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November 2015

Offshore Wind Application of HVDC PLUS

Electric Power Industry Conference 2015
Matthew Korytowski

Introduction
Siemens Is Leading in Offshore Grid Access

10 offshore grid connections with
3.5 gigawatts capacity in AC technology

Completed projects

- **2007** – Lillgrund, SE (110 MW)
- **2008** – Lynn & Inner Dowsing, GB (194 MW)
- **2010** – Thanet, GB (300 MW)
- **2010** – Greater Gabbard, GB (500 MW)
- **2010** – Bard 1, DE (400 MW)
- **2011** – Galloper, GB (140 MW)
- **2013** – London Array, GB (630 MW)
- **2014** – Lincs, GB (270 MW)
- **2015** – Gwynt y Mor, GB (576 MW)

Ongoing projects

- Dudgeon, GB (502 MW)

Cable links longer than around 80 km are more economical and technically better when HVDC technology is used

5 offshore grid connections with
3.8 gigawatts capacity in DC technology

Completed projects

- **2015** – BorWin2, DE (800 MW)
- **2015** – HelWin1, DE (576 MW)
- **2015** – SylWin1, DE (864 MW)
- **2015** – HelWin2, DE (690 MW)

Ongoing projects

- BorWin3, DE (900 MW)

Introduction
Ambitious Offshore Objectives in Europe

- The largest offshore-markets are Great Britain and Germany
- Significant expansion of offshore wind power planned in both countries

Germany

	6.5 gigawatts planned by 2020
+	8.5 gigawatts planned by 2030
+	23 gigawatts (potential further expansion)
=	38 gigawatts

Offshore wind share in power mix

4% by 2020 10% by 2030

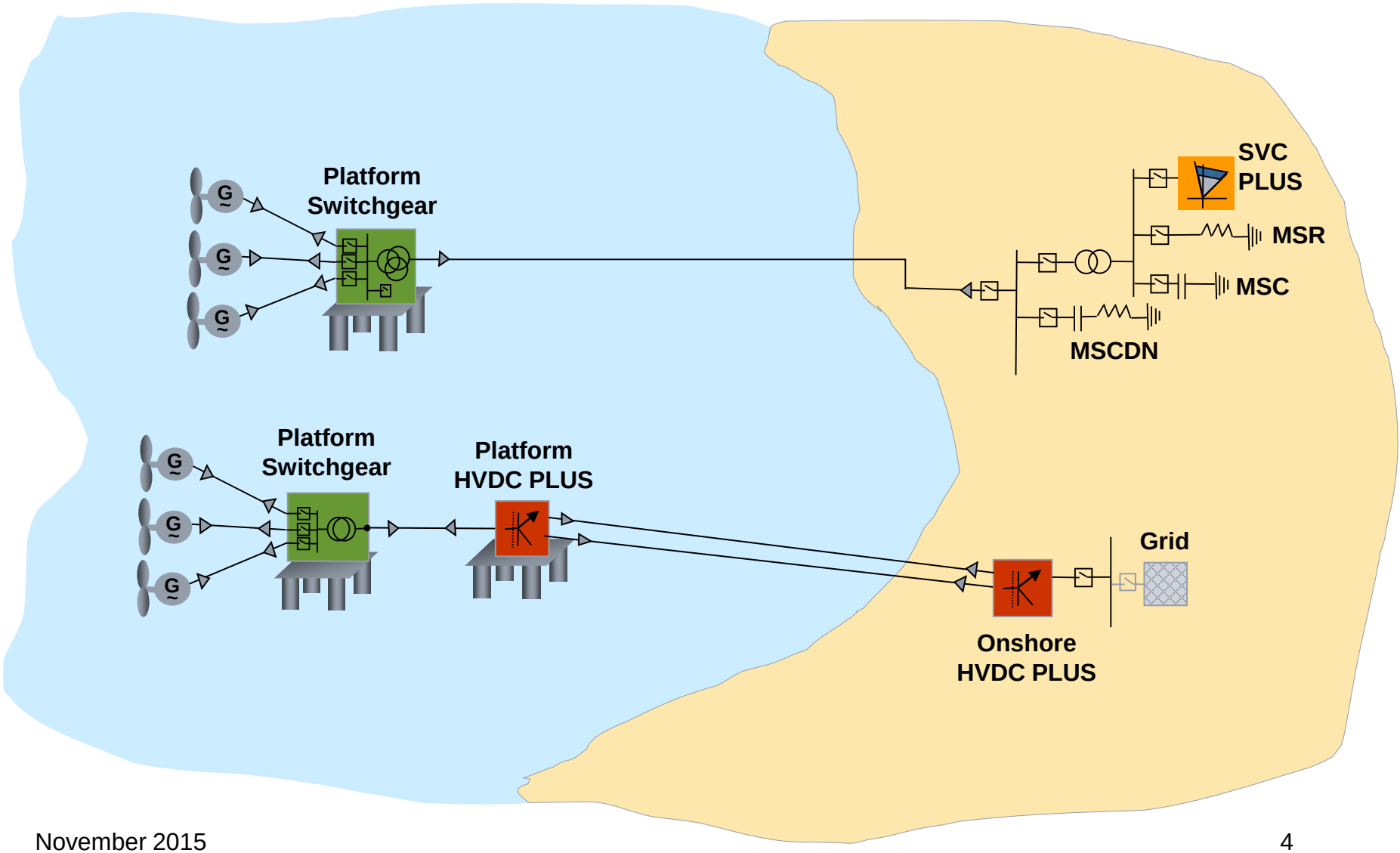
Great Britain

	1 gigawatt	(Round 1 → completed)
+	7 gigawatts	(Round 2 → ongoing)
+	2 gigawatts	(Expansion 1&2 → ongoing)
+	32 gigawatts	(Round 3 → planned)
+	9 gigawatts	(Scotland → planned)
=	51 gigawatts	

