Substation Engineering

HVDC Substations (Part 3)

Milav Dabgar

HVDC Substations (Part 3)

- High Voltage Direct Current (HVDC) Substations
- Part 3 of 3: System Configurations and Topologies
- Course: Substation Engineering (DI04009011)

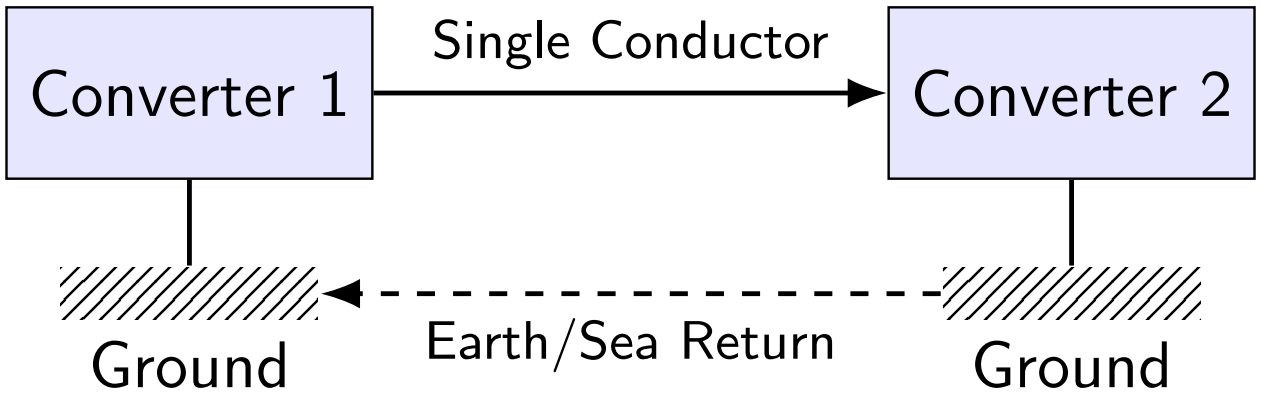
Agenda

- Introduction to HVDC Link Topologies
- Monopolar Links (Ground and Metallic Return)
- Bipolar Links and Redundancy
- Homopolar Links (Brief Overview)
- Back-to-Back HVDC Systems
- Multi-Terminal HVDC (MTDC) Networks
- HVDC Grids of the Future
- Summary and Q&A

Why Different Configurations?

- Cost considerations: Number of conductors drastically affects line cost.
- Reliability requirements: Ability to transmit partial power if one line or converter fails.
- Environmental limits: Restrictions on ground currents in certain areas.
- Application type: Submarine cable vs. overhead line vs. asynchronous connection.

Monopolar Link: Ground Return

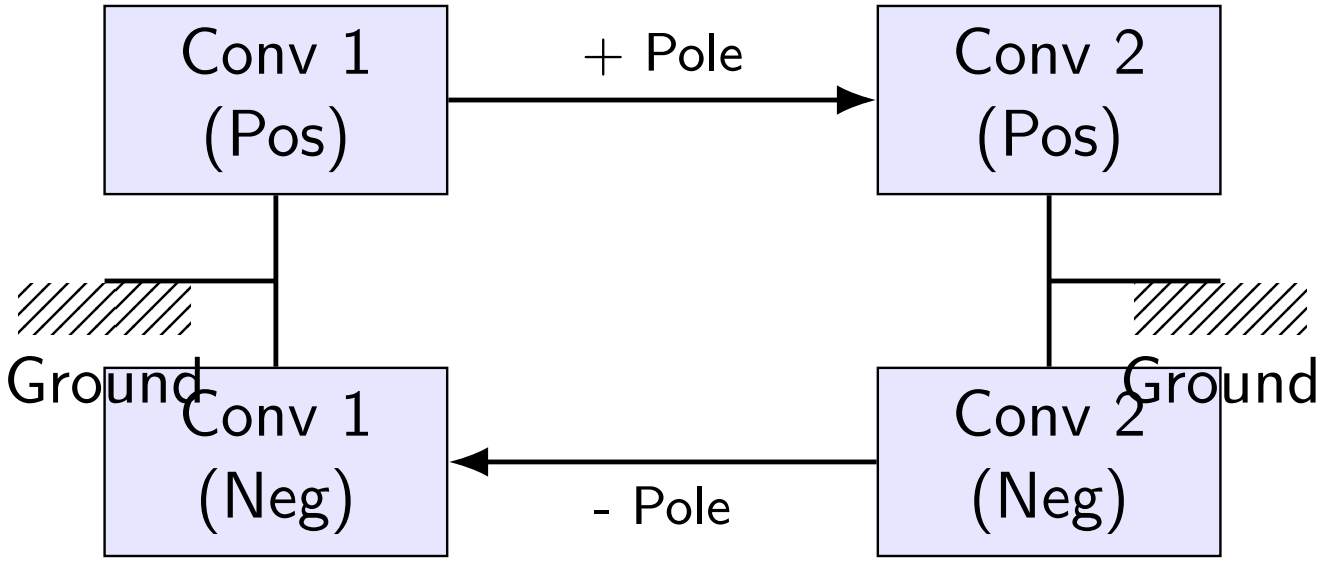


- Single high-voltage conductor (typically negative polarity to reduce corona).
- Return path is through the Earth or sea.
- Requires large ground electrodes at both converter stations.

