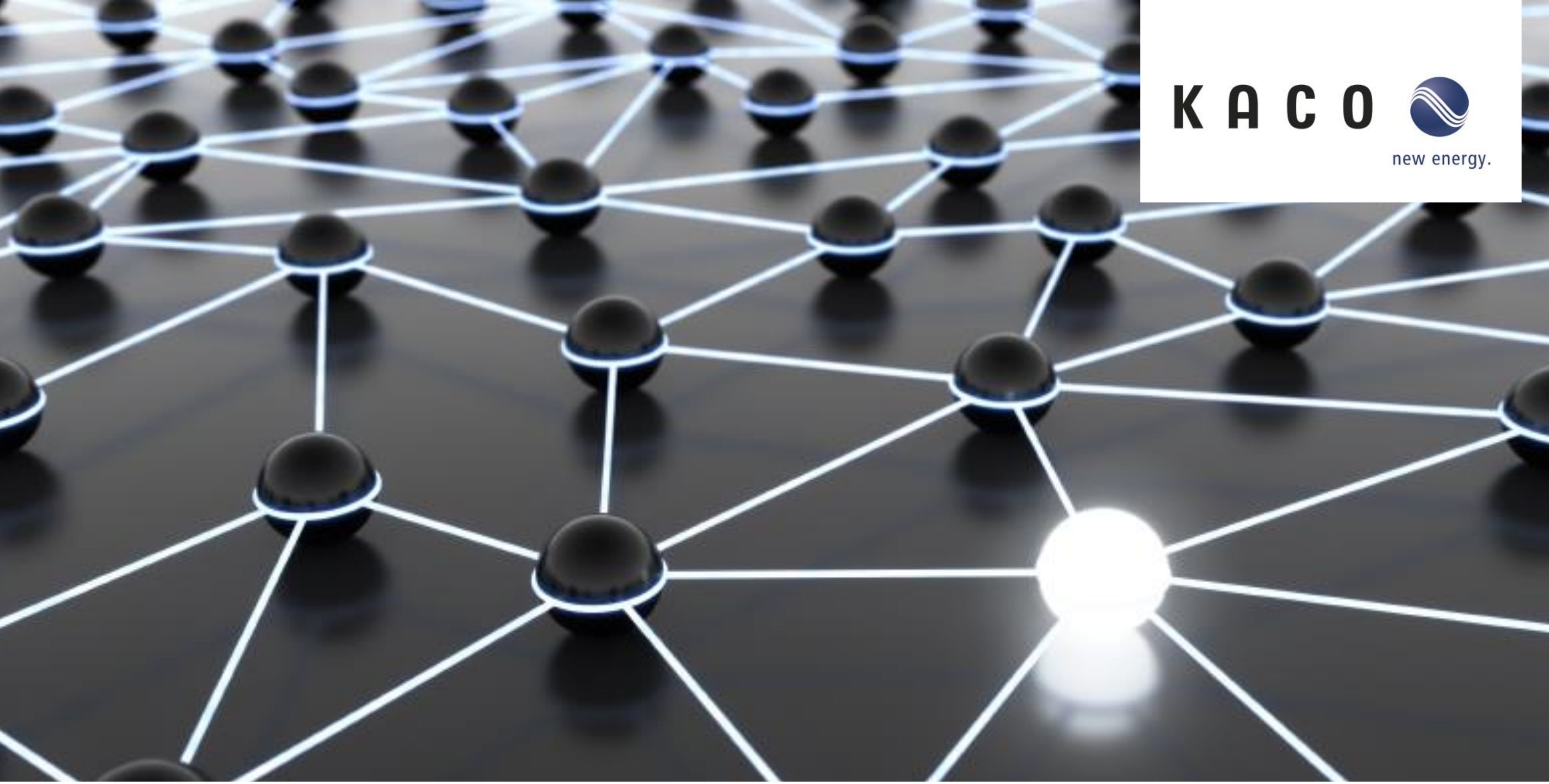

Supporting Power Quality in Distribution Networks with Inverters

Andreas Schlumberger / Thomas Schaupp – KACO new energy

May 18th, 2016

Topics

1 Installed power today

2 Critical issues

3 Today's solutions

4 Solutions in standardization
CENELEC TS 50549

5 Looking ahead

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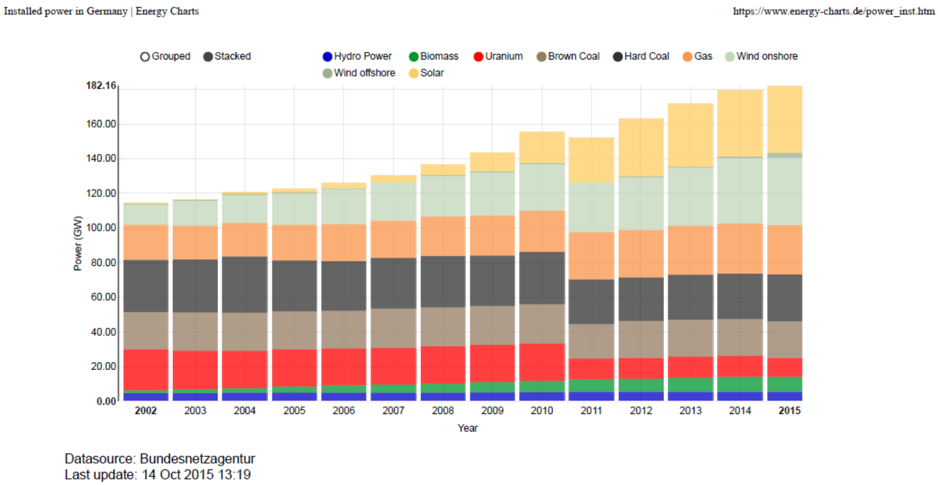
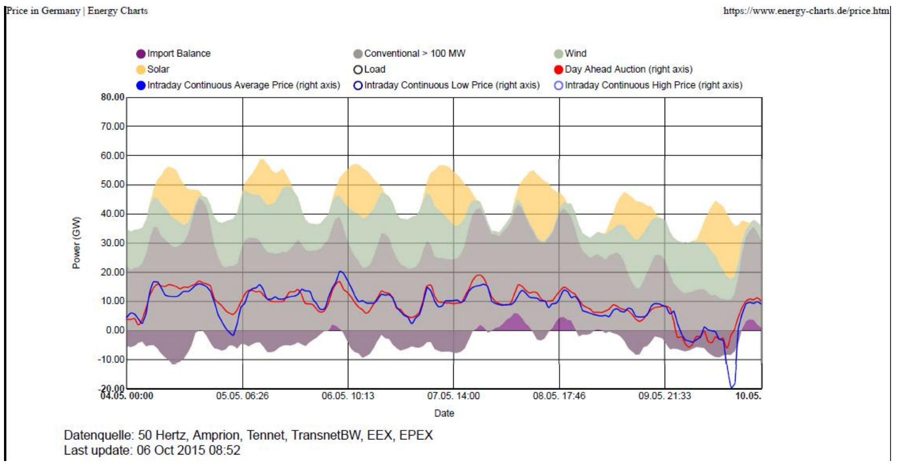
Installed Power Today

