Le Tang, ABB Inc.

High MW Electronics – Industry Roadmap Meeting at NIST, Dec. 11, 2009

Smart Grid and Power Electronics - Why Do We Need High MW Electronics

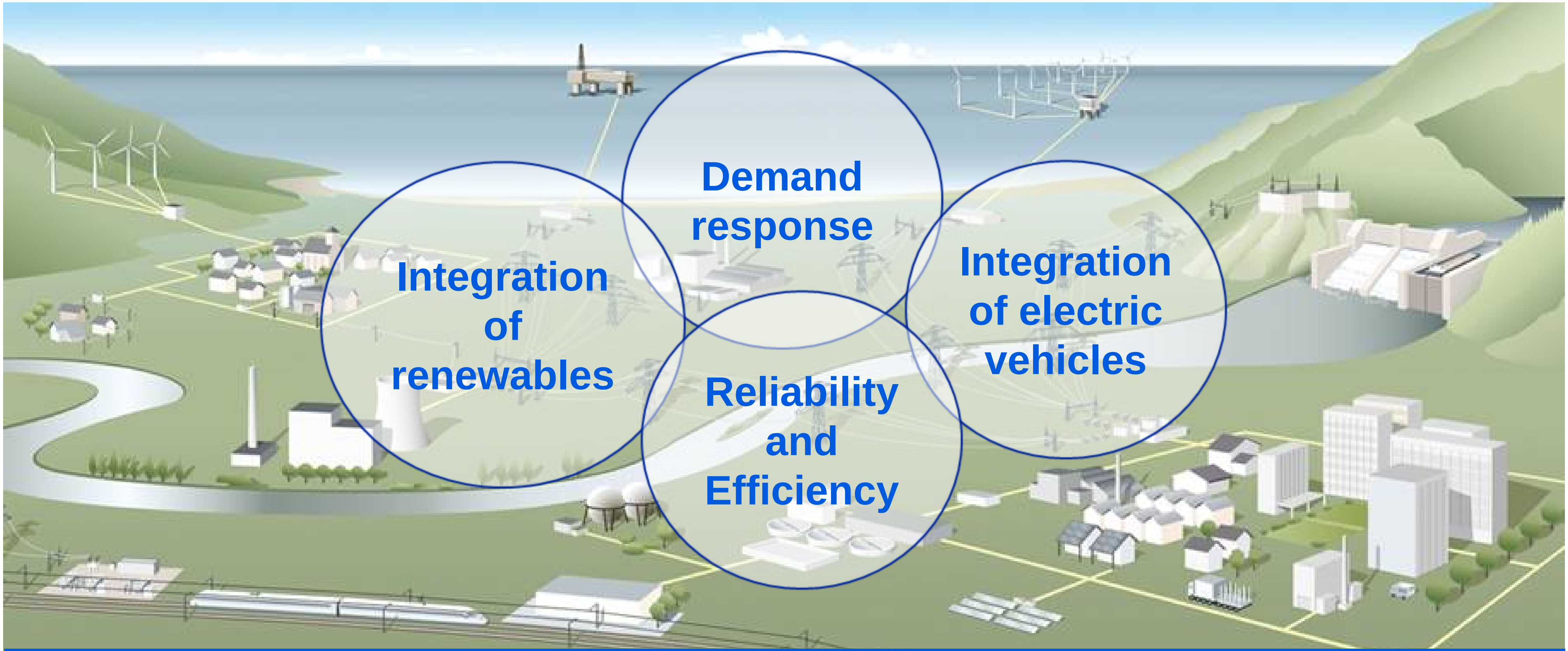
Smart electricity – efficient power for a sustainable world

A smart grid is the evolved system
that manages the electricity demand
in a
sustainable, reliable and economic manner
built on
advanced infrastructure
and tuned to facilitate
the integration of behavior of all involved

The visionary smart grid
Summing up the major requirements

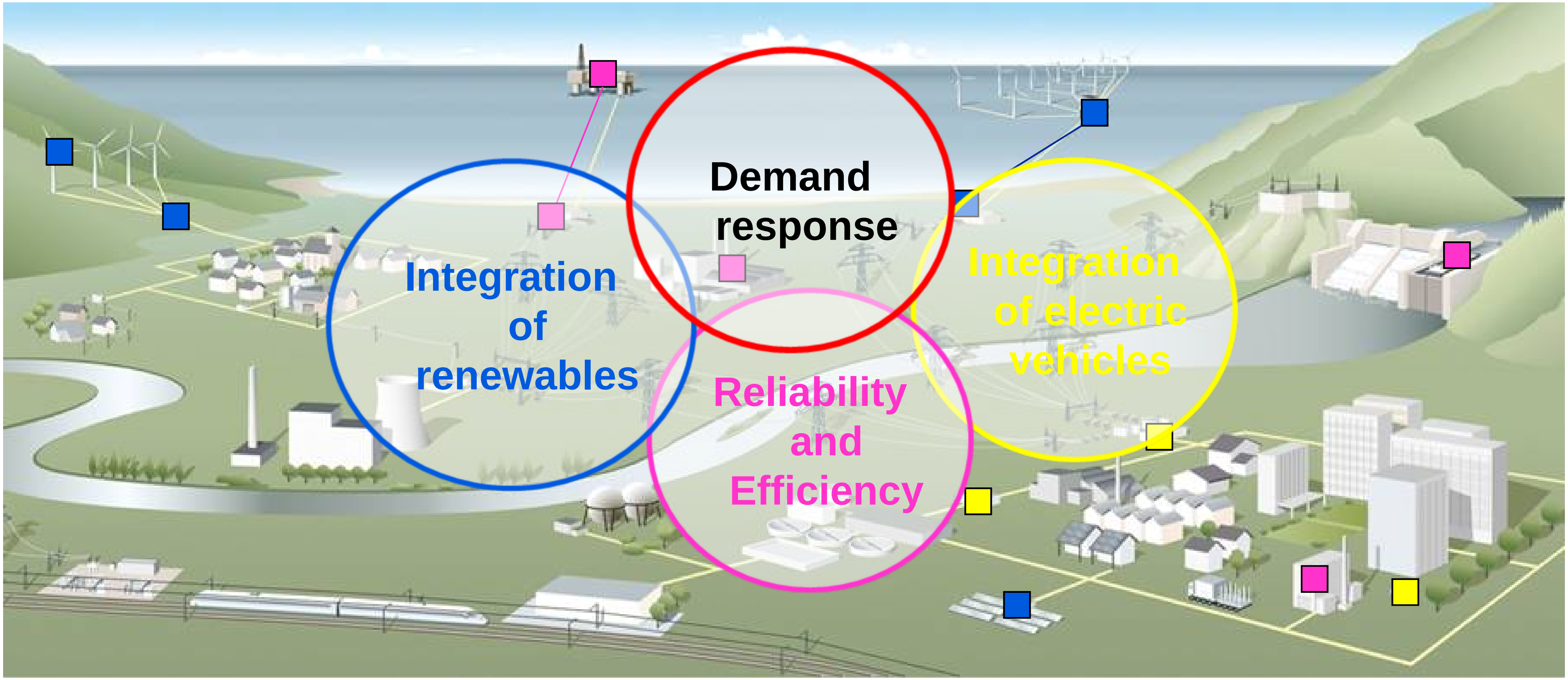
Capacity	Upgrade/install capacity economically Provide additional infrastructure (e-cars)
Reliability	Stabilize the system and avoid outages Provide high quality power all the time
Efficiency	Improve efficiency of power generation Reduce losses in transport and consumption
Sustainability	Connect renewable energy to the grid Manage intermittent generation

Smart Grid Requirements
Integration from supply to demand – 4 pillars

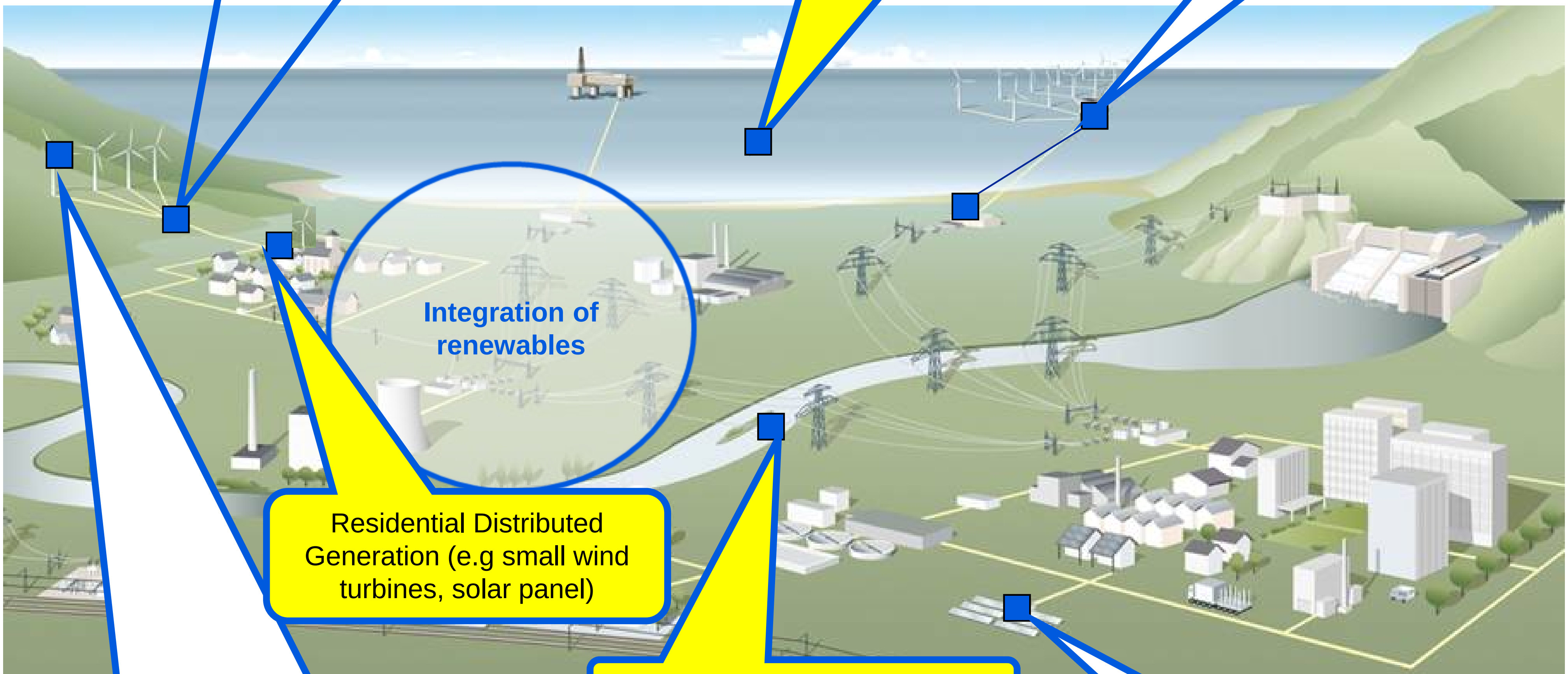


- **Smart Grid is more than only smart meters.**
- **Smart Grid includes both transmission and distribution.**
- **Smart Grid includes both automation/IT and power devices.**

