

GE
Grid Solutions

Static Var Compensator Solutions



imagination at work

Today's Environment

Today's transmission grid is changing and becoming more complex to manage. Utilities globally are experiencing challenges such as:

- Increase in global demand for electricity
- Thermal plant retirements coupled with an increase in renewable generation, often remote from load centers
- Stringent requirements by regulatory authorities on power quality
- Interconnected grids
- Aging transmission infrastructure

These challenges can make power flow stability more complex for network operators as they manage stability issues under fault clearing and post-fault conditions.

The increase in demand and renewables combined with aging infrastructure can cause voltage on the grid to fluctuate, including harmonics, flicker phenomena, unbalanced loads and power oscillation which can impact power quality and power transfer capability.

The solutions that the utility customers are now looking for are more technically sophisticated than in the past, including networked solutions to wide area networks and hybrid Flexible AC Transmission Systems (FACTS) solutions. Today's grid challenges are complex and demand significant engineering analysis and studies to ensure the right solution is being put in place.

GE's Solution

GE's Static Var Compensator (SVC) solution allows grid operators to gain accurate control of reactive network power, increase power transfer capability and improve steady-state and dynamic stability of the grid.

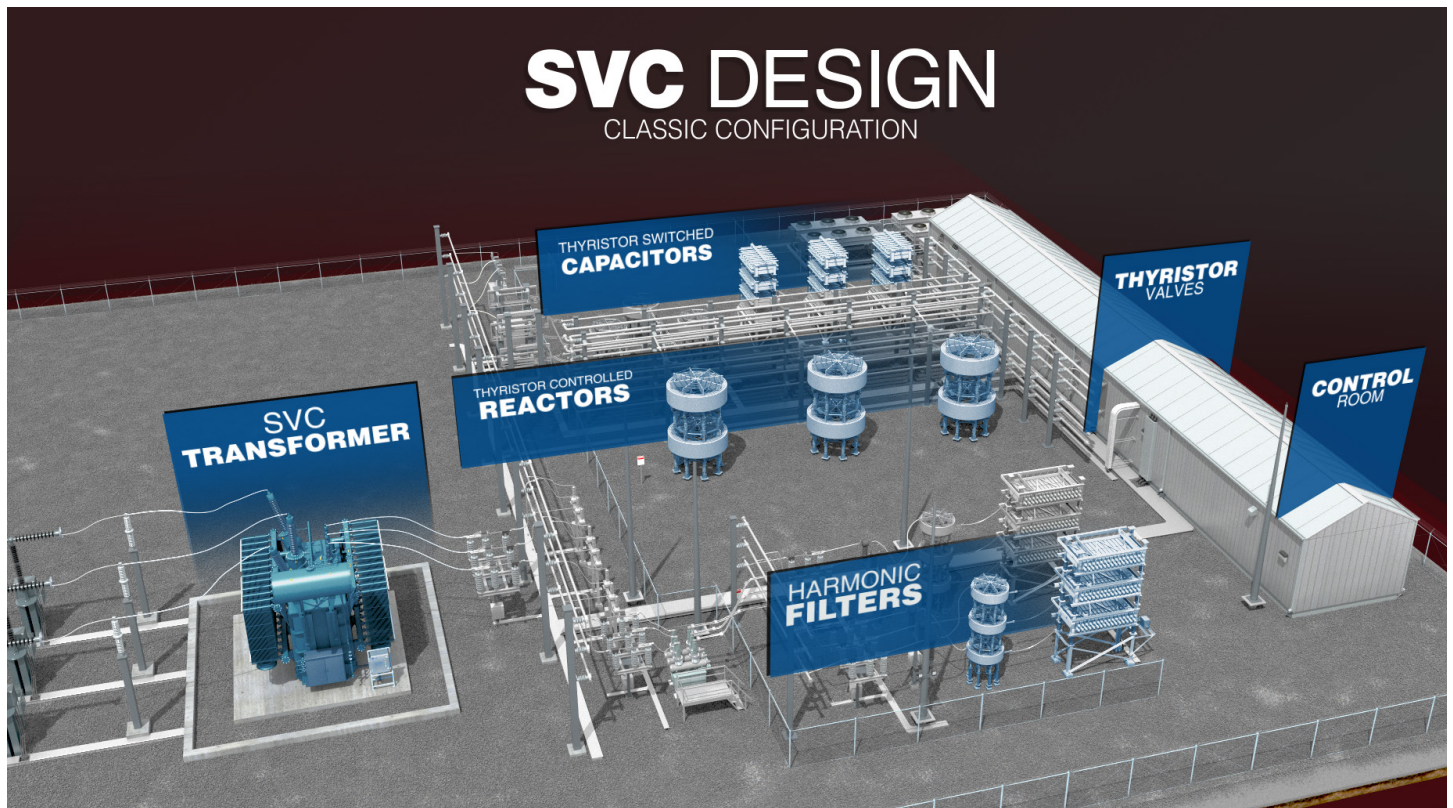
SVC controls transmission line voltage to compensate for reactive power balance by absorbing inductive reactive power when voltage is too high and generating capacitive reactive power when voltage is too low.

