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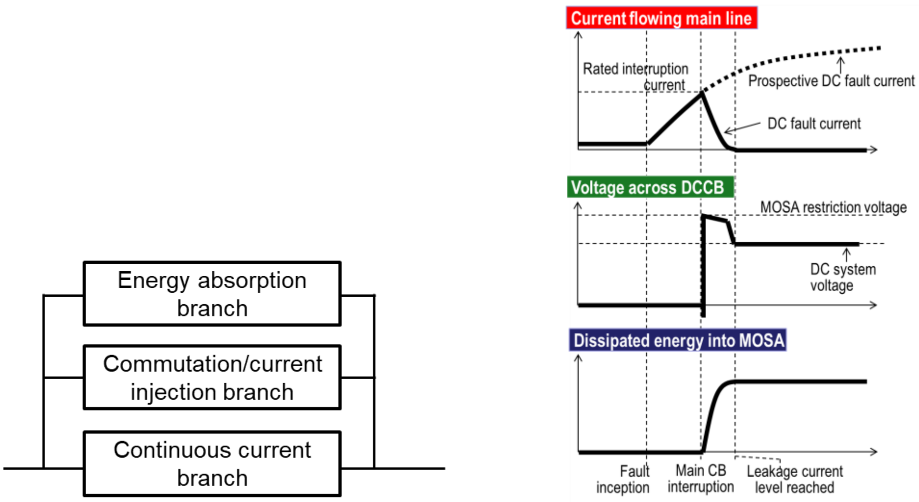
Q2: HVDC switching equipment is on the way to become 'standardized' technology, while discussions are continuing based on the experiences in the field or laboratories as presented in 10545 and 10773. Can experts provide relevant issues or proposals for the standardization of HVDC switchgear?

Effectiveness of the unit testing and multi-part testing for an HVDC circuit breaker

High voltage DC circuit breakers (HVDC CBs) are expected to play an important role in the protection of the future multi-terminal HVDC grids. It is required to quickly isolate the faulted section of a DC transmission grid, minimising the impacts on healthy system parts and thus avoiding large-scale system outages.

In general, scaling up the voltage level of an HVDC CB, such as 320 kV and higher involves series connection of modules, where each module typically composes three main branches; namely, continuous current branch, commutation/current injection branch and energy absorption branch as shown in Figure 1 (a). At first, current is interrupted in the continuous current branch on the rising edge of fault current with rate of rise of di/dt, by power electronics or by mechanical switchgear with an auxiliary circuit as shown in Figure 1 (b). After the continuous current branch blocks the current passage, current is forced to commutate into the commutation/current injection branch where transient interruption voltage (TIV) is developed which peak value is determined by the protection level of a metal-oxide surge arrestor (MOSA) bank in the energy absorption branch. The MOSA serves two purposes ; one is to provide counter voltage for the HVDC system and thus suppress the fault current; the other is to absorb (and dissipate) the fault energy during a current breaking event. Therefore, an HVDC is required to interrupt the fault current and withstand the subsequent TIV while the MOSA dissipates the energy and these stresses have to be reproduced with the testing equivalent to what can be seen in the real system. Although an obstacle in testing larger HVDC CBs is that the power of megawatts is needed to be provided by the source to prove the breaker's energy dissipation capability. Due to inherent limitation in test circuit capabilities to provide such a high power with direct testing, unit testing, multi-unit testing and multi-part testing are proposed.



(a) (b)

Figure 1 Typical HVDC CB configuration and the image of the applied stresses to the breaker

Figure 2 shows the concept of the proposed unit testing and multi-unit testing using an example of four 80 kV modules connected in series to achieve 320 kV HVDC CB[1]. For the unit testing, only an 80 kV module is tested and for the multi-unit testing, two or more modules are tested (Figure 2 (c) shows an example of testing two modules). The interrupting current will be the same in any of the test cases, although the TIV and MOSA energy stresses can be reduced proportionally according to the number of the tested modules as shown in Figure 3. This is acceptable as long as the stresses in the unit/multi-unit testing are equivalent to those of corresponding to unit of the HVDC CB in a real HVDC system. Difference between the unit testing and multi-unit testing in terms of energy supply is that unit testing can supply the higher energy to the module because the maximum energy provided by the test circuit can be supplied to one module, whilst the energy for single module would reduce as the number of the tested modules increase. The benefit of the multi-unit testing is that it might enable to verify the stress distribution among series connected breaker units, as well as any mutual coupling or EMI issues between the breaker units. Therefore, using the appropriate testing methods depending on the requirements is important.

