Martin Näf, ABB Corporate Research Center Switzerland – 21. 1. 2016

Innovationen im Verteilnetz

Trends, Entwicklungen und Lösungen aus Sicht der Forschung

Agenda

Trends and developments

Changes in the distribution grid

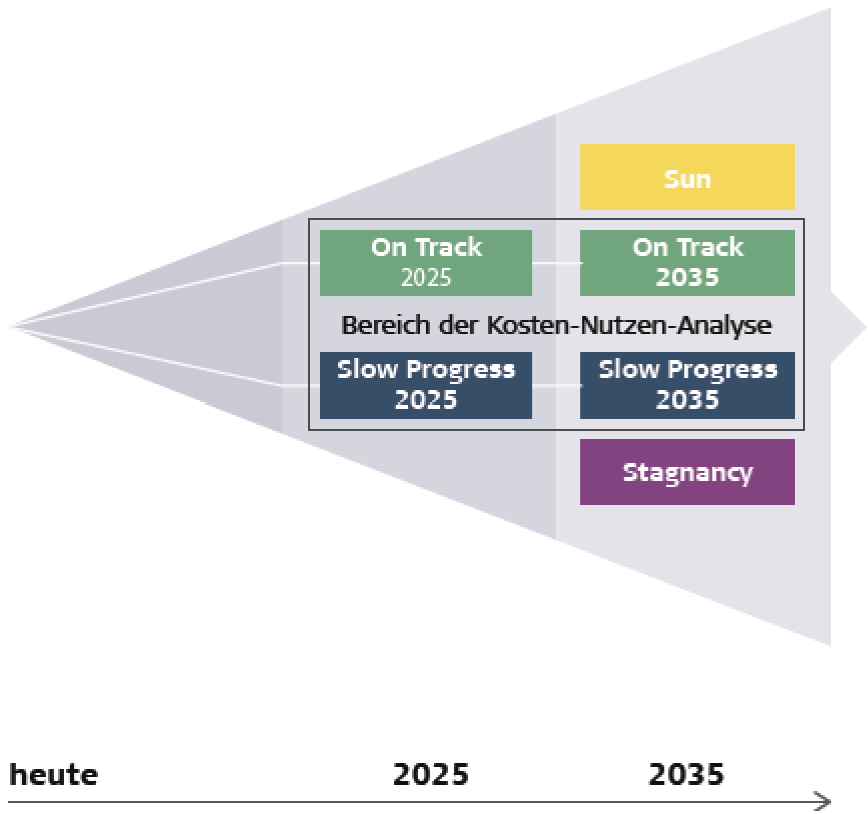
Residential battery storage

Technical solutions

- Local
- Distributed

Summary

Electric industry - development scenarios
Swissgrid «Strategisches Netz 2025»



Kernszenarien (2025 & 2035)

On Track – Anstieg der Erneuerbaren und bis 2035 KKW-Ausstieg

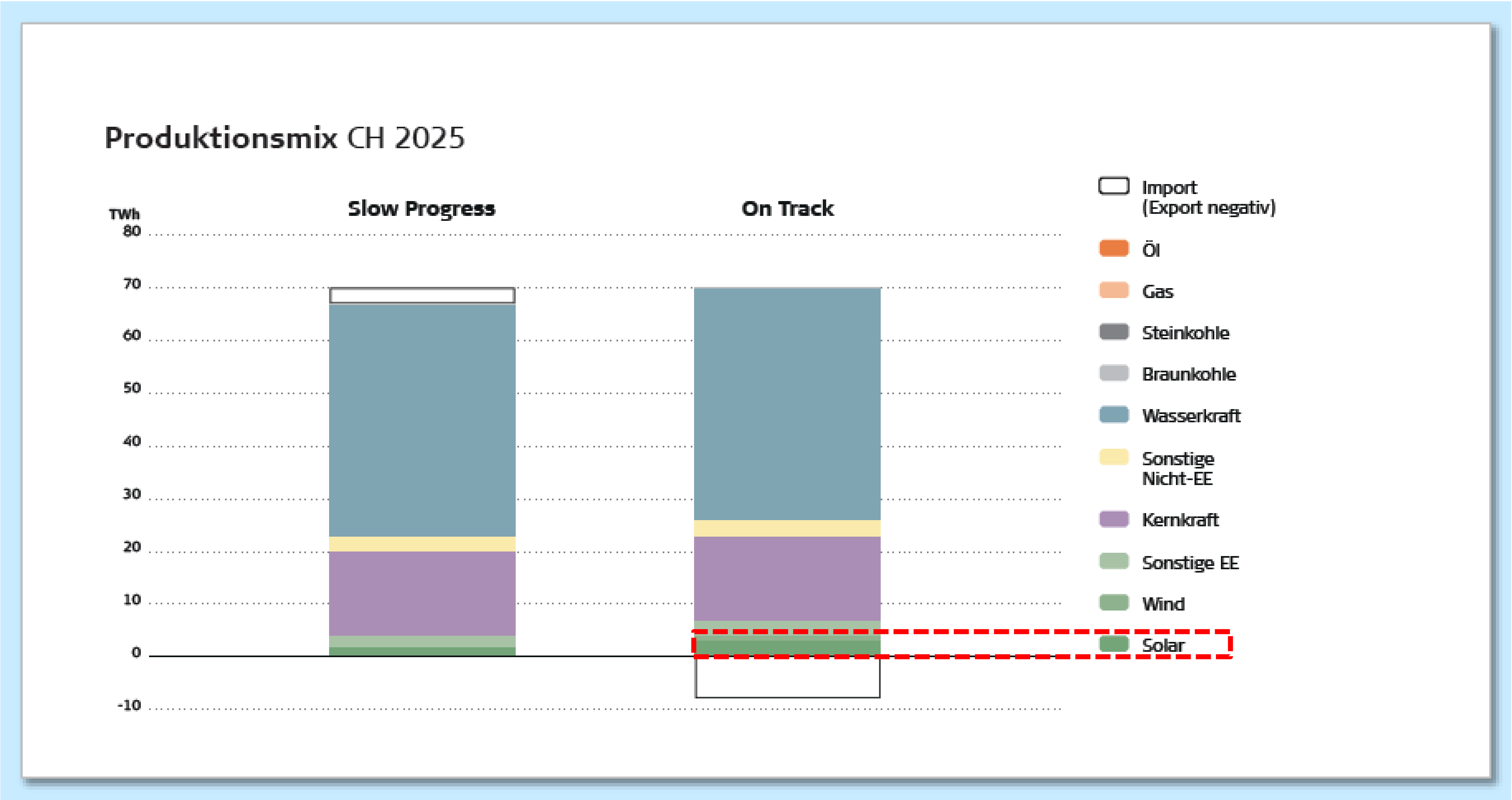
Slow Progress – geringer Ausbau von Erneuerbaren und kein vollständiger KKW-Ausstieg bis 2035

Randszenarien (2035)