Integration of power into the German transport grid

- In mid 2016
  - Approx. 40 GW PV power installed
  - Approx. 41 GW wind power installed
- The base load range significantly reduced

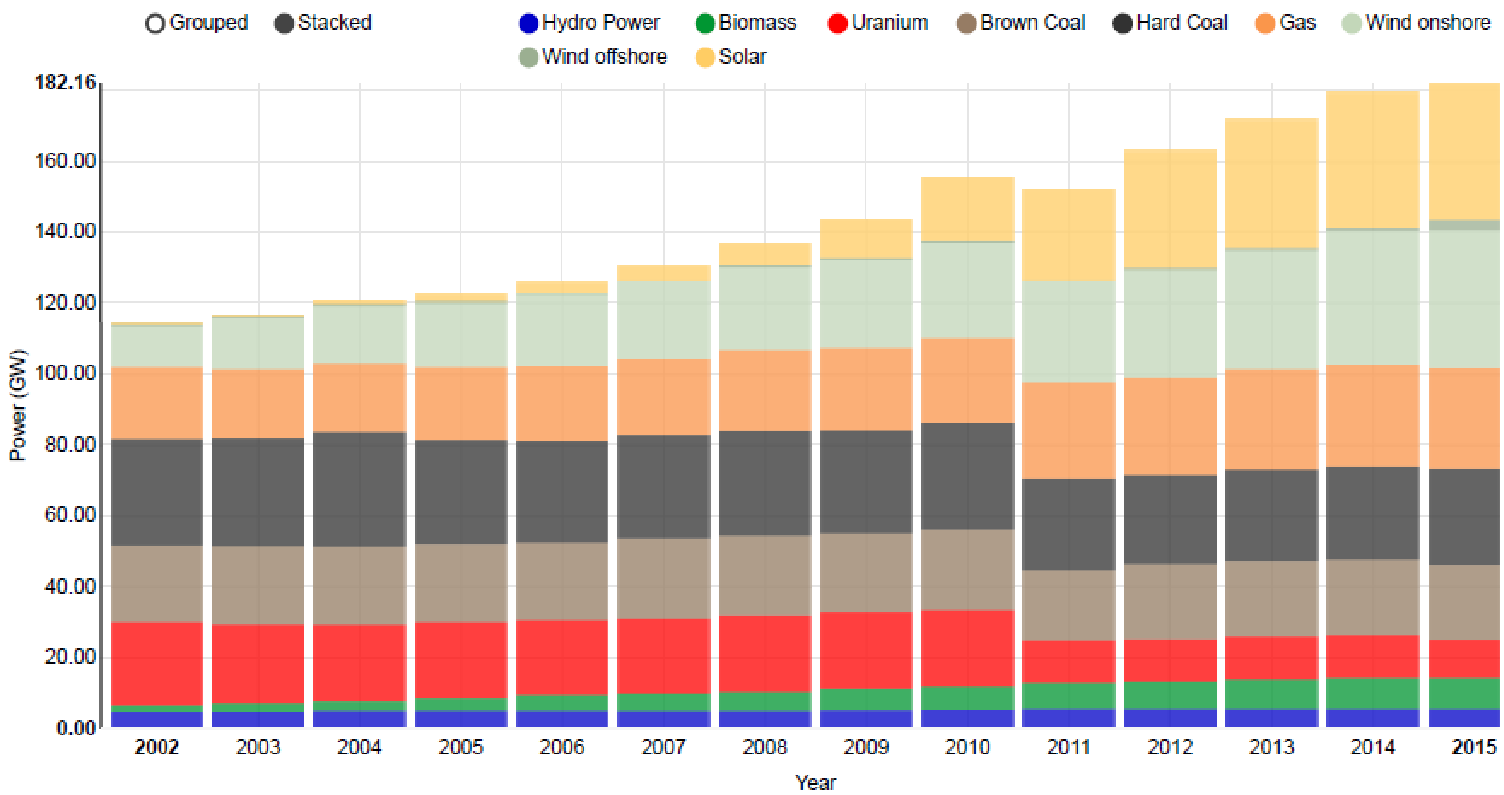




Installed Power Today

Installed power in Germany | Energy Charts

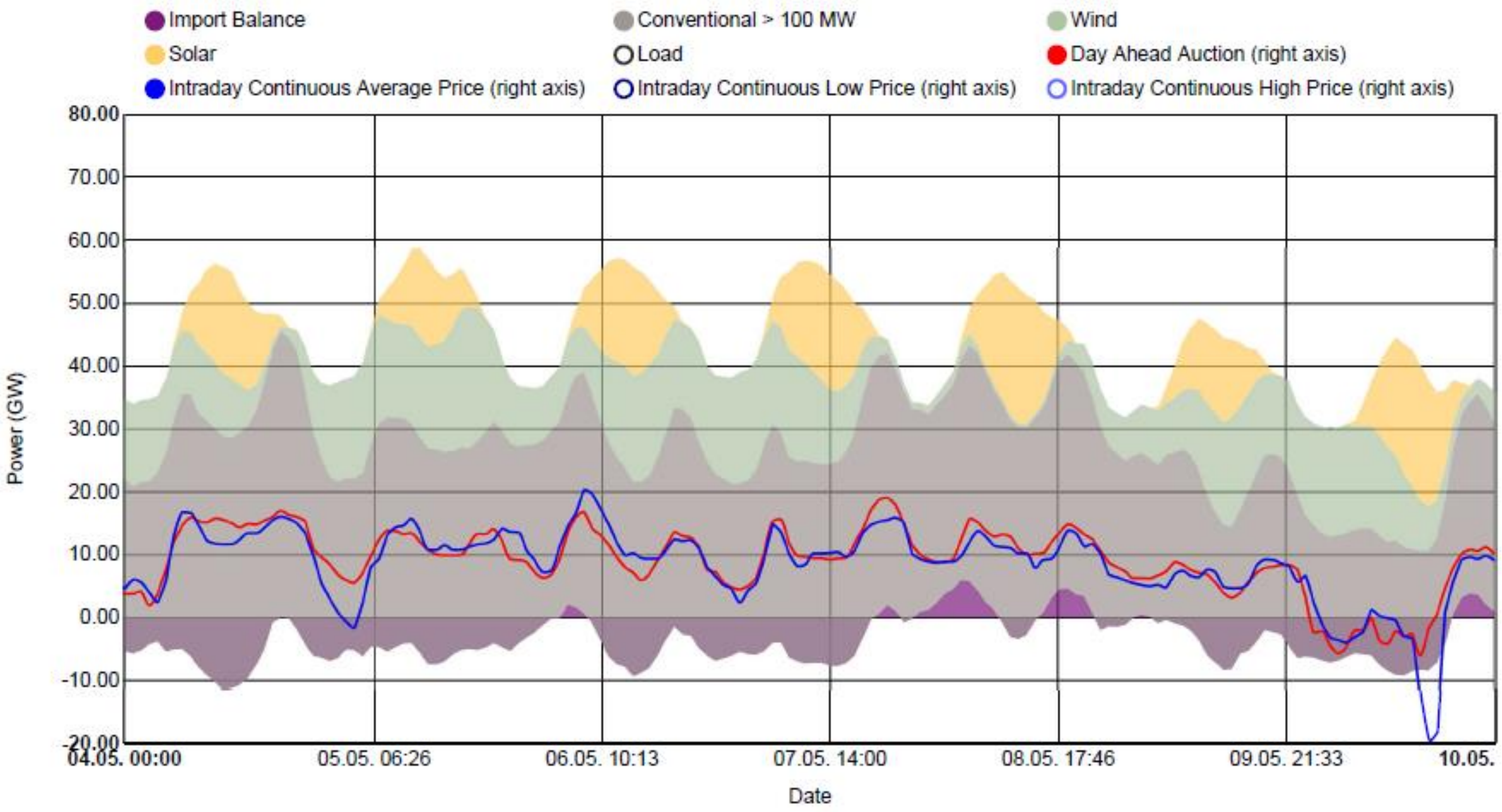
https://www.energy-charts.de/power_inst.htm



