Hubbell Industrial Controls

STATCOM and SVC in Steel industry

STATCOM and SVC Technology overview

STATCOM – A controlled current source

- STATCOM is a dynamic compensator
    - Reactive power
    - Harmonics
    - Unbalance
- STATCOM-module can be understood as a controlled current source
    - Capable of producing any current waveform in real-time
    - Structure similar to an APEX active filter but much bigger
- Hubbell module
    - 2MVAR
    - 2 kV
    - Independent control unit

STATCOM – A controlled current source

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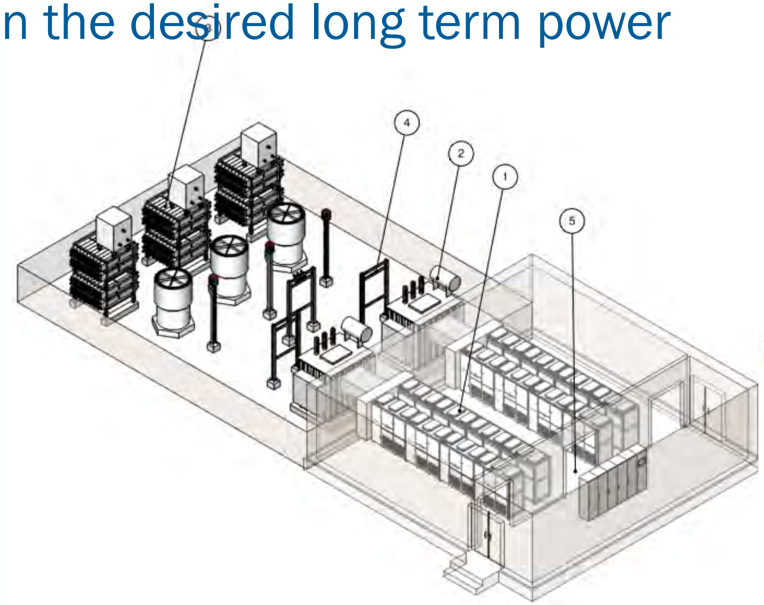
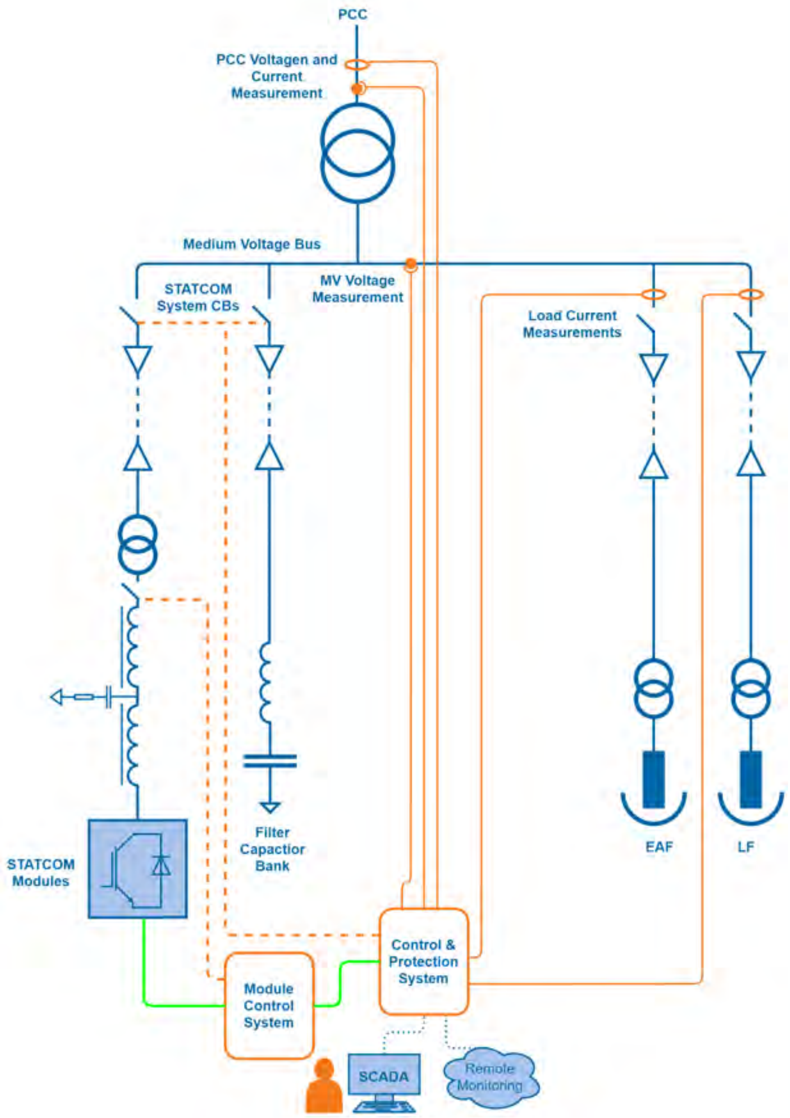
- STATCOM-system consist of multiple STATCOM-modules
- In typical steel industry applications ~half of the reactive power is taken from filter capacitor bank(s)
    - Filter capacitors typically tuned at some harmonic frequency
- Master controller controls individual STATCOM-modules
    - Response time <1 ms for EAF and LF load changes
    - Slower control to maintain the desired long term power factor at PCC





