Study Committee B4

HVDC AND POWER ELECTRONIC SYSTEMS

Paper 10329

System Commissioning Test of UHV LCC-VSC MTDC Project

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Background

- The China Southern Power Grid (CSG) has implemented a HVDC project named WDD UHVDC to deliver the hydropower in western China to load center in southern China.
- The WDD UHVDC is multi-terminal and rated at ±800 kV. The rectifier which adopt LCC sends 8000MW and the two inverters which adopt VSCs receive 5000MW and 3000MW respectively, as shown in Fig. 1.
- The field commissioning lasted from May to December 2020. Key designs such as the series connection of VSCs up to 800kV, the hybrid VSC topology with DC fault self-healing capability, control strategies of LCC-VSC-MTDC system were verified. Key functions such as the deblocking, ac fault ride through, OHL fault clearance and re-start, converter switch in/out, station switch in/out, steady state operation were fulfilled.

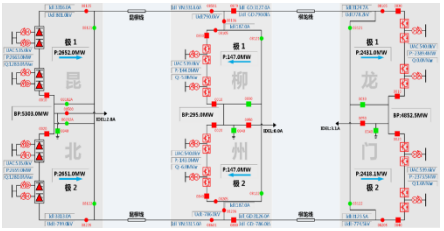

Fig. 1. HMI of the single-line diagram of the WDD project

Field comissioning results — Deblocking

- Fig. 2 shows the field commissioning test of deblocking process in the Kunbei-Longmen LCC-VSC mode.
- At the uncontrolled rectifying stage of VSC station, the dc voltage was determined by Longmen station at about 690 kV.
- Then the Longmen station deblocked firstly, and the dc voltage was increased gradually to 800kV according to the pre-set increasing rate.
- The voltage of 400kV and 800kV bus are stabilized at 400kV and 800kV, respectively.
- After about 300ms, the Kunbei station deblocked with the minimum current order, the alpha decreased according to the pre-set curve until the dc current was established steadily. The deblock was finished.

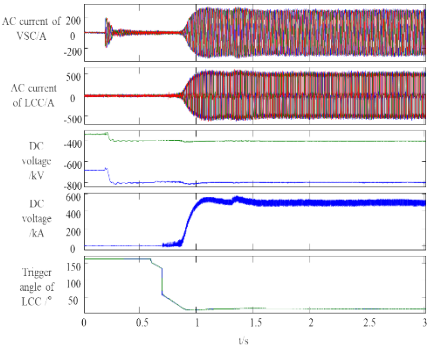

Fig. 2. Deblock waveform of the WDD project

Field comissioning results — AC fault ride-through

- Fig. 3 shows the field commissioning test results of Longmen station during an AC single phase to ground fault.
- In total, 7 AC single phase to ground faults at the Longmen station have been successively carried out.
- During the test, the LCC-HVDC projects in the near area experienced commutation failure, while the WDD project achieved full ride-through without the interruption of power transmission and also provided reactive power support for the AC system during failures.

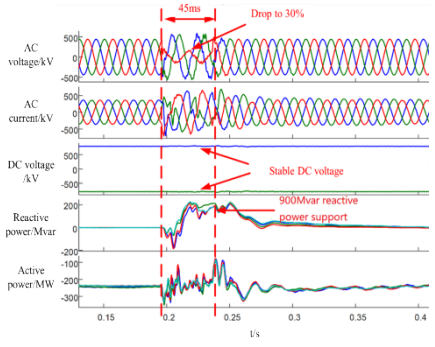

Fig. 3. AC fault ride-through waveform of Longmen station

Field comissioning results — OHL fault clearance and restartd

- Fig. 4 shows the field commissioning test results during a single pole to ground DC fault at Liuzhou station under full power operation.
- In this system, a mixed topology was adopted: both the full-bridge and half-bridge sub-modules (with a ratio of 7:3) were mixed for used within in the converter. By using the full-bridge sub-modules to generate negative DC voltage can clear the DC line fault without opening of the AC breakers.
- During this process, the Kunbei station implemented emergency fast phase shift after DC fault was detected, and the Liuzhou and Longmen stations switched to constant current control mode to gradually decrease DC current to 0 after detected DC fault.

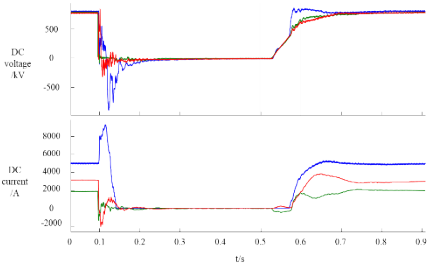

Fig. 4. OHL fault clearance and restart waveform of WDD project (bule line: Kunbei station; red line: Longmen station; green line: Liuzhou station)

Field comissioning results — Converter switch-out

- Fig.5 shows the field commissioning test results during the online converter switch-out process of Longmen station under scheduled condition.
- After receiving the converter switch-out command, the 400kV bus voltage was gradually reduced to 0 followed by closing the BPS of the lower valve group. After confirming that BPS was closed in place, the valve group was blocked, and the current was transferred to BPS. The converter planned to exit without interrupting power or disturbing the system.

