U.S. DEPARTMENT OF ENERGY | OFFICE OF ELECTRICITY

High-Voltage Direct Current (HVDC) COst REduction (CORE) Initiative

Cross-cutting initiative from the Office of Electricity and the Office of Energy Efficiency and Renewable Energy

Aug. 30, 2023

Goal of the CORE Initiative

"The Department is directed to develop a high voltage direct current (HVDC) moonshot initiative to support research and development to reduce the costs of HVDC technology and long-distance transmission, including for nascent superconducting technology."

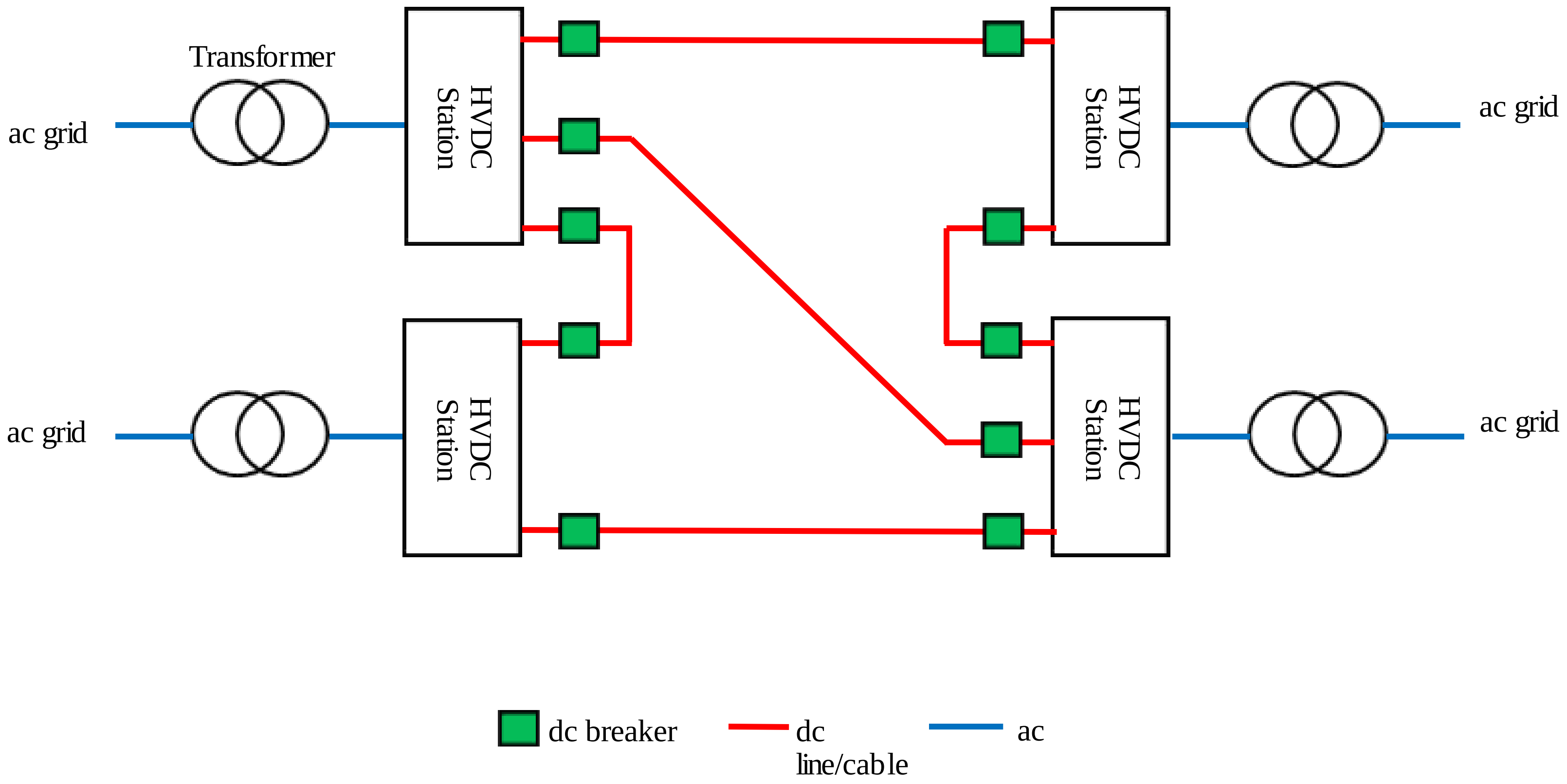
– House Report to the Consolidated Appropriations Act, 2023

Establish metrics for cost reduction of HVDC technologies and work to achieve those metrics by a given timeframe

