

Synchronous condenser systems

Ensuring grid stability for tomorrow's
power systems



Sustainability is the goal

Decarbonization targets are driving the retirement of traditional thermal power plants and increased adoption of renewable generation sources such as solar and wind. Inverter based non-synchronous energy sources and transmission systems, such as certain renewables and HVDC systems, don't have the critical characteristics needed to ensure grid stability.

As grids become more decentralized, with less spinning mass and greater complexity, their transmission systems need to be reinforced to avoid blackouts, economic disruptions, and equipment damage.

Grid strength

TRADITIONAL GRID STRONG

- Centralized generation
- Unidirectional flow
- Frequency control by spinning mass
- Inverter-based generation
- Few sensors
- Manual monitoring and restoration

FUTURE GRID COMPLEX

- Distributed generation
- Multidirectional flow
- Less generation by spinning mass
- More power electronics
- Smart sensors
- High complexity and automation

Stability is the key

Synchronous condensers have been relied on to provide grid stability since the dawn of the electric age—and their demand is increasing now because of the energy transition. Grid stability is measured in three key parameters: Reactive power, inertia and short-circuit contribution.

Synchronous condensers are unique in their ability to provide all three parameters in one machine. With quick response to short circuits, reactive power, and inertia contribution, they have the stability needed to support increased penetration of renewables in power grids around the world.



Key performance criteria across available technologies

The continuous rotating energy of a synchronous condenser has many advantages over the alternative static technologies. It has reactive power and voltage control as well as rotating inertia and short-circuit capability that support network system stability. Use of a synchronous condenser can also eliminate or mitigate problems associated with power electronics switching transients, electrical harmonics, excessive voltage levels, and electrical resonance.

Key advantages

- Enhances frequency stability during grid disturbances
- Maintains system protection integrity by providing fault current support up to 6 times rated power
- Supports fault ride-through capability in renewables through dynamic voltage and reactive power control
- Enables HVDC and renewable energy connection in weak grids
- Stabilizes power quality of large industrial applications

Download case study: [Northeastern US Grid Strengthening](#)

