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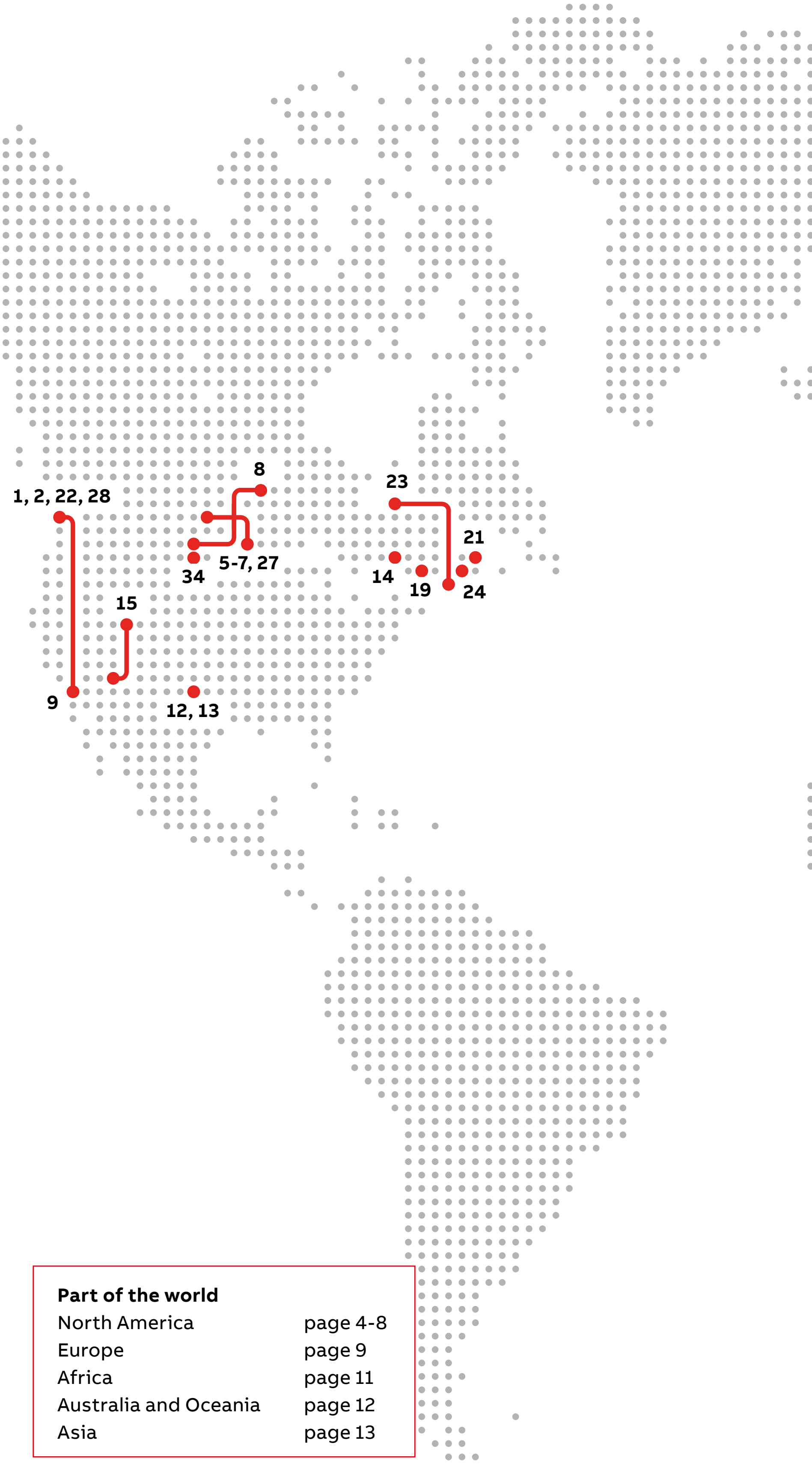
HVDC Care upgrades

