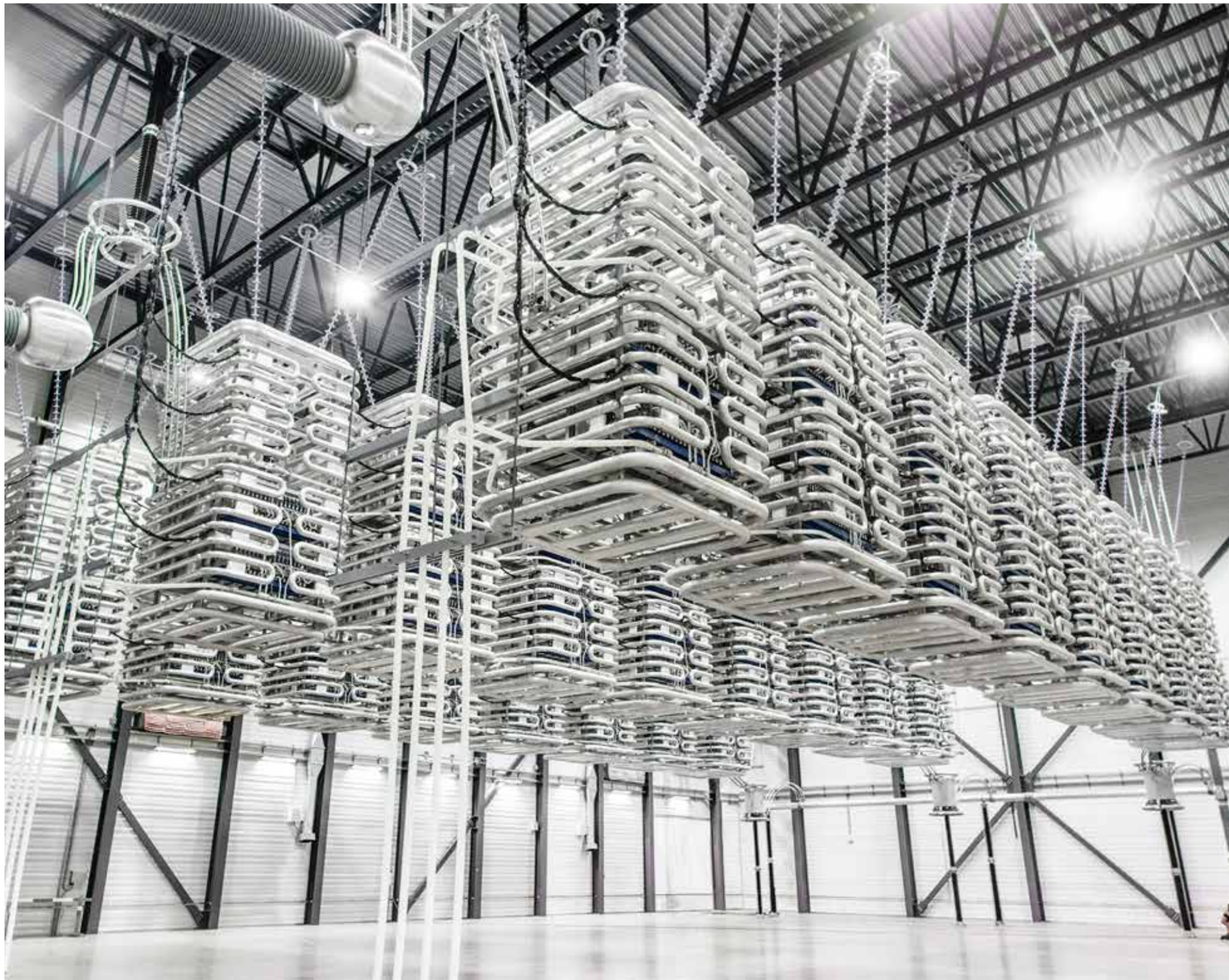
REFERENCE LIST

HVDC Light®

The original VSC technology



