Grid Interconnection and Grid Integration Features of PV Inverters

Andreas Gast| November 28, 2012

Agenda

1. **Company**
2. News for Israel: transformer compact station + SMA service hub
3. Current PV situation in Germany
4. Grid management tools

SMA is a true growth story – more than 60 % p.a. sales increase in last five years

- > Founded in 1981
- > Sales 2011 EUR 1.7 billion
- > Shares in exports of 53.7 % (Q1-Q2/2012)
- > More than 5,500[1)] employees all over the globe
- > Represented in 21 countries on four continents
- > Best efficiency worldwide (9[illegible] %)

On-grid

Off-grid

Backup

Residential
< 2 kW

Residential
2 kW to 30 kW

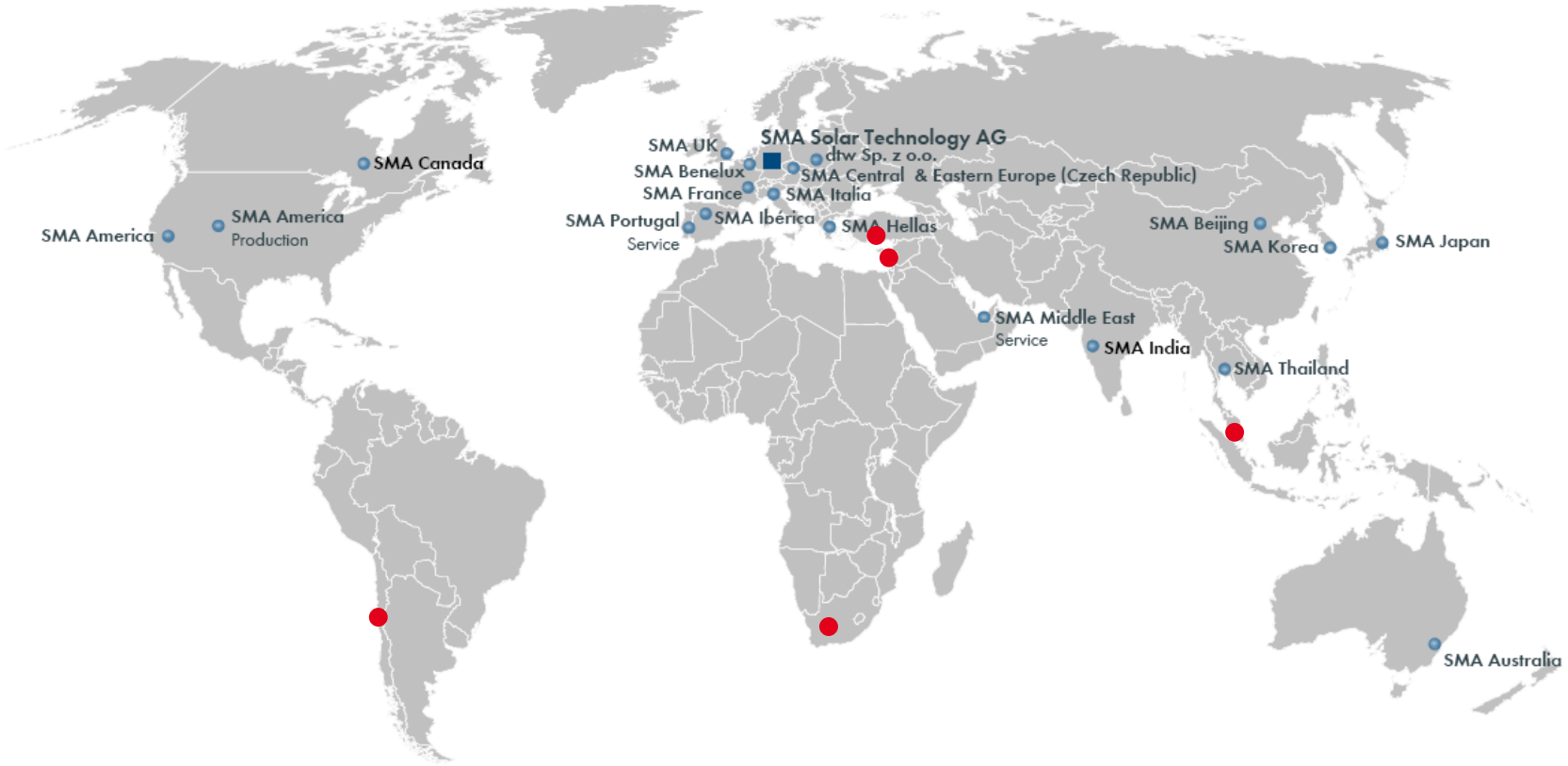
Commercial
30 kW to 500 k[illegible]

Industrial
To > 1 MW

> SMA was again customers´ first choice in 2011

(1) Plus temporary seasonal employees

SMA is represented in 19 markets all over the globe



- **In 2011, we achieved over 50% in sales abroad.**

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SMA Service Hub for central inverters in Israel

> Commissioning of the first 3 projects with Sunny Central in Q1 2013 in Israel, total volume18 MW

> Project pipeline of large scale projects in Israel > 80 MW in 2013

> SMA is market leader for PV inverters in Israel

SMA offers 100% service and support in Israel

SMA Service – Sunny Central Service concept for Israel

Custom fit – Security thanks to modular design principle

> Modular, individually combinable, flexible

> Long-term, adjustable period

> Higher availability

> Amount of self-responsibility vs. SMA support can be selected individually

TCS and transformers ready for Israel

TCS - TRANSFORMER COMPACT STATION

> Description: Steel Housing, transformer, LV distribution and MV Switchgear
> Power classes: 800 /1600 kVA ready for sales, more comming soon
> Voltage-level: 6,6 – 24kV others on request
> Accessories: LV cable set, basement for CP
> **Operation temperature range: -20 up to 50 °C**

TRANSFORMER

> Description: stand-alone indoor and outdoor medium voltage transformer
> Power classes: 800 /1600 kVA ready for sales, more comming soon
> Voltage-levels: from 6,6 kV - 35kV
> ONAN and KNAN (biodegradable oil) version
> Vector group: Dy11, Dy11y11, YNd11, YNd11d11
> **Operation temperature range: -20 up to 50 °C**

