HVDC Integration in the Alberta Transmission System

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Overview

• History of DC vs AC
• What Alberta is building
• What we need to answer around HVDC Operation
• HVDC Operational principals
• HVDC Operational studies
• Questions
The first commercial electric power transmission (developed by Thomas Edison in the late nineteenth century) used direct current.

During the initial years of electricity distribution, Edison's direct current was the standard for the United States.

Supporting Technologies/Applications DC Generators….DC Motors…. Batteries….

DC Transmission faced limitations because at that time (Voltage cannot be raised easily, which is needed to avoid using large current carrying conductors)….No DC/DC Transformer
History of HVDC
AC Transmission Dominance

• Advent of AC Technology and transformation in Europe and in USA (Westinghouse), gave AC Transmission an edge over DC.

• The “War of Currents AC vs DC” between Westinghouse and Edison…… AC (Westinghouse) wins

• As the use of electricity increased, the AC Transmission faced several major challenges:
  – Long Distance Transfer Capability Limitations e.g.: Stability Problems, Cost
  – Technical issues with Underground and Submarine cables e.g. capacitive charging
DC Transmission Milestones

- Early 1920’s: It was recognized that DC transmission could overcome the AC Transmission limitations.

- Late 1920’s: The mercury arc rectifier emerged as a potential AC/DC/AC converter technology for transmission.
  - 1954: The Mercury Arc Valve technology was used in a commercial transmission project (Gotland, Sweden).
  - 1971: Nelson River, Manitoba, HVDC is the largest mercury arc rectifiers ever built.

- At the same time: A new technology, the silicon semi-conductor thyristor, began to emerge as a viable technology for the valves of HVDC systems.
  - 1972: The first project incorporated thyristor valves was the Eel River project in New Brunswick,

- As a result of advancement of AC/DC conversion technology, DC Transmission made a comeback and is spreading !!!
Polarity of dc transmission lines is to be determined by the TFOs.

Source: AESO Edmonton to Calgary HVDC Projects Functional Specifications Rev 6, Feb 24, 2011
North South Projects Summary

• Two 1000MWs 500kV HVDC lines
  • 500kV Bi-Pole Structures with Neutral Conductor
  • ±Stage-1: Operated as Monopole (1000MW rating). ISD Dec. 2014

• West Corridor HVDC (WATL)
  – From Genesee to Langdon
  – Approximately 350km

• East Corridor HVDC (EATL)
  – From Heartland to Cassils/WB
  – Approximately 500km
  – ISD, April 2015
500 kV HVDC Transmission Line – Typical Tower Outline

- Optimized to 2000 MW; max capacity of 4000 MW
- Bi-pole with neutral return
- Overhead shield wires; OPGW
- Stage 1- monopole -1000 MW
- Stage 2- bipole – capacity to be determined through future planning
- Conductor: 4-1590 MCM ACSR per pole
Existing HVDC Facilities

• Very Limited Group of Facilities:
  – Around 140 HVDC systems worldwide
  – Of these, around 40 are Back-to-back systems
  – Only 3 manufacturers have historically provided HVDC systems, namely:
    • Siemens
    • Alstom Grid
    • ABB
• In contrast, there are 434 nuclear reactors
Overall Operational Questions

- How far can you push HVDC till the system breaks?
- Where should you set HVDC economically?
- How does HVDC effect areas / interchange?
- What may also limit HVDC?
- Can the system take the HVDC testing?
- When do you use HVDC when you restore the system?
Operating Principles

• Develop the HVDC operating Philosophy
  1. Maintain system reliability
  2. Relieve transmission congestion
  3. Optimally minimize system losses
HVDC Study Components

HVDC Design studies
- Capacity Study
- Model Check
- Genesee Islanding
- Optimize System Losses
- Additional HVDC Studies

Area Studies
- SOK
- South Area
- SOA
- KEG / Heartland
- Interchange
- Central East

Fine tuning of HVDC Operations
- Voltage and VAR
- Fault level
- RAS Operations

Commissioning Studies - EATL
Commissioning Studies - WATL

External Review - Studies
Restoration studies
Capacity Study Objective

WATL Flow (MW)

EATL Flow (MW)

- Max

+100

-100

+ Max

+100

-100

- Max

+ Max

+100

-100

- Max
Capacity Study Objective

WATL flow (MW)

EATL flow (MW)

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+100

+ Max

+100

+100

+ Max

EATL flow (MW)
Capacity Study Result – 1 of 22 Nomograms

![HVDC Flow Limits - 2014SL-1B Nomogram]
Capacity Study Result – RAS
HVDC Operational Strategy

- Operational Strategy
  - Meet Reliability
  - Unconstraint Market
  - Minimize System losses
What is Transmission Loss?