Metric Creation Process

1. **Technology Assessment**
   - Assess current state of art of HVDC system and stations
   - Identify performance targets and metrics
   - Identify barriers in achieving these targets
   - Define role of industry, national labs, academia, and DOE
2. **Data Gathering Process**
   - Questionnaire responses from industry
   - Workshop with key stakeholders
   - Data gathering from researchers and organizations with significant HVDC technology expertise
3. **Outcome**
   - HVDC CORE goal defined for the system and converter substation

HVDC System Definitions



Schematic: An example of a multi-terminal HVDC system with different components marked

HVDC System

Factors Influencing HVDC System Cost

Underground cable:

- Cost dependent on installation method, location (urban or rural), soil, obstacles, and crossings

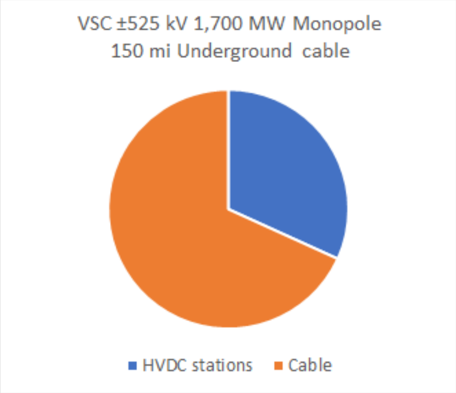
Overhead line:

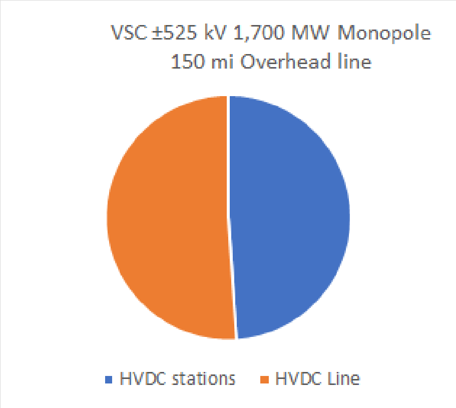
- Cost impacted by voltage level, terrain, soil conditions, and ability to handle faults

Submarine transmission:

- Cost dependent on installation method, transportation of components, housing of components, offshore soil conditions

Reliability and dc fault protection may add costs





Illustrative example

Performance Targets

1. Standardize the technology to reduce project-specific design tailoring
2. Promote interoperability of multi-vendor systems
3. Increase power density of converters & cables
4. Develop modular and standard circuit breakers
    - Multi-terminal/meshed HVDC and scalability (offshore/onshore)
    - Better ways to handle protection with overhead lines
    - Intelligent operation of substations, cables, lines, and components within the station (reduce downtime)

Barriers to Adoption/Cost Reduction

- **Lack of:**
  - HVDC standards
  - Worldwide DC grid code
  - Modeling capabilities (Inaccessibility of proprietary models)

  → System Planning

  - Robust & cost-effective DC circuit breakers
  - Confidence in the reliability and security of system operations

  → HVDC design and implementation

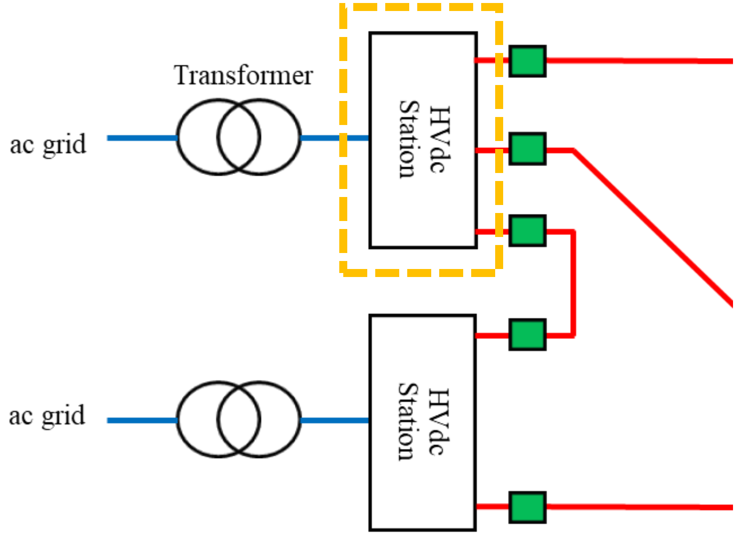
  - Well-defined revenue for ancillary services
  - Interoperability of the systems with multiple vendors and scalability of controls