Datasource: Bundesnetzagentur
Last update: 14 Oct 2015 13:19

Installed Power Today

Price in Germany | Energy Charts https://www.energy-charts.de/price.htm



Datenquelle: 50 Hertz, Amprion, Tennet, TransnetBW, EEX, EPEX
Last update: 06 Oct 2015 08:52

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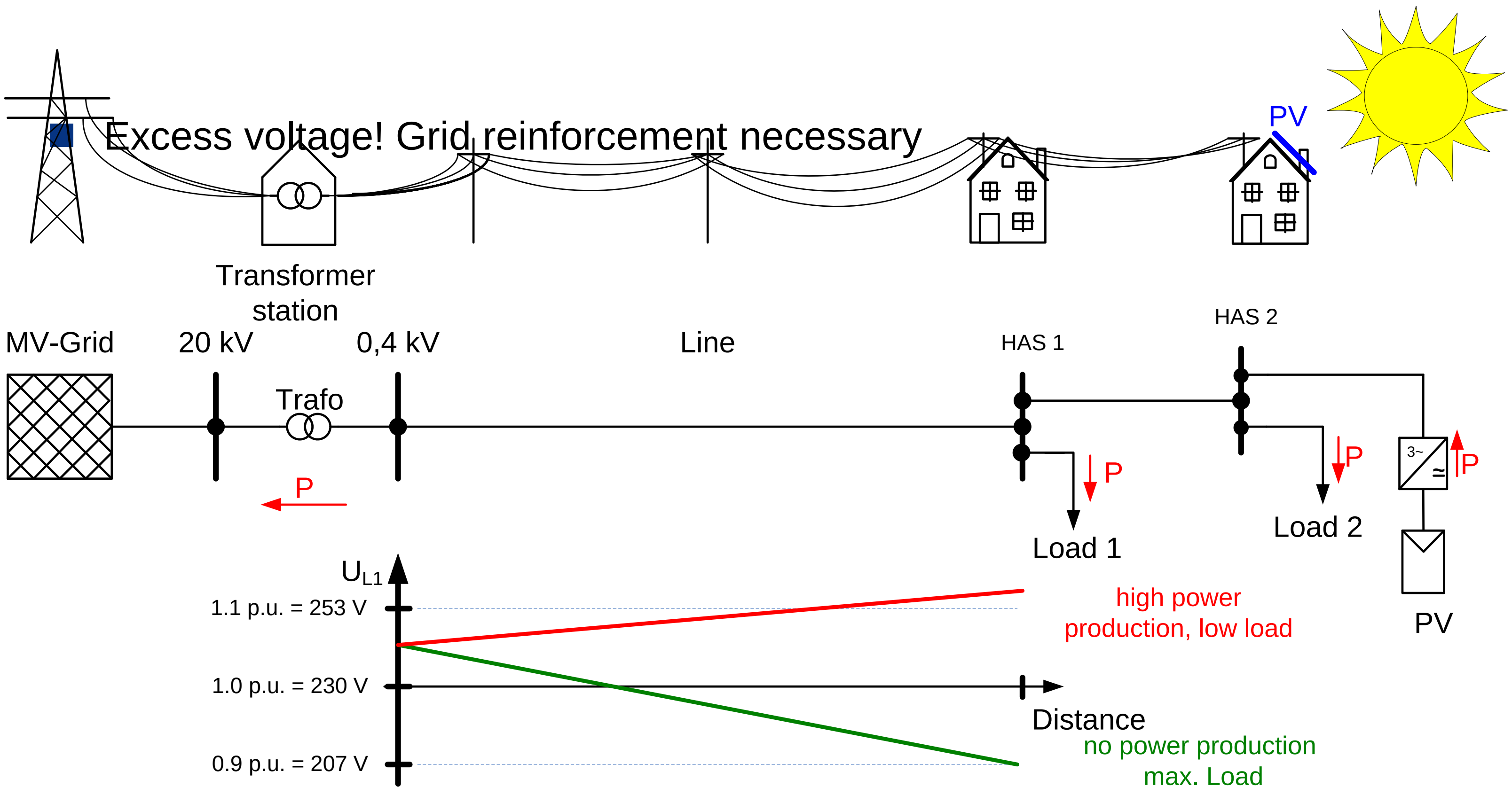
Critical Issues in the distribution grid

