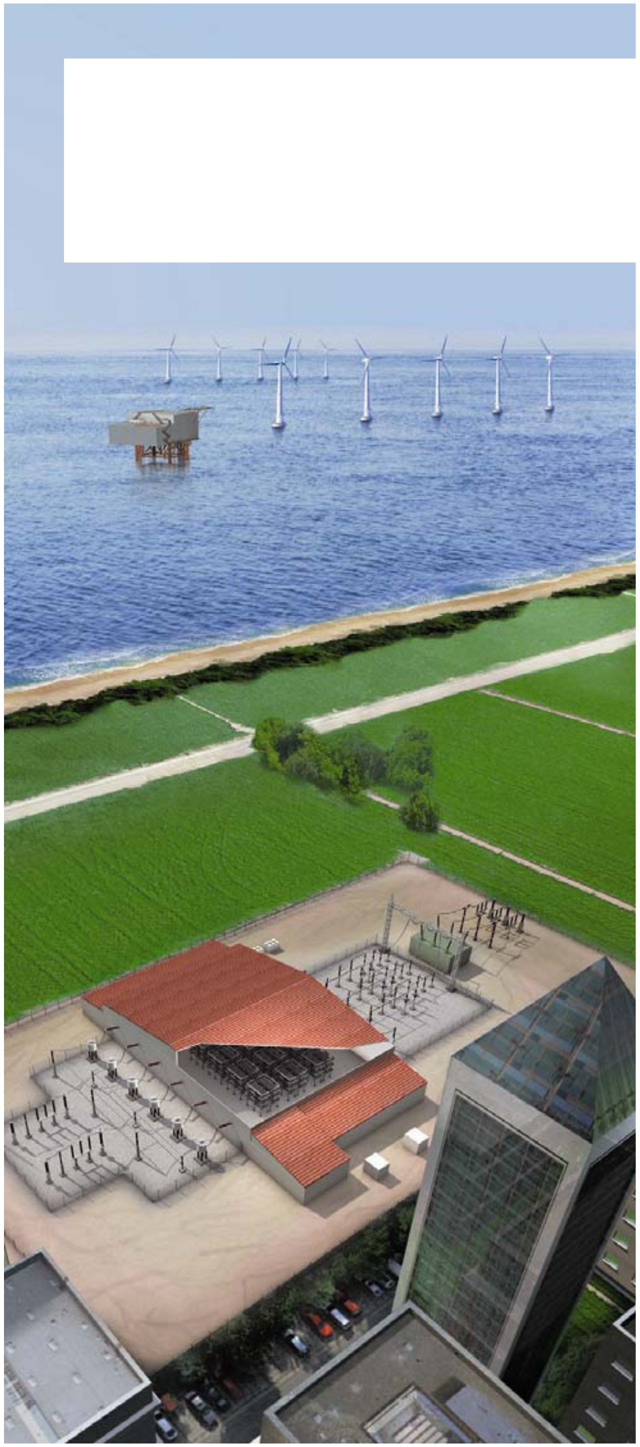


SIEMENS

HVDC PLUS

Voltage Source Converter Solution HVDC

Technology, Benefits, Applications

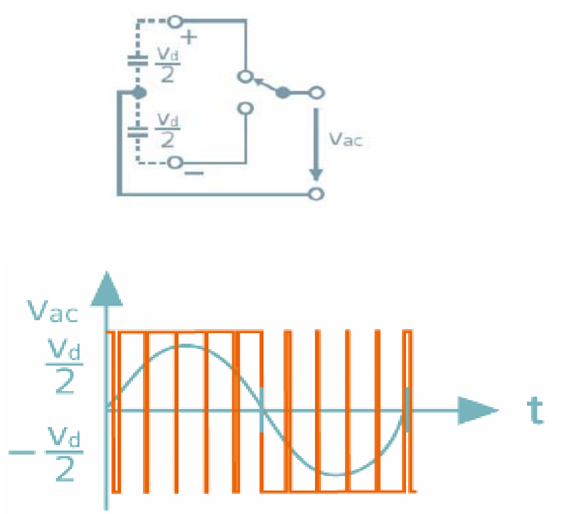
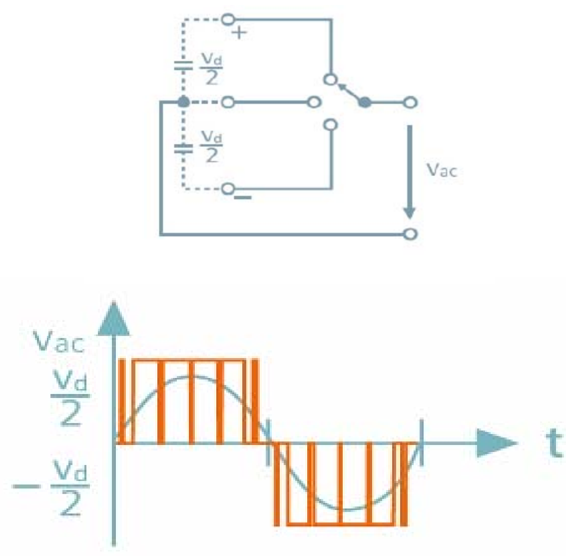
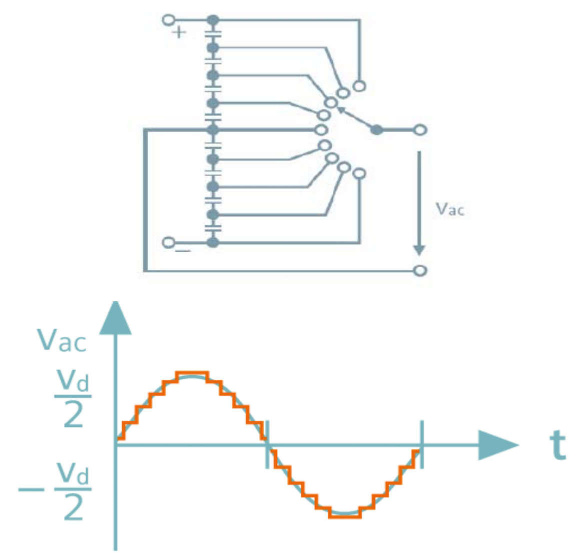
SIEMENS

Advantages over HVDC Classic

- Large reactive power consumption (50-60% of active power flow) at both rectifier and inverter ends
- Extensive filtering requirements due to low order harmonics
- Large footprint
- Dependence on strong AC systems
- Power reversal involves voltage polarity reversal
- Commutation failure

