HVDC Workshop

Organized by:

Coordinador Eléctrico Nacional

The Canadian Embassy

Presented by:

TransGrid Solutions Inc.

www.transgridsolutions.com

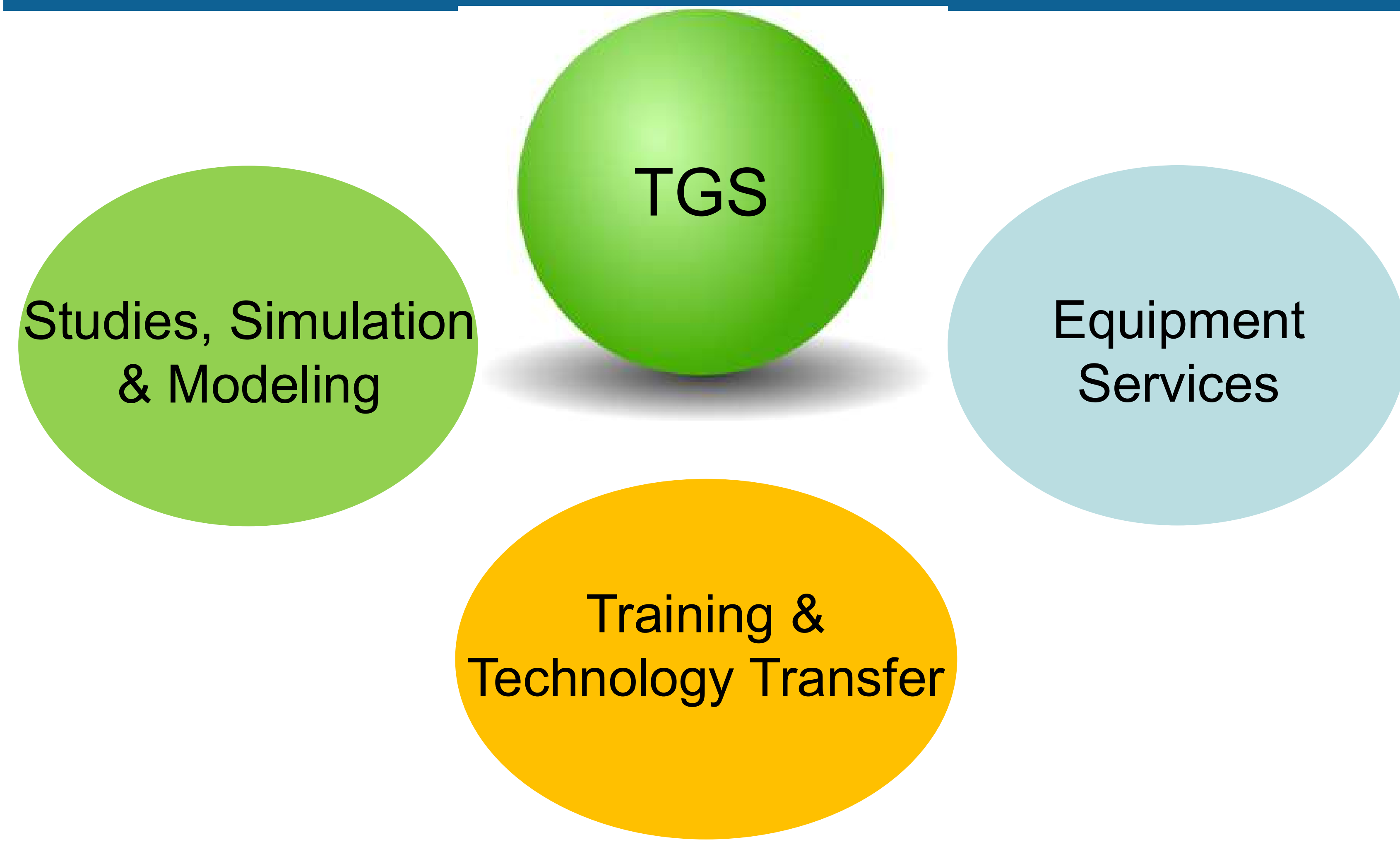
Who Are We?

- Power systems consulting company
- Years of practical **Utility, Manufacturer, Consulting, Simulation** and **Academic** experience
- Involved with IEEE and CIGRE
- Located in Winnipeg, MB, Canada

Who Are We?

- Best known for our world-renowned expertise in **HVDC/FACTS**
- Very experienced in **AC systems, Energy Storage** and **Renewable Energy Sources**

What do we do?


TGS
Studies, Simulation & Modeling
Equipment Services
Training & Technology Transfer

HVDC Experience

HVDC Link	Country	Rating (MW)	Pre-specification/Feasibility Studies	Specification Development	Tender evaluation strategy	Tender evaluation	Design review	Training	Control and Protection Design	EMT-Type Studies	Computer Model Assessment	Stability Model Studies	Witness of factory tests	Valve type testing	Reliability assessment	Loss evaluation	Commissioning	Life cycle assessments	Maintenance program development	Documentation review	Post-commissioning support	Spares assessment	Condition assessment
VSC Projects																							
Nelson River BP3	Canada	2000	√	√			√			√		√	√										
DolWin-3	Germany	900											√				√						
Nalcor VSC	Canada	900	√																				
TransBay Cable	USA	400	√	√		√				√		√		√			√				√		
Skagerrak 4 VSC	Denmark	700	√	√		√	√	√		√	√	√								√			
CobraCABLE	Denmark	700		√																			
Ultranet	Europe	3000	√						√	√	√												
ALEGrO	Europe	1000	√						√	√	√												
Maritime Link	Canada	500	√	√		√	√																
	USA					√																	
LCC Projects																							
Moyle Interconnector	UK	500					√	√		√					√		√	√	√	√	√	√	√
Lamar B2B	USA	210					√	√	√	√	√	√		√			√	√	√	√	√	√	√
Nelson River BP1	Canada	1620	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Nelson River BP2	Canada	1800	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Vizag-II	India	500								√													
East-South	India	2000						√	√	√	√		√								√		
Sasaram	India	500								√													
Basslink	Australia	600						√	√	√										√		√	√
Gui-Guang	China	3000						√	√	√					√		√				√		
Tian-Guang	China	1800						√	√	√					√						√		
TNB-EGAT	Malaysia	300						√	√	√					√						√		

