STUDY COMMITTEE B2, JWG B2-17/B4/C1

HVDC Transmission Configurations and Intermediate Stations

Tutorial of JWG-B2/B4/C1.17 on HVDC Transmission Systems – Design and Economics

Converter Configurations – John Graham, ABB Brasil

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Converter Configurations : Introduction

To start discussing **converter configurations we need to consider:**

1. **Line configuration, bipolar or monopolar**
2. **Transmitted power and voltage**
3. **Location, especially regarding transportation**

While many configurations are possible, we discuss in detail only those applicable to overhead line transmission.

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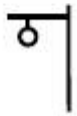
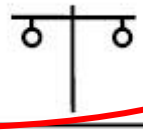
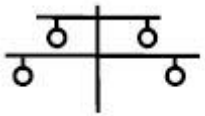
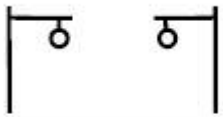
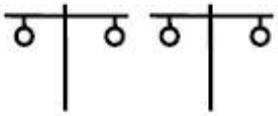
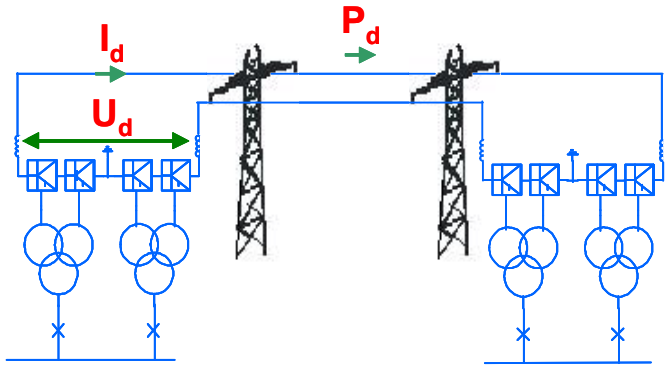
HVDC Transmission Configurations and Intermediate Stations

Variant	Tower Configuration	Remaining Transmission Capacity			Relative cost %
		Loss of one pole		Tower breakage	
		Ground return permitted	Ground return not permitted		
Single monopolar line		0	0	0	85
single bipolar line		50 (100)	0	0	100
double bipolar line		100	100	0	114
Two monopolar lines		50 (100)	0	50 (100)	126
two lines (bipolar or homopolar)		100	100	100	136

Cigré Technical Brochure 186 from WG 14.20 - 2001



In all CSC cases, bi-polar operation only considered, except in emergency or maintenance.

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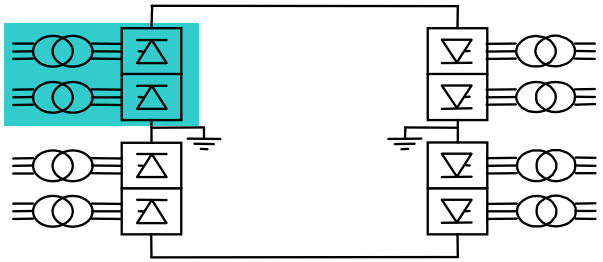
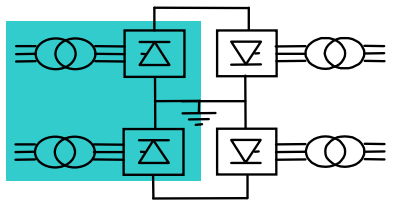
HVDC Transmission Configurations and Intermediate Stations



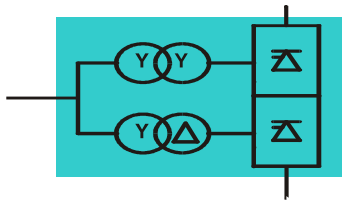
Bipole

Monopole

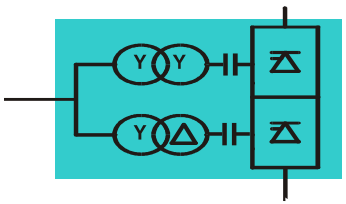


Back-to Back

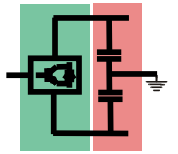
In all CSC cases, 12-pulse converters only considered



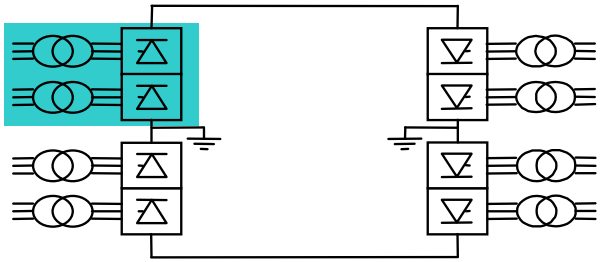
HVDC Classic



HVDC CCC

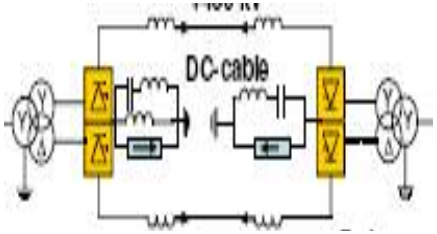


HVDC VSC



Bipole

Monopole



12-pulse centre-tap

In all CSC cases, bi-polar operation only considered, except in emergency or maintenance.

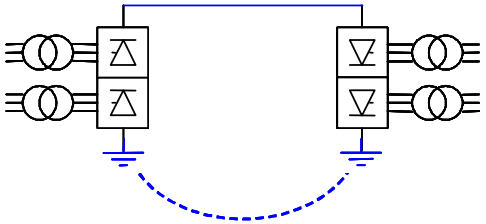


Figure 3.2.a Ground Return

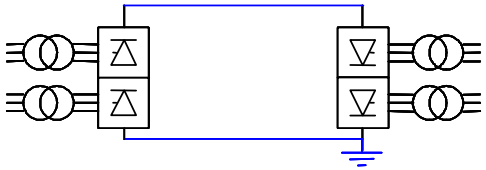


Figure 3.2.b Metallic Return

Basic types of Converters

- Naturally commutated converters (Thyristors) (current source converters : CSCs)
  - Classic HVDC Transmission
    Itaipu, Three Gorges, Baltic Cable, (many)
  - Capacitor Commutated Converters (CCC)
    Garabi, Rapid City
- Voltage source converters (VSCs)
  - HVDC Light, HVDC Plus (IGBT)
    Cross Sound, Murray Link, Troll A
  - VSC using GTO (statcom or industrial)

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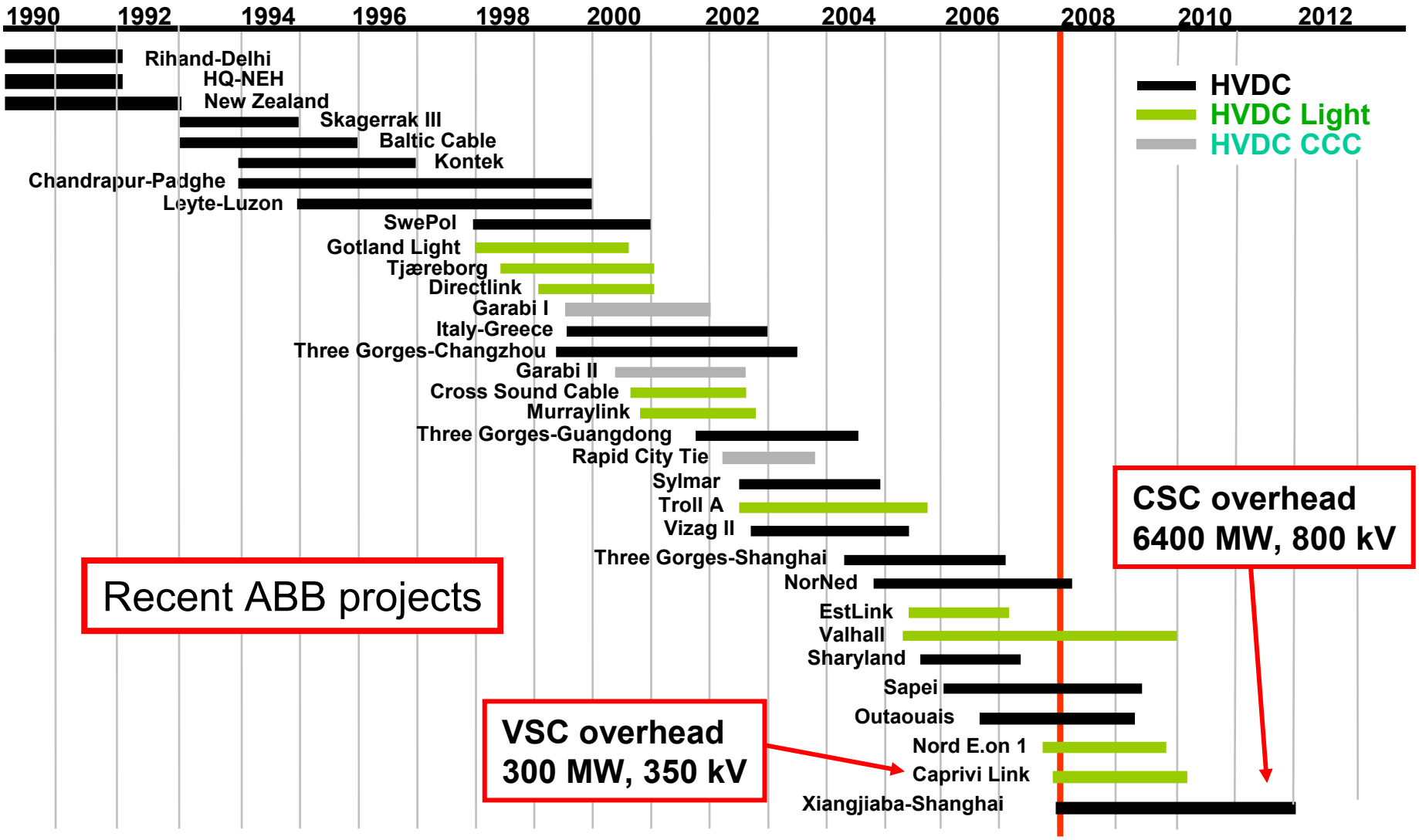
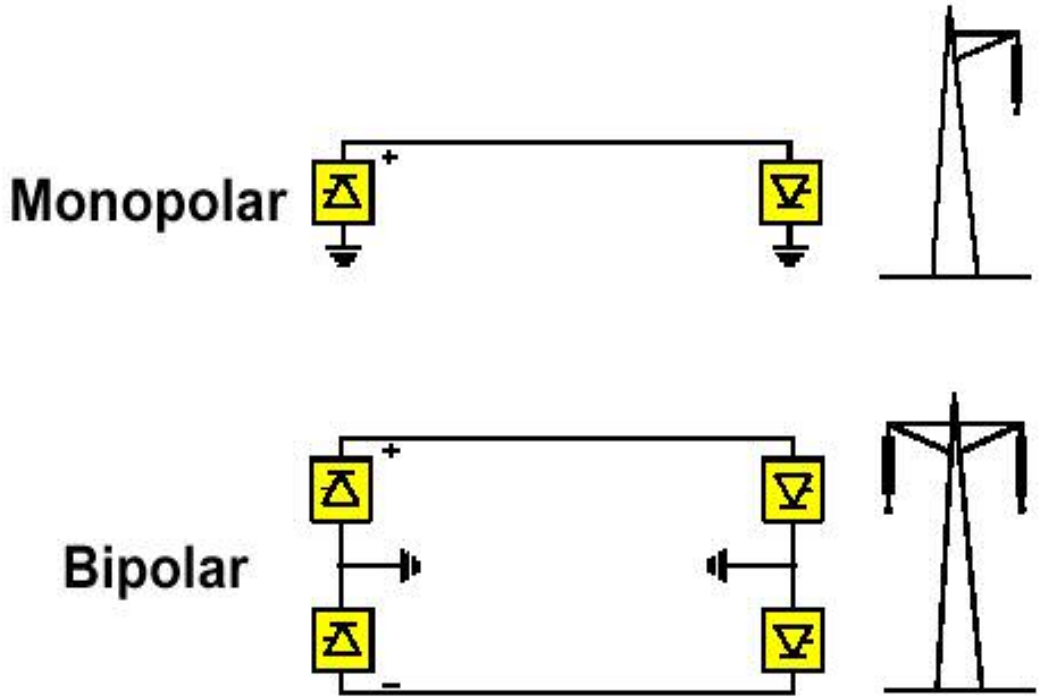
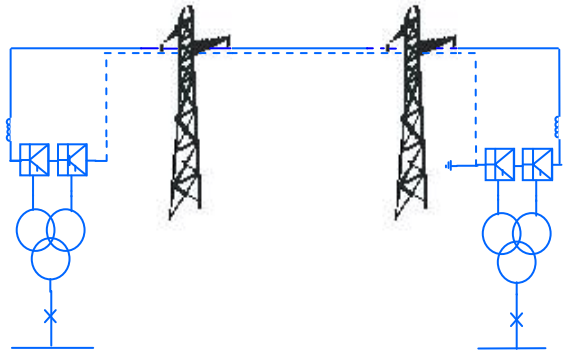
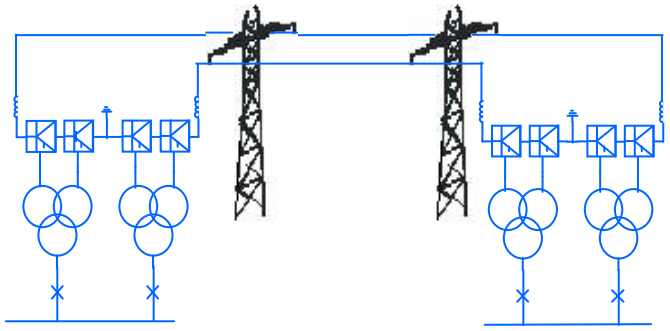
HVDC Transmission Configurations and Intermediate Stations




