HVDC projects in USA

Requirements definition

What defines HVDC system requirements?
Can we copy paste HVDC systems?

SIEMENS energy

- DC voltage
- Power
- DC transmission line (Cable, OHL, Cable & OHL)
- Temperature range
- Dynamic performance
  - AC fault ride trough (AC FRT)
  - DC fault ride trough
- Ancillary services (e.g. Black Start)
- Max. single contingency / Availability
- ...

HVDC is not just about transmitting power!

In Europe and USA, the LCC systems have no advantages compared to modern VSC-HVDC systems

We know how to build HVDC systems
What are the specific network connection requirements?

HVDC Grid Systems and connected Converter Stations -
Guideline and Parameter Lists for Functional Specifications -
Part 1: Guidelines

CLC_TS_50654-1

Technical requirements for grid connection of high voltage direct current systems and direct current-connected power park modules (TCR HVDC)
English translation of VDE-AR-N 4131:2019-03

VDE - 4131

What are the requirements for network connections?
What are the requirements in USA?

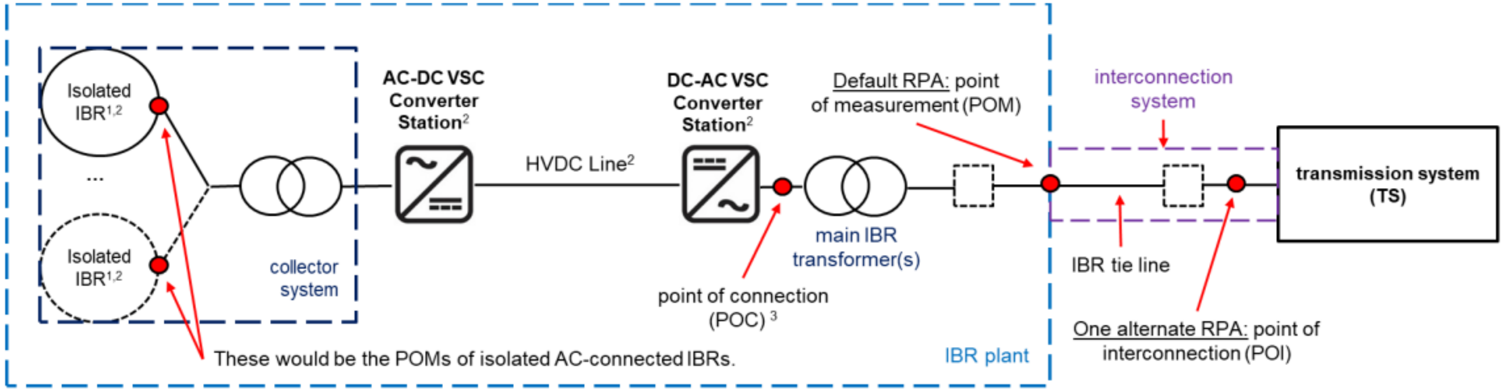
IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces
IEEE Std 1547 - 2018

PRC-024-3 —Frequency and Voltage Protection Settings for Generating Resources

- General standards do not include any HVDC specific requirements
- General standards do not consider any HVDC specific capabilities (e.g. ancillary services)

What are HVDC specific requirements?
IEEE 2800

IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems



[1] Includes IBR units like type IV wind turbine generators

[2] May serve as a supplemental IBR device that is necessary for the IBR plant with VSC-HVDC to meet the requirements of this standard at the RPA

[3] Depending on design, the POC may be on the TS side of the main IBR transformer.

NOTE 1—This standard applies to isolated *inverter-based resources (IBRs)* interconnected via dedicated voltage source converter (VSC) high-voltage direct current (HVDC) transmission facilities.

NOTE 2—This standard is not intended to apply to voltage source converter high-voltage direct current (VSC-HVDC) connecting two ac interconnections with each other.

NOTE 3—This standard is not intended to specify requirements for VSC-HVDC that connect two buses within a meshed/networked synchronous ac system.

NOTE 4—The requirements for cases where IBR are integrated with a multi-terminal VSC HVDC transmission schemes may be specified by the *TS owner*.

