
REFERENCE LIST

HVDC Care upgrades

Extending lifetime



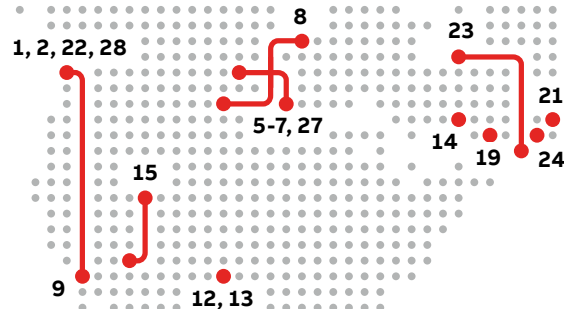
HVDC Care upgrades

Projects worldwide

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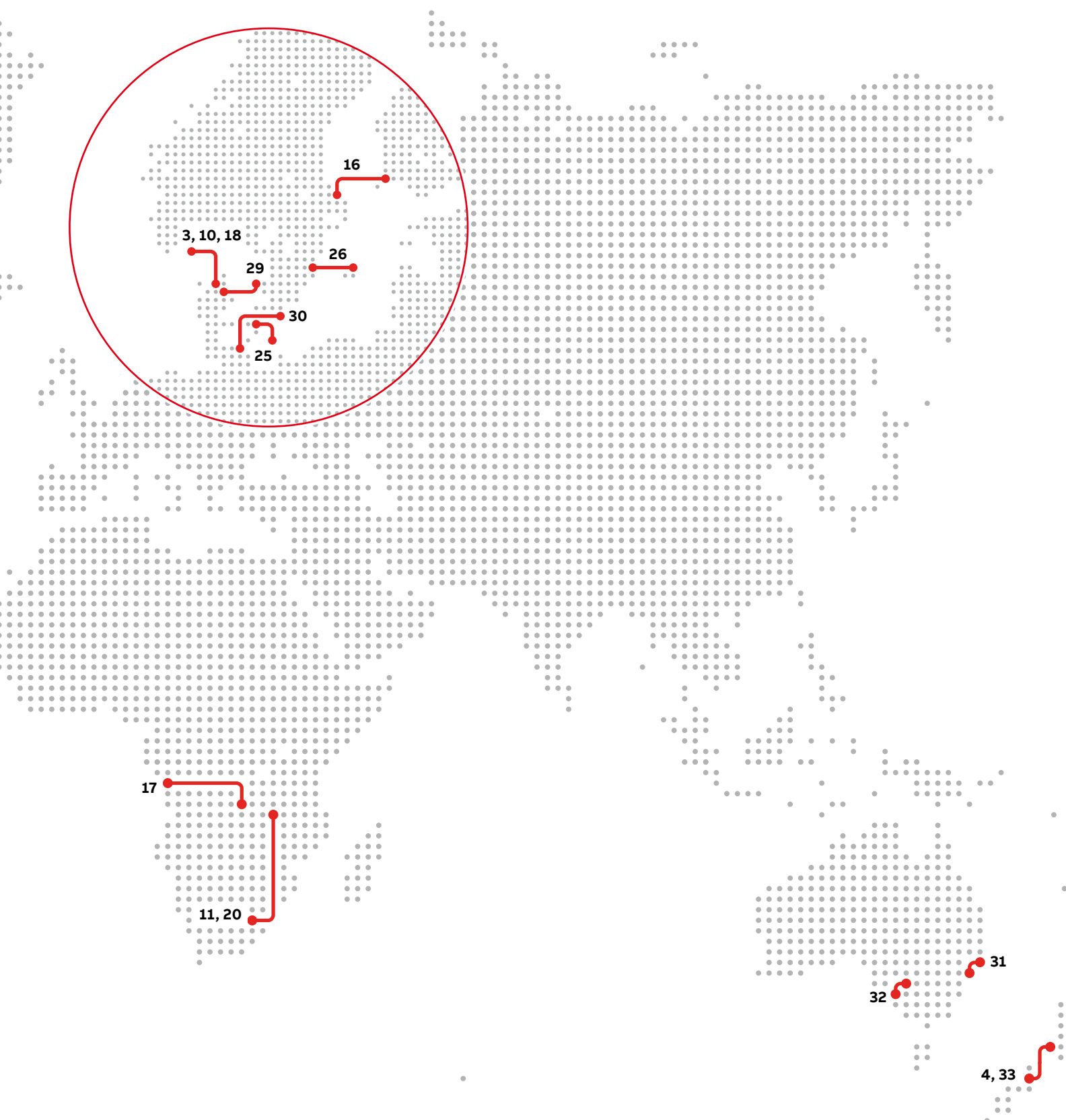