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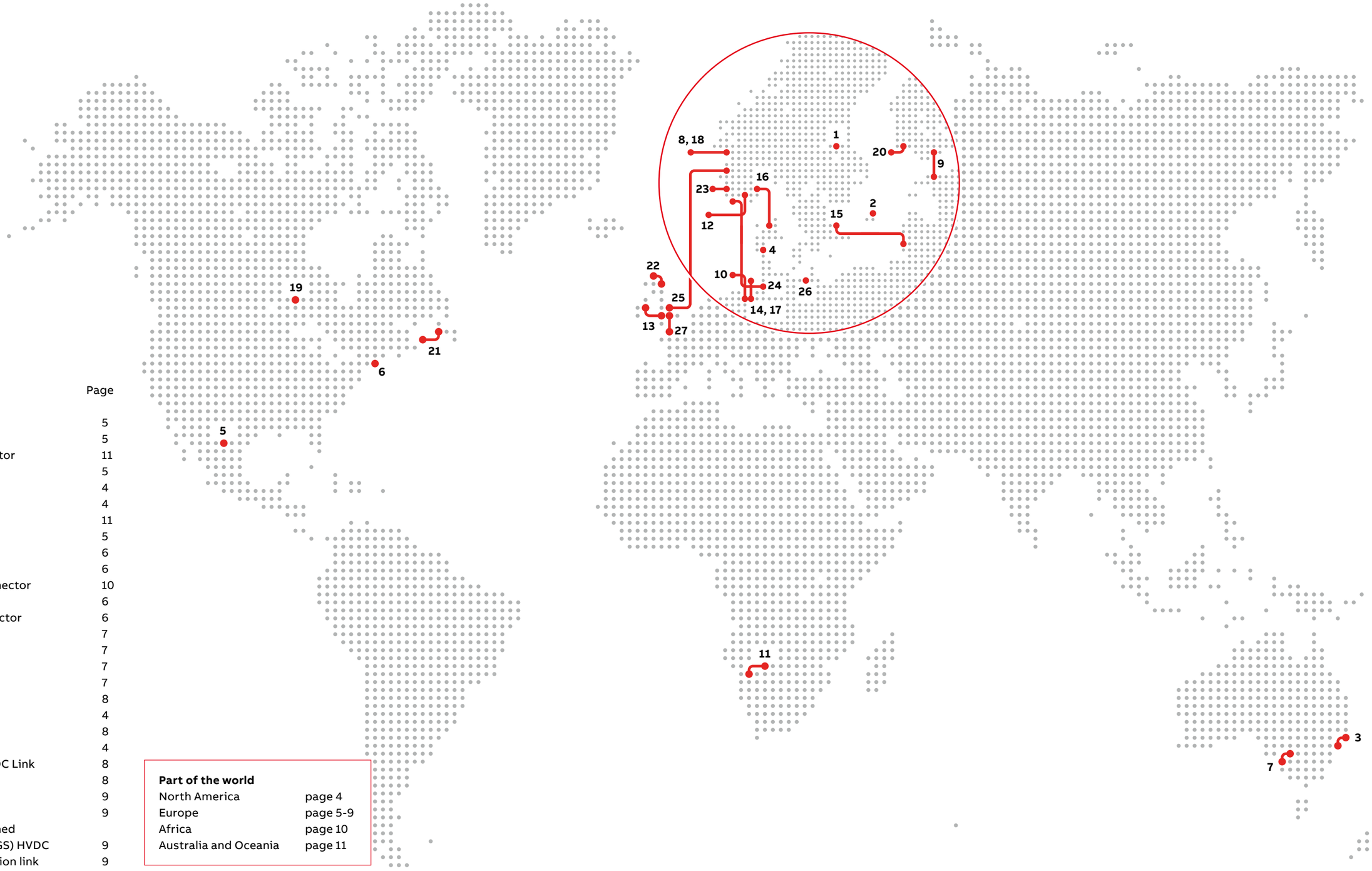
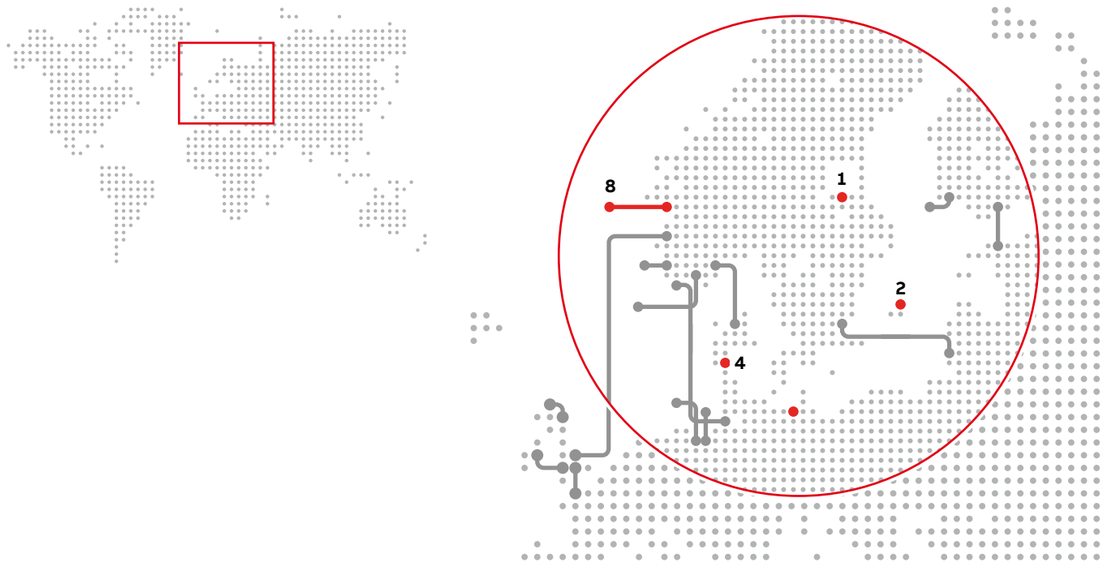


