International Experience from Distributed Generation

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1st Virtual Technical Dialogue, Regional Technical Forum of Energy Planners

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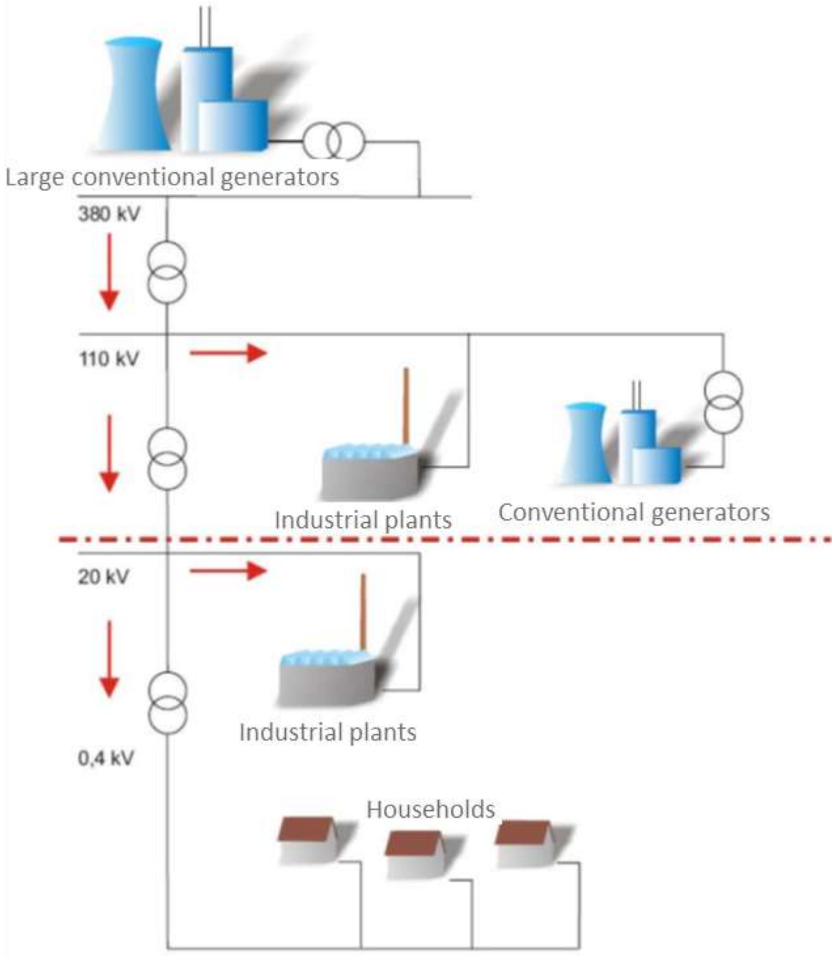
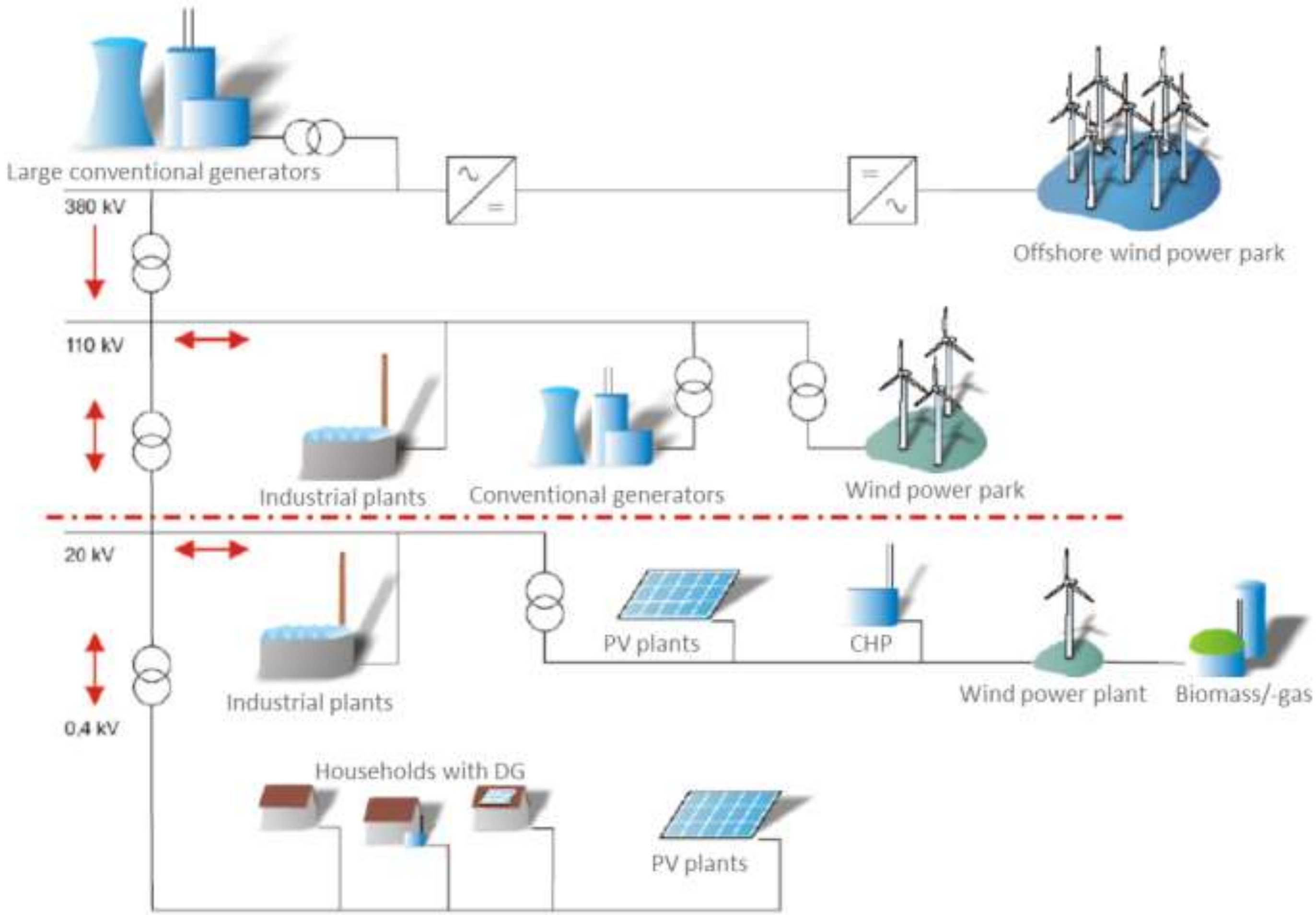
Transforming Energy Sectors Globally