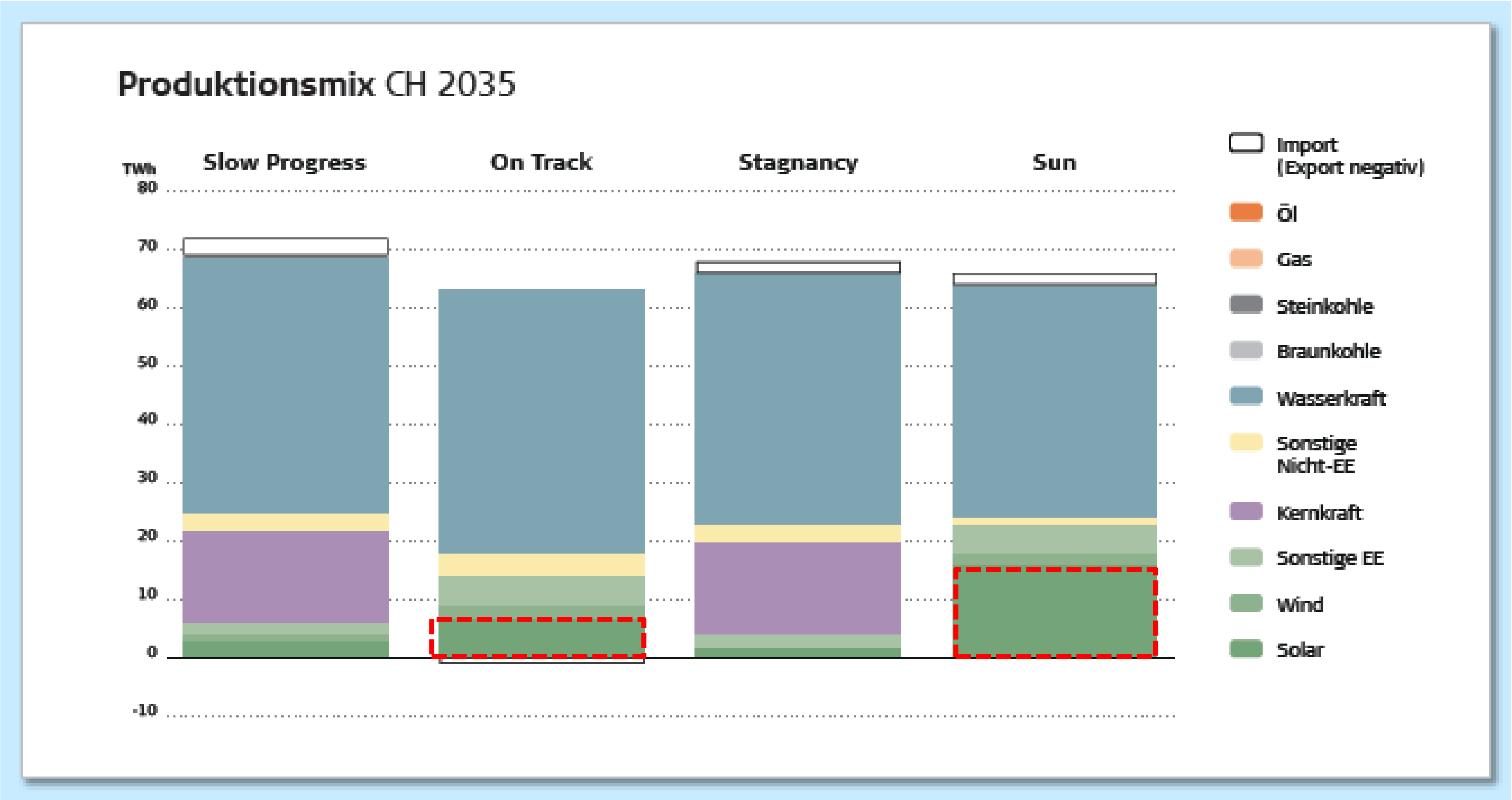
Sun – starker Ausbau von Photovoltaik

Stagnancy – Energiepreise verharren auf heutigem Niveau

Electric industry - development scenarios
Swissgrid «Strategisches Netz 2025»



Electric industry - development scenarios
Swissgrid «Strategisches Netz 2025»



Electric industry – development scenarios
Trends and solutions

Trends

- ✓ Enviromental concerns, policy and renewables:
  - Renewable integration in distribution grids
  - Electric mobility – EU transportation roadmap specifies by 2050 «no more conventionally-fueled cars in the cities»*
  - Integrated energy systems
- ✓ Aging infrastructure
- ✓ Social media and reliability – high expectation from the customer

Technology and Solutions

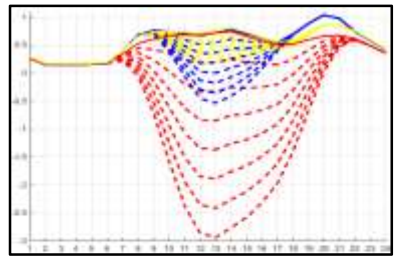
- Regulation transformers for distribution
- PV converters with reactive power support
- Battery energy storage
- Communications
- Adaptive protection
- Integrated energy management systems

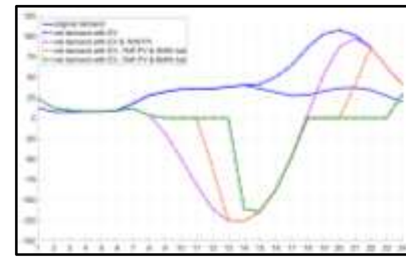
New technologies can support network operators in addressing raising challenges

* EC "Roadmap to a single European transport area — Towards a competitive and resource efficient transport system"

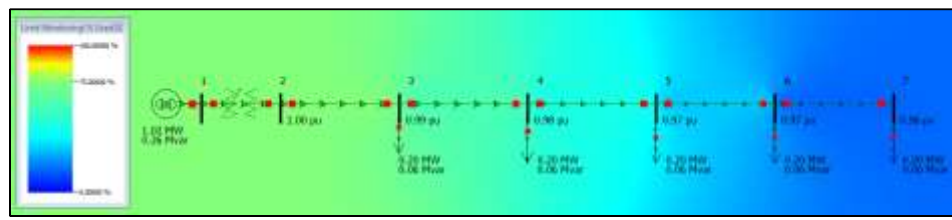
Electric industry – Rising challenges

Changing demand profile

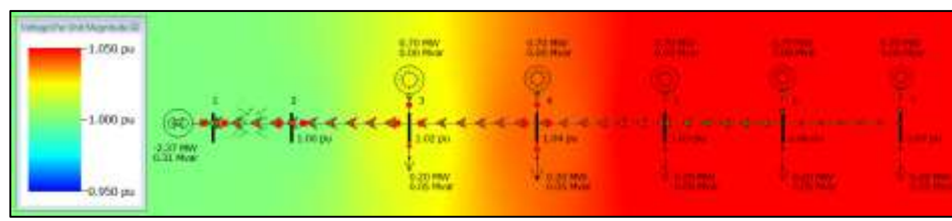




Volatile & reverse power flows



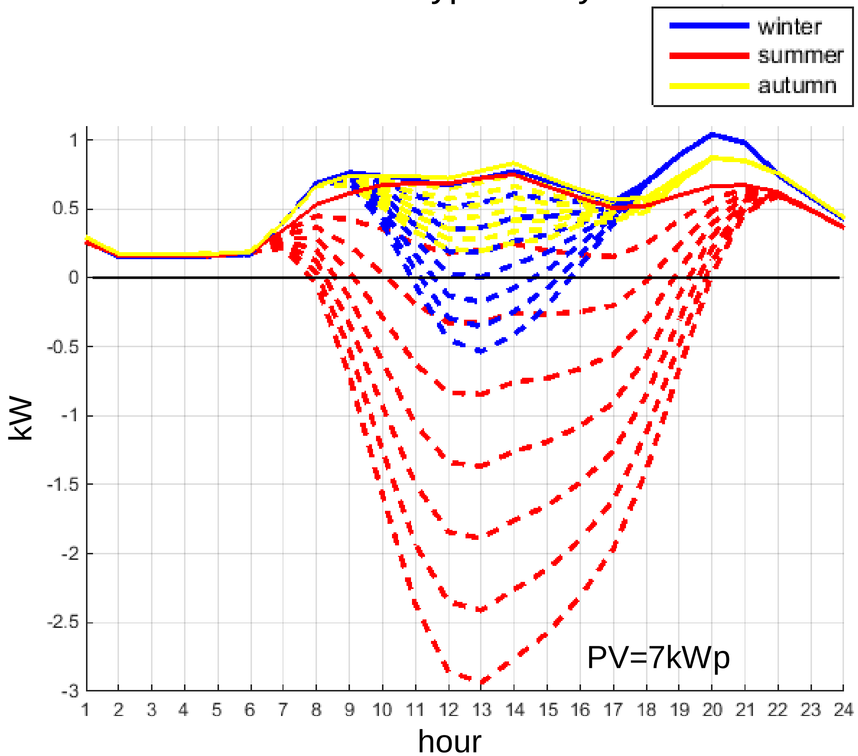
Voltage variations



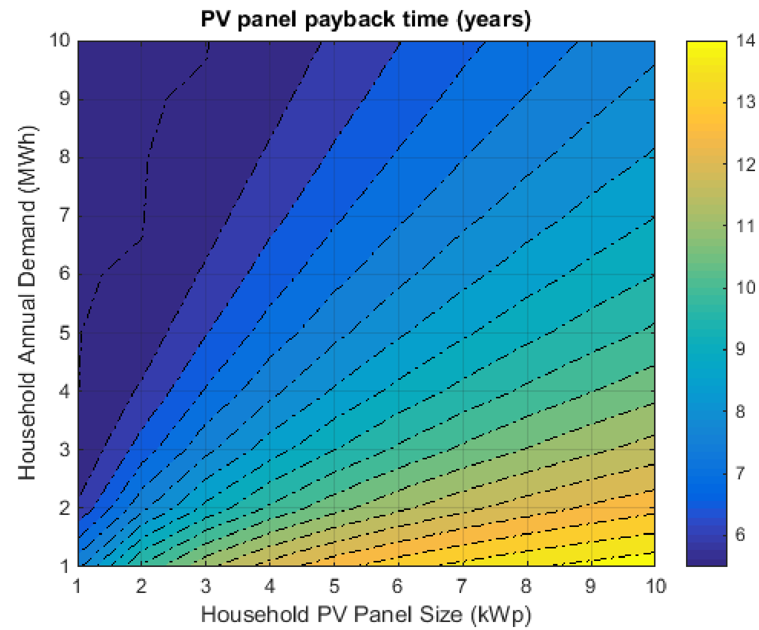
Large-scale proliferation of renewables in distribution grids results in new phenomena and technical challenges

