

# FACTS

ADVANCED FACTS TECHNOLOGY  
FROM MITSUBISHI ELECTRIC



# STRENGTHENING YOUR POWER SYSTEM WITH **FACTS**

MITSUBISHI ELECTRIC POWER PRODUCTS, INC.



**Today's power grid** is under mounting stress as utilities grapple with the rapid retirement of coal power plants, prevalence of renewable energy sources, and load growth into new areas. This combination of load growth supplied by intermittent sources of electric power can create unstable voltage conditions that constrain power system operation. Fortunately, there is a solution. By providing power electronics based reactive power compensation, Flexible AC Transmission Systems (FACTS) enable power systems to operate at optimal capacity.

Manually operated synchronous condensers were once the primary means of compensation and regulation. Today, advanced power electronics systems like Static Synchronous Compensators (STATCOMs) and Static Var Compensators (SVCs) have automated the process for robust and reliable operation. These solutions stabilize the power system voltage by balancing the supply and demand of reactive power. This results in a tremendous improvement in the overall operation and performance of the transmission system. Mitsubishi Electric can also supply Fixed Series Capacitor (FSC) systems that provide series compensation to increase the power transfer capacity of AC lines.

Mitsubishi Electric has been a worldwide leader in the development, design and manufacture of power electronics solutions since the early 1970s. In 1979, Mitsubishi Electric developed the world's first Voltage Sourced Converter (VSC) based STATCOM system. In 1984, Mitsubishi Electric installed the world's first commercial conventional SVC using direct Light Triggered Thyristor (LTT) technology. And in 2017, Mitsubishi Electric commissioned its first Modular Multilevel STATCOM.

Mitsubishi Electric has supplied more than 180 power electronics systems throughout the world. Notable projects include Mitsubishi Electric's +/- 450 Mvar STATCOM for Chubu Electric Power Company in Japan, which was commissioned in 2012. Mitsubishi Electric delivered the first 765 kV SVC in North America, which was located at a substation in Virginia and commissioned in 2018.

Mitsubishi Electric Power Products, Inc. (MEPPI) was founded in 1985 to supply power products, services and systems to utility companies throughout North America. MEPPI offers engineering, procurement, management, construction, commissioning, and maintenance for all aspects of these complex turnkey projects. MEPPI has delivered over thirty FACTS installations to customers throughout North America.

## FACTS SOLUTIONS

# SUPERIOR PERFORMANCE AND FEATURES

## SVC AND STATCOM

MEPPI sells a wide variety of high-performance, power electronics based systems ranging from transmission system voltage levels of 69kV to 765kV, with typical overall ratings from 50Mvar to 800Mvar.

Applications include:

- ◆ Voltage control
- ◆ Mitigation of Fault-Induced Delayed Voltage Recovery (FIDVR)
- ◆ Voltage stabilization for renewables integration
- ◆ Var reinforcement due to generation retirement
- ◆ System voltage regulation improvements under varying load conditions
- ◆ Increased steady state power transfer capacity
- ◆ Improved transient stability
- ◆ System damping augmentation
- ◆ HVDC link performance improvement
- ◆ Subsynchronous resonance mitigation

MEPPI has delivered numerous SVC and STATCOM systems over a wide range of capacities and voltage levels for customers throughout North America.

## FIXED SERIES CAPACITORS

MEPPI offers a highly reliable gapless Fixed Series Capacitor system to provide series compensation for long or overburdened AC transmission lines. Benefits of Fixed Series Capacitors include:

- ◆ Increase of real power capacity of existing lines
- ◆ Increase of voltage stability
- ◆ Decreasing angular separation
- ◆ Mitigation of transmission line DC currents
- ◆ Load sharing between parallel lines
- ◆ Reduction of losses
- ◆ Deferral of major transmission investments

MEPPI has local expertise in FSC design to work closely with customers and vendors in order to provide exceptional project execution.

