WORLD'S LARGEST
RATED AIR-COOLED SALIENT-POLE SYNCON

SYNCHRONOUS CONDENSER

Your solution for grid stability services

ANDRITZ

Maintaining the reliability of the grid

Demanding new regulatory requirements and a cleaner, more diversified energy mix pose new challenges for electricity system operators tasked with maintaining a stable energy supply. The synchronous condenser is a reliable, proven, and cost-effective solution.

A CHANGING POWER SECTOR

The power sector faces new challenges on both the demand and generation sides. While the integration of renewable energy sources is crucial to decarbonize the power sector, new electrical consumers, such as data centers and electric vehicles, must also be reliably supplied. These challenges make it significantly more difficult for system operators to ensure a stable, reliable, and secure transmission and distribution network.

LESS INSTANTANEOUS FREQUENCY RESPONSE RESERVE

The frequency of a power grid is an indicator of the balance between generation and demand. Major imbalances – such as when a generation plant trips off the grid – cause deviations in frequency from its nominal value. A sufficiently large amount of inertia in the power system can dampen the Rate of Change of Frequency (RoCoF).

Conventional thermal and hydropower plants are coupled to the power grid via synchronous generators, which inherently provide inertia due to their rotating masses. In contrast, wind and solar photovoltaic (PV) power plants, as well as high-voltage direct current (HVDC) systems, use power electronic inverters to exchange power with the grid. Due to the absence of rotating masses, inverter-coupled equipment does not provide physical inertia. The reduced level of inertia increases the RoCoF in the event of large imbalances between generation and demand. System operators therefore seek to maintain a minimum level of inertia to prevent RoCoF from exceeding certain thresholds.

> "Synchronous condensers are the only solution capable of providing all grid stabilization services."

SYSTEM STRENGTH

System strength indicates the resilience of a power system against operational fluctuations and its ability to recover after disturbances. The higher the system strength, the higher the resilience and recovery capability. System strength at a specific point in the power grid is often defined by its short-circuit level, which plays a vital role in the proper functioning of the protection system and in ensuring voltage stability.

In order to be granted a grid connection permit, it is typically mandatory that the available short-circuit level at the point of common coupling (PCC) is sufficiently high. A high penetration of non-synchronous, inverter-coupled power generation – such as solar PV, wind power plants, or HVDC connections – provides little or no short-circuit level, thereby reducing the overall system strength.

MORE VOLTAGE FLUCTUATIONS

System operators are obligated to keep grid voltage within defined limits, covering both steady-state operation and transient disturbances (e.g., short circuits on a transmission line, switching operations in large substations). The transition towards volatile renewable energy sources leads to increased voltage fluctuations in the power grid. In addition, the decrease in short-circuit level results in lower resilience against such fluctuations.

Steady-state voltage control is performed by managing reactive power flows in the power system.

In the event of transient disturbances, high reactive currents must be injected during and after the event to prevent voltage collapse.

SYNCHRONOUS CONDENSERS AS A COUNTERMEASURE

Synchronous machines can generally be used as generators or motors. A synchronous condenser is a conventional synchronous machine operated without a prime mover, used specifically to stabilize the grid. Due to their electrical design and the large rotating mass of their rotors, they can provide a variety of grid services beyond reactive power supply. In recent years, a distinct shift in the grid services demanded from synchronous condensers has been observed.

Synchronous condensers are typically installed in existing or new substations, providing the following main functions:

Increasing instantaneous frequency response reserve: Synchronous condensers are the ideal instrument for providing inertia, which is naturally produced by the rotating mass of the machine and can be further increased through the addition of external flywheels.

Increasing the short-circuit level: Due to its low internal impedance, a synchronous condenser increases the short-circuit level at its point of common coupling (PCC), enhancing the grid's capability to integrate renewable energy plants or HVDC systems. Synchronous condensers can provide up to five times more short-circuit current than their rated capacity, making them major contributors to short-circuit strength in grids dominated by renewable generation.

Steady-state and dynamic voltage control: Synchronous condensers have been used for decades to provide reactive power for steady-state voltage regulation. If system voltage is too high, the synchronous condenser operates under-excited (inductively) and absorbs reactive power to reduce voltage. If system voltage is too low, it operates over-excited (capacitively) and supplies reactive power to increase voltage.


BURONGA SUBSTATION / Australia

The injection of high reactive currents during and after grid faults is of fundamental importance to prevent voltage collapse. Synchronous condensers are designed to provide such a response and can offer an extended, time-limited overload capability.