HVDC PLUS
The Evolution of HVDC PLUS and VSC Technology

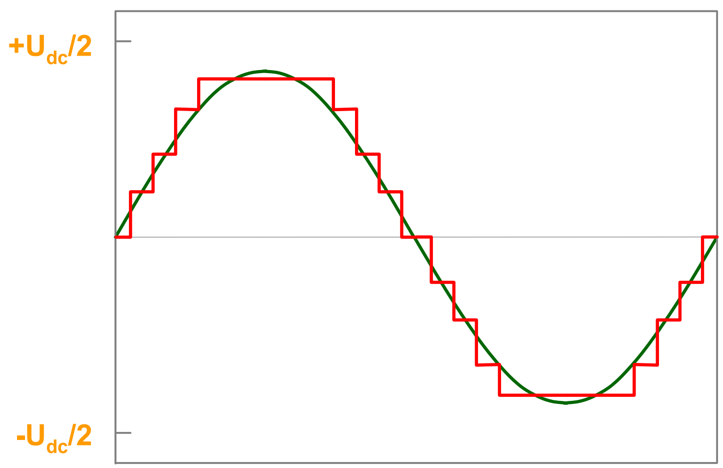
Topology of VSC

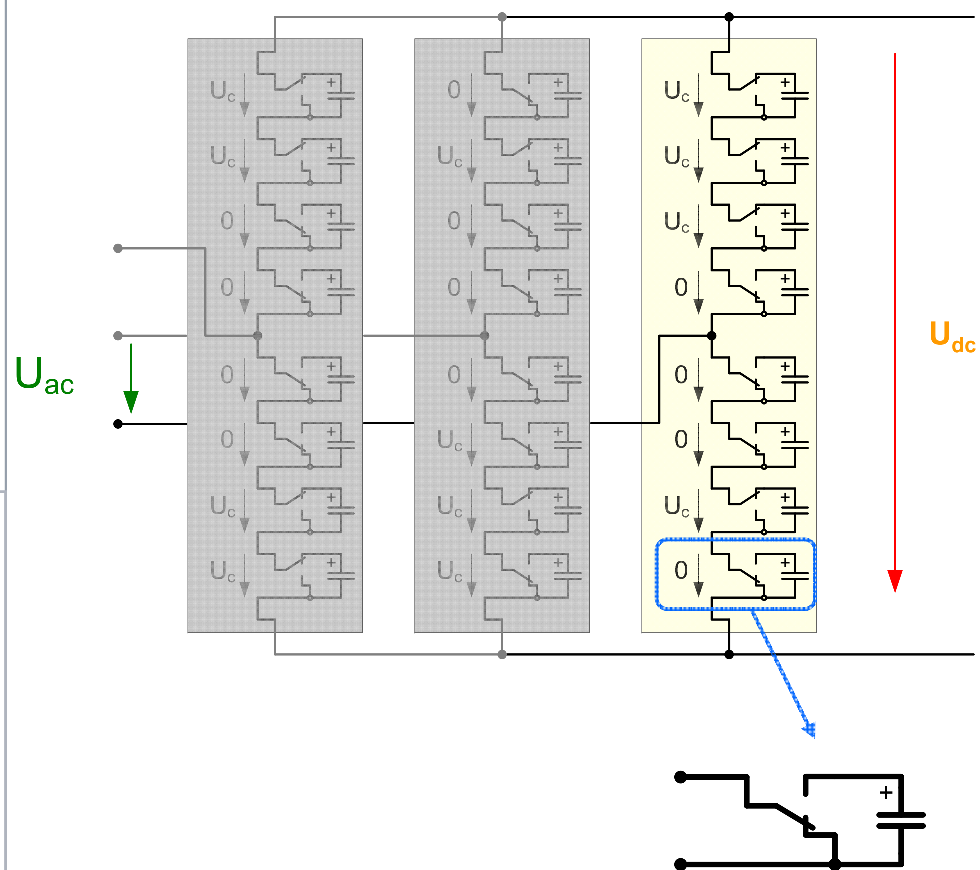
Two-Level	Three-Level	Multilevel
		

Power Electronic Devices

GTO /IGCT	IGBT in PP	IGBT Module
		

Modular Multilevel Converter





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

HVDC PLUS Converter
AC Voltage Generation

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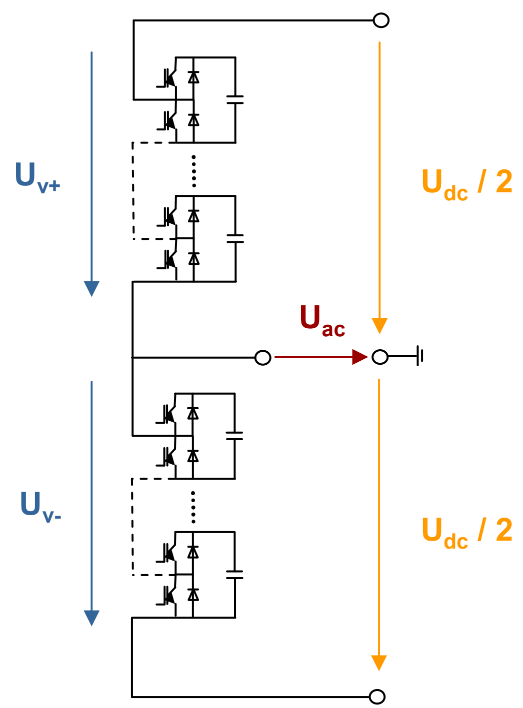
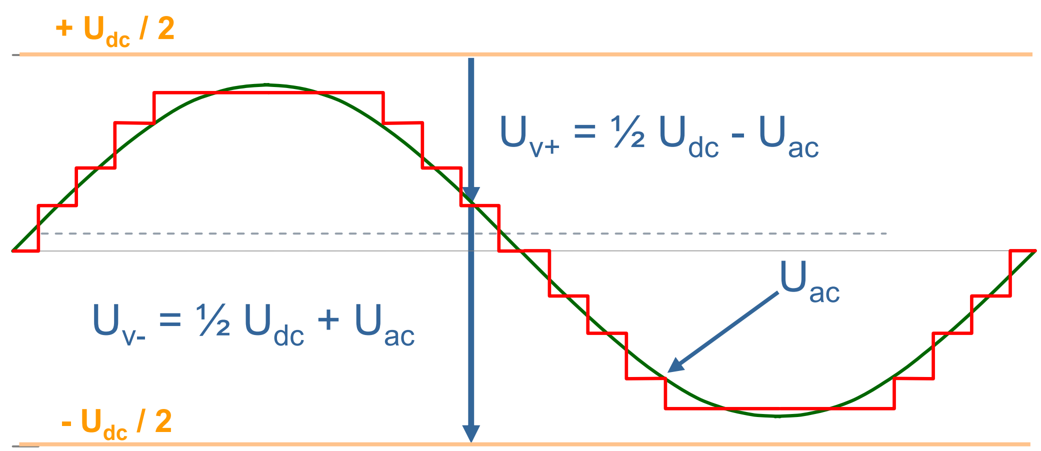
Simplified Block Diagram	Multilevel Technology





Characteristics

- Switching of individual Power Modules:
  1. Tolerance Band of AC Voltage
  2. Voltage Balance of Power Modules
- No fix Pulse Pattern