Compared to the investment required for additional transmission networks, SVC provides customers with a flexible solution that has minimal infrastructure investment, low environmental impact, rapid implementation time and improved return on investment.

Leveraging Design Best Practices with the GE Store

GE's power electronics scope is one of the largest in the industry serving both utility and industrial customers. The fundamental building blocks in GE's SVC solution, such as thyristor valves, cooling schemes and control systems, are jointly developed and shared with GE's High Voltage Direct Current (HVDC) designs so that all of the solutions benefit from the best practices that have been generated from over 50 years of experience in these technologies.

Typical SVC system and main components



Static Var Compensator Solution – The GE Advantage

GE's SVC solutions are customized based on the utility's technical and economic requirements for their network such as fault level and load parameters. GE provides one of the broadest range of SVC configurations with two types of SVC design: classic and patented Main Reactor.

GE provides an extensive services portfolio comprised of feasibility and network studies, project management, engineering capabilities, equipment, installation services and long term maintenance contracts, delivering an integrated and robust system that provides utilities with the following competitive advantages.

Model based design control system ensures optimal and accurate performance of the SVC by direct deployment into the system software

- Rapid technical responsiveness to the customer, from planning support and project execution to commissioning
- Intuitive graphical interface provides fast, automatic, and error free code generation from control models, ensuring a greater level of confidence to the customer
- Ease of integration into control system software with power system modelling tools such as PSCAD provides an accurate representation of system performance for planning and transients analysis
- Modular hardware design based on commercial off-the-shelf components which provide extensive scalability to any project rating, while maintaining quick system delivery time and simple life-cycle management

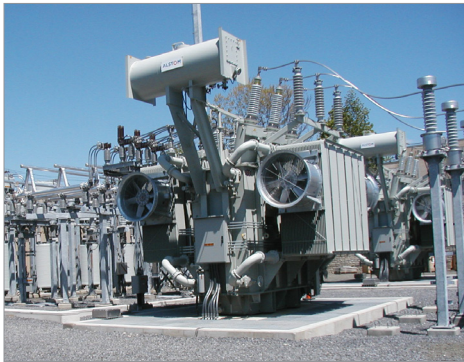
Classic SVC and GE's patented Main Reactor SVC provides more design flexibility to ensure optimized system performance

- Broad range of SVC configurations including: classic, hybrid, Main Reactor, fixed, modular, relocatable, low noise, and reduced footprint designs
- Ground level power to the thyristor valves provide system voltage independency and benefits operation at very low voltages, increasing SVC readiness during severe system events
- Unique Main Reactor configuration improves harmonic performance, reduces operational losses and design footprint, and ensures regulatory compliance at the point of interconnection

Manufacturing excellence and deep domain technical expertise providing full system lifecycle support resulting in simplified and streamlined commercial offerings

- More than 50 years' experience on more than 380 global installations ranging from small industrial to large utility projects, in diverse applications and extreme environmental conditions
- Full range of lifecycle support competencies including network analysis, system design, engineering, procurement, civil works, installation, testing and commissioning and asset management, eliminating project and logistical complexities of multiple vendor projects
- SVC main components are vertically integrated within GE's advanced manufacturing facilities, which are certified to ISO® 9001, ISO 14001 Environmental Standards and OHSAS® 18001