Previously common compensation devices, such as Static VAR Compensators (SVCs) and conventional Static Synchronous Compensators (STATCOMs), contribute little or nothing to increasing instantaneous frequency response reserve or short-circuit level. Synchronous condensers are therefore the only solution that can support system operators across all grid stabilization services simultaneously. Furthermore, they provide instantaneous frequency response and short-circuit contribution inherently, without relying on control mechanisms.

Consequently, synchronous condensers are becoming increasingly important in managing grid stability in the face of the accelerating energy transition.

Why synchronous condensers from ANDRITZ?

ANDRITZ's synchronous machine portfolio covers a vast and complex range of applications, demonstrating technical expertise across a wide variety of technologies. ANDRITZ offers several synchronous condenser series with rated power up to 330 MVA, available for both 50 Hz and 60 Hz grids. This broad portfolio allows ANDRITZ to select the optimum solution for each customer's specific requirements.

With more than 120 years of experience in supplying synchronous and non-synchronous machines, ANDRITZ has approximately 5,000 units in service worldwide. Our global track record across the entire power generation sector – from large hydropower and pumped storage to high-voltage systems – is unrivaled. Based on this experience, synchronous condensers designed and manufactured by ANDRITZ deliver several unique advantages.

The starting point for developing a synchronous condenser plant is the definition of all critical parameters, typically derived from transient stability studies and performance analyses. ANDRITZ's industry-leading engineering uses modern modeling and simulation tools, compatible with Building Information Models (BIMs), to deliver the most cost-effective solution across the entire power portfolio. This makes ANDRITZ a market leader in the implementation of synchronous condenser solutions globally.

HIGHER INSTANTANEOUS FREQUENCY RESPONSE RESERVE

Synchronous condensers can be designed with either a cylindrical rotor (turbo generator) or a salient-pole rotor. Our salient pole rotor design has a clear advantage in terms of inertia. The inertia time constant (H) exceeds 3.5 seconds in our salient pole rotor design, compared to 1.5–2.0 seconds in cylindrical rotor designs.

IMPROVED REACTIVE POWER CONTROL

While other compensation systems (e.g. STATCOMs) provide symmetrical under-excited and over-excited reactive power ranges, conventional synchronous condensers are generally limited in their under-excited range, restricting their ability to decrease system voltage.

ANDRITZ's synchronous condenser series with salient pole rotors and a static excitation system overcomes this limitation: lower synchronous reactance and negative field voltage allow an expansion of the under-excited reactive power range compared to competing solutions. As a result, our synchronous condenser can absorb more reactive power than others with the same rated power, substantially enhancing the prevention of local over-voltage in the power system – particularly important during periods of high generation and low demand.

KEY ADVANTAGES OF SYNCHRONOUS CONDENSERS BY ANDRITZ

- Superior natural inertia (without flywheel)
- Extended reactive power range
- Higher reliability and durability
- Lower maintenance effort
- Vacuum-free flywheel design
- Full lifecycle support
- Proven global track record
- Lower system losses

HIGHER TOLERANCE AGAINST TORQUE OSCILLATIONS AND UNBALANCED GRID CONDITIONS

By equipping our salient pole synchronous condenser series with a physical damper winding, the machines benefit from an additional reluctance torque, leading to higher synchronizing torque than cylindrical rotor designs. This series therefore shows higher tolerance against torsional oscillations.

Furthermore, our damper winding design increases the machine's continuous negative sequence current capability, making our synchronous condenser more tolerant of unbalanced grid conditions – such as those near electric arc furnaces or aggregations of single-phase consumers.