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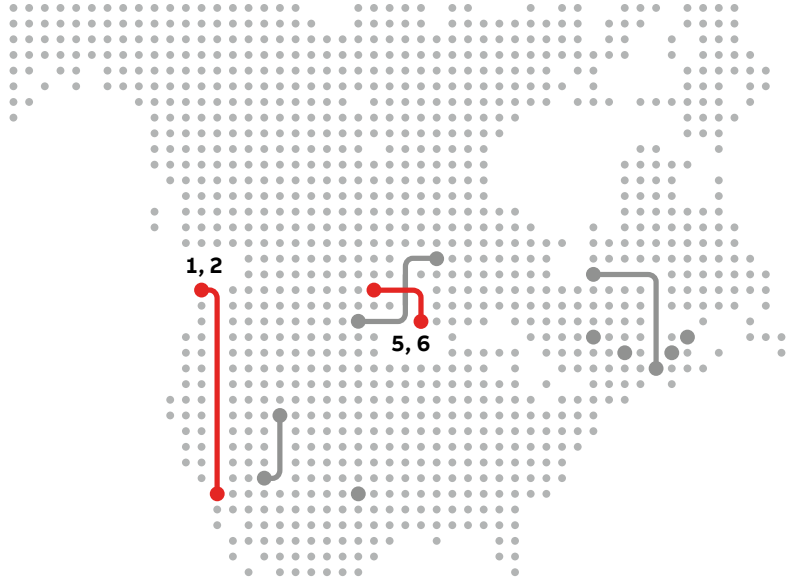
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For more information about the
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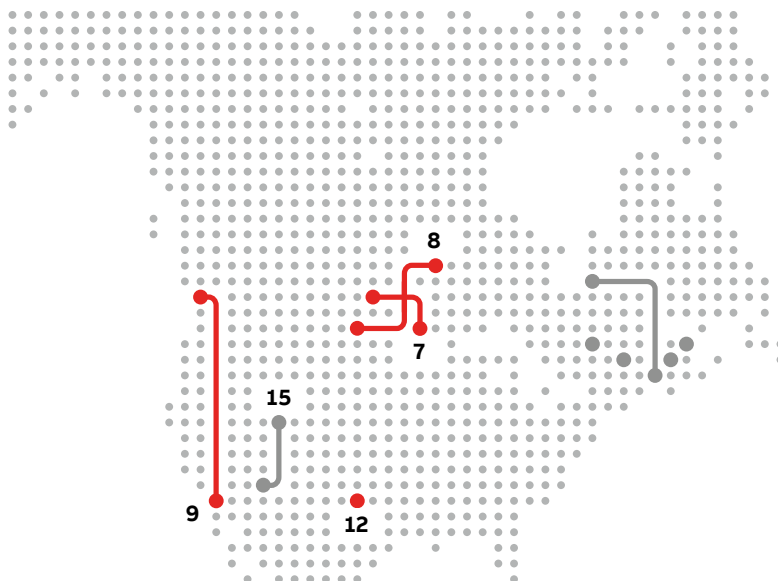