HVDC Experience

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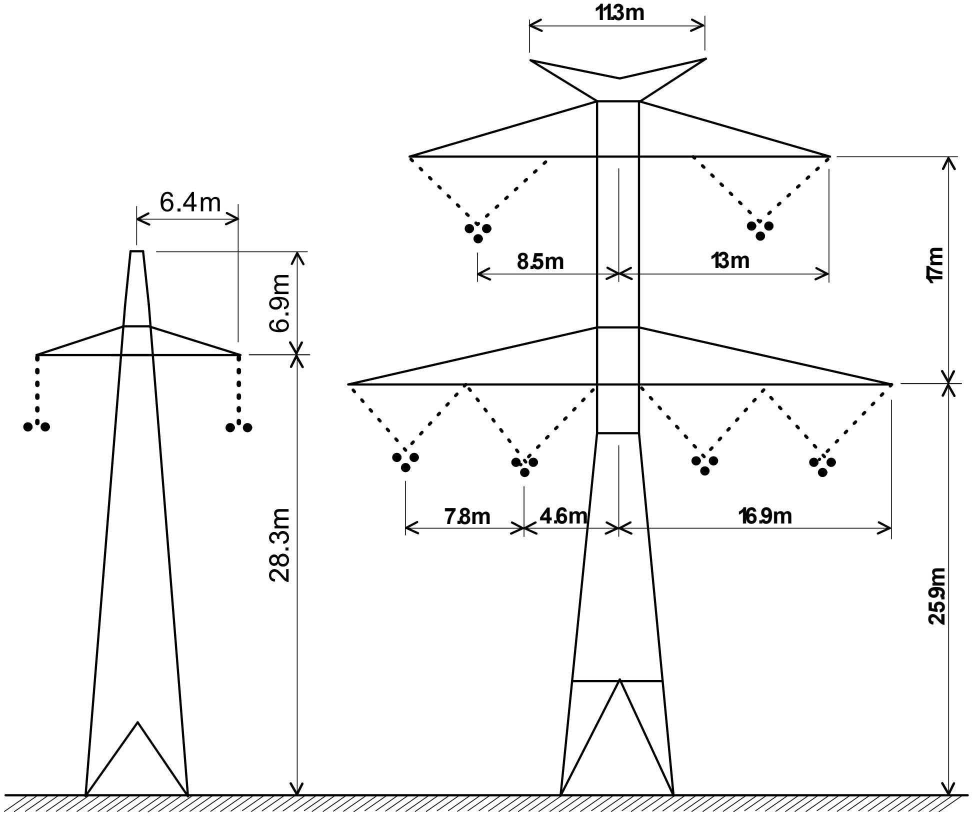
LCC Projects																							
Vancouver Island	Canada	312														√		√					
Forest Kerr	Canada	110	√					√	√														
Pacific Intertie Uprate	USA	3800	√	√	√	√	√		√	√	√	√	√										
Bakun	Indonesia	2800		√	√	√	√						√	√			√			√			
Cahora Bassa	South Africa	1920						√							√	√		√	√	√	√	√	√
Kepco HVDC #2	South Korea	300	√					√		√													
Transpower inter-island	New Zealand	1400	√	√	√	√	√	√		√	√	√	√	√			√	√	√	√		√	√
Lower Churchill	Canada	900	√				√		√	√	√	√											
PLN Java-Sumatra	Indonesia	3000	√	√				√				√								√			
Western Grid	Canada	2000	√						√	√		√											
Nelson River BP3	Canada	2000	√	√	√				√	√	√	√											
Transelec	Chile	1050	√	√				√	√			√			√	√							
Neptune	USA	600						√	√	√		√	√				√		√			√	√
Rock Island	USA	3750	√									√											
Plains & Eastern	USA	4300	√	√		√			√	√	√	√											
Champa-Kurukshetra1	India	3000					√																
Champa-Kurukshetra2	India	3000					√																
Eqypt-Saudi Arabia	Egypt, Saudi Arabia	3000			√																		
NER-Agra	India	6000					√																
Kenya-Ethiopia	Kenya, Ethiopia	2000	√	√		√																	

OUTLINE

- Advantages of HVDC
- Examples of International Applications of HVDC
- HVDC Technologies
- Typical Converter Topologies
- Development and Implementation Phases of an HVDC Project
- Tender Process

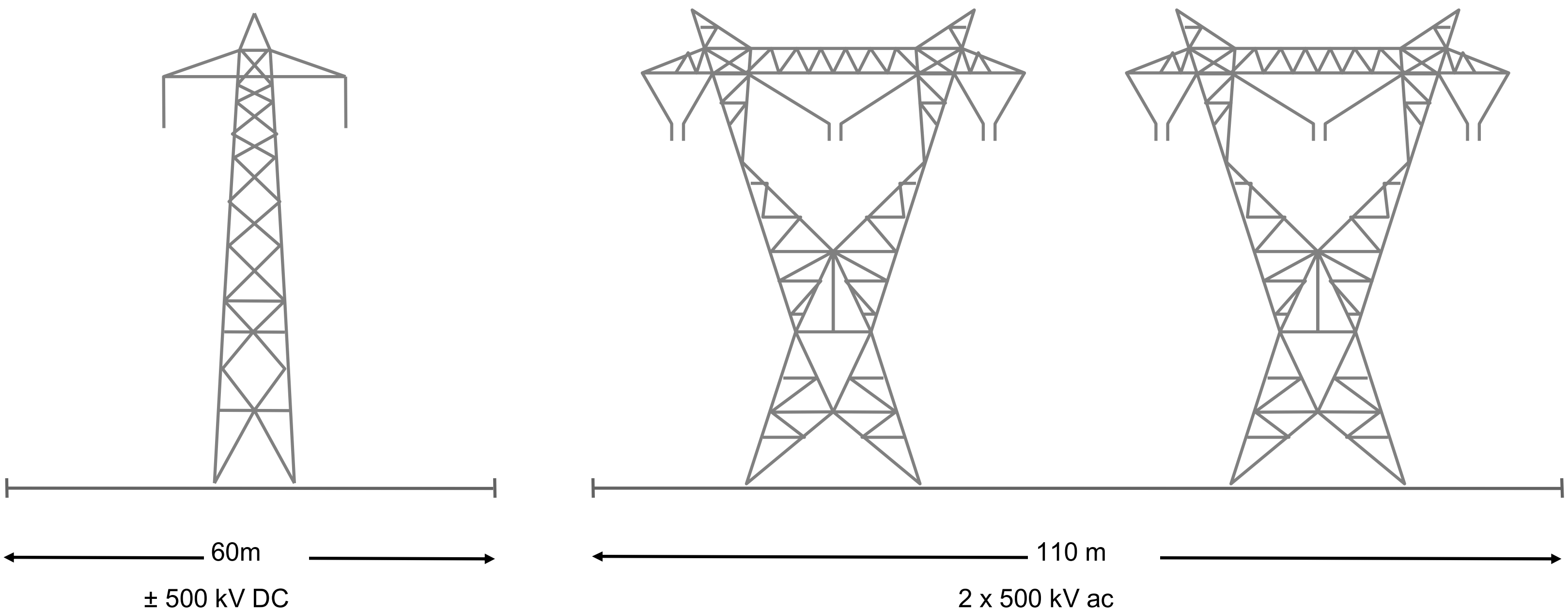
Advantages of HVDC



- HVDC towers are smaller and simpler than HVAC towers with similar transmission power rating

