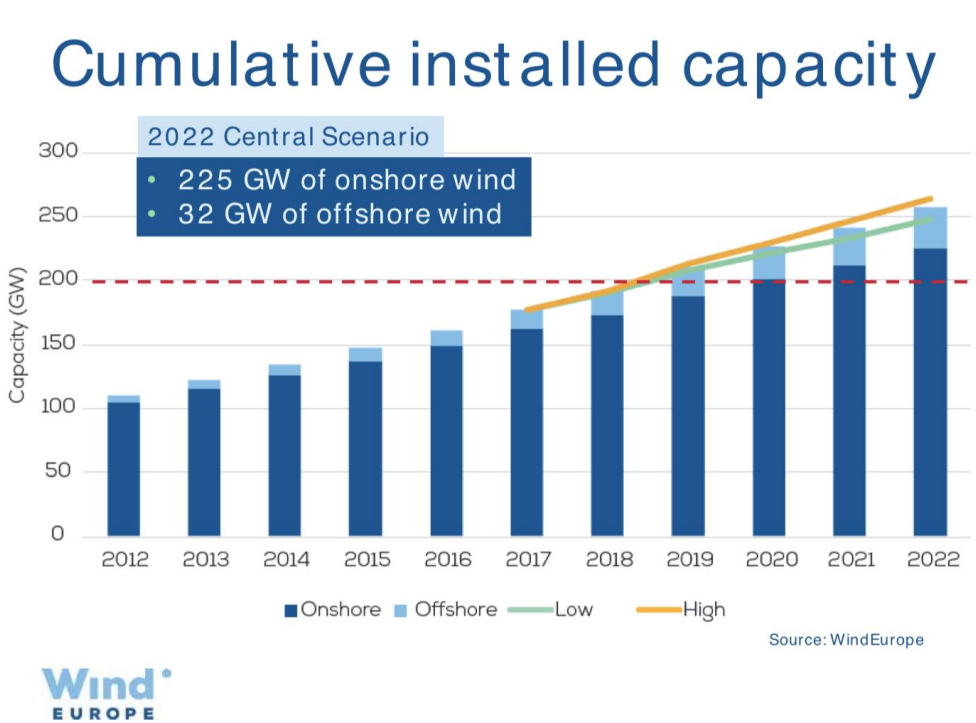
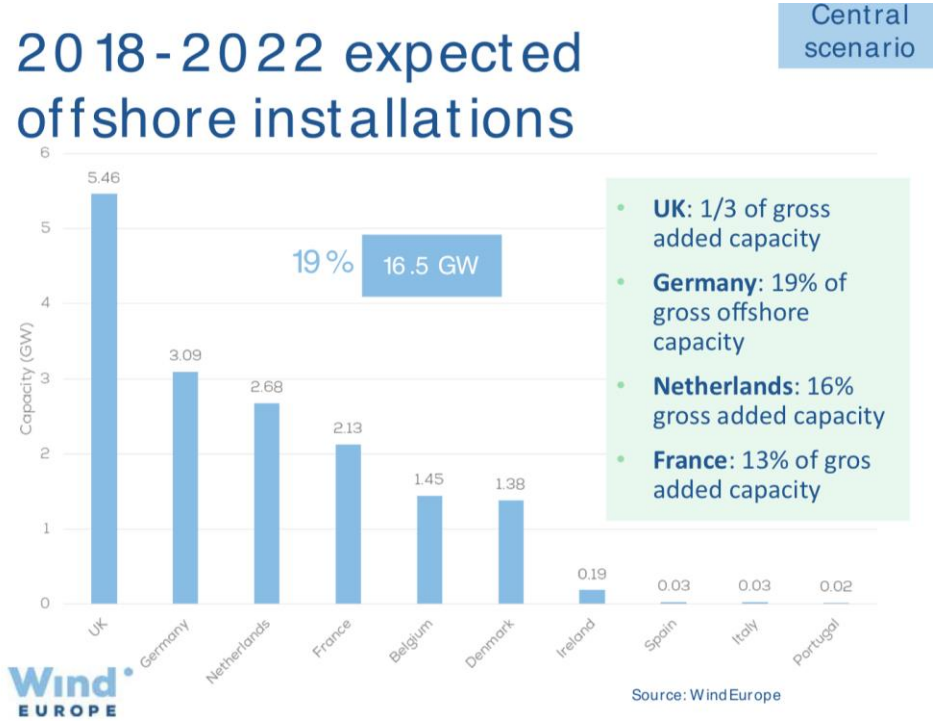
HAMBURG, 27 SEPTMEBR 2018