Extending lifetime

HVDC Care upgrades
Projects worldwide



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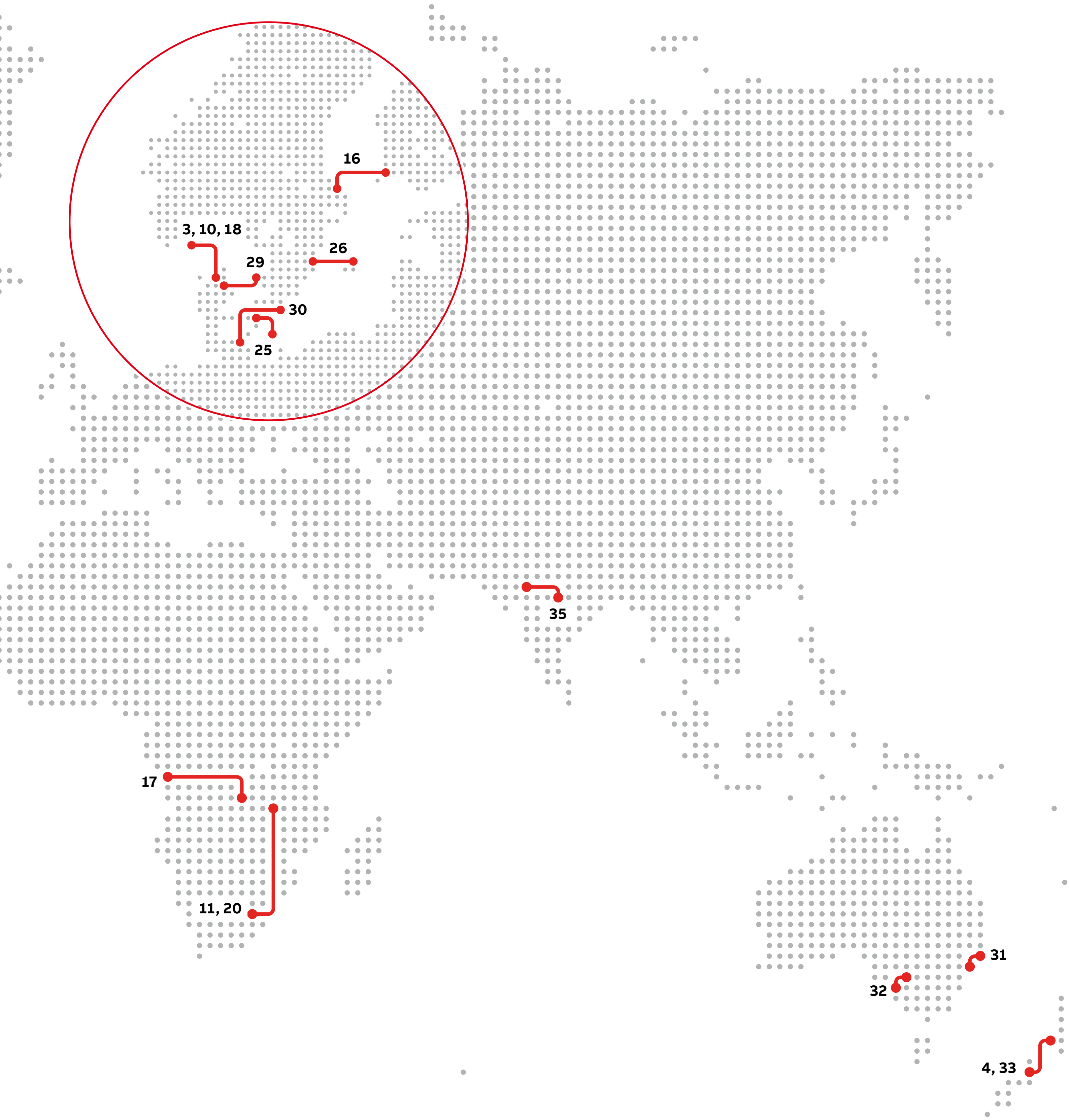
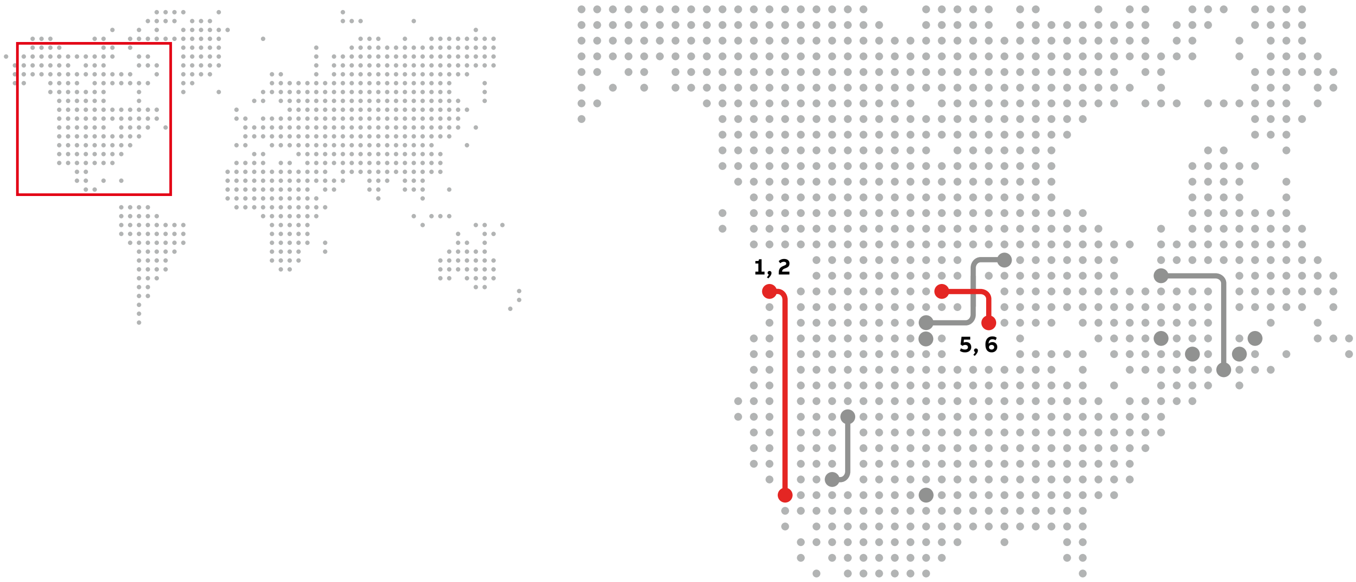
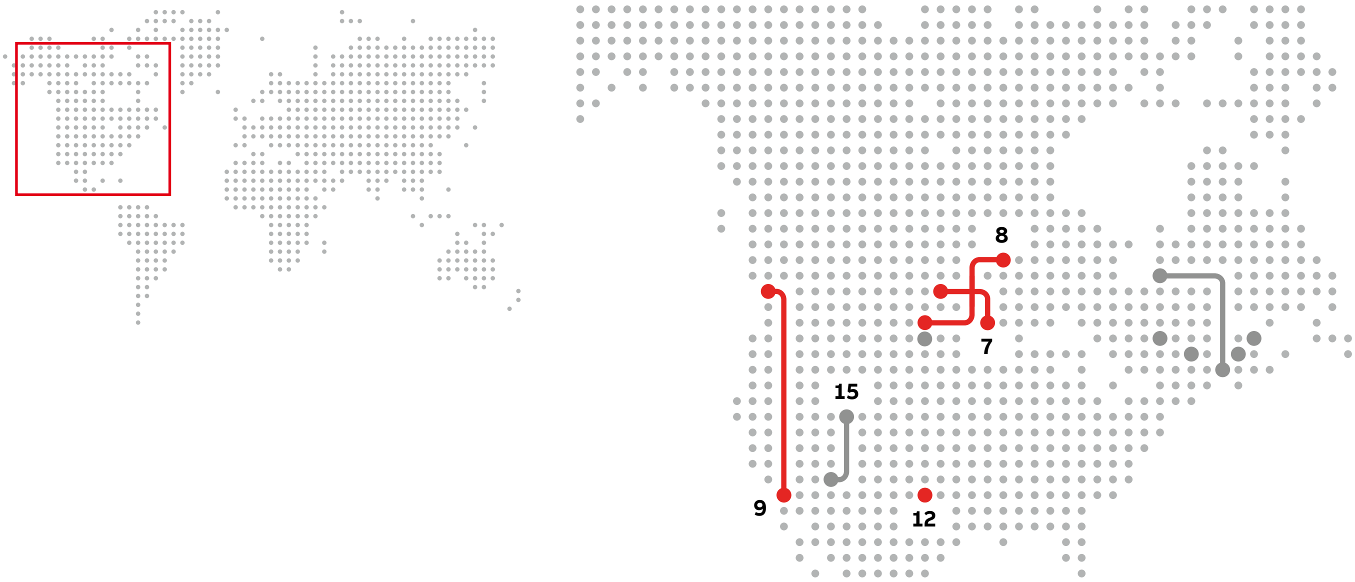