Sample HVDC and HVAC Tower Configurations,
+/- 500kV DC vs. double circuit 500kV AC

Advantages of HVDC

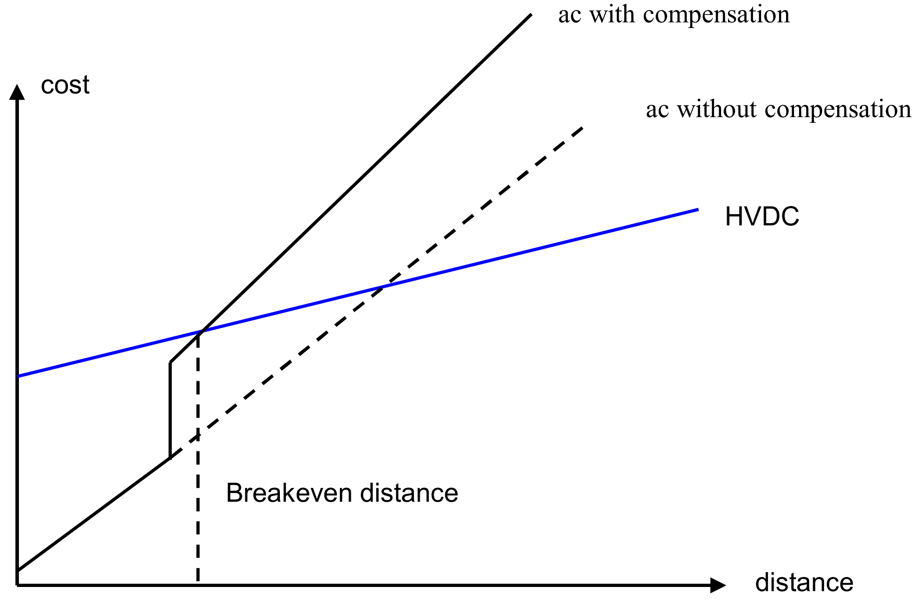


Typical transmission line right of way for 3000 MW if two ac towers are used

Advantages of HVdc

- No need for Series or Shunt Compensation
  - Long AC lines require compensation
- Controllable power flow
  - Power flow in AC line is dictated by impedance
- Zero or little contribution to short circuit current

Advantages of HVDC



Comparison of capital cost for HVDC and HVAC

Advantages of HVDC

AC cables are limited in length due to the charging current,

HVDC cables have no length limitation

Typical charging currents for land cables*

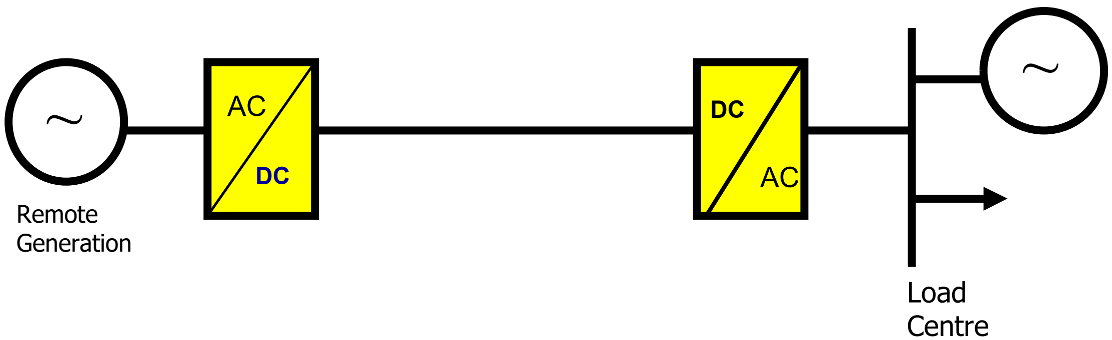
Cross section (mm^2)	Current rating (A)	Charging current (A/km)
800	870	12.3
1000	960	13.7
1200	1115	15.1
1400	1205	15.9
1600	1280	16.6
2000	1410	17.6
2500	1540	19.2

* 500kV XLPE at 65C, flat formation

Applications for HVDC

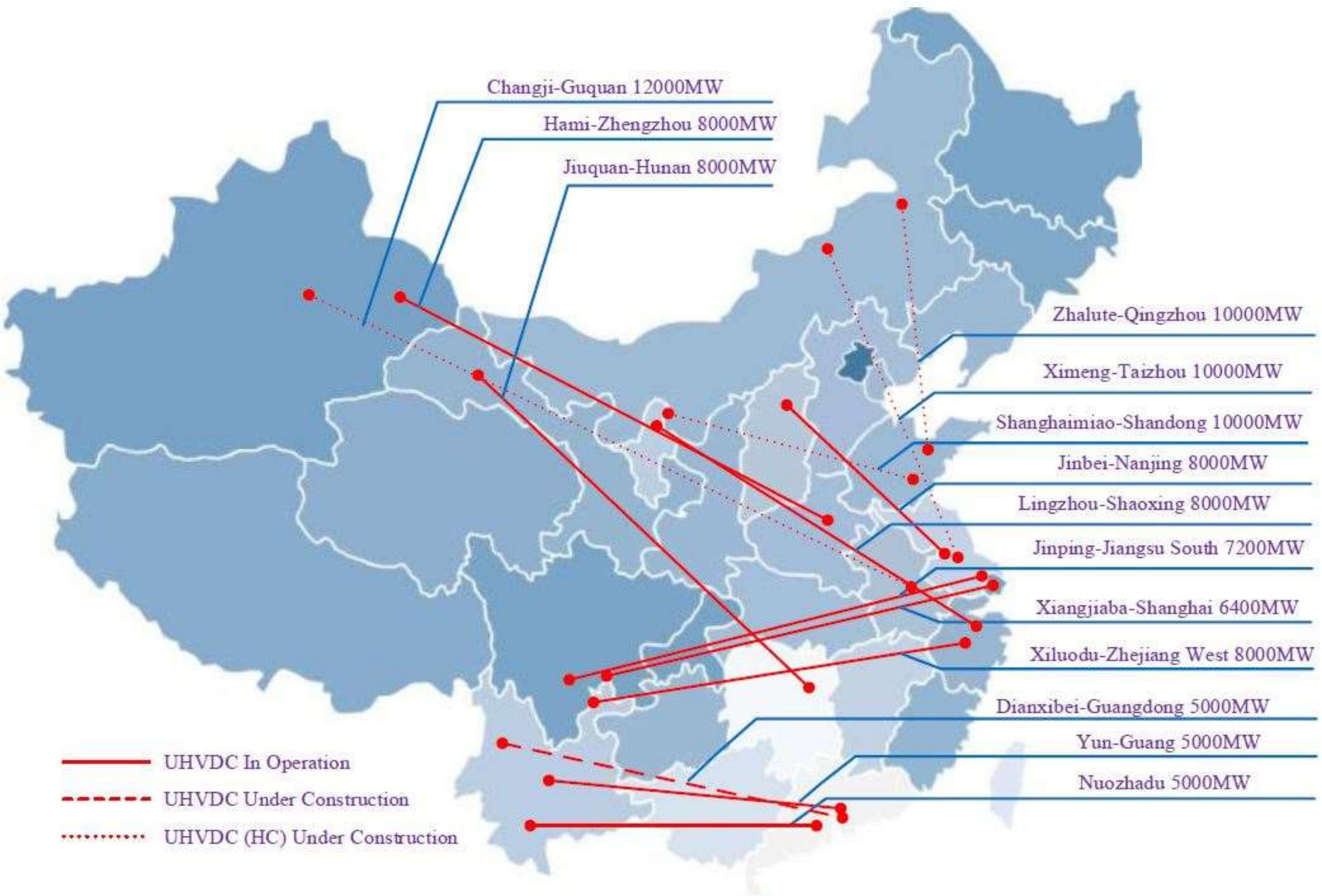
- Moving large amounts of power long distances
- Moving power by cable over moderate to long distances.
- Moving power between asynchronous systems
- Controlled power flow

