# HVDC Planning Considerations for Offshore Wind Integration

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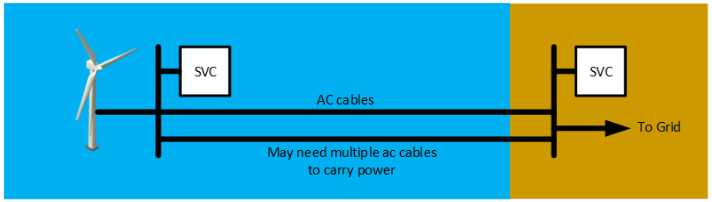
# Context of offshore wind

- Massachusetts: Target 3.2 GW offshore capacity by 2035, Martha's Vineyard 800 MW operational by 2021
- Rhode Island/Connecticut: 400 MW Revolution Wind project
- New York: 2.4 GW offshore capacity by 2030
- New Jersey: 3.5 GW offshore capacity by 2030
- Virginia: 5.5 GW of renewable energy with at least 2 GW offshore
- Ohio: Icebreaker wind 21 MW project in Lake Erie
- California: Redwood Coast Energy Authority (RCEA) submitted a lease application for 100-150 MW of floating offshore wind

**Clear need for planners to develop an understanding of the planning challenges and studies required for the integration of offshore wind**

# Connection Methods for Offshore Wind

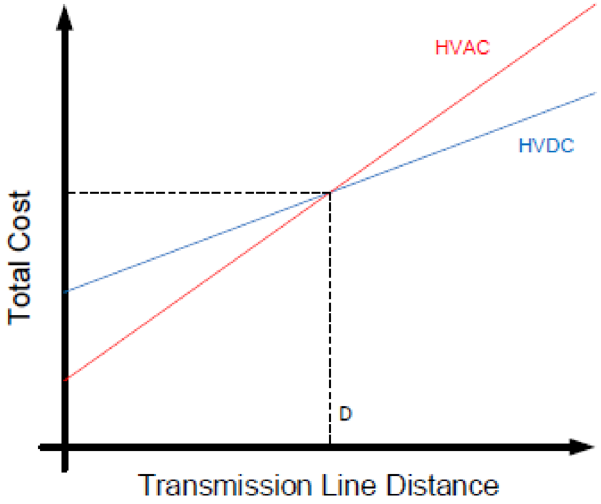
- AC Interconnection
  - Underground cable/Overhead line plus subsea cable
  - Near-shore (<30-60 miles)
  - Capacitive charging current in subsea cable limits transmission distance
  - Significant reactive compensation needs with AC cables





- HVDC Interconnection
  - Underground cable/overhead line plus subsea cable
  - Far offshore (>60 miles), HVDC converter stations required

- Other options in conceptual stage:
  - Low frequency AC transmission
  - Use of diode rectifier for offshore unit





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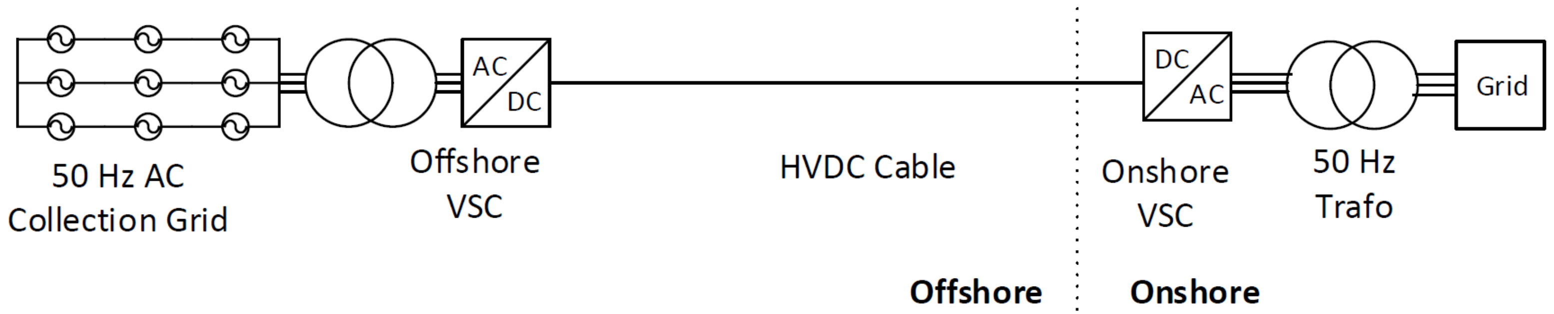
# VSC HVDC the leader for offshore HVDC