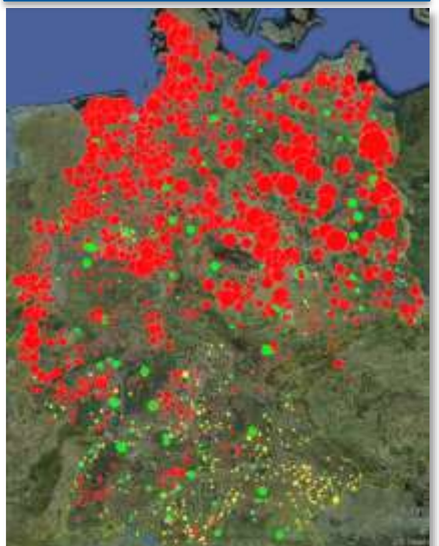
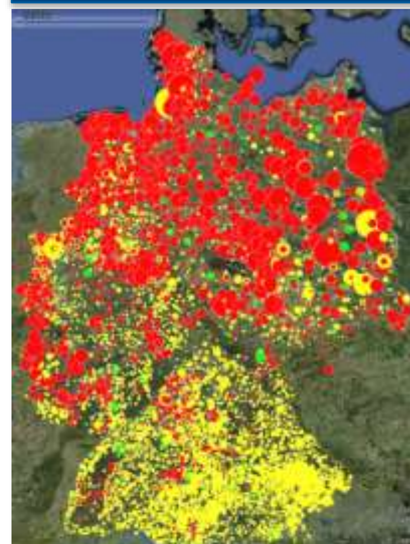
The Distribution System Changes from pure Consumption…



...to a Production System with Bi-directional Load Flow.



Development of Renewables in Germany

2000	2006	2016	**Today** (early 2020)
			**Wind: 64 GW** (incl. 7 GW Offshore) **PV: 52 GW** **Biomass: 8 GW** **Min. Demand: 32 GW**

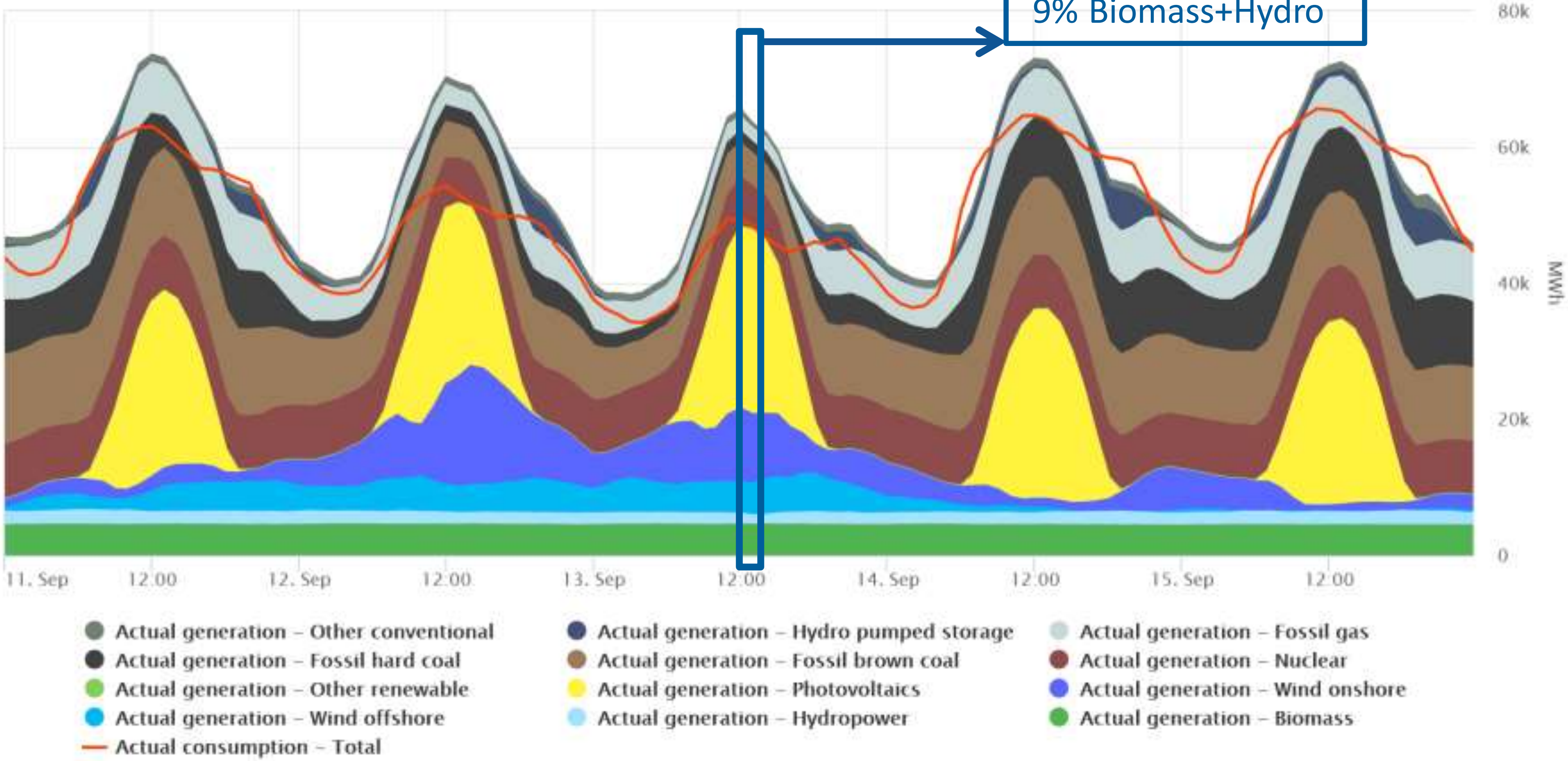
Wind   Solar   Biomass

SOURCE: 50Hertz, Amprion, TenneT, Transnet BW, Google Earth

Electricity Generation in Germany 11th to 15th Sept 2020

75% RES:

30% rooftop PV
13% utility PV
23% wind power
9% Biomass+Hydro



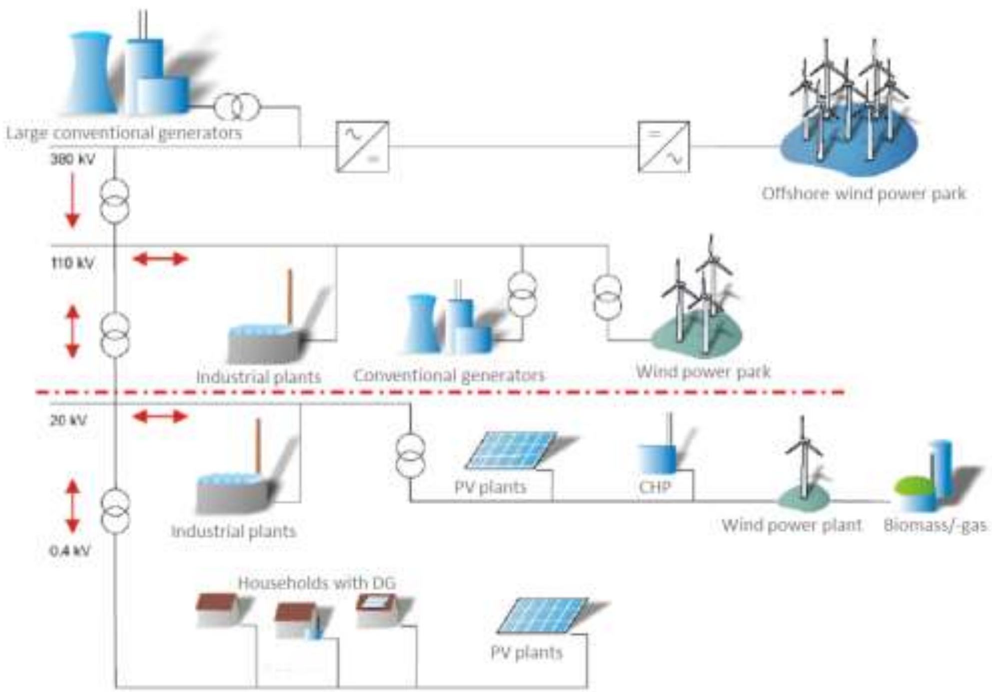
Source : Bundesnetzagentur, https://www.smard.de/en