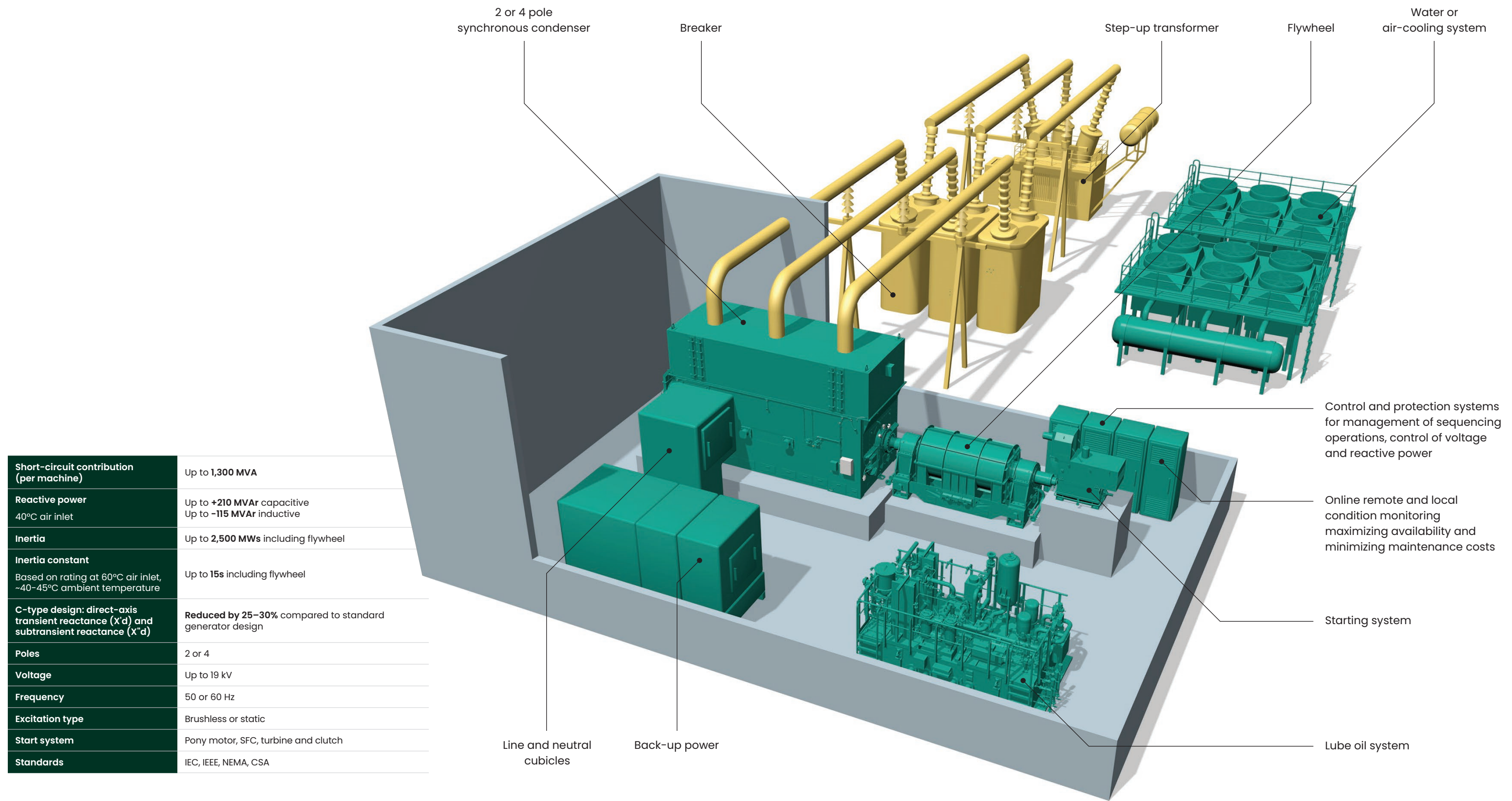


	BRUSH Power Generation Synchronous Condenser		STATCOM Static Synchronous Compensator	SVC Static VAr Compensator	Capacitor/Reactor
	A rotating electrical machine that provides all elements of grid stability in one device		Static power electronics based device to inject or absorb reactive power dynamically	Thyristor switched reactive power compensator	Fixed or mechanically switched reactive element used to correct power factor
Short circuit current contribution	①	HIGH	NONE	NONE	NONE
Inertia contribution for frequency stability support	②	GOOD	NONE*	NONE	NONE
Voltage control	GOOD		GOOD	MEDIUM	LOW
Reactive power capability	Dynamic, assymetrical		Fastest, symmetrical	Dynamic, reactive power capability drops rapidly at low voltages	Fixed or switched MVar output
Reactive power dynamic response time	③	MEDIUM	FASTEST	MEDIUM	SLOW
Short term overload	④	HIGH	MEDIUM	NONE	NONE
Capital cost	HIGH		HIGH	MEDIUM	LOW
Operational losses	MEDIUM – HIGH		LOW – MEDIUM	LOW – MEDIUM	MEDIUM
Maintenance needs	HIGH		MEDIUM	MEDIUM	LOW
Typical use case	Provides short-circuit power and inertia to stabilize weak grids		Fast reactive power support for grid code compliance in renewables	Cost-effective reactive power support where low-voltage performance is non-critical	Simple power factor correction for long transmission lines

- BRUSH Power Generation Synchronous Condenser initial symmetrical short circuit current contribution **up to 6 to 8 times** rated current.
- Instantaneous** support. Inertia may be increased further with **flywheel**.
- Fast response time is possible** with advanced BRUSH Power Generation **PRISMIC controller**.
- Superior fault ride through support. Sustained overload capability. **Ideal for grid stability.**