SVC Transformers



Thyristor Controlled Reactors



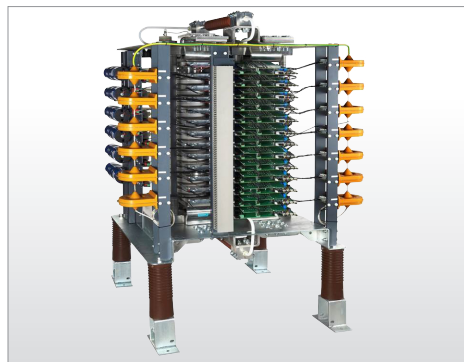
Thyristor Switched Capacitors



Harmonic Filters



Thyristor Valves



Control System



Classic SVC Design

GE's Classic SVC design is customized based on the utility's key requirements for system performance. Every system is tested extensively during factory acceptance testing and site commissioning to guaranteed performance.

Benefits of the classic SVC design:

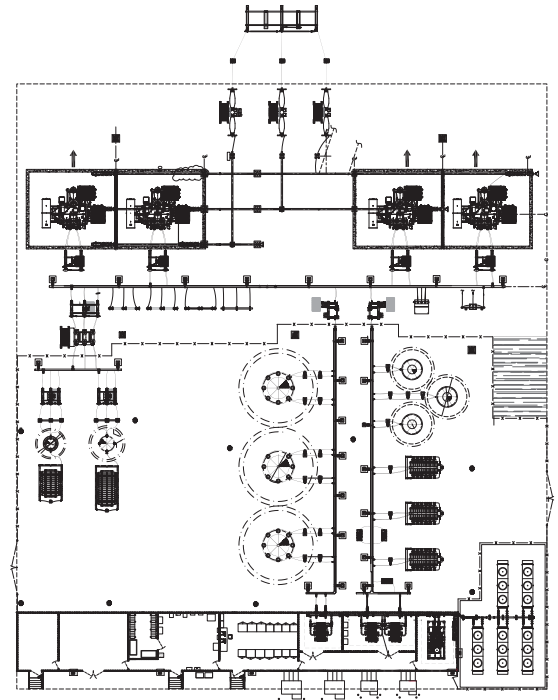
- Allows grid operators to gain accurate control of network reactive power and voltage
- Increases power transfer capability
- Improves steady-state and dynamic stability of the grid

Main components of the system include:

- SVC transformers
- Thyristor Controlled Reactors (TCR)
- Thyristor Switched Capacitors (TSC)
- Harmonic Filters
- Advanced Thyristor Valve (ATV)
- Advanced Digital Control (ADC)
- Protection and Auxiliary systems
- Thyristor valve cooling system

System ratings include:

- Typical utility voltage levels: approx. 69<kV<800
- Typical utility overall ratings: approx. 40<Mvar<1,200

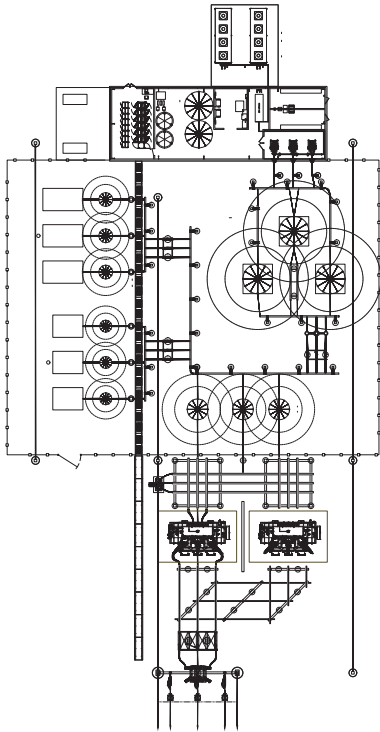


-100/+200Mvar classic SVC design

Example of a classic SVC design



Patented Main Reactor SVC Design



-100/+200Mvar Main Reactor design with reduced footprint

GE's patented Main Reactor SVC design is customized based on the utility's key requirements for system performance. Every system is tested extensively during factory acceptance testing and site commissioning to ensure guaranteed performance.

Traditionally, the SVC medium voltage bus is connected directly to the SVC coupling transformer, but with the main reactor configuration there is a reactor connected between SVC bus and coupling transformer.