Monopolar
+
Bipolar
+
–

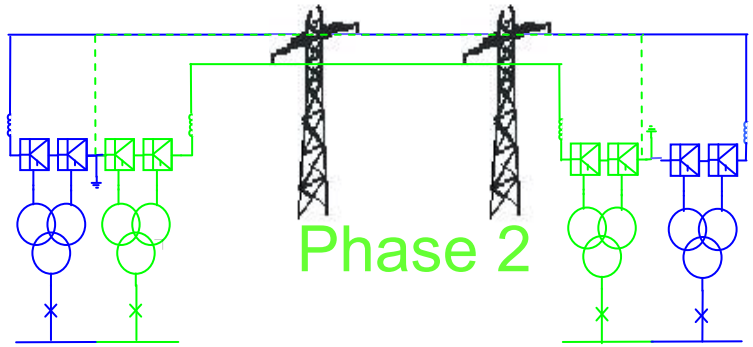


Investment Cost	+
Losses	-
Availability	-

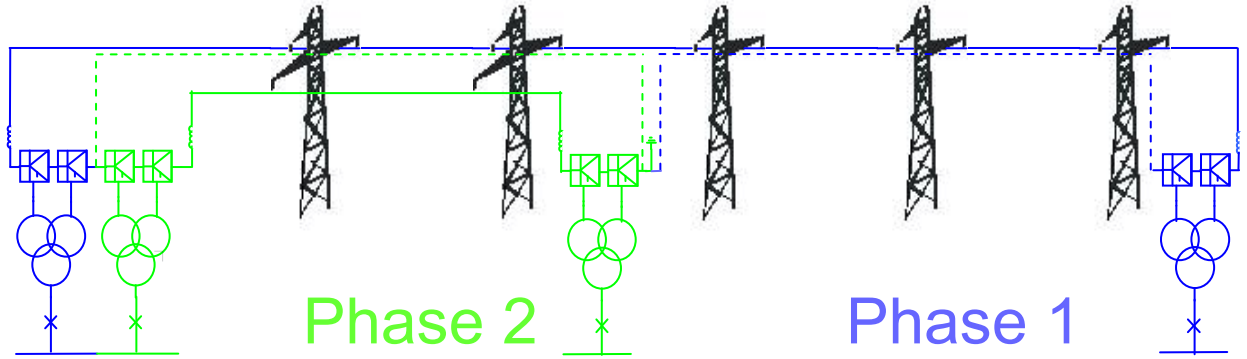


Availability	+
Losses	+
Investment Cost	o

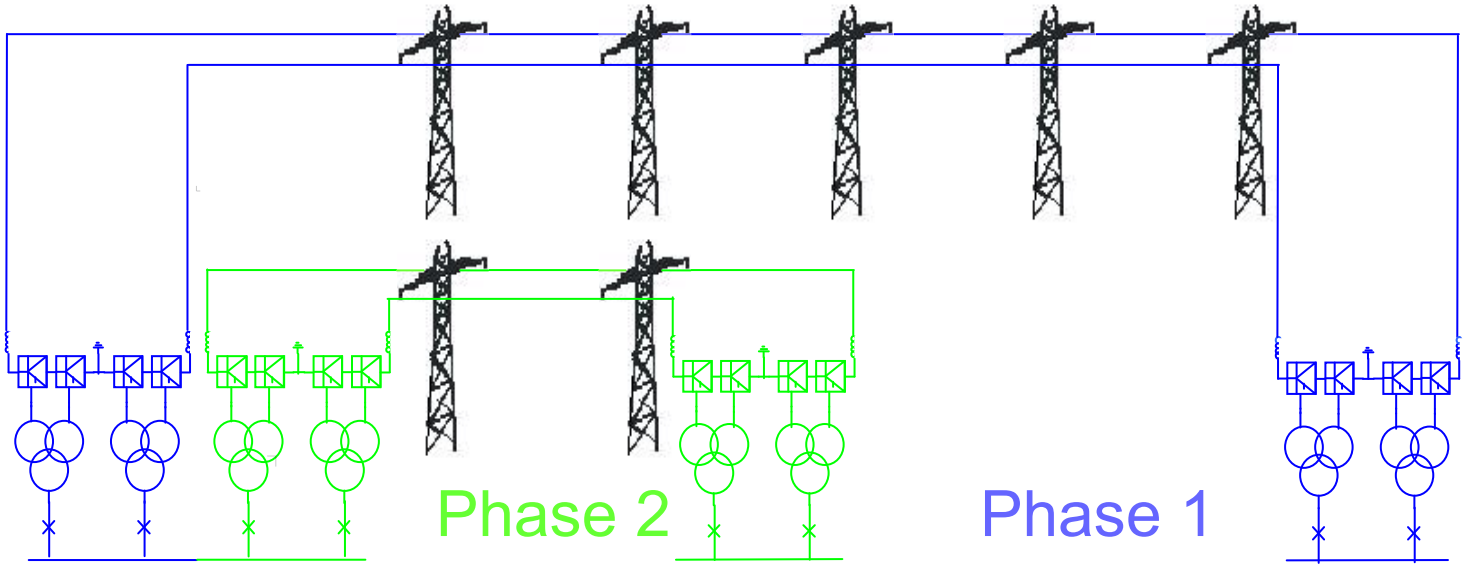
Phase 1



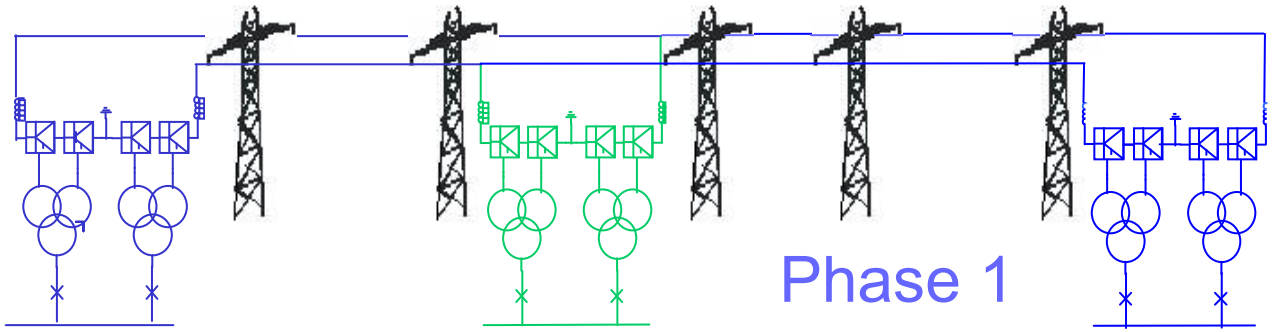
Investment Cost	+
Losses Phase 1	-
Availabity Phase 1	-



Investment Cost	+
Losses	-
Availabity	-

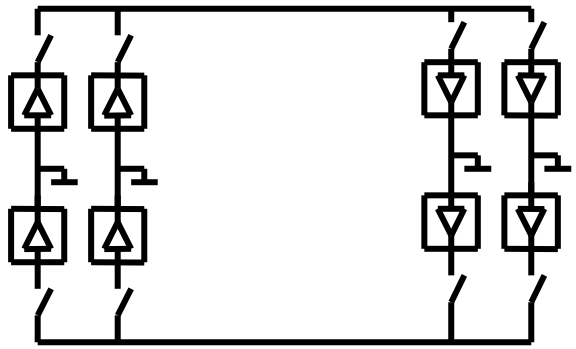


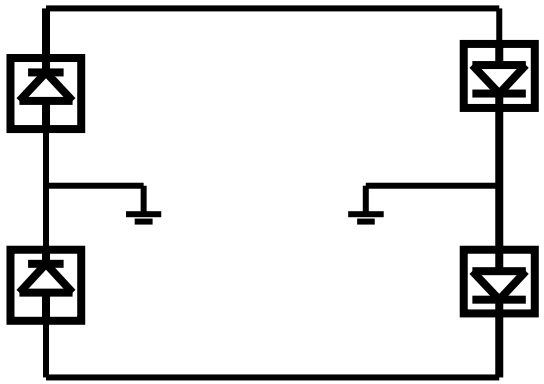
Investment Cost	-
Losses	+
Availabity	+

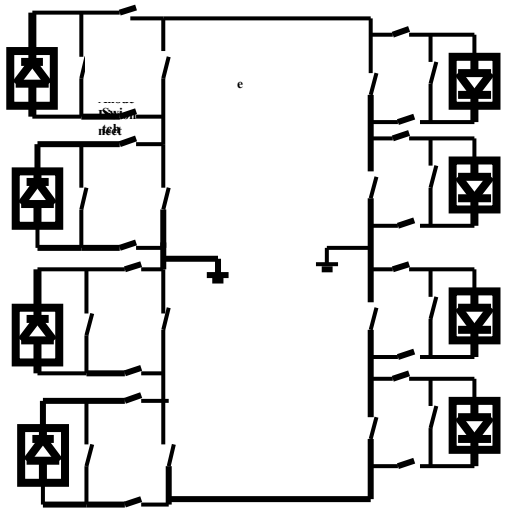


Initial rating ?

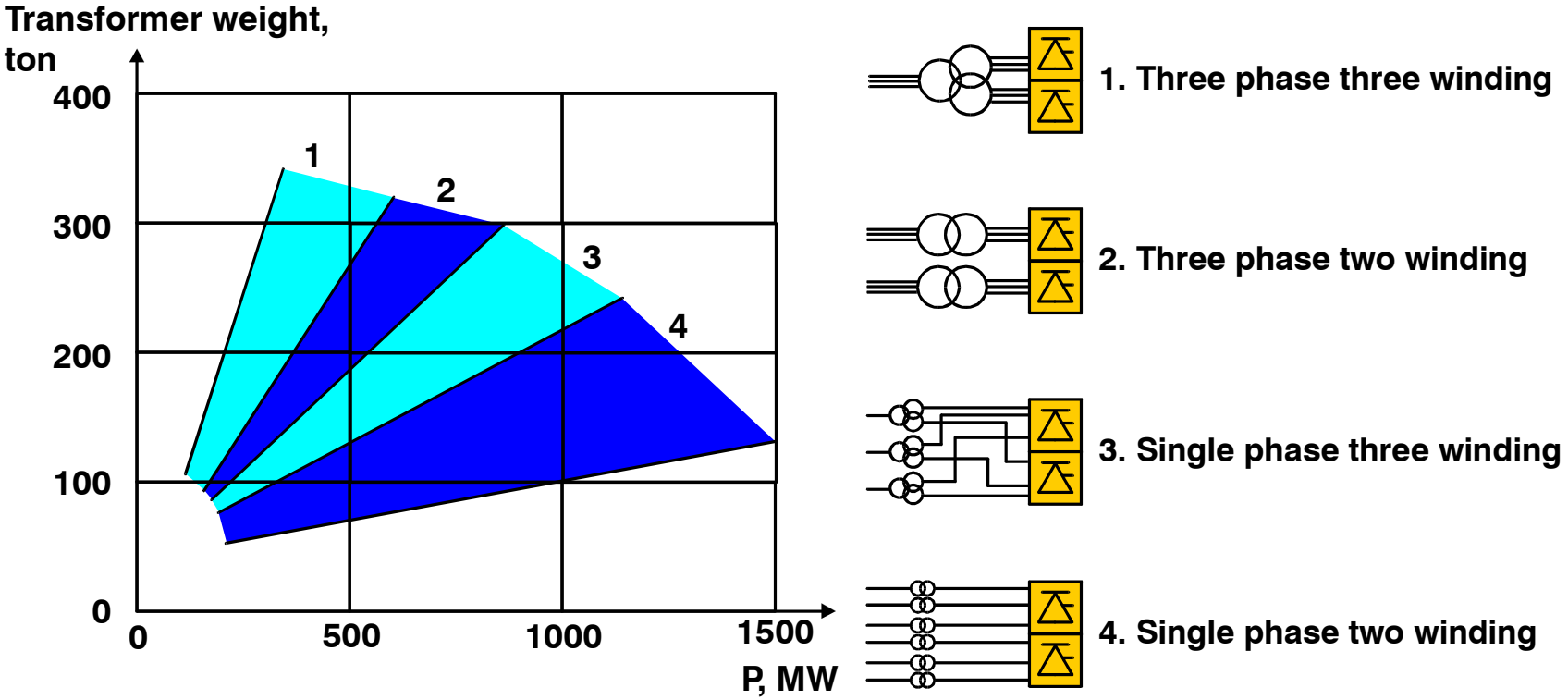
Investment Cost: line/stations	+/o
Losses	+
Availabity	o