How technology development will enable a most cost efficient grid development?

Setting the scene – European offshore wind market outlook

Offshore wind installed capacity: 30 GW by 2022 … and another 30 GW by 2028





Large amount of power generation concentrated and decentralized from consumer: we need to think big

 Dara source: WindEurope and Make Q2/2018 market outlook

Scale and collaboration will drive costs down

Oersted ABB partnership

ABB wind order to connect world largest offshore wind farm

- Hornsea2
- 1.4 GW - clean power for more than **1.3 million homes** annually
- **100 km** from shore - AC connection
- ABB scope
  - Onshore and offshore **transformers**
  - Onshore and offshore **high voltage GIS**
  - Reactors and variable shunt **reactors**
  - **Harmonic filters**
  - The largest **FACTS** system to connect offshore wind to the grid
  - ABB Ability™ enabled MicroSCADA **automation**
  - Advanced mission critical technology **communications**

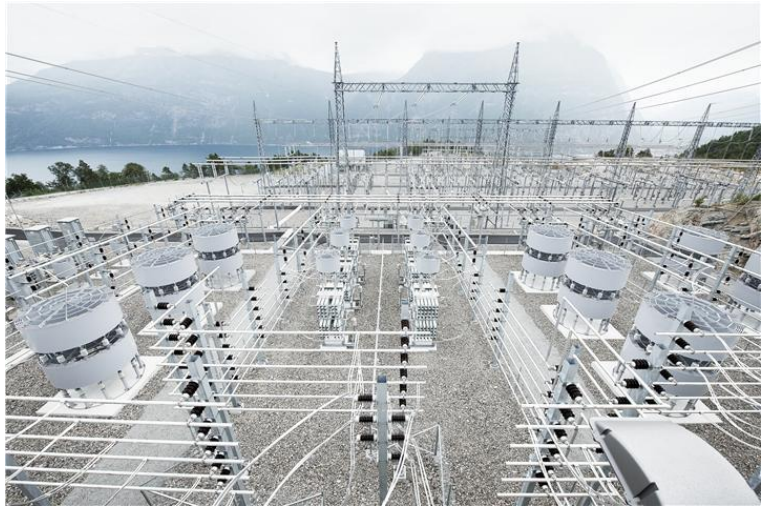
Collaboration Ørsted ABB

- Address the **complete grid connection** system
  - onshore and offshore substation
  - one common substation automation platform
  - grid code compliance
- **Standardization** and **modularization** to deliver on a solid project pipeline
- **Lead time** reduction: design, specification, contracting, delivery, installations and commissioning. All phases can be optimized under the framework.
- **Technology** collaboration between the largest offshore wind developer and the leading T&D technology supplier embracing digital, … enabling total project cost reduction
- **Early collaboration** and ABB global footprint contributes to derisk projects as offshore enters into new markets

Use existing technologies

Increase transmission capacity

FATCS



- Static VAR compensation (SVC)
- SVC Light or STATCOM
- Series compensation

Characteristics and benefits

- Dynamic control of voltage and reactive power flow in the network, assuring voltage stability and optimal reactive power balance
- Active power flow through AC transmission lines in order to increase power transfer capacity and mitigate disturbances.
- Grid code compliance (LVRT, HVRT)
- Improve power quality allowing for active filtering of harmonics and flicker from WTG, cables and capacitors at PCC
- Assure a safe and reliable system operation (switching transients)
- Line loss optimization by load flow control

