



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

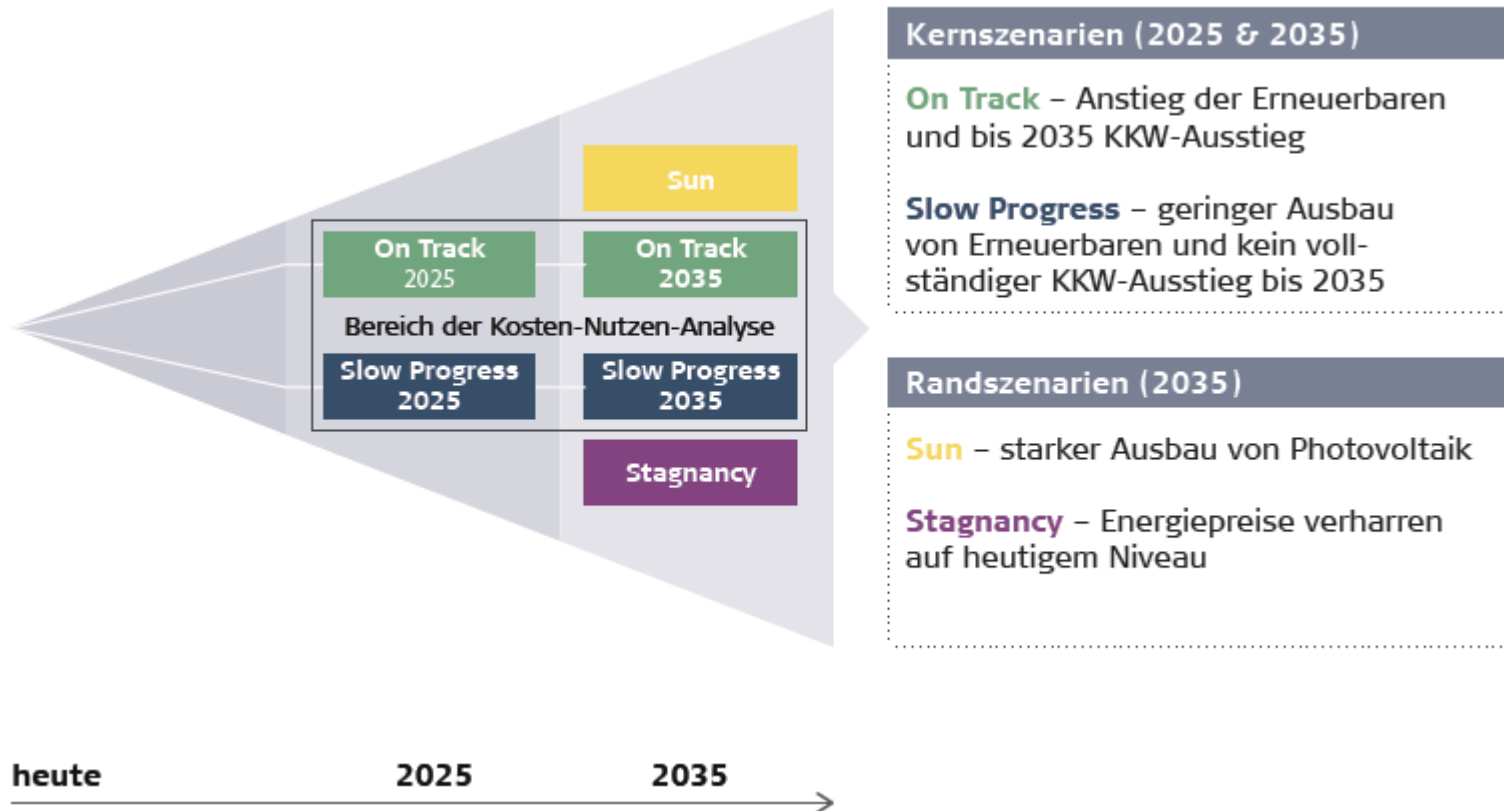
Technical solutions

- Local
- Distributed

Summary

Electric industry - development scenarios

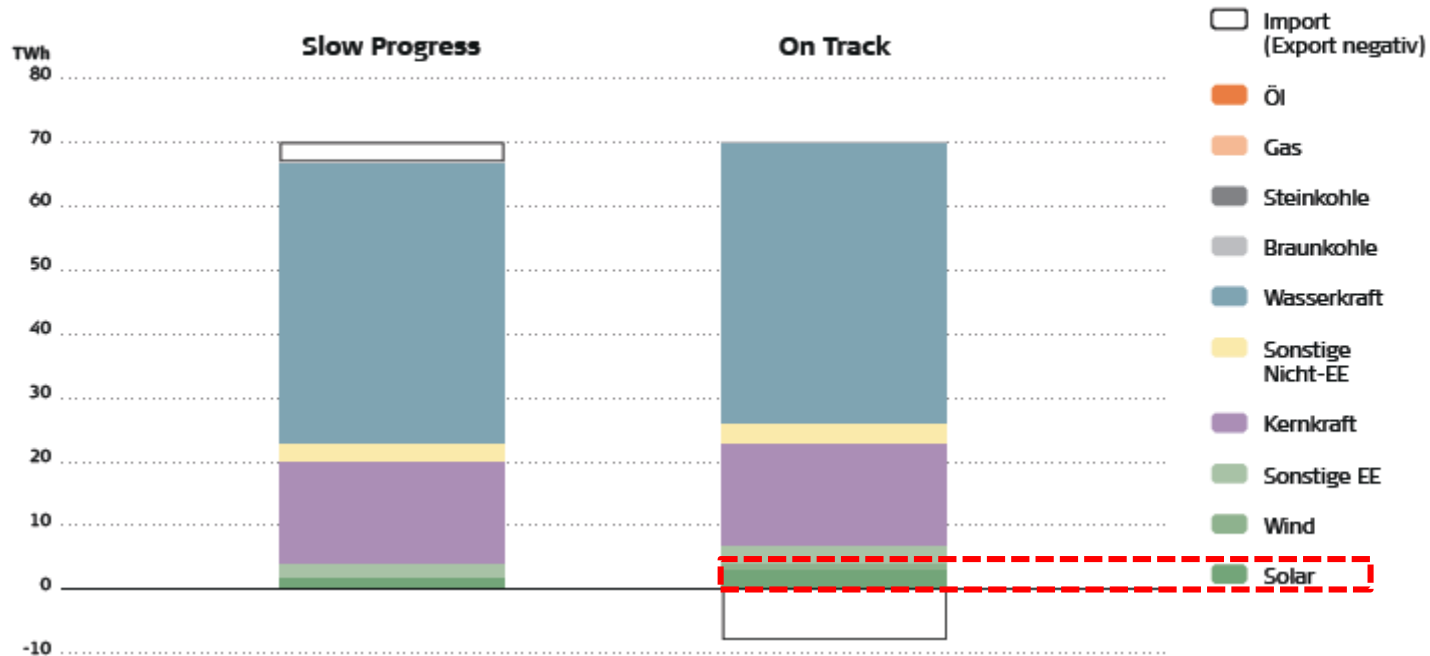
Swissgrid «Strategisches Netz 2025»



Electric industry - development scenarios

Swissgrid «Strategisches Netz 2025»

