RWE

Large Scale Battery Storage System

Today’s & future usage in power grids

Workshop: Operation of Thermal Power Plant: A bridge to decarbonized energy system

12.10.2023

Raipur - India | Essen - Germany (Remote)

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V1.1

Purpose of this presentation

- Today's power grids and the challenges + opportunities we face as part of the **energy transition**, especially in respect to design and operation

- How storage can help to **increase flexibility** in the power grids, especially when facing fundamental changes in power generation (thermal + renewable)

- Providing insights in how **renewable energy** sources in conjunction with **energy storage** have been deployed in power systems already

Agenda

1	Introduction Team RWE - Storage Engineering	**5 min.**
2	Today's power grids and their needs amidst current energy transition (power system stability)	**10 min.**
3	Energy Storage Systems for today's & future power grids (power applications)	**10 min.**
4	RWE – Battery Power Plants	**5 min.**

1 Team RWE Storage Engineering

RWE Storage Engineering

Who we are

Team	**~60 EMPLOYEES** employees distributed globally (US, EU, APAC)	**~13 NATIONALITIES** diverse and dynamic	**9 YEARS** track record of delivering energy storage projects
Project development, construction & technology	**~1,325 MWh** energy storage project in execution worldwide	**660 MWh DC** largest project currently in execution	**17** stationery and EV batteries integrated
Outlook and ambition	**15,000 MWh** RWE storage pipeline	**15** countries in which we will operate projects	**TOP 5** ambition to be within first 5 storage players

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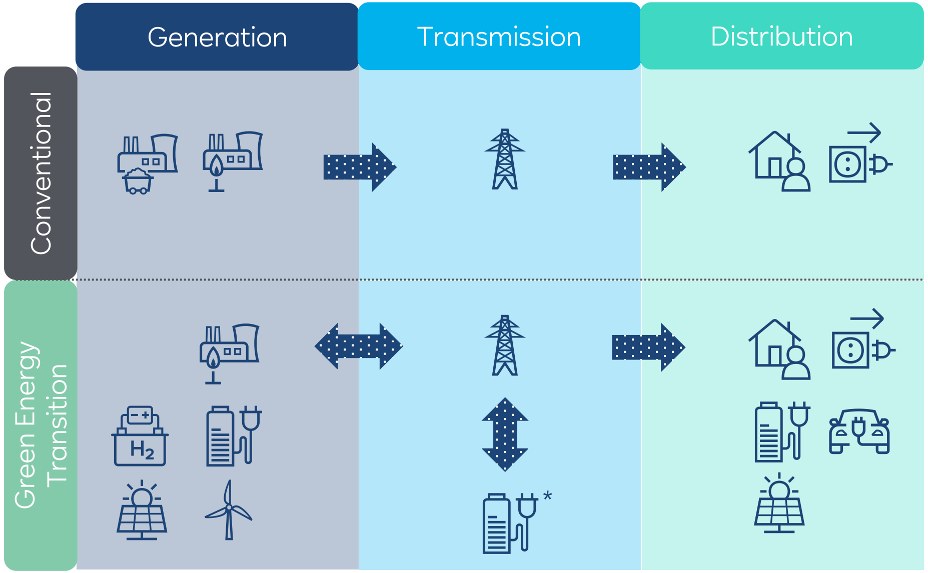
Power grids amidst today’s energy transition

