HITACHI

Hitachi Energy

Power Electronics Technologies

Andrew Owens

Global Product Manager

High Power Solutions

About Hitachi Energy

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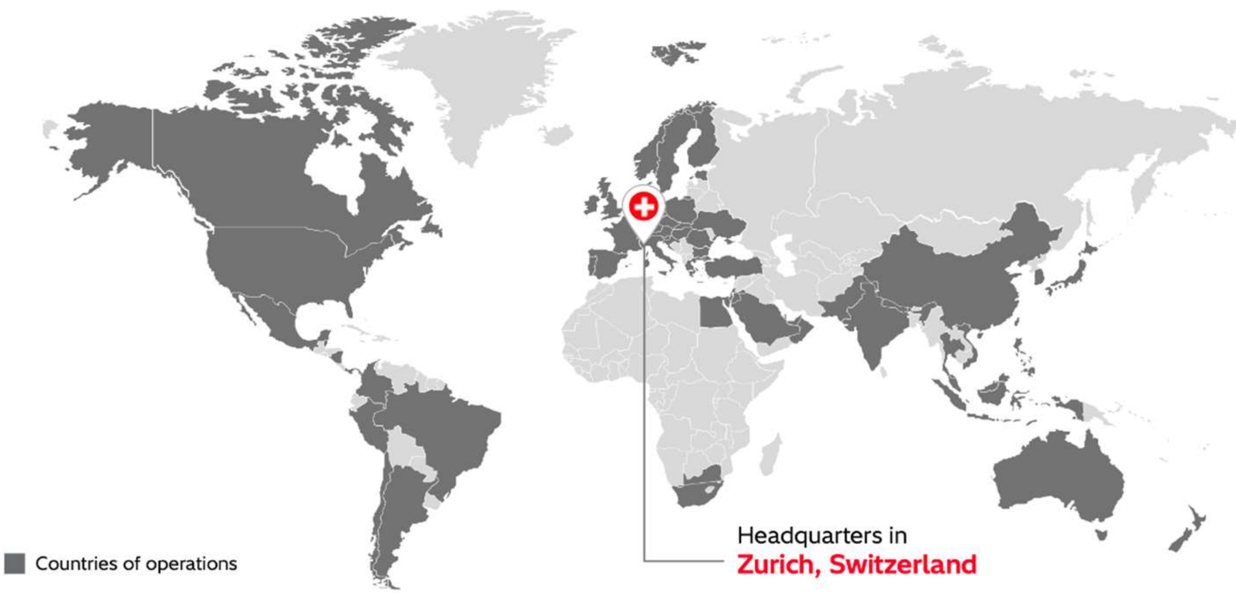


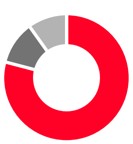
50,000+ employees	**170** nationalities
60+ countries	**100+** years of heritage
1,800+ field engineers	**2,600+** R&D experts

~$16 billion USD business revenues

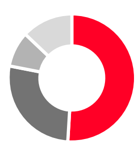
Business Units

- **Grid Automation**
- **Grid Integration**
- **High Voltage Products**
- **Service**
- **Transformers**

Customers



Offering



Geographies

Business mix by revenue FY2024

Public

Grid Integration | World's largest installed base

9,000+ employees delivering solutions and services in **90+ countries**

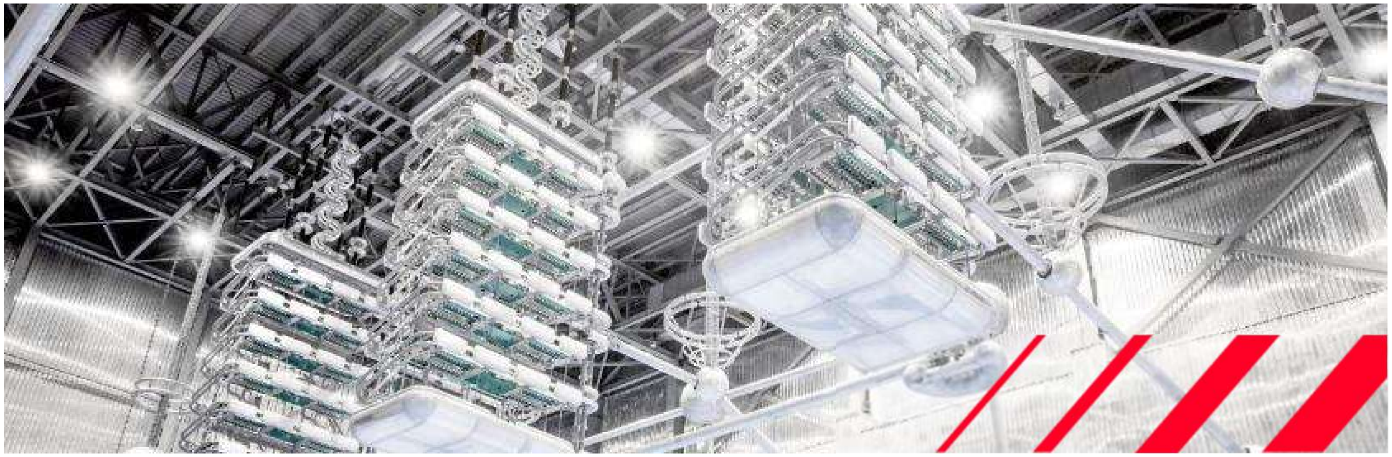
~60 Operating Units around the world

4,000+ projects delivered in the last 15 years

~15,000 systems operating globally

#1 in HVDC globally: **200 GW installed** systems

1,000+ employees dedicated to consulting and services



Comprehensive portfolio of solutions…

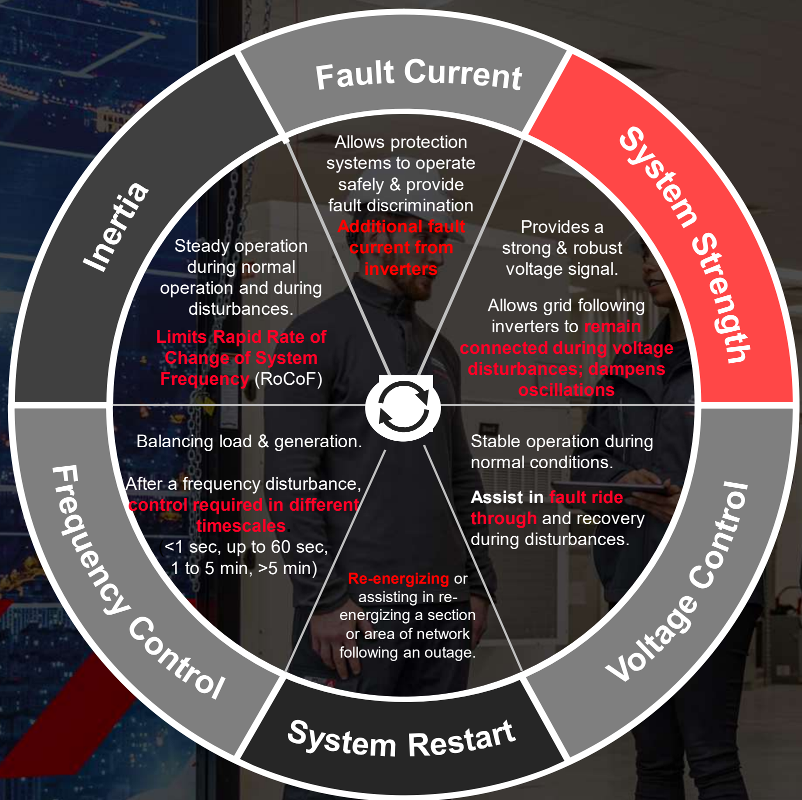
Power Consulting	High Voltage Direct Current	Grid & Power Quality Solutions	Semiconductors	Service Solutions

…addressing all key segments connected to the energy system

Renewables	Transmission Distribution	Industries	Transportation	Infrastructure

We need to maintain grid stability – Past, Present and Future

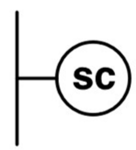
What services are required to operate a stable and secure grid both now and into the future?