North America



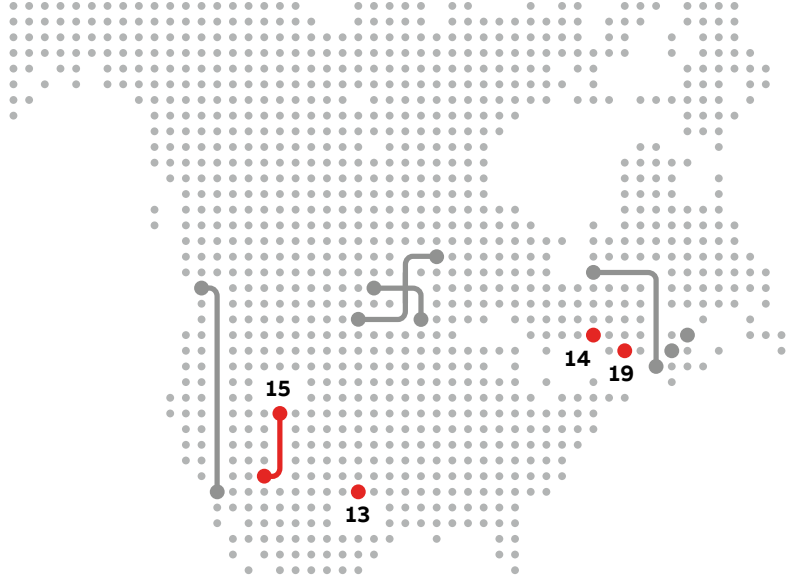
Scheme	1. Pacific Intertie	2. Pacific Intertie	5. CU-Project I	6. CU-Project II
Original Plant Commissioning year	1970	1970	1978	1978
Upgrade	1985	1989	2001	2002
Power	2000	1100	1000	1000
Scope	Voltage upgrade 400-500 kV.	Adding of parallel convertes at Sylmar & Celilo stations.	Valve control and valve electronics replacement	Voltage upgrade ± 10 kV (2.5 %), + 25 MW
Power Company	Bonneville Power Administration The Department of Water and Power of the City of Los Angeles, CA, USA	Bonneville Power Administration The Department of Water and Power of the City of Los Angeles, CA, USA	Great River Energy, MN, USA	Great River Energy, MN, USA
Owner/Original customer/ Country	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	
Power transmitted, MW	2000	3100	1000	
Direct voltage, kV	± 500	± 500	± 400	
Converters per station	4x2	5x2	2	
Direct voltage per converter, kV	133+100	133+100+500	400	
Direct current, A	2000	3100	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	-	-	-	
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/GE	ABB/GE	ABB	

