Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Grid Integration at the Distribution Level: Challenges and Trends

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Deep Dive Workshop, Asia Clean Energy Forum (ACEF)

5 June 2018, 09:00-17:30

Asian Development Bank Headquarters, Manila, Philippines

Lecturer: Dr.-Ing. Thomas Ackermann

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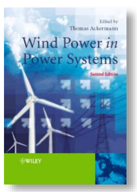
Founder and CEO of energynautics

Dipl.-Wi.-Ing. Economics and Mechanical Engineering, TU Berlin

Master of Science in Physics, Otago University (New Zealand)

Ph.D. from Royal Institute of Technology (KTH), Stockholm



Editor: “Wind Power in Power Systems”

Worked as a consultant in the renewable and power system industry for the past 25 years:

- Germany, Sweden, China, New Zealand, Australia, India, Denmark, Japan, Costa Rica, Guatemala, Honduras, Philippines, Seychelles, Barbados, USA, Indonesia, Mongolia and Vietnam

Lecturer at:

- Royal Institute of Technology (KTH), Stockholm (ongoing)
- Karlsruhe Hector School, Germany (ongoing)
- Technical University Darmstadt (2010-2012)
- Various Capacity Building Courses for GIZ, SINDA, World Bank

Denmark: 1980 to 2004

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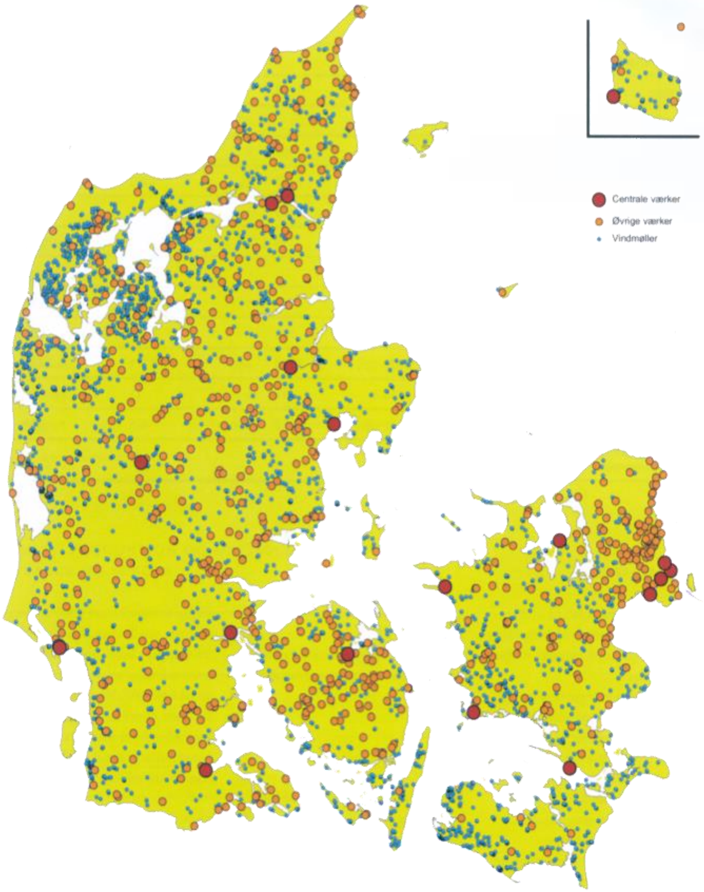
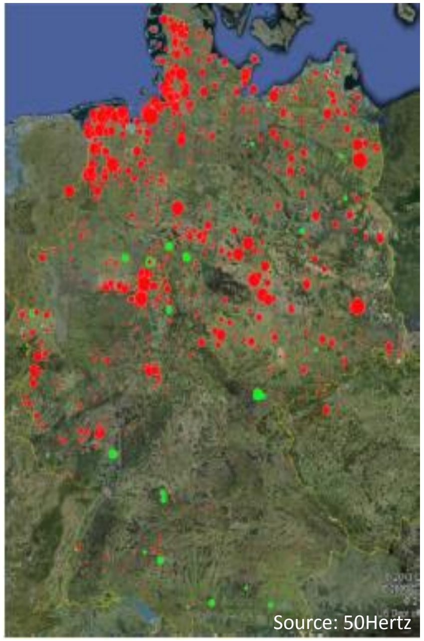
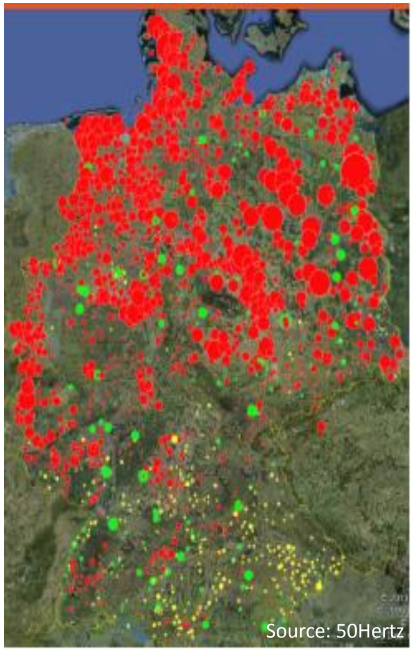
Primary generation

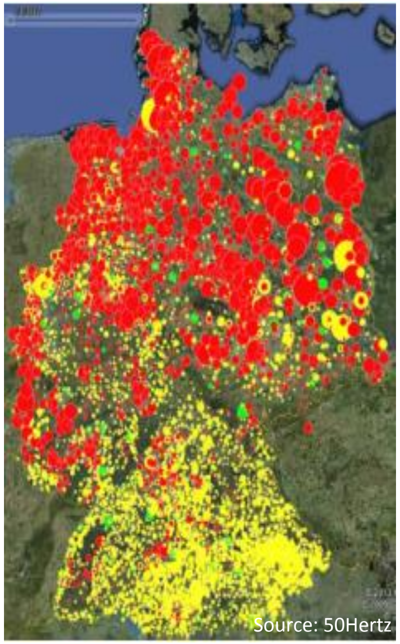
Local generation



Distributed Generation Example: Development in Germany







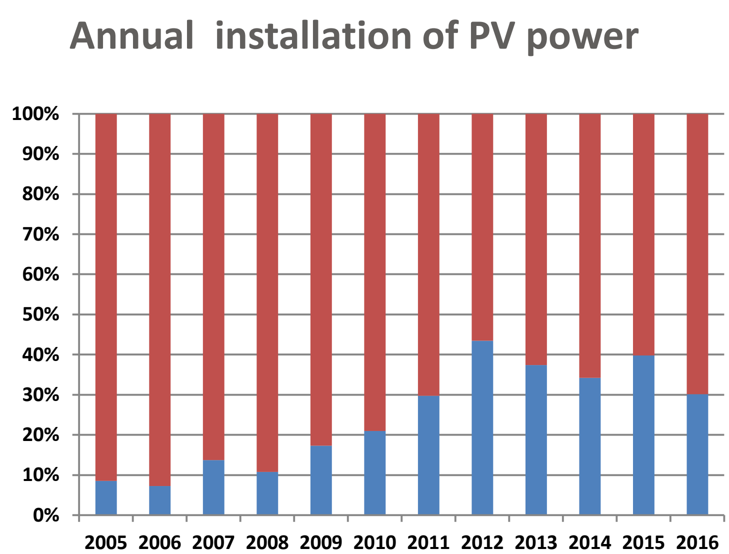
2000	2006	2014
around 30.000 plants	around 220.000 plants	around 1.500.000 plants

