MARCH 2018

Battery Energy Storage

The power to control the energy

Marcus Sousa, Territory Market Manager, Europe

Challenges of the future power grid

Long-term drivers for energy storage

Electricity consumption on the rise
- Electrification of everything – moving towards electricity as the primary source of power
- Economic and population growth will lead to increasing demand for power

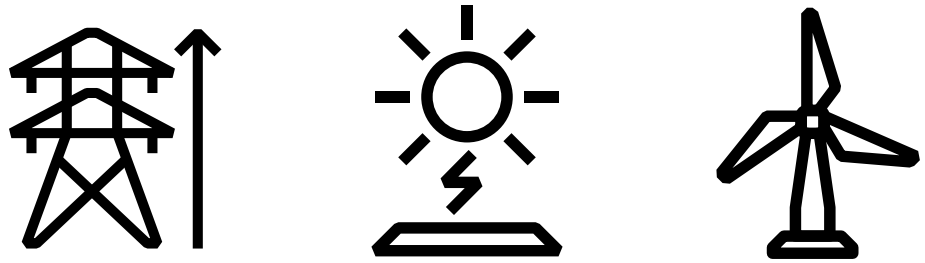
Coal plant retirements
- Reducing baseload power capacity
- Limited resources for ancillary services on the utility grid

Growth in renewables
- Governments and industry moving towards solar and wind
- Intermittent generation sources can reduce reliability on the electrical grid

Electrification of transportation
- More users of EVs can increase peak loads placing more strain on the electrical grid
- Increase in high speed rail

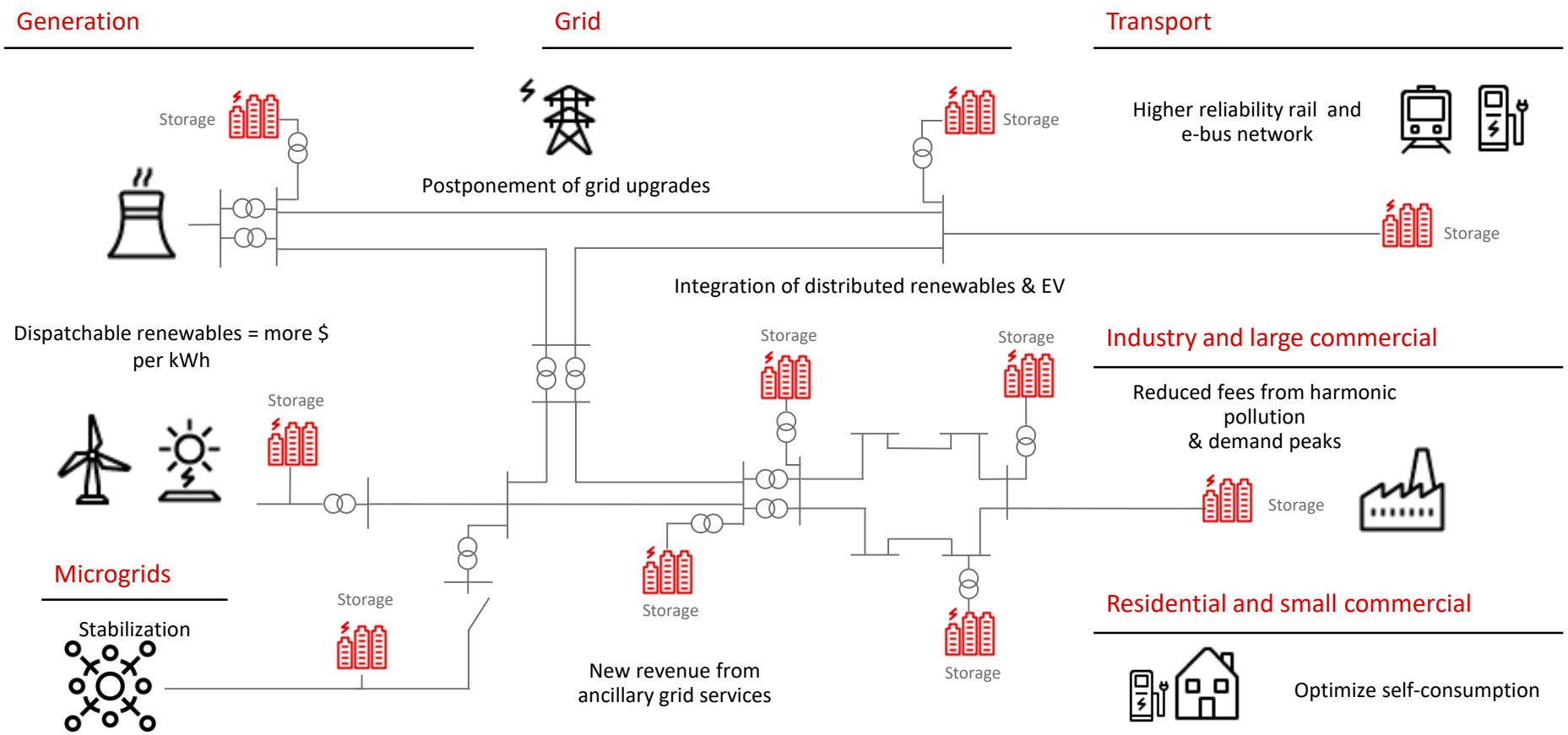
Proliferation of smart grid technology
- Bi-directional flow of power requires additional coordination between power supply and demand

