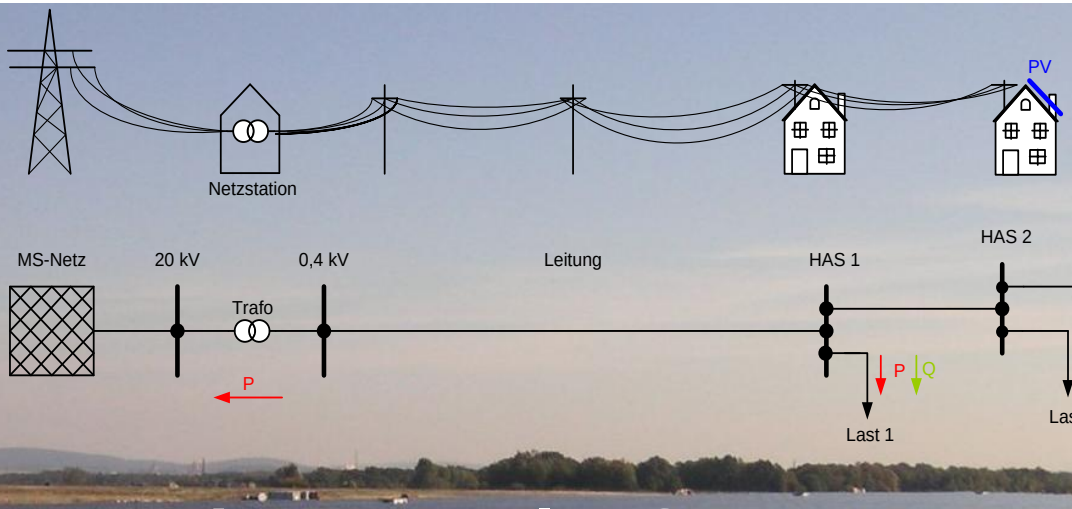


PV Aggregation Results from Germany

Dr.-Ing. Bernhard Ernst
Director Grid Integration, SMA Solar Technology AG

UWIG Solar Integration Workshop, Maui, October 11, 2011

Overview of presentation

1. **Company profile**
2. Aggregating and analyzing of output power
3. System services
4. Future roadmap
5. Summary

SMA is market and technology leader for PV inverters

All PV applications

On-Grid

Off-Grid

Backup

All performance ranges

From <1 kW

To >1 MW

All module types

Thin film

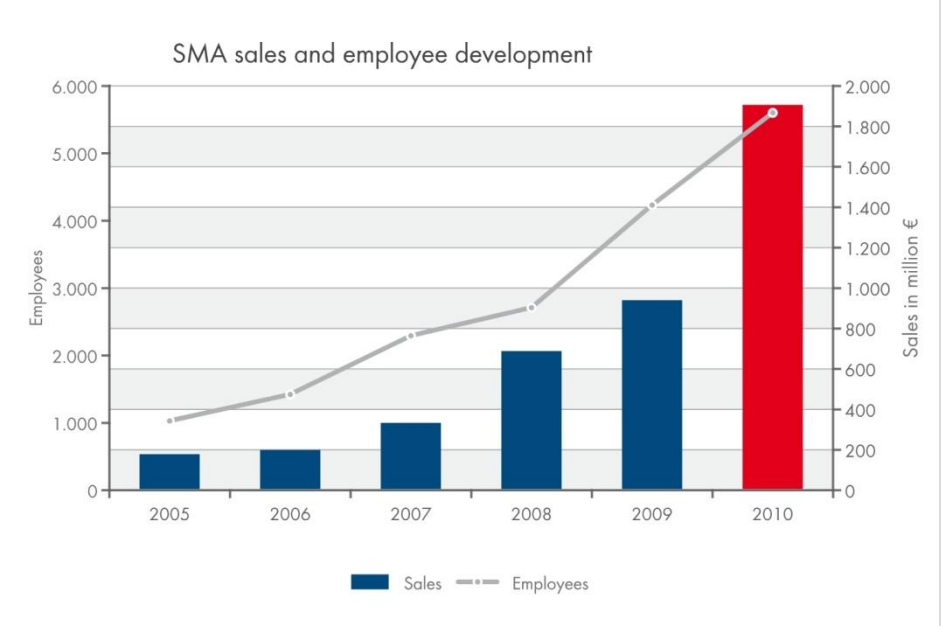
Crystalline modules

Concentrator modules

- SMA offers inverters for all applications in photovoltaics.

SMA will benefit from the worldwide growth of the solar market due to the good market positioning

- Founded in 1981
- Turnover of $2.6 billion in 2010
- 7.8 gigawatt produced in 2010
- More than 5,500 employees all over the globe, approx. 330 trainees
- 17 foreign subsidiaries on four continents
- Best efficiency worldwide (99 %)



- In 2010, SMA achieved nearly 45 % in sales abroad.

Leading solutions for Utility Scale PV Plants

Montalto di Castro, Italy

85 MWp

Sun Power PV modules

124 Sunny Central 630HE

Blue Wing, Texas

16 MW, 22 Sunny Central 630 HE-US

- 12 MW - Dover, Delaware, USA (12x SC800CP, 1xSC500CP)
- 1 MW - Kauai, Hawaii, USA (2x SC 500HE-US)
- 10 MW – Sicily, Italy (11x800CP)
- 9 MW – Ginosa Tarent, Italy (13x630CP)
- 4 MW – Foggia, Italy (6x630CP)
- 2 MW - Ponce, Puerto Rico (4x SC 500HE-US)

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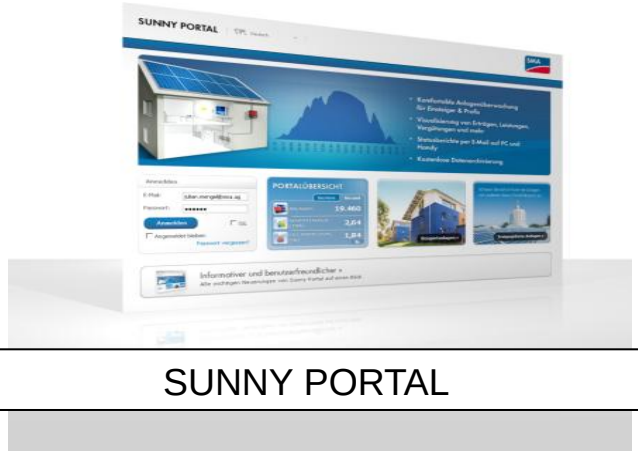
Developement of PV in Germany / Lookout

- **New installation in 2010: 7,400 MW**
- **Total installation by end of 2010: ca. 17,000 MW**
- **Total installation by 10/2011: 19,000 MW**
- **Forecast for 2020: ca. 50,000 MW**