HVDC PLUS
General Features of VSC Technology

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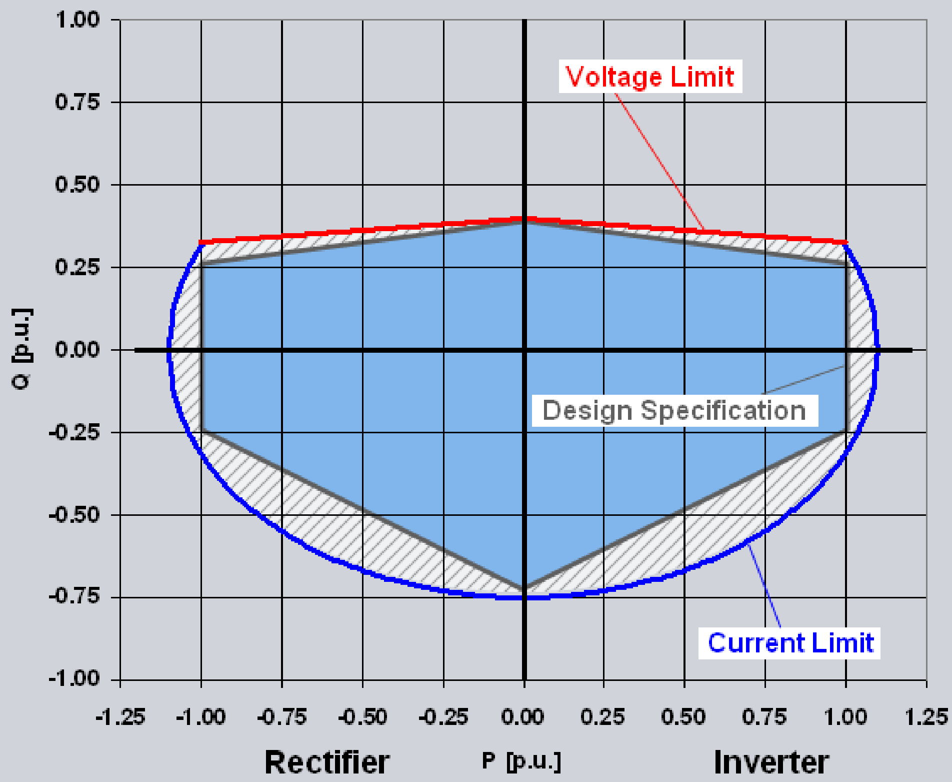
Additional Features and Benefits of HVDC PLUS

- Grid Access of weak AC Networks
- Independent Control of Active and Reactive power
- Supply of passive Networks and Black Start Capability
- High dynamic Performance
- Low Space Requirements



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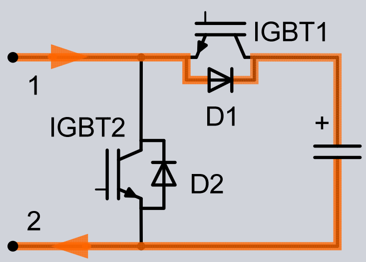
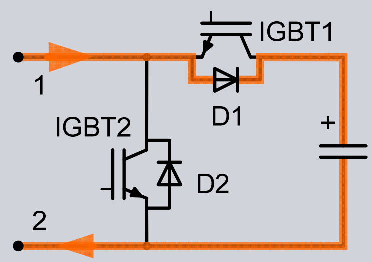
States of Submodules

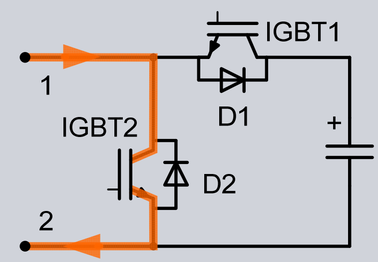
Energization (converter blocked)	Capacitor On	Capacitor Off

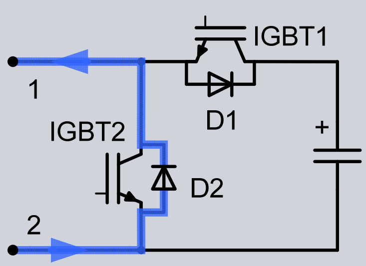


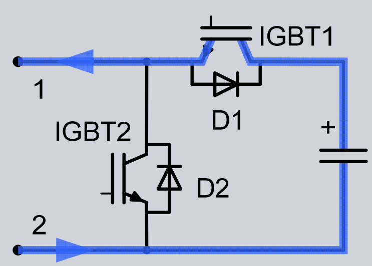
(charging)



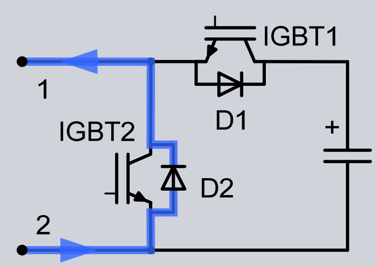
(charging)



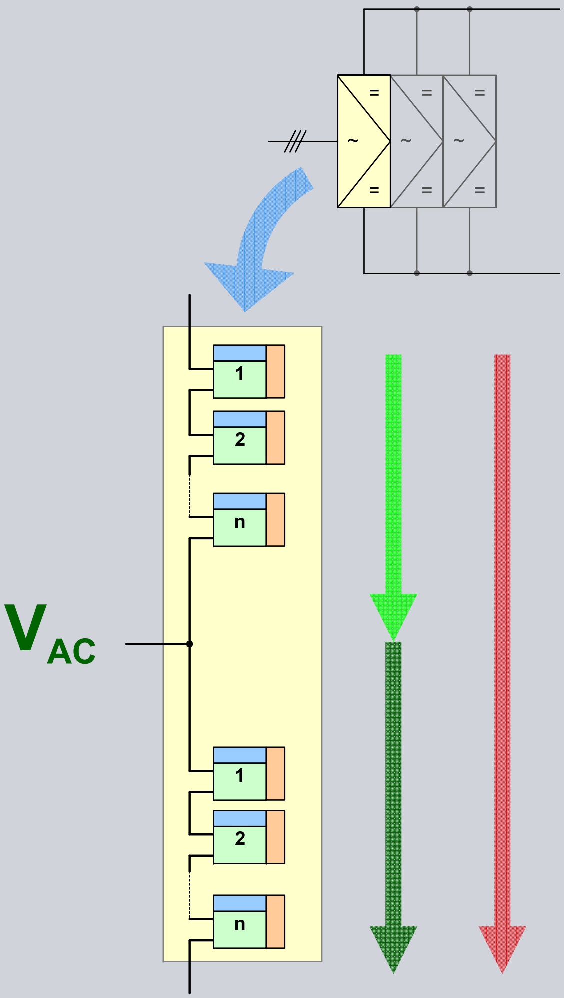




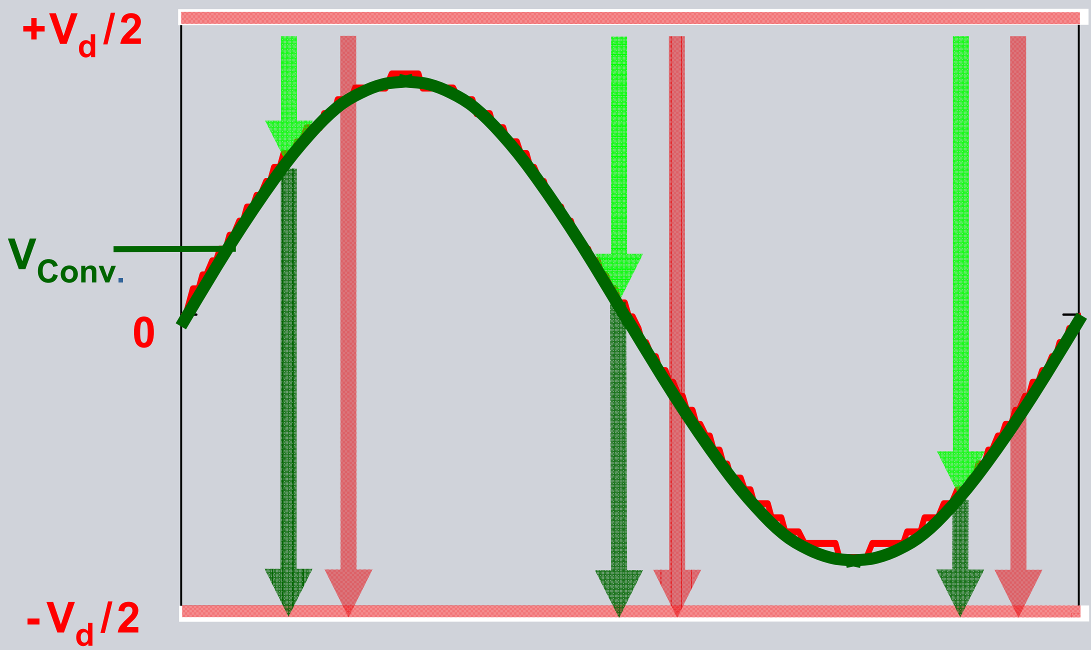
(discharging)