SVC – A controlled impedance

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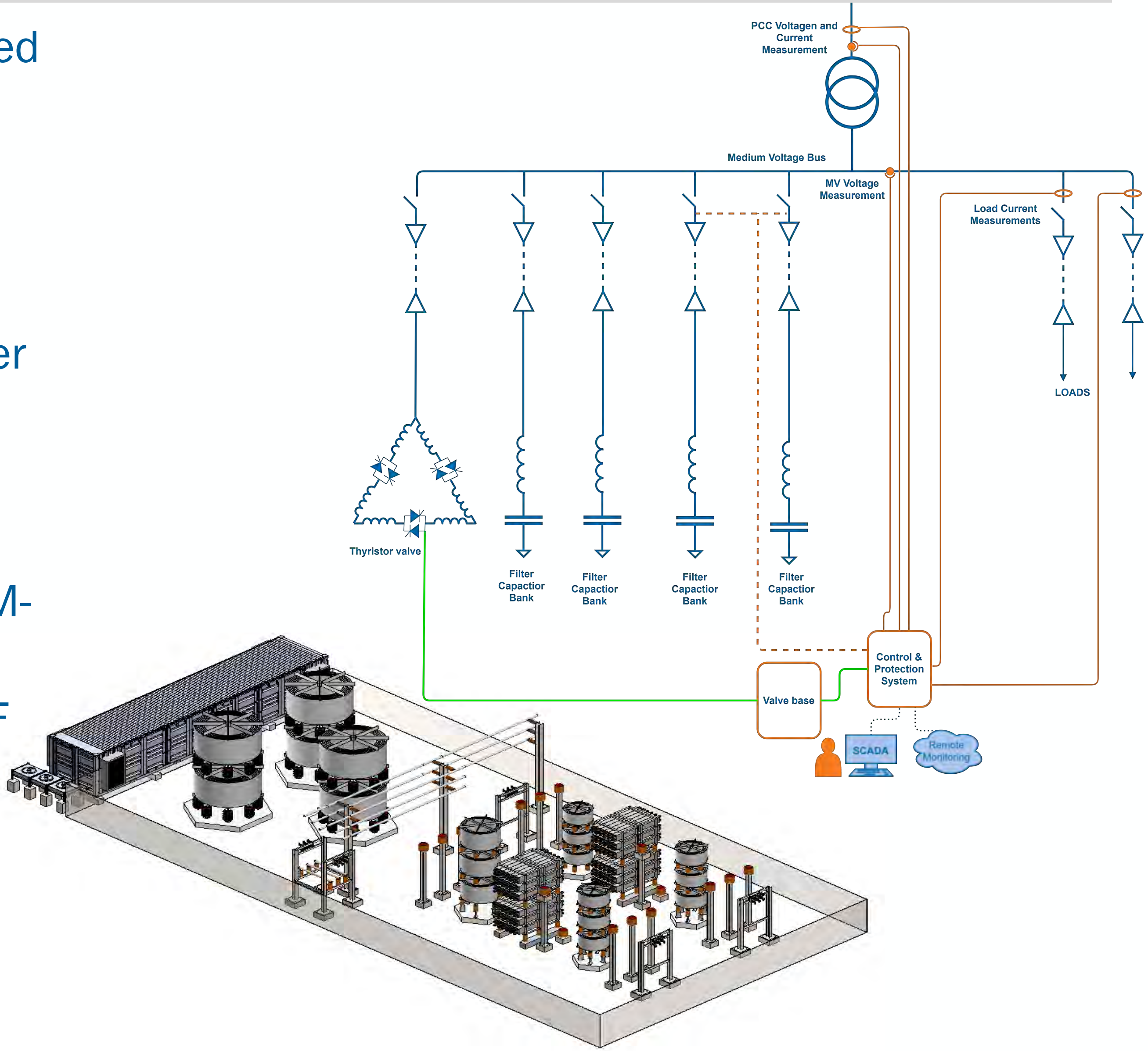
- A thyristor valve used to control inductive current through an air core reactor
- The thyristor controlled reactor (TCR) is a controlled impedance
- Hubbell Power thyristor valve
  - Nominal voltage up to 38.5kV
  - Nominal current up to 2500A
  - Nominal 3-phase power up to 250Mvar
  - Efficiency ~ 99.8 %
  - Water cooling, max flow 40 m2 / h
  - Two (2) redundant disck levels
  - Simple disk replacement