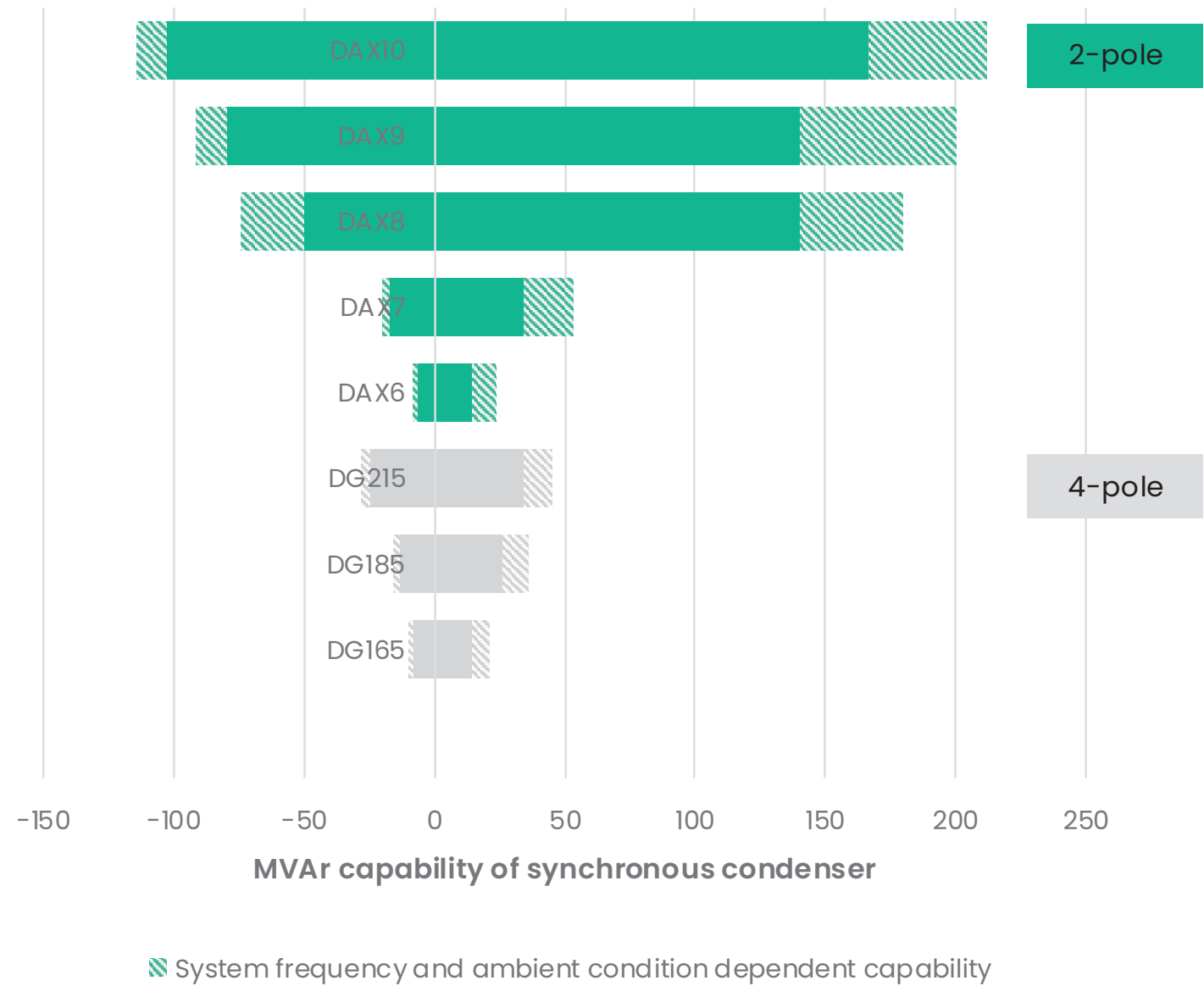
* Advanced STATCOMs with grid-forming inverters and energy storage can support frequency stability by providing synthetic inertia. However, this comes at a significantly higher cost and typically responds with a ~100 ms delay compared to natural inertia.

