HVdc Transmission

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Presented by:

TransGrid Solutions Inc

www.transgridsolutions.com

About TransGrid Solutions (***TGS***)

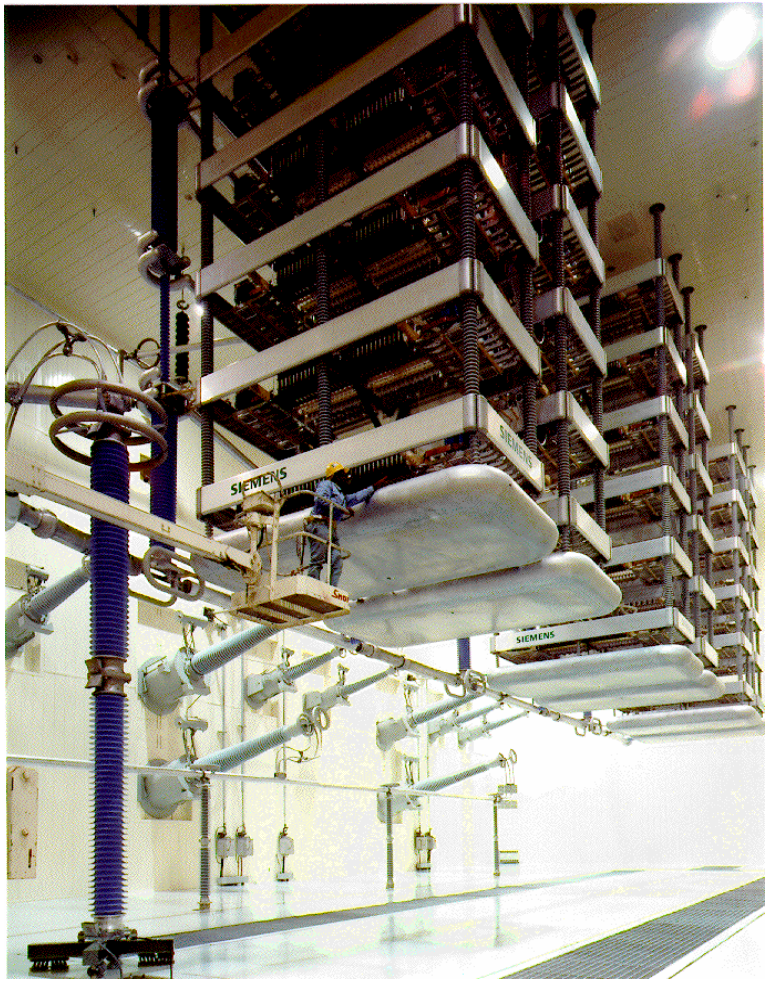
- ***TGS*** provides expert technical consulting services in the field of power transmission technologies including:
  - All aspects of transmission feasibility studies, technical evaluation, specification development, tender evaluation, commissioning, testing, system operation, maintenance
  - A full range of power system simulation with particular expertise in application of power electronic devices and their controls.

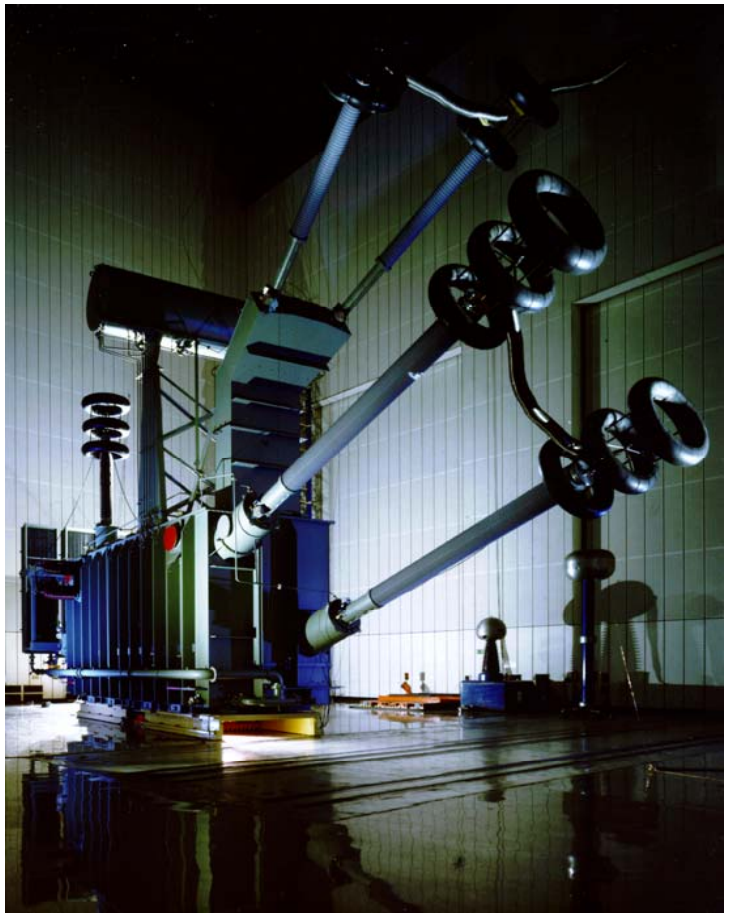
TGS Core Services

- ***P***ower system simulation
  - Loadflow & transient stability – **PSS/E**
  - Electromagnetic transients - **PSCAD/EMTDC**
  - Real time simulation studies including independent control and protection hardware verification – **RTDS**
- ***P***ower electronics and their application to ac/dc systems
  - HVDC
  - SVC
  - FACTS
  - Design, development and testing of controls and protections
- ***T***echnology transfer and training.