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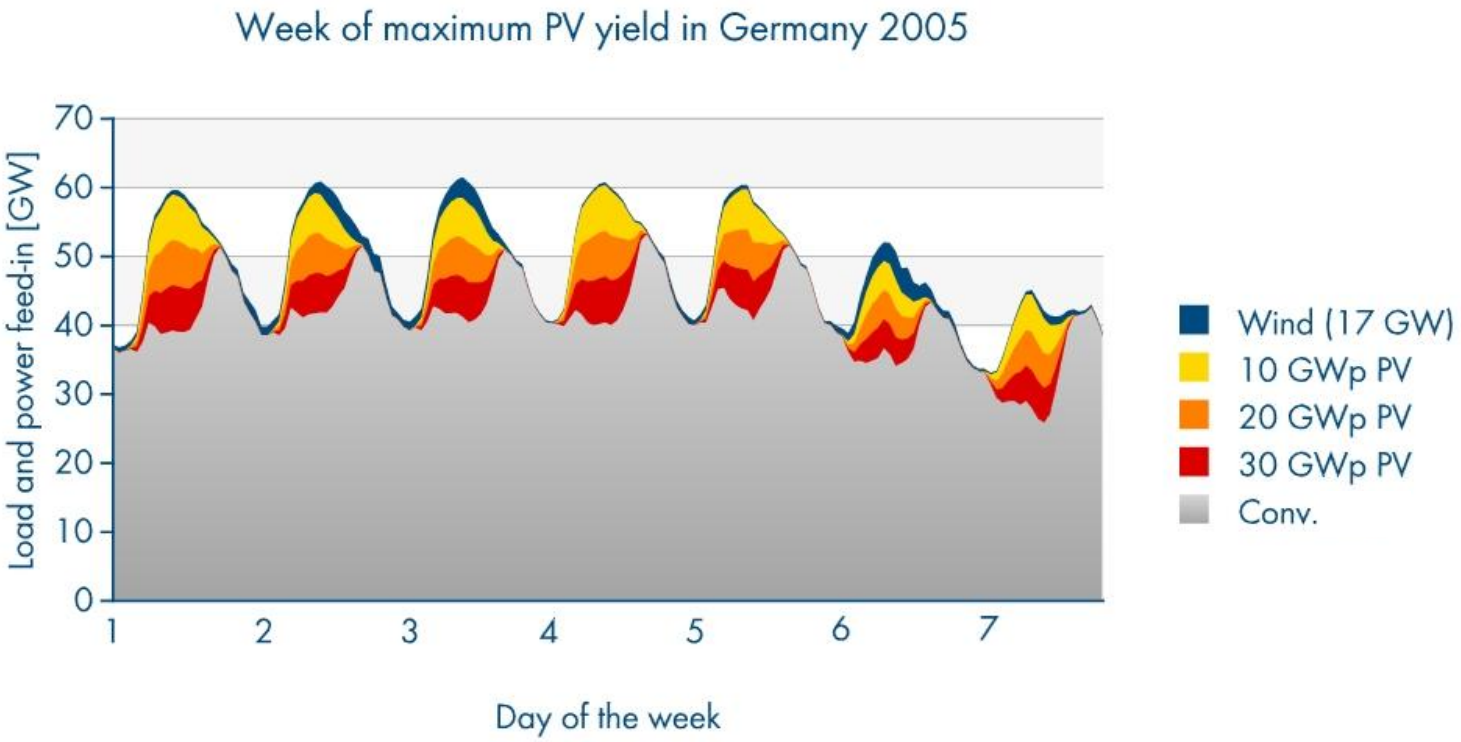
How much PV-power does the German grid support?