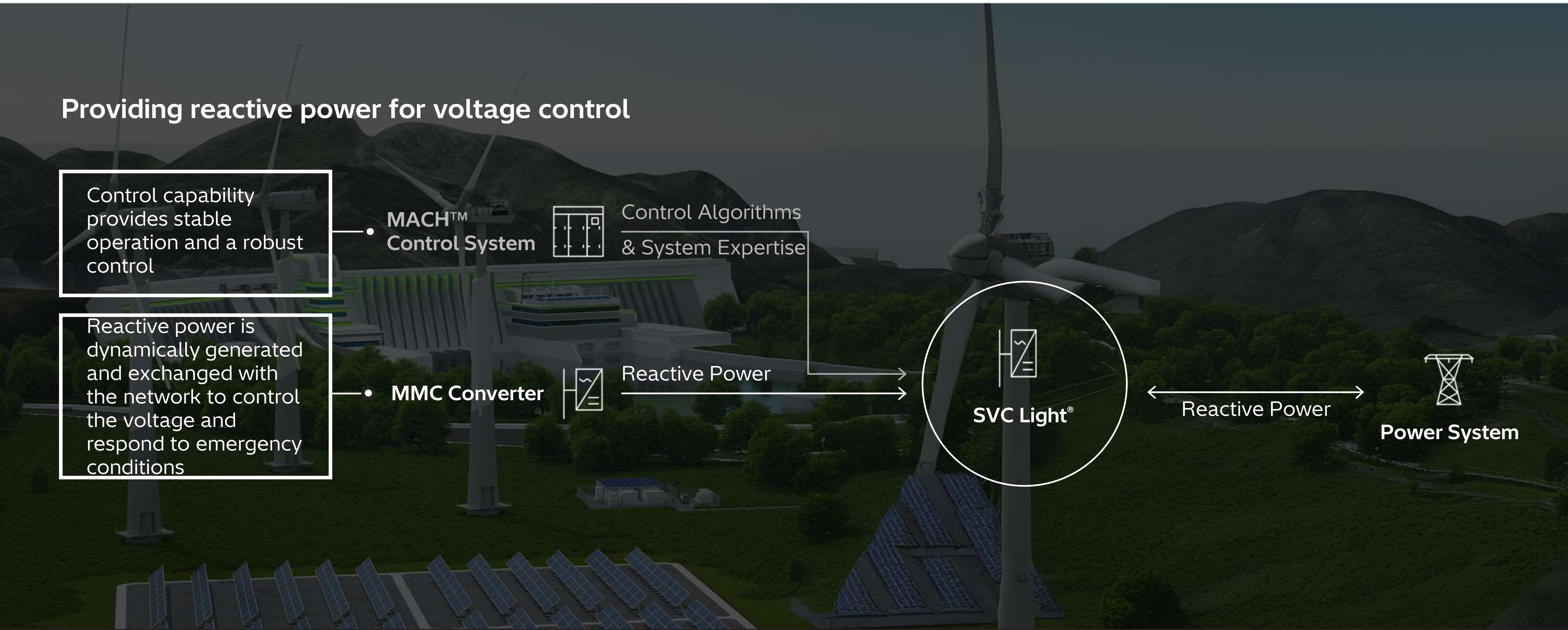
Characteristic	Traditional SG Dominant	Low Renewable Penetration	High Renewable Penetration
Inertia	High	Medium	Low
SCR	High	High	Low
Protection	Traditional	Traditional	Adaptive
Frequency Stiffness	High	High	Low
Voltage Stiffness	High	High	Low

Source: Tuckey, Round, Grid-Forming Inverters for Grid-Connected Microgrids, IEEE Elec Mag, March 2022

Multiple services for future grid stability

Grid-stabilizing services	 Traditional STATCOM	 Synchronous condenser	 Enhanced STATCOM
Voltage regulation	● ● ●	● ●	● ● ●
Inertia		● ●	● ● ●
Short-circuit current contribution	●	● ● ●	● ●
Flexibility/modularity	● ● ●		● ● ●
Controllability	● ●	●	● ● ●

SVC Light® STATCOM - a proven solution

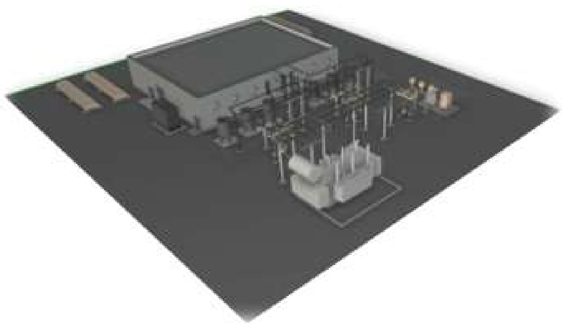


Core competence: Power Electronics and Control

STATCOM Continuous Technological Development

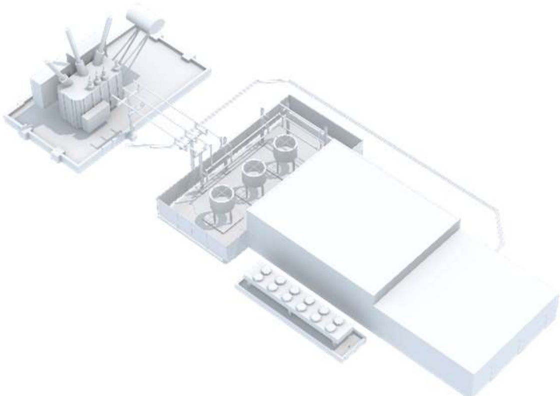
Yesterday

- Traditional STATCOM
- Multiple VSC Branches over 150 MVAR



Today

- Traditional STATCOM
- Single branch up to 400 MVAr



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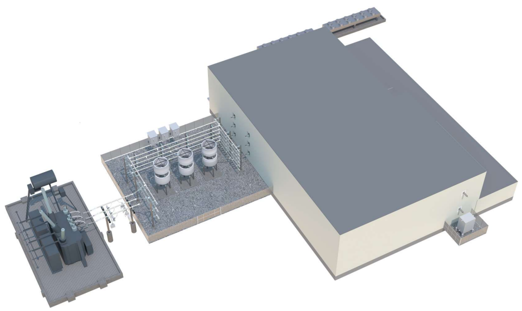
- **Grid Forming Control / Zero-Inertia**
- **Multiple topologies**

Tomorrow

- Enhanced STATCOM Technologies
- Active and Reactive Power Capability



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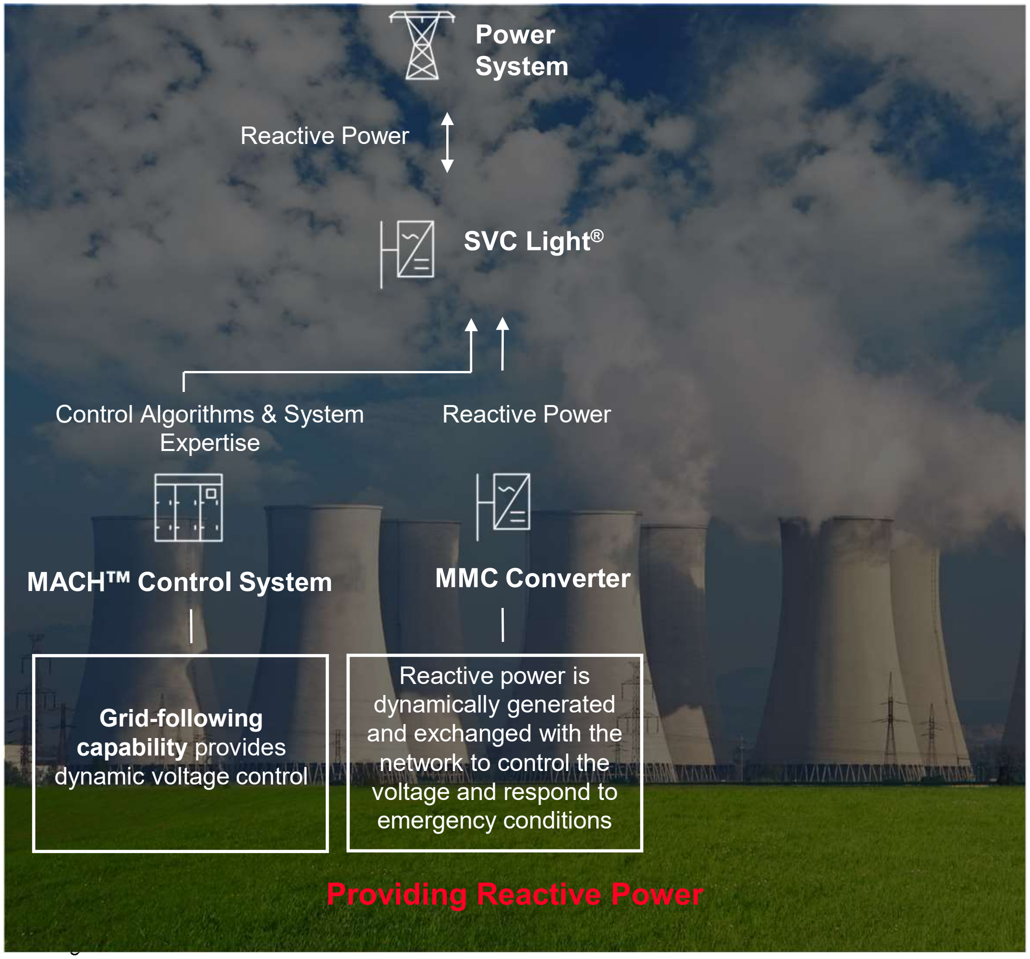
- **Double Star topology**
- **Inertia Response**

