Study Committee B4

DC systems and power electronics

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System Study and Commissioning Test of the Hida-Shinano HVDC Link

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Introduction

- As different frequencies are used in Japan, two regions are interconnected via frequency converters of which total capacity is 1200 MW until March 2021(Figure 1).
- The Hida-Shinano HVDC link (bipole LCC-HVDC, shown in Table 1) was recently installed to increase the interconnection capacity between east and west region transmission networks.
- Since DC transmission lines pass through one of the highest mountainous areas in Japan, downsizing the transmission tower height has been one of the major concerns from the viewpoint of maintainability hence low DC voltage rating is preferred. Bi-pole 200 kV-2250 A LCC system configuration was selected.
- This poster presents considerations in the system design and characteristic results of the commissioning test cases of the Hida-Shinano HVDC link that started commercial operation in March 2021.

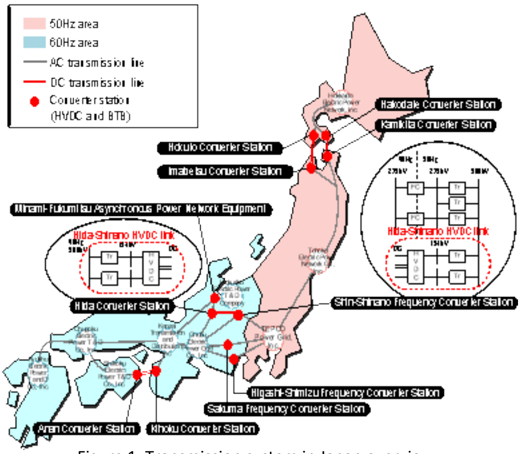

Figure 1. Transmission system in Japan overview

Table 1 . System specifications of Hida-Shinano HVDC Link

Configuration (pole number)	2pole (one bi-pole)
Rated active power	900MW (450MW ×2)
DC voltage	DC 200kV
DC transmission line	overhead line (all sections: approximately 90km)
Method of the return path	Dedicated metallic return
AC system voltage	AC 500kV (both 50Hz side and 60Hz side)
AC Converter system voltage	AC 154kV (both 50Hz side and 60Hz side)

Multi-Vendor and Real Time Simulator (RTS)

- Since the Hida-Shinano HVDC link was designed and manufactured by different TSOs and manufacturers at both converter stations, a control and protection systems combination test done in advance, using a real-time simulator (RTS) that enables cooperative confirmation using the actual control equipment is important.
- This test was carried out using the actual master control, pole control, and DC protection machines from each manufacturer while other parts were tested using simulators(Figure 2) .
- Figure 3 shows the waveform of an emergency start test that raises the output from the floating state to the full capacity as quickly as possible.
- It shows that the output of the rated DC voltage was raised to 90 % in 185 ms from Deblock and in 465 ms the system reached 90 % of the full capacity.

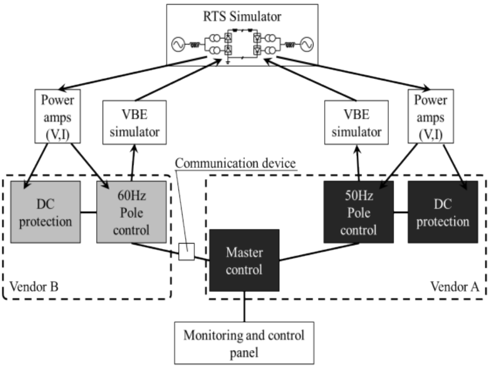

Figure 2. RTS test configuration

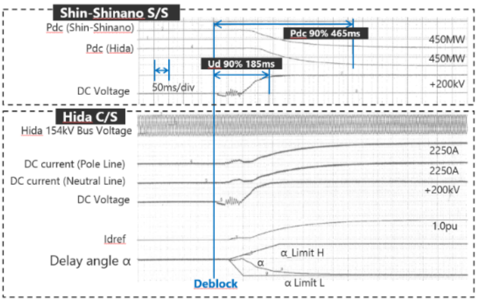

Figure 3. Result of emergency start test in RTS

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Specific schemes in Shin-Shinano substation

- The Shin-Shinano substation on the 50 Hz end of the link is located at far end of the 50 Hz AC system, and large amount of filter capacitor banks are installed belonging to existing two 300 MW LCC frequency converters (600 MW in total) and Hida-Shinano HVDC link (900 MW) .
- Therefore, temporary overvoltage, low-order harmonic resonance and unexpected multiple commutation failures on the FCs and HVDC LCC converters are concerned.
- A specific scheme to protect against low order resonances is applied in which damped harmonic filters, circuit breakers with pre-insertion resistors, and circuit breakers with controlled switching devices are combined.
- In commissioning test cases where inrush current amplitudes and voltage waveform distortions were measured upon transformer energisations (Figure 4, Figure 5), the scheme was confirmed to effectively limit over voltages to within an acceptable level (1.5 P.U) and ensure voltage distortions are not significant for nearby frequency converter plants to operate.