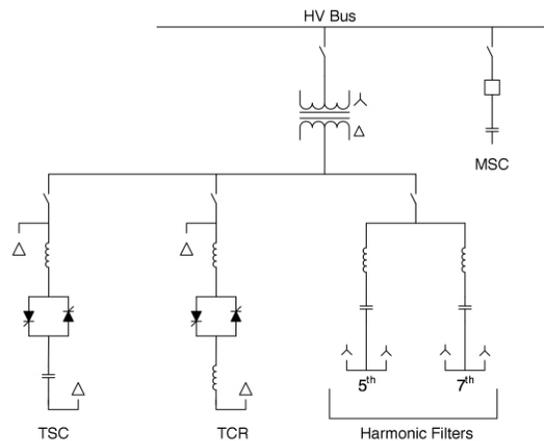
FACTS SOLUTIONS

# STATIC VAR COMPENSATORS (SVC)

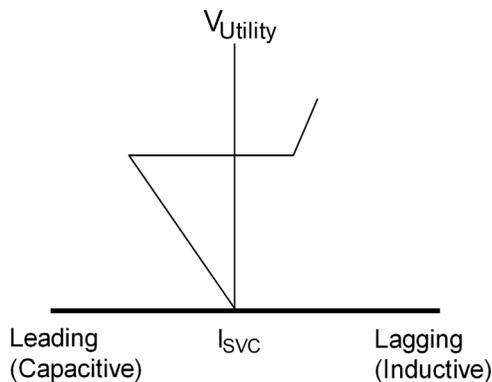
SVC systems typically consist of a Thyristor Controlled Reactor (TCR), a Thyristor Switched Capacitor (TSC) and a Fixed Capacitor (FC) in a harmonic filter arrangement.

The TCR consists of reactors and thyristor valves which control the reactive power by varying the current amplitude flowing through the reactors. The TSC consists of capacitors, reactors, and thyristor valves which switch the capacitors on and off. AC filters are also used to provide fixed reactive power and absorb the harmonic currents generated by the other branches of the circuit.

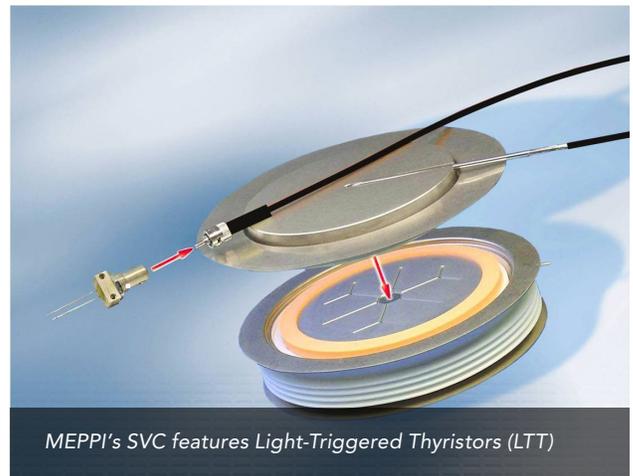
In these systems, the TSC and TCR coordinate to provide linear control over the entire range of rated reactive power output, and can be tuned to minimize losses at the most frequent operation point. Applications using only TSCs are also available to provide stepwise control of capacitive and reactive power.



Example of SVC One-Line Diagram



V-I Diagram of SVC System



MEPPI's SVC features Light-Triggered Thyristors (LTT)

## KEY COMPONENTS OF AN SVC

### THYRISTOR VALVES

Thyristor valves are used to control the level of inductive or capacitive reactive power. The thyristor valves use solid-state silicon controlled rectifiers (thyristors) connected in anti-parallel pairs to control AC current. These anti-parallel pairs are then connected in series to operate at distribution voltages. The thyristors control the reactors and capacitors in the circuit, and can operate on a per-cycle basis, allowing fast, precise voltage control.

### VALVE COOLING SYSTEM

Mitsubishi Electric has developed a high-efficiency liquid cooling system for our FACTS installations using a combination of deionized water and propylene glycol. These cooling systems come complete with filters and deionizers to remove excess heat generated in each thyristor. Designs are fully redundant for reliability, compact, and ensure that the thyristors operate at their maximum capability.