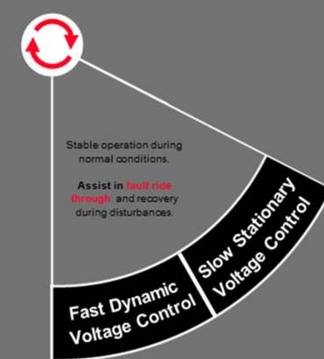
Larger Capacity → Reduced Footprint → Increased Functionality

Public

What services are required to operate a stable and secure grid?

Conventional STATCOM with Grid Following Control (GFL)





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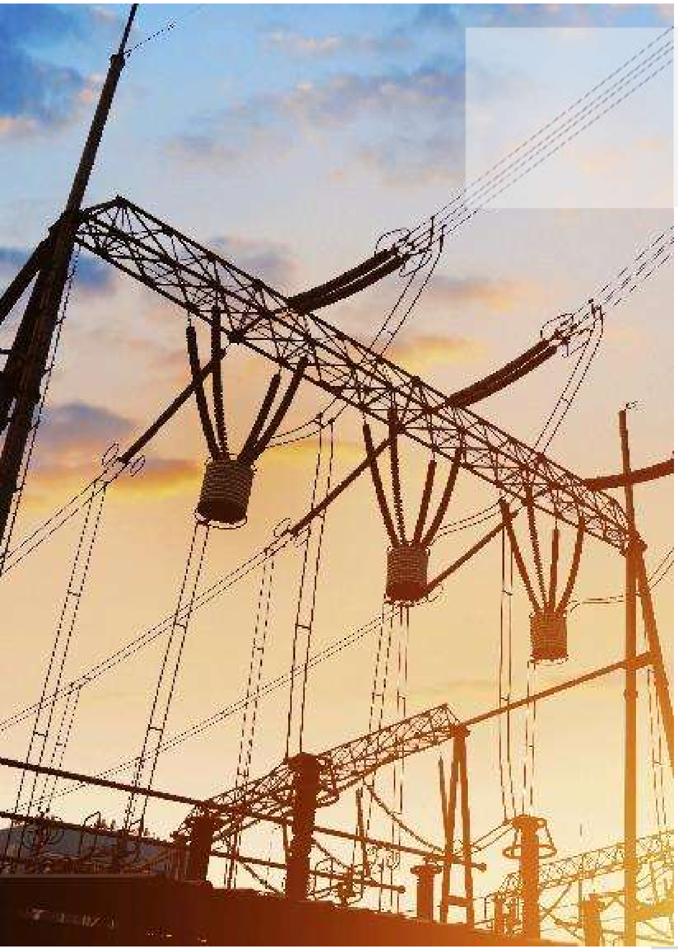


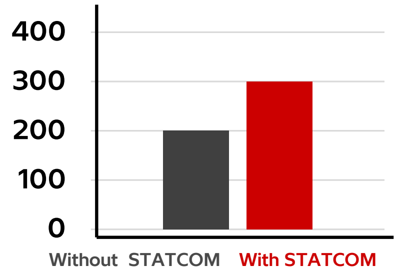
Increase in transmission capacity for utilities

Up to **50% increase in AC power** transmission capacity

Based on case study: Utility - EGAT, Thailand, 230 kV Bang Saphan substation

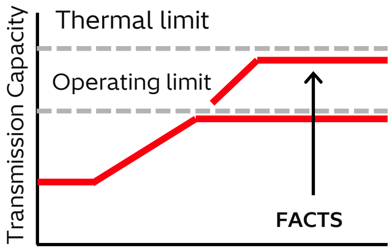
Without dynamic compensation, the power transmission capacity limited to:

Below 200 MW



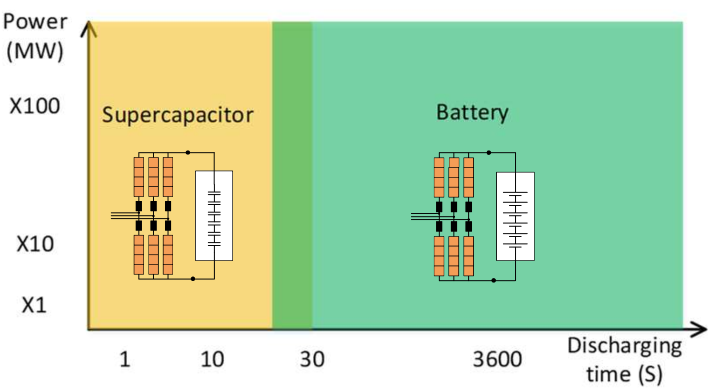
With dynamic compensation, the power transmission capacity has been raised to:

Over 300 MW



Market Driver – German Market – Phase 1

Supercap vs. Battery



"Necessity for the development of grid-forming STATCOM systems"

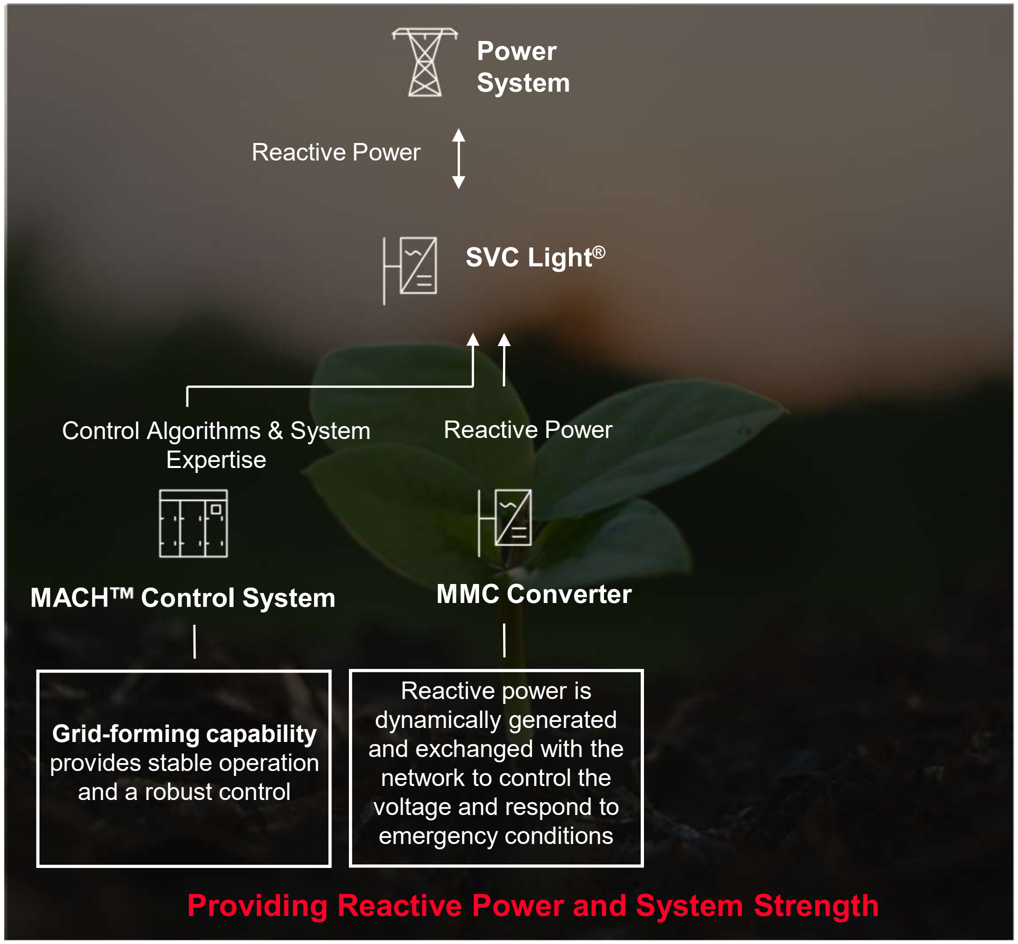
- On December 8th, 2020 German TSOs position paper[1] identifying the need for 23-28 GVAr reactive compensation with systems of 250-600 MVAr:
- **Phase 1:**
  - STATCOM topology maintained
  - The grid-supporting control concept replaced by a grid-forming control concept
  - Only limited provision of an inertial response is possible
- **Phase 2:**
  - Topological changes are needed
  - Grid-supporting control concept has to be replaced by a grid-forming control concept.
  - The limited energy reserves in the capacitors of the converter modules have to be expanded to provide a certain share of inertia (e.g. by integrating supercapacitors). Here, it has to be possible to provide active power within the rated limits of the converter in a single-digit second range.