The Main Reactor concept efficiently isolates harmonics, even in demanding network conditions. This design requires fewer harmonic filters enabling a compact, optimized SVC layout.

The Main Reactor has many other inherent benefits for improved harmonics, simpler design and cost savings, including:

- Main Reactor blocks harmonics generated by the SVC
- Lower amount of filtering is needed
- Improved harmonic distortion at the Point of Common Coupling
- Less harmonic stress on the SVC coupling transformer
- Lower voltage stress on all components
- Minimized requirement for Thyristor Switched Capacitors (TSC), potentially eliminated
- Thyristor Controlled Reactors (TCR) has smaller coils, lower losses and reduced number of thyristor valve levels
- Only low order filters are needed (reactor blocks high order), wide filtering band can be used

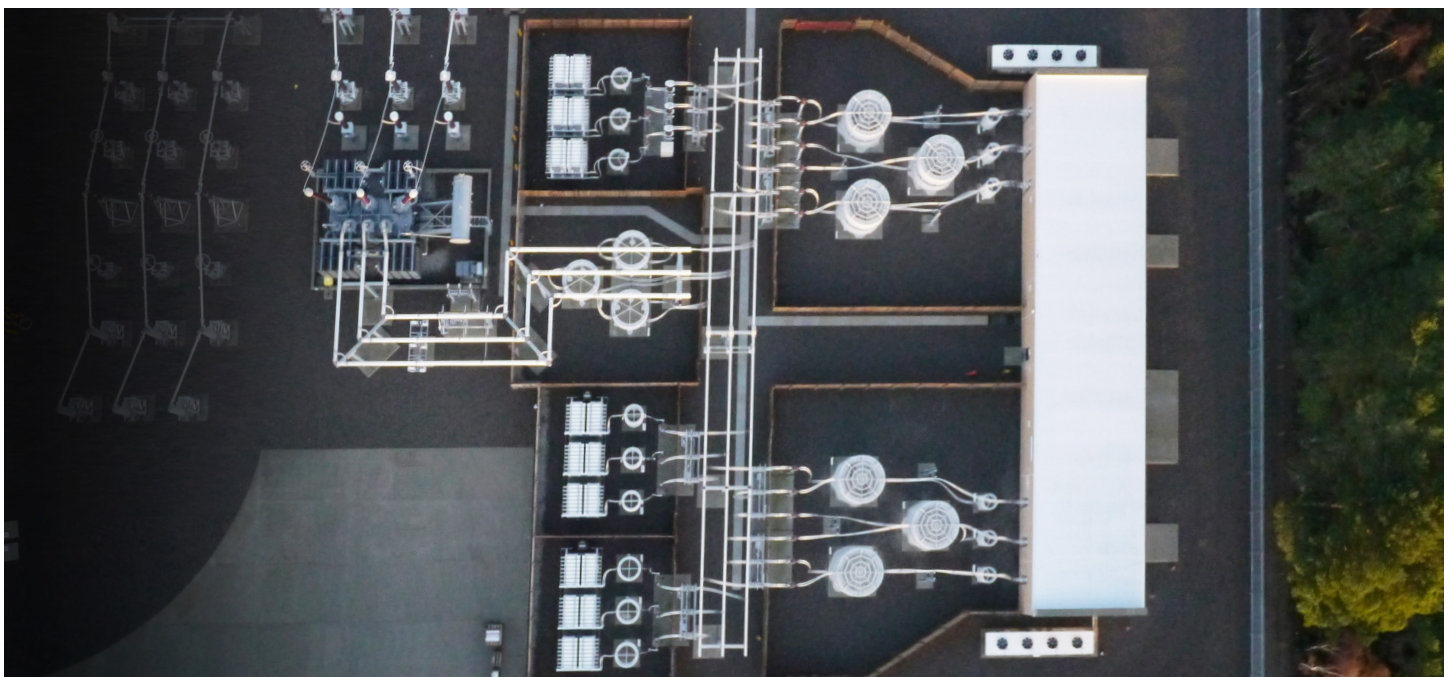
Main components of the system include:

- SVC Transformers
- Thyristor Controlled Reactors (TCR)
- Main Reactor
- Harmonic filters
- Advanced Thyristor Valve (ATV)
- Advanced Digital Control (ADC)
- Protection and Auxiliary systems
- Thyristor valve cooling system

