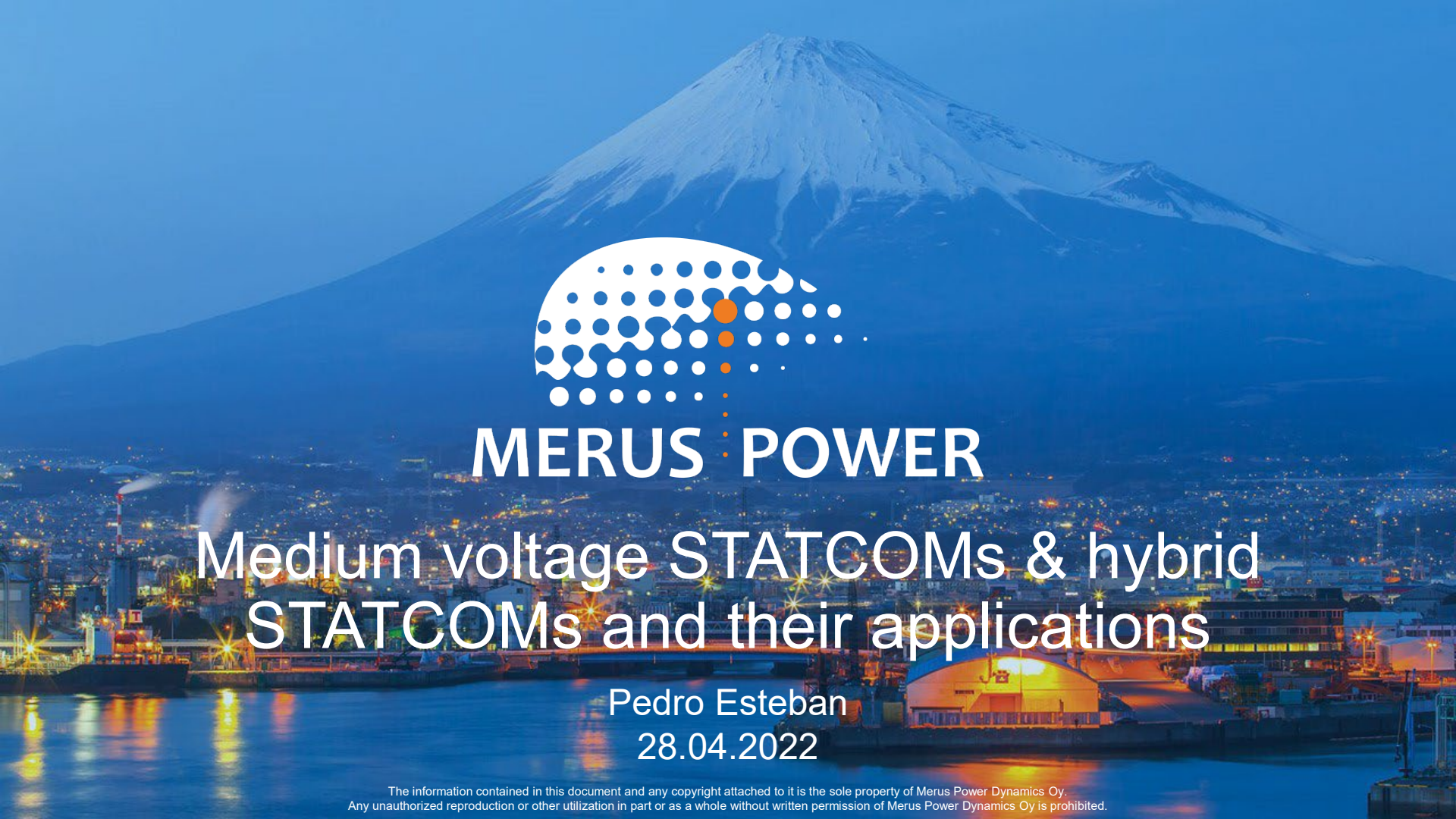

MERUS POWER

Medium voltage STATCOMs & hybrid STATCOMs and their applications

Pedro Esteban

28.04.2022

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Introduction

Modern electric power systems

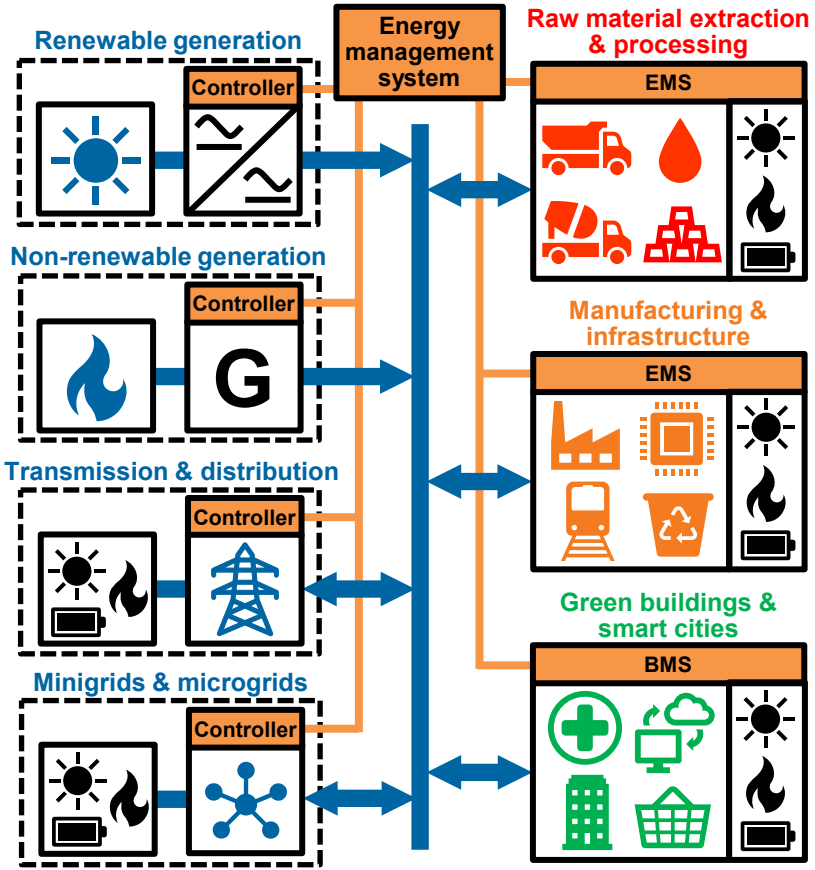
End users

Renewable generation
Non-renewable generation
Transmission & distribution
Minigrids & microgrids

Mining
Oil & gas
Minerals & cement
Steel & metals

Conventional manufacturing
Critical process industries
Transport
Water & wastewater

Healthcare facilities
Critical process facilities
Industrial & office facilities
Retail & leisure facilities



Modern electric power systems Requirements

Grid code compliance

Power quality improvement

Waveform distortions
- ~~DC offset~~
- Harmonics
- Interharmonics
- Notching
- ~~Noise~~

Short duration variations
- Voltage sags
- Voltage swells
- Interruptions

Long duration variations
- Undervoltages
- Overvoltages
- Sustained interruptions

Transients
- Impulsive transients
- Oscillatory transients

Other PQ problems
- Unbalances
- Voltage fluctuations (flicker)
- Power frequency variations

Ancillary services

Frequency support
- Fast frequency reserve (FFR)
- Frequency containment reserve (FCR)
- Frequency restoration reserve (FRR)
- Replacement reserve (RR)
- Synchronous inertial response (SIR)
- Ramp rate control (RRC)
- Load following

Voltage support
- Voltage control
- Reactive power control (RPC)
- Power factor control (PFC)
- Fast reactive current injection (FRCI)
- Fault ride through (FRT) capability

System restoration support
- Black start capability
- Islanding capability

Other ancillary services