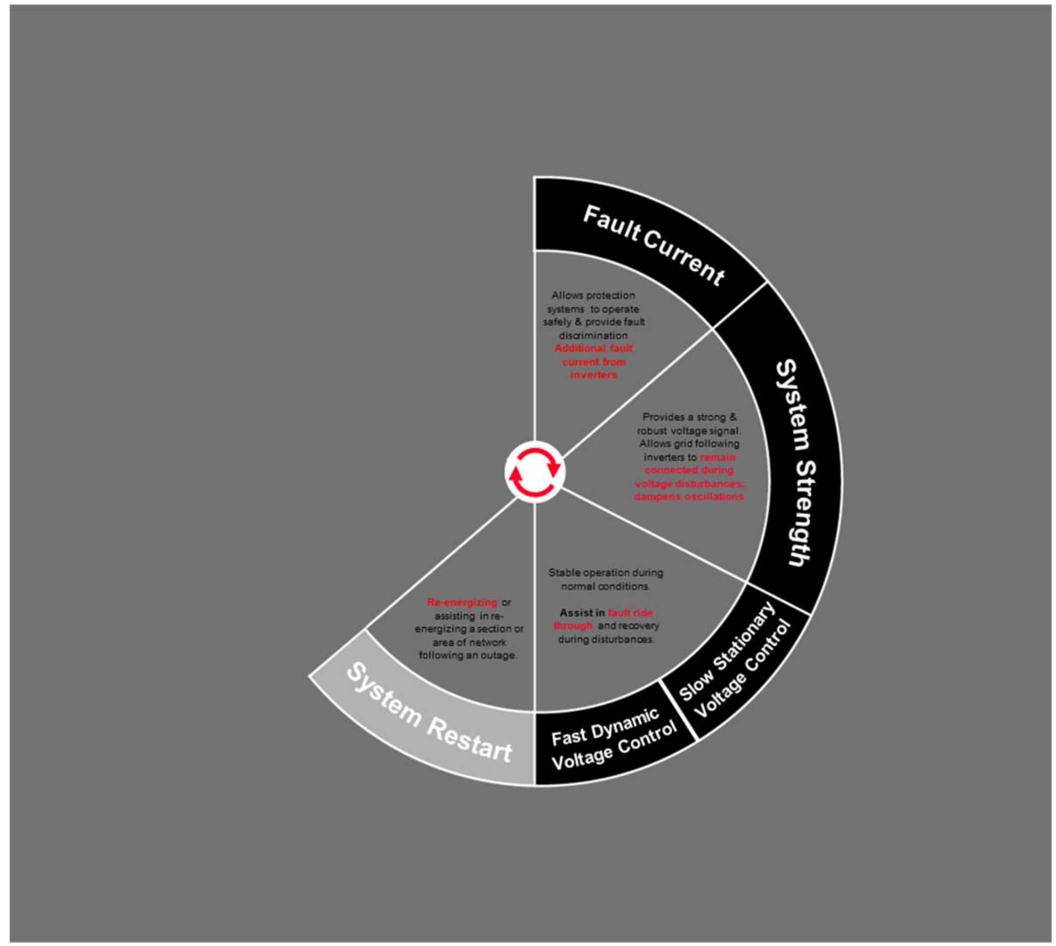
23-28 GVAr of STATCOM and Synchronous Condensers Installed by 2030

1. https://www.netztransparenz.de/portals/1/Content/Weitere%20Ver%C3%B6ffentlichungen/4%C3%9CNB_Positionspapier_netzbildende_STATCOM_final_EN.pdf

What services are required to operate a stable and secure grid?

SVC Light® - STATCOM with grid forming capability (GFM)





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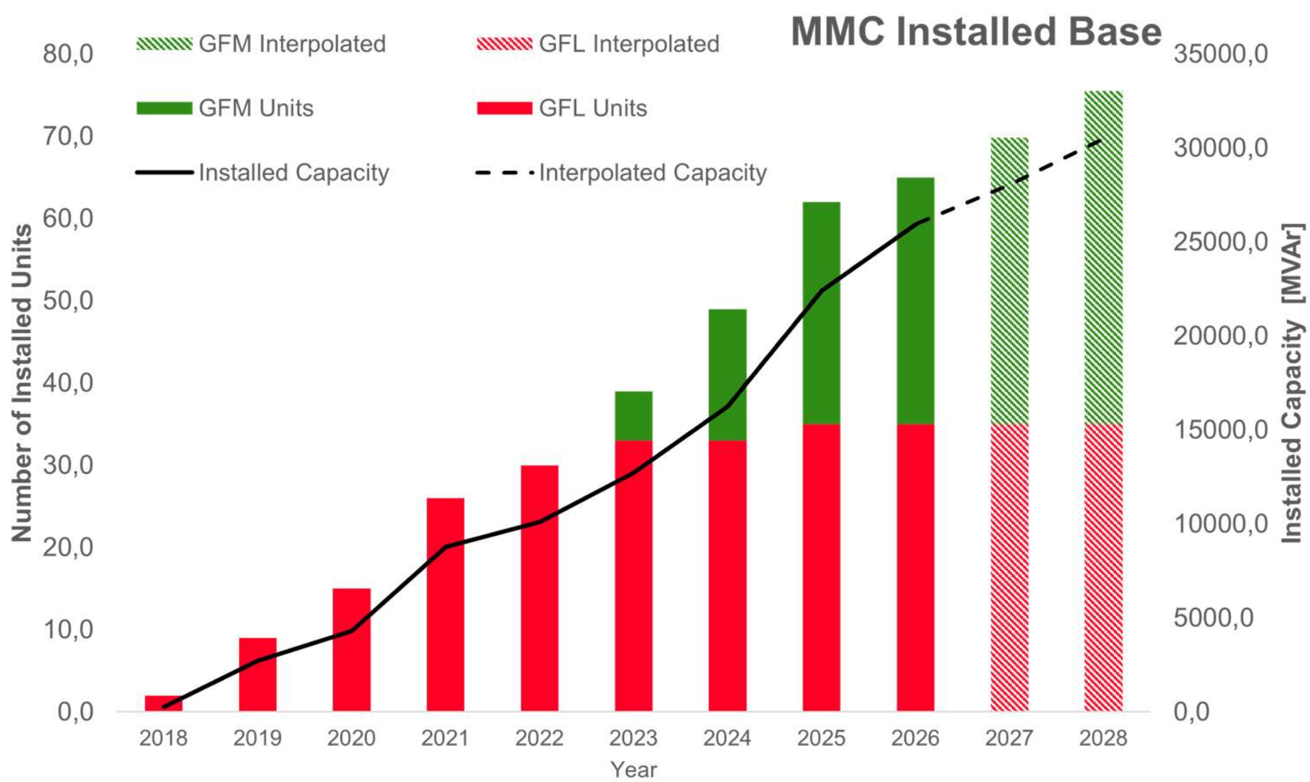
Grid Following vs. Grid Forming STATCOM global installed base