### STATION CONTROL SYSTEM

A digital controller is supplied with every power electronics system. The digital controller incorporates data from high-precision digital signal processors (DSP) through multiple processing units to control the thyristor valves and all ancillary equipment throughout the station. The digital control system offers high flexibility, reliability and easy maintenance. The digital controller enables remote accessibility through highly customizable LAN and SCADA interfaces. Its LINUX-based operating system has a proven track record of stability and security with a minimal level of software patch releases.



*Three-phase Thyristor Valve*



*Cooling System Pump Skid*

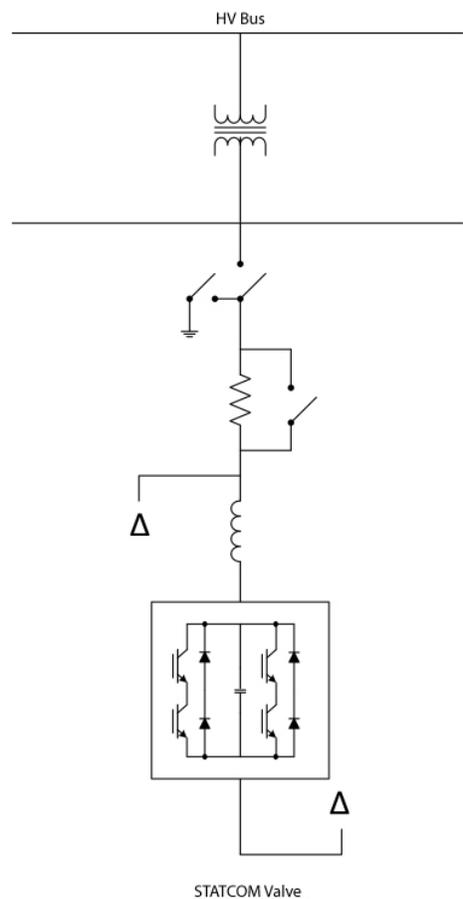
FACTS SOLUTIONS

# STATIC SYNCHRONOUS COMPENSATORS (STATCOM)

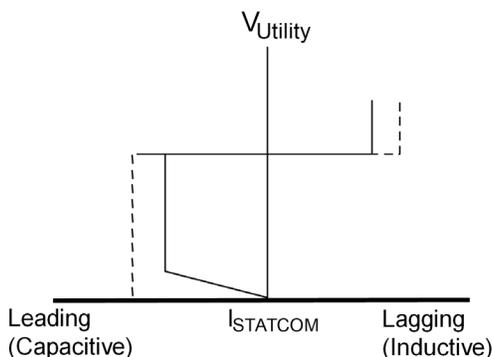
As electric utilities experience an increasing array of challenges to meeting consumer demand, Mitsubishi Electric's SVC-Diamond®, STATCOM can help electric utilities take some of the stress off the electric power transmission grid and supply their customers with high-quality power 24/7.

Within the STATCOM valve, a number of sub-modules are connected in series. Through switching combinations of the sub-modules by PWM (Pulse Width Modulation), the output waveform is "built" through a large number of precise, small switching steps. This process results in a near perfect sine wave output.

The amplitude of the STATCOM's AC output is controllable to compensate for the voltage conditions measured on the high voltage bus. The STATCOM's reactive output capacity is directly proportional to system voltage. As a result of this feature, the STATCOM has superior low-voltage output capacity compared to an SVC.