Today's Power Grid

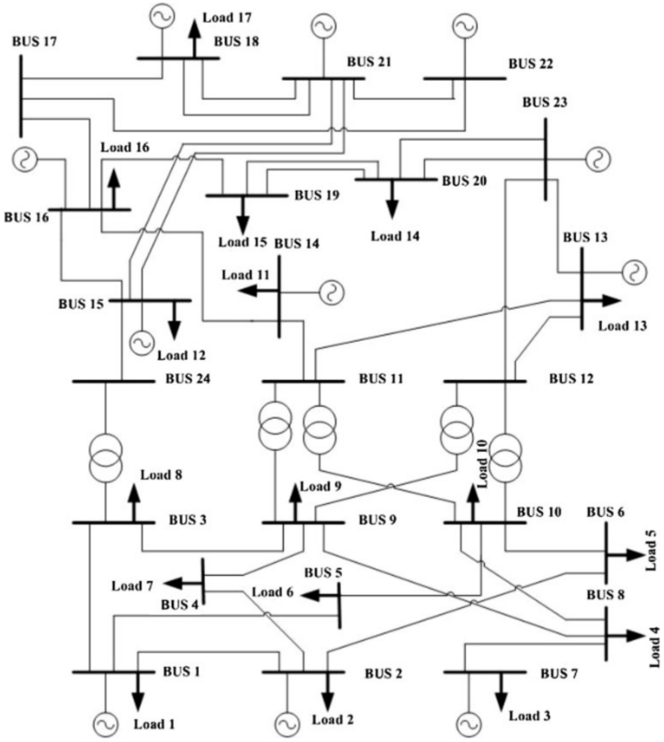
- Typical concept of generation, transmission and distribution of electric energy
- Transmission system build around centralized power plants, close to industry
- Decentralized renewable energy source (wind, solar, bio-mass) deployed
- **Complexity** of the over all power system is **increasing**:
  - Bi-directional power flow
  - Quantity of intermittent power generation units rapidly increase (add. power nodes)
  - New assets with different dynamic behaviors that contribute to the change the overall power system dynamic



*in exceptional cases

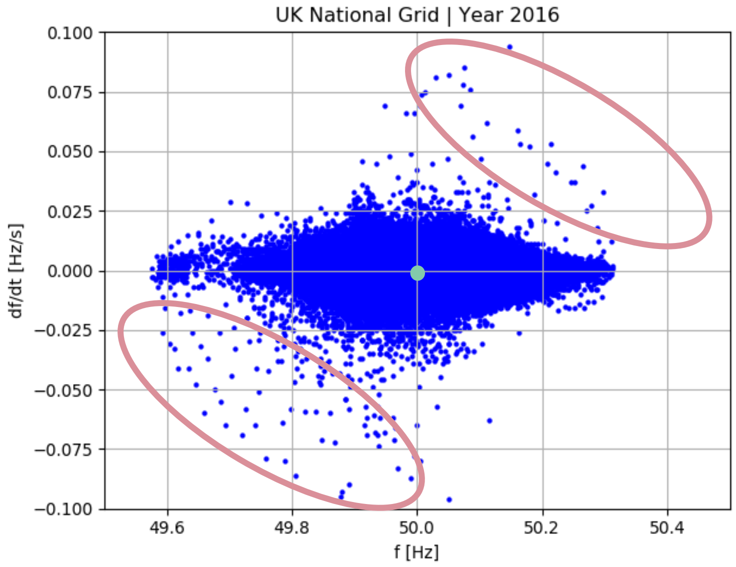
Today’s Power Grid

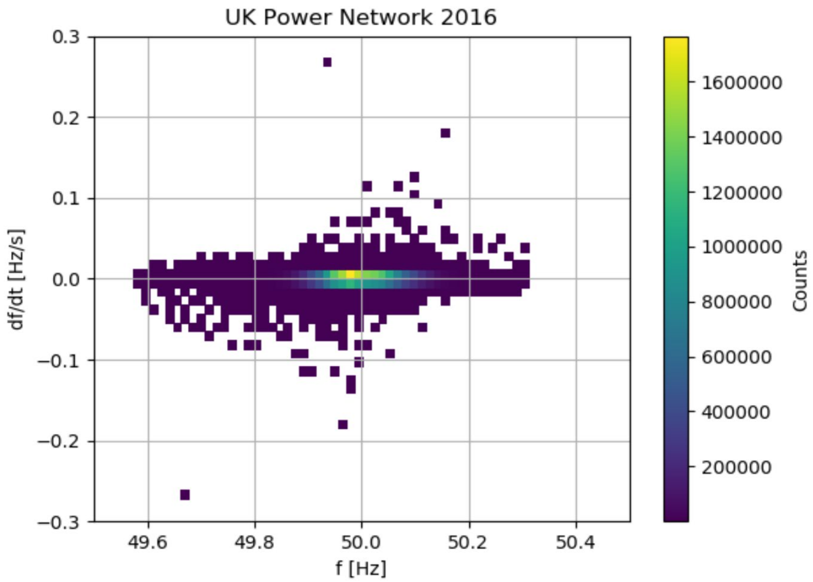
- Today’s power systems consist of thousands of power nodes, bus-bars, generation assets, transformers, consumers with different characteristics
- Each deployment of new renewable energy sources or removal of conventional power plants is posing a change to the overall power system
- All changes in the system need to be assessed in advance in order to examine the potential impact on the power system - Load flow analysis, protection studies, transient Analysis, etc.
- **Flexibility** within the power grid becomes essential