North America



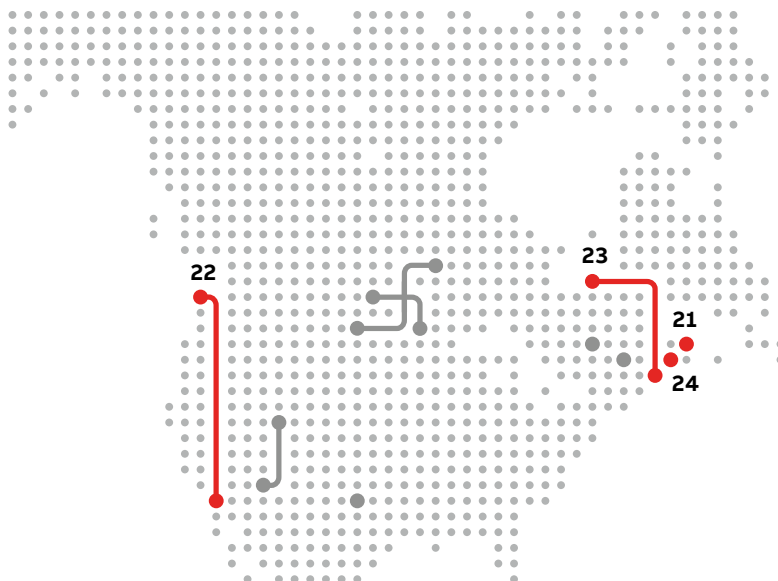
Scheme	7. CU-Project III	8. Square Butte HVDC	9. Pacific Intertie. Sylmar	12. Blackwater I
Original Plant Commissioning year	1978	1977	1970	1985
Upgrade	2004	2004	2004	2008
Power	1025	500	3100	200
Scope	Control and protection upgrade	Control and protection upgrade	Re-building of the Sylmar East converter station from 1100 to 3100 MW	Valve cooling
Power Company	Great River Energy, MN, USA	Minnkota Power Coop., Grand Forks, ND, Minnesota Power, Duluth, MN, USA	The Department of Water and Power of the City of Los Angeles, CA, USA	Public Service Company of New Mexico (PNM), USA
Owner/Original customer/ Country	CPA, USA and UPA, USA	Minnesota Power's/Minnkota Power Cooperative's and Minnesota Power's/GE, USA	The Department of Water and Power of the City of Los Angeles, USA	Public Service Company of New Mexico, USA
Power transmitted, MW	1000	500	3100	200
Direct voltage, kV	±400	±250	500	56.8
Converters per station	2	2	2	1+1
Direct voltage per converter, kV	400	±250	500	56.8
Direct current, A	1250	1000	3100	3600
Reactive power supply	Capacitors Power generator	Capacitors	Capacitors	Capacitors
Converter station location and AC grid voltage	Coal Creek, 235 kV Dickinson, 350 kV	Center, 230 kV Arrowhead, 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	-	-	-	-
Grounding of the DC circuit	For full current in two ground electrode stations (intermittent)	One ground electrode at each station	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/GE	ABB

North America



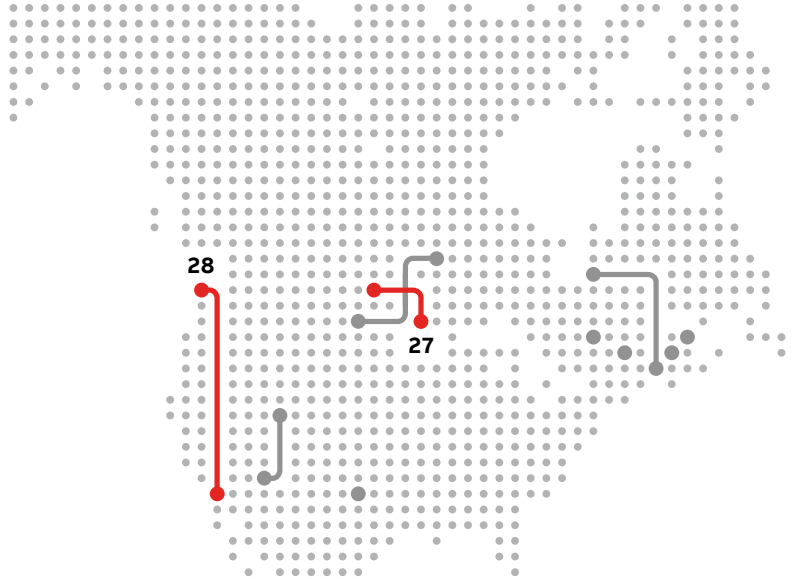
Scheme	13. Blackwater II	14. Châteauguay	15. Intermountain Power Project	19. Highgate
Original Plant Commissioning year	1978	1984	1986	1985
Upgrade	2009	2009	2010	2012
Power	200	2 x 500	2400	200
Scope	Control and protection system upgrade	Control and protection system upgrade	Control and protection system upgrade, additional AC filters, cooling system and power upgrade	Valve, valve cooling and control and protection system upgrade
Power Company	Public Service Company of New Mexico (PNM), USA	Hydro-Québec, Canada	Intermountain Power Agency with Los Angeles Department of Water and Power, USA	Vermont Electrical Power Company VELCO, USA
Owner/Original customer/ Country	Public Service Company of New Mexico, USA	Hydro-Quebec, Quebec, Canada	Intermountain Power Agency, USA. Agent: The Department of Water and Power of the City Los Angeles, USA	Vermont Electric Power Company Inc., USA
Power transmitted, MW	200	2 x 500	1920	200
Direct voltage, kV	56.8	2 x 140.6	±500	57
Converters per station	1+1	2 + 2	2	1+1
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	-	-		
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 reduction triggered by AC-signal
Main supplier of converter equipment	ABB	ABB/Siemens	ABB	ABB