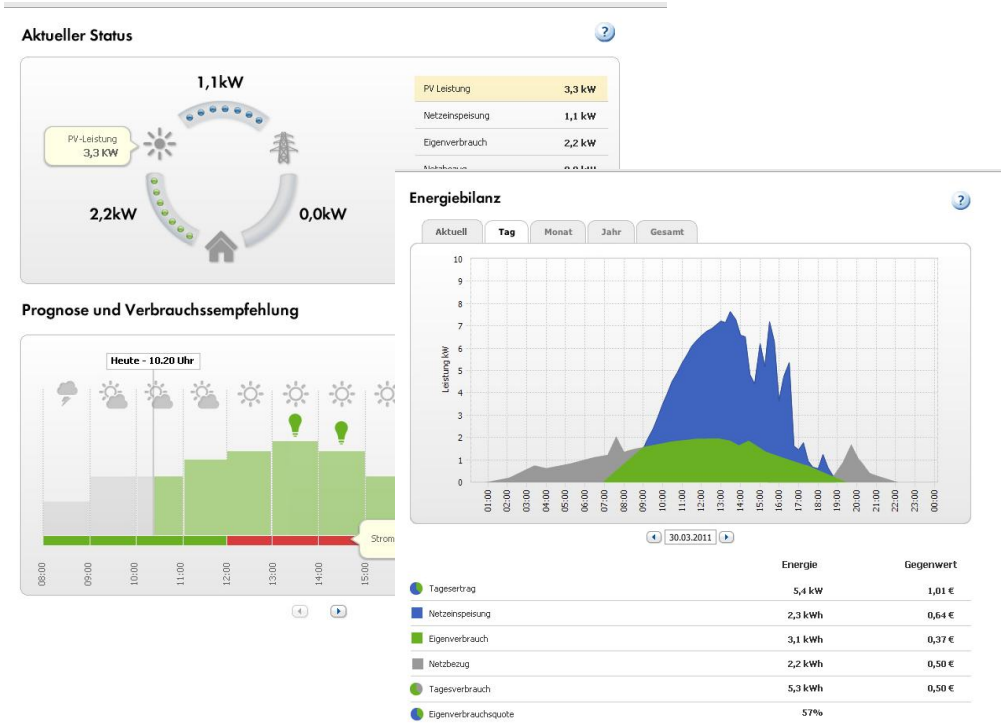
Source: BSW-Solar, Roland Bernger, Prognose, www.solarwirtschaft.de, Bundesnetzagentur



SUNNY PORTAL

> Visualization
> Administration

- Largest PV data portal world wide (>60.000 units)
- 5 min values collected online or once a day
- Central data base for customers and units
- Access via internet PC, smart phones, etc.)
- Service (inverter updates, etc.)
- Optimization of self consumption
  - > Status consumption
  - > Prediction
  - > Customers advise



www.sunnyportal.com

Data availabe from our service providers ***energy & meteo systems*** and ***enercast***

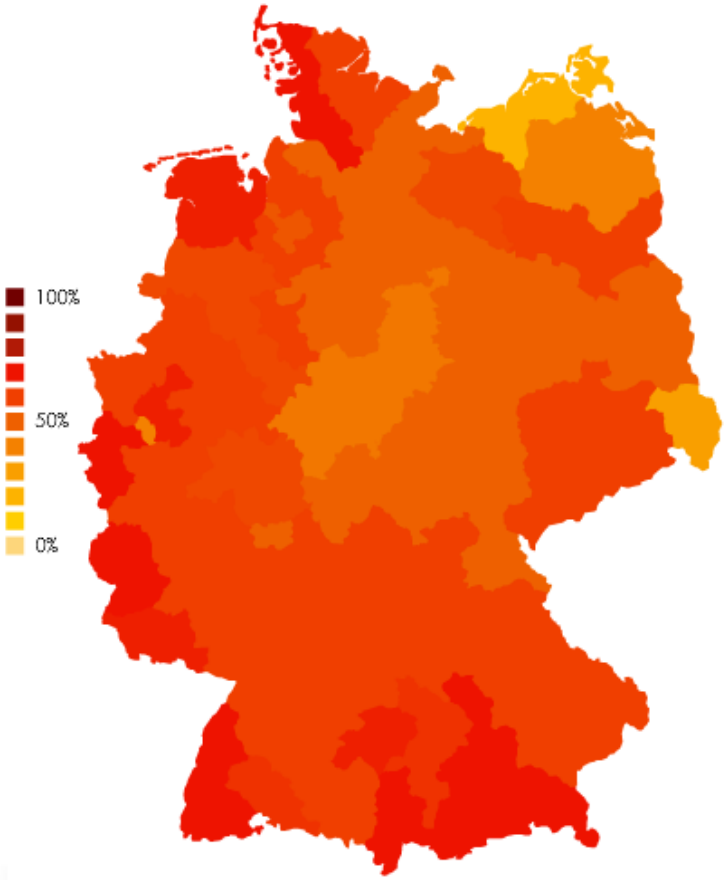
PV Performance in Germany

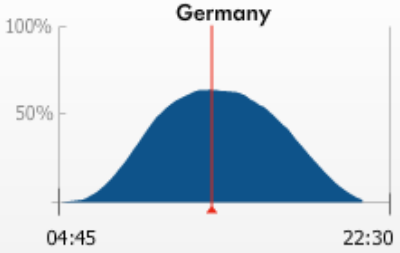
(http://www.sma.de/en/news-information/pv-electricity-produced-in-germany.html)

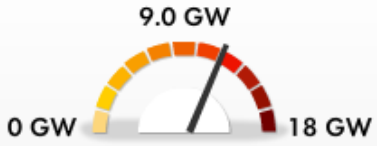
Performance of Photovoltaics (PV) in Germany

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

Based on the data provided by Sunny Portal »







