



< BACK

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Generator circuit breakers bring advantages to power plant owners

Towards more flexibility and efficiency 06/03/2012 - 5.20 pm

 **CIRCUIT BREAKERS**  **GRID RELIABILITY & EFFICIENCY**
 **POWER PLANT**

Besides playing a major role in power plant protection, Generator Circuit Breakers (GCB) offer more flexibility for plant operation and enable the implementation of efficient solutions to reduce investment cost. Maintenance, energy efficiency and carbon footprint are now also enhanced thanks to GCB architecture optimization.



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What are Generator Circuit Breakers (GCB)?

Generator circuit breakers are power plant devices located between the generator (which produces electricity at a voltage of around 15-25 kV) and the step-up transformer (which increases this voltage up to the grid transmission voltage – 200 kV to 800 kV). They play a key role in the protection of the transformer and the generator in case of fault (short circuit on the power transmission system), and their major function in normal operation is to connect and disconnect the generator to and from the grid with high availability and reliability. For decades, generator circuit breakers have existed for generator ratings ranging from 50 MVA to 1,400 MVA. More than 7,000 units are in service today throughout the world, and they have improved the overall life cycle cost of power plants through efficient protection of generators and transformers and simplifying synchronization to the grid.



What concerns a power producer is to generate and deliver energy. With a generator circuit breaker, a producer can gain flexibility by making the plant's strategic connections safer; it can also reduce the effects of a generator or transformer failure by reducing its duration. "Equipment today has reached a very low failure rate, but a rare phenomenon can still have disastrous effects," says Jean-Marc Willième, Senior Expert at GE Renewable Energy's Grid Solutions' High Voltage Switchgear Research Centre in France.

"Generator circuit breakers are something of an insurance policy: as long as everything goes well, it could be seen as an unnecessary cost, but when things go wrong, what a relief to have it there!"



A financial study, based on life cycle cost, has compared the situation of power plants with and without a generator circuit breaker. Analyzing the risk of fault, which includes, on the one hand, the cost of not producing, and on the other hand, the cost of a generator circuit breaker solution, it validated the installation of generator circuit breakers. "A typical example, based on a 400 MW power plant, demonstrates that the generator circuit breaker solution is cost effective if, during 20 years, the presence of the breaker has avoided less than 14 hours of outage," explains Willième. Moreover, if some cost reductions in generator circuit breaker schemes are taken into account, such as eliminating HV circuit breakers and HV/MV transformers and replacing them by a generator circuit breaker and an MV/ MV transformer to feed auxiliaries (see sidebar 2),

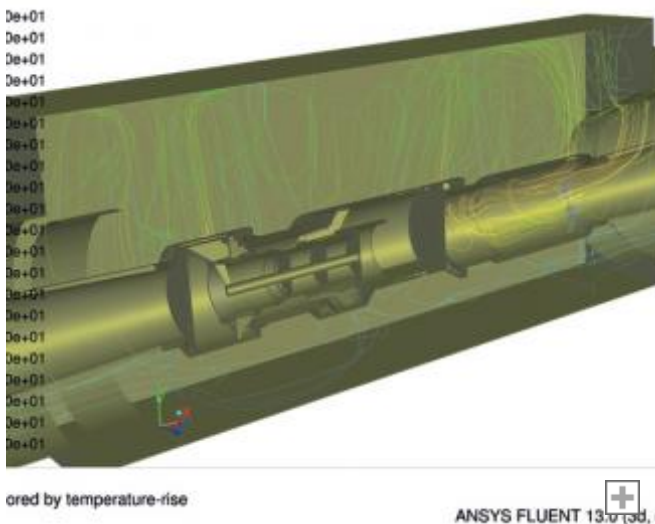
“savings could be identified from the very beginning of the project”.

2 __ Continuously enhanced and upgraded generator circuit breakers



In the world of circuit breakers, breaking capability is a very important feature to have adequately specified in case of a major fault in a power plant. This kind of failure is extremely rare, but has very heavy consequences, so the design of the interrupting chamber – the heart of the generator circuit breaker – is a crucial factor.

