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SACE INFINITUS FOR THE FUTURE OF ELECTRICAL DISTRIBUTION

One of a kind

SACE Infinitus, the premier all-in-one certified solution, gives new protection perspectives for DC grids today and in the future. With power electronic, mechanics, cooling, control, sensing and communication included, low voltage fault protection and isolation issues reach a new level.

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With the electrical transformation in full swing and expected to expand, efforts to reach carbon neutrality are intensifying. DC power solutions are expected to play an increasingly important role in electrical distribution systems – especially for low voltage (LV) systems. Characterized by high efficiency, compared to AC solutions, DC solutions are enabling the electrification of a variety of loads, transportation, industry automation, heating, etc. This will foster the integration of renewables and the deployment of energy storage in the grid [1].

DC solutions are enabling the electrification of a variety of loads, thereby fostering the integration of renewables.

With economic benefits possible in various applications, DC technology has high growth potential; especially due to higher efficiency and reduced energy costs, which are improved by DC-coupled energy storage. Because of this efficiency edge, DC application solutions are increasingly applied to the marine transport sector →01. And yet, important hurdles remain: adequate fault protection and isolation.

The major challenge stems from the low-inductive nature of high-power DC applications

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01 DC distribution is gaining in popularity within the marine transport sector ranging from cruise ships (shown here) to cargo ships.

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02 From traditional IGCT bi-directional arrangement to the novel RB-IGCT of SACE Infinitus.

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03 Comparision of loss of RB-IGCT against other semiconductors [7].

combined with additional high-power, directly-coupled, energy storage. In case of a short circuit, due to low inductivity (and low resistivity), the rise-time of the fault current is dramatically shorter than in AC applications: several microseconds or less – a significant challenge for a typical circuit breaker. To limit and extinguish the fault current, the device must quickly build up a counter voltage that matches, at least, the nominal operation voltage of the system. Existing DC and AC systems with electromechanical circuit breakers use arc quenching mechanisms to split, cool and dissipate the arc energy generated, via an arc chute. Despite this being an appropriate current interruption for most applications, this process requires tens of milliseconds to clear a fault – too slow for these emerging DC applications.

Instead, solid-state circuit breakers (SSCB) rely on microsecond-fast power semiconductor devices to achieve the required open-circuit disconnection and enable ultrafast and safe current interruption suitable for the aforementioned fast-rising current in DC [2-3].

Intended to enable the DC electrical systems of the future, thereby paving the way for the sustainable energy transition, ABB developed SACE Infinitus, a unique solid-state circuit breaker – the premiere, all-in-one-device that solves these fault protection and isolation issues [1].

RB-IGCT – a winning solution

Compared to conventional circuit breakers, one historical hurdle to the adoption of SSCBs has been the higher on-state losses resulting from the higher voltage drop across the power semiconductor, compared to the typically small resistance of the contacts inside an electromechanical breaker. Apart from the impact on efficiency,

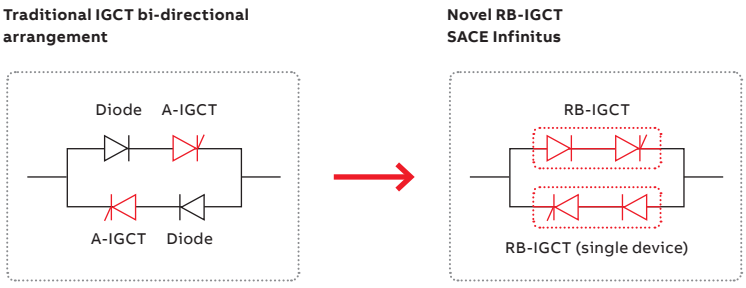
Adequate fault protection and isolation is an important hurdle to applying DC application solutions to the marine sector.

another drawback of increasing losses is the need to remove the dissipated heat; even an effective cooling system will result in an undesired increase of size, complexity and costs [3].

