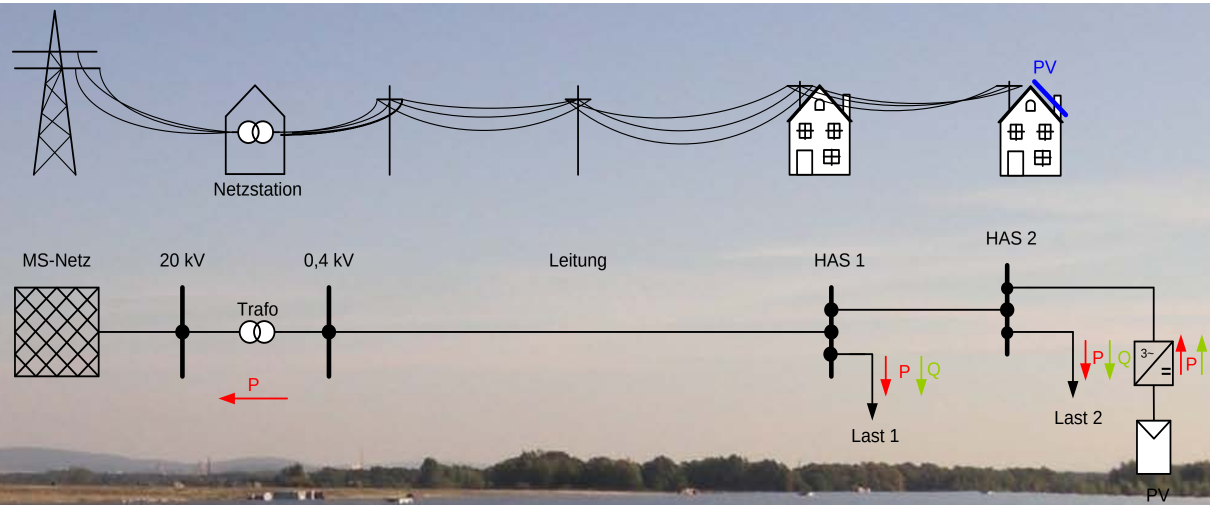


Improved Grid Integration for more PV in Europe

Dr.-Ing. Bernd Engel
Senior Vice President Technology, SMA Solar Technology AG

Driving future PV deployment–electricity utility PV business models

IEA PVPS Programme Workshop, Hamburg, September 7, 2011

Overview of presentation

1. Developing renewable energy sources in the German power supply grid
2. System services
3. Current guidelines
4. Future roadmap
5. Summary

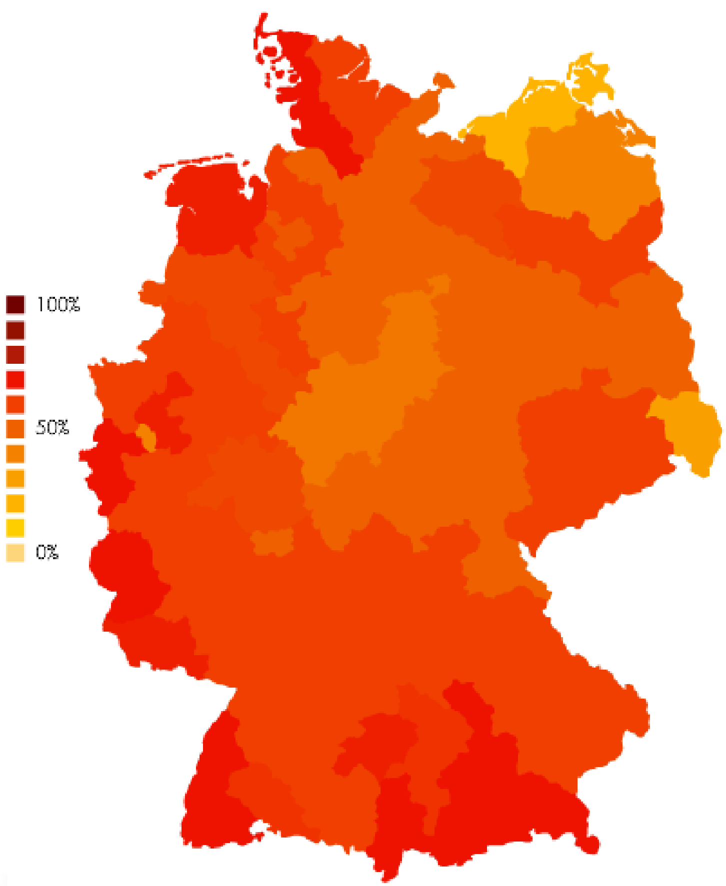
PV Performance in Germany

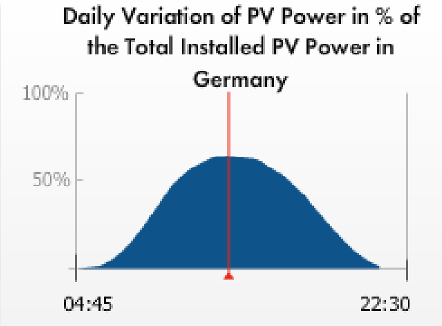
(http://www.sma.de/en/news-information/pv-electricity-produced-in-germany.html)

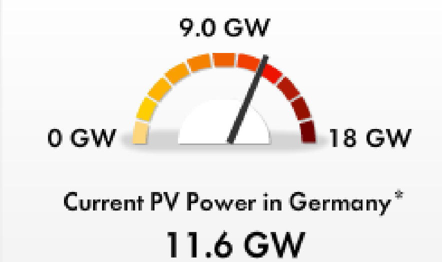
Performance of Photovoltaics (PV) in Germany

Relative output from 06/12/2011 - 13:00 CET

Based on the data provided by Sunny Portal »







*projected, current output of all PV plants installed before 05/31/2011 with a total 18.38 GW nominal power according to the German Federal Network Agency.