Source: Composite power system reliability evaluation using modified minimal cut set approach, T. Bharath Kumar | https://www.sciencedirect.com/science/article/pii/S1110016817302934#f0020

Today's Power Grids
Grid frequency – UK 2016





*Source: Frequency Data – National Grid UK,
Report: Master Thesis – Deployment of large-scale energy storage systems in power grid for ancillary services, 2018-06-11, Christian Kurfiß | University of Queensland –St. Lucia, Australia

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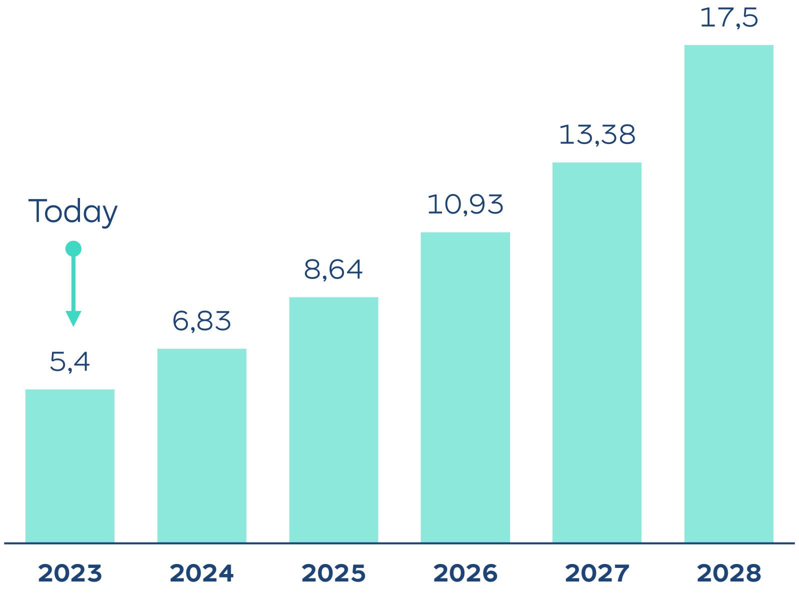
Energy Storage Systems for today’s & future power grids

Market Size
Battery Energy Storage

- Transition to **green energy** with its new power applications is demanding more energy storage solutions, thus pushing the market for battery storage
- New production lines and subsequently '*economy of scale*' effects are reducing costs for battery cells/modules
- Cost-advantages on technology side + increasing need for system services (ancillary market) result in a positive business case for '**large-scale-energy storage systems**'
- Currently in a 'bullish' market environment with high growth rates

+220% in 5 years

Forecast battery energy storage market value worldwide (in billion U.S. dollars)



Source: https://www.statista.com/statistics/1307133/forecast-battery-energy-storage-market-value/