Tax and regulatory incentives
- Renewable mandates and incentives increasing demand for clean grid technologies
- Potential tax benefits for storage systems (residential, commercial and utility)



Battery energy storage systems

Used today across various industry segments, behind and in front of the meter applications

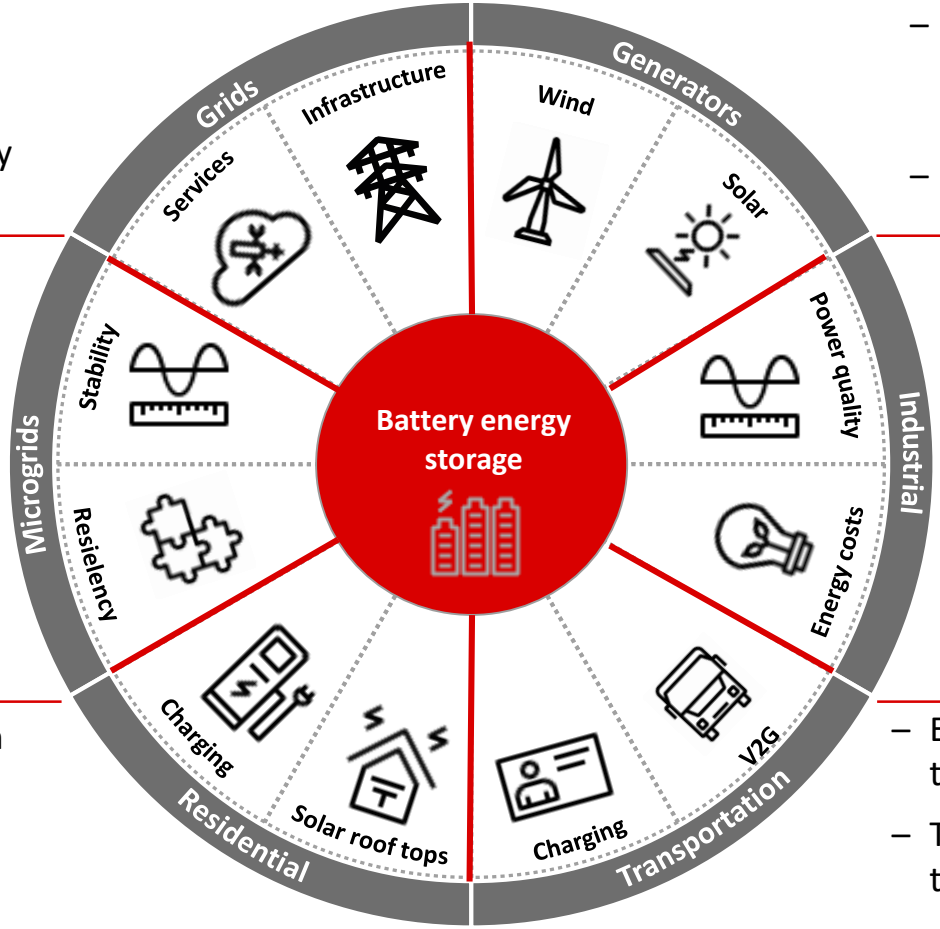


Market segments and their main characteristics

Majority of use cases expected to be behind the meter

- deferral of investments but business case not always present
- Grid services – regulations do not allow in many markets