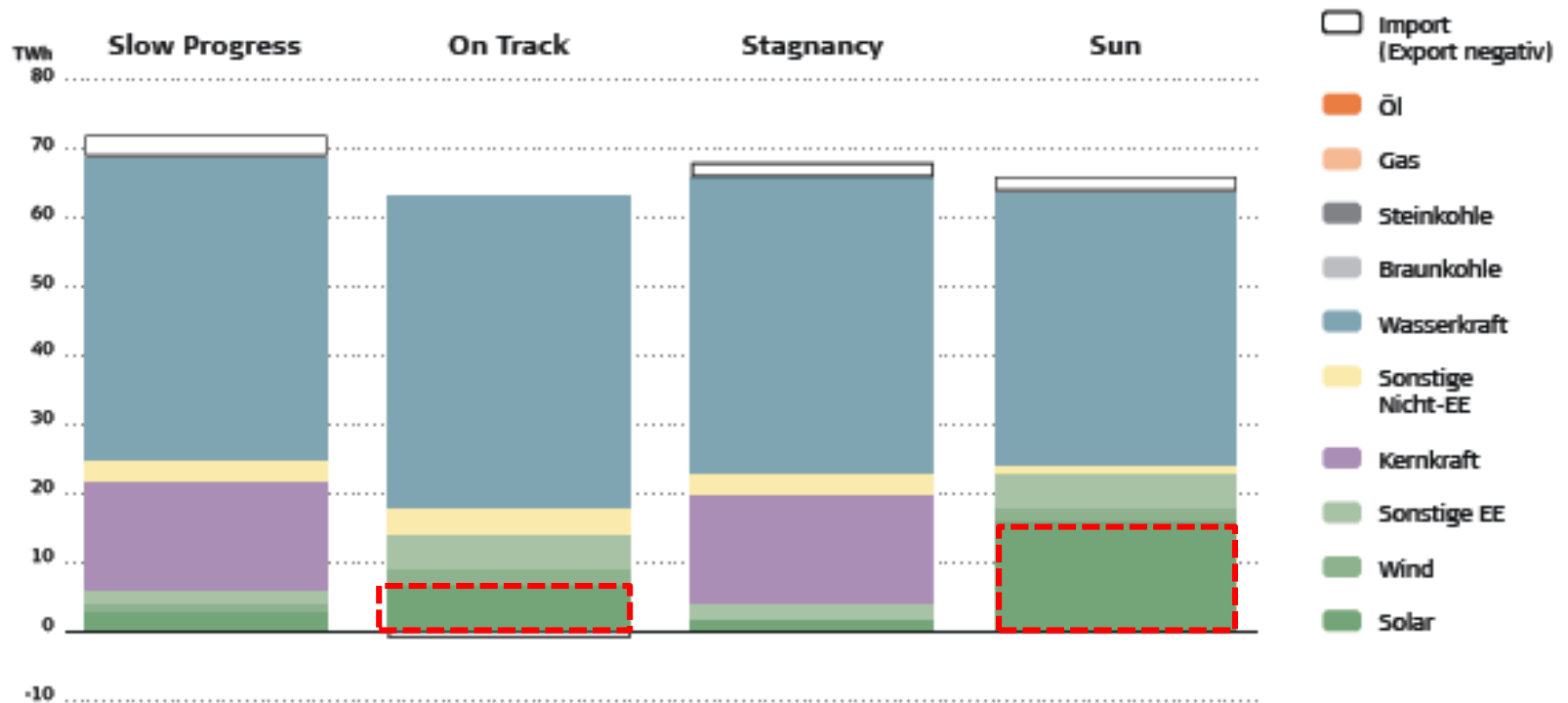
Produktionsmix CH 2025



Electric industry - development scenarios

Swissgrid «Strategisches Netz 2025»

Produktionsmix CH 2035



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

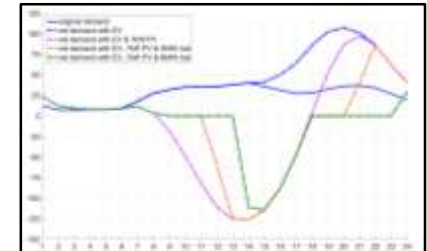
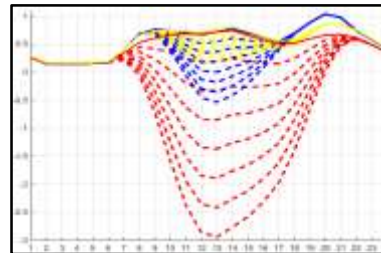
Technology and Solutions

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

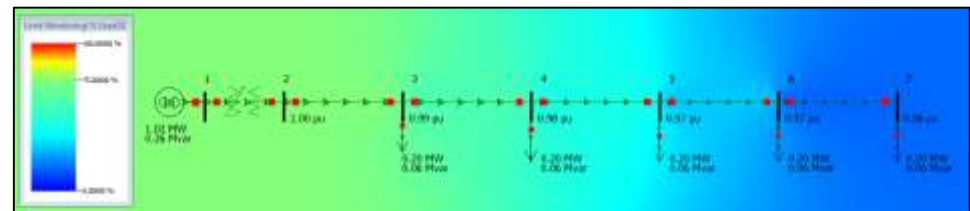
New technologies can support network operators in addressing raising challenges

Electric industry – Rising challenges

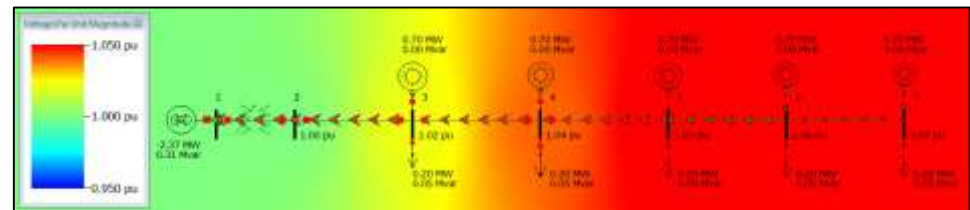
Changing demand profile



Volatile & reverse power flows



Voltage variations

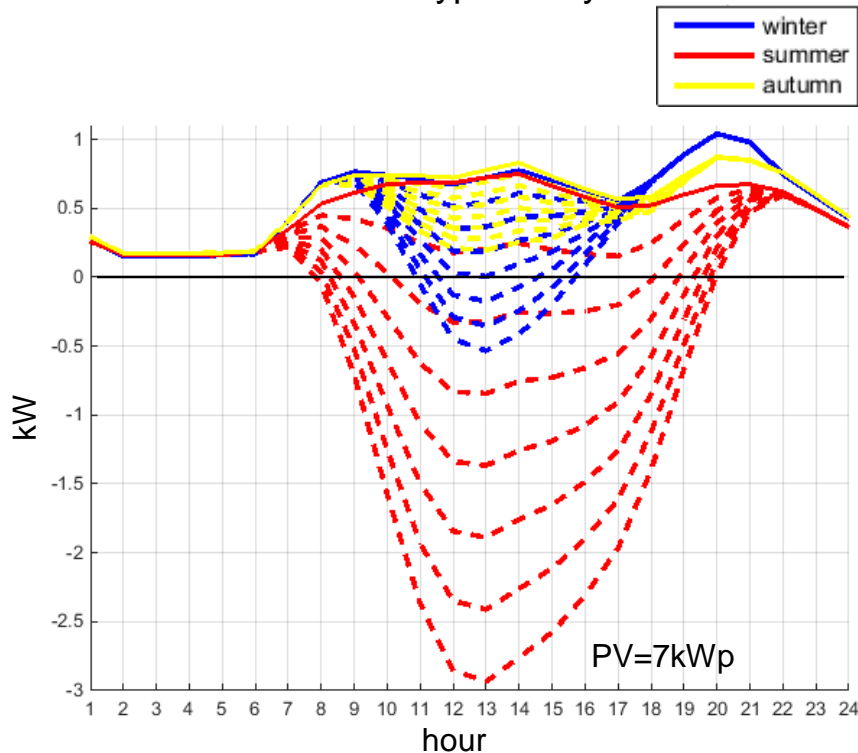


Large-scale proliferation of renewables in distribution grids results in new phenomena and technical challenges