North America

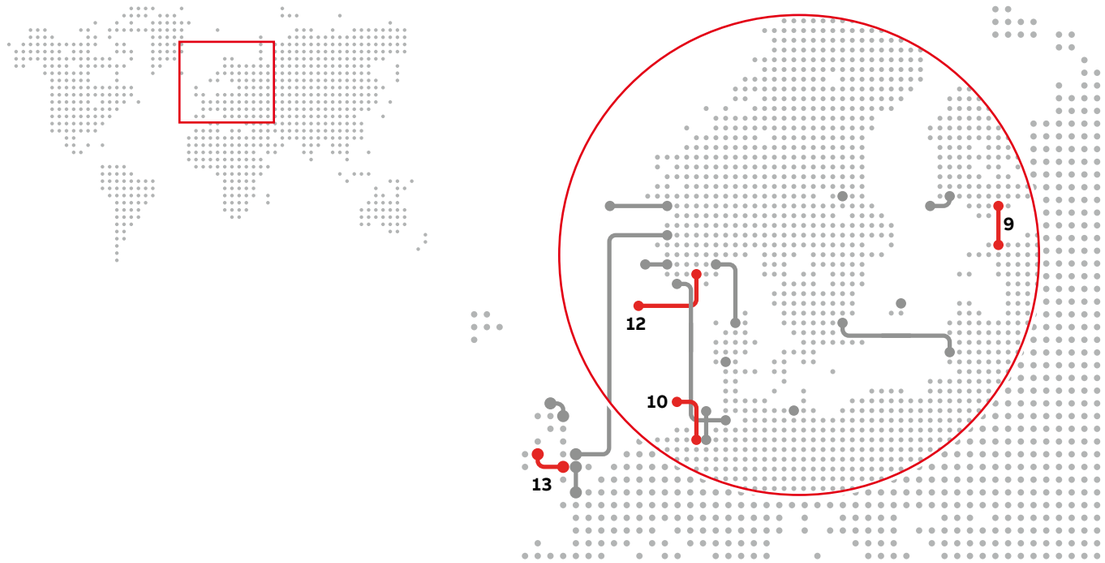
Scheme	5. Eagle Pass	6. Cross Sound Cable	19. Mackinac	21. Maritime Link
Commissioning year	2000	2002	2014	2017
Owner/Original customer/Country	AEP, USA	TransEnergie US, USA	American Transmission Company (ATC), USA	NSP Maritime Link Inc, NL, Canada
Main reason for choosing VSC system	Interconnecting grids, grid stability, energy trade	City center infeed, energy trade, controllability	DC links in AC grids, weak networks, grid stability	Connecting remote generation, interconnecting grids, stabilizing features
Power Transmitted, MW	36	330	200	2 X 250
Direct voltage, kV	±15.9	±150	±71	±200
Direct voltage per converter, kV	31.8	300	142	400
Direct current, A	-	1200	1408	1250
Reactive power range, MVAr	±36	±150	±100	±125
Converter station location and AC grid voltage	Eagle Pass, 138 kV	New Haven, 345 kV Shoreham, 138 kV	Mackinac, 138 kV, both sides	Bottom Brook 230 kV Woodbine 345 kV
Cable route length, km	0 (Back to Back)	40	0 (Back to Back)	180
Length of overhead DC line, km	-	-	-	187
Length of DC submarine cable. km	-	2 x 40	-	170
Length of DC underground cable, km	-	-	-	1
System arrangement	-	Bipole	-	Bipole with ground electrodes
AC grids at both ends	Asynchronous	Synchronous	Synchronous	Asynchronous
Control	Active and reactive power, AC voltage	Active and reactive power, AC voltage	Active and reactive power, STATCOM mode at outage of one converter, AC line emulation, islanded network control	Active and reactive power, AC voltage, frequency control, damping control
Emergency change of power flow	Runback implemented	Runback implemented	Automatic runback, Black start	Automatic runback, Black start