Rising challenges – Available distribution capacity
Residential PV economics

- Average daily demand profiles of household with annual demand = 4.5 MWh
- Illustration for three typical days



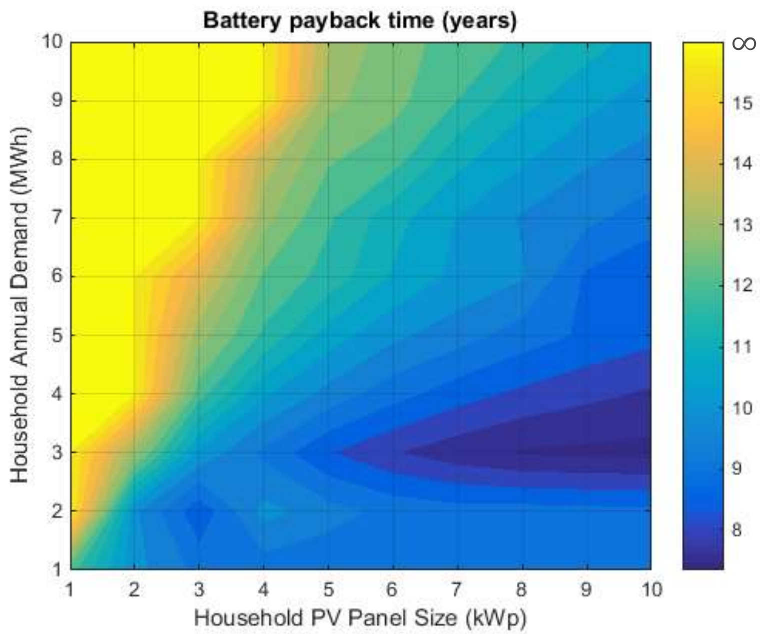
- Business case for residential PV
- Assumptions: a) res. elec. price = **0.3** $/kWh, b) res. production remuneration = **0.1** $/kWh, c) PV system inv. cost = **1'500** $/kWp, d) PV system lifetime = **20** years



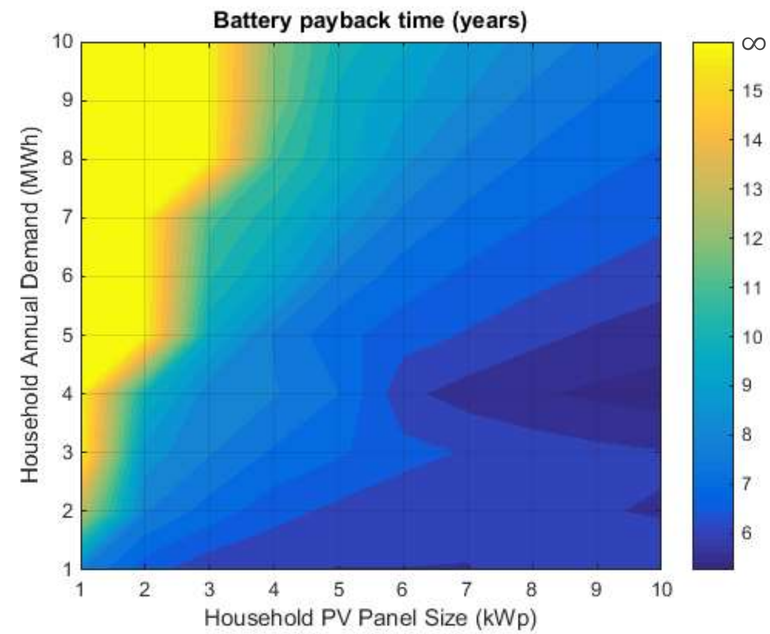
PV is attractive depending on the retail price and remuneration scheme. Potential for combined PV-battery systems.

Rising challenges – Available distribution capacity
Optimal sizing of battery for profit maximization

- Business case for residential battery
- Assumptions: a) res. elec. price = **0.3** $/kWh, b) res. production remuneration = **0.1** $/kWh, c) battery investment cost = **500** $/kWh, d) battery lifetime = **15** years

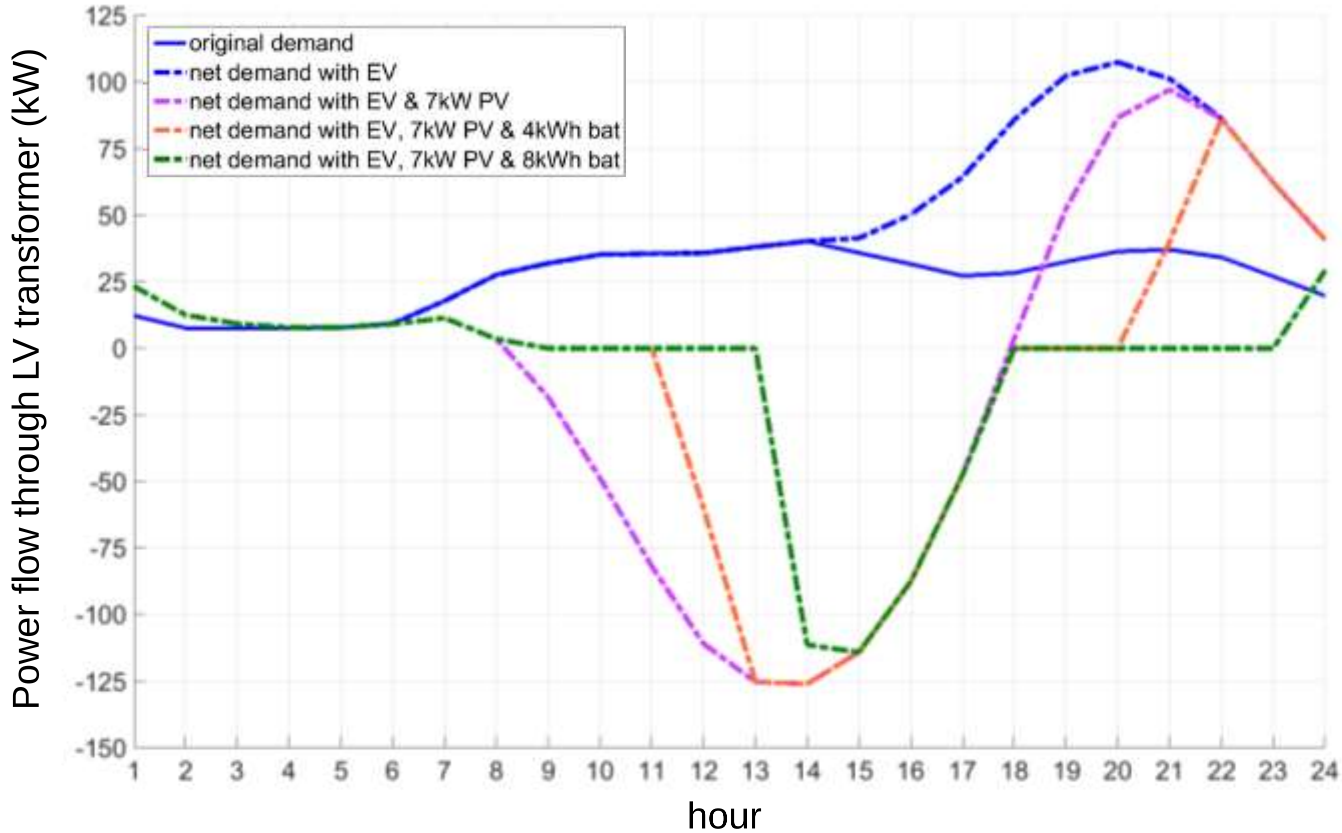


- Business case for residential battery
- Assumptions: a) res. elec. price = **.35** $/kWh, b) res. production remuneration = **.05** $/kWh, c) battery investment cost = **500** $/kWh, d) battery lifetime = **15** years