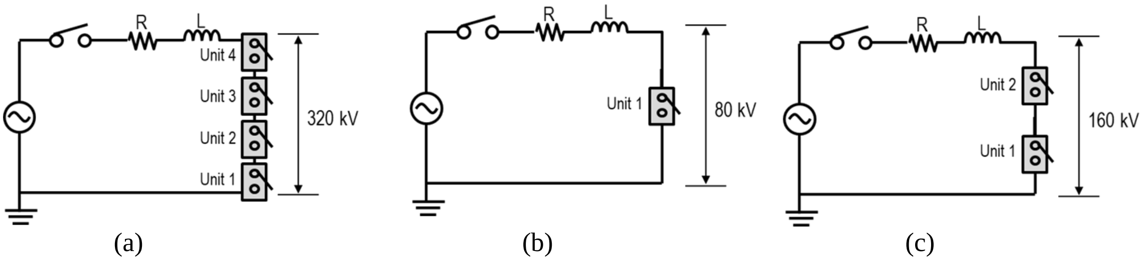


Figure 2 Concept of the proposed testing methods (a) Full-pole testing (b) Unit testing (c) Multi-unit testing

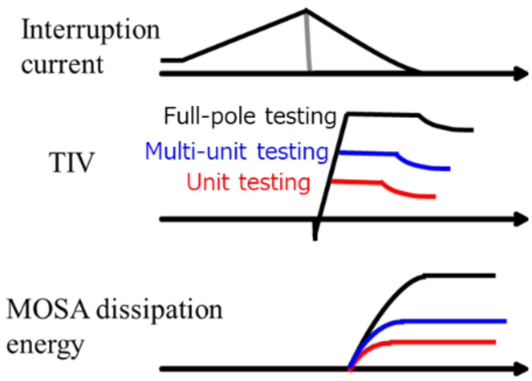
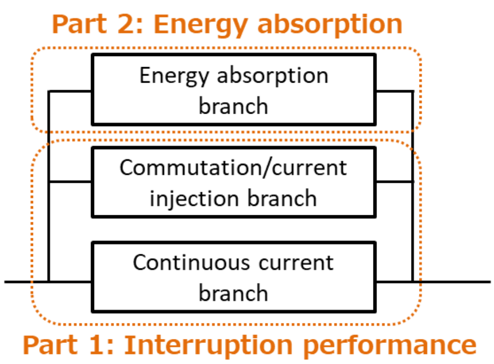


Figure 3 Image of the HVDC CB stresses in each proposed testing methods

Further to the testing of which unit testing and multi-unit testing cannot supply the required stresses to the breaker unit, a multi-part testing shall be allowed as far as it can provide the equivalent stresses expected in the practical HVDC systems. Figure 4 shows an example of the multi-part testing procedure for HVDC CB evaluation. A multi-part testing will test the different functionalities of an HVDC CB in different tests. The 1st part targets the verification of the interruption performance and the 2nd part targets the MOSA energy dissipation performance, since these two performances will not affect each other.



Part	Stresses for DCCB					
	Breaking current		TIV			MOSA energy
	Rate of rise	Peak	Rate of rise	Peak	Recovery Voltage(1)	
1	✓ Full	✓ Full	✓ Full	✓ Full	✓ Full	Small
2	None	None	None	None	None	Full

(1) Synthetic solution might be needed.

Figure 4: Example of multi-part testing procedure for HVDC CB evaluation

As alternative testing methods of an HVDC CB that direct test with such as AC short-circuit generator method is difficult to impose the necessary stresses to the breaker due to the limitation of the testing facilities capability, unit-testing, multi-unit testing and multi-part testing shall be allowed as far as these methods can provide the equivalent stresses expected in the practical HVDC systems. The idea has already been applied to a testing method of AC circuit breakers (IEC62271-100) and the similar testing procedure can be used for HVDC CB.

References

[1] PROMOTioN Deliverables 5.6, "Software and analysis report on candidate test-circuits and their effectiveness "