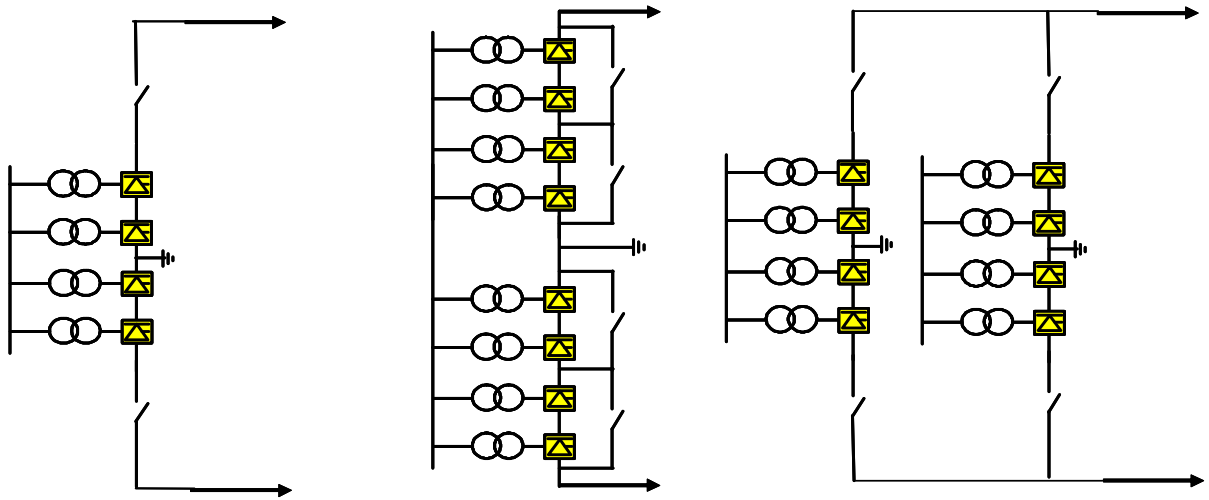




<u>Configurations for maximum power</u>
Transport restrictions on transformers are normally limiting



- The transformer topology is adopted to the requirements:
  - Size influences choice of topology (power and voltage increase size)
  - Spares strategy influences choice of topology



One converter per pole, 3000 MW, Two converters, 6000 MW Two parallel, 6000 MW
Figure 3.3 Basic station configurations for 12-pulse converters

- The transformer topology is adopted to the requirements
- Valve current rating may determine parallel converters

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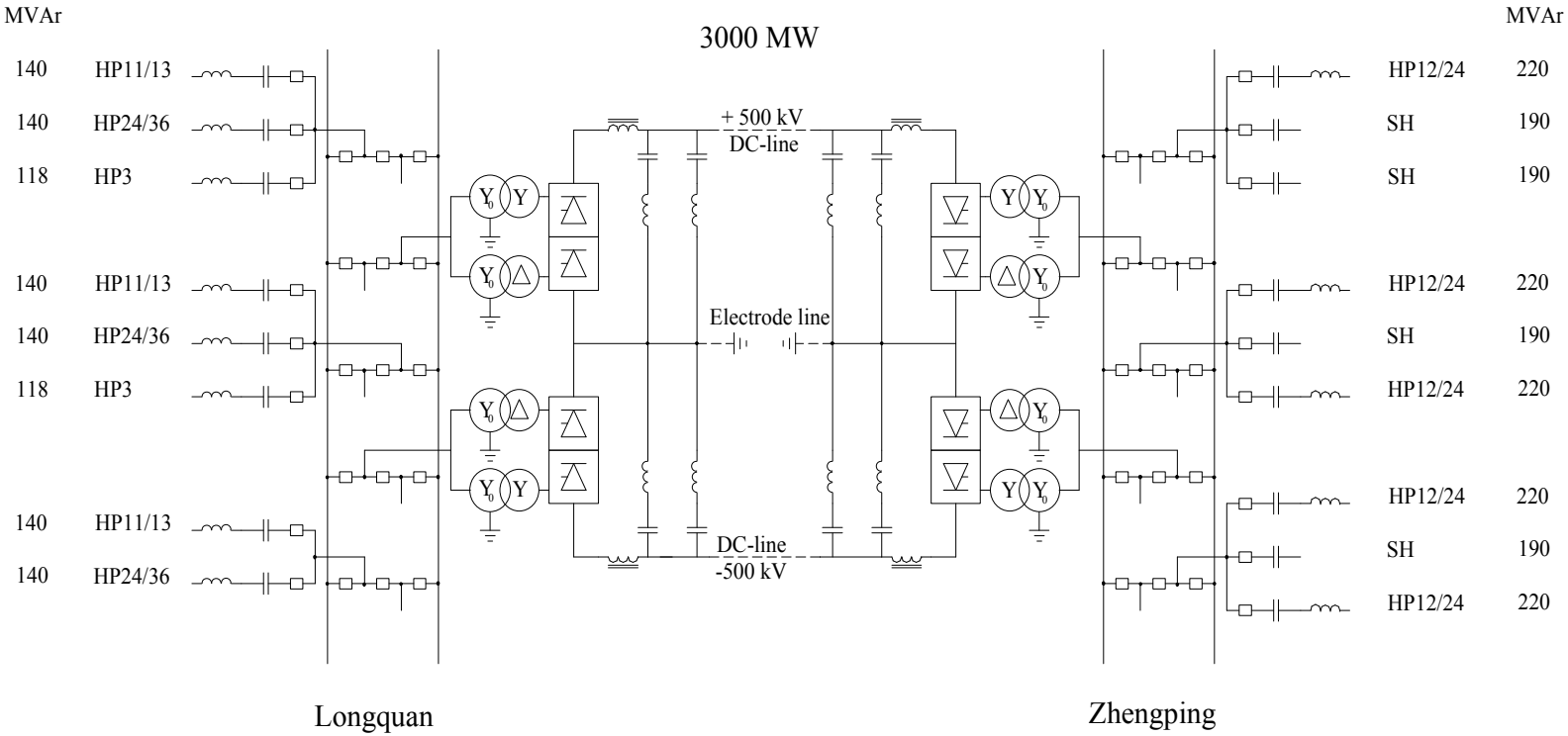
HVDC Transmission Configurations and Intermediate Stations

Three Gorges - Changzhou HVDC Transmission Project



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HVDC Transmission Configurations and Intermediate Stations

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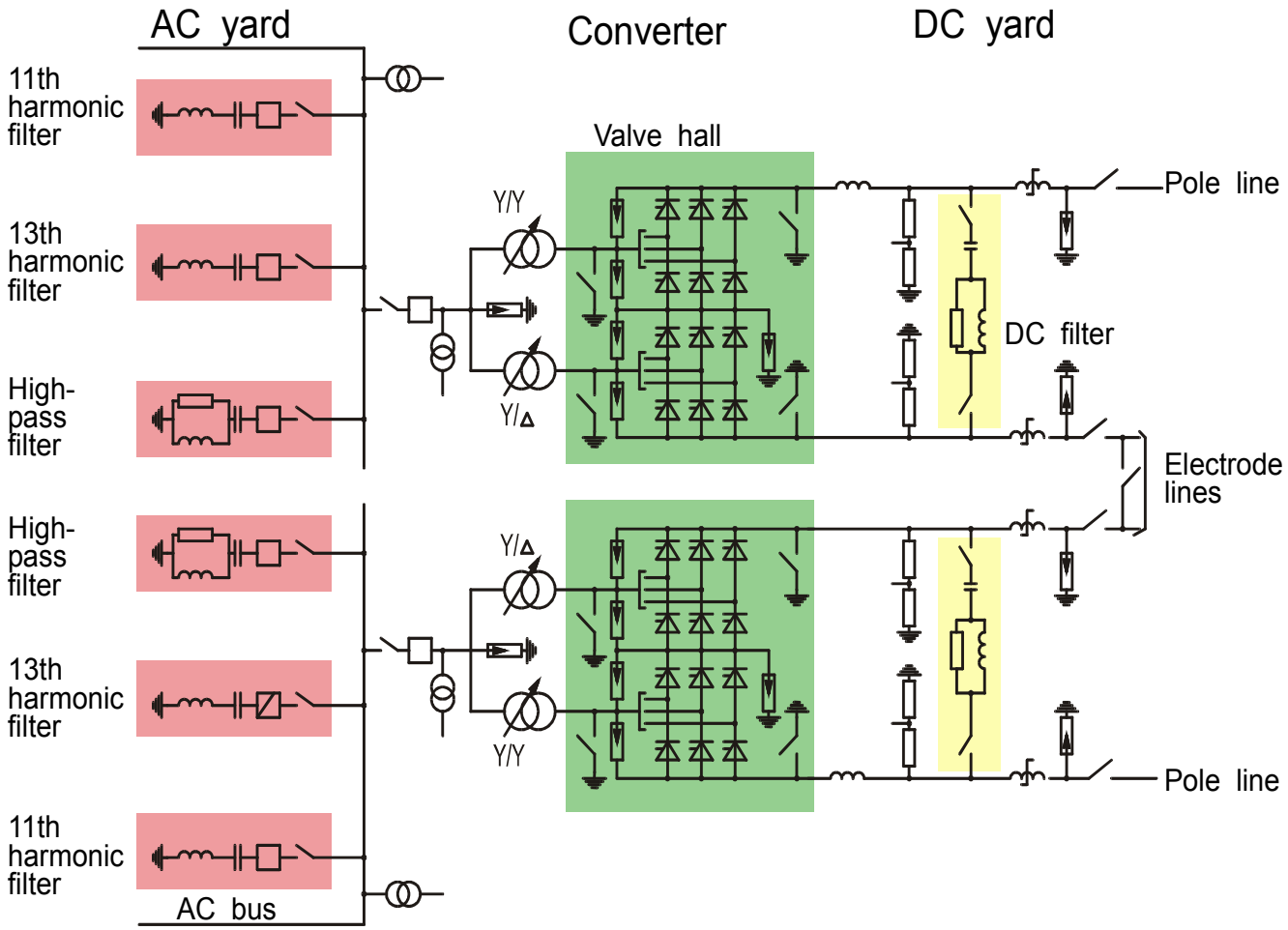
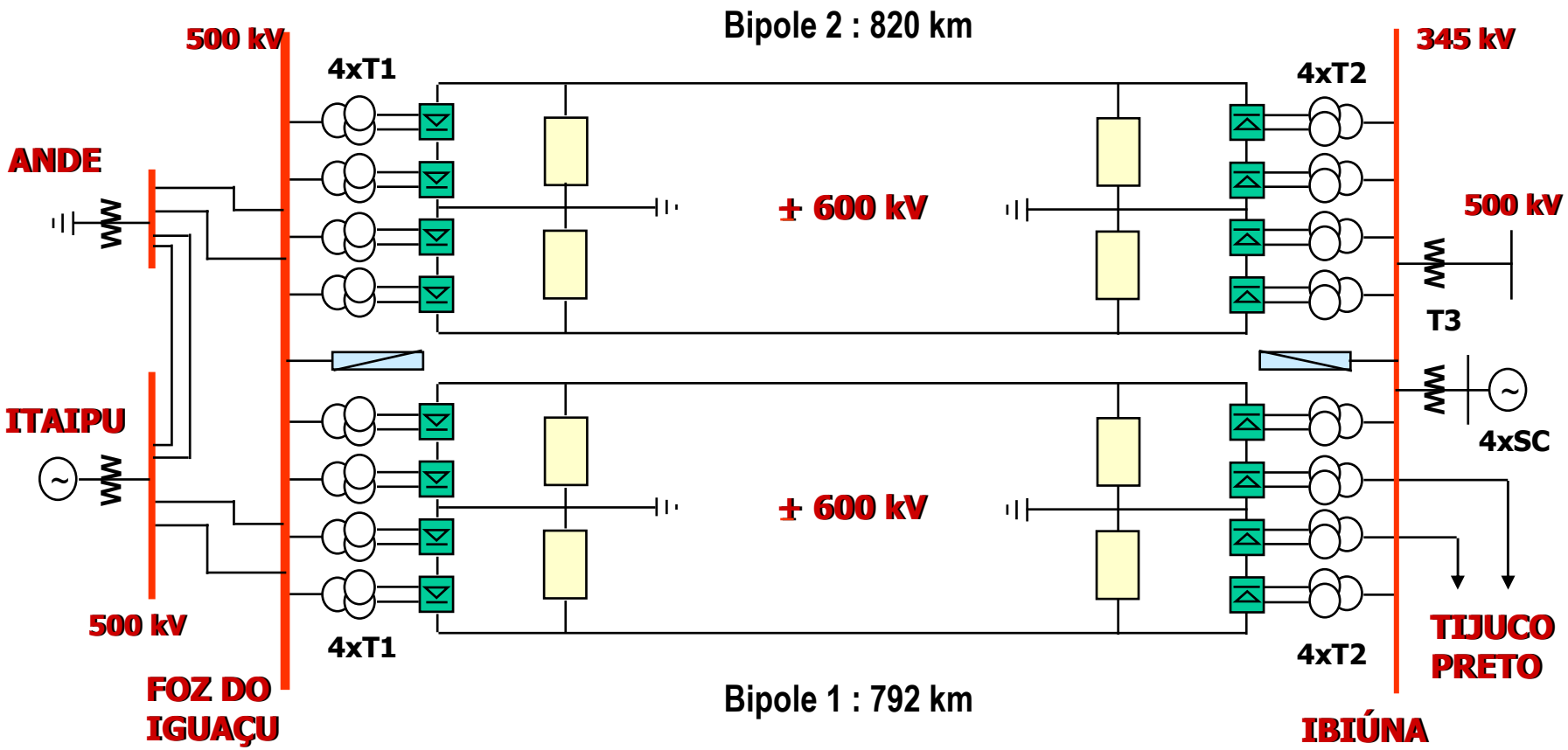