An advance reactive power control of the grid increase the transmission capabilities

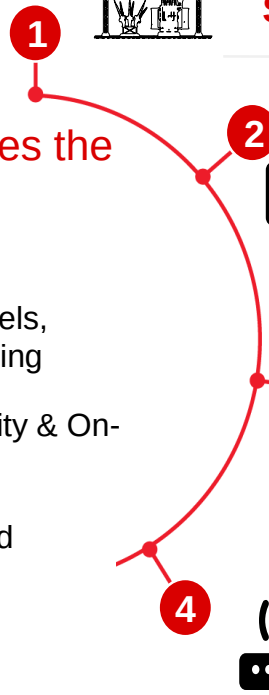
Unlock grid flexibility

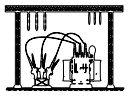
Digitalizing the grid

ABB Ability™ enables the digital grid

Key Capabilities

- Common data models, services & onboarding
- Cloud Interoperability & On-premise instances
- Digital channels and ecosystems





Digital Substation

Future grid needs flexible, real-time managed integrated **T&D** approach (protection, control, monitoring & communication)

Connected Asset Lifecycle Management

Automated business operations for maintenance

Vendor agnostic platform with packaged policies & analytics

Converged, Automated Operations and Planning

Digital Distribution

Integrated ADMS & DERMS s/w , multiple Digital assets for distribution operations , [Microgrids, BESS,

Seamless integration of utility and non-utility data (public and private cloud services) enables new business models & markets

Communication & Cybersecurity

Key enabler for effective deployment of other solutions

Digitally-enabled Services with increased customer connectivity, awareness & increasing value

