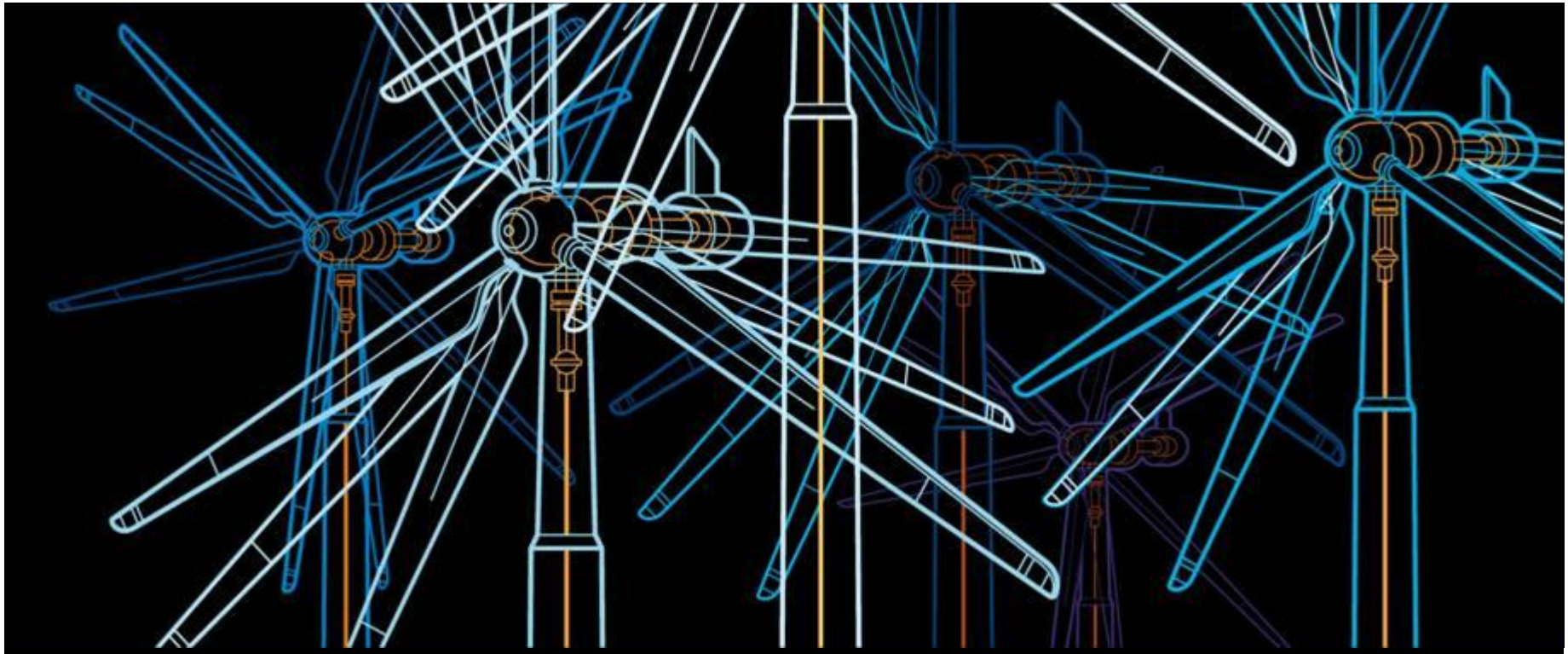


Michael Neutz, MV Power Converters, ABB Switzerland Ltd – Jornadas Técnicas ABB en Chile 2013

Power Quality

Voltage Stabilisation for Industrial Grids and Wind Farms with STATCOM

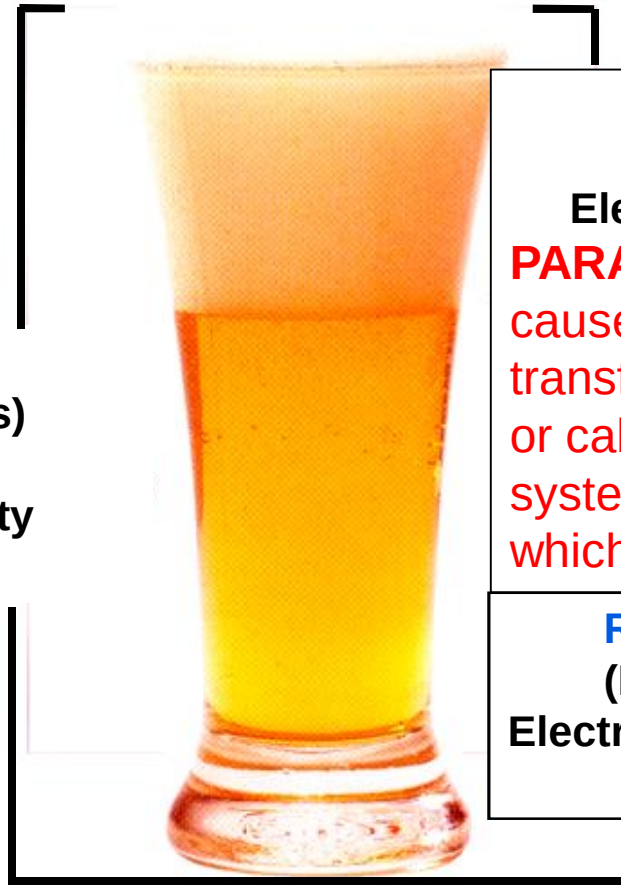
STATCOM Systems
Objectives

The aim of this presentation is to give:

- An understanding of the voltage stabilisation principle.
- An overview of the power quality technologies available and some guidelines for choosing between them
- Presentation of ABB's PCS 6000 STATCOM
- Voltage stabilisation examples in different industrial applications

STATCOM Systems
How to explain REACTIVE POWER???

APPARENT POWER
(Beer = Full glass)
Electricity = Available from utility



REACTIVE POWER
(Beer = Foam)
Electricity = Unable to do work
PARASITIC electrical power, caused by components such as transformers, motors (inductive) or cables capacitive) for what the system has to be designed and which has to be paid to the utility

REAL POWER
(Beer = Drinkable)
Electricity = Able to do work

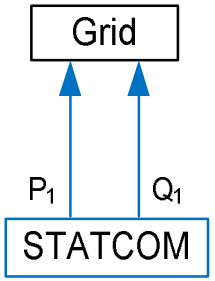
STATCOM Systems
Problems Encountered

- Large loads consume huge amounts of power and cause an excessive voltage drop which at the extreme becomes a complete collapse of the voltage
- In the other direction load shedding of a capacitive line or heavily compensated line can cause over voltages
- Switching of loads or power factor capacitors causes steps in voltage (inrush current factor 5…9 of rated power) which can cause tripping of Motors
- Rapidly varying loads or pulsing (choppering) cause voltage flickers
- Industrial grids (plants) with many different participants (loads) have network specific harmonics

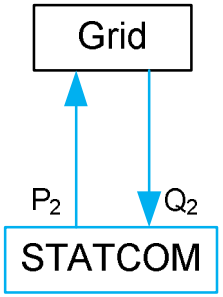
STATCOM Systems
Introduction – Reactive Power Definition

Voltage Stabilisation = Supporting the grid voltage with reactive power

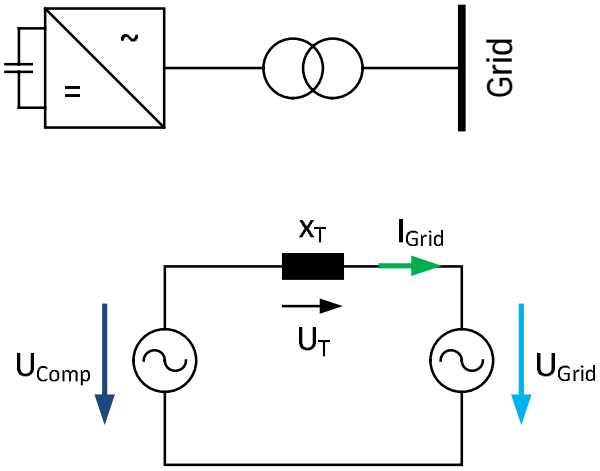
- Increase of the grid voltage by injecting reactive power to the grid over-excited behavior of the FACTS capacitive (inductive grid)

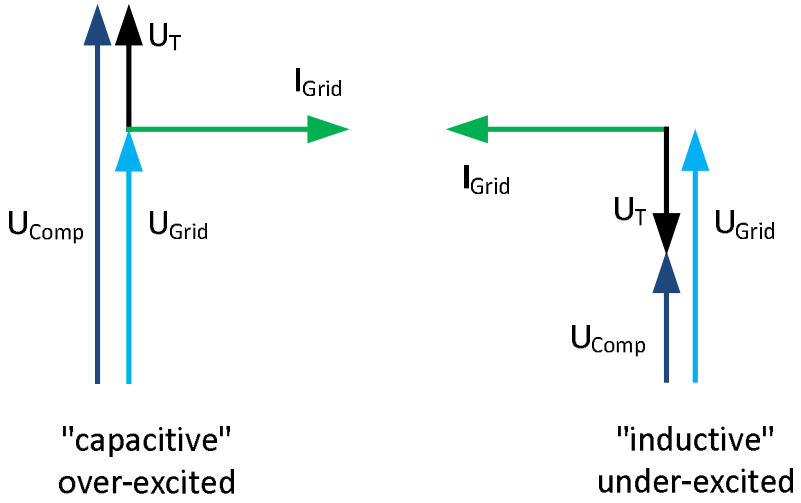


- Reduction of the grid voltage by absorbing reactive power from the grid under-excited behavior of the FACTS inductive (capacitive grid)



