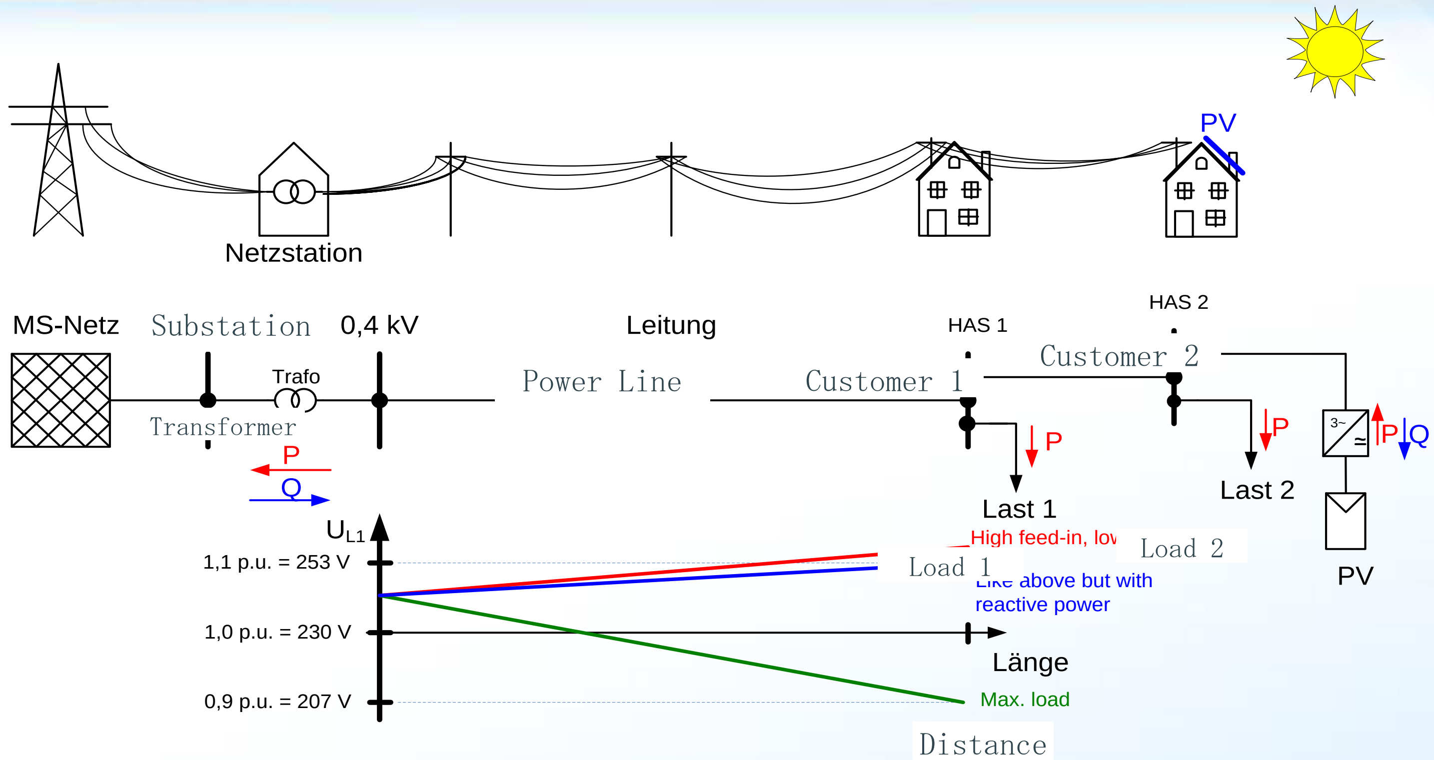


4 primary units:	1,488 MW
5 primary units:	1,914 MW
offshore wind:	960 MW
15 local CHP units:	569 MW
545 local CHP units:	1,087 MW
4,074 wind power units:	2,214 MW