Electricity market management

Integrate renewables in the energy market

Energy trading platforms

- ABB Network Management (MMS)
- ABB Market Management System

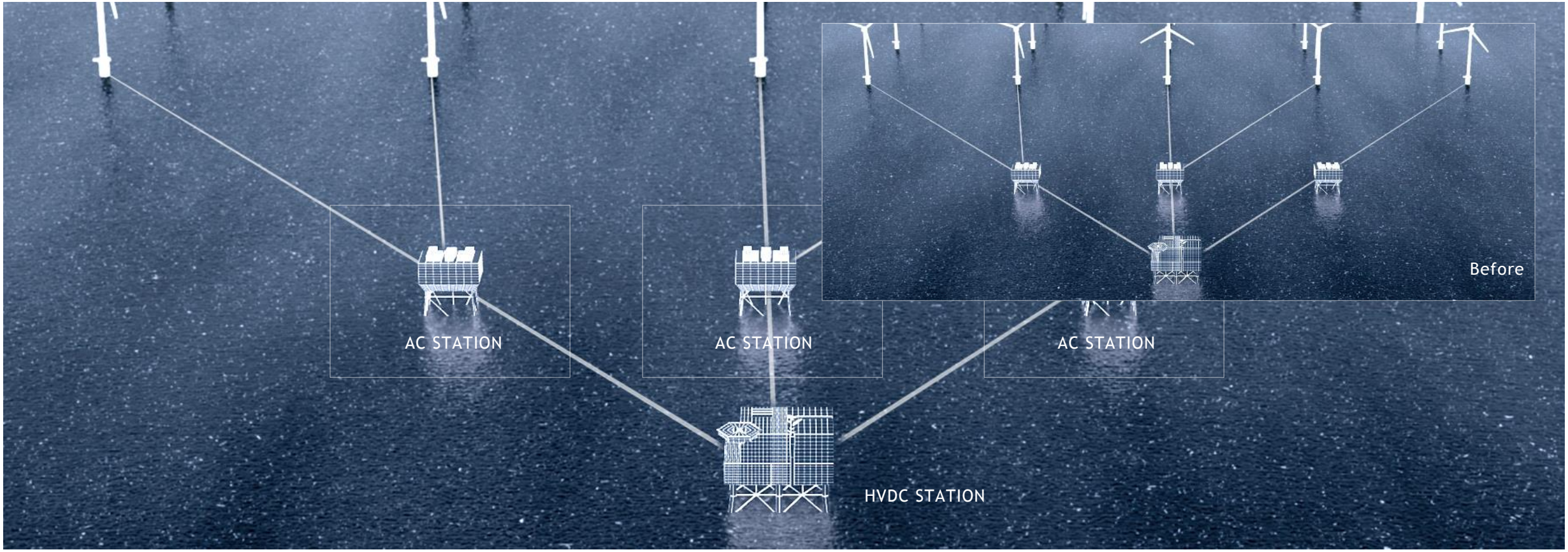
Characteristics and benefits

- Market clearing and congestion management for nodal and zonal markets for forward, day-ahead, week-ahead, intraday and real-time/ balancing timeframes
- Support regional market integration across both highly AC-meshed and/ or HVDC connected grids
- Wholesale trading and co-optimization of energy, ancillary services and financial transmission rights
- Incorporation of phase shifters within dispatch and scheduling optimization
- Resource and network modelling including (N-x) contingencies and transmission protection schemes