Example STATCOM One-Line Diagram



V-I Diagram of STATCOM System



Mitsubishi Electric IGBT

## INNOVATIVE MODULAR MULTI-LEVEL CONVERTER (MMC) TECHNOLOGY

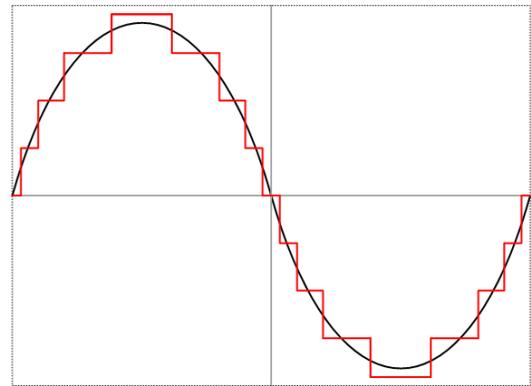
Mitsubishi Electric uses Modular Multi-Level Converter (MMC) topology in our SVC-Diamond® STATCOM systems that feature:

- ◆ Near-Perfect Sine Wave Output
- ◆ Typically No Harmonic Filtering
- ◆ Low Losses Due to Low Switching Frequency
- ◆ Standard Modules (Cells) Optimally Connected in Series
- ◆ Economical Design
- ◆ Compact Size
- ◆ Open Rack Design for Easier Maintenance

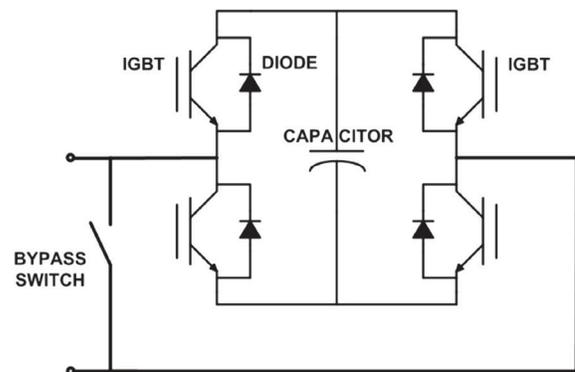
MEPPI's SVC-Diamond® STATCOM design begins with the Insulated Gate Bipolar Transistor (IGBT), which is the fundamental power electronic device. IGBT sub-modules or cells are the "building blocks" of MMC technology that enable STATCOM systems to deliver superior performance which results in higher operating efficiencies with lower losses. Mitsubishi Electric manufactures its own IGBT's and has provided more than 40,000 IGBTs for STATCOM and HVDC applications worldwide.

These IGBT sub-modules are connected in a Full-Bridge configuration within the sub-module. A number of these submodules are connected in series depending on the reactive power output rating of the STATCOM.

By connecting a large number of submodules in series, the STATCOM is able to reconstruct an output waveform that is nearly sinusoidal in shape. This means that the STATCOM produces a low level of harmonics, so additional filtering is unnecessary. The STATCOM submodules also operate at a relatively low switching frequency, which reduces switching losses and improves overall efficiency.



MMC STATCOM: Simplified Output Voltage



Simplified MMC Sub-module Diagram



MMC Sub-module

## SUPERIOR DYNAMIC PERFORMANCE

In the case of a STATCOM, the shunt reactive power compensation is achieved through precisely controlling the voltage amplitude of the AC output of the STATCOM Voltage Source Converter (VSC) valve. Because the reactive power is derived from the voltage amplitude and not from external capacitors or reactors, the overall installation footprint is more compact. Arm reactors are installed to limit currents during faults, and pre-insertion resistors prevent high inrush currents during initial energization.

STATCOM's key features and benefits include:

- ◆ Superior Low-Voltage Output Capacity
- ◆ Superior Overvoltage Suppression
- ◆ Stable Operation When Applied to Weak Systems
- ◆ Extremely Low Levels of Harmonics produced, such that filters are not typically required
- ◆ Reduced Voltage Loss
- ◆ Small Footprint



## ACTIVE FILTERING CAPABILITY

Many utilities are experiencing severe harmonics on their distribution and transmission systems. These harmonics are generated by inverter-coupled energy resources such as PV solar and wind farms as well as DC loads and motors connected through Variable Frequency Drives. All these power electronic converters can inject high levels of harmonic content on the power system. Fortunately MEPP's STATCOM can be applied to reduce the harmonic content measured on the transmission system through its active filtering functionality.

During normal operation the STATCOM controls the fundamental voltage magnitude to adjust reactive power output. With Active Filtering functionality, the STATCOM controls harmonic current in addition to the fundamental current. Additional sub-modules are used to superimpose the harmonic current and fundamental current. The end result is an overall reduction in the harmonic levels seen on the high voltage transmission system.