North America



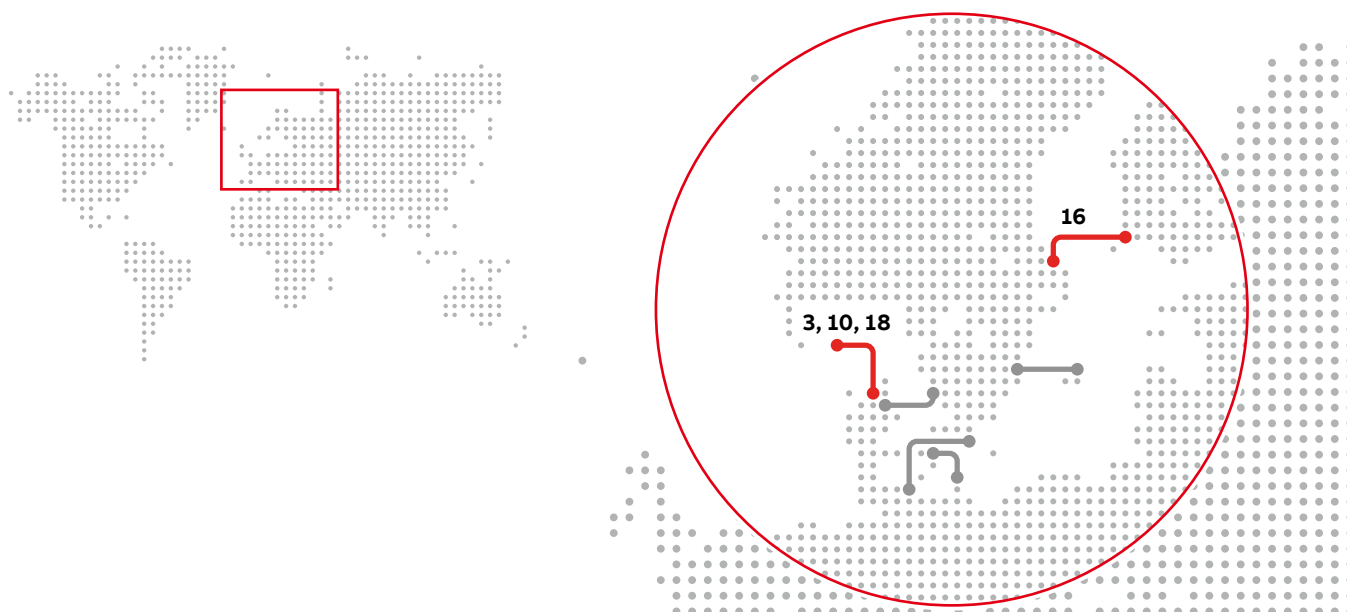
Scheme	21. Eel River	22. Pacific Intertie. Celilo	23. Québec - New England	24. Madawaska
Original Plant Commissioning year	1972	1970	1990	1985
Upgrade	2014	2016	2015, 2016	2016
Power	350	3800	2000	
Scope	Converter valves, control and protection system, DC apparatus and cooling systems	Re-building of the Celilo converter station from 3100 MW to 3800 MW	Control and protection system MACH	Control and protection system, MACH. Valves and valve cooling system
Power Company	New Brunswick Power (NB), Canada	Bonneville Power Administration (BPA), USA	Hydro-Québec, Canada National Grid, USA	Hydro-Québec, Canada
Owner/Original customer/ Country	NB Power	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
Power transmitted, MW	350	2 x 500	2000 (Multiterminal)	350
Direct voltage, kV	80	2 x 140.6	±450	130
Converters per station	2+2	2 + 2	2	1+1
Direct voltage per converter, kV	80	140.6	450	130
Direct current, A	2188	2 x 3600	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, 500 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	-	-	-	-
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	Synchronous NB, Asynchronous HQ	Synchronous	HQ synchronous NEH asynchronous	Asynchronous
Control	Constant Power, Frequency Control	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