Power Electronics in Smart Grids
A key technology in at least 3 of the 4 pillars



Power Electronics in Smart Grids
Integration of renewables

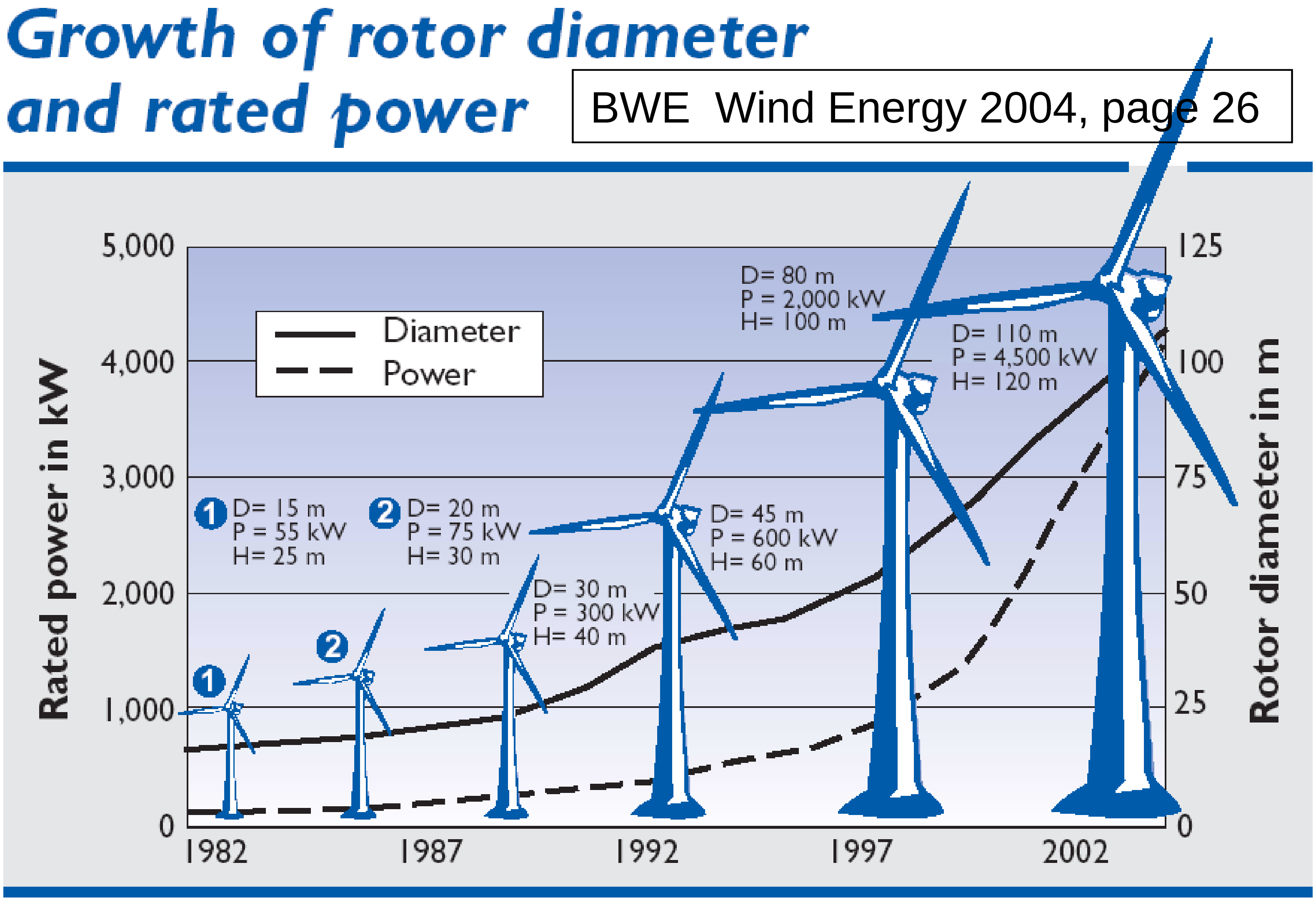


At wind farm point of connection to grid:

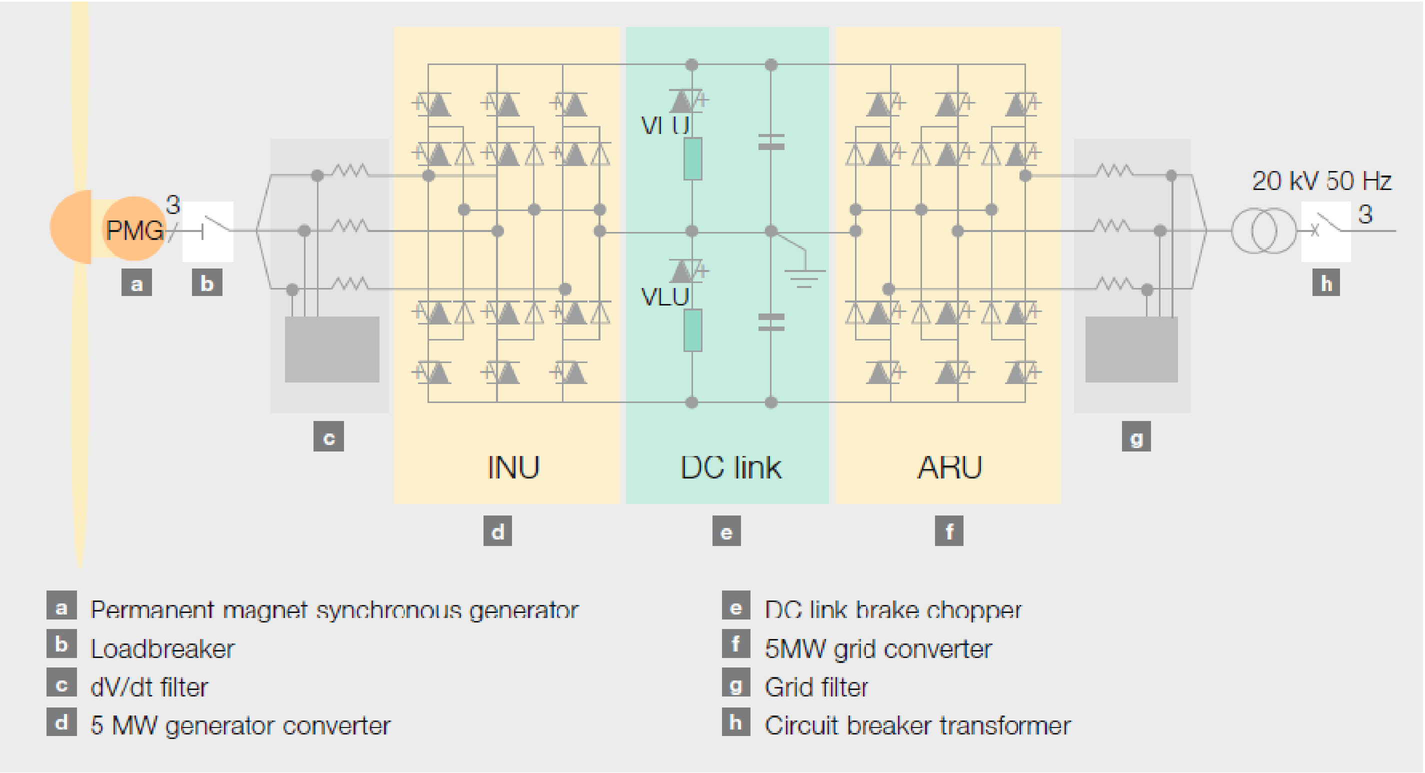
- SVC/STATCOM for grid code compliance
- Synchronous condenser
- Energy storage e.g. Dynapow for improving stability and decrease power fluctuations

Wind turbine trends

BWE Wind Energy 2004, page 26

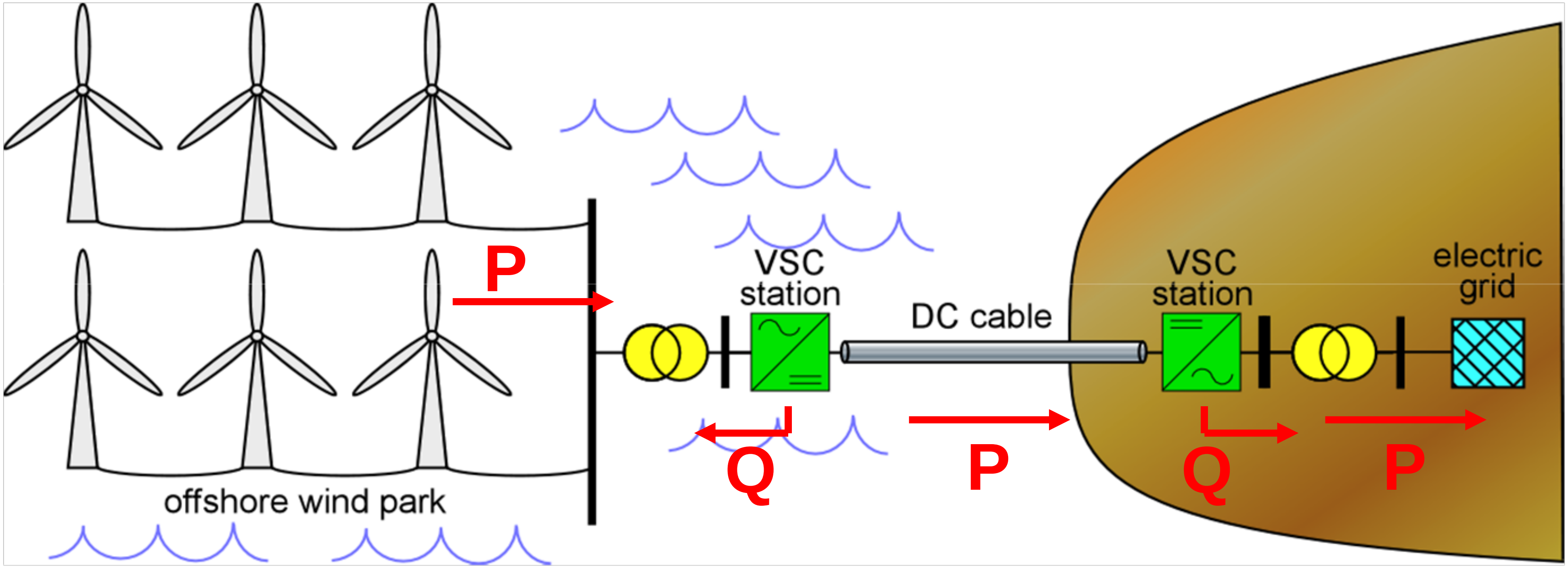


Wind Turbine Converters



- Fit inside the mast of the turbine
- Convert the generated power to the desired frequency and voltage
- Help support weak grid by supplying or absorbing reactive power