Applications for HVDC



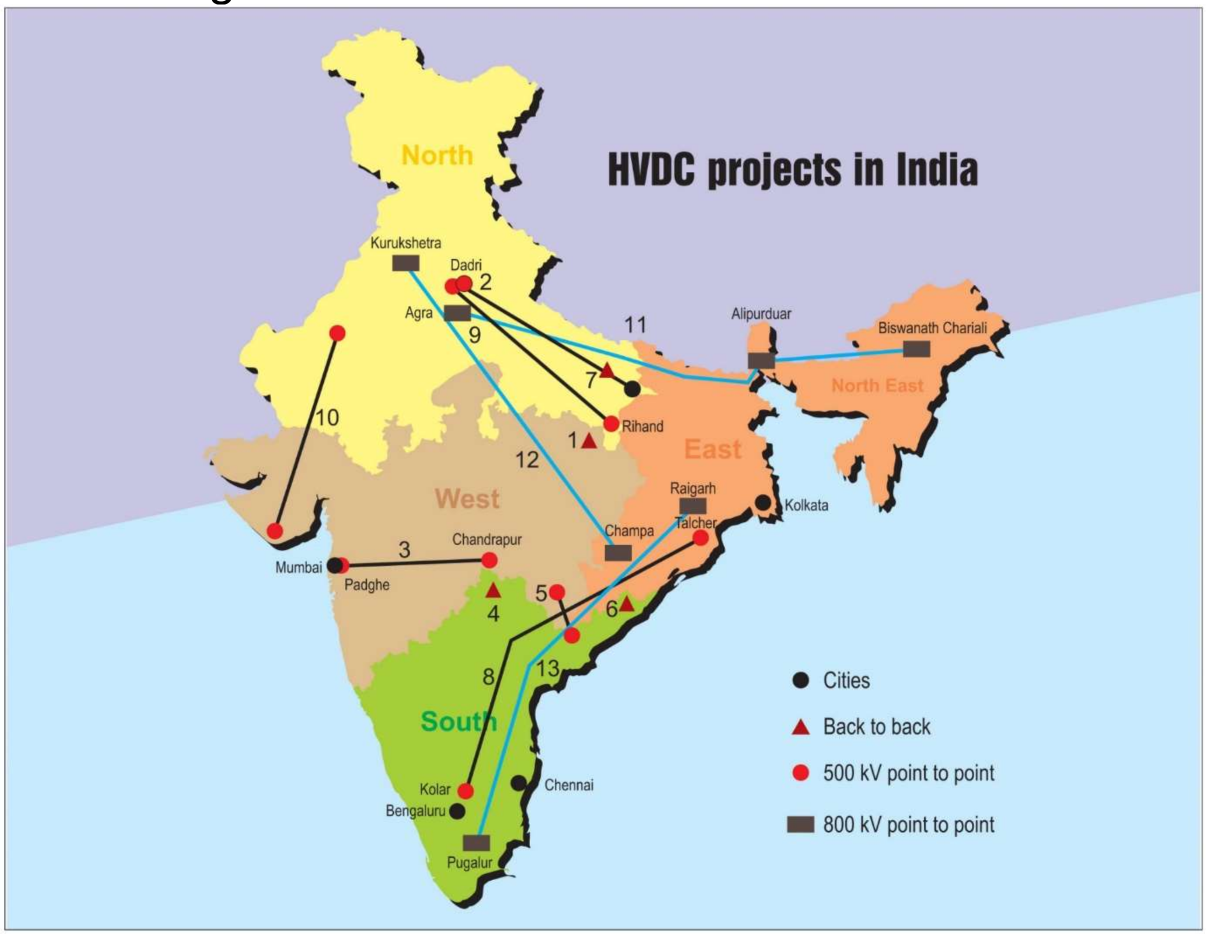
Applications for HVDC

Long Distance Transmission - China



Applications for HVDC

Long Distance Transmission - India



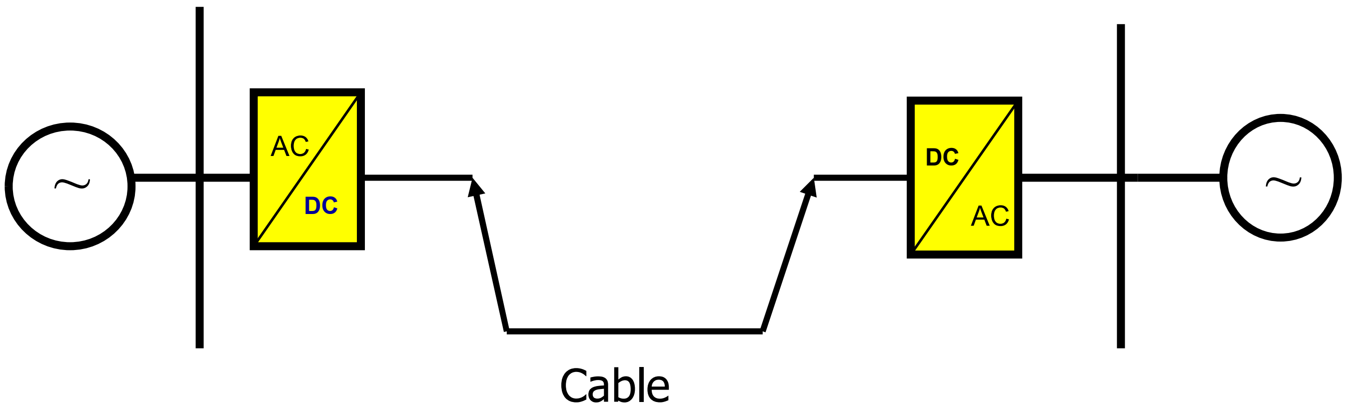
Applications for HVDC

Long Distance Transmission - North America

Name	Converter station 1	Converter station 2	Total Length (Cable/Pole) (km)	Volt (kV)	Power (MW)	Year	Type
Pacific DC Intertie	Celilo, OR	Sylmar, CA	1362 (0/1362)	±500	3100	1970	Thyr
Nelson River Bipole 1	Canada - Gillam, Manitoba	Canada - Dorsey, Manitoba	895 (0/895)	463.5	1854	1971	Thyr
Vancouver Island 2	Canada - Delta, BC	Canada - North Cowichan, BC	75 (33/42)	280	370	1977	Thyr
Square Butte	USA - Center, ND (Young)	USA - Adolph, MN (Arrowhead)	749 (0/749)	250	500	1977	Thyr
Nelson River Bipole 2	Canada - Sundance, Manitoba	Canada - Rosser, Manitoba	940 (0/940)	500	2000	1978-1985	Thyr
CU	USA - Underwood, ND (Coal Creek)	USA - Rockford, MN (Dickinson)	687 (0/687)	400	1000	1979	Thyr
Intermountain	USA - Intermountain, UT	USA - Adelanto, CA	785 (0/785)	±500	1920	1986	Thyr
Quebec - New England Transmission	Canada - Radisson, QC	Canada - Nicolet, QC USA - Ayer, MA	1105 (5/1100)	450	2250	1991	Thyr
Cross Sound Cable	USA - New Haven, CT	USA - Shoreham, Long Island, NY	40 (40/0)	150	330	2002	IGBT
Neptune Cable	USA - Long Island (Hicksville) NY	USA -Sayreville, NJ	105 (105/0)	500	660	2007	Thyr
Trans Bay Cable	USA - Pittsburg, CA	USA - San Francisco, CA	85 (85/0)	200	400	2010	IGBT
Eastern Alberta Transmission Line	Canada – Newell, AB	Canada – Heathfield, AB	485 (0/485)	500	1000	2015/2016	Thyr
Western Alberta Transmission Line	Canada – Genesee, AB	Canada – Langdon, AB	350 (0/350)	500	1000	2015	Thyr
Nelson River Bipole 3	Canada - Keewatinohk, Manitoba	Canada - Riel, Manitoba	1324 (0/1324)	500	2000	2018	Thyr
Labrador-Island Link	Canada - Muskrat Falls, NL	Canada - Soldiers Pond, NL	1135 (35/1100)	350	900	2017	Thyr
Maritime Link	Canada - Bottom Brook, NL	Canada - Woodbine, NS	360 (170/190)	200	500	2017	IGBT