Europe



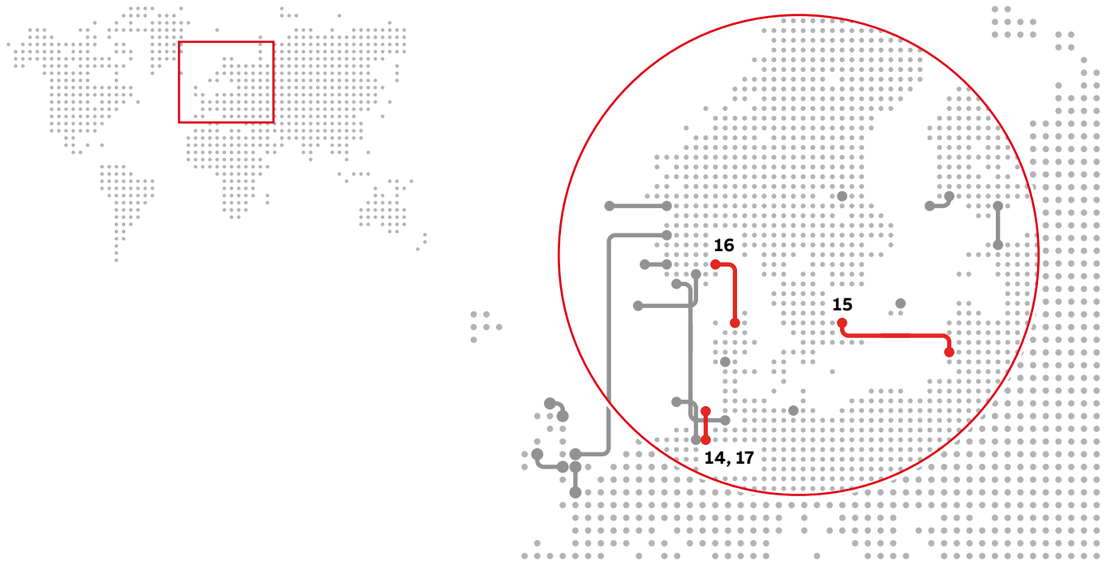
Scheme	1. Hällsjön	2. Gotland	4. Tjaereborg	8. Troll A 1&2
Commissioning year	1997	1999	2000	2005
Owner/Original customer/Country	VB Elnät, Sweden	GEAB, Sweden	Eltra, Denmark	Statoil, Norway
Main reason for choosing VSC system	Test installation	Interconnecting grids, environmental, controllability	Offshore wind connections, environment, controllability	Power from shore, environment, CO2-tax, compactness of converter on platform
Power Transmitted, MW	3	50	7.2	2 x 44
Direct voltage, kV	±10	±80	±9	±60
Direct voltage per converter, kV	20	160	18	120
Direct current, A	150	360	358	400
Reactive power range, MVAr	±3	+50/-55	-3/+4	Troll A: NA Kollsnes: +24/-20
Converter station location and AC grid voltage	Hällsjön, 10 kV Grängesberg, 10 kV	Näs, 77 kV Bäcks, 77 kV	Enge, 10.5 kV Tjaereborg, 10.5 kV	Troll A, 56 kV Kollsnes, 132 kV
Cable route length, km	0.2	70	4.3	70
Length of overhead DC line, km	10	-	-	-
Length of DC submarine cable. km	-	-	4 x 4.3	70
Length of DC land cables	-	2 x 70	-	-
System arrangement	Bipole with metallic neutral? or sym. monopole?	Bipole	Bipole	Bipole
AC grids at both ends	Synchronous	Synchronous	Synchronous / asynchronous	-
Control	Active and reactive power	Active and reactive power, AC voltage	Active and reactive power, AC voltage, islanded network control	Motordrive and VHV motor, AC voltage, islanded network control
Emergency change of power flow	-	-	-	-