The Converter Station

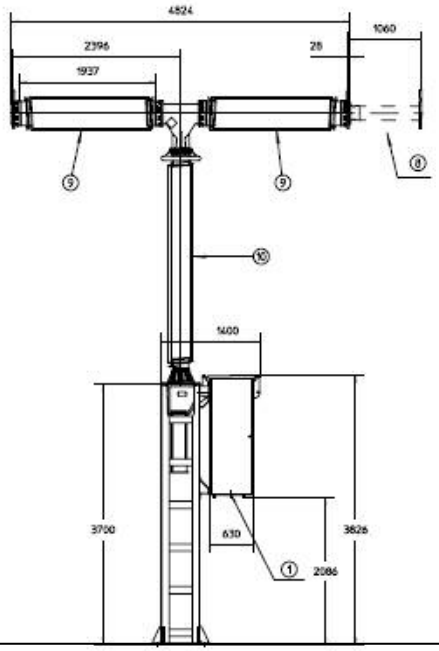


ITAIPU HVDC SYSTEM

Disjuntor de by-pass de conversor : By-pass Breaker

Câmaras SF_6

Externo compósito



BPB de baixa

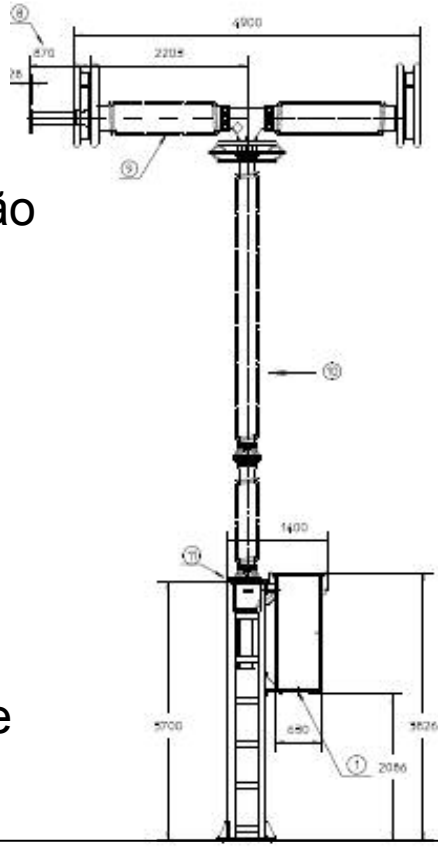
Metade da tensão de pólo para terra.

BPB de alta

Tensão de pólo para terra.

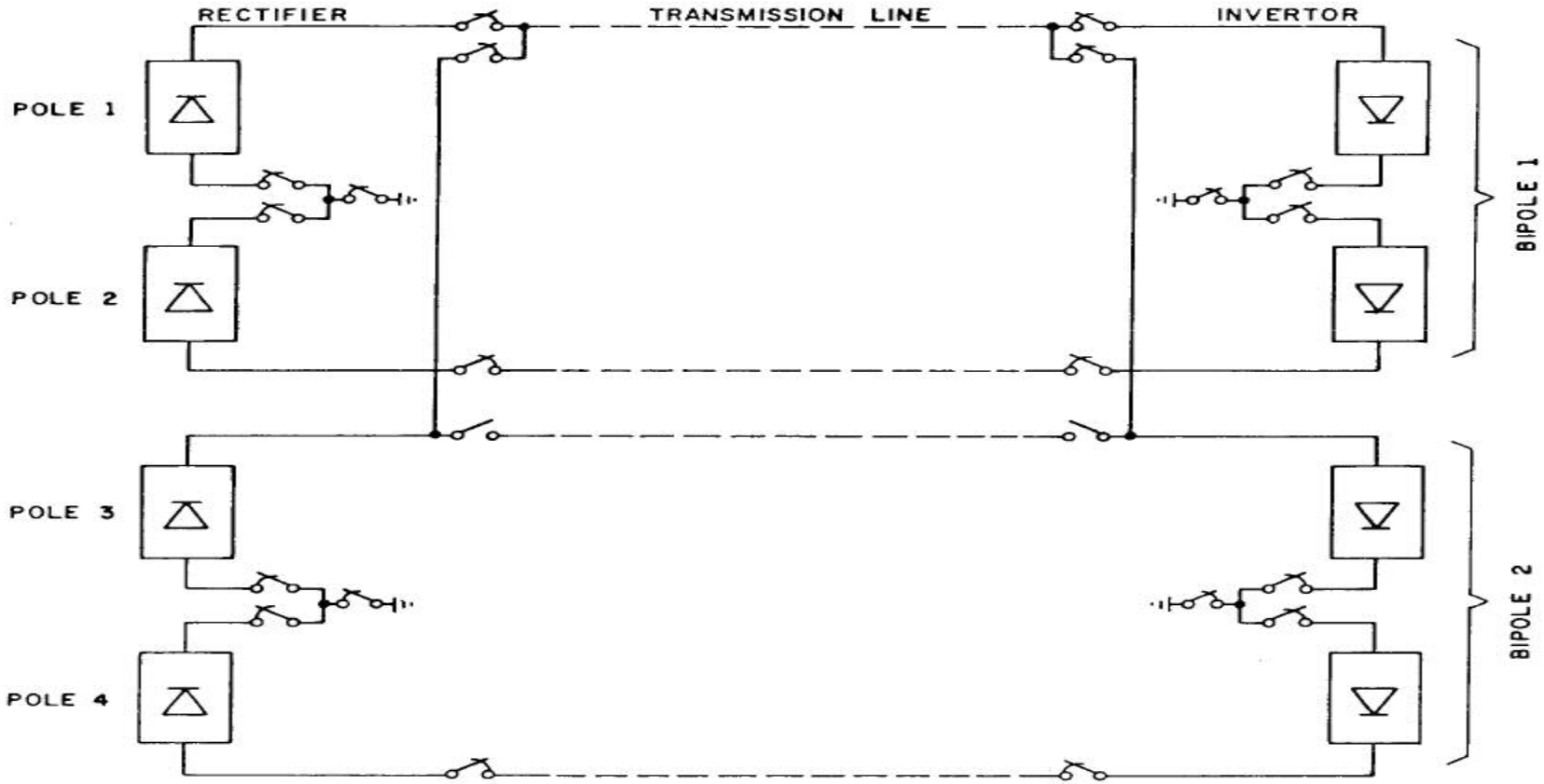
Ambos:

Tensão de conversora entre contatos.