- Power oscillation damping (POD)
- Subsynchronous resonance damping
- Congestion management (CM)
- Grid loss (GL) compensation

Sustainable energy management

Clean energy development

Renewable energy integration
- Renewable energy time-shift
- Capacity firming
- Distributed energy storage capacity
- Fossil fuel consumption reduction

Energy efficiency improvement
- Power factor correction (PFC)
- Power transfer capacity increase
- T&D upgrade deferral
- Reduction of energy losses

Affordable energy access

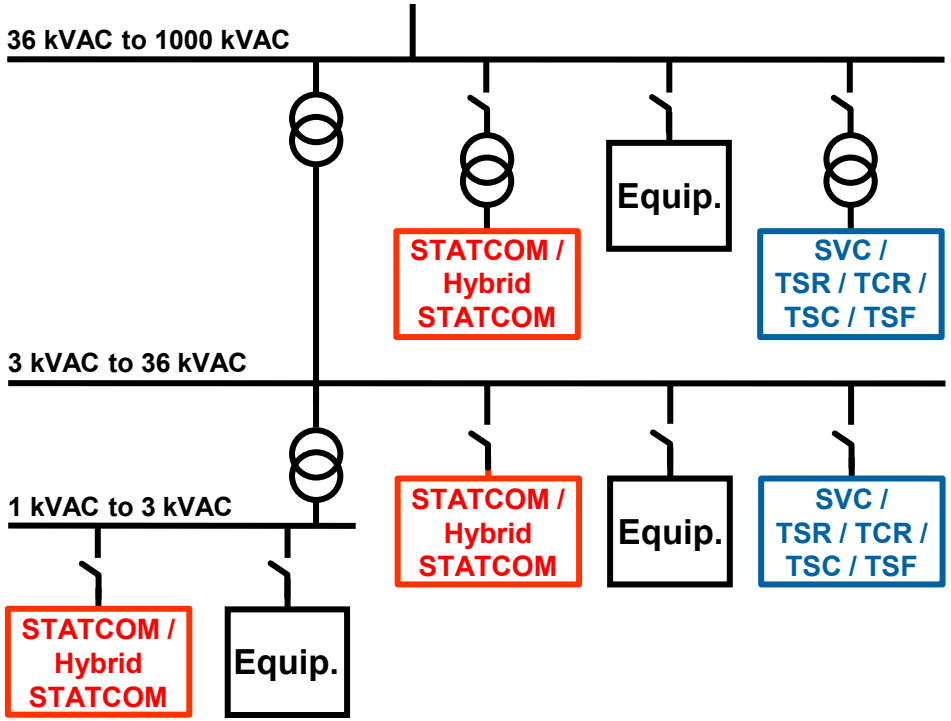
Energy supply management
- Energy arbitrage
- Curtailment avoidance
- Electric supply capacity
- Backup power supply

Energy demand management
- Peak shaving
- Load levelling
- Load shifting
- Electric bill management

Modern electric power systems
Power electronics-based shunt compensation devices

Group	Category	Solutions
Low voltage shunt compensation devices	Thyristor switched compensation devices	Thyristor switched capacitor banks (TSC). Thyristor switched reactors (TSR).
	IGBT switched compensation devices (active power filters)	Static var generators (SVG). Active harmonic filters (AHF). Active load balancers (ALB). Hybrid var compensators (HVC). Low harmonic drives (LHD).
High voltage shunt compensation devices	Thyristor switched compensation devices (static compensators)	Static var compensators (SVC). Thyristor switched capacitor banks (TSC). Thyristor switched filter banks (TSF). Thyristor switched reactors (TSR). Thyristor controlled reactors (TCR).
	IGBT switched compensation devices (static compensators)	**Static synchronous compensators (STATCOM).** **Hybrid STATCOMs.**