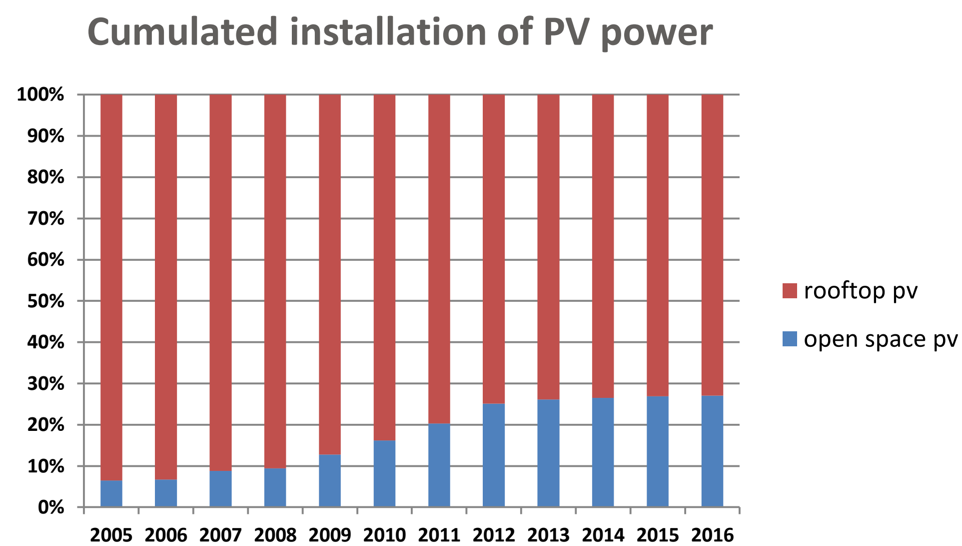
Wind · Photovoltaics · BIOMASS

Actual share of roof-top PV-plants < 100 kW in Germany

Total Installed PV: 43 GW, 1.6 Million PV Systems
Of which
30 GW is roof top PV (distributed generation)

Minimum demand in Germany: around 40 GW





Actual share of roof-top PV-plants < 100 kW in Germany

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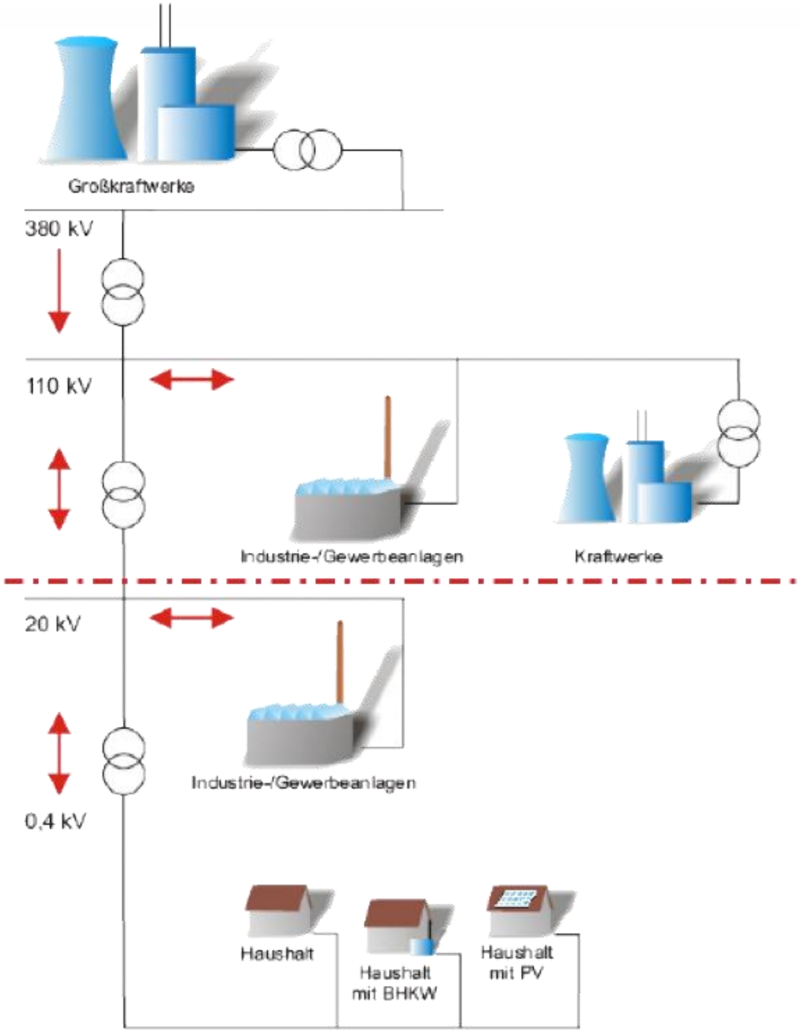
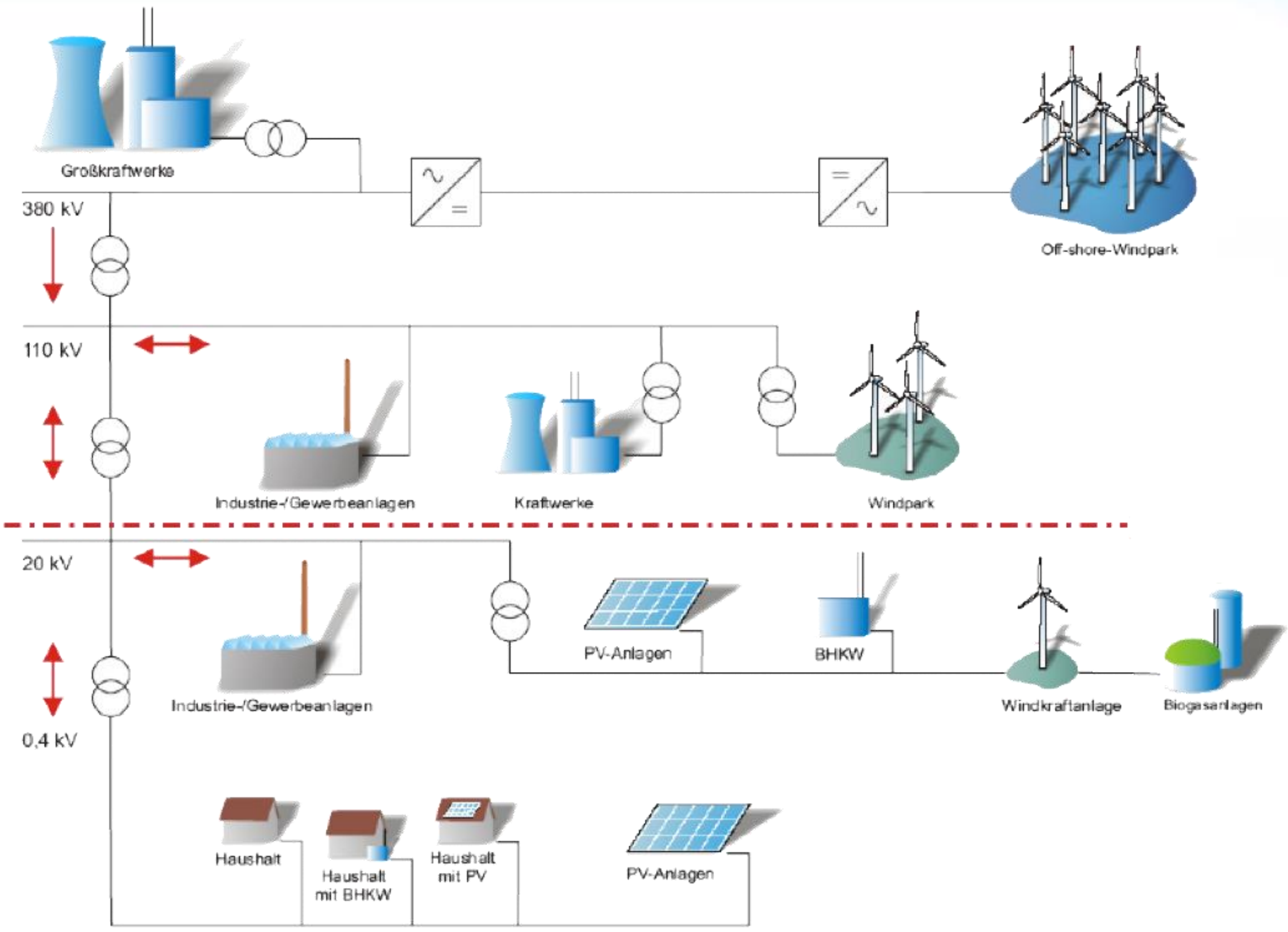
High Shares
– even larger >100% –
are now very common
in many distribution networks

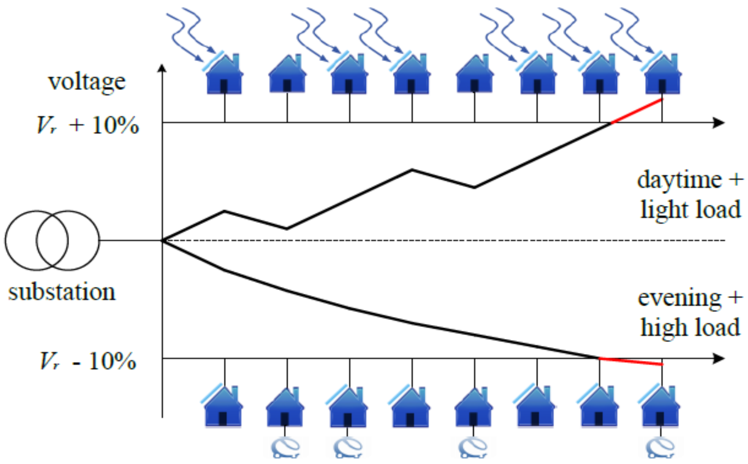
The Distribution System Changes from pure Consumption...



