High Voltage Direct Current and Alternating Current Transmission Systems Conference

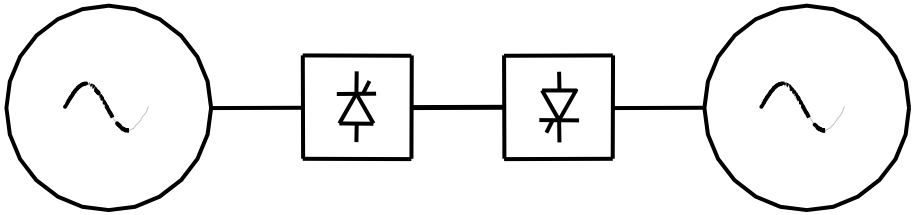
at EPRI Palo Alto CA

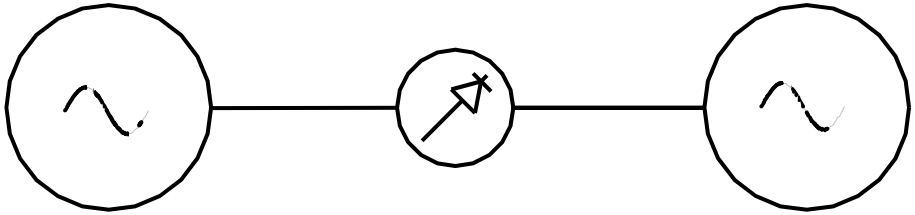
August 30-31 2011

Scope of VSC Based Technology in HVDC and FACTS

Nari Hingorani

HVDC and FACTS: Complementary Solutions





HVDC:

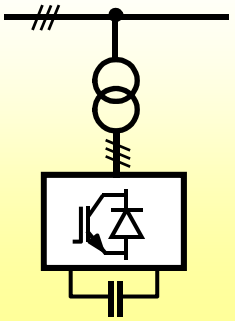
- **Independent frequency control**
- **Lower line costs**
- **Power control, voltage control, stability control**
- **Market power**

FACTS:

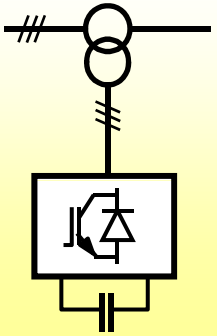
- **Power control, voltage control, stability control**
- **Much lower cost if independent frequency control is not an issue**
- **Market power**

Voltage Sourced Converters
Applications for HV systems

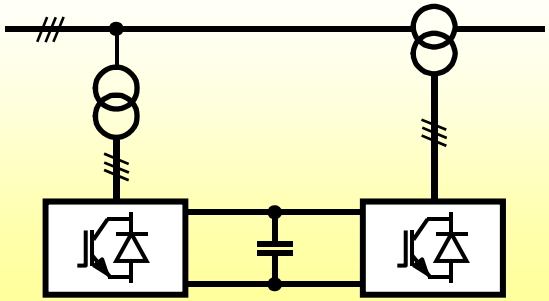
STATCOM



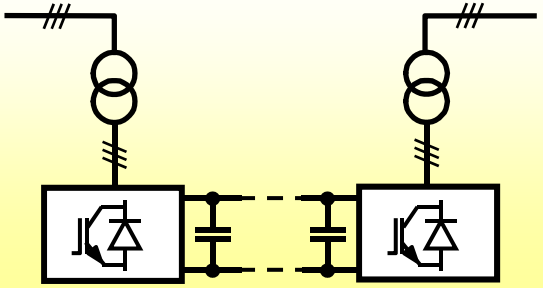
Static Synchronous Series Compensator



Unified Power Flow Control



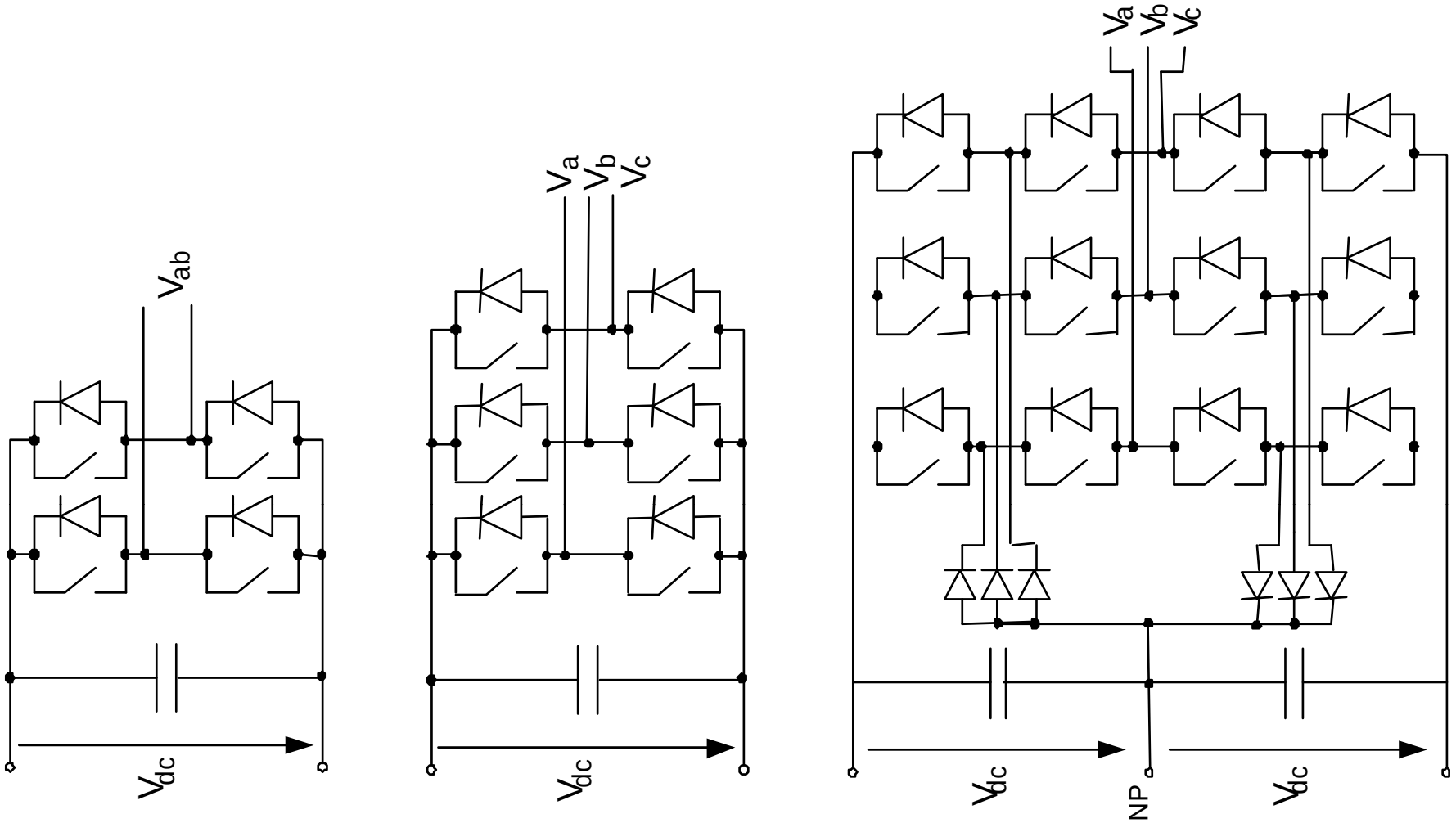
Back to Back or Long Distance Transmission



STATCOM can do all of the following.

Steady State Voltage Control
Dynamic Voltage Control
Flicker control
Supply leading or lagging reactive power
Active harmonic filter
Storage connection
Does not require significant ac Filters, if any