- Island formation
- Overload of equipment
- Voltage maintenance

Voltage maintenance



Critical Issues in the transport grid

- Balance between consumption and generation is necessary for frequency stability
- Imbalance results in frequency fluctuations
- Overload of equipment
- Sudden power drop in the GW range
  - resulting from frequency cut-off of distributed generation
  - Protective tripping in the event of short interruptions
  - System Split due to overloaded connections
  - Drop in power results in imbalance between generation and consumption

Topics

Today's solutions

Distribution System

- Voltage Support by reactive power
- Supply management (Curtailment)
- Island detection (critical since contradicting power system stability)

Transport System

- Power reduction in case of overfrequency
- Immunity to dips and swells
- Dynamic voltage support contribution to short circuit power

Topics

General assumption

- Standardization is required to write down state of the art
- Manufacturers require standardization to produce unified equipment for all countries
- Due to different network topology network operators have different needs to integrate dispersed generation
  - But the general problems are the same

Solution

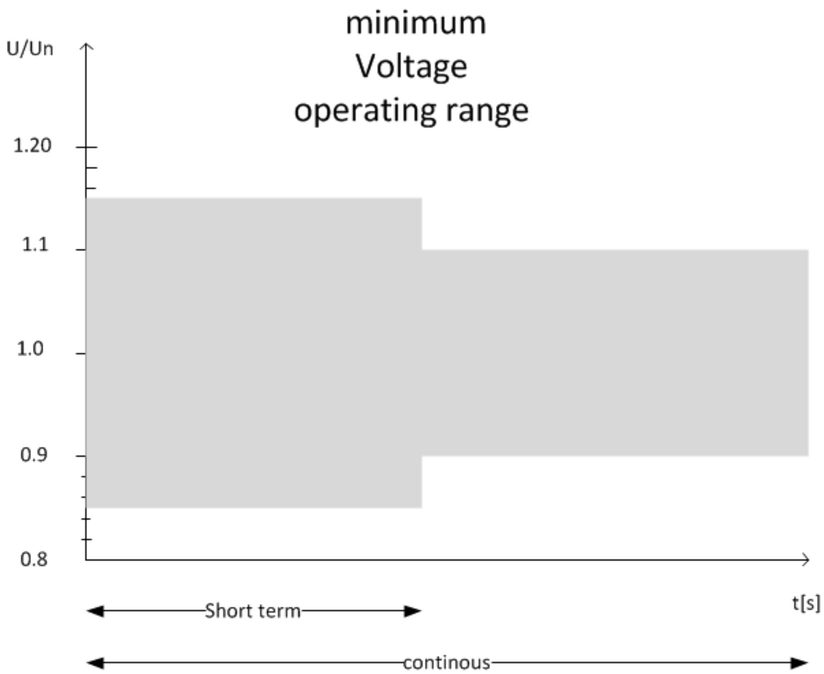
- Define standard behavior for dispersed generation
- Allow adjustment to local needs

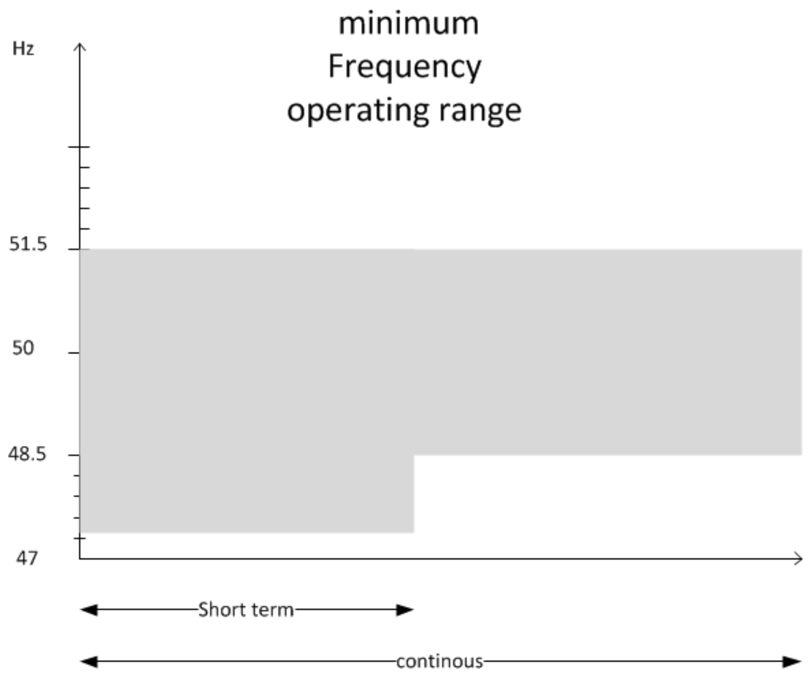
- Analysis of system impact is very specific to the local topology of the grid → excluded from scope