Non-dispatchable and beyond central control

Source: Energinet.dk

Typical Issues: Voltage Control



Common & partly recommended concepts

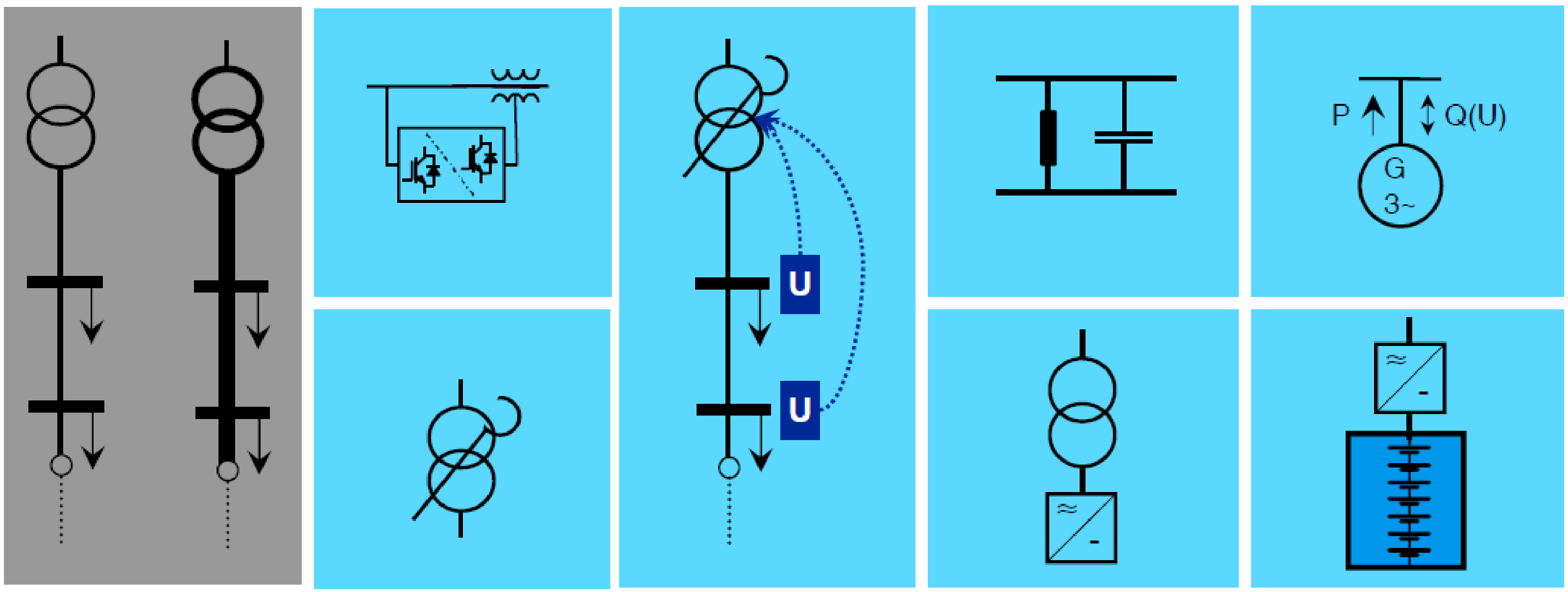
Pf_{fix} constant power factor

PF(P) power factor due to actual active power feed-in

Q(V) reactive power depending on actual grid voltage

Possible Voltage Control Solutions

Conventional	Voltage regulation unit		Indirect via power management	
Network enhancement	Electronic voltage regulator vs. tap changer	„Wide area“-regulator	Reactive power compensation equipment	Cos φ - regulation Storage / Demand Site Mgt



Source: ABB

Cos φ - Regulation
Specification by BDEW, Germany

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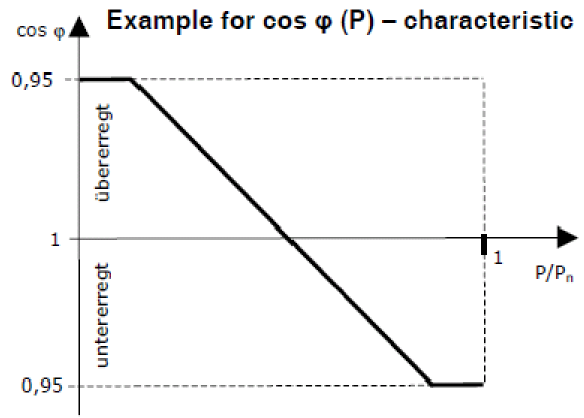
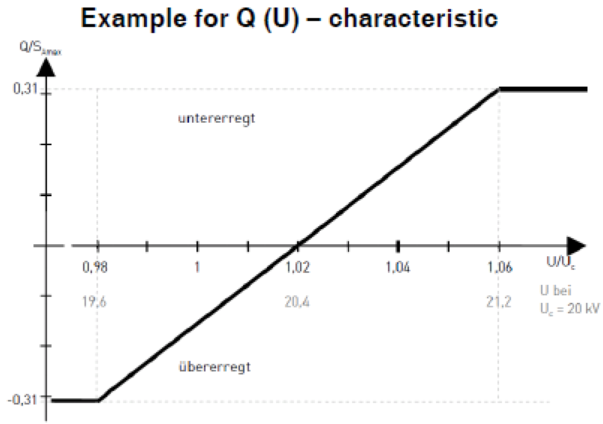