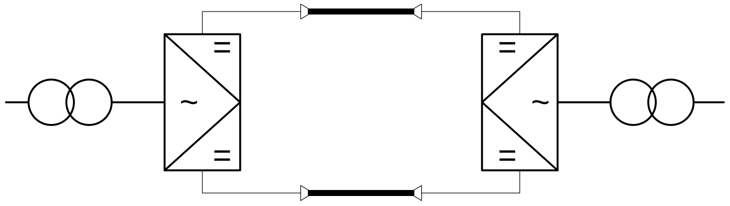
NOTE 5—The requirements for cases where IBR and non-IBR are connected via VSC-HVDC, i.e., hybrid resource facilities, may be specified by the *TS owner*.

What needs to be done?

- IEEE 2800 covers relevant aspects for HVDC design but is only applicable to offshore connections
- Grid codes from other countries cover more aspects such as Grid Forming (operating in weak networks)
- Grid Code brings more security to the developers and HVDC suppliers

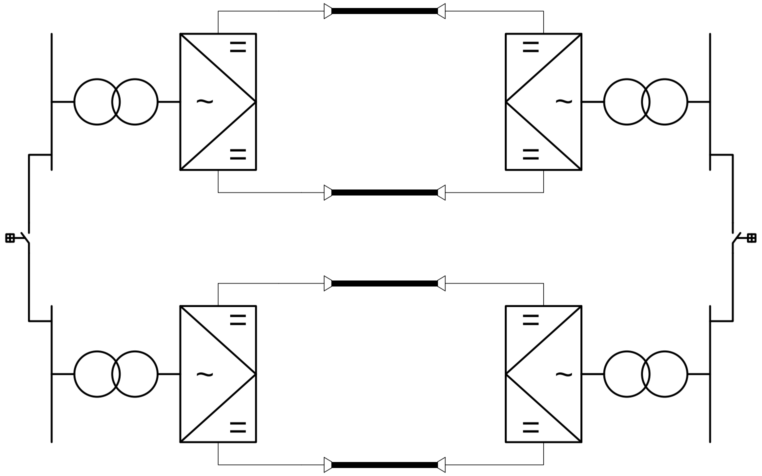
Steady state requirements are not sufficient to fully define the HVDC system

DC circuit topologies
Symmetrical Monopole (SMP)



Symmetrical Monopole

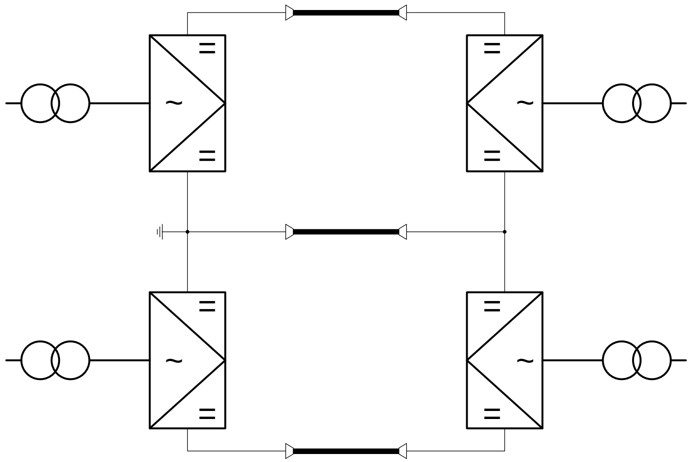
Projects in USA:
- Trans Bay Cable
- Sunrise Wind
- *Offshore connections*



Dual Symmetrical Monopole

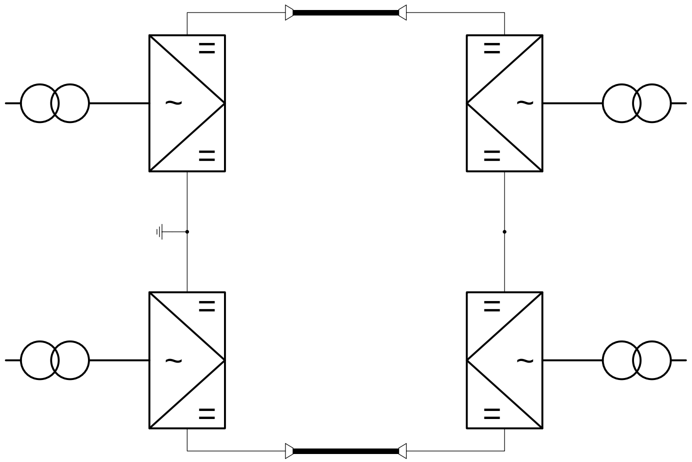
Projects:
- INELFE
- PK2000

DC circuit topologies
Bipole (BIP)