Current PV Power in Germany*

11.6 GW

*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

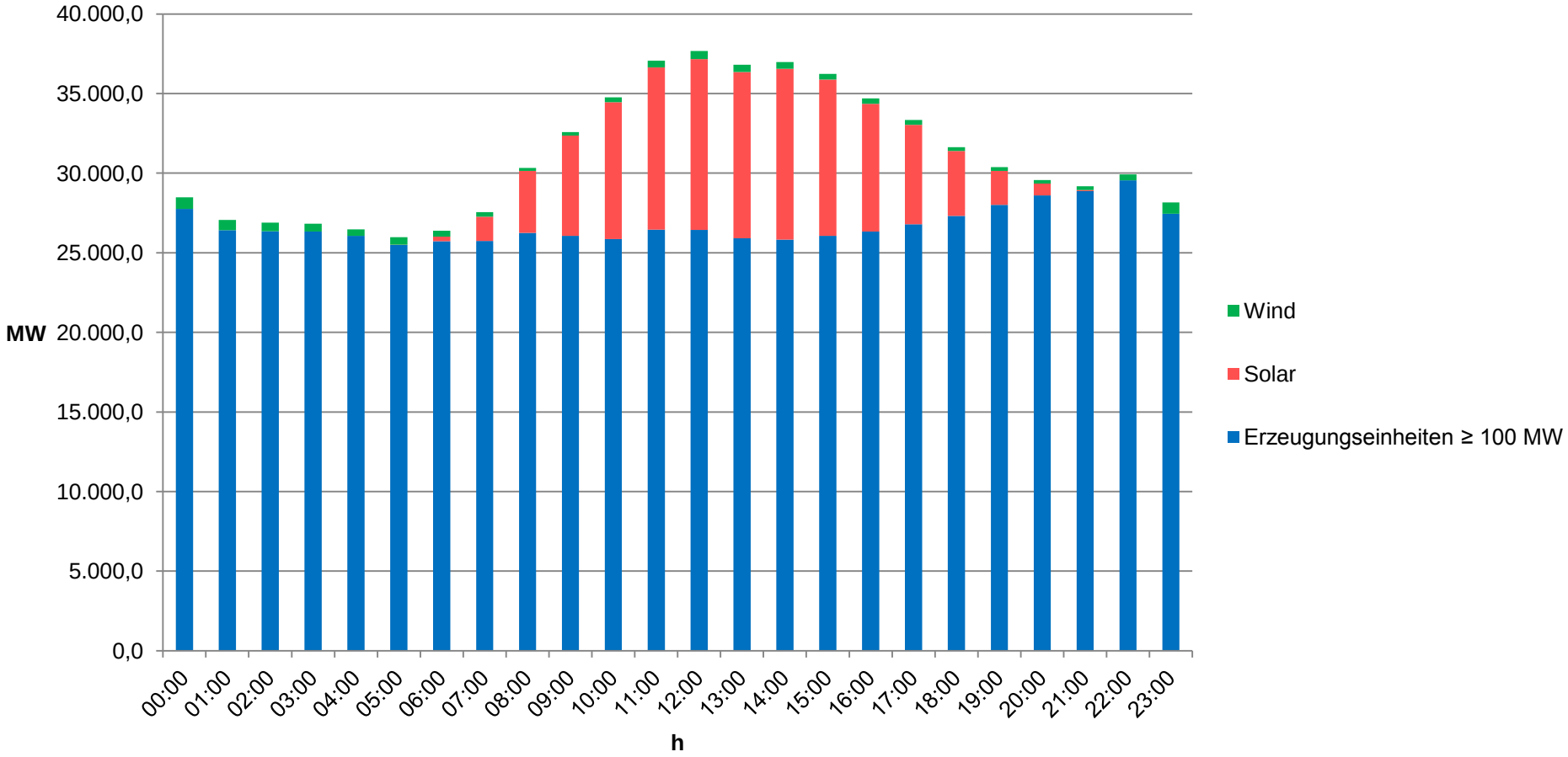
What is the current status of photovoltaics in Germany? This is an interesting question, and one to which you will receive a clear answer on this website based on daily updated information. Here, you can view at any time the total output of all PV plants in Germany installed up to the specified cutoff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

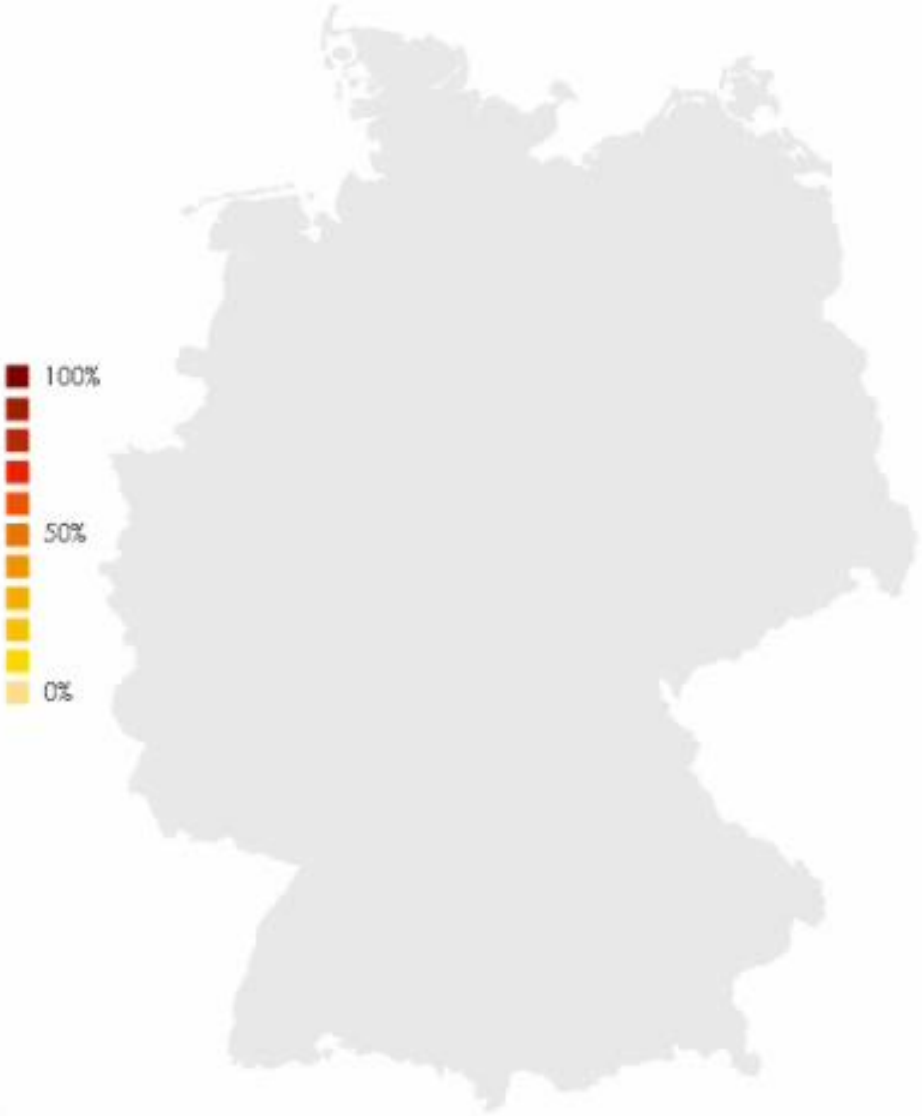
Generation in Germany on Sunday June 12, 2011
PV performance compared with convential generation

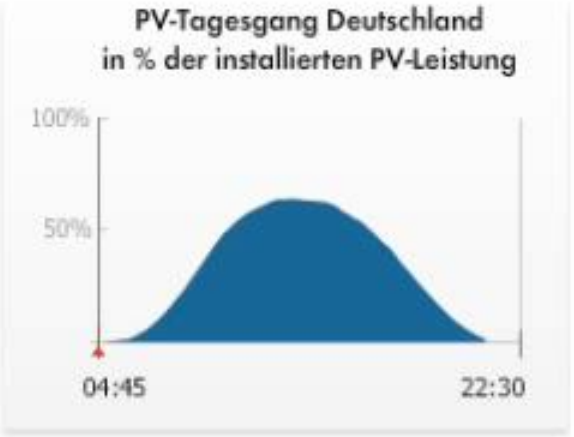


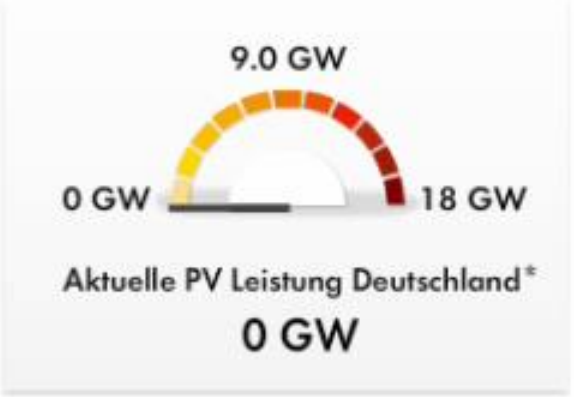
European Energy Exchange (EEX) 12 a.m.:
Convential generation 26.4 GW / Wind 0.52 GW
Share of PV at noon: 30.1 %