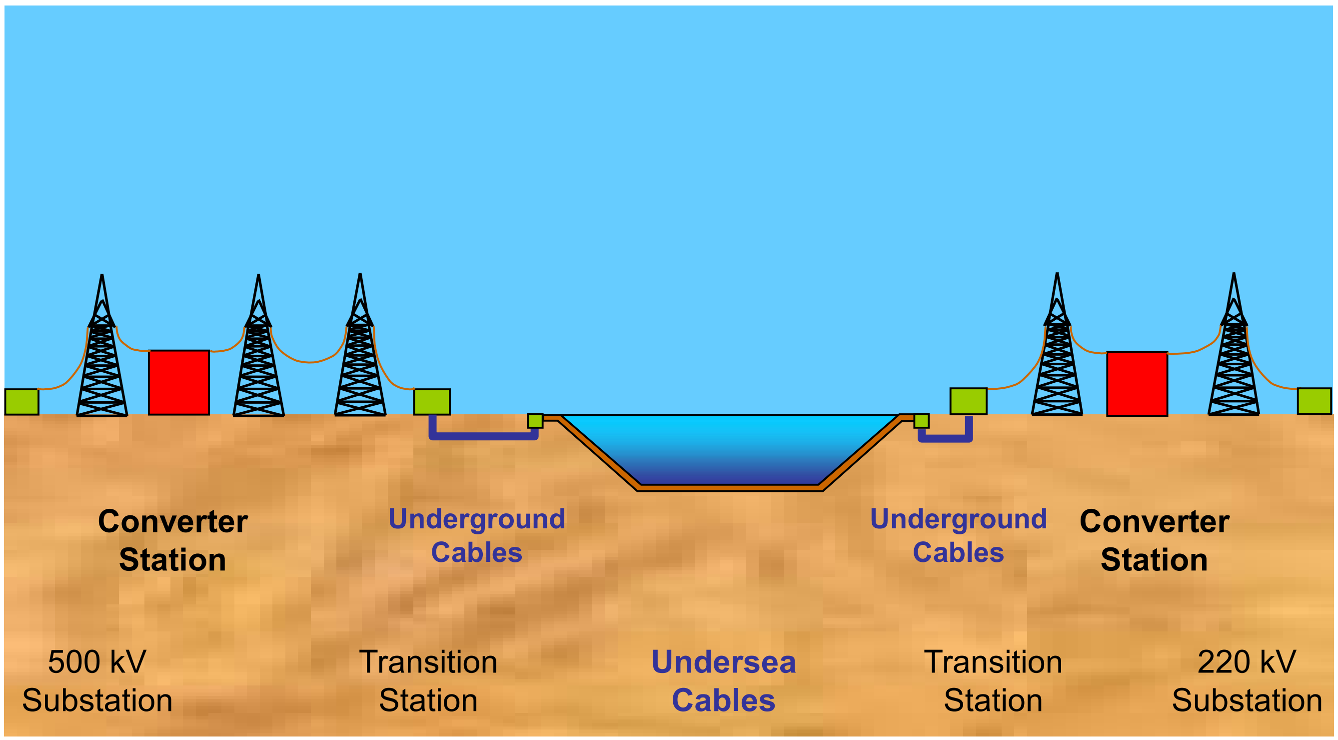
Applications for HVDC

Submarine Cable Transmission



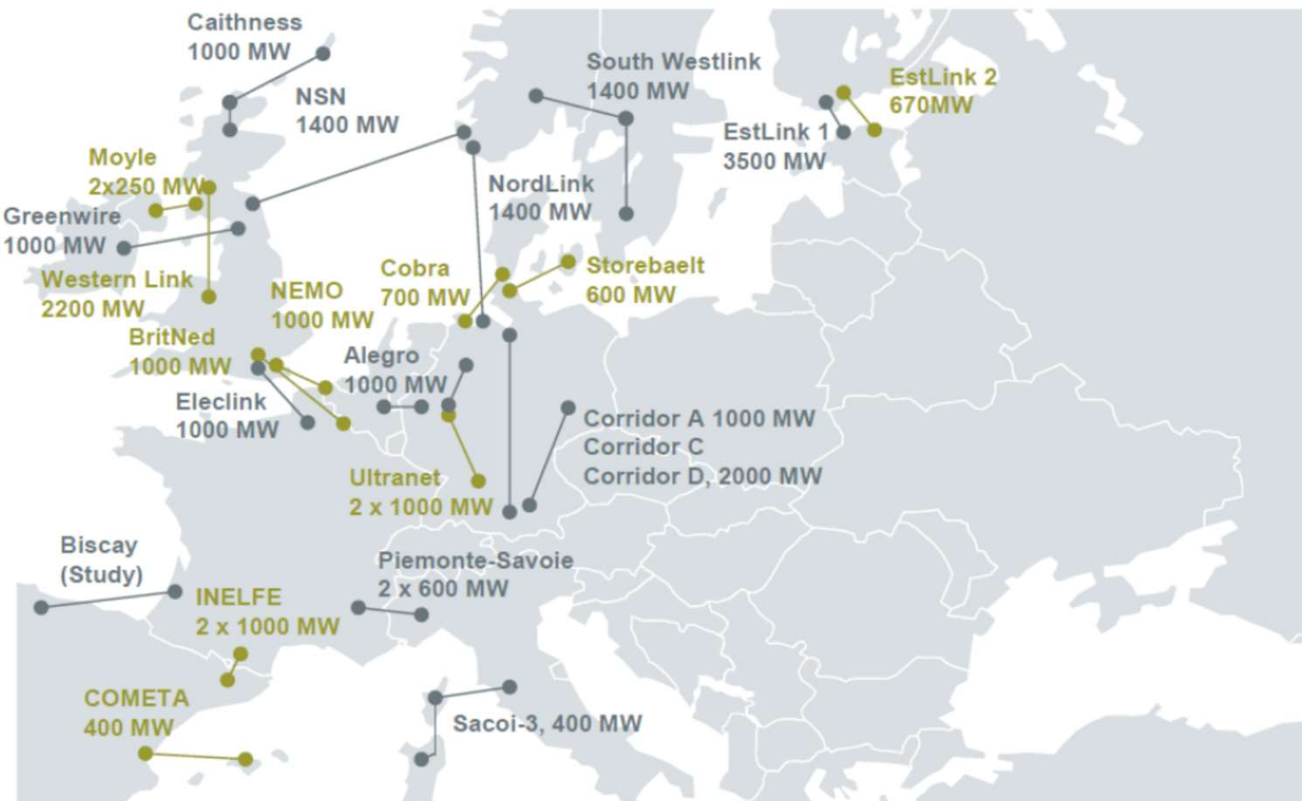
Applications for HVDC

Submarine Cable Transmission



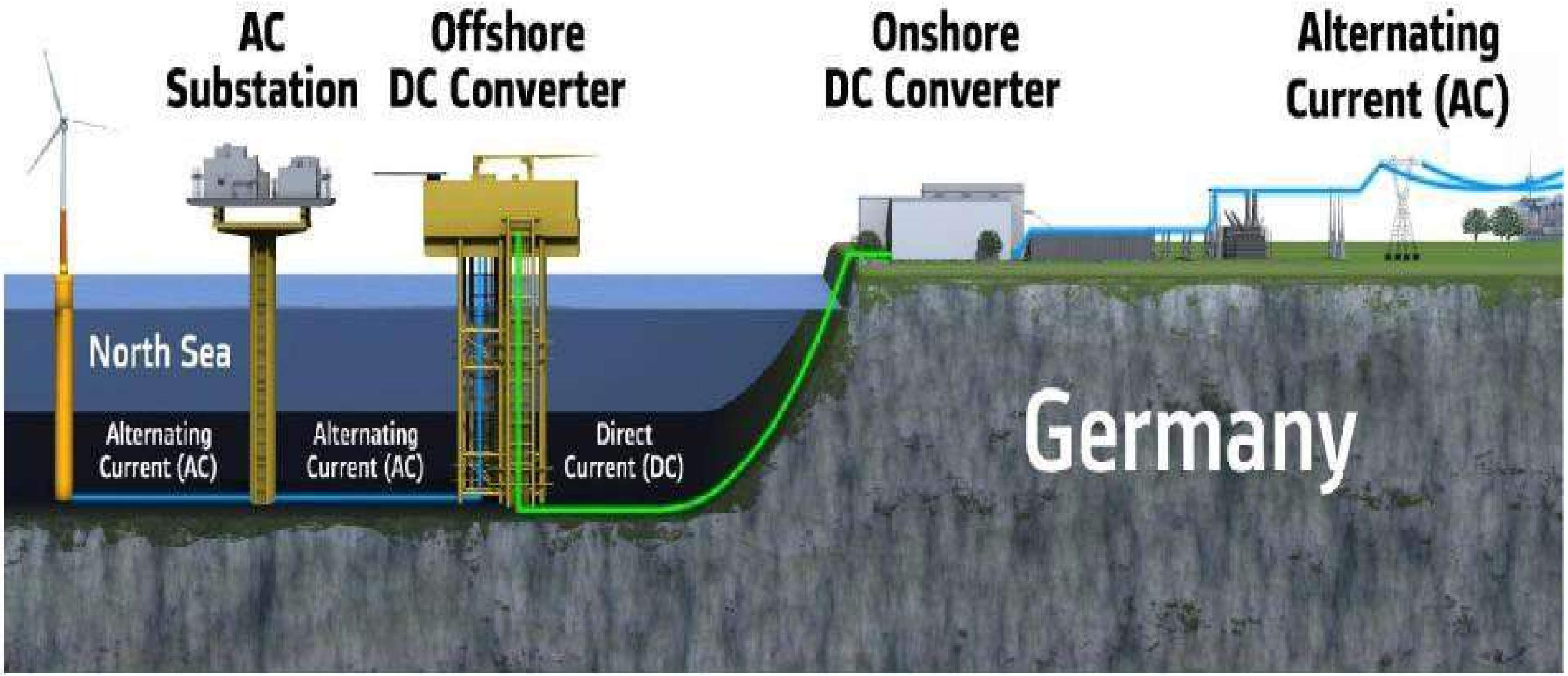
Applications for HVDC

HVDC Cables - Europe



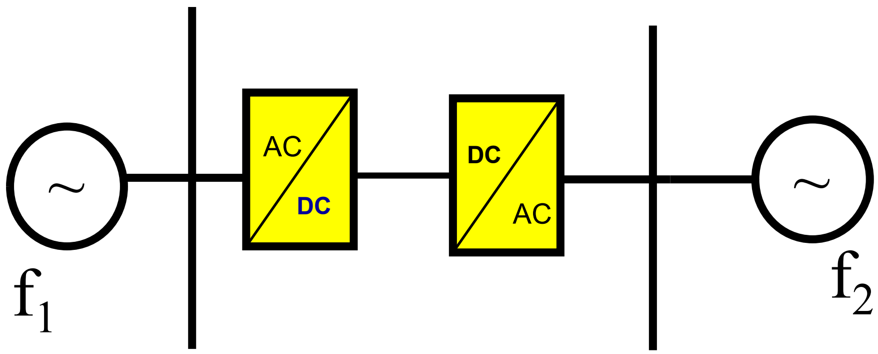
Applications for HVDC

Offshore wind integration



Applications for HVDC

Connecting systems with different frequencies



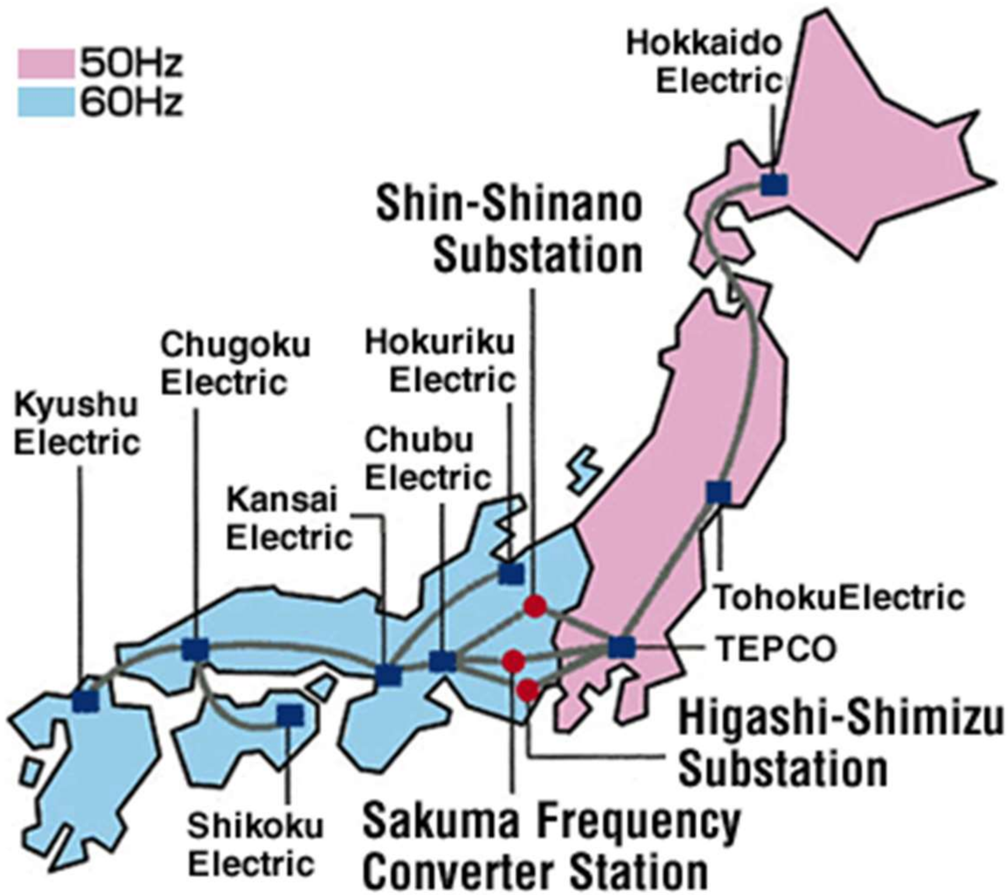
$$f_1 \neq f_2$$

Applications for HVDC

Argentina-Brazil (Garabi) HVDC interconnect

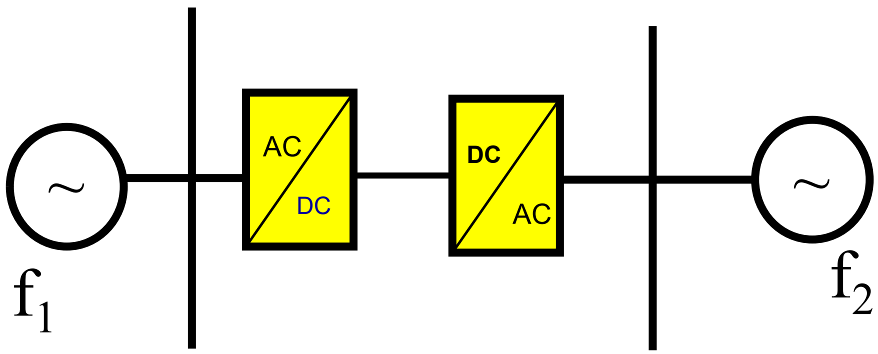
Applications for HVDC

Connecting systems with different frequencies - Japan



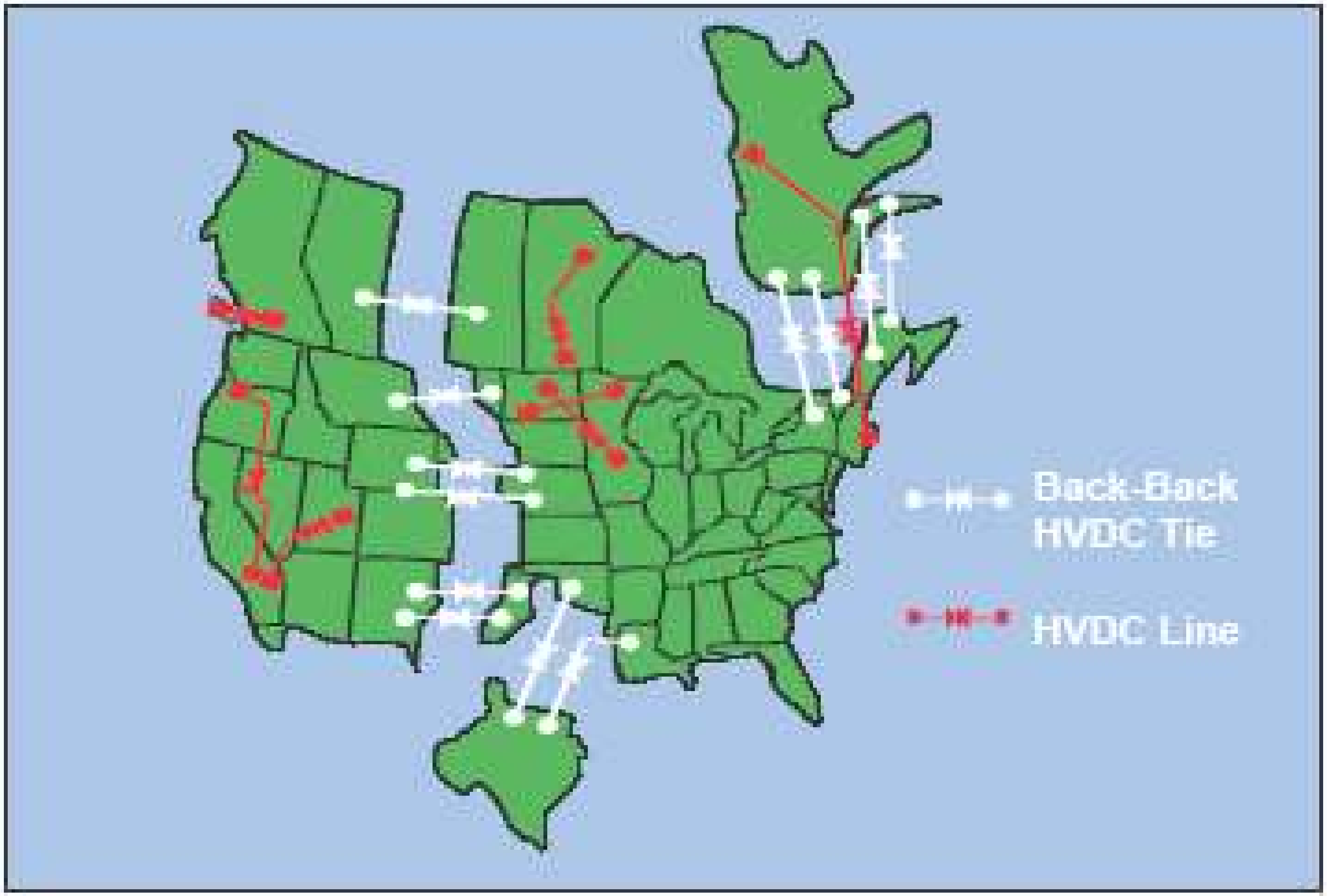
Applications for HVDC

connecting non-synchronous systems with the same frequency



$$f_1 = f_2\,,$$
$$\theta_1 \neq \theta_2$$

Applications for HVDC



Connections between US east, west, Texas and Quebec systems

HVDC Technologies

Two Parallel Technology Paths

Line Commuted Converter (LCC)

- Based on Thyristor
- Mature
- Available up to +/- 1100 kV, 12000 MW

Voltage Source Converter (VSC)

- Based on IGBT
- Developing and Growing
- Available up to +/- 500 kV, 3000 MW

Factors that may Drive Selection of one Option

LCC

- Lower Losses
- High Power