The insulated gate bipolar transistor (IGBT) technology can turn on and off rapidly, making it extremely effective at switching, as well as easy to control; IGBTs are state-of-the-art in converter technology. Nevertheless, they exhibit high on-state losses in circuit breaker applications – a serious challenge at high nominal currents.

ABB introduced the integrated gate-commutated thyristor (IGCT) in 1996 in the context of MV power converters [4]. The IGCT integrates a low-inductance gate driver with a fully controllable gate. This enables the semiconductor to conduct current with very low losses, similar to a thyristor, while being able to turn on and off like an IGBT or a transistor [3-6]. This is a good foundation for a solid-state circuit breaker.

SACE Infinitus goes even further; it employs a special reverse-blocking IGCT (RB-IGCT) that integrates a thyristor and a diode in series for protection against reverse voltage all within the same silicon wafer. This wafer-level integration results in a best-in-class low on-state voltage drop. A second anti-parallel RB-IGCT is used to enable conduction and turn off of bi-directional currents →02 [6]. The result is 70 percent lower power losses compared to an equivalent IGBT's conduction→03 [7]. Consequently, ABB's IGCT solution features efficiency up to 99.9 percent, at 1 kA, 1 kV compared to 99.5 percent for



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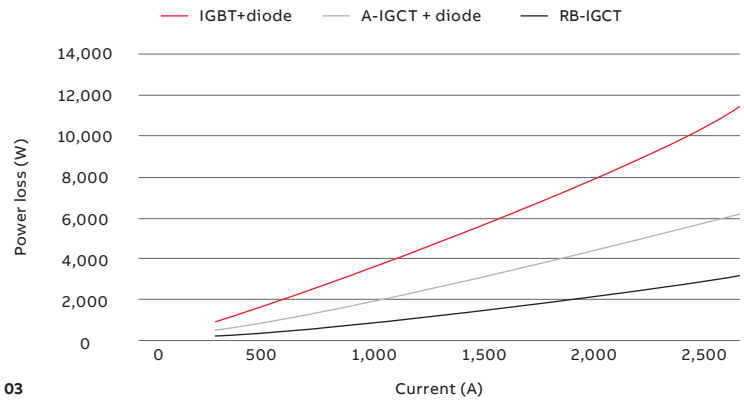

03

IGBT-based solutions →03 [6]. This translates to a 70 percent reduction of power losses and related carbon footprint.

Employing this optimized RB-IGCT solution, ABB presented its ground-breaking solid-state circuit breaker concept to the public at the Hanover Fair in Germany in 2019 [7].

All-in-one design

Beyond overcoming the challenges of developing an optimal semiconductor and cooling system, integration is key. In 2022, ABB unveiled the revolutionary SACE Infinitus →04 – the premiere all-in-one protection solution that achieves the seamless integration of all necessary components – power electronic, mechanics, cooling, control, sensing and communication – to create an installation-friendly and compact all-in-one solution. Through simplicity of design, ABB aimed to minimize efforts and thus, cost generated during the product deployment phase, compared to a custom-built complex and error-prone compound device solution. With SACE Infinitus, it is no longer necessary to provide space, and logic to coordinate an external switch for galvanic insulation, required for maintenance; this significantly improves ease-of-installation and safety, and lowers costs.

Unveiled in 2022, SACE Infinitus, with an optimized RB-IGCT, is an all-in-one protection solution that resolves fault challenges.

Despite significant challenges arising from the integration of such a broad variety of technologies, ABB created the first-of-its-kind solid-state breaker solution. The compartmentalized design within a single frame means the footprint is compact, and the breaker is easy to install, maintain and service. The well-established draw-out racking system is deployed in two mobile parts: one comprising the power electronics, with the integrated liquid cooling and the quick shut-off couplings; and the second containing the switch for the galvanic isolation →04.

Moreover, communication modules based on ABB's Ekip can be plugged-in, allowing integration of the SSCB into digital systems. The integrated voltage and current sensors of the breaker enable the continuous monitoring of the electrical parameters, including power.