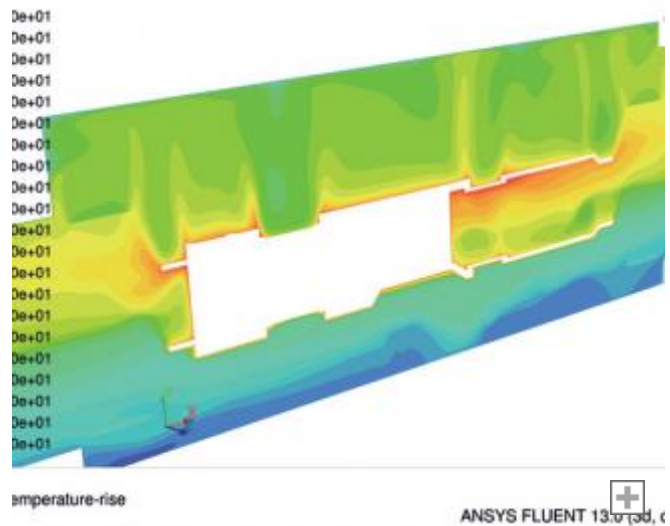
« *Generator Circuit Breakers are something of an insurance policy* »



Grid Solutions has continually developed and improved this mechanism. Thanks to the thermally assisted puffer-type technology, it is possible to interrupt short-circuit currents of at least 160 kA with a spring-operating

mechanism. Some years ago, a CIGRE study on high voltage circuit breaker failures and defects in service revealed that the availability of the circuit breakers depends mainly on the reliability of the operating mechanism, and that the most reliable mechanism, by far, is the full spring mechanism. For its latest generation of generator circuit breakers,

Grid Solutions has optimized and enhanced its spring-operating mechanism to make it simpler, save energy and reduce stresses and impacts during operation. As a result, the improvement in reliability and availability of the generator circuit



breakers using spring mechanisms is now accessible for power plants up to 1,400 MVA. Generator circuit breakers originally used air blast technology for electric arc extinction. Air blast was progressively replaced in the mid-80s by sulphur hexafluoride (SF₆) technology, where the SF₆ is used instead of compressed air.

3 __ Keeping losses as low as possible



To reduce life cycle cost, the conception of a generator circuit breaker focuses on the status of the arcing contacts, which suffer heavy wear when operating and can be considered as strategic for the breaker. However, “another important feature of the generator circuit breaker is its capability in terms of rated current,” says Willième.

« The most reliable mechanism, by far, is the full spring mechanism. »

Although this is around one-tenth of the breaking capability, manufacturers have to carefully design their breaker around this issue. “As the main current specification is related to a function that is active almost 100 % of the operational lifetime of the

generator circuit breaker, what is needed is a current-carrying capability with losses as low as possible.” This concern is reinforced by the fact that circuit breakers are traditionally associated in series with line disconnectors, whose role is to provide personnel with visible safety during maintenance. Unfortunately, disconnectors also have permanent disadvantages: they are a source of loss during energy production phases; they also increase the occurrence rate of minor risks such as mechanical failure, and major risks such as thermal runaway of contacts; consequently, they need more maintenance.

The sizing of both circuit breaker and disconnector for loss reduction requires the full attention of the designer. This is reinforced by the fact that the environmental footprint of electrical equipment is mainly related to the energy dissipated during the total generator circuit breaker's life operation, rather than to the energy or material consumed during manufacturing process. “The most efficient way to avoid energy waste in this equipment is to reduce energy sources by design,” Willième points out.

4 __ A breakthrough in efficiency and environmental friendliness



The classical SF₆ circuit-breaker layout is not 100 % effective regarding loss reduction. As SF₆ pressurized volume is linked to contact sizing, designers have to make compromises between Joule loss reduction and minimizing SF₆ volume. Another drawback is that the main contacts are in the same environment as the arcing contacts and consequently are subjected to the hot, current-breaking gas flow as well as corrosive SF₆ by-products. “An innovative architecture – the FKGA2 – avoids these

compromises by allowing the main contacts to be completely isolated from the heated current-breaking SF₆ gases, contaminated particles and the associated by-products within the interrupter chamber,” explains Willième. Their lifetime is therefore independent of the breaking events experienced by the interrupter chamber. The integration of the circuit-breaker main contacts and disconnecter function into a single piece of equipment is particularly effective in decreasing losses: the electrical resistance is far less compared to the classical solution (circuit breaker and disconnecter in line), so heat dissipation is reduced throughout the equipment lifetime. Additional benefits include a reduction of the equipment’s total phase length; hence less material is used, and manufacturing processes are reduced, resulting in less impact on the environment. The combination of these different factors, including reduction of SF₆ volume, leads to a significant decrease in the equipment’s environmental footprint.