Offshore wind share in power mix

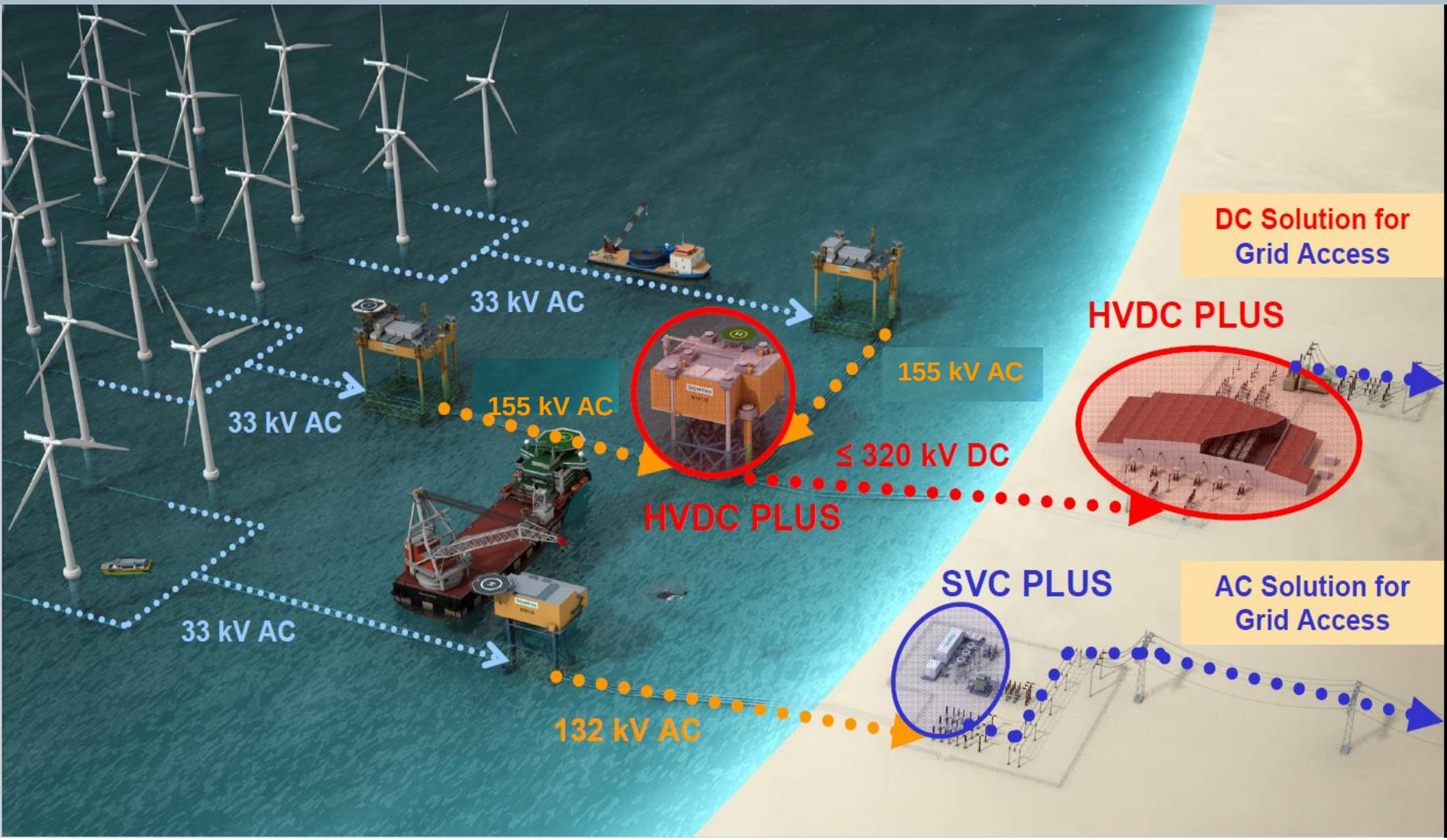
10% by 2020 27% by 2030

Introduction
Typical AC and DC Transmission for Offshore



Introduction

Grid Access AC and DC with SVC PLUS and HVDC PLUS



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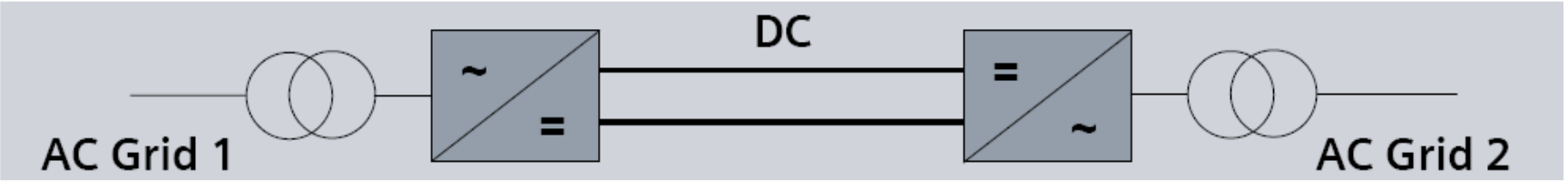
Benefits, How Does It Work?, Layout

HVDC PLUS Overview

Basics of HVDC PLUS
Comparison of HVDC Classic – HVDC PLUS



HVDC Classic

Line-commutated
current-sourced Converter

Thyristor with turn-on Capability only

- Direct-light-triggered Thyristor (LTT)
- Up to 10000 MW
- MI Cable up to 600 kV
- OHL up to 800 kV

HVDC PLUS

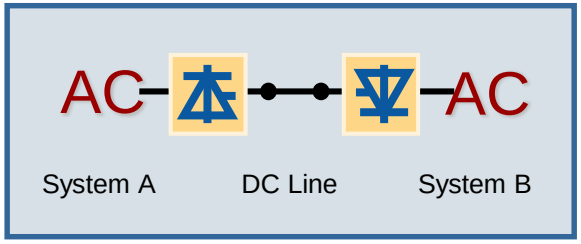
Self-commutated
voltage-sourced Converter (VSC)

Semiconductor Switches with turn-on only and turn-off Capability, e.g. IGBTs

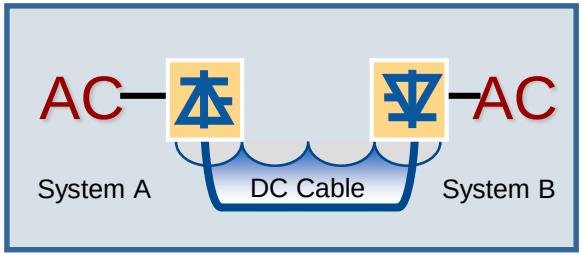
- XPLE Cable up to 320 kV DC
- Half bridge up to 1,56 kA
- Full bridge up to 2 kA

Basics of HVDC PLUS
HVDC Applications

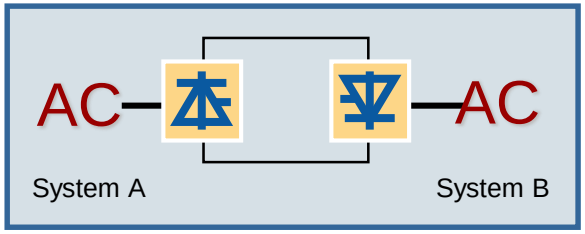
- Long Distance



- DC Cable



- Back-to-Back



Basics of HVDC PLUS
Technical Advantages of HVDC Controllability

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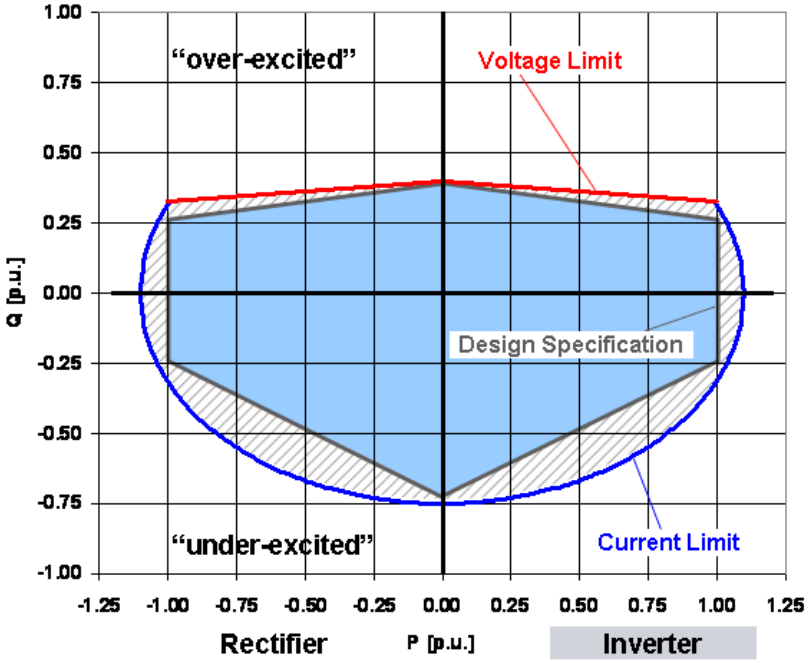
HVDC Controllability is beneficial for:

