

Substation Engineering

HVDC Substations (Part 1)

Milav Dabgar

HVDC Substations (Part 1)

- High Voltage Direct Current (HVDC) Substations
- Part 1 of 3: Introduction and Fundamentals
- Course: Substation Engineering (DI04009011)

Agenda

- Historical Background of DC Transmission
- HVAC vs. HVDC Transmission
- Advantages of HVDC
- Basic HVDC System Configuration
- What is an HVDC Converter Station?
- Main Components of an HVDC Substation
- Applications of HVDC
- Summary and Q&A

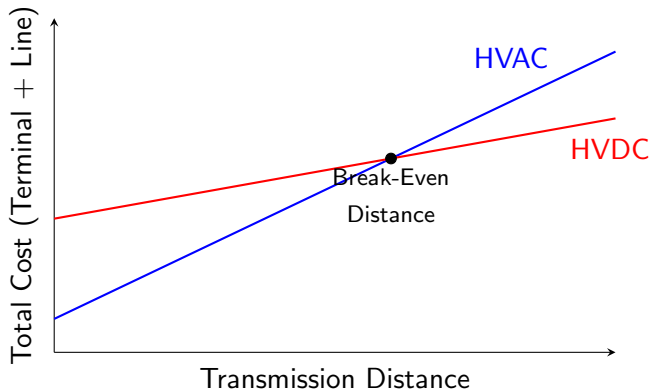
The War of the Currents

- Late 19th Century: Edison championed DC, while Tesla/Westinghouse championed AC.
- AC won for general transmission due to the invention of the transformer (easy voltage stepping).
- DC transmission was limited by the inability to efficiently step up/step down voltages.
- 1950s: Development of high-voltage mercury-arc valves made HVDC viable.
- Modern Era: Thyristors and IGBTs revolutionized HVDC transmission.

HVAC vs. HVDC Transmission

Parameter	HVAC	HVDC
Number of Conductors	3 (3-phase)	2 (Bipolar) or 1 (Monopolar)
Skin Effect	Present	Absent (full cross-section utilized)
Reactive Power	Requires compensation	None (no charging current)
Right of Way (RoW)	Wider	Narrower
Terminal Station Cost	Lower	Significantly Higher

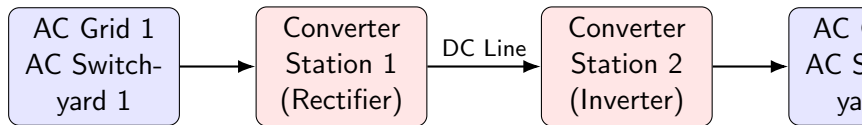
Break-Even Distance



Technical Advantages of HVDC

- No asynchronous issues: Can connect two AC grids operating at different frequencies (e.g., 50Hz and 60Hz).
- Power flow control: Precise and rapid control of active power flow.
- No stability limits: Distance is not limited by stability considerations.
- Lower line losses: No reactive power flow means lower I^2R losses.
- Less corona loss and radio interference compared to HVAC.

Basic HVDC System Architecture



What is an HVDC Converter Station?

- A specialized substation that converts alternating current (AC) to direct current (DC) or vice versa.
- Acts as the interface between the AC grid and the DC transmission line.
- Can operate in either rectifier mode (AC to DC) or inverter mode (DC to AC).
- Contains massive power electronic valves, transformers, and filters.

Main Components of an HVDC Substation

- AC Switchyard: Connects to the AC network.
- Converter Transformers: Step voltage and provide galvanic isolation.
- Valve Hall: Houses the thyristor or IGBT valves for conversion.
- AC Filters: Filter out harmonics generated by the conversion process.
- DC Filters: Smooth the DC voltage output.
- Smoothing Reactor: Reduces ripple in the DC current.

The Valve Hall

- The most critical and sensitive area of the HVDC substation.
- A large, electromagnetically shielded building.
- Contains the thyristor or IGBT valve structures.
- Requires strict climate control and air purification to prevent flashovers.
- Cooling systems (usually deionized water) remove heat generated by the valves.

HVDC Applications: Long Distance Bulk Power

- Transmitting massive amounts of power from remote generation to load centers.
- Example: Hydropower from remote mountains to distant cities.
- Lower transmission losses and narrower right-of-way make it ideal.
- Ultra-High Voltage DC (UHVDC) links operate at 800 kV or even 1100 kV.

HVDC Applications: Submarine Cables

- AC cables have high capacitance, leading to large charging currents.
- Beyond roughly 50-80 km, an AC submarine cable would carry mostly charging current, leaving no capacity for active power.
- DC cables have no continuous charging current.
- Used for offshore wind farm connections and interconnecting countries across bodies of water.

HVDC Applications: Asynchronous Interconnections

- Connecting two grids that operate at different frequencies (e.g., 50 Hz and 60 Hz in Japan).
- Connecting two grids at the same frequency but not synchronized.
- Back-to-Back HVDC Stations: Rectifier and Inverter are in the same building.
- Prevents cascading failures from spreading between grids.

Summary

- HVDC is economically viable for long-distance overhead lines and long submarine cables.
- HVDC provides superior control over active power flow and connects asynchronous grids.
- An HVDC converter station is the interface, converting AC to DC or DC to AC.
- Key components include the valve hall, converter transformers, and filters.

Next Lecture Preview

- Deep dive into HVDC Converter Station Equipment.
- Thyristor Valves vs VSC (Voltage Source Converters).
- Converter Transformers: How they differ from standard power transformers.
- Harmonic filtering and Reactive Power compensation.