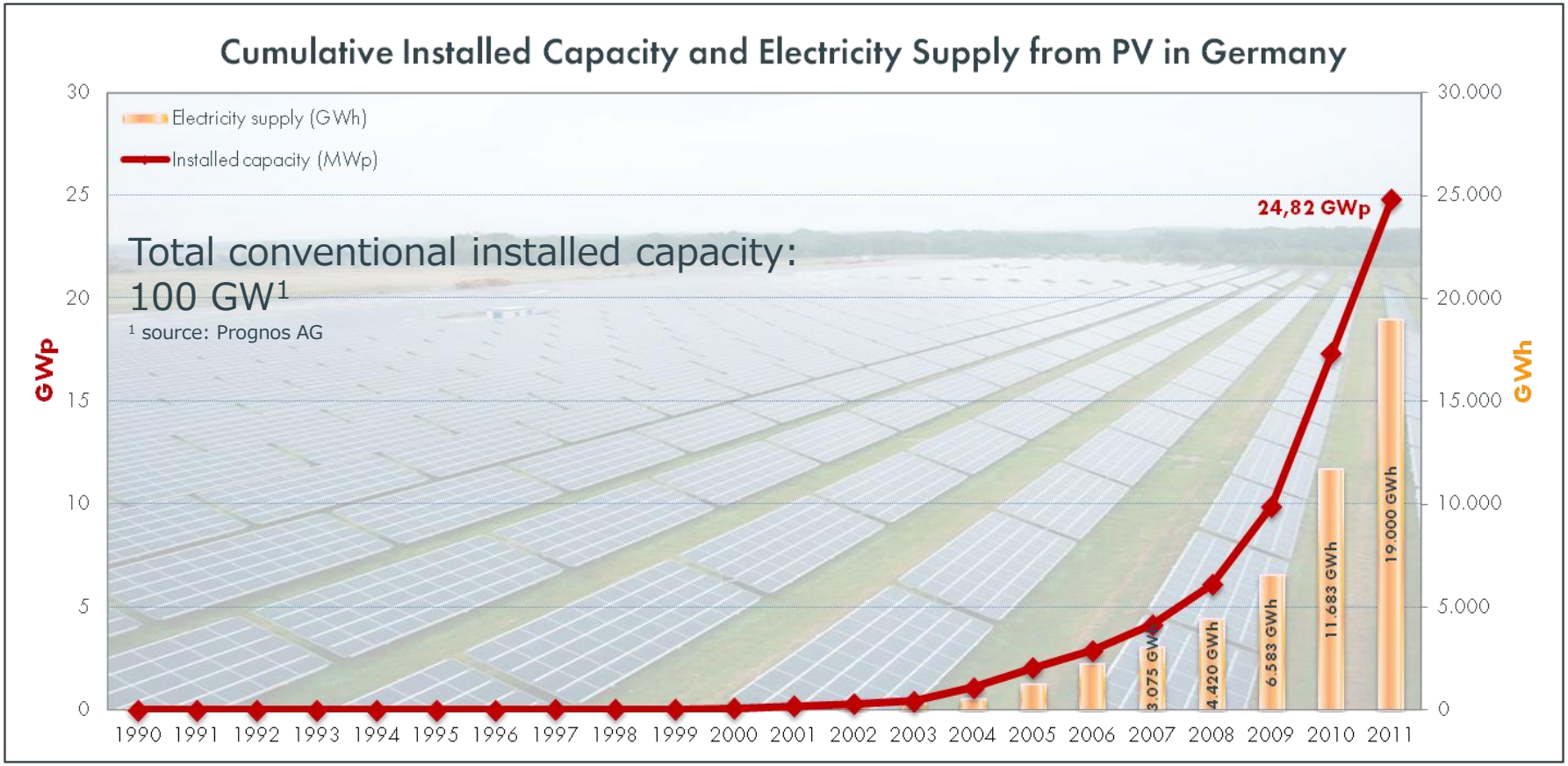


PV power is peak load power!

"Dynamic investigation into the correlation between PV feed-in and grid load fluctuations"
Partial result of the study "The role of solar power production in future energy supply structures – value of solar power"[1]

[1] Carried out by: ISET, ISE, meteo control

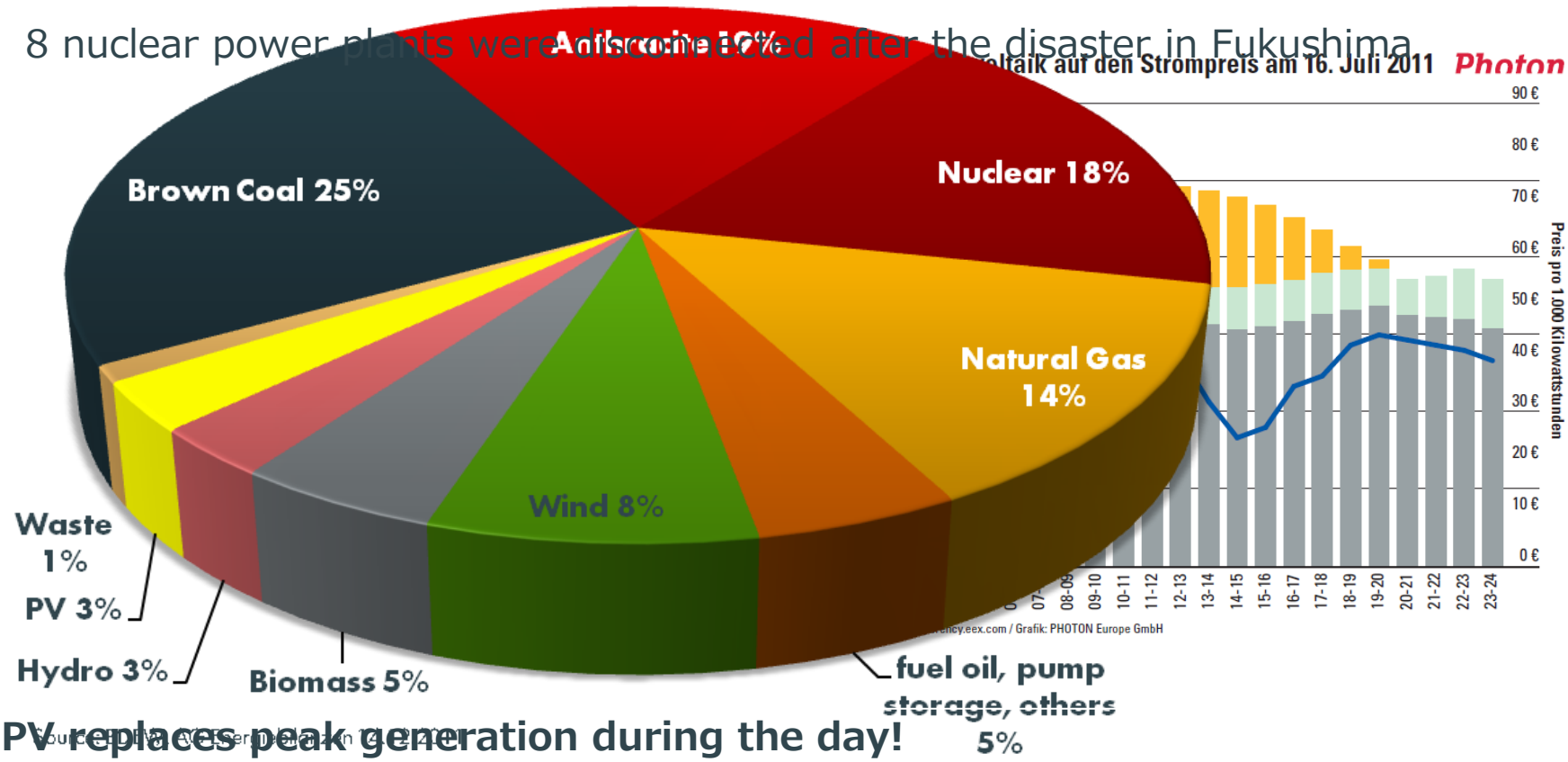
Actual PV situation in Germany



Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, BMU-KI III 1, Working Group RE