- Exact Control of Power Flow in either Direction
- Enhancement of AC System Stability
- Reactive Power Control / Support of AC Voltage
- Frequency Control
- Overload Capability
- Emergency Power Functions
- Power Oscillation Damping

→ HVDC is a Firewall against Cascading Disturbances

Basics of HVDC PLUS
Advantages of VSC Technology

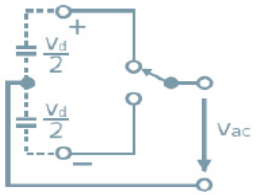
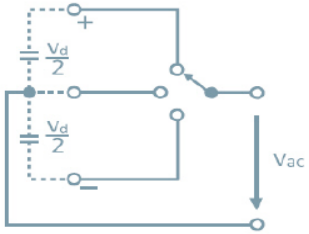
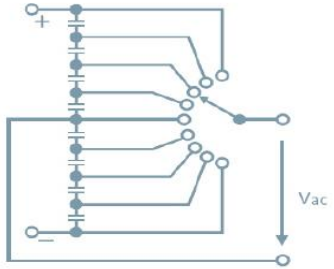
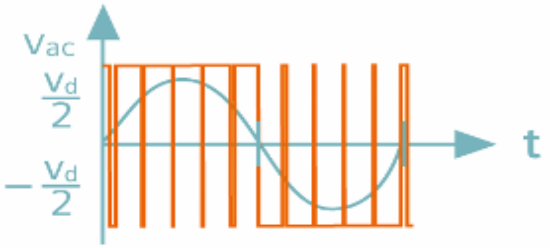
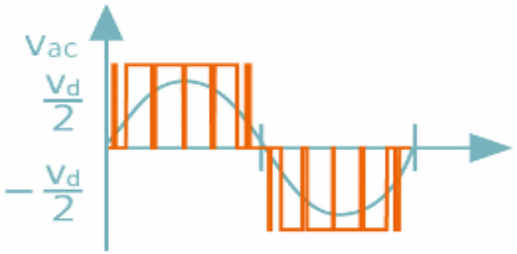
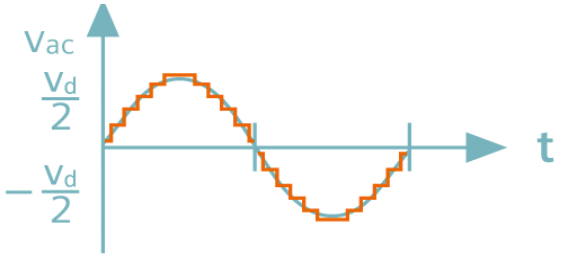
- Grid access for weak networks becomes possible
- Active and reactive power can be adjusted independently of one another
- Passive networks can be fed (Black-Start Capability)
- Good dynamic performance makes it easier to handle fault situations
- In comparison with classical line-commutated HVDC technology, less space is needed



The reactive power can be controlled to any value within the limiting characteristics

Basics of HVDC PLUS
The Evolution of VSC Technology

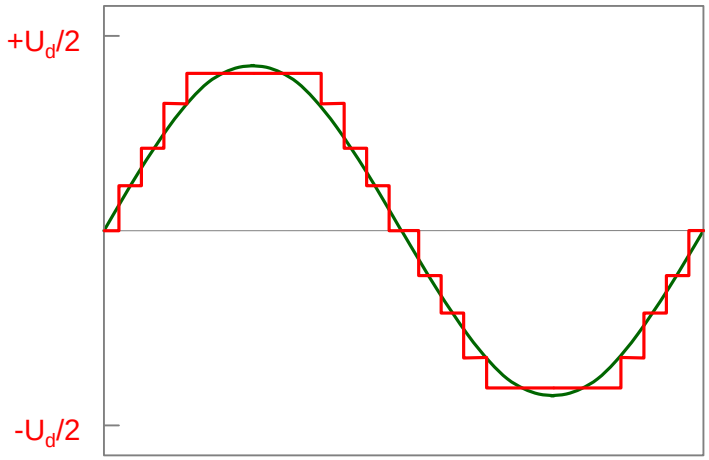
Topology of VSC

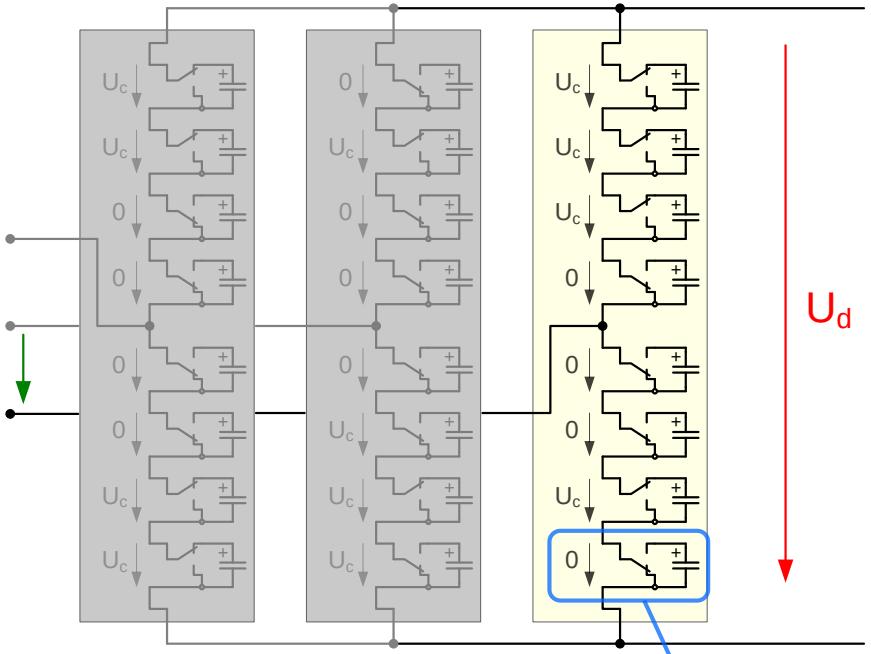
Two-Level	Three-Level	Multilevel
		
		

Power Electronic Devices

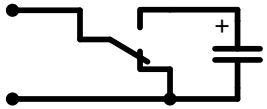
GTO /IGCT	IGBT in PP	IGBT Module
		

Modular Multilevel Converter - MMC





- Low level of harmonics and HF noise
- Low switching losses
- Modular arrangement with identical two-terminal power modules