Source: Technical Guideline of the BDEW, Generation Plants at the Medium Voltage Grid



Source: Standard Q(U)- characteristic of EnBW Regional AG (Germany)

MV-Network

- Each dispersed generation unit muss be operated with a displacement factor of cos φ = ±0,95
- Reactive power determined by set-point value or by remote controlled value
- Set-point value
  - fixed displacement cos φ,
  - cos φ (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

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- **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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Example: The Cell Controller Concept in Denmark "The largest Smart Grid Project in Europe"

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- **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**

New Controll Architecture for the Cell Concept

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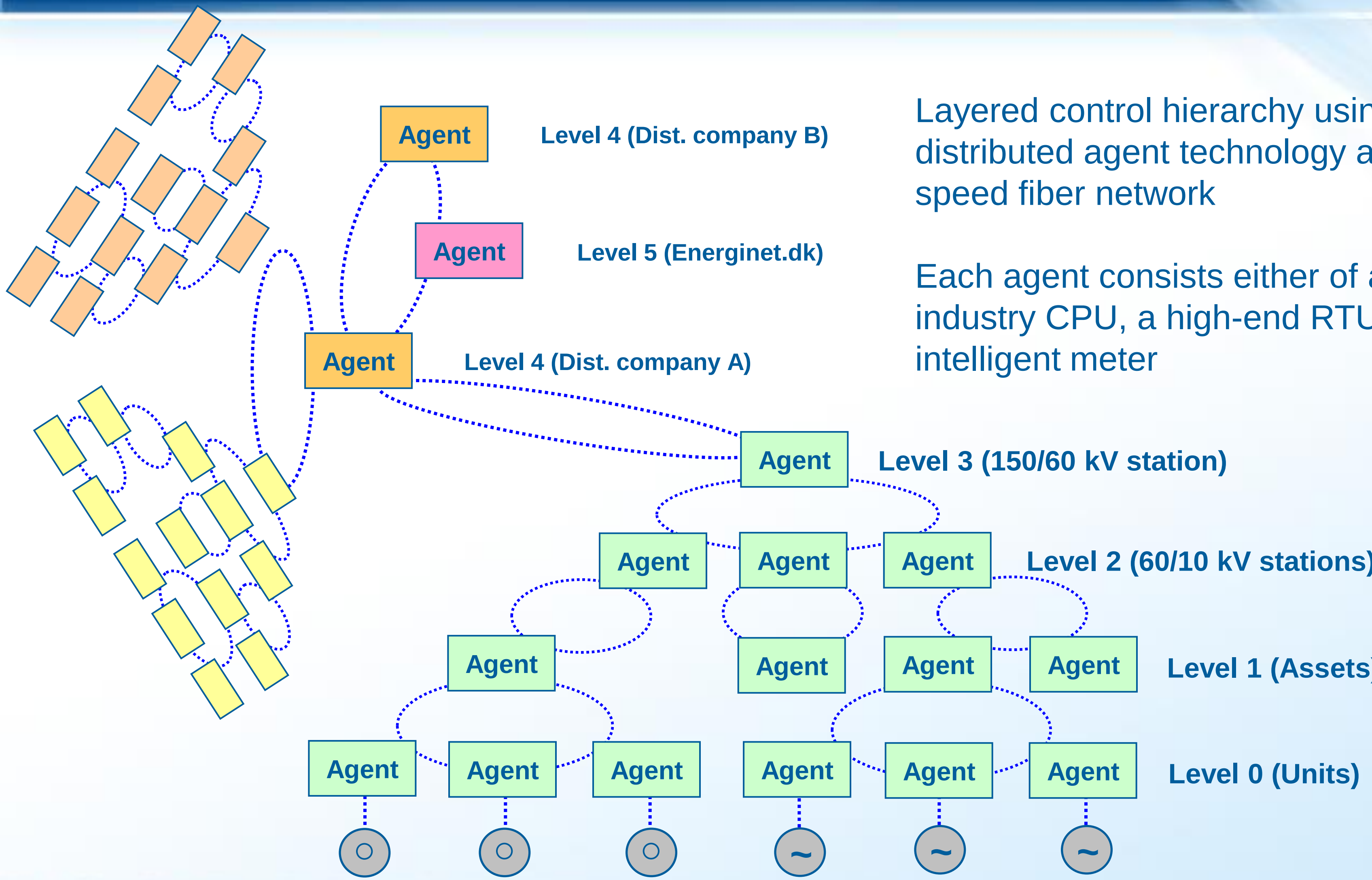