- Combined with renewable plants to reduce fluctuations and further improve dispatchability
- Mitigates trading risks when integrated in fleets of generators



- Good complement with renewables powered microgrids
- Key element for securing system stability and resiliency

- Addresses capacity and peak consumption issues
- Improves power quality and can reduce energy bill

- Used in combination with solar roof top to gain energy independency or reduce energy bill
- Enabler to enable fast charging at home

- Enables fast charging in cities and weak points of the grid
- Together with bidirectional smart charging, enables the vehicle to grid (v2G) concept

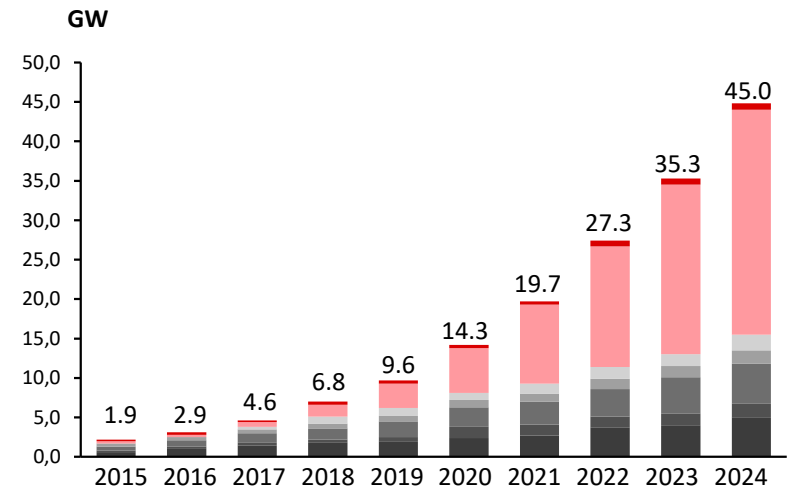
Energy storage market outlook

In $ terms the utility storage market is expected to grow with a CAGR ~19%

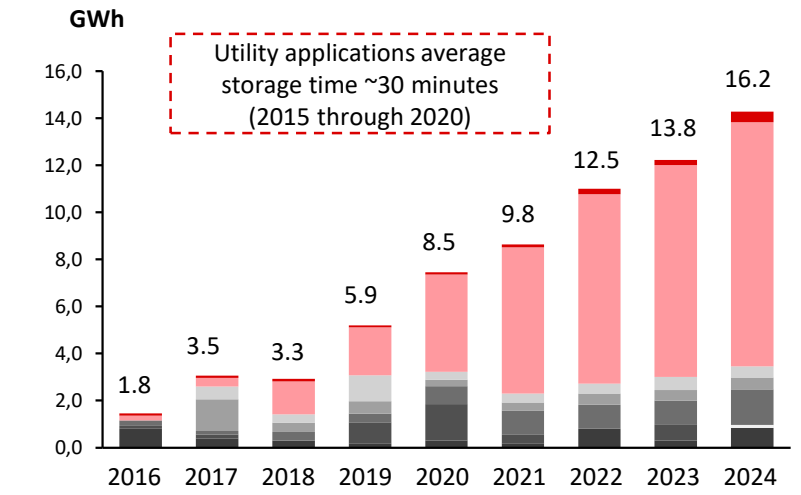
Frequency regulation
Renewable integration
Distribution load levelling
Behind-the-meter: Peak shaving
Peaking capacity
Transmission load levelling
Behind-the-meter: PV + storage