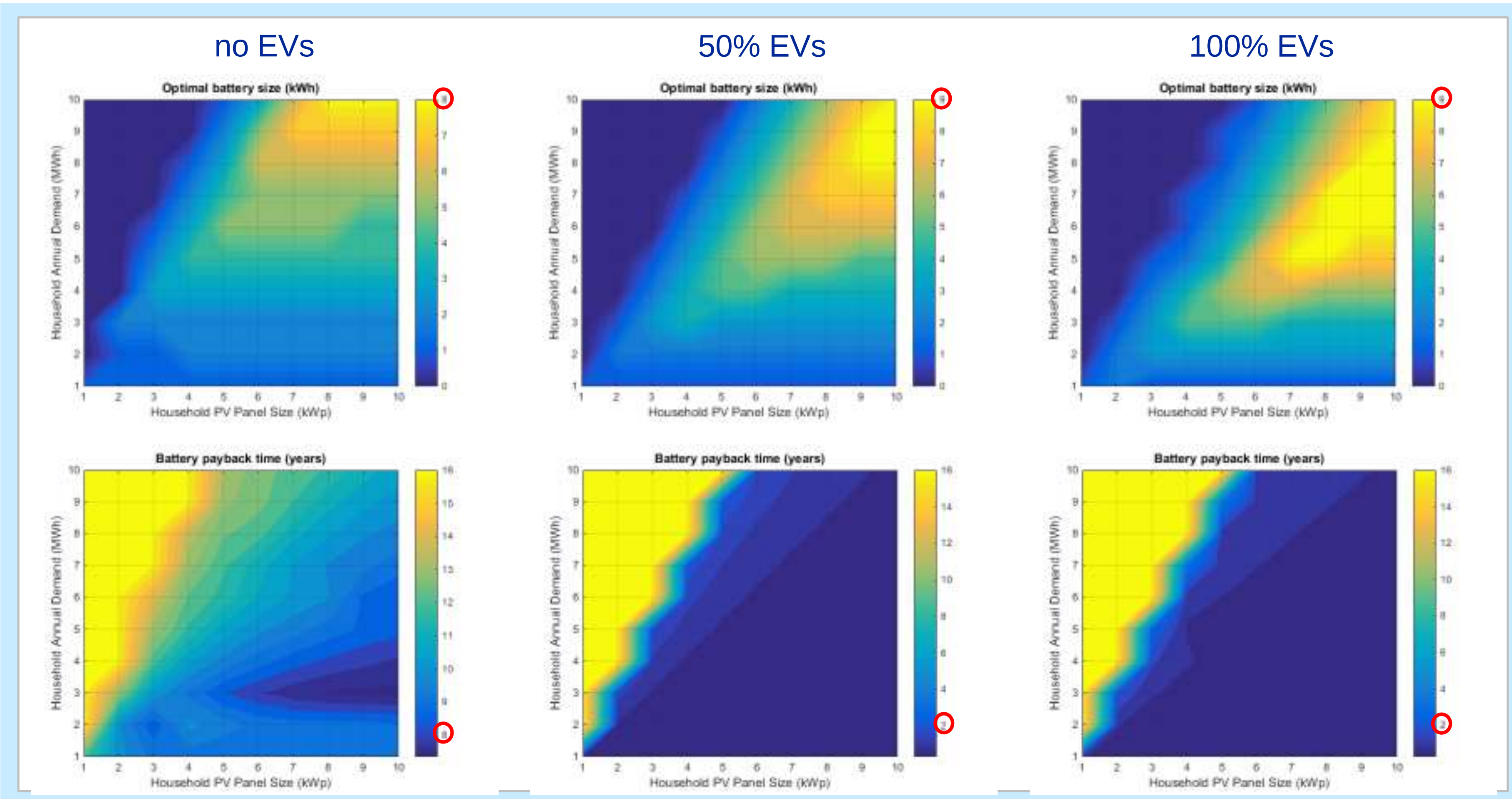
PV–battery systems become more economically attractive in presence of growing tariffs and reducing technology costs

Rising challenges - Available distribution capacity
Impact of EVs on demand profile



Significant impact on net demand especially during evening peak (w/o battery).

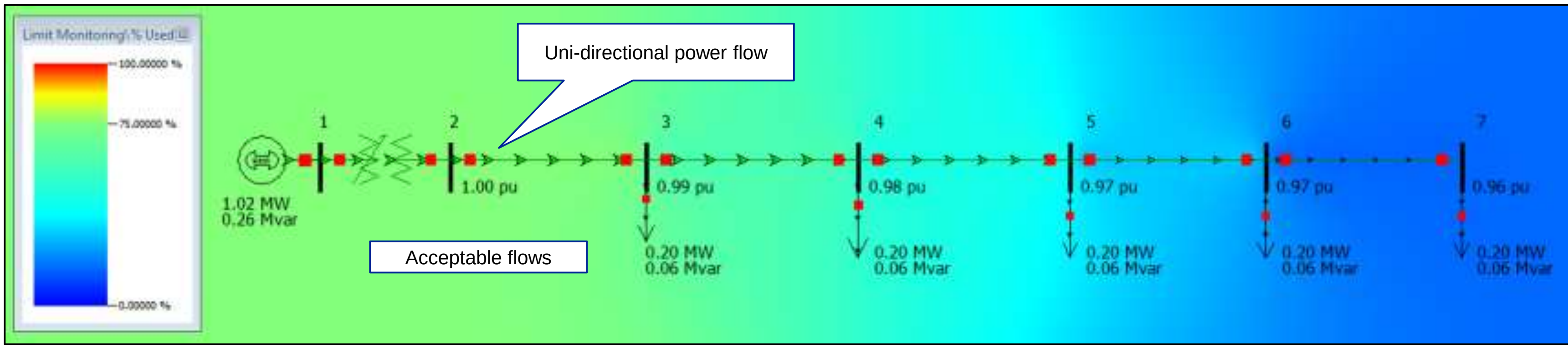
Rising challenges - Available distribution capacity
Residential PV-battery and EV economics



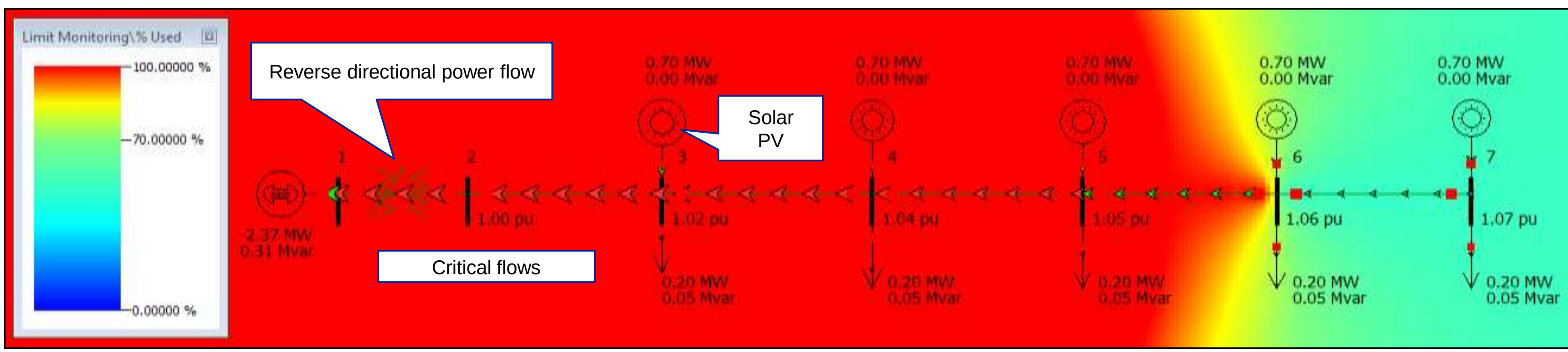
Electric vehicles, combined with PV, create a clear business case for a household to install batteries.

Rising challenges – Available distribution capacity
Residential PV impact on flows

- LV distribution feeder

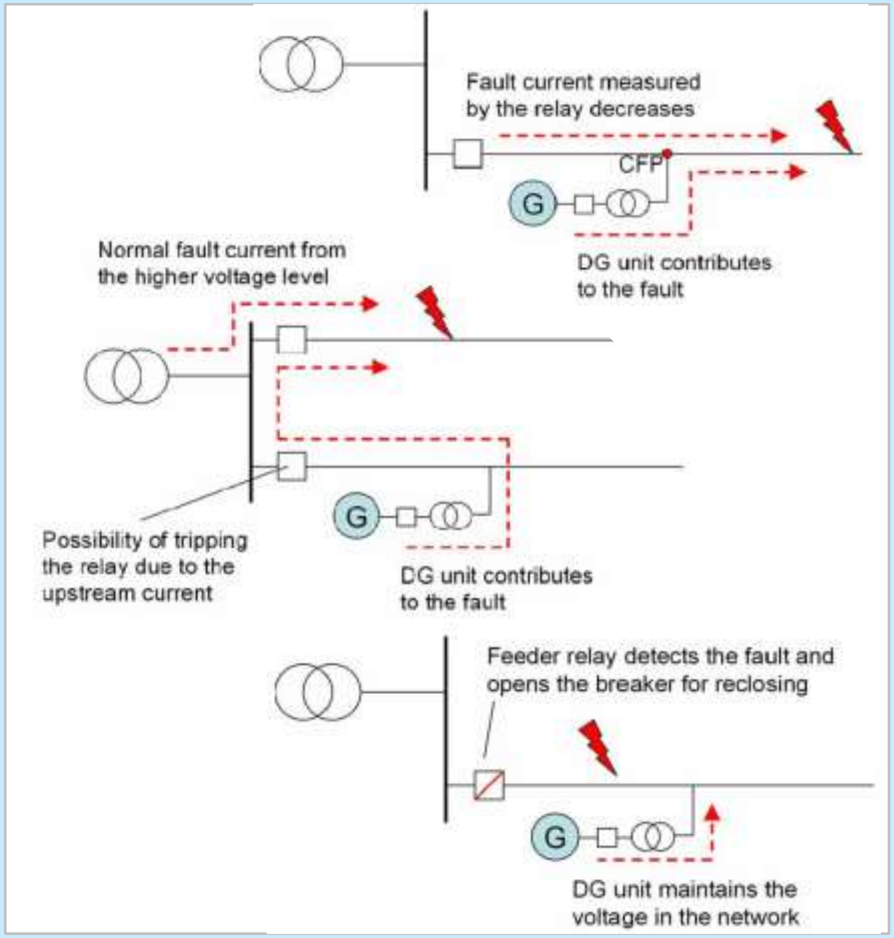


- LV distribution feeder with residential solar PV (solar PV/load = 3.5 times)