- High Short Time Overload
- Isolation of DC/AC faults
- Very Fast Recovery from DC Line Faults
- Multiple OHL fault clearing
- Lower Converter Cost
- Requirements for reactive power
- Cannot work with weak AC Systems (needs Synchronous Condensers)
- Large footprint due to the AC filters and reactive power shunt banks

HVDC Technologies

Factors that may Drive Selection of one Option

VSC

- Cost effective if long land cables are necessary
- Smaller footprint compared to LCC because of the absence of AC filters
- Can be applied in very weak ac system and immunity to commutation Failure
- System Restoration (Black Start) capability
- Converters can operate as a STATCOM
- Not suitable for overhead line transmission due to slow clearing of DC faults (unless DC breakers or full bridge converter is used)
- Higher converter cost per MW

Development and Implementation Phases of an HVDC Project

- Owner’s studies
- Owner’s investigations
- Technology selection
- Specification
- Bid review
- Contract
- Design review
- Test witnessing
- Commissioning
- Trial Operation
- Commercial Operation

Development and Implementation Phases of an HVDC Project

Owner's Studies

- Feasibility studies
- Load flow
  - **AC System Upgrade requirements**
- Transient stability
  - **Overload requirements**
  - **Supplementary controls and modulations**
    - Power Oscillation damping
    - Frequency limiter
    - Fast power transfer between poles
    - Runback, Run up, coordination with generator tripping and underfrequency load shedding
- Short circuit
  - **ESCR**
  - **UIF to determine susceptibility to SSTI**
- Harmonic Impedance Studies
- Reliability Assessment (to asses the need for Major Spares)
- Equivalents for Performance Demonstrations

Development and Implementation Phases of an HVDC Project

Owner's Investigations

- Site Selection
- Environmental Planning and Permitting
- Preliminary Soils Investigation
- Background Harmonic Measurements
- Telephone Interference Assessment
- Line and/or Cable Routing
- Electrode Site Selection (if applicable)

Development and Implementation Phases of an HVDC Project

Technology Selection

Application	LCC	VSC	Comment
Back-to-Back	Yes	Yes	
Long Distance Transmission	Yes	Yes	
Connecting Isolated systems	Yes	Yes	VSC has advantage for weak isolated systems
Connecting Offshore Wind	Less Suitable	Yes	
Frequency Changer	Yes	Yes	
Overhead Lines	Yes	Yes	VSC requires FB, HyB, DC Breaker for fast fault clearing
Cable systems	Yes (MI, MIPPL, OF)	Yes (as LCC+ Extruded)	
Multi-terminal Operation	Yes	Yes	More difficult with LCC
Very High Power	Yes	*	* VSC is under development
