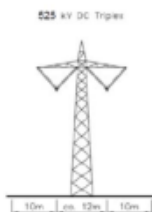
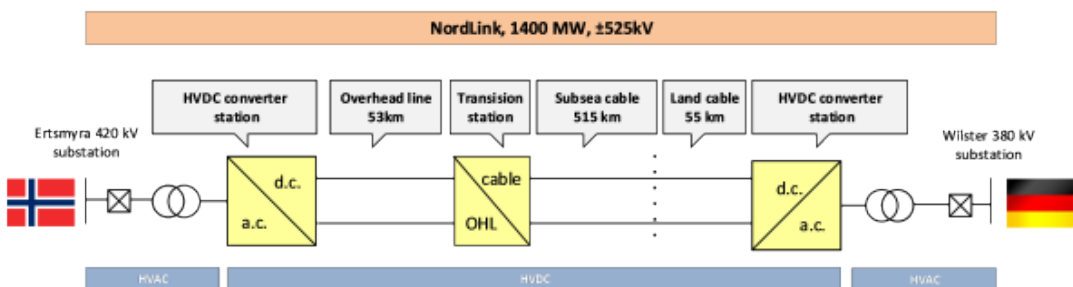


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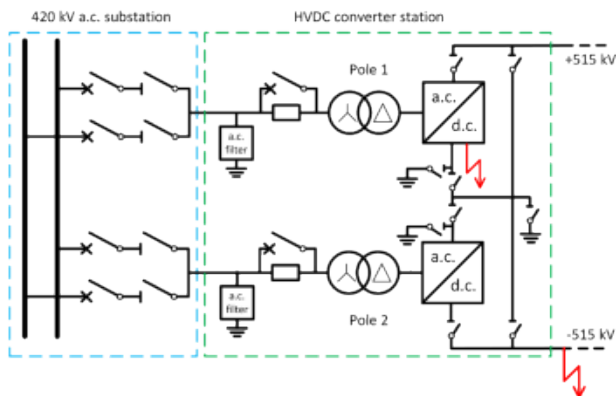
Transmission system testing of a VSC based HVDC System

Magne Meisingset	Sigmund Bødal	Kees Koreman	Arul Vinot
Statnett SF	Statnett SF	TenneT	Hitachi Energy
Norway	Norway	Netherlands	Sweden



System testing for verification of two control functions

- Test 1: Fast transition from bipole to monopole operation when a fault occurs in one converter pole in Norway
- Test 2: Auto-reclosure for temporary faults in the HVDC overhead line between the transition station and the converter station in Norway



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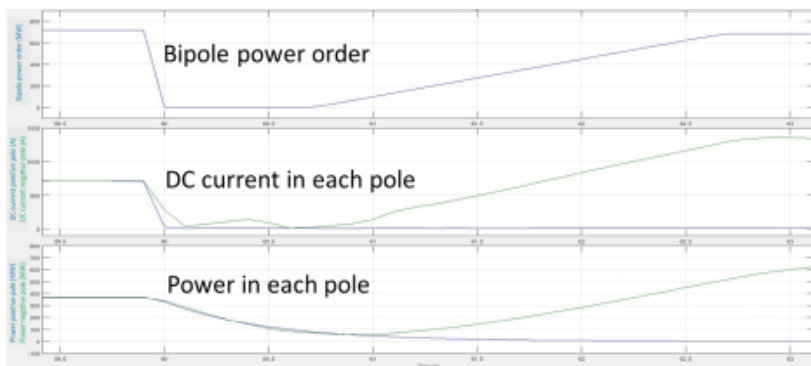
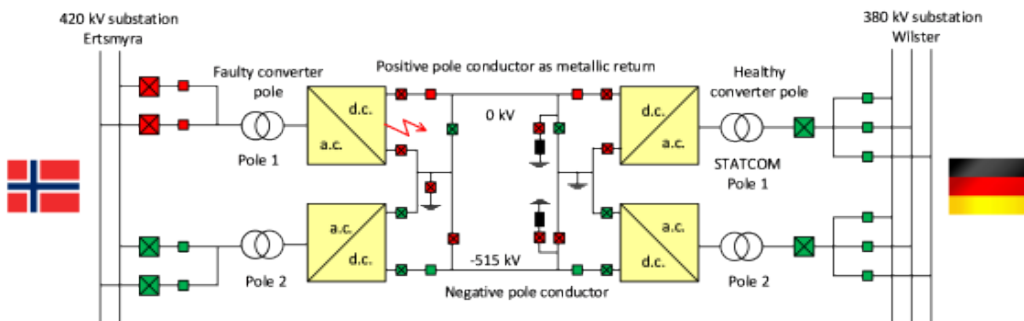
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Test 1: Fast transition from bipole to monopole operation

- The occurrence of a fault causing trip in one converter pole, initiates a transition from balanced bipolar operation to monopolar metallic return operation to maintain continued power transmission within the available capacity of one pole (i.e. 685 MW).
- The transition sequence was initiated by a valve cooling pump failure in converter pole 1 at Ertsmyra
- The purpose of this functionality is to lower the risk of a bipole trip and avoid instantaneous surplus or deficit of 1400 MW in the synchronous Nordic transmission system.



