GE Power

Solutions for Power Quality and Supply

GE's Power Conversion Business

gepowerconversion.com

Challenge & GE Value

The Grid Stability Challenge

How do you maintain grid stability and voltage control in both steady-state and transient conditions? The evolving world of power generation is becoming ever more challenging for transmission system operators. A larger share of renewables, the retirement of base-load plants, increased environmental regulation and greater cross-border trading are all making grid stability more complex.

To maintain the reliability and quality of power supply in these conditions, you need efficient solutions to provide dynamic voltage support and reactive power compensation.

GE's power quality solutions comprise FACTS devices. We've designed our power electronics-based Static Var Compensator (SVC) and Static Synchronous Compensator (STATCOM) solutions to ensure dynamic voltage control, as well as increased power transfer capabilities.

Our SVC is built around our proven high-power thyristor valves which are widely used for industrial and transmission applications. GE's STATCOM is based on our tried and tested range of Voltage Source Converters (VSC) with a demonstrated capability in energy and industrial applications. These include wind, power, mining, melting shops and other industries using IGBT technology.

To Improve Productivity and Grid Stability, GE's Power Quality Solutions Provide Dynamic Voltage Control and Fast Reactive Power Compensation

Power Quality & Supply Solutions

Energy efficiency is key to ensuring safe, affordable and sustainable energy systems for the future. Our variable-speed drive systems (VSDS) and power quality and supply solutions help to increase the flexibility, efficiency, stability and reliability of power and grid operations.

Full System Solutions

GE offers full SVC or STATCOM substation system solutions, including power analysis, engineering, electronics, controls and dielectrics. Our solutions for power supply and stability also include rotating stabilizers, and MVDC technology.

- 20-plus years' industry experience
- 100 SVCs and STATCOMs installed
- 6,000+ MVAr installed

Benefits

- Proven technology – for reliable operations
- Local grid strengthening and Var support – enabling higher productivity and power quality
- Easy integration into new and existing grid infrastructure
- Helps reduce network extension investment costs
- Meets grid code compliance requirements
- Modular hardware – for maximum flexibility and optimized footprint
- Low noise emissions – both audible and electrical

Power Quality & Supply Product Portfolio

Static Var Compensator (SVC)

GE's SVCs are built around our proven high-power thyristor valves, which are widely used for industrial and transmission applications.

System Capability

- Thyristor-based technology
- From 20 MVAr to 600 MVAr
- Controls based on industry-standard components
- Remote monitoring and diagnostics
- Solutions for industrial and grid applications
- Containerized options

SVC Thyristor Valves

- Range up to 600 MVAr
- Voltages up to 63 kV
- Power circuit consisting of two or three stacks
- Snubbers and divider resistors for thyristor protection
- Water-cooled
- Easy to maintain

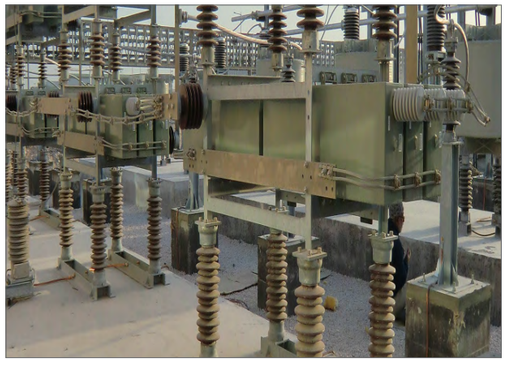
Static Synchronous Compensator (STATCOM)

GE's STATCOMs are based on our proven range of Voltage Source Converters (VSC) with demonstrated capability in energy and industrial applications. This includes wind power, mining, melting shops and other industries using IGBT technology.

A STATCOM offers better dynamic performance than an SVC. In particular, it provides a faster response time, as well as the ability to generate or absorb reactive power when the grid voltage drops. It therefore helps increase reliability and availability of the grid operation.

System Capability

- Valve based on IGBT press-pack technology
- Power range up to 300 MVAr
- Step-less adjustable cos phi
- Transformer to connect to high-voltage grid
- Air- or water-cooled
- Air-conditioned option
- Remote monitoring and diagnostics
- Controls based on industry-standard components
- Containerized options



Rotating Stabilizers

GE's rotating stabilizers are high-inertia rotating machines that can support the grid network in delivering efficient and reliable synchronous inertia and can help stabilise frequency deviations by generating and absorbing reactive power.