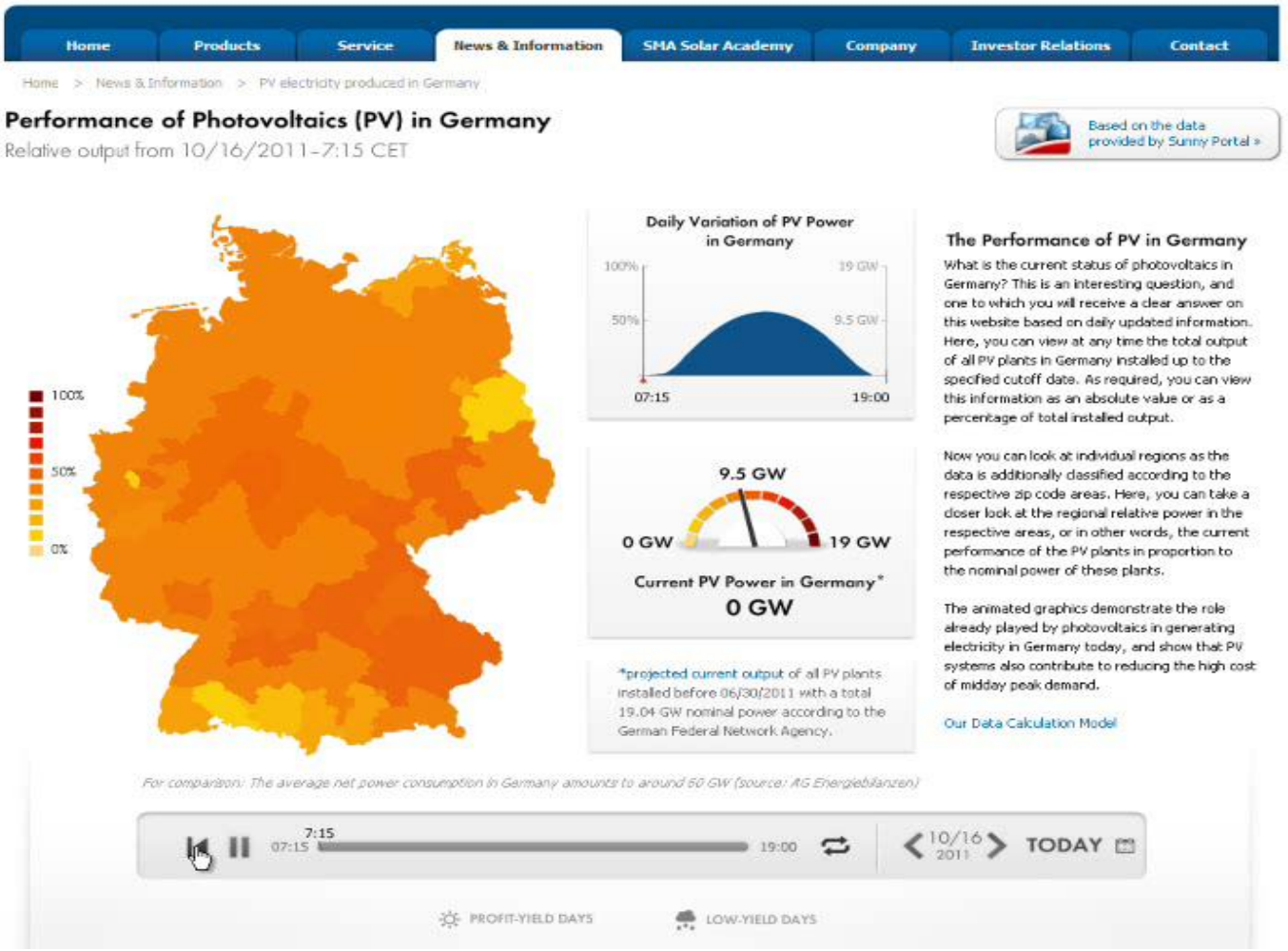
PV is a reality in Germany

- Gross electricity generation in Germany in 2011: 612 TWh
- **More than 25 % share** of PV in generation power on a summer day in 2011 at noon
- 8 nuclear power plants were disconnected after the disaster in Fukushima



- **PV replaces peak generation during the day!**
- **High PV penetration requires the participation of the PV-inverters to the grid management**

Example for PV output during a sunny day in Germany



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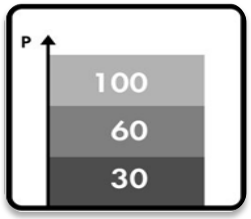
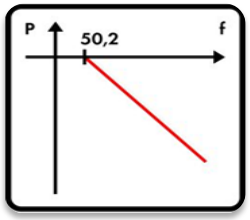
Grid management tools