Included topics

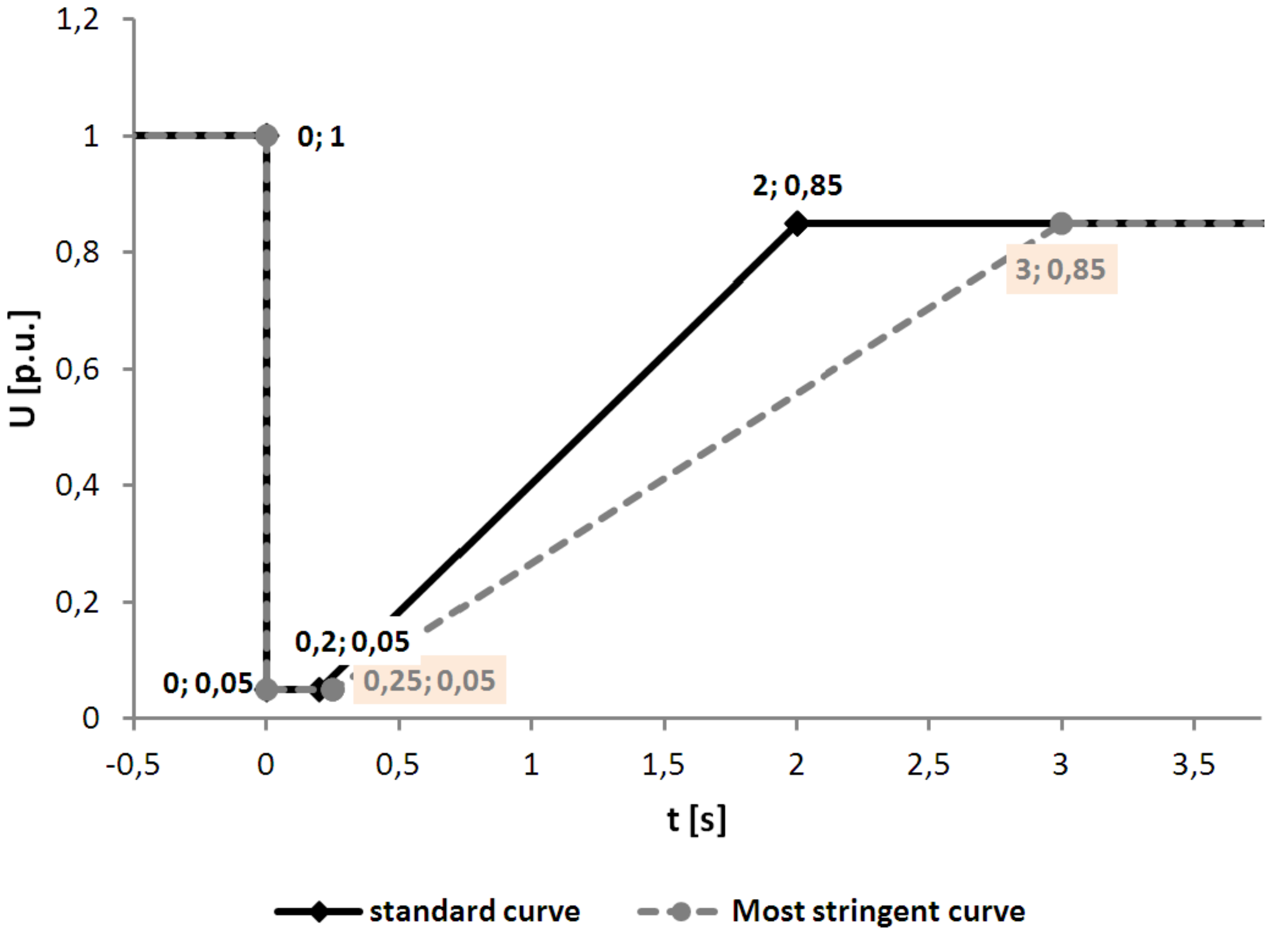
- Range of operation (not protection)
- Immunity to disturbance
  - Voltage dips
  - Rate of change of frequency
- Reactive power provision
- Standard control modes for reactive power
- Dynamic grid support
- Protection (voltage and frequency)
- Communication