System Capability

The rotating stabilizer can provide several services including

- Synchronous Inertia Response (SIR)
- Steady/Dynamic Reactive Power, (SSRP/DRP
- Option for Fast Frequency Response (FFR) with larger converters

Value

- Range up to 200 MVAr
- Similar grid support capabilities as a CCGT power station
- No grid disturbance with variable speed drive start
- Stability at point of non-synchronous generation
- Voltage support to enable more active power
- Easy to maintain

MVDC

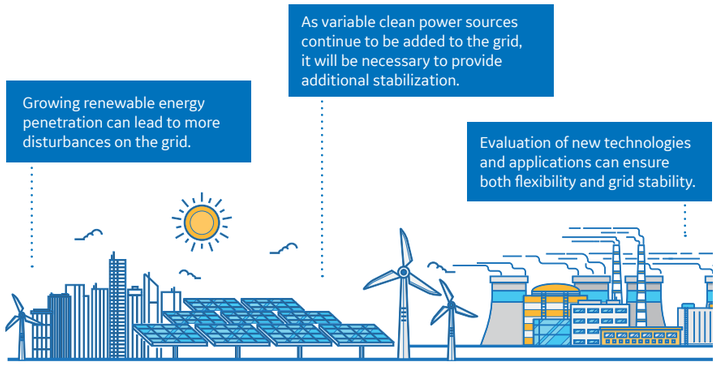
GE has extensive experience in energy transmission technology and a proven track record including electrifying the central European railways. GE Power Conversion's Medium Voltage Direct Current (MVDC) technology can transform the grid to reach higher capacity without the need to overhaul existing infrastructure or install new power distribution assets.

System Benefits

- Enabling more efficient power transmission to and from remote areas – both onshore and offshore.
- Control of active and reactive power
- Voltage optimisation
- Higher power flow over same cables
- No increase to fault levels

Rotating Stabilizers

CO_2 free, high-inertia machines to help stabilize weak grids and enable higher penetration of renewable energy.



Ensuring Grid Stability

Fossil fuel-based power generation has been around for decades, and traditionally, the continuous rotating mass of synchronous gas- or coal-powered generators inherently stabilize grid frequency. The advantage of coal, oil or gas power generation is that while it cannot be turned on or off easily as demand dictates, the rotating turbines and generators have a lot of built-in inertia. This means a long lead time to ramp up and down, even under fault conditions. The result is a more robust grid that makes managing trips or blackouts easier.

However, the increasing use of non-synchronous wind and solar energy is reducing the amount of synchronous generation on the grid and is changing the rules of dispatchable power. This possible instability could lead to grid operators constraining renewable generation to ensure grid stability or having to run costly coal or gas power plants in reserve.

As the power generation landscape is being reinvented around renewable energy, so are national grid codes that define performance – especially in countries with weaker grid infrastructures – are changing in response to this new power generation mix. These grid codes specify the power quality of electricity that plant and grid technologies must deliver – both in normal operation and under fault conditions – and are now giving rise to a range of creative solutions such as GE's rotating stabiliser.

The global energy mix is changing, with more clean renewable energy sources being added to the grid. The intermittency of renewable energy sources has raised clear challenges to grid integration and its stability.

Leveraging our vast experience in rotating machine technology, GE's rotating stabiliser solution provides a CO_2 free and cost-effective solution to replicate the synchronous inertia response povided by traditional thermal power generation.

Rotating Stabilizers

GE's rotating stabilizers are high-inertia rotating machines that can support the grid network in delivering efficient and reliable synchronous inertia and can help stabilize frequency deviations by generating and absorbing reactive power.

Rotating stabilizers can help reduce emissions and maintain grid performance by providing the same synchronous inertia as coal or gas power plants without the associated CO_2 emissions and high running costs. This flexible technology can be deployed as/when required by the system operator.