Typical system layout

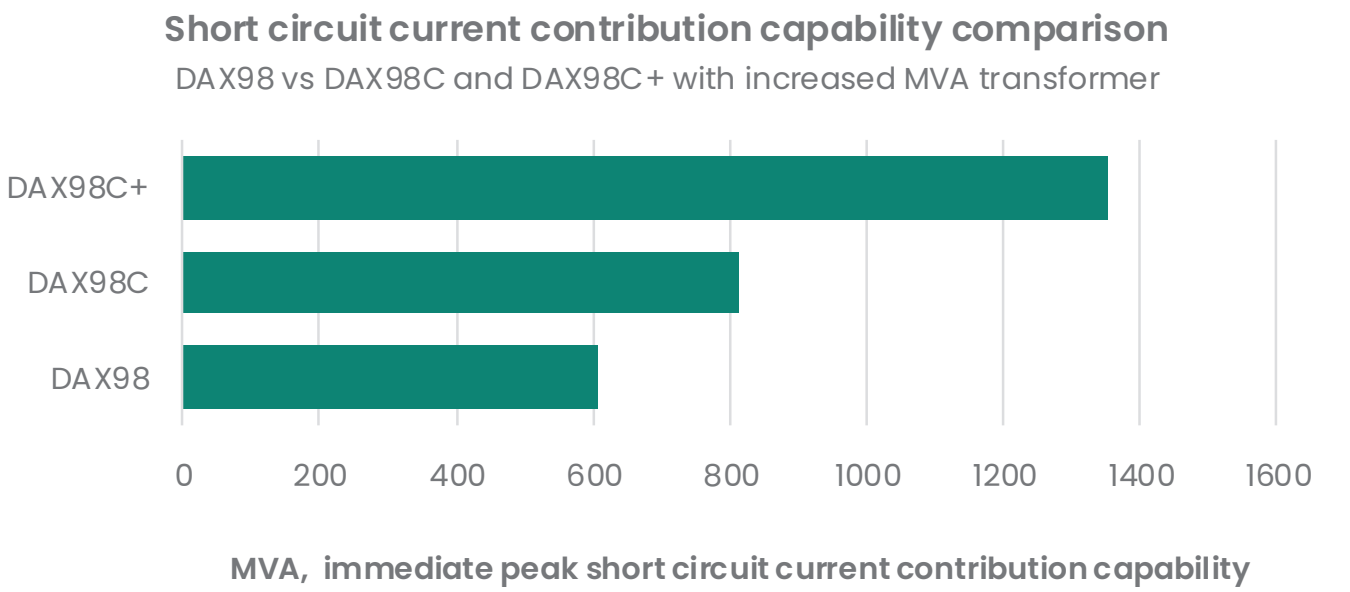


Product range

Based on reactive power and short circuit power capability



Frame	Standard condenser design	High short circuit power condenser
Transient and Subtransient reactance		-25..-30%
Short circuit power	5-6 times rated power	Up to 8-9 times rated power
DAX6	✓ Available	
DAX7	✓ Available	
DAX8	✓ Available	✓ Available
DAX9	✓ Available	✓ Available
DAX10	✓ Available	



Why low reactance matters: Advantages of high fault power design

Higher fault current contribution

Improves short-circuit strength and ensures reliable protection operation

Better voltage stability during faults

Enables faster voltage recovery and supports fault ride-through (FRT)

Stiffer voltage source behavior

Strengthens weak grids and improves stability for inverter-based resources (IBR)

Enhanced oscillation damping

Reduces both low-frequency and high-frequency oscillations for dynamic stability

SYNCON TYPE	BDAX98	BDAX98C		
MVar	145	141		
(Sub)transient reactance X_d' , X_d''		-25% compared to BDAX98		
Assumed transformer MVA	125	130	200	340
Initial peak SCC, MVA	600	>800	>1,100	>1,300

Custom engineered

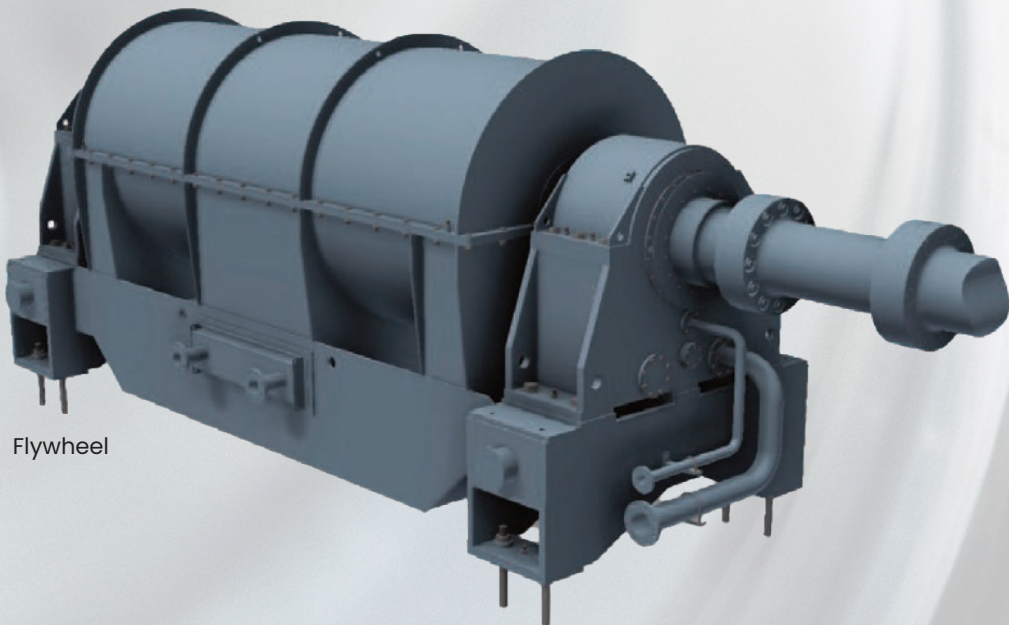
Every power grid has different loads, different topographies, and different requirements. Our BRUSH™ Power Generation teams have extensive experience in electrical machine design to right-size each synchronous condenser solution to your project's exact needs.