Software solution to enable synergies between market and renewable energies

Improve existing technologies

Eliminating the need for AC substations

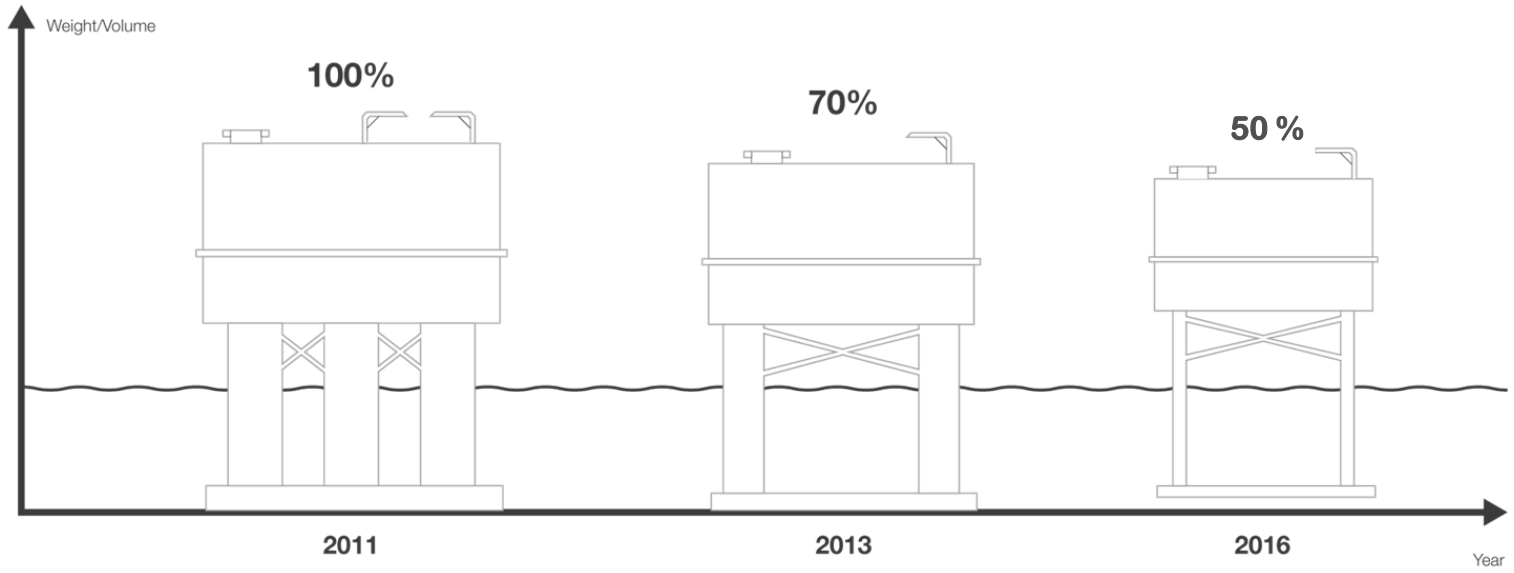


Improve existing technologies

HVDC offshore wind compact solution: 50% reduction in weight/volume

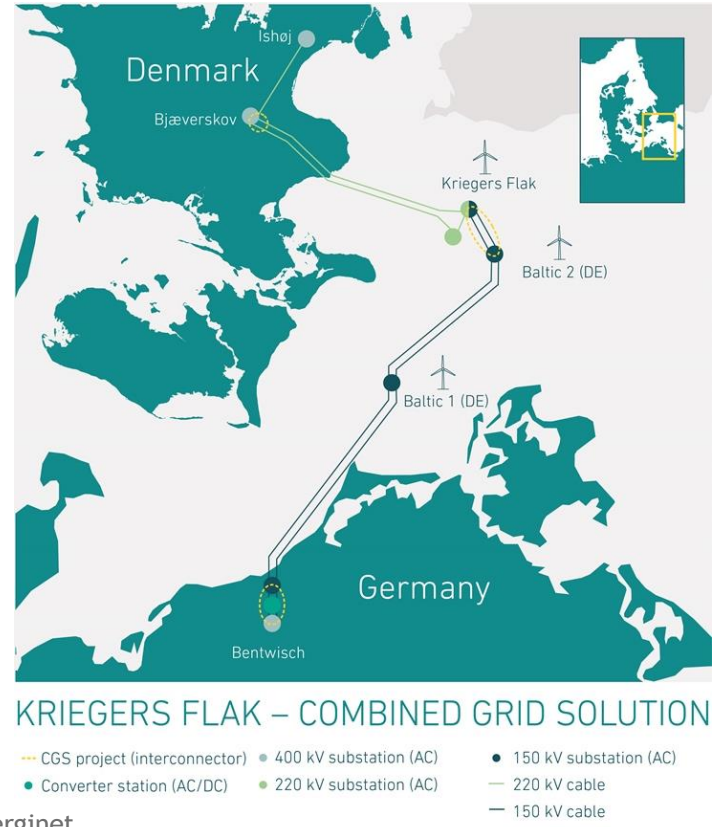
Optimization of equipment

- No permanent living quarters
- Optimized redundancy with maintained availability
- Minimize number of active platform systems
- Layout optimization



Dual-purpose interconnections

Reference project: Kriegers Flak Combined Grid Solution



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Project motivation

Two existing offshore wind farms in Germany, Baltic 1 (48 MW) and Baltic 2 (288 MW)

Denmark erecting offshore wind farm Kriegers Flak (600 MW)

Wind farms Kriegers Flak (Denmark) and Baltic 2 (Germany) located less than 30 kilometres away → interconnection by two submarine cables

Denmark and Germany are different synchronous areas → back-to-back HVDC converter installed onshore in Bentwisch, Germany, for frequency transformation