Transition sequence

- ramping down the pre-fault bipole power flow to zero (0.1 s)
- reconfiguration in the d.c. bypass arrangement (0.8 s)
- power ramping back to the pre-fault power flow level limited by the capacity in one pole (1.95 s)
- The faulty converter pole will trip by opening the a.c. circuit breakers and be isolated from the d.c. side
- On the other end of the HVDC Interconnector, the healthy converter of the disconnected pole will also be isolated on the d.c. side, but it remains connected to the a.c. side and transfers into STATCOM operation mode
- The time from fault detection to the reconfiguration of the bypass arrangement has been completed, is approx. 1 s
- The ramping speed for the power order was set to 350 MW/s

Conclusion

- The total transition time from pre-fault bipole to monopole operation was performed in less than 3 s
- The test verified that the functionality worked correctly within the specified time response

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Test 2: Clearance of a d.c. overhead line fault with restart of NordLink

- NordLink is equipped with an automatic reclosure functionality when pole-to-ground faults occur in the overhead HVDC transmission line between the converter station at Ertsmyra and the transition station at Vollesfjord.

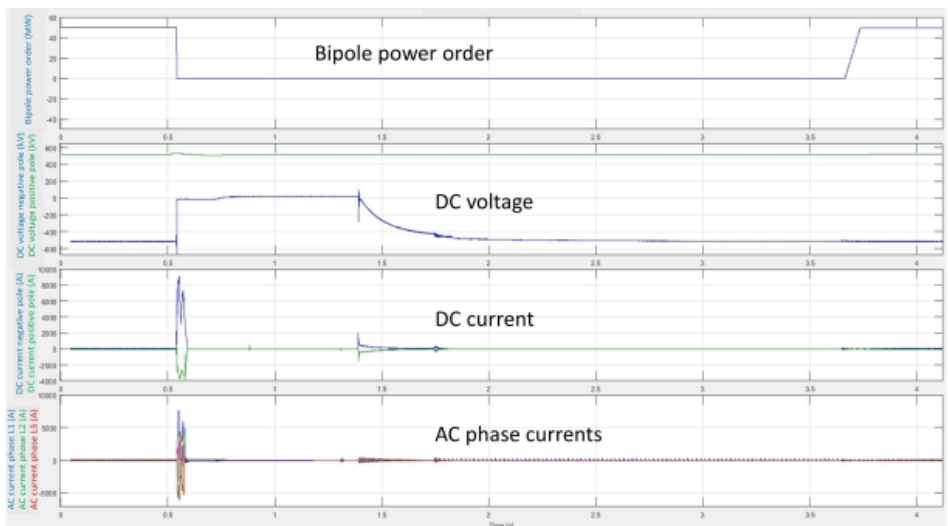


- Two full-scale field tests and one software test were conducted to verify the auto-reclosure function when a temporary pole-to-ground fault occurs in the overhead line section of the HVDC Interconnector.
- The two full-scale field tests were performed by intentionally subjecting a pole-to-ground fault on the negative pole 2 on a temporary extension of the permanent busbar arrangement in the DC yard in the converter station at Ertsmyra.
- These tests activated the overhead line differential protection and initiated the auto-reclosure sequence to restore the power transmission.
- Field test 1 was unsuccessful – caused NordLink unintentionally to trip due to an activation of the pole current differential protection in the faulty converter pole (the settings of this protection was adjusted)
- Field test 2 verified the auto-reclosure functionality was working properly, but not within the required restoration time
- The software test verified the functionality within the required (1 sec.) restoration time (after reducing the time delay between the opening and closing of the converter a.c. circuit breakers from 730 to 400 ms)



Field test 2 of a fault on the overhead DC line section of NordLink.

Field test arrangement for an overhead DC line fault at the negative pole 2 conductor at Ertsmyra converter station.



Conclusion

- The three tests verified that the auto-reclosure function was working properly. The active power transmission was restored to the 50 MW pre-fault value within 1 second after the clearance of the fault in the d.c. overhead transmission line.