GE's rotating stabilizers have three operating modes:
- Synchronous inertia support to the grid with instantaneous response to change in grid frequency
- Power factor correction to provide continuous leading or lagging Vars
- High-power pulse generation enabling a high-power pulse from a weak power source

Extended Power Quality Offering

Our wide range of electrification solutions include motors, generators and power electronics-based turbine starting static frequency converters (SFC) and static excitation equipment (SEE), variable-speed drive systems for power plant auxiliary systems, MVDC, power quality systems and automation and controls.

Typical Ratings

	Power (MVAr)	Energy (MW-s)	Inertia (Kg-m2)	Speed (rpm)	Volts (kV)	Rotor mass (tonnes)	No load losses (kW)
Horizontal Axis Machine	65	486	355000	500	15	200	840
Vertical Axis Machine	200	2115	1416000	522	22.9	400	1670
Example Synchronous Condenser	50	75	4965	1500	11	28	355

Key Features and Benefits

Extended System Services

The rotating stabiliser can provide several services including Synchronous Inertia Response (SIR), Steady/Dynamic Reactive Power, (SSRP/DRP) and an option for Fast Frequency Response (FFR) with larger converters.

- Supports the network grid when increasing non-synchronous penetration, and with wide-scale distributed generation
- Similar grid support capabilities as a CCGT power station
- No grid disturbance with variable-speed drive start

Proven Technology

Based upon mature hydro-power generator technology to deliver high reliability and low maintenance

- Co-located Distributed Generation
- Optimize grid connection agreement and reduce overall costs
- Stability at point of non-synchronous generation
- Voltage support to enable more active power

Worldwide Services Support

Our focus on service keeps us actively engaged, both when things are going right, and when they are going wrong. With a comprehensive global network of experts, GE is uniquely positioned to provide the knowledge, experience and skills for your full range of industrial service requirements – protecting your assets and maximizing productivity.

MVDC Power Transmission

As demand for electricity increases power grids will be required to transmit more power, more efficiently. Today's grid is structured around transmitting electricity from large, centralized power plants running on coal, oil, gas and nuclear. While these will continue to dominate the energy mix for years to come, renewable energy is expected to supply a third of global power by 2040, creating new challenges for the power distribution network operators.

Better efficiency, greater control

GE Power Conversion's Medium Voltage Direct Current (MVDC) technology can transform the grid to reach higher capacity without the need to overhaul existing infrastructure or install new power distribution assets. Traditional grids transmit power from large thermal power stations over High Voltage AC lines and then step down to lower voltages for distribution to consumers.