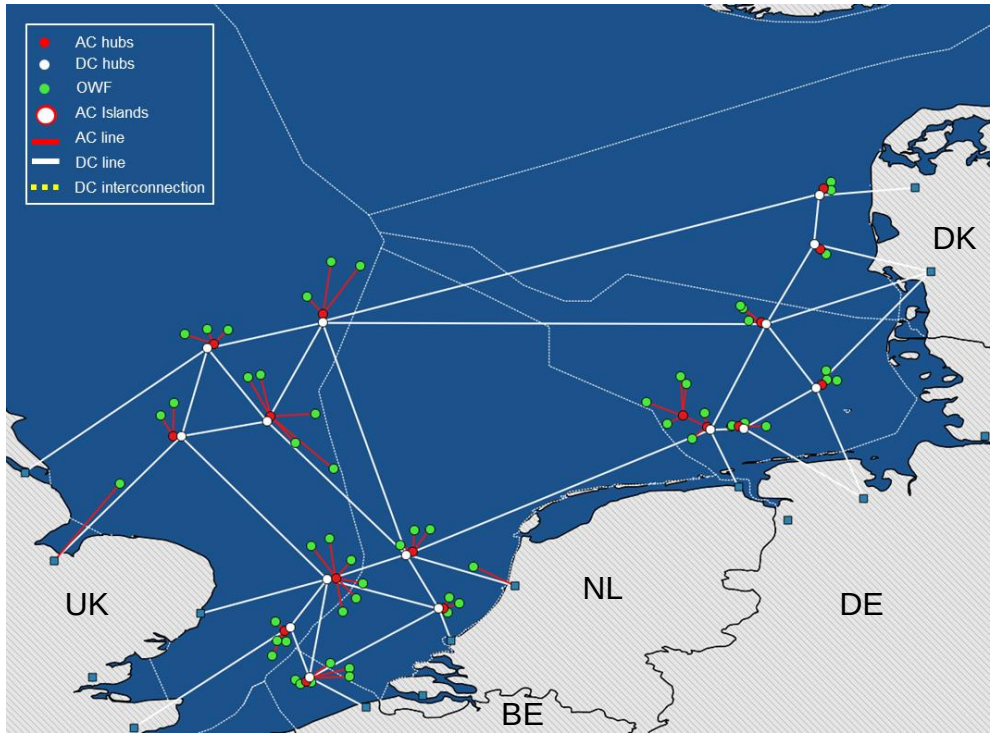
Project of Common Interest

Kriegers Flak Combined Grid Solution is a “project of common interest” (PCI)

Bridges a gap in the European power system and facilitates the development of a common European energy market.

DC Grids

A natural evolution from offshore wind connections



Source: PROMOTioN

Benefits

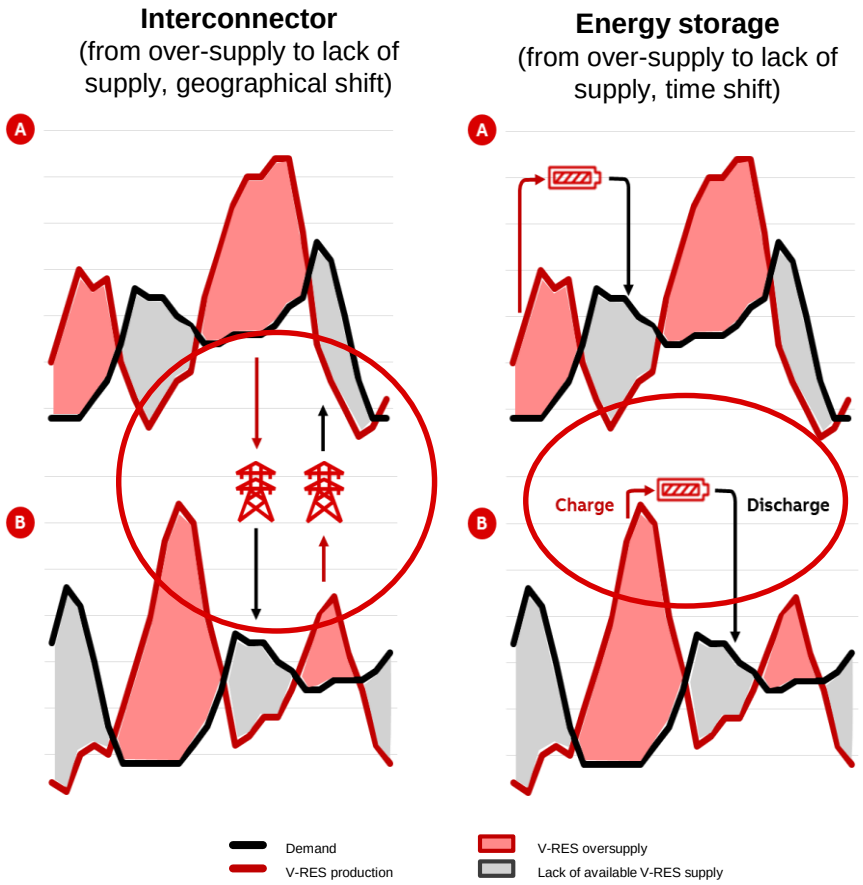
- Combining interconnections and wind power generation
  - Increased security of supply
  - Enables trading
  - Decrease variability
  - Better utilization of wind farm investments
  - Frequency and voltage support in connected grids
  - POD (Power Oscillation Damping)
- High efficiency grid (low losses)
- Black start capability