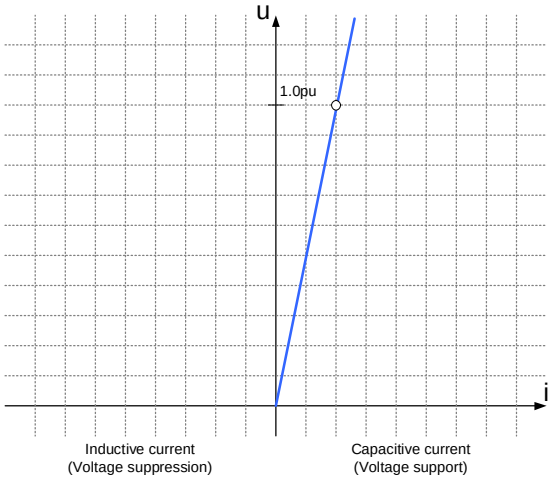
STATCOM Systems
Introduction – Basic Operation Principle of STATCOM



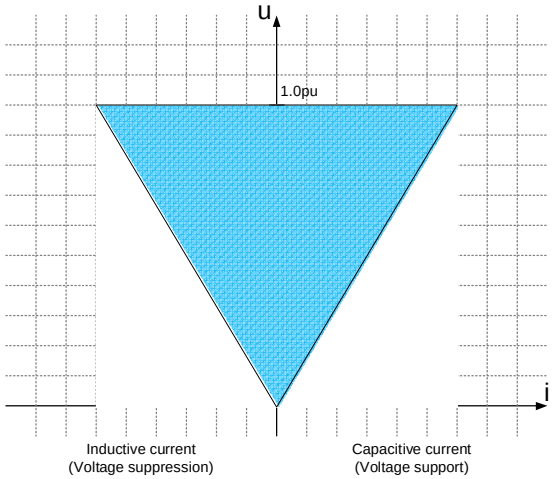


- Each voltage drop/swell of U_Grid caues an inherent, immediate reactive current over the transformer which works against the disturbance.
- Reactive power injection after STATCOM voltage increase (U_Comp) starting within <10ms.

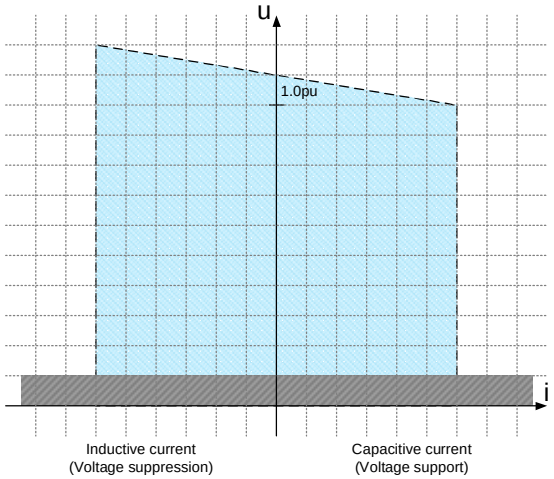
STATCOM Systems
Introduction – FACTS devices



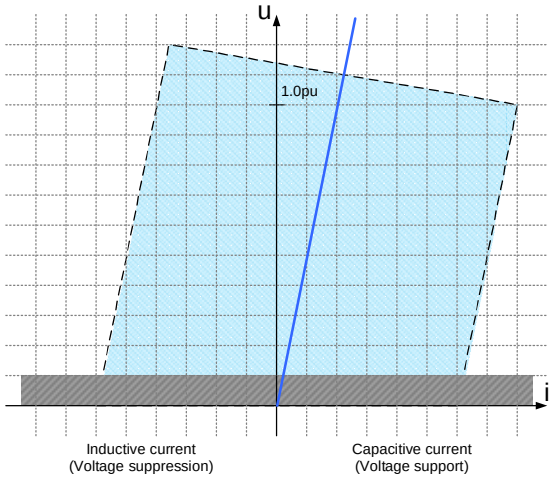
Fixed passive component (Cap.)



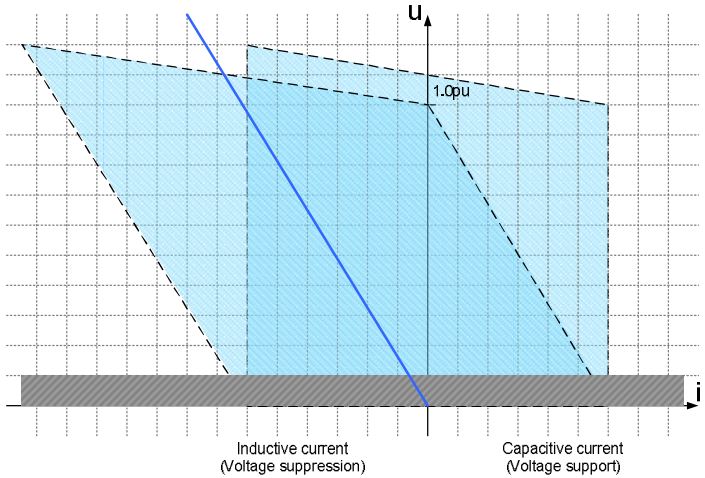
SVC



STATCOM



STATCOM with fixed passive (Cap.)



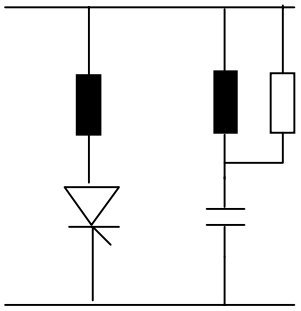
STATCOM with mechanically switched passive (MSR)

Switched Capacitors / Reactors

- ✓ Inexpensive
- × Switching not synchronised with waveform: inrush = transients = network stress
- × Limited by response time of switchgear (>70ms)
- × Need to be discharged between operations
- × Not Suitable for continuously varying load requiring frequent switching (steady state)
- × Fixed steps cause new harmonics, filters required
- × V^2 characteristic: Voltage steps get bigger as line limit is reached and smaller just when you need it most

Static VAR Compensators (SVC)

- ✓ Fast response (20-30ms)
- ✓ Continuous control – No steps
- ✓ Inductive as well as capacitive
- ✓ Economies of scale with large systems
- × Generates harmonics. – Care required in design
- × V^2 characteristic

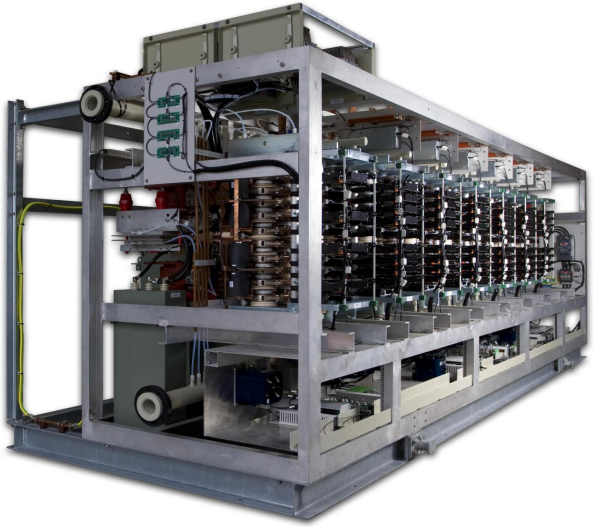


Synchronous Condenser

- ✓ Immediate response (<10ms)
- ✓ Continuous control. – No steps
- ✓ Inductive as well as capacitive
- ✓ Provides inertia (spinning reserve = active power)
- ✓ Cheap active power storage (compared with BESS)
- × Constantly high losses (~5%)
- × Expensive in operation (Rotating machine requires higher maintenance)

STATCOM

- ✓ Ultra dynamic response (<10ms)
- ✓ No steps
- ✓ Ind. + cap. capabilities
- ✓ Constant current characteristic. – VAR's fall with V – not V^2
- ✓ Low harmonics no filters required
- ✓ Integrated AHF (Active Harmonic Filtering)
- ✓ Cheaper than SVC below ≈50MVAR
- ✓ Suited to a hybrid solution of STATCOM plus switched capacitors



FACTS Comparison

	Speed of response	Repeated operation possible	Steps	“Inductive” control	Inertia (active power)	Cost CAPEX / OPEX
Switched capacitors (reactors)	Slow	Discharge time and wear of switchgear	Fixed	No	No	Low
Thyristor switched capacitors	Fast	Yes	Fixed	No	No	Medium
SVC	Fast	Continuous	Continuous	Yes	No	Cheaper than STATCOM for large systems
Synchronous condenser	Fast	Continuous	Continuous	Yes	Yes	High OPEX, bad MTTR, permanent losses
STATCOM	Fast	Continuous	Continuous	Yes	Possible with added energy storage	High CAPEX if no hybrid solution