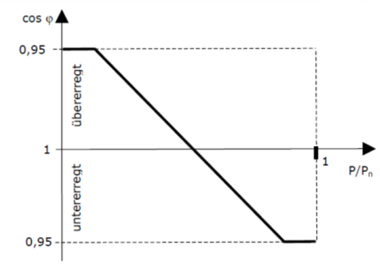
…to a Production System with Bi-directional Load Flow.

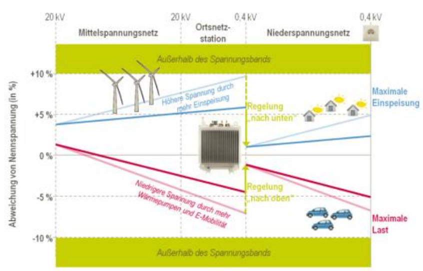


Volatage Deviations



Source: Uhlig, CIRED Workshop 2014





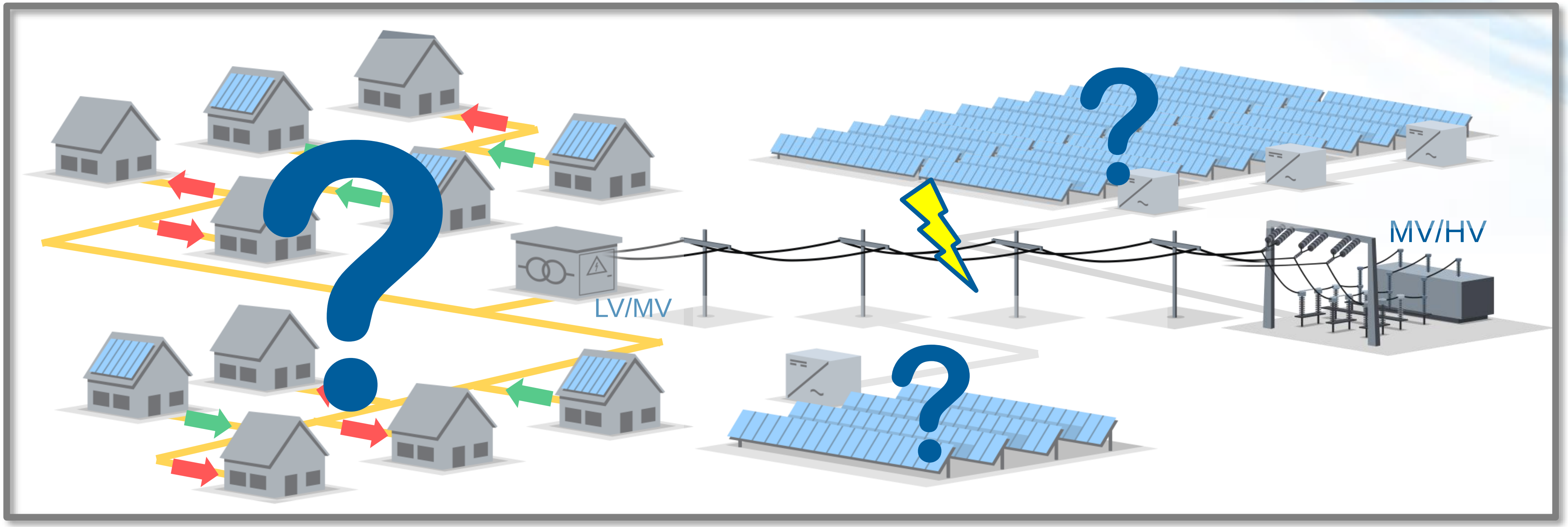
Source: Maschinenfabrik Reinhausen GmbH

Transformer from high voltage to medium voltage is usually the last instance of voltage control. Reversal of power flow at high VRE feed-in may lead to unacceptably high line voltage (which frequently happens in German rural LV grids with high PV share).

Solutions:

VRE generators with reactive power control, on-load tap changers in MV/LV transformers

Short Circuit Situation



→ How should the DER react during this time? Should the all have the same behaviour?

→ How will the short-circuit be cleared? How does the grid protection react?

* Source: K. Heuck, K.-D. Dettmann und D. Schulz, Elektrische Energieversorgung, Wiesbaden: Vieweg + Teubner Verlag, 2010.

The Typical Vision

The future power grid will be bidirectional and intelligent

Electricity and information flow in power grid

Source: IFEU

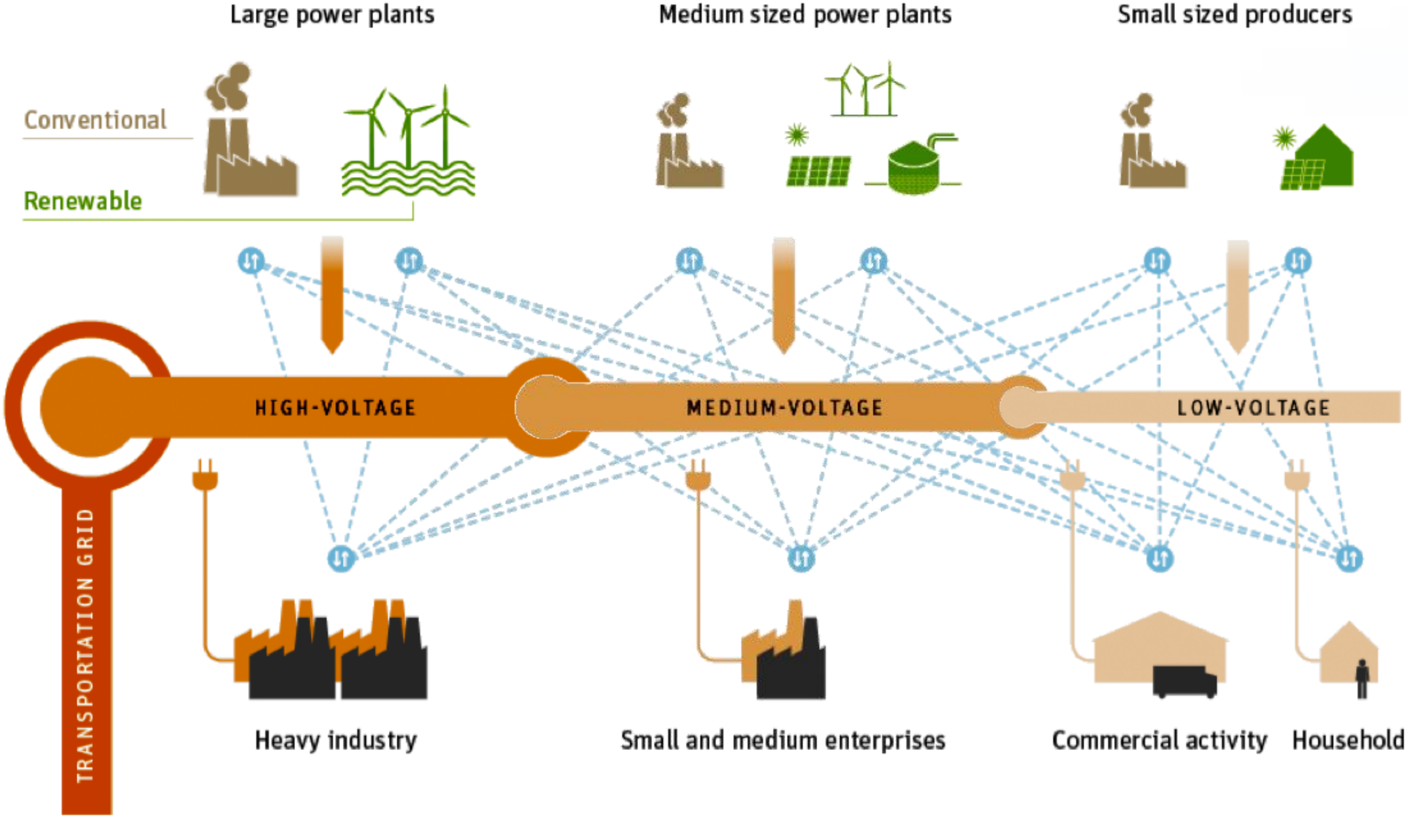
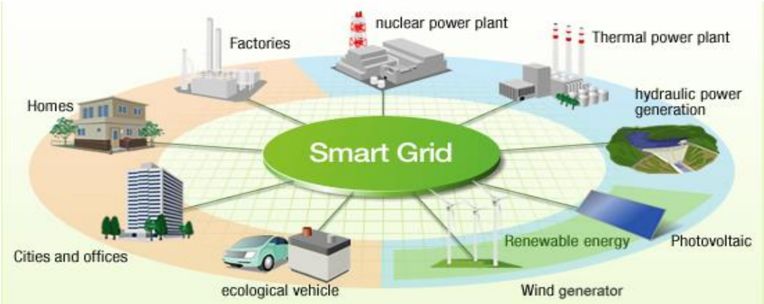