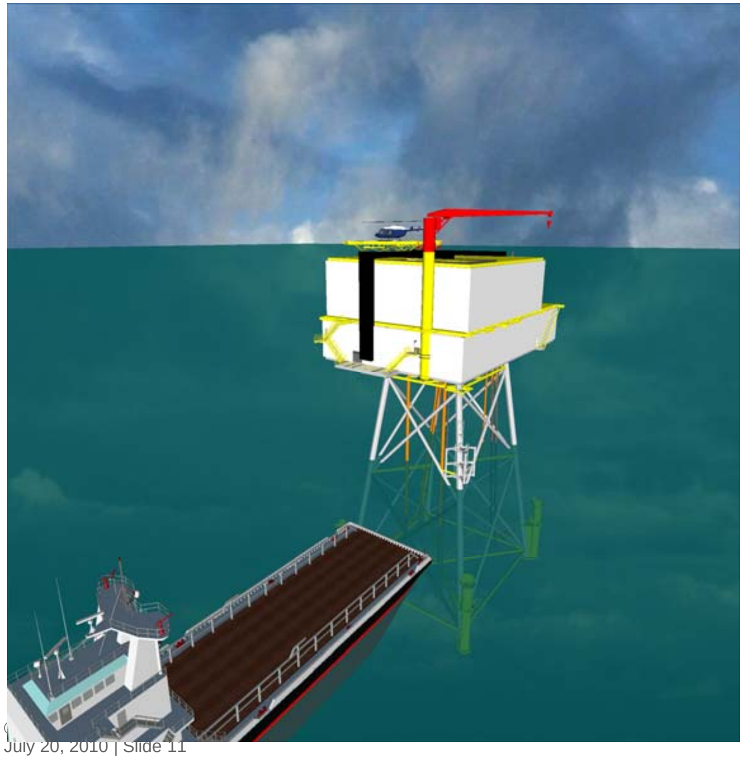
HVDC Light for Offshore Wind Park Connection (1)



- Transistor-based HVDC
- No compensation needed as reactive power is produced by the converter stations
- Can be connected to weak grids

NORD E.ON 1, 400MW off-shore windpark connection

NORD E.ON 1



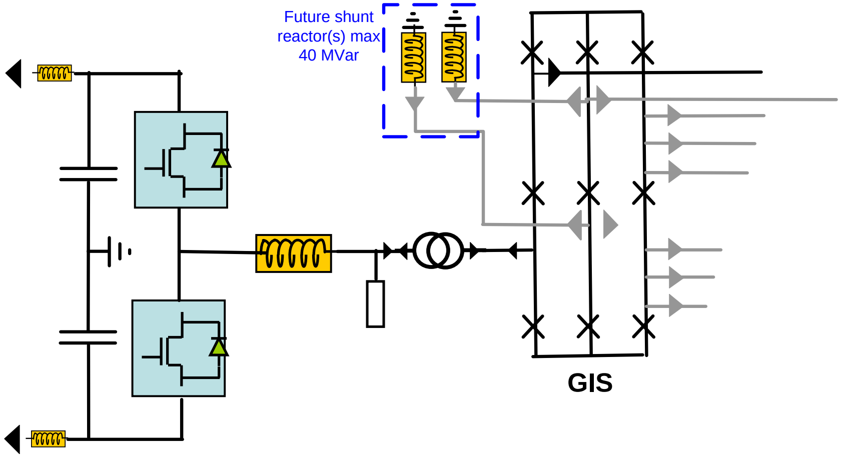
Customer

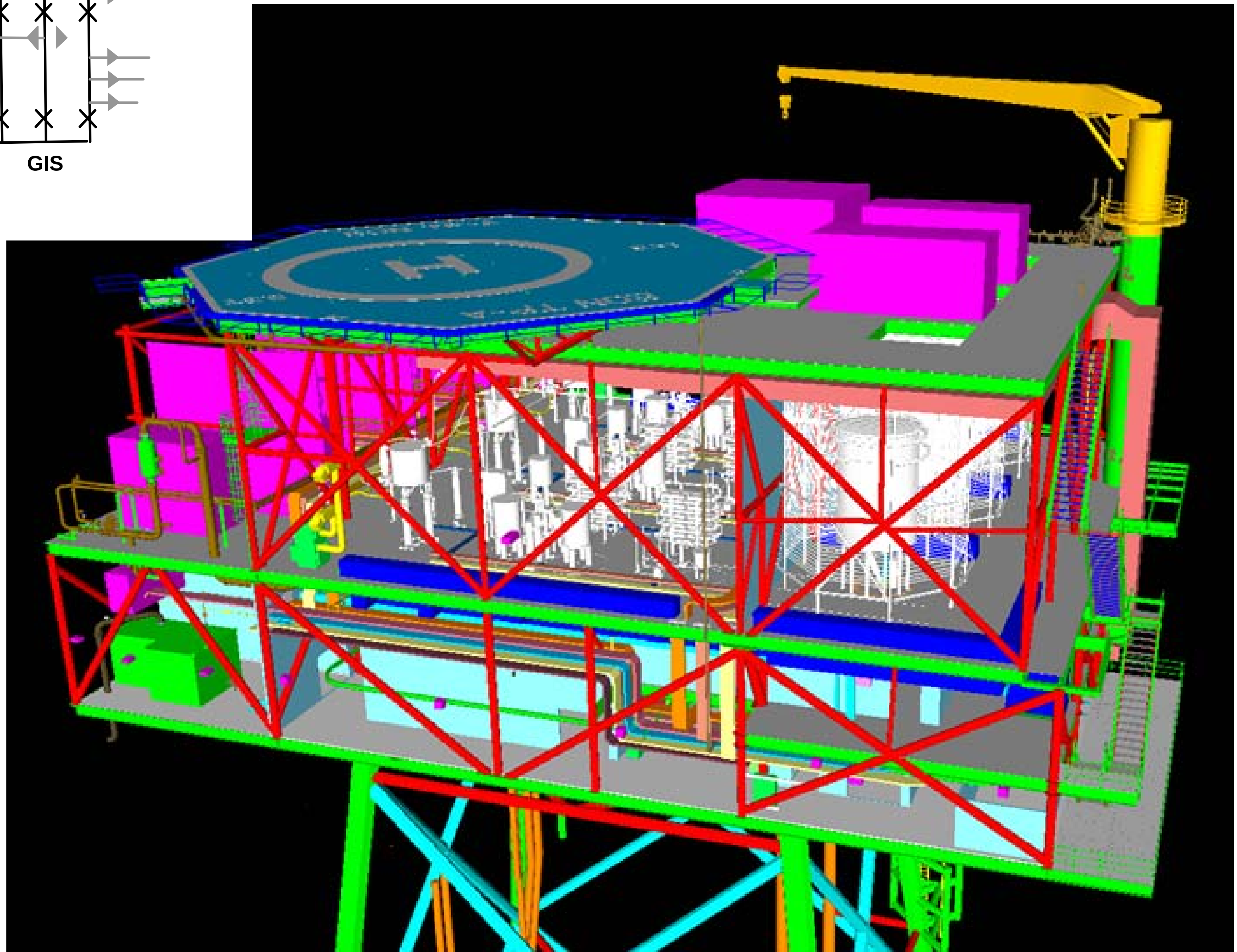
- E.ON Netz GmbH, Germany

Scope

- **400 MW HVDC Light System**
  - Two HVDC Light converter stations
  - DC Cable system
    - DC cable submarine to onshore connection (2x128km)
    - DC cable on land (2x75km)
    - 200 MW Submarine AC cable 170kV (1x1200 m)
    - Fiber optic cable (203 km)
- **170 kV GIS on platform**
- **Offshore platform structure** - jacket and topside
- … **and all Auxiliary Systems** needed to operate and maintain the Offshore station.
  - Sea Water System, HVAC, Dieselgenerators, Fire Protection, etc