Rising challenges – Short circuit behavior
DG causes change in short circuit currents

- Proliferation of DGs in distribution grids and increased grid interconnection (moving from radial to meshed grids) lead to unanticipated flows for existing protection systems:
  - Changes in the magnitude and the direction of short circuit currents
  - Reduction of fault detection sensitivity and speed in tapped DGs connections
  - Unnecessary tripping of utility breaker for faults in adjacent lines due to fault contribution of the DGs
  - Auto-reclosing concept of the utility line breaker may fail



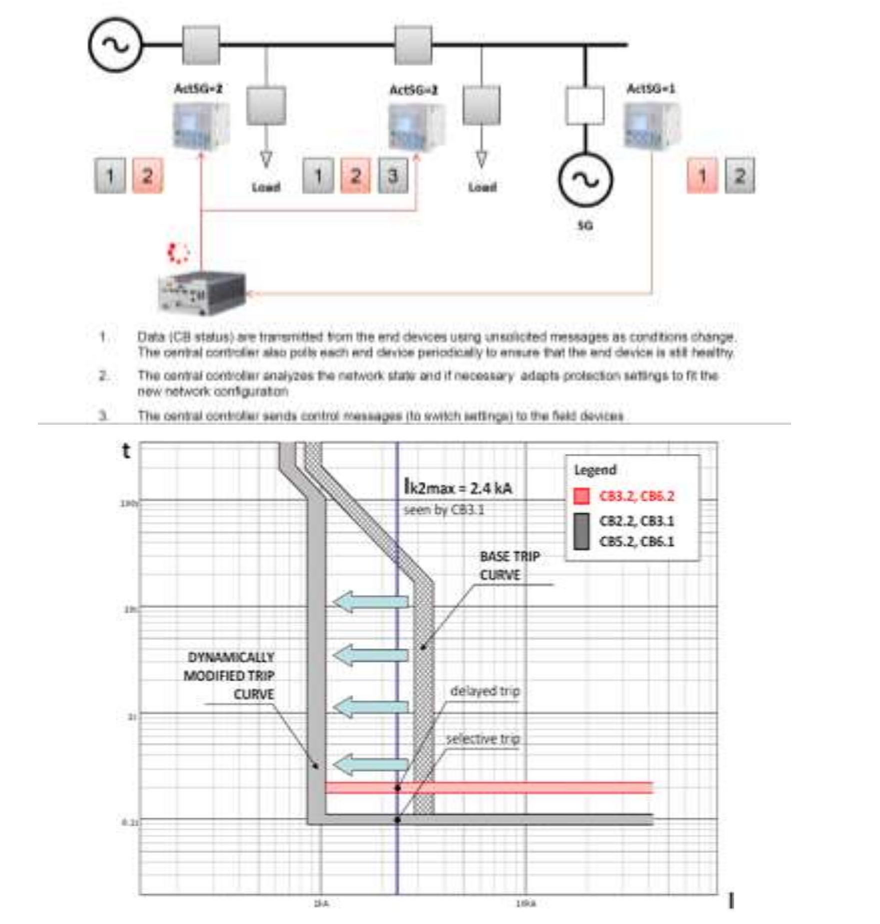
Technology and Solutions
Adaptive Protection in distribution grids with DG

ABB solution:

- Adjusts protection settings to correspond to the observed state of the active grid
- Accomplished by monitoring actual protection settings and DG/network connectivity
- After changes in circuit breaker status a programmable logic application executes and switches between trusted (i.e. verified by the protection department) setting groups

Requirements for implementation:

- IEDs with directional over-current protection function and multiple setting groups
- Communication infrastructure and standard protocols to exchange information between IEDs and a central controller (e.g. substation computer or RTU)



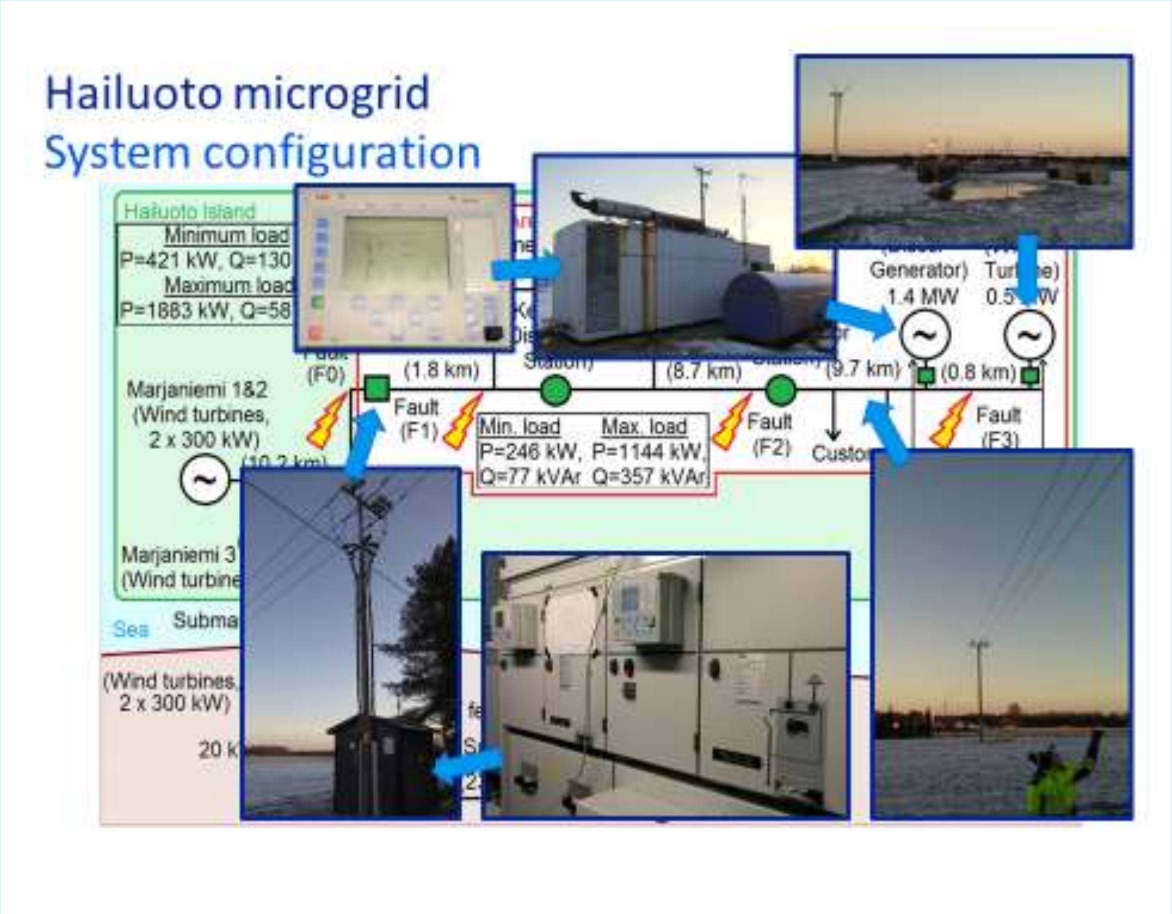
Technology and Solutions
Adaptive Protection in distribution grids with DG

Field and Lab Tests

Centralized approach has been tested in the lab (focus on data exchange) with a realization for MV (IEC61850) and LV (Modbus) grids