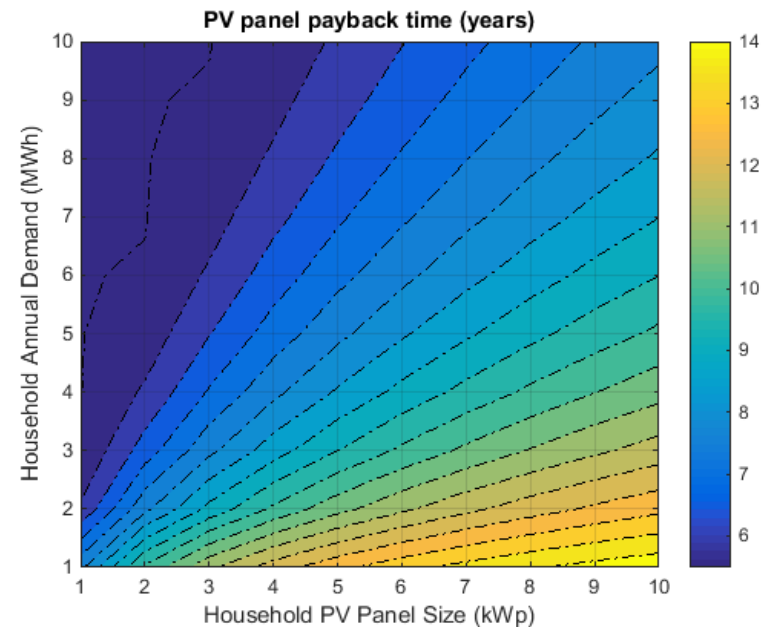
Rising challenges – Available distribution capacity

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

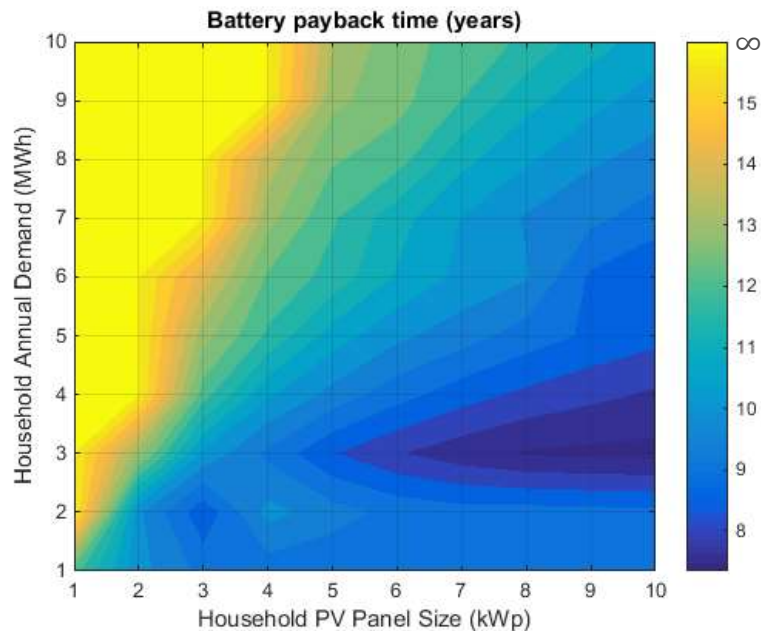


PV is attractive depending on the retail price and remuneration scheme. Potential for combined PV-battery systems.

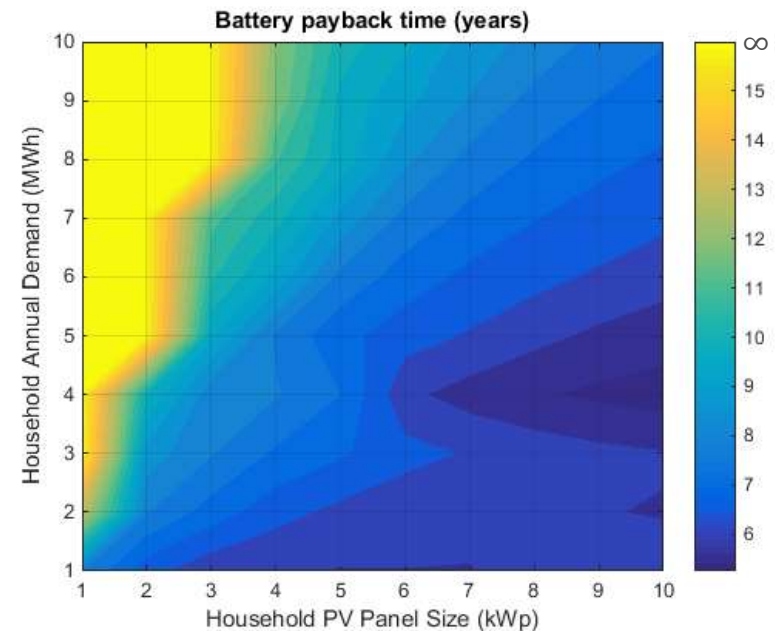
Rising challenges – Available distribution capacity

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



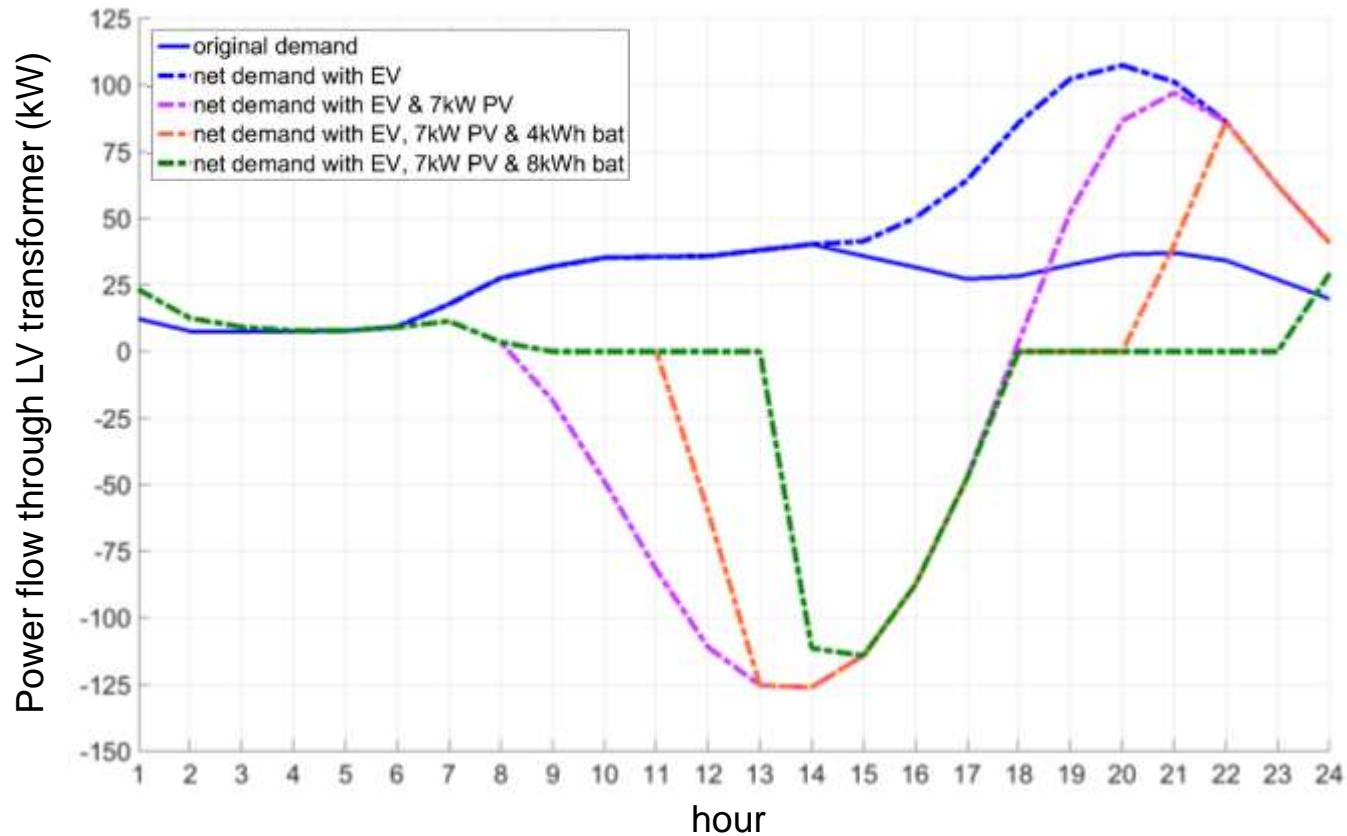
- Business case for residential battery
- Assumptions: a) res. elec. price = **.35** \$/kWh, b) res. production remuneration = **.05** \$/kWh, c) battery investment cost = **500** \$/kWh, d) battery lifetime = **15** years