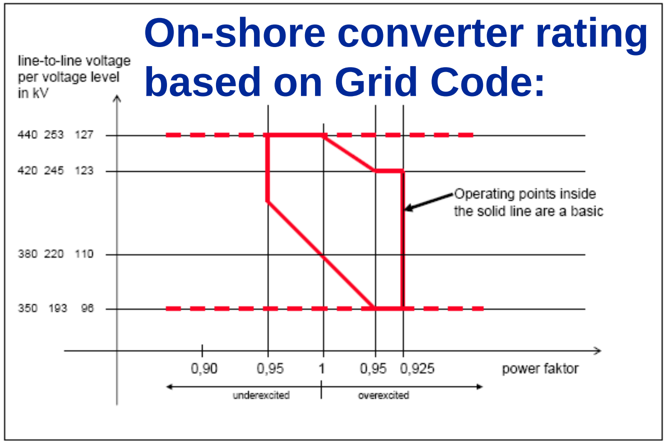
Layout platform





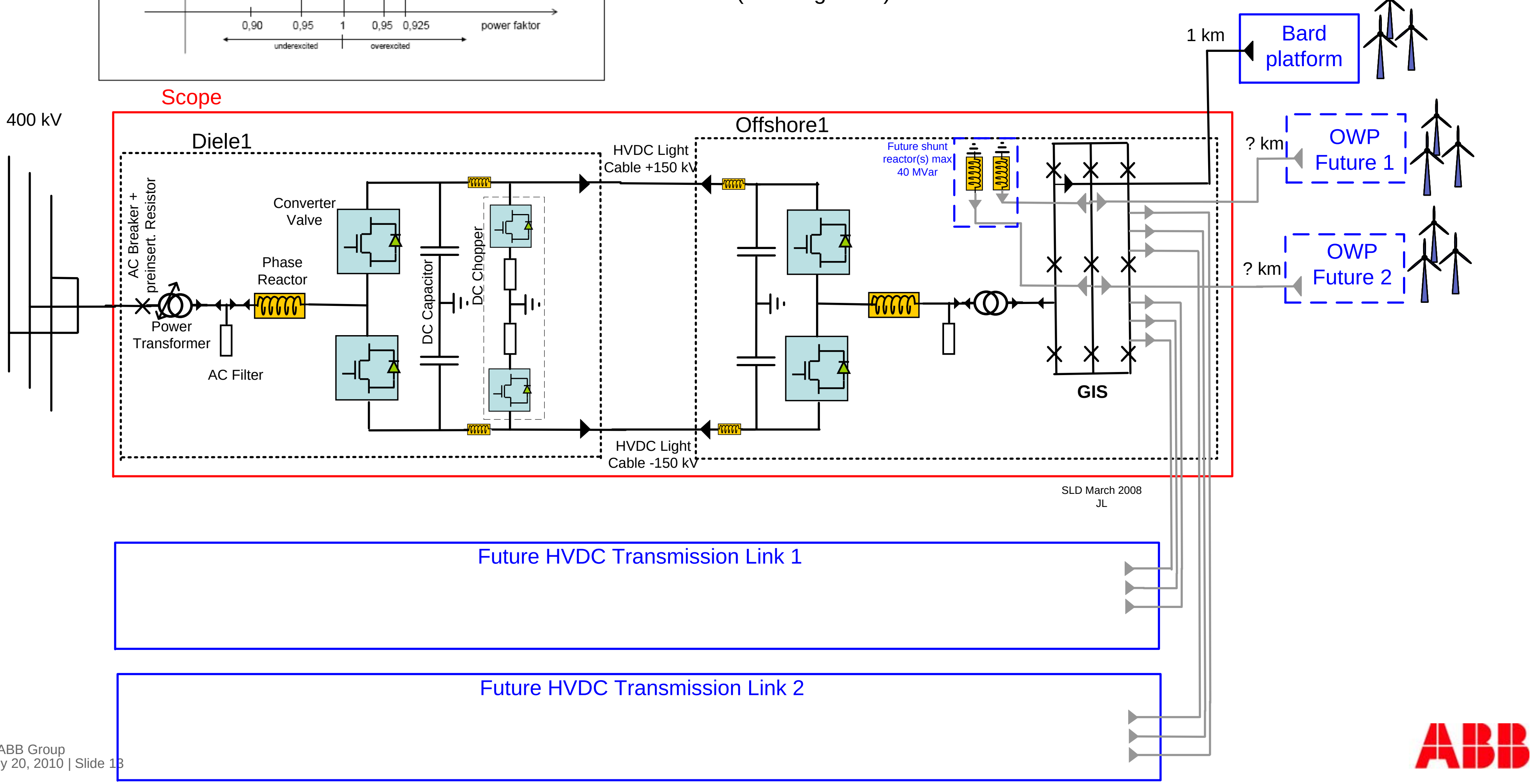
Overview, 400 MW HVDC Light System
E.ON 1

Nord



Offshore rating conditions

- No tap-changer
- Wind park Q
- Cable grid Q
- Fault ride through
- Future scenarios (Pre-Eng. ABB)



Integrating renewable power
Intermittent power generation

- Capacity
- Reliability
- Efficiency
- **Sustainability**

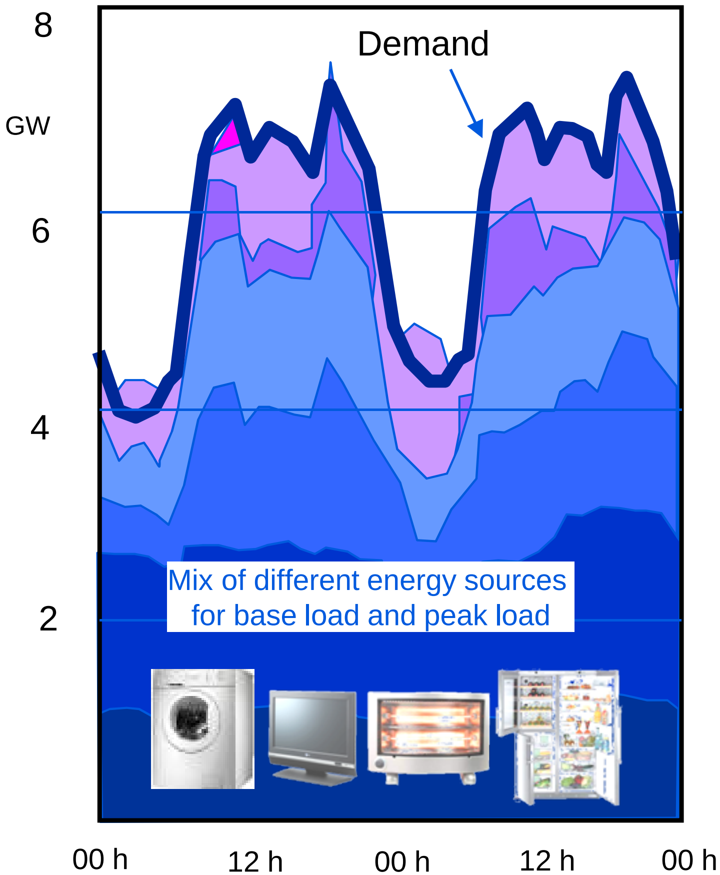
- Electricity from wind and solar plants is intermittent
- Spinning reserves between 5 and 18 percent of installed wind energy are required[1]
- Plant interconnections and a wide range of storage technologies could reduce the need for reserves

[1] Wind impact on power system, Bremen 2009

The future electrical system must be able to cope with these challenges

Optimizing supply and demand
Adjusting the energy mix

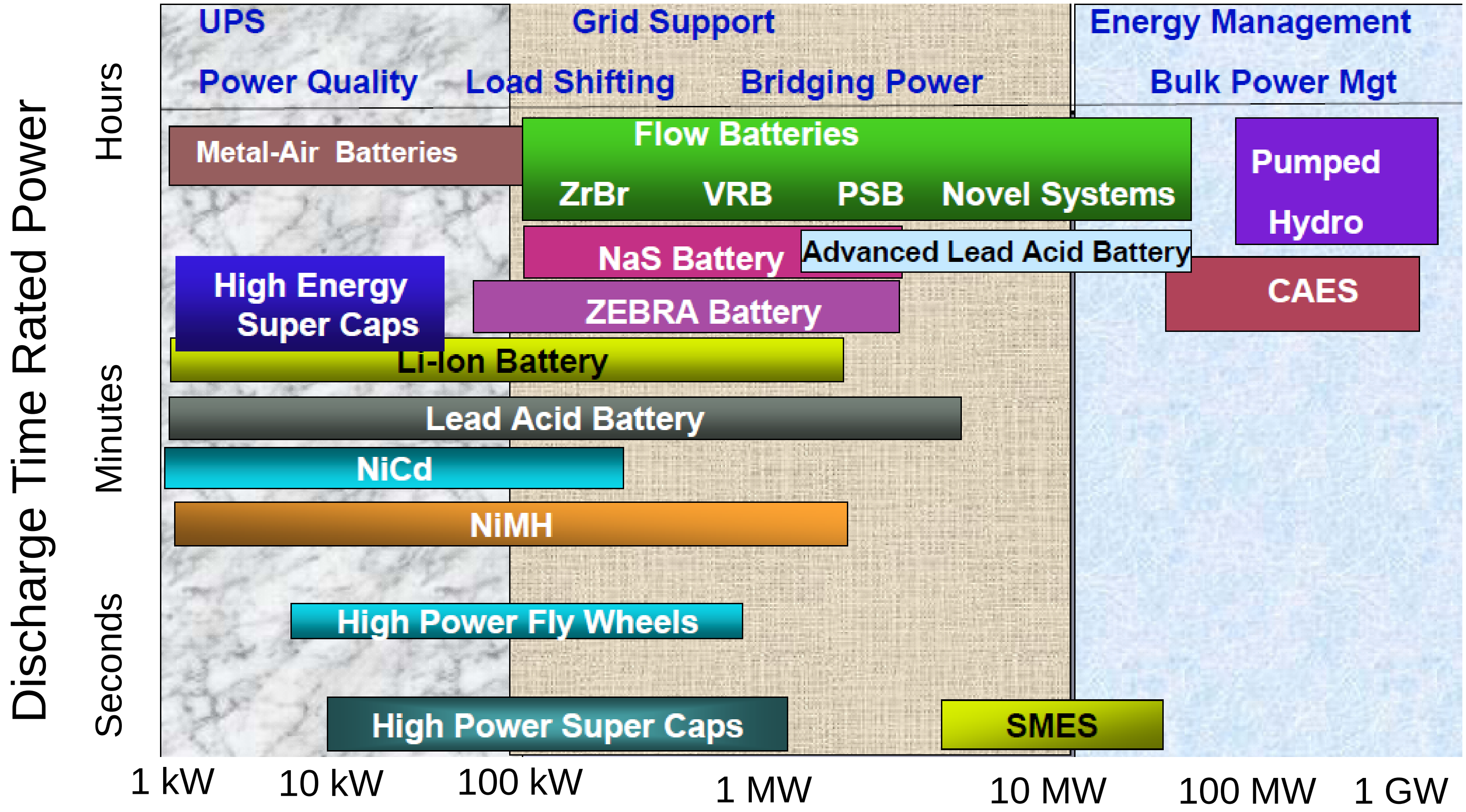
- Capacity
- Reliability
- Efficiency
- Sustainability



- Power consumption varies over the year and during the day and night
- To satisfy demand all the time reserve capacity is required. For environmental reasons reserves should be minimal.
- The challenge of reliability grows with more intermittent renewable energy
- A wide range of electrical storage technologies could mitigate the problem