Hingorani

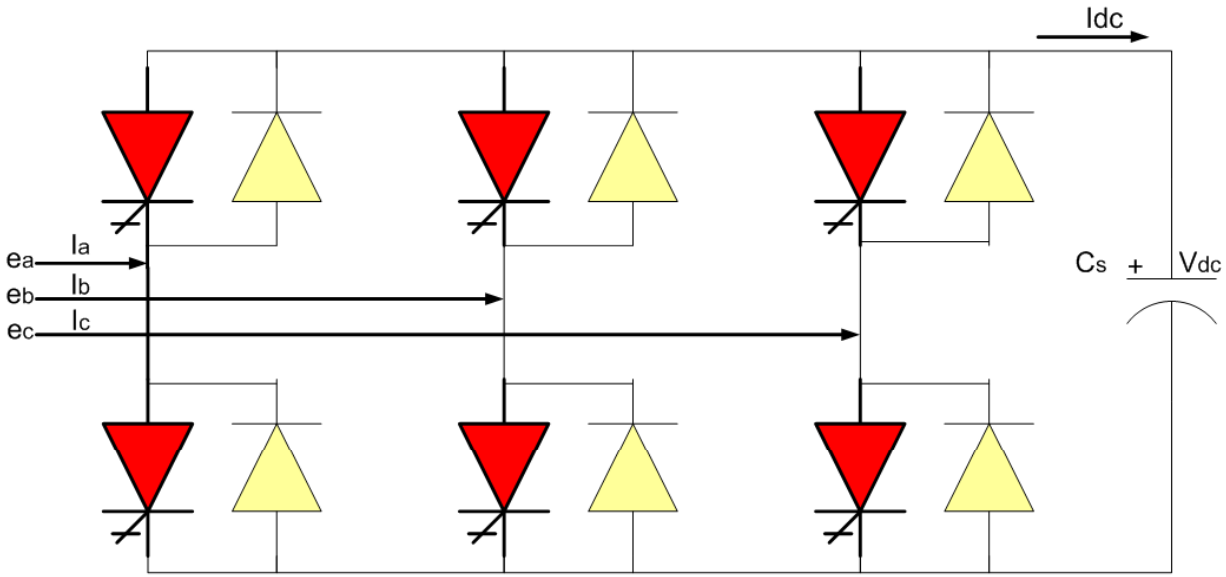


Single-phase
two-level H-bridge

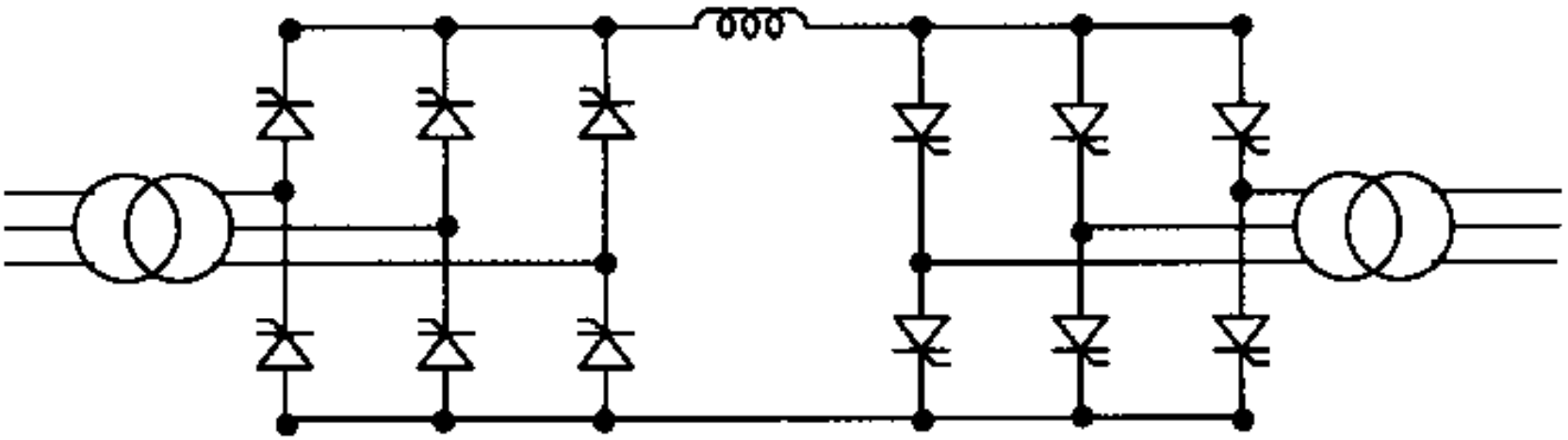
Three phase
two-level converter

Three-phase
three-level converter

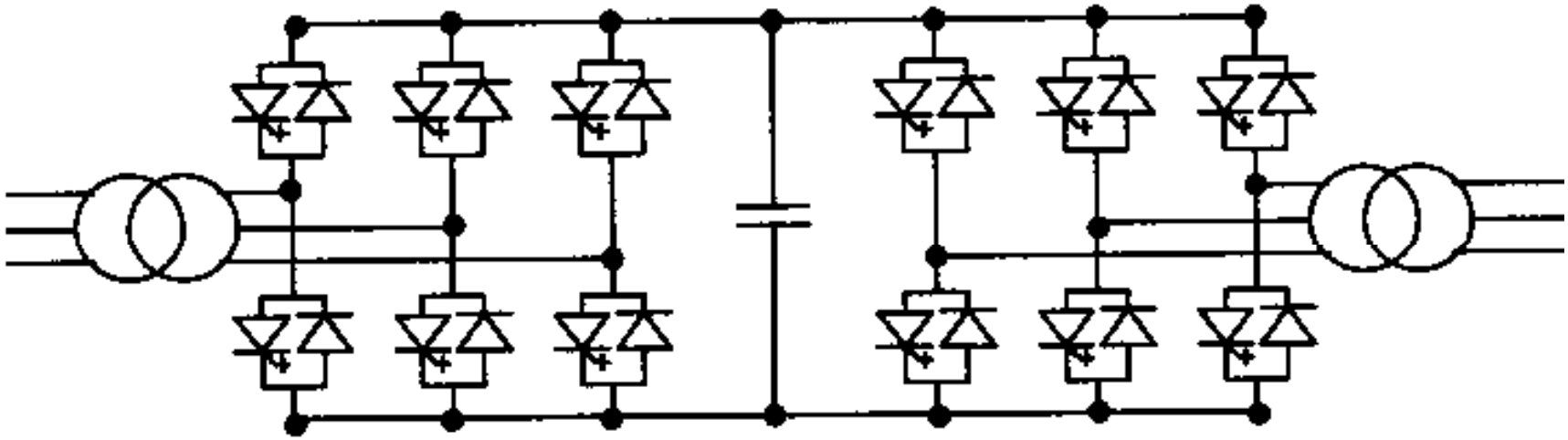
Principal types of Voltage Sourced Converters



Voltage Source Converter



Current Sourced Converter System, which requires unidirectional current flow



Voltage Sources Converter System which requires unidirectional dc voltage

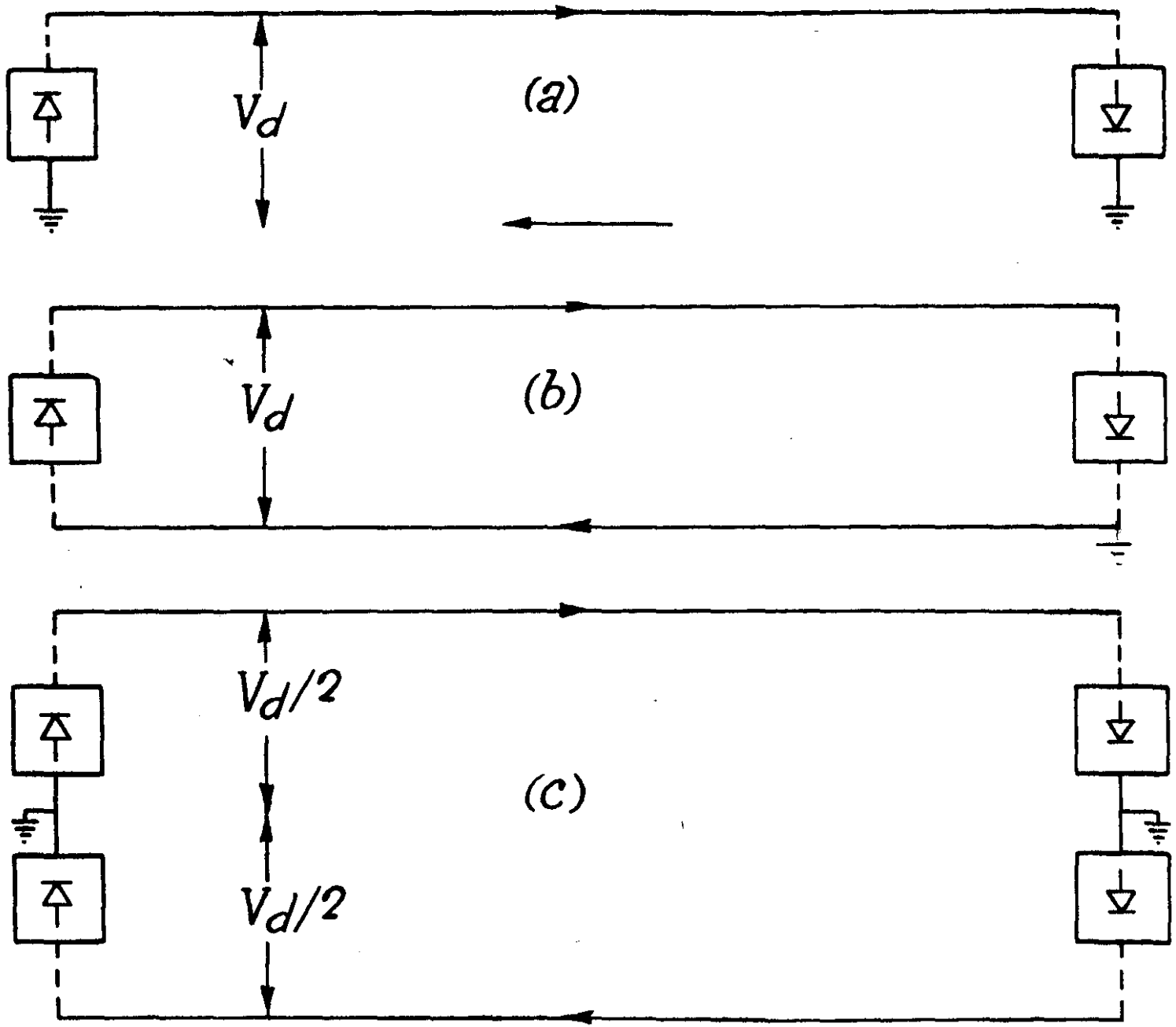
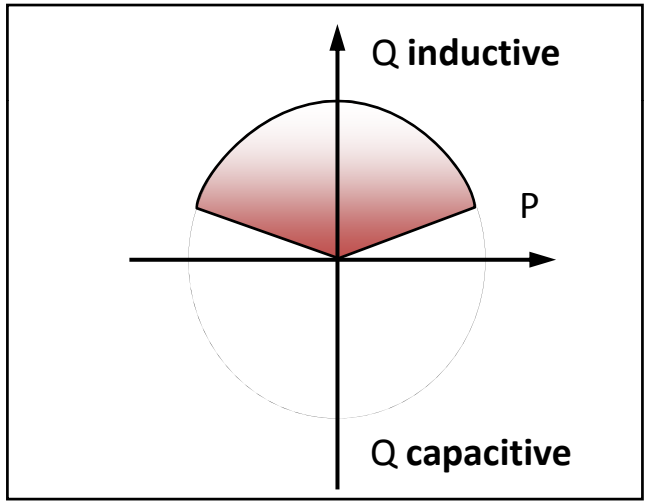
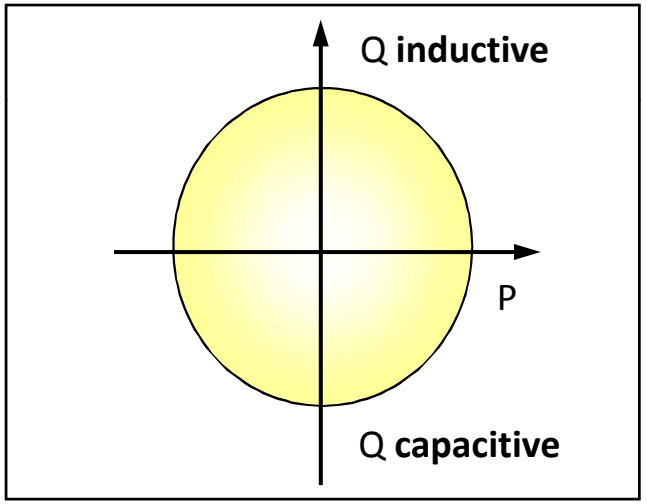