The Performance of PV in Germany

What is the current status of photovoltaics in Germany? This is an interesting question, and one to which you will receive a clear answer on this website based on daily updated information. Here, you can view at any time the total output of all PV plants in Germany installed up to the specified cutoff date. As required, you can view this information as an absolute value or as a percentage of total installed output.

Now you can look at individual regions as the data is additionally classified according to the respective zip code areas. Here, you can take a closer look at the regional relative power in the respective areas, or in other words, the current performance of the PV plants in proportion to the nominal power of these plants.

The animated graphics demonstrate the role already played by photovoltaics in generating electricity in Germany today, and show that PV systems also contribute to reducing the high cost of midday peak demand.

Our Data Calculation Model

PV Performance in Germany compared with convential generation

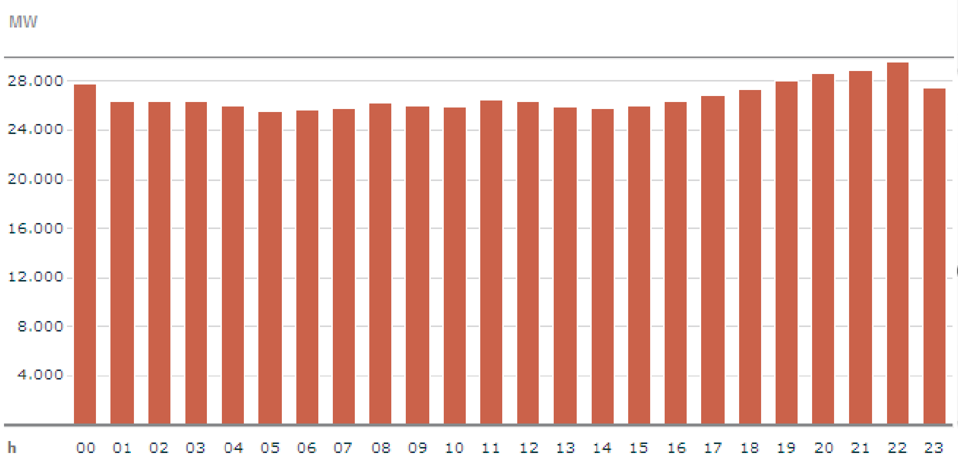
Tatsächliche Produktion von Erzeugungseinheiten ≥ 100 MW

Aggregierte ex-post-Information über die tatsächliche Produktion.

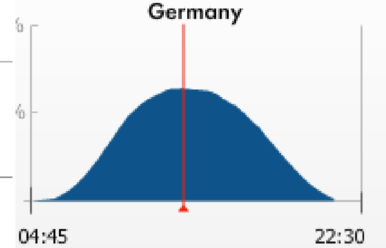
Die Veröffentlichung erfolgt stündlich mit einem maximalen Zeitversatz von zwei Stunden. Eine spätere Korrektur der Werte insbesondere zur Verbesserung der Datenqualität ist möglich.

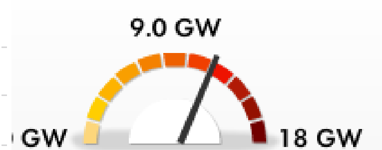
DE/AT | **DE** | AT

Angezeigter Zeitraum: 12.06.2011, 00:00 Uhr - 12.06.2011, 23:59 Uhr
Letzte Aktualisierung: 22.07.2011, 16:35:45 Uhr



Daily Variation of PV Power in % of the Total Installed PV Power in Germany





Current PV Power in Germany*
11.6 GW

The Performance of PV in Germany

What is the current status of photovoltaics in Germany? This is an interesting question, and one to which you will receive a clear answer on this website based on daily updated information. Here, you can view at any time the total output of all PV plants in Germany installed up to the specified cutoff date. As required, you can view this information as an absolute value or as a percentage of total installed output.