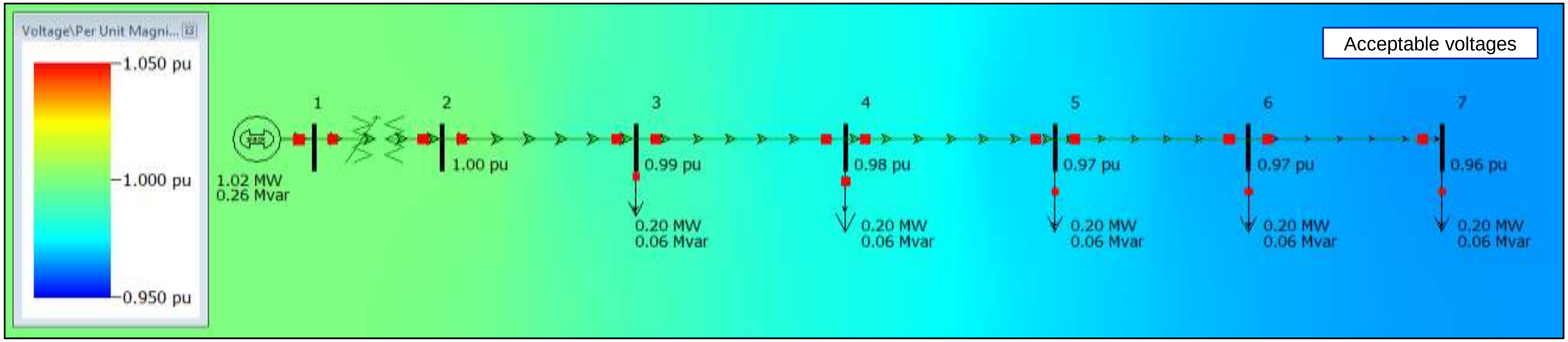
In addition a real-time HIL simulations have been conducted for the MV case

Adaptation process is limited by communication system/protocol capability and takes <100 ms in the MV case and ~700 ms (per circuit breaker) in the LV case

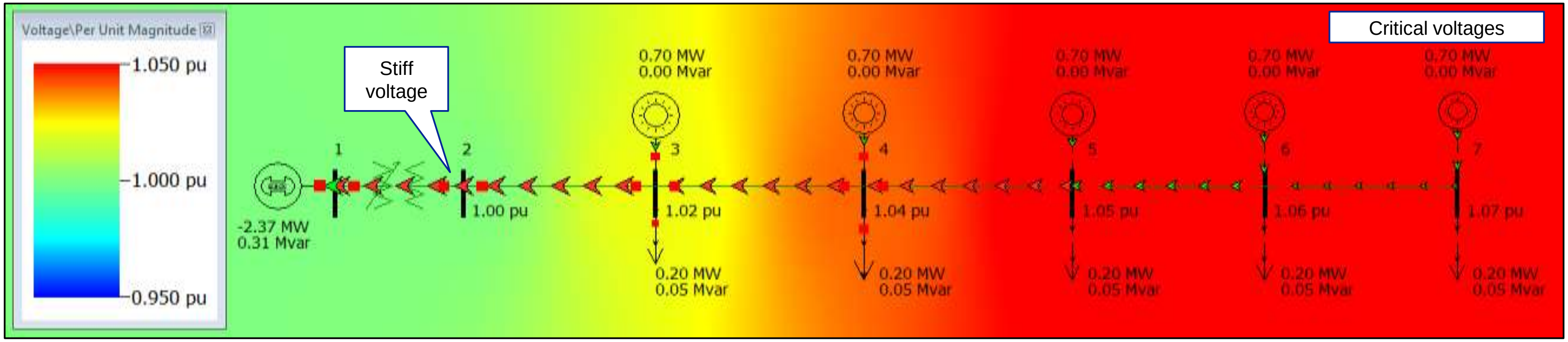


Rising challenges – Distribution voltage
DG causing overvoltage

- LV distribution feeder



- LV distribution feeder with residential solar PV (solar PV/load = 3.5 times)

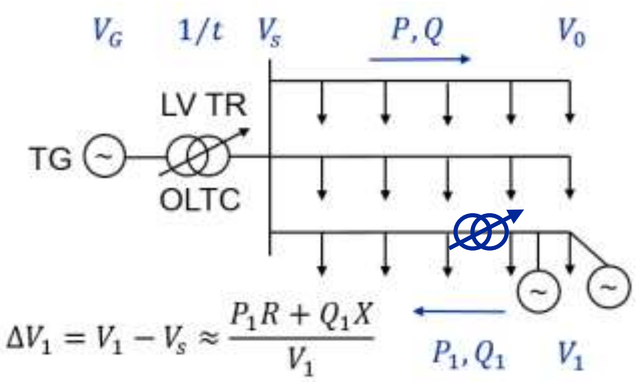


Technology and Solutions

Ways to mitigate the overvoltage problem

Solution:

1. Increase the size of the wires ($\Rightarrow R \ll X$)
2. Reduce the secondary LV transformer voltage by adjusting the tap
3. Curtail the power of distributed generators
4. Store the power surplus for later use
5. Install line voltage regulator
6. Force the distributed generators to absorb reactive power



Disadvantage:

1. Effective but expensive
2. Difficult to find a proper tap setting ensuring acceptable voltages to all feeders
3. Available power remains unused
4. Need to oversize batteries
5. Similar to 2 (but to smaller extent), it also introduces more complexity
6. a) Higher currents and losses in the feeder, b) lower power factors at the input of the feeder, c) the apparent power of the inverters might need to increase

New German Grid Code

PV connected to MV should contribute to reactive power control ($-0.95 \leq cos\varphi \leq 0.95$)

Expected to be extended to LV soon

California is also following

Coordinated control of devices (voltage regulators, batteries, PV inverters) is necessary at very high distributed RES penetration levels

Technology and Solutions
Voltage regulation – Solution with the transformers

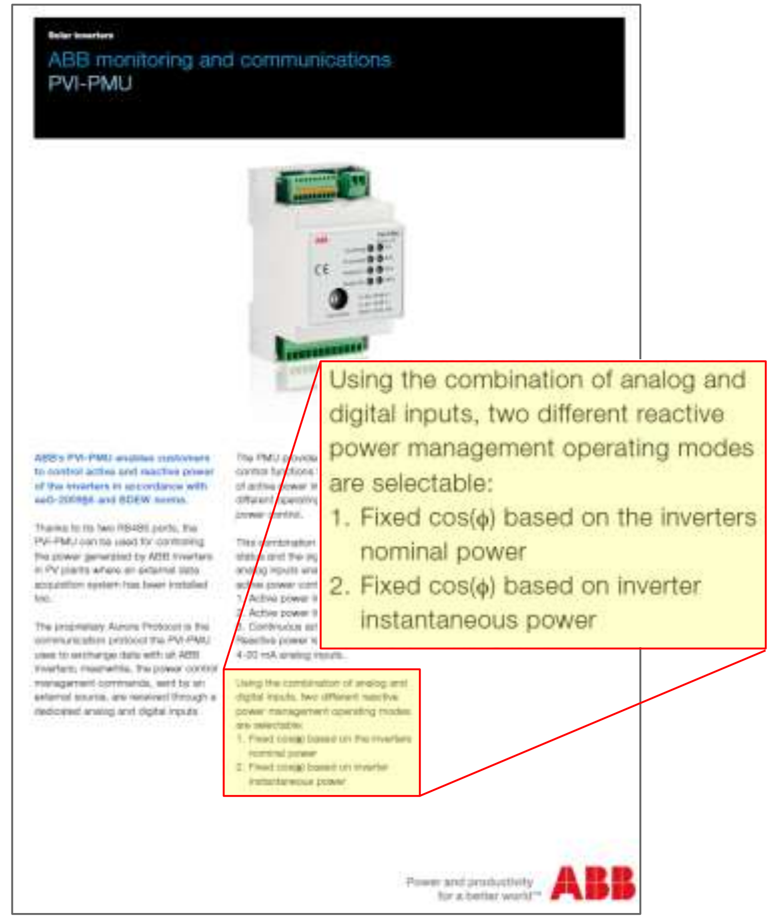
ABB Solutions

- Active Voltage Control
- On-load tap changing transformers for MV/LV
- Regulation transformers for distribution – MV
- Regulation transformers for distribution – LV
- Responsibility and costs stay with network operator

Technology and Solutions
Solar inverters providing volt/VAR control

Inverter VAR control methods:

- Fixed power factor, Q = 0
- Fixed power factor, Q (P)
  - Adjusts reactive flow depending on the inverter's active power output
- Variable power factor, Q (P, R/X)
  - Reactive output depends on both the inverter's active power output and the R/X ratio at the point of interconnection
- Volt/VAR control
  - The inverter monitors its own terminal voltage and responds with a custom reactive response determined by the utility



New "smart inverters" are able to contribute to grid stability, such as voltage control