System Ratings:

- Typical utility voltage levels: approx. 69<kV<800
- Typical utility overall ratings: approx. 40<Mvar<1,200

Example of a Main Reactor SVC design



GE's Advanced Digital Control for SVC Systems

GE's approach to SVC Control System represents the latest in design methodology by utilizing a powerful Model Based Design approach. With this approach the SVC Control System software is built using a core library of complex control algorithms that represents over 50 years of FACTS experience within GE. Model Based Design utilizes a graphical interface for the design stage and translation of control models with automatic code generation for all testing and verification stages. With this approach, GE has enhanced the quality, reliability, and maintainability of the Advanced Digital Control system for SVCs.

Extensive self diagnostic capabilities are built-in to maximize reliability, any degradation of performances or fault of components is pinpointed in real-time and can be easily replaced. When availability is at stake, the control system is configured in a dual lane redundancy concept which allows for the highest availability.

A built-in event logger with automatic time stamping of 1 millisecond resolution and a synchronized transient fault recorder with up to 10 μ s sampling will allow for post event detailed analysis by experts. The control system can also be remotely accessed via internet using secured protocol. It allows remote monitoring (using the built-in real-time monitoring function) and fault detection including diagnostic. To fulfill modern remote control interfacing requirements, the control platform supports an extensive set of industry standard protocols including IEC[®] 61850, DNP3 and IEC 60870. Custom protocols can be implemented as an option.

Based on commercial off-the-shelf (COTS) hardware, the control platform runs on VPX military technology and meets all the requirements of the Flexible AC Transmission System (FACTS) market. Depending on the application complexity, the control platform consists of single or multiple racks, interconnected by high speed serial fiber optic interfaces. The fiber optic interface enables the boards in different racks to communicate with each other as if they were installed in the same rack without any software change.

Control Software

The platform's software now leverages entirely new state-of-the-art features and technology. Using model based design, real-time algorithms are deployed to speed up development and reduce software design errors in the early stages of development.

Model Based Design Advantages

- With Model Based Design, programming and customization of control functions is simplified by the use of a graphical programming interface.
- Testing and verification of the control system at the design stage starts early using real-time control models in closed loop with the SVC power electronics and the power grid.
- Simulation environment uses real-time control models providing the most accurate representation of control performance. The control models can be easily exported to PSCAD™ or similar tools with one-to-one representation for further testing and simulations.
- Automatic code generation allows direct conversion of graphical control models into real-time control software, eliminating the manual "coding stage", resulting in improved quality and reliability.
- Complete traceability of customer requirements throughout the control model provides easy and efficient way for software modifications and new feature implementation at any stage of the project.
- Model Based Design approach adopted by GE has already revolutionized the development approach for critical control software in aviation, space and automotive industries, resulting in significant improvement in software quality for critical and life-supporting applications.



Advanced Digital Control platform for SVC systems

GE's Advanced Thyristor Valve for SVC Systems

Thyristor Controlled Reactor and Thyristor Switched Capacitors

Thyristor valves are used for controlling the reactive power output of Static Var Compensators. TCR valves are used to control the effective fundamental frequency current in the reactors by controlling the firing angle of the thyristors. TSC valves are used for switching capacitor banks on or off according to the reactive power demand.