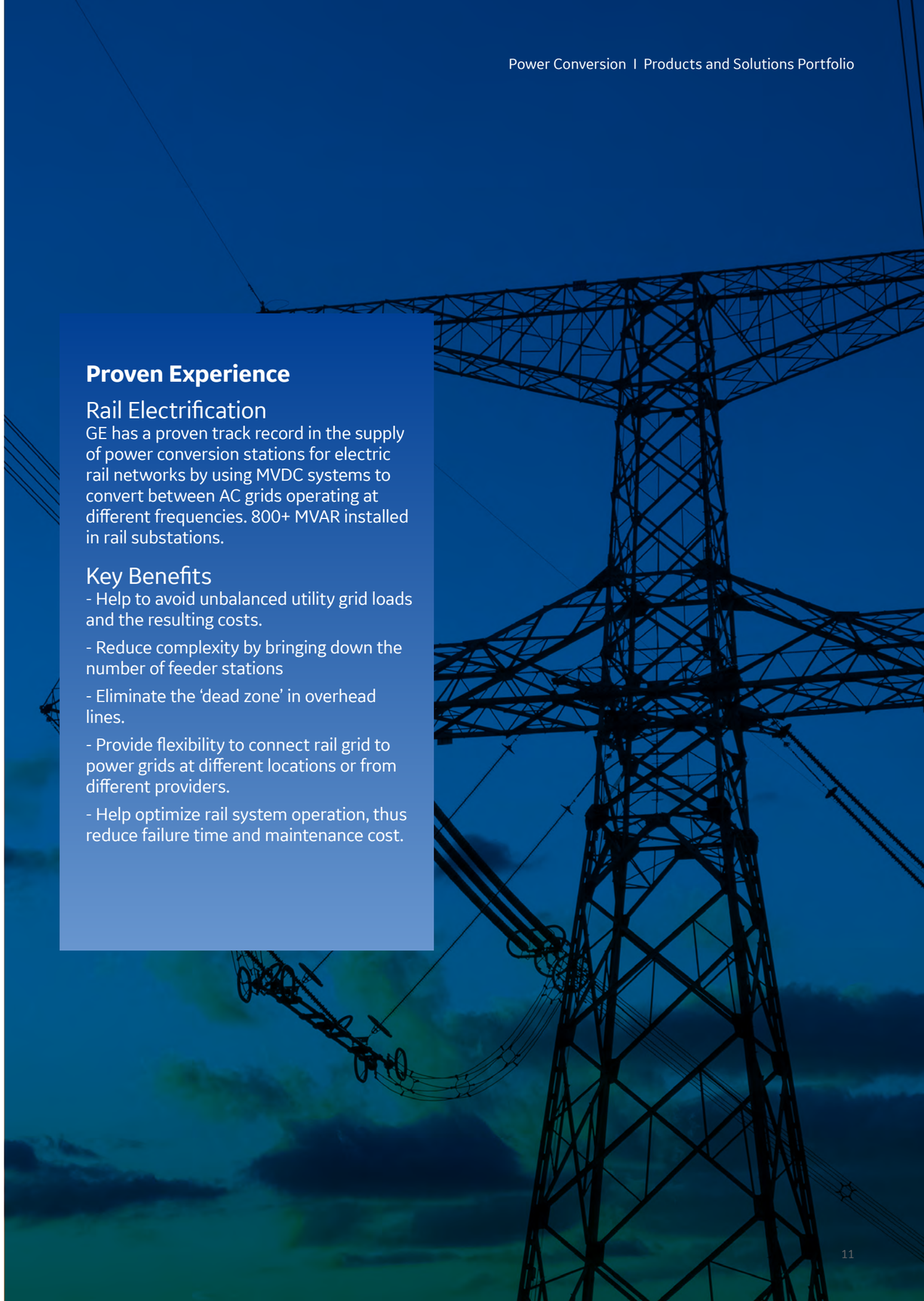
GE's MVDC technology helps to stabilize the process and maximize productivity by managing dynamic voltage support and fast acting reactive power compensation. MVDC systems have several advantages over traditional AC distribution:

- Control of active and reactive power
- Voltage optimization
- Higher power flow over same cables
- No increase to fault levels

At GE's Power Conversion business, we're developing the use of DC to enable more efficient power transmission to and from remote areas—both onshore and offshore. MVDC systems can connect remote systems to the central grid where it is not economical to use High Voltage DC links (eg. island communities. This will reduce the use of diesel generation and cut $C0_2$ emissions.

Reliable technology

Critical systems demand efficient and reliable technology. At the centre of GE Power Conversion's MVDC power transmission technology is the MV7000 variable frequency converter. Cutting-edge power electronics coupled with decades of process expertise come together in the MV7000 — a world-class water-cooled medium voltage converter suitable for a wide range of power conversion applications, which help to improve efficiency, control accuracy and operational flexibility.



Proven Experience

Rail Electrification

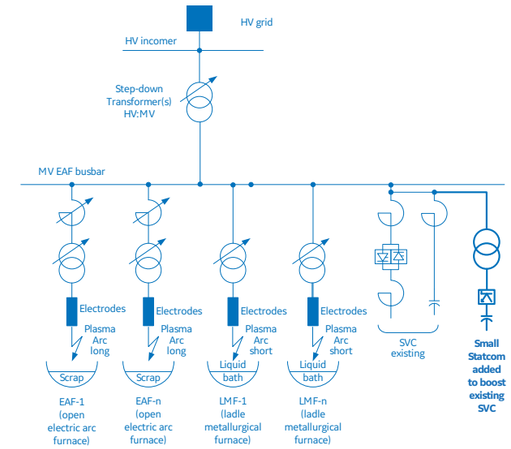
GE has a proven track record in the supply of power conversion stations for electric rail networks by using MVDC systems to convert between AC grids operating at different frequencies. 800+ MVAR installed in rail substations.

