

Study Committee B4

DC systems & Power Electronics

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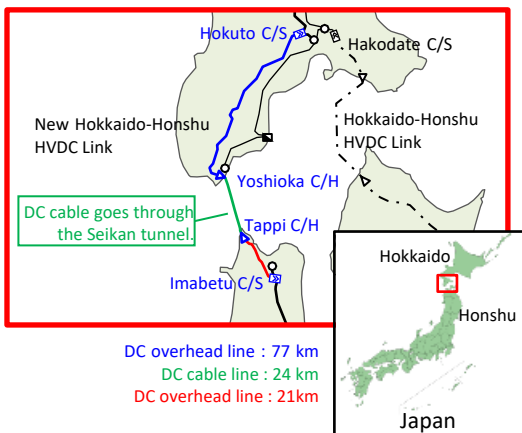
Results of Ground Fault Test and Response to actual Ground Fault of the New Hokkaido-Honshu HVDC Link

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Overview of the New Hokkaido-Honshu HVDC Link

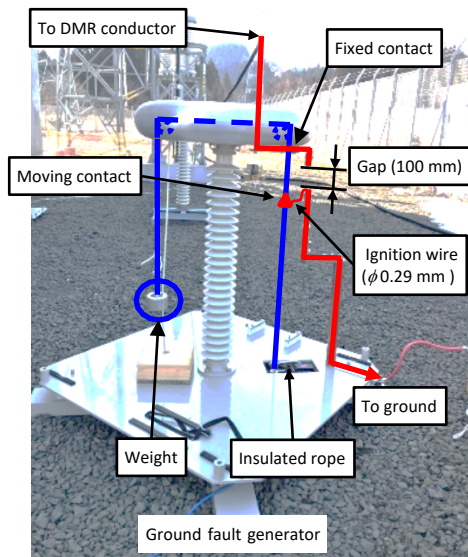
- Hokkaido and Honshu are interconnected by Hokkaido-Honshu HVDC Link (bipolar LCC-HVDC 600 MW) and New Hokkaido-Honshu HVDC Link (monopole VSC-HVDC 300 MW±100Mvar, since 2019).



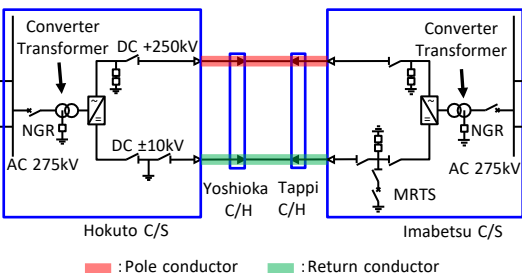
- The circuit of New Hokkaido-Honshu HVDC Link is asymmetrical monopole configuration adopting the dedicated metallic return conductor and the return conductor is grounded at Hokuto C/S.
- One MRTS (Metallic Return Transfer Switch) is installed at Imabetsu C/S (non-grounded side).
- The purpose of installing the MRTS is to clear a self-recoverable ground fault while continuing HVDC operation.

The purpose of the Artificial Ground Fault Test and used equipment

- The purpose of the test is as follows.
- Compare the Dynamic Performance Study (DPS) results and the test results.
- Confirm the operation of Control & Protection (C&P) system and electrical phenomena as designed.
- Verification of the effect of NGR installed at each C/S.
- Verification of influence on AC systems by the DC stray current
- The ground fault generator as shown in below was used in the artificial ground fault test.



- Release the insulated rope which holds weight.
- Weight falls.
- Moving contact rise and contact with fixed contact.
- Ground fault occurs by connecting the ignition wire to ground.
- Ignition wire melts immediately.
- The arc occurs between gap.



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Selection of test site

- There are 6 candidate sites for the test.
- Grounding arc can be expected sustaining and the site have enough space for place the equipment.

Sites	Reason
Hokuto C/S	Since the site is a grounded point, there is no possibility of ground fault.
DC OHL (Hokkaido side and Honshu side)	It is difficult to place the equipment, because the return conductor is directly above the pole conductor.
Yoshioka C/H	There is low risk of spontaneously disappeared the arc by strong wind etc:
Tappi C/H	Since it is an environment where strong wind blow continuously, there is high risk of disappeared the arc by the wind.
Imabetsu C/S	Since the installation point of MRTS and fault point is the same, it is a severe condition to be commutated the fault current to MRTS.

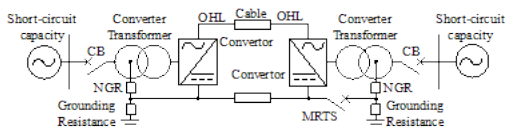
Test cases

- Each test case was carefully examined to confirm no problem in the test result shown below to go to next test case.
- The measured waveform is not significantly different from the DPS results.
- The return line protection and the MRTS operation are as designed.
- The DC stray current is smaller than pre analysis result.
- Transmission power flows Honshu to Hokkaido.