Cooling made simpler

While conduction losses are significantly lower in SACE Infinitus compared to IGBT solutions, they are not trivial, about 3 kW for a circuit rated at 2,500 A. To keep the temperature of the semiconductor junction (where the highest temperature occurs during operation) in the safe operating area (SOA), integrated cooling is essential. For the package of a conventional IGCT, the power terminals also serve as thermal interfaces, enabling the cooling of the core. This comes at a cost; the cooling system must be insulated; typically with an insulating cooling fluid eg, deionized water for MV motor drives. But, cooling with deionized water can be impractical since it requires a purification circuit to be added to the system.

In response, ABB developed an innovative solution to alleviate space and weight issues yet insulate and cool without the disadvantages of the complexity of commonly-used approaches →04. In SACE Infinitus, the thermal management concept is based on aluminum-nitride cold plates that combine electrical insulation and high thermal conductivity, achieving properties close to that of aluminum. Thus, the cooling liquid can be the well-known mixture of water and glycol obviating the need for additional equipment and reducing complexity.

Establishing control and protection

The SACE Infinitus control and protection functionality stems from a microprocessor-based trip unit that fulfills both the conventional "slow" long range, short range, instantaneous and ground fault (LSIG) protection, in timescale of milliseconds and seconds, and the ultrafast short-circuit protection in the timescale of microseconds →04. Moreover, it ensures the crucial interplay of the power electronic and the electromechanical isolation switch of the SACE Infinitus. Ultrafast current measurement, a prerequisite yet challenge in DC systems, required the development of dedicated current transducers using Hall-effect sensors: the bandwidth is high enough to discriminate current transients up to 80 A/µs.

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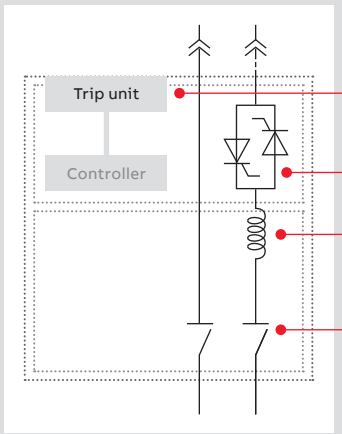
04 SACE Infinitus all-in-one device integrates cooling, protection, inductance, power electronic and insulation switch into one easy to install device. The withdrawable rack solution uses electrical and hydraulic connections/ disconnections for the in/out motion.

When interruptions occur, Infinitus steps up

SACE Infinitus clears faults lightning-fast, in tens of microseconds; but how? In DC systems, where sources are generally inverters with large DC capacitor banks located at their output →05, a short circuit on the bus will generate a high di/dt fault current that cannot be effectively managed by standard electromechanical breakers. Relying on a technological breakthrough, the SACE Infinitus protection system resolves this issue →04. Here, the breaking time is so short that the fault current is interrupted before it can reach more than twice the nominal current, typically. This ultrafast current limiting function will, in practice, act as an immediate DC disconnection mechanism during a fault event. SACE Infinitus can disconnect the circuit in about 20–50 µs – a remarkable result →05. The inductive energy of the grid is absorbed in the metal oxide varistor (MOV) path parallel to the semiconductor until current zero is reached.

ABB's premier solution clears faults lightening-fast, in tens of microseconds – a remarkable result.

In most installations, fault current rises at a much lower rate than the critical di/dt, ensuring that the semiconductor can operate in its SOA. At such di/dt rates, interruption capability is almost unlimited. In rare cases when this limit is exceeded, SACE Infinitus is equipped with an internal inductance limiting the di/dt to values within the SOA.