- Controllability of offshore collection network without extra equipment (SVC/STATCOM)
- Independent control of active and reactive power
- Reactive power consumption or generation can be controlled to meet the needs of the network
- Ability to connect to AC grids with low short circuit ratio
- Limited harmonics produced by the converters
- Black start capability
- More compact converter stations – particularly advantageous to offshore
- LCC requires extra equipment (STATCOM/SVC) offshore, and harmonic filtering which further increases the offshore station size

# What’s different offshore?

- Onshore station maintains DC link voltage
- Offshore station controls collection grid voltage
- Imposes system angle and frequency on AC collection network via AC voltage controller
- Grid forming – no PLL at offshore VSC
- Wind turbines synchronise to grid formed by offshore VSC station via individual PLLs



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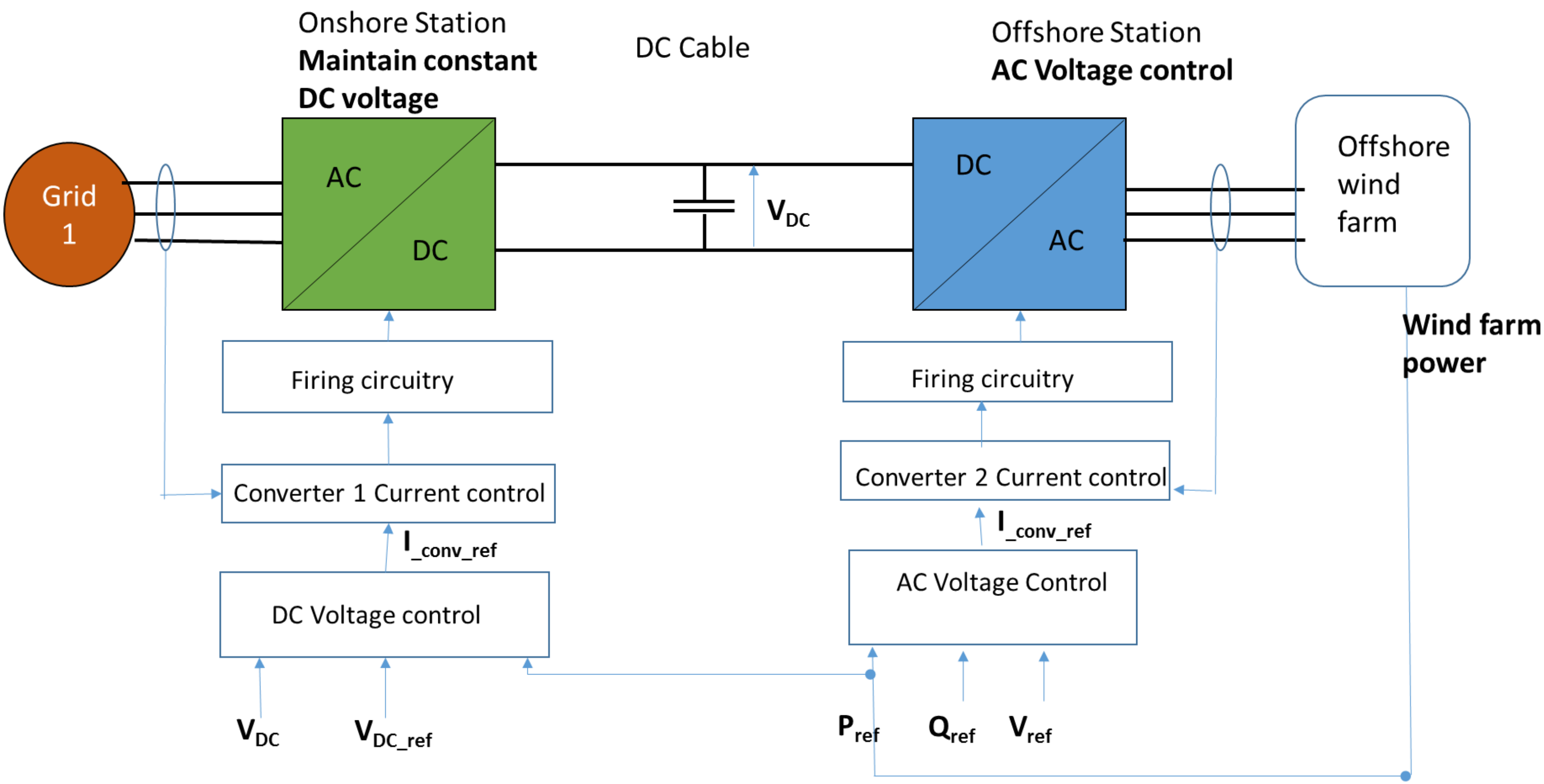
# VSC HVDC Control objectives offshore