STATCOM
In Summary

- A STATCOM is used where traditional solutions won't work
  - Able to autonomously control the voltage resulting in a much faster power factor correction
  - Continuously variable output without steps, no harmonics, no transients
  - Can generate and absorb reactive power.
  - Amount linear to voltage.
  - Reacts practically instantaneously. Reaction starts <10ms after event, full power result in 20-50ms.
  - Is always in "hot stand-by", power losses <1%
  - **Will work on a system near the stability limit**

ABB STATCOM Products

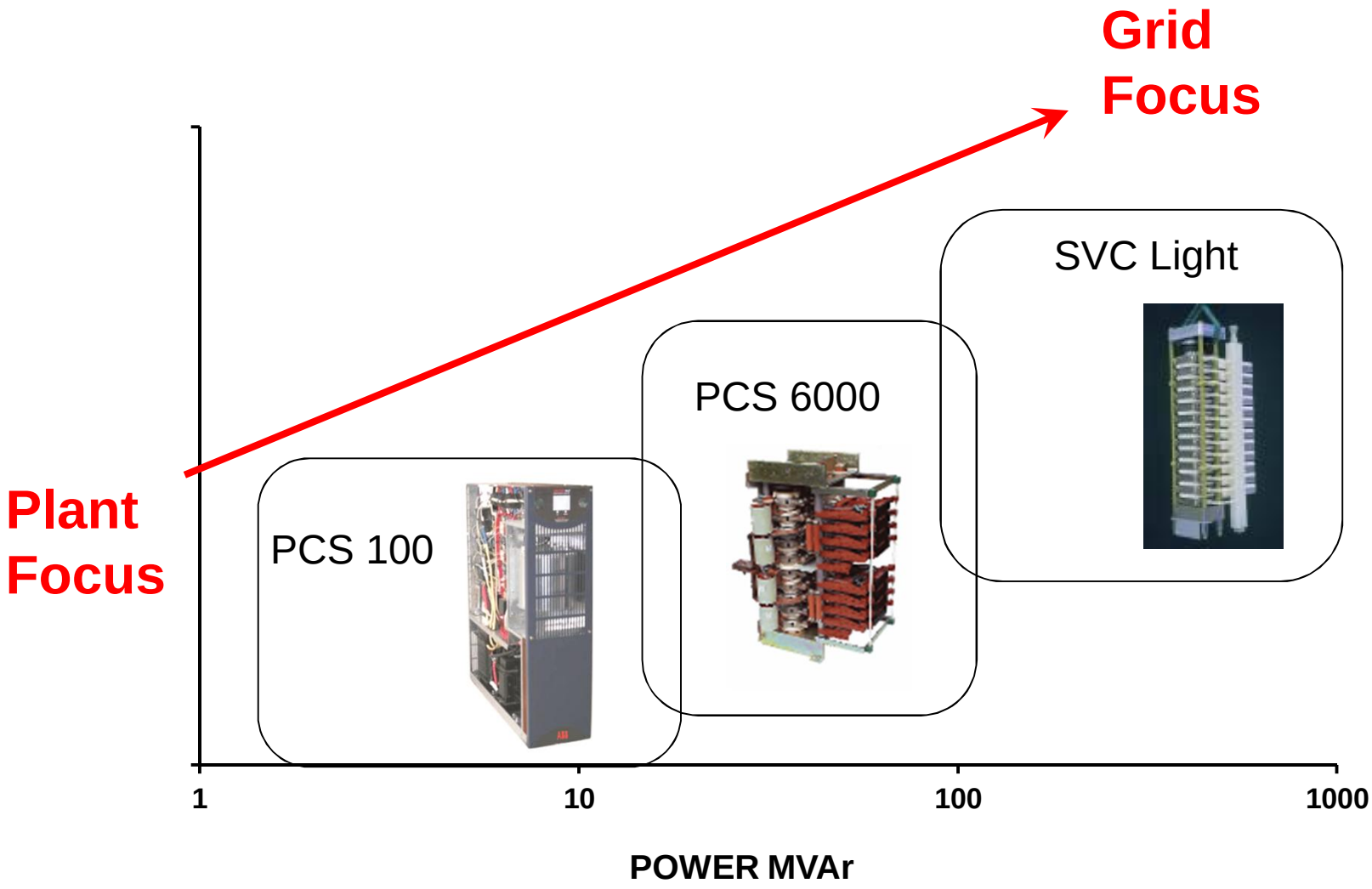


ABB STATCOM Products

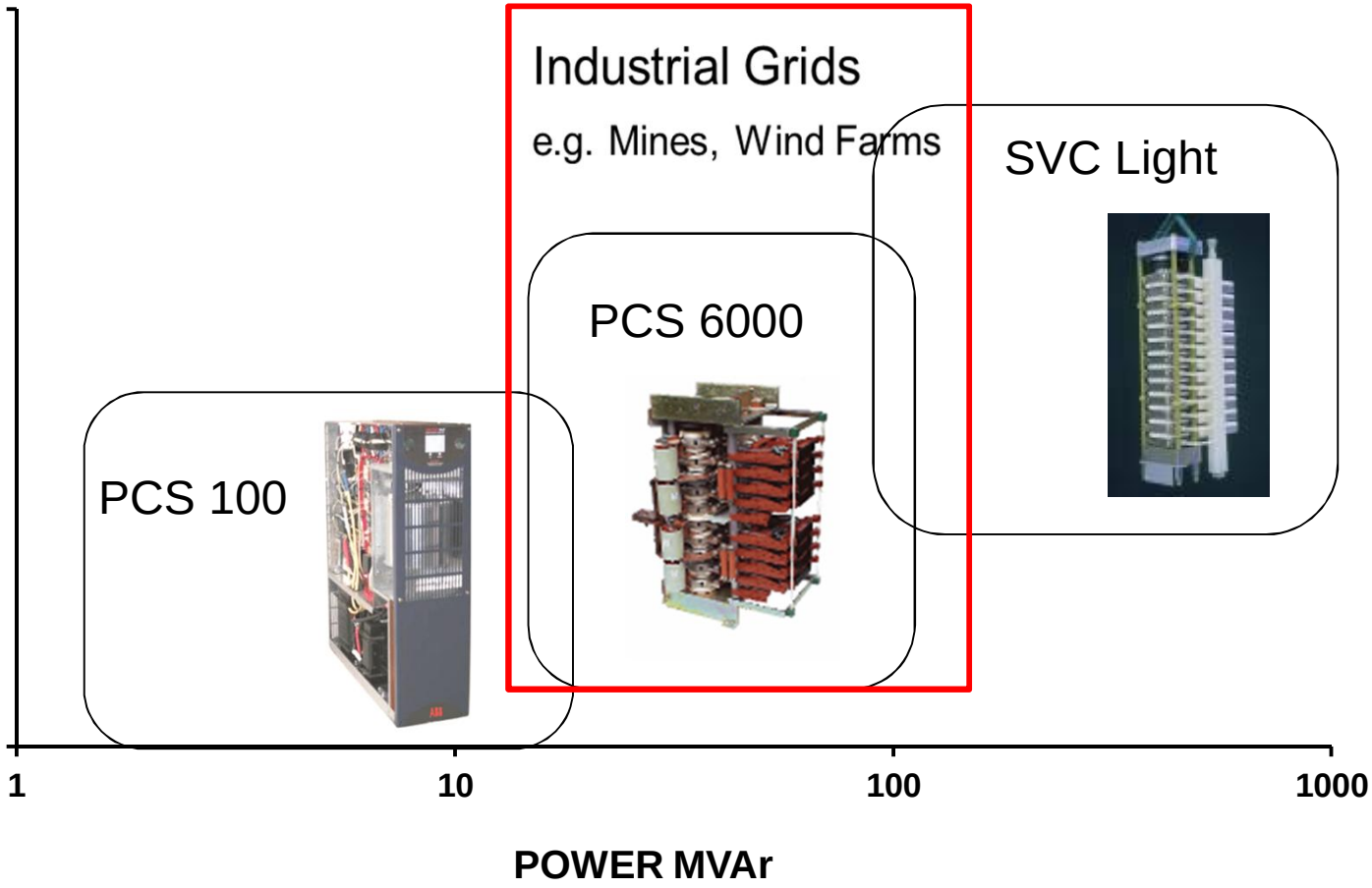


ABB STATCOM Products
Applications

Renewables

- Reactive power capability and fault ride through for wind farms

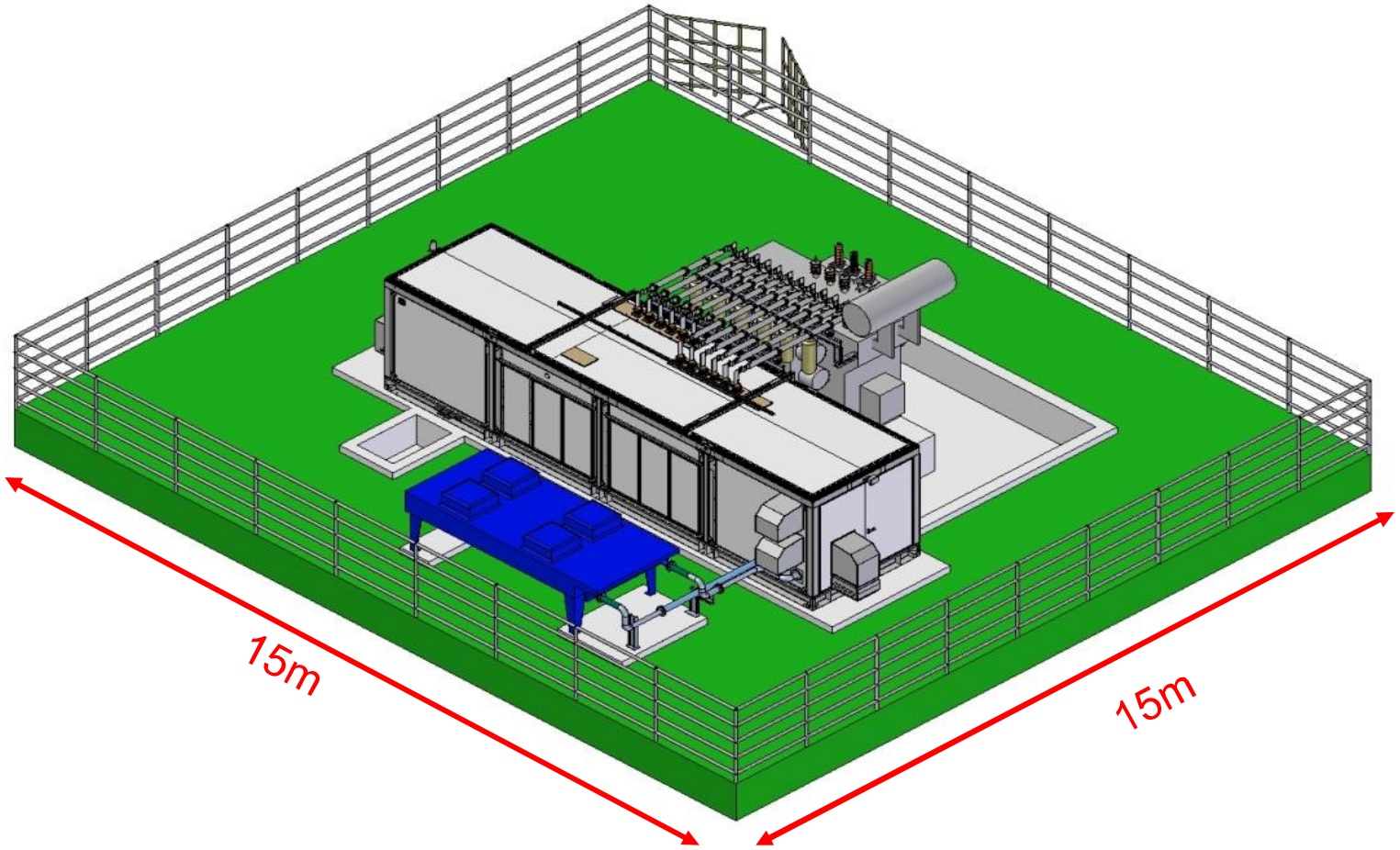
Industrial

- Compensation of starting current for large motors
- Compensation of unbalanced loads
- Power factor improvement
- Flicker control of fluctuating loads like arc furnaces, shredders, spot welders, saw mills etc.