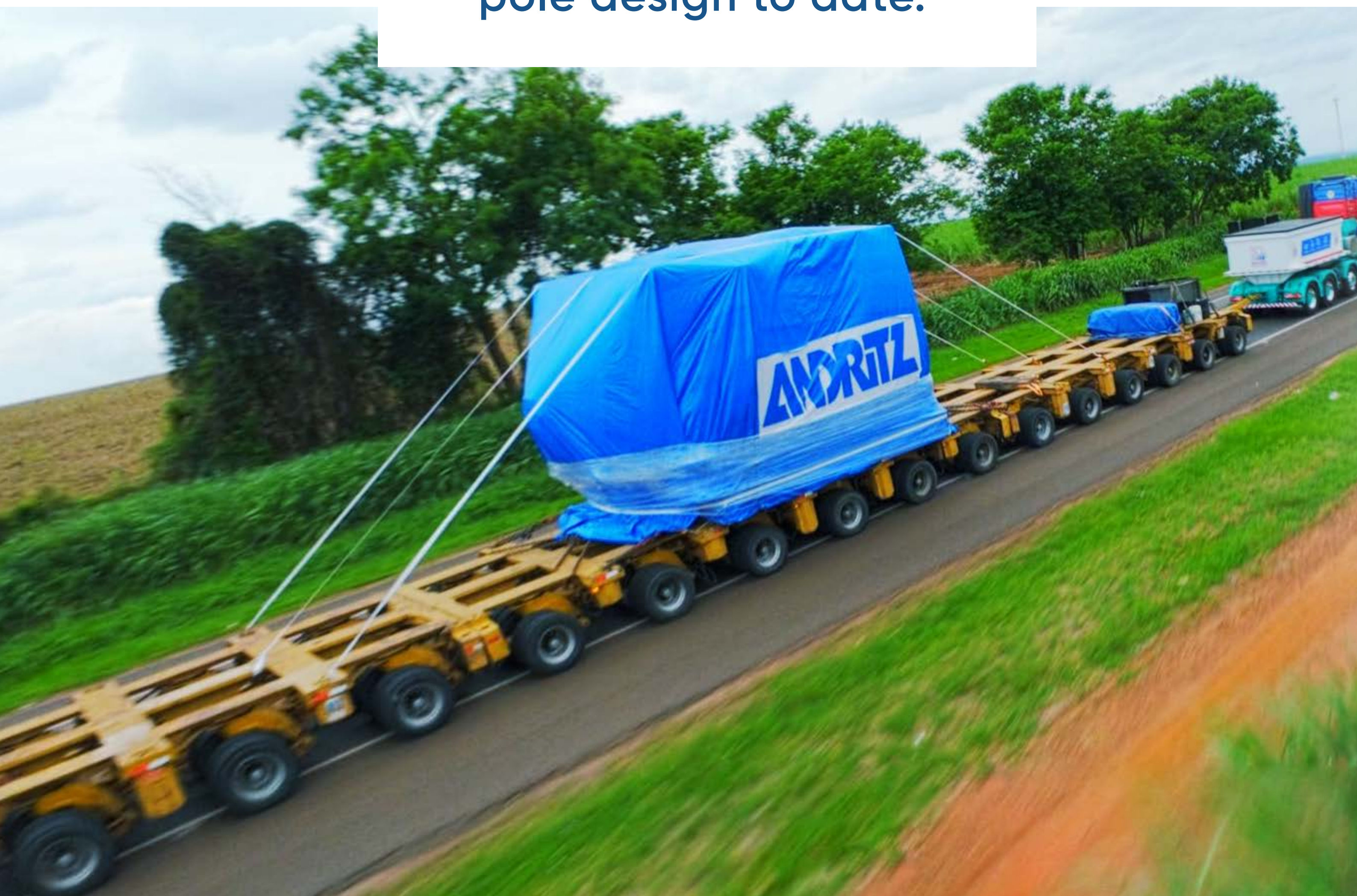
HIGHER RELIABILITY DUE TO SIMPLE DESIGN

For our synchronous condenser series, we apply the simplest and most robust design approach. We completely avoid hydrogen (H_2) cooling in our system, thereby eliminating all associated drawbacks: complex auxiliary units, limited accessibility, specialized sealings, constant leak risks, and associated safety hazards.

Instead, totally enclosed water-to-air cooled (TEWAC) or open air cooling (OAC) systems are used to maintain optimal operating temperatures, ensuring efficient heat dissipation and extended machine lifespan. TEWAC systems additionally provide enhanced protection against contaminants such as dust and moisture, thereby reducing maintenance requirements and improving overall reliability.

For start-up and synchronization, our standard option uses a static frequency converter, avoiding a maintenance-intensive pony motor. Furthermore, our latest patented innovation introduces a new starting method that further reduces maintenance requirements and operating costs, while increasing reliability considerably.

> "ANDRITZ manufactures the world's largest rated air-cooled synchronous condensers with salient-pole design to date."



LIFECYCLE ASSET MANAGEMENT & DIGITAL SERVICES

Lifecycle Asset Management represents ANDRITZ's systematic approach to managing the asset throughout its entire service life, maximizing value, performance, and longevity while minimizing costs and risks. This process encompasses planning, operational support, maintenance, and the eventual renewal of the asset.