Europe



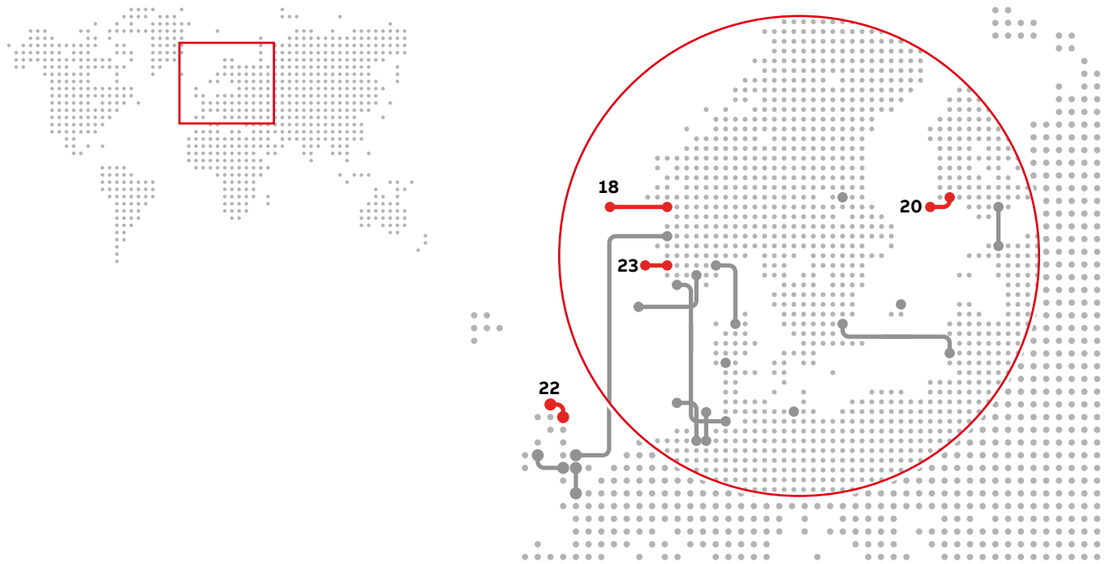
Scheme	9. Estlink	10. BorWin1	12. Valhall	13. East West Interconnector
Commissioning year	2006	2012	2011	2013
Owner/Original customer/Country	Nordic Energy Link AS, Estonia	TenneT/E.ON, Germany	BP, Norway	Eirgrid, Ireland
Main reason for choosing VSC system	Interconnecting grids, energy trade, controllability, black start	Offshore wind connections	Power from shore, environment, CO2-tax, compactness of converter on platform	Interconnecting grids, energy trade, AC voltage control, black start
Power Transmitted, MW	350	400	78	500
Direct voltage, kV	±150	±150	150	±200
Direct voltage per converter, kV	300	300	150	400
Direct current, A	1230	1200	573	1250
Reactive power range, MVAr	±125	±150	Valhall:-10/+48, 110 transient Lista: ±50	± 150
Converter station location and AC grid voltage	Espoo, 400 kV Harku, 330 kV	Diele, 380 kV BorWin alpha, 170 kV	Lista, 300 kV Valhall, 11 kV	Woodland, 400 kV Shotton, 400 kV
Cable route length, km	105	200	292	261
Length of DC underground cable, km	2 x 31	2 x 75	-	2 x 75
Length of DC submarine cable, km	2 x 74	2 x 125	292	2 x 186
System arrangement	Bipole	Bipole	Asym. monopole with metallic return	Bipole
AC grids at both ends	Asynchronous	Asynchronous	50 Hz, 60 Hz isolated	50 Hz, Asynchronous
Control	Active and reactive power, AC voltage, frequency control, damping control	Active and reactive power, AC voltage, islanded network control	AC voltage, islanded network control	Active and reactive power, AC voltage, frequency control, damping control
Emergency change of power flow	Runback implemented black start	Runback implemented	-	Black start