TGS Core Services continued

- ***T***ransmission planning and operating studies.
- ***P***roject management.
- ***E***quipment specification and inspection.
- ***E***quipment maintenance.
- ***O***n site services.
- ***P***ower system de-regulation issues.
- Power Quality Issues

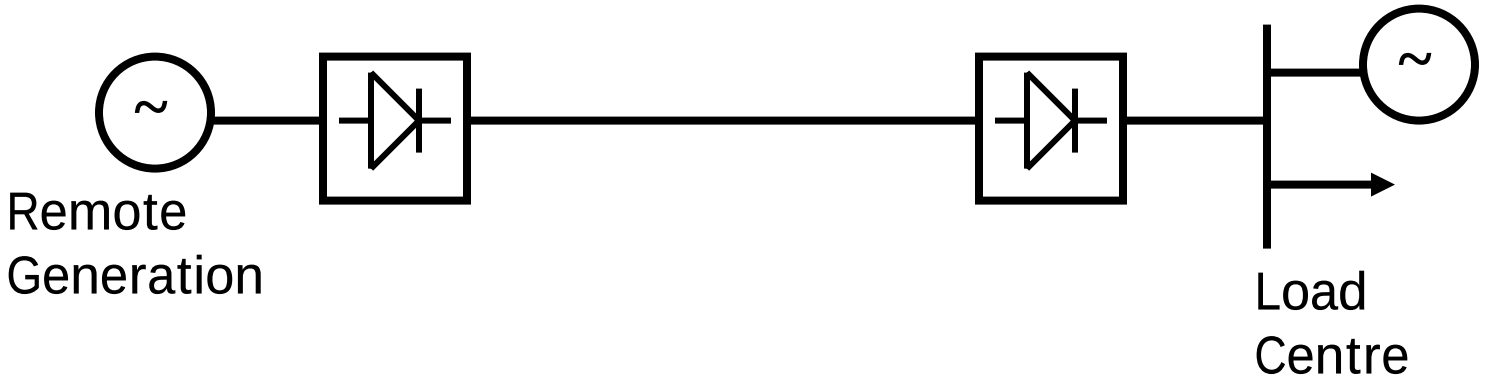




HVDC Technology

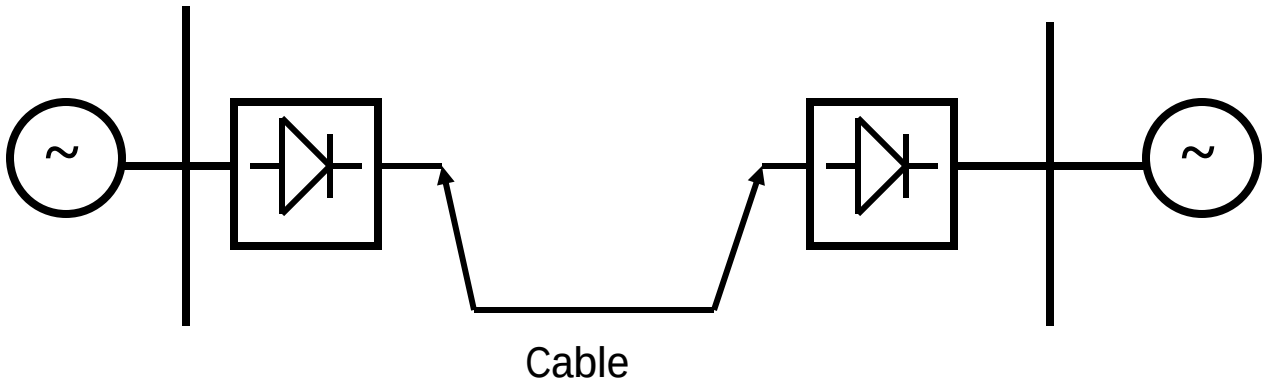
Applications for HVdc

- Moving large amounts of power long distances.



