ENERGY

Improved generator circuit breaker enhances power plant protection

A generator circuit breaker (GCB) plays a vital role in power plants: It protects key equipment and increases plant availability. ABB's successor to the HEC 7/8 – the HEC 10 GCB – offers additional benefits, eg, improved switching capability, lower SF_6 volume and leakage rate, extended lifetime and a smaller footprint →1.

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A GCB plays an important part in switching the circuit between the generator and the transformer in a power plant. The GCB protects key equipment while simplifying operational procedures to improve power plant availability. ABB's GCBs have been protecting all types of power plants since 1954 and more than 8,000 are installed in over 100 countries. ABB offers the widest and most modern portfolio of GCBs in SF_6 and vacuum technology with a range of short-circuit currents from 50 kA to 300 kA and nominal currents from 3 kA to 50 kA. To meet the most stringent standards and customers' needs, ABB continues to invest in GCB research and development.

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In the late 1990s, for the high-end segment, ABB introduced the GCB type HEC 7/8, which caters for short-circuit currents up to 210 kA. In 2012, HEC 9 – the world's largest GCB for power plants up to 2,000 MW – was launched.

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01 ABB's new GCB, the HEC 10, successor to the HEC 7/8.

Recently, ABB introduced another high-performing GCB for the HEC platform: Encompassing decades of successful field experience, the HEC 10 is the successor to the HEC 7/8. The HEC 10 offers additional benefits such as improved switching capability, lower SF_6 volume and leakage rate, and extended lifetime - all in a smaller footprint.

Designed to protect the most critical generator applications, the HEC 10 is available in two types:

- HEC 10-170: with rated short-circuit current of 170 kA and rated voltage of 31.5 kV
- HEC 10-210: with rated short-circuit current of 210 kA and rated voltage of 33 kV

Each type is available in two versions:

- L: fully naturally cooled for rated normal currents up to 20 kA
- XL: with an innovative hybrid cooling system for rated normal currents up to 29 kA.

Third generation of HEC technology
The HEC 10 interrupting chamber design is an enhancement of the proven technology found in the rest of the HEC product family. All GCBs within this family are "self-blast breakers." In such breakers, the electric arc is blown away from the heating chamber by a gas stream during the current zero-crossing, with the blowing pressure being generated by the arc energy itself.

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The HEC 10 interrupting chamber design is an enhancement of the "self-blast" technology found in the rest of the HEC product family.

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CLASS G1

A class G1 GCB having a rated generator-source short-circuit breaking current equal to I_{scg} (the root-mean-square value of the symmetrical component of the prospective short-circuit current for faults fed by the generator) shall be proved by two tests: one with a current equal to I_{scg} with a degree of asymmetry of 110 percent and one with a current equal to 0.74 x I_{scg} and a degree of asymmetry of 130 percent.

CLASS G2

A class G2 GCB having a rated generator-source short-circuit breaking current equal to I_{scg} shall be proved by one test with a current equal to I_{scg} with 130 percent degree of asymmetry.

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Over the past few decades, ABB has been actively studying and investigating gas circuit breakers. Most recently, major efforts have been directed toward the investigation of thermal and dielectric switching. In close collaboration between scientists and development engineers, the latest findings were implemented in the design of the HEC 10 arc quenching zone. For instance, new design rules for the flow cross-sections around the tulip contacts were used. Moreover, experience gathered during the HEC 9 development, where extensive experiments took place, allowed further optimization of the dielectric switching capability.

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The efforts resulted in a significantly improved switching capability for the HEC 10 compared to its predecessor.

These efforts resulted in a significantly improved switching capability for the HEC 10 compared to its predecessor. An improved switching capability allows shorter arcing times – which are necessary for the pressure buildup – and enables enhanced current switching ratings that also cover switching under 180° out-of-phase conditions (a demanding task). The HEC 10's interrupting capability significantly exceeds the minimum requirements of the IEC/IEEE 62271-37-013 standard for GCBs. The whole type test series has been passed without a single failure, proving the unique quality and robustness of the interrupting chamber.

New industry standards

In October 2015, the International Electrotechnical Commission (IEC) and the Institute of Electrical and Electronics Engineers (IEEE) revised the industry standard for GCBs. IEEE C37.013-1997(R2008) was replaced by the new dual logo standard, IEC/IEEE 62271-37-013. HEC 10 is fully type-tested in accordance with – and, indeed exceeds – the mandatory requirements of this new standard.

Meeting the most stringent generator-source short-circuit current requirements

One of the major differences between IEC/IEEE 62271-37-013 and the old IEEE C37.013 is the requirement on the degree of asymmetry of the generator-source short-circuit currents, which are characterized by having delayed natural zero-crossings for a certain period. This requirement was raised from 110 percent to 130 percent to better represent the requirements of real applications [1]. In particular, the new dual logo standard defines two classes, G1 and G2; the latter being of higher performance →2.