Industry references in offshore wind, transmission, and steel-making

First installations online in **2023**



GFM = Grid Forming; GFL = Grid Following; MMC = Modular Multi-level Converter

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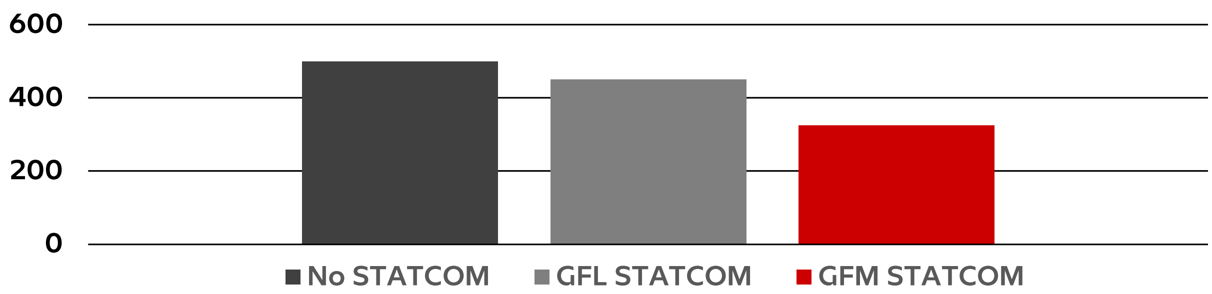
Impact on consumers

Preventing motor stalling equivalent to the load of **15 stadiums** during peak events

Dynamic simulations run analyzing the same network contingency in three scenarios:

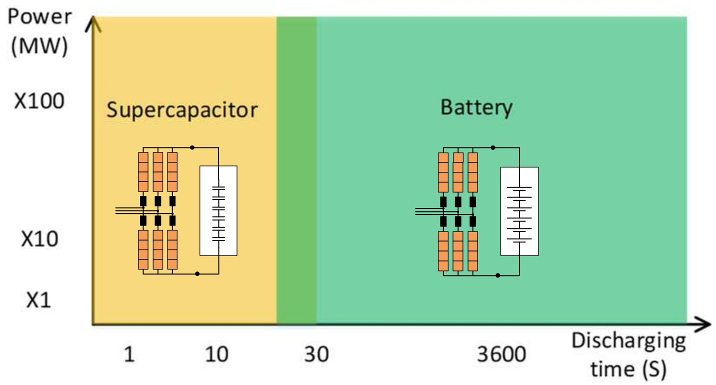
- No Dynamic Reactive Compensation
- 300 Mvar GFL STATCOM
- 300 Mvar GFM STATCOM

GFM STATCOM avoids the stalling of over 150 MW of load



Market Driver – German Market – Phase 2

Supercap vs. Battery



"Necessity for the development of grid-forming STATCOM systems"

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23-28 GVAr of STATCOM and Synchronous Condensers Installed by 2030

1. https://www.netztransparenz.de/portals/1/Content/Weitere%20Ver%C3%B6ffentlichungen/4%C3%9CNB_Positionspapier_netzbildende_STATCOM_final_EN.pdf

Supercapacitor Basics

Energy storage component for high power application

Battery-based systems

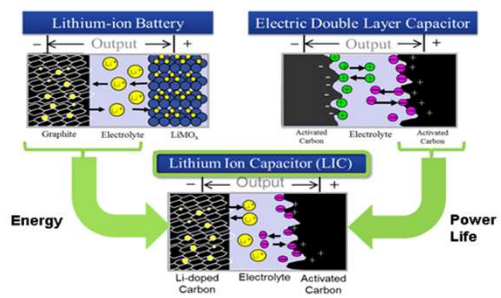
- Energy is stored in the form of chemical energy; a chemical reaction is needed to generate electricity.
- Higher energy density compared to ultra-capacitors
- Lower power density compared to ultra-capacitors

Because of the high-energy density, batteries[1] are the most cost-effective solution for applications which requires rated power for minutes to hours.

Supercapacitor-based systems

- Energy is stored in a combination of electrostatic field and electrochemical reaction. For electric double layer capacitors, the dominant mechanism is the electrostatic field.
- Lower energy density compared to batteries
- Higher power density compared to batteries

Because of the high power density, supercapacitors are the most cost-effective solution for applications which requires rated power for up to 10 seconds.