Utility storage applications
Non-utility storage applications

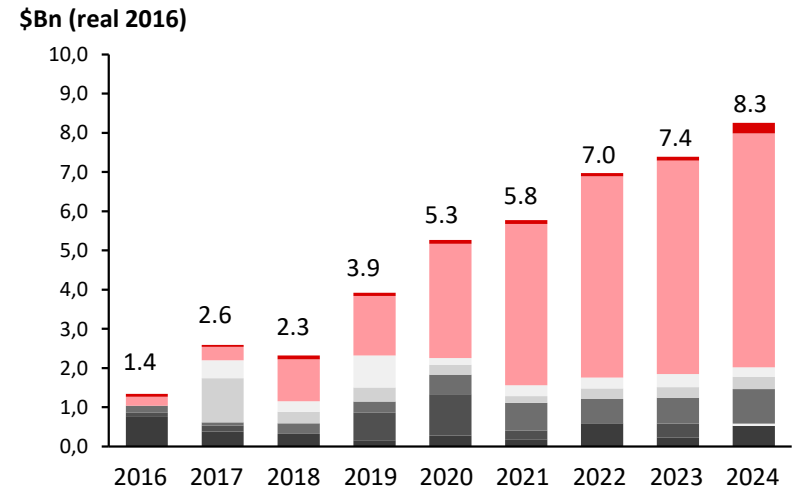
Utility applications CAGR (2016-2020) ~ 32%



Utility applications CAGR (2016-2020) ~ 24%



Utility applications CAGR (2016-2020) ~ 19%



In 2016, the utility storage market was ~$1Bn rising to ~$2.2Bn by 2020

Energy storage applications description

A range of utility and non-utility applications sustain the growth of energy storage market

Utility Storage Applications

Frequency regulation	– The provision or absorption of short bursts of power to maintain the balance of supply and demand & [hence] the frequency – Often procured by the system operator
Peaking capacity	– The provision of capacity to meet demand peaks
Renewable integration	– Storage connected to renewable generators (solar, wind) in order to smooth the output before connection to the grid
Transmission load levelling	– Investment deferral: installed in the transmission grids, as alternative to increasing the capacity of one or more lines – Can also be used to improve power quality (reactive power compensation)
Distribution load levelling	– Investment deferral: installed in the distribution grids, as alternative to increasing the capacity of one or more lines – Can also be used to improve power quality (reactive power compensation)

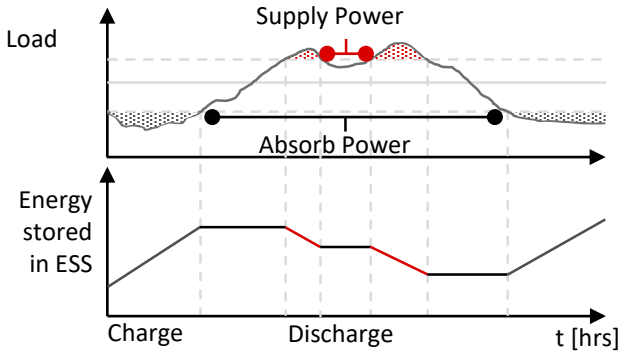
Non-Utility Storage Applications

Behind-the-meter: **PV + storage**	– Energy storage integrated with residential & commercial roof top solar PV – Main application is to increase % of self-consumption
Behind-the-meter: **Peak shaving**	– Energy storage for commercial and investment customers – Main application is to reduce peak demand charges