MMC – perfect Voltage Generation



AC and **DC** Voltages controlled by Converter Module Voltages:



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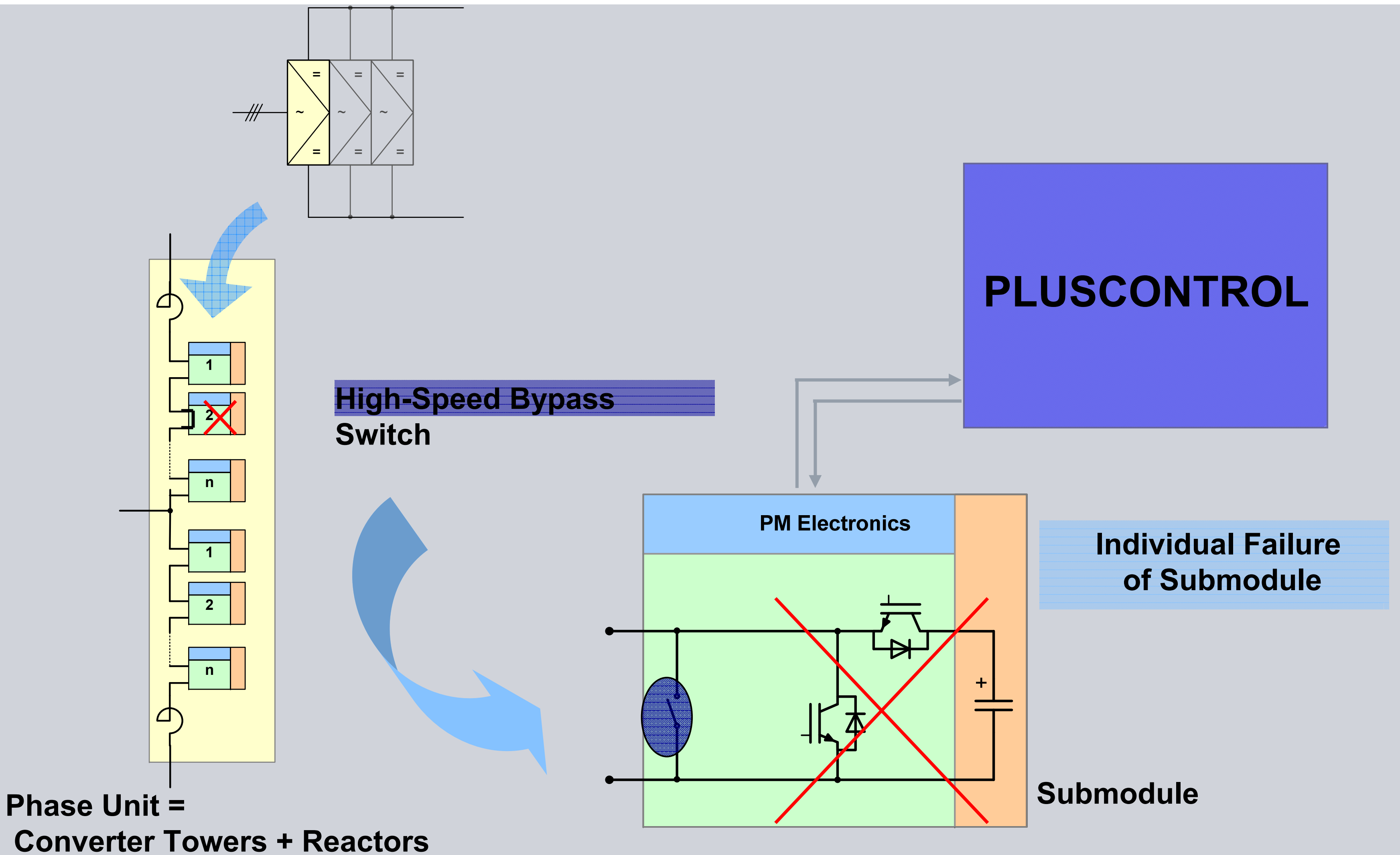
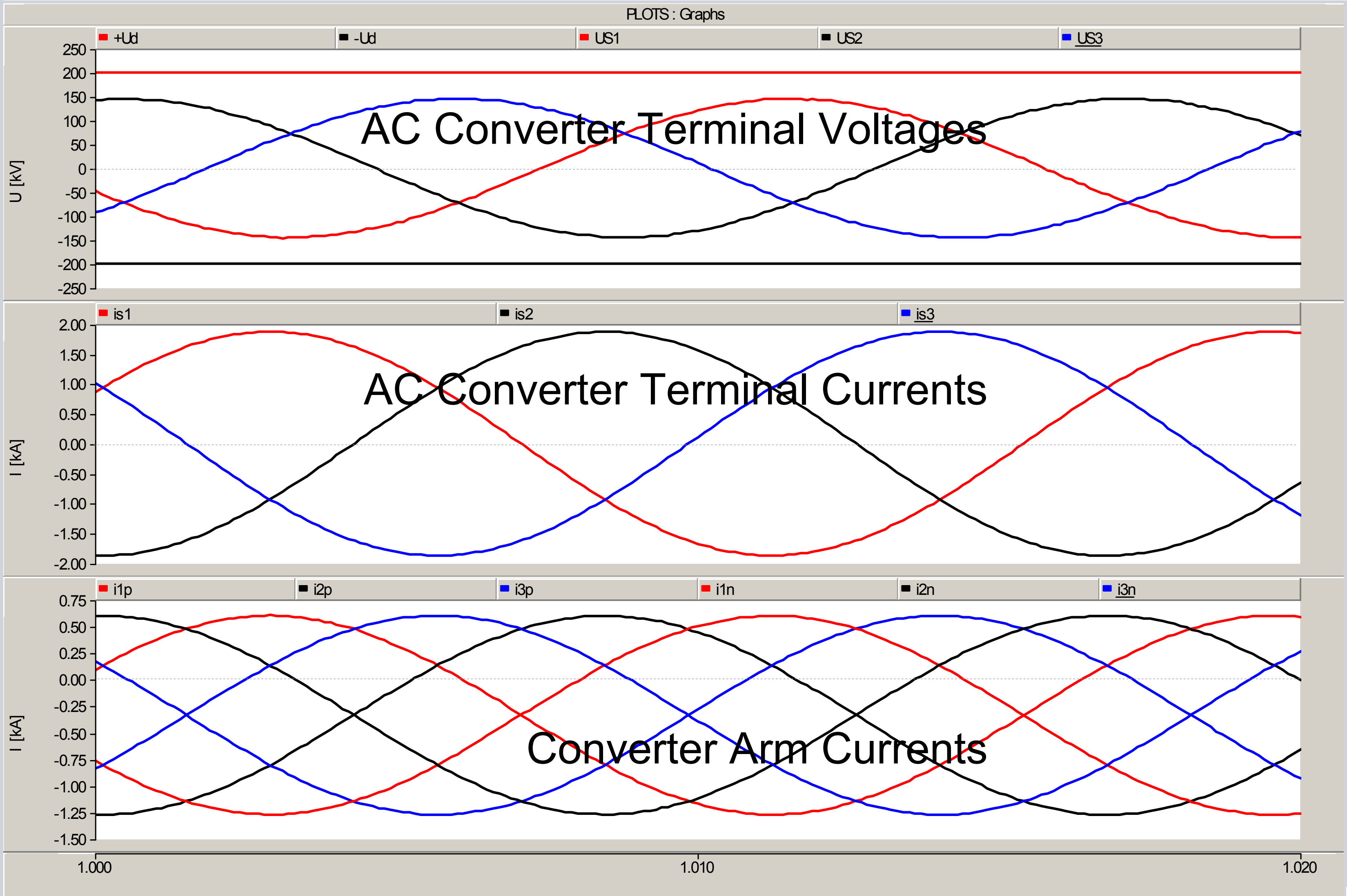
Power Electronics Module - Redundancy