Figure 2.8 Main types of system arrangements viewed from the d.c. side

Advantages of Voltage Source Converter Compared to Thyristor Based HVDC Technology

- With phase angle control of ac voltage, converters can independently supply leading and lagging reactive power along with real power
- There are no commutation failures
- With same polarity voltage (no voltage reversal) cable is much cheaper
- Site area required is half that for thyristor based HVDC converters
- Black start capability
- Can operate in a passive ac system.
- Since there is no voltage reversal, VSC system is suitable for multi-terminal system and future expansion
- No need for close tolerances of transformer leakage reactance

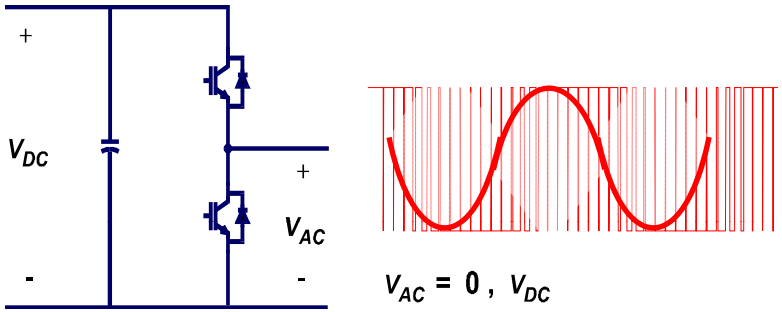
LCC HVDC vs. VSC based HVDC
Power Diagram (Converter+Transformer)

LCC HVDC	VSC based HVDC
	
• filter- and C-banks required (Q ca. 50% P)	• capacitive as well as inductive reactive power
• reactive power demand depends on active power	• independent active and reactive power control

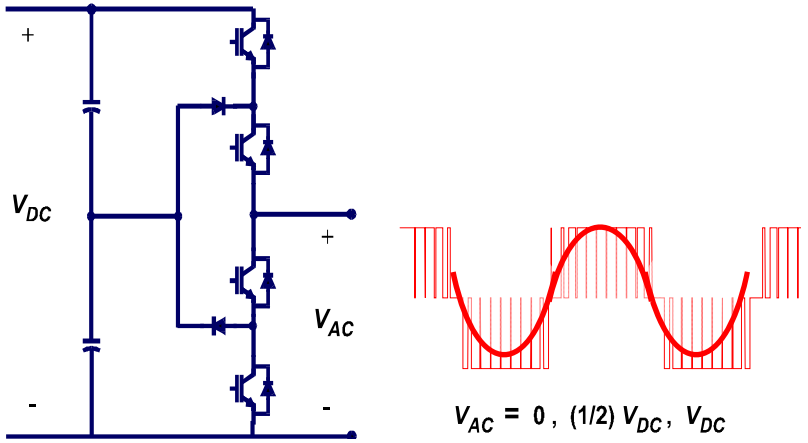
Disadvantages of Voltage Source Converter Compared to Thyristor Based HVDC Technology

- **Need many more devices in series and also diodes in parallel with each controlled device**
- **Higher cost**
- **Higher losses**
- **Device Technology not as robust as thyristor technology**
- ***Difficult to clear dc line faults and multiple restarts for HVDC with overhead line***