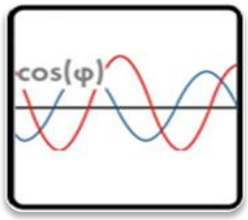
> Power curtailment



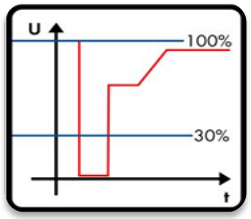
> Frequency Control



> Voltage Control



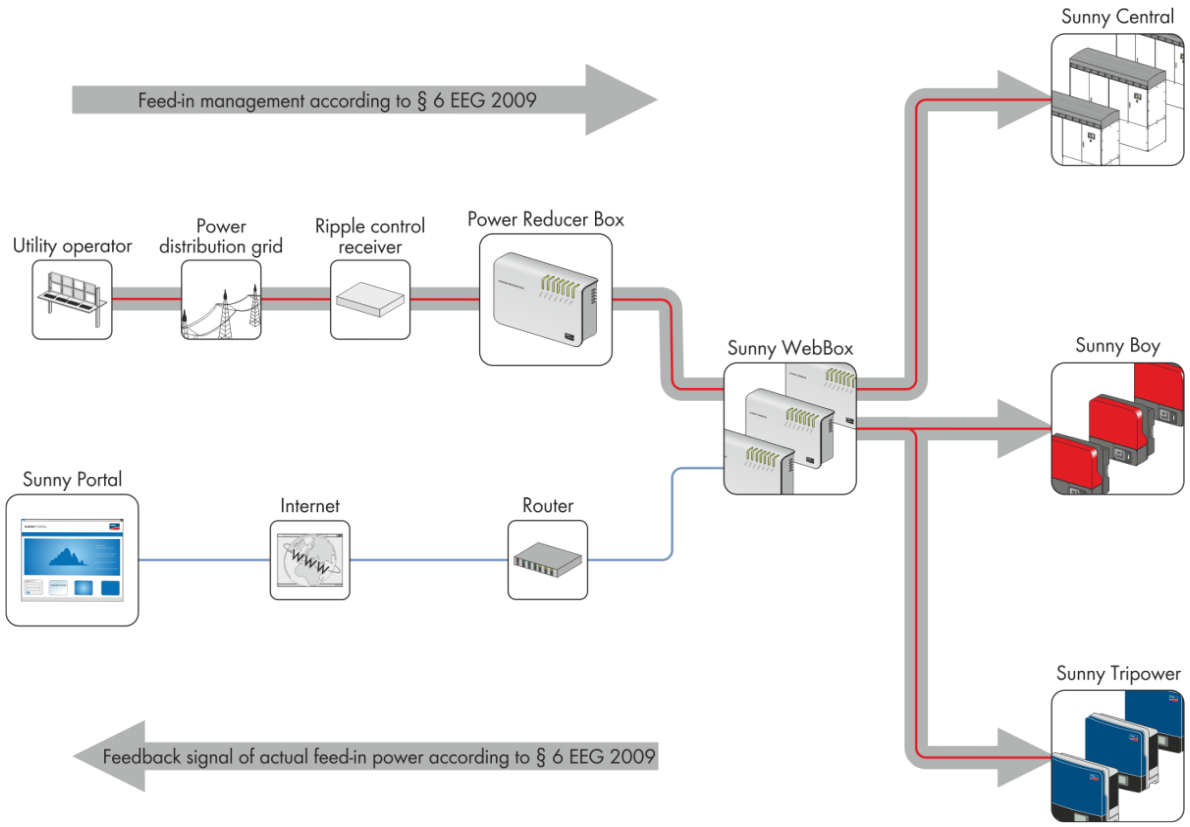
> Dynamic Grid Support (fault ride through)



Power curtailment

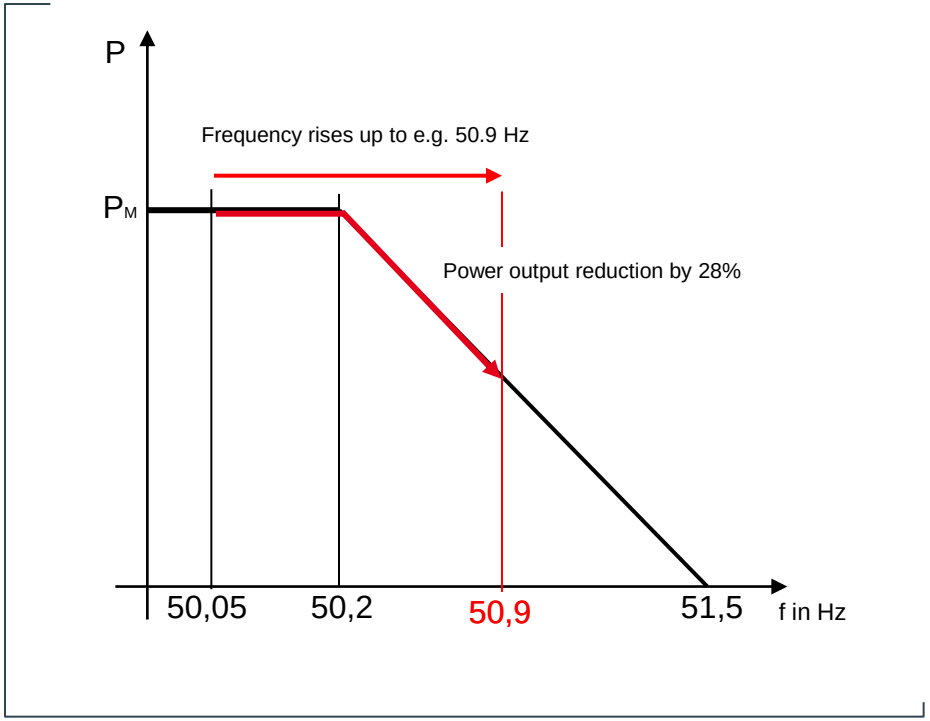
> Manage temporary generation/load imbalance conditions in local grid sector

> Limit power generation via remote control and SMA Power Reducer Box to e.g. 100%, 60%, 30% or 0% of maximum power



Frequency control

- Temporary reduction of generated power depending on frequency
  - in case of emergency
  - in case of generation/load imbalance
  - to avoid instability



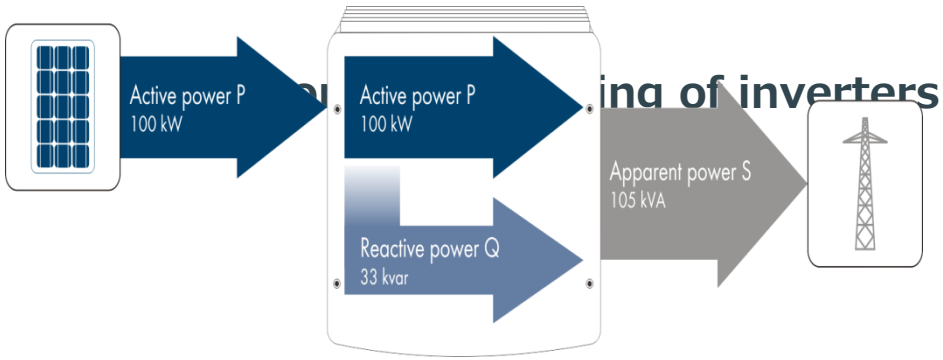
Voltage control

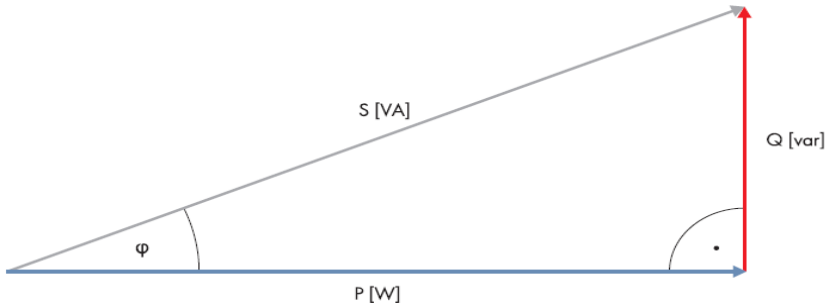
> Feed-in of active power has influence on grid voltage (voltage rise)

> Voltage rise can be compensated **via feed-in of reactive power**

> Available reactive power modes:
  > cos Phi = const.
  > Q = const.
  > cos Phi (P)
  > Q(V)

⏩ Parameters are adjustable remotley!