What is Distributed Generation?

Different countries have different definitions for distributed generation

Broadly, it can be specified as:

➔ Generation that is connected to the distribution network



Transmission network with utility-scale VRE

Distribution network with distributed generation

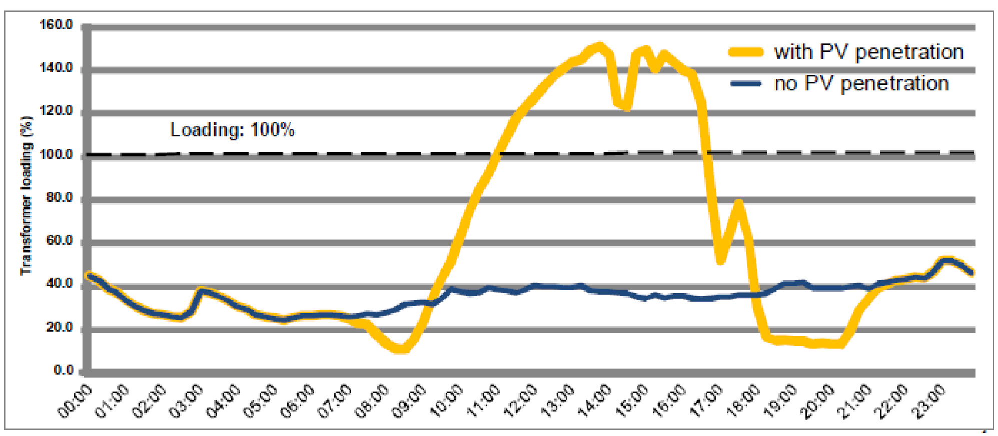
Impact on Distribution Systems

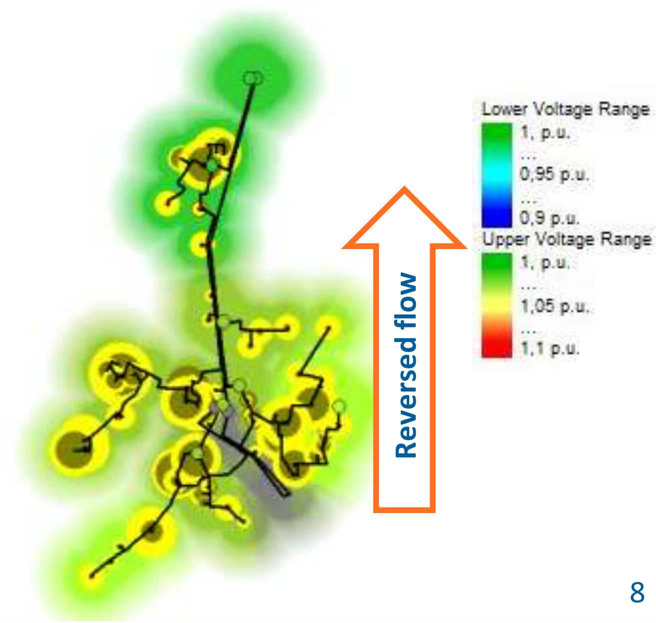
During high DG infeed and low demand, reverse power flow can lead to:

- **Overloading of distribution assets (transformers, lines)**
- **Overvoltages outside of regulated limits (90 – 110%)**
- **Protection issues**

➔ How much DG should be allowed?

➔ How can DG impact be mitigated?





DG Grid Codes

Germany: PV generation cap at 70% of installed PV panel capacity

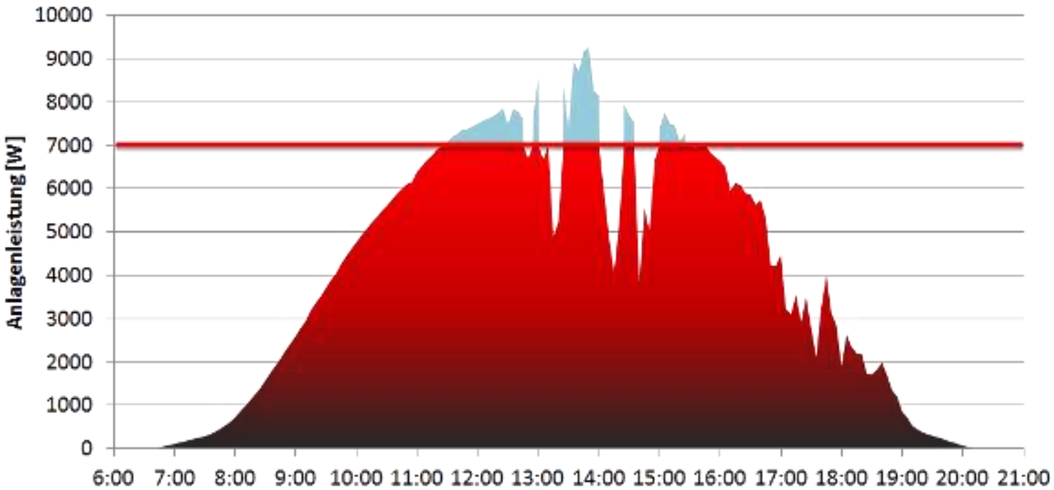
Background: PV plant only rarely reaches more than 70% of its PV panel capacity (sunshine availability, reduced efficiency from high temperatures and dust)

Aim: Limit PV inverter capacity to 70% of PV panel capacity, so that the peak of PV infeed is shaved off, i.e. maximum PV infeed is reduced to 70%