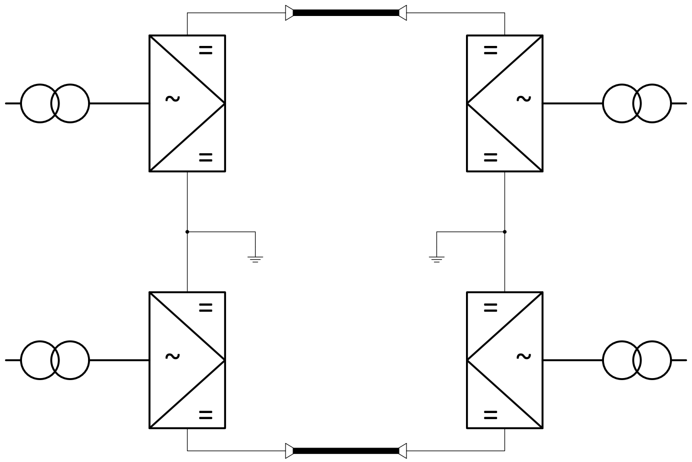
Bipole with
Dedicated Metallic Return

Projects in USA:
- Grain Belt Express



Rigid Bipole

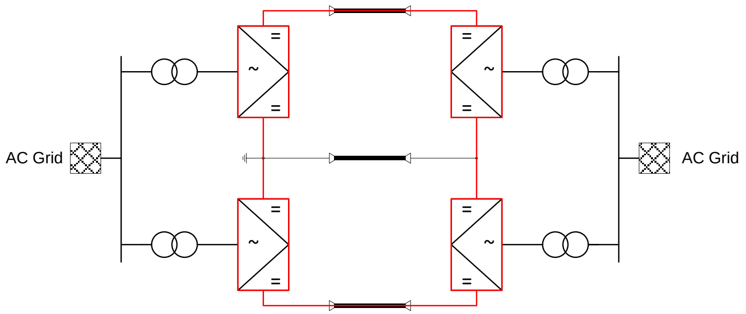
Projects in USA:
- SOO Green



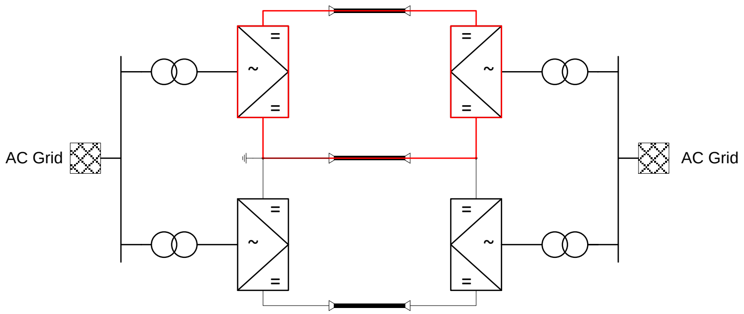
Bipole with
Earth Electrode

Projects in USA:
- Trans West Express

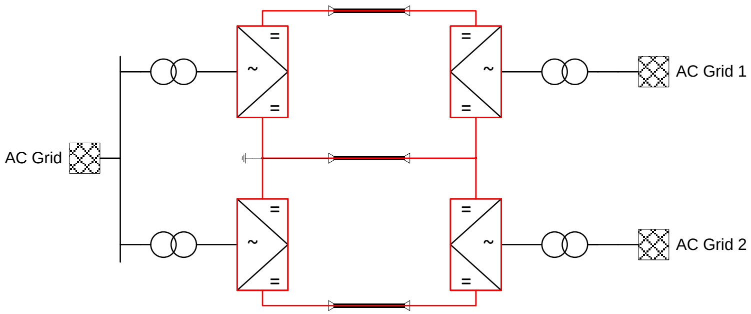
BIP Operation Modes
Why to spend money for the third conductor?