Das leistet Photovoltaik in Deutschland

Relative Leistung vom 12.06.2011 - 4:45 Uhr







*Hochgerechnete, momentane Leistung aller lt. Bundesnetzagentur am Stichtag 31.05.2011 installierten PV-Anlagen mit insgesamt 18.38 GW Nennleistung.

Solar power Measurements

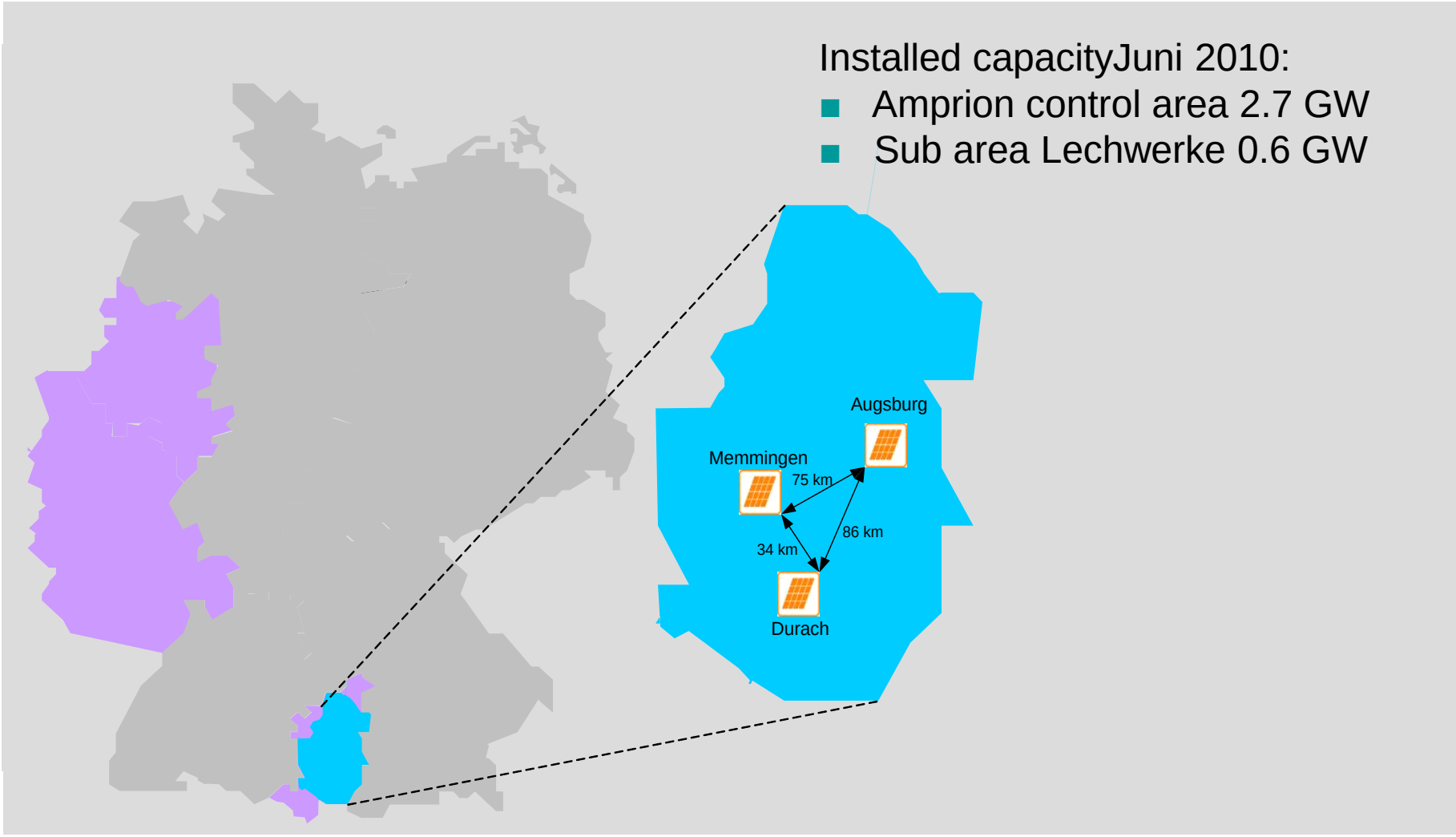
010

100%
50%
0%

05:30

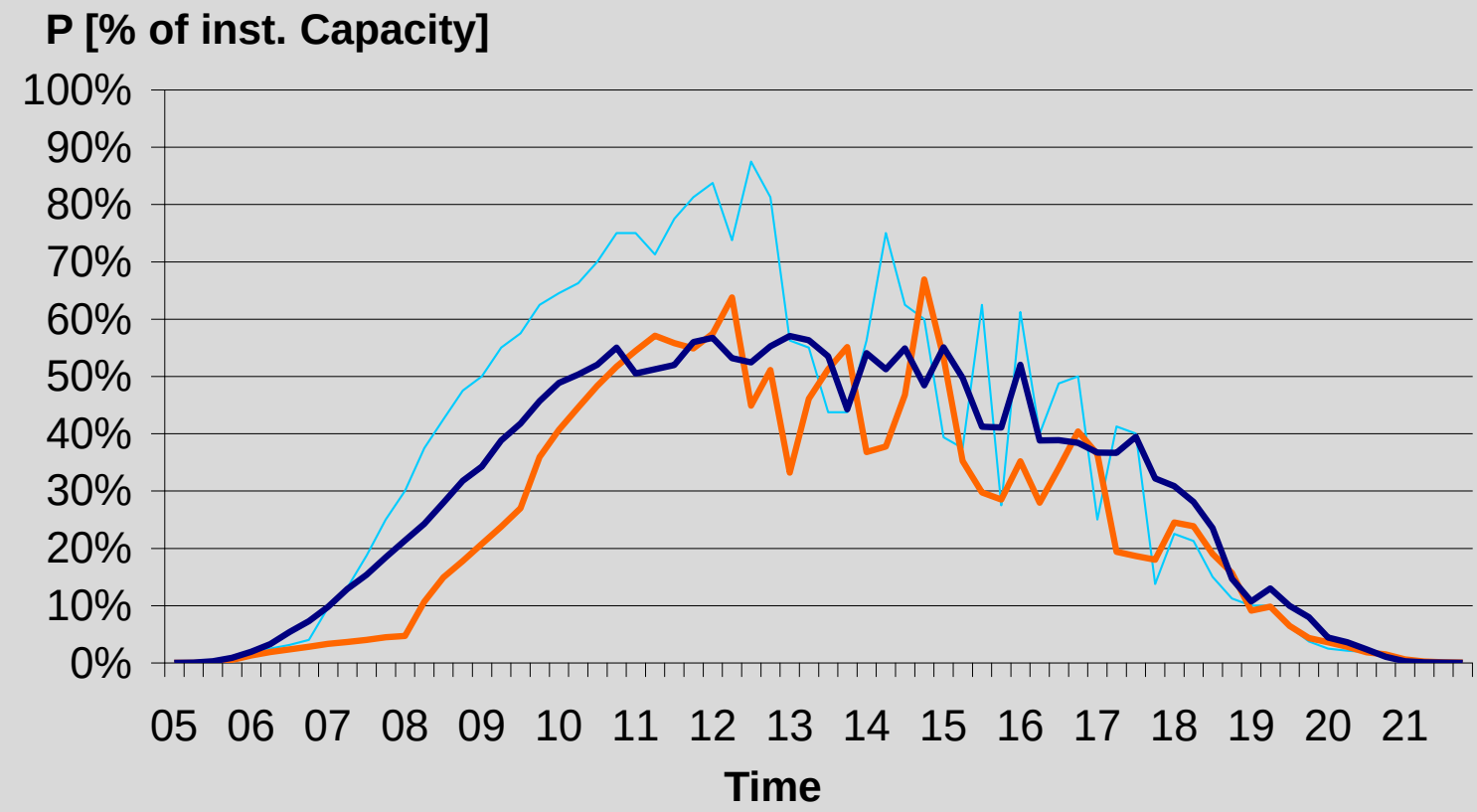