Rotating inertia can be significantly increased by coupling one of our custom engineered flywheels directly to the synchronous condenser's rotor. Inertia typically increases by factor of three, but can be greater if required. Inertia constant H and stored energy (MWs) increase while producing the same amount of reactive power—reducing the machine size needed to meet your overall requirements. The flywheel is an integral part of the rotor drive train, and runs up to synchronous speed in tandem with the condenser by the chosen starting method.

A variety of configurations are available to get equipment up to synchronous speed, including pony motors, static frequency converters (SFCs), or turbine and clutch assembly, which gives operators the flexibility to generate power and operate as a synchronous condenser.

We can provide a synchronous condenser alone or optimized to work as a hybrid solution with other technologies—including static systems such as SVC and STATCOM, or battery systems such as liquid-air and compressed-air energy storage.

We also have a unique track record for optimizing synchronous condenser designs to incorporate unique requirements and new technologies.



Flywheel

Lifecycle support

Our BRUSH Power Generation teams have provided comprehensive lifecycle support for grid-level equipment for over 100 years—and we continue today with tailored solutions to meet your specific needs. The scope ranges from initial system analysis and product design through regular maintenance and upgrades, all the way to eventual repurposing or decommissioning. The maintenance and availability of your critical infrastructure equipment is in safe hands with our experts.

[Download case study: New midwest US transmission line](#)





Typical applications



Transmission and Distribution

- Provide localized reactive power and compensate for reactive components along transmission lines—reducing losses and enabling higher real power transfer through existing infrastructure
- Enhance grid resilience by dynamically supporting voltage stability and short-circuit strength for reliable operation under varying load and generation conditions



Heavy Industry (e.g. steel mills, mines)

- Stabilize voltage and frequency during rapid load changes caused by arc furnaces, crushers, and other dynamic equipment
- Provide short-circuit strength and inertia to maintain protection integrity and grid stability in weak industrial networks
- Dampen harmonics and switching transients, improving overall power quality for sensitive equipment



Supporting Wind and Solar in Weak Grids

- **Ideal for grids with high penetration of inverter-based renewables (wind and solar).** Delivers fault current, voltage control, and inertia to enable fault ride-through, maintain system protection integrity, and stabilize weak networks