Figure: The Future Power Grid. Source: energytransition.de

Progress of RES in Germany Accomplished **without any Large Grid Problems**, and



NO Smart Grids / Micro-Grids

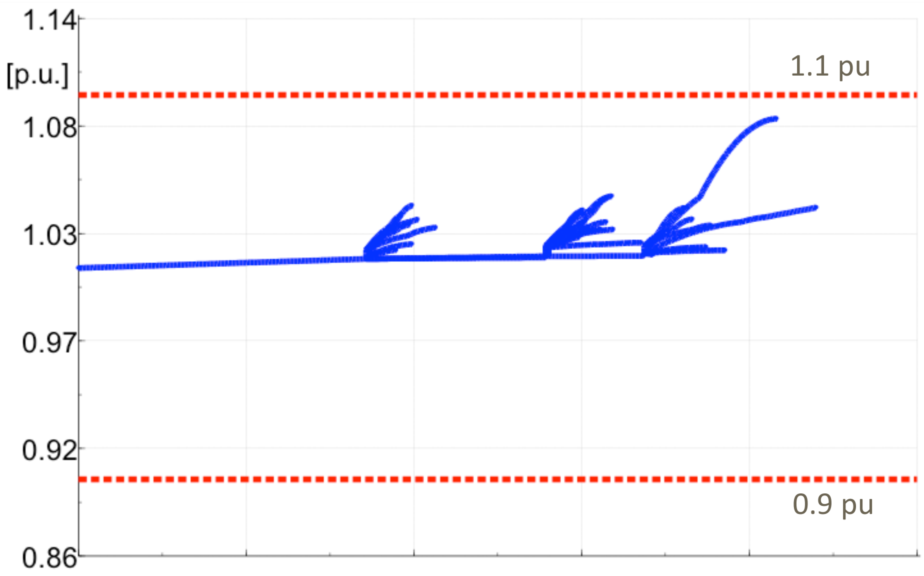
ALMOST NO NEW Energy Storage

But with a strong interconnected European Power System and significant grid upgrades in Germany/Europe

Sometimes an Investment in more Copper is also very „Smart“, particular in Countries with fast Demand Increase

Example from Case Study in India with 100% PV Penetration level

Voltage



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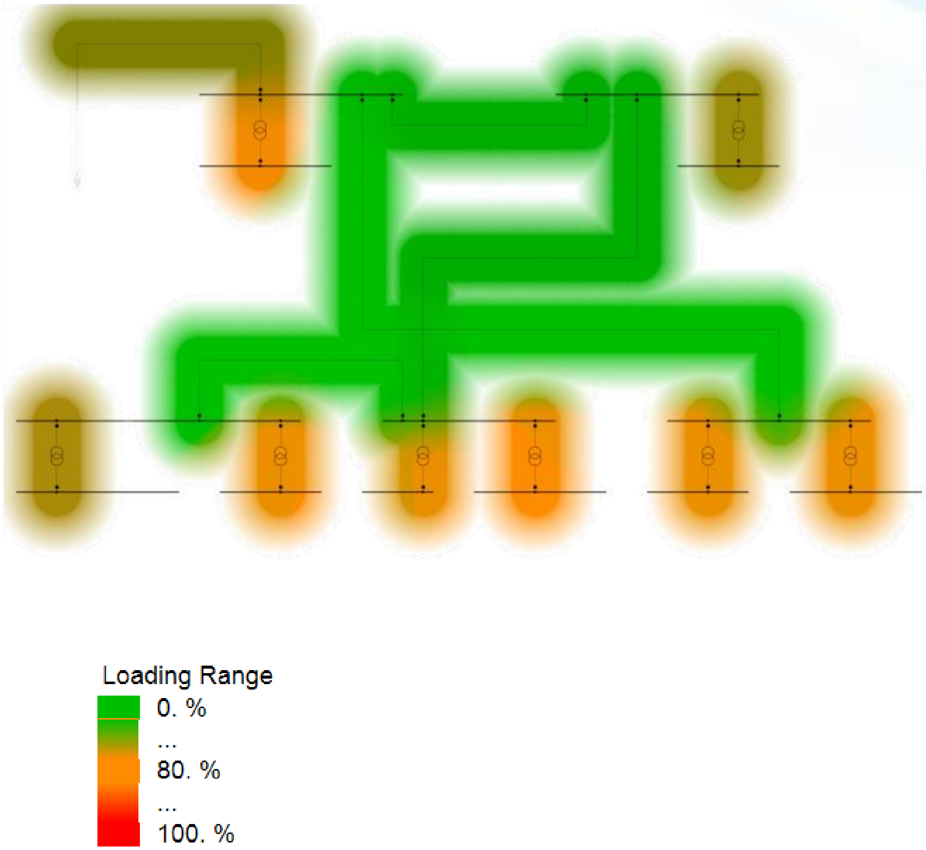
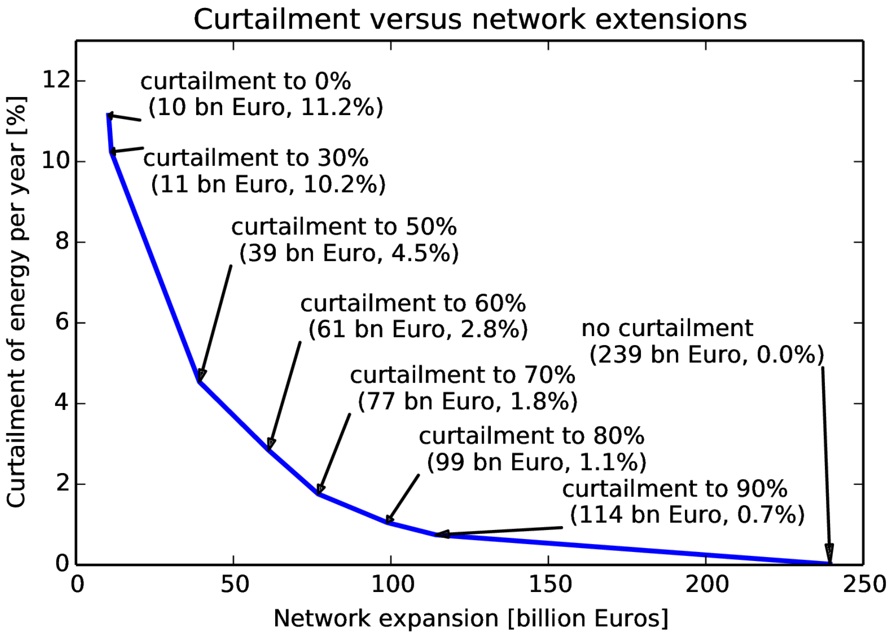
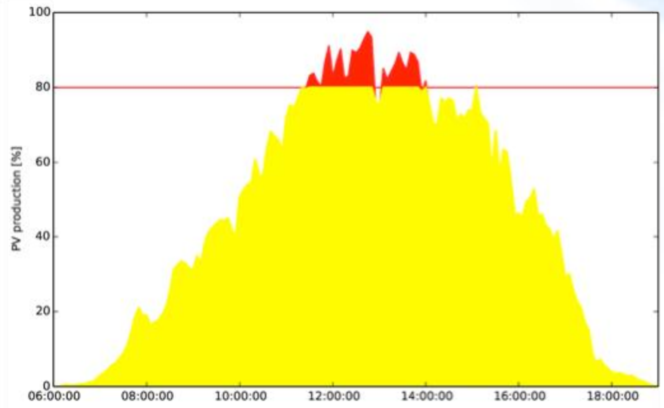


PV Penetration:
100 % of DTs

Very Smart: Curtailment (vs. Grid Expansion)





- Grid expansion can be avoided by curtailing a small part of the renewable energy in case of grid congestion
- Example Europe: Curtailment with 2.8 % energy loss reduces grid expansion cost to 25 %.
- Even a little curtailment goes a long way...