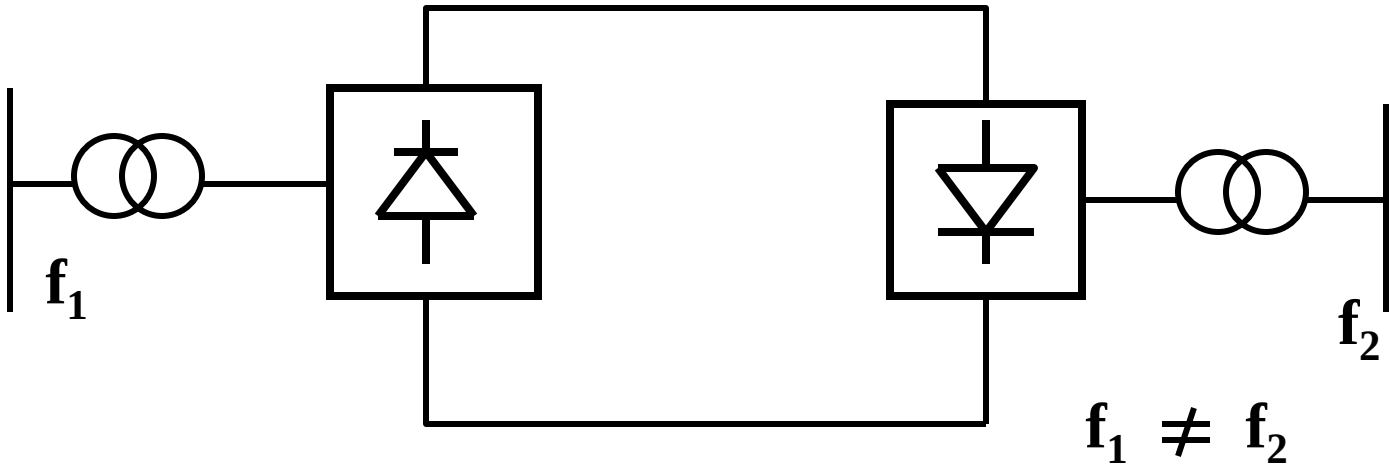
Applications for HVdc

Moving power by cable over moderate to long distances



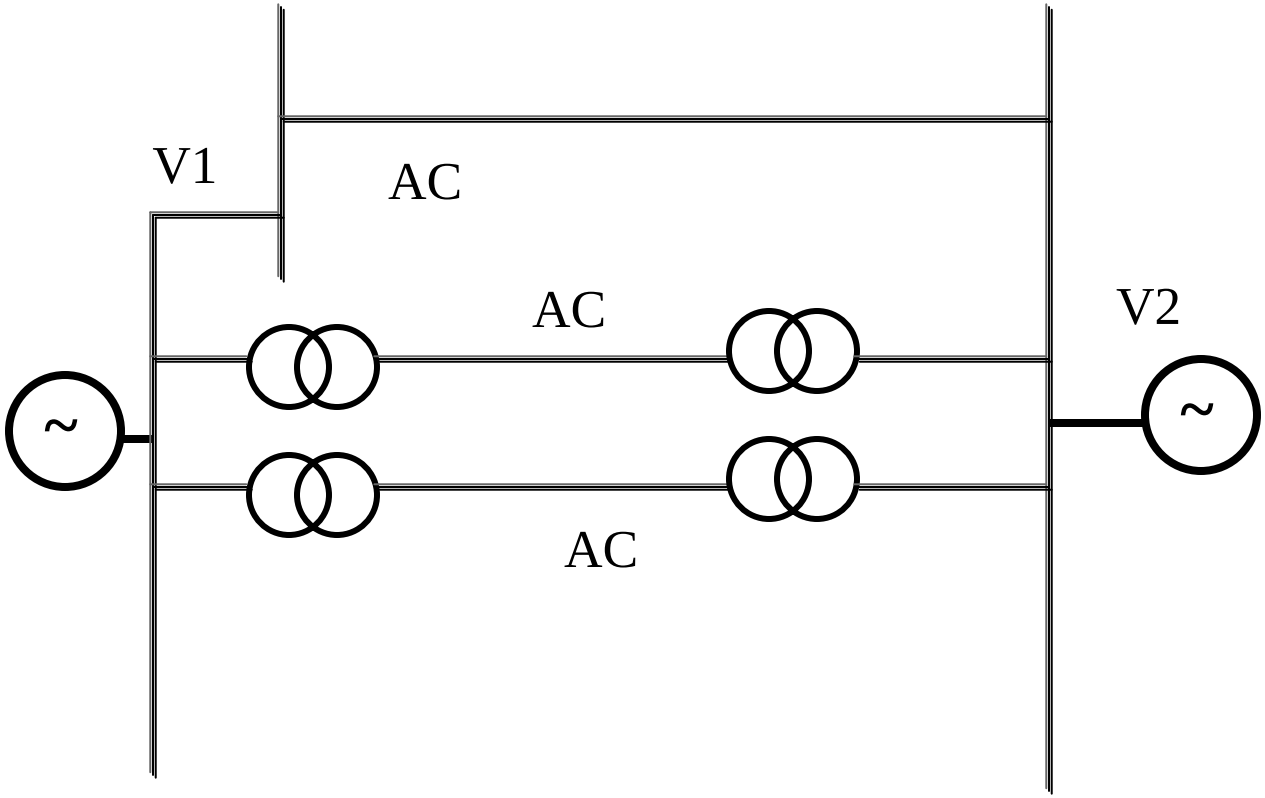
Applications for HVdc

- Moving power between asynchronous systems.



Applications for HVdc

- Forcing power into an area (e.g. loop flow).



Applications for HVdc

- Forcing power into an area (e.g. loop flow).

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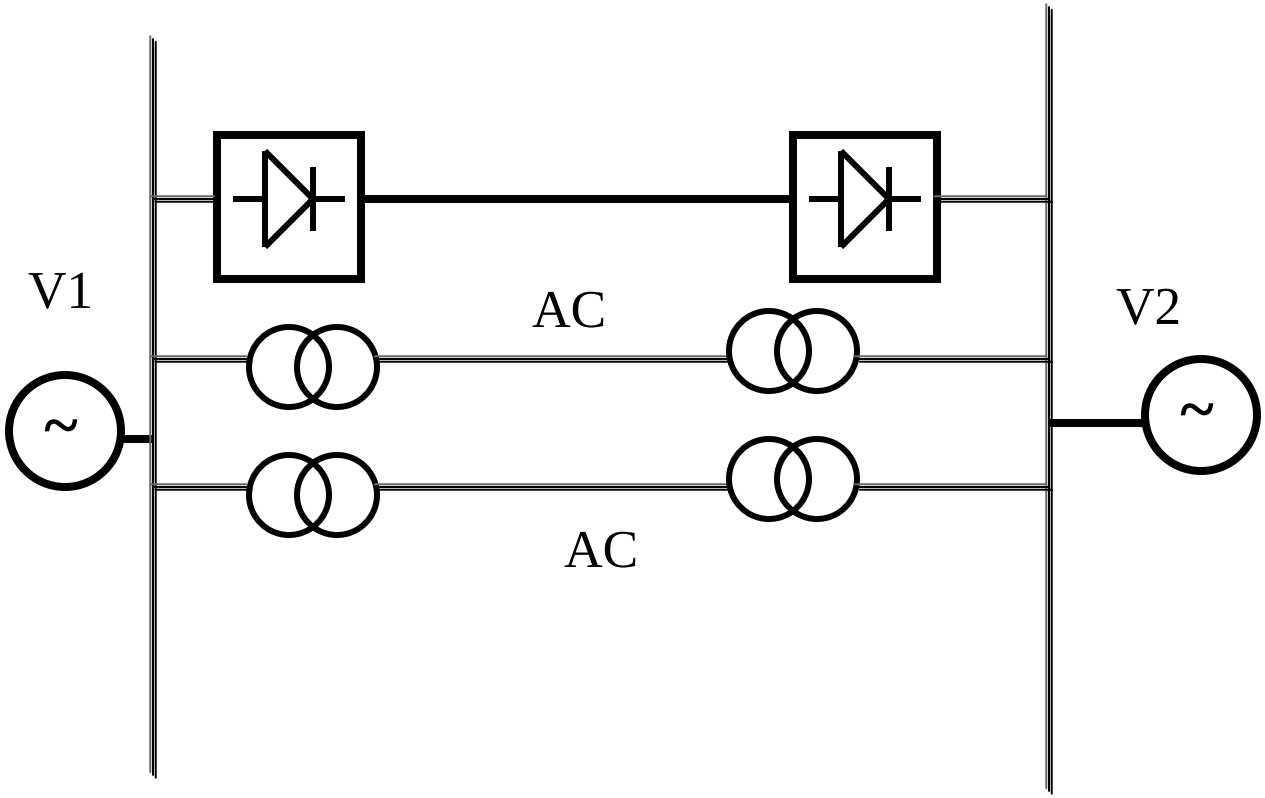


Types of HVdc Converters

- Line Commutated Converters (LCC) Using Thyristor Valves
- Voltage Source Converters (VSC) Using Solid State devices with turn-off capability, mainly Insulated Gate Bipolar Transistors (IGBT)

HVdc Systems Around the World

System	Mercury/ Thyristor/ VSC	Line = L Cable = C BTB = B	Location	DC Voltage kV	Capacity Mw	Year Commissioned
Acray	Thy	B	Paraguay	26	50	1981
Blackwater	Thy	B	USA	57	200	1985
Broken Hill	Thy	B	Australia	2x17	40	1986
Baltic Cable	Thy	C 255km	Sweden-Germany	450	600	1994
Bass Link	Thy	C 360 km	Australia	400	500	2005
C.U.	Thy	L 702 km	USA	±411	1128	1979
Cahora-Bassa	Thy	L 1420km	Mozambique-South Africa	±533	1920	1978
Chandrapur-Ramagundum	Thy	B	India	2x205	2x500	1997
Chateauguay	Thy	B	Canada	2x140	2x500	
Cross Channel	Thy	C 71km	France-UK	±270	2x1000	1986
Chandrapur-Padghe	Thy	L 736km	India	± 500	1500	1998
Cross Sound	VSC	C 40km	USA	+/-150	325	2002
David Hamil	Thy	B	USA	50	100	1977