• What is the losses
  – Transmission equipment line heating
  – \( I^2R \)
    • \( I \) = current
    • \( R \) = resistive component
      – Lines
      – Transformers
Losses - Simple Example

- Transmission Line
- HVDC Losses
- Total Losses
• When you get to a more complex system … the simplicities goes away
  – Some of the individual line loss go down with increase of HVDC flow
  – Some of the individual line losses go up with and increase of HVDC flow
  – Some line loss are not effected with HVDC set point changes.
Losses with Respect to HVDC Flow

2014SL-1B
HVDC Flow Limits and System Losses

-1500 -1000 -500 0 500 1000 1500

WATL HVDC DISPATCH (MW)

EATL HVDC DISPATCH (MW)

Cat B (Normal Rating)
- Min System Loss
- Min System Loss + 5 MW
- Min System Loss + 10 MW
- Min System Loss + 15 MW
- Min System Loss + 20 MW
- Min System Loss + 25 MW
- Min System Loss + 30 MW
- Min System Loss + 35 MW
- Min System Loss + 40 MW
- Min System Loss + 45 MW
- Min System Loss + 50 MW
- Min System Loss + 55 MW
- Min System Loss + 60 MW
- Min System Loss + 65 MW
- Min System Loss + 70 MW
- Min System Loss + 75 MW
- Min System Loss + 80 MW
- Min System Loss + 85 MW
- Min System Loss + 90 MW
- Min System Loss + 95 MW
- Min System Loss + 100 MW
Calculating Systems Losses

- The HVDC dispatches can be determined by weighted sum of the line groups’ flow
- Different line groups to monitor are identified to determine optimal HVDC dispatches
- Developed a calculation for each HVDC Line
Two Line Groups for WATL Dispatch Based on:

- Transfer flow from Wabamun area to south

- Transfer to Calgary area from North

  - NOC (North of Calgary)
  - SOK (South of KEG)
Loss Study

• Final results were
  – 5 sets of weighting factors to compensate for outages
  – Monitoring status of 13 transmission elements
  – Easy to implement in real time
  – Accurate
    • Average error is 1.42 MW (0.5 %)
    • Tested using 8 wide HVDC initial flows

• Overall effort
  – Used 34 Load flow cases considering 409 system contingencies
  – Tested addition 8 HVDC set point starting points
  – Total Load flow runs…
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• Overall effort
  – Used 34 Load flow cases considering 409 system contingencies
  – Tested addition 8 HVDC set point starting points
  – Total Load flow runs…. 3,003,696… ya that’s 3 million!
Genesee Islanding

• Potential for Genesee to Island onto HVDC
  – Loss of one of the 500 KV lines causes Genesee to be connected only with a single radial connection
  – need for preparation in anticipation of the next possible contingency
  – Considered
    • Entering into the island
    • Operation of the island
    • Resynchronizing
HVDC Response with AC Fault (700 MW PREFAULT)
Proposed HVDC Controllers

- Proportional Gain (667 MW/Hz)
- Proportional plus integral control region

- FLC Deadband
- FC Deadband

- Frequency Controller
  Proportional only with or without deadband
Area Studies

• Determine the effect HVDC has on the individual areas and tie lines
Comm Studies

• Commissioning Dates
  – Aug 2014 - East Line (EATL)
  – Q1 2015 - West Line (WATL)

• Push HVDC hard to prove out the equipment
  – Can the system take it?
  – What does the Market need to be like?

• Two stages
  – Early 2013 Study
  – Just before commissioning
HVDC Fine Tuning Studies

- Voltage and Var
  - Is there VAR interaction?
  - When would you put the HVDC in Voltage responsive mode?

- Fault Levels
  - HVDC is sensitive to low fault level
  - What does the system look like to get to these levels

- RAS Operations
  - How should the operator consider the RAS and RAS blocking
Current HVDC Project Status

- On schedule.
- Managing associated outages for transmission infrastructure cut in
- All HVDC operational studies to be complete by Dec 2013
- HVDC training is underway
- Starting the development of Real time operating procedures.
- Real time tools are being built
Questions