Lessons learned...

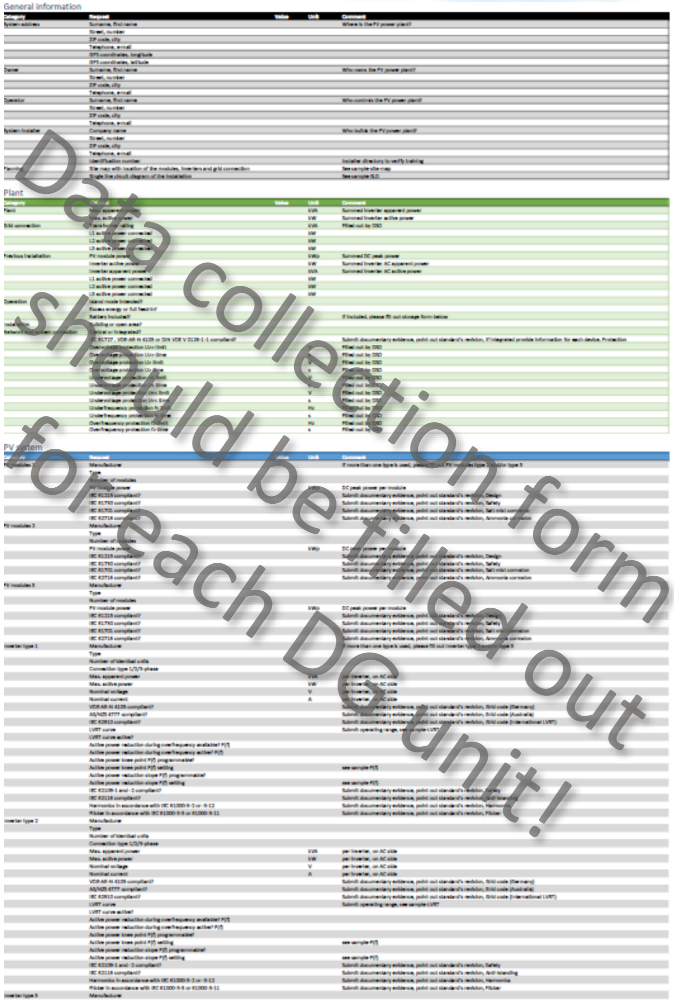
VRE Shares of 75-100% of the transformer rating can often be integrated without any major Smart Grid Innovation.

Lesson 1:
Learn by doing – and collect data about your system

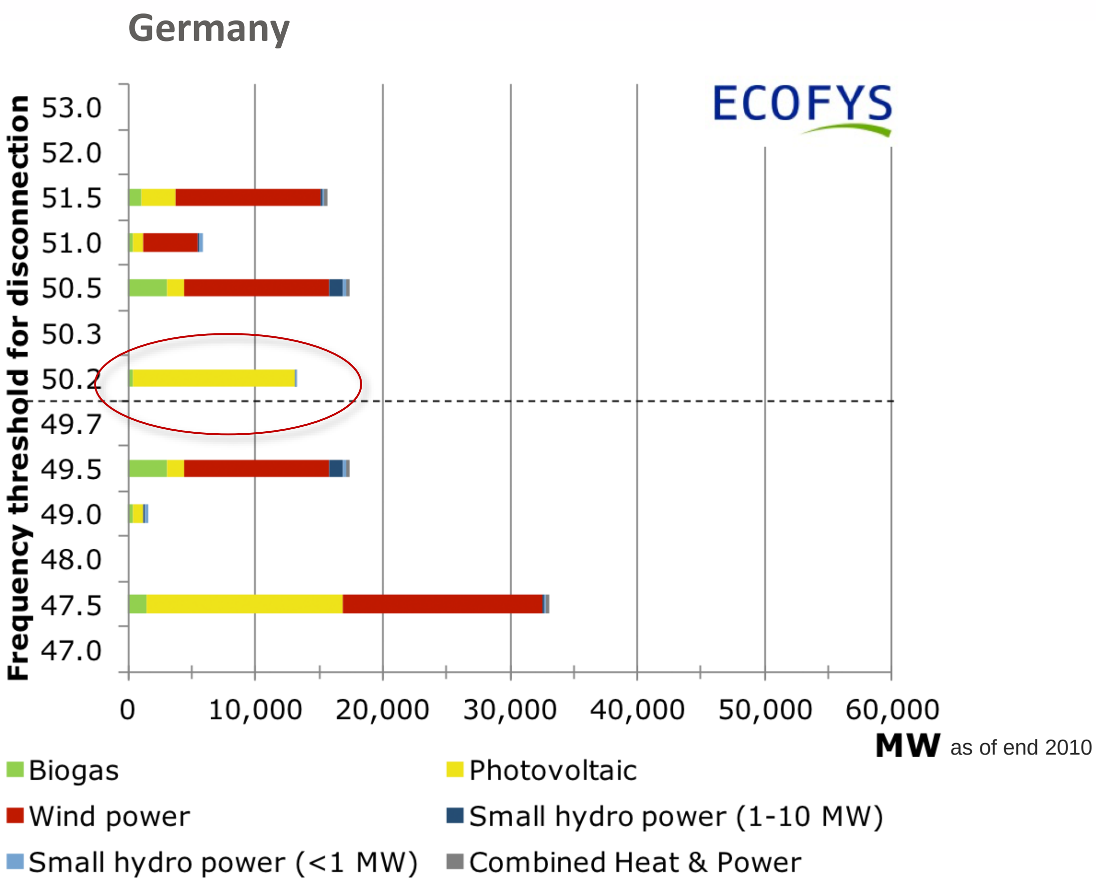
Lesson 2:
Start to pepare for increasing share of VRE,
learn with „Smart„ Grid Demonstration projects

Lesson 3:
Cooperation between DSOs and TSOs are very important, particular regarding grid codes!!!!

Draft application form for data collection



The 50.2 HZ Problem in Germany: Several thousand megawatts of installed renewable capacity disconnect at unfavorable frequency thresholds