HVdc Systems Around the World

System	Mercury/ Thyristor/ VSC	Line = L Cable = C BTB = B	Location	DC Voltage kV	Capacity Mw	Year Commissioned
Direct Link	VSC	C 59km	Australia	±80	180	2000
Eddy County	Thy	B	USA	82	200	1983
Eel River	Thy	B	Canada	2x80	320	1972
East-South	Thy	L 1400km	India	±500	2000	2003
Estlink	VSC	C	Estonia-Finland	±150	275	2006
Fenno-Skan	Thy	C 234 km	Finland-Sweden	400	572	1989
Fenno-Skan 2	Thy	L 233km	Finland-Sweden	500	800	P 2010
Gesha	Thy	L 1046km	China	±500	1200	1989/90
Gotland	Thy	C 98km	Sweden	150	260	1983/87
Garabi 1&2	Thy	B	Argantina-Brazil	70	4x500	2000/02
Grita	Thy	C 313km	Greece-Italy	400	500	2001
Gotland HVdc Light	VSC	C 70km	Sweden	±60	50	1999
Gui-Guang	Thy	L 936 km	China	±500	3000	2004
Haenam-Cheju	Thy	C 101km	South Korea	±180	300	1998

HVdc Systems Around the World

System	Mercury/ Thyristor/ VSC	Line = L Cable = C BTB = B	Location	DC Voltage kV	Capacity Mw	Year Commissioned
Higashi-Shimizu	Thy	B	Japan	125	300	2001
Highgate	Thy	B	USA	56	200	1985
Hokaido-Honshu	Thy	C 167km	Japan	±250	600	1979/80/93
Intermountain Power Project	Thy	L 784km	USA	±500	1920	1986
Inga Shaba	Thy	L 1700km	Zaire	±500	560	1982
Itaipu 1	Thy	L 796km	Brazil	±600	3150	1986
Itaipu 2	Thy	L 796 km	Brazil	±600	3150	1987
Konti-Skan 1&2	Thy	C 150km	Denmark-Sweden	±285	740	1965/88/2005
Kontec	Thy	C 171km	Denmark-Germany	400	600	1995
KII Channel	Thy	C 102km	Japan	±250	1400	2000
Leyte-Luzon	Thy	C 443km	Philippines	350	440	1998
Lamar	Thy	B	USA	±63	211	2005
Madawaska	Thy	B	Canada	140	350	1985
McNeil	Thy	B	Canada	42	150	1989

HVdc Systems Around the World

System	Mercury/ Thyristor/ VSC	Line = L Cable = C BTB = B	Location	DC Voltage kV	Capacity Mw	Year Commissioned
Mile City	Thy	B	USA	82	200	1985
Moyle Interconnector	Thy	C 64km	Scotland-N. Ireland	2x250	2x250	2001
Minami-Fukumitzu	Thy	B	Japan	125	300	1999
Murray Link	VSC	C 176km	Sweden	±150	220	1999
Nelson River 1	Thy	L 890km	Canada	±463	1854	1973/93/2005
Nelson River 2	Thy	L 940km	Canada	±500	2000	1978/85
Neptune	Thy	C 70km	USA	500	600	2006
New Zealand Hybrid	Merc/Thy	C/L 612km	New Zealand	+/270/-350	1240	1965/92
Norned	Thy	C 580km	Netherlands-Norway	±450	700	2007
Oklaunion	Thy	B	USA	82	220	1985
Pacific Intertie	Thy	L 1361km	USA	± 500	3100	1989/2005
Quebec New England	Thy	L 1500km	Canada/ USA	±500	2250	1986/90/92 Multi-Terminal
Rihand-Delhi	Thy	L 814km	India	±500	1500	1992

HVdc Systems Around the World

System	Mercury/ Thyristor/ VSC	Line = L Cable = C BTB = B	Location	DC Voltage kV	Capacity Mw	Year Commissioned
Rivera	Thy	B	Uruguay		70	
Rapid City	Thy	B	USA	±13	200	2003
Sacoi	Thy	C/L 385km	Italy-Corsica-Sardinia	±200	300	1967/85/93
Sapei	Thy	C 440km	Italy-Sardinia	500	500	
Sakuma	Thy	B	Japan	125	400	1993
Shin-Shinano 1	Thy	B	Japan	125	300	1977
Shin-Shinano 2	Thy	B	Japan	125	300	1992
Sileru- Barsoor	Thy	L 196km	India	±200	100	1989
Skagarak 1-3	Thy	C 240km	Norway-Denmark	250/350	1050	1976/77/93
Square Butte	Thy	L 749km	USA	±250	150	1977
Swedpol	Thy	C 230km	Sweden-Poland	450	600	2000
Sasaram	Thy	B	India	205	500	2002
Tian-Guang	Thy	L 960km	China	±500	1800	2001

HVdc Systems Around the World

System	Mercury/ Thyristor/ VSC	Line = L Cable = C BTB = B	Location	DC Voltage kV	Capacity Mw	Year Commissioned
Thailand Malaysia	Thy	L 100km	Thailand-Malaysia	±300	600	2001
Three Gorges Changzhou	Thy	L 890km	China	±500	3000	2003
Three Gorges Guandong	Thy	L 900km	China	±500	3000	2004
Trol	VSC	C 70km	Norway	2x60	2x40	2004
Uruguaianai	Thy	B	Brazil-Uruguay	18	54	1987
Vancouver Island	Merc/Thy	L/C 74km	Canada	+260/- 280	682	1968/77/79
Vindhychal	Thy	B	India	69.7	2x250	1989
Virginia Smith	Thy	B	USA	50	200	1987
Volgograd-Donbass	Merc	L 470km	Russia	±400	720	1962
Vyborg	Thy	B	Russia-Finland	1x170 (+/-85)	4x355	1981/82/84/02
Vizag 1	Thy	B	India	205	500	1998
Vizag 2	Thy	B	India	±88	500	2005
Welsh	Thy	B	USA	162	600	1995

Present status of HVDC long distance for moderate powers

- Thyristor size is 5 inch capable of a blocking voltage of 8 to 8.5 KV and dc current of between 3500 A to 4000 A depending on how the thyrestors are applied.
- DC voltage of +/- 500 KV
- DC power of up to 3000 MW on a single bipole
- Distances of up to 1800 km
- A single converter per pole

Present status of HVDC for very long distance & high power levels powers

- Thyristor size is 6 inch capable of a blocking voltage of 8 to 8.5 KV and dc current of 5500 A
- DC voltage of +/- 800 KV
- DC power of up to 7500 MW on a single bipole
- Distances of 2500 KM
- The present rating of 3000 MW, +/- 500 kV for Zephyr/Chinook is based on the largest single contingency loss for the system to withstand.