System Recovery Services	No	Yes	Black Start

Development and Implementation Phases of an HVDC Project

Technology Selection

Performance Characteristics	LCC	MMC HB AC breaker	MMC HyB	MMC FB	MMC HB DC breaker
DC fault current interruption	****	*	****	****	****
Decoupling of DC faults from ac system (di/dt)	****	0	***	***	***
DC line fault recovery fast recovery sequences	****	0	****	****	***
Repetitive Recovery Sequences	****	0	****	****	***
Reactive power support during dc fault clearing	*	0	***	***	**
Reduced DC Voltage Operation Due to Pollution	****	0	**	****	0
Demonstrated service history	****	***	*	**	*
Increases Short Circuit Level	0	*	*	*	*

Development and Implementation Phases of an HVDC Project

Specification

1. Purpose of the HVDC System
2. General Requirements (Life time, standards, guarantees …)
3. Contracting Strategy (Turn key with review, T&C)
4. Scope and Interfaces
5. Contractor’s Studies
6. Active Power Transfer Ratings
   1. **Continuous Ratings**
   2. **Short-time overload ratings**
7. Transient Performance - Fault recovery, LV ride through
8. Reliability and Availability
9. Emissions - Harmonics, Audible noise , RFI, PLC Interference
10. Reactive Power Requirements
11. Losses
12. Commissioning, Trial Operation, Reliability and Availability Verification

Thank you !