- Bipolar operation – Balanced mode
- Poles are running with at the same power
- No current is running through the DMR
- Losses optimized operation



- Monopolar operation
- Emergency mode operation
- System design relevant



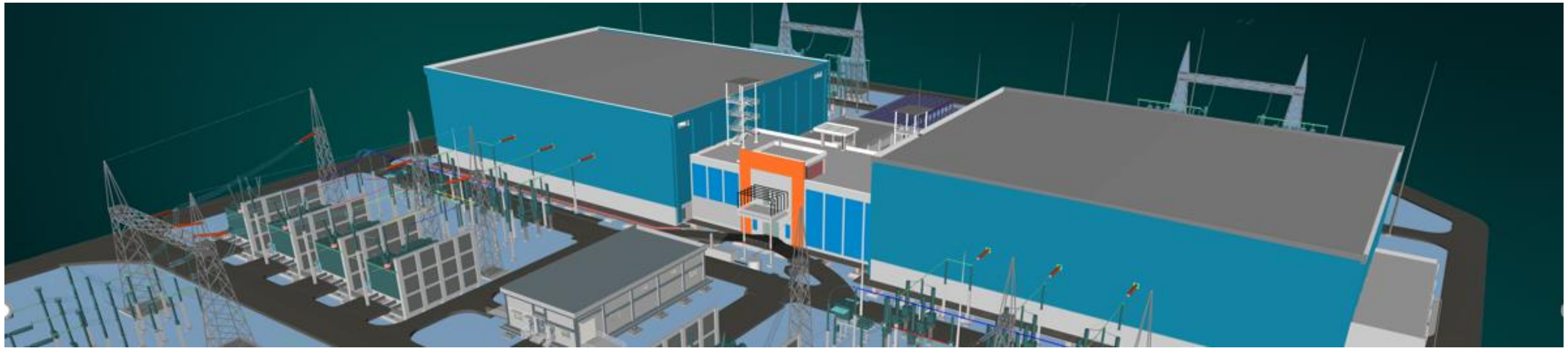
- Bipolar operation – Unbalanced mode
- Split-Busbar
- Current running through the DMR in case of different power flow in the AC Grid
- Reduced redundancy
- Not a permanent mode for earth electrode configuration

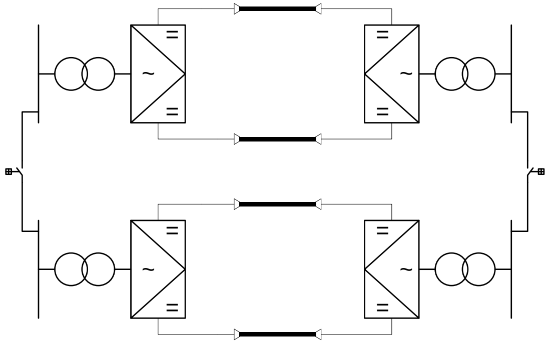
DC circuit topologies

	Symmetric Monopole Dual Symmetrical Monopole	Rigid Bipole	Bipole with Metallic Return Bipole with Earth Electrode
DC conductors	2 / 4	2	3 2 + Earth Electrode
Power transmission in case of converter fault	0 % / 50%	50 %	50 %
Power transmission in case of DC conductor fault	0 % / 50%	0 %	50 %
Economical DC voltage	≤ 400 kV	> 500 kV	> 500 kV
Max. Power	1330 MW / 2000 MW	2000 MW	3000 MW

- **Is the Bipole availability sufficient to fulfil the single contingency requirements? ISOs have different opinions ...**

India’s first DC link using VSC technology
Features combination of OHL and land cable





PK2000
India

Main data

Customer	Power Grid Corporation of India
Project Name	Pugalur – Kerala (PK2000)
Location	Pugalur (Tamil Nadu) – North Trichur (Kerala), India
Power Rating	2x 1000 MW, Symmetrical Monopole
Type of Plant	HVDC PLUS in half-bridge topology, 143 km OHL & 32 km land cable
Voltage Levels	± 320 kV DC | 400 kV AC, 50 Hz