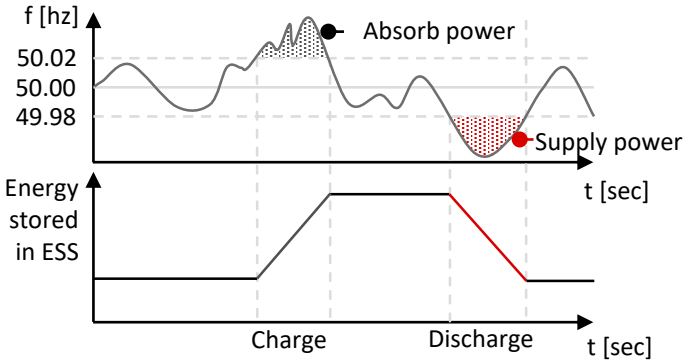
Applications of energy storage

Advanced control algorithms enable applicability of BESS in every market segment

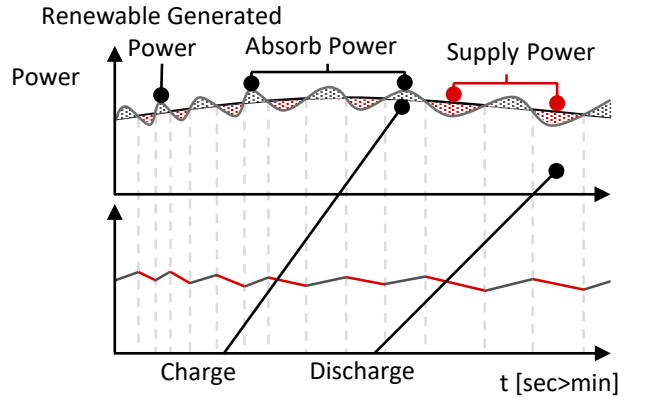
System adequacy



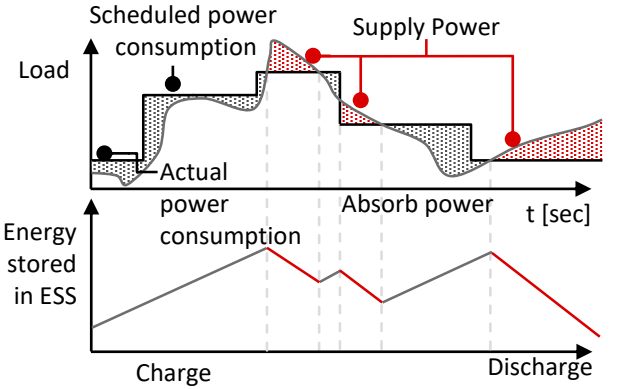
Ancilliary services



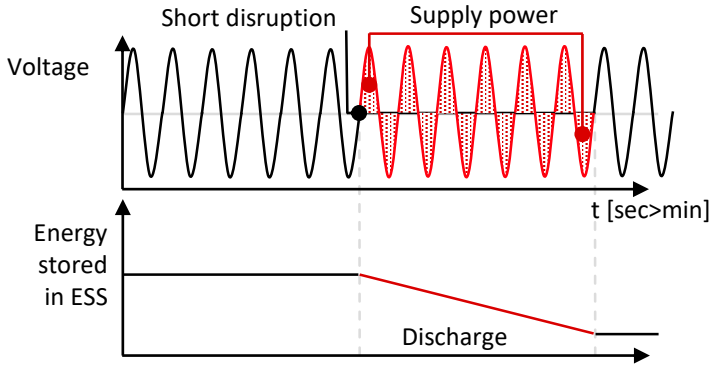
Integration of renewable resources



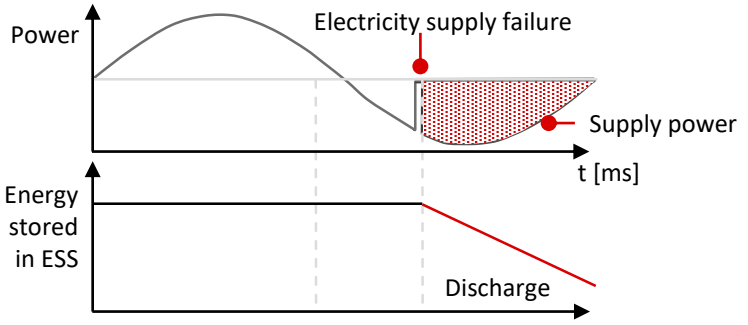
Energy resiliency



Power quality



Energy storage systems



Battery energy storage systems

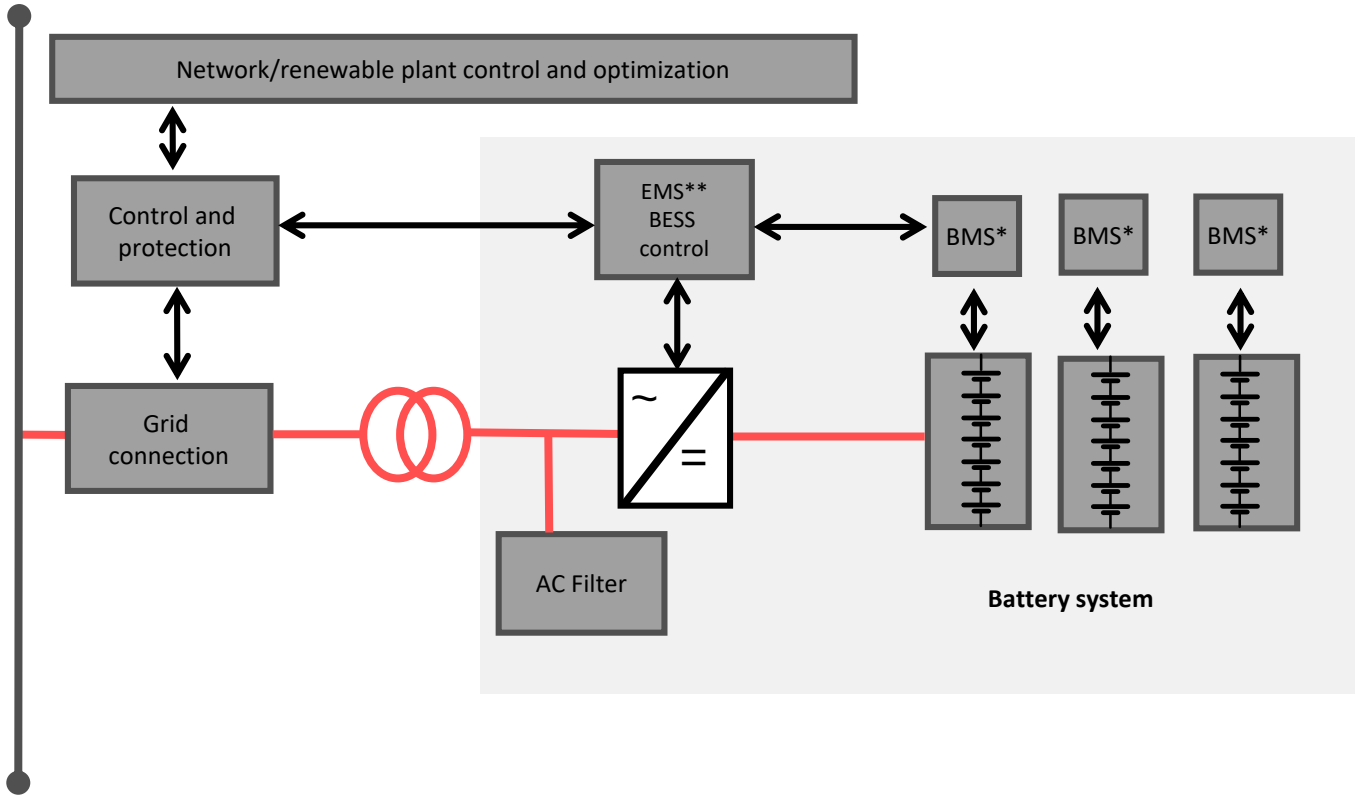
System overview

System architecture

- Power conversation system (PCS)
- Energy storage batteries
- Local level controller (EMS) based on PLC
- High level controller based on cloud services and computing

Optional items:

- MV transformer, switchgear
- MV control and protections
- Scada control system



*BMS - Battery management system

**EMS – Energy management system/ Master BESS control

The right energy storage solution for every need

ABB provides productized and customized solutions for all applications

Storage Media	Power Conversion Systems	Energy Storage System Control	Turnkey energy storage systems	System design and applications
Optimized battery technologies	Low voltage (LV) and medium voltage (MW) converters	Local control system for power and energy management	Turnkey grid-connected or off-grid battery energy storage system (BESS)	Optimized energy storage system design for each application
Flywheels	Containerized and productized solutions	Remote monitoring for battery energy storage systems	Residential photo-voltaic (PV) together with BESS	Microgrids
Hydro-power			Customized solutions	Virtual Power Plants (VPPs)
				Integration in Energy Management Systems
				Integration in Grid Management Systems

ABB advises | **ABB provides**

Battery energy storage systems

Indoor Installation

Nordhavn - Denmark

- Complete battery system for storage of renewable energy from a residential harbour district
- Connected to Nordhavn's electricity grid to supply 200 households with electricity
- Urban laboratory for energy solutions
- Solution: ABB's BESS
  - Installed power: 630 kW
  - Installed energy: 460 kWh
  - Battery technology: Li-ion
  - Commissioning: January 2017