North America



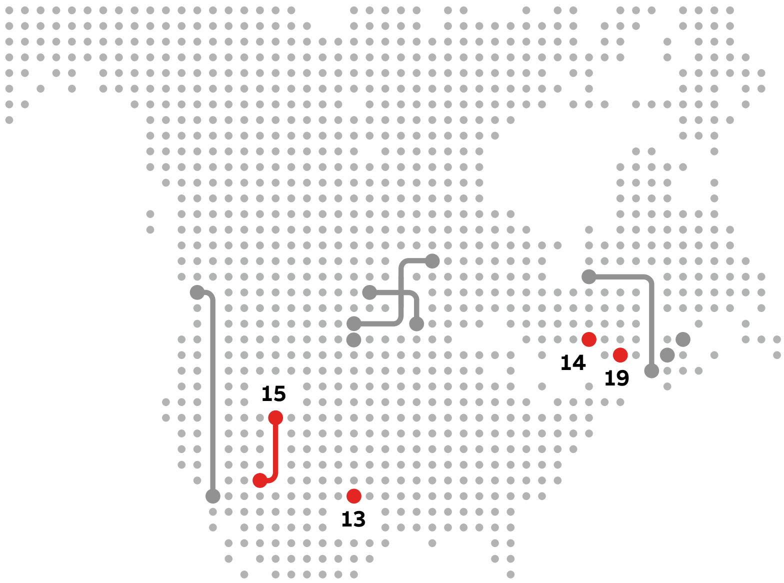
Scheme	1. Pacific Intertie	2. Pacific Intertie	5. CU-Project I	6. CU-Project II
Commissioning year	1970	1970	1979	1979
Commissioning year upgrade	1985	1989	2001	2002
Type of upgrade	Voltage upgrade 400-500 kV	Adding of parallell convertes at Sylmar & Celilo stations	Valve control and valve electronics replacement	Voltage upgrade ±10 kV (2.5 %), + 25 MW
Upgrade scope	-	Valves		
Owner/Original customer	Bonneville Power Administration, USA and The Department of Water and Power of the City of Los Angeles, USA	Bonneville Power Administration, USA and The Department of Water and Power of the City of Los Angeles, USA	CPA, USA and UPA, USA	CPA, USA and UPA, USA
Main reason for choosing HVDC system	Connecting remote generation, Stability benifits	Connecting remote generation, Stability benifits	Connecting remote generation, Environment, Stability benefits	
Power transmitted, MW	1440	1440	1000	
Direct voltage, kV	±400	±400	±400	
Converters per station	6	6	2	
Direct voltage per converter, kV	133	133	400	
Direct current, A	1800	1800	1250	
Reactive power supply	Capacitors	Capacitors	Capacitors Power generator	
Converter station location and AC grid voltage	Celilo, 230 kV Sylmar, 230 kV	Celilo, 230 kV +500kV Sylmar, 230 kV	Coal Creek, 235 kV Dickinson, 350 kV	
Length of overhead DC line	1360 km	1360 km	687 km	
Cable arrangement	-	-	-	
Cable route length, km	-	-	-	
Grounding of the DC circuit	For full current in one ground and one sea electrode station (intermittent)	For full current in one ground and one sea electrode station (intermittent)	For full current in two ground electrode stations (intermittent)	
AC grids at both ends	Synchronous	Synchronous	Synchronous	
Control	Constant power in either direction and small signal modulation	Constant power in either direction and small signal modulation	Constant power, damping control	
Emergency change of power flow	On manual or automatic order to preset values	On manual or automatic order to preset values	-	
Main supplier of converter equipment	ABB	ABB	ABB	