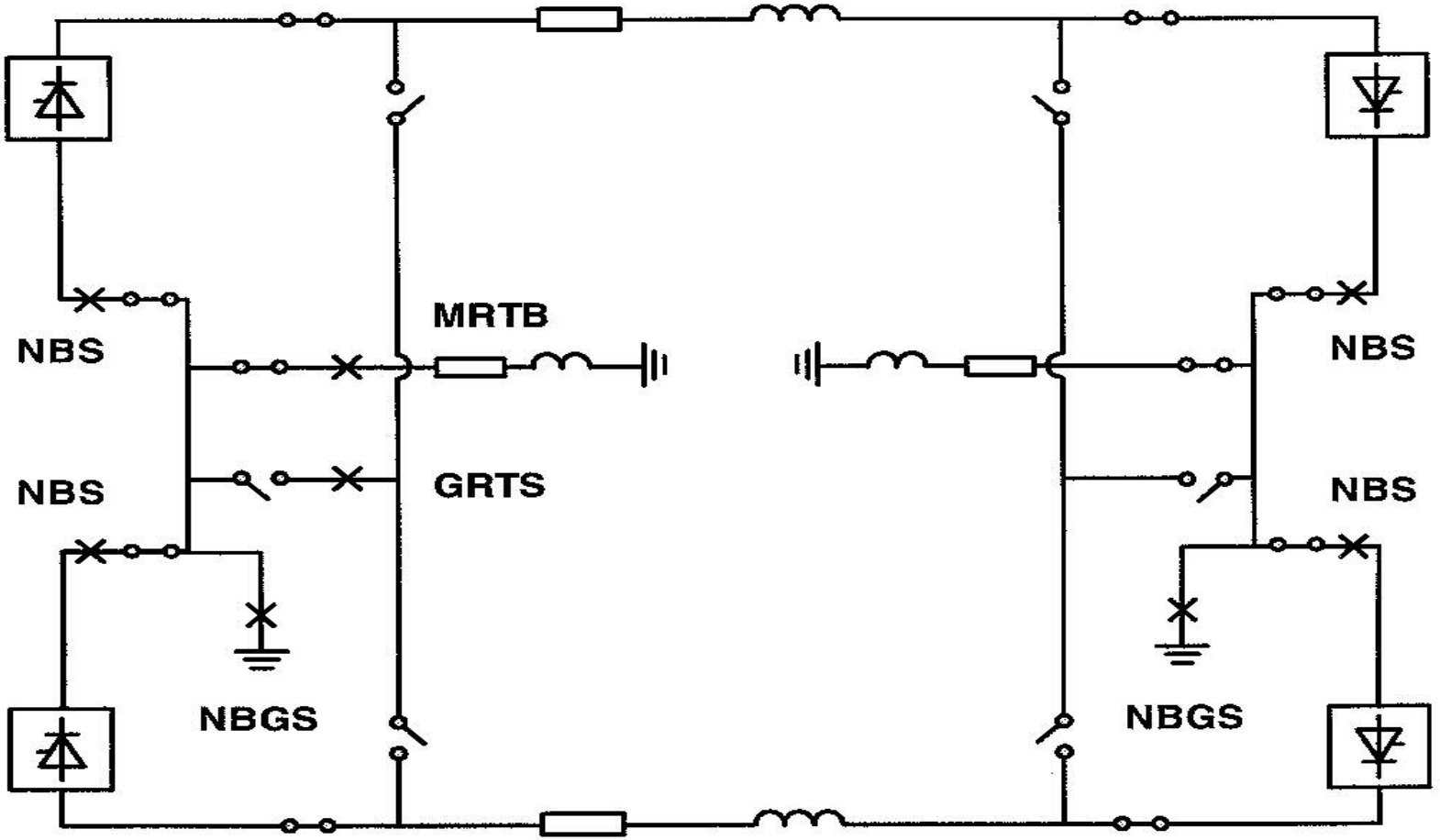


BPB de baixa

BPB de alta



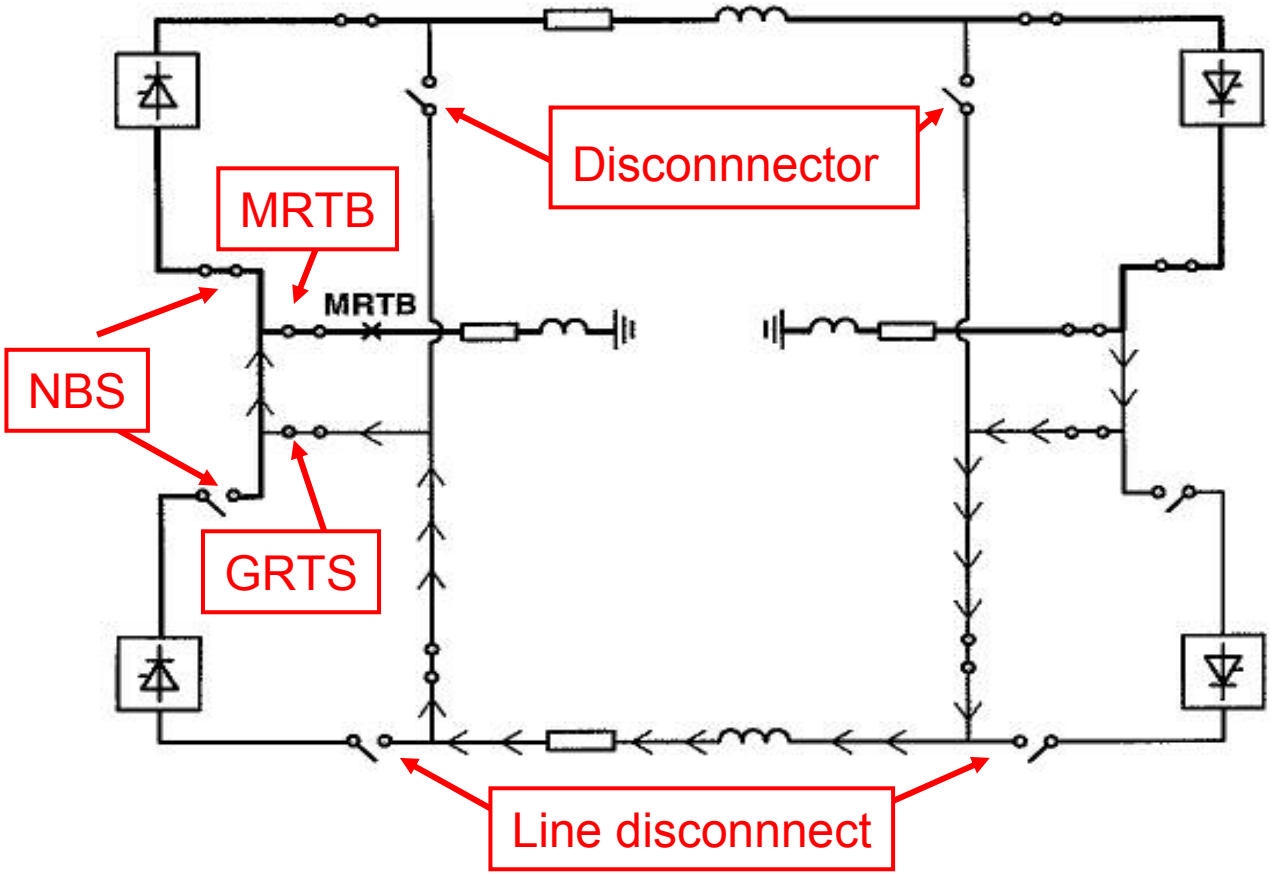
ITAIPU HVDC SYSTEM : Pole Paralleling



Transferência de retorno metálico : MRTB

Metallic Return Transfer Breaker

Transferência de retorno metálico : MRTB usado para comutar o corrente do eletrodo de terra para o caminho de retorno metálico quando transmitindo em modo monopolar.

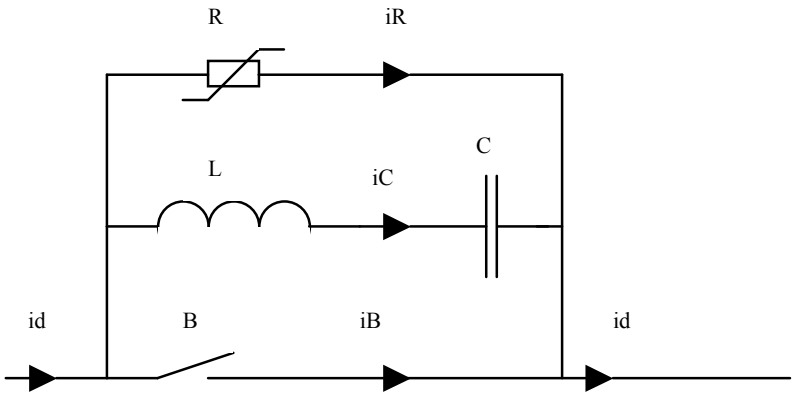


Metallic return is used to avoid ground currents during pole outages in the station, for example when carrying out maintenance.

Componentes:

- Disjuntor SF_6
- Capacitor de Comutação
- Reator de Comutação
- Resistor Não-linear de ZnO

Valores uma função do comprimento da linha e corrente. Hoje ate 5 kA.



MRTB – Disjuntor de transferência metálico

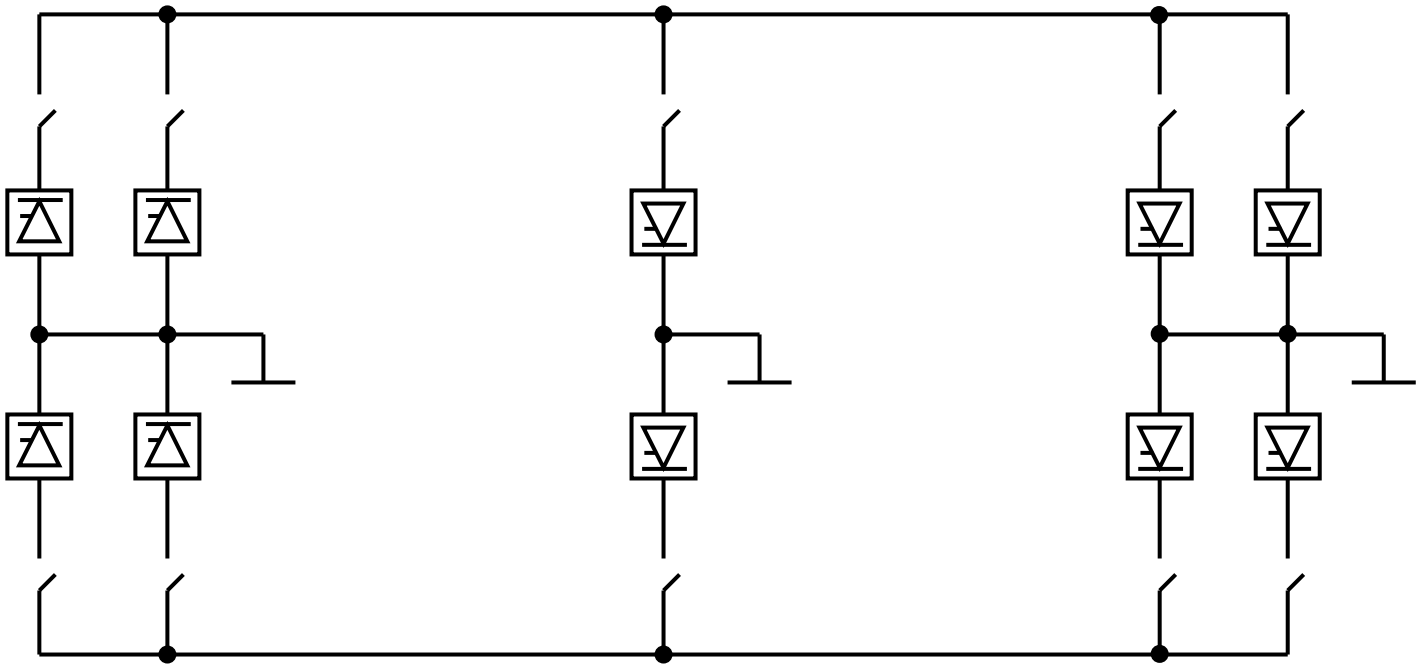
Longquan 3000 MW, ± 500 kV Valve Hall : Double-valves

Longquan 3000 MW

Large 500 kVac Station

3000 MW HVDC Rating
Converter part relatively small
One converter per pole
Single phase two winding trafos
Simple passive filter design
Metallic Return
Electrode Balancing

Considerations regarding multi-terminal and “Tapping”.



Converters in parallel with classic CSC tapping:

Generation or Load

Requires active network for CSC

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HVDC Transmission Configurations and Intermediate Stations

HQ – NEPOOL Multi-terminal

Technical Data:

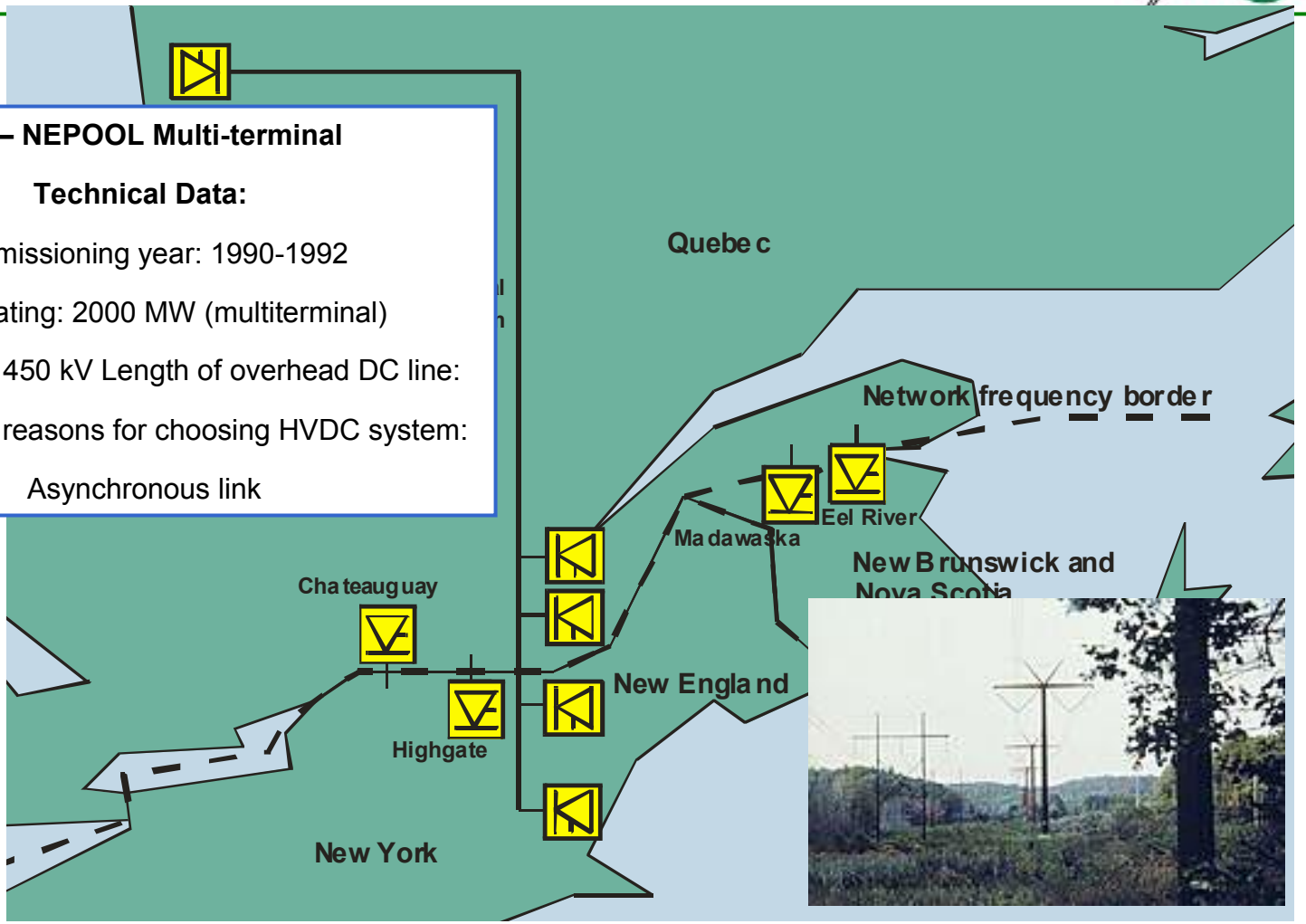
Commissioning year: 1990-1992

Power rating: 2000 MW (multiterminal)