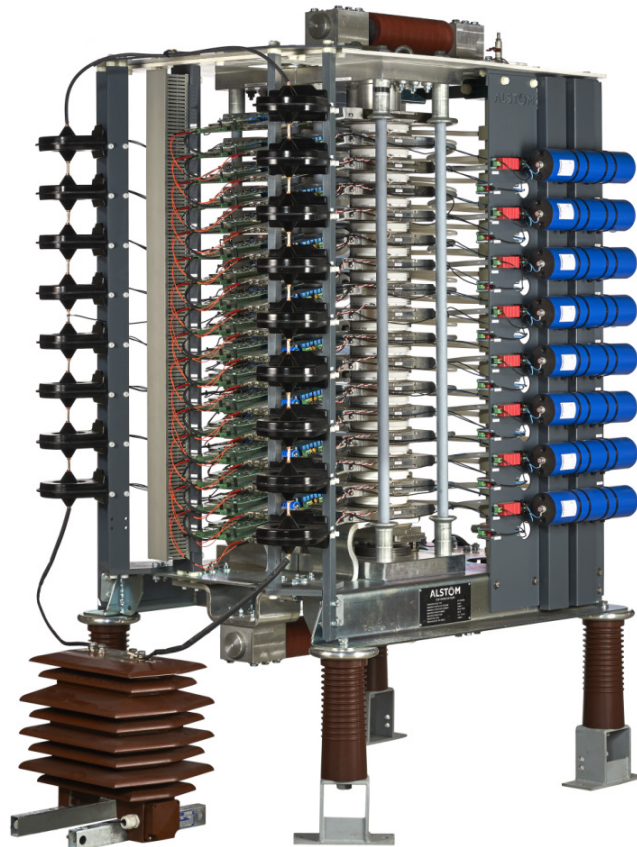
Advanced Thyristor Valve

The Advanced Thyristor Valve (ATV) is GE's latest range of liquid-cooled thyristor valves for Static Var Compensator applications. These thyristor valves have been developed by drawing on GE's extensive experience of more than 50 years of applying thyristor based SVCs both for transmission and industrial applications. The ATV provides a very compact, versatile and standardized platform for both TCR and TSC variants.

ATV Features Meet Demanding Customer Requirements

Type and routine tests according to IEC 61954, other normative references are IEC 60060-1 (HV tests) and 60270 (partial discharge)

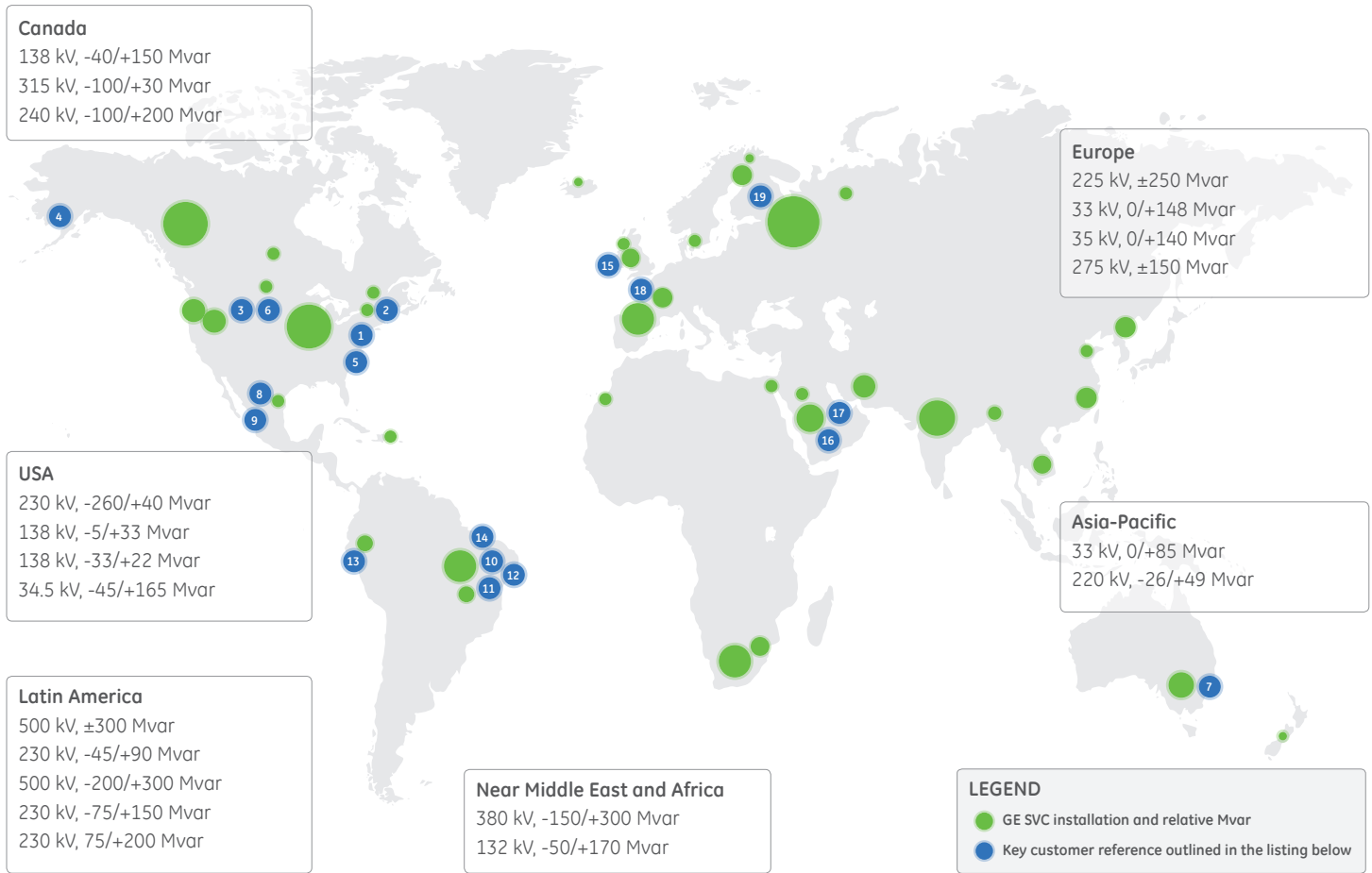
- Rated up to 36 kV and 4 kA
- Ground Level Power Supply (GLPS) enables proper valve operation when severe under-voltage conditions are foreseen
- Minimized footprint and weight
- Easy maintenance due to efficient dedicated tools
- Efficient and optimized coolant circulation
- Universal advanced state of the art control platform
- Built in diagnostics for thyristor valve condition surveillance