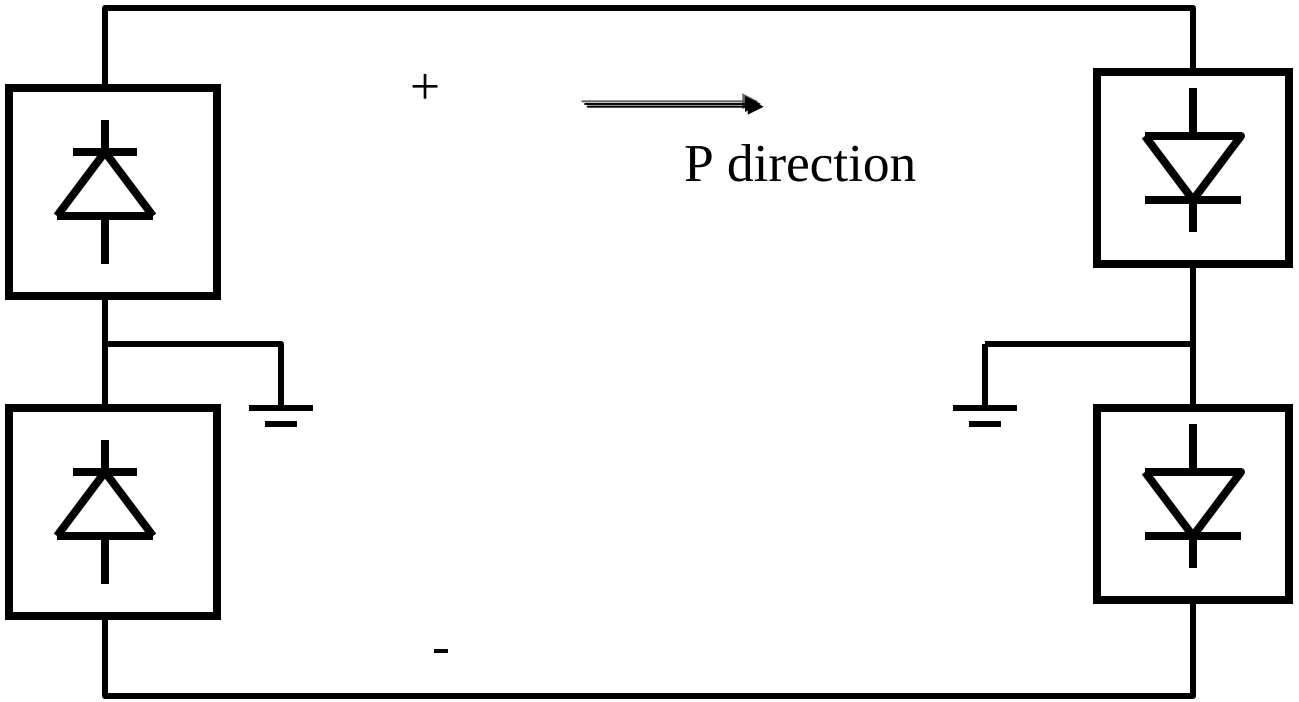
Advantages of HVdc Transmission

- **Controlled Power Exchange**
- **Limitation of Short Circuit Currents**
- **Transmission at reduced voltages**
- **Overload Capability**
- **No fault cascading**