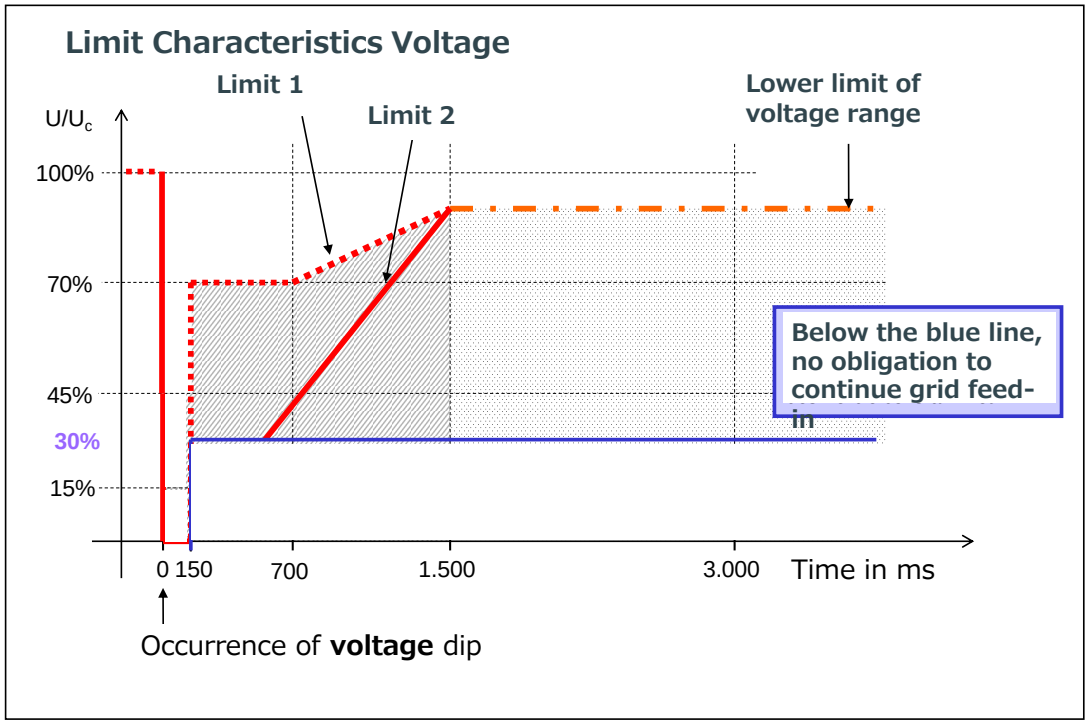
Dynamic Grid Support (fault ride through)

> Generating facility **must not disconnect** during voltage fault!

> Required behavior:
  > Above „Limit 1“
  → *Continuous, stable operation*

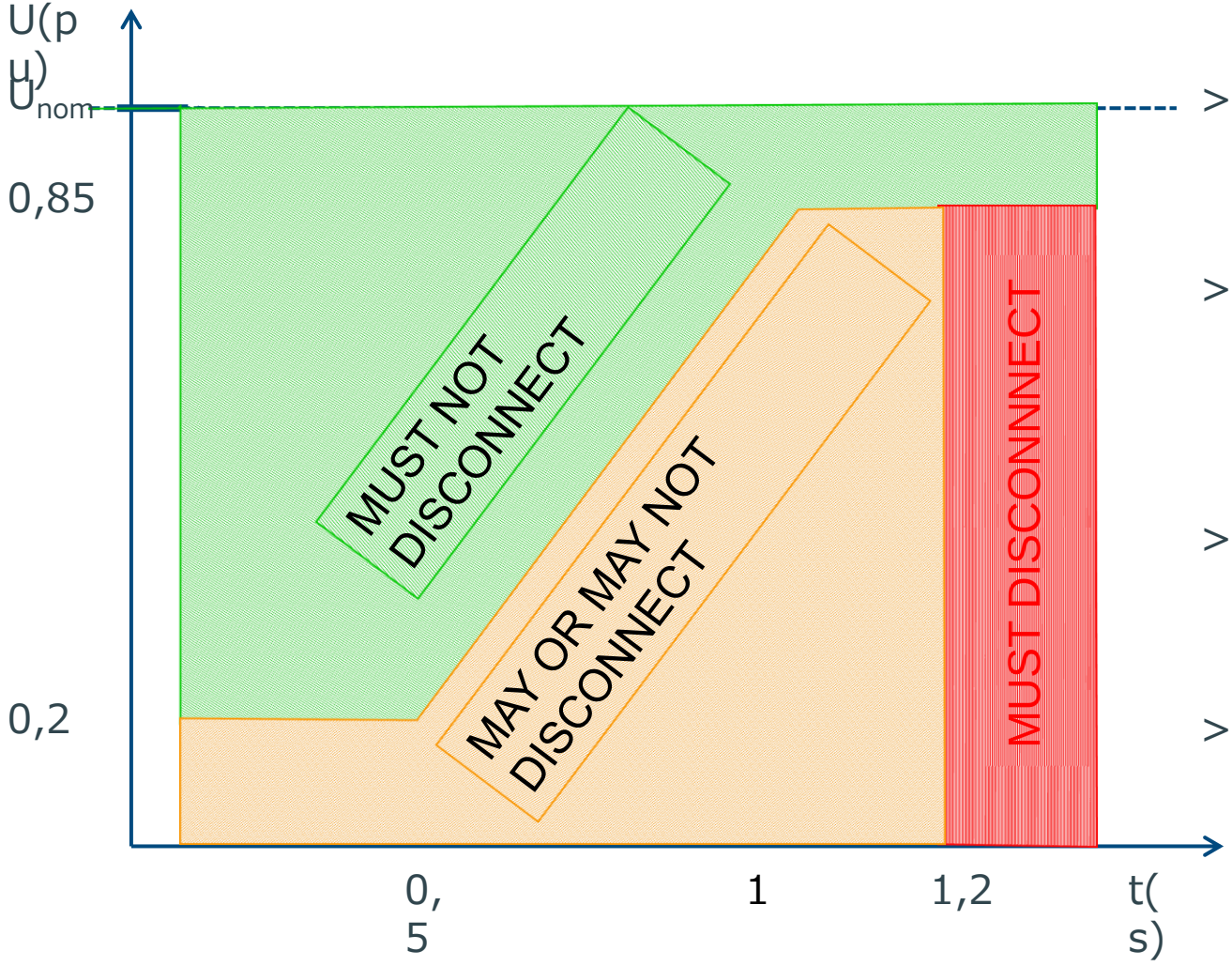
  > Between „Limit 1“ and „Limit 2“
  → *May disconnect in accordance with grid operator*