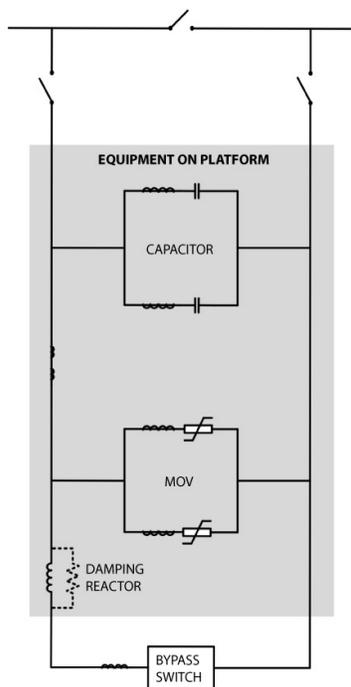


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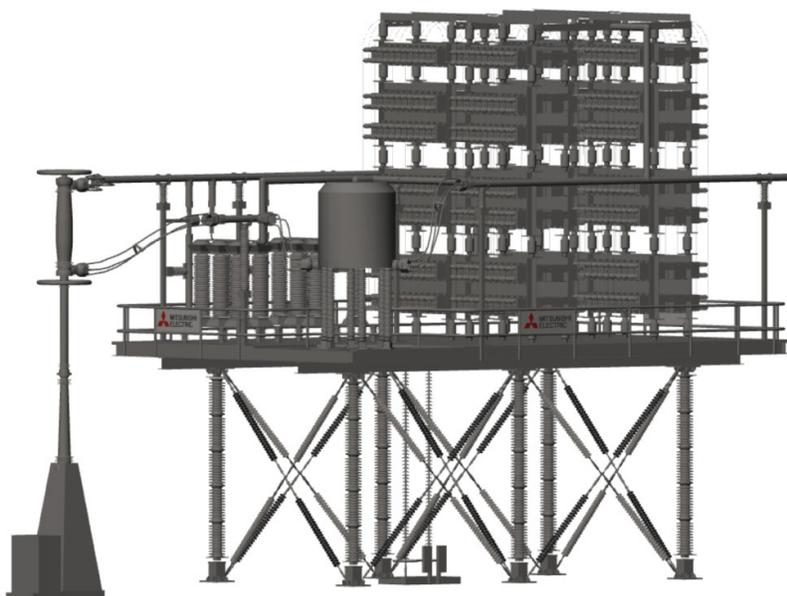
# FIXED SERIES CAPACITORS (FSC)

As the worldwide demand for power continues to grow, it is critical to ensure that transmission systems are able to both effectively and economically support this increased capacity. MEPPI's Fixed Series Capacitor systems provide an economical solution to increase the power transmission capacity of existing long lines and can defer the need to build new transmission lines that are subject to high costs, long lead times, and severe environmental constraints.

One of the main limitations when transmitting power over long distances is the natural inductive impedance of the transmission lines. By installing capacitors in series with a transmission line, they reduce the natural inductive impedance of the line, thereby reducing the voltage drop across the line and increasing the magnitude of real power flow.



*Simplified One-Line*



*Fixed Series Capacitor Installation Rendering*

## BENEFITS OF FIXED SERIES CAPACITOR SYSTEMS

- ◆ Increase of real power capacity of existing lines
- ◆ Increase of voltage stability
- ◆ Decreasing angular separation
- ◆ Mitigation of transmission line DC currents
- ◆ Load sharing between parallel lines
- ◆ Reduction of losses
- ◆ Deferral of major transmission investments