13.12.2010

Fluctuation of PV, 15 minute intervall



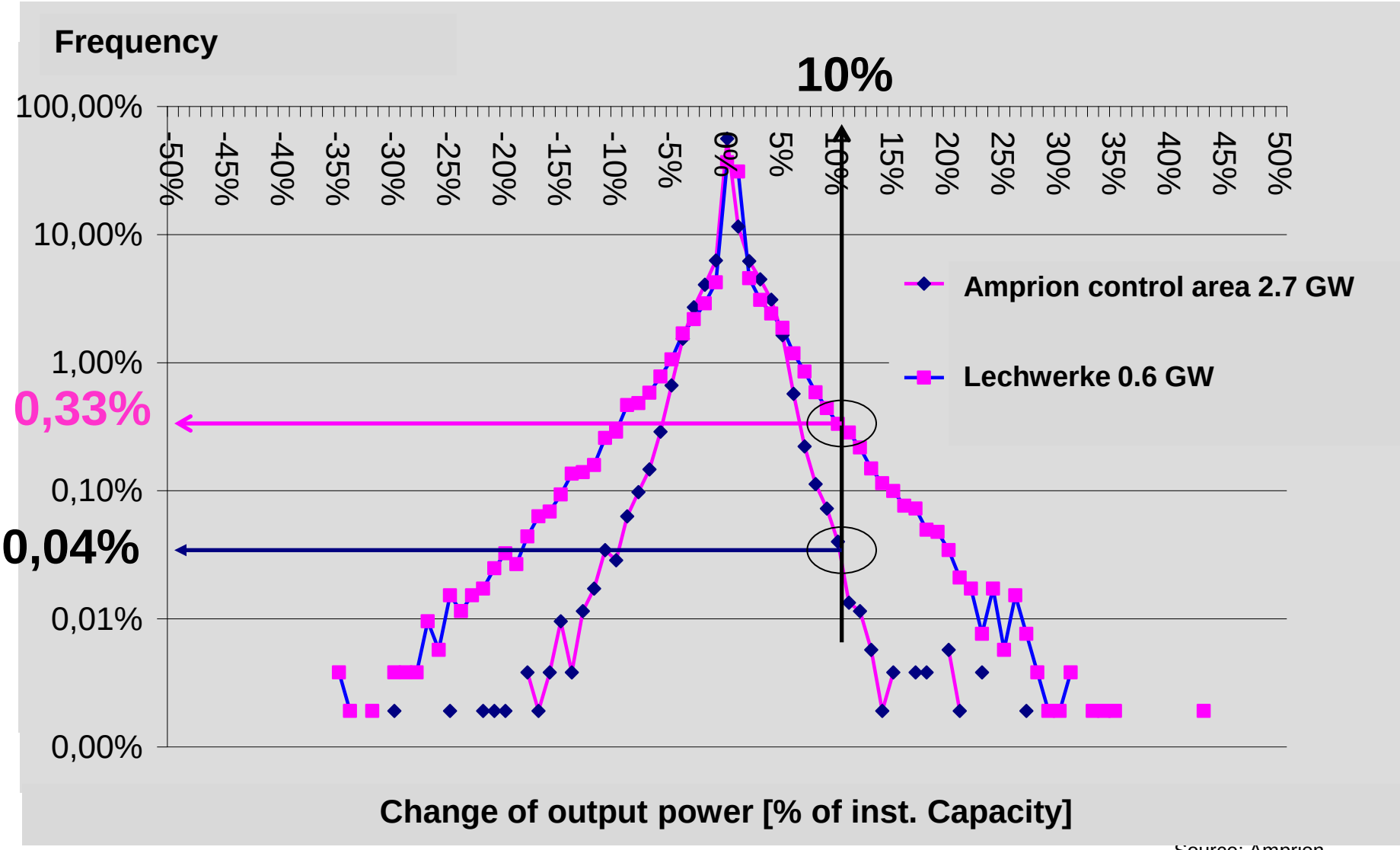
Source: Amprion

Fluctuation of PV, 15 minute intervall



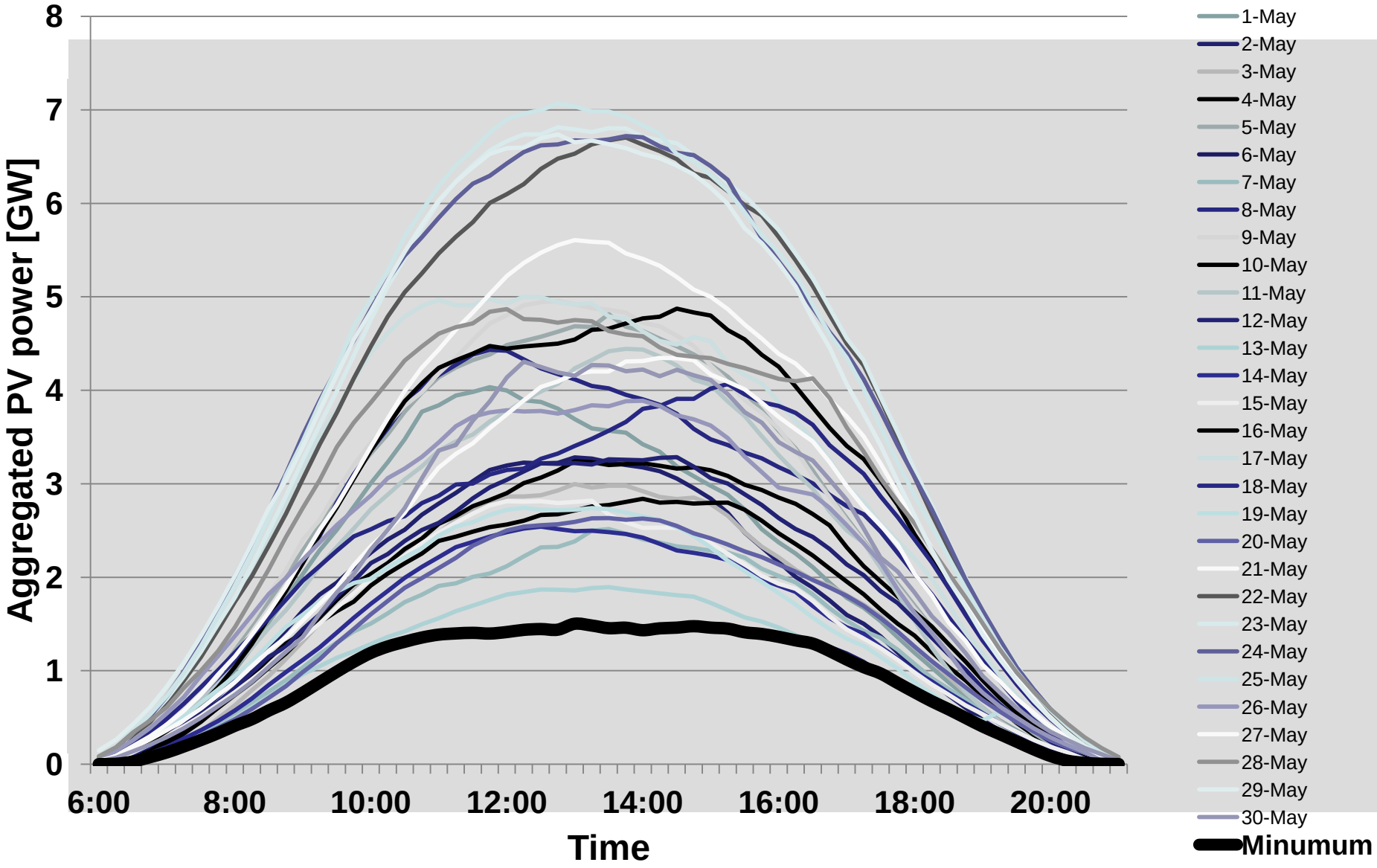
Source: Amprion

Fluctuation of PV, 15 minute intervall

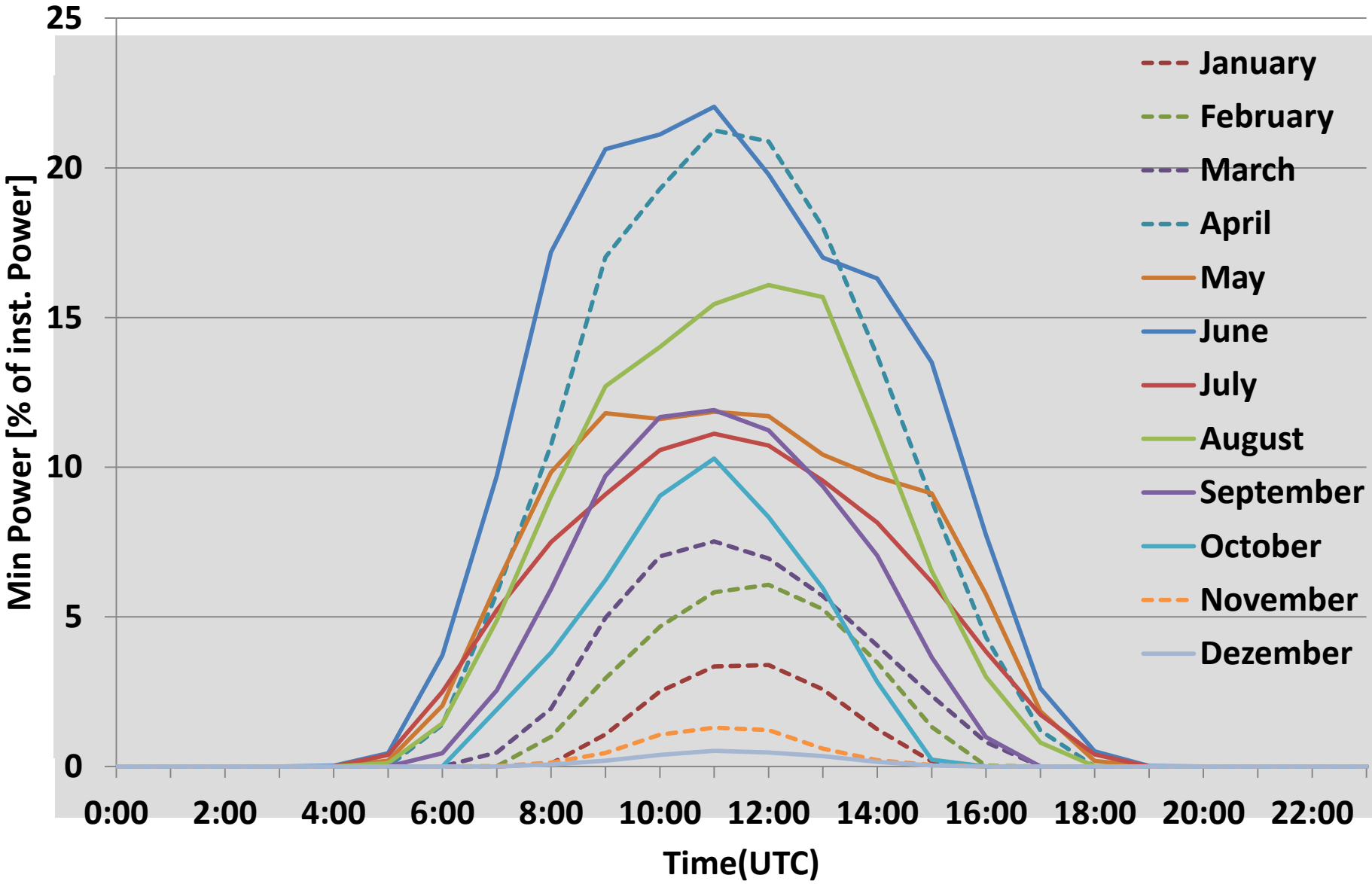


Source: Amprion

Minimum PV-Power in Germany