Standard range of Operation Voltage / Frequency

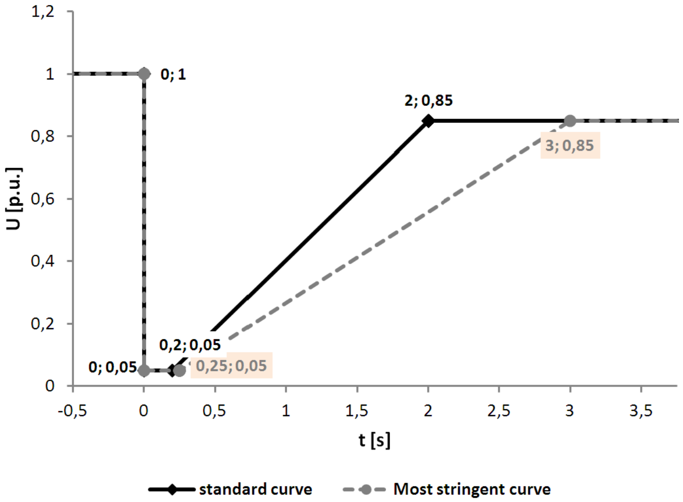




Immunity to Disturbance



Immunity to Disturbance

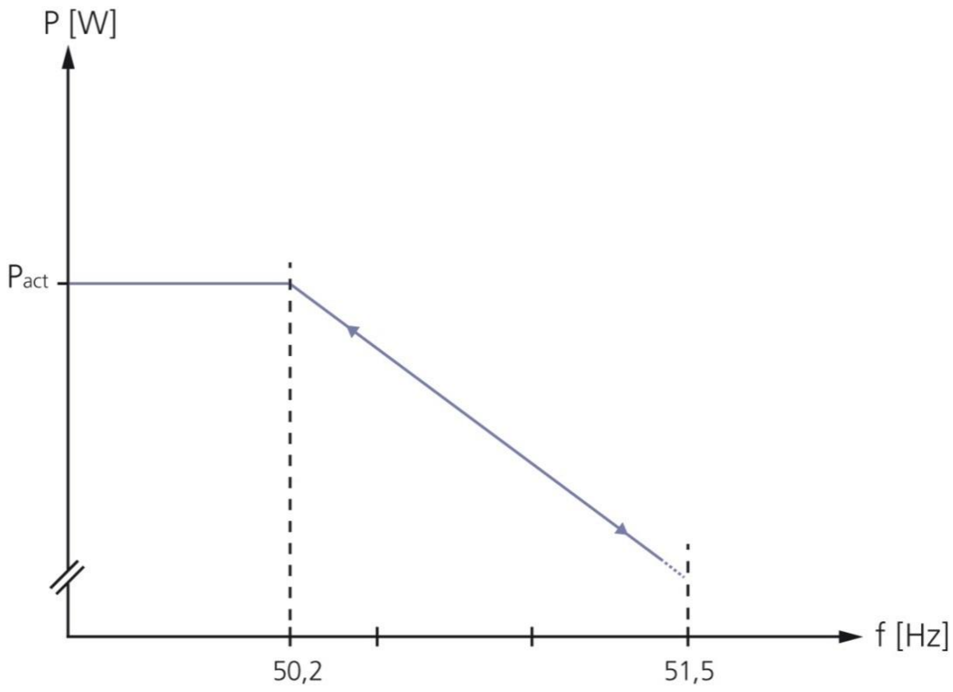


- Rate of change of Frequency
  - 2.5Hz/s → no disconnection allowed

- For system stability it is mandatory that short disturbance does not lead to loss of generation → Immunity is important

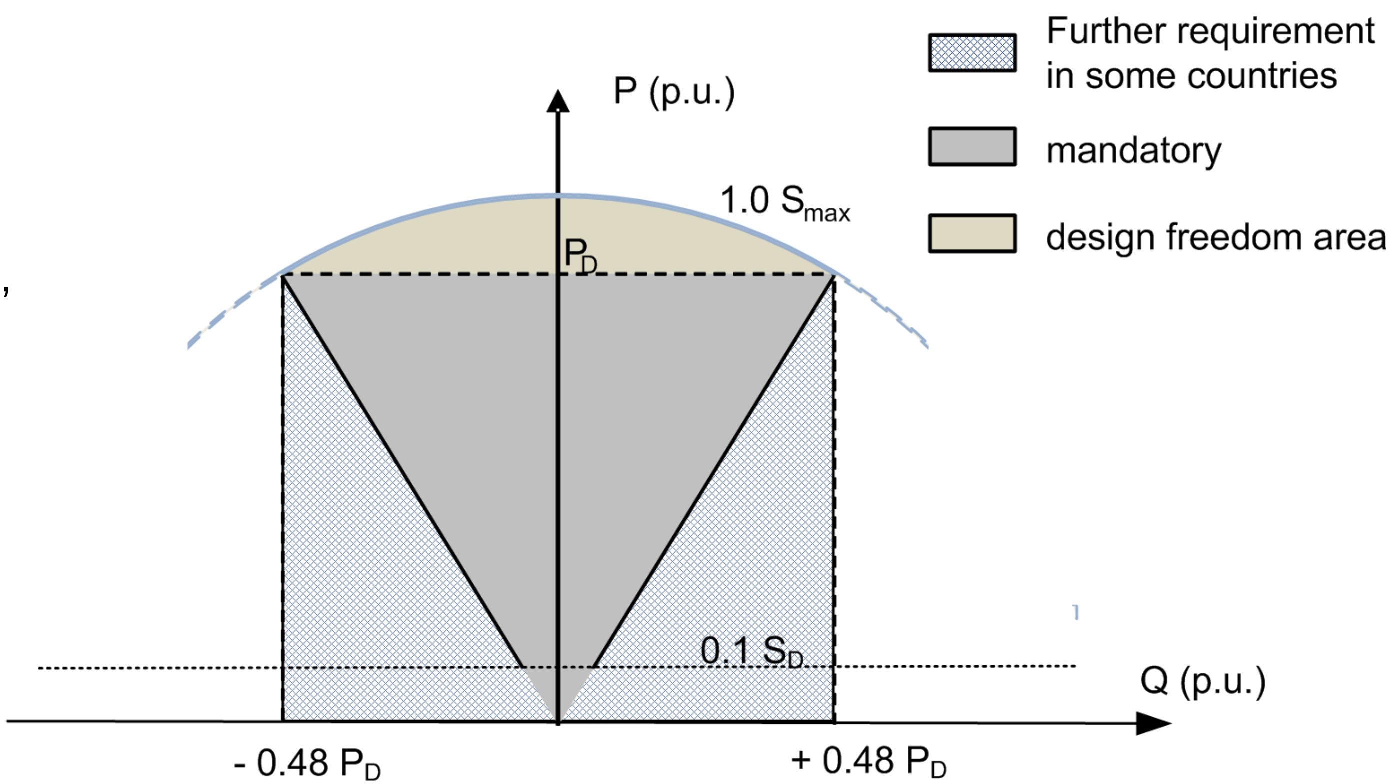
Power Reduction in the Event of Overfrequency

- power reduction in the event of overfrequency
- Gradient 40% Pactual/Hz
- Response time as fast as possible,
  best below 2 seconds
- No automatic disconnection from the grid in the range of 47.5 Hz to 51.5 Hz