Drawback: 2-4% of annual PV energy production is lost

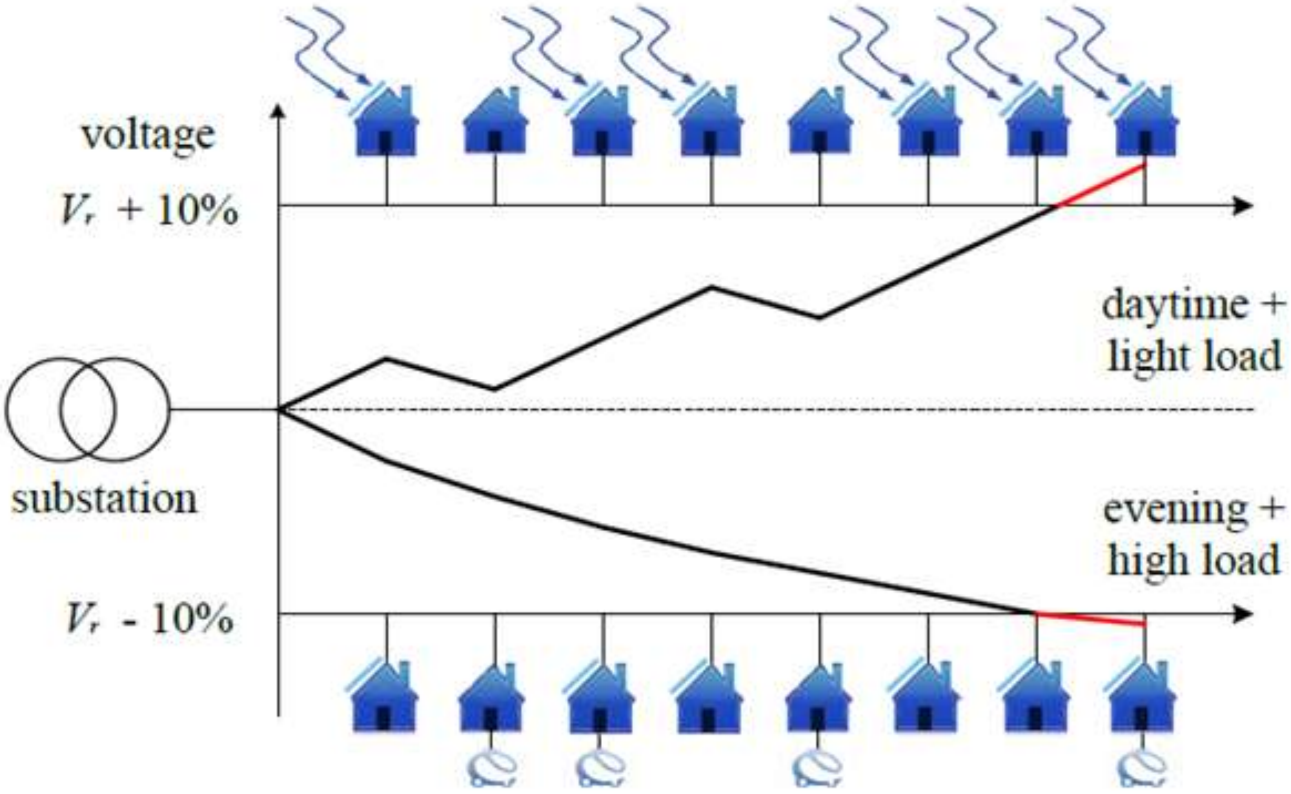
Advantage: Lower inverter size reduces cost, offsetting some of the drawback

➔ **German requirement for < 30 kW PV plants***



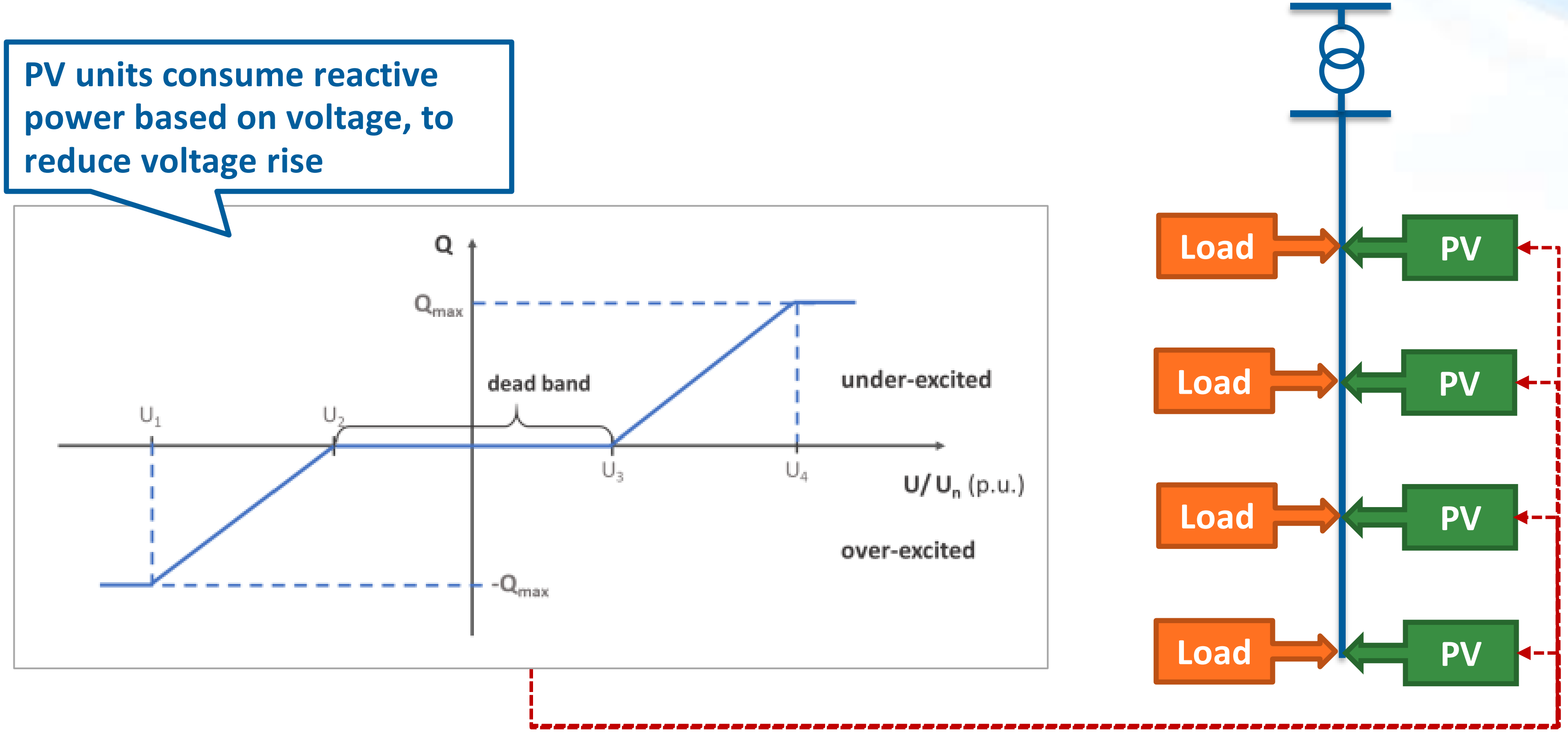
*not required if PV plant has communication link to distribution system operator

