
REPORT

ABB Power Grids Hybrid HVDC Breaker

Full-Scale Test: A Breakthrough Towards HVDC Grid Realization

Arman Hassanpoor, Jürgen Häfner

Technical Report, ABB Power Grids, Ludvika, Sweden

March 2020

Abstract

A full-scale prototype of an ABB Power Grids Hybrid HVDC breaker was tested in the independent laboratory of KEMA in Arnhem as part of ABB's collaboration with the EU-funded project, PROMOTioN. The HVDC breaker is a key component for both offshore and onshore HVDC grids, which enhances the power system stability during system failures. As an essential milestone in the grid development, a live demonstration was witnessed by European TSOs and grid developers to ensure mature technology readiness level of the ABB Power Grids Hybrid HVDC breaker. Unlike previous experiments, this test exposed the breaker to realistic system voltage stress after the current interruption and full power dissipation. The demonstration proved the reliable control system, robust component design and safe mechanical design of the breaker. This technical report describes the test object and summarizes the technical feature of the latest development on ABB Power Grids' Hybrid HVDC breaker.

1. Technology Development

ABB announced the world's first commercial modular technology for hybrid HVDC breakers back in 2012 for the DC grid application [1]. The development of the breaker continued during the past years, following extensive tests on the component, unit, and system-level.

A. Component-level Tests

Standard power components are used in the ABB Power Grids Hybrid HVDC breaker. The main components are broadly used in different applications. BIGTs, arresters, capacitors, diodes, and resistors are the major components that form the Hybrid HVDC breaker. Various component tests, including destruction tests, are conducted to ensure the high reliability of the selected components.

B. Unit-level Tests

The Hybrid HVDC breaker consists of three major units i.e. load commutation switch (LCS) [2], ultra-fast disconnecter (UFD) [3], and main-breaker (MB). Different units are exposed to different stress levels during normal operation and current interruption mode, so each unit is tested based on its own stress levels.

1) Load commutation switch unit:

The load commutation switch (LCS) is designed with in-built reliability to ensure continuous operation under different failure situations. Its scalable design includes series and parallel connected BIGTs to increase the voltage and current capability, respectively. The major tests which are performed on LCS unit are:

- Current sharing test,
- Voltage sharing test,
- Turn-off capability test,
- Failure mode test.

2) Ultra-fast disconnecter unit:

The ultra-fast disconnecter (UFD) is a fast mechanical switch based on a known gas-insulated switch-gear technology. It has multiple overlapping contacts with double motion and a dual current path which is capable of conducting high current. Uniquely, the UFD can interrupt the residual current shortly after the contact separation and build-up high dielectric withstand capability. Some particular tests are done on UFD as:

- Temperature rise test,
- Endurance test for 2500 operation along with current interruption,
- Power test after the endurance test,
- Operation-time test,
- Dielectric test.

Table 1.

| Item | Dimensions | Values |
|--------------------------------------|------------|--------|
| Internal current commutation time | ms | <3 |
| Maximum interruption current | kA | 20 |
| Rated system voltage | kV | 350 |
| Transient Interruption Voltage (TIV) | kV | <520 |
| Rated energy | M J | 10 |



a)



b)

Fig. 1. a) Artistic view of the hybrid HVDC breaker, b) The hybrid HVDC breaker in KEMA lab.

3) Main breaker unit:

A compact design of the main-breaker (MB) stack is secured by utilizing StakPak 5.2kV BIGTs and resistor-capacitor (RC) snubbers for uniform voltage distribution. A unique optically-powered gate unit is designed to not only operate the BIGT devices but also to monitor the device conditions in real-time. Each main-breaker unit is rated for 40kV and integrated open blocks of metal-oxide varistor for energy absorption. A vast number of tests are done on MB such as:

- Current interruption test on single BIGT and stack level (up to 30kA)
- Voltage sharing test
- Snubber verification test
- Temperature rise test
- Counter voltage capability test
- Failure mode test

2. Performance evaluation

Following the aforementioned technology development of the ABB Power Grids Hybrid HVDC breaker, a full-scale and full-rated prototype of a 350kV HVDC breaker was built up in the KEMA laboratory in Arnhem, Netherlands. Fig.1(a) shows an artistic view of the Hybrid HVDC breaker which was developed for this demonstration. A photo of the full breaker system is also depicted in Fig.1(b). The rating of the Hybrid HVDC breaker is shown in Table I.