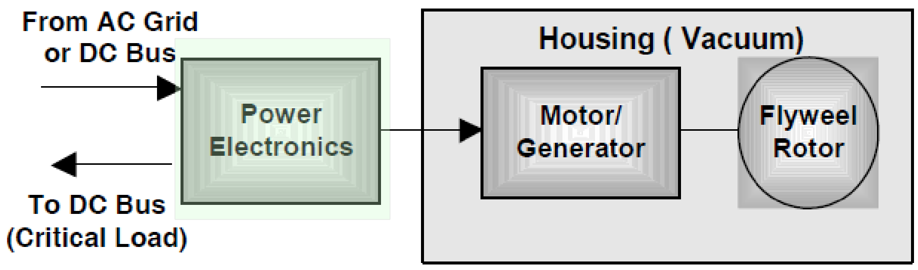
The future electrical system must provide optimal solutions

Energy Storage - Options

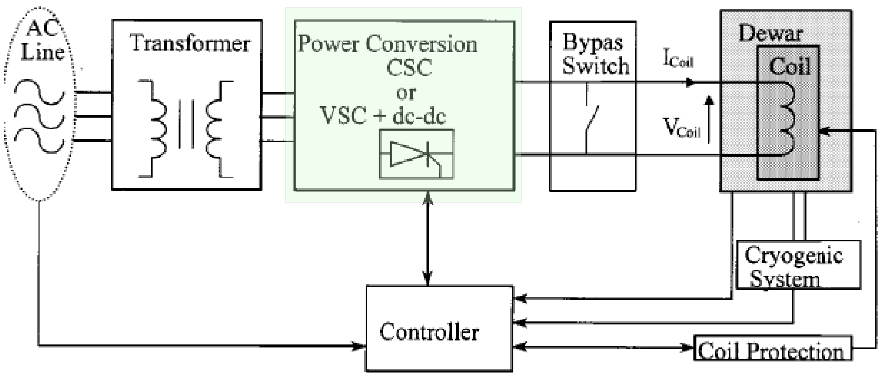


- Ref.:EPRI, "Overview of Electric Energy Storage Options for the Electric Enterprise

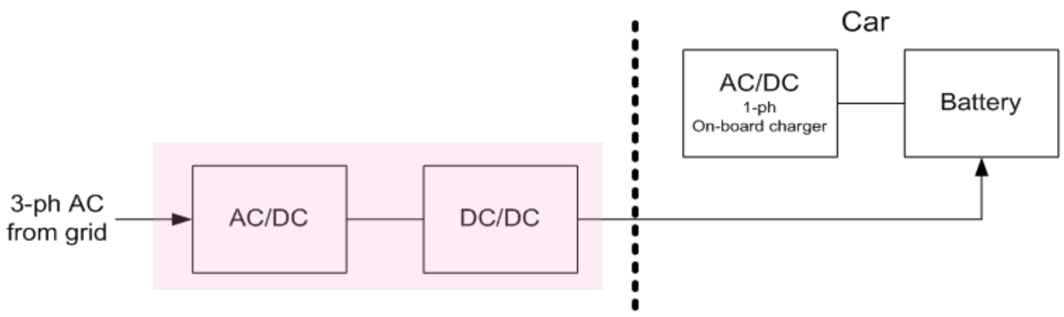
Power Electronics in Energy Storage – Examples



Simplified view of a flywheel energy storage system



Components of a typical SMES system

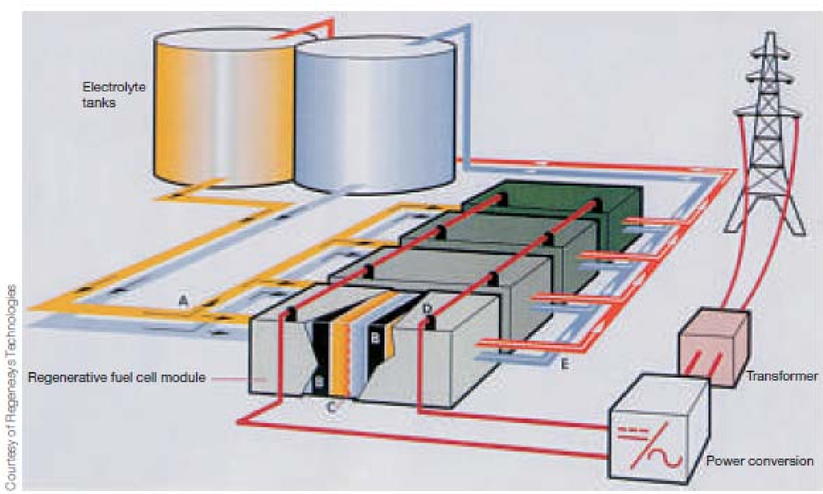


Fast charging system for a car battery

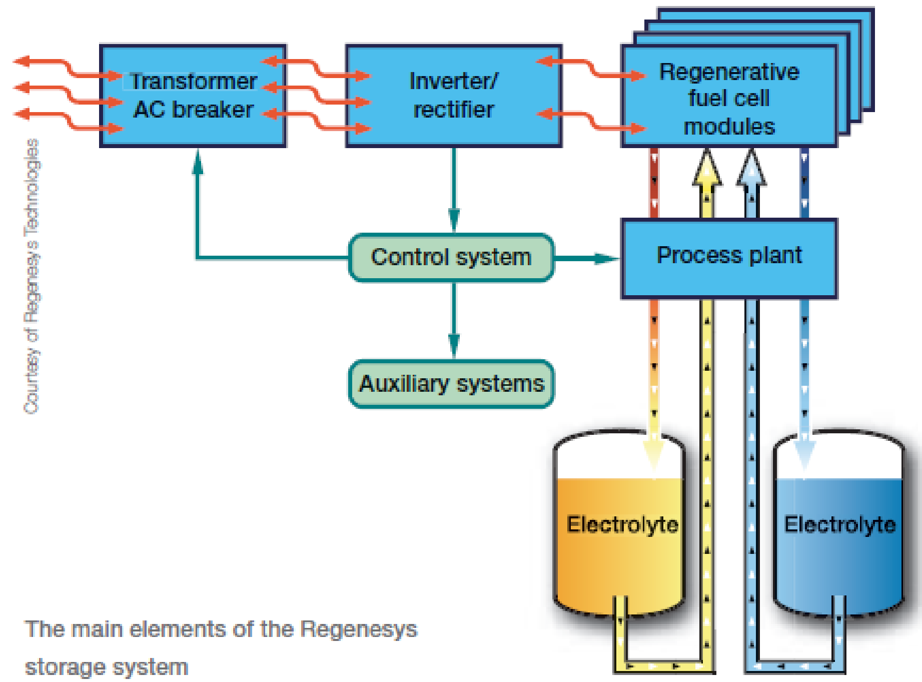
Ref:

- PAULO F. RIBEIRO, BRIAN K. JOHNSON, MARIESA L. CROW, AYSEN ARSOY, “Energy Storage Systems for Advanced Power Applications”
- Edward Furlong, Marco Piemontesi, Prasad P, Sukumar De, “Advances in energy storage techniques for critical power systems”.

Power Electronics in Energy Storage – Regensys Battery Energy Storage System (BESS)



System view of Regensys BESS plant



Main elements of the Regenesys system

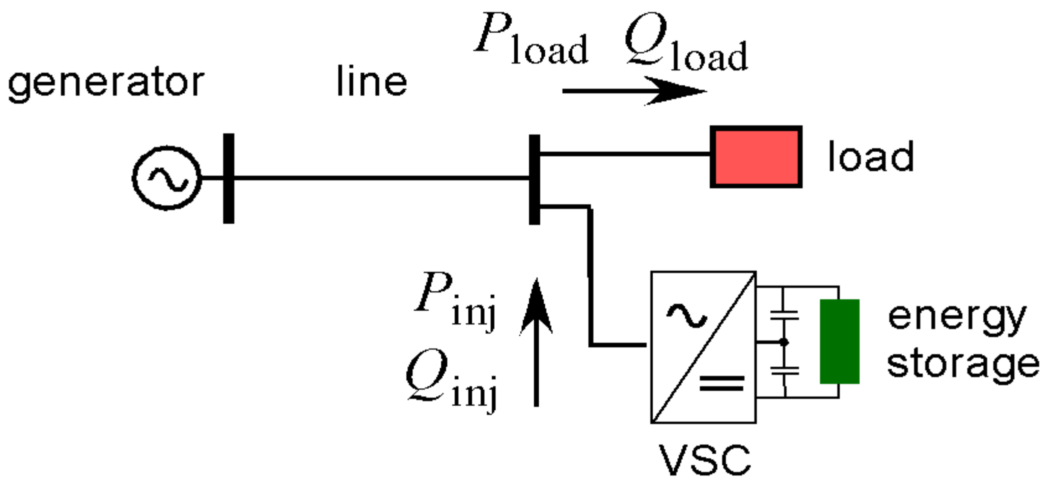
Storage
Project example: Battery Energy Storage for GVEA

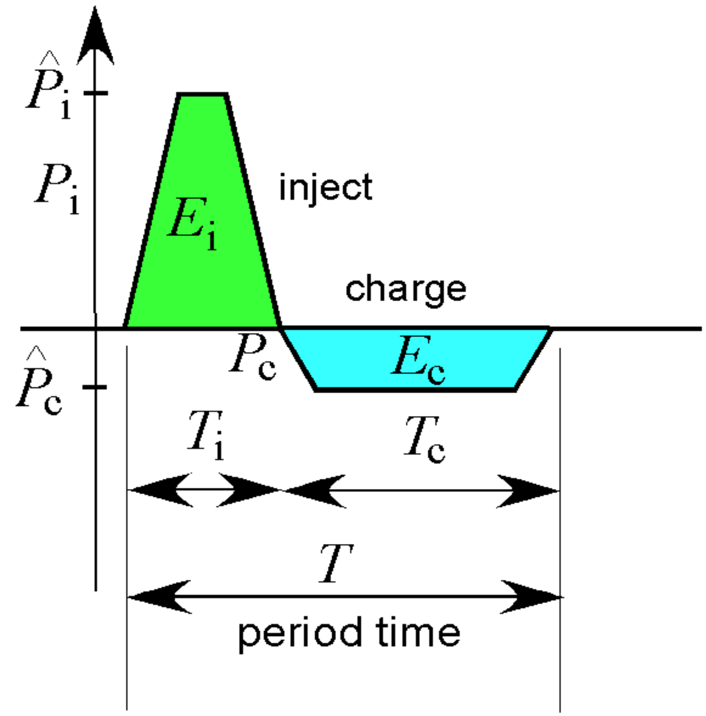
Golden Valley Electric Association BESS Project