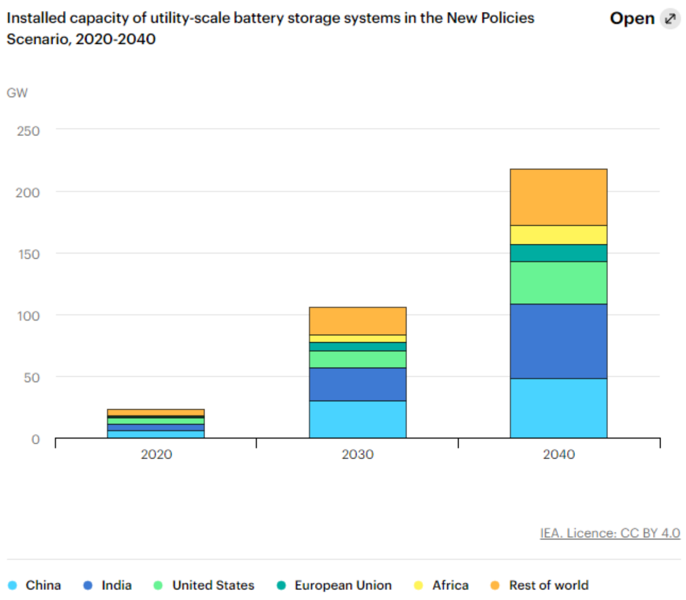
Market Size
Battery Energy Storage

> *Another factor set to drive the battery storage boom is the **need for peaking capacity**, which is projected to increase by three-quarters globally to 2040 … **batteries become competitive on a cost and value basis in many regions …***

Region	2020	2030	2040
World	21 GW	106 GW	220 GW
India	5 GW	27 GW	61 GW

IEA

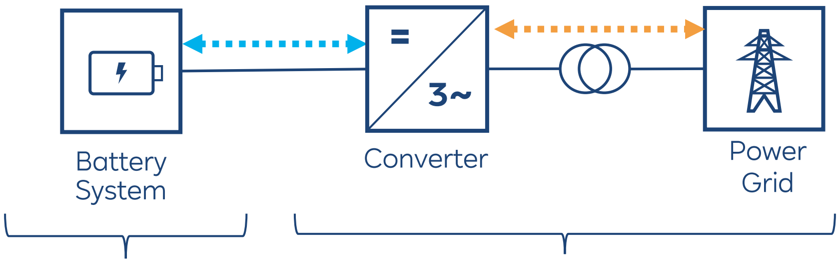
"Battery Storage is (almost) ready to play the flexibility game", iea.org, 7th Feb. 2019, Mrs. Claudia Pavarini



Source: https://www.iea.org/commentaries/battery-storage-is-almost-ready-to-play-the-flexibility-game/

Battery Energy Storage System

Main components



Energy Storage

- Large-Scale energy storage system can serve as short-term storage to make large amounts of renewable energy quickly accessible to the power grid
- **Equalizes supply & demand**

Power Converter

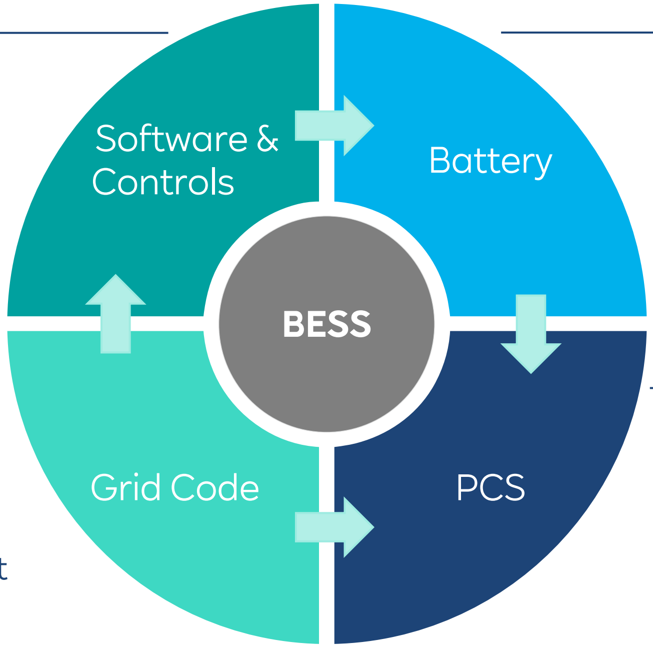
- Limiting the need for grid expansions as battery storage can reduce 'congestions' in the transmission lines
- PCS in '**grid forming**' mode can dynamically **stabilize** and control power grids in the future

Battery Energy Storage System

Factors for success

Software & Controls
Battery Storage Plants req. tailored plant control solutions. Agile development environment is essential.