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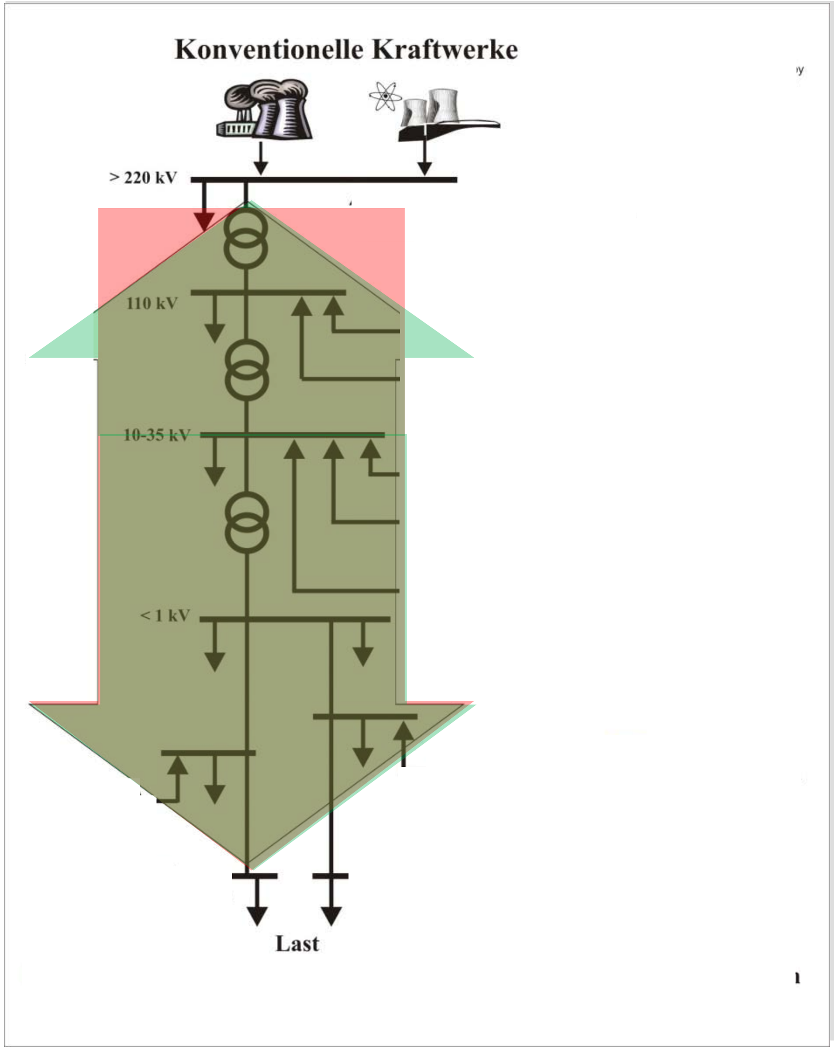
The animated graphics demonstrate the role already played by photovoltaics in generating electricity in Germany today, and show that PV

European Energy Exchange (EEX) 12 a.m.:
Convential generation 26.4 GW / Wind 0.52 GW
Share PV: 30.1 %

Integration of renewable energy into the grid structure

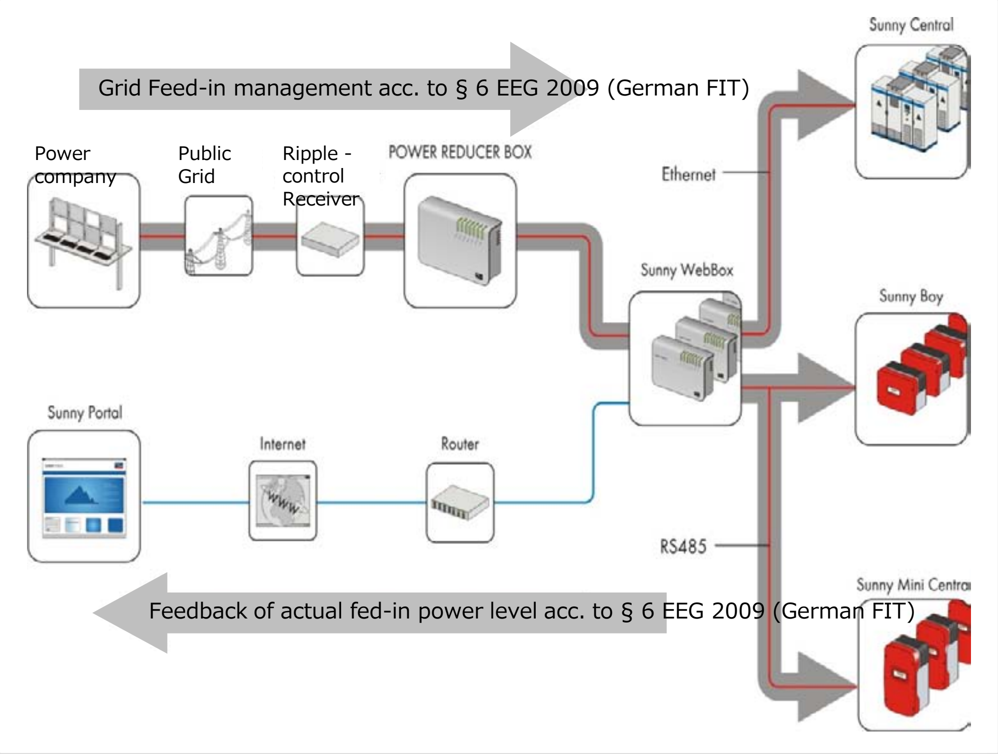


- Typical PV feed-in:
  - approx. 85 % of LV level (230 V/400 V)
  - approx. 15 % of MV level (10 - 30 kV)
  - few plants in the HV level (110 kV)
- **Paradigm replacement** necessary in electrical power supply:
  - From top-down structure to fluctuating bidirectional power flows
  - Distribution grids need to be "collection grids".