- Active harmonic filtering

Utilities

- Compensation of weak transmission lines to remote areas
- Compensation of unbalanced loads
- Improve power transmission capability of transmission lines

PCS 6000 STATCOM
Outdoor Installation for 15…34MVAr



PCS 6000 STATCOM
Definition of a STATCOM System

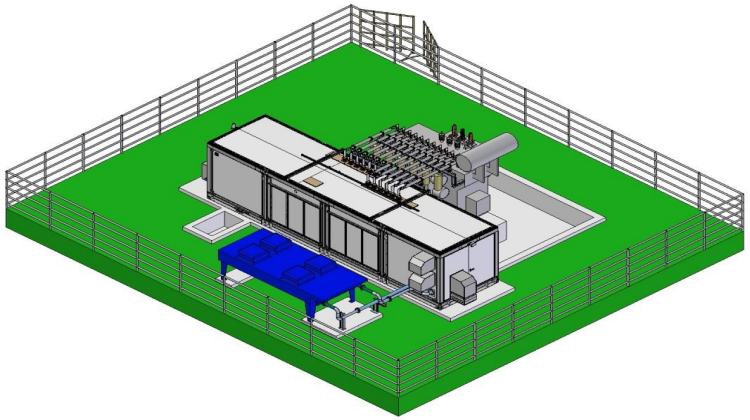
Unit Size:
12MVAr -
34MVAr

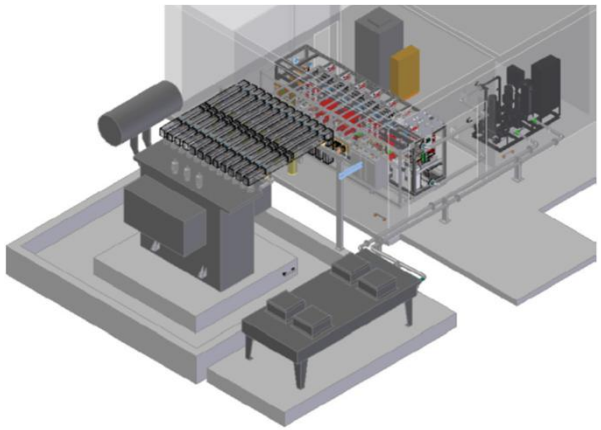
System Rating:
12MVAr -
100MVAr

POC:
10-145kV

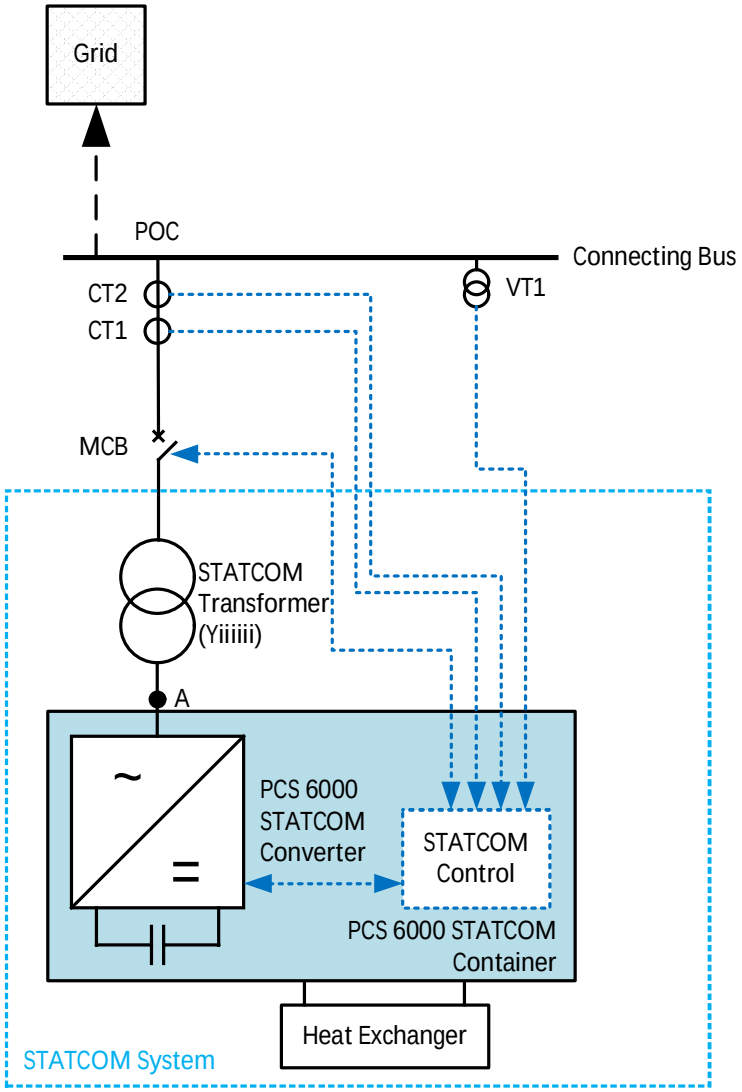
Installation:
Indoor IP00
Outdoor IP54

- PCS 6000 STATCOM in an IP54 outdoor container or indoor installation:
  - Voltage source converter (VSC),
  - Local Control via GUI (standard: remote control)
  - Uninterruptable power supply (UPS for Control),
  - Complete Water-cooling system with piping and 100% redundant pumps
  - Pre-charging unit (soft-start = no inrush current)
- Step-up transformer with busbar connections (between the STATCOM and the transformer) and dv/dt filters