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

Considered in the Philippines Grid Code

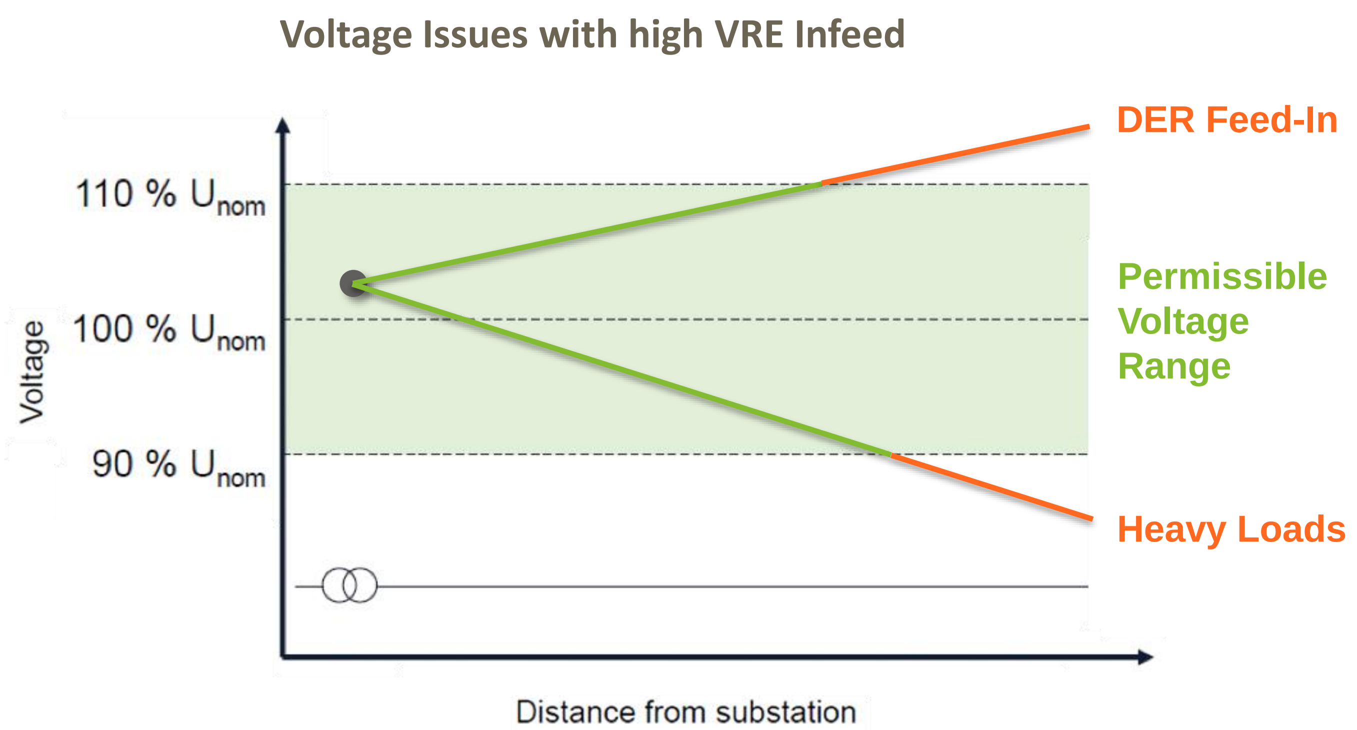
Reasons

- Underestimation of DG development
- Slow grid code updating
- Missing coordination between DSOs and TSOs

Examples of Smart Grid Solutions

Challenges at Distribution Level

Voltage Issues with high VRE Infeed



Priority List of Technical Solutions for LV Grid

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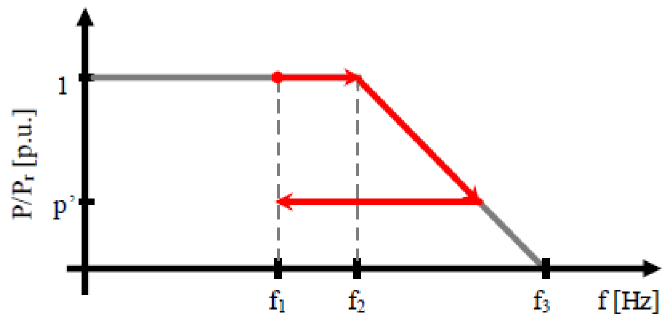
Effectiveness of solutions	Technical solution	CZ	DE	ES	IT
HIGH EFFECTIVNESS	Curtailment of power feed-in at PCC				
	Network Reinforcement				
	Reactive power control by PV inverter Q(U) Q(P)				
	Active power control by PV inverter P(U)				
	Prosumer storage				
	On Load Tap Changer for MV/LV transformer				
HIGH EFFECTIVNESS	Network Reinforcement				
	Reactive power control by PV inverter Q(U) Q(P)				
	Active power control by PV inverter P(U)				
	Prosumer storage				
	On Load Tap Changer for MV/LV transformer				
	SCADA + direct load control				
	Network Reconfiguration				
	Self-consumption by tariff incentives				
HIGH EFFECTIVNESS	Network Reinforcement				
	Reactive power control by PV inverter Q(U) Q(P)				
	Active power control by PV inverter P(U)				
	Prosumer storage				
	On Load Tap Changer for MV/LV transformer				
	SCADA + direct load control				
	Network Reconfiguration				

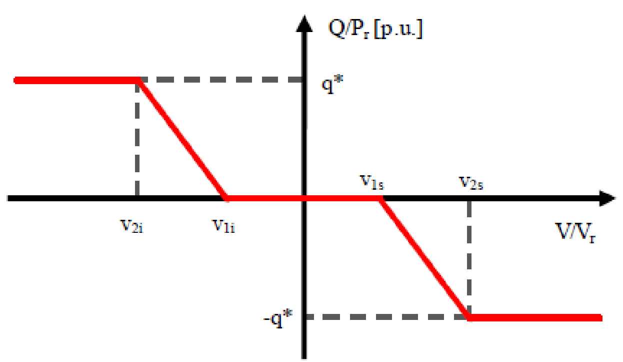
	Curtailment of power feed-in at PCC
HIGH EFFECTIVNESS	Network Reinforcement
	Reactive power control by PV inverter Q(U) Q(
	Active power control by PV inverter P(U)
	Prosumer storage
	On Load Tap Changer for MV/LV transformer
	SCADA + direct load control
	Network Reconfiguration
	Self-consumption by tariff incentives
	Wide area voltage control

P&Q support of inverter based DGs

Overfrequency support



Voltage support

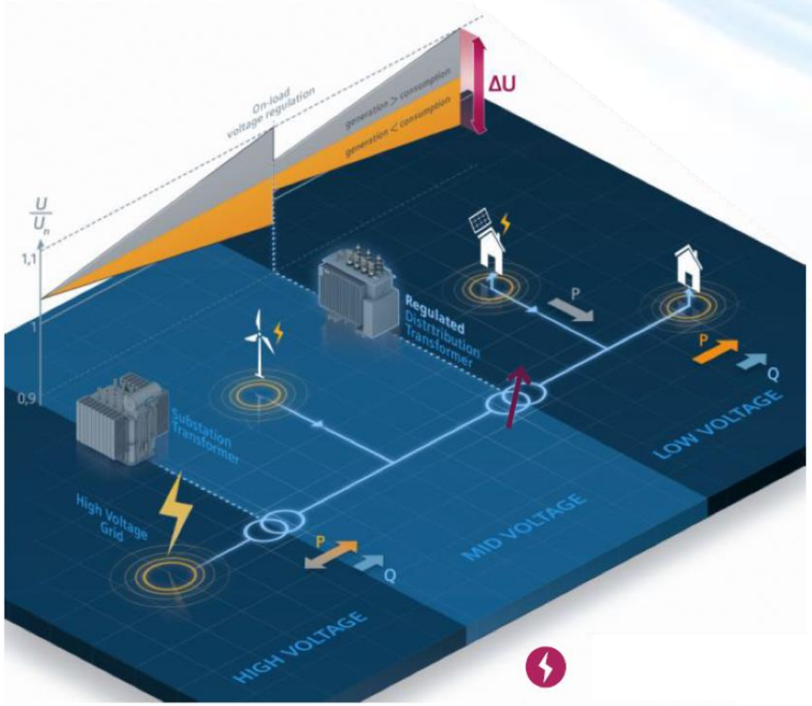


Courtesy to Must

Voltage Regulation on LV Secondary Transformer
(Automatic voltage regulators / On-load tap changers)

- Control the voltage on the LV side
- **<u>Increase</u>** voltage during high load situations
- **<u>Decrease</u>** voltage during situations with high PV generation