Battery System
Energy storage unit. Primarily based on Li-Ion technology which improved over recent years

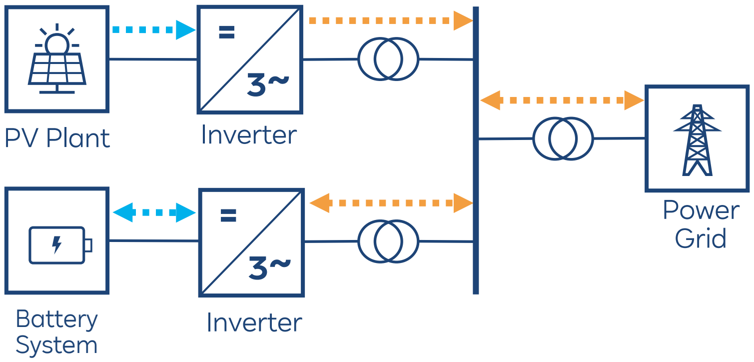


Grid Code Requirements
System performance requirements for new technologies. Agnostic approach needed. Available technologies not fully incorporated yet.

Power Conversion System
Power converter (AC/DC) Strong impact on overall system performance

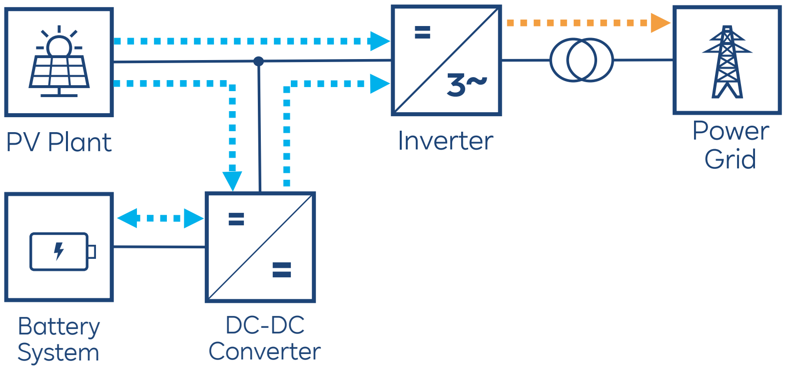
Hybrid Power Plants
Solar & Storage

AC-Coupled

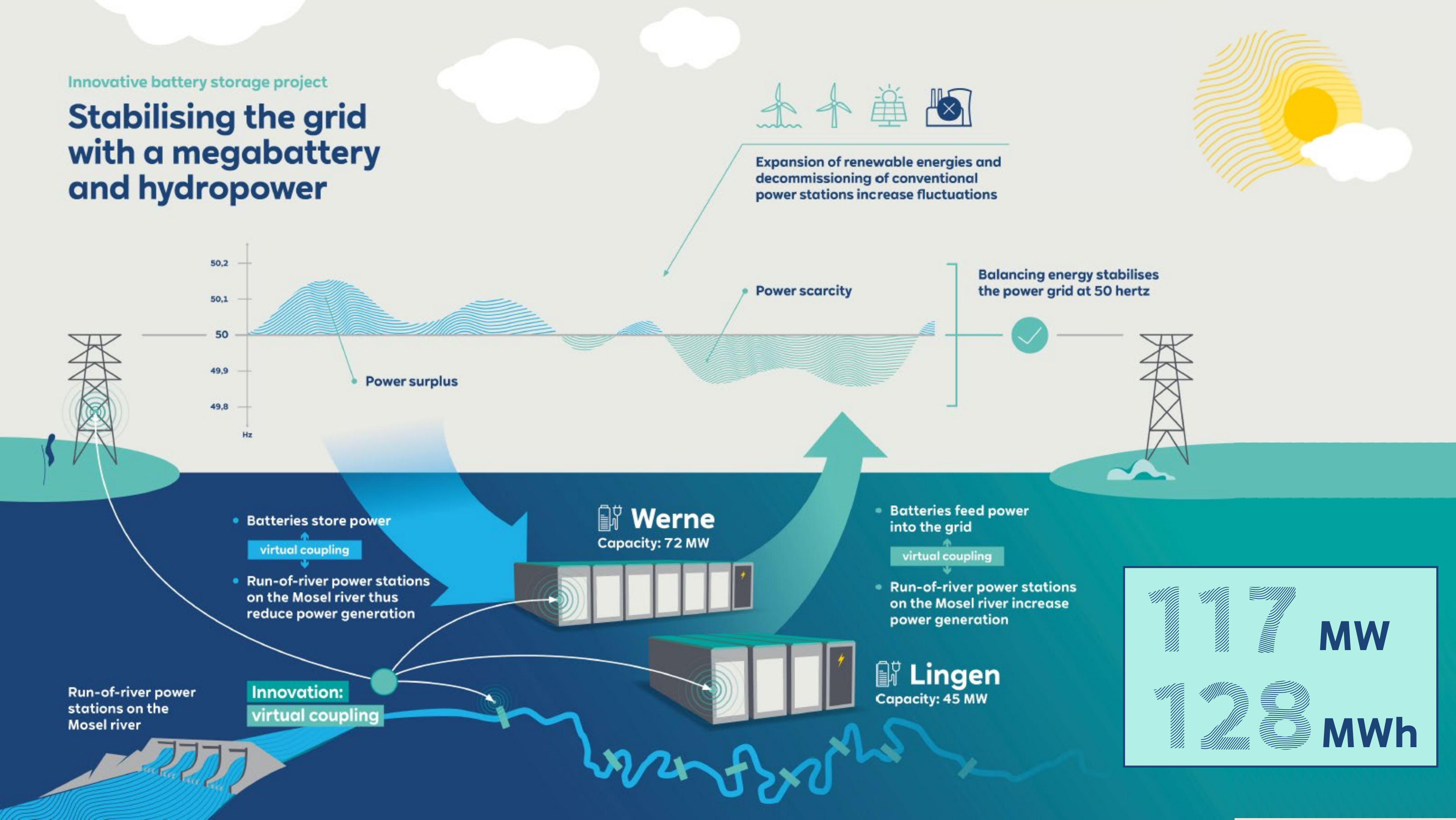


- Multiple Power Conversion Systems (Converter) for each power asset
- Connected to common bus on AC-side

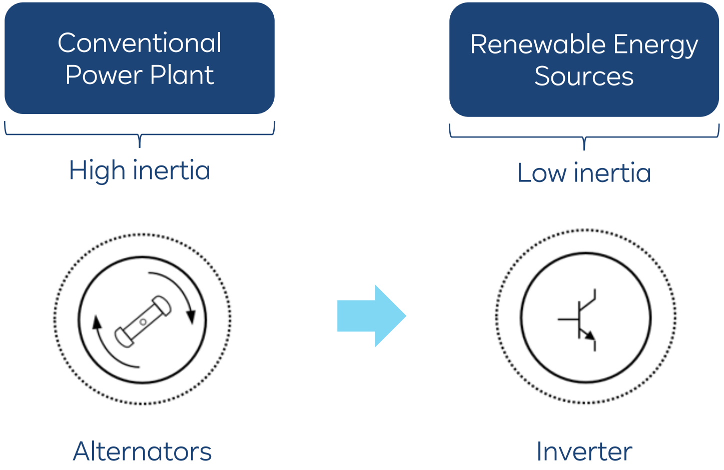
DC-Coupled



- Centralized power conversion system
- Connected to common bus on DC-side

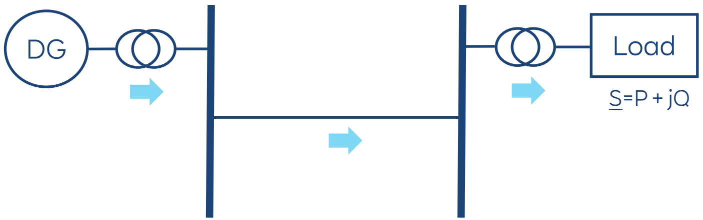

Innovative battery storage project
Stabilising the grid with a megabattery and hydropower
Expansion of renewable energies and decommissioning of conventional power stations increase fluctuations
50,2
50,1
50
49,9
49,8
Hz
Power surplus
Power scarcity
Balancing energy stabilises the power grid at 50 hertz
Batteries store power
virtual coupling
Run-of-river power stations on the Mosel river thus reduce power generation
Werne
Capacity: 72 MW
Batteries feed power into the grid
virtual coupling
Run-of-river power stations on the Mosel river increase power generation
Lingen
Capacity: 45 MW
Run-of-river power stations on the Mosel river
Innovation: virtual coupling
117 MW
128 MWh