Simulation Results:

400 MW with about 200 Submodules per Converter Leg



HVDC PLUS
Monopolar Configuration – Overview

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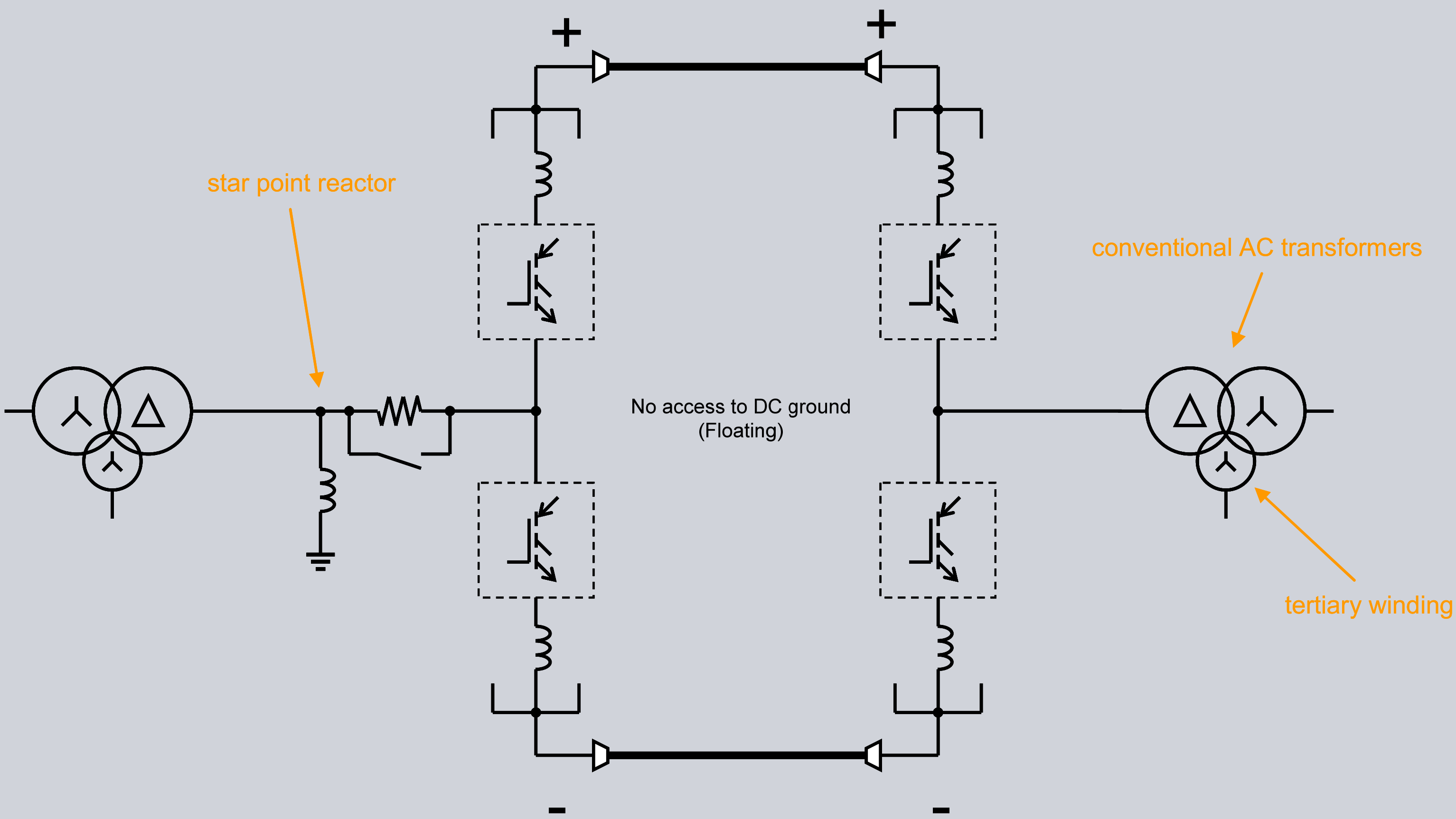

HVDC PLUS
Monopolar Configuration (contd..)

SIEMENS

- Monopole has only one converter at each end (rectifier and inverter)
- Each AC phase is divided into two arms: positive & negative
- In each side DC terminal has one positive and one negative voltage output (corresponding to positive and negative arms)
  - Makes it symmetric
  - Thus no DC offset at AC quantities
  - Makes it possible to use standard transformer design
- With symmetric monopole if there is any fault in either pole conductor the entire HVDC links needs to taken out

Basic Controls

5 possible control variables (reference set points)

1. Active power (P_{ref})
2. DC link voltage (V_{dc})
3. AC side reactive power (Q_{ref})
4. AC side voltage magnitude (V_{ac-ref})
5. AC side voltage phase angle (θ_{ac-ref})

Two variables can be controlled at each end but NOT in any combination

DC link voltage is controlled at one end

- Balances in-flow and out-flow of active power at that end

Other end controls active power by setting either P_{ref} or V_{ac-ref} and θ_{ac-ref} (e.g. offshore side converter for wind farm connections)