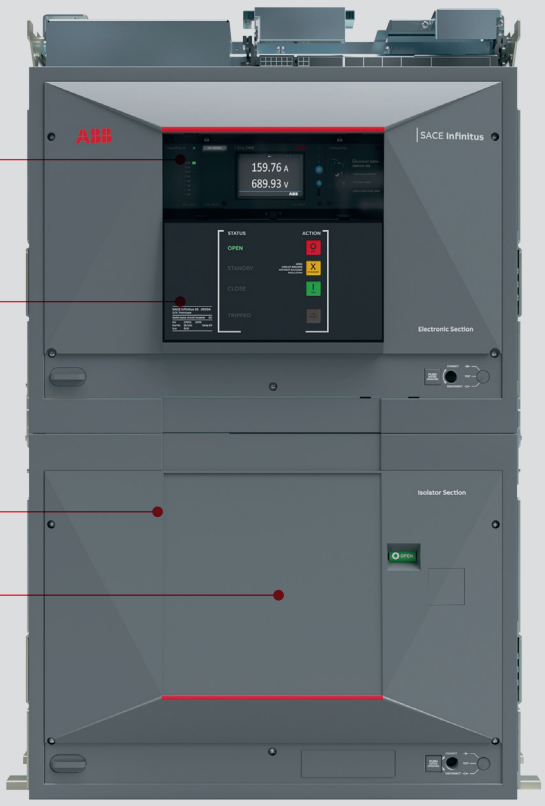


Protection unit
- advanced protections
- network analyzer
- energy metering
- communication …

Power electronic
- low-loss RB-IGCT technology
- cooling system

Inductance
- control of dI/dt

Isolator switch
- CAT IV
- motor controlled



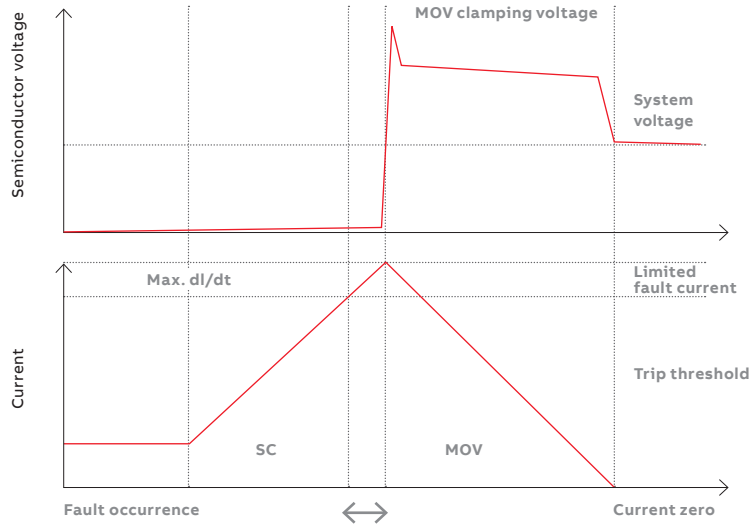
- Withdrawable frame; frame size: up to 2500A
- Rated voltage: 1.000 Vdc
- Fully bidirectional
- 1p and 2p switching, 2p isolation
- High-speed overcurrent protection: <25 microseconds
- Power losses: 1.3 kW @ 1kA, single pole
- Liquid-cooling/ withdrawable version
- All-in-one solution for low total cost of ownership:
  - Advanced Protection w/ power, voltage, directional
  - Switch
  - Isolator
  - Energy metering
  - Connectivity: 7 communication protocols
  - IEC 60947-2 certification, DNV-GL

One solution – unlimited protection – an economic advantage

Deployment of SACE Infinitus as a highly integrated protection device means:

- extremely fast breaking time – 100 times faster than traditional protection systems, and maximum service continuity
- isolation of the faulty zone – avoids full system shut down
- near zero arc energy exposure; this mitigates the risk of arc flashes
- maximal energy efficiency thanks to new switching technology with the lowest power losses in the semiconductor-based breaker category
- more than 100 times better endurance – extraordinary electric life to match the future demanding needs of microgrids

As a result, ABB's customers benefit from total system efficiency with lower cost of ownership and improved availability as they transition to sustainable energy.