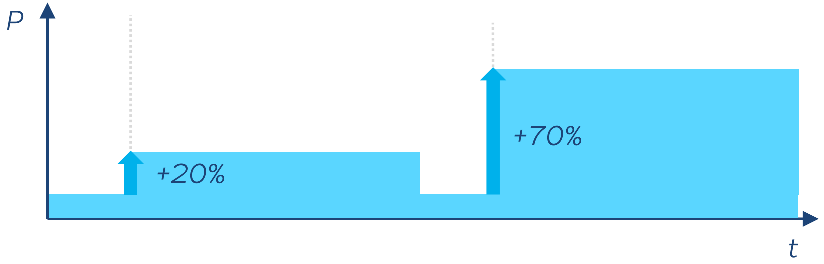
Today’s Power Grid
System Dynamics



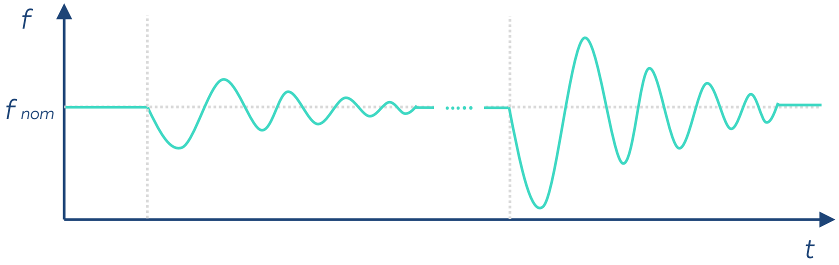
- Conventional power system are based on alternators (rotating masses)
- These rotating masses inherently have inertia, the ‘*degree of continuation in its current motion*’
- The sum of all rotating masses in a power system form the overall system inertia which is damping rapid changes in power supply/consumption
- Diminishing number of rotating masses posing a risk of grid instability – countermeasures are essential to increase **renewable share** while maintaining **power system stability**
- Battery systems + renewable energy sources based on power conversion systems are able to provide **‘synthetic inertia’** – new controls!

Power System Stability
Conventional Power Plants





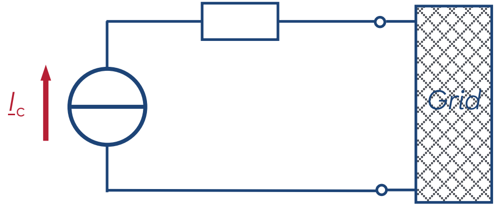
- Conventional power supply based on combustion processes (diesel/gas) + alternators
- Rapid changes in load will cause frequency fluctuations as an overall system response
- Level of inertia + level of instant load jump impacts the degree of frequency excursions



Power Conversion System
Modes of operation

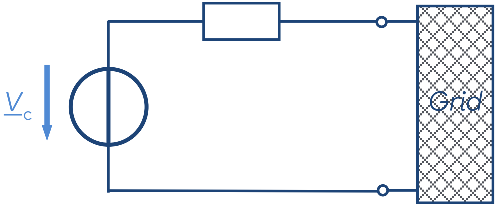
Current Controlled

- Inverter is acting as a '**current source**' and requires voltage to be provided by other sources such as an alternators
- Shifting phase angle allows provision of active power P and reactive power Q at full range. Power factor 0-1, ind. & cap.
- Grid Support controls implemented (FRT, P(f), Q(V), etc.