The HEC 10 has been type-tested to interrupt generator-source short-circuit currents of up to 160 kA with a degree of asymmetry of up to 130 percent, as per the G2 class, hence meeting the most stringent requirements of the largest generators worldwide.

Tested parameters for out-of-phase	Breaking current (kA)	Peak value (kV)	Rate-of-rise (kV/µs)	Time delay (µs)
90°	85	2.6 x Ur	5.2	1
180°	159	3.2 x Ur	8.1	0.7

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02 Class G1 versus G2 according to IEC/IEEE 62271-37-013.

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03 Tested values of HEC 10 for out-of-phase at angles of 90° and 180°.

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04 HEC 10 cooling system.

Exceeding the latest standard's minimum mandatory requirements
Out-of-phase synchronizing may occasionally happen – mainly due to wiring errors during commissioning or maintenance – while connecting voltage transformers and synchronizing equipment. Even though IEC/IEEE 62271-37-013 covers requirements for an out-of-phase angle of only 90°, it is recognized that synchronization with out-of-phase angles of up to 180° can occur. The incidence of a 180° out-of-phase condition can impose very severe stresses on the GCB [1,2] that are not necessarily covered by an out-of-phase 90° test.

In order to guarantee maximum safety in the power plant, the HEC 10 exceeds the minimum requirements laid down in IEC/IEEE 62271-37-013: The HEC 10 has also been tested to cover the requirements for out-of-phase conditions up to 180°. →3 shows a comparison between the tested values for the HEC 10 at out-of-phase angles of 90° and 180°. The high magnitude of the breaking current

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In order to guarantee maximum safety in the power plant, the HEC 10 exceeds the minimum requirements laid down in IEC/IEEE 62271-37-013.

and the very steep transient recovery voltage (rate-of-rise equal to 8.1 kV/µs) are evidence of the severity of an out-of-phase 180° test. The successful testing of the HEC 10, also for this duty, proves the high performance of its interrupting chamber design.

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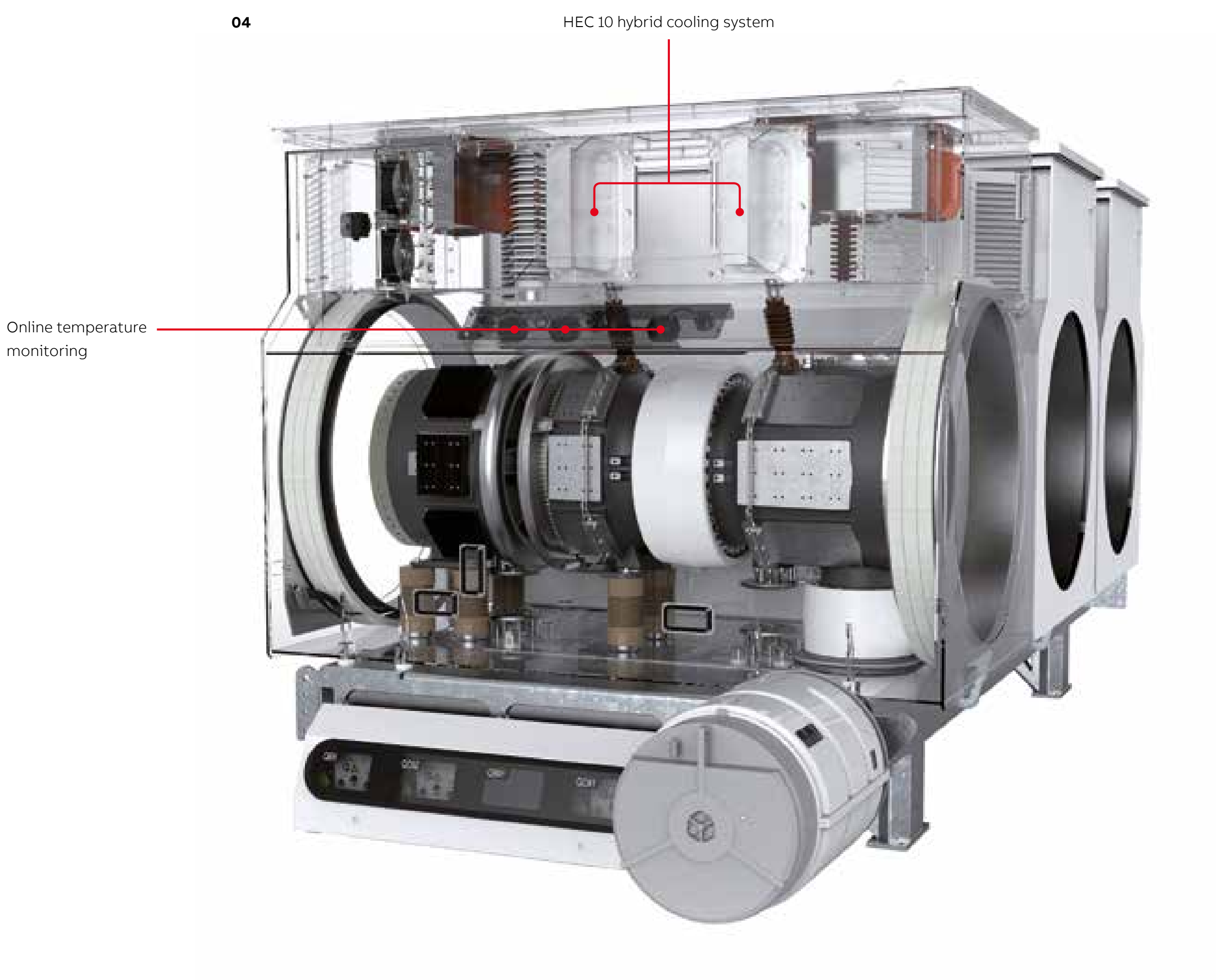