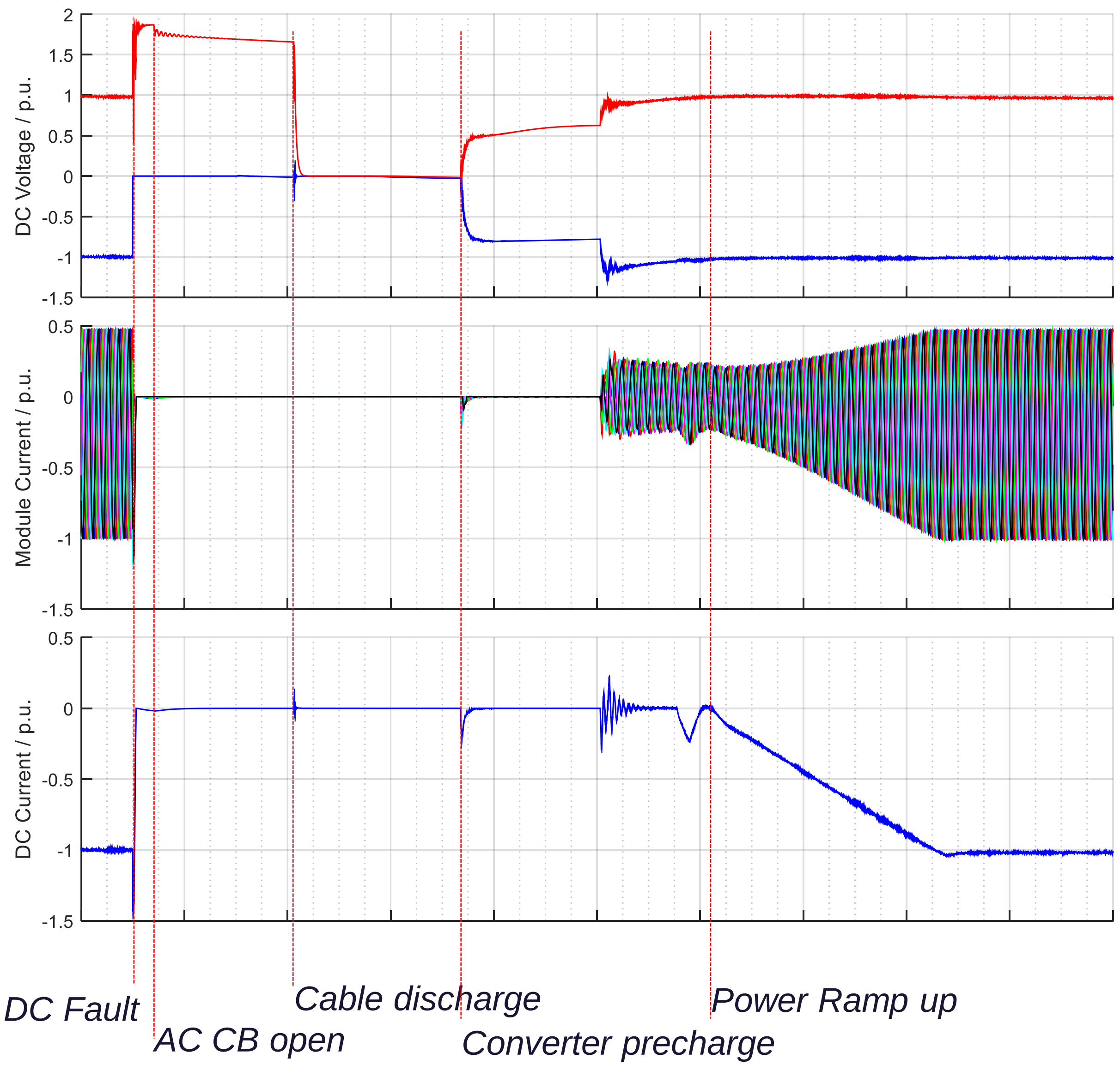
PK2000
Project has many features

- DC transmission
  - Combination of cable and OHL
  - Transition station between cable and OHL
  - Selective recovery depending on the fault location

- Pugalur station has a VSC and LCC converter from different suppliers

- DC FRT
  - One of the key requirements in the system design
  - The guaranteed performance was fulfilled
  - Practical implementation is the challenge

DC Fault handling – SMP Half Bridge



DC Fault handling – Half Bridge