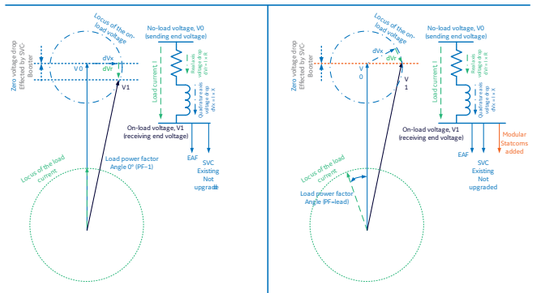
Key Benefits

- Help to avoid unbalanced utility grid loads and the resulting costs.
- Reduce complexity by bringing down the number of feeder stations
- Eliminate the 'dead zone' in overhead lines.
- Provide flexibility to connect rail grid to power grids at different locations or from different providers.
- Help optimize rail system operation, thus reduce failure time and maintenance cost.

SVC Booster with STATCOM for Electric Arc Furnaces (EAF)

Typical SVC Booster Connection





With properly sized SVC for PF unity average ±1.5 improved voltage variations

With added single STATCOM unit, residual voltage drops are further reduced

How STATCOM Helps Boost Productivity

Electric Arc Furnaces (EAF) are high-power industrial loads which cause power-quality problems at all voltage levels due to their unbalanced and non-linear characteristics. The rapid swings in real and reactive power they require cause voltage drops, rapid voltage variation and distortion across the AC supply network. This not only has a negative impact on power system quality and other loads, but also on arc furnace operation. This can include reduced power output, increased electrode consumption and poorer efficiency, which in turn lead to higher operational costs.

As a result, some sort of dynamic reactive compensation is required to limit the voltage disturbances injected by the arc furnace. This is normally achieved through an SVC with TCR. Despite sizing the SVC for PF unity, residual voltage drops remain due to active power.

Therefore, instead of increasing or revamping the SVC with TCR to further increase the EAF output, our idea is to add a small STATCOM to further increase productivity. The power quality performance remains that of the existing SVC, enabling the STATCOM to increase EAF production.

Key Benefits

- Boosted productivity
- Quick return on investment
- Easy fitting
- Off-the-shelf design
- Better use of existing system

Preventive Maintenance for SFC/SEE Drives

Reduce Maintenance Cost and Risk of Unplanned Outages While Extending the Lifetime of Your System

Any unplanned outage of your asset will significantly impact plant operations. Fixing it can then be costly and time consuming.

Building on our years of design and manufacturing experience in critical electrical equipment, GE has structured a preventive maintenance program to suit the operational requirements of your plant's SFC and SEEs.

Both these programs are tailored to ensure maximum availability of your asset. As well as maintaining records of all functional parameters and spares requirements, we identify any obsolete parts and advise on suitable replacements.

Preventive Maintenance Programs

Regular maintenance ensures efficient drive operation and reduces failure risk. We offer structured inspections and planned maintenance programs through our specialized technical team. These are geared to the drives' operating environment, ensuring that the cost of maintenance and failure risk are reduced.

We offer two types of preventive maintenance programs:

- **Preventive Performance Maintenance** (annual) – includes basic visual inspections and drive performance checks
- **Preventive Major Maintenance** (once every five to ten years) – includes advanced visual inspections, drive performance drive checks and systematic component replacement