Power electronics-based shunt compensation devices Connection



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STATCOM
and
hybrid STATCOM

STATCOM and hybrid STATCOM Functions

Power quality improvement	
Waveform distortions	Harmonics
	Interharmonics
Short duration variations	Voltage sags
	Voltage swells
Long duration variations	Undervoltages
	Overvoltages
Other power quality problems	Unbalances
	Voltage fluctuations (flicker)
Ancillary services	
Voltage support	Voltage control
	Reactive power control (RPC)
	Power factor control (PFC)
	Fast reactive current injection (FRCI)
	Fault ride through (FRT) capability
Other ancillary services	Power oscillation damping (POD)
	Subsynchronous resonance (SSR) damping
	Congestion management (CM)
	Grid loss (GL) compensation
Clean energy development	
Energy efficiency improvement	Power factor correction (PFC)
	Power transfer capacity increase
	T&D upgrade deferral
	Reduction of energy losses

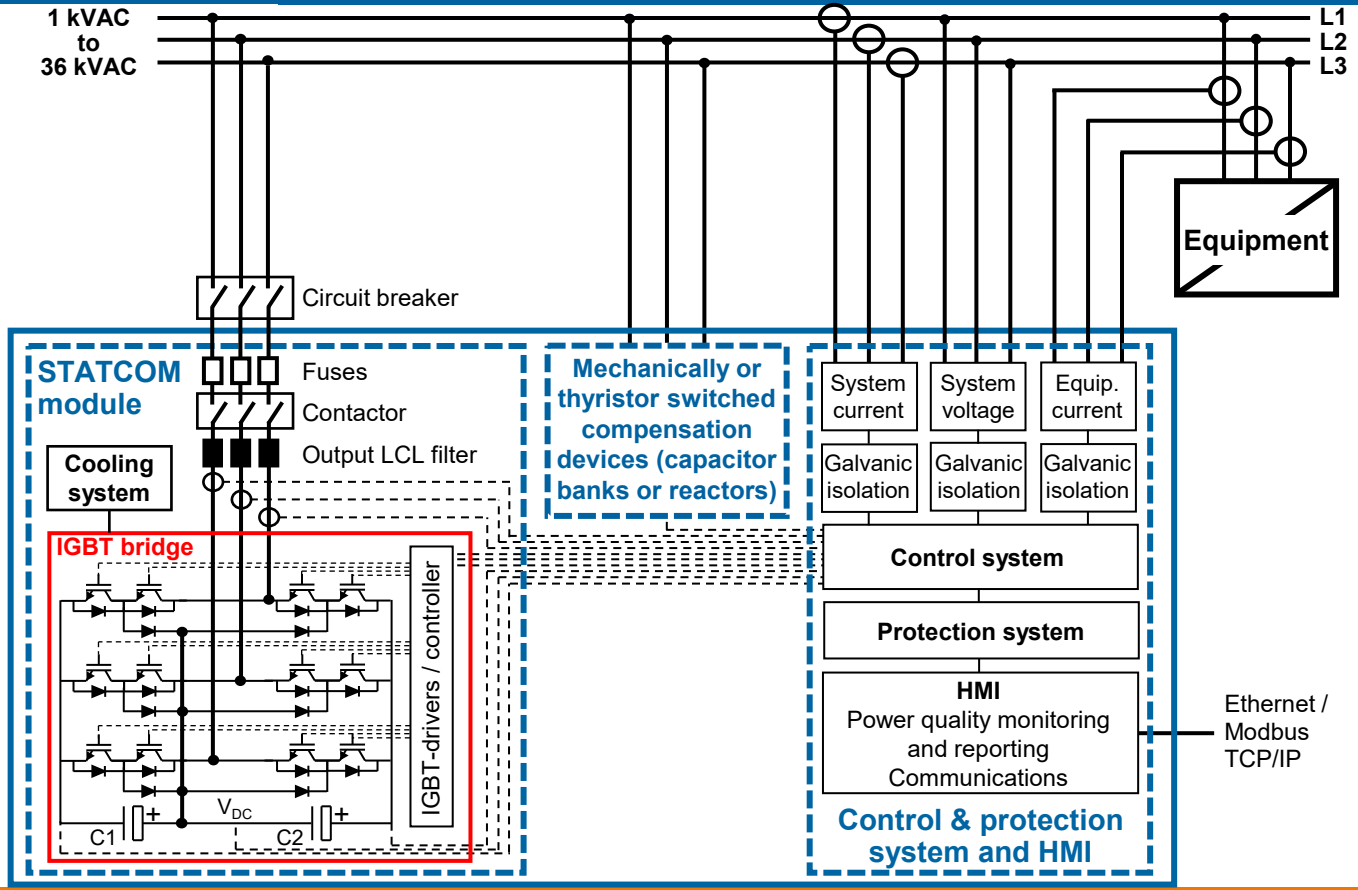
STATCOM and hybrid STATCOM
Markets and applications

Markets	Segments	Application
Smart grid	Renewable generation	Suitable
	Non-renewable generation	Possible
	Transmission & distribution	Suitable
	Minigrids & microgrids	Possible
Raw material extraction & processing	Mining	Suitable
	Oil & gas	Suitable
	Minerals & cement	Suitable
	Steel & metals	Suitable
Manufacturing & infrastructure	Conventional manufacturing	Possible
	Critical process industries	Possible
	Transport	Suitable
	Water & wastewater	Possible
Green buildings & smart cities	Healthcare facilities	Unsuitable
	Critical process facilities	Unsuitable
	Industrial & office facilities	Unsuitable
	Retail & leisure facilities	Unsuitable