Towards a 100% wind & solar future

How to best integrate large amount of wind energy

How to transform the transmission system to accommodate new generation locations and managing large scale penetration of variable renewable generation (V-RES)

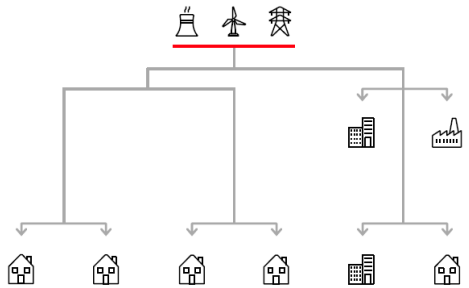
- More interconnections between regions
- Storage (batteries, fuel cells, pump storage)
- Intelligent autonomous network management

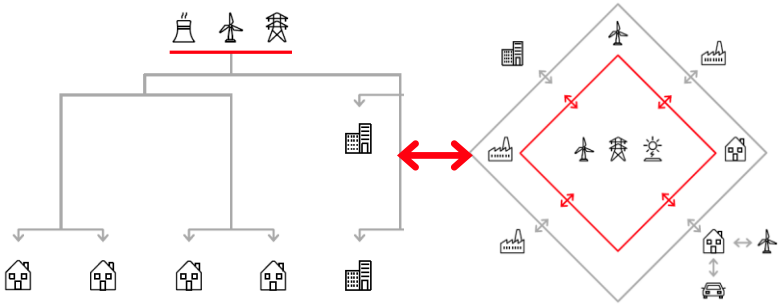


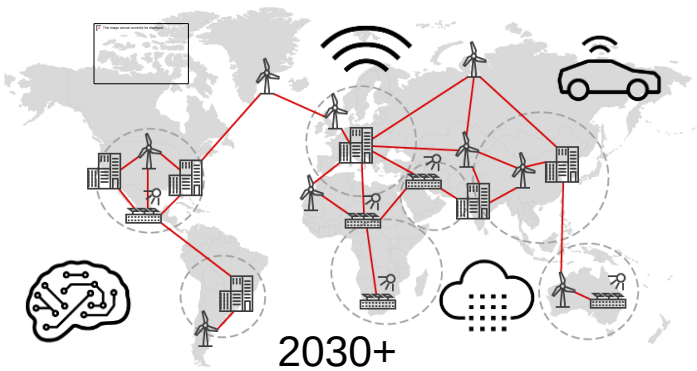
Power systems of the future

Renewables, grid edge technologies and digitalization drive the evolution of future power systems

Yesterday	Today	Tomorrow







2000 — 2020 — 2030+

Long term vision – Mid term pipeline visibility
Efficient use and improve existing technologies
R&D – Innovation – Collaboration
Demonstration projects


ABB