Results on Increasing PV Penetration



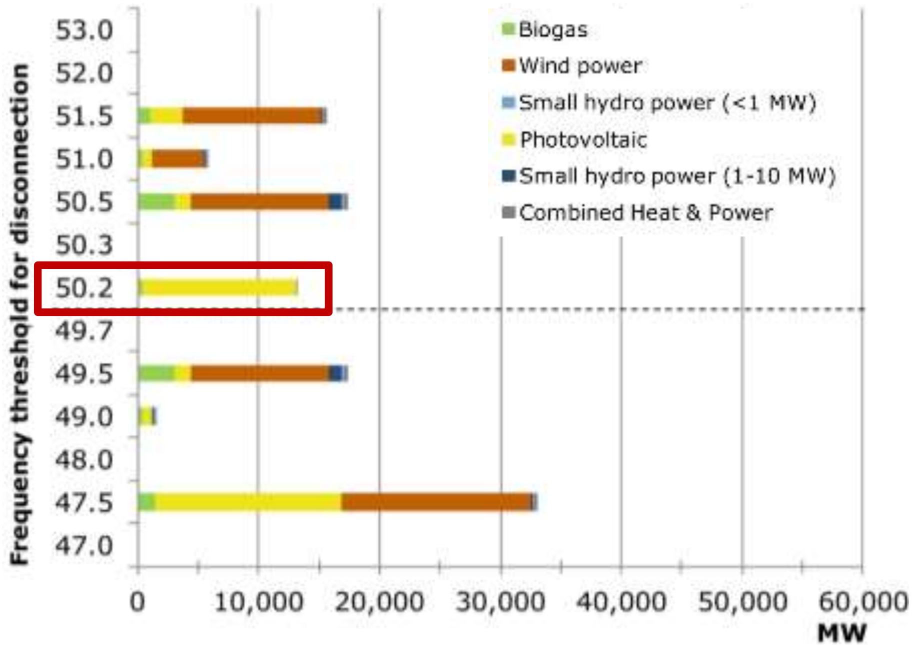
Reactive Power Support from Inverters

PV units consume reactive power based on voltage, to reduce voltage rise



Key Issues: Grid Code and Ancillary Services
Example: The 50.2 HZ Problem in Germany

Several thousand megawatts of installed renewable capacity disconnect at unfavorable frequency thresholds



as of end 2010

Grid Code development is an ongoing issue – Significant ongoing learning process around the world

The Challenge: Think about the possible requirements in 15-20 years!

SOURCE: Source: EEG-registry of TSOs (1997-2008) and Federal Netzwork Agency (2009-2010)

Grid Code Requirements on Inverter Capabilities

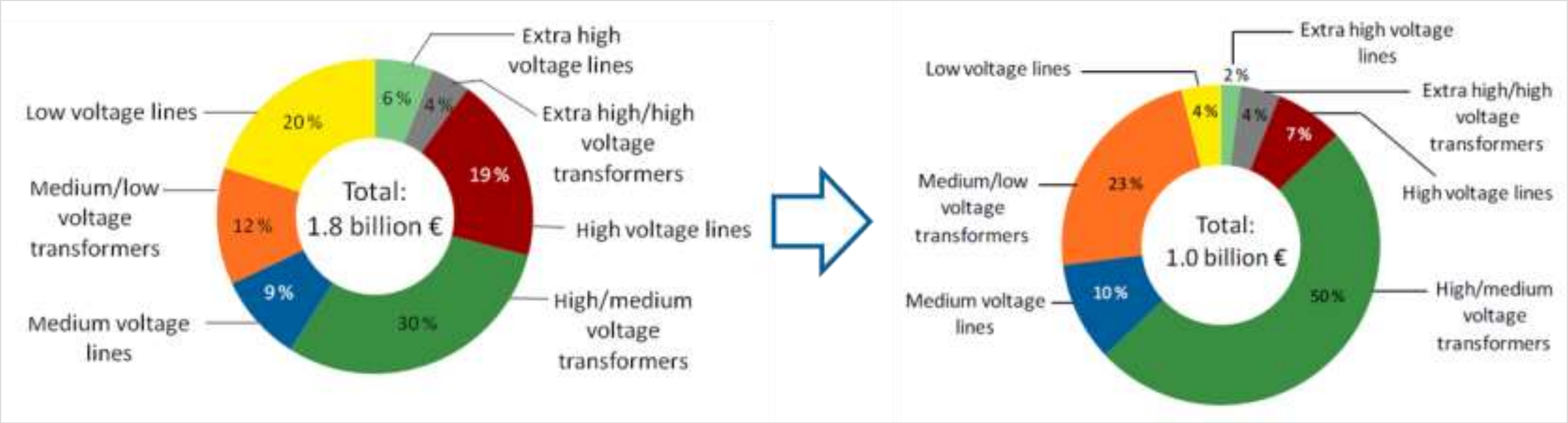
Inverter capability*	International recommendation
Low/high frequency ride-through	Highly recommended
Response to frequency deviations (frequency-watt mode)	Highly recommended
Low/high voltage ride-through	Highly recommended
Reactive power capability	Highly recommended
Reactive power control modes (constant power factor, volt-var, watt-var)	Highly recommended
Active power control modes (volt-watt)	Optional
Ramp rate limitations	Optional
Communication capability	Recommended above defined DG size

* See e.g. IEEE 1547-2018 for US specification of inverter capabilities
More information: IRENA, The role of grid codes, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Grid_Codes_2016.pdf

Assessment of Distribution Impact and Hosting Capacity

Aim of distribution system studies (1)