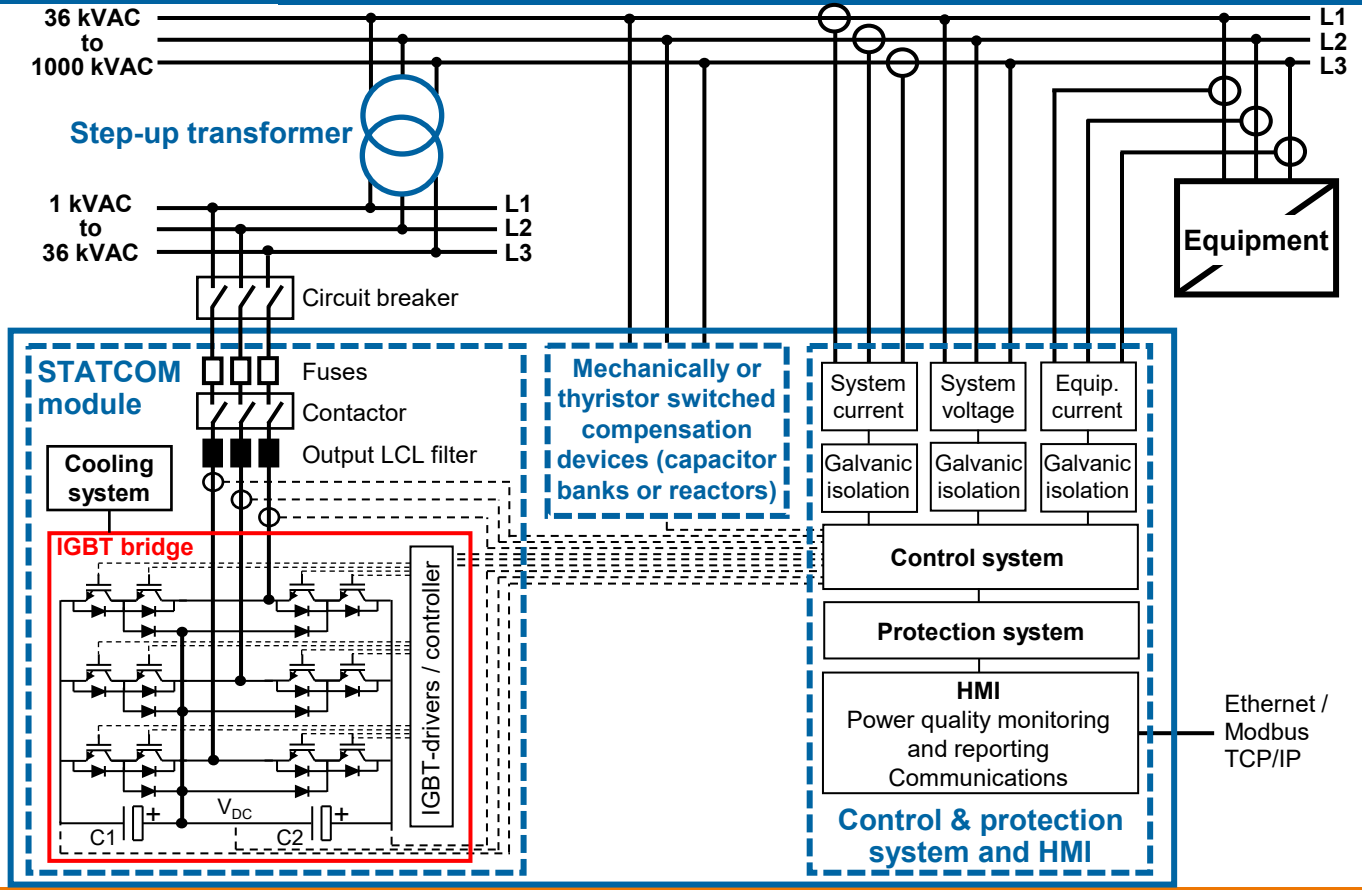
Typical applications

- Solar inverters
- Wind turbine generators.
- Transmission & distribution substations and lines.
- Installations with fast changing reactive power demand
  - Electric arc furnaces (EAF) and ladle furnaces (LF).
  - Ball mills.
- Highly dynamic loads (power factor fluctuates rapidly or in big steps)
  - Rolling mills, cranes, hoists, winders, crushers, shredders, presses, arc welders, conveyors and head & band saws.
- Reactive power generation for the start-up of large motors
  - Wood chippers and pumps.
- Railway electrification systems.
- Modulated phase controllers, cycloconverters and thyristor-controlled AC voltage regulators.
- Hot-dip galvanization & electrogalvanization lines.

STATCOM and hybrid STATCOM Design - Direct connection



STATCOM and hybrid STATCOM Design - High voltage connection



STATCOM and hybrid STATCOM Design - Components

Passive part

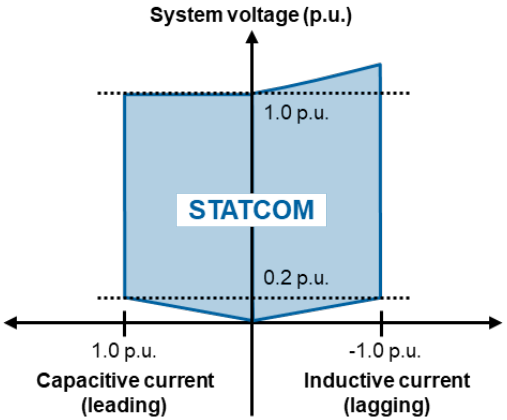
- Step-up transformer
- Switchgear
- MSC banks
- MSR reactors
- TSC banks
- TSR reactors