Basics of HVDC PLUS
Features and Benefits of MMC Topology

Features	Benefits
High Modularity in Hardware and Software	High Flexibility, economical from low to high Power Ratings
Low Generation of Harmonics	Only small or even no Filters required
Low Switching Frequency of Semiconductors	Low Converter Losses
Use of well-proven Standard Components	High Availability of State-of-the-Art Components
Sinus shaped AC Voltage Waveforms	Use of standard AC Transformers
Easy Scalability	Low Engineering Efforts, Power Range up to 1000 MW
Reduced Number of Primary Components	High Reliability, low Maintenance Requirements
Low Rate of Rise of Currents even during Faults	Robust System

Basics of HVDC PLUS
Power Module – Single Unit

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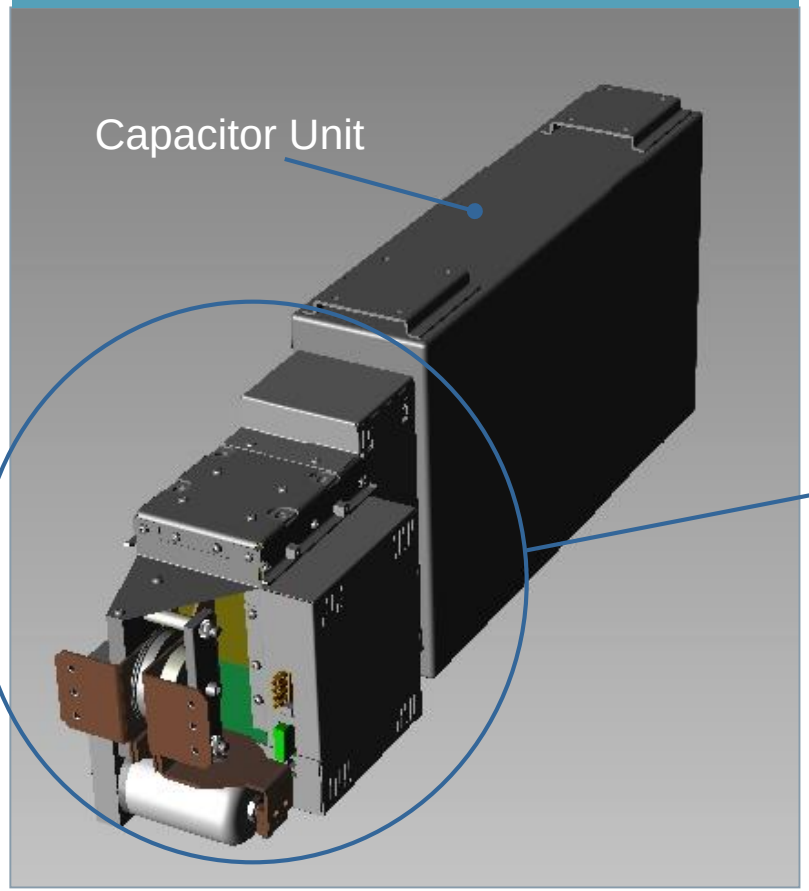
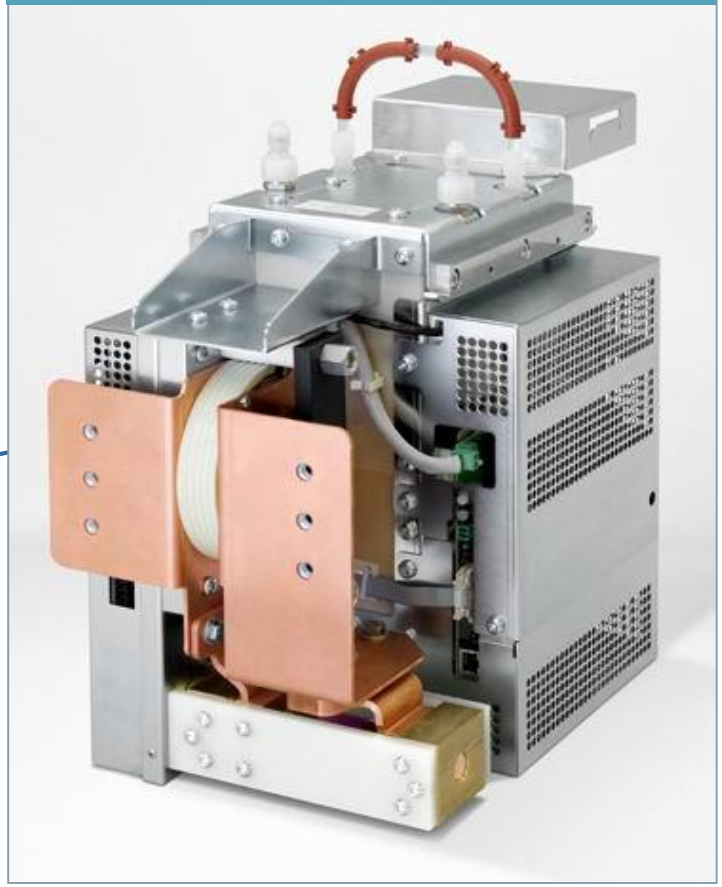
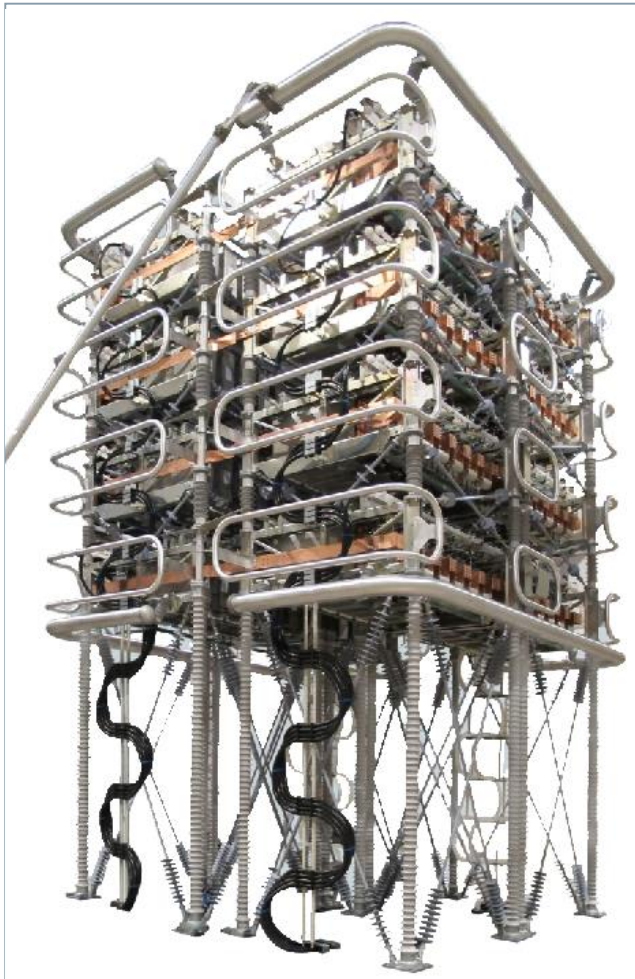
The Power Module
- a two terminal component