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# Initial planning decisions: Who owns/builds what?

- Different design, build, owner and operator practices in Europe:
  - Germany: Offshore and on-shore grids built/operated by TSO
    - Coordinated network planning offshore by TSO
  - Netherlands: Wind farm developer builds offshore grid, then transfers offshore grid ownership to TSO
  - UK: Offshore transmission grid is built by wind farm developer, then transfers ownership to an offshore transmission owner (OFTO) selected by competitive tender

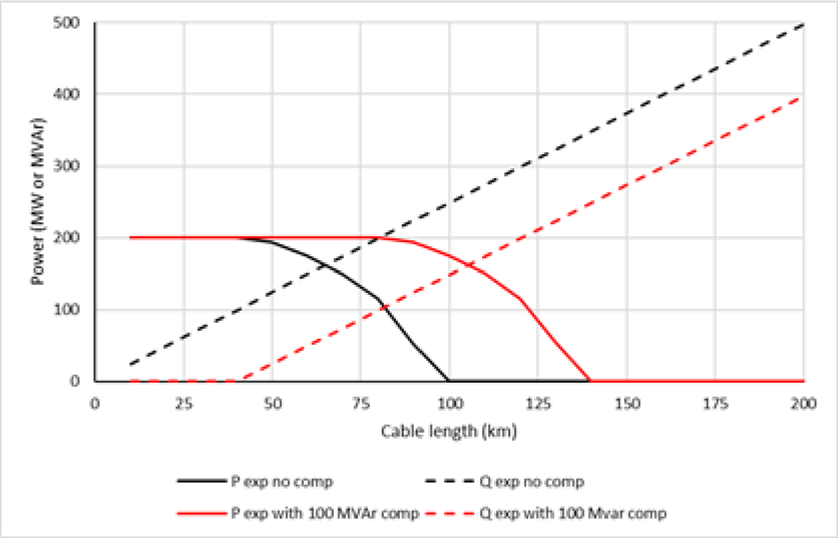
# Network planning studies of importance to utility

- Initial feasibility Studies
  - Power flow and stability analysis to assess basic feasibility
  - Reliability and availability studies
- Pre-specification Studies
  - Reactive Power Requirements and Dynamic Performance Studies
  - AC Impedance Scans for Harmonic Filter Design
  - Sub Synchronous Torsional Interaction Screening Studies
  - Control Interaction Screening Studies
- Building an AC 3-phase System Equivalent for EMTP studies
- Control system design
- Model development and verification for operational planning