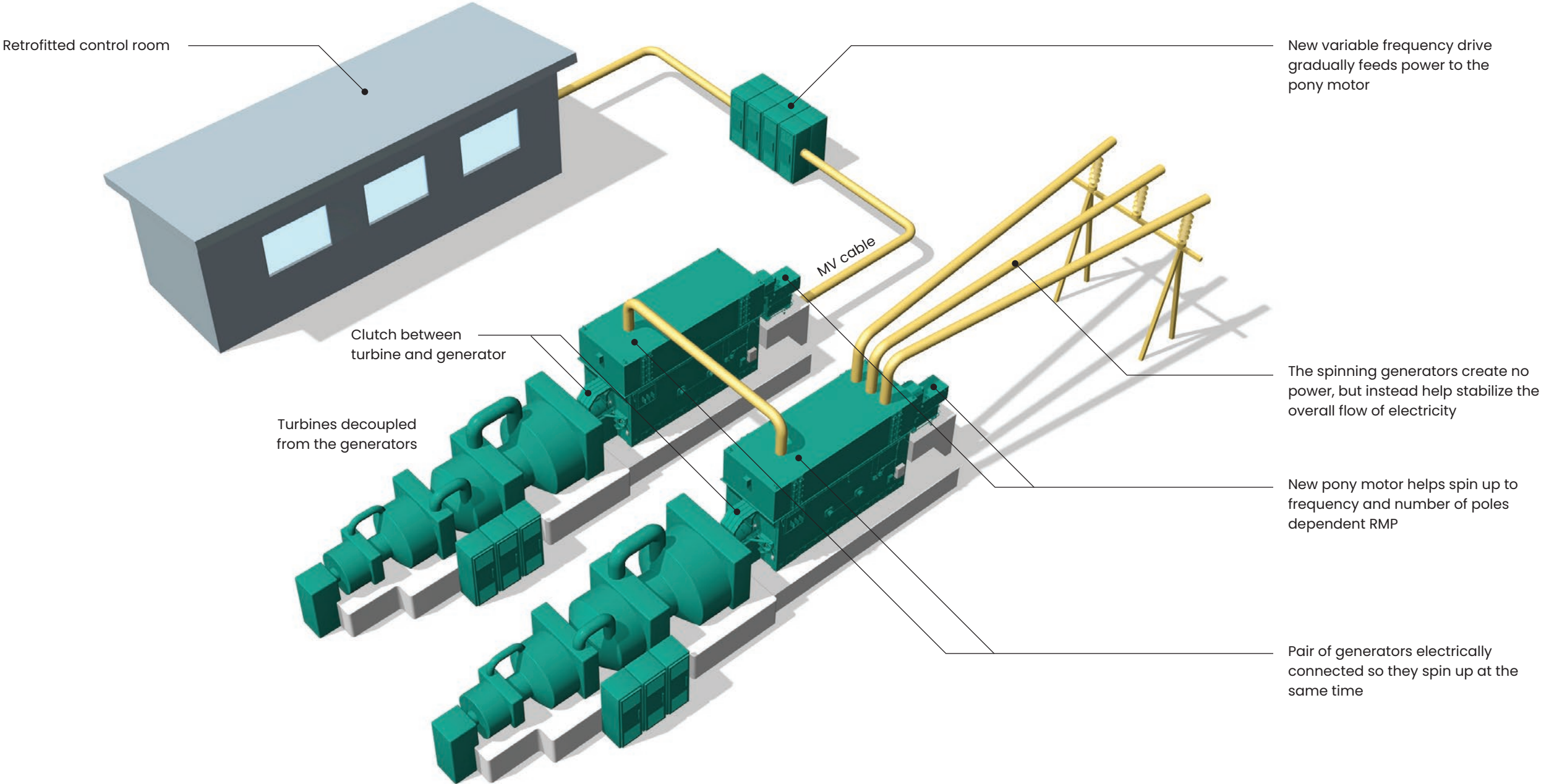
Data Centers

- Provide inertia, short-circuit strength, and dynamic reactive power to maintain grid stability and voltage control during sudden load changes or disturbances
- Enhance power quality by damping harmonics and transients from UPS systems and power electronics, ensuring reliable operation of mission-critical infrastructure

Retrofit

Our solutions are cost effective with high reliability and flexibility. For instance, one of our generators can be easily converted to a synchronous condenser—extending its economic life by many years while providing reactive power, short-circuit capability, and inertia to the grid.