North America



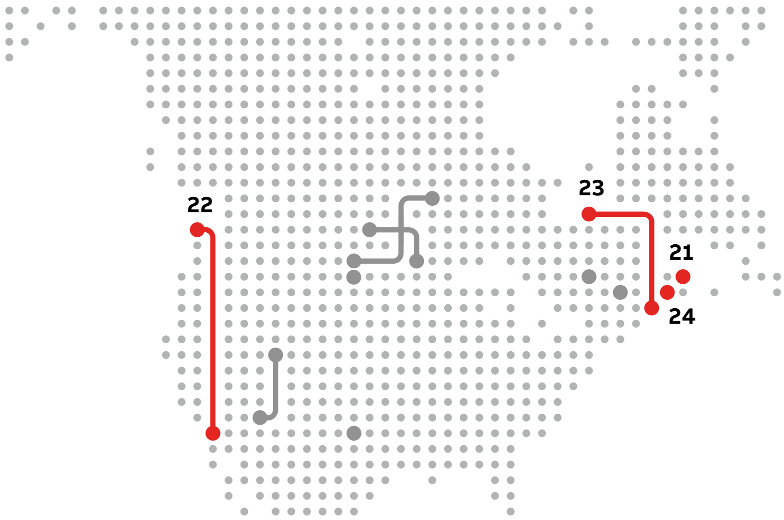
Scheme	7. CU-Project III	8. Square Butte HVDC	9. Pacific Intertie. Sylmar	12. Blackwater I
Commissioning year	1979	1979	1970	1985
Commissioning year upgrade	2004	2004	2004	2008
Type of upgrade	Control and protection upgrade	Control and protection upgrade	Re-building of the Sylmar East converter station from 1,100 to 3,100 MW.	Valve cooling
Upgrade scope	C&P	C&P	Valves, C&P	Valve
Owner/Original customer	CPA, USA and UPA, USA	Minnkota Power Cooperative and Minnesota Power	Bonneville Power Administration, USA and The Department of Water and Power of the City of Los Angeles, USA	Public Service Company of New Mexico, USA
Main reason for choosing HVDC system	Connecting remote generation, Environment, Stability benefits	Connecting remote generation, Environment, Stability benefits	Connecting remote generation, Stability benifits	Interconnecting grids
Power transmitted, MW	1000	500	1440	200
Direct voltage, kV	±400	±250	±400	56.8
Converters per station	2	2	6	2
Direct voltage per converter, kV	400	250	133	56.8
Direct current, A	1250	1250	1800	3600
Reactive power supply	Capacitors Power generator	Capacitors Power generator	Capacitors	Capacitors
Converter station location and AC grid voltage	Coal Creek, 235 kV Dickinson, 350 kV	Arrowhead, 235 kV Center, 350 kV	Celilo, 230 kV Sylmar, 230 kV	New Mexico side, 345 kV Texas side, 230 kV
Length of overhead DC line	687 km	749 km	1360 km	Back-to-back
Cable arrangement	-	-	-	-
Cable route length, km	-	-	-	-
Grounding of the DC circuit	For full current in two ground electrode stations (intermittent)	For full current in two ground electrode stations (intermittent)	For full current in one ground and one sea electrode station (intermittent)	One point grounded
AC grids at both ends	Synchronous	Synchronous	Synchronous	Asynchronous
Control	Constant power, damping control	Constant power, reactive power control	Constant power in either direction and small signal modulation	Constant power, reactive power control
Emergency change of power flow	-	-	On manual or automatic order to preset values	-
Main supplier of converter equipment	ABB	GE	ABB	ABB

North America



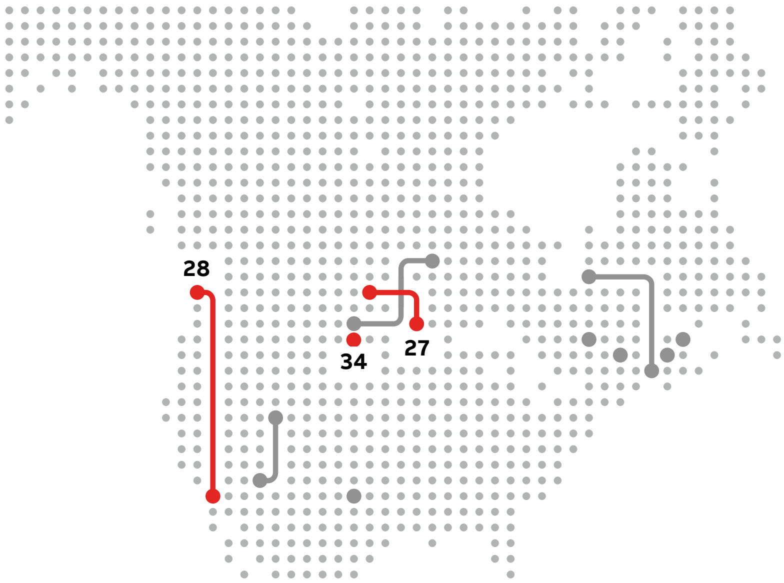
Scheme	13. Blackwater II	14. Châteauguay	15. Intermountain Power Project	19. Highgate
Commissioning year	1985	1984	1986	1985
Commissioning year upgrade	2009	2009	2010	2012
Type of upgrade	Control and protection upgrade	Control and protection upgrade	Control and protection system upgrade, additional AC filters and cooling system	Valve, valve cooling and control and protection system upgrade.
Upgrade scope	C&P	C&P	C&P, Valves, main circuit	C&P, Valve
Owner/Original customer	Public Service Company of New Mexico, USA	Hydro-Quebec, Quebec, Canada	Intermountain Power Agency with Los Angeles Department of Water and Power, USA	Vermont Electrical Power Company VELCO, USA
Main reason for choosing HVDC system	Interconnecting grids	Interconnecting grids	Connecting remote generation	Interconnecting grids
Power transmitted, MW	200	2 x 500	1920	200
Direct voltage, kV	56.8	2 x 140.6	±500	57
Converters per station	2	2 + 2	2	2
Direct voltage per converter, kV	56.8	140.6	500	57
Direct current, A	3600	2 x 3600	1920	3600
Reactive power supply	Capacitors	Capacitors and SVC	Capacitors	Capacitors
Converter station location and AC grid voltage	New Mexico side, 345 kV Texas side, 230 kV	Hydro-Quebec side, 315 kV U.S. side, 120 kV	Intermountain, 345 kV Adelanto, 500 kV	Highgate North, 120 kV Highgate South, 115 kV
Length of overhead DC line	Back-to-back	Back-to-back	785 km	Back-to-back
Cable arrangement	-	-	-	-
Cable route length, km	-	-	-	-
Grounding of the DC circuit	One point grounded	One point grounded	For full current in two ground electrode stations (intermittent)	One point grounded
AC grids at both ends	Asynchronous	Asynchronous	Synchronous	Asynchronous
Control	Constant power, reactive power control	Constant power	Constant power, damping control	Constant power in either direction
Emergency change of power flow	-	-	-	Automatic power reducti-on triggered by AC-signal
Main supplier of converter equipment	ABB	ABB/Siemens	ABB	ABB