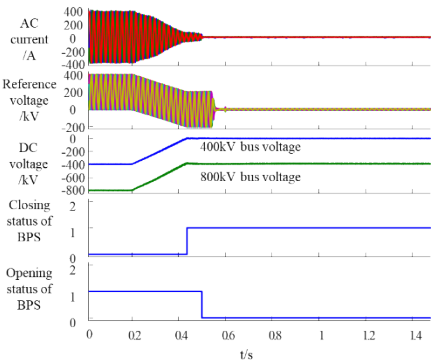

Fig. 5. Converter switch-out waveform of Longmen Station under scheduled condition (Lower valve group of P2)

Field comissioning results — Converter switch-in

- Fig.6 shows the field commissioning test results during the online converter switch-in process of Longmen station.
- After the converter to be switched in was charged, deblocked the converter and maintained its DC voltage at 0, the DC current flowed through the converter and BPS at the same time. Then, injected harmonic current to produce BPS zero crossing point.
- For the converter switch-in, to simplify the sequence of the BPS and disconnectors at the dc side, a special charging strategy for the VSC in case of short circuit at dc side was developed., as shown in Fig.7.
- Due to the short circuit at the dc side, the half-bridge was not charged. When the full-bridge sub-modules were weak-up and working, the controlled charging process I began.
- In this stage, the full-bridge sub-modules were triggered to generate negative voltage to force the half-bridge sub-modules to be charged. When the half-bridge sub-modules were weak-up and working, the controlled charging process II began. In this stage, the full-bridge sub-modules were triggered like the half-bridge sub-modules, and an active charging strategy were designed to charge both the full-bridge sub-modules and half-bridge sub-modules to its rated operating voltage and keep balanced.

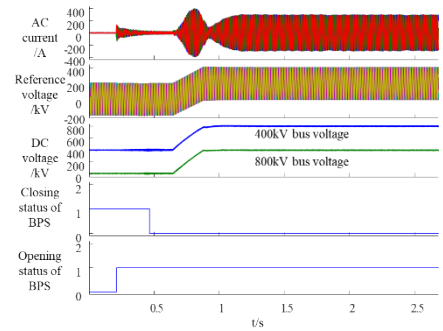

Fig. 6. Converter switch-in waveform of Longmen Station under scheduled condition (Lower valve group of P1)

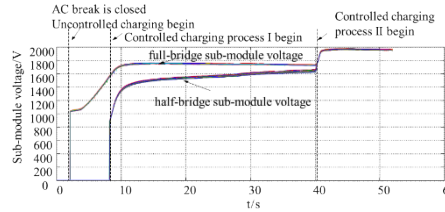

Fig. 7. Waveforms of the VSC's charging process in case of short circuit at dc side

Field comissioning results — Converter switch-out

- Fig. 8 shows the field commissioning test results during the online station switch-out process of Longmen station pole 2 under faulted condition.
- After receiving the blocking signal from the Longmen station, the Kunbei station performed an emergency phase shift, and the Liuzhou station switched to voltage control mode to reduce DC voltage to 0 before it blocked.
- Then, disconnected the HSS of Liuzhou-Longmen DC line after the line current was less than the preset value.
- Finally, restarted the Kunbei-Liuzhou part after the HSS was confirmed disconnected.
- When a VSC station plans to swich-out, it will be blocked after reducing the power to the minimum value.

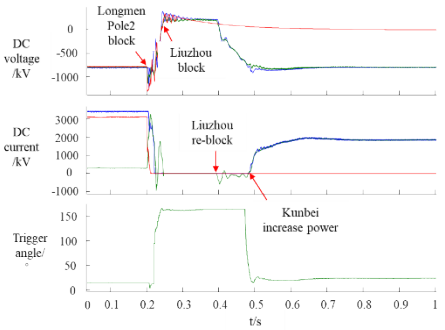

Fig. 8. Station switch-out process waveform of Longmen station pole 2 (bule line: Kunbei station; red line: Longmen station; green line: Liuzhou station)

Field comissioning results — Converter switch-in

- Fig. 9 shows the field commissioning test results during the scheduled online station switch-in process of Longmen station pole 1.
- In total, 7 AC single phase to ground faults at the Longmen station have been successively carried out.
- During the test, the LCC-HVDC projects in the near area experienced commutation failure, while the WDD project achieved full ride-through without the interruption of power transmission and also provided reactive power support for the AC system during failures.

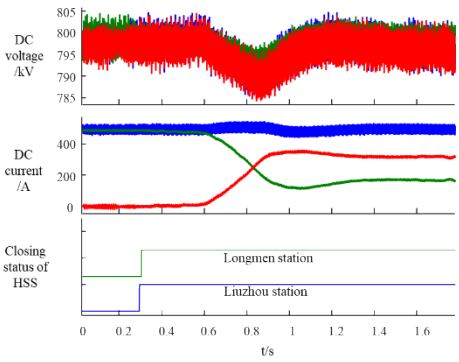

Fig. 9. Station switch-in process waveform of Longmen station pole 1 (bule line: Kunbei station; red line: Longmen station; green line: Liuzhou station)

CONCLUSIONS

- The LCC-VSC HVDC combined the technical advantages of LCC and VSC, especially the low cost, low power loss and large capacity of LCC and the no commutation failure and reactive power support of VSC. By carrying out the WDD project, the UHV hybrid multi-terminal DC transmission was verified, providing a new path for the long-distance bulk power transmission in future:
- 1) The station-station typed hybrid HVDC using LCC at the sending end and VSC at the receiving end was feasible and performed better than LCC-HVDC. It makes full use of the VSC's technological advantages to ride through faults at the receiving end by avoiding the commutation failures. In addition, the VSC, compared with LCC, can provide reactive power support during a fault.
- 2) By using the mixed topology, in which both the full-bridge and half-bridge sub-modules were mixed for used within in the converter, the self-clearing of OHL faults at dc side can be realized, and power can be recovered quickly.
- 3) Through the series connection of converters, the dc voltage of VSC can be increased to ±800kV. By using the bypass switch and HSS, the converter switch-in/out and station switch-in/out can be realized. Therefore, high reliability and flexibility were achieved.