ANDRITZ offers a comprehensive range of services aimed at optimizing the efficiency and reliability of synchronous condenser operation, including:

- 24/7 remote monitoring, complemented by expert support.
- Collaborative local first-line support as well as on-site second-level interventions as needed.
- Use of the ANDRITZ-customized platform, Metris DiOMera, to facilitate proactive problem detection and enable real-time assessment of component ageing, improving maintenance schedules, plant availability, and lifespan of the equipment.
- A meticulously developed maintenance strategy tailored to the customer's needs.
- A robust framework for plant and spare parts management, certified to ISO 55000 standards.

The ANDRITZ lifecycle plant management concept is designed to ensure performance and availability throughout the entire service life of the plant, and to enable an extended service life through continuous optimization based on predictive maintenance.

PLANT DIGITAL TWIN

The Plant Digital Twin redefines how customers interact with their synchronous condensers. Designed as a dynamic, 3D virtual replica of the physical plant, it integrates engineering data, operational metrics, and maintenance records into a single, intelligent digital environment.

This solution delivers real-time insights, intuitive 3D visualization, and predictive analytics – enabling teams to anticipate issues, optimize performance, and reduce downtime. With AI-powered assistants and immersive interfaces, the Digital Twin makes complex data accessible and actionable.

The Plant Digital Twin supports seamless integration with other operational platforms, offering flexible solutions and services. It optimizes access to documentation, enables remote support, and allows simulation of operational scenarios. By transforming raw data into strategic insights, the Plant Digital Twin helps plant stakeholders operate smarter, safer, and more sustainably.

TUCUMÃ SUBSTATION IN ACRE
Brazil

Flywheels for increased inertia

ANDRITZ's synchronous condensers, when combined with a top modern high-inertia flywheel ensure a secure energy supply and a long reliable operational life of your asset.

The modularity of the ANDRITZ flywheel series is based on standardized discs with a constant outer diameter. Customers can choose the number of discs (one, two, or three) depending on the required inertia. The system offers significant synergy effects by utilizing already available components, and is characterized by reliable, safe operation and optimized maintenance.

ANDRITZ flywheel systems can increase the available inertia up to 16 seconds. For example, a 250 MVA synchronous condenser has a natural inertia of over 1,000 MWs and can be increased to up to 4,000 MWs by adding a compact flywheel. By providing more inertia to the power system, the RoCoF can be significantly reduced in the event of sudden changes in generation or load.

SIMPLE ASSEMBLY CONCEPT

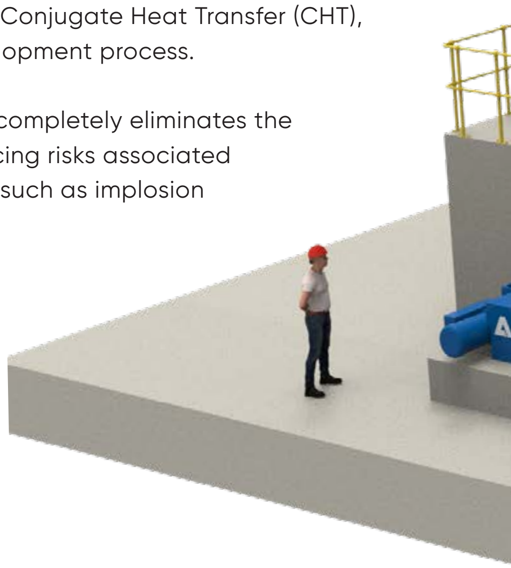
The dimensions and weight of ANDRITZ flywheel discs are within practicable limits for transportation and assembly. The rotor components of the flywheel are mounted in the pre-assembly area before the entire flywheel rotor is lifted into the bearings. Both the synchronous condenser and the flywheel assembly can be carried out quickly and efficiently.

Without the need for vacuum enclosures, our vacuum-free flywheel can be installed without special containment or pressure systems. This results in lower initial infrastructure costs and faster assembly.

SAFE AND ROBUST DESIGN

The rotor is designed to be short-circuit proof, and the rotor dynamic behavior shows high stability. Using appropriate centering devices, the shafts and flywheel discs are precisely machined and bolted together to form a compact rotor unit. ANDRITZ employs the most advanced methods – including Computational Fluid Dynamics (CFD) and Conjugate Heat Transfer (CHT), throughout the development process.