Multi-Level Power Conversion Concept



Two-Level Power Conversion



Three-Level Power Conversion

ABB

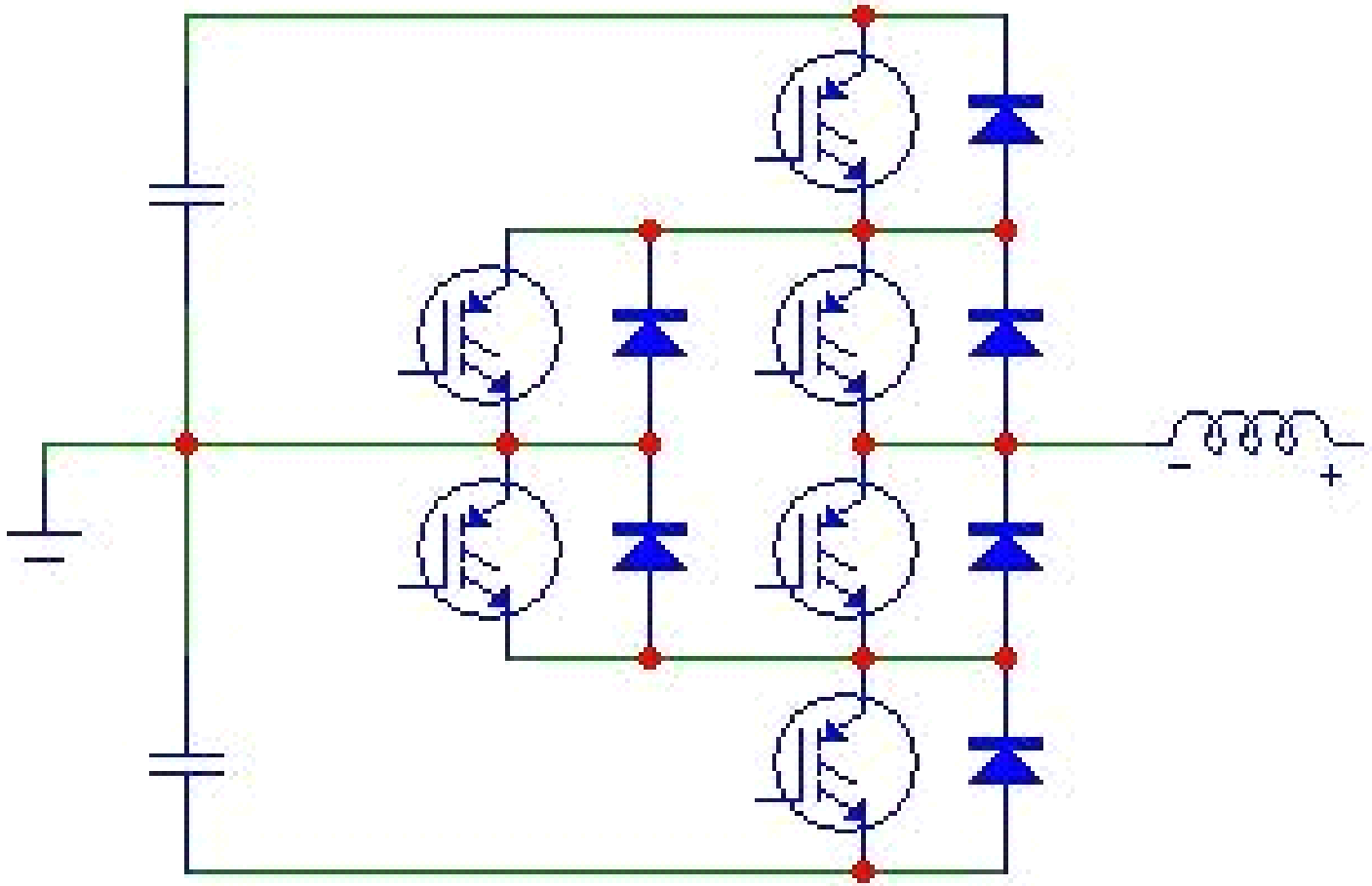
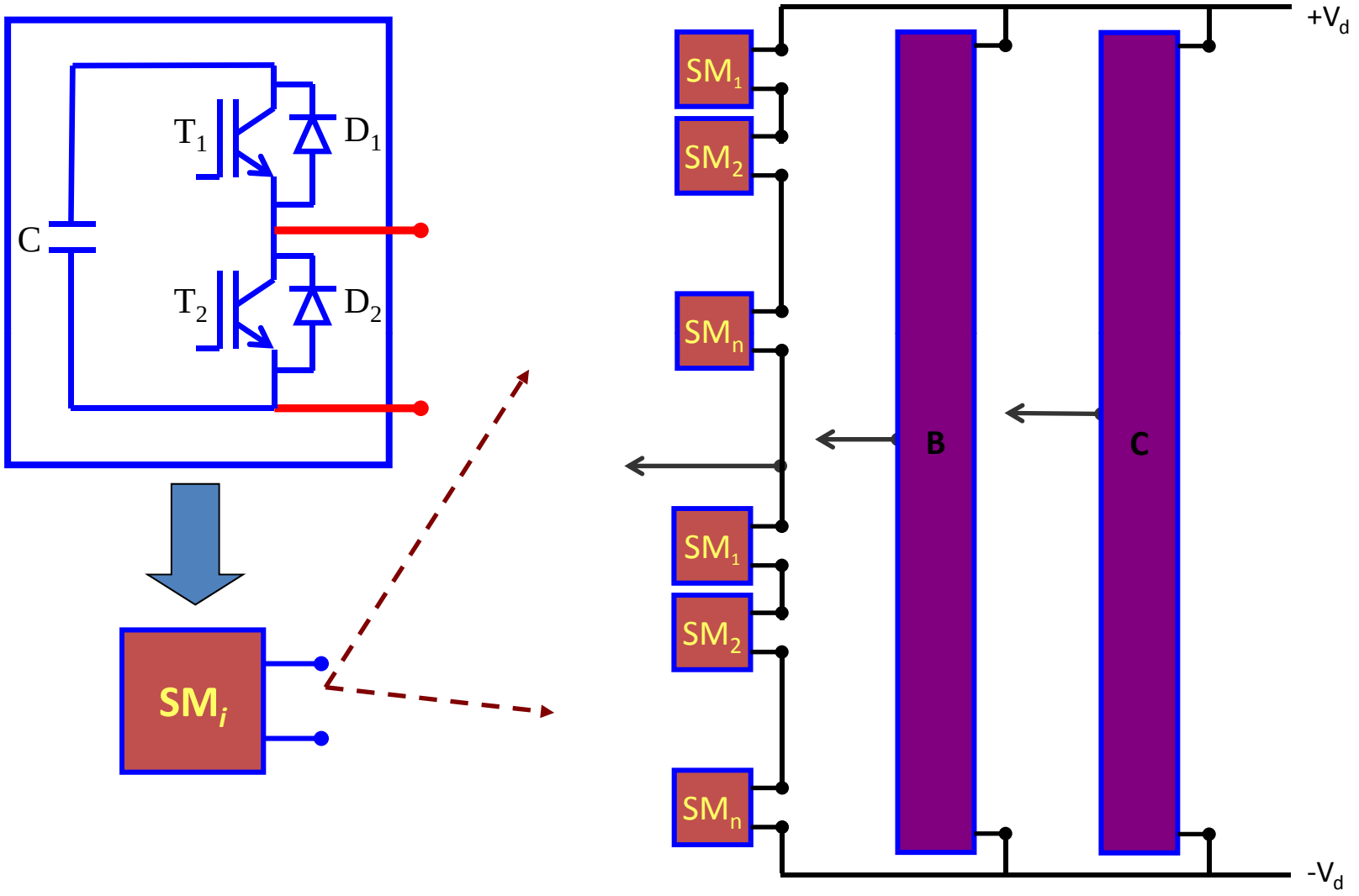


ABB Three-level converter principal circuit diagram for one phase. Each IGBT / diode symbol is in reality made up of more than 150 presspack IGBT modules in Cross Sound Cable USA and Murraylink Australia. CIGRE 2010

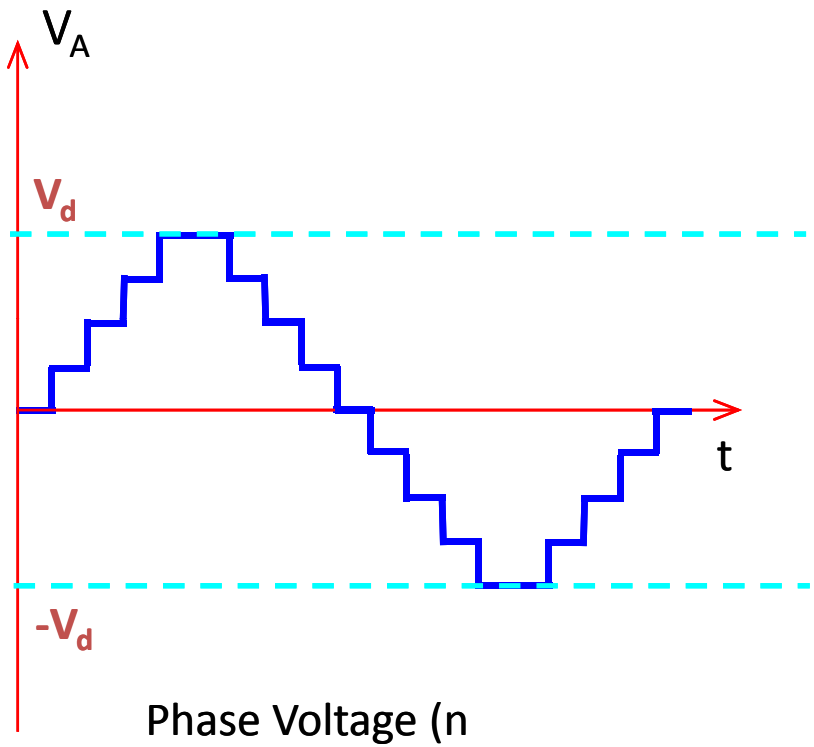
Berri Australia Converter Station ABB Cigre 2010