  → System Operation/HVDC Integration

HVDC Converter Substation

Factors Influencing HVDC Substation Cost

1. **Voltage/Power**
2. **Topologies:** Monopole or Bipole
3. **Converter:** Half-Bridge or Full-Bridge Modules
4. **Power Electronics**
5. **Operations & Maintenance**
6. **Limited lifetime (~25 years)**



Snapshot of image displayed previously to showcase the area this section is targeting

Performance Targets and Metrics

Capital Cost:

- Reduce cost up to 35% to promote U.S. adoption of HVDC for renewables deployment

Lifetime:

- Increase lifetime by to 60% from 25 years to 40 years
- Increase availability by 50%

Standardization:

- Interoperability
- Flexibility/scalability
- Multi-functional substations (that integrate wind, solar, and energy storage)
- HVDC station building block

Barriers to Adoption/Cost Reduction

Lack of:

- Standard semiconductor devices for multiple applications with increased voltage/current ratings that can operate for up to 40 years
- HVDC standards
- High-voltage, hardware-in-the-loop, and efficient simulation facilities in the US
- Manufacturers of power electronics transformers (with DC current and harmonics capabilities)
- Sufficient manpower to develop HVDC technologies

Based on the results presented, DOE devised **HVDC CORE Metrics** to aid in the execution of the mission.

CORE Initiative Metrics

35% by ‘35

1. **Reduce the levelized cost of energy transmitted by HVDC systems by 35% by 2035**

2. **Reduce the capital and O&M cost of the:**
   a. HVDC substation by 35% to $210 MW/kV by 2035
   b. HVDC system with overhead lines by 35% to $1000 MW/mi by 2035
   c. HVDC system with cables by 35% to $4000 MW/mi by 2035

*Cost reduction targets were extrapolated from the average system and substation costs provided to DOE by the industry via the questionnaire and workshop referenced previously

Roles of DOE, National Labs, Academia, & Industry

DOE:

- Fund early-stage risky research & demonstrations
- Coordinate multiple stakeholders

National Lab:

- Provide facilities (HIL labs, simulation labs, high-voltage labs, etc.)
- Disseminate research knowledge and expertise
- Coordinate multiple stakeholders

Academia:

- Training
- Education
- Research

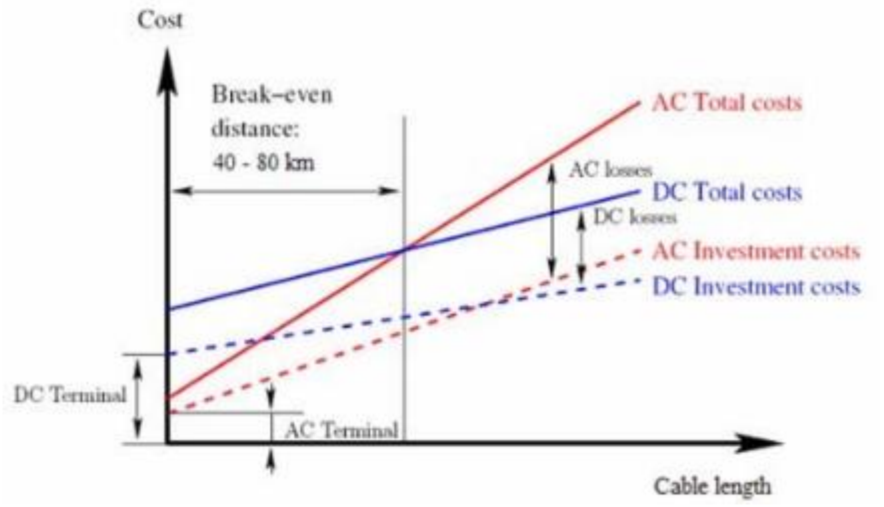
Industry:

- Demonstration
- Domestic production
- Advise on direction of initiative

Impact of the HVDC CORE Initiative

Adoption of HVDC Technology can lead to increased:

- Resiliency and security of the system through the interconnection of multiple regions
- Reliability of operation across regions through reserve sharing
- Penetration of renewables such as wind & solar
- Access to cheaper power
    - e.g., reduced cost to integrate using dc compared ac as shown in the figure



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Appendix A

- The initiative is based on stakeholder input collected and summarized by the following entities and as presented at the stakeholder workshop on May 10, 2023 in conjunction with a larger effort to develop an HVDC Technology Roadmap
  - Oak Ridge National Laboratory
  - National Renewable Energy Laboratory
  - Pacific Northwest National Laboratory
  - Electric Power Research Institute
- The roadmap aims to provide a pathway to wide-spread adoption of HVDC technology to aid in the deployment of renewable energy resources and achieve the administrations net zero carbon emissions goals
- December 2023 is the tentative release date of the roadmap