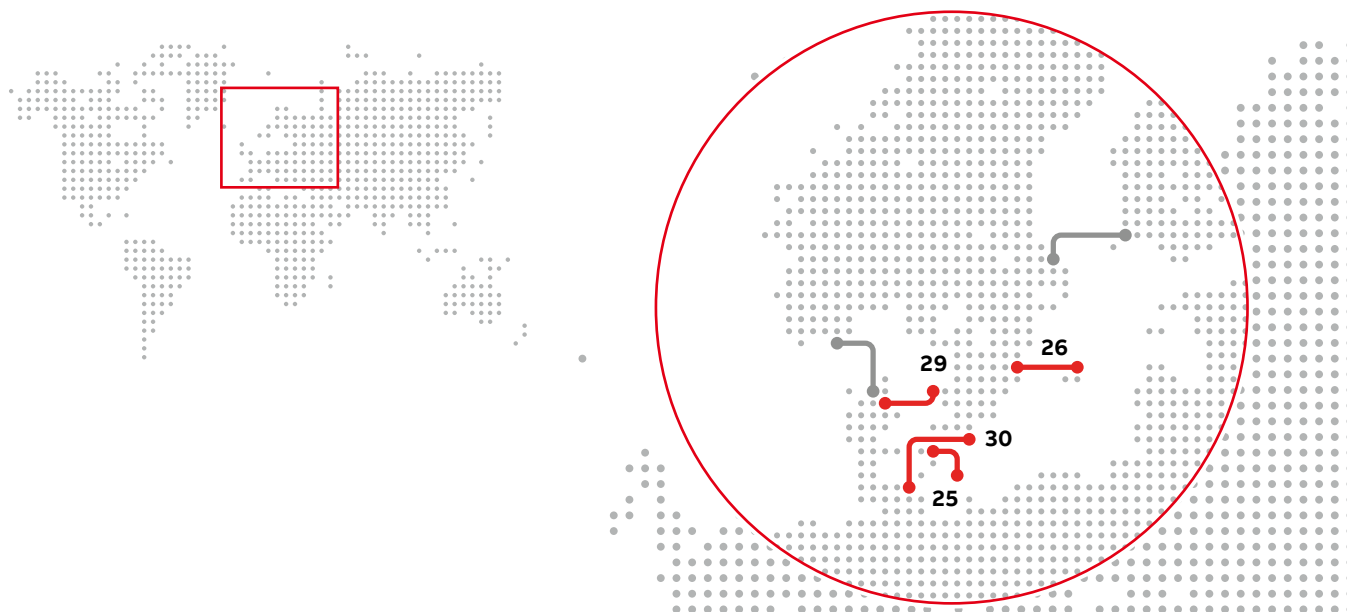
Scheme	27. CU-Project III	28. Pacific Intertie. Sylmar
Original Plant	1978	1970
Commissioning year		
Upgrade	2019	2019
Power	1025	3224
Scope	Thyristor valves Cooling system	AC and DC filters, shunt reactors, measurement, auxiliary equipment, Control and protection system, MACH.
Power Company	Great River Energy, MN, USA	The Department of Water and Power of the City of Los Angeles, CA, USA
Owner/Original customer/ Country	CPA, USA and UPA, USA	The Department of Water and Power of the City of Los Angeles, CA, USA
Power transmitted, MW	1000	3224
Direct voltage, kV	±400	±500
Converters per station	2	2
Direct voltage per converter, kV	400	±500
Direct current, A	1250	3220
Reactive power supply	Capacitors Power generator	Capacitors
Converter station location and AC grid voltage	Coal Creek, 235 kV Dickinson, 350 kV	Sylmar 230 kV
Length of overhead DC line	687 km	1360 km
Cable arrangement	-	-
Cable route length	-	-
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)
AC grids at both ends	Synchronous	Synchronous
Control	Constant power, damping control	Constant power in either direction and small signal modulation
Emergency change of power flow	-	On manual or automatic order to preset values
Main supplier of converter equipment	ABB	ABB