Q_{ref} or V_{ac-ref} can be controlled independently at either end

Decoupled Control

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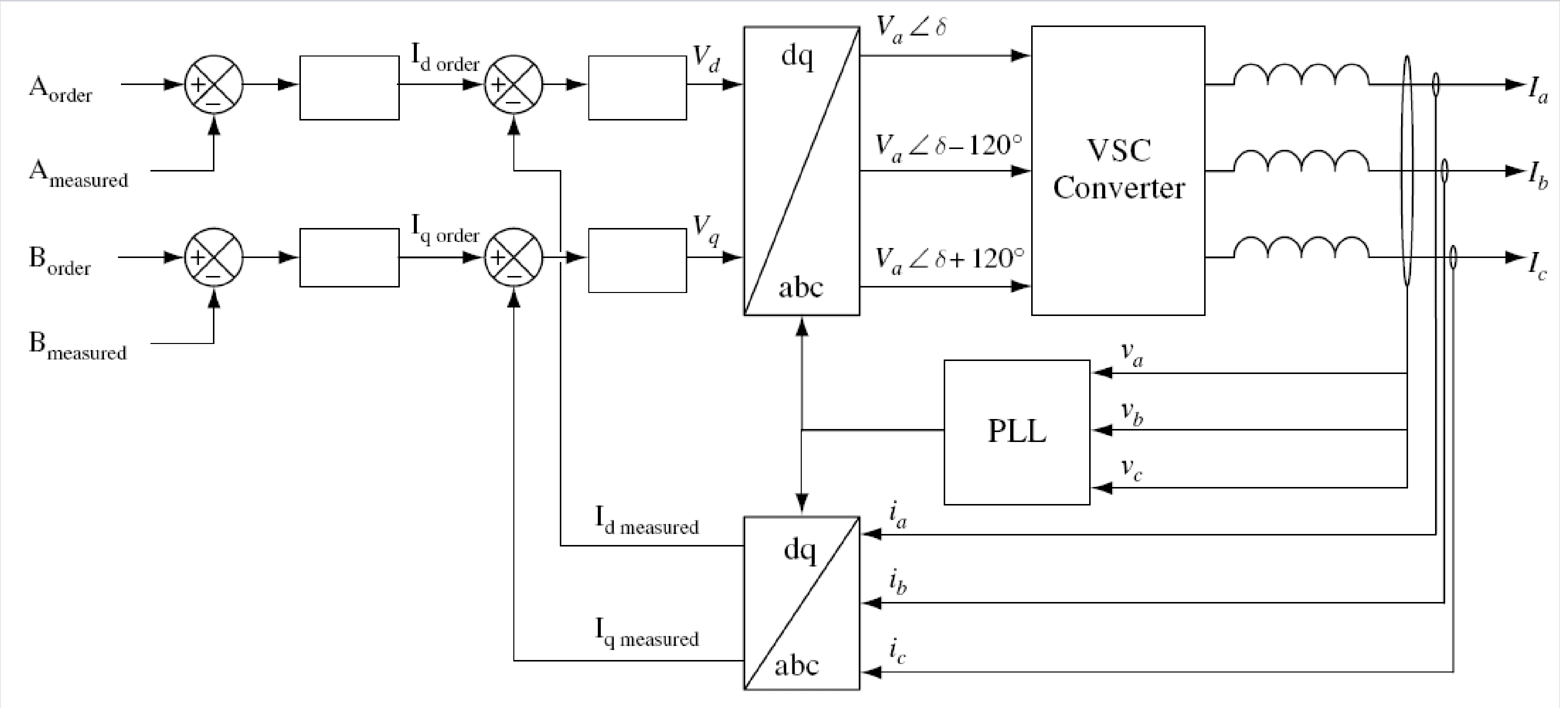

- Synchronously rotating *d-q* frame of reference is used to translate the sinusoidal set point tracking problem into equivalent DC set point tracking
- Inner loop current control is used to protect the IGBTs from over current
- Proper choice of d-q frame can decouple the control loops

Control and Protection
System Hierarchy Win-TDC with PLUSCONTROL

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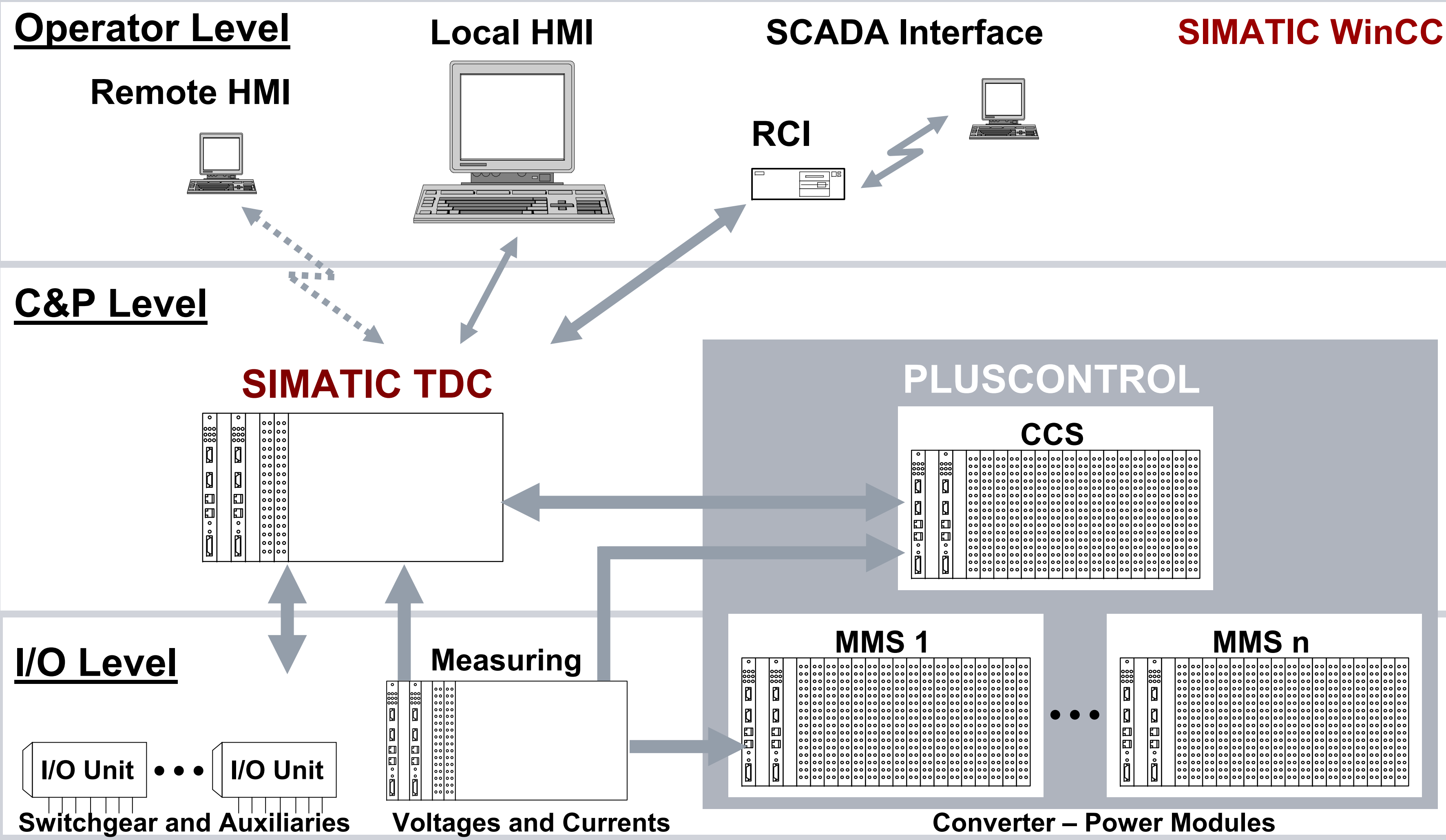