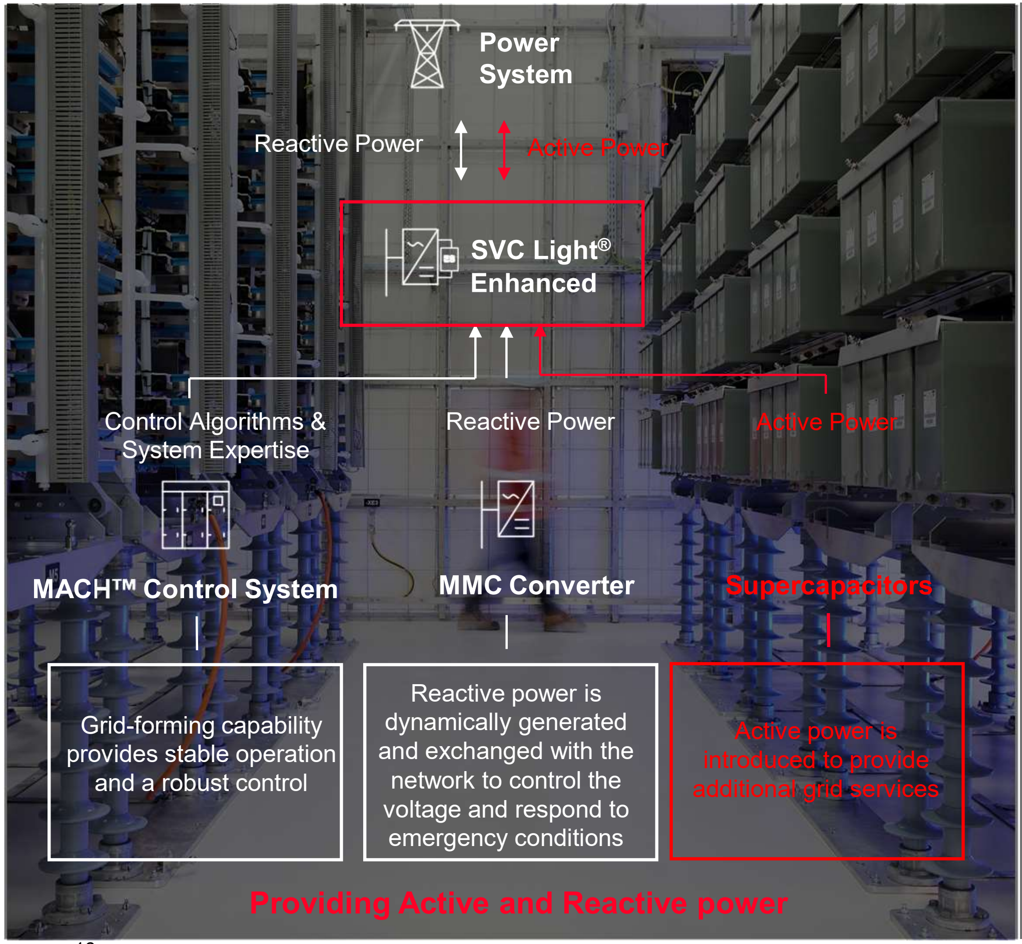
Energy

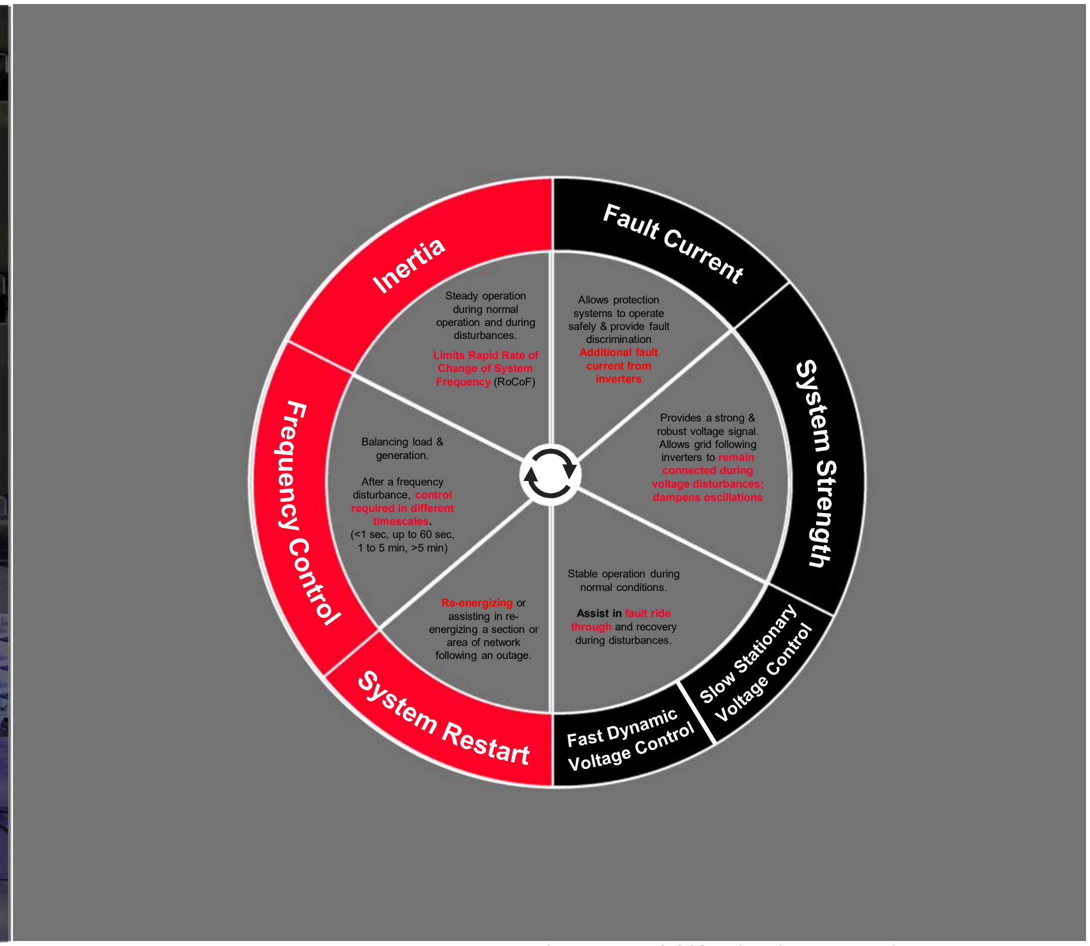
Power

Public

What services are required to operate a stable and secure grid?

SVC Light® Enhanced - STATCOM with grid forming control (GFM) and short-term active power





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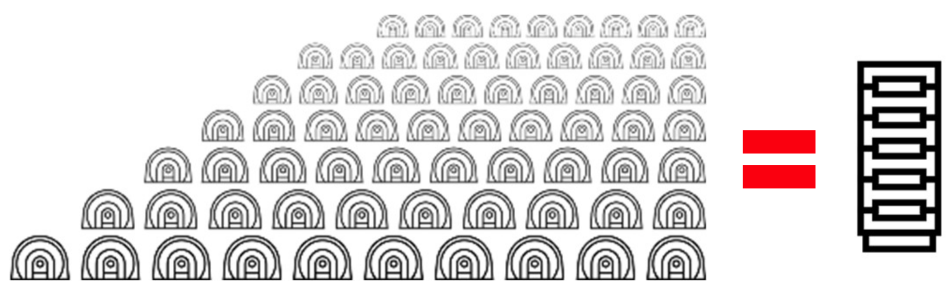
04 Enhanced STATCOM vs. Synchronous Condensers

Enhanced STATCOM is much more efficient in exchanging energy with the grid compared to machine-based solutions.

- 69 Synchronous Condensers of 100 MVA
- 17 Synchronous Condensers with flywheel of 100 MVA



69 Synchronous Condensers = **1 eSTATCOM**

SVC Light® - Enhanced | Key Market Segments

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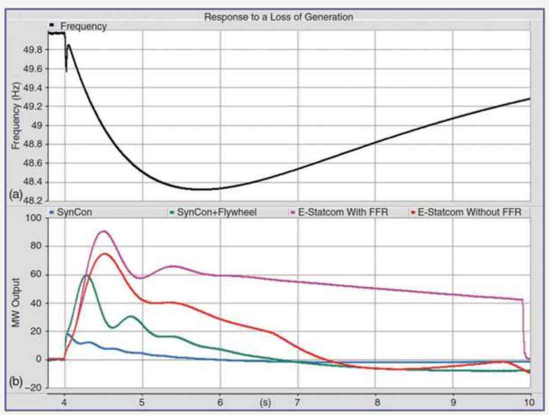
Transmission

Customer Pains

- Reduced power system inertia, stability and security due to higher renewable penetration and decommissioning of traditional rotating generators.

Value Proposition

- High power GFM E-STATCOM able to provide both inertia and voltage support.



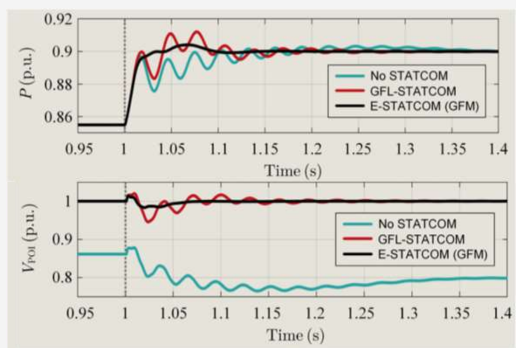
Renewables

Customer Pains

- Comply to demanding grid code requirements connecting to weak systems.

Value Proposition

- Proven installed base in challenging offshore wind environment
- GFM and control functionality for complex configurations improving system strength, fault recovery and operation stability.



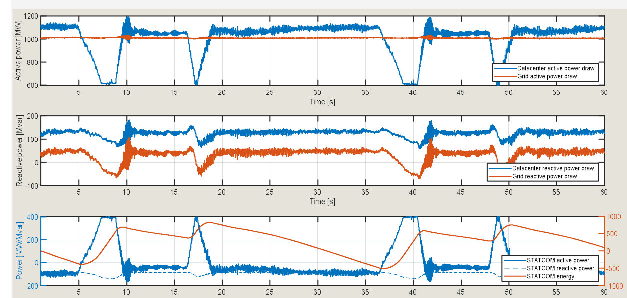
AI Data Centers

Customer Pains

- Comply to grid code requirements connecting large loads with major and frequent power consumption fluctuations.

Hitachi Energy Value Proposition

- Industrial flicker compensation applications track record. Mitigations of fluctuations with significant components in the 1-20 Hz range.
- E-STATCOM technology and energy medium fit for AI data centers duty cycles.



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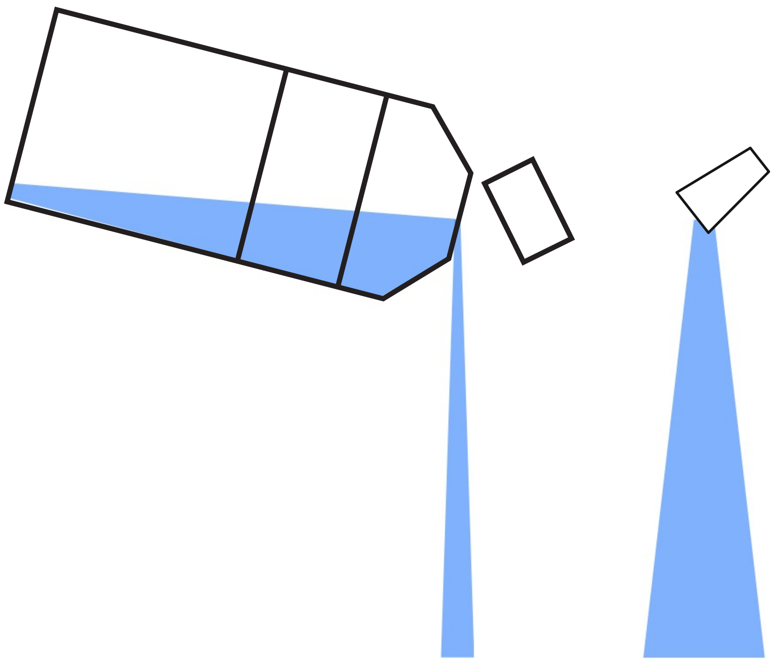
Power Electronic Enabled Grid Services – Technology split

BESS
- **High energy density**
- **Low power density**

E-STATCOM
- **Low energy density**
- **High power density**



Function	Conventional STATCOM	Enhanced STATCOM	BESS
Fault Current	+ +	++	+
System Strength	++	+++	++
Voltage Control	+++	+++	++
System Restart		+	+++
Frequency Control		+	+++
Inertia		+++	++
Energy Shifting			+++

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Power Electronic Enabled Grid Services – Technology split

E-STATCOM | BESS | Operational & market driven

Inertia
- 0–1 s
- Limits RoCoF

Immediate, physics-driven response that limits the rate of change of frequency (RoCoF) after a disturbance, buying time for controls to act.