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

Rising challenges - Available distribution capacity

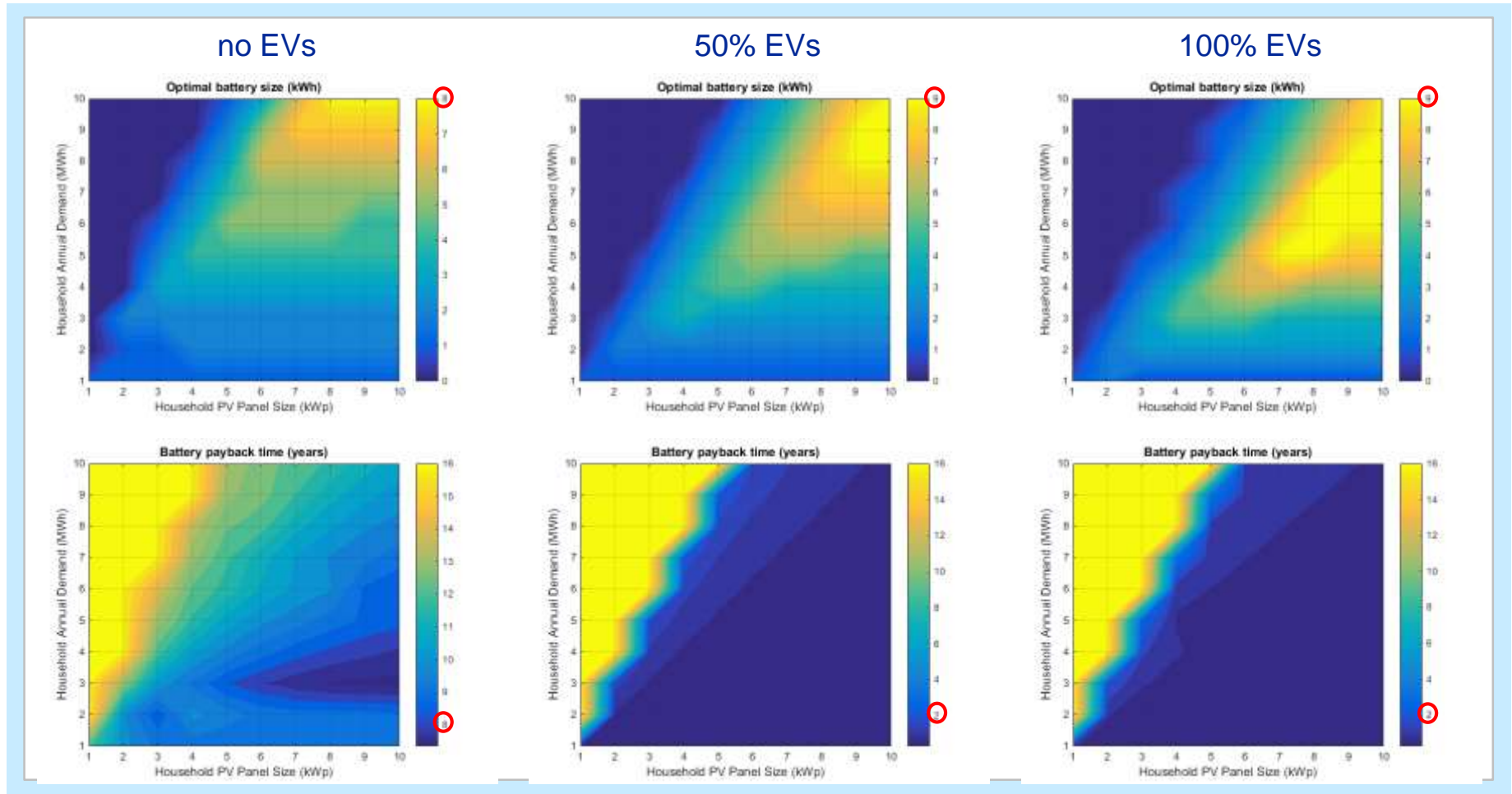
Impact of EVs on demand profile



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

Rising challenges - Available distribution capacity

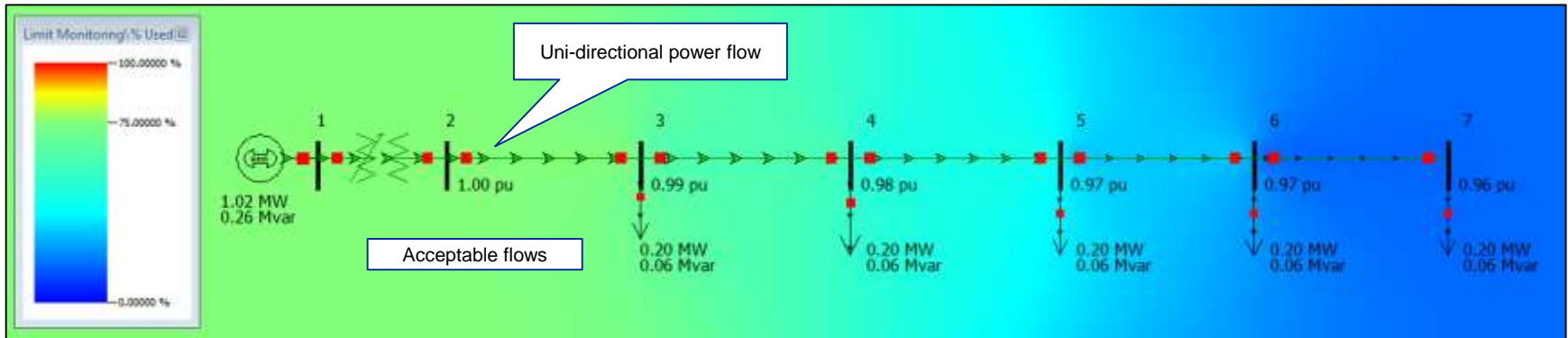
Residential PV-battery and EV economics



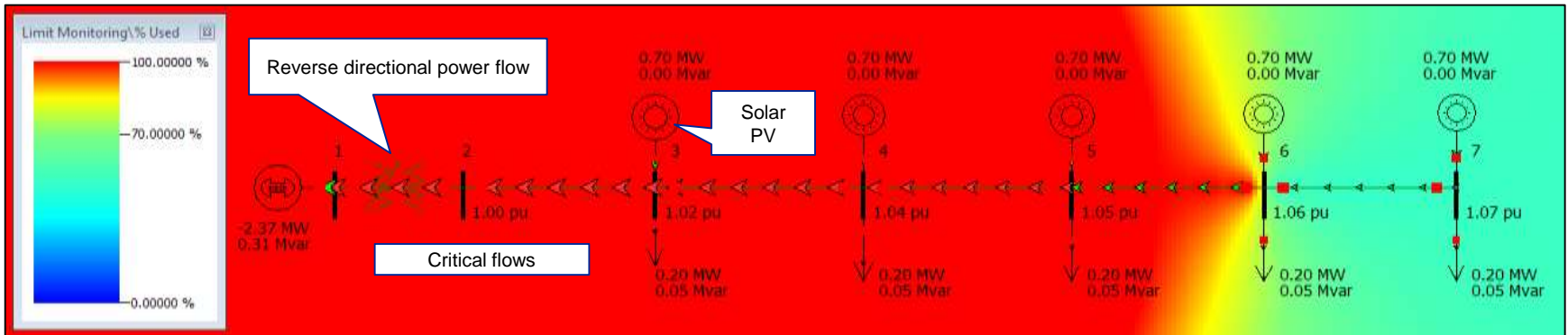
Rising challenges – Available distribution capacity