Europe



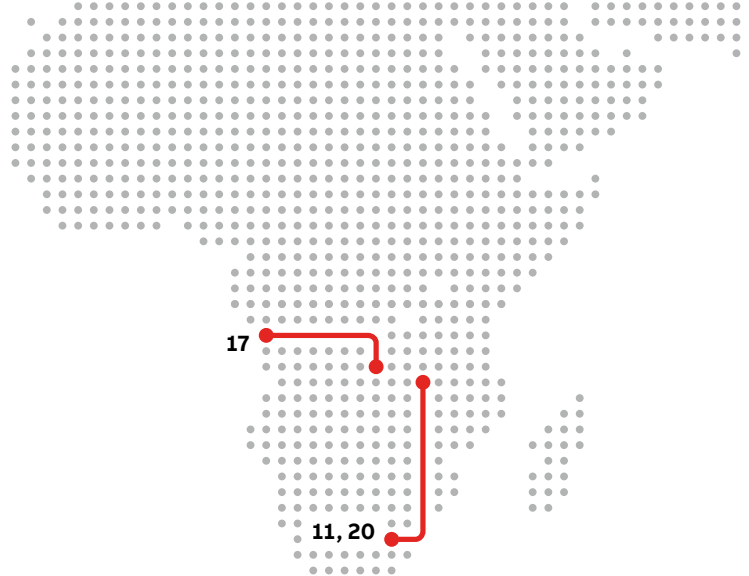
Scheme	3. Skagerrak 1 & 2	10. Skagerrak 1 & 2	18. Skagerrak 3	16. Fenno-Skan I
Original Plant Commissioning year	1976 - 77	1976 - 77	1993	1989
Upgrade	1991	2007	2015	2012
Power	500	2 x 250	440	550
Scope	Valve control and valve electronics replacement	Control and protection upgrade	Control and Protection system upgrade	Control and protection system upgrade
Power Company	Elsam, Denmark, Statkraft, Norway	Energinet.dk, Denmark, Statnett, Norway	Energinet.dk, Denmark, Statnett, Norway	Svenska Kraftnät, Sweden Fingrid, Finland
Owner/Original customer/ Country		Statkraft, Norway and Elsam, Denmark		Statens Vattenfallsverk, Sweden and Imatran Voima Oy, Finland
Power transmitted, MW		500		500
Direct voltage, kV		±250		400
Converters per station		2		1
Direct voltage per converter, kV		250		400
Direct current, A		1000		1250
Reactive power supply		Capacitors Synchronous condensers		Capacitors
Converter station location and AC grid voltage		Kristiansand, 275 kV Tjele, 150 kV		Dannebo, 400 kV Rauma, 400 kV
Length of overhead DC line		113 km		33 km
Cable arrangement		1 cable per pole		1 cable
Cable route length		127 km		200 km
Grounding of the DC circuit		For full current in two ground electrode stations		For full current in two sea electrode stations
AC grids at both ends		Asynchronous		Synchronous
Control		Constant power in either direction		Constant power, damping control
Emergency change of power flow		On manual or automatic order to preset value		-
Main supplier of converter equipment		ABB		ABB