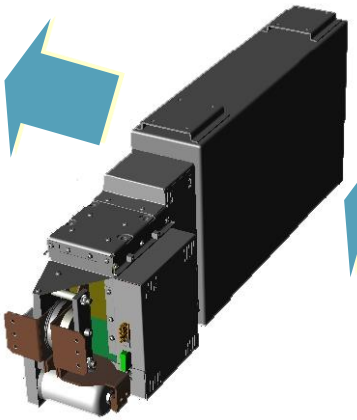
The Power Electronics



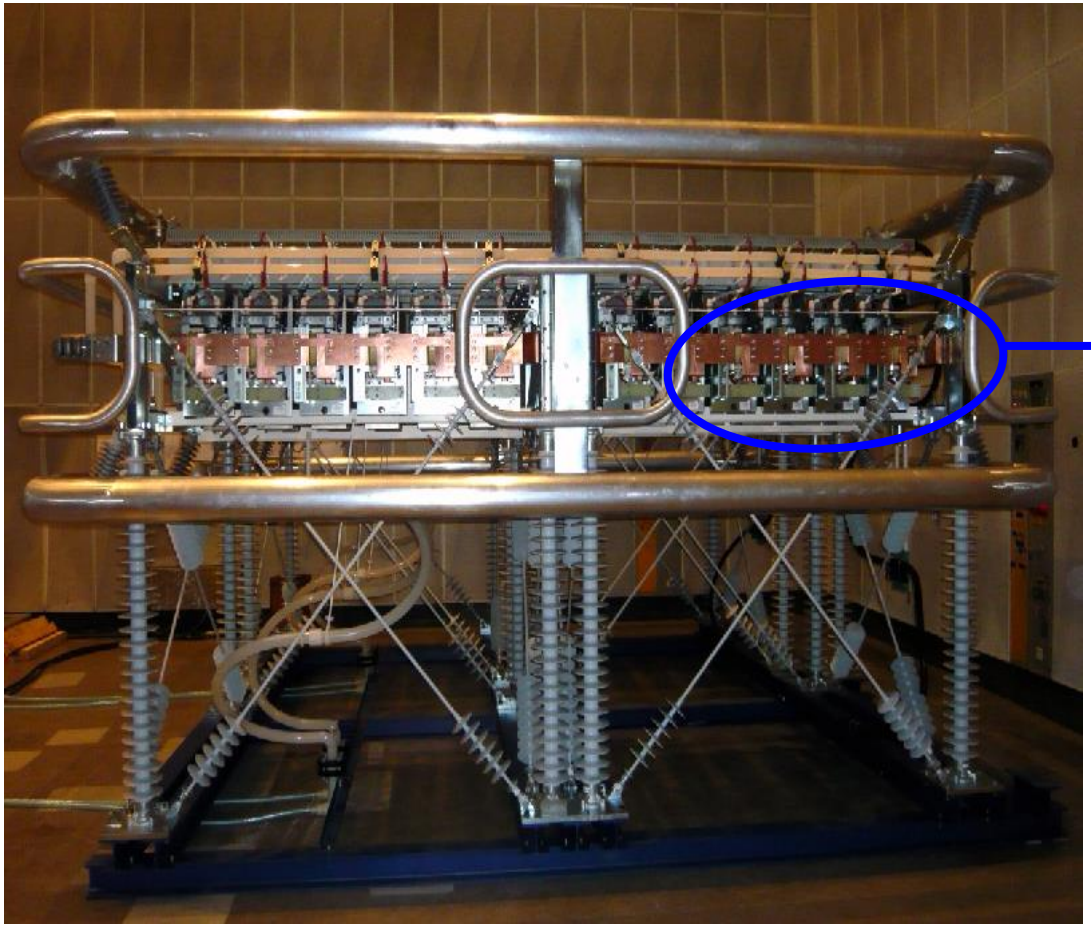
Basics of HVDC PLUS
Power Module – Complete Installation

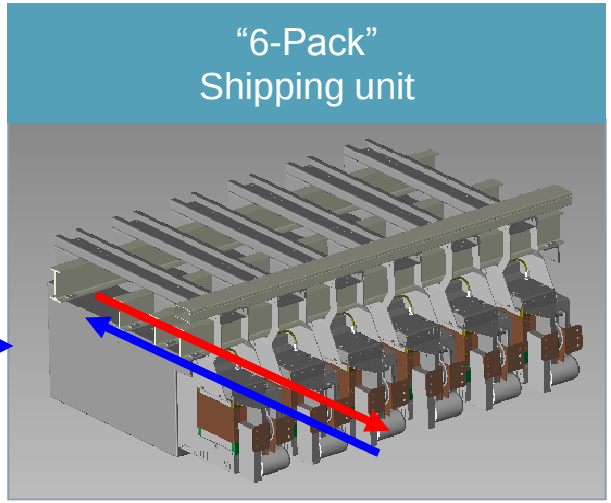


- Compact Design
- Modular Design
- Lower Space Requirements
- Advanced VSC Technology
- Maintenance friendly