Active part

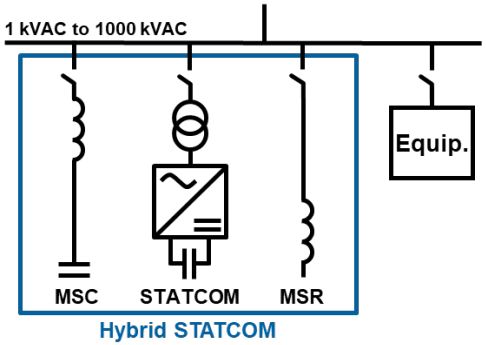
- STATCOM modules
- Cooling system
- Control system
- Protection system
- HMI
- Thyristor valves

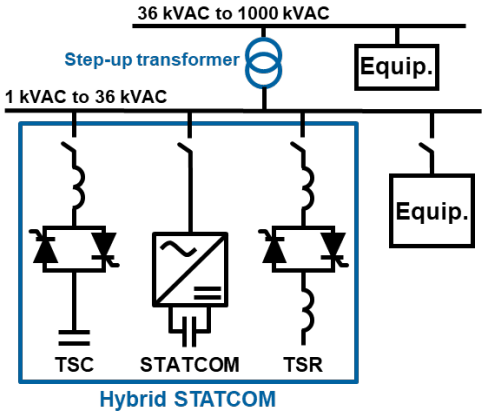
STATCOM and hybrid STATCOM
Operating principle

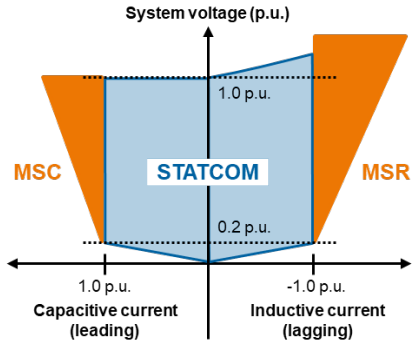
A STATCOM works as a controlled current source providing any kind of compensation current waveform in real time.



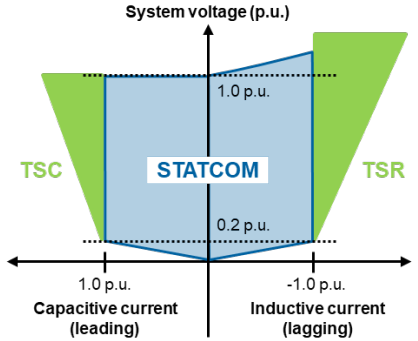
Continuous dynamic operating range of a STATCOM







Continuous dynamic operating range of a STATCOM (blue) with additional steady-state (orange) output



Continuous dynamic operating range of a STATCOM (blue) with additional dynamic (green) output

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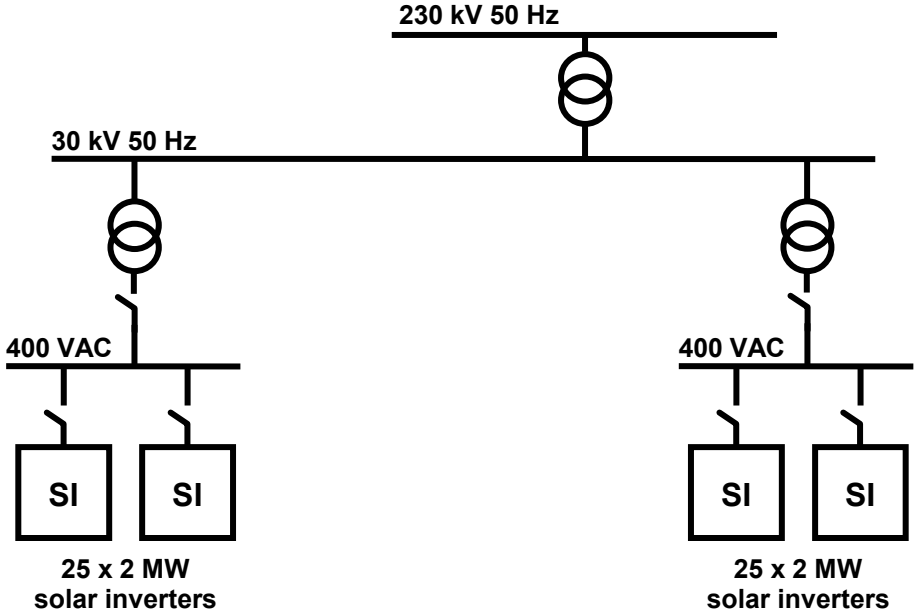
Application examples