North America



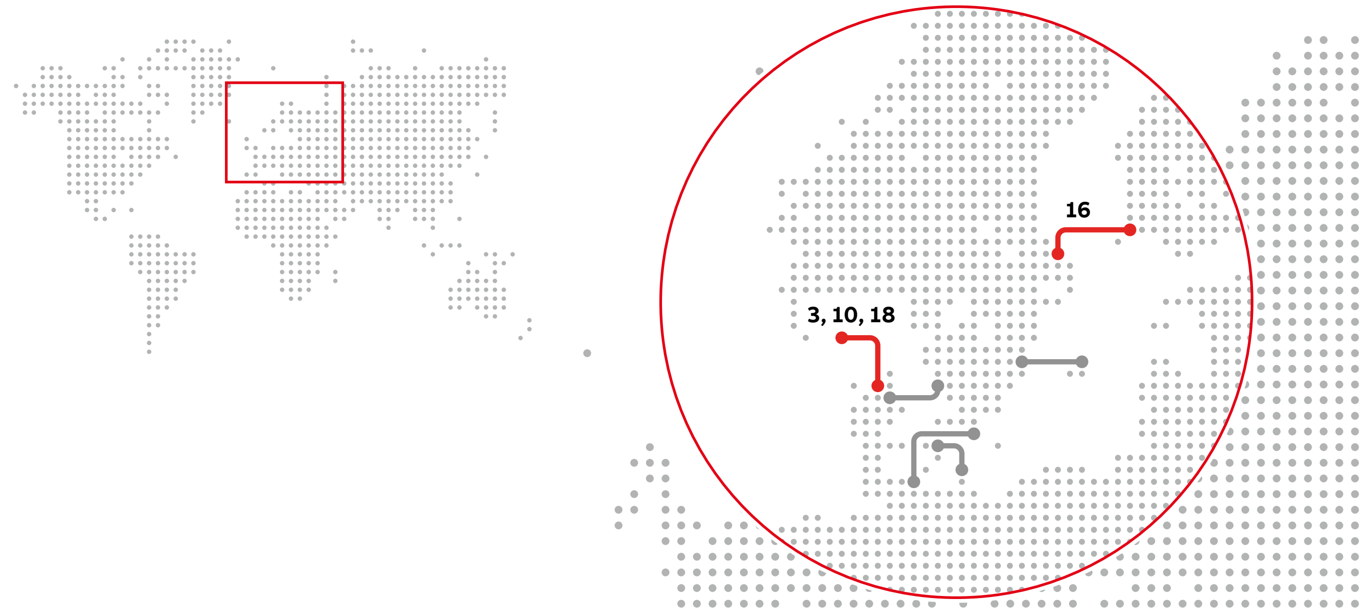
Scheme	21. Eel River	22. Pacific Intertie. Celilo	23. Québec - New England	24. Madawaska
Commissioning year	1985	1970	1990-1992	1985
Commissioning year upgrade	2014	2016	2015-2016	2016
Type of upgrade	Valve, valve cooling and control and protection system upgrade.	Re-building of the Celilo converter station from 3100 MW to 3800 MW.	Control and protection upgrade	Valve, valve cooling and control and protection system upgrade.
Upgrade scope	C&P, Valve	Transformers, C&P, Valves, main circuit	C&P	Control and protection system, MACH. Valves and valve cooling system
Owner/Original customer	Vermont Electric Power Company Inc., USA	Bonneville Power Administration, USA and The Department of Water and Power of the City of Los Angeles, USA	Hydro Quebec, Quebec, Canada and New England Hydro Transmission Electric Company Inc., USA	Hydro-Québec, Canada
Main reason for choosing HVDC system	Interconnecting grids	Connecting remote generation, Stability benifits	Connecting remote generation, Interconnecting grids	Interconnecting grids
Power transmitted, MW	350	1440	2000 (Multiterminal)	350
Direct voltage, kV	80	±400	±450	130
Converters per station	2	6	2	1+1
Direct voltage per converter, kV	80	133	450	130
Direct current, A	2188	1800	2200	2671
Reactive power supply	Capacitors, Synchronous Condensers	Capacitors	Capacitors	Filter banks
Converter station location and AC grid voltage	New Brunswick, 230 kV Hydro-Quebec, 230 kV	Celilo, 230 kV Sylmar, 230 kV	Radisson, 315 kV Sandy Pond, 345 kV Nicolet, 230 kV	Quebec 315 kV New Brunswick 345 kV
Length of overhead DC line	Back-to-back	1360 km	1480 km	Back-to-back
Cable arrangement	-	-	-	-
Cable route length, km	-	-	-	-
Grounding of the DC circuit	One point grounded	For full current in one ground and one sea electrode station (intermittent)	All stations grounded by totally three electrode stations	Neutral bus grounded at one point
AC grids at both ends	Asynchronous	Synchronous	HQ synchronous NEH asynchronous	Asynchronous
Control	Constant power in either direction	Constant power in either direction and small signal modulation	Multiterminal, constant power control, frequency control	Constant power control, frequency control
Emergency change of power flow	On manual or automatic order to preset values	On manual or automatic order to preset values	Isolation of Radisson from the AC system at severe AC disturbances	-
Main supplier of converter equipment	GE	ABB	ABB	GE