Our flywheel system completely eliminates the use of vacuum, reducing risks associated with vacuum failures such as implosion



Grid stability is not a future challenge – it is today's priority. ANDRITZ's synchronous condensers deliver proven, reliable, and cost-effective grid stabilization for a world increasingly powered by renewables. Contact our team to find the right synchronous condenser solution for your system.

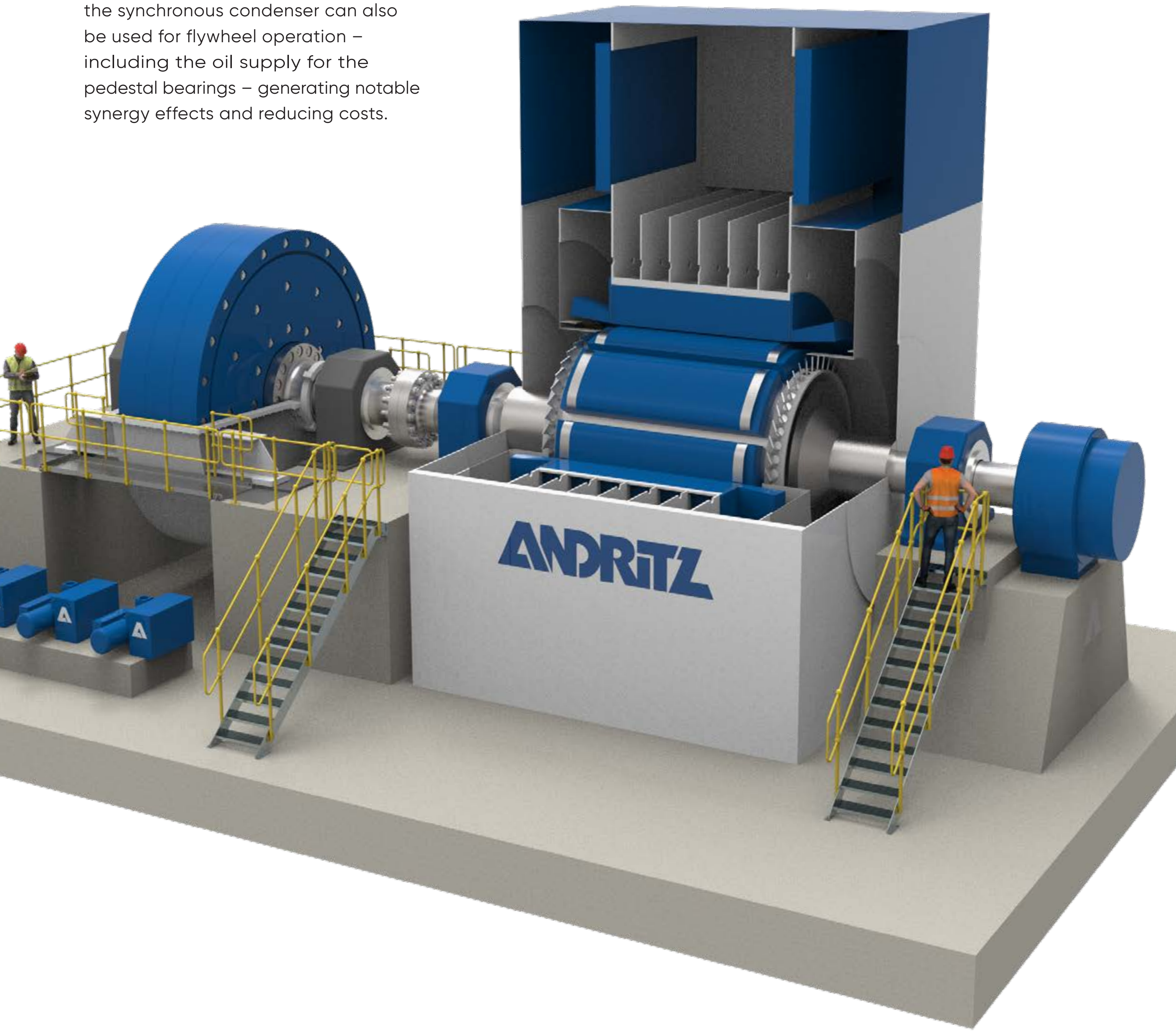
www.andritz.com/syncon

or seal degradation. Vacuum-free systems are inherently more robust under fluctuating environmental conditions and are safer to handle and maintain, making them particularly suitable for applications where reliability and safety are paramount.