SVC – A controlled impedance

- SVC system consist of three thyristor controlled reactors (TCR) and multiple filter capacitor banks
  - Filter capacitors typically tuned at some harmonic frequency
- In typical steel industry applications the power range from slightly inductive to capacitive
  - TCR power >= than the sum of the filter capacitor powers
- Master controller controls individual STATCOM-modules
  - Response time one network cycle for EAF and LF load changes
  - Slower control to maintain the desired long term power factor at PCC



STATCOM vs SVC – Overview

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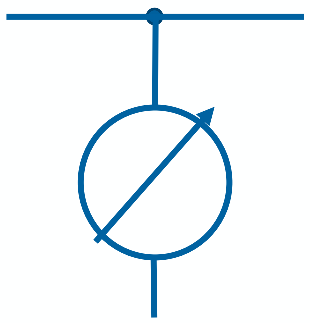
Statcom

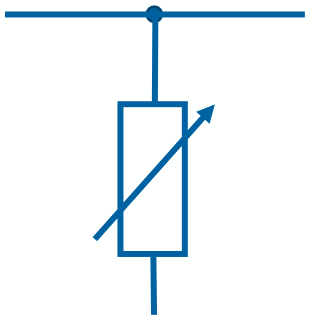
Controlled current source



$$Q_{STATCOM} = U * I_{AF} = 1 * I_{AF} = 100\%$$

SVC

Controlled impedance



$$Q_{SVC\rightleftarrows} = \frac{U^2}{Z_{svc}} = \frac{1^2}{Z_{svc}} = 100\%$$

STATCOM vs SVC – Operation principle