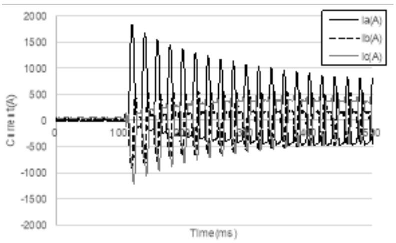

Figure 4. Inrush current (without controlled switching of a specific scheme)

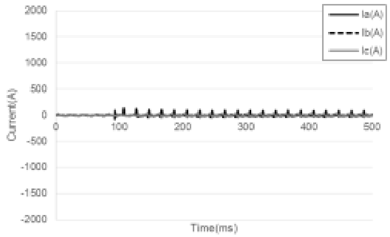

Figure 5. Inrush current (with controlled switching of a specific scheme)

Specific scheme of Hida converter station

- The AC filter is configured in two groups for redundancy(Figure 6), and it also compensates the reactive power of the converter. When the converter output is low, only one group of AC filters is turned on, and when the converter output is high, the second group of AC filters is turned on sequentially.
- If a filter bank in one AC filter group breaks down, the identical filter bank in another group will promptly be put into operation to continue the whole system operation. During the commissioning test, it was confirmed that no problems occurred during the transitioning period of the first AC filter group to the second AC filter group was done (Figure 11).

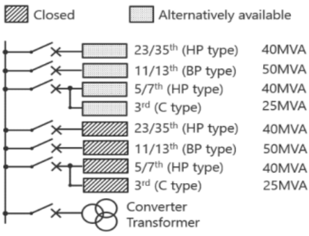

Figure 6. AC-Filters configuration at Hida converter station

Resonance frequency of the DC circuit

- It is necessary to design the resonance frequency of the DC circuit so that it avoids the multiples of both the 50 Hz and 60 Hz fundamental frequencies.
- In this system, the resonance frequencies were determined with considering the manufacturing tolerances of the equipment.
- Frequency lower than 150 Hz was chosen to achieve the filtering performance of the DC filter.

Table 2. Resonance frequency of DC circuit with regards of equipment's manufacturing tolerance as parameter

System condition	Short-circuit capacity of AC system	Minimum			Maximum	
	DC transmission line	60 Hz INV, 0.1 pu, monopole, with 1 neutral line return				
	DC filter capacitance	2 uF		1.5 uF		
	Assumed equipment's manufacturing tolerance	Maximum(*1) of '+' side	No tolerance			Maximum(*1) of '-' side
Resonance frequency of DC circuit		135 Hz	137 Hz	141 Hz	141 Hz	144 Hz

(*1) The maximum equipment's manufacturing tolerance includes tolerances for DC filter, DC reactor, DC transmission line, etc.

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Protection system for the dedicated metallic return conductor

- A bipole forced outage might be caused by long lasting grounding arcs in case of simultaneous bi-directional operation or simultaneous flashover on a pole conductor and dedicated metallic return conductor (Figure 7), control schemes for decreasing such possibilities are required.
- That is, the coordination between the allowable time to have DC stray current and the time for waiting autonomous clearing of faults was the key issue for the protection system.
- In order to avoid the bipole forced outages as much as possible, in the Hida-Shinano HVDC link, the effect of the DC stray current caused by DC line faults was studied.
- Simulation cases for wide ranges of the stray current, high stray current cases due to broken and grounded metallic return line to low stray current cases with branched DC transmission current with a grounding fault due to a lightning, were studied.
- Two step protection scheme is applied where around T1 second of delay time for large fault current cases and around T2 second time delay for other cases (Figure 8).

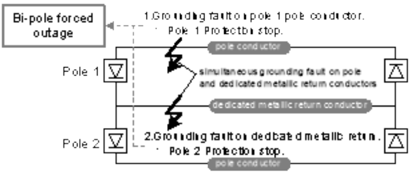

Figure 7. Blocking order to a bipole forced outage on simultaneous flashover on pole conductor and dedicated metallic return conductor

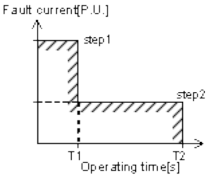

Figure 8. Protection settings of the dedicated metallic return protection

Commissioning test

- In the commissioning test, in addition to the basic operation test cases, special operation test cases were also carried out.
- Fast start operation test where transmission power is changed from floating to full power within around 500 ms is the test for the emergency power control (Figure 9, Figure 10).
- And starting operation test and transient response test with existing two frequency converters in service are the tests for the stable operation of both the frequency converter and the HVDC link.
- All the test results were satisfactory.

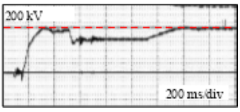

Figure 9. DC voltage in a fast start operation test case

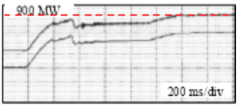

Figure 10. DC transmission power in a fast start operation test case

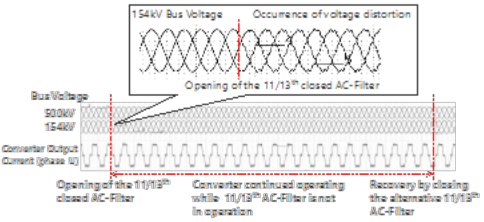

Figure 11. Result of AC-Filter recovering test at Hida converter station

Conclusion

- Foreseen problems in the Hida-Shinano HVDC link such as problems originated from linking two different frequency AC networks and the problems of low order resonances due to close installation to existing frequency converters were solved by introducing adequate components, damping resistor for example.
- All the solutions were confirmed through the commissioning tests.
- Through the commissioning tests involving emergency power control and the tests involving simultaneous operation of the FCs and the HVDC, confirmations were performed so that the AC bus voltage disturbances are within regulation range and stable operation of the FCs and the HVDC system operation is achieved.