HVdc Long Distance Transmission

- Two Terminal
- Multi Terminal

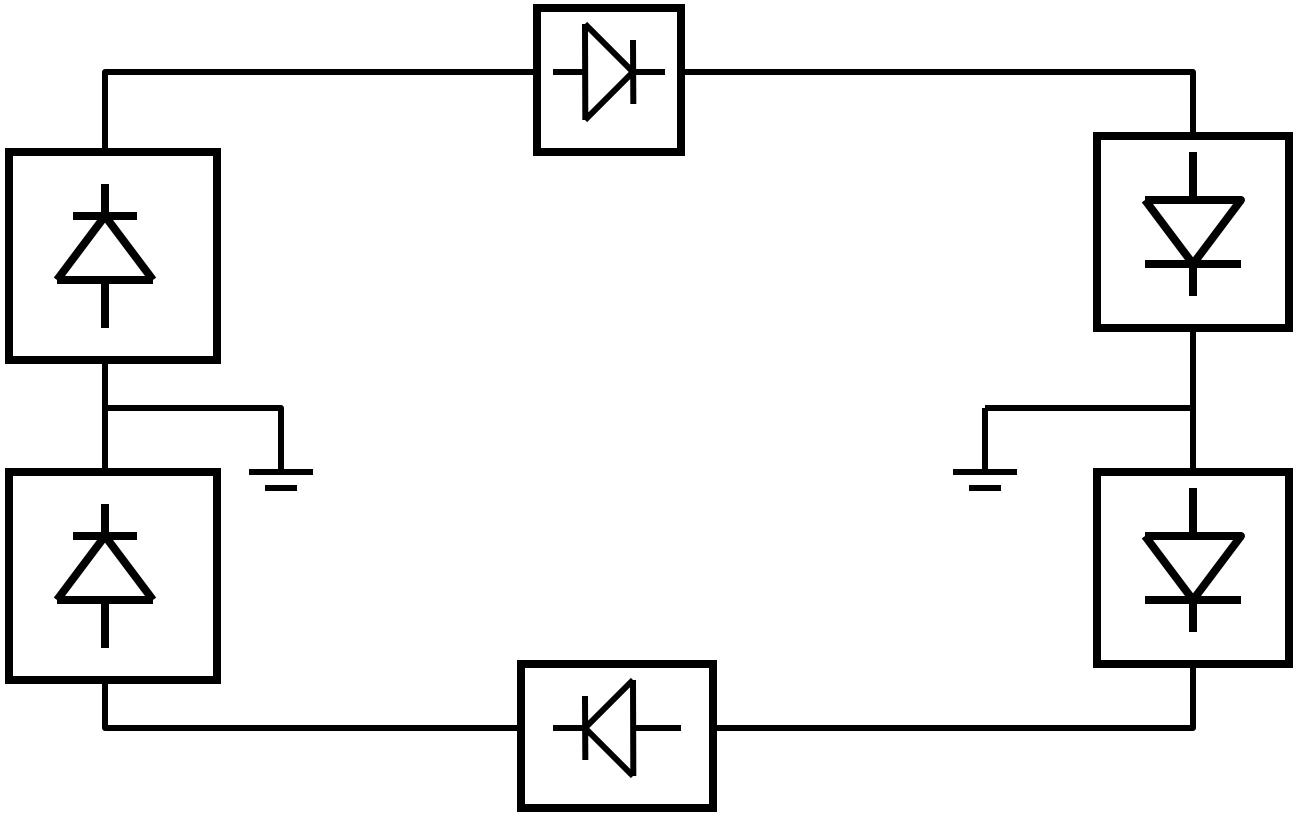
Two Terminal Bipolar System



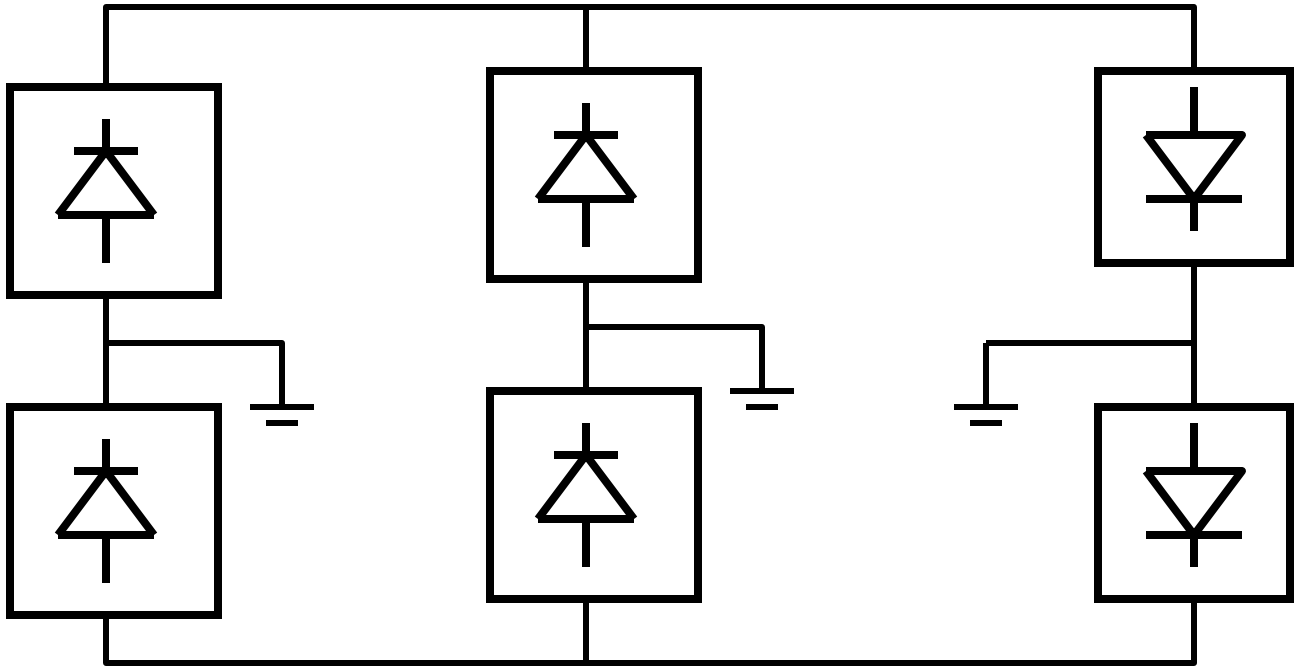
Two Terminal Mono-polar System Ground Return