Basics of HVDC PLUS
Power Module - Modular Converter Design



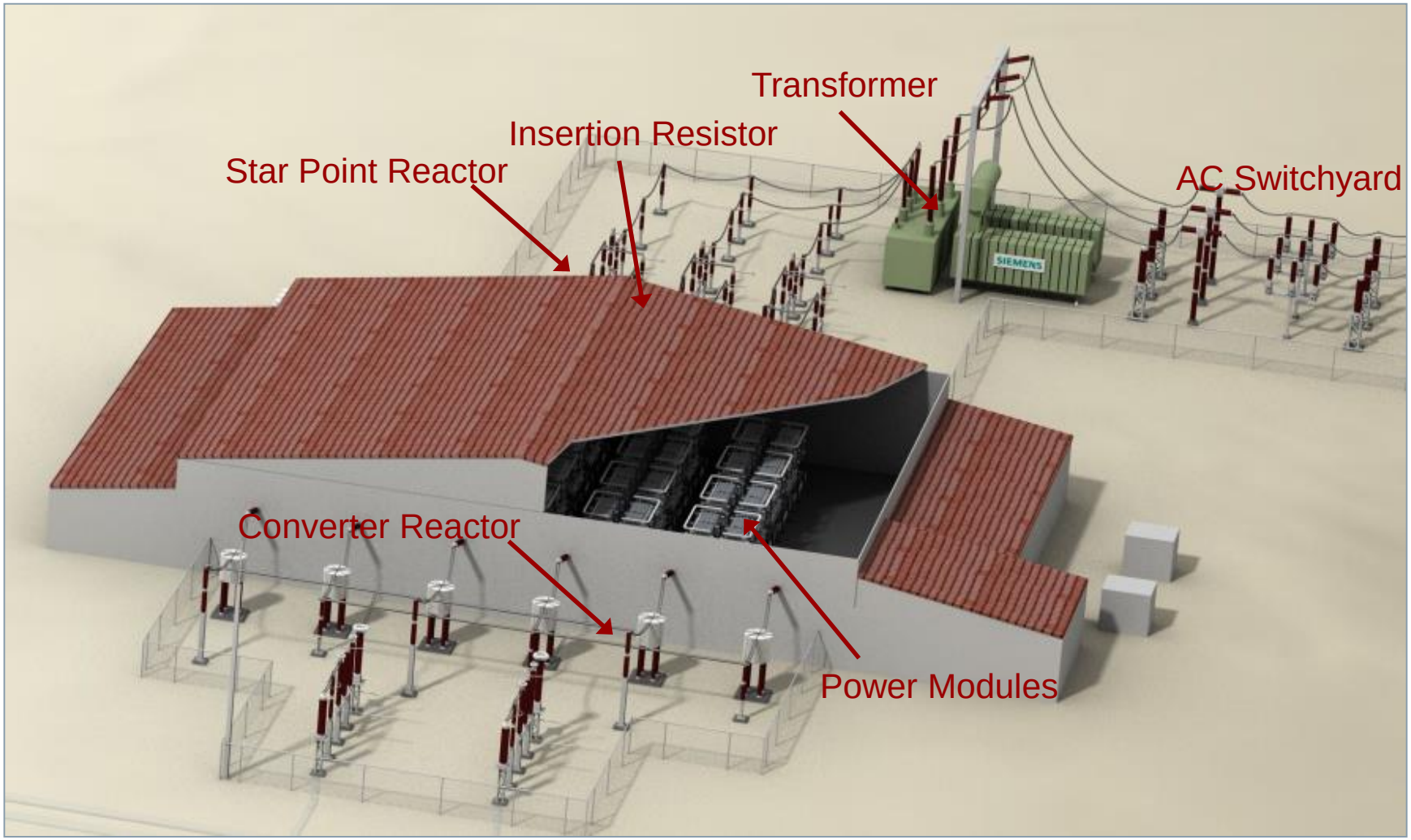


Replacement of single Power Modules

Double Tower with:

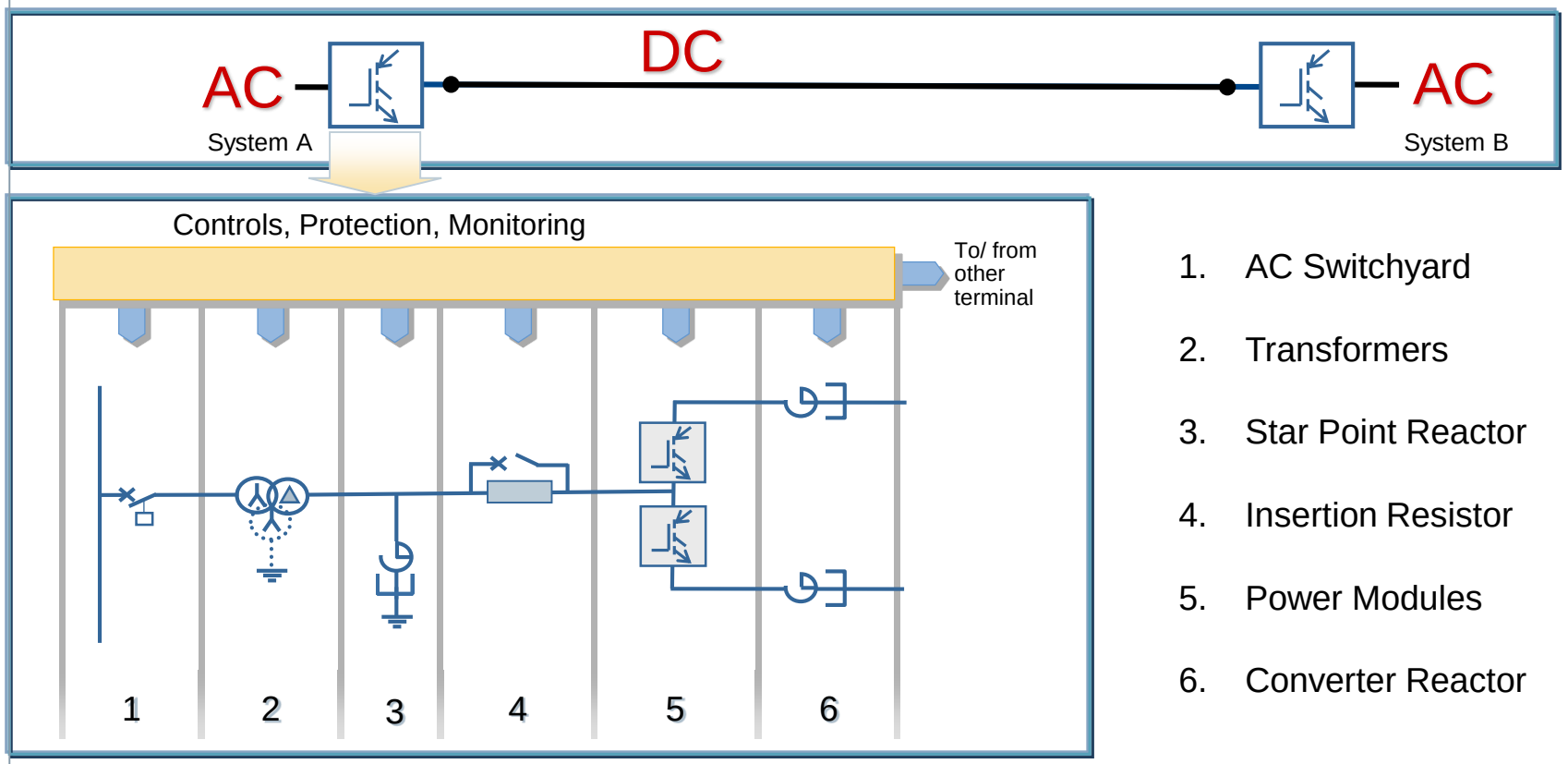
- 3 Floors (72 Power Modules)
- 4 Floors (96 Power Modules)
- Defined internal Voltage Stress
- Compact Installation

Basics of HVDC PLUS
Station Design



Basics of HVDC PLUS
Key Components

Example: Symmetrical Monopole



1. AC Switchyard
2. Transformers
3. Star Point Reactor
4. Insertion Resistor
5. Power Modules
6. Converter Reactor

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Converter Requirements, DC Chopper

HVDC PLUS Application

Offshore Windfarm Grid Access with HVDC System
Requirements for Converter Control

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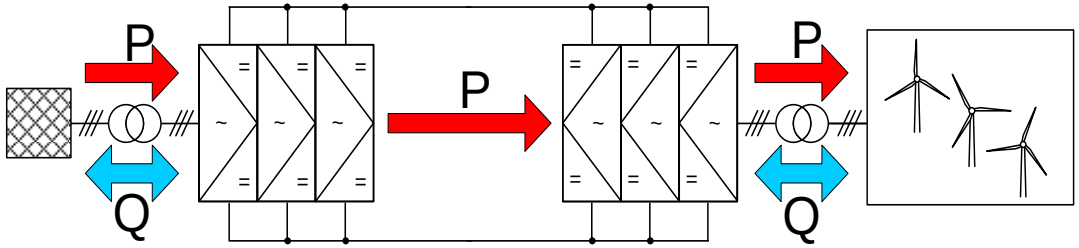
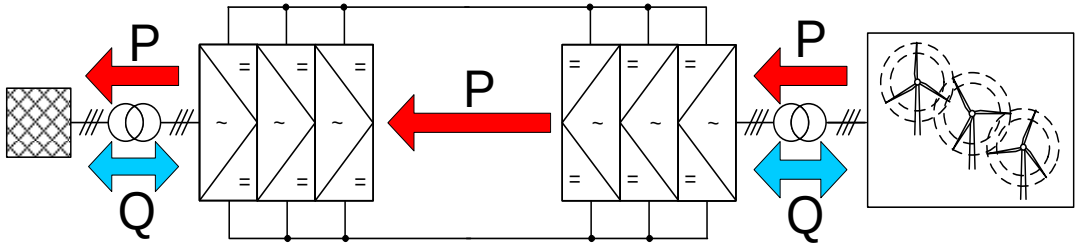
Power system management via offshore converter