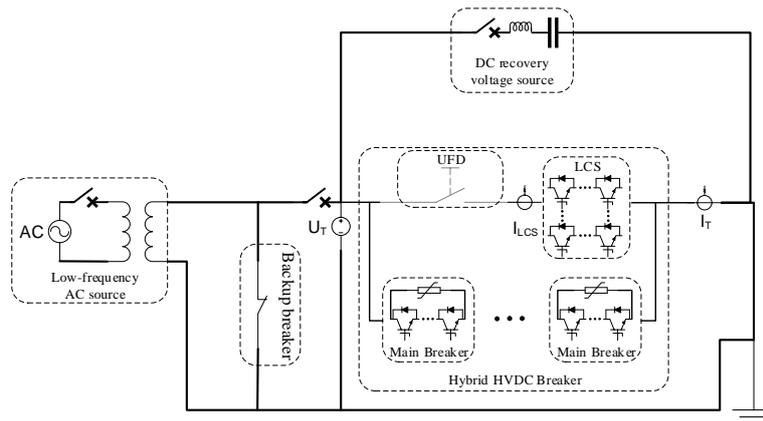


Fig. 2. Test circuit schematic diagram

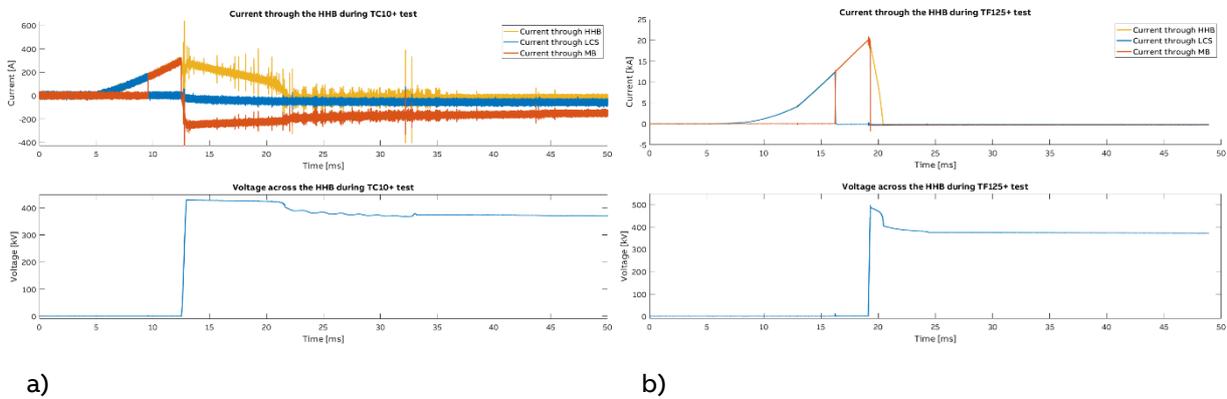


Fig. 3. a) Low-current (330A) interruption test result , b) High-current (20kA) interruption test result.

A specially designed test circuit enabled both current and voltage stresses over full breaker. Fig.2 illustrates the schematic diagram of the test circuit. The current is provided by low-frequency AC generators while the voltage is maintained by a precharged capacitor over the test object. This combination ensures the needed power to resemble the realistic stresses over each component and unit.

ABB Power Grids Hybrid HVDC breaker was tested for various current interruption levels from a few amperes to 20kA. The results show that the operation time of 3ms is similar for all ranges of the interrupted current level and it is not dependent on the current level. This is one of the most significant advantages of the ABB Power Grids solution. Fig. shows a typical oscilloscope output curve for both low and high current interruption test.

3. Summary

Years of experience in HVDC system operation and power component manufacturing enabled ABB Power Grids to develop a robust, reliable, and self-protective Hybrid HVDC breaker for off- and onshore DC grids. ABB Power Grids has not only the vast knowledge in HVDC system operation but has also supplied semiconductors and GIS products for many years. This was a great advantage when integrating all reliable components into the Hybrid HVDC breaker as a stand-alone solution. StakPak BIGTs are mainly developed for HVDC applications and have significantly low failure rates which makes both, the load commutation switch and the main breaker a very reliable unit of the Hybrid HVDC breaker. The mechanical unit of the breaker, the ultra-fast disconnecter, is also a single compact and reliable device that can cover a vast range of the voltage levels with no need for several series connections.

The ABB Power Grids Hybrid HVDC breaker has a straightforward modular topology with a minimum number of main circuit units. The Hybrid HVDC breaker permits independent fast interruption time for all range of the current with no need for commutation capacitors. The latest ABB Power Grids control and protection system, MACH3, is utilized to operate and monitor the full breaker system in real-time. Additionally, a maintenance-friendly mechanical design is achieved by having separate structures and a low number of components in place. A reliable HVDC breaker was the last missing piece of the puzzle which was ultimately realized through significant years of development by ABB Power Grids.

References

- [1] J. Häfner and B. Jacobson, "Proactive hybrid hvdc breakers - a key innovation for reliable HVDC grids," in Cigré International Symposium, Bologna, Italy, 13-15 September 2011.
- [2] A. Hassanpoor, J. Häfner, and B. Jacobson, "Technical assessment of load commutation switch in hybrid hvdc breaker," IEEE Transactions on Power Electronics, vol. 30, no. 10, pp. 5393–5400, Oct 2015.
- [3] P. Skarby and U. Steiger, "An ultra-fast disconnecting switch for a hybrid hvdc breaker - a technical breakthrough," in Cigré International Symposium, Alberta, Canada, 9-11 September 2013.