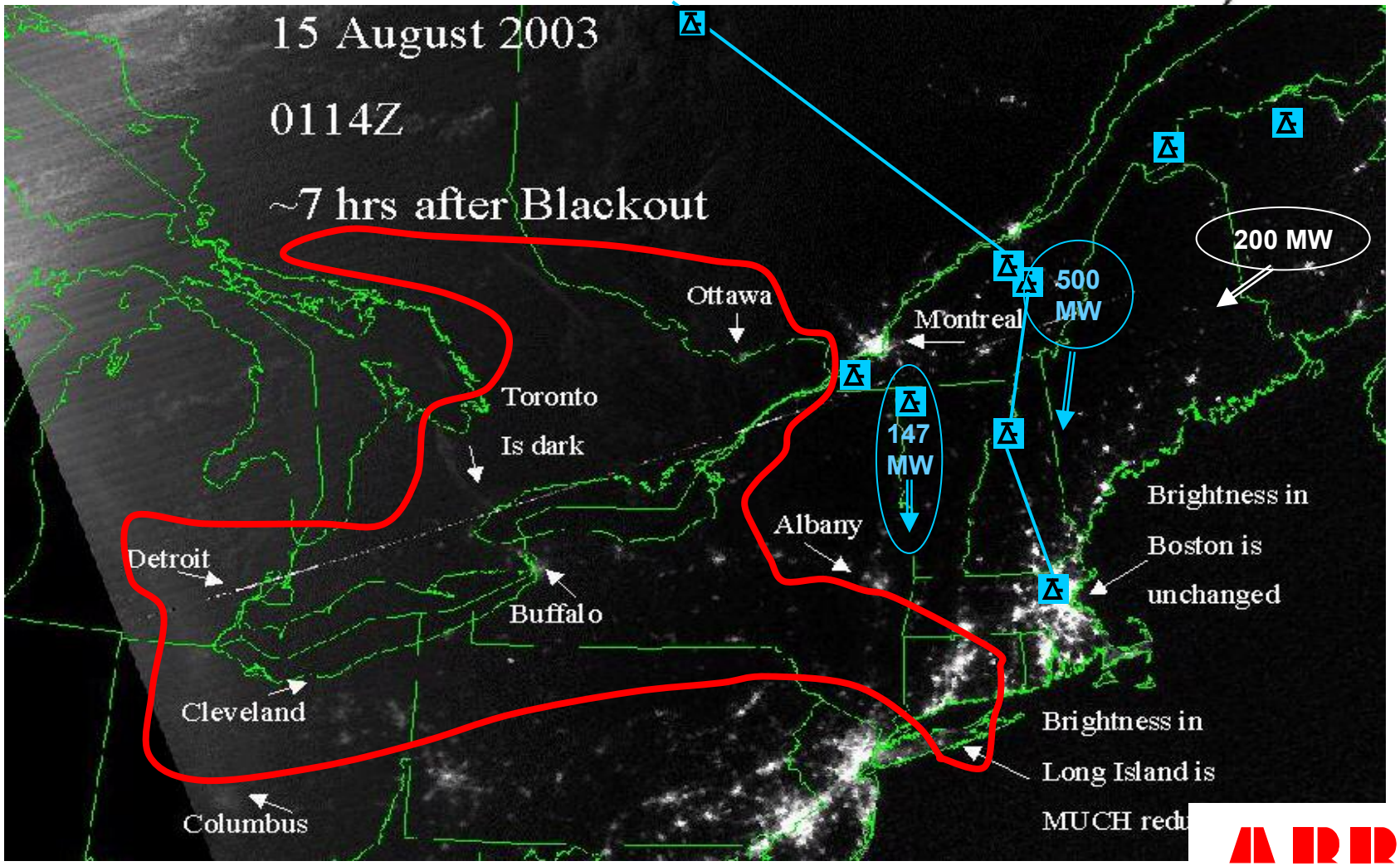
DC voltage: ± 450 kV Length of overhead DC line:

1480 km Main reasons for choosing HVDC system:

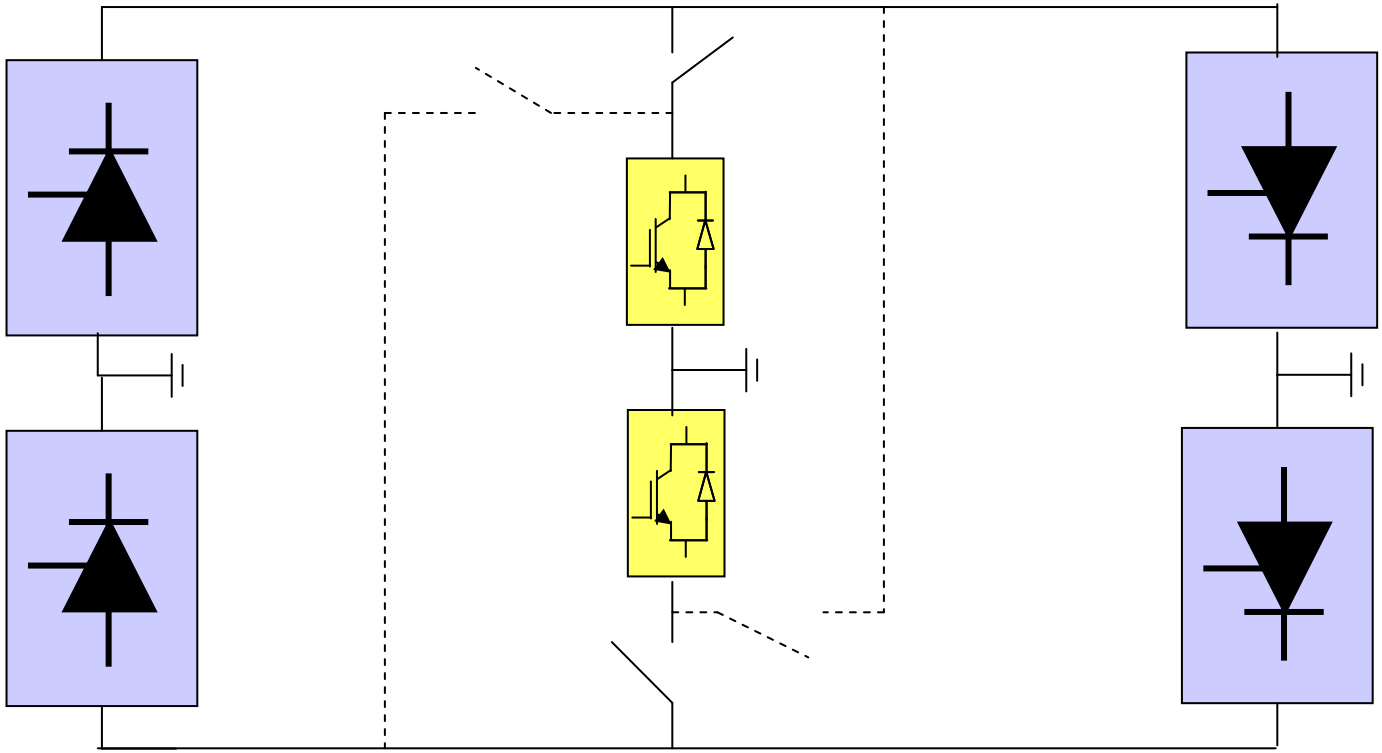
Asynchronous link



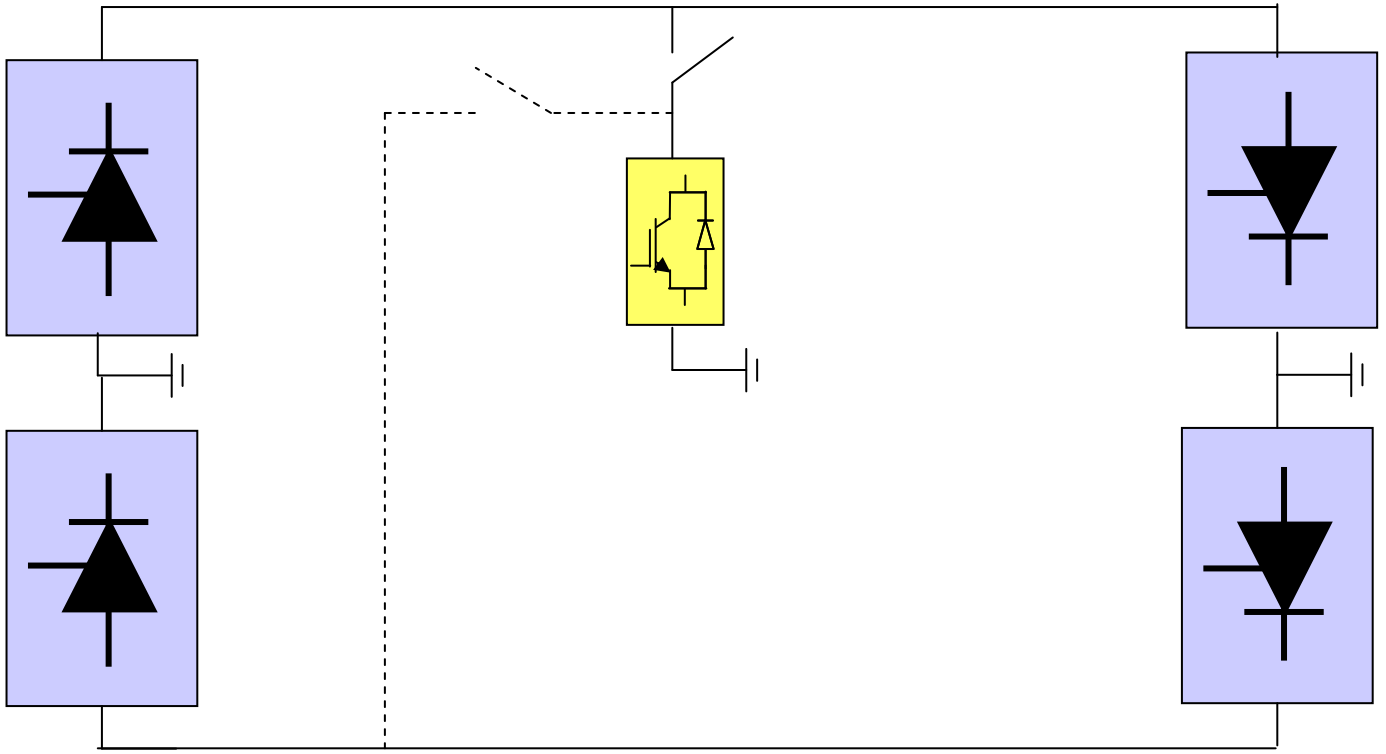
Exemplo de Multi-terminal: Hydro Quebec – New England



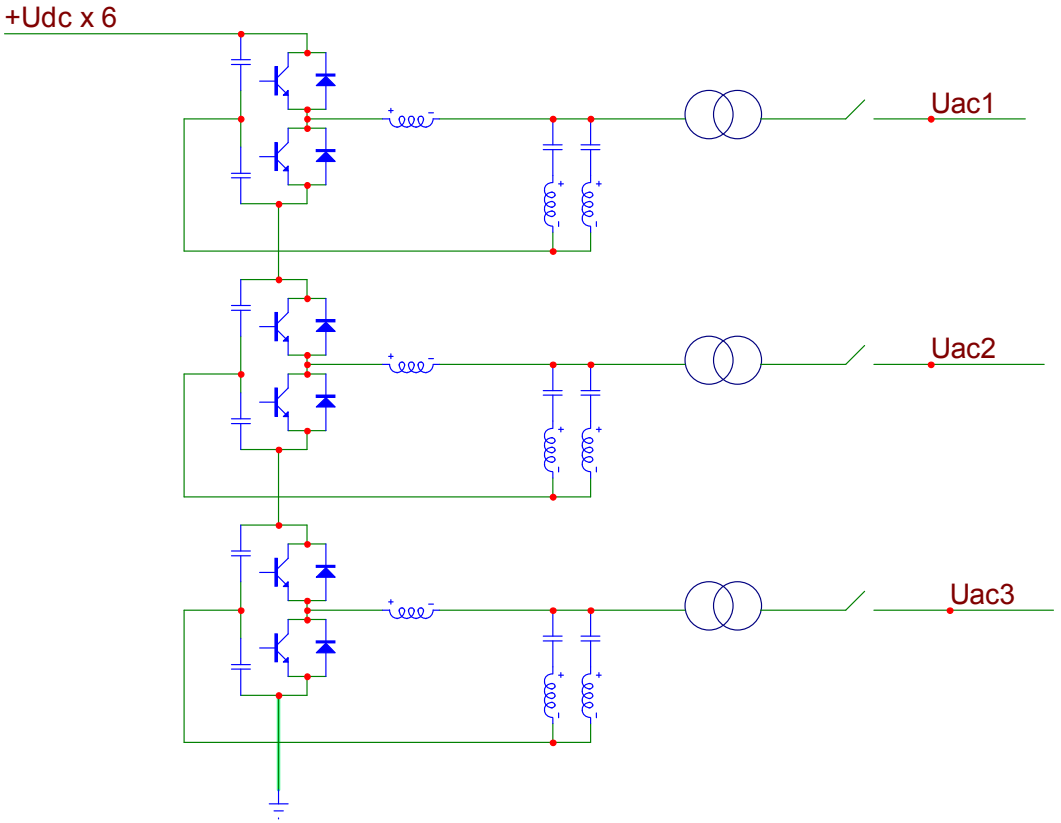
Blackout Aug 14, 2003 **Source: Public Power Weekly, August 25, 2003**



"Tapping" with bi-polar VSC converter:
Generation or Load
Can feed passive network or give "black start".