MMC Topology

MMC basic scheme



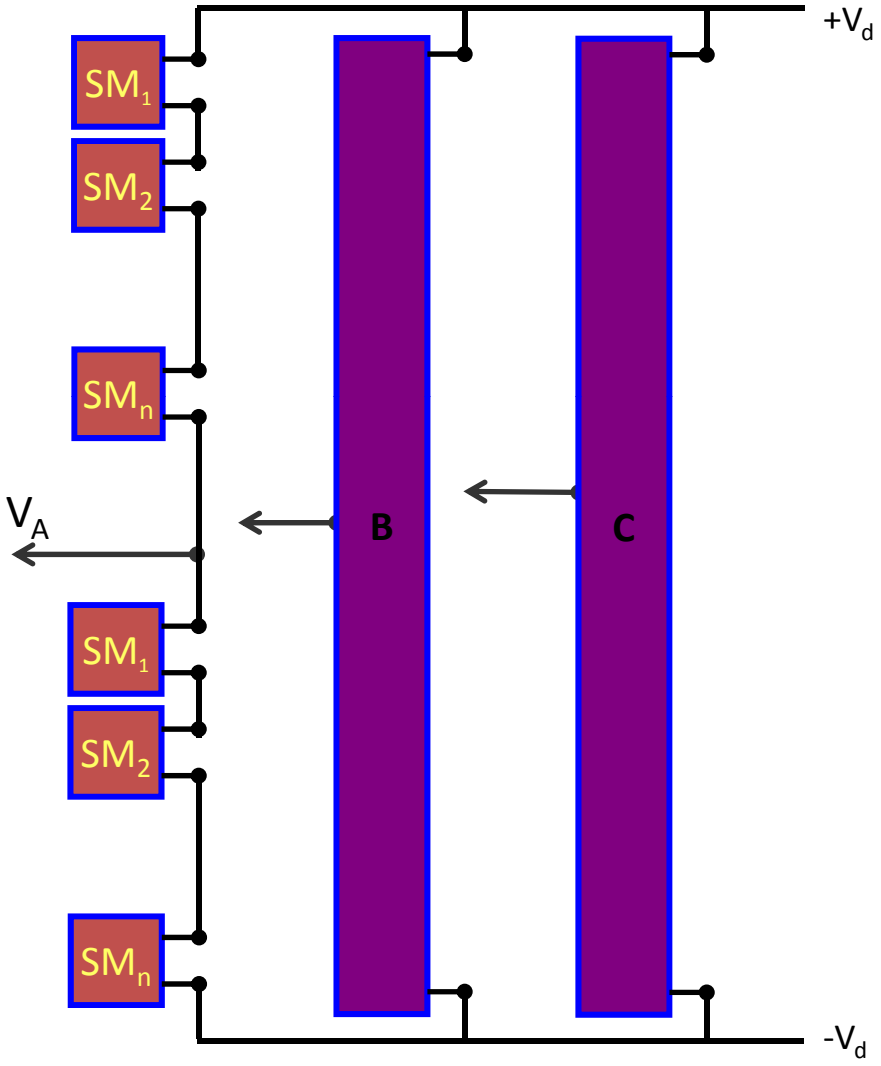
Introduction – MMC Topology



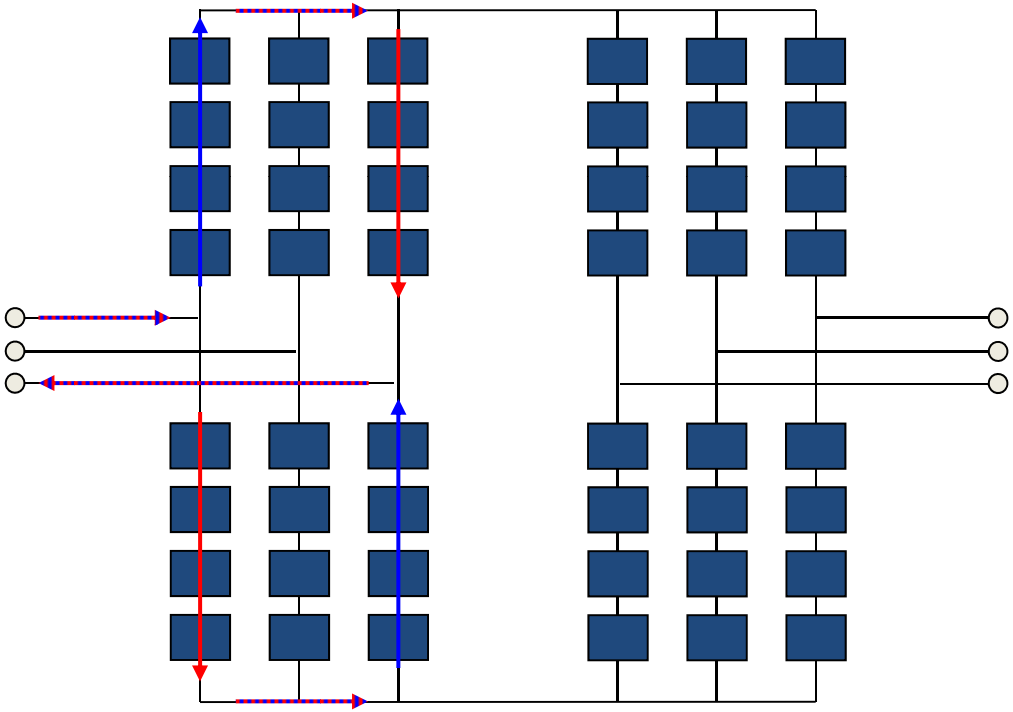
Phase Voltage (n = 10)