Residential PV impact on flows

- LV distribution feeder



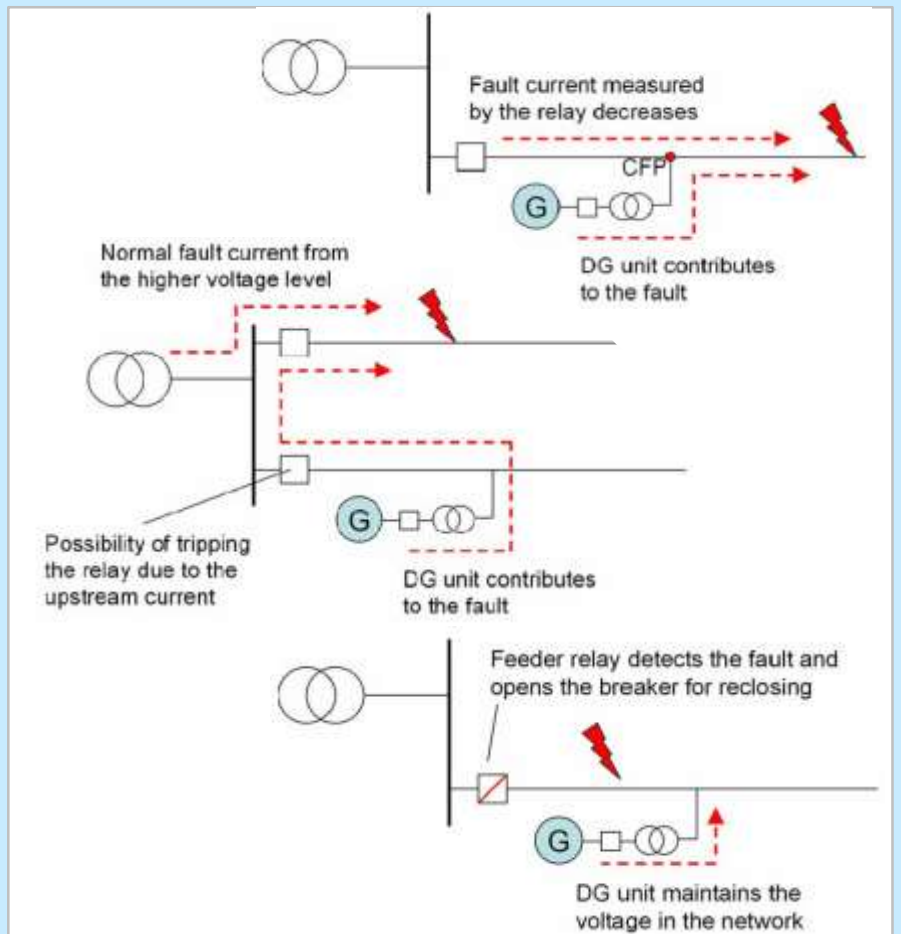
- LV distribution feeder with residential solar PV (solar PV/load = 3.5 times)



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

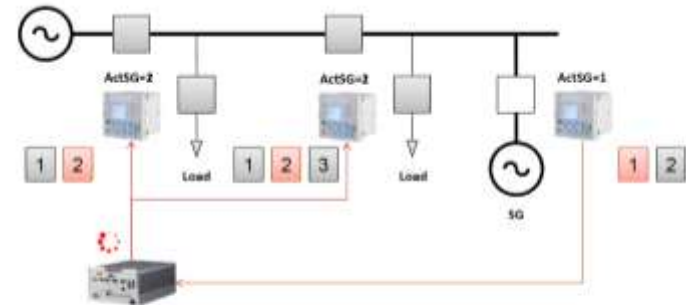
Adaptive Protection in distribution grids with DG

ABB solution:

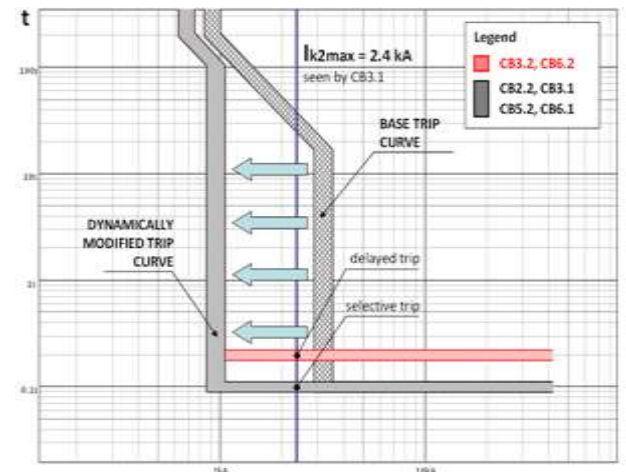
- Adjusts protection settings to correspond to the observed state of the active grid
- Accomplished by monitoring actual protection settings and DG/network connectivity
- After changes in circuit breaker status a programmable logic application executes and switches between trusted (i.e. verified by the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



1. Data (CB status) are transmitted from the end devices using unsolicited messages as conditions change. The central controller also polls each end device periodically to ensure that the end device is still healthy.
2. The central controller analyzes the network state and if necessary adapts protection settings to fit the new network configuration.
3. The central controller sends control messages (to switch settings) to the field devices.