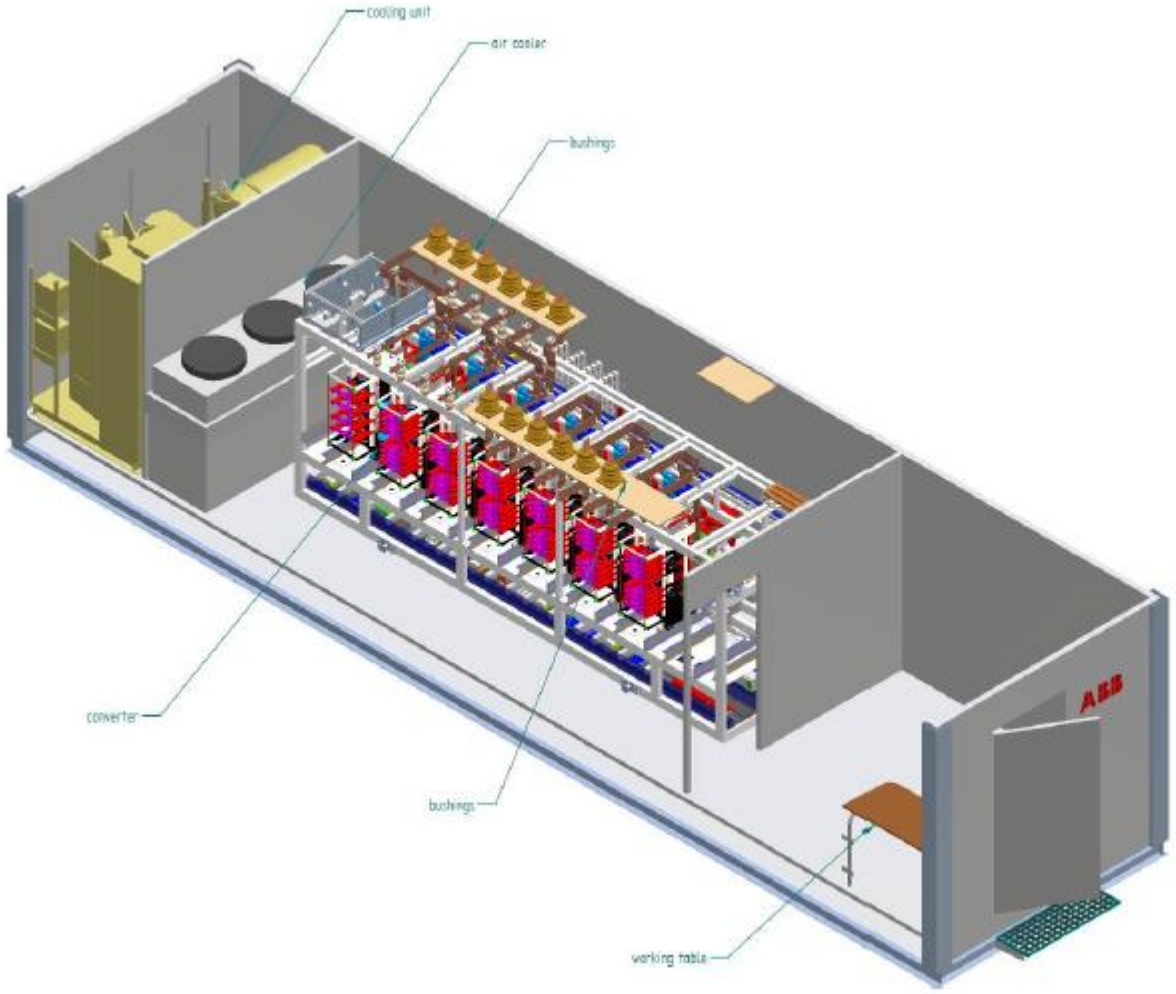




PCS 6000 STATCOM
Single Line Diagram (SLD)

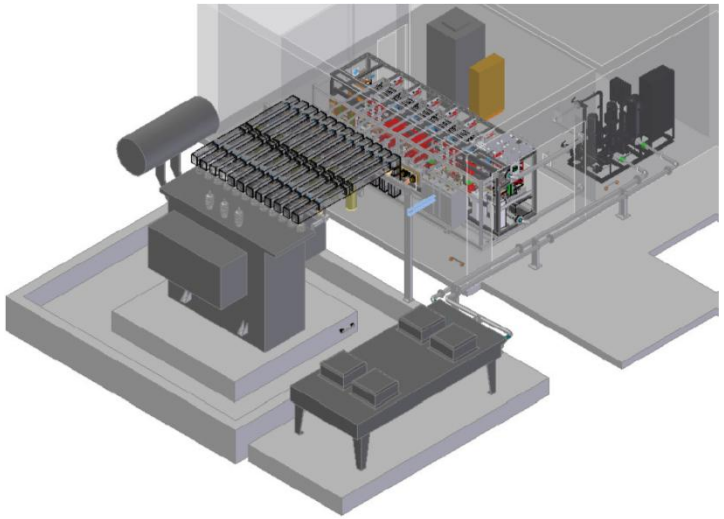


PCS 6000 STATCOM
Installation in IP54 Outdoor Container



PCS 6000 STATCOM
Converter IP00 Indoors

- Converter indoors
- Controls and cooling unit indoors
- Transformer outdoors
- Water / Air heat exchanger outdoors
- Ideal for bigger systems / extremely polluted environment



PCS 6000 STATCOM
Cooling System

- Closed loop cooling system with de-ionized water / glycol
- Two options available for external cooling
  - Industrial raw water circuit for extreme conditions
  - External heat exchanger with fans
- 100% redundant pumps
- External heat exchanger (water-air) and piping included

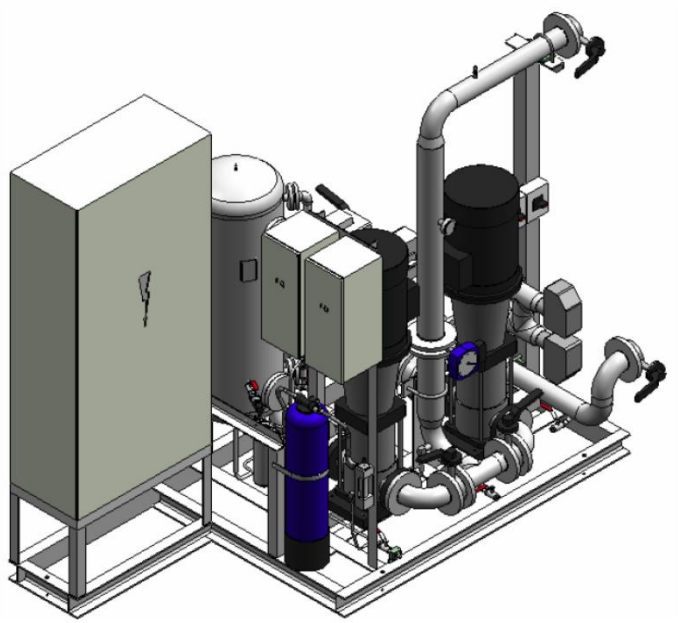
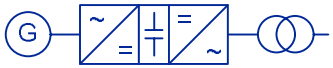
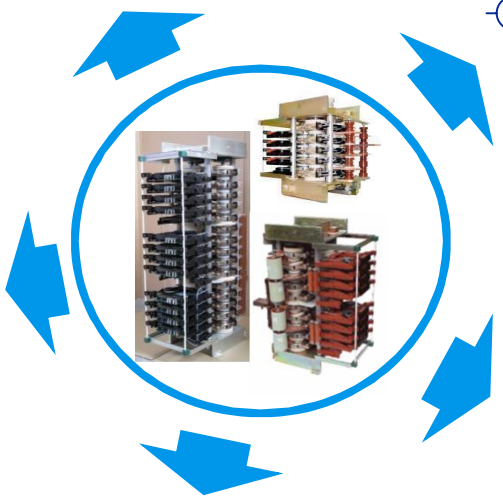


ABB MV Converter Technology
Field Proven IGCT Platform

PCS 6000 Wind
Frequency converter for application in wind turbines
> 700 MVA delivered



ACS 6000 MV Drive
Frequency converter to drive an electrical motor
> 13'000 MVA delivered



PCS 6000 STATCOM
Frequency converter for reactive power control
> 500 MVA delivered

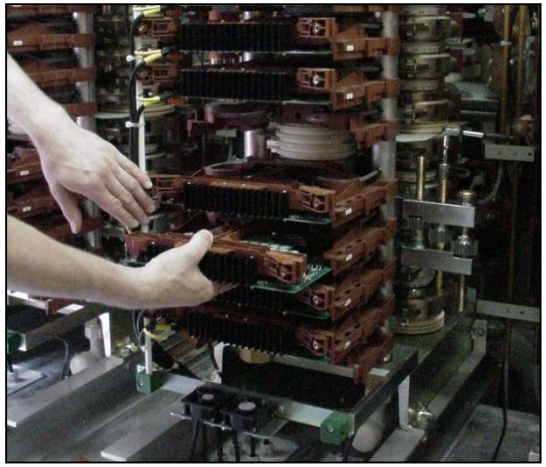
PCS 6000 Rail
Frequency converter to connect railway with regular grid
> 1000 MVA delivered

PCS 8000
Frequency converter for Pumped storage power plants
ACX Avce, Seebach 2x, Massaboden
XLD 100 MVA Grimsel 2

PCS 6000 STATCOM
Converter Design for High Reliability and Availability

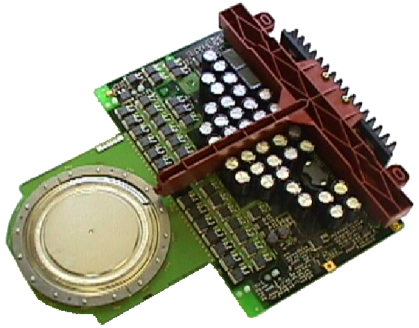
PCS 6000 Converter Family Design Philosophy:

- Use redundant components, where reliability is limited (fans)
- Use of least possible amount of components that are maximum reliable (best MTBF)
- Keep access to components simple (fast exchange, best MTTR)
- Ideal for remore area operation due to maximum remote control as used in offshore wind converters



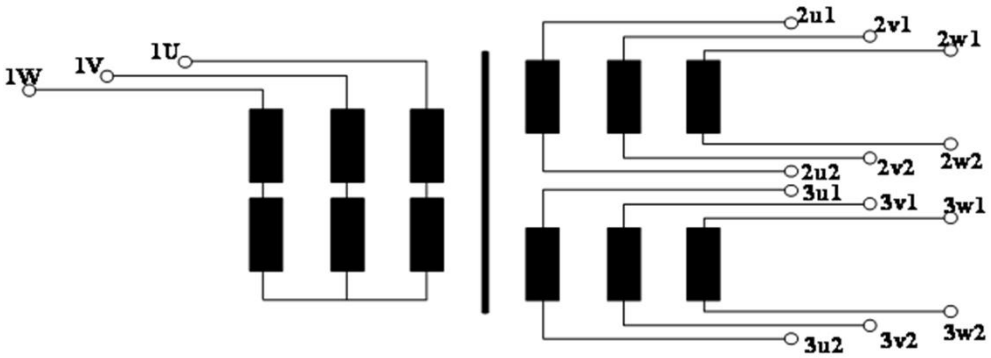
PCS 6000 STATCOM
Voltage Source Converter (VSC)

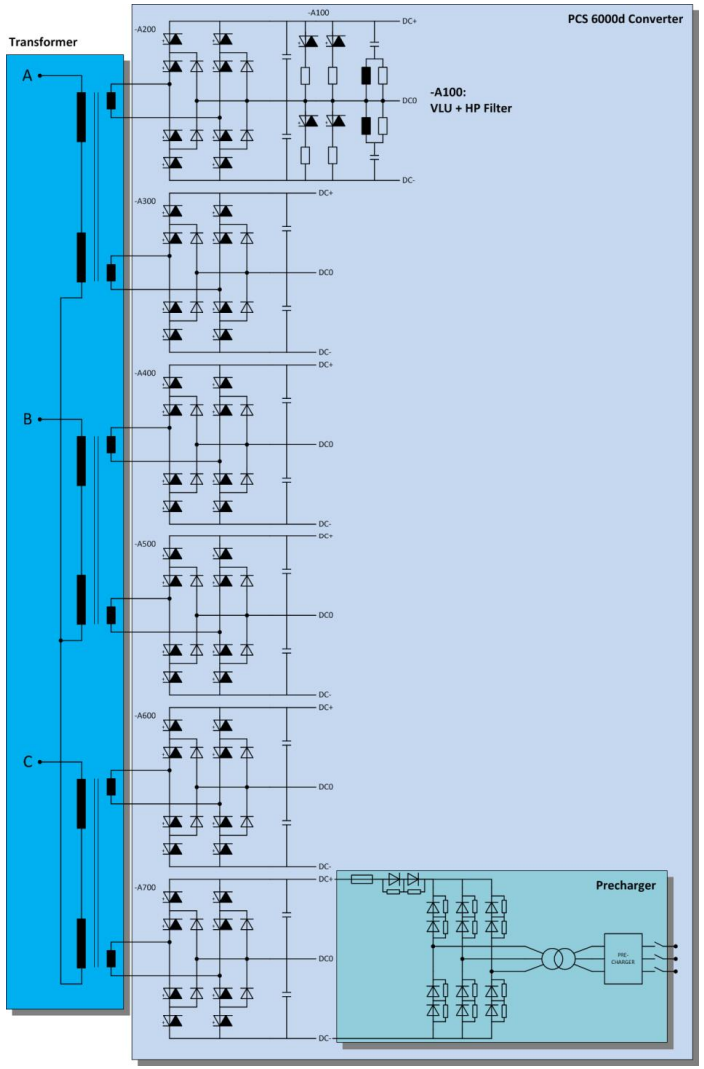
- IGCT (Integrated Gate Commutated Thyristor)
  - Switch, which can be turned on and off by a fibre optic signal, good control capabilities (“first failure”)
  - Very low conducting losses → slow switching possible to avoid transients (drawback of IGBT)
  - Robust design
    - Very good balance between robustness, efficiency, cost and reliability for medium voltage converters



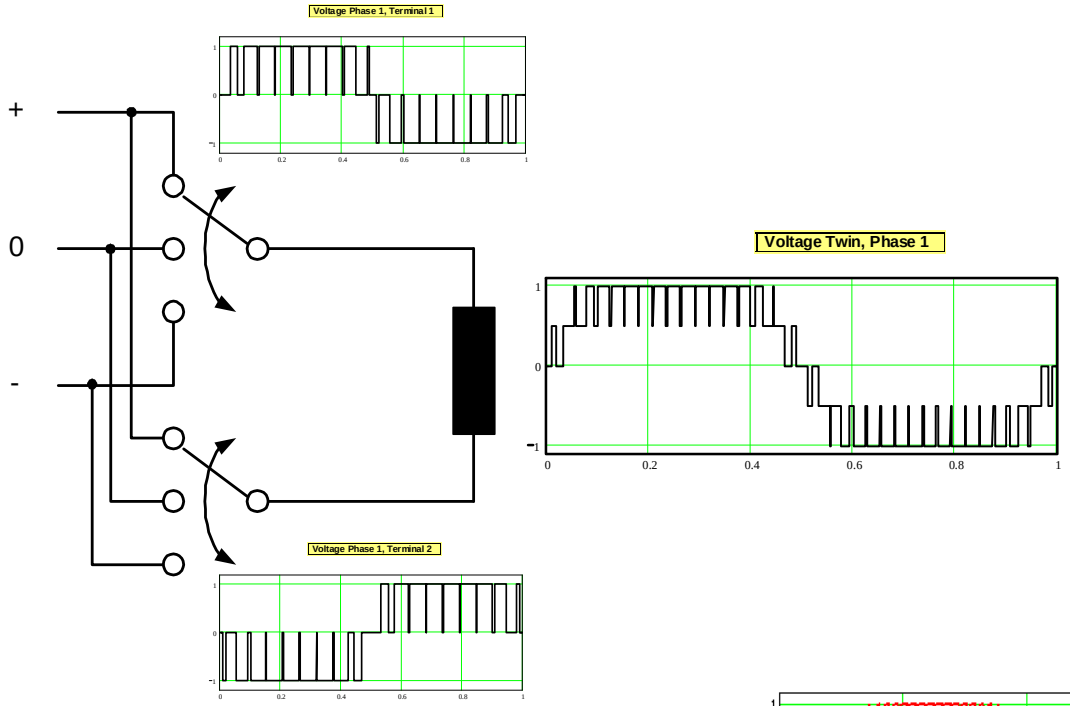
PCS 6000 STATCOM
Transformer Connection

- Double twin topology
- Both secondary winding ends are brought out and connected to one converter terminal
- Two secondary windings are coupled to form the voltage on the primary side
- Advantage: virtually 17 output voltage levels