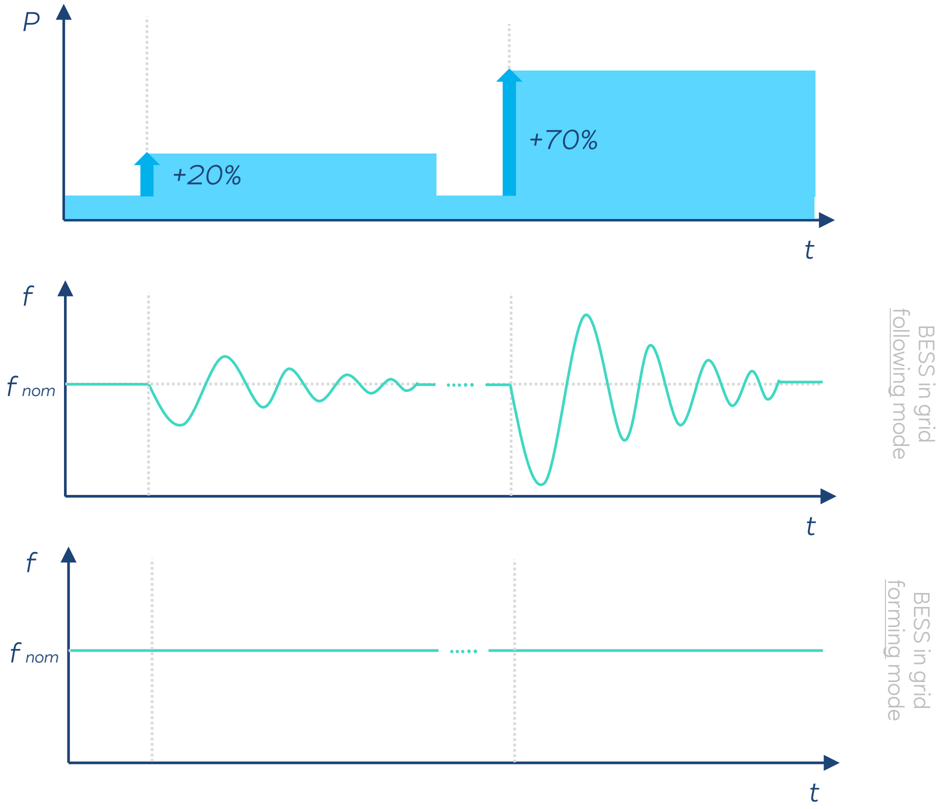
Voltage Controlled

- Inverter acting as a **'voltage source'** and provides both, voltage + current (**grid forming**).
- System behavior and system response fundamentally different to alternators such as synchronous machines. Frequency & voltage can be controlled **easier and faster**
- Grid Support controls implemented (Inertia, f(P), etc.)



Power System Stability
Key component

- In contrast to alternators, semi-conductor based power conversion system can **'define' the grid-frequency independently**
- In grid-forming mode (isochronous), an inverter can cope with instant load jumps of >100% without notable changes in grid frequency
- This behavior can be defined via software controls and algorithms tailored to the needs of the individual power system
- **PCS units + Software are the key components for grid stability** and enable the operator to make use of the full range of available **renewable sources**



*Scenarios with low inertia in the power grid

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RWE Battery Power Plants


Location: Germany
Size: 15 MW | 15 MWh
In operation: Q4 - 2018
Owner & Operator:
eins energie in Sachsen GmbH


Location: Germany
Size: 15 MW | 15 MWh
In operation: Q4 - 2018
Owner & Operator:
eins energie in Sachsen GmbH


RWE
Location: Germany
Size: 45 MW | 49 MWh
In operation: Q3 - 2022
25VD
SUNNY CENTRAL STORAGE UP
SMA


RWE
25VD
Location: Germany
Size: 45 MW | 49 MWh
In operation: Q3 - 2022


RWE
Location: Ireland
Size: 60 MW | 34 MWh
In operation: Q3 - 2022


RWE
Location: USA, TX
Size: 37 MW | 37 MWh
In operation: Q3 - 2023


RWE
Location: USA, CA
Size: 137 MW | 486 MWh
In operation: Q2 - 2023


RWE
Location: USA, TX
Size: 100 MW | 200 MWh
In operation: *In construction*

Thank you for your attention

| www.rwe.com/