Minimum PV-Power in Germany based on one year data



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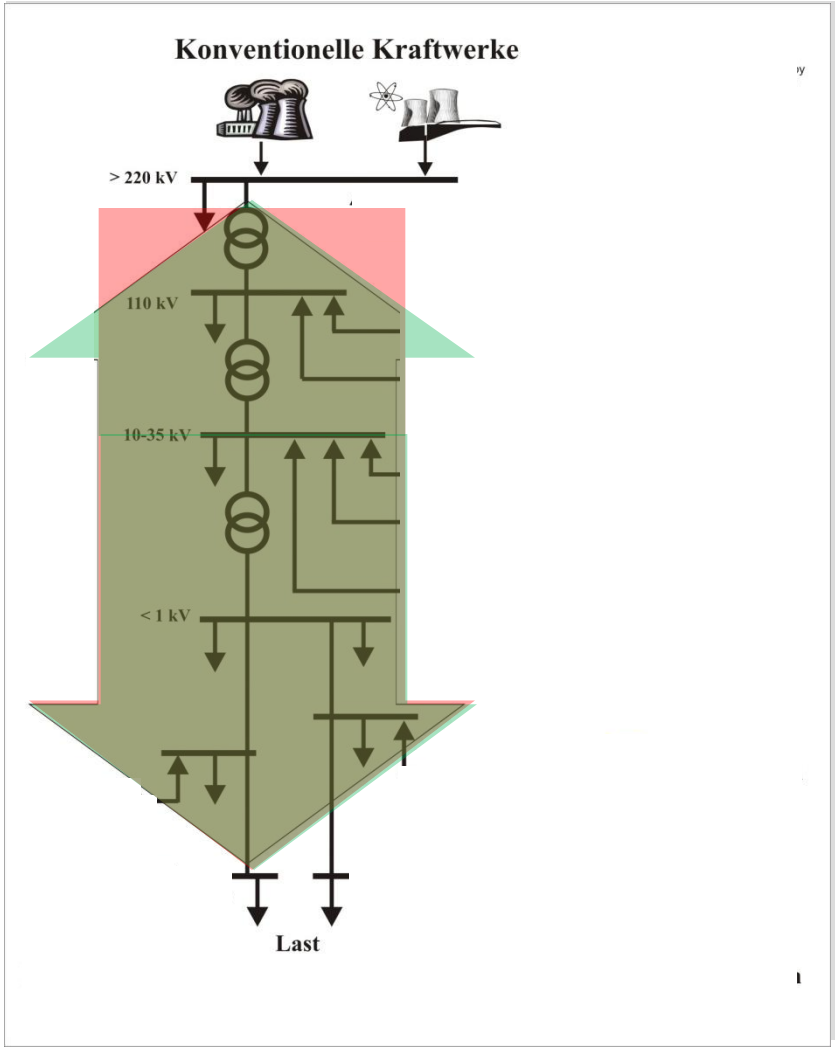
Integration of renewable energy into the grid structure

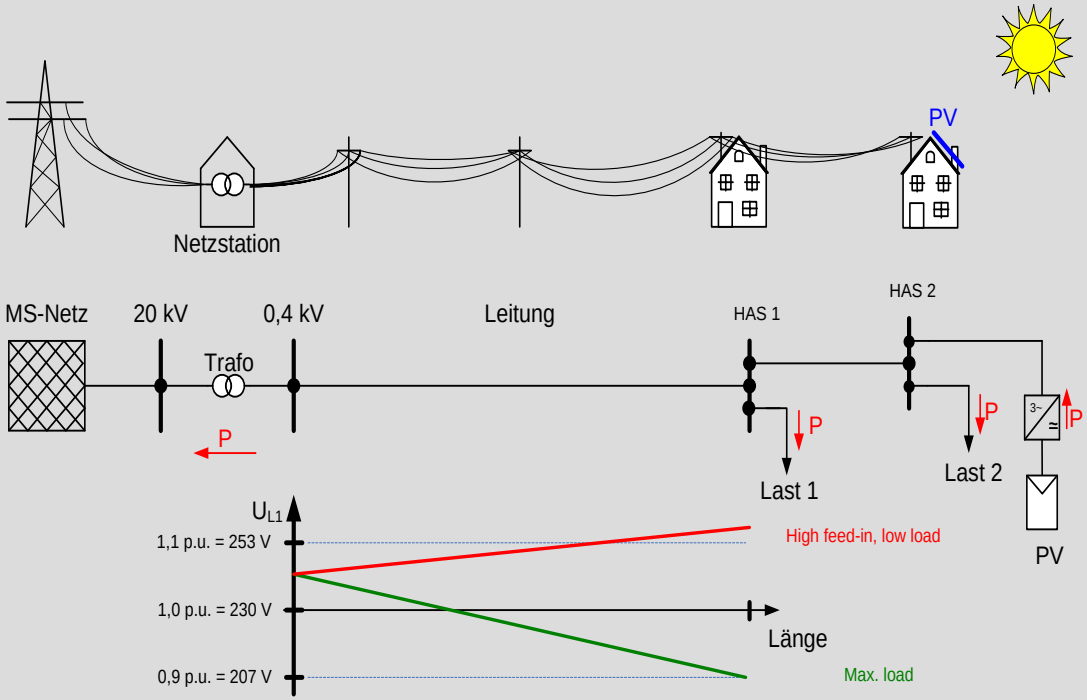


- Typical PV feed-in:
  - approx. 85 % of LV level (230 V/400 V)
  - approx. 15 % of MV level (10 - 30 kV)
  - few plants in the HV level (110 kV)
- **Paradigm replacement** necessary in electrical power supply:
  - From top-down structure to fluctuating bidirectional power flows
  - Distribution grids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

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

Voltage support: power flow reversal – a technical issue?