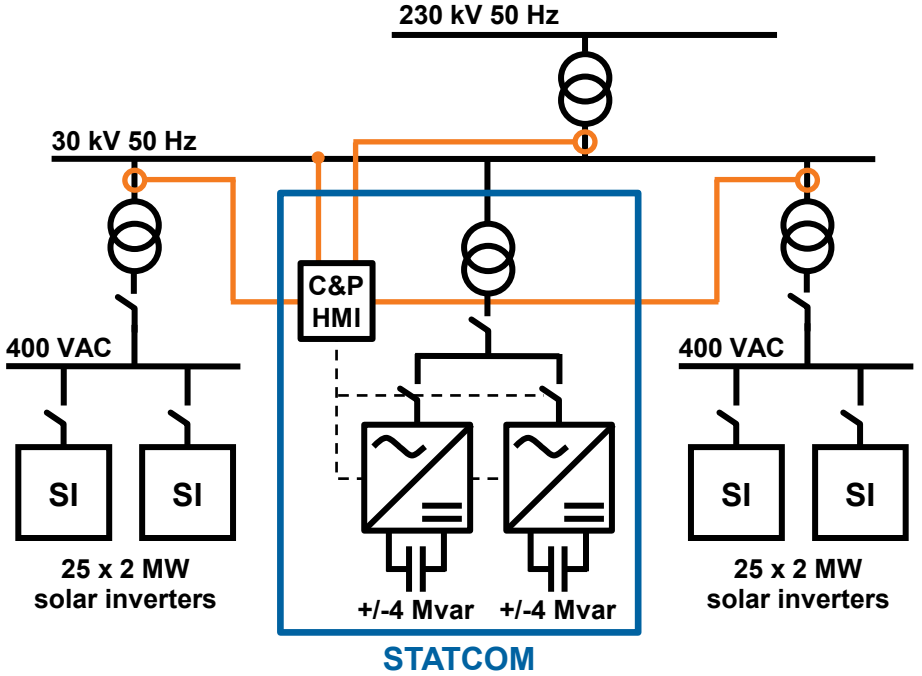
STATCOM
Application: Solar inverters

Segment	Renewable generation.
Application	Solar photovoltaic (PV) power plant.
Requirements	Harmonics mitigation. Voltage control. Reactive power control. Power factor control. Fault ride through capability.
Solution	STATCOM 30 kV 50 Hz +/-8 Mvar.



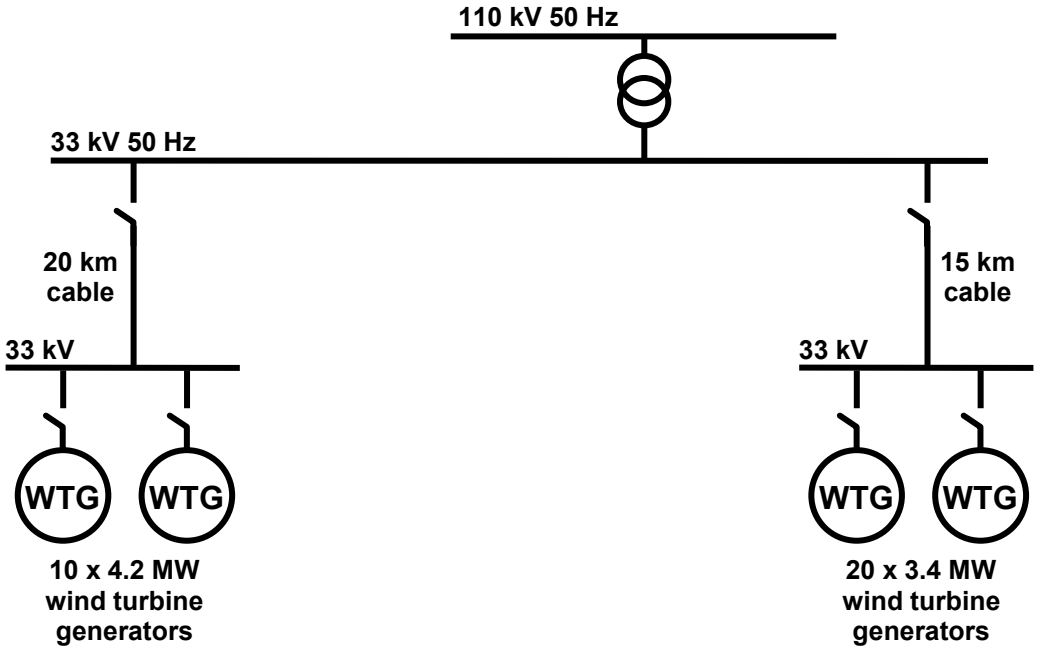
STATCOM
Application: Solar inverters

Mitigation of harmonics	Target THDi under 5% and target THDv under 3%.
Voltage control	Target voltage between 0.95 pu and 1.1 pu.
Reactive power control (RPC)	Ability to provide full range of reactive power support at voltages between 0.9 pu and 1.15 pu.
Power factor control (PFC)	Target power factor between 0.98 inductive and 0.98 capacitive.
Fault ride through (FRT) capability	LVRT: 15% retained voltage at connection point for 500 ms.



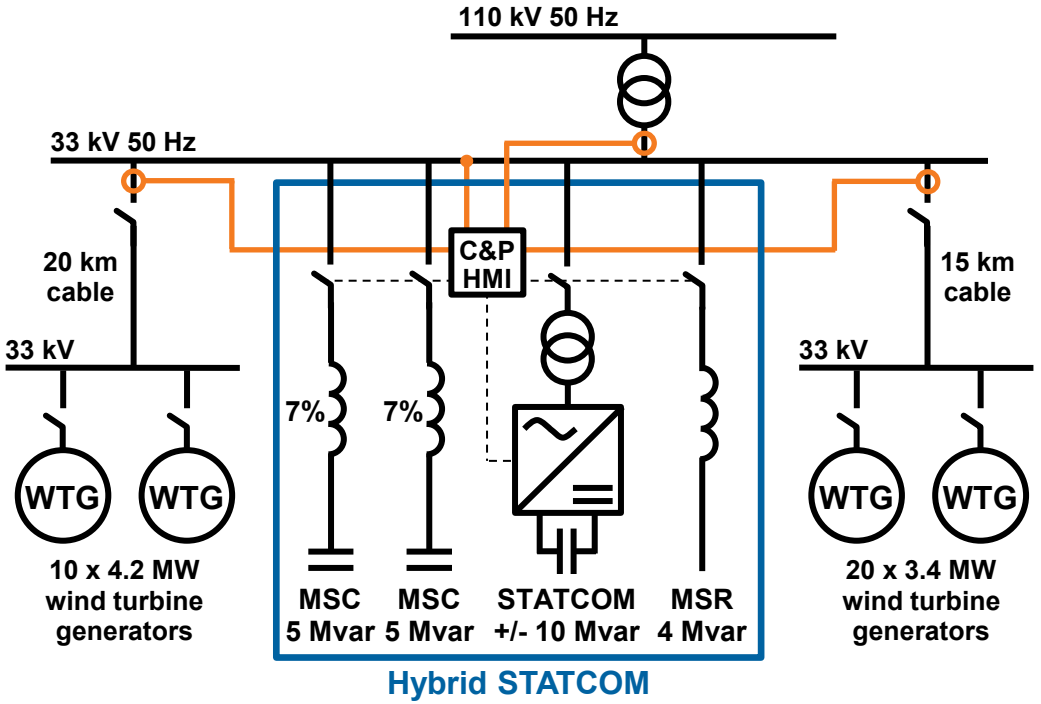
Hybrid STATCOM
Application: Wind turbine generators