MELSEC System Q Programmable Controllers

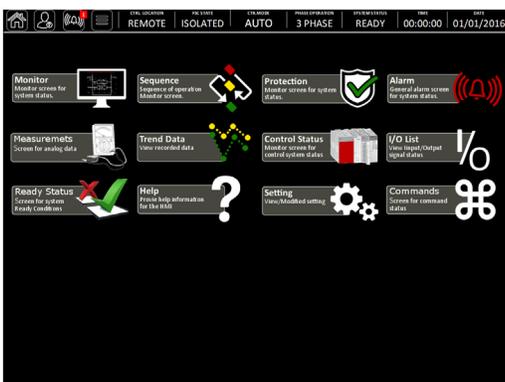
## FEATURES OF MEPPI'S FSC SYSTEMS

- ◆ Modular design for long life
- ◆ Ease of Maintainability
- ◆ State-of-the-art Protection and Control Technology
- ◆ Domestic US engineering design, field service and warranty support

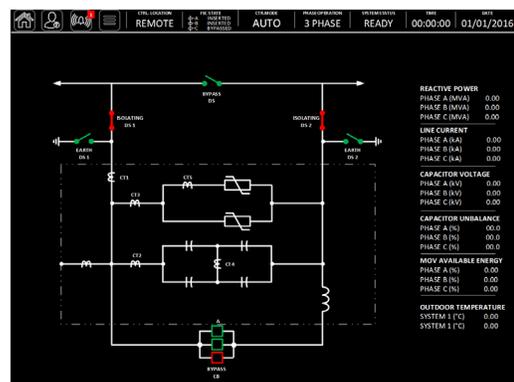


Mitsubishi Electric GOT2000 HMI Platform

Through its locally based FSC equipment and control system experts, MEPPI offers a high degree of customization to tailor its solutions for the customer's requirements and preferences. MEPPI's design principles focus on reliability and operational efficiency through computational speed and a clear, intuitive operator interface



Customizable HMI Menu Options



HMI Screen of FSC One-Line Diagram

# QUALITY PRODUCTS, UNRIVALED SERVICE

MITSUBISHI ELECTRIC POWER PRODUCTS, INC.



MEPPI corporate values focus on providing the highest standards in individual performance, integrity and customer commitment. Over time we have developed a comprehensive and detailed approach that underlies successful performance in all disciplines.

## QUALITY ASSURANCE AND CONTINUOUS IMPROVEMENT

MEPPI is committed to providing products and services of the highest possible quality. A documented Quality Assurance Program specifies product performance standards from design and manufacturing, through installation, to the end of the commissioning process. This program offers prescriptive details for engineering procedures, accounting, material handling, testing and reporting.

Continuous improvements on engineering processes and product strategy are made on each project. Events are analyzed to identify root causes and actions defined to correct or avert. This proactive approach supports the on-going improvement and refinement of the Mitsubishi Electric products and services.

## SITE SERVICES

MEPPI field engineers perform new equipment installation and commissioning tasks. High and low-voltage testing of switchgear and transformers is performed using sophisticated test equipment owned by Mitsubishi Electric and brought to each site. Routine diagnostics and examination of high-voltage problems developed on customer's pre-existing equipment are also available, in addition to full turnkey replacement or repair.

Available field engineering services include:

- ◆ FACTS Substation Maintenance Contracts
- ◆ Spare Parts Sales
- ◆ Personalized training seminars for engineers and technicians
- ◆ Diagnostics Testing and Equipment Monitoring
- ◆ Site installation management, commissioning, and supervision
- ◆ Telephone support with 24/7 answering service
- ◆ Cybersecurity Compliance Consulting

Mitsubishi Electric Power Products' reputation for engineering and manufacturing excellence is built on our commitment to customer satisfaction and quality service.

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Mitsubishi Electric Power Products, Inc. serves the North American power systems, rail transportation, and large visual display markets with electrical and electronic products, systems and services. The products offered include gas circuit breakers, vacuum circuit breakers, power transformers, gas-insulated substations, power electronics and electricity transmission technologies including high voltage DC, battery energy storage systems, generator services, nuclear power plant control systems, uninterruptible power supplies, rail transportation equipment, and high-definition LED displays for sports, commercial, and retail installations. For more information and to learn more, [www.MEPPi.com](http://www.MEPPi.com)



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for a greener tomorrow