  > Below „Limit 2“ and below 30% V_{nom}
  → *May disconnect*



Source: German technical guideline for generating plants connected to the medium voltage grid. BDEW, June 2008

Interpretation of the curve V-t: Spanish example



> Curve V-t depends on the typical fault to earth in each country

> Curve V-t defines a minimum area, where the installation must not disconnect.

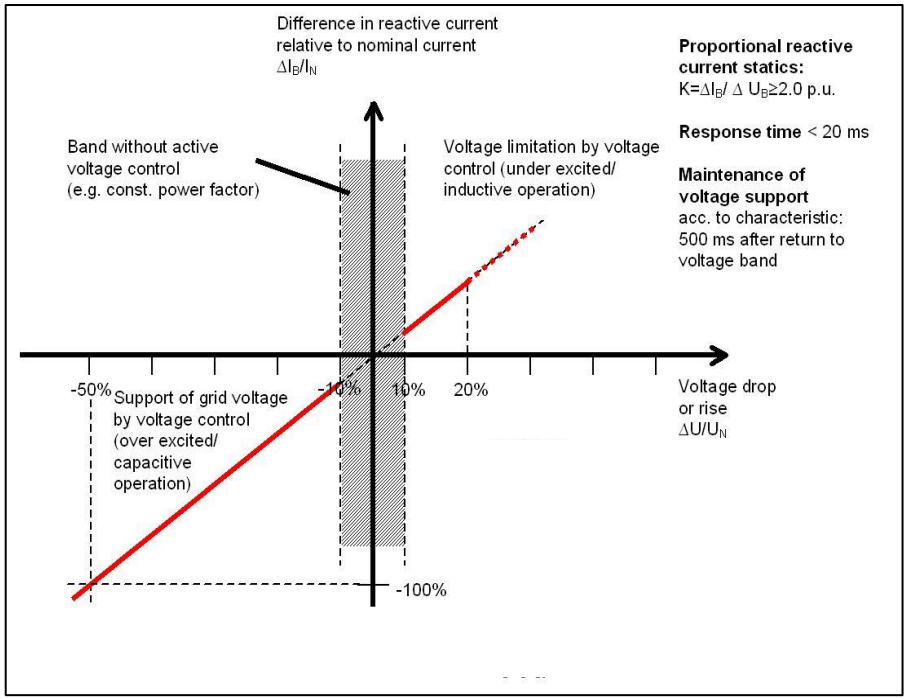
> Below the curve V-t the installation may remain connected

> Curve V-t must be compatible with the setting of the disconnection relays (red area)

Full Dynamic Grid Support

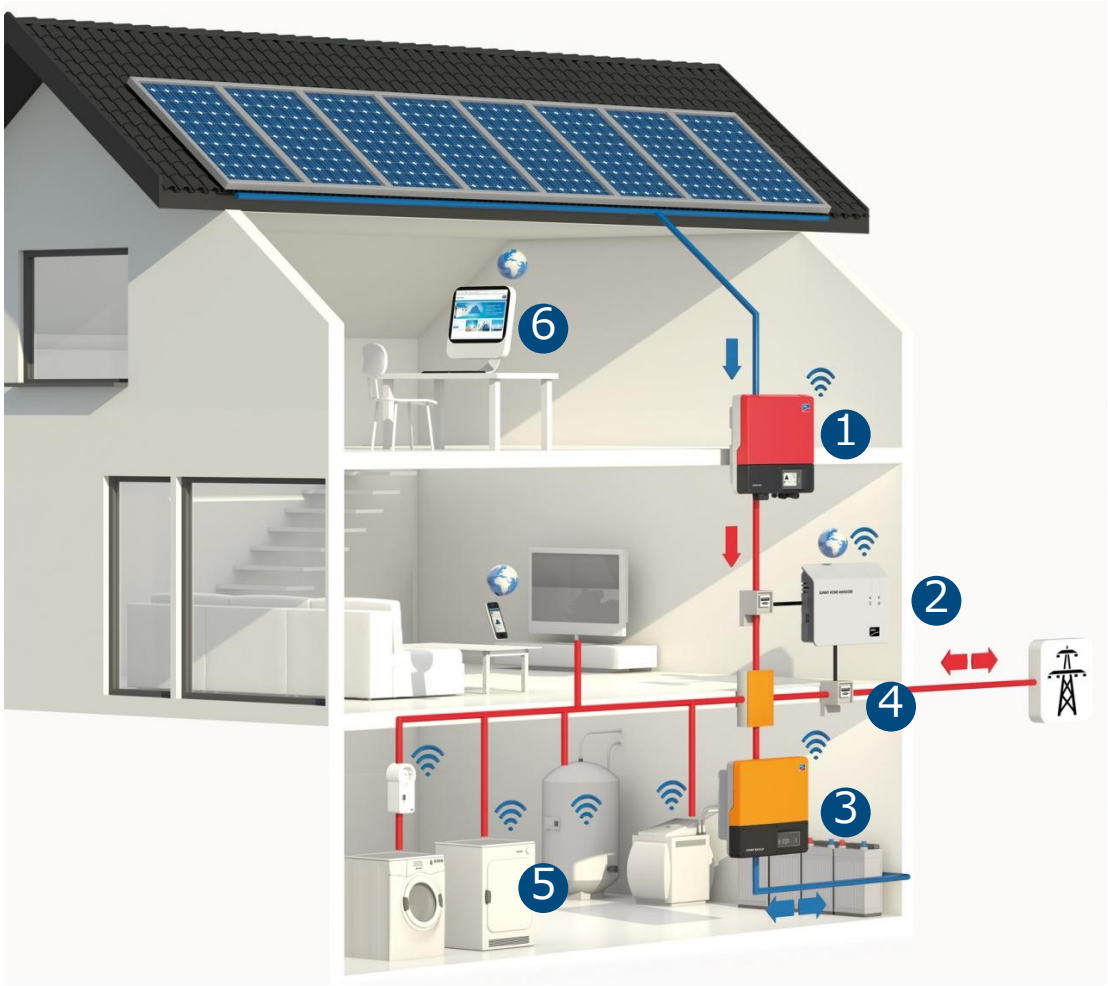
- Provide reactive current during voltage dips
- Limits the influence of voltage dips in transmission lines on the grid
- **Prevention of**
  - *Simultaneous disconnection of large generating facilities*
  - *Blackouts!*