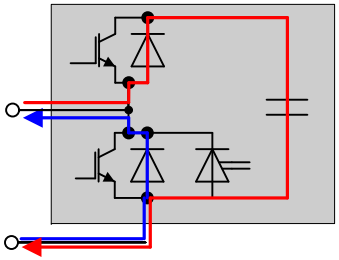
Siemens

MMC basic scheme

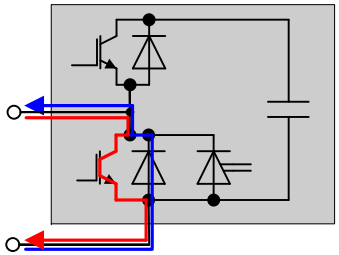


Trans Bay Cable HVDC PLUS Project
MMC topology: Current Paths

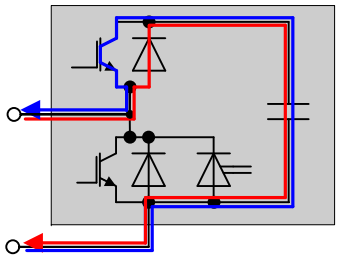




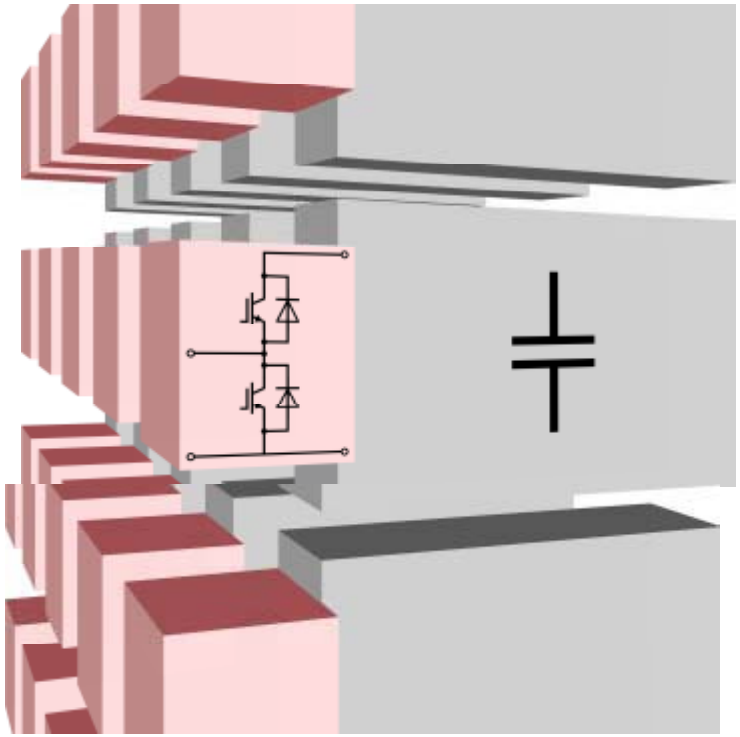
0, 0: Charging of capacitor



0, 1: Module OFF



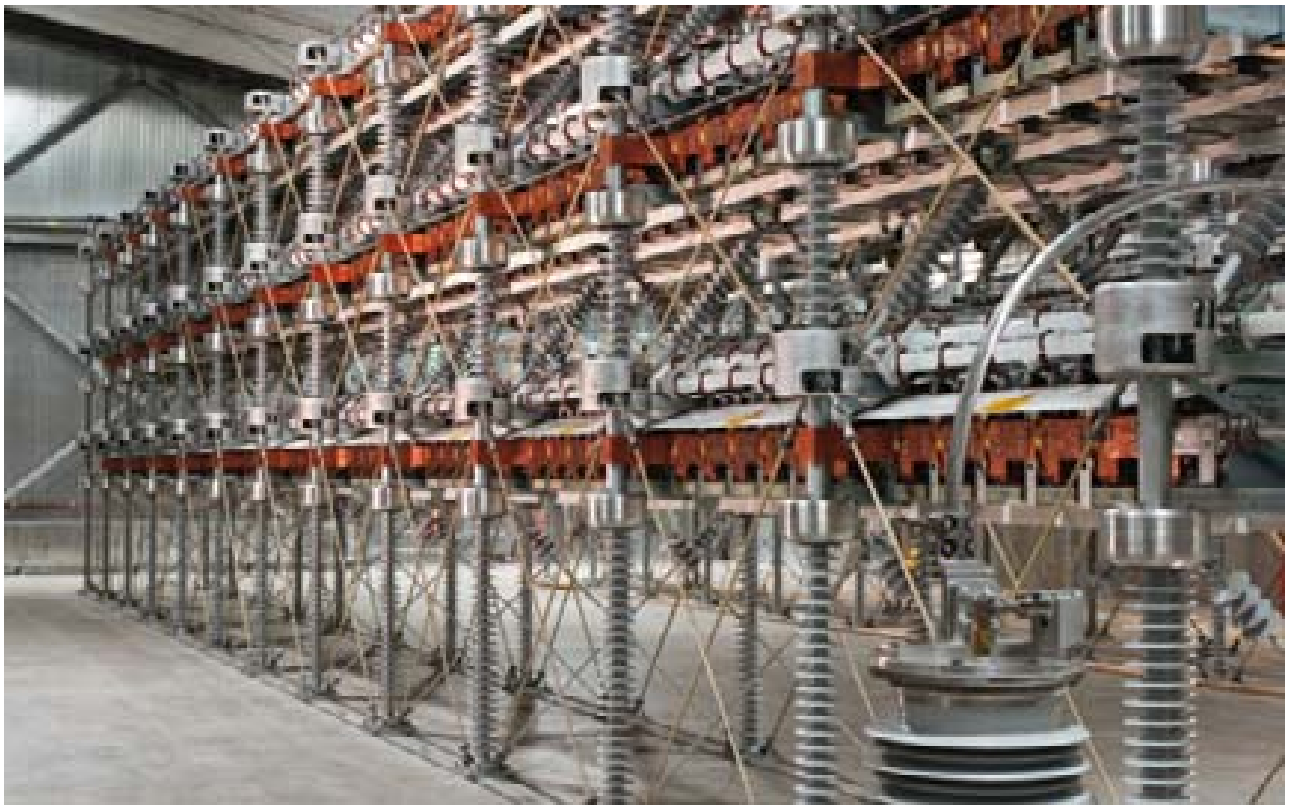
1, 0: Module ON



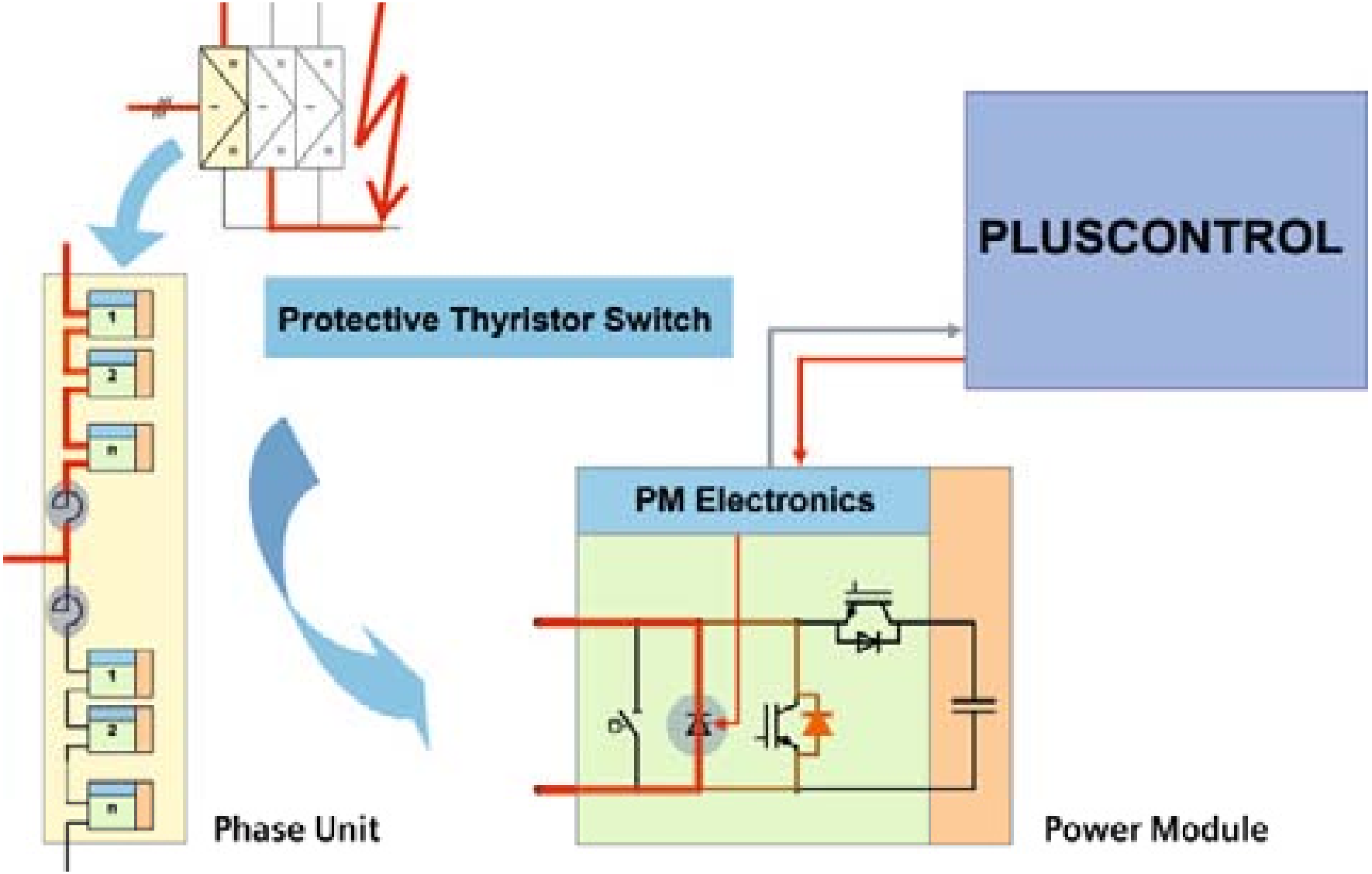
MMC topology and inverter cell arrangement in converter hall. Siemens

Converter Arm Segment

Typical Converter Arrangement for 400 MW – each of the six Converter Arms has 216 Power Modules



Siemens MCC Technology – 400MW ±200kV 88km Submarine Cable Trans Bay Project in California


PLUSCONTROL
Protective Thyristor Switch
PM Electronics
Phase Unit
Power Module

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Voltage Source Converter Compared to Thyristor Based HVDC Technology

- **With MMC topology the ac voltage produced by the converter has very low harmonics there is no need for ac or dc filters**
- **With MMC topology, switching losses are greatly reduced and the total losses are reduced to less than 1%, although still some what higher than thyristor based converter.**
- **With floating dc side (if adapted), transformers no longer have dc voltage bias and become standard ac transformers**