North America



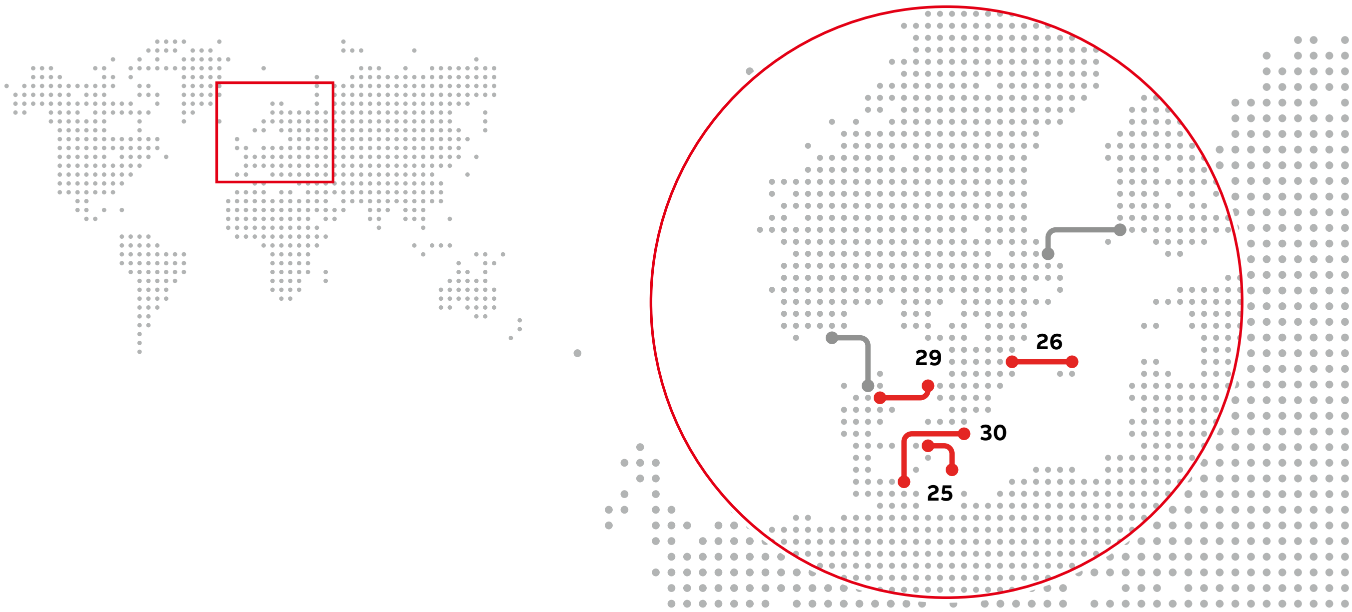
Scheme	27. CU-Project IIII	28. Pacific Intertie. Sylmar	34. Rapid City
Commissioning year	1979	1970	2003
Commissioning year upgrade	2019	2018-2019	2020
Type of upgrade	Control and protection upgrade, valves, valve cooling	AC and DC filters, shunt reactors, measurement, auxiliary equipment, Control and protection system, MACH.	-
Upgrade scope	C&P, valves	C&P, Valves, main circuit	Control and protection system, MACH
Owner/Original customer	CPA, USA and UPA, USA	Bonneville Power Administration, USA and The Department of Water and Power of the City of Los Angeles, USA	Basin Electric Power , Black Hills Power
Main reason for choosing HVDC system	Connecting remote generation, Environment, Stability benefits	Connecting remote generation, Stability benifits	Interconnecting grids
Power transmitted, MW	1000	1440	2 x 100
Direct voltage, kV	±400	±400	±13
Converters per station	2	6	2 + 2
Direct voltage per converter, kV	400	133	26
Direct current, A	1250	1800	3930
Reactive power supply	Capacitors Power generator	Capacitors	Capacitors
Converter station location and AC grid voltage	Coal Creek, 235 kV Dickinson, 350 kV	Celilo, 230 kV Sylmar, 230 kV	Rapid City, South Dakota, USA, 230 kV both sides
Length of overhead DC line	687 km	1360 km	Back-to-back
Cable arrangement	-	-	-
Cable route length, km	-	-	-
Grounding of the DC circuit	For full current in two ground electrode stations (intermittent)	For full current in one ground and one sea electrode station (intermittent)	Midpoint grounded no ground current
AC grids at both ends	Synchronous	Synchronous	Asynchronous
Control	Constant power, damping control	Constant power in either direction and small signal modulation	Power Control, emergency power control, voltage control
Emergency change of power flow	-	On manual or automatic order to preset values	-
Main supplier of converter equipment	ABB	ABB	ABB

Europe



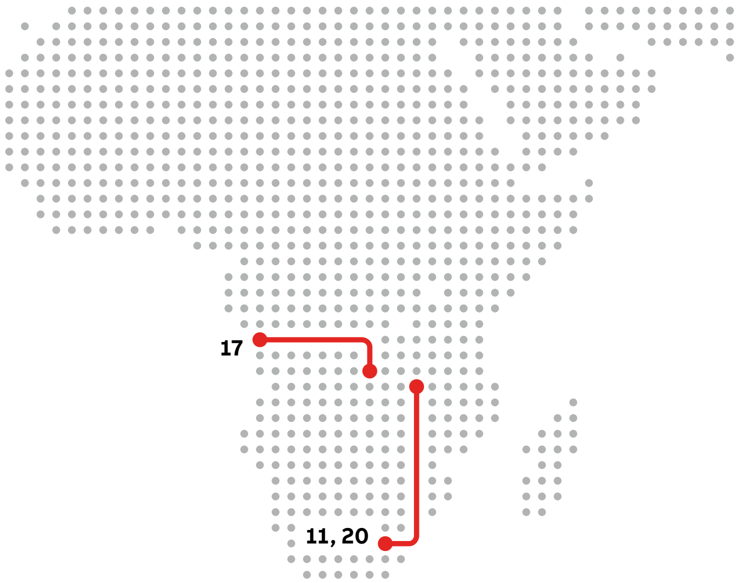
Scheme	3. Skagerrak 1 & 2	10. Skagerrak 1 & 2	18. Skagerrak 3	16. Fenno-Skan I
Commissioning year	1976 - 77	1976 - 77	1993	1989
Commissioning year upgrade	1991	2007	2014	2012
Type of upgrade	Valve control and valve electronics replacement.	Control and protection upgrade	Control and protection upgrade. Bipolar functio-nality with new pole	Control and protection upgrade. Bipolar functio-nality with new pole
Upgrade scope	Valves	Control and protection upgrade	Control and Protection system upgrade	Control and protection system upgrade
Owner/Original customer	Statkraft, Norway and Elsam, Denmark	Statkraft, Norway and Elsam, Denmark	Statnett, Norway and Elsam, Denmark	Statens Vattenfallsverk, Sweden and Imatran Voima Oy, Finland
Main reason for choosing HVDC system	Interconnecting grids, Sea crossing		Interconnecting grids, Sea crossing	Interconnecting grids, Sea crossing
Power transmitted, MW	500		440	500
Direct voltage, kV	±250		350	400
Converters per station	2		1	1
Direct voltage per converter, kV	250		350	400
Direct current, A	1000		1260	1250
Reactive power supply	Capacitors Synchronous condensers		Capacitors Synchronous condensor	Capacitors
Converter station location and AC grid voltage	Kristiansand, 275 kV Tjele, 150 kV		Kristiansand, 300 kV Tjele, 400 kV	Dannebo, 400 kV Rauma, 400 kV
Length of overhead DC line	113 km		113 km	33 km
Cable arrangement	1 cable per pole		1 cable	1 cable
Cable route length, km	127 km		127 km	200 km
Grounding of the DC circuit	For full current in two ground electrode stations		For full current in two ground electrode stations	For full current in two sea electrode stations
AC grids at both ends	Asynchronous		Asynchronous	Synchronous
Control	Constant power in either direction		Constant power in either direction	Constant power, damping control
Emergency change of power flow	On manual or automatic order to preset value		On manual or automatic order to preset value	-
Main supplier of converter equipment	ABB		ABB	ABB