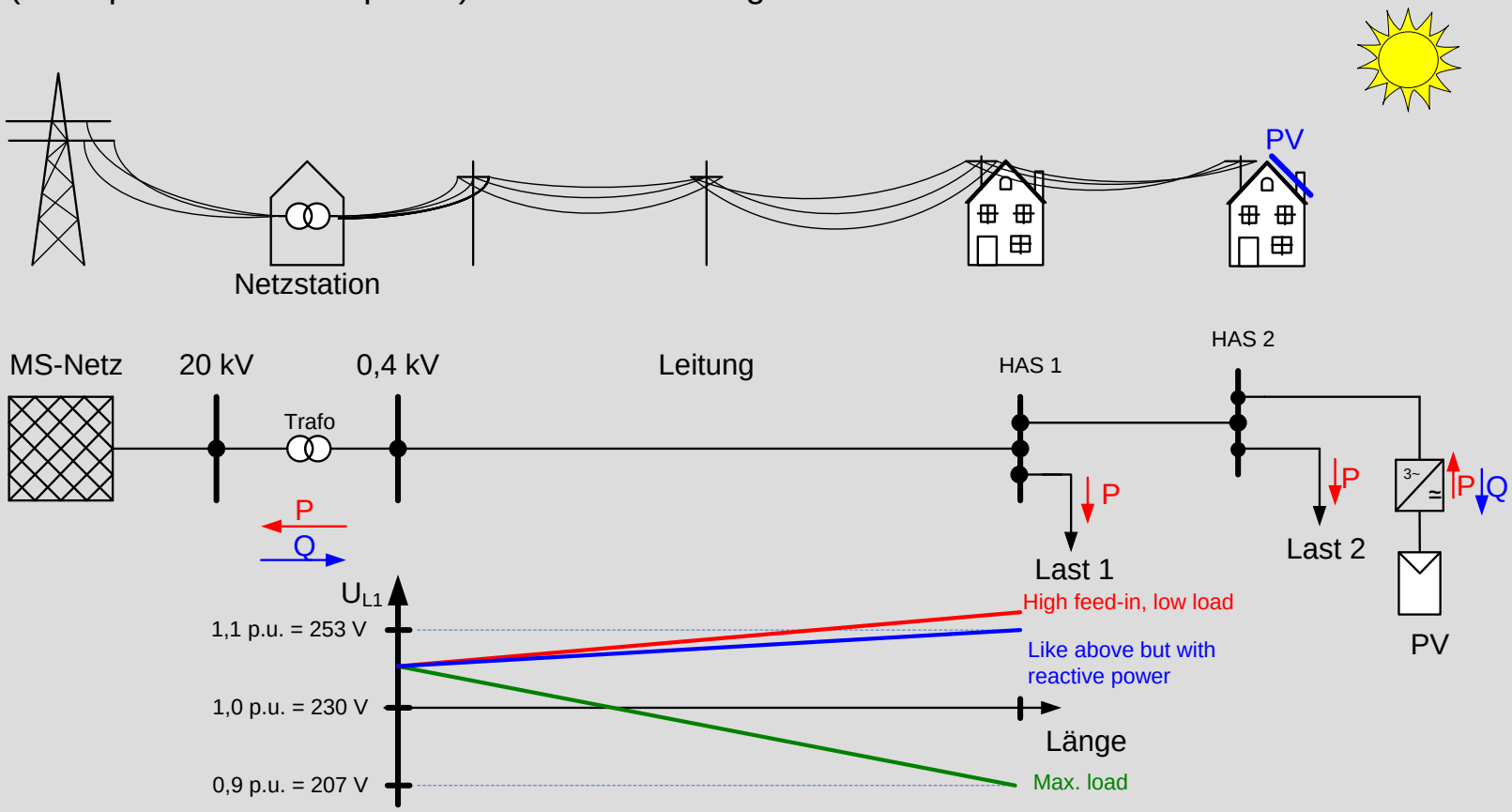
> Example: PV plant installation: In the low load hours before lunch, a **power flow reversal** occurs. **Violation of the voltage criterion** in accordance with EN 50160



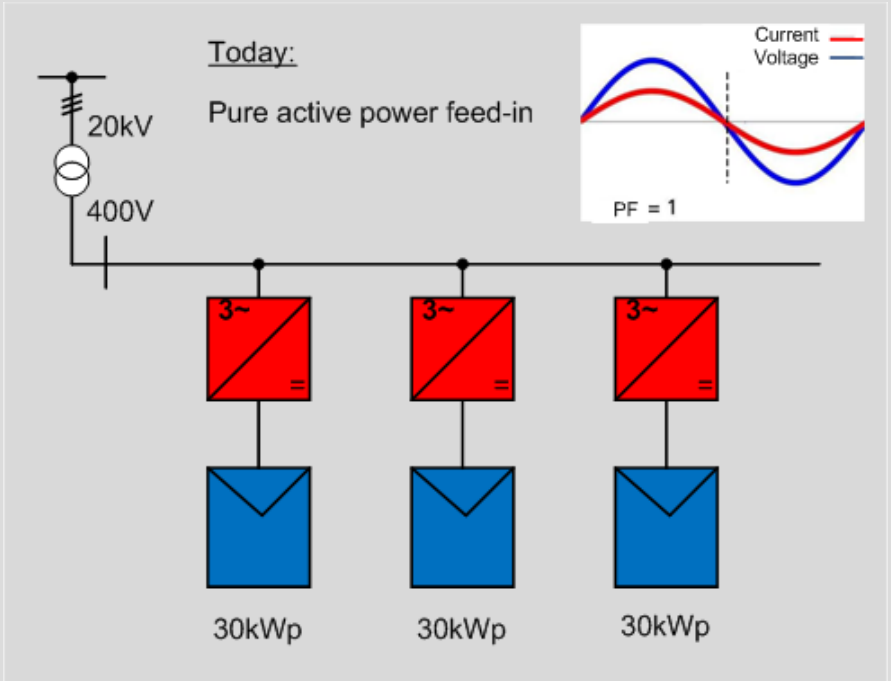
- Voltage Problems were previously associated with costly grid development involving increased amounts of copper, new cables and more powerful transformers.

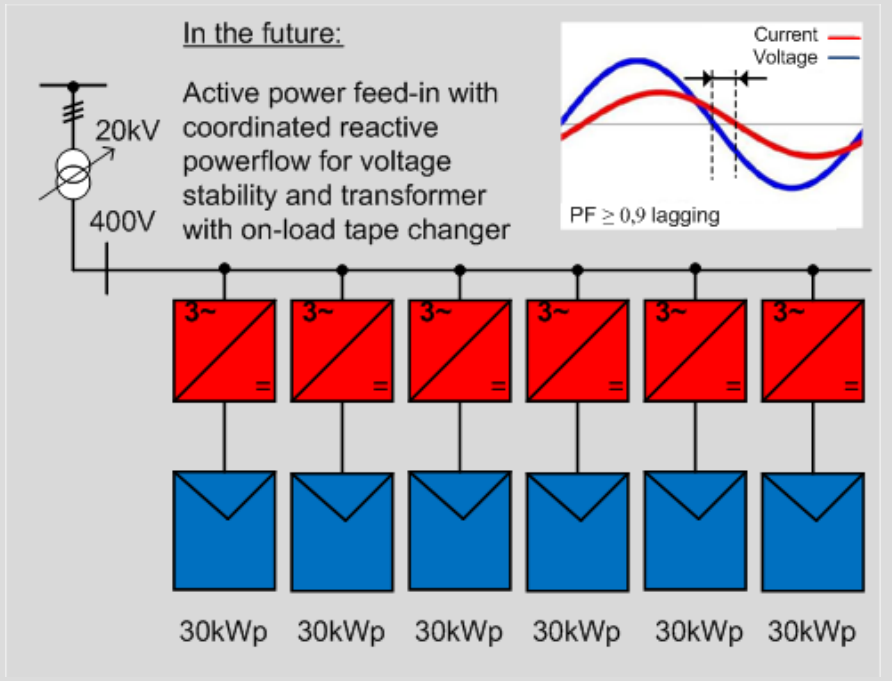
Supporting voltage through reactive power supply

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



Supporting voltage through reactive power supply





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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

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

Summary

- **SMA Portal** gives large database of PV production world wide
- **Fluctuations** significant smaller by aggregation of large areas
- **PV** provides significant load share during **peak demand**
- **Grid system services** can be provided by PV plants to the transmission grid as well as to the distribution grid
- **Paradigm change:** From top-down structure to fluctuating bidirectional power flows

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

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

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