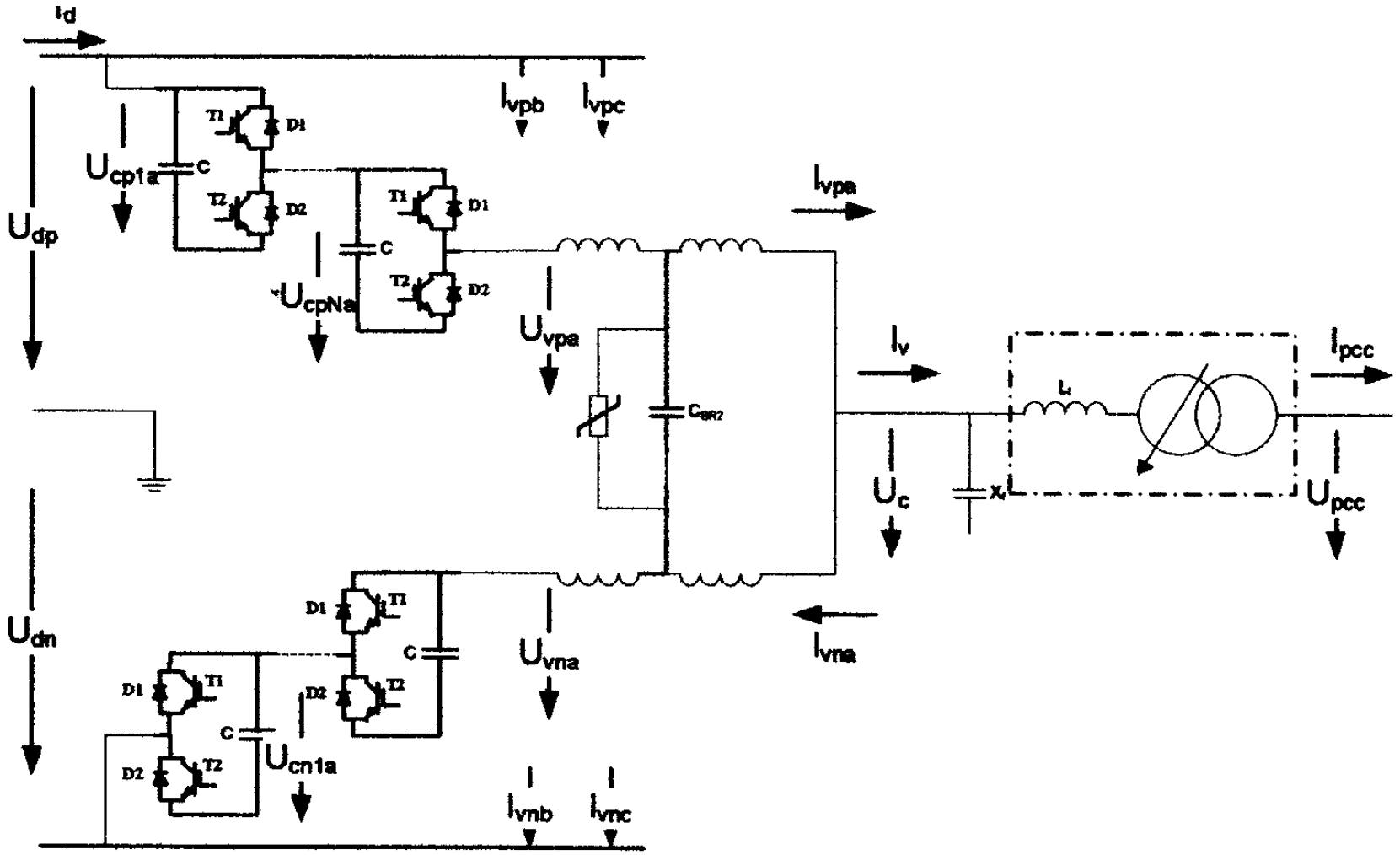
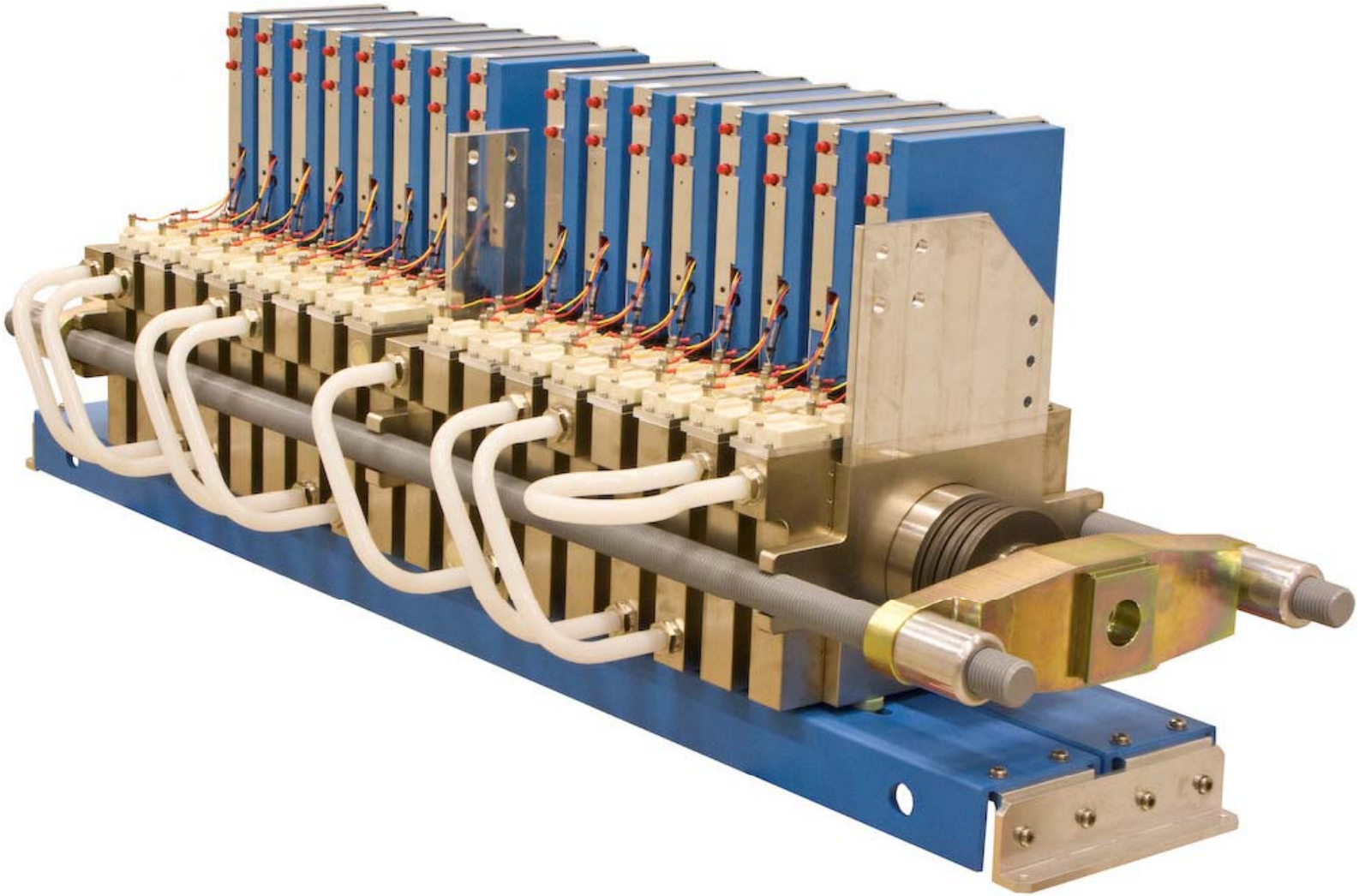
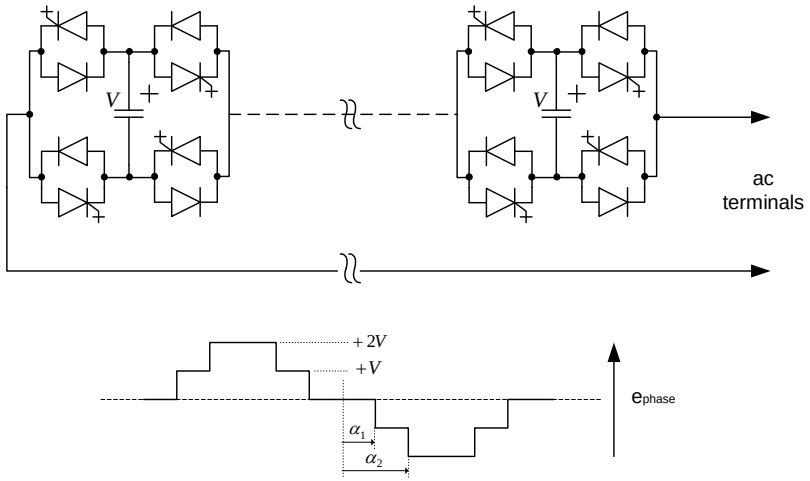


ABB Converter with Cascaded Two – Level (CTL) Converter CIGRE 2010

ABB CTL Cell Module with two valves of half Bridge each with 8 series connected press-pack IGBTs