GE's Advanced Thyristor Valve

GE's Static Var Compensator References

GE has designed, delivered and supports over 380 Static Var Compensator Systems globally in a broad range of applications and environments. The below details are a selected representation of recent projects, a complete reference list is available upon request.



Customer References

- Location: West Wharton, NJ, USA
Rating: -260/+40 Mvar, 230 kV
- Location: St-Marc-de-Figuery, Quebec, Canada
Rating: -100/+300 Mvar, 315 kV
- Location: Alberta, Canada
Rating: -100/+200 Mvar, 240 kV
- Location: Alaska, USA
Rating: Refurbishment of 3 SVCs - (-22 to +22 Mvar) - Wasilla, AK - (-5 to +33 Mvar) - Fairbanks, AK - (-33 to +22 Mvar) - Healy, AK
- Location: Roanoke, VA, USA
Rating: -45/+165 Mvar, 34.5kV (138 kV)
- Location: Pasqua, Saskatchewan, Canada
Rating: -40/+150 Mvar in 2x (-20/+75) Mvar, 138 kV
- Location: State of Victoria, Australia
Rating: -26/+49 Mvar, 220 kV
- Location: Veracruz, Mexico
Rating: -60/+180 to 0/+240 Mvar, 34.5 kV
- Location: Mexicali, Mexico
Rating: -75/+200 Mvar, 230 kV
- Location: Brazil
Rating: -200 / +300 Mvar, 500 kV
- Location: Brazil
Rating: -75 / +150 Mvar, 230 kV
- Location: Brazil
Rating: -75 / +150 Mvar, 230 kV
- Location: Peru
Rating: ±15 Mvar, 138 kV
- Location: Imbirussu, Brazil
Rating: ±100 Mvar, 230 kV
- Location: Scotland, UK
1st Installation of GE's patented Main Reactor design
Rating: -150 / +150 Mvar, 275 kV
- Location: Quway'iyah, Saudi Arabia
Rating: +170 / -50 Mvar SVC
- Location: Saudi Arabia
Rating: +300/-150 Mvar SVC and expansion of 110kV GIS at 380kV BSP and two 110kV, 100Mvar bus connected shunt capacitors at 380kV BSP
- Location: La Merlatiere and Domloup, France
Patented Main Reactor Design
Rating: ±250 Mvar at 225 kV
- Location: Kangasala, Finland
Rating: -200/+240 Mvar, 400 kV
- Location: Albany, New Zealand
Rating: ±100 Mvar, 220 kV

Project Management and Execution

The GE project team represents unsurpassed worldwide power system engineering capabilities, comprehensive system design expertise, and unequalled project management experience. GE delivers highly reliable solutions that fully meet the customers power system requirements. With each reactive compensation project GE undertakes, this team is committed to delivering 100% satisfaction.