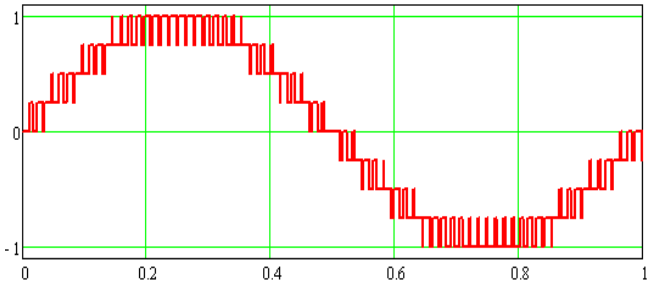




PCS 6000 STATCOM
Double Twin Topology

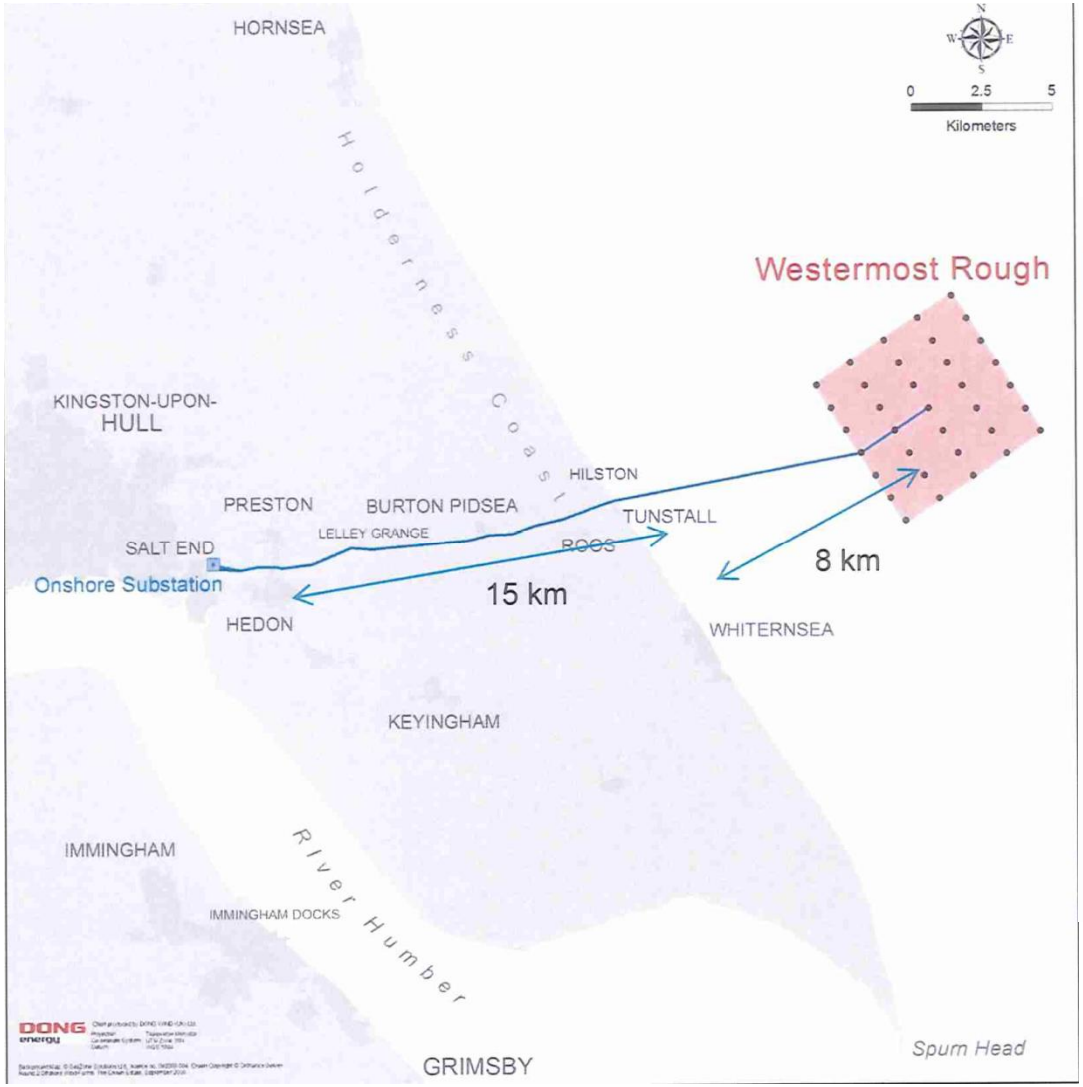


- Transformer secondary winding voltage (5 levels)
- Due to double-twin topology, the transformer primary winding has then virtually 17 voltage levels.



PCS 6000 STATCOM
Case Study 1:
Westermost Rough Offshore Wind Farm

Case Study 1:
Westermost Rough WF



Area: 35 km2

Capacity: 180 - 240 MW

Turbine Rating: 3 - 7 MW

Cable Landing: Tunstall

Onshore Substation: New Hedon

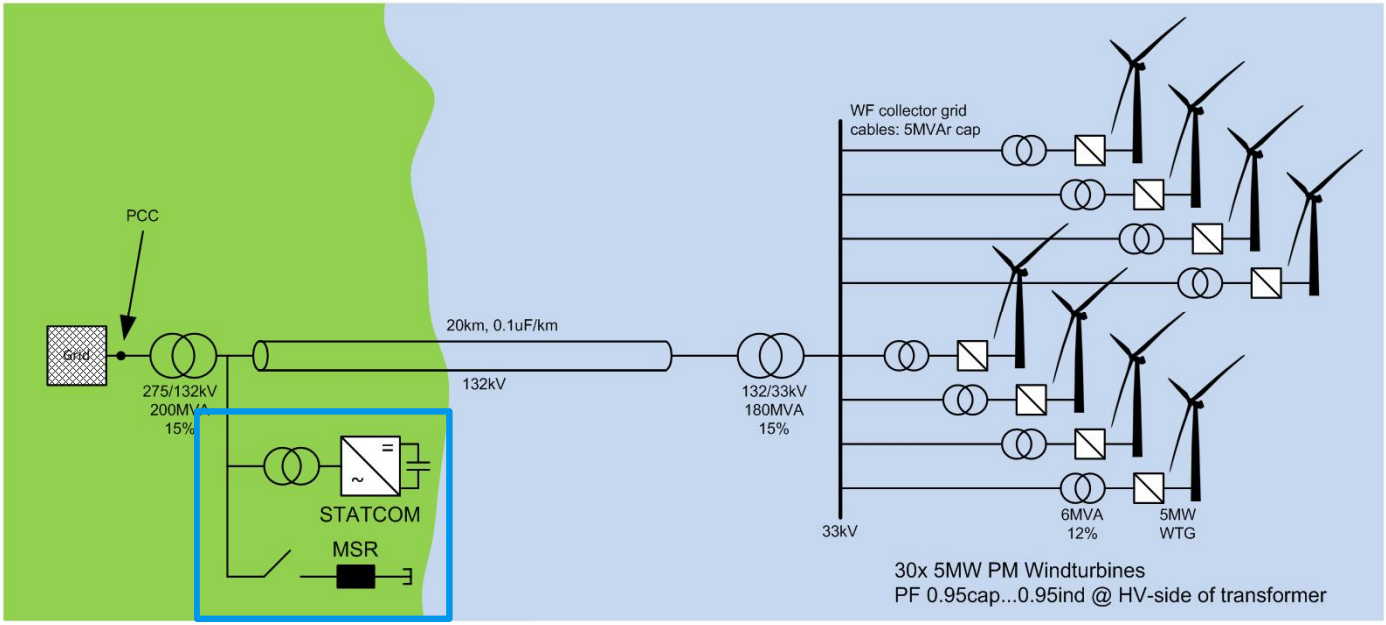
Water Depths: 12 – 28 m LAT

Construction: 2014

Indicative turbine lay-out

Case Study 1:
Westermost Rough WF

- **Addition of a STATCOM System**
  - Ensures AC Windfarm grid interconnections
  - Ensures Grid Code requirements



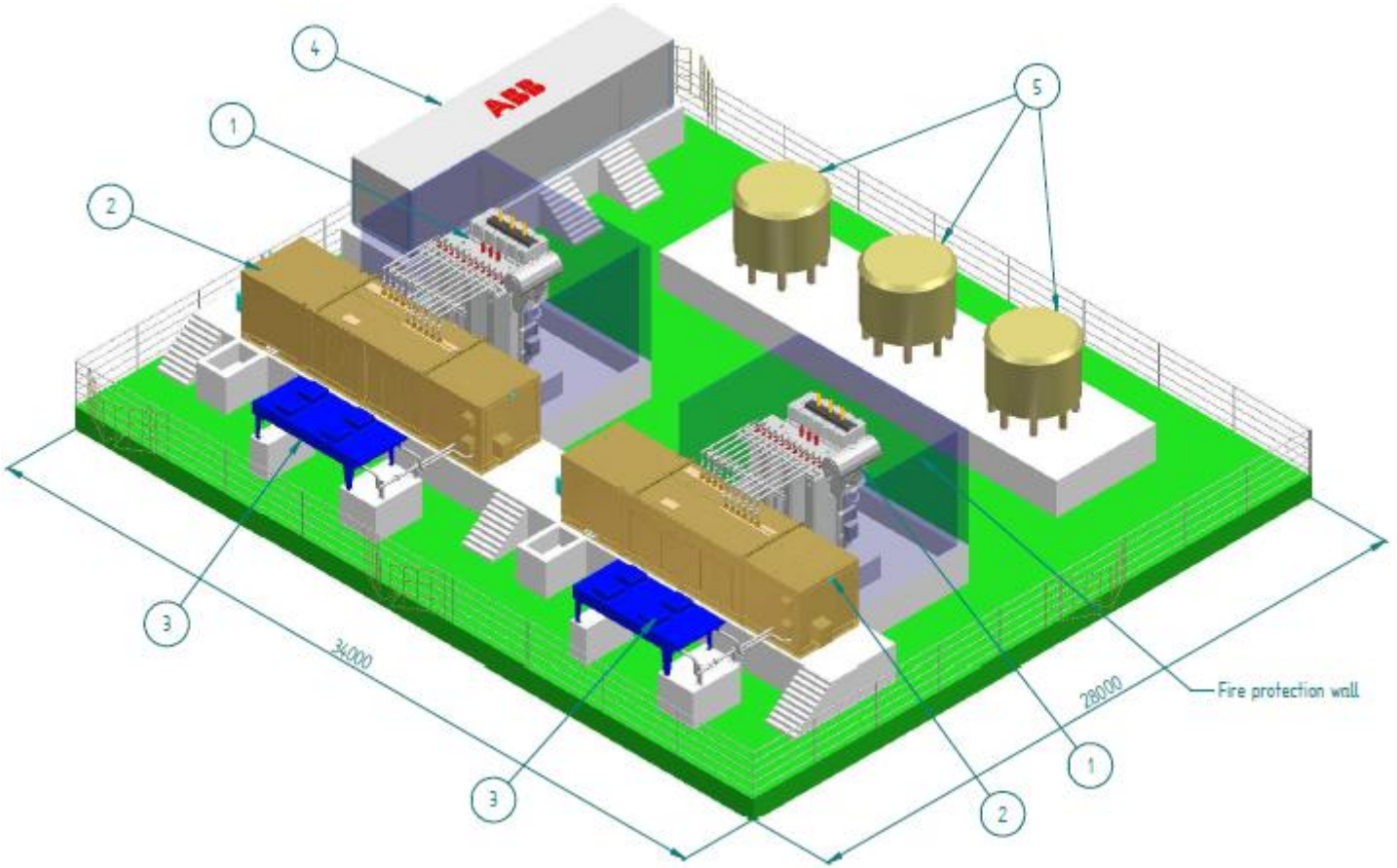
Case Study 1:
Westermost Rough WF

Requirement «GRID COMPLIANCE»:

- Power Factor Correction of WF + long cables (steady state conditions)
  50MVAr MSR + 0..50MVAr STATCOM
- UK Grid Code Requirements (Voltage Stabilisation, FRT, Harmonics,)

- Main Supply:
  2x 25MVAr PCS 6000 STATCOM in container + 50MVAr MSR; Switch gear, aux. power, X-formers, cables; Turnkey

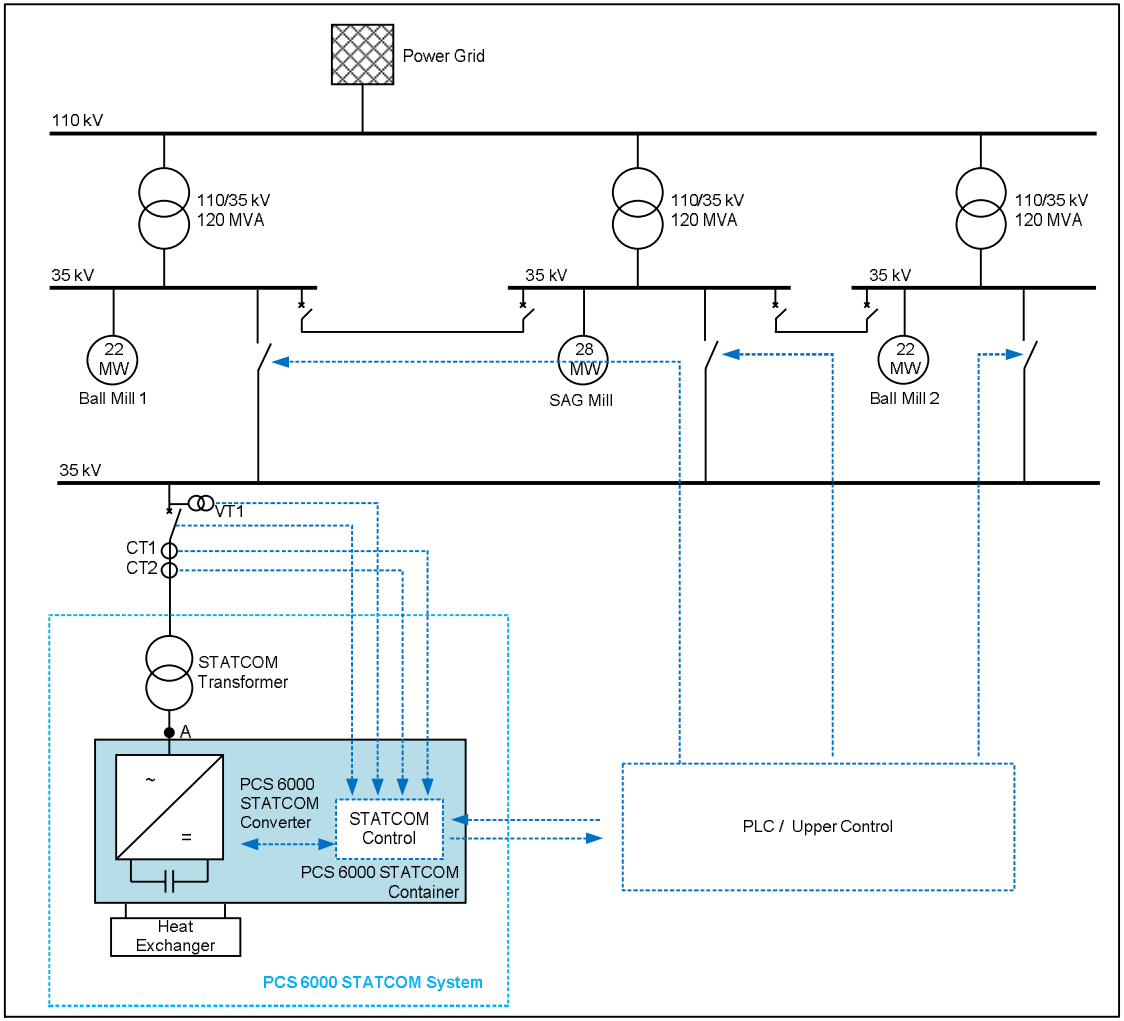
Case Study 1:
Westermost Rough WF



Main Supply: 2x 25MVAr PCS 6000 STATCOM in container + 50MVAr MSR;
Switch gear, aux power, X-formers, cables. Turnkey

PCS 6000 STATCOM
Case Study 2:
Voltage Stability in Industrial Plant

Case Study 2:
Voltage Stability in Industrial Plant



Case Study 2:
Voltage Stability in Industrial Plant

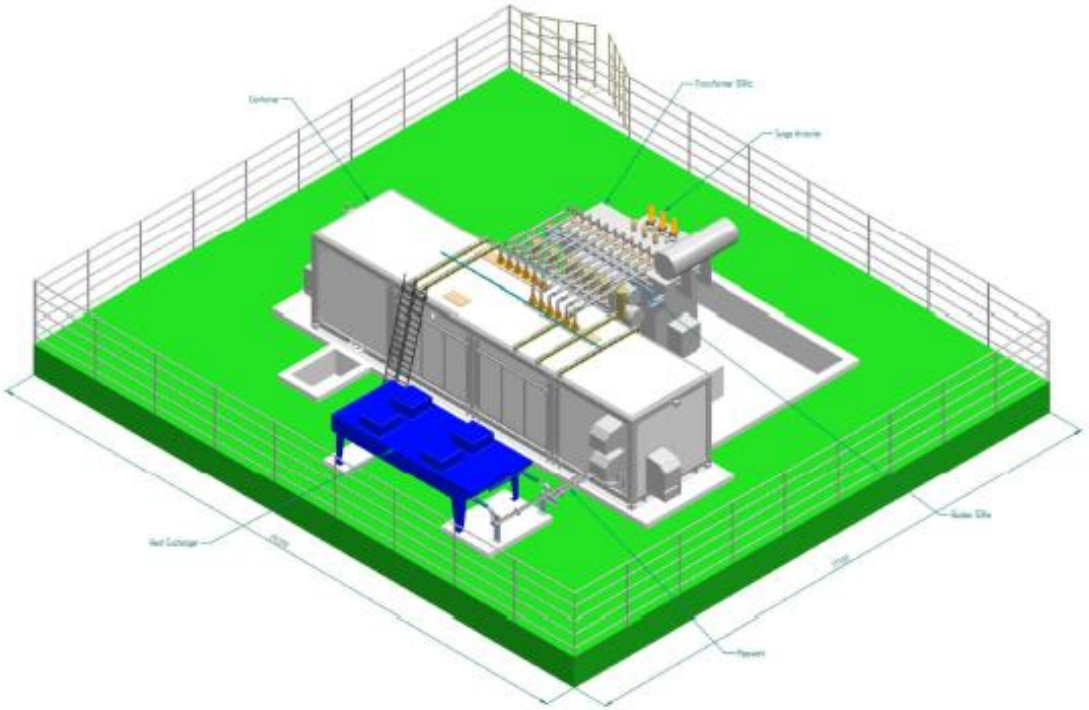
Requirement «Voltage Stability»:

- Remote and weak grid conditions in Kazakhstan
- 3 Gearless Mill Drives at one bus bar

Generalized STATCOM performance:
Immediate inherent reaction providing
80% of rated current within 20ms (not controlled).
100% of rated current within 60ms (controlled).

- Main Supply:
  1x 32MVAr PCS 6000 STATCOM System in container, cooling, X-formers

Case Study 2:
Voltage Stability in Industrial Plant



Scope of Supply:
PCS 6000 STATCOM System 1x32MVAr in container
Transformers, Busbars, dv/dt Filter, HEX
+ Delivery, Unloading, Installation, Commissioning, Spare Parts

No cables to SG, no civil works

STATCOM Systems
Outlook

- ABB has expertise for complete interconnections in Industrial Networks
  - Inhouse system components knowledge (switchgear, transformers, SCADA, ...) due to ABB's vast offerings
  - Inhouse understanding of best solution due to knowledge STATCOM systems to meet Grid Code requirements
  - Complete SVC plants for AC grid interconnections
  - Grid integration analysis and study capabilities
  - Reference projects for Grid Compliance, Voltage Stability, Flicker Compensation, Various Control Philosophies

- **Thank you for your attention and questions!**

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for a better world™