Monopolar Link: Metallic Return

- Single high-voltage conductor for the forward path.
- A low-voltage metallic conductor is used for the return path.
- No current flows through the earth.
- Advantage: Solves environmental and corrosion issues of ground return.
- Disadvantage: Increased cost due to the second conductor, higher losses.

Bipolar Link



- Most common configuration for overhead HVDC transmission.
- Two high-voltage conductors: One positive pole, one negative pole.
- The midpoint of the converters at both ends is grounded.

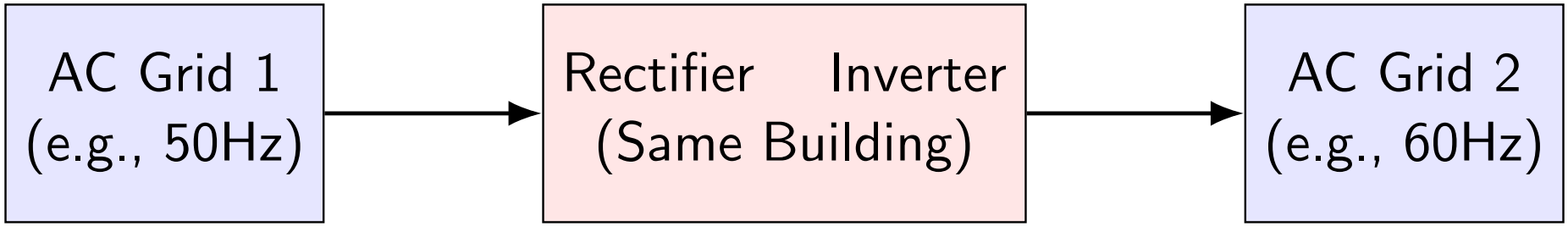
Advantages of a Bipolar Link

- High Reliability: If one pole (conductor or converter) fails, the other can continue operating.
- In case of a pole failure, the system temporarily operates as a monopolar link with ground return (if permitted).
- Provides double the power capacity of a monopolar link.
- Zero continuous ground current during normal, balanced operation.

Homopolar Link

- Rarely used in modern applications.
- Two or more conductors having the same polarity (usually negative to minimize corona).
- Return path is always through the ground or a metallic return.
- If one conductor faults, the converter equipment can be switched to the healthy conductor.

Back-to-Back HVDC System



- Rectifier and Inverter are located in the same substation.
- No DC transmission line is used.
- Connects two asynchronous AC grids or grids at different frequencies.
- Allows precise control of power flow between regions without synchronization issues.

Comparison of Topologies

Topology	Cost	Reliability	Ground Current	Main Application
Monopolar (Ground)	Lowest	Low	Continuous	Early subsea cables
Monopolar (Metallic)	Medium	Low	Zero	Environmentally sensitive subsea
Bipolar	High	High	Zero (Normal)	Long distance overhead
Back-to-Back	N/A	High	Zero	Asynchronous grid ties

Multi-Terminal HVDC (MTDC)

- More than two converter stations connected to the same DC network.
- Can be Series connected or Parallel connected (Parallel is more common).
- Highly complex control systems required to coordinate power flow between multiple terminals.
- VSC technology makes MTDC much more feasible than classic LCC.

Challenges of MTDC and DC Grids

- DC Circuit Breakers: Interrupting DC current is extremely difficult because there is no natural 'zero crossing' like in AC.
- Protection Coordination: Faults on a DC grid propagate very rapidly; isolation must occur in milliseconds.
- Standardization: Currently, different manufacturers' HVDC equipment does not easily interface on the DC side.

Future Trend: The Supergrid

- Concept of a wide-area DC grid overlaying the existing AC network.
- Facilitates massive integration of renewable energy (e.g., offshore wind in the North Sea to load centers inland).
- Relies entirely on advanced VSC technology and fast DC breakers.
- Increases overall continental grid stability and resilience.

Summary of HVDC Module

- HVDC is critical for long-distance, bulk power, and subsea transmission.
- LCC provides brute power; VSC provides flexibility and control.
- Bipolar configurations offer the best mix of reliability and power capacity for overhead lines.
- Multi-terminal DC grids represent the future of renewable energy integration.

Next Lecture Preview

- Introduction to Substation Automation Basics.
- Evolution of control systems in substations.
- Introduction to SCADA (Supervisory Control and Data Acquisition).
- The shift from hardwired relay logic to microprocessor-based IEDs.