The renewable energy market needs to provide system services in the distribution grid

Generation management / feed-in management

- Legal basis:
  - §6 Paragraph 1 Renewable Energy Sources Act (EEG) 2009 from 100 kW (30 kW, EEG 2012)
  - §13/14 EnWG (Energy Economy Law): grid safety guaranteed by the transfer grid operator/supply grid operator
- Proven increments: limits at 100%, 60%, 30%, 0% P_{NOM}

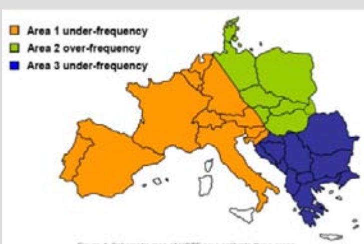


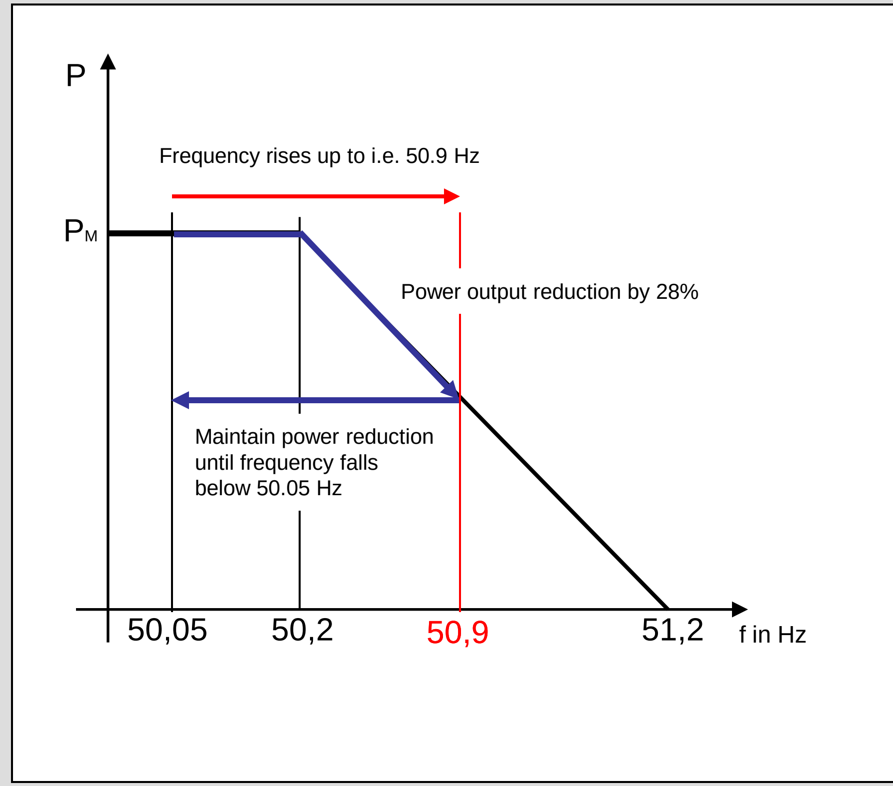
Generation management as a stepping stone to grid development

Frequency-dependent active power reduction

> Reduction to active power feeding-in depending on the frequency
  > in the event of a failure
  > to avoid instability (currently > 12 GW would switch off at 50.2 Hz)

> Example of use: UCTE malfunction in November 2006





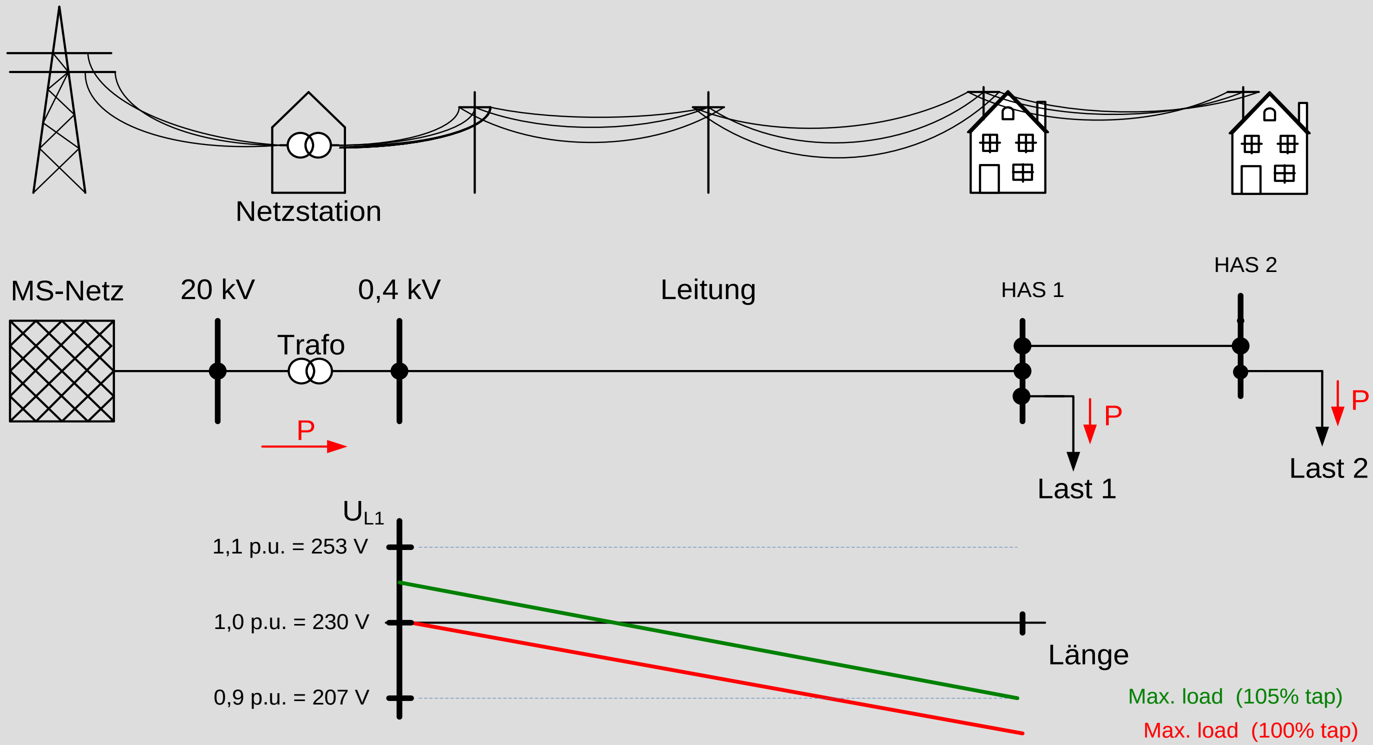
- The "50.2 Hz issue" is solved – retrofit will be done
- The frequency-dependent active power reduction is a step in the right direction for primary control.