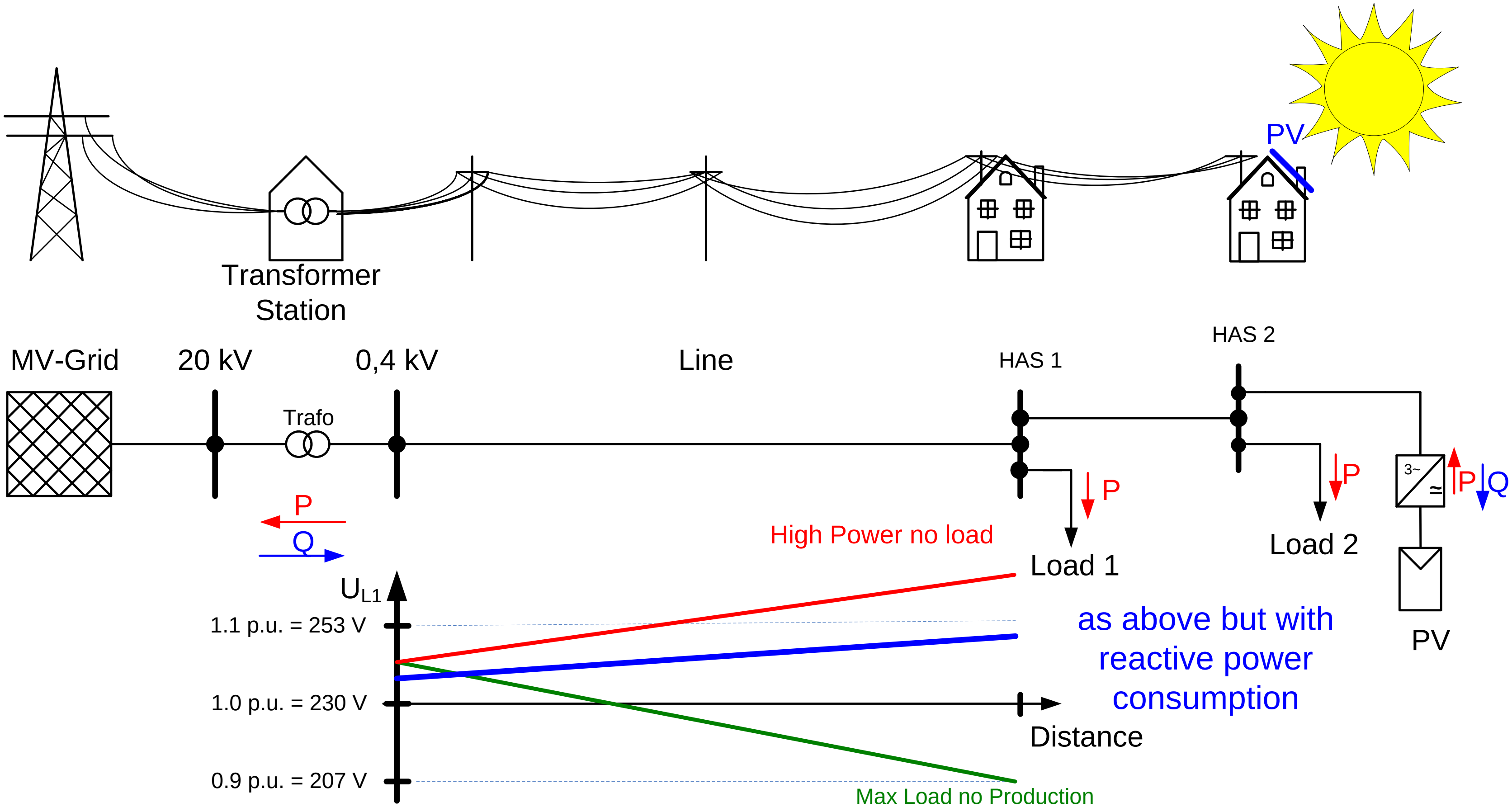
Reactive Power Capability

- PD=P-Design, the maximum active power of the Plant where Qmax might be delivered