OPERATION AND MAINTENANCE

A considerable number of auxiliary components already available for the synchronous condenser can also be used for flywheel operation – including the oil supply for the pedestal bearings – generating notable synergy effects and reducing costs.

ANDRITZ's automation, control, protection, and monitoring systems ensure reliable and safe operation, as well as optimized maintenance. Our vacuum-free flywheel design reduces the number of components requiring regular inspection or replacement, making maintenance routines less complex and more cost-effective over the lifetime of the system.



The world of ANDRITZ's synchronous condensers

The following projects represent a selection of ANDRITZ's global references – a proof of our worldwide presence across nearly every continent, where system operators trust ANDRITZ synchronous condensers to deliver reliable grid stability.

GLENCLOOSAGH & QUARRY LANE, IRELAND
COLERAINE & COOLKEERAGH, UK

ANDRITZ is supplying four synchronous condenser systems and four flywheels to the Low-Carbon Inertia Service projects in Glencloosagh and Quarry Lane (Ireland), and Coleraine and Coolkeeragh (UK). All four units will provide short-circuit power, inertia, and reactive power – improving grid stability and enabling the integration of renewable energy sources into the transmission systems operated by EirGrid and SONI.

Technical Details:
Rated condenser output:
3 x 250 MVA and 1 x 110 MVA (Coleraine)
Rated voltage: 15.5 kV, 50 Hz
Inertia contribution to PCC:
4 x ~2,000 MWs (incl. flywheel)
Nominal system voltage: 110 – 275 kV

BAKERSFIELD, USA

ANDRITZ provides two synchronous condenser systems to the LCRA Transmission Services Corporation project at the 345 kV Bakersfield substation in West Texas. They help manage electricity flow and prevent power outages by increasing short-circuit strength, ensuring consistent and reliable power supply to homes and businesses.

Technical Details:
Rated condenser output: 2 x 210 MVA
Rated voltage: 15.0 kV, 60 Hz
Inertia contribution to PCC: 2 x 1,100 MWs (natural)
Nominal system voltage: 345 kV

CRATEÚS AND SÃO JOÃO DO PARAÍSO, BRAZIL

ANDRITZ supplies two 330 MVA synchronous condenser systems to Brazil. One supports the transmission lines between Bahia and Minas Gerais; the other supports the Ceará Crateús region. These installations represent an important step towards stabilizing the Brazilian power system and ensuring a more reliable power supply for the future.

Technical Details:
Rated condenser output:
2 x 330 MVA, +300/-200 Mvar @ PCC
Rated voltage: 18.0 kV, 60 Hz
Inertia contribution to PCC: 2 x ~1,200 MWs (natural)
Nominal system voltage: 500 kV

BURONGA AND DINAWAN, NSW AUSTRALIA

ANDRITZ has provided four synchronous condenser units including electrical power systems (EPS) for two substations at Buronga and Dinawan in New South Wales. The supply is related to the EnergyConnect project built by Elecnor Australia for Transgrid, a nation-critical infrastructure project vital to Australia's transition to renewable energy.

The EnergyConnect interconnector increases renewable energy sharing between New South Wales, Victoria, and South Australia, with the four synchronous condenser units providing system resilience services – including inertia, short-circuit contribution, and reactive power compensation – to maintain grid stability and enable National Energy Network connecting additional large-scale renewable energy sources.

ANDRITZ also provides a long-term maintenance service, covering annual maintenance, condition monitoring and predictive maintenance.

Technical Details:
Rated condenser output:
4 x 120 MVA, +100 / -50 Mvar @ PCC
Rated voltage: 12.0 kV, 50 Hz
Inertia contribution to PCC: 4 x ~840 MWs (natural)
Nominal system voltage: 330 kV

TUCUMÃ, BRAZIL

For Transmissora Acre II, part of the Zopone Group, ANDRITZ supplied a synchronous condenser at the 230 kV Tucumã substation near Rio Branco, the capital of Acre, supporting the expansion of the transmission grid in northern Brazil. The supply included the rotating unit, electrical power systems, and a digital control and protection system.

Technical Details:
Rated condenser output: 165 MVA, +150 / -90 Mvar @ PCC
Rated voltage: 11.0 kV, 60 Hz
Inertia contribution to PCC: ~ 400 MWs (natural)
Nominal system voltage: 230 kV

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