- ✓ Blackstart capability
- ✓ Converter is controlling the offshore frequency and amplitude
- ✓ For AC faults offshore: Converter delivers short circuit current, reliable protection of the offshore grid

✓ Startup Windfarm

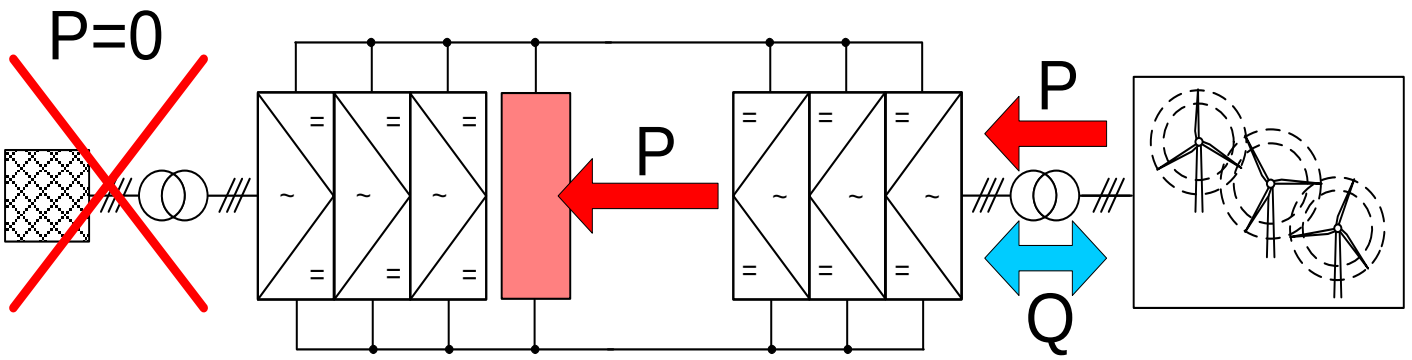


✓ Steady State Operation



Offshore Windfarm Grid Access with HVDC System
Onshore DC Chopper

- Absorbs windfarm power in case of onshore grid faults
- Continuous operation for windfarms in case of onshore grid faults
- For longer lasting faults, the windfarm can be shut down regularly – no emergency shut off
- Onshore Installation of chopper – minimize space needed offshore



Offshore Windfarm Grid Access with HVDC System
DC Voltage - Braking Chopper HVDC PLUS

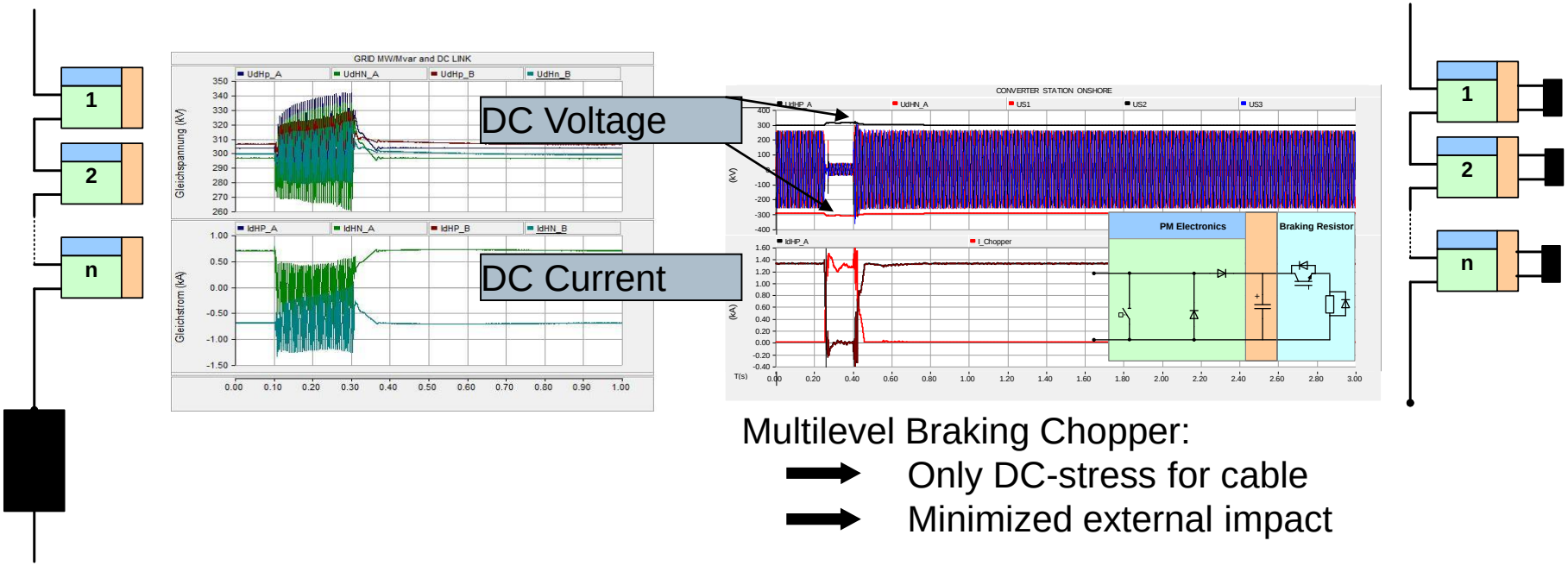
No central DC Capacitor for Multilevel VSC

➡ Stabilization of DC Voltage with Chopper Operation

- Central Braking Resistor
- Series connection
- Large ripple on DC voltage +/- 50kV

vs.

- Multilevel Braking Chopper
- Integrated resistor
- Controlled, smooth DC voltage