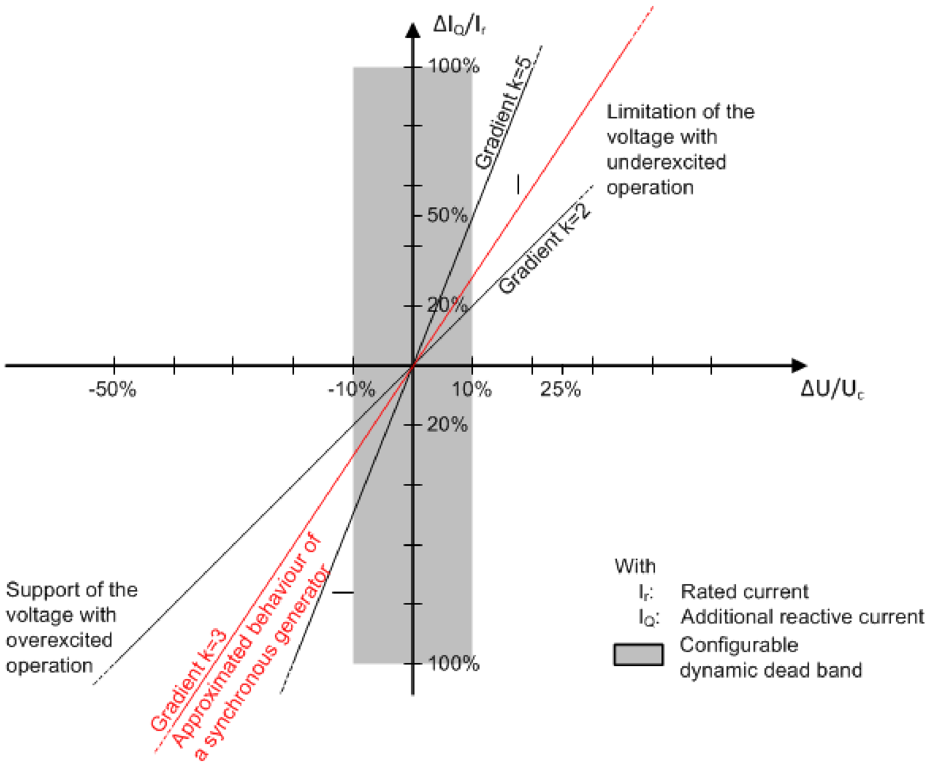
Voltage Maintenance

by means of reactive power supply

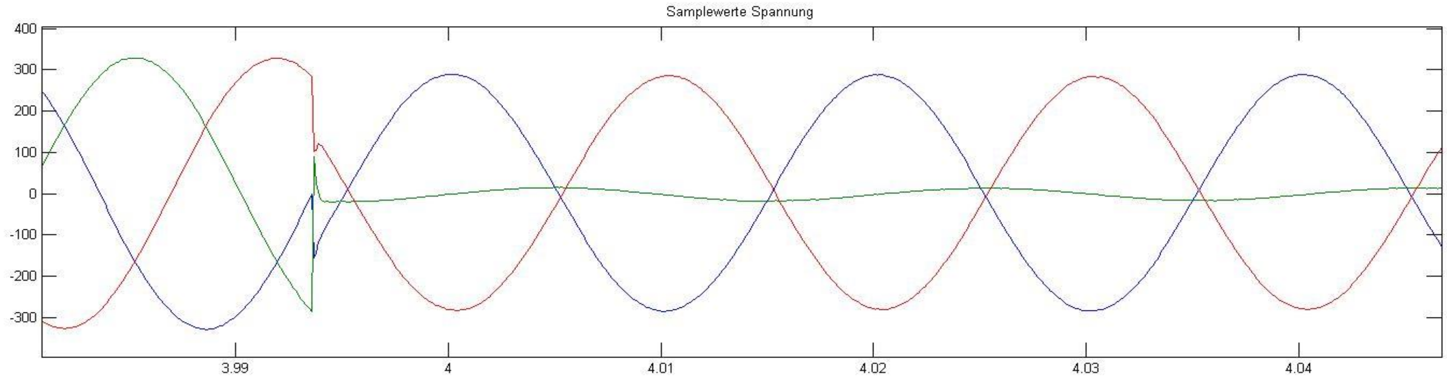


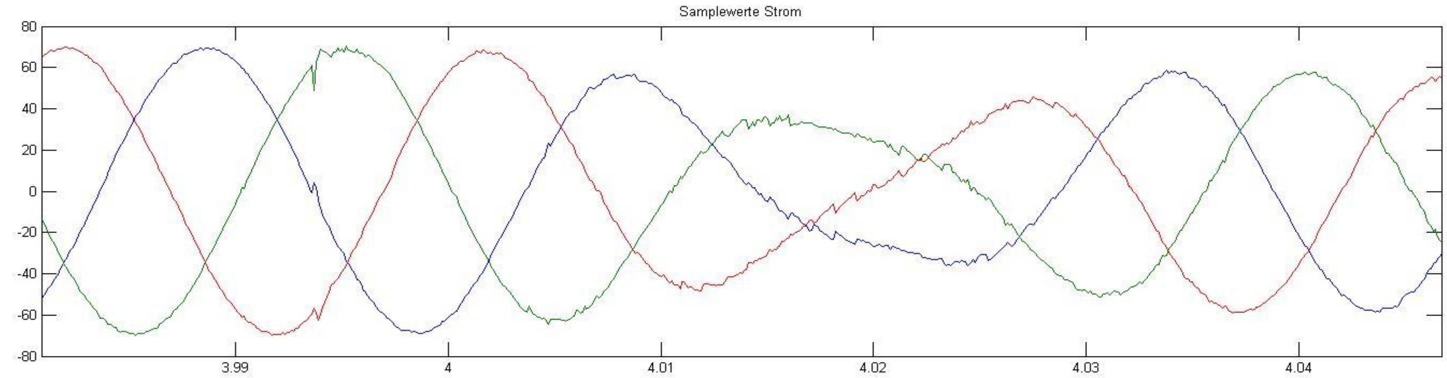
Dynamic Grid Support with reactive Current

- Reactive current to feed into the grid fault (short circuit) eg. in transmission system
- Trigger line protection devices
- Increase voltage in case of remote fault
- Reduce region of impact



Dynamic Grid Support with reactive Current





Protection

Available Protection Function

- Voltage
  - Over/Under-voltage Phase-Phase
  - Over/Under-voltage Phase-Neutral
  - Over/Under-voltage Positive/Negative/Zero sequence
  - Overvoltage Average values (eg. 10 min average RMS)
- Over/Under Frequency

- Line protection / overcurrent is considered mandatory in installation standards and is not included in TS50549

Topics

Looking ahead

- **The key question**
  - Which technical features will a power system need to run stable with a penetration of 40% ... 60% ... 80% ... 100% of inverter-based power generation?
  - The instantaneous penetration of inverter based generation will vary during a day from 0% to 100%

- **Features possibly necessary in the future**
  - Provide power in negative sequence
  - Provide primary reserve
  - Provide inertia
  - New protection design
  - Black start capability

So …

How far can we go with inverters only?

- **100% inverter-based grid is possible**
  - Already implemented in small scale, e.g. UPS, island grids
  - Research for large scale needed

So …

How can we minimize installation costs?

- **Reduction in material costs for inverters and modules will continue**
- **Harmonization of requirements will reduce engineering costs**
  - We’ve let go by the chance for harmonization in context of RfG, national implementation allows to many variations
  - The goal should be: Harmonization similar to Low Voltage Directive (2014/35/EU) or EMC-Directive (2014/30/EU)
- **Connection procedure**
  - a) Connection evaluation based on plant requires evaluation procedure for each plant including costs for each plant
  - b) Connection evaluation based on unit allows to type evaluation and faster / more cost effective connections
  - Some European countries use b) up to several MW plant size, some (GER) introduce a) above 100 kVA

Thank for your attention.

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