Exceeding the latest standard's minimum mandatory requirements: mechanical endurance
The mechanical reliability of GCBs is tested using mechanical endurance tests. The corresponding standards require 1,000 or 3,000 no-load CO (close-open) operations for the GCB as well as 1,000, 2,000 and, sometimes, 10,000 CO operations for the disconnector and the earthing switches.

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The HEC 10 was developed with the goal of simplification and optimization. For instance, the number of parts was significantly reduced compared to the HEC 7/8.

Extended mechanical endurance type tests that exceed the standard requirements have been passed for the HEC 10: 10,000 CO operations for the GCB and the disconnector and 5,000 CO operations for the earthing switches. These tests demonstrated the high reliability and quality of the new system.

Fully separated disconnector and interrupting chamber
The interrupting chamber design of the HEC 10 follows the ABB standard of having both main and arcing contacts in SF_6 with a disconnector provided in series on the transformer side of the breaker. This design provides safe and visible isolation between the step-up transformer and the generator without compromising the safety of the power plant.

Optimized for a compact design
The HEC 10 was developed with the goal of simplification and optimization. For instance, the number of parts was significantly reduced compared to the HEC 7/8, thus enabling a compact design.

Further, the contact systems of the disconnector and the earthing switches were improved by introducing a newly developed calibration-independent bearing system that allows an increased fault tolerance. On the kinematic side, a turning shaft linkage instead of a push-pull one was implemented, thus increasing the intrinsic system safety. In addition, the disconnector's short-stroke design (by ABB) contributes to the HEC 10 compact footprint without compromising the insulation level. Finally, the introduction of field control elements, common in high-voltage engineering, reduces the space required for installation.

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05 The ABB GCB digital monitoring system, GMS600.

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References

[1] M. Palazzo and M. Delfanti, "New Requirements for the application of generator circuit breakers," IPST Vancouver, Canada, July 18-20, 2013.

[2] M. Palazzo, et al., "Revision of TRV requirements for the application of generator circuit breakers," Electric Power Systems Research, volume 138, pages 66–71, September 2016.

An innovative cooling system

An efficient cooling scheme guarantees the safe and reliable operation of the GCB. Based on accurate simulation studies, the cooling scheme of the HEC 10-XL was chosen to be a hybrid system consisting of passive heat pipes and heat sinks equipped with simple and redundant low-maintenance fans that allow the GCB to operate with normal currents of up to 29 kA →4. This innovative cooling system enables temperature and fan operation to be fully monitored online using a GMS600 monitoring system, thus allowing condition-based maintenance.

By avoiding the use of SF_6 cooling radiators, the HEC 10 provides the highest reliability. And with an SF_6 leakage rate of less than 0.1 percent per year, the HEC 10 comes in well below the maximum allowed by the standards. When needed, the fans can be easily exchanged online without shutdown of the generator, thus ensuring maximum power plant availability.

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Additional safety features

The integration of the main drive train into the longitudinal supports of the pole frame is part of the comprehensive HEC 10 layout optimization strategy. The resulting combination of the structural components with the protective functions provides a simple and robust design. Special care in the pole frame design assures protection from unintended access to moving parts between the operating mechanism and the switching components, and thus provides the highest levels of safety for operation and maintenance engineers.

Digital monitoring via GMS600

The HEC 10 is fully integrated with the ABB GCB digital monitoring system, GMS600 →5. The GMS600 can perform many functions – for example, data logging, disturbance recording, drive supervision, and temperature and SF_6 density monitoring. The long-term operation of the hybrid cooling system is also monitored by constantly comparing the fans' speeds against expected values.

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Customers who opt for remote monitoring support from ABB will regularly receive reports about the state of their equipment.

Key cooling system data is logged by the GMS600 and thereby made available for regular analysis in order to give the customer additional information on the safe operation of the GCB. Customers who opt for remote monitoring support from ABB will regularly receive reports about the status of their equipment. Data logged through the GMS600 can be connected via the cloud to appropriate ABB Ability™ tools. ABB Ability is a unified, cross-industry digital capability - extending from device to edge to cloud - with devices, systems, solutions, services and a platform that enables more knowledge of the system, more capabilities and improved performance delivered by the connectivity of ABB Ability enabled equipment, including GCBs. ●