Expertise

GE's experienced project managers have access to industry leading project tools and processes to execute projects on-time and on budget. GE's engineering teams have advanced internal design tools that provide customers with the most robust and proven designs to ensure a fully executed system with the highest level of quality and reliability.

GE's Energy Consulting works with customers to understand the overall system and project objectives. Through comprehensive analysis and studies the team develops the optimal, most cost effective technology solution based on customers requirements.

Global Capabilities

GE provides engineering excellence to design and deliver complete reactive compensation projects tailored to each customer's requirements and needs.

Providing dedicated engineering teams that are located in regions around the world, GE's subject matter experts bring a wealth of international experience to every project. Customers benefit from GE's local systems subject matter experts who are able to drive and comply with regional/local requirements ensuring the customers business and technical objectives are met.

Post Installation Service

GE's commitment to customer satisfaction is a primary goal – just because the project is complete, our job is not done. A primary responsibility is continued support of the implemented system throughout its lifecycle.

Offering an extensive network of field engineering locations and service centers around the world, GE is uniquely capable of responding immediately to urgent situations that may arise once the equipment is placed in service. Customers are provided with 24/7 field and application call center support.

Project Process and Key Activities

GE's project management approach follows a well-established set of processes and procedures that have resulted in the highest on-time delivery in the industry. GE has the people, process and rigor that customers require for the planning and execution of complex projects, including defined processes for the definition, analysis, design, implementation and post service support that is required for successful projects.



Energy Consulting

GE has a dedicated staff of consultants that provide engineering, technical support and expertise to the electrical power industry to support Flexible AC Transmission Systems (FACTS) projects worldwide. Below are details of the support and services GE provides its customers.

Electric Power Industry Support Activities

GE's technical subject matter experts, contribute towards advancements in the electric power industry through supporting the following activities:

- Deliver industry-leading technology webinars answering the most pressing challenges related to reactive power
- Specialized instruction through its Power Systems & Energy Course (PSEC) including:
 - Surge Analysis and Equipment Application
 - Reactive Power Compensation and Voltage Control
 - Power System Dynamics
 - Power Electronic Applications in Transmission
- Participation in standards committees such as IEEE® and IEC®
- Authoring of technical papers that are published and presented at numerous industry conferences



Preliminary System Analysis and Solution Definition (Pre-RFP Support)

GE works with customers to understand the overall system and project objectives through comprehensive analysis and studies developing the optimal, most cost effective technology solution. Examples of the types of studies include:

- Load Flow Study
- Transient Stability Study
- Voltage Profile
- Auto-Reclosing Requirements
- Overload Requirements
- Swing Current Analysis
- Transient Recovery Voltage (TRV) Analysis
- Equipment Sizing (Amps, Ohms, MJ, Mvar)
- Development of Project Specification Document
- Harmonic analysis
- Feasibility study



Final System Design (Post Award)

GE's subject matter experts work seamlessly with customers to finalize the system and equipment design to meet the customer's system requirements. In this stage we:

- Finalize system studies
- Develop protective relays settings,
- Specify control and operation coordination for integration into existing systems
- Finalize equipment design and sizing studies
- Generate equipment specifications



Implementation and Testing

During the project implementation phase, GE is focused on executing on the agreed design with the customer to meet the project requirements. Activities include:

- Integration of new equipment with existing equipment
- Definition of, and participation in, type testing, factory acceptance testing and field testing
- Commissioning support including highly trained field engineer and site technical advisory support.
- On-site and off-site specialized system training



Project Support

GE's commitment to customer satisfaction is a primary goal – just because the project is complete, the job is not. A primary responsibility is continued support of the implemented system throughout its lifecycle. GE provides:

- Incident analysis and troubleshooting support
- System recovery services
- Equipment upgrades and retrofits to meet changing system needs





Beuly Substation, Scotland, UK
1st Installation of GE's Patented Main Reactor Design

For more information about
GE's Static Var Compensator visit
GEGridSolutions.com/SVC



GE

2018 Powers Ferry Road
Atlanta, GA 30339 USA

1-877-605-6777 (toll free in North America)
1-678-844-6777 (direct number)

GEGridSolutions.com

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