Calculate the impact of DG on distribution network expansion



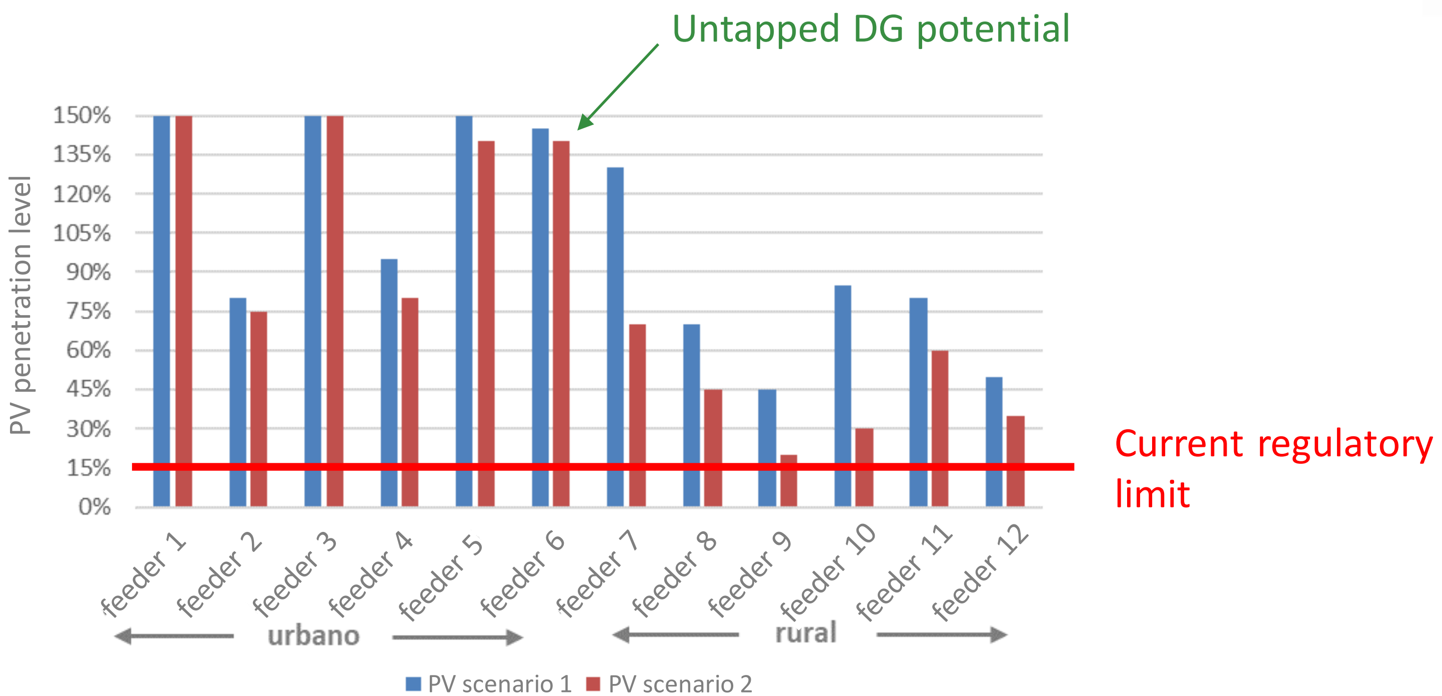
Example: Calculation of network expansion cost for 100% RE in the German state Rhineland-Palatinate

➔ Reduction by almost 50% through smart technologies (optimized voltage control, reactive power control of inverters, storage, demand side management, …)

Source: Distribution System Study Rhineland-Palatinate
http://energynautics.com/content/uploads/2016/10/distribution_system_study_RLP_summary_eng.pdf

Aim of Distribution System Studies (2)

Show regulatory limitations and possible improvements to regulatory design to maximize DG utilization (hosting capacity)



Source: Energynautics, Permissible PV penetration level in the Dominican distribution grids

Aim of Distribution System Studies (3)

Show effectiveness and cost of technical solutions

Effectiveness of solutions	Technical solution	CZ	DE	ES	IT
HIGH EFFECTIVNESS	Curtailment of power feed-in at PCC	Red	Red/yellow hatched	Red	Red
	Network Reinforcement	Green	Green	Green	Green
	Reactive power control by PV inverter Q(U) Q(P)	Red	Green	Red	Green
	Active power control by PV inverter P(U)	Red	Red	Red	Red
	Prosumer storage	Red	Green	Red	Green
	On Load Tap Changer for MV/LV transformer	Green	Green	Green	Green
NORMAL EFFECTIVENESS	SCADA + direct load control	Red	Red	Red	Red
	Network Reconfiguration	Green	Green	Green	Green
	Self-consumption by tariff incentives	Green	Green	Red	Red
	Wide area voltage control	Yellow	Yellow	Green	Yellow
	Static VAr Control	Green	Green	Green	Green
	Booster Transformer	Green	Green	Green	Green
	SCADA + PV inverter control (Q and P)	Yellow	Red	Yellow	Yellow
	DSO storage	Red	Red	Red	Red
LOW EFFECTIVENESS	Demand response by local price signals	Red	Red	Red	Red
	Advanced voltage control for HV/MV transformer	Green	Green	Green	Green
	Demand response by market price signals	Yellow	Yellow	Yellow	Red
	Advanced Closed-Loop Operations	Grey	Green	Yellow	Grey

Red: Adoption of solution requires regulatory development
Yellow: Adoption of solution requires regulatory and technology development
Green: Solution can be applied where problems occur
Grey: Technology for the solution is not mature

Results from the project PVGRID

www.pvgrid.eu

Simulation Capabilities of Distribution System Operators

Distribution system operators should know how to assess DG impact accurately and efficiently as well as technological solutions to increase DG capacity

Requires:

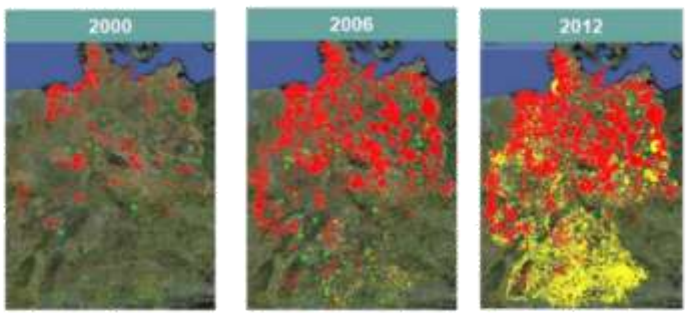
- **Accurate data, linked to geographic information systems**
- **Advanced inverter capability requirements**
- **Simulation capabilities**

! This will not only be important for DG but also for electric vehicles! !

DG Data Collection

DATA COLLECTION

Data Collection Relevance

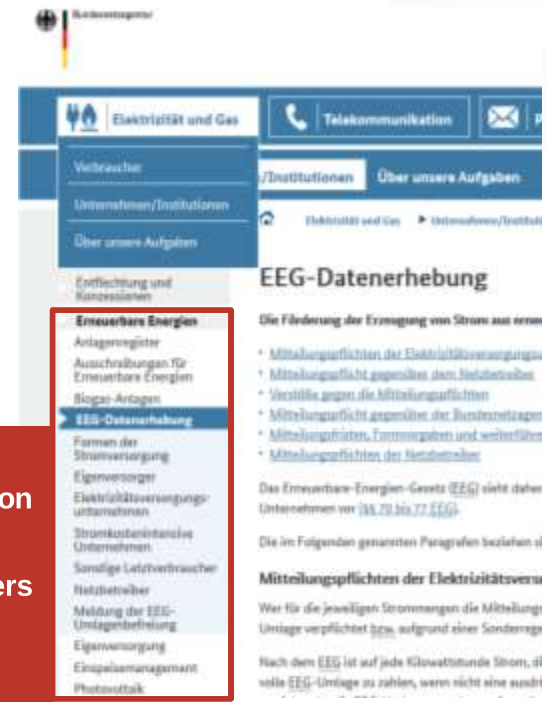


- Wind
- Photovoltaic
- Biomass

Source: 50Hertz, Amprion, Tennet, Transnet BW, Google Earth

As of 19th February 2014:
- Wind = 33 GW
- PV = 37 GW
- Biomass = 8 GW

Example: German regulatory agency keeps track of all generators and publishes lists



- **Generators**
- **Self consumption**
- **DSOs**
- **Large consumers**
- **Curtailment**
- **….**

Number of generation sites increases from a few large power stations to hundreds, thousands or even millions of distributed sites.