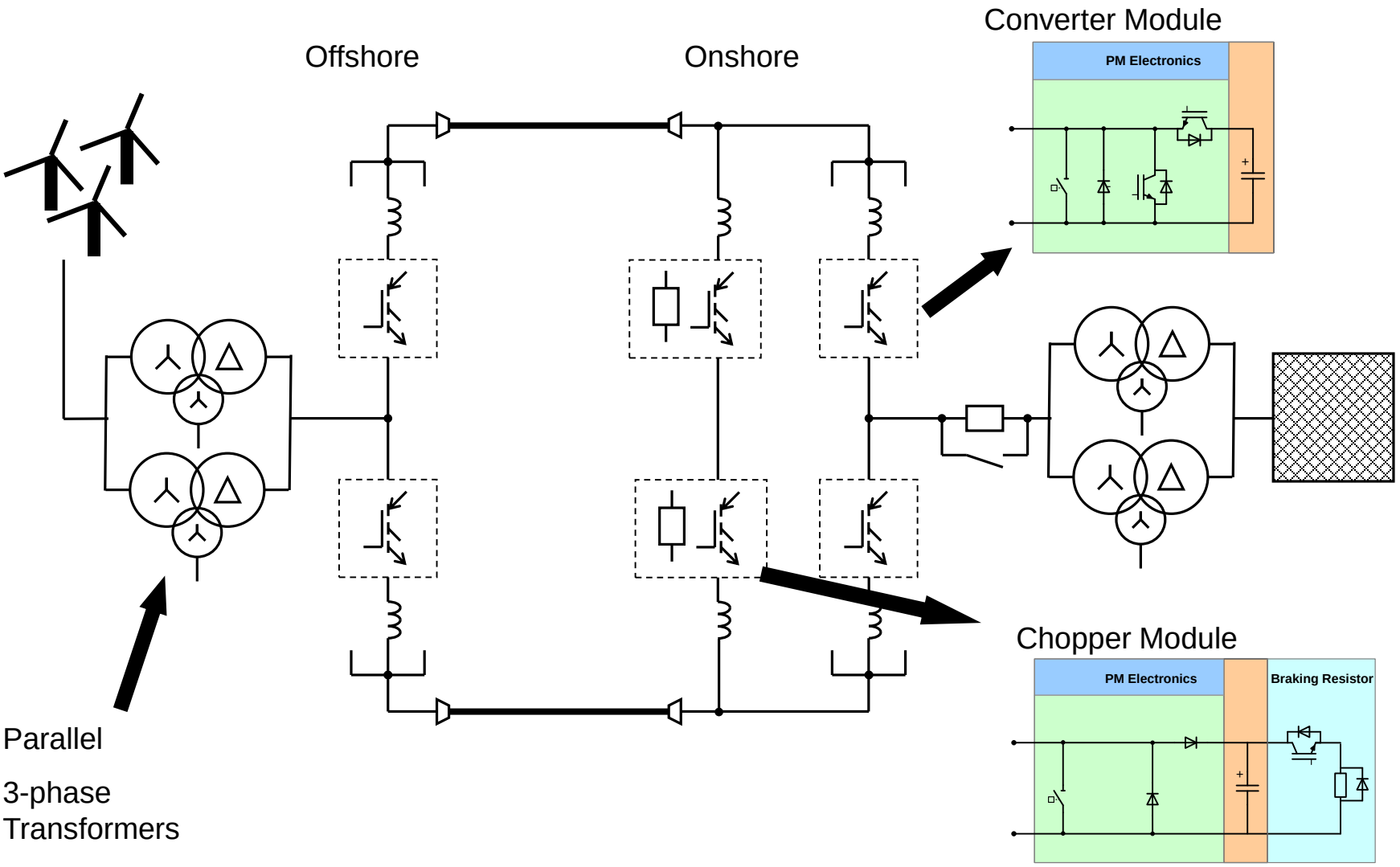
Multilevel Braking Chopper:

➡ Only DC-stress for cable

➡ Minimized external impact

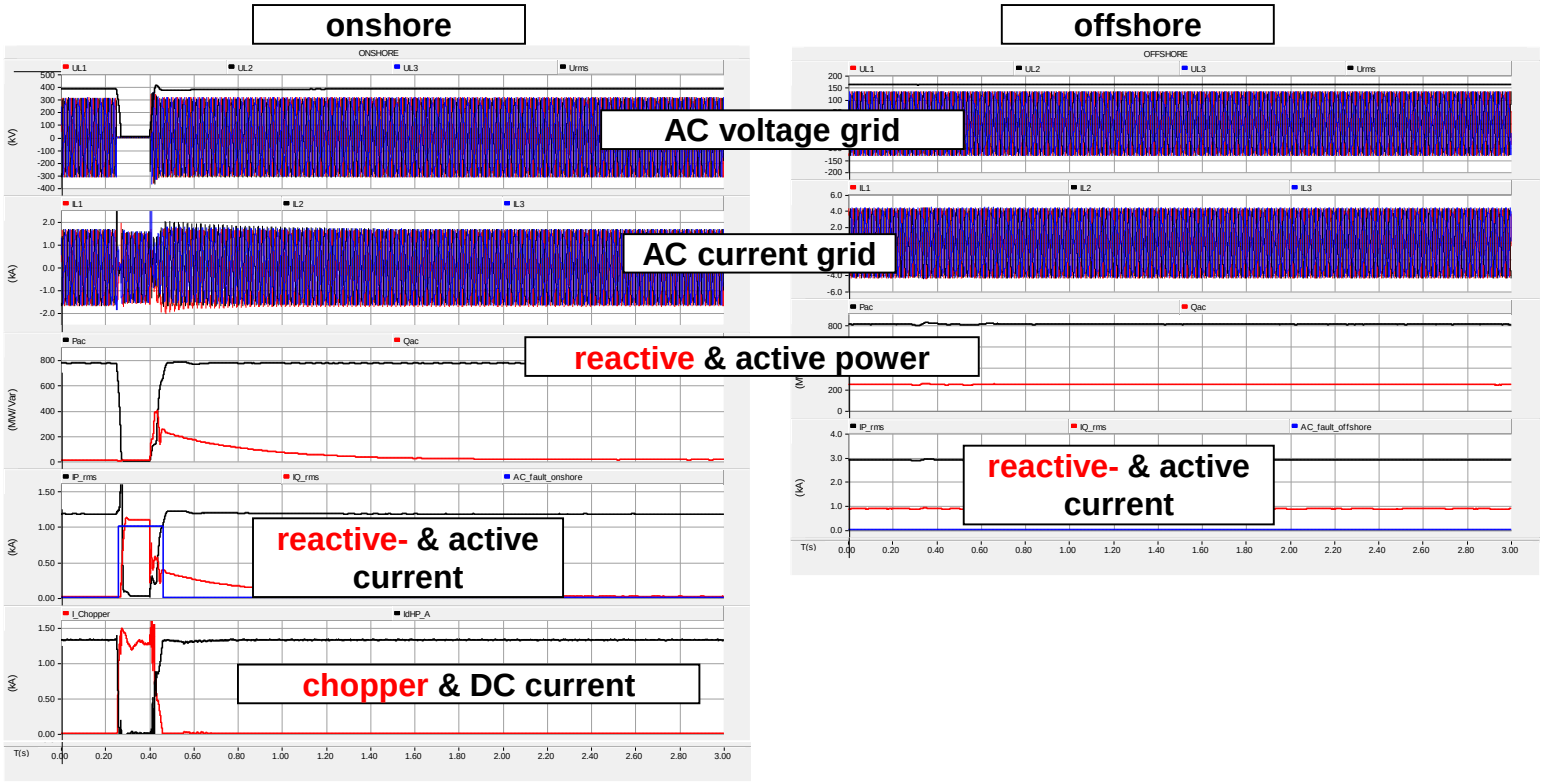
Offshore Windfarm Grid Access with HVDC System

DC System with Onshore Braking Chopper



Offshore Windfarm Grid Access with HVDC System

Onshore Station – DC Chopper performance



3-Phase-to-Ground Fault

Enables Fault-Ride-Through of the Windfarm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Thank you for your attention!
Any questions?