Introduction to HVDC

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What is an HVDC Transmission System?
Power Flow

HVAC

\[ P = \frac{U_1 \cdot U_2 \cdot \sin(\alpha_1 - \alpha_2)}{X} \]

(\( \alpha_1 = \alpha_2 < 30^\circ \)) to maintain transient stability

HVDC

\[ P = U_{DC} \cdot I_{DC} \]

\( 0 < I_{DC} < I_N \)

Power flow independent from system angles
And impedance of line

HVDC Classic Transmission Modes

- **Monopole, ground return**
  - 12-pulse groups
- **Monopole, metallic return**
  - 12-pulse groups
- **Monopole, midpoint grounded**
  - 6-pulse groups

**Capacity up to appr. 1500 MW**

- **Bipole**
  - 12-pulse groups

**Capacity up to appr. 3000 MW (6-7000 MW)**

- **Back to Back**

**Capacity up to appr. 1000 MW**
HVDC Classic Transmission

- Current source converters
- Line commutated thyristor valves
- Requires approx. 50% reactive compensation
- HVDC converter transformers
- Minimum short circuit capacity > 2 times converter rating

HVDC Converter Transformers

Sylmar, Los Angeles 621 MVA, 500 kV DC
Monopole Classic Converter Station

Typical measurements:
Length: 180 meters
Width: 90 meters

Another type of HVDC Classic Transmission - CCC

Location of the Commutation Capacitors

Q=0.45 p.u.  Conventional circuit

Q=0.13 p.u.  CCC circuit

The Capacitors are located between the converter transformers and thyristor valves
**HVDC Classic Transmission - CCC**

- Lower overvoltage at load rejection
- Less risk of lower order harmonics
- Fewer CB operations

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**Third type of HVDC VSC (Light/Plus) - Principles**

- Converter station 1
- Transmission System, normally Cables
- Converter station 2
HVDC VSC (Light/Plus) 330MW block

Building
90 x 18 m

HVDC VSC (Light/Plus) - Principles

IGBT Stack Assembly
HVDC - Alberta’s Choices

Alberta's choices

- Type of HVDC?
  - Classic or Light/Plus

- Ground Electrode
  - Now or defer?

- Metallic Return?
  - Now or defer?
HVDC Scheme with ground Electrodes

HVDC Ground Ring Electrodes

Dorisson Electrode (Manitoba Hydro Bipole 1 - North) Diameter – 381 m, approximate distance from the converter station – 12 km

Henday Electrode (Manitoba Hydro Bipole 2 - North) Diameter – 304 m, approximate distance from the converter station – 12 km

Dorsay Electrode (shared between Manitoba Hydro Bipole 1 and Bipole 2 - Winnipeg) – two rings, inner diameter – 254 m and outer diameter 304 m
Deferred Ground Electrodes

Deferred Neutral Return
HVDC Neutral Return Conductor

HVDC Applications in Alberta
What is Proposed

- Two high-capacity 500 kV HVDC transmission lines
  - Approx 300 - 500 km of line
- Four HVDC converter stations will be required at each hub (one at each point of source and one at each destination point)
  - Wabamun Lake area,
  - Langdon area,
  - Heartland area (northeast of Edmonton) and
  - Brooks area.
- Planned ISD of Dec. 2013

Typical Tower Line

- Bipole configuration with neutral return
- Optimized for 2000 MW
  - max. capacity of 4000 MW
- Planned operating loads

<table>
<thead>
<tr>
<th>Phase</th>
<th>Mode</th>
<th>Loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>Monopole</td>
<td>1000 MW</td>
</tr>
<tr>
<td>Stage 2</td>
<td>Bipole</td>
<td>1500 MW</td>
</tr>
<tr>
<td>Stage 3</td>
<td>Bipole</td>
<td>2000 MW</td>
</tr>
</tbody>
</table>
Converter Stations

- 4 – 3,000 MW (ultimate configuration) converter stations
  - transformers, breakers, converter valves, reactors, filters
  - 240 kV and 144 kV line terminations

Initial Converter Configuration

- Monopole configuration
- 2 - 1000 MW DC Converter Stations
Future Converter Configuration

- Bipole configuration
- Increases DC Converter Station capacity to 2000 MW Bipole
- Possible future addition of parallel valves for another 1000 MW for a 3000 MW Bipole

Why HVDC

- Provides long-term infrastructure
  - capacity can be staged as needed by increasing the terminal sizes
    - line configuration remains unchanged expandable up to 3000 MW
  - avoid having to repeatedly approach landowners and communities about building transmission
  - reinforces the backbone of the Alberta Grid
- Flow control capability of HVDC
  - allow the system to force power north during high wind generation and south during low wind;
  - prevents the existing AC system from overloading
- Provides high capacity transmission with smaller footprint relative to comparable AC options
Why is transmission development needed between the Edmonton and Calgary areas?

Reinforcement of the transmission system is needed to:

- Avoid reliability issues for consumers in southern and central Alberta;
- Improve the efficiency of the transmission system;
- Avoid congestion, which prevents the market from achieving a fully competitive outcome.
- Restore the capacity of existing inter-ties as required by the Transmission Regulation.

Source: AESO Long-term Transmission System Plan - 2009
**Current Calgary - Edmonton Infrastructure**

- Six 240 kV transmission lines in the Edmonton to Red Deer area
- Seven 240 kV lines between Red Deer and Calgary.
- Lower voltage lines (138 kV and 69 kV) also contribute
  - majority of the capacity is provided by the 240 kV lines.

**Reliability Concerns**

- Edmonton to Calgary system has not been upgraded in over 20 years.
- Increasing demand for electricity in southern and central Alberta is stressing the existing system
- Capacity will fall short of reliability requirements by 2014.

Source: AESO Long-term Transmission System Plan - 2009
**Increasing System Efficiency**

- Adding transmission capacity will reduce how often the system must operate near its limit.
- Operating the system near its limit increases line losses which are a waste of energy.
- Improving system efficiency saves money and is environmentally beneficial
  - reduces greenhouse gases and other emissions created during the production of wasted energy.

**System Congestion**

- Transmission constraints slow development of new competitive generation.
- Important that all generation developers have access to load centers
  - HVDC permits flow control from generation to demand centers
- Unconstrained transmission enables competition for generation development and ensures a competitive price for electricity.
Restoring Interties

- Existing 240 kV system between Edmonton and Calgary is insufficient to fully utilize interties
  - Interties with BC and Saskatchewan cannot be operated at full design capacity

- Expansion of the backbone of the system (500kv HVDC) will restore the interties to their full design capability.

Additional Benefits

- Provides transmission capacity to:
  - deliver future generation to market and
  - reliably meet the electricity needs of people in central and southern Alberta.

- Encourage greater development of green energy.
  - facilitate access between renewable generation zones and the market
  - transport large quantities of electricity when the wind is blowing or when high river flows occur at hydro plants.