Voltage support: power flow reversal – a technical issue?

> Objective: To support the voltage criterion in accordance with EN 50160 (U_N ± 10 %)

> Example: Compensation for the voltage drop in the cabling:

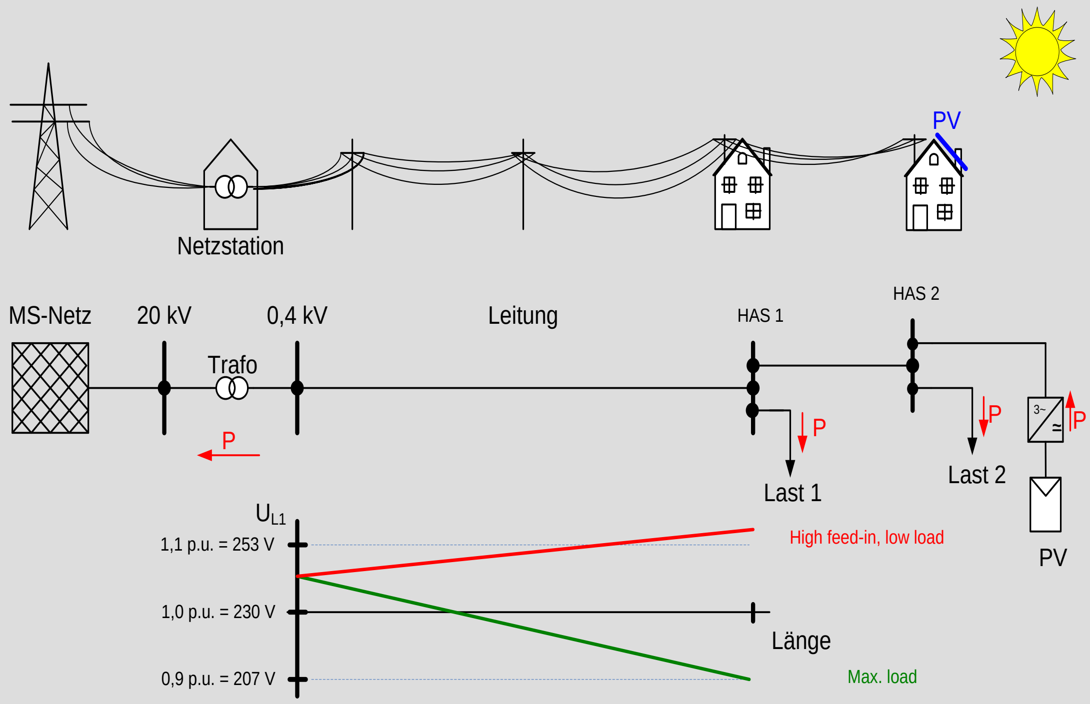
stationary adjustment to the transformation ratio at the transformer on the grid station



▶▶ Until now, the distribution grid was designed for consumption

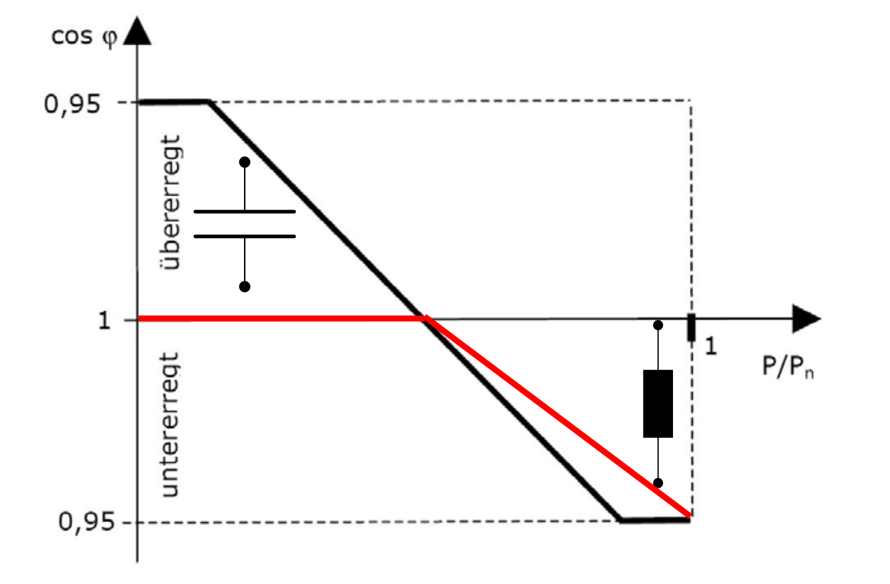
Voltage support: power flow reversal – a technical issue?