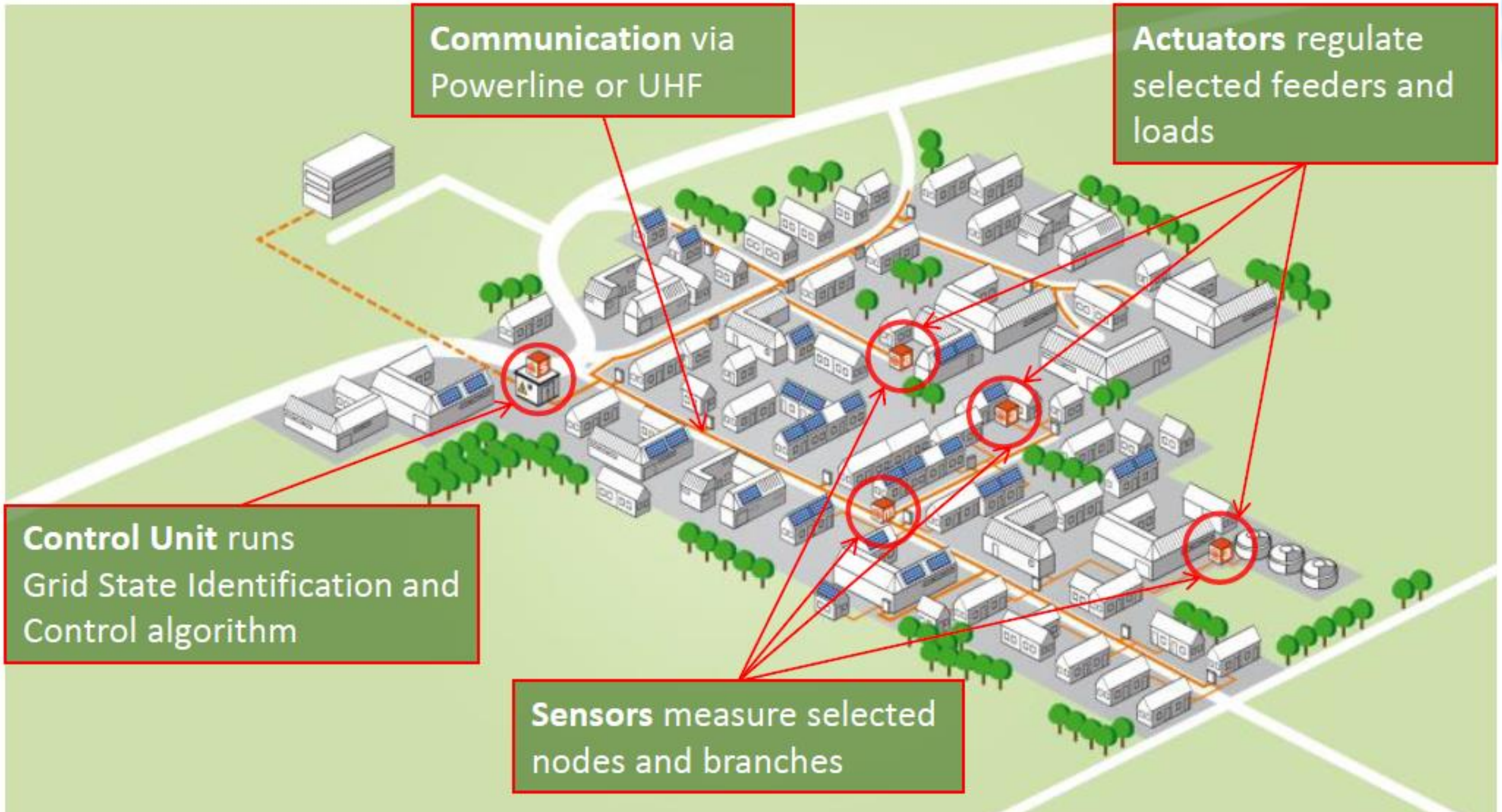
→ **Increases capability of distribution grid to integrate demand and distributed generation**



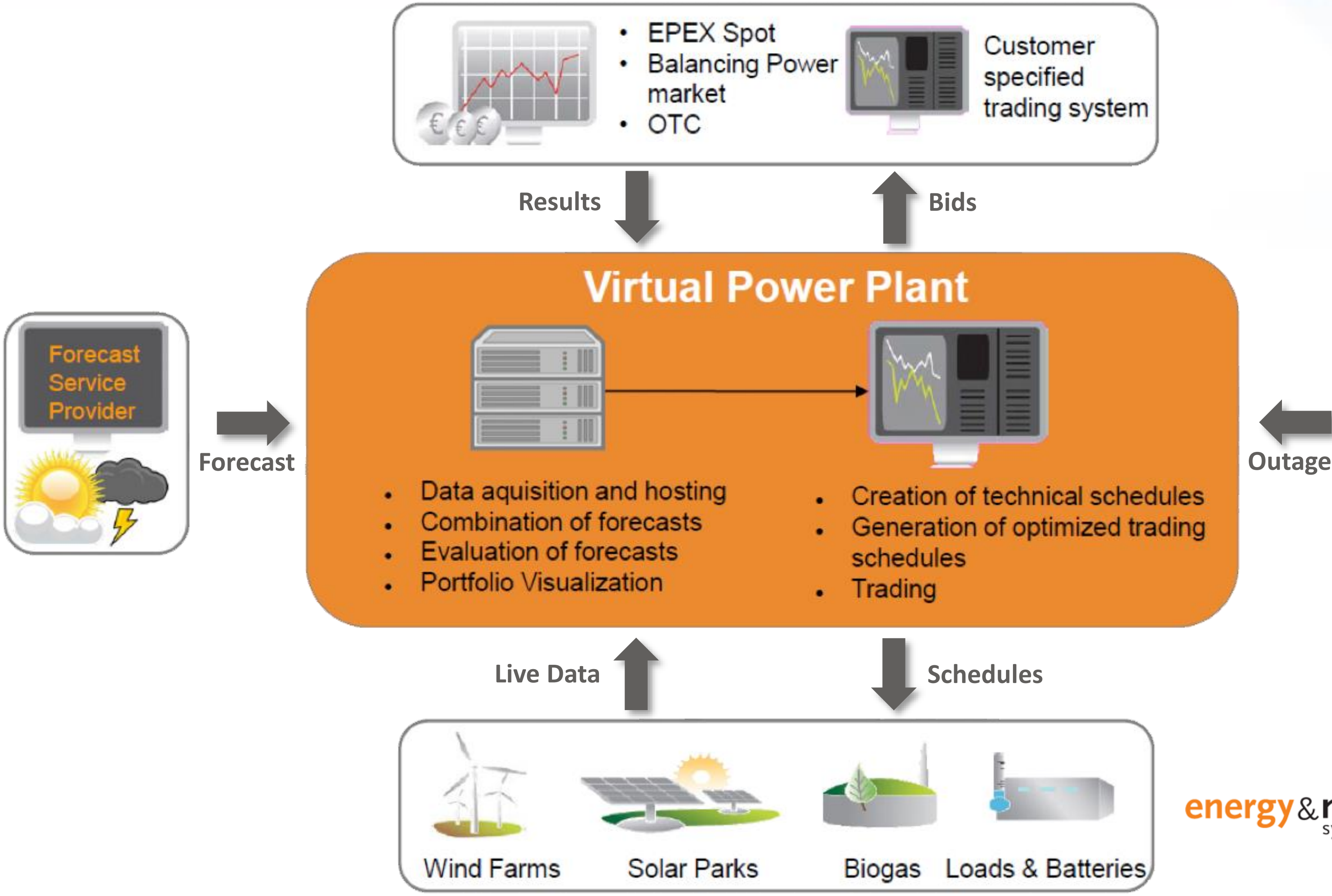
Courtesy to ABB

Voltage Regulation on LV Secondary Transformer

Innovative Energy/Distribution Network Management System Solution



Virtual Power Plant (i)