Technology and Solutions

Adaptive Protection in distribution grids with DG

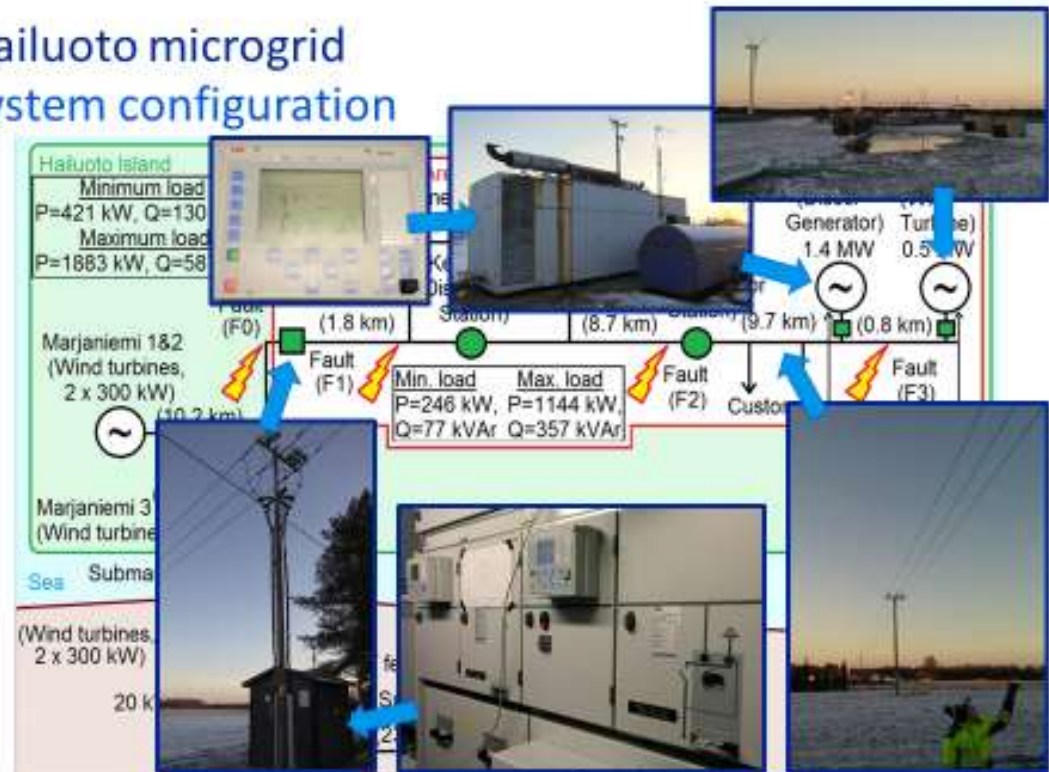
Field and Lab Tests

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

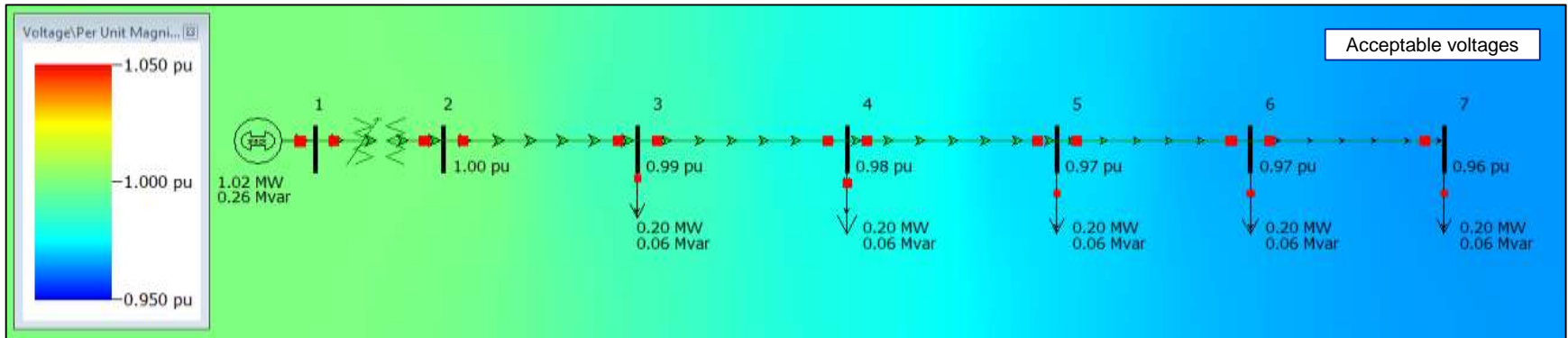
Adaptation process is limited by communication system/protocol capability and takes <100 ms in the MV case and ~700 ms (per circuit breaker) in the LV case

Hailuoto microgrid System configuration

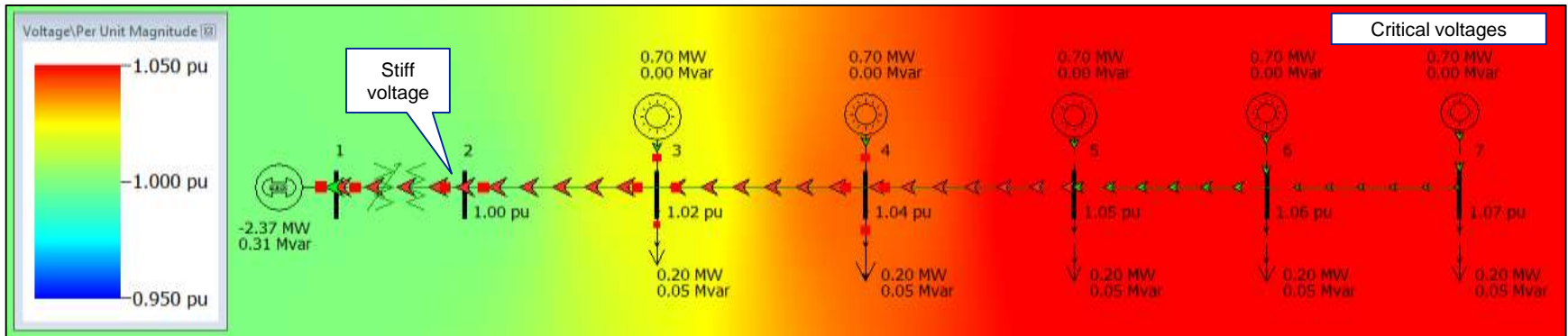


Rising challenges – Distribution voltage DG causing overvoltage

- LV distribution feeder



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

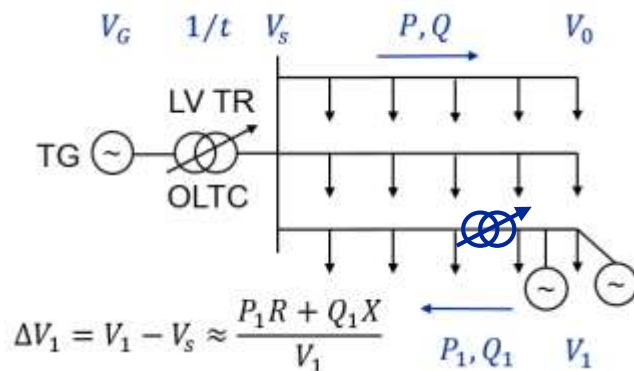


Technology and Solutions

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

Produkt information

Spannungsregler für das Mittelspannungsnetz mit RESIBLOC® Technologie

Zuverlässige Antwort auf Spannungsschwankungen

Distribution transformers

Smart-R-Trafo – voltage regulation solution for distribution transformers

Produkt information

Spannungsregler für das Niederspannungsnetz

Zuverlässige Antwort auf Spannungsschwankungen

Der innovative Niederspannungsregler ermöglicht eine automatische Anpassung des Spannungspegels im Niederspannungsnetz. Diese zuverlässige und effiziente Lösung stellt eine wirtschaftliche Alternative gegenüber konventionellem Netzschutz dar. Insbesondere bei Wind- und PV-Anwendung!

Intuitive Problemlösung

Die stark zunehmende Erzeugung erneuerbarer Stroms aus erneuerbaren Ressourcen, insbesondere durch Photovoltaik, bewirkt eine Änderung der Struktur des elektrischen Energieversorgungsnetzes. Die Verteilung des Stroms wird zunehmend ungleichmäßiger. Dies führt zu einem zunehmenden Bedarf an intelligenten Spannungsreglern, die die Spannungspegel im Niederspannungsnetz automatisch anpassen. Die ABB Spannungsregler für das Niederspannungsnetz sind das ideale Werkzeug, um dieses Problem zu lösen. Sie sind einfach zu installieren und zu betreiben. Der Vorteil des Spannungsreglers liegt darin, dass er die Spannungsschwankungen automatisch ausgleicht und so die Lebensdauer der elektrischen Anlagen verlängert. Dies ist eine wirtschaftliche Lösung gegenüber konventionellem Netzschutz.

Kundenanforderungen auf einen Blick

- Energieeffizienz und Umweltfreundlichkeit
- Flexibilität: vollständig digital
- Optimierte Spannungsregelung für hohe Spannungspegel und niedrige Schaltverluste
- Autonome Spannungsregelung auf Basis von Laständerungen
- Einfache Installation
- Hohe Lebensdauer
- Keine oder sehr geringe Wartungskosten
- Wirtschaftliche Lösung gegenüber konventionellem Netzschutz

Distribution grid evolution

Over time changes in the distribution network infrastructure and the transfer from traditional to smart grid configuration. While the type of automatic voltage regulation is unique and important for distribution system operators (DSOs). As power generation becomes more distributed and more power comes from renewable resources, the distribution grid will need to accommodate and absorb more fluctuations in power quality and increasing power flow. While becoming more responsive to changes in customer demand.

The power flow in modern networks is changing to become more complex

Traditional grid **Future grid**

Dank der hohen Flexibilität der Spannungsregelung im Mittelspannungsnetz ist es gleichzeitig möglich, Spannungsprobleme in den unterliegenden Niederspannungsnetzen zu lösen.

Kundenanforderungen auf einen Blick

- Ersatz der bewährten RESIBLOC® Transformertechnologie
- Standardisierte, vollständig digital
- Energieeffizienz und Umweltfreundlichkeit
- Leichter, anstandslos montieren in Stationen
- Einfache und schnelle Installation
- Optimierte Spannungsregelung für eine gute Spannungsqualität und minimale Schaltverluste
- Autonome Spannungsregelung auf Basis von Laständerungen oder unabhängigen Sensoren
- Anbindung an Netzsysteme zur Fernsteuerung oder Überwachung des Netzes möglich
- Einfache Anbindung an das bestehende Niederspannungsnetz
- Die Änderung der Netzstruktur an neuen Standorten möglich
- Erhöht den Einsatz von OHTL durch RCHT
- Wirtschaftliche Lösung gegenüber konventionellen Netzausbau


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

Better Inverters
ABB monitoring and communications
PVI-PMU



ABB's PVI-PMU enables customers to control active and reactive power of the inverters in accordance with IEEE 1547-2008 and IEEE 1547-2018.