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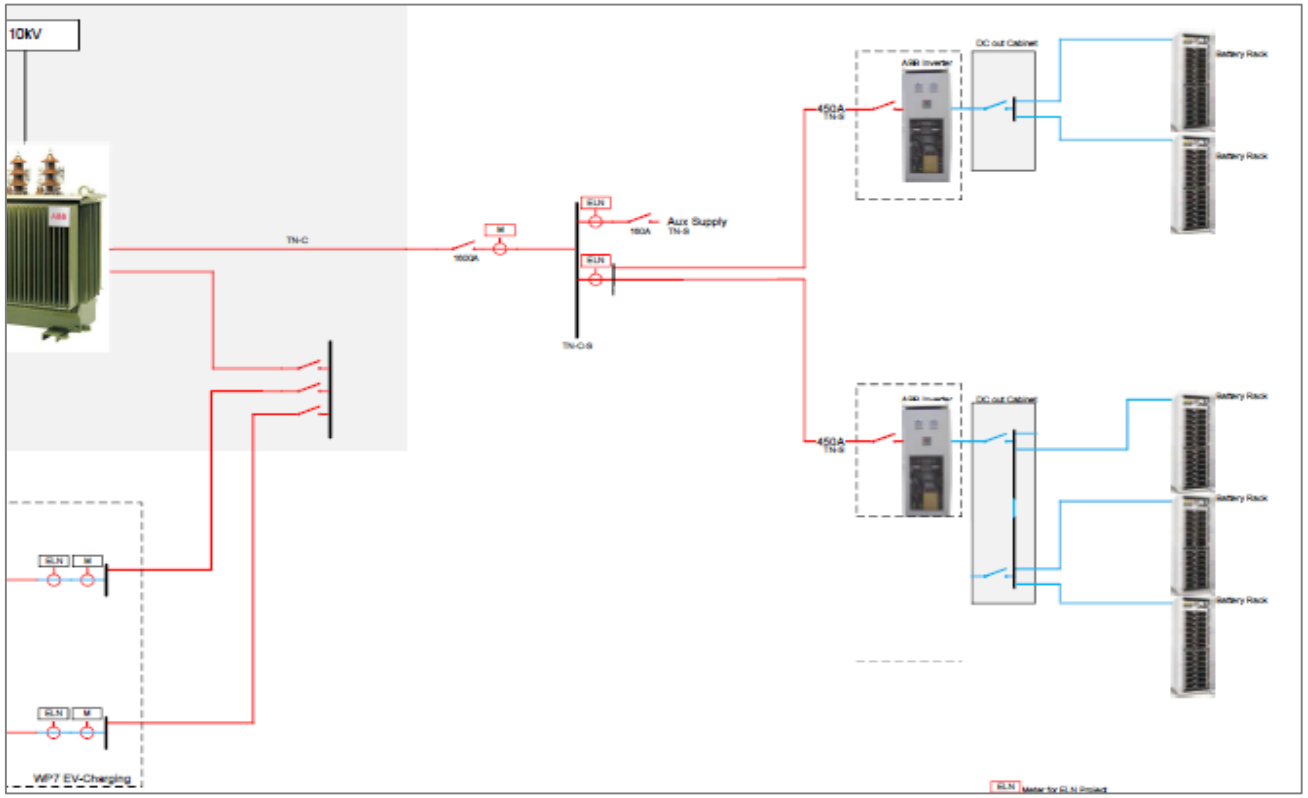
Battery energy storage systems

Indoor installation

Nordhavn - Denmark

- Nominal Power 600kW
- Total Installed energy BOL 465kWh
- Total usable energy BOL 400kWh
- Total usable energy EOL 320kWh
- Design life time 20 years
- Round trip efficiency > 90%
- Max ambient temperature (40°C/25°C)
- Communication protocol IEC 60870 -5 - 104
- Power application 2 C
- Inverters ESI 315kW
- Batteries LG Chem 92kWh