"Tapping" with mono-polar VSC converter
For smaller loads (100 MW, 500 kV)
Note: Ground current



"Tapping" with VSC converter.
One pole connected to line voltage

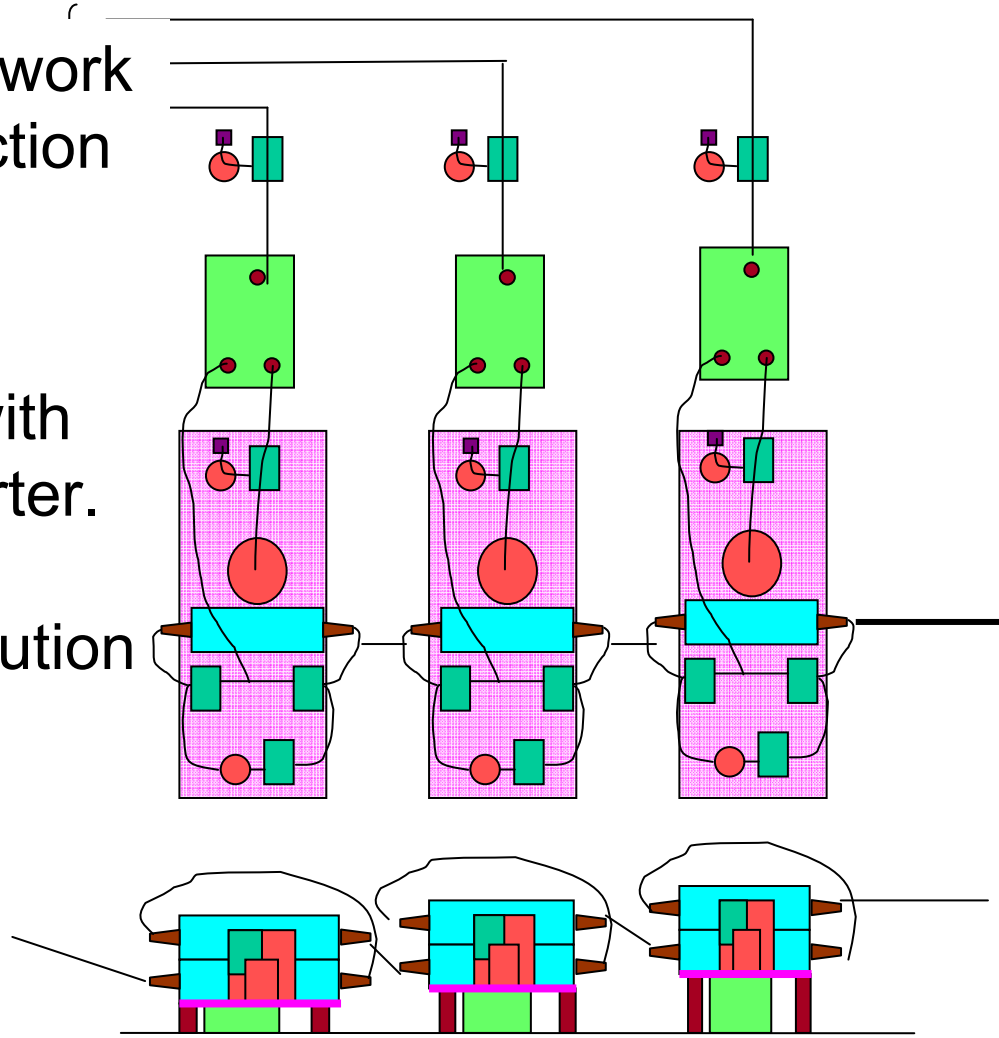
Voltage C.C.	500 A	1000 A	1500 A
+/- 480 kV	M1- 2x95 MVA	M2- 2x190 MVA	M3- 2x285 MVA
+/-900 kV	M4- 2x178 MVA	M5- 2x356 MVA	M6- 2x535 MVA

"Tapping" with VSC converter.
Available ratings

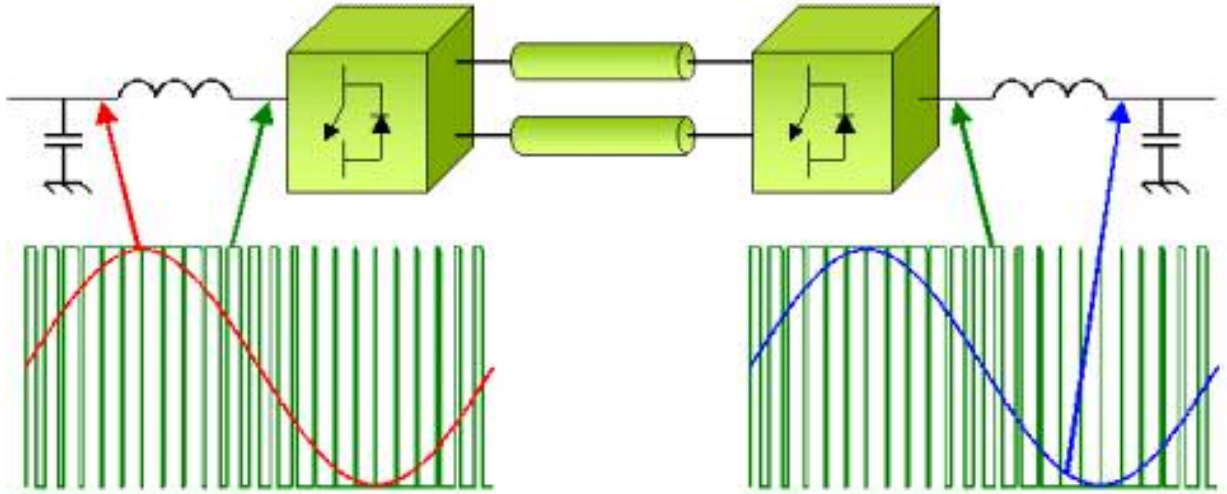
AC network connection

HVDC Line

"Tapping" with VSC converter. One pole: Outdoor solution

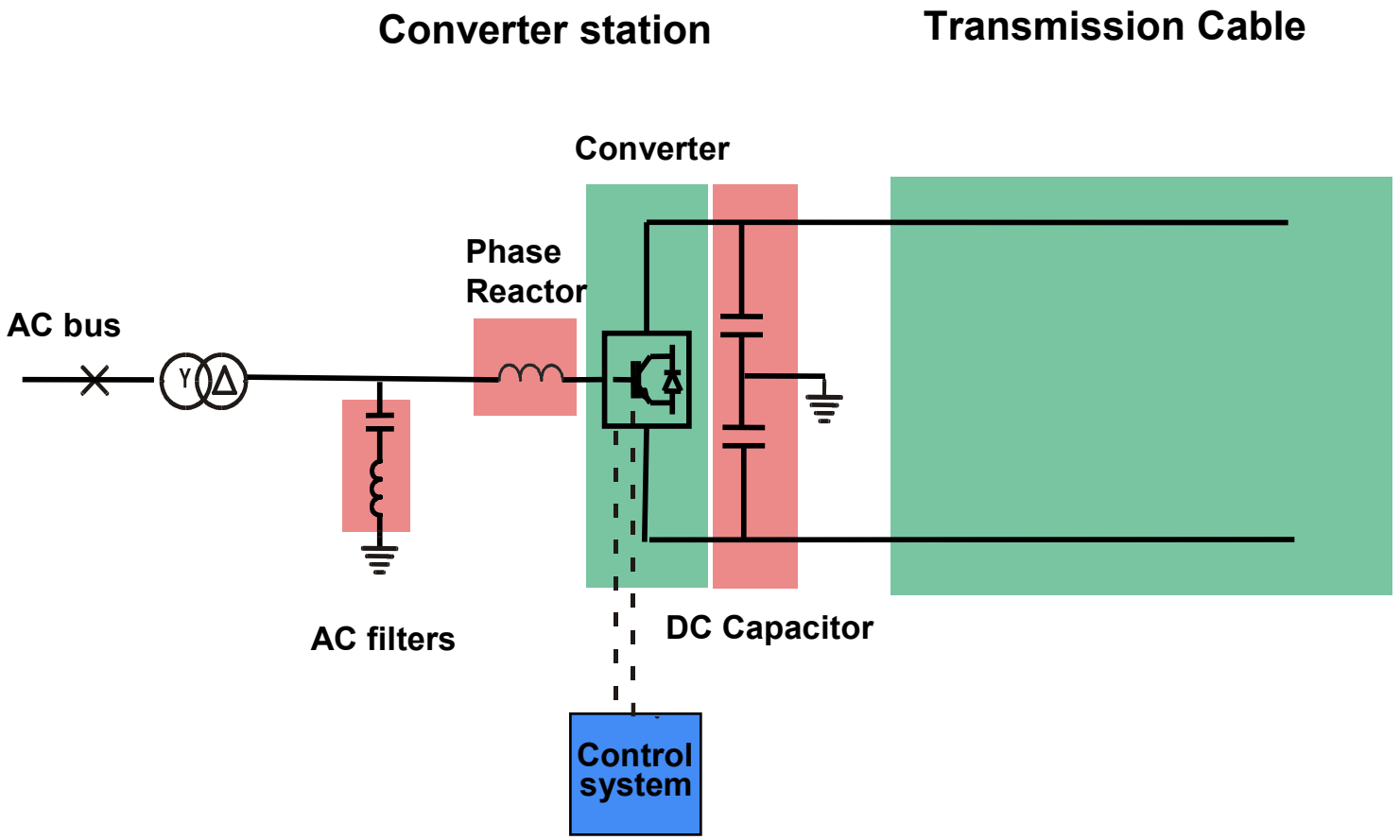


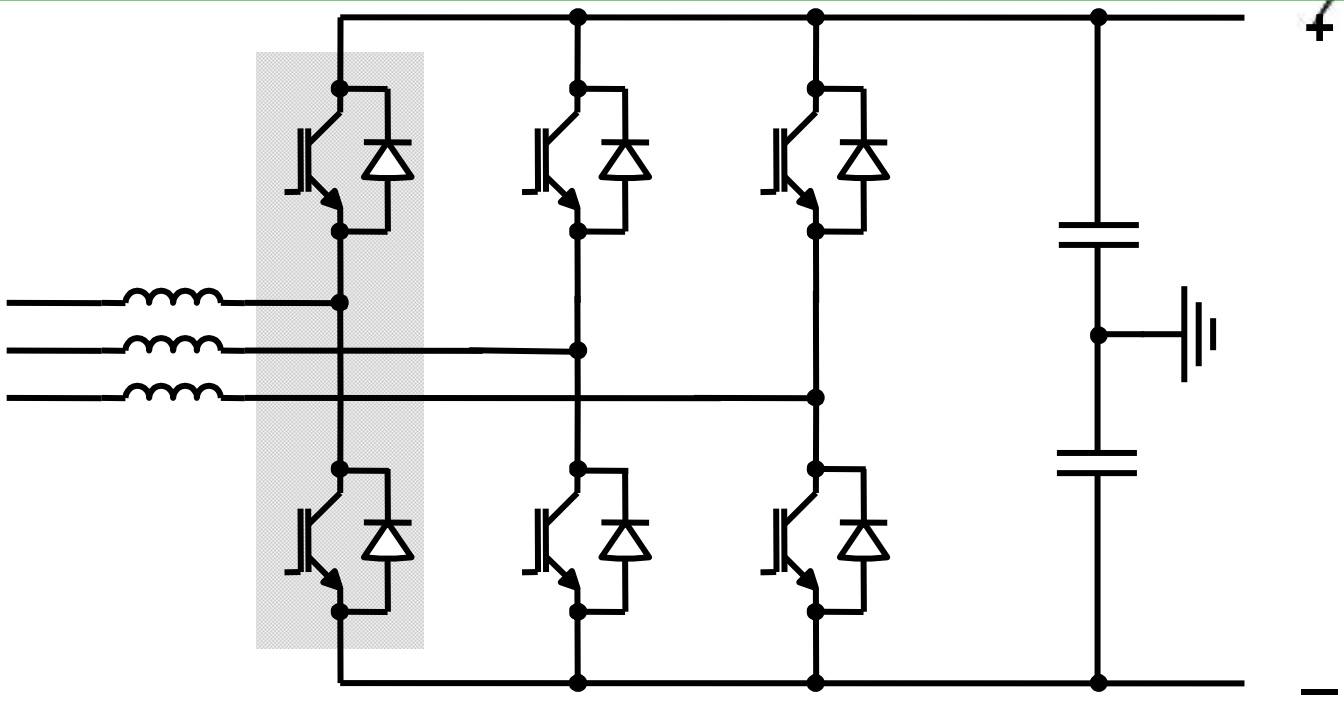
Voltage source converters (VSCs)