Thanks to its two RS485 ports, the PVI-PMU can be used for controlling the power generated by ABB inverters in PV plants where an external data acquisition system has been installed.

The proprietary Aurora Protocol is the communication protocol the PVI-PMU uses to exchange data with an ABB inverter. Meanwhile, the power control management commands, sent by an external source, are received through a dedicated analog and digital inputs.

The PVI-PMU provides control functions of active power in different operating power control.

The combination status and the analog inputs and active power control.

1. Active power
2. Active power
3. Continuous active power
4. 0-100 mA analog inputs.

Using the combination of analog and digital inputs, two different reactive power management operating modes are selectable:

1. Fixed $\cos(\phi)$ based on the inverter's nominal power
2. Fixed $\cos(\phi)$ based on inverter instantaneous power

Using the combination of analog and digital inputs, two different reactive power management operating modes are selectable:

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Power and productivity for a better world™ **ABB**

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

ABB PV + Storage
REACT-3.6/4.6-TL
3.6 to 4.6 kW



ABB energy solutions with energy storage systems, can help increase self-consumption and energy self-sufficiency.

One of the biggest challenges with solar energy is that it is intermittent and its output is not constant. Moreover, the limited A to D conversion range, storage and load management capability with a dedicated PV inverter.

In this way, self-consumption and energy self-sufficiency can be increased significantly.

The combination of the technology with storage can increase the self-consumption of solar energy and reduce the grid dependency of the system.

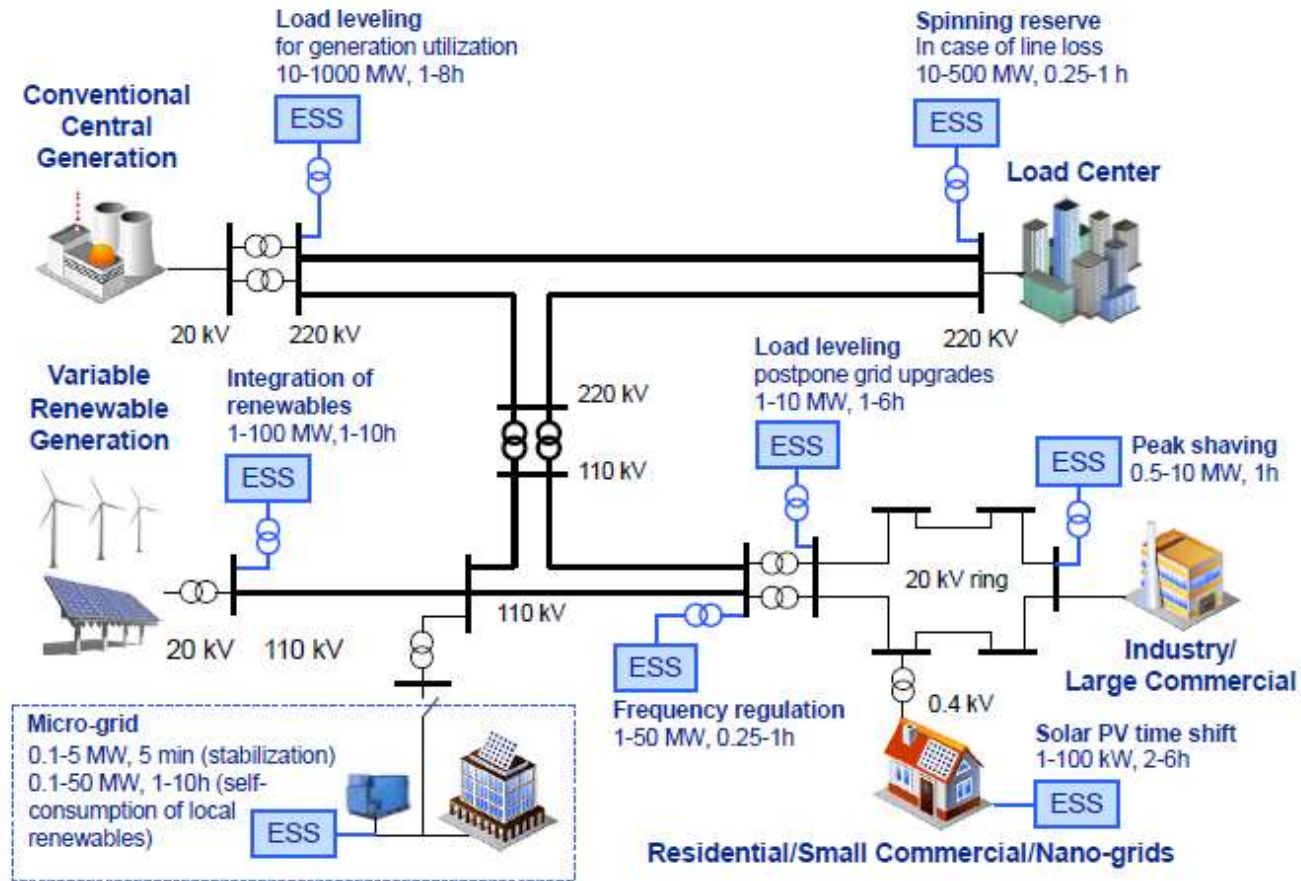
The advantages of a single fully integrated system:

- Contribution of all the energy flows with the goal of aligning PV energy production and home consumption.
- ABB's integrated architecture, an all-in-one solution.
- One unit, one interface, with simple installation, to monitor, manage and control production and storage from one place.



Technology and Solutions

Battery energy storage: overview of the applications

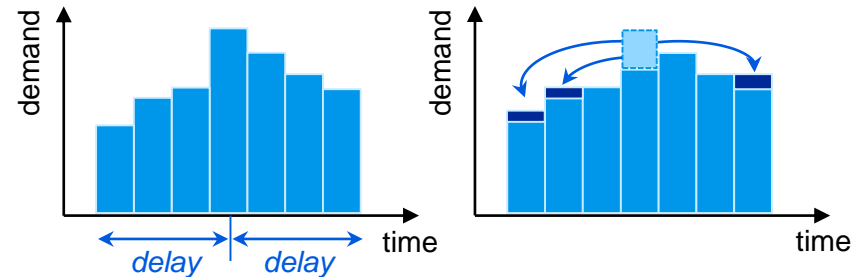


Technology and Solutions

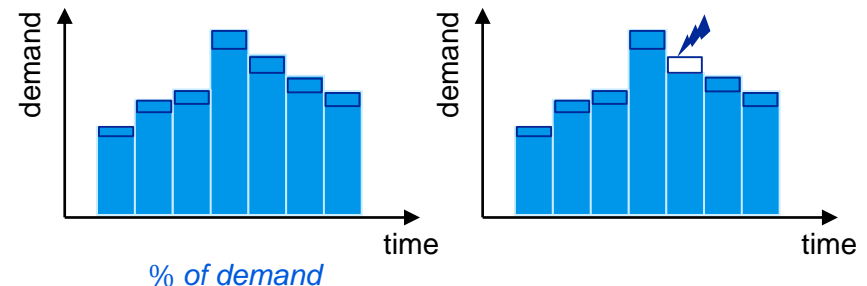
Demand side management: types of demand response