Layered control hierarchy using distributed agent technology and high speed fiber network

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

Cell test area is approx. 1000 km^2 and includes 28,000 customer meters

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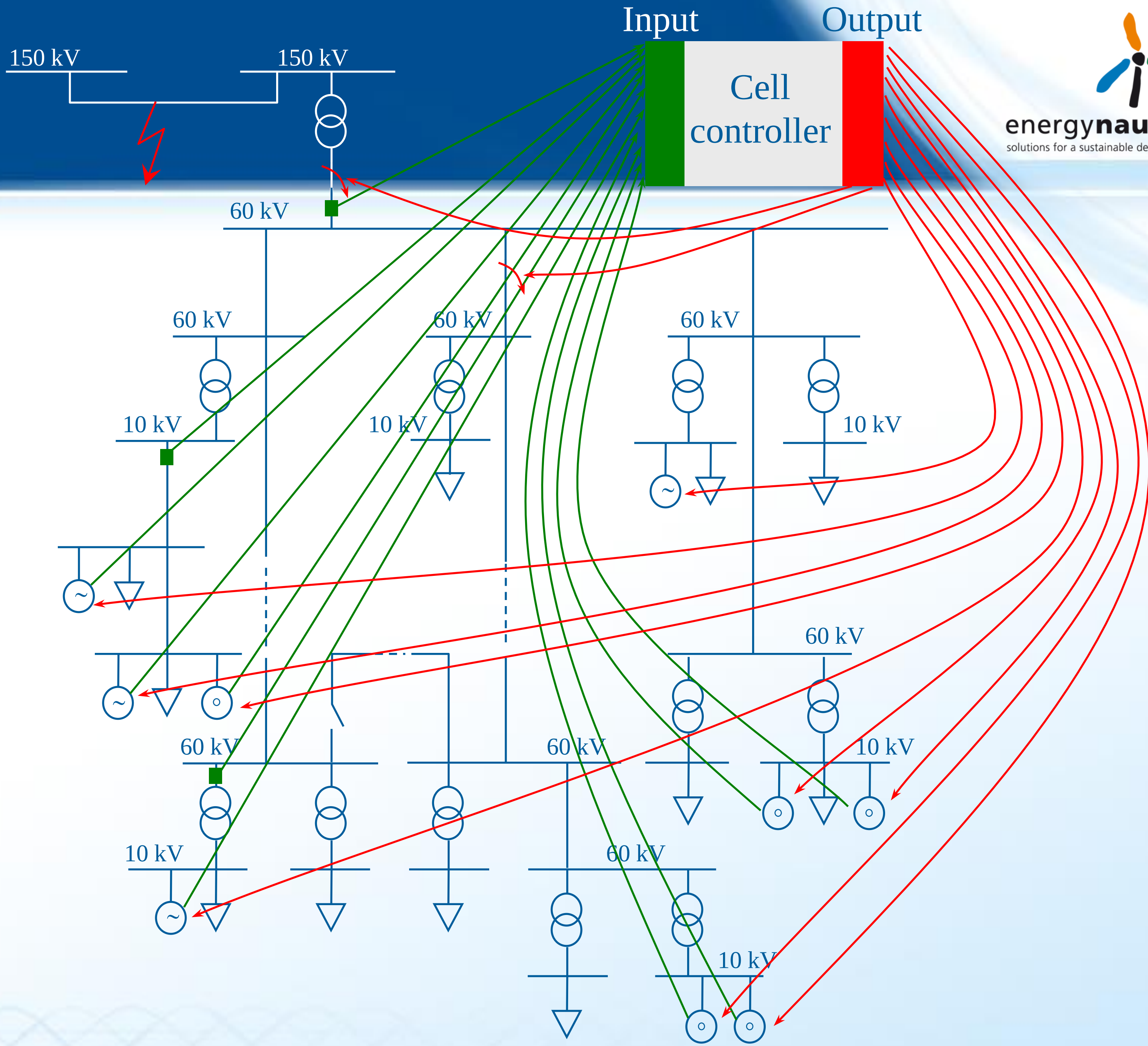
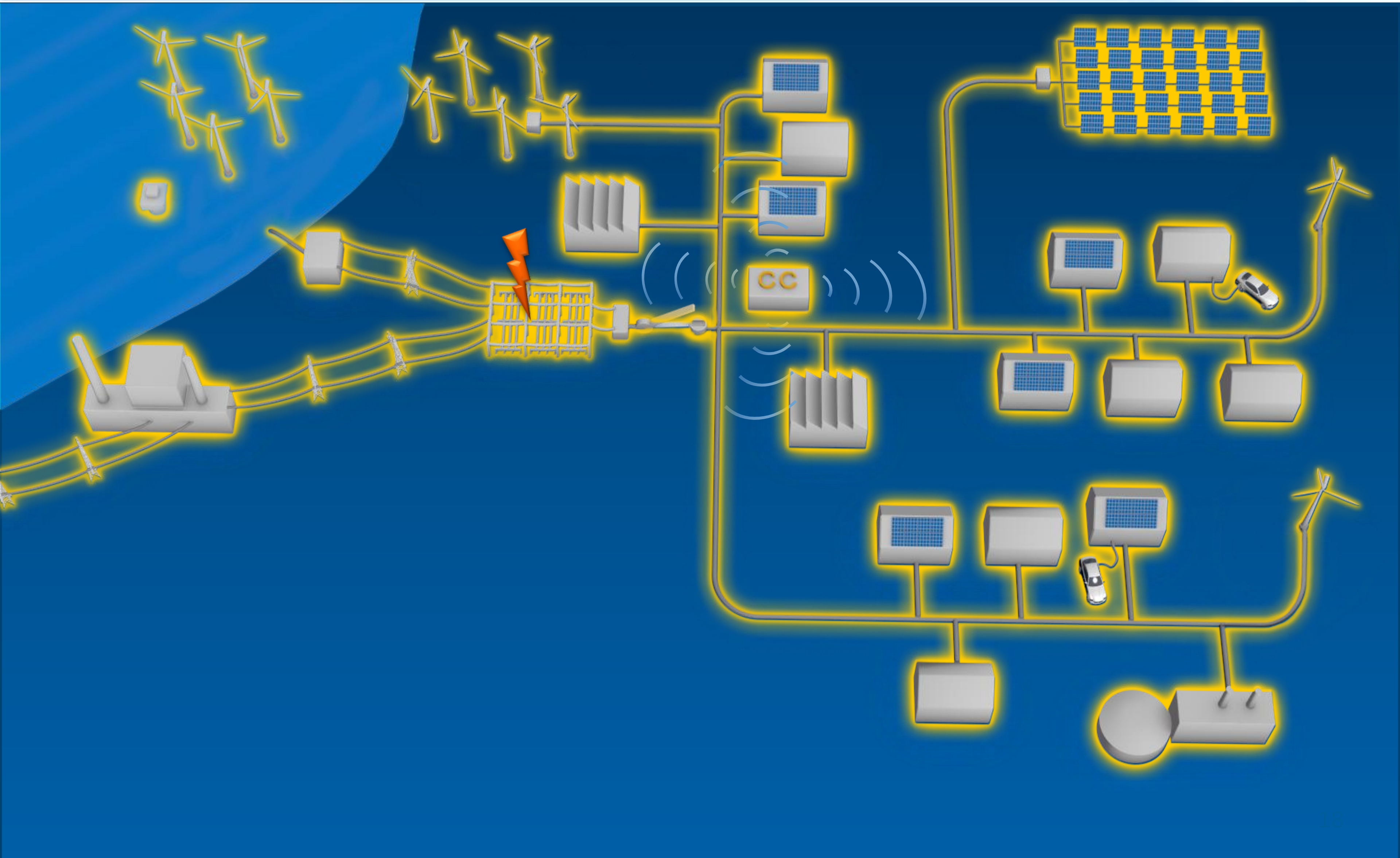
- One 150/60 kV substation with tap changer controlled transformer
- 13 substations (60/10 kV) with tap changer controlled transformers
- 5 CHP plants with a total of 11 gas engine driven synchronous generators totalling 33 MW
- 47 Danish-style wind turbines, all larger than 600 kW, with a total installed 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



Input
Output
Cell
controller
150 kV
150 kV
60 kV
60 kV
60 kV
60 kV
10 kV
10 kV
10 kV
60 kV
60 kV
60 kV
10 kV
10 kV
60 kV
10 kV

Principal Controll Approach Pilot Project



Important Lessons Learned:

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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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DSO Own Responsibility*

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 and Proof of Needs

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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

Ancillary Services Provision

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

Distribution grids upgrade/planning should consider future DG levels

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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

Conclusion

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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.


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