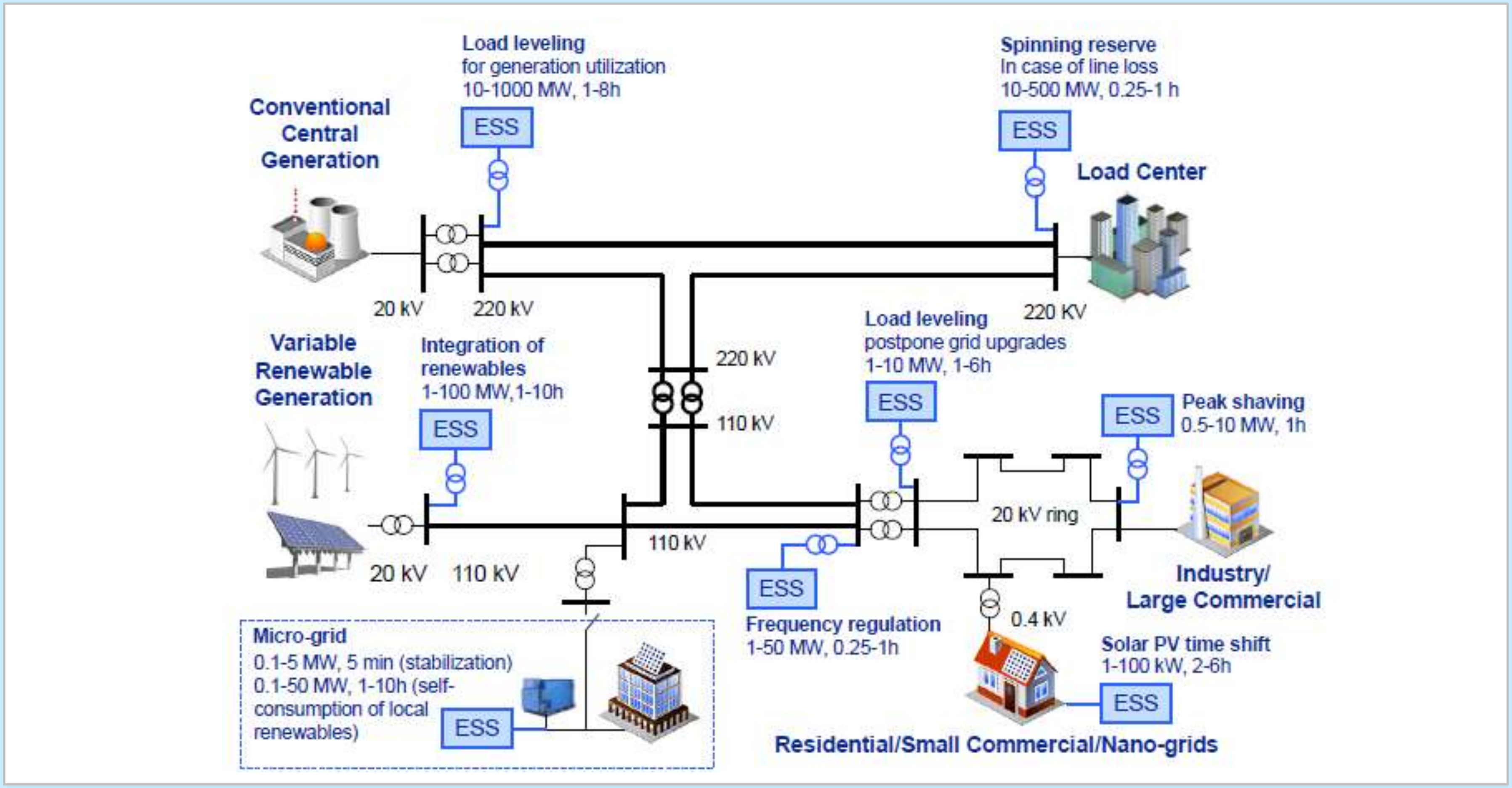
Technology and Solutions
Storage

ABB Solutions

- Residential inverters with integrated storage
  - REACT
- Utility-scale battery systems
  - Complete ABB solutions
  - Third party solutions using ABB inverters and control systems

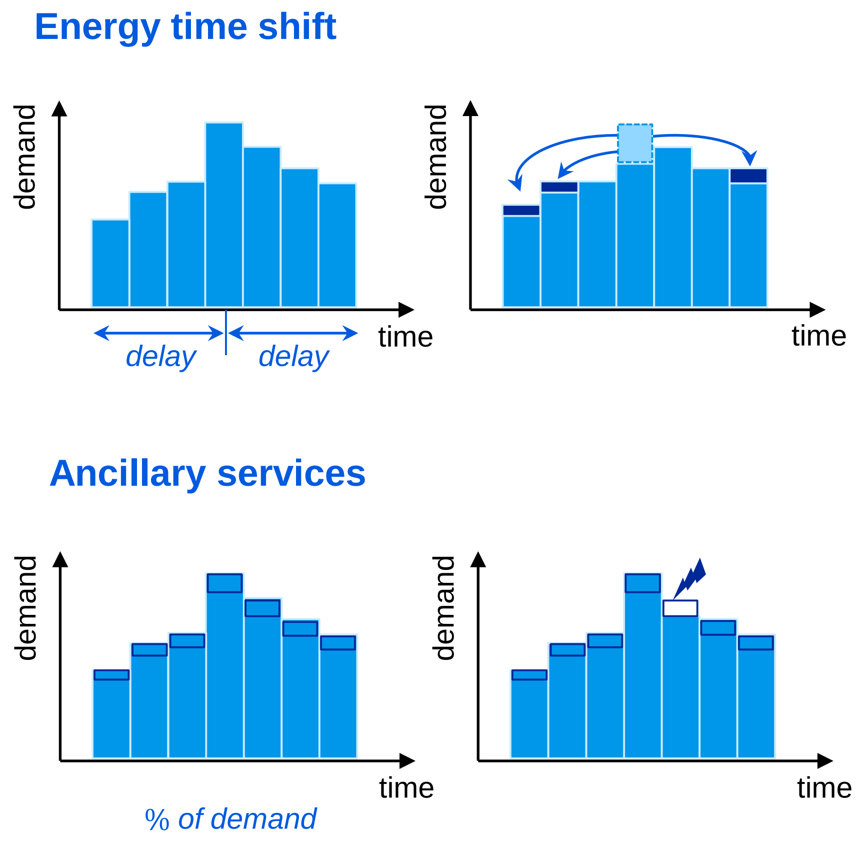
Cost-effective solutions with integrated storage

Technology and Solutions
Battery energy storage: overview of the applications



Technology and Solutions
Demand side management: types of demand response

- Demand Response (DR) is defined as the change in the electricity use in response to the electricity price changes or the system operator's control signal
- Energy time shift: a percentage of demand can be anticipated or postponed within a given time delay
- Ancillary services (e.g. frequency regulation): a percentage of demand can be changed by the system operator in case of contingency



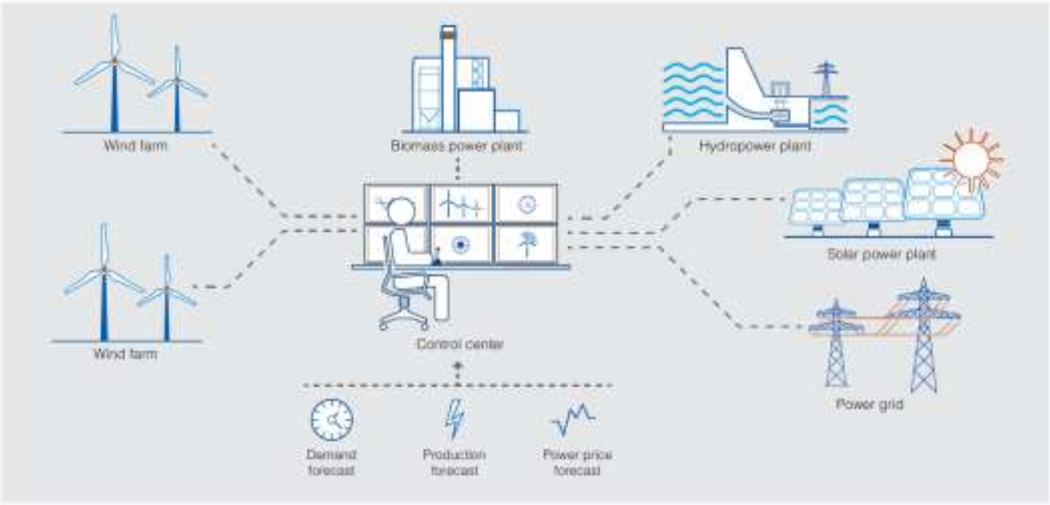
Technology and Solutions
Virtual Power Plant (VPP)

Definition: VPP

- VPP is a group of decentralized energy providers
- Many resources are connected to be commonly represented in the market
- City Networks have virtual pools of the providers that can be commonly traded

Solution: ABB OPTIMAX POWERFIT

- Optimal distribution of the participation factors to qualified providers
- Control of the appliances via signal to the NextBox



Technology and Solutions
Virtual Power Plant (VPP) – Optimax Powerfit

Customer: Next Kraftwerke

- Markets the power at the electricity market and provides capacities of the virtual power plants
- Participation factors to the secondary and tertiary frequency control are distributed to the providers
- Participation can be requested at any instance