Fast Frequency Response (FFR)
- 1–10 s
- Shapes frequency nadir

Controlled active-power response that shapes the frequency nadir and supports stability beyond the inertial window.

Primary Frequency Response
- 5–30 s
- Arrests frequency deviation

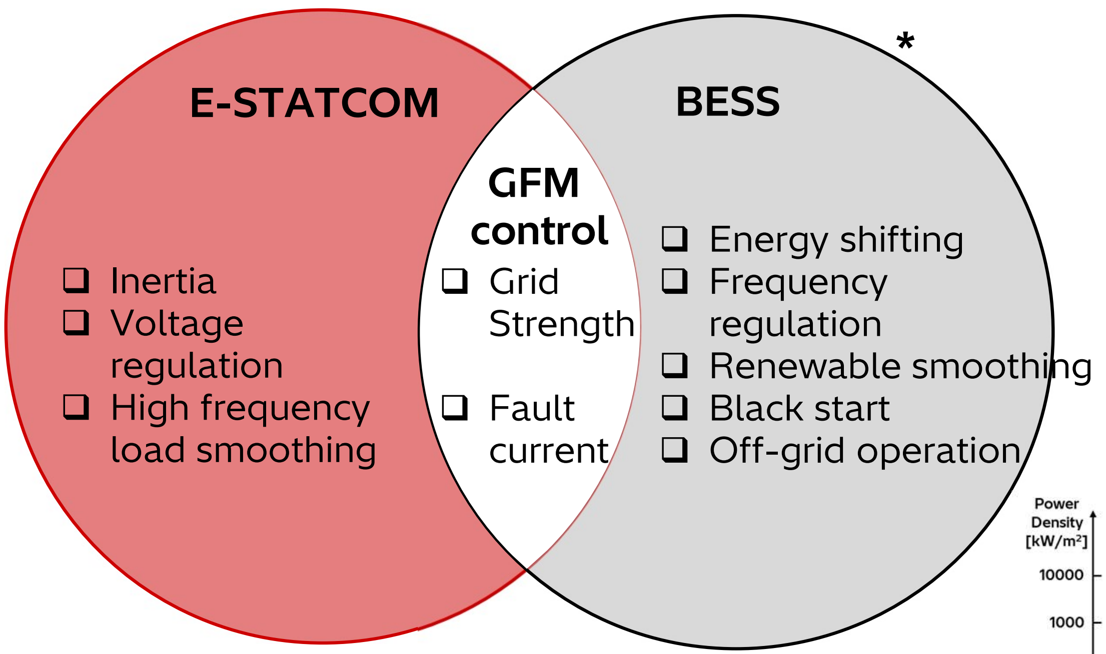
Controlled active-power response that shapes the frequency nadir and supports stability beyond the inertial window.

Secondary / Tertiary Reserves
- >30 s
- Restores balance

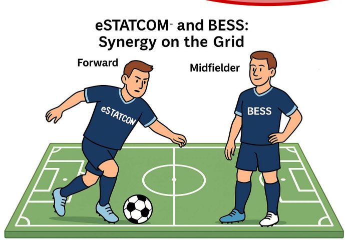
Centralized control actions that restore frequency to nominal and rebalance generation economically over minutes to hours.

Function	Conventional STATCOM	Enhanced STATCOM	BESS
Fault Current	+ +	++	+
System Strength	++	+++	++
Voltage Control	+++	+++	++
System Restart		+	+++
Frequency Control		+	+++
Inertia		+++	++
Energy Shifting			+++

E-STATCOM and BESS – applications mapping

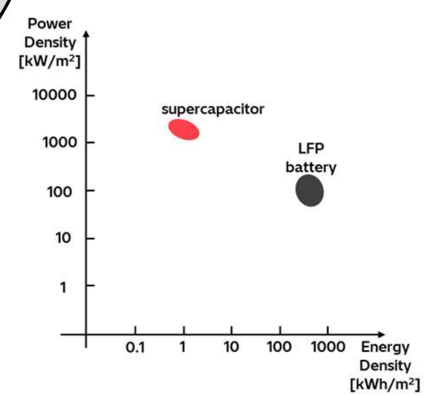


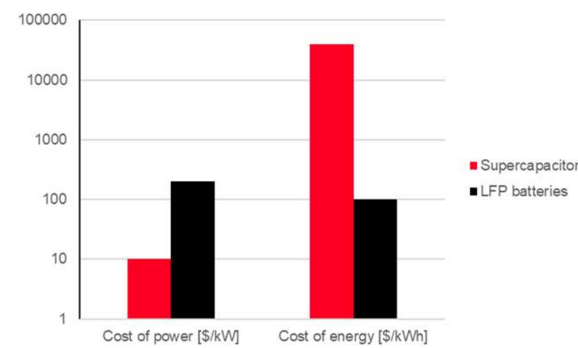
- Energy medium differentiates **E-STATCOM** and **BESS** key target applications:
  - E-STATCOM: short duration → transient stability
  - BESS: long duration → frequency regulation, power balancing and energy shifting
- **Grid-forming** control enables both solutions to operate in weak grids, contribute to system strength and deliver fault current.



Power electronic solutions are flexible by definition and can play in different roles.

Top team players specialize in their role and synergize to achieve team victory.



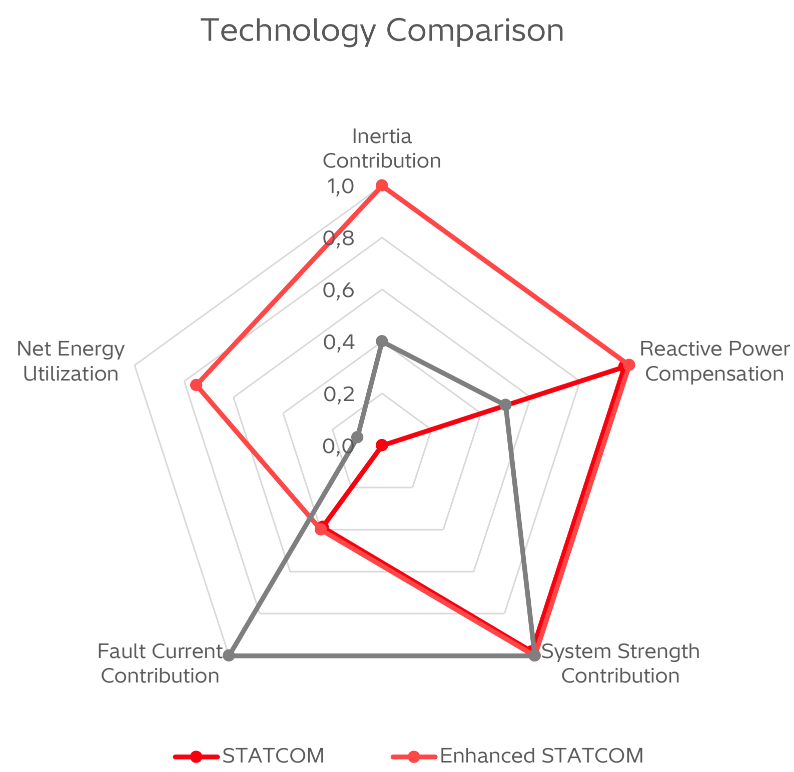


* represents targeted services for GPQSS by solution

Future Planning Considerations

Dimensioning Factors

	STATCOM	Enhanced STATCOM	Synchronous Condenser
Inertia Contribution	0,0	1,0	0,4
Reactive Power Compensation	1,0	1,0	0,5
System Strength Contribution	1,0	1,0	1,0
Fault Current Contribution	0,4	0,4	1,0
Net Energy Utilization	0,0	0.75	0.1