Segment	Renewable generation.
Application	Wind farm.
Requirements	Harmonics mitigation. Voltage fluctuations (flicker) mitigation. Voltage control. Reactive power control. Power factor control. Fault ride through capability.
Solution	Hybrid STATCOM 33 kV 50 Hz -14/+20 Mvar. • STATCOM 33 kV 50 Hz +/-10 Mvar. • Detuned filter capacitor bank 33 kV 50 Hz 10 Mvar (2x5 Mvar contactor switched steps). • Shunt reactor 33 kV 50 Hz 4 Mvar.



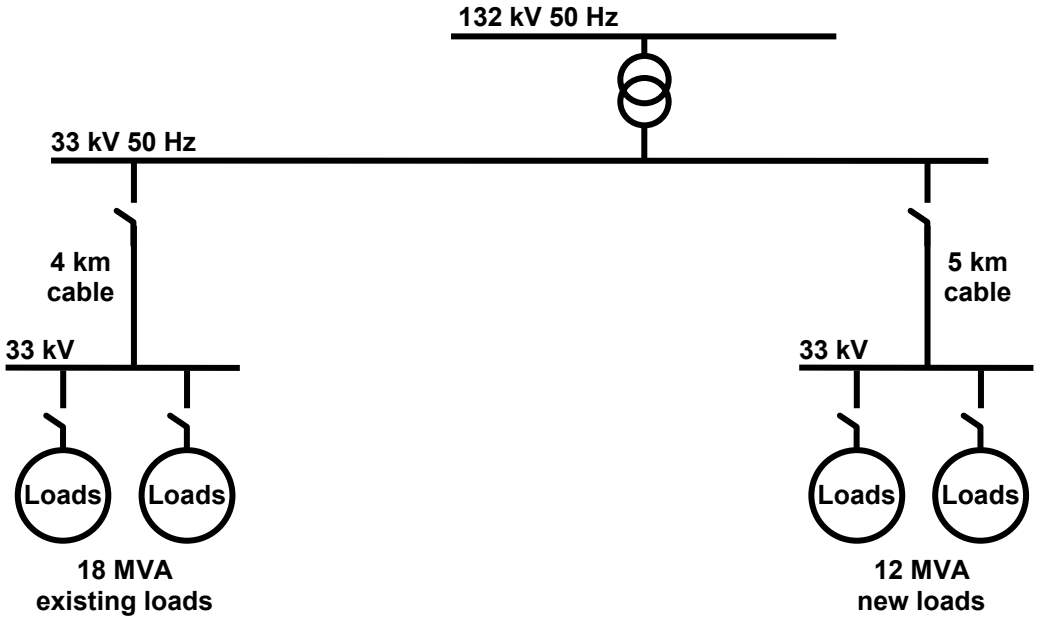
Hybrid STATCOM
Application: Wind turbine generators

Mitigation of harmonics	Target THDi under 5% and target THDv under 3%.
Mitigation of voltage fluctuations (flicker)	Maximum flicker allowed, Pst < 1.
Voltage control	Target voltage between 0.95 pu and 1.1 pu.
Reactive power control (RPC)	Ability to provide full range of reactive power support at voltages between 0.9 pu and 1.15 pu.
Power factor control (PFC)	Target power factor between 0.98 inductive and 0.98 capacitive.
Fault ride through (FRT) capability	LVRT: 15% retained voltage at connection point for 500 ms.



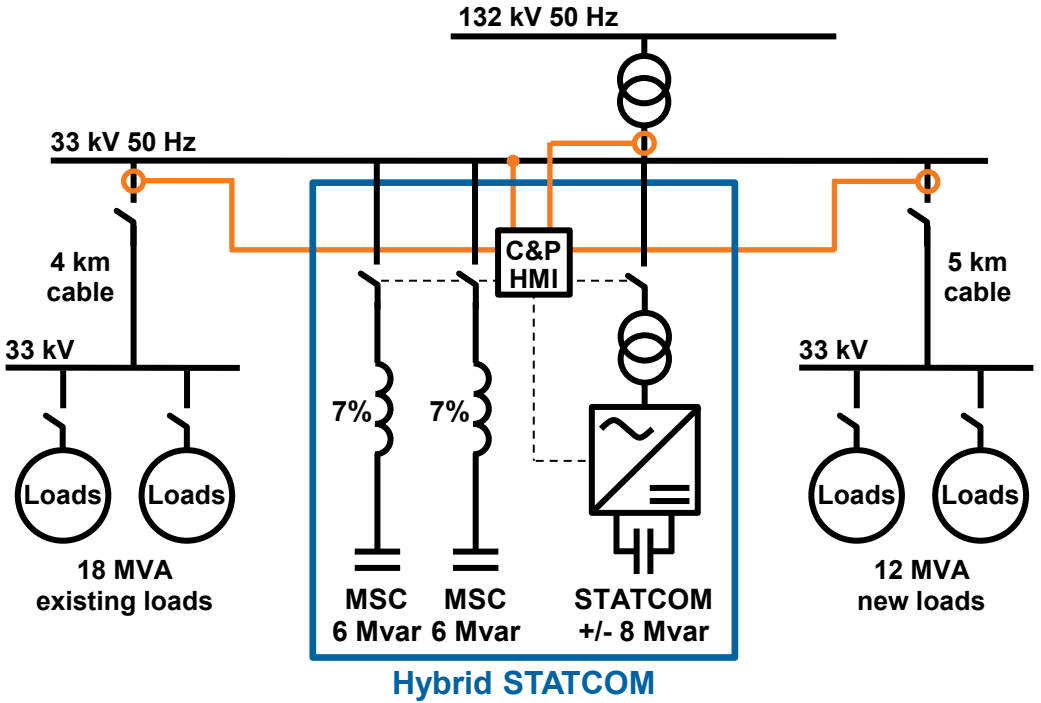
Hybrid STATCOM
Application: Mine site expansion