No.	Test date	Fault point	Transmission power [MW]	Fault type
1	March 5-6, 2019	A: Yoshioka C/H	50	Temporary
2			50	
3			100	
4			300	
5	March 8-9, 2019	B: Imabetsu C/S	50	Permanent
6			50	
7			50	Temporary
8			100	
9			300	
10			50	Permanent

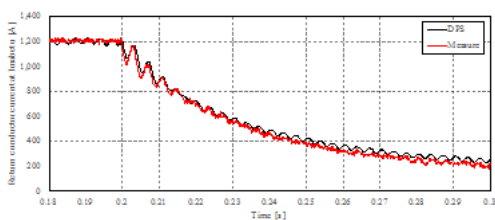
DPS model

- The converters are modeled based on Type 4 of CIGRE WG-57.
- OHL and cables are modeled by distributed constant circuit (frequency dependent).
- AC grids which connects to converter station is modeled by short-circuit capacity.

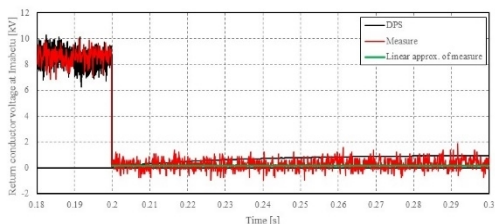


Comparison between DPS result and test result

- Compare the DPS results of grounding point current and voltage with the test result of these.
- DPS result and test result are in case No.9



Return conductor current at Imabetsu C/S



Return conductor voltage at Imabetsu C/S

- There is no significant difference between DPS result and test result.
- Because the arc resistance is smaller than $1\ \Omega$ simulated in DPS, there is a slight difference between DPS result and test result.

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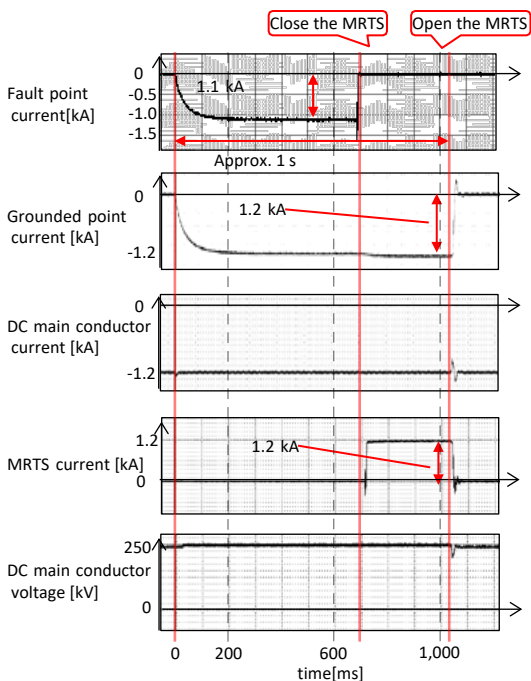
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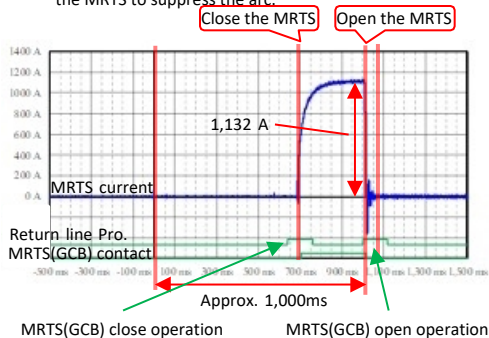
Result at test case No.9

- Test result waveforms are shown in below.



Actual Ground Fault during operation

- The actual ground faults of the DMR conductor had occurred 7 times as of June 2022.
- The actual fault due to lightning strike on April 4th, 2019.
- Transmission power of HVDC Link was 289 MW (power direction was Hokkaido to Honshu, DC current reference was 1,156 A).
- The fault was cleared successfully without intermitting transmission power because of proper operation of the return line protection system and the MRTS to suppress the arc.



Ground fault generator during arcing

Conclusion

- There are no significant difference between DPS results and test results, so that the C&P system and MRTS operates as designed.
- The MRTS properly operates and clears the temporary fault as designed.
- The fault is cleared by the MRTS operation in the actual fault events as well as in the artificial fault test results.
- It is conceivable to verify by these artificial ground fault tests when constructing OHL-HVDC installing a new C&P method as an example.
- At present, for the purpose of carbon neutrality, is processing to plan the additional pole with the aim of starting commercial operation in March 2028.