- **40 MW Rating**
- **10 MWH Battery Capacity**

ABB

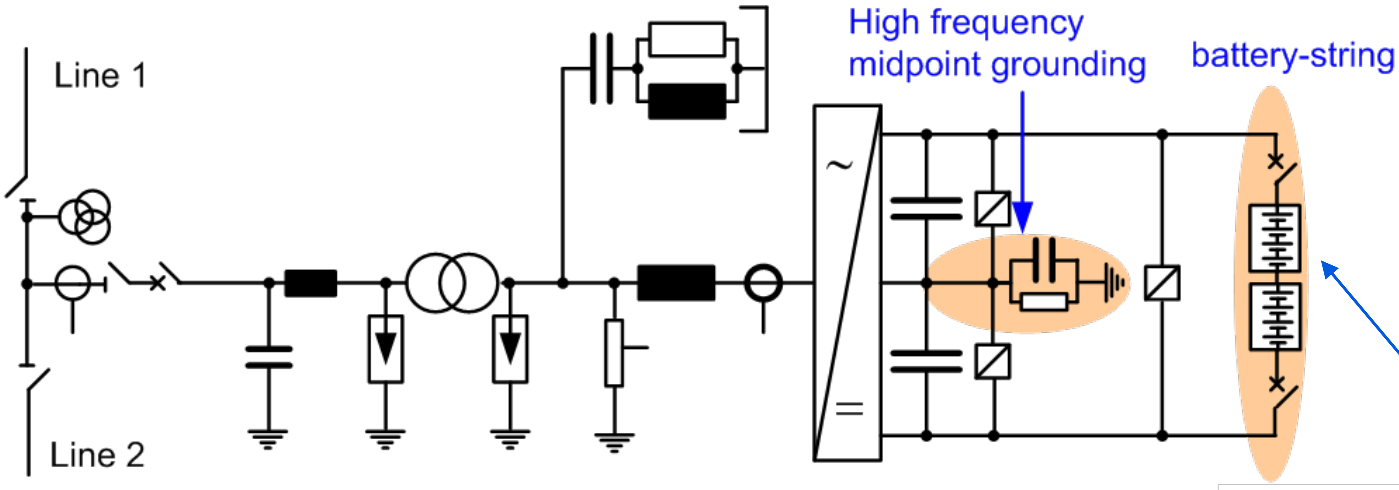
ABB FACTS: Dynamic Energy Storage





- Energy storage connected on DC-side of converter (SVC Light)
- Size depends on power level and duration
- Charge energy equal to load energy
- Focus on “dynamic”, manages:
  - High number charge and discharge cycles
  - High Power at medium duration
- Chosen high performance battery as energy storage

Storage
FACTS pilot project with active & reactive power comp.



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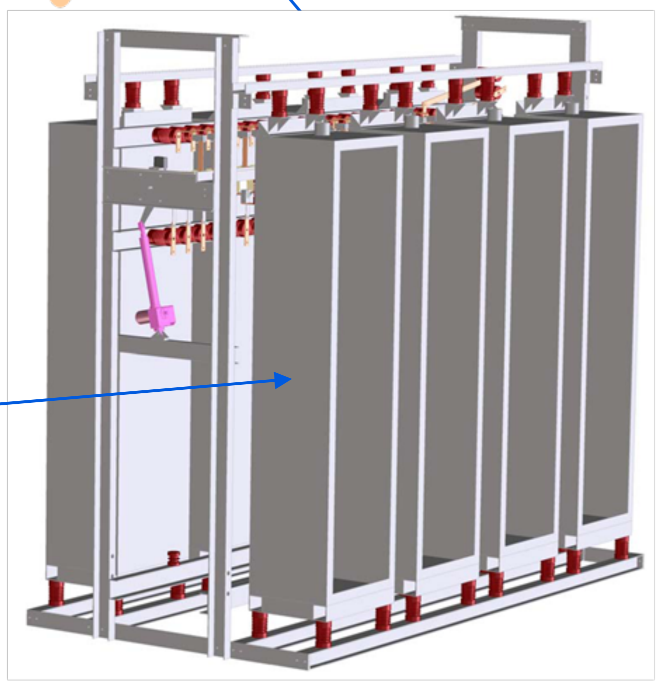


Battery: Li-Ion (Saft)

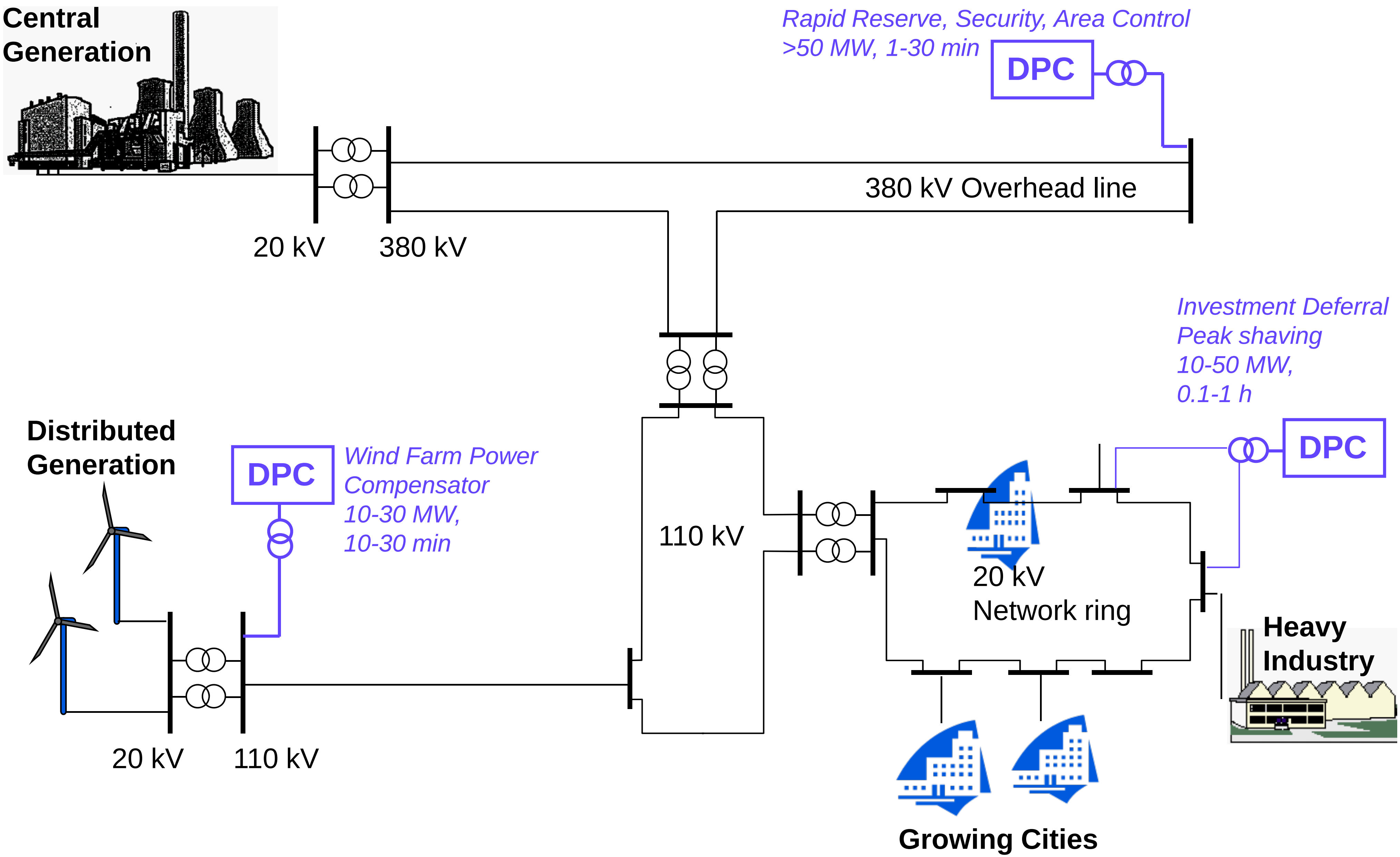
- Pilot: 8 stacks x 13 cells
- Customer: EDF UK
- Per stack: 720 V, 400 kg
- Total: 200kW for 1h, or 600kW short time
- Factory acceptance test: 6/2009
- Target installation: Q4/2009

ABB

Installation of Field Demonstrator

- ABB UK has a contract on an installation of a field demonstrator installation in distribution network
- Customer is EDF Energy, UK
- 11 kV Energy Storage and Voltage Control
- Data:
  - System Voltage: 11 kV ±6%
  - Reactive Power: 600 kVAr inductive to 600 kVAr capacitive
  - Active Power: 600 kW (short time), 200 kW during 1 hour