It is necessary to keep track of installed capacities to know the behavior that can be expected from the power system, both at transmission and distribution level!

Data Collection Utilization

Solar forecasting systems:

- Detailed location and size of the PV system
- Quality of the forecasting system will significantly improve with more details

Update of grid codes:

- Which inverter follows which technical rule
- Which inverter need to be upgraded to guarantee a secure power operation

Future grid studies:

- Detailed location and size of the PV system
- Relevant technical capabilities of the inverter
- Grid code rules and protection settings

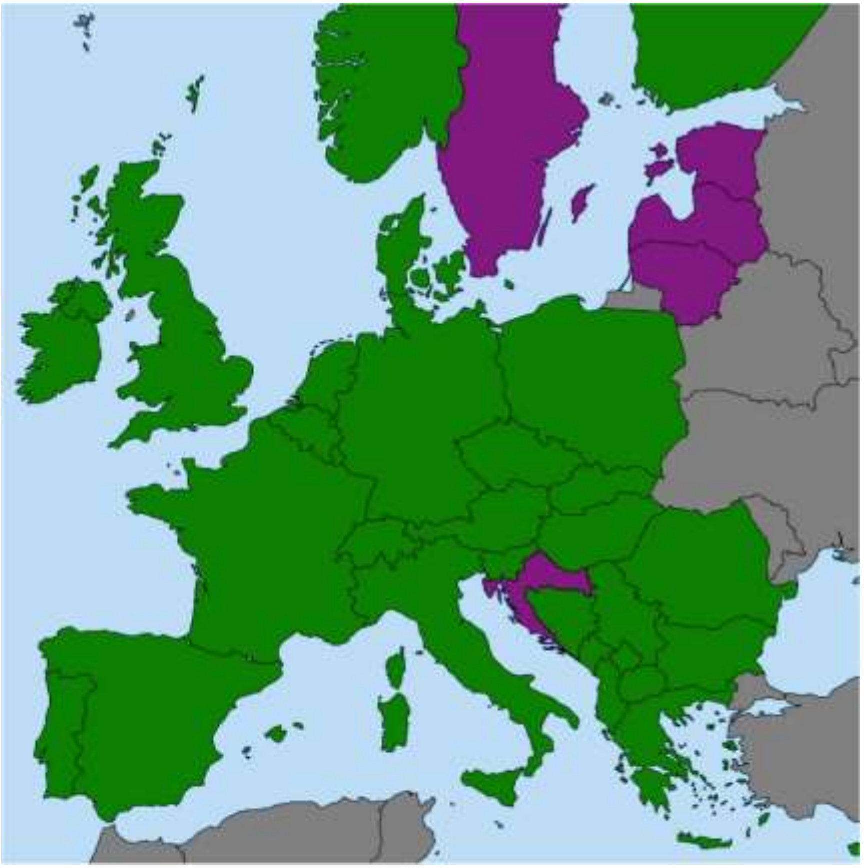
System maintenance:

- Detailed location and size of the PV system for
  - System planning
  - Security aspects

! **It will be extremely time consuming to collect missing data after the systems have already been installed** !

Regulatory Design

Shallow vs. Deep Connection Charges



Deep connection charges　Shallow connection charges

Deep connection charges

Charge the responsible party for every cost incurred through the grid connection, including grid reinforcement

Shallow connection charges

Charge the responsible party for every cost up to the connection to the existing grid

Reinforcement costs must be borne by the system operator

Both have been applied in Europe

Shallow connection charges have emerged as the most practical system

Connection Application Procedure

The procedure for connecting a new consumer or a new generator to the power system always follows this general pattern:

Rough Planning

Submission of Application

Application Evaluation and Approval

Detailed Planning and Construction

Conformance verification

Permission to connect

Operation

Recommendations:

- Require strict deadlines to not increase backlog of applications and enforce efficiency at the utility
- Require clear data requirements to allow connection

What is Net Metering/Feed in Tariff?

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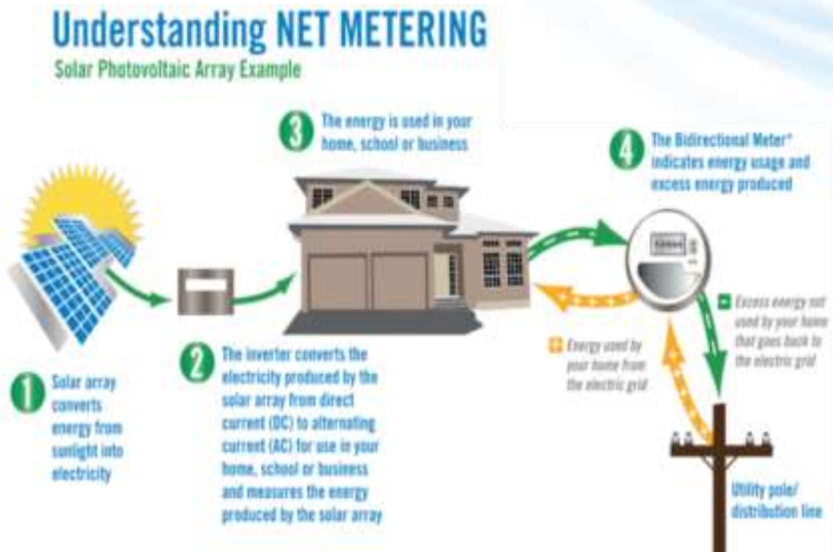
Net Metering is a billing mechanism that credits solar energy system owners for the electricity they send to the grid

- 1 meter spins both directions
- No cash transfer
- @ retail rate (usually)

A ***Feed in Tariff*** are payments to ordinary energy users for the renewable electricity they generate.

- 2 meters
- Cash transfer
- Fixed rate for fixed time period



Source: FPL.com

Regulator Issues with Net Metering: Size/capacity of allowed net metering Over what period can you „store“ electricity in the network, any payment for not used power „stored“, value of “stored“ power?

The Issue of Net Metering

Net metering is a form of subsidy!