Use of multi-physics optimization for designing circuit breakers

The development of digital simulation tools and the exponential increase in computer power allow engineers to greatly accelerate the design of industrial applications such as high voltage breakers. They can pre-evaluate a design on computer models to examine its behavior for different operating conditions and therefore optimize the product before the first prototype is built and tested. As a result, test duration and cost can be substantially reduced. “Generator circuit breakers are extreme products due to the very high currents imposed by their position on the network,” says Gwenael Marquezin, HV Switchgear Expertise Development Manager. “Optimizing their design for higher performance and efficiency, making them more robust and compact (such as in the FKG series), leads to

increasingly complex problems to solve as design constraints are closer to the limits.” Therefore, “multi-physics simulations are necessary to better understand and evaluate the combination of physical constraints and their effects on the breaker’s behavior, performance and lifecycle. ” Besides the complex simulations of breaking tests, generator circuit breaker designers rely on the simulation teams to recognize such effects as the electromagnetic forces generated by the high short-circuit currents, Joule power and related temperature rise due to the high nominal current, seismic response of the equipment, etc. However, beyond theoretical knowledge, these teams “must possess the practical competencies to be able to cast a very critical eye at simulation results, their significance and correlation with test results.” Dielectric, thermal and mechanical phenomena involved in the circuit-breaker design are nowadays relatively well understood; others, like coupled electromagnetic and fluid approaches, are highly complex and require extra care.



This station is among the best performing power plants in the world with low NO_x , SO_2 and CO_2 emissions. It features a high operational flexibility, since it can run at base load and part loads as well as in two-shift operation mode. It is designed around two GT26 combined cycle modules rated at 435 MW each for a gross output of 870 MW at 59 % efficiency.

5 __ Easier inspection for the main contacts



Beyond environmental considerations, power plant owners are concerned by the reliability and availability ratio of their plant and by the immediate negative consequences of a failure. For this reason, it is crucial to detect the predictive signs of future failure at the earliest possible stage. As the main contacts are a major contributor for the transmission of the energy produced by the power plant, it is a big advantage to be able to easily observe the main contacts throughout the equipment's lifetime in order to detect any trace of abnormal wear on the contact surface. The value of having accessibility to the main contacts is enhanced by the fact that contact resistance measurement cannot alone be considered as reliable evidence of an increase in temperature. Furthermore, the new joint IEEE-IEC GCB standard draft recommends visual inspection of main contacts as an efficient "verification of the capability of the generator circuit breaker to carry the rated normal current".

« Heat dissipation is reduced throughout the equipment lifetime. »

Contact inspection consumes a large portion of maintenance time with a classical breaker architecture, where main contacts are hidden in a sealed envelope containing SF₆ gas under pressure and subjected to hot gas flow; currently it is only possible to inspect the contacts during complete overhaul sessions of several weeks. By segregating the main contacts from the interrupting SF₆ gas, the new FKGA2 provides simple access from outside the breaker during a short, normally scheduled power plant shutdown. The main contact inspection is considerably easier

than with the conventional GCB architecture and, when necessary, parts replacement is also significantly less burdensome.

Generator circuit breaker solutions – lower cost, flexible and more protective

There are 2 major options when designing the electrical single line diagram for a power plant:

- the **block diagram scheme**: the generator output is directly connected to the Generator Step-Up Transformer (GSUT), and the connection of the unit to the grid is through an HV circuit breaker; this scheme requires a Station Service Transformer (SST) to feed the unit auxiliaries when the generator is not connected to the grid;
- the **generator circuit breaker scheme**: the HV circuit breaker always remains closed and the unit auxiliaries are permanently fed through the GSUT and the Unit Auxiliary Transformer (UAT).

For the user, the generator circuit breaker scheme has 3 main advantages:

- it is a more economical solution, as the generator circuit breaker's cost is made up for by the savings from avoiding an SST and its associated connection to the HV grid;
- it avoids auxiliary power supply changeovers at unit starting and stopping; for large power plants these changeovers may be complex and induce important transients if the 2 supplies are not in phase;
- generator circuit breakers enable fast elimination of faults (80 ms) on the energy transmission system (GSUT, UAT, busbars), and therefore limits the consequences of the fault, whereas with the block diagram scheme, the

generator will continue to feed the fault for several seconds until the generator is fully de-excited.

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