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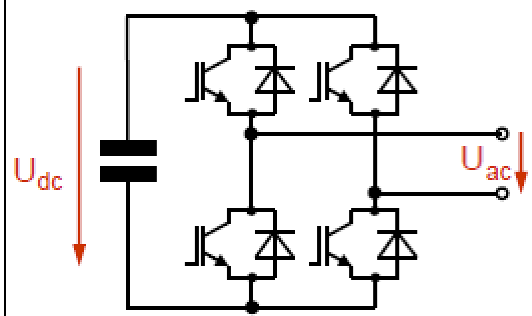
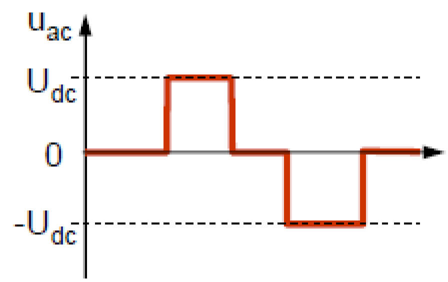
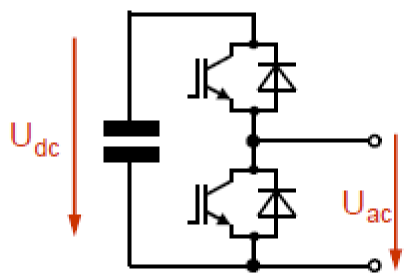
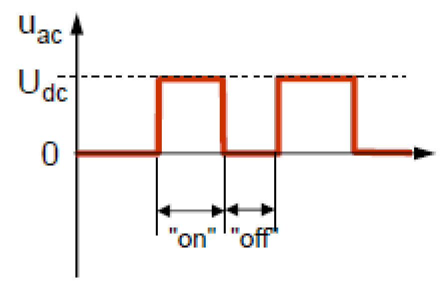
Full Bridge Power Modules

Full Bridge Type MMC: Topology of cascaded Full Bridge Modules patented 1975		
Half Bridge Type MMC: Topology of cascaded Half Bridge Modules patented 2002		

Full Bridge
AC Voltage is independent of DC Voltage

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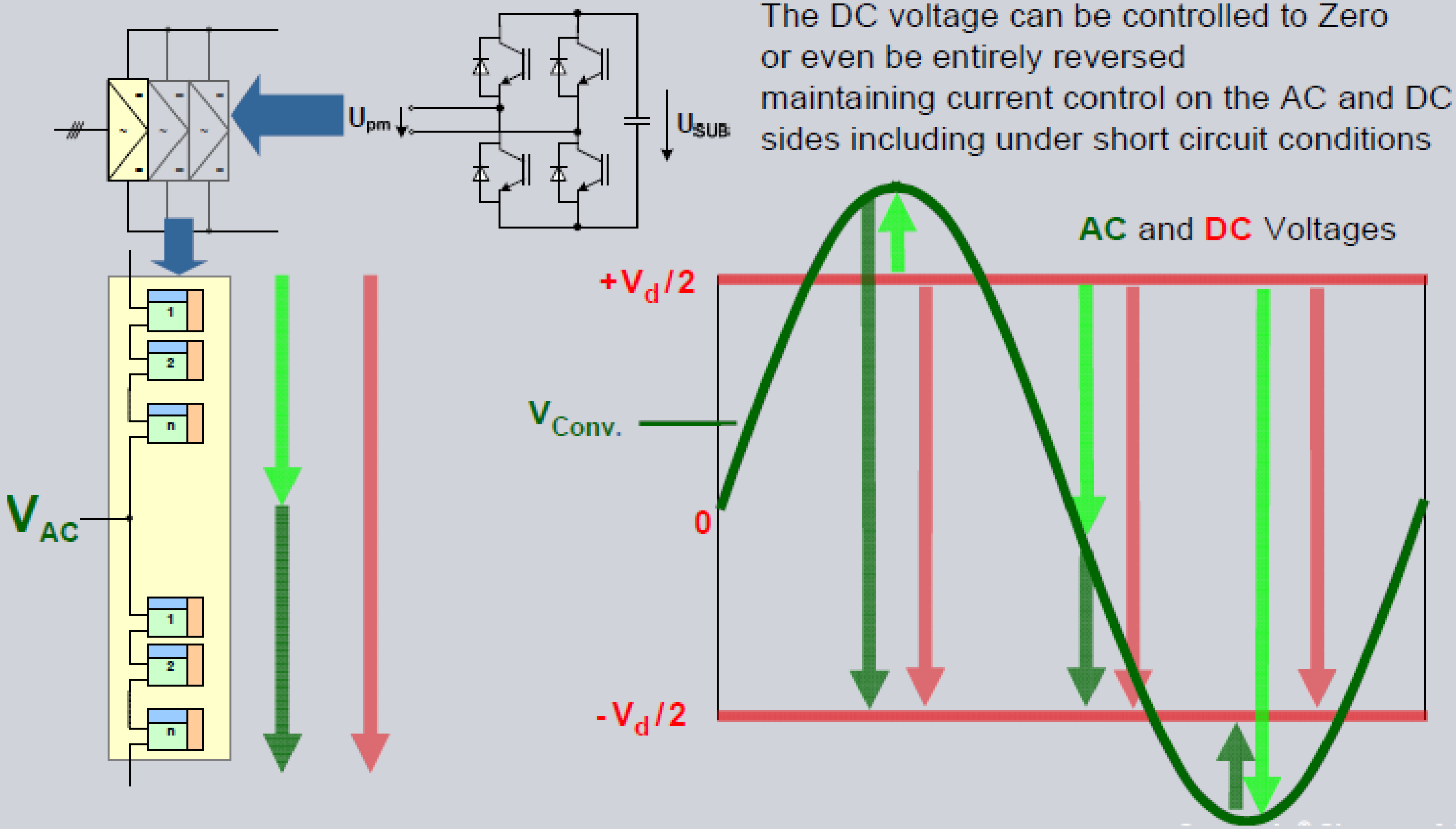

The DC voltage can be controlled to Zero or even be entirely reversed maintaining current control on the AC and DC sides including under short circuit conditions

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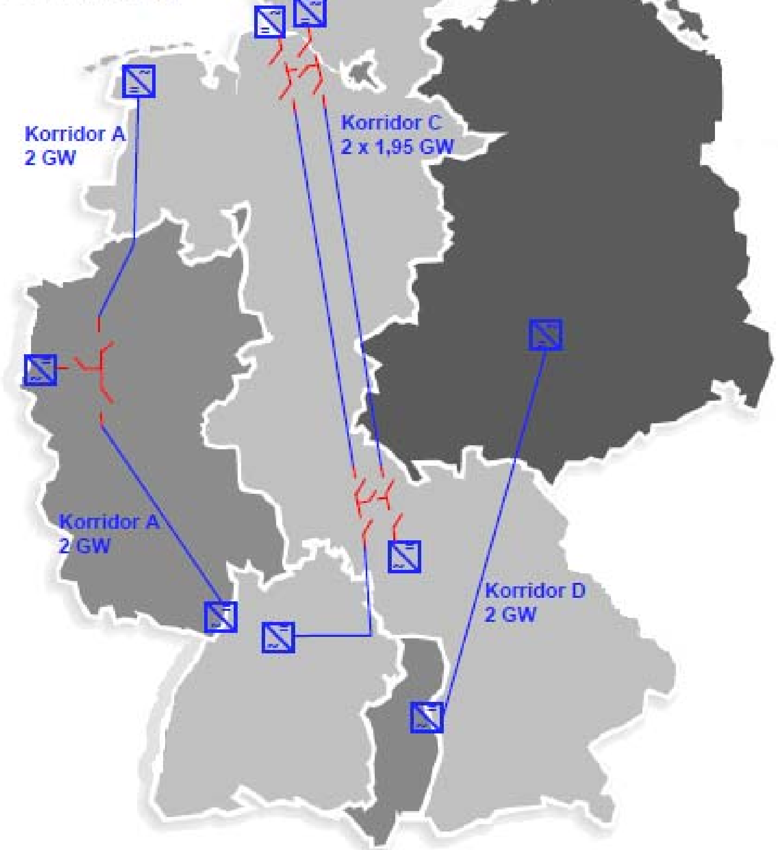
Siemens View of German Grid