SVC Light - Enhanced | Dissemination

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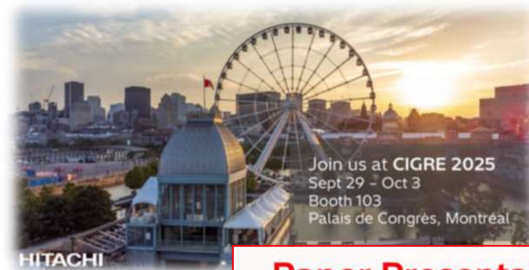
- IEEE and CIGRE events participation and paper publications
  - R. Heydari, et al., “Stability Enhancement in Weak Grids with High Renewable Penetration: Synchronous Condenser vs. Converter-based Technologies,” in CIGRE 2025 International Symposium.
  - A. Duque Gomez et al.,”Performance Assessment of BESS and E-STATCOM for Wind Power Support in the Nordic System,” in 4th Wind & Solar Integration Workshop, Berlin, Germany, 7–10 Oct 2025.
  - L. Lu et al., “Enhancing System Stability with GFM STATCOMs: A Case Study of the DK2 2020 Incident in the Danish Power System,” in 4th Wind & Solar Integration Workshop, Berlin, Germany, 7–10 Oct 2025.
  - F. Zhao et al., "Energy-Storage Enhanced STATCOMs for Wind Power Plants," in IEEE Power Electronics Magazine, vol. 10, no. 2, pp. 34-39, June 2023.
  - A. Viatkin et al., "Hybrid Energy Storage Enhanced STATCOMs," 2024 IEEE 15th International Symposium on Power Electronics for Distributed Generation Systems (PEDG), Luxembourg, Luxembourg, 2024.
  - T. Engelbrecht et al., "STATCOM Technology Evolution for Tomorrow’s Grid: E-STATCOM, STATCOM With Supercapacitor-Based Active Power Capability," in IEEE Power and Energy Magazine, vol. 21, no. 2, pp. 30-39, March-April 2023.
- Podcasts and webinars
  - Current Affairs: The High Power Podcast - Andrew Owens, Global Product Manager at Hitachi Energy



Paper Presentation at CIGRE US – Grid of the Future

November 12th, 10:05am MST
Capitol 7 – Hyatt Regency Denver, Colorado

Grid-Forming Enhanced STATCOMs for Wind Power Plant Stability: Design, Modeling, and Control

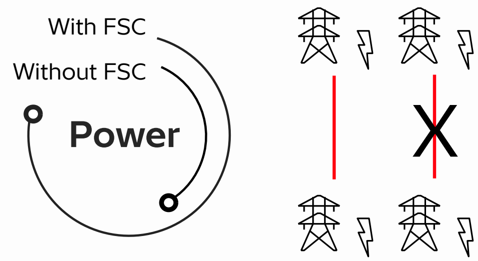
Series compensation capabilities
For grid stability

Fixed Series Compensation (FSC)

Transfer up to

50%

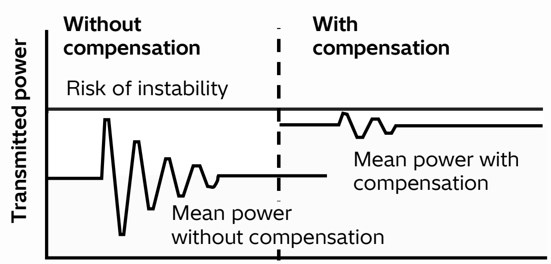
More power through new and existing power lines while maintaining or even increasing stability.



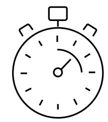
Thyristor Controlled Series Compensation (TCSC)

Controllability for the series compensation of the transmission line is added through power electronics.

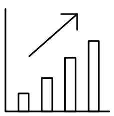
This gives important benefits in mitigating power oscillations and other dynamic disturbances.



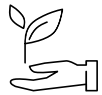
Benefits



Increased power transfer



Power oscillation damping (POD)



Less environmental impact

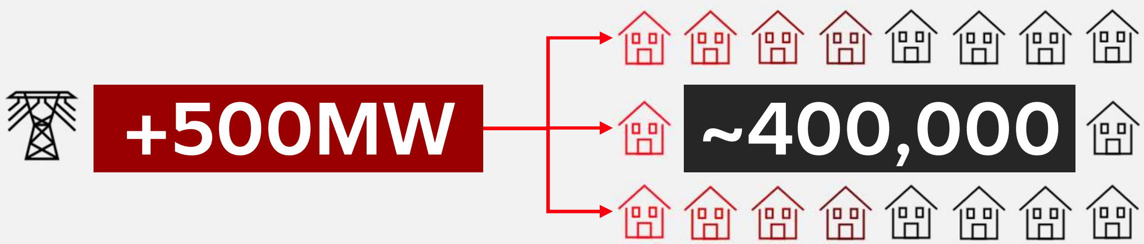
Unlock 2x more transmission capacity without adding new lines

FSC increases the power transfer capability of existing corridors, reducing the need for costly and time-consuming new line construction. This means **faster delivery of power to growing demand centers at lower CAPEX**.

Rationale

FSC reduces line reactance, boosting MW transfer in existing corridors. Reference: Cape Corridor (SA) saw >2x transfer increase over 1,400 km with 450–1300 Mvar FSC banks.

Equivalence



The transmitted power to the number of homes roughly the size of San Francisco

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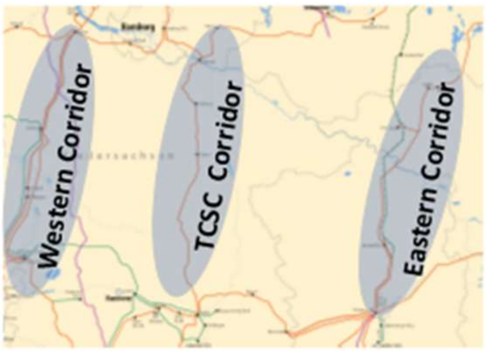
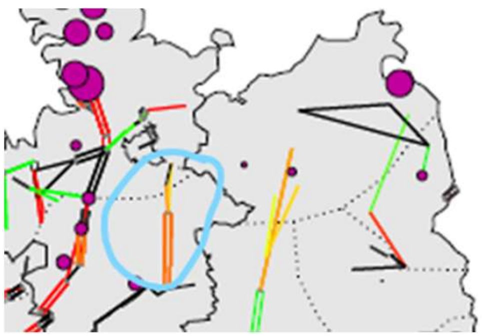
TenneT – Stadorf TCSC for Power Flow Control

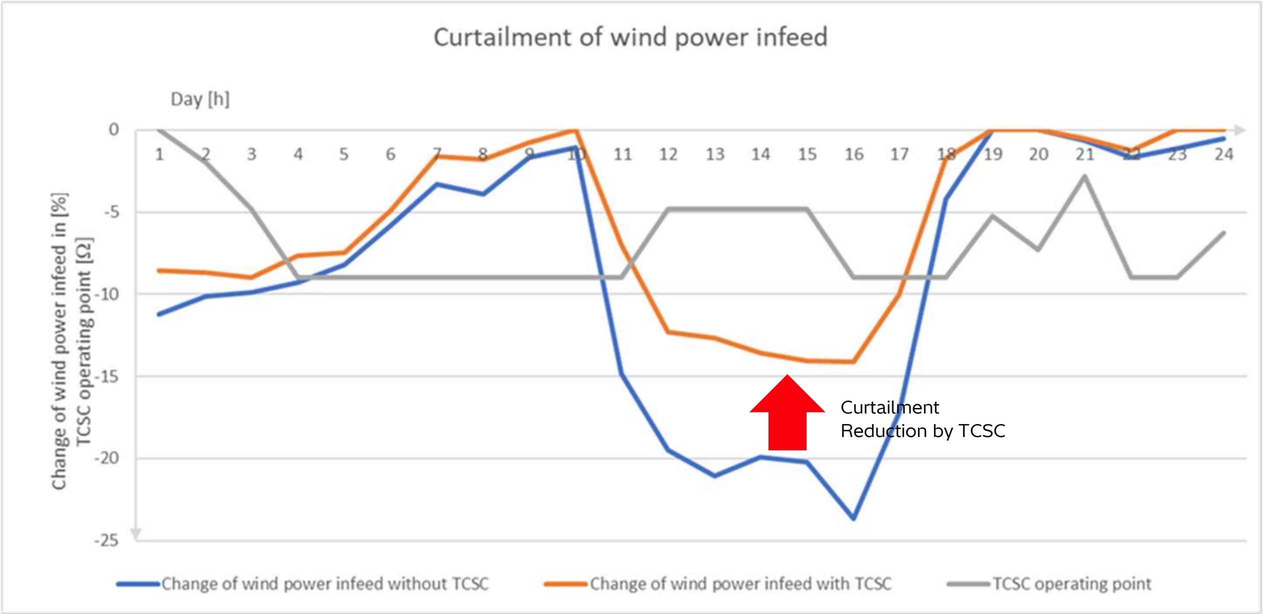
TCSC grid section



Congested area



TCSC effectiveness



TCSC contributes to the integration of renewable resources by reducing costly redispatch actions!

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