Europe



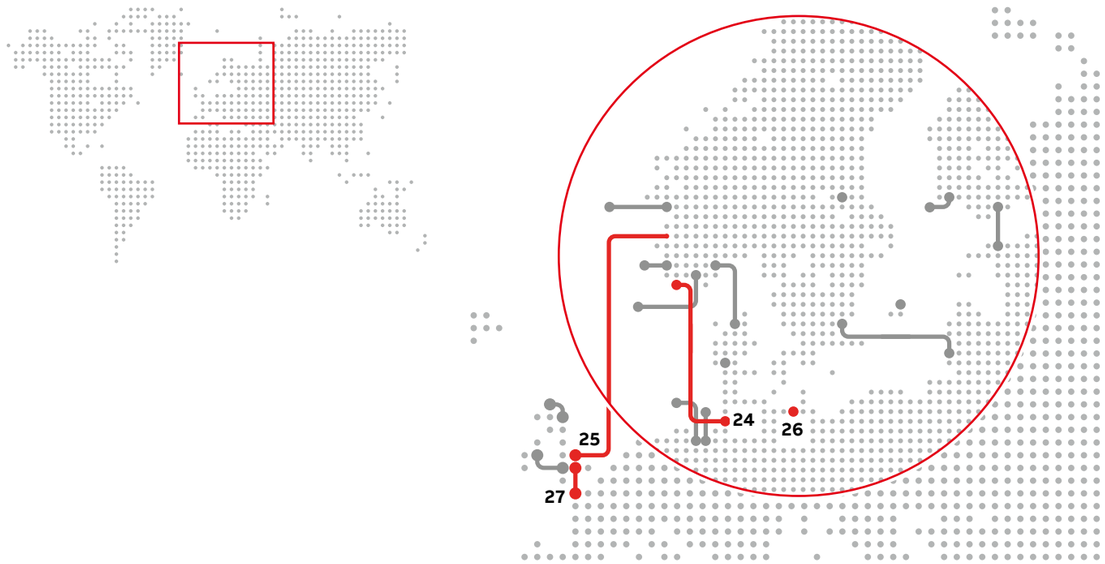
Scheme	14. DolWin1	15. Nordbalt	16. Skagerrak 4	17. DolWin2
Commissioning year	2015	2015	2014	2017
Owner/Original customer/Country	TenneT/transpower offshore, Germany	Svenska Kraftnät, Sweden Litgrid Turtas AB, Lithuania	Statnett, Norway Energinet.dk, Denmark	TenneT, Germany
Main reason for choosing VSC system	Offshore wind connection, length of cables	Interconnecting grids, prepare for future DC grid, black start	Interconnecting grids, grid stability, black start	Offshore wind connection, length of cables
Power Transmitted, MW	800	700	700	900
Direct voltage, kV	±320	±300	500	±320
Direct voltage per converter, kV	640	600	500	640
Direct current, A	1250	1250	1430	1406
Reactive power range, MVAr	±260	±350	±80	-300/+380
Converter station location and AC grid voltage	Dörpen, 380 kV DolWin alpha, 155 kV	Klaipeda, 330 kV Nybro, 400 kV	Kristiansand, 400 kV Tjele, 400 kV	Dörpen, 380 kV DolWin beta, 155 kV
Cable route length, km	165	450	244	135
Lenth of DC land cable route, km	-	40 (Swedish side) 10 (Lithuanian side)	104	-
Length of DC underground cable, km	2 x 90	-	-	2 x 90
Length of DC submarine cable, km	2 x 75	400	140	2 x 45
System arrangement	Bipole	Sym. monopole, prepared for multi-terminal	Bipole	Bipole
AC grids at both ends	Asynchronous	Asynchronous	Asynchronous	Asynchronous
Control	Active and reactive power, AC voltage, islanded network control	Active and reactive power, AC voltage, additionally, islanded network control, damping control	Active and reactive power, AC voltage, frequency control, damping control	Active and reactive power, AC voltage, islanded network control
Emergency change of power flow	Black start	Black start	Black start	Black start