> Example: PV plant installation: In the low load hours before lunch, a **power flow reversal** occurs. **Violation of the voltage criterion** in accordance with EN 50160



Voltage Problems were previously associated with costly grid development involving increased amounts of copper, new cables and more powerful transformers.

Supporting voltage through reactive power supply



Source: PV plants in the medium-voltage grid BDEW (German Association of Energy and Water Industries), drafted April 2008

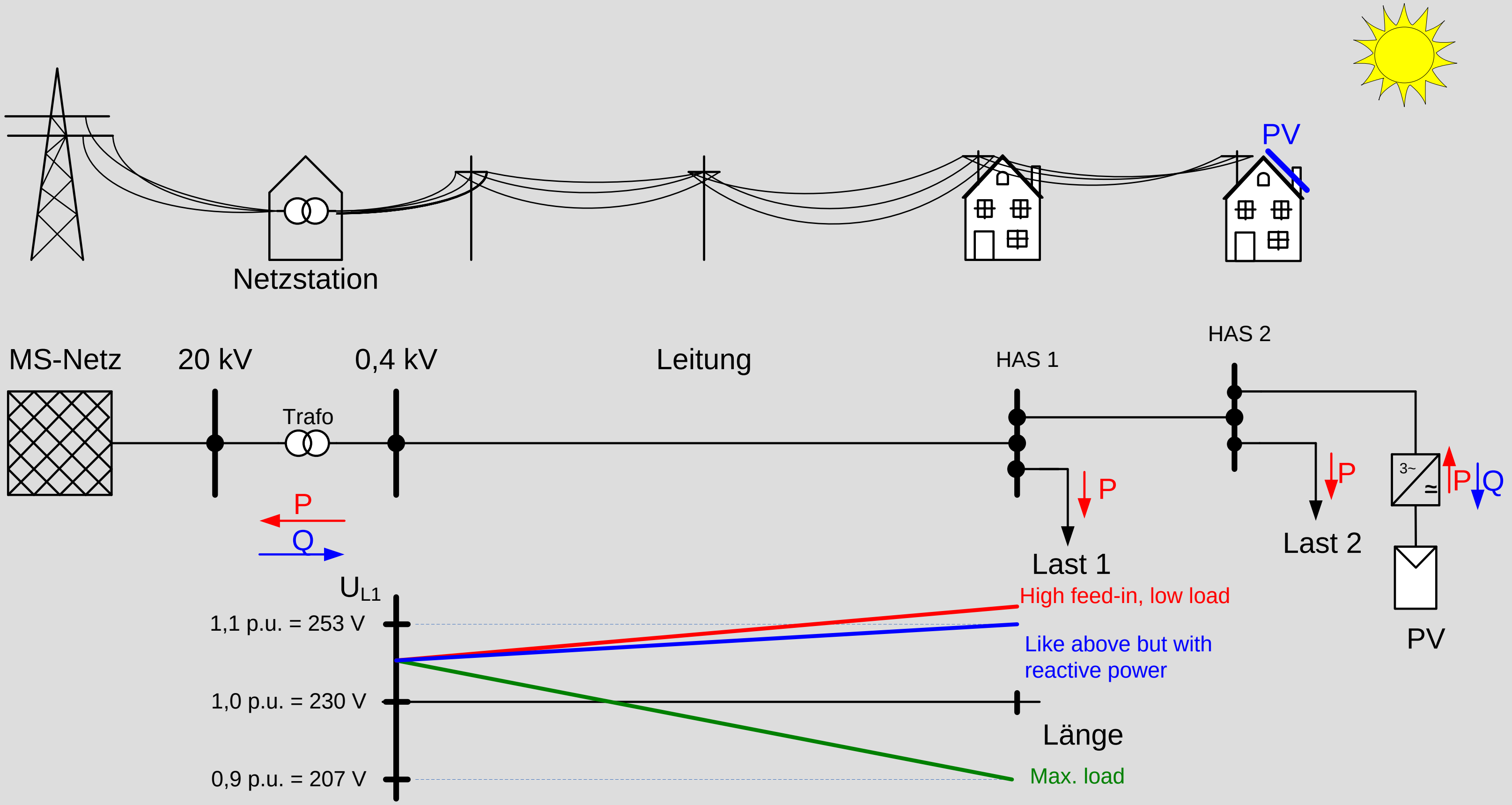
>> By supporting the voltage in the inverter, the capacity of the low-voltage grid can potentially be tripled
(source: Federal Ministry for Environment, Nature Conservation and Nuclear Safety project PV-EMS)

- New grid connection directives:

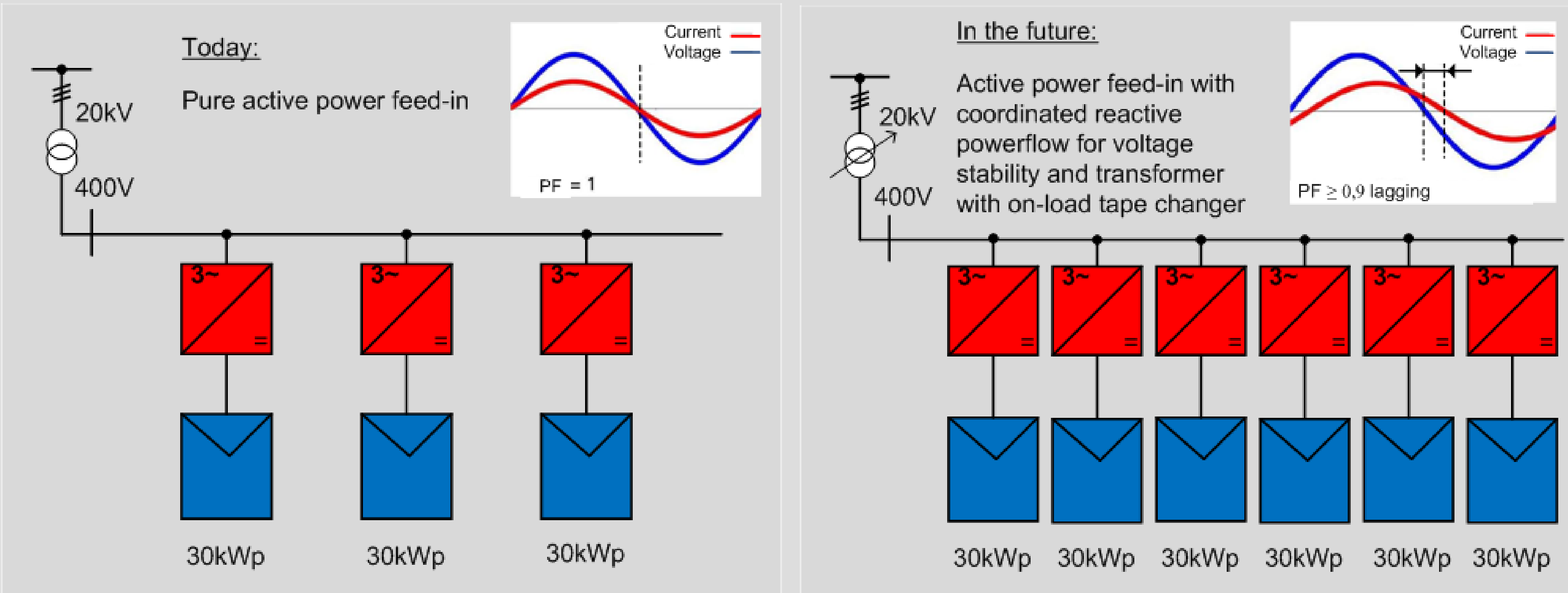
  PV plants must make their **reactive power** available during normal operation
- Grid operator specifies Q_{Set}, $\cos\varphi_{Set}$ or $\cos\varphi(P)$,Q(U) characteristics
- **MV guidelines:** Operate with a shift factor ranging from
  $\cos\varphi = 0.95_{inductive}$ to $0.95_{capacitive}$
- **LV directives**: Operate with a shift factor ranging from
  $\cos\varphi = 0.90_{inductive}$ to $0.90_{capacitive}$

Supporting voltage through reactive power supply

> Example: **Inductive/underexcited operation of the PV inverter** (absorption of reactive power) reduces the voltage boost

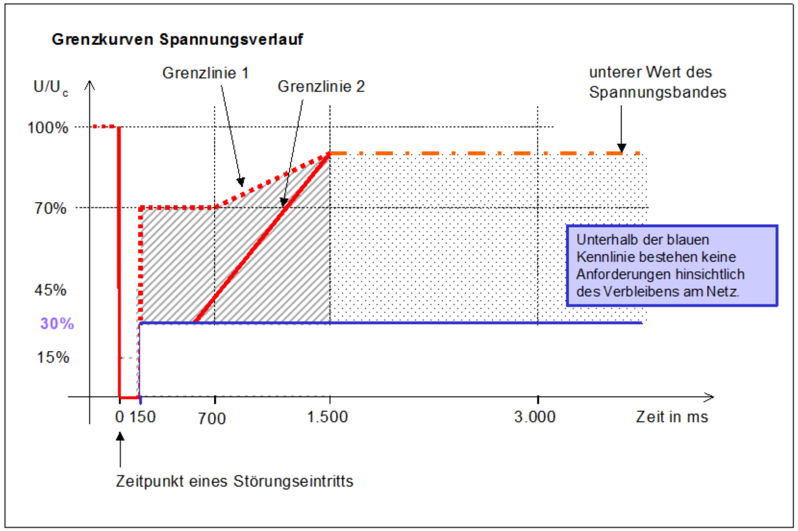


Supporting voltage through reactive power supply



Dynamic grid support: Fault Ride Through (FRT)

- As a general rule,
  in the event of a failure, PV plants should not be disconnected from the grid!
- Behavior required:
  - upper boundary 1:
    Stable operation
  - between boundary 1 and 2:
    Instability permitted
  - below boundary 2 (30 % U_{Nom}):
    Immediate disconnection allowed
- In the **LV grid,** feed-in of a capacitive reactive current is not desired: **limited dynamic grid support** through **temporary blocking of the semiconductor**



>> PV plants can even provide support in the event of failure to the grid.

"PV Plants Connected to the Medium-Voltage Network" Directive of the BDEW (Federal Association of German Energy and Water Industries).