Dynamic Power Compensation Markets

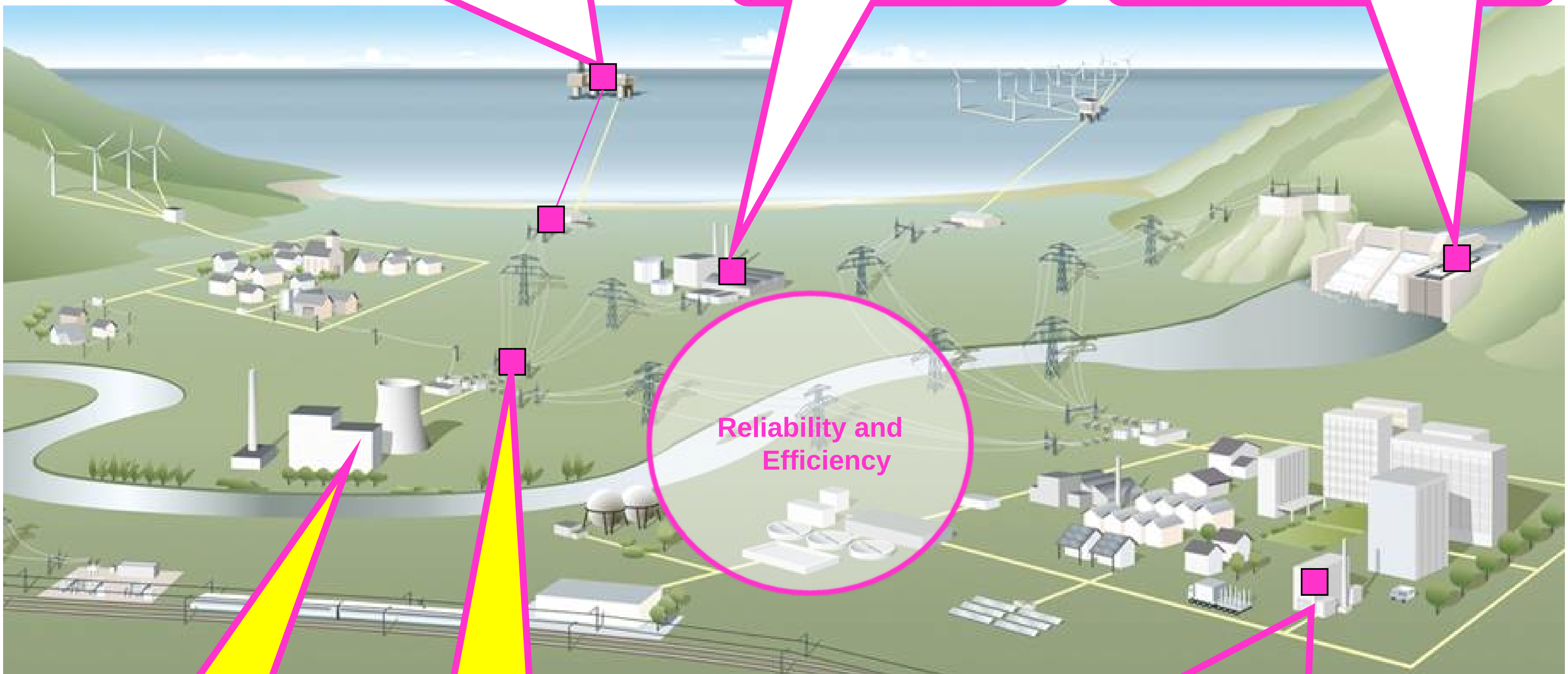


Power Electronics in Smart Grids
Reliability and efficiency

Efficient long-distance transmission with HVDC

Variable speed drives in industrial plants

Variable speed drives in pumped hydro stations



Converter and Machine with higher efficiency

Power flow control converters for transmission

Power quality solutions for industry:
- SVC
- SVC Light
- LV & MV STATCOMs

Reduced losses with HVDC

- Capacity
- Reliability
- **Efficiency**
- Sustainability

- HVDC is especially beneficial for long distance transmission with low losses
- Lower cost for infrastructure (fewer and smaller pylons, fewer lines) compensate higher investment in converter stations
- ABB will save 30 percent transmission losses by installing an ultra-high voltage direct current (UHVDC) connection more than 2,000 km long in China
- One of the world’s longest and powerful transmission systems from ABB operates at ± 800 kV, transporting 6,400 MW

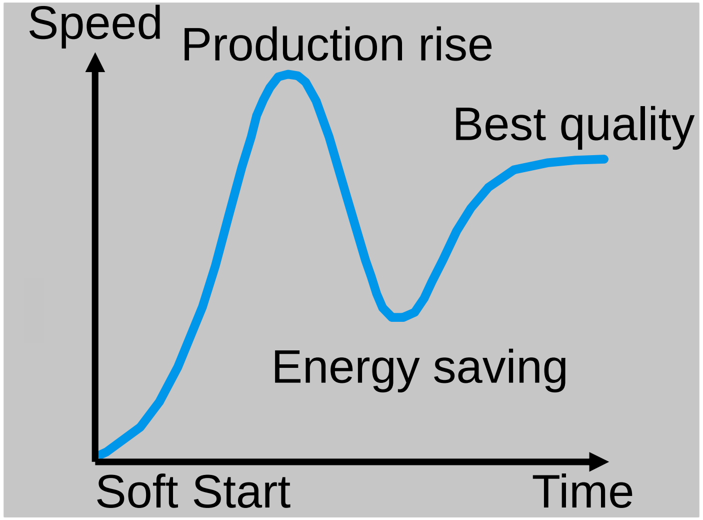
ABB has delivered most of the world’s installed HVDC systems

MV Drives
Why variable speed drives?

- 60 - 65% of industrial electrical energy is consumed by electric motors
- For each 1 USD spent to purchase a motor, 100 USD are spent for energy cost during its lifetime
- Today, only 5% of these motors are controlled by variable speed drives
- 30% of existing motors can be retrofitted with variable speed drives

- The installed base of ABB drives saves more than 120 TWh of energy per year, the equivalent of 15 nuclear power plants
- ABB drives reduce CO_2 emissions by approx. 60 million tons per year

MV Drives
Benefits of variable speed control



- Energy savings
- Improved product quality through better process control
- Reduced process equipment wear and longer lifetime of equipment
- Soft start and stop reduce waste and save raw material
- Noise reduction
- Improved process efficiency

MV Drives
Medium voltage AC drives for…

Cement, Mining & Minerals

Chemical, Oil & Gas

Marine

Metals

Power

Pulp & Paper

Water

Special applications, e.g. wind tunnels

MV Drives
Products

ACS 1000, ACS 1000i

- Cooling: air / water
- Power range: 315 kW – 5 MW
- Output voltage: 2.3 – 4.16 kV
- Air-cooled ACS 1000 available with integrated input transformer and input contactor (ACS 1000i)

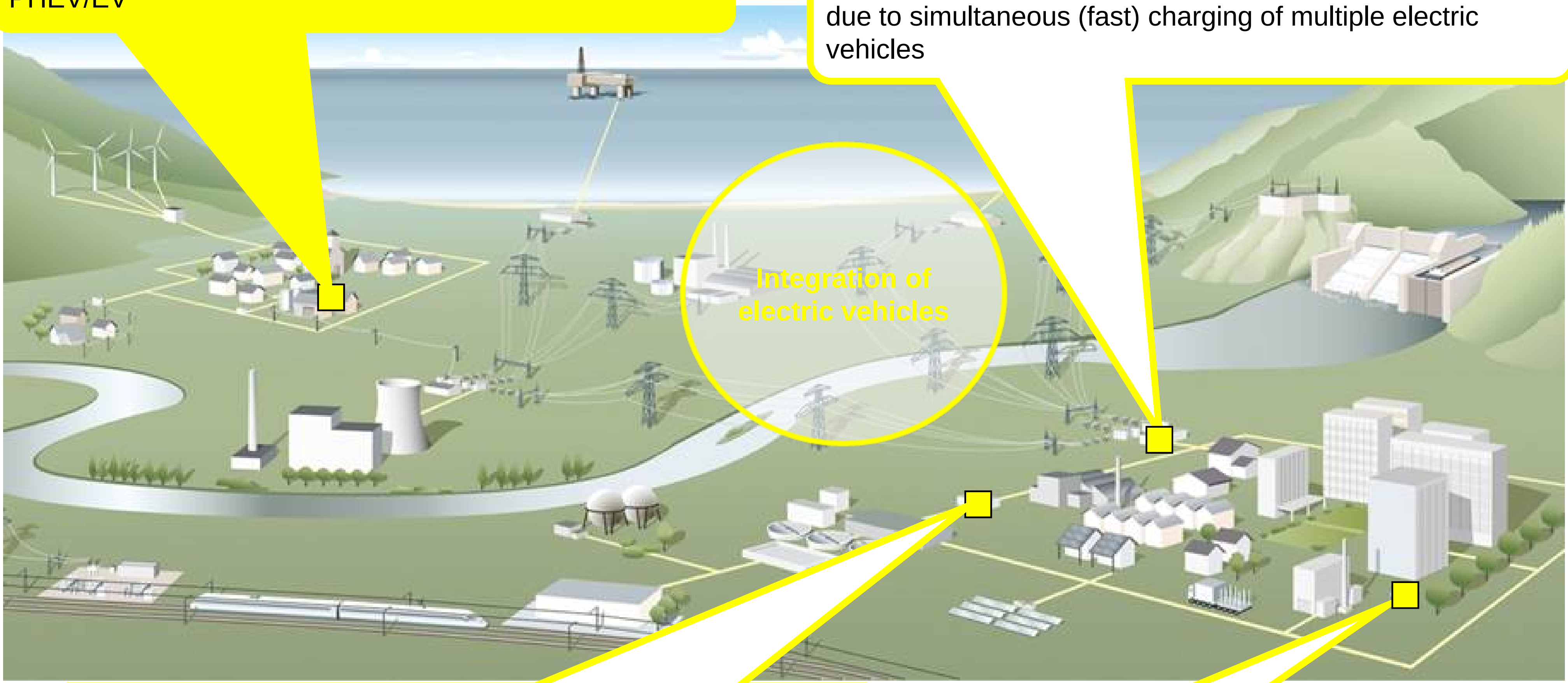
ACS 5000

- Cooling: air / water
- Power range: 2 – 22 MW
- Output voltage: 6.0 – 6.9 kV
- Air-cooled ACS 5000 available with integrated input transformer

Power Electronics in Smart Grids
Integration of electric vehicles

Residential inverters for energy storage, renewables, and PHEV/EV

Centralized energy storage (Dynapow) to absorbe peaks due to simultaneous (fast) charging of multiple electric vehicles



Stations for fast charging of electric vehicles

Traction drives for (hybrid) electric vehicles

Power Electronics for Battery Fast Charging Station

- **<u>What is ‘Battery charging station’?</u>**
  A battery charging station is a place supplying electricity for the recharging of electric vehicles including plug-in hybrid electric vehicles. Charging stations can be found on the road (fast), in parking lots (slow), and in garages at home (slow).