Segment	Mining.
Application	Mine site expansion.
Requirements	Harmonics mitigation. Voltage fluctuations (flicker) mitigation. Power factor improvement.
Solution	Hybrid STATCOM 33 kV 50 Hz -8/+20 Mvar. - STATCOM 33 kV 50 Hz -8/+8 Mvar. - Detuned filter capacitor bank 12 Mvar (2x6 Mvar circuit breaker switched steps).



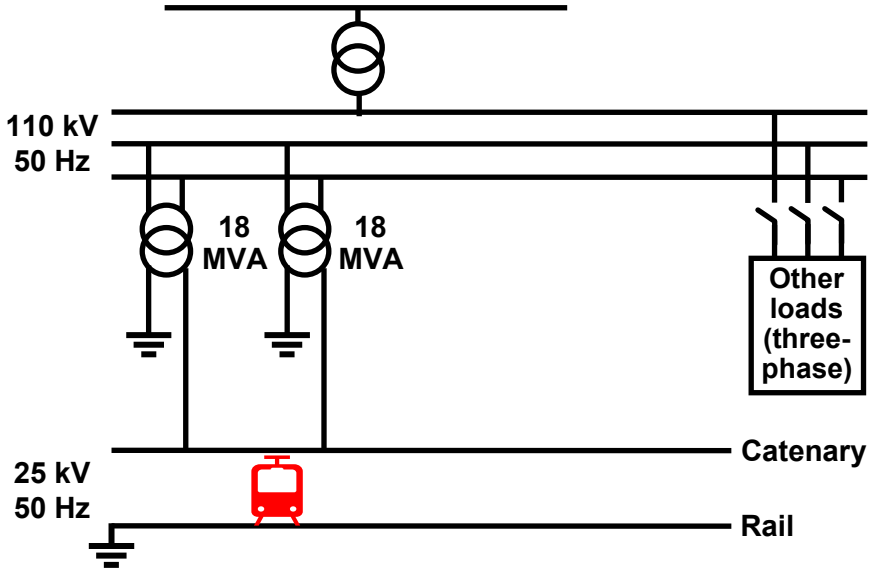
Hybrid STATCOM
Application: Mine site expansion

Mitigation of harmonics	Target THDi under 5% and target THDv under 3%.
Mitigation of voltage fluctuations (flicker)	Maximum flicker allowed, Pst < 1.
Power factor correction (PFC)	Target power factor 1.



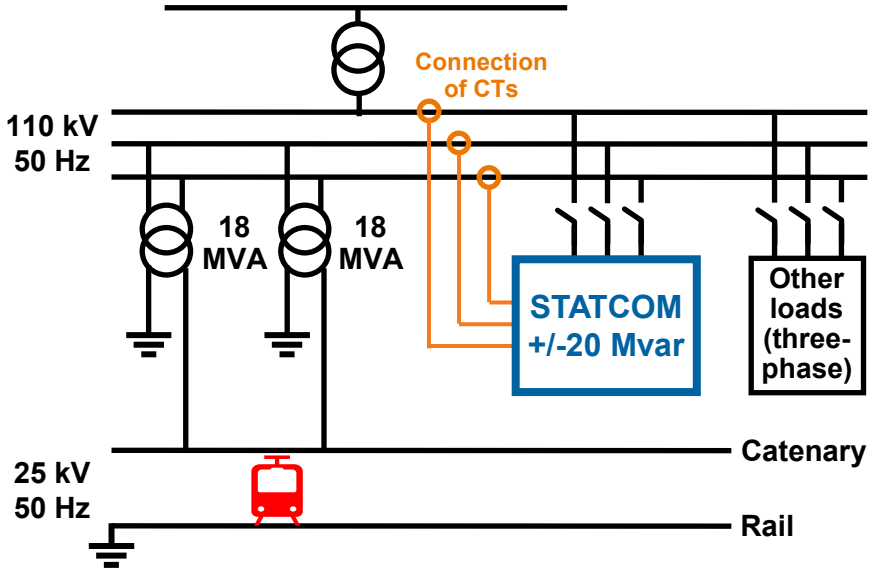
STATCOM
Application: Railway electrification systems

Segment	Transport.
Application	Railway electrification systems.
Requirements	Harmonics mitigation. Load balancing.
Solution	STATCOM 110 kV 50 Hz +/-20 Mvar.



STATCOM
Application: Railway electrification systems

Mitigation of harmonics	Target THDi under 5% and target THDv under 3%.
Mitigation of unbalances	Maximum current unbalance allowed, UNBi < 2%, and voltage unbalance UNBv < 2%.



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