Regelungen und Übergangsfristen für bestimmte Anforderungen in Ergänzung zur technischen Richtlinie

Erzeugungsanlagen am Mittelspannungsnetz - Richtlinie für Anschluss und Parallelbetrieb von Erzeugungsanlagen am Mittelspannungsnetz

Ausgabe: Juni 2008, BDEW

Textentwurf 23.7.2010

Ergänzung zur Technischen Richtlinie

Erzeugungsanlagen am Mittelspannungsnetz - Richtlinie für Anschluss und Parallelbetrieb von Erzeugungsanlagen am Mittelspannungsnetz

Ausgabe: Juni 2008, BDEW

Festlegung von Übergangsfristen für bestimmte technische Anforderungen der Richtlinie für Photovoltaikanlagen, Brennstoffzellenanlagen und Erzeugungsanlagen mit Verbrennungskraftmaschinen

Stand: Januar 2009

Technische Richtlinie

Erzeugungsanlagen am Mittelspannungsnetz

Richtlinie für Anschluss und Parallelbetrieb von Erzeugungsanlagen am Mittelspannungsnetz

Ausgabe Juni 2008

bdew

Energie. Wasser. Leben.

- > Developed by grid operators in the German Association of Energy and Water Industries (BDEW)
- > Valid from January 1, 2009 with transitional periods until April 1, 2011
- > First and foremost calls for power plant characteristics in the distribution grid
  - Feed-in management and frequency-dependent reduction in active power
  - Static voltage support (reactive power)
  - Dynamic grid support

>> Grid system services in the distribution grid for the first time with medium-voltage directives

FNN directive "generator plants on the low-voltage grid"

August 2011

	VDE-AR-N 4105	VDE
	Dies ist eine VDE-Anwendungsregel im Sinne von VDE 0022 unter gleichzeitiger Einhaltung des in der VDE-AR-N 100 beschriebenen Verfahrens. Sie ist nach der Durchführung des vom VDE-Präsidium beschlossenen Genehmigungsverfahrens unter der oben angeführten Nummer in das VDE-Vorschriftenwerk aufgenommen und in der „etz Elektrotechnik + Automation" bekannt gegeben worden.	FNN

ICS 29.160.40

Erzeugungsanlagen am Niederspannungsnetz –
Technische Mindestanforderungen für Anschluss und Parallelbetrieb von Erzeugungsanlagen am Niederspannungsnetz

Generators connected to the low-voltage distribution network –
Technical requirements for the connection to and parallel operation with low-voltage distribution networks

Générateurs reliés au réseau de distribution de basse tension –
Exigences techniques pour la connexion des générateurs et leur fonctionnement parallèle aux réseaux de distribution à basse tension

Gesamtumfang 80 Seiten

Preisgr. 44 K
VDE-Vertr.-Nr. 0105029

> First grid code of the FNN (forum for grid technology and operation) in the VDE

> Draft published in July 2010

> After considering the 1,200 objections, the directive came into effect on August 1, 2011 with transitional period until January 1, 2012

> Paradigm replacement now also in LV grid:

- Feed-in management
- frequency-dependent reduction in active power above 50,2 Hz
- Voltage support (reactive power)
  - From 13.8 kVA from July 7, 2011
  - From 3.68 kVA from January 1, 2012

>> The low-voltage grid code is urgently required!

Roadmap of grid integration on a distribution grid level

> Voltage support

Reactive power on MV grid German Association of Energy and Water Industries (BDEW) directive from 2010)

Reactive power on LV grid (FNN directive VDE-AR-N 4105 from 2011)

Intelligent controllable local sub stations

> Energy management in Smart Grid

Optimizing the self-consumption, even with local battery bank

Local feed-in management in the LV grid << 100 kWp (voltage-dependent/Smart Grid)

Local battery bank with local peak shaving in the distribution grid

Self-contained start capability

2010 2015 2020 2025

Evaluation of measures with regard to facilitating grid integration in the low-voltage grid

Measure	To what extend are photovoltaics possible [1]?	Comment
Voltage support for reactive power	40-200 %	
Voltage support for controllable local sub stations	40-100 %	
Local/central feed-in management	20 – 50 %	reduces profit
Self-consumption	<5-30%	reduces the transfer costs
Peak shaving with battery	>100 %	most expensive option

- The absorption capability of the low-voltage grid can even be increased without incurring costly development costs.

(1) In contrast to the standard scenario without grid development, pure active power feed-in

Roadmap of grid integration in terms of system stability (responsible transmission system operator)

> Feed-in management

PV management > 100 kW (Renewable Energy Sources Act (EEG))

> Frequency control

Frequency-dependent reduction in power (German Association of Energy and Water Industries (BDEW) directive from 2009/FNN directive from 2011/2012)

Simulation of rotating synchronous generators with positive control reserves (actual reserves, primary control)

> Measures for the energy sector

Solar forecast

Self-consumption with variables, generation-dependent tariffs (Smart metering), demand-side management (e.g. heat pump)

Central peak shaving with battery bank, virtual power plants

DSM: electrical storage heater, electric mobility/methanation of PV

2010 — 2015 — 2020 — 2025

Summary

> **Grid system services** can be provided by PV plants to the distribution grid

> The new grid guidelines are the basis

> This thereby **reduces** the number of conventional power plants' "**must run units"** to a bare minimum – even to 0!

> **Reduction in grid development costs** thanks to new **intelligent measures** in the distribution grid:

  > **Reactive power supplied by inverter**

  > **Intelligent local sub station with electrical on-load tape changer**

Scenarios such as "**grid faces collapse"** can be **avoided** – despite developing renewable energy sources

> **Thank you very much for your attention**

> **I'm more than happy to answer any questions you may have**

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