Europe



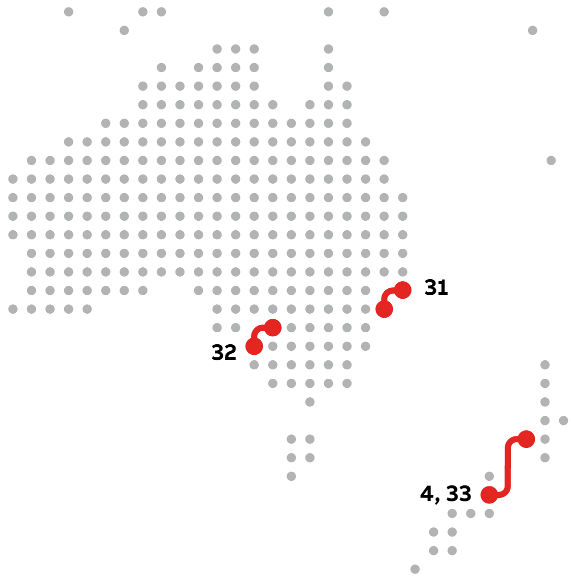
Scheme	25. Kontek	26. Gotland 2&3	29. Kontiskan	30. Baltic cable
Commissioning year	1995	1983/1987	1988/2006	1994
Commissioning year upgrade	2016	2018	2019	2019
Type of upgrade	Control and protection upgrade, Change of capacitors in Bentwisch (Germany). HVDC systemHVDC system	Control and protection upgrade. Valve, Valve cooling	Control and protection upgrade	Control and protection upgrade
Upgrade scope	C&P, valve	C&P, valve	C&P	C&P
Owner/Original customer	Elkraft, Denmark VEAG, Germany	Statens Vattenfallsverk, Sweden	Statens Vattenfallsverk, Sweden and Elsam, Denmark	Baltic Cable AB, Sweden
Main reason for choosing HVDC system	Interconnecting grids, Sea crossing	Interconnecting grids, Island connection, Long sea crossing, frequency control	Interconnecting grids, Sea crossing	Interconnecting grids, Sea crossing
Power transmitted, MW	600	130	550	600
Direct voltage, kV	400	150	285, 300	450
Converters per station	1	1	2	1
Direct voltage per converter, kV	400	150	285, 300	450
Direct current, A	1500	914	1050	1364
Reactive power supply	Capacitors	Capacitors Synchronous condensers	Capacitors	Capacitors
Converter station location and AC grid voltage	Bjæverskov, 400 kV Bentwisch, 400 kV	Västervik, 130 kV Visby, 70 kV	Lindome, 130 kV/400 kV Vester Hassing, 400 kV	Kruseberg, 400 kV Herrenwyk, 380 kV
Length of overhead DC line	-	7 km	61 km	12 km
Cable arrangement	1 cable	1 cable, ground return	2 cables	1 cable
Cable route length, km	170 km (120 km under ground)	96 km	88 km	261 km
Grounding of the DC circuit	For full current in two sea electrodes	For full current in two sea electrode stations	For full current in two sea electrode stations	For full current in two sea electrodes
AC grids at both ends	Asynchronous	Asynchronous	Asynchronous	Asynchronous
Control	Constant power, frequency and damping control	Constant frequency on Gotland	Constant power in either direction	Constant power, frequency and damping control
Emergency change of power flow	On manual or automatic order to preset value	-	On manual or automatic order to preset value	On manual or automatic order to preset value
Main supplier of converter equipment	ABB	ABB	Konti-Skan 1: Areva Konti-Skan 2: ABB	ABB