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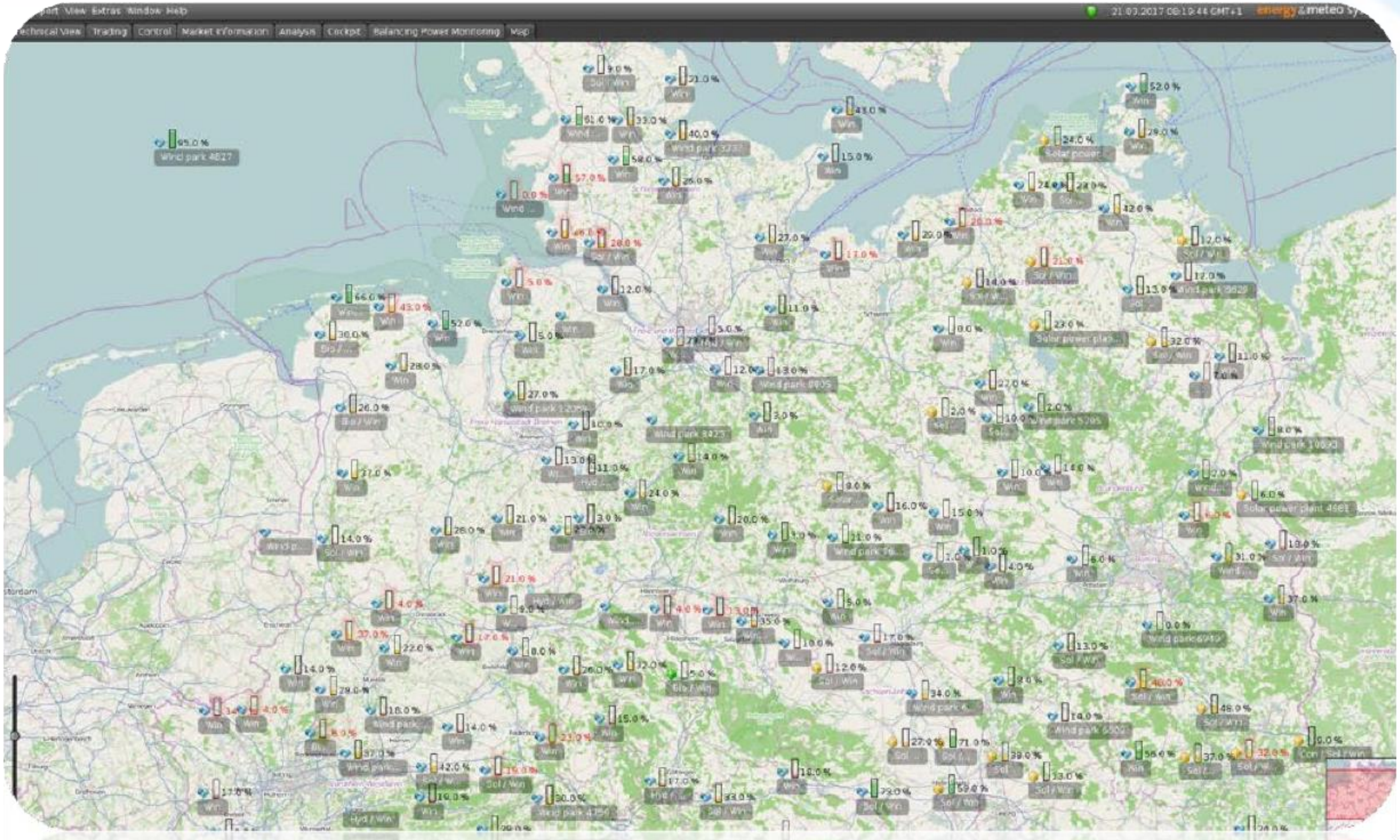
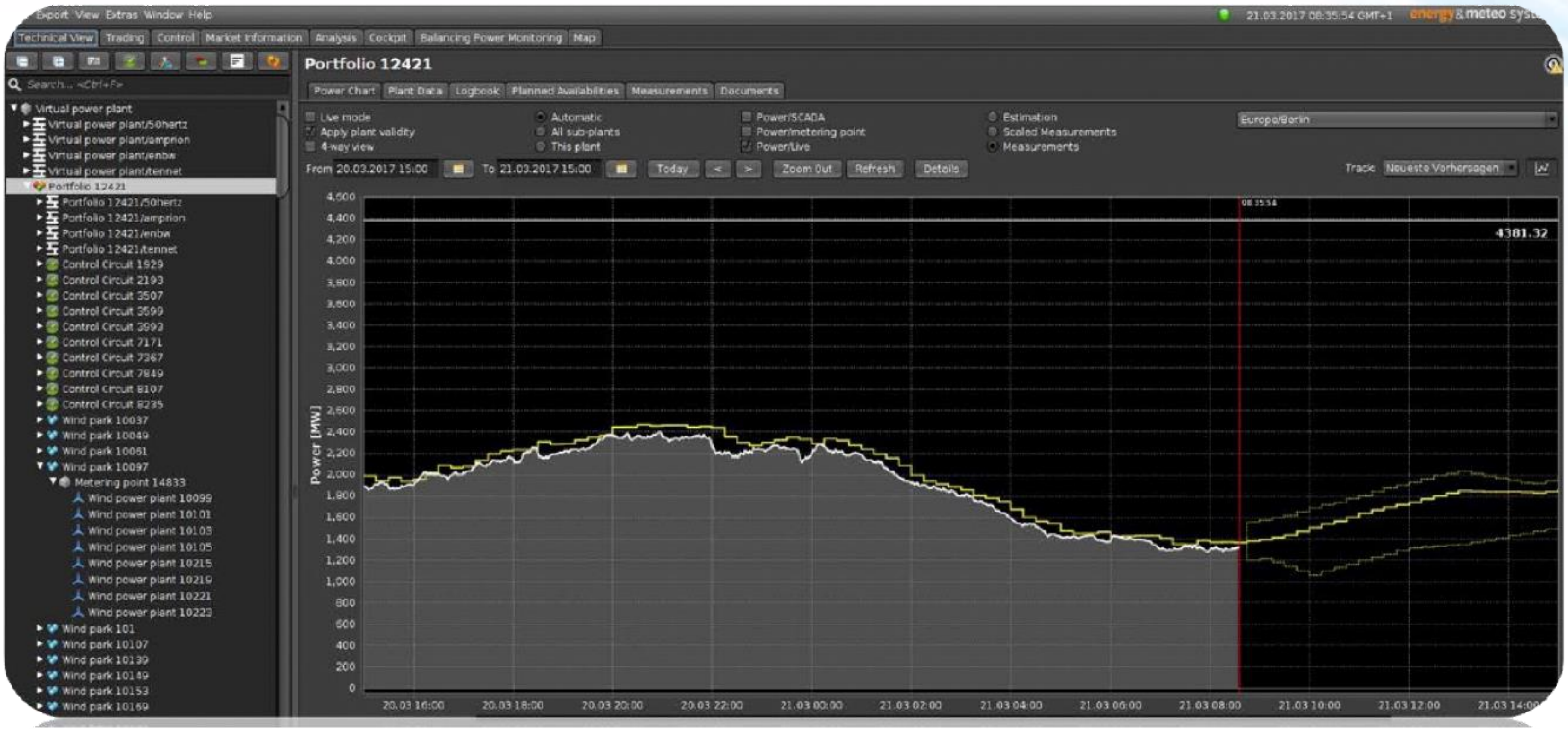
Map of Aggregated Power Plants



Virtual Power Plant (ii) - Operation



Conclusion

- There is no reason to be afraid of VRE in the distribution network;
- Allow DG in your system –
  but monitor (SCADA System) it to allow lessons to be learned;
- Understand the challenges with increasing VRE in your system
  and try to develop simple solutions;
- The biggest challenges are often regulatory challenges

Example of a typical three Class Consumer Power Tariff – an Issues!

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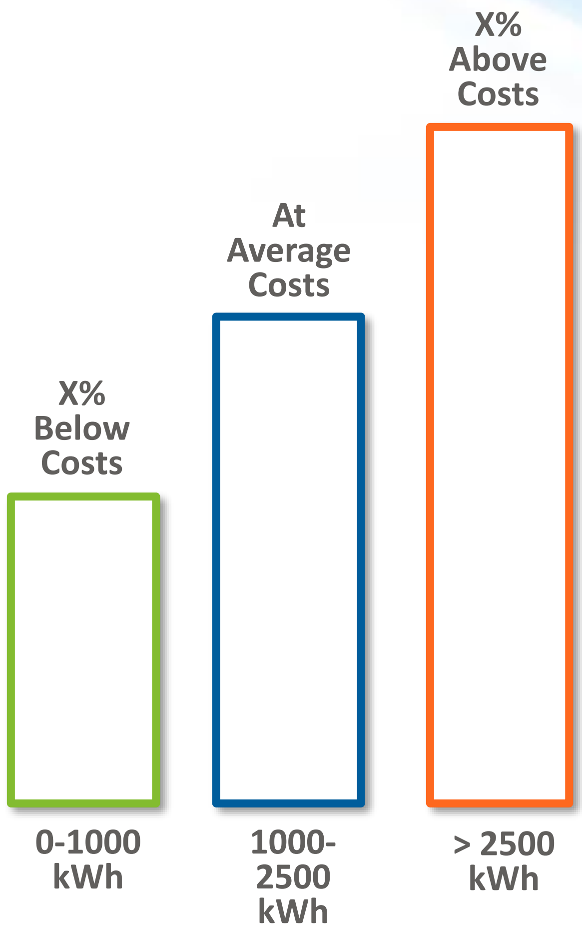
Basic Idea

- Large (wealthy) consumer subsidize small (poor) Consumer;
- This way all network/generation costs are paid for by all consumer (plus be may some profit for the utility)

Introduction of net-metering and/or feed-in tariff

- Large (wealthy) consumer 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!
- Utility are fully or partly government owned, so they will complain directly about the introduction of the net-metering and/or feed.in tariff, but:
- Utilities start to mention „technical issues“… „grid limits“ …. „grid instability due to renewables“

This was the same in Europe 20 years ago!



Thank you for your attention.