- Retail power prices are much higher than wholesale prices as they include grid charges etc.
- Net metered generation (usually rooftop PV) basically get the local power price as the feed-in tariff
- Scheme is easy to implement, but feed-in tariff degressions with lowering LCOE are not possible
- Problem: PV becomes profitable for customers with the highest tariffs first, lowering utility/retailer income

Net-metering recommendations

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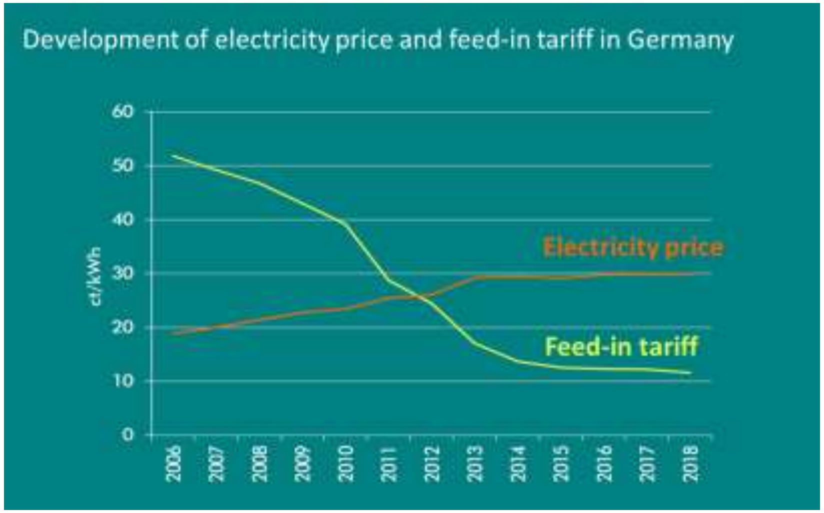
Use feed-in tariffs (decouples feed-in price from consumption price)



Adapt net-metering design, e.g. by:

- **Requiring bidirectional metering** (allowing to measure consumption and generation independently)
- **Allocating certain charges to total, not net, consumption** (US: “nonbypassable charges”)
- **Time-of-use (TOU) rates** (incentivizing shifting generation to peak demand, e.g. with storage)
- **Grandfathering** (ensure policy certainty for customers)

NET METERING VERSUS CONSUMER TARIFFS

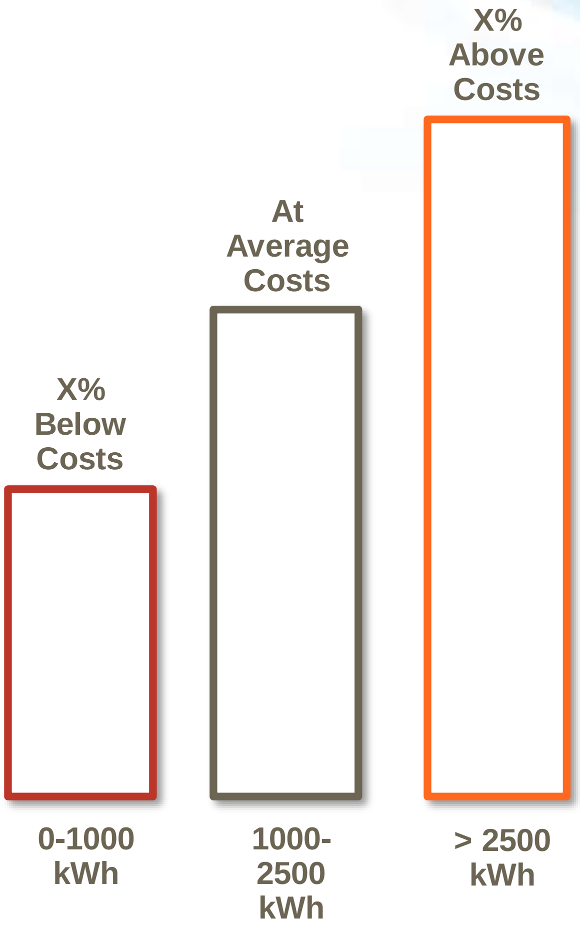
Structure prevalent in developing countries:
Tariffs increase with consumption

Basic Idea:

- Large (wealthy, commercial) consumers subsidize small (poor, residential) consumers;

Issues with the introduction of net-metering:

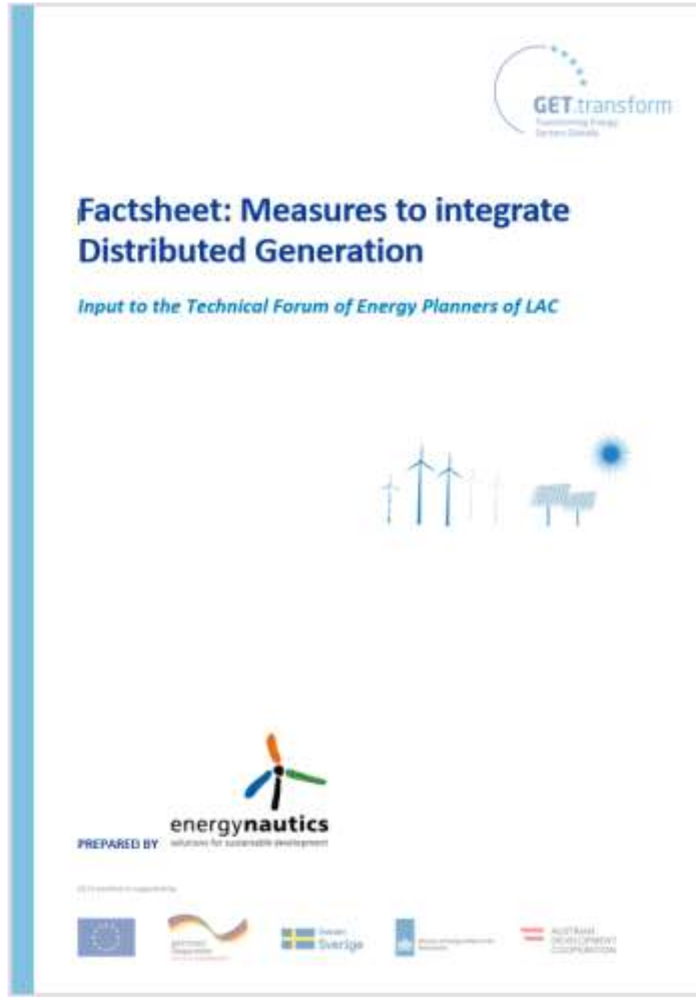
- Large (wealthy) consumers invest into rooftop PV systems; this way they reduce their consumption
  and drop to a lower tariff;
- Less consumers are available to subsidize small consumers
- Utility cannot recover its costs anymore!
- Utilities are fully or partly government owned, so they will not complain directly about the introduction of renewables, but:
- Utilities start to mention „technical issues"…
  „grid limits" …. „grid instability due to renewables"



Summary: What do we need to maximize the use of DG in distribution systems?

DG requires…

- **… assessment capabilities of distribution system operators**
- **… good data collection**
- **… defined plant behaviour through DG grid code and certification**
- **… appropriate incentive schemes and regulatory design such as:**
  - improved net-metering or feed-in tariff
  - regulation that incentivizes peak shaving of PV generation
  - appropriate scheme to compensate utilities for distribution upgrade cost


Factsheet: Measures to integrate Distributed Generation

Input to the Technical Forum of Energy Planners of LAC

PREPARED BY energynautics

Upcoming Factsheet

Energynautics - Areas of Expertise

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SUSTAINABLE DEVELOPMENT FOR POWER AND ENERGY

- Renewable Energies
- Distribution Systems
- Electromobility
- Smart Grids
- Combustion Engine Power Plants
- Electricity Markets
- Grid Codes
- Island & Microgrids
- Transmission Systems