- IGBT based Voltage Source Converter
  - Successful technology in industrial drives
- Fast, independent control of active and reactive power flows
- High switching frequency, compact filters, no synchronous condenser
- HVDC Light Cable™: Flexible, cost-effective extruded polymer HVDC cable

VSC station components



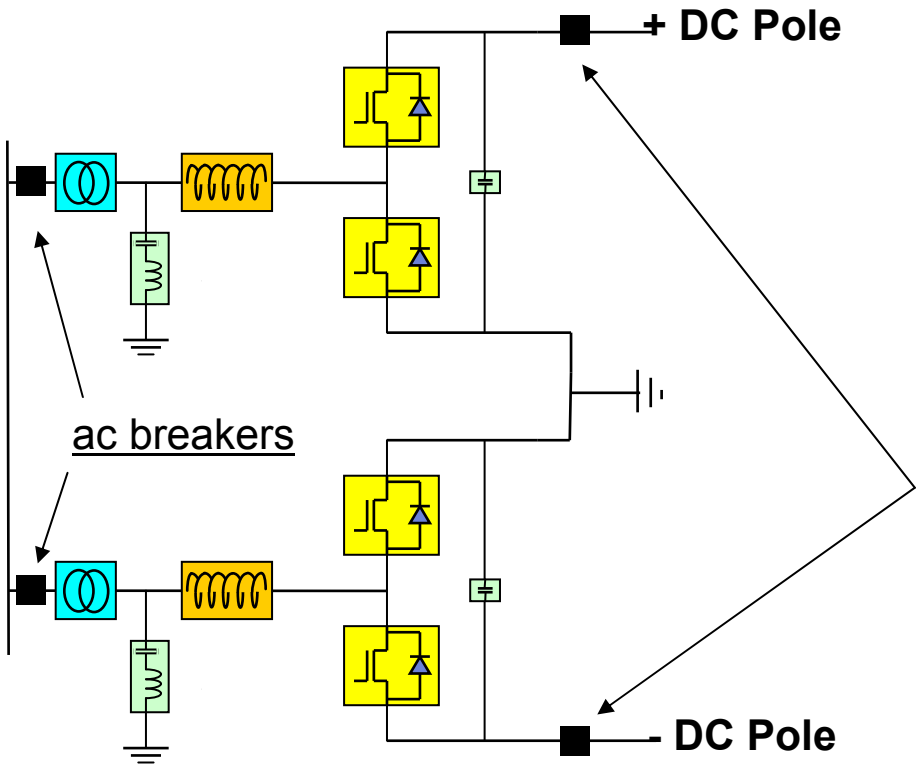


Valves

- **Commutation between valves in same phase**
- **Reverse voltage capability only**
- **Conducts current in both directions**

VSC converter with IGBTs and PWM

VSCs in bipolar configuration



When using OH Line

DC breakers must be installed in both ends.

At DC line fault the following sequence must be initiated:

- Open ac breakers in both ends of faulty pole (to stop injection of fault current).
- After around 200 ms open the dc breakers in both ends.
- After around 400 ms close the ac breakers and run both converters in SVC mode
-after around 500 ms close the dc breakers and start power transmission.
-**Total about one second**

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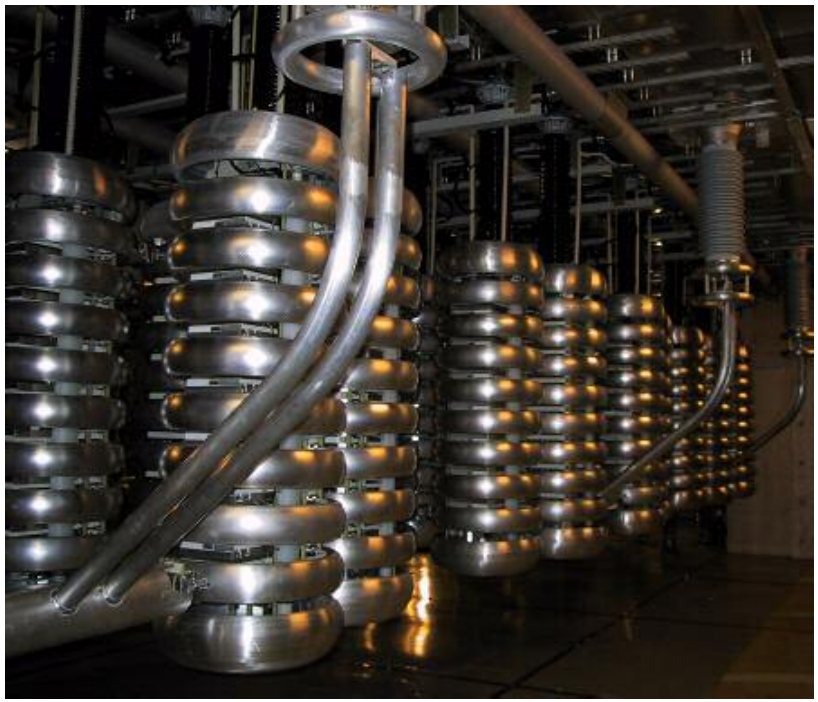
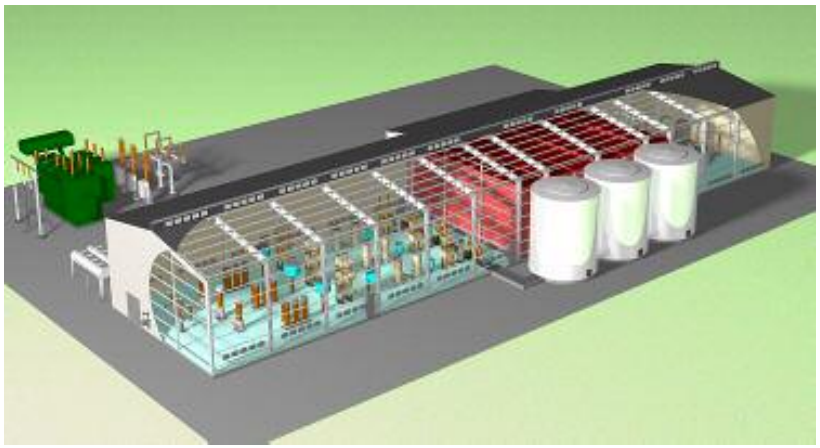
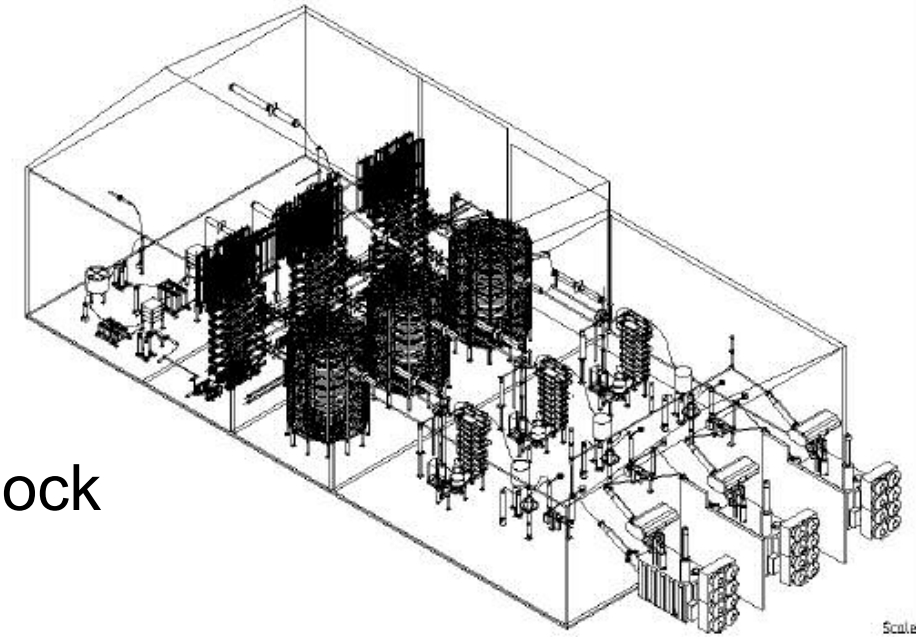
HVDC Transmission Configurations and Intermediate Stations







Converter valves in module

VSC 300MW block

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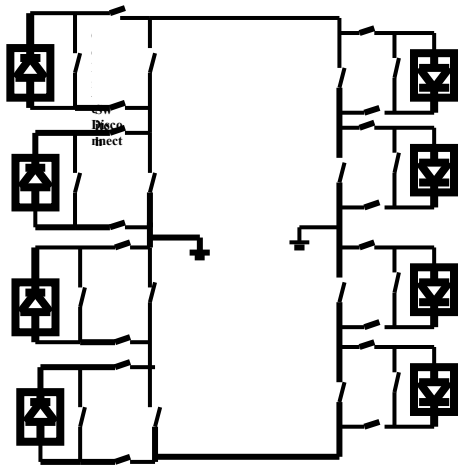
HVDC Transmission Configurations and Intermediate Stations

JWG B2.17 has at 12 converter ratings/configurations to consider:

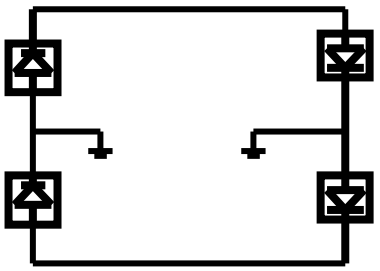
	1	2	3	4	5	6	7	8	9	10	11	12
Bipolar	750 MW	750 MW	750 MW	750 MW	1500 MW	1500 MW	3000 MW	3000 MW	3000 MW	6000 MW	6000 MW	6000 MW
Rating	± 300 kV	± 300 kV	± 300 kV	± 500 kV	± 300 kV	± 500 kV	± 500 kV	± 600 kV	± 800 kV	± 600 kV	± 800 kV	± 800 kV
conv/pole	VSC	1x6pulse	1	1	1	1	1	1	1	2 par	2 ser	2 par

Bipole	750 MW	1500 MW	3000 MW	6000 MW
750 km	± 300 kV	± 300 kV ± 500 kV	± 500 kV	
1500 km	± 300 kV ± 500 kV	± 500 kV	± 500 kV ± 600 kV ± 800 kV	± 600 kV ± 800 kV
3000 km			± 500 kV ± 600 kV ± 800 kV	± 600 kV ± 800 kV

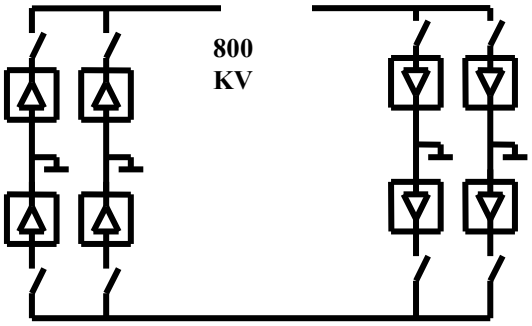
- **Many configurations for lower powers**
- **One converter per pole intermediate**
- **Series vs parallel for high powers**



Case 11



Cases 3 to 9



Cases 10 and 12

STUDY COMMITTEE B2, JWG B2-17/B4/C1

HVDC Transmission Configurations and Intermediate Stations

Tutorial of JWG-B2/B4/C1.17 on HVDC Transmission Systems – Design and Economics

Converter Configurations – John Graham, ABB Brasil

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