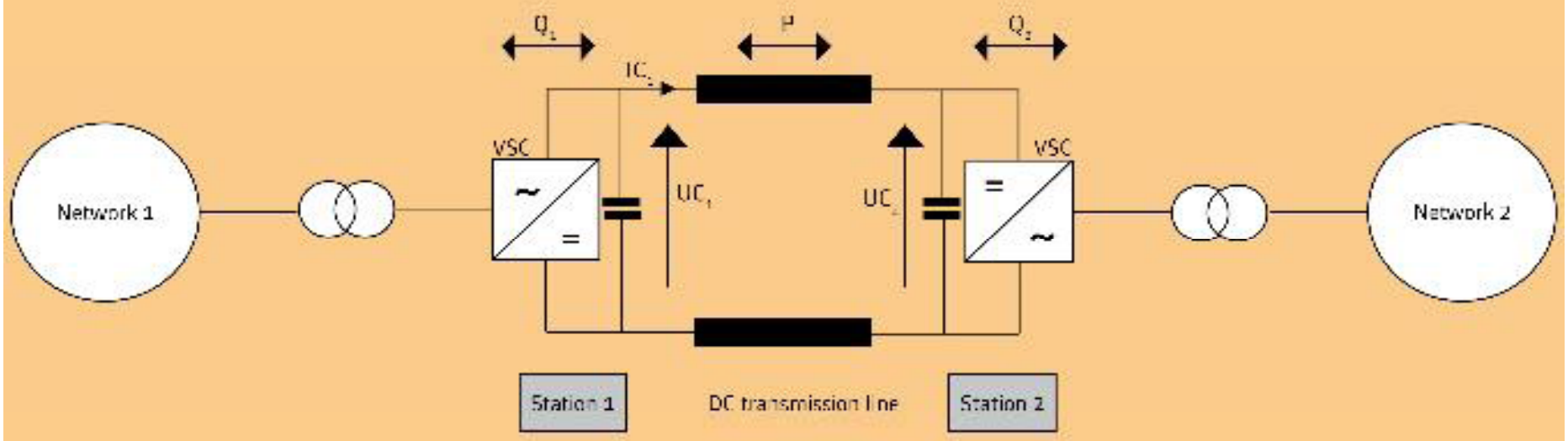


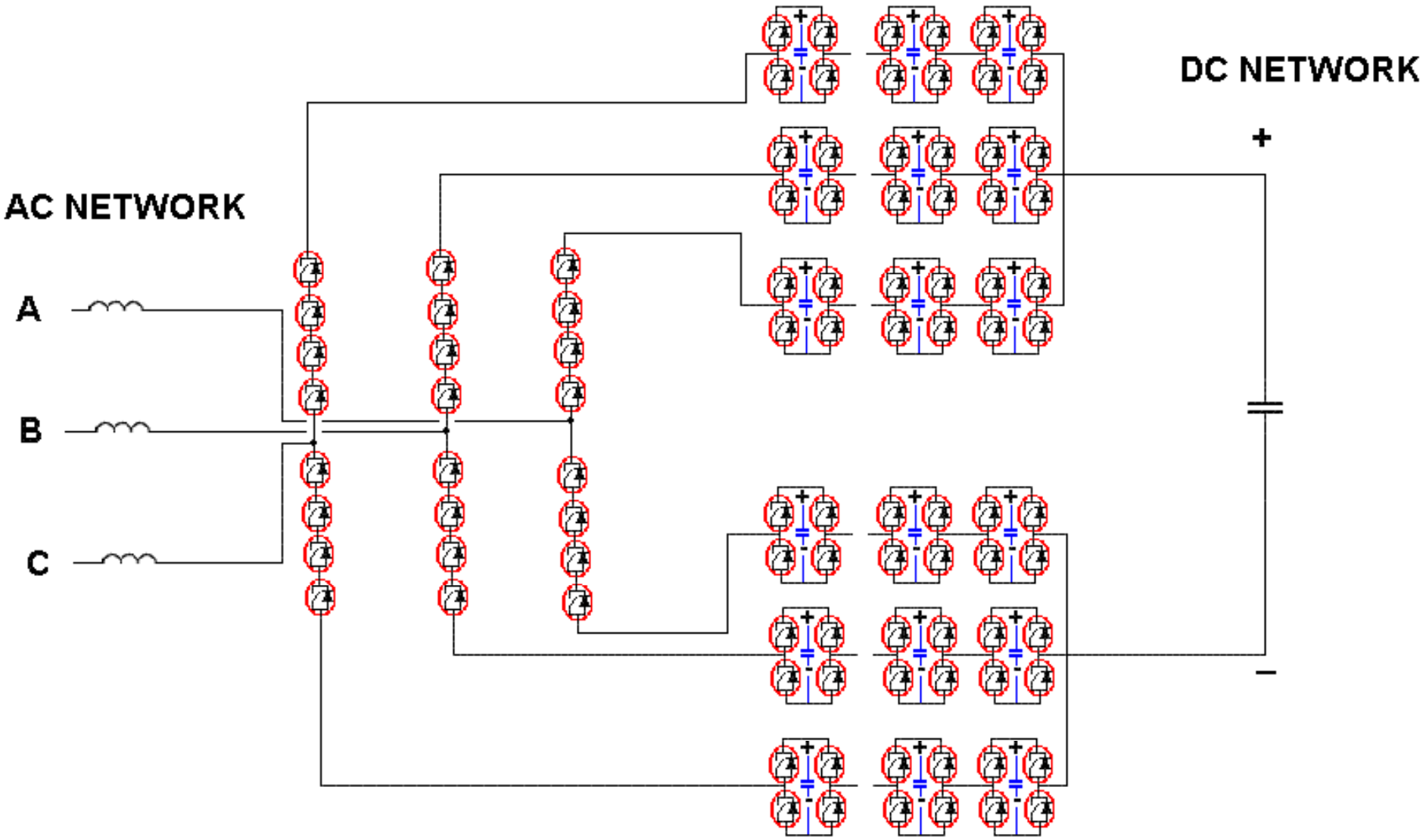
Alstom Chain Link Converter



Alstom VSC Module (PEBBs) for series and parallel connections

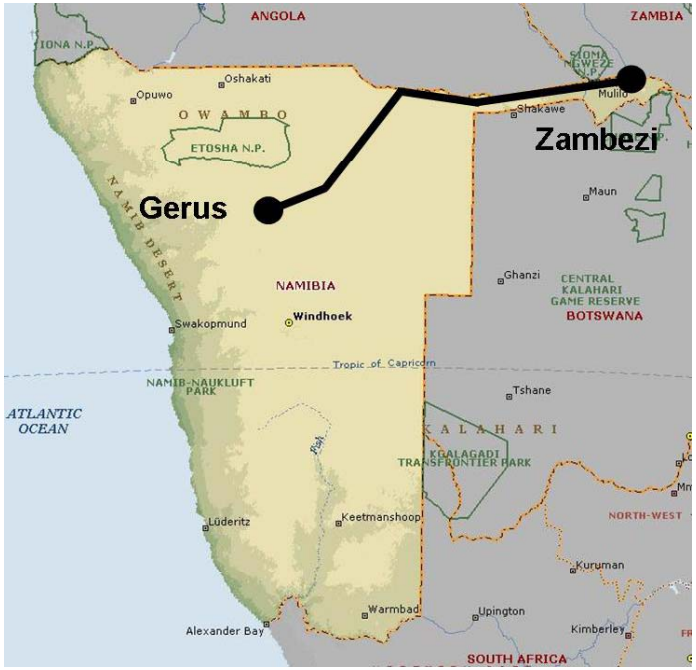
ALSTOM VSC HVDC based on IGBTs

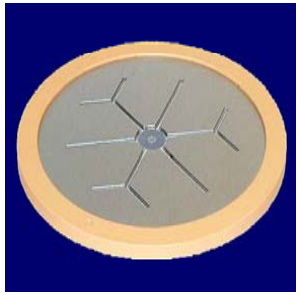




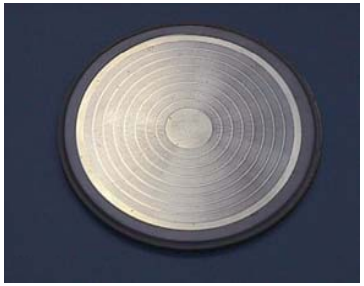
Alstom Series Hybrid Circuit with full bridge Chain-Links and Series IGBTs

Caprivi HVDC Link 300MW, 970km, ± 350 kV HVDC Light® system stabilizes two weak networks in Namibia and enables power trading in the expansive region of southern Africa. The first time the technology is used for overhead transmission. Continuous adjustment of the reactive power between - 130 Mvar and + 130 Mvar. Combined AC /HVDC Breakers with 500ms clearing time for DC Line faults

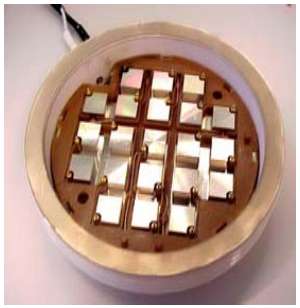




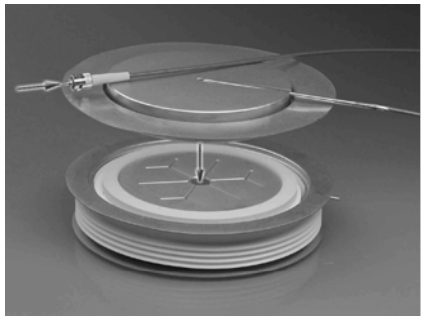
Conventional Thyristor



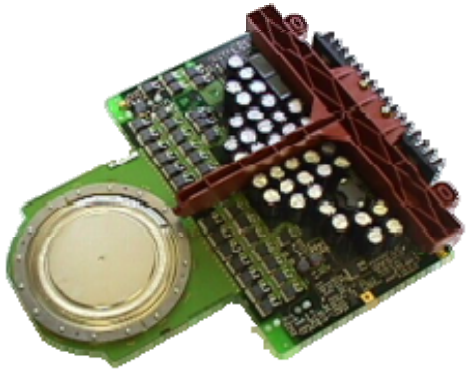
GTO



IGBT High Power Device



Direct Light Triggered Thyristor Siemens



Integrated Gate Commutated Thyristor ABB

Wire-Bonded IGBT Package

IGBT High Power Press pack Device ABB

High Power Devices

Available IGBTs

Dynex:

- 6500V at 900A,
- 4500V at 900A
- 3300V at 1200A
- 1700V at 2400A

Infinion:

- 6500V, 600A
- 3300, 1500A

FUJI:

- 3600V, 1700A

Powerex:

- 6500V, 600A
- 4500V, 900A
- 3300V, 1500A

ABB:

- 6500V, 750A
- 4500V, 1200A
- 3300V, 1200A

Hitachi:

- 6500V, 750A
- 4500V, 1200A
- 3300V, 1500A
- 2500V, 1200A

A Near Perfect Power Semiconductor Switch

- Turn on and off instantaneously on command
- Near zero switching losses
- Near zero conduction losses
- Zero gate power requirements (accept digital signal for turn-on turn-off)
- High continuous current capability
- High fault Current capability
- Fail in short circuit
- High voltage capability

Key advances needed for VSC Technology

- **Advanced devices (High Voltage, High Current, Fail in short circuit, Lower losses, High surge current capability)**

- **DC line fault clearing with multiple restarts**