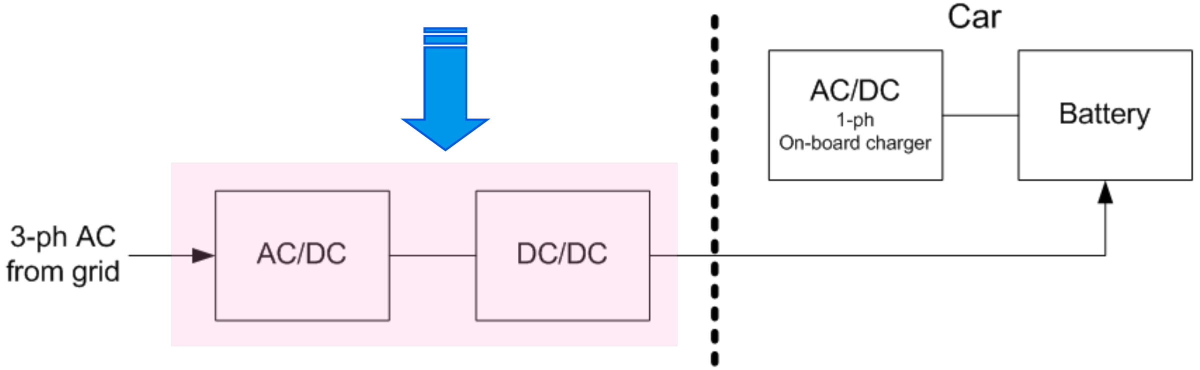
- **<u>What is ‘Fast charging’?</u>**

  Fast charging is expected to charge batteries within 10 minutes or less for complete replenishment, which is equivalent to existing ‘Fuel Stop’.

- **<u>Why is ‘Charging station and Fast charging’ needed?</u>**
  - All major automobile manufacturers are actively developing alternative fuel vehicles.
  - All major automobile manufacturers have PHEV & BEV on their short-mid term planning horizon.
  - Substantial EV market growth worldwide by 2030.
  - PHEV/BEV/EV require charging infrastructure, especially fast charging station equivalent to existing ‘gas station’.

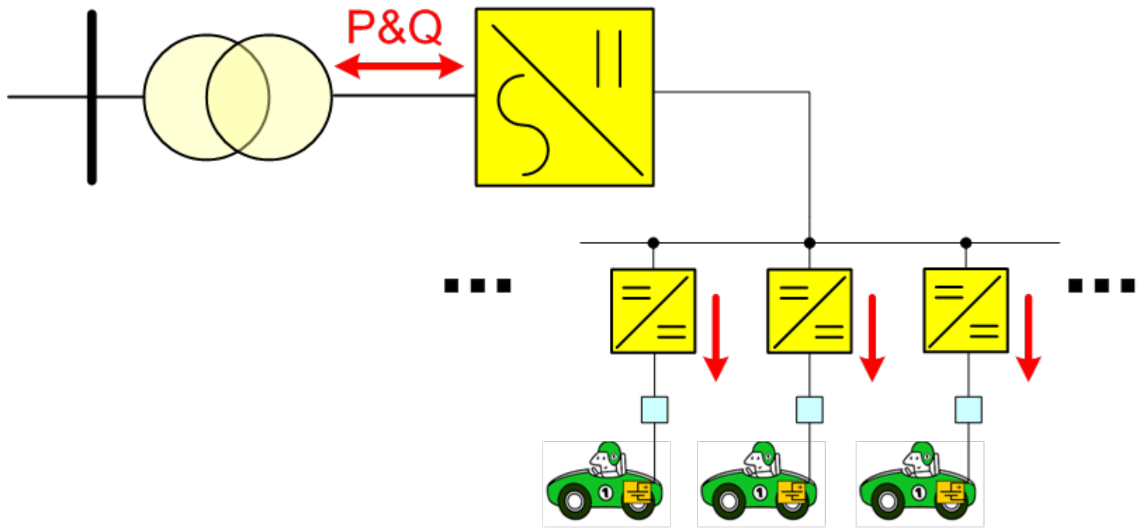
- **<u>Power Electronics for Fast Charging</u>**

  Fast charging requires dedicated AC/DC & DC/DC power conversion



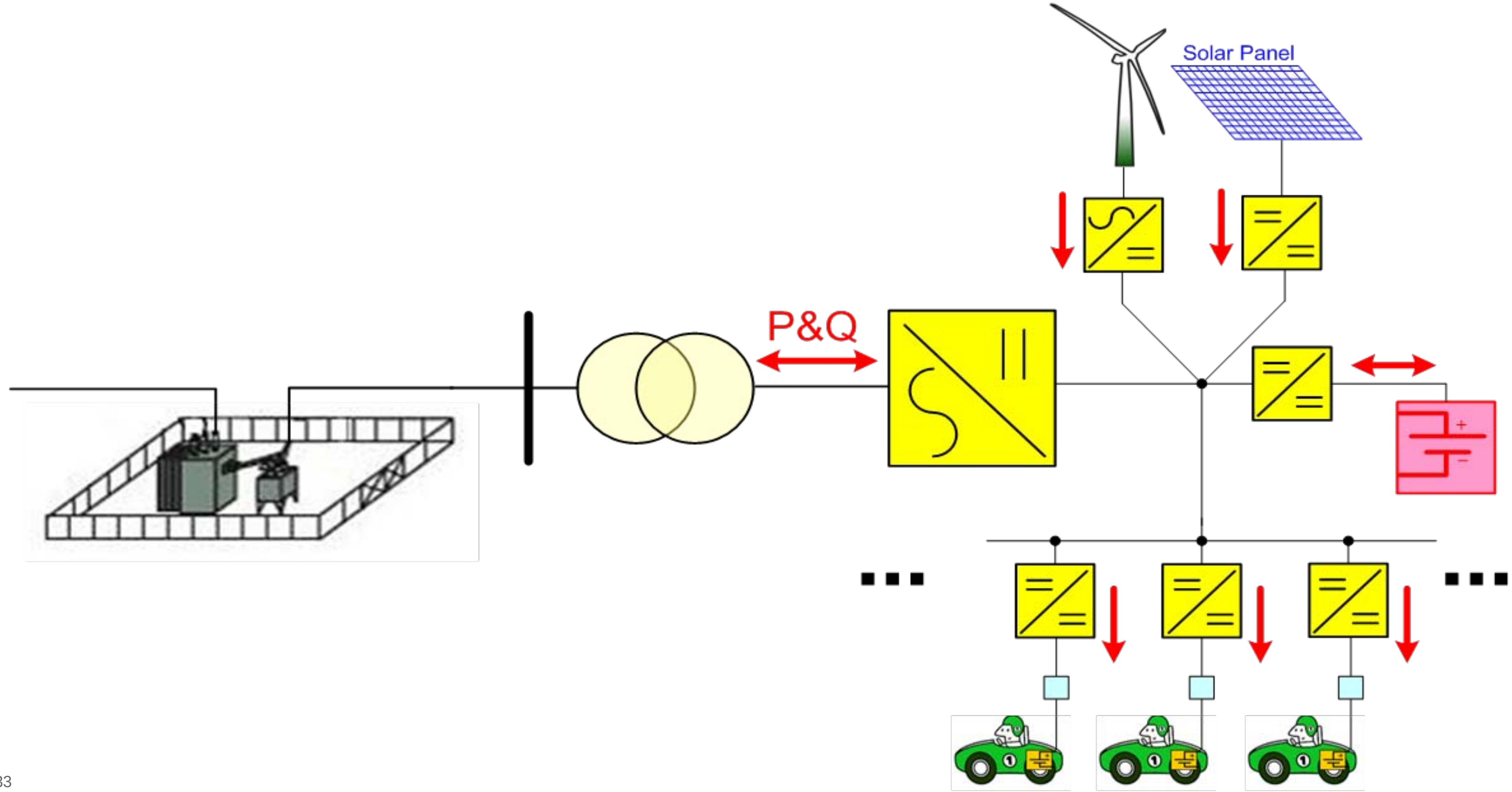
Infrastructure of Battery Fast Charging Station

- Assumption:
  - A fleet of all electric vehicles with battery packs in the range of 25-50kWh (driving range of 100 – 200km)
- Scenario:
  - A ten-minute quick charge from 10% to 90% capacity for 25kWh battery pack would require a power draw of about 120kW from the grid.
  - If average charging station is capable of serving 10 cars simultaneously, a ten-minute quick charge for all 10 vehicles refers to 1.2MW load. Charging station load would continuously fluctuate in the range of 0-1.2MW.
  - If there are 20 fast charging stations in a city, there will be continuous load fluctuation in the range of 0-24MW from a grid perspective.



Opportunities for Power Electronics in Charging Station

- High efficient 3-ph DC-AC and DC-DC converters
- Grid side active rectifier for large fast charging station
- Integration of renewable energy source into fast charging station with bulk electrical energy storage.
- Island mode of fast charging station with electrical energy storage + renewable energy source
- Protection from various situations such as lightening.

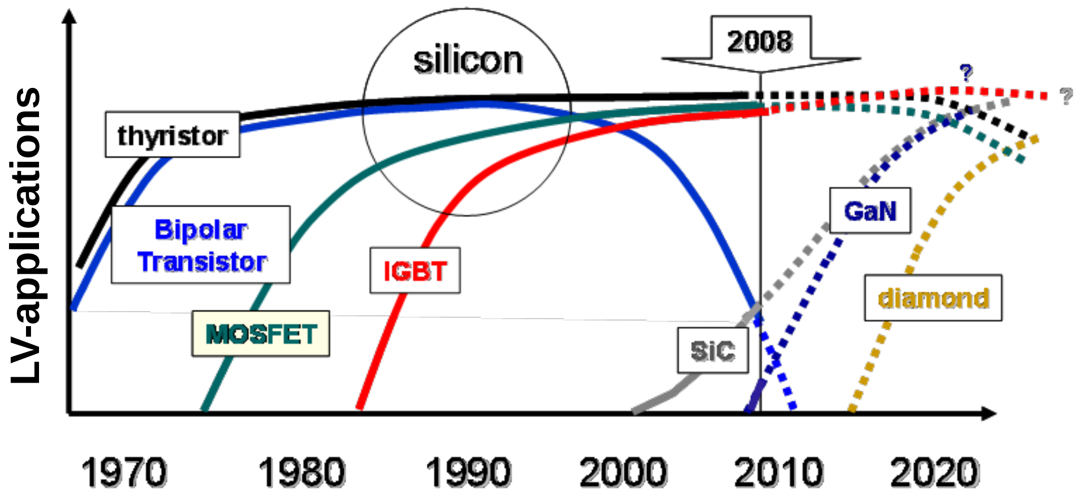


Conclusion: Smart Grid Needs High MW Electronics

- Current switching
- Current interrupting
- Current limiting
- Transformer

→ **Solid-state substation**

- **Main Challenges:**
  - High reliability
  - Low losses
  - Thermal Management/Cooling
  - High switching frequency
  - High blocking voltage for direct M connection
  - High power density/Footprint
  - Low cost



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