Holistic solution for distribution grids
An «involved» operation and management

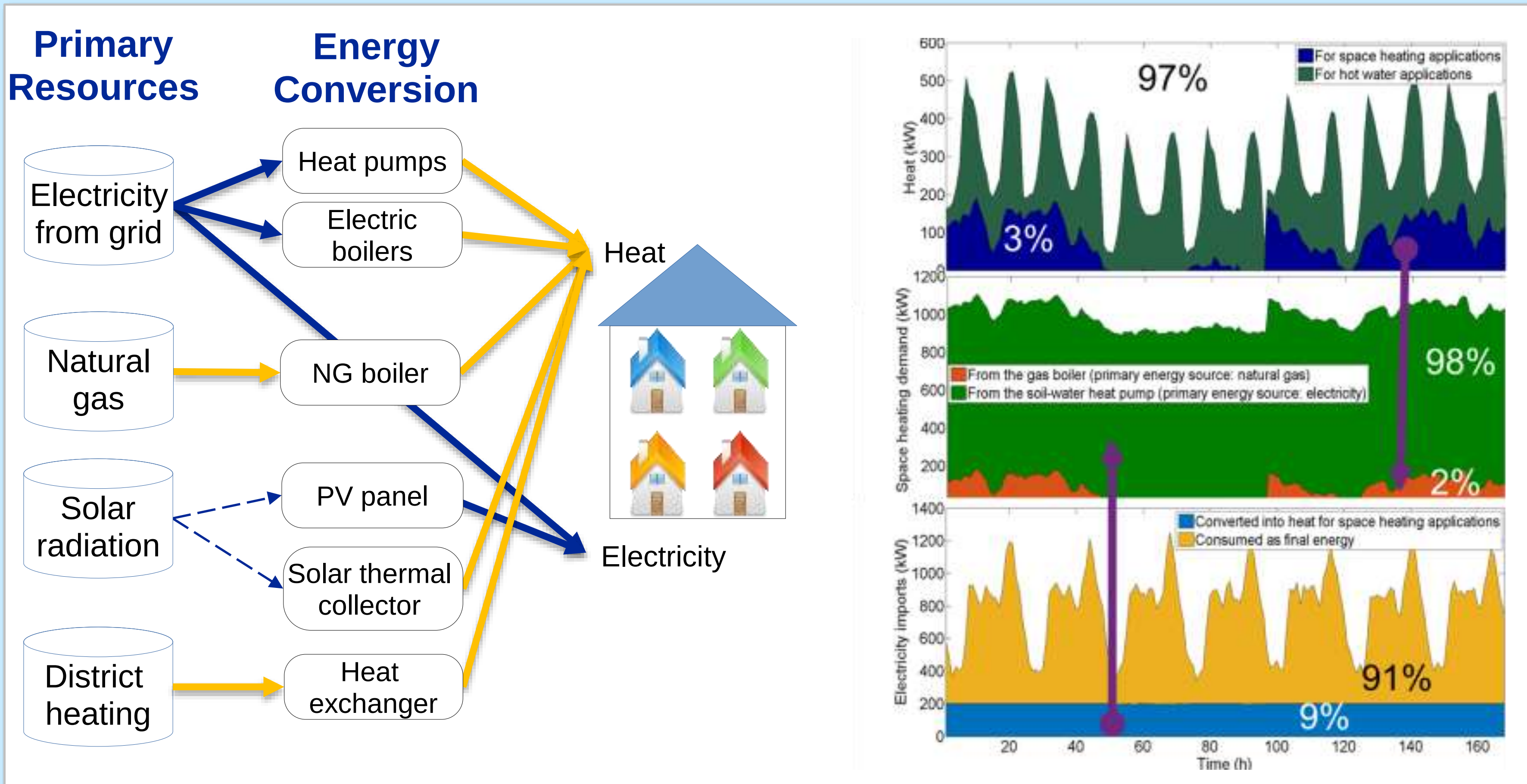
Functionality

- Monitoring
- Control
- Management
- Automation
- Protection
- Interaction with transmission grid operator

Benefits

- Enables provision of ancillary services
- Maximizes renewable output while maintaining reliability and security of the service
- Considers NE1 – NE7 operating requirements

Holistic solution for distribution grids
Further sustainability potential – multi-energy systems (MEGS)



Co-optimization of multiple infrastructures may help increasing the energy efficiency as well as the proliferation of clean sources

Innovation in Distribution Grids
Summary

- Power industry has been exposed to drastic changes with significant challenges in the recent years in some European countries. Similar challenges may hit Swiss utilities.
- These significant challenges can be addressed by new technologies that will bring the highest benefits once carefully evaluated and integrated into a new holistic concept.
- Technologies offered by ABB can effectively support emerging operating principles, rules and regulations set by industry players such as DSOs, TSOs, legislation etc.
- Certain practices might limit economic feasibility of the technology applications, simultaneously limiting the value these applications could offer to the operators, asset owners and end-consumers.

Lets work together for sustainable future with a reliable and economic power supply!

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A.Oudalov, C. Y. Evrenosoglu, A. Marinakis, M. Zima for the materials in this presentation

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for a better world™

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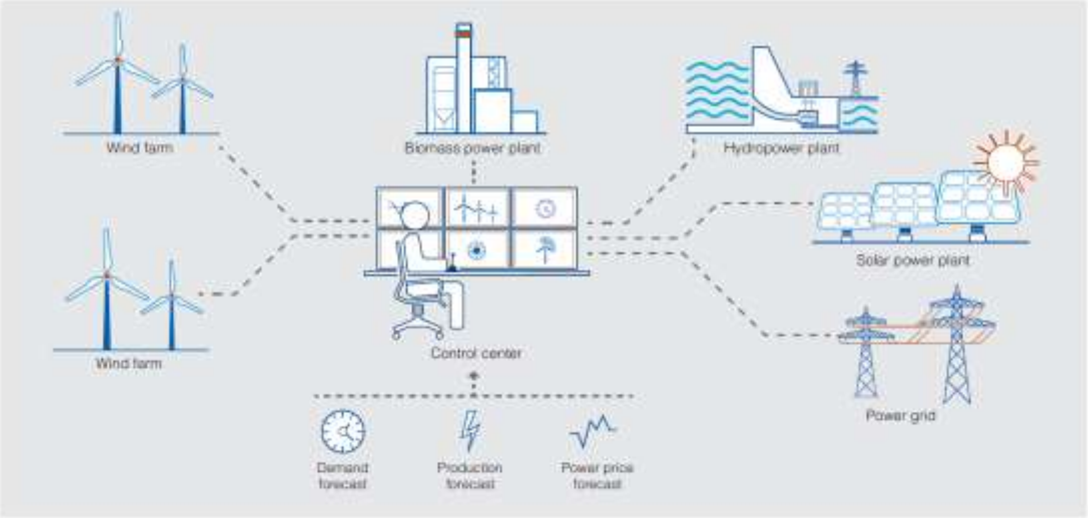
Technology and Solutions
Virtual power plant - Optimax Powerfit

Definition

- Virtuelles Kraftwerk ist ein Verbund dezentraler Erzeugungseinheiten (TEs)
- Mehrere kleinere Anlagen werden zusammengeschlossen, um gemeinsam am Markt aufzutreten
  - Stadtwerke haben Virtuelle Kraftwerk-pools, in denen sie alle Erzeugungs-einheiten zusammenfassen und gemeinsam vermarkten

Erweiterung:

- Speicherfähige Einheiten
- Regelbare Verbraucher



Regelung von Energieangebot und Nachfrage
Quellen für Regelenergie

Microgrids und Bilanzgruppenoptimierung

- Batteriespeicher
- Flywheel
- Demand Response

Netzebene

- Konventionelle Generatoren, Gaskraftwerke
- Pumpspeicherwerke
- Alternative Speichertechnologien (Batterien, CAES, etc.)

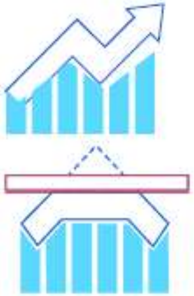
Regelung von Energieangebot und Nachfrage
Reduktion des Regelenergiebedarfs

Geographische Verteilung

- Starke Netze ermöglichen Ausgleich über weite Distanzen

Regeln für die Einspeisung

- Limitierung der maximalen Rampen
  - Intelligente Steuersysteme
  - Prognosen (kurz-, mittel- und langfristig)
  - Lokale Speicher
- Reduktion der Spitzen
  - Ausrichtung der PV Anlagen



Einbindung in Marktmechanismen

- Virtual Power Plants, Bilanzgruppenoptimierung
- Voraussetzung für Wirtschaftlichkeit der technischen Massnahmen

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Netzintegration von Wind & Photovoltaik
Fazit

Die Integration ist anspruchsvoll, aber technologisch machbar

Die Rahmenbedingungen müssen angepasst werden

- Neue Regeln für die Einspeisung
- Förderinstrumente sollen die Anreize zur bedarfsgerechten Produktion nicht unterwandern

ABB steht hinter den erneuerbaren Energien

- Führender Anbieter für Solarwechselrichter
- Breite Produkt- und Systempalette für Solar, Wind und Wasserkraft
- Engagement für Solar Impulse 2 als Hauptsponsor und Technologiepartner

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