- **No influence on dimensioning of inverters**



Source: German Transmission Code 2007

The inverter is the center of an intelligent energy management system – today –

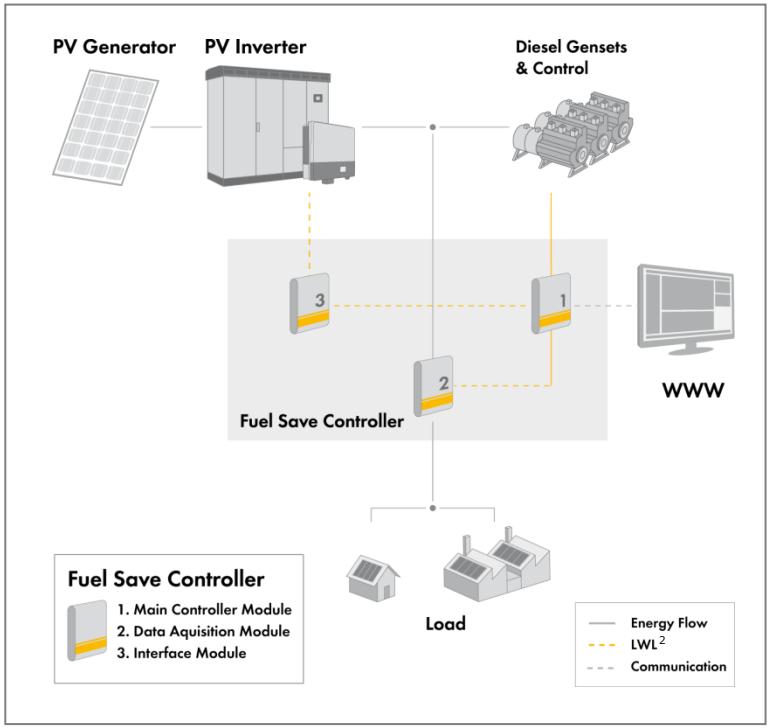


1. **Sunny Boy** converts direct current into alternating current and provides reactive power to stabilize the grid
2. **Sunny Home Manager** controls consumers and Sunny Backup System
3. **Sunny Backup System** provides for temporary storage and offers a grid-quality power supply with protection against outages
4. **Socket with measuring function** provides for the activation of appliances via the Sunny Home Manager
5. ***Bluetooth*® radio-controlled consumers**
6. **SMA Sunny Portal** for energy forecast, remote monitoring and home energy management

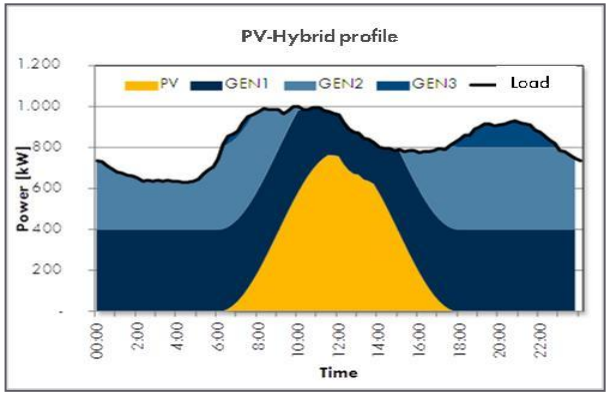
> **With SMA products, the solar power can be consumed directly in the place where it is produced**

Managing PV-Diesel hybrid systems with the SMA fuel save controller

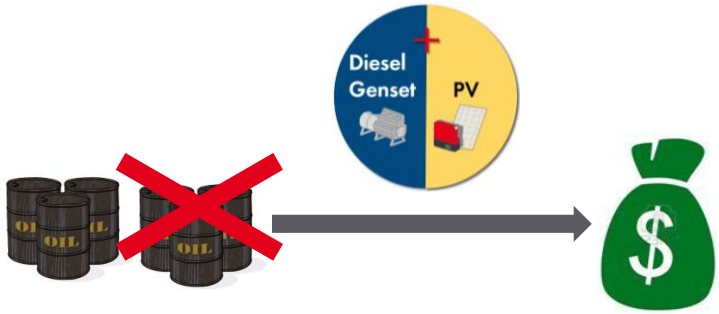
tegration of the FSC[1] into the Hybrid pla



Optimized system solution …



… and highest fuel saving potential



- **Given this system design, PV penetration levels[5] up to 60% can be achieved while still securing overall system stability and smooth genset control.**

1. Fuel Save Controller 2. Optic fibre technology („Lichtwellenleiter") 3. E.g. minimum genset load, spinning reserve
4. Supervision of all values measured by the FSC 5. Ratio between nominal PV power and nominal

SMA has the global utility-grade experience

- **Strong global presence** and first mover strategy
- **Over 6 GW Sunny Central** capacity installed worldwide
- More than **800 large-scale projects** in over **30 countries in 2010** alone
- **Highly bankable** with a solid balance sheet

- Our business is global – wherever our customers plan projects, we support you with l l local expertise

SOLAR TECHNOLOGY