Preventive Maintenance Program Features

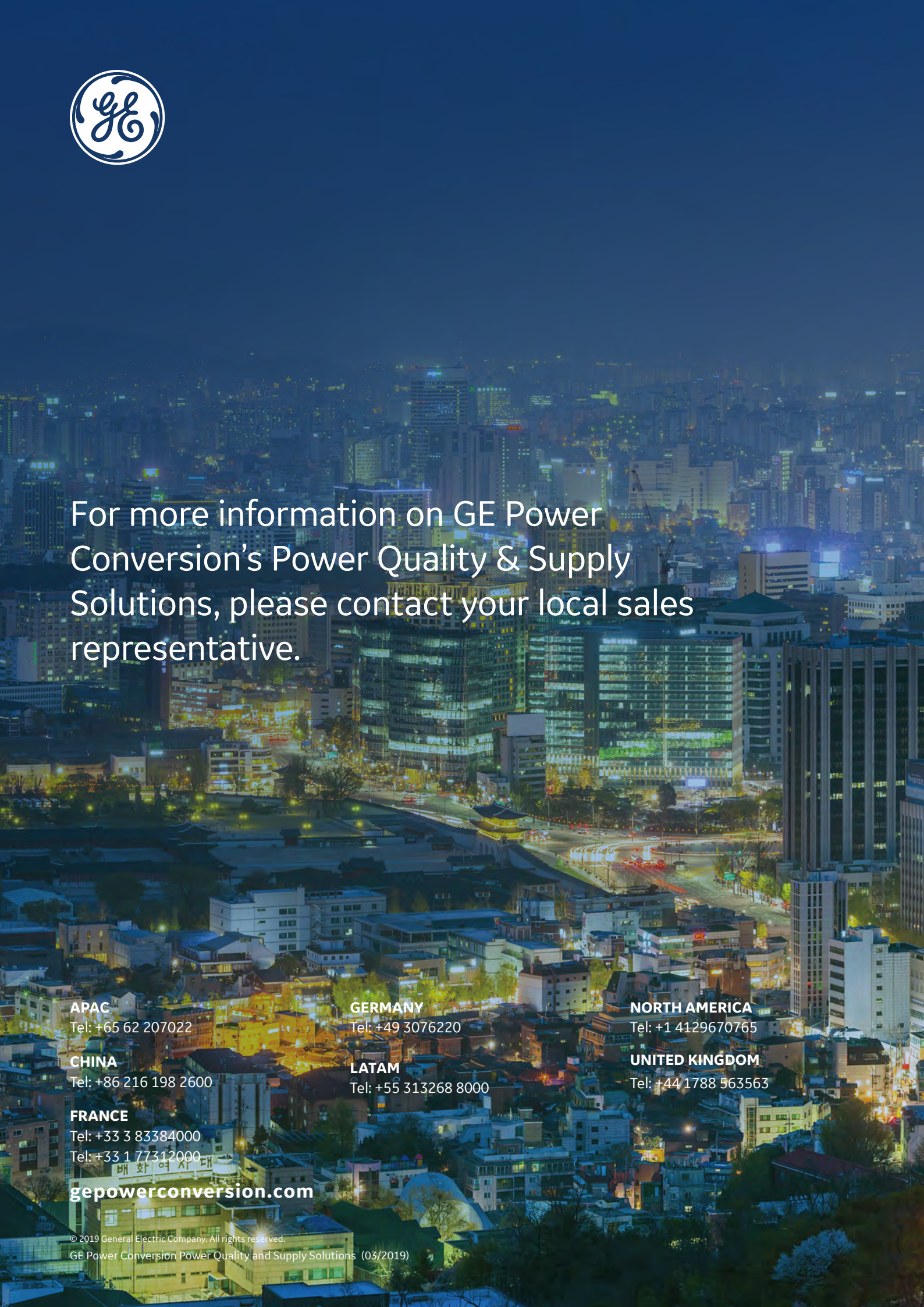
GE's preventive maintenance programs are tailored to suit your application and needs. Our field service experts carry out inspections and performance checks on drives quickly, effectively, when it's convenient for you. We'll also work with you to understand historic maintenance, environmental conditions, budget and operational constraints and business imperatives. Any lessons learned can be applied to your system to enhance drive performance.

During the preventive maintenance service, we:

- Perform and record preventive actions – according to a prescribed schedule of appropriate checks and tests
- Identify safety-critical issues – bringing them to your attention immediately and proposing resolutions
- Prioritize the dispatch of parts needed to resolve any such issues – if necessary, the field service engineer will remain or return to site to supervise
- Identify operational-critical issues – bringing any deterioration in performance or critical items affecting reliability to your attention and recording them in the maintenance report
- Audit and record an inventory of spare parts

After the preventive maintenance service, we issue a maintenance report, document the status of the drive value (used to compare with thyristor health in future maintenance schedules) and recommend:

- **Critical spare parts** – providing a list of those you should consider holding
- **Replacement parts** – suggesting obsolete parts you may wish to plan to replace
- **Upgrade packages** – appropriate for your equipment and circumstances



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