Two Terminal Mono-polar System
Metallic Return

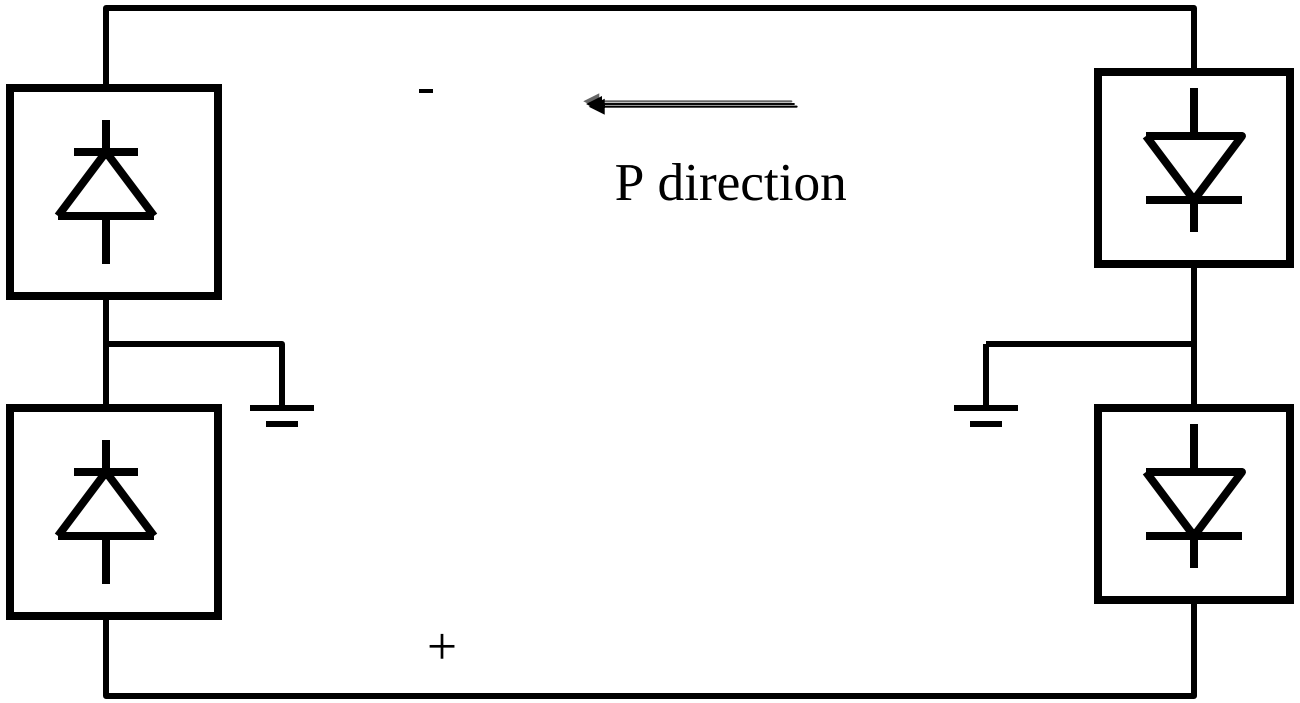
Multi-Terminal Series Tap



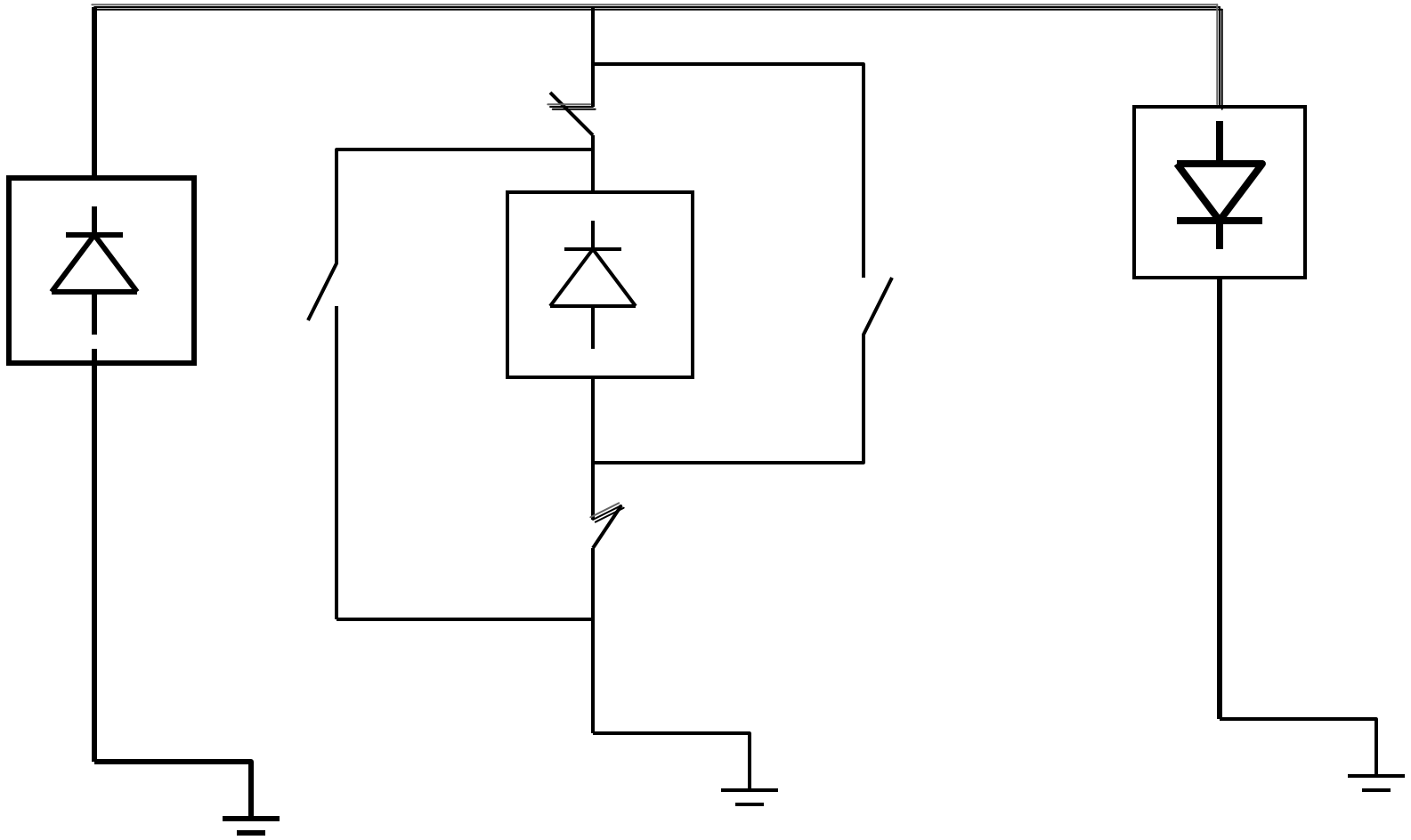
Multi-Terminal Parallel Tap



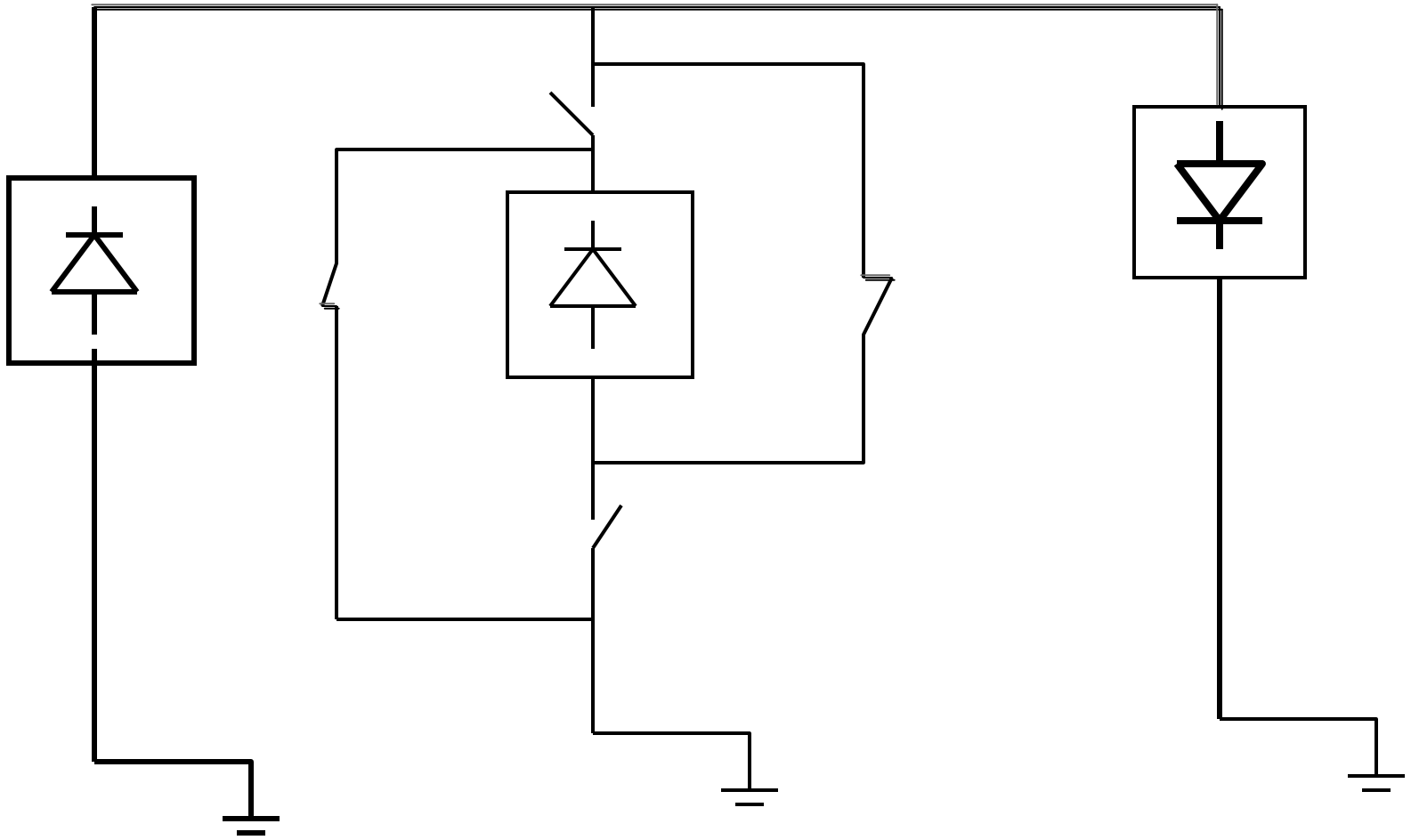
Reversal of Power direction



Reverse of power direction in one terminal



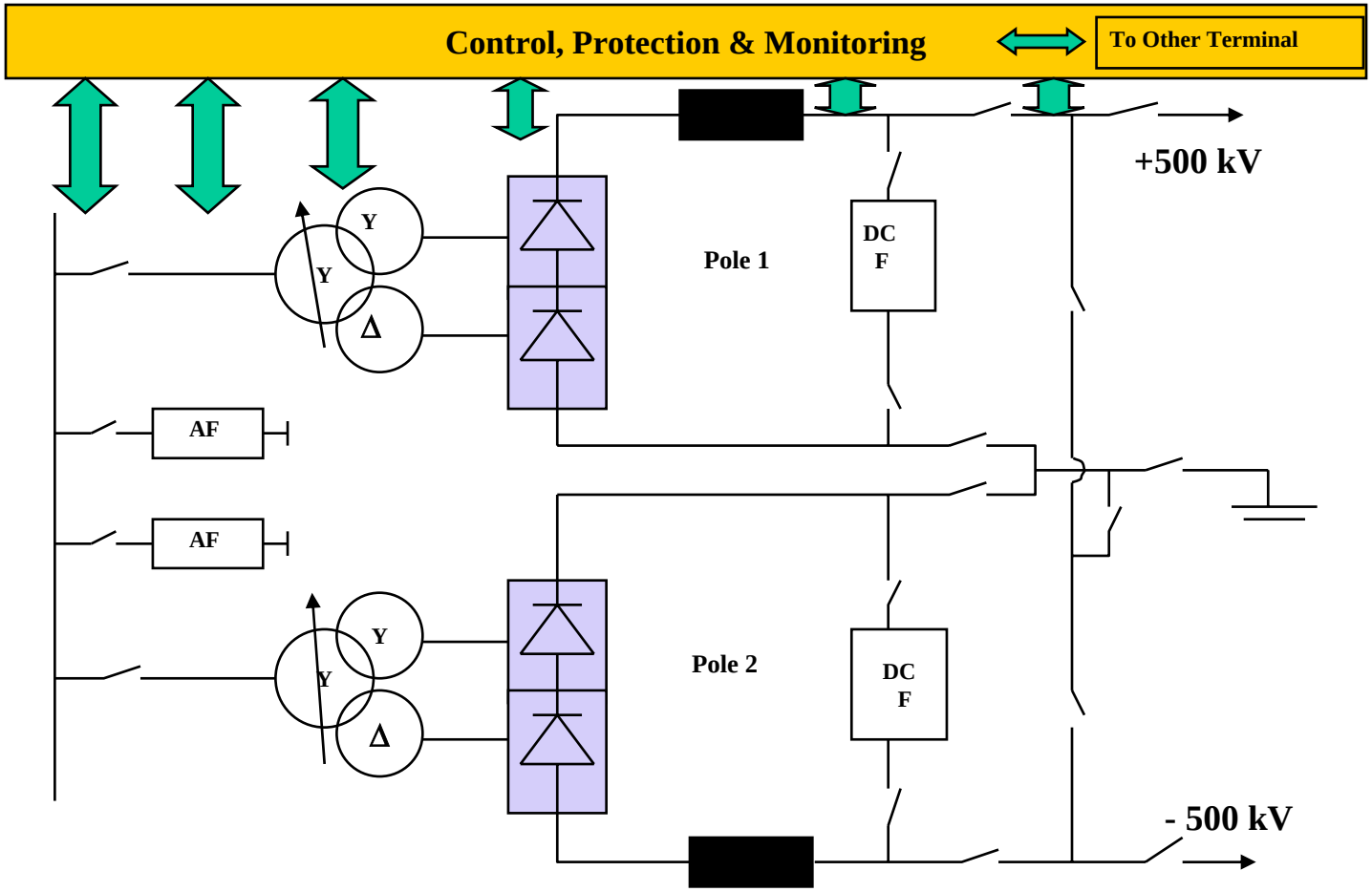
Reverse of power direction in one terminal



Multi Terminal HVDC Experience

- Nelson River bipoles one and two emergency operation in parallel
- Pacific Inter-Tie
- Itaipu bipoles one and two emergency operation in parallel
- Sacoi
- Hydro Quebec to New England

HVDC Station Equipment
Zephyr/Chinook



Conclusions

- HVDC is a mature technology, it has been around for 50 years
- HVDC multi-terminal is a proven technology that is already in operation
- HVDC provides high reliability
- HVDC provides flexibility in operation of the overall integrated system
- HVDC is suitable for wind integration and provides flexibility

Thank You