Europe



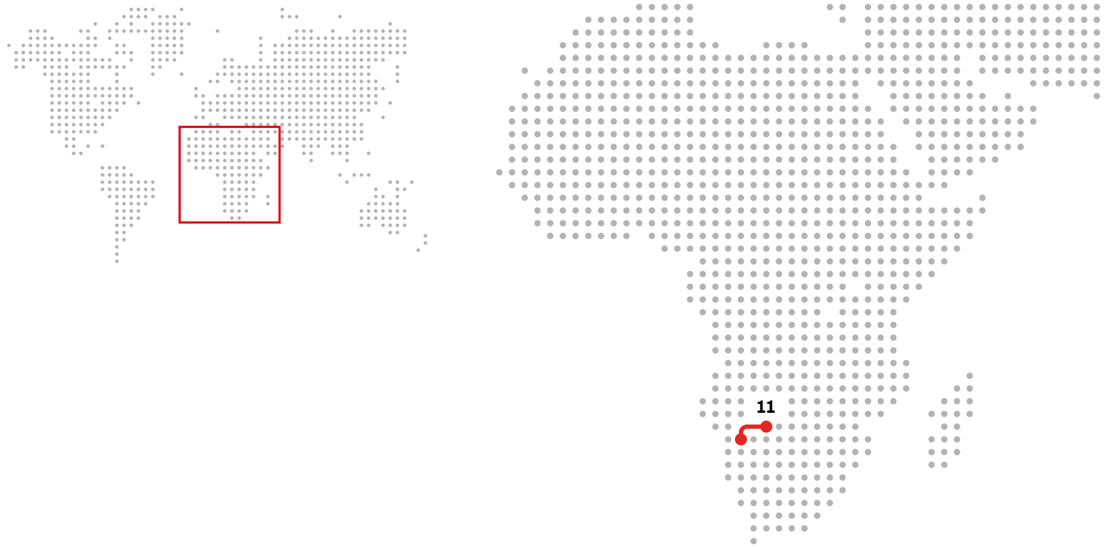
Scheme	18. Troll A 3&4	20. Åland	22. Caithness Moray HVDC Link	23. Johan Sverdrup
Commissioning year	2015	2015	2018	2019
Owner/Original customer/Country	Statoil, Norway	Kraftnät Åland AB, Finland	Scottish Hydro Electric Transmission Ltd (SHETL), UK	Statoil, Norway
Main reason for choosing VSC system	Power from shore, environment, CO2-tax, compactness of converter on platform	Interconnecting grids, asynchronous networks and length of sea crossing	Interconnecting grids, reinforcement of AC network	Power from shore, environment, CO2-tax, compactness of converter on platform
Power Transmitted, MW	2 X 50	100	800 and 1200	100
Direct voltage, kV	±60	±80	±320	±80
Direct voltage per converter, kV	120	160	640	160
Direct current, A	460	625	1881	700
Reactive power range, MVAr	±24	±30	Spittal: ±263 Blackhillock: ±394	-
Converter station location and AC grid voltage	Troll A, 66 kV Kollsnes, 132 kV	Ytterby, 110 kV Naantali, 110 kV	Spittal, 230 kV Blackhillock, 400 kV	Haugeneset, 300 kV Johan Sverdrup, 33 kV
Cable route length, km	70	158	160	200
Length of DC submarine cable, km	4 x 70	158	-	2 x 200
System arrangement	Bipole	Sym. monopole, prepared for multi-terminal	Sym. monopole, prepared for multi-terminal	Bipole
AC grids at both ends	-	Asynchronous	Synchronous	-
Control	Motordrive and VHV motor, AC voltage, islanded network control	Active and reactive power, AC voltage, frequency control, damping control	Active and reactive power, AC voltage, frequency control, damping control	Active and reactive power, AC voltage, additionally, islanded network control
Emergency change of power flow	-	Black start	Black start	Black start