Europe



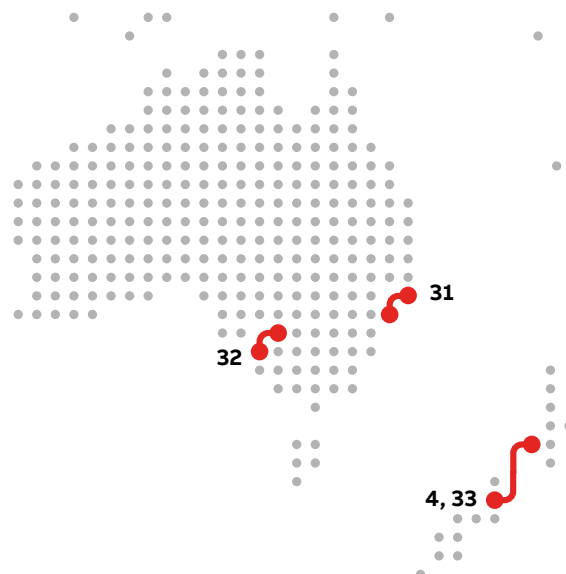
Scheme	25. Kontek	26. Gotland	29. Kontiskan	30. Baltic cable
Original Plant Commissioning year	1995	1954	1988/2006* *2006 is Non-abb stations	1994
Upgrade	2016	2018	2019	2019
Power	500	260	600	600
Scope	Control and protection system, MACH. Valves and valve cooling system	Control and protection system, MACH	Control and protection system, MACH	Control and protection system, MACH
Power Company	Energinet.dk, Denmark, 50 Hertz, Germany	Vattenfall Eldistribution AB	Svenska Kraftnät and Energinet Denmark	Baltic Cable AB
Owner/Original customer/ Country	Elkraft, Denmark VEAG, Germany	Statens Vattenfallsverk, Sweden	Statens Vattenfallsverk, Sweden and Elsam, Denmark	Baltic Cable AB, Sweden
Power transmitted, MW	600	(20) + 10	300	600
Direct voltage, kV	400	(100) + 50	285	450
Converters per station	1	(2) + 1	1	1
Direct voltage per converter, kV	400	50	285	450
Direct current, A	1500	200	1050	1364
Reactive power supply	Capacitors	Capacitors Synchronous condensers	Capacitors	Capacitors
Converter station location and AC grid voltage	Bjæverskov, 400 kV Bentwisch, 400 kV	Sylmar 230 kV	Lindome, 130 kV Vester Hassing, 400 kV	Kruseberg, 400 kV Herrenwyk, 380 kV
Length of overhead DC line -	-	-	61 km	12 km
Cable arrangement	1 cable	1 cable, ground return	1 cable	1 cable
Cable route length	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	ABB	ABB

Africa



Scheme	11. Cahora Bassa, Apollo	17. Inga-Kolwezi	20. Cahora Bassa, Songo
Original Plant Commissioning year	1977-79	1982	1977
Upgrade	2008	2015	2015
Power	1920	500	1920
Scope	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
Power Company	ESKOM, South Africa	Société National d'Électricité, Democratic Republic of Congo	Hidroeléctrica de Cahora Bassa, Mozambique
Owner/Original customer/Country	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
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	-	-	-
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
Original Plant Commissioning year	1965	2000	2002	1992
Upgrade	1992	2019	2020	2020
Power	2 x 300	3 x 60	220	560
Scope	Paralleling of mercury-arc poles. Total control replacement	Control and protection system, MACH	Control and protection system, MACH	Valve and Valve control Upgrade
Power Company	Trans Power New Zealand Ltd., Wellington, New Zealand	APA Group	APA Group	Trans Power New Zealand Ltd., Wellington, New Zealand
Owner/Original customer/Country	Trans Power New Zealand Ltd., New Zealand	APA Group Australia/ TransEnergy, USA and North Power, Australia	APA Group Australia/ TransEnergie US, USA	Trans Power New Zealand Ltd., New Zealand
Power transmitted, MW	560	3 x 60	220	560
Direct voltage, kV	-350	±80	±150	-350
Converters per station	1	3	1	1
Direct voltage per converter, kV	350	160	300	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	42 km	59	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



Notes

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Notes

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ABB AB

Grid Systems - HVDC

SE-771 80 Ludvika

Sweden

Phone: +46 240 78 20 00

abb.com/hvdc



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