The Siemens' Vision towards a first DC Grid in Germany

— Multi-teminal links using full bridge converters and fast DC switches



Highest availability

- **In corridor A: selective fault clearing and fast recovery**
- **In corridor C: parallel operation of two lines with fast take over in case of a fault on one line**

Based on
Szenario B-2022
Bestätigung NEP 2012

HVDC PLUS – Trans Bay Cable Project Overview

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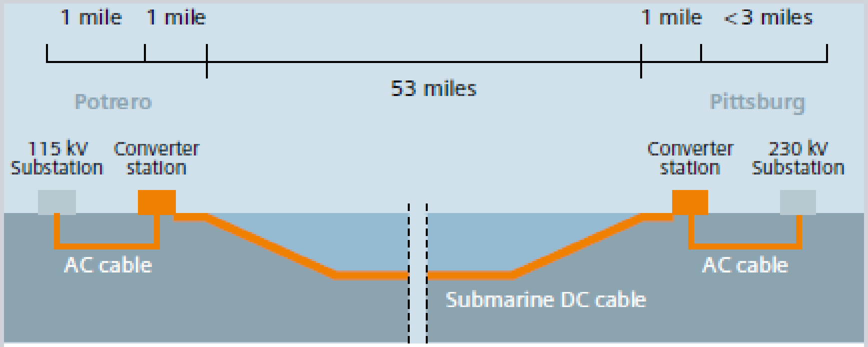
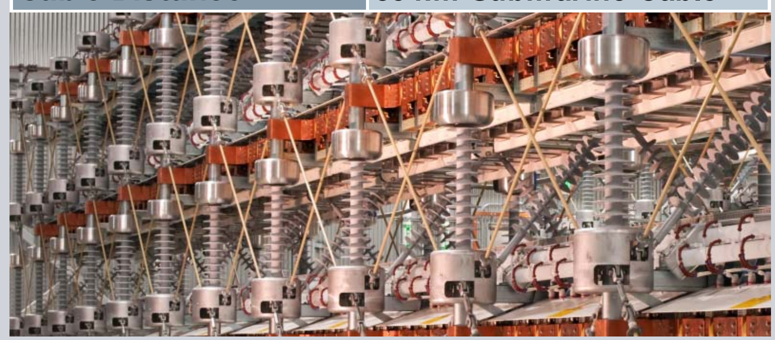


Customer	Trans Bay Cable LLC
Project Name	Trans Bay Cable Project
Location	Pittsburg, CA San Francisco, CA
Power Rating	400 MW
Type of Plant	HVDC PLUS
Voltage Levels	± 200 kV DC 230 kV/138 kV AC, 60 Hz
Semiconductors	IGBT
Cable Supplier	Prysmian
Cable Voltage	± 200 kV
Cable Type	XLPE
Max. Depth	50 m
Cable Distance	85 km Submarine Cable



HVDC PLUS – Trans Bay Cable Project
World's first MMC-VSC Technology in Commercial Operation

Trans Bay Cable Project
Valve Hall

INELFE, France-Spain, 2014
Overview

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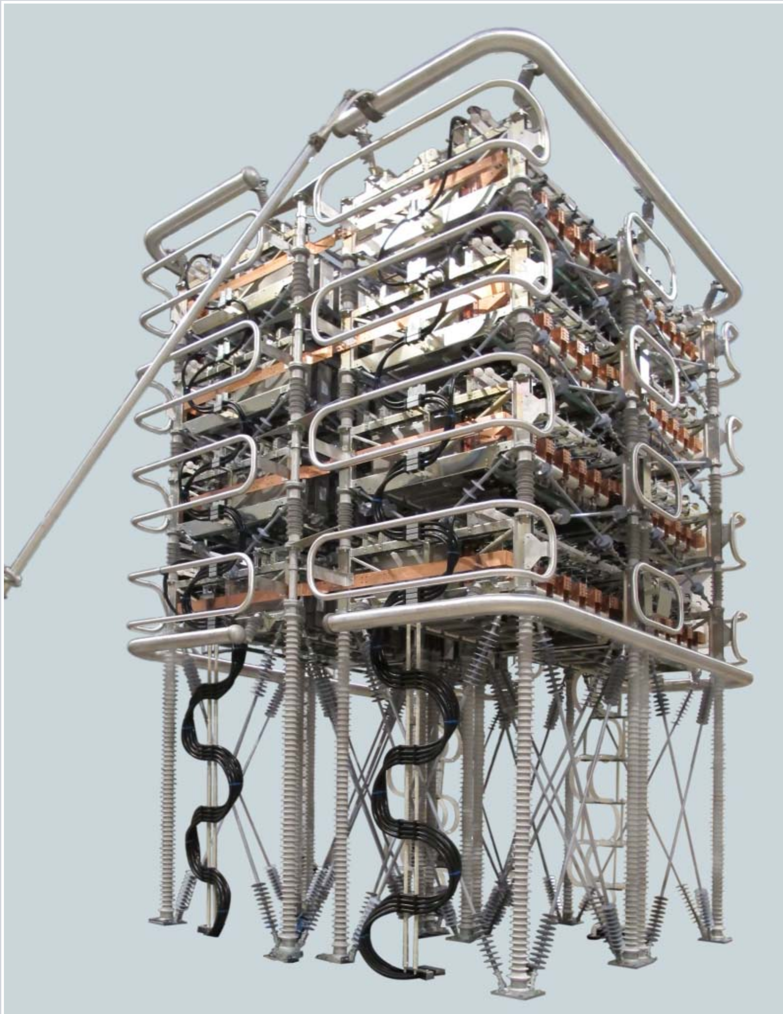

Customer	INELFE (RTE and REE)
Project Name	INELFE
Location	Baixas, France - Santa Llogaia, Spain
Power Rating	2 x 1000 MW
Type of Plant	HVDC PLUS
Voltage Levels	± 320 kV DC AC 400 kV, 50 Hz
Distance	65 km underground cable
Semiconductors	IGBT

HVDC PLUS
INELFE Converter Station Valve Hall

BorWin2 - Project Construction Photos
Diele Land Station

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Converter Transformer

BorWin2 - Project Construction Photos
Diele Land Station

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Works go on in the Converter Hall – May, 2012 (13 months after mobilisation)

BorWin2 - Project Construction Photos
Offshore Platform (Construction Site: Nordic Yard’s Dock, Wismar)

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Top Side Temporarily Towed Out of the Dock for the Swap of Dock Position with the SylWin Barge

Questions?