Europe



Scheme	24. Nordlink	25. NSL	26. Kriegers Flak Combined Grid Solutions (KF CGS) HVDC	27. IFA2 HVDC transmission link
Commissioning year	2020	2021	2019	2020
Owner/Original customer/Country	Statnett, Norway TenneT, Germany	Statnett, Norway National Grid, UK	50Hertz, Germany Energinet.DK, Denmark	National Grid (UK) and RTE (FR)
Main reason for choosing VSC system	Interconnecting grids, energy trade	Interconnecting grids, energy trade	Interconnecting grids, asynchronous networks, offshore wind connection	Interconnecting grids
Power Transmitted, MW	2 x 700	2 x 700	410	1000
Direct voltage, kV	±500	±515	±140	±320kV
Direct voltage per converter, kV	500	515	140	320
Direct current, A	1400	1400	1477	1601
Reactive power range, MVAr	-	-	±100	±330
Converter station location and AC grid voltage	Ertsmyra, 400 kV Wilster, 380 kV	Kvilldal, 420 kV Blyth, 400 kV	Bentwish, 400 kV/150kV	Chilling (UK), 400kV Tourbe (FR), 400kV
Cable route length, km	571	730	0 (Back-to-Back)	228
Length of overhead DC line, km	53	-	-	-
Length of DC submarine cable, km	2 x 154	-	-	-
System arrangement	Bipole without return	Bipole without return	-	Bipole
AC grids at both ends	Asynchronous	Asynchronous	Asynchronous	Asynchronous
Control	Active and reactive power, AC voltage, frequency control, damping control	Active and reactive power, AC voltage, frequency control, damping control	Active and reactive power, AC voltage, frequency control, damping control, islanded network control	Active and reactive power, AC voltage, frequency control
Emergency change of power flow	Black start	Black start	Black start and Emergency Power Control (EPC)	Black Start

Africa



Scheme	11. Caprivi Link Interconnector
Commissioning year	2010
Owner/Original customer/Country	NamPower, Namibia
Main reason for choosing VSC system	Interconnecting grids, energy trade, weak networks
Power Transmitted, MW	300
Direct voltage, kV	350
Direct voltage per converter, kV	350
Direct current, A	857
Reactive power range, MVAr	± 200
Converter station location and AC grid voltage	Zambezi, 330 kV Gerus, 400 kV
Cable route length, km	-
Length of overhead DC line, km	950
System arrangement	Monopole with metallic neutral
AC grids at both ends	Synchronous
Control	Active power, AC voltage, additionally, islanded network control
Emergency change of power flow	Runback implemented, power supply of black network

Australia and Oceania

Scheme	3. Terranora Interconnector	7. Murraylink
Commissioning year	2000	2002
Owner/Original customer/Country	APA Group Australia/TransEnergy, USA and North Power, Australia	APA Group Australia /TransEnergie US, USA
Main reason for choosing VSC system	Interconnecting grids, energy trade, environment, controllability	DC link in AC grid, Energy trade, environment, controllability
Power Transmitted, MW	3 x 60	220
Direct voltage, kV	±80	±150
Direct voltage per converter, kV	160	300
Direct current, A	375	739
Reactive power range, MVAr	+90/-165	+140 / -150
Converter station location and AC grid voltage	Terranora, 110 kV Mullumbimby, 132 kV	Berri, 132 kV Red Cliffs, 220 kV
Cable route length, km	59	180
Length of DC underground cable, km	6 x 59	2 x 180
System arrangement	Bipole	Bipole
AC grids at both ends	synchronous	Synchronous
Control	Active and reactive power, AC voltage	Active power and AC voltage
Emergency change of power flow	-	Runback implemented

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Notes

Notes