05 Time to interrupt: <25µs

Setting the standard

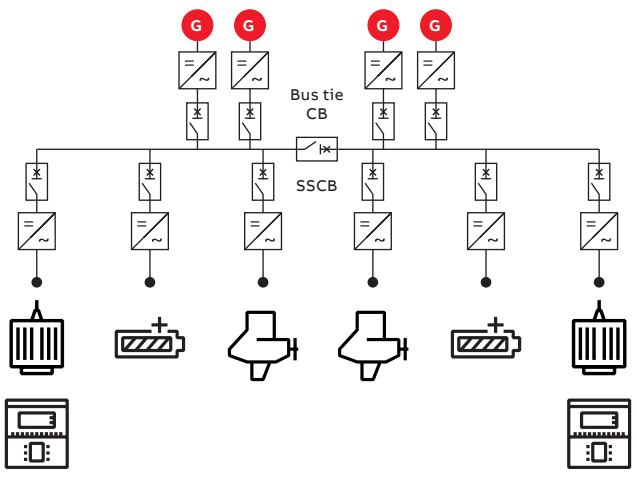
The SACE Infinitus circuit breaker is the world's first breaker certified according to IEC 60947-2 based on semiconductor interruption technology. Intensive work is underway to develop further specific standards. With their SACE Infinitus solid-state breaker project experience, ABB is co-driving the development of a new specific IEC standard – project PT60947-10 – for solid-state breaker technology (DC and AC applications) with an expected release in 2025.

ABB's technology is the world's first IEC circuit breaker based on solid-state technology; it offers nearly infinite possibilities.

Marine application

The marine segment is an early adopter of DC onboard grids with ABB at the forefront of this enabling technology. With energy savings up to 20 percent, ever more vessels are being designed with DC distribution systems.

In →06 a bus tie breaker connects the starboard and portside sections; this typically allows an optimal usage of the power generators. If a fault occurs, the sections must be protected by the circuit breaker to prevent a total outage and ensure service continuity by disconnection of the faulty section. In situations that are too challenging for traditional technology due to the high and fast rising (in milliseconds) short circuit currents, ABB's SACE Infinitus excels.



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With low losses, arc-free, ultrafast current interruption speed, SACE Infinitus is ideal for preventing severe risks to people and assets. Elsewhere, when fault current is not the only major concern, it provides the fast protection needed to prevent the DC bus voltage from dropping to a level at

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05 Ultra-fast fault current interruption principle based on SSCB technology.

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06 Example of a DC distribution grid in a marine vessel with SSCB as bus-tie circuit breaker.

which the system becomes inoperative, ie, by the capacitors of the DC bus discharging. The DNV certification, relevant for marine applications, will be available for the circuit breaker.

With DC toward the future

The applications for ABB's new solid-state circuit breaker go beyond the marine transport sector, enabling a new level of sustainability. This revolutionary breaker will impact the evolution of electrical systems for ground transportation. The pilot installation of dynamic road-side EV-charging and a novel industry application that improves energy efficiency are some of the examples currently underway.

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SACE Infinitus has the potential to generate new perspectives for building DC grids in a safe and economical manner.

SACE Infinitus is a core component for mastering the challenges of DC protection; it has been created for high current DC applications with a view to the future; providing switching, insulation and DC protection in a single compact device up to a rating of 2.5 kA at a rated voltage of 1000 VDC.

With power electronics and advanced software algorithms that control the power, interrupting extreme currents lightning-fast, ABB's customers will be positioned to address the challenges of future energy requirements. With its simple and safe design, allowing ease of system integration, and ultrafast protection, SACE Infinitus satisfies the needs of new emerging applications economically.

By introducing an ultra-fast breaker solution that enables next-generation DC architectures, ABB demonstrates their commitment to the sustainable transformation of electrical energy. SACE Infinitus is the world's first IEC circuit breaker based on solid-state technology, and it has the potential to generate new perspectives for building DC grids in a safe and economical manner; this innovative all-in-one device offers customers nearly infinite possibilities. •

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References

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