Africa



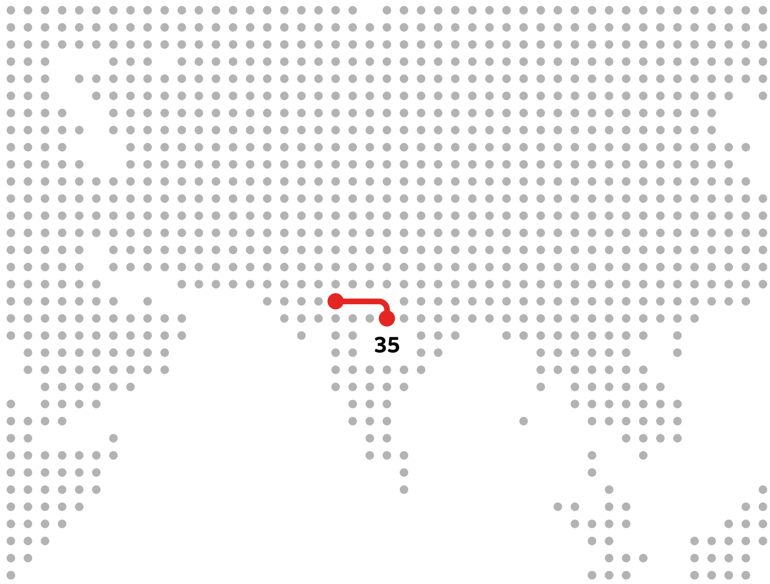
Scheme	11. Cahora Bassa, Apollo	17. Inga-Kolwezi	20. Cahora Bassa, Songo
Commissioning year	1977-1979	1982	1977-1979
Commissioning year upgrade	2008	2013	2013
Type of upgrade	New outdoor valves, AC filters and control and protection system.	Valves, control and protection system and high-voltage apparatus.	Transformers, smoothing reactor and DC current measurement system.
Upgrade scope	C&P, Valve, main circuit	C&P, valves, main circuit	Main circuit
Owner/Original customer	Hidroelectrica de Cahora Bassa, Mocambique and Electricity Supply Commission, South Africa	SNEL, DR Congo	Hidroelectrica de Cahora Bassa, Mocambique and Electricity Supply Commission, South Africa
Main reason for choosing HVDC system	Connecting remote generation, Interconnecting grids	Connecting remote generation, Interconnecting grids	Connecting remote generation, Interconnecting grids
Power transmitted, MW	1930	560	1930
Direct voltage, kV	±533	±500	±533
Converters per station	8	2	8
Direct voltage per converter, kV	133	500	133
Direct current, A	1800	560	1800
Reactive power supply	Capacitors	Capacitors Synchronous condensers	Capacitors
Converter station location and AC grid voltage	Songo, 220 kV Apollo, 275 kV	Inga (Zaire River), 220 kV Kolwezi (Shaba), 220 kV	Songo, 220 kV Apollo, 275 kV
Length of overhead DC line	1420 km	1700 km	1420 km
Cable arrangement	-	-	-
Cable route length, km	-	-	-
Grounding of the DC circuit	For full current in two ground electrodes	For full current in two ground electrode stations	For full current in two ground electrodes
AC grids at both ends	Asynchronous	Asynchronous	Asynchronous
Control	Constant power	Constant power or constant frequency in Shaba	Constant power
Emergency change of power flow	-	-	-
Main supplier of converter equipment	ABB/Siemens/AEG	ABB	ABB/Siemens/AEG

Australia and Oceania



Scheme	4. New Zealand DC hybrid link	31. Directlink	32. Murraylink	33. New Zealand
Commissioning year	1965	2000	2002	1991-1992
Commissioning year upgrade	1992	2019	2020	2020
Type of upgrade	Paralleling of mercury-arc poles. Total control replacement.	3 x 60	220	Valve upgrade
Upgrade scope	-	Control and protection system, MACH	Control and protection system, MACH	Valve
Owner/Original customer	Paralleling of mercury-arc poles. Total control replacement.	APA Group Australia/Trans-Energy, USA and North Power, AUSTRALIA	APA Group Australia /TransEnergie US, USA	Trans Power New Zealand Ltd., New Zealand
Main reason for choosing HVDC system	Interconnecting grids, Sea crossing	Interconnecting grids, energy trade, environment, controllability	Interconnecting grids, energy trade, environment, controllability	Interconnecting grids, Sea crossing
Power transmitted, MW	560	3 x 60	220	560
Direct voltage, kV	±250	±80	±150	-350
Converters per station	2	3	1	1
Direct voltage per converter, kV	250	160	±150	350
Direct current, A	1600	375	739	1600
Reactive power supply	Capacitors Synchronous condensor	+90/-165	+140 / -150	Capacitors Synchronous condensor
Converter station location and AC grid voltage	Benmore, 220 kV Haywards, 220 kV	Terranora, 110 kV Mullumbimby, 132 kV	Berri, 132 kV Red Cliffs, 220 kV	Benmore, 220 kV Haywards, 220 kV
Length of overhead DC line	575 km	-	-	575 km
Cable arrangement	2 cables + 1 spare	Bipolar	Bipolar	2 cables + 1 spare
Cable route length, km	42 km	65	180	42 km
Grounding of the DC circuit	For full current in one ground and one sea electrode station	-	-	For full current in one ground and one sea electrode station
AC grids at both ends	Asynchronous	Asynchronous (when delivered)	Synchronous	Asynchronous
Control	Constant power, frequency and damping control	Active and reactive power, AC voltage	Active power and AC voltage	Constant power, frequency and damping control
Emergency change of power flow	Frequency control of isolated Wellington area	-	Runback implemented	Frequency control of isolated Wellington area
Main supplier of converter equipment	ABB	ABB	ABB	ABB

Asia



Scheme	**35. Rihand - Dadri**
Commissioning year	**1990**
Commissioning year upgrade	**2021**
Type of upgrade	**-**
Upgrade scope	**Control & protection system, valve cooling system and TCUs**
Owner/Original customer	**Powergrid Corporation of India Limited**
Main reason for choosing HVDC system	Connecting remote generation, Stability
Power transmitted, MW	1568
Direct voltage, kV	±500
Converters per station	2
Direct voltage per converter, kV	500
Direct current, A	1568
Reactive power supply	Capacitors
Converter station location and AC grid voltage	Rihand, 400 kV Dadri, 400 kV
Length of overhead DC line	814 km
Cable arrangement	-
Cable route length, km	-
Grounding of the DC circuit	For full current in two ground electrode stations (intermittent)
AC grids at both ends	Synchronous
Control	Constant power, damping control
Emergency change of power flow	On manual or automatic order
Main supplier of converter equipment	BHEL, India, main contractor ABB subcontractor to BHEL under licence agreement

Index

Notes

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