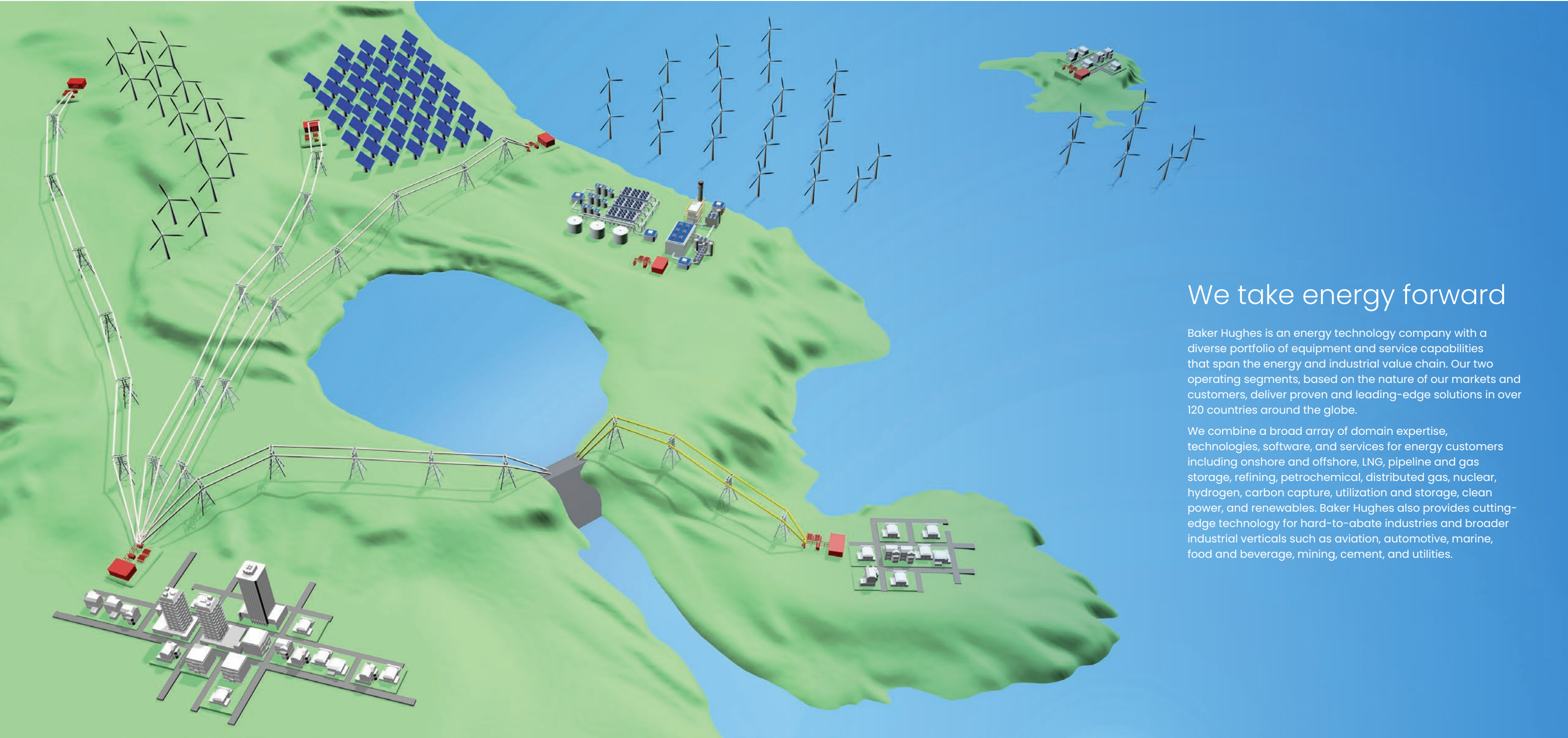
Services include all engineering, power-system study, and design to ensure that equipment is suitable for your application and fully compliant with your project specifications, applicable grid codes, and other regulations.



Keystones of grid stability

BRUSH Power Generation synchronous condensers are versatile and can be deployed in many nodes of electrical energy systems for voltage support, increased network inertia, and short-circuit power capacity. They are the intelligent, reliable, engineering-led solutions needed for today's grid stability challenges.

With over 140 years of operating experience across a global installed base of over 4,000 generators and condensers and 200 power management systems, we have the expertise to enable deeper penetration of renewable energy sources around the world—and to ensure quality power supply.



We take energy forward

Baker Hughes is an energy technology company with a diverse portfolio of equipment and service capabilities that span the energy and industrial value chain. Our two operating segments, based on the nature of our markets and customers, deliver proven and leading-edge solutions in over 120 countries around the globe.

We combine a broad array of domain expertise, technologies, software, and services for energy customers including onshore and offshore, LNG, pipeline and gas storage, refining, petrochemical, distributed gas, nuclear, hydrogen, carbon capture, utilization and storage, clean power, and renewables. Baker Hughes also provides cutting-edge technology for hard-to-abate industries and broader industrial verticals such as aviation, automotive, marine, food and beverage, mining, cement, and utilities.



BRUSH Power Generation