- 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

Energy time shift



Ancillary services



Technology and Solutions

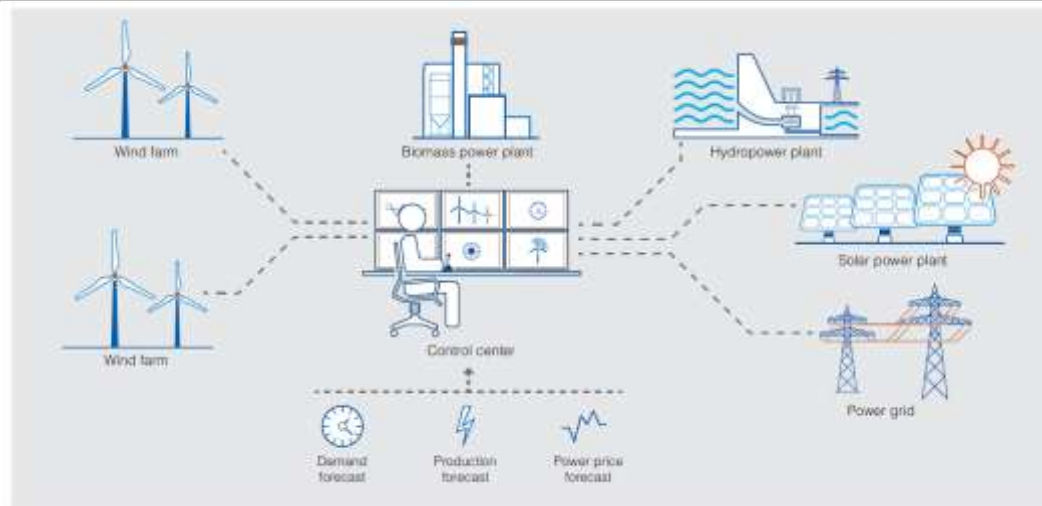
Virtual Power Plant (VPP)

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

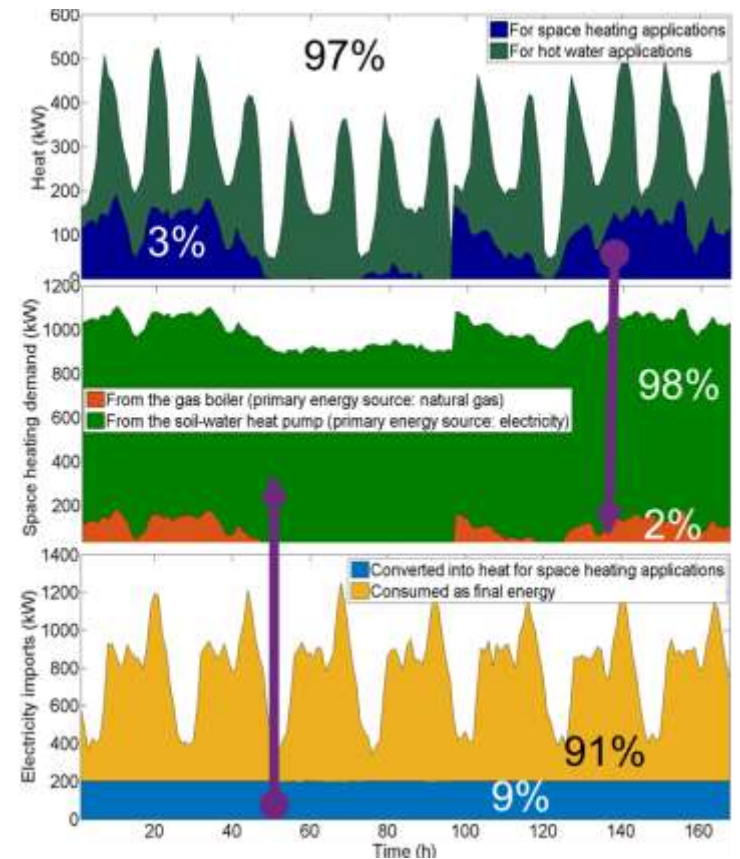
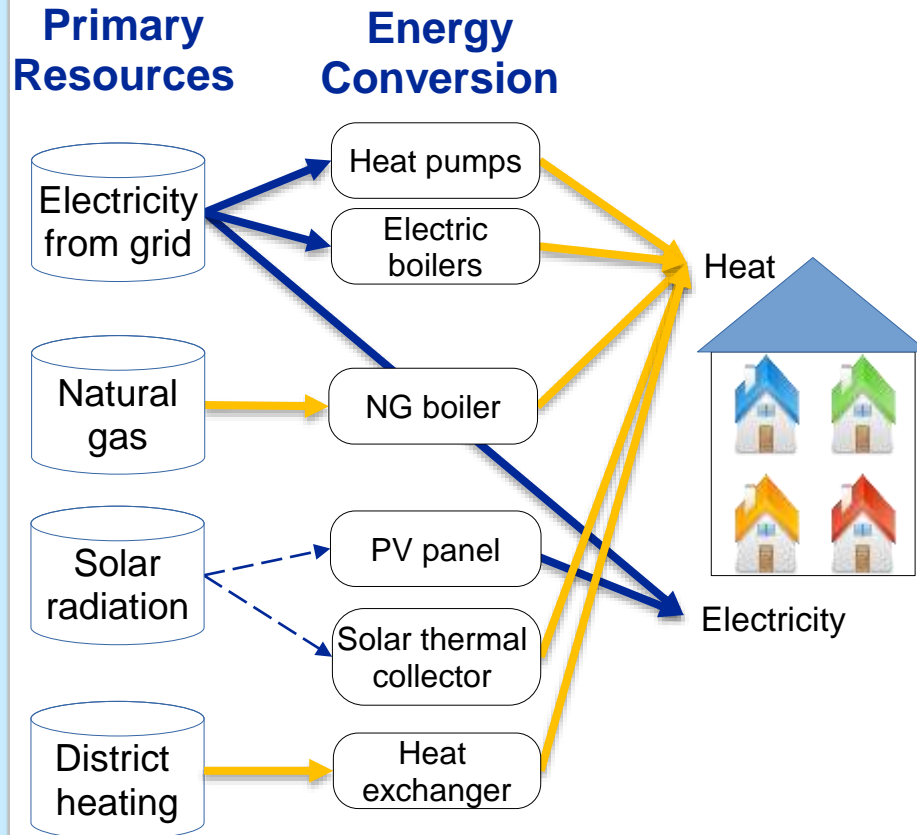
- Monitoring
- Control
- Management
- Automation
- Protection
- Interaction with transmission grid operator

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!

Special thanks to the Power and Energy Systems Group at ABB Corporate Research –
A.Oudalov, C. Y. Evrenosoglu, A. Marinakis, M. Zima for the materials in this presentation

Power and productivity
for a better world™



Technology and Solutions

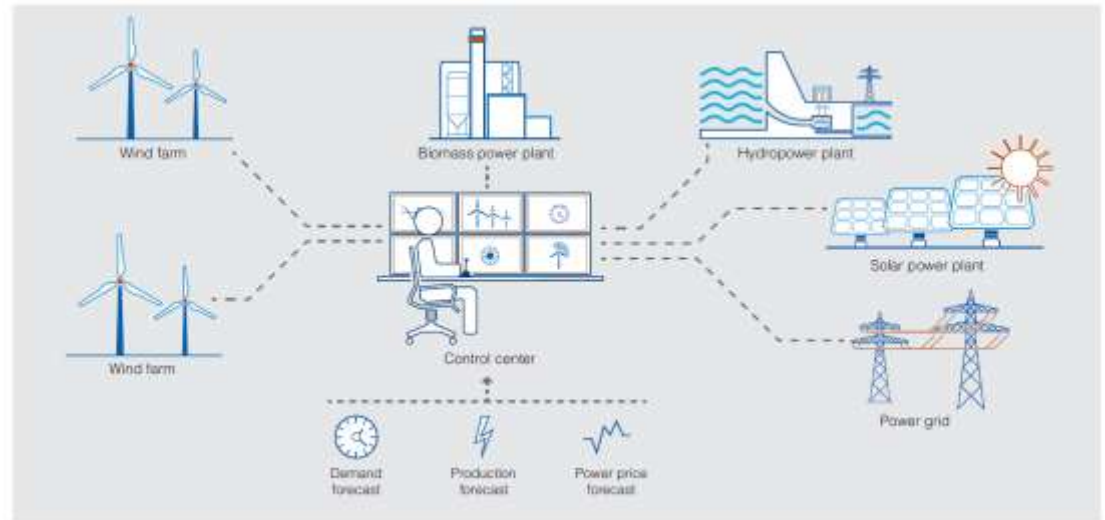
Virtual power plant - Optimax Powerfit

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 Erzeugungseinheiten 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

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