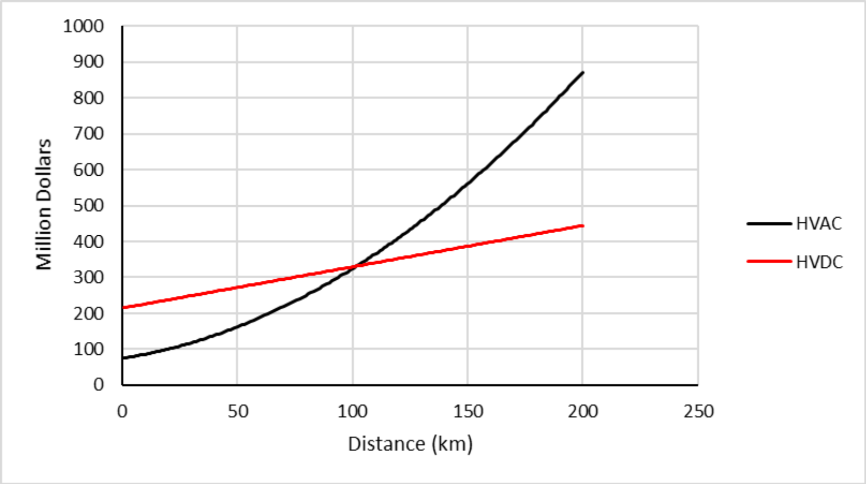
*The WECC HVDC Task Force in collaboration with EPRI have developed generic HVDC models for planning studies with HVDC available in most major vendors' software packages.*

# Sample offshore wind integration initial study

- 200 MW, 150 km (93 miles) offshore
- AC and DC options considered




**Active and reactive power exported to onshore grid for AC cable connected 200 MW offshore wind farm**

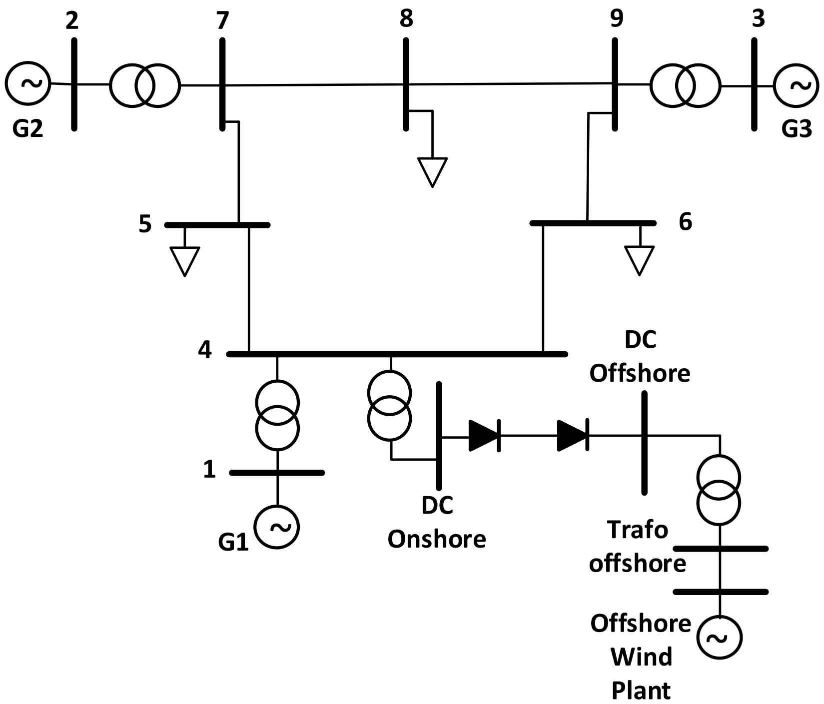



**Cost of HVAC transmission and HVDC transmission for offshore wind**

- Note that cost comparisons are based only on available cost data within literature. A detailed cost comparison should be undertaken in conjunction with developers to determine the appropriate choice of transmission option

# Determining initial reactive power requirements

- 9 bus system edited to include offshore wind connected via HVDC




| BUS | Powerflow (MW) |
|---|---|
| BUS1 | 50.0000 |
| BUS2 | 36.2703 (Slack bus on main grid) |
| BUS3 | 35.0000 |
| Wind Farm | 208.9613 (Modeled as slack bus offshore) |

| At Bus 4 | Voltage with no Q | Power from VSC | Q required to control Voltage to 1 pu |
|---|---|---|---|
| | 1.0320 | 200 | 62.8 |
| | 1.0334 | 150 | 64.9 |
| | 1.0318 | 100 | 62.8 |
| | 1.0281 | 50 | 56 |
| | 1.0221 | 0 | 44.1 |

Minimum MVA rating of converter

$$S = \sqrt{200^2 + 64.9^2} = 210.26\ MVA$$

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