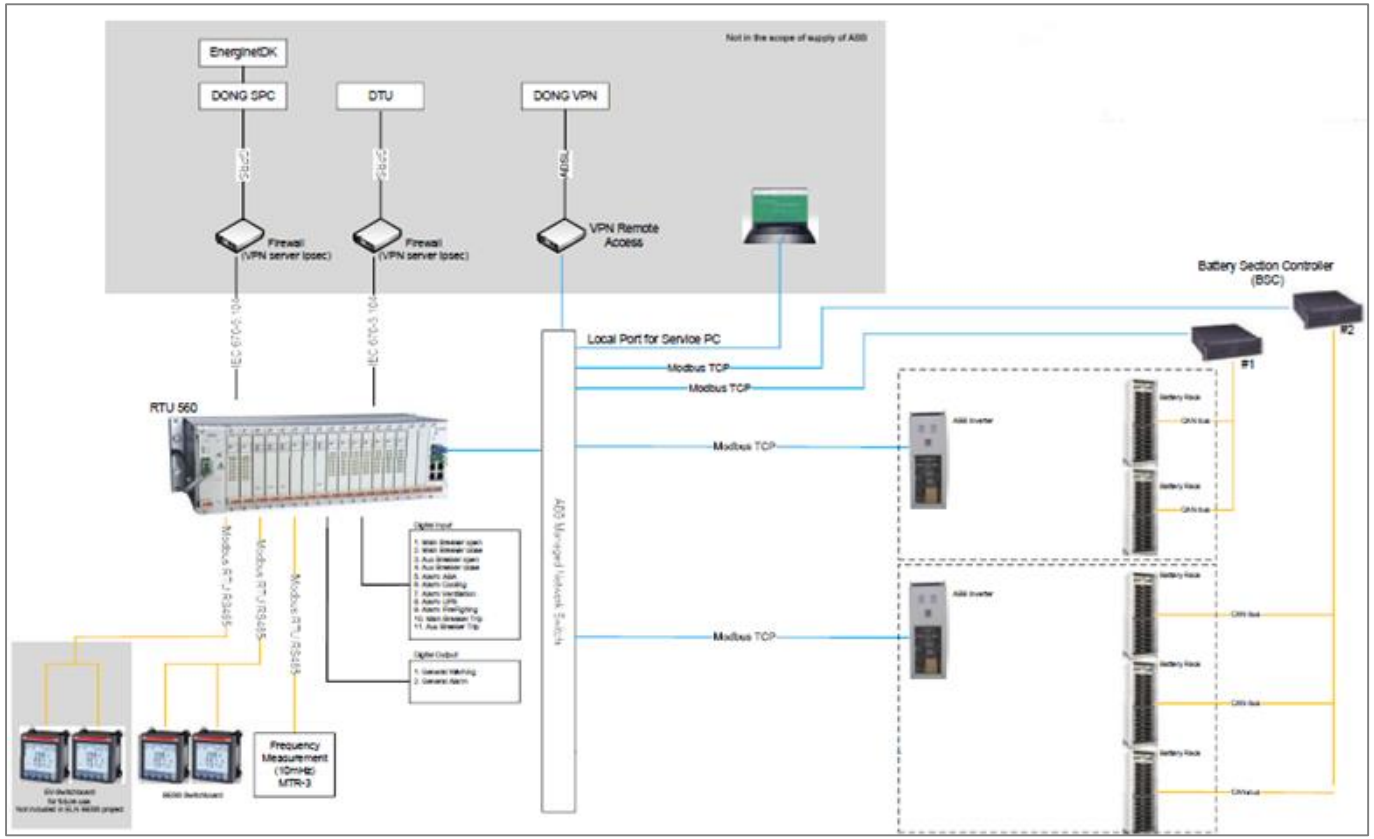


Battery energy storage systems

Indoor installation

Nordhavn - Denmark

- RTU 560
- Peak shaving
- Frequency control
- EV chargers integration
- Renewables integration
- Remote control and monitoring
- Web service application
- Redundant



Battery Energy Storage Systems

Outdoor Installation

Dong Energy - UK

End Customer: Dong Energy Wind Power (DEWP)

Location: Burbo Bank Wind farm, Walassey, UK (on shore installation)

Power: 2000 kW

Energy: 2000 kWh

Application:

– FFR/EFR - National Grid

Solution: **Complete containerized BESS**

– ESI-I inverters

– Li-Ion Batteries from LG

– Control & Protection

– Complete System Supply

Thank you