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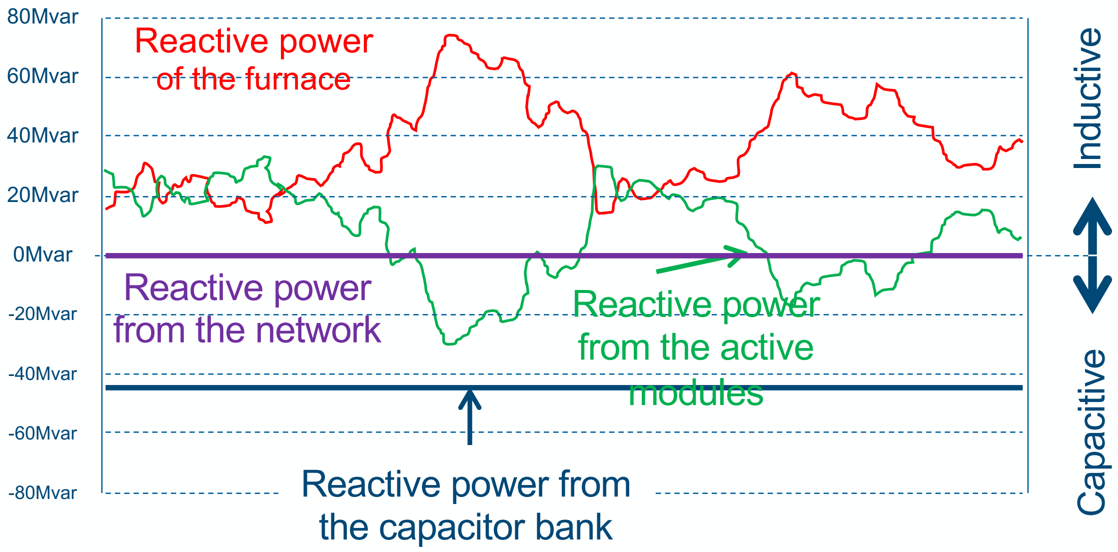
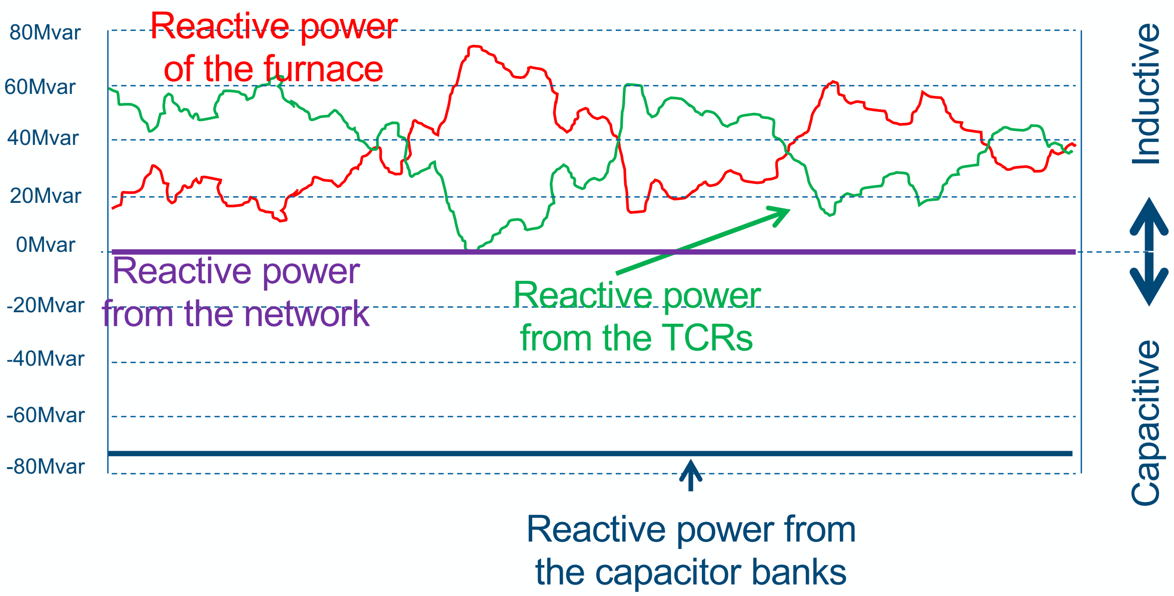
STATCOM

- Capacitor banks produce constant capacitive reactive power
- STATCOM modules produce variable reactive power
  - STATCOM module reactive power is controlled, so the reactive power from the grid is always zero



SVC

- Capacitor banks produce constant capacitive reactive power
- TCRs produce variable inductive reactive power
  - TCRs module reactive power is controlled, so the reactive power from the grid is always zero



STATCOM vs SVC – Reactive power output

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- STATCOM = controlled current source → Reactive power output linearly proportional to the voltage
- STATCOM can be overloaded momentarily
- Unlike SVC the overload can be controlled

$$Q_{STATCOM} = UI_{STATCOM} = 1 \cdot I_{STATCOM} = 100\%$$

$$Q_{STATCOM} = UI_{STATCOM} = 0.9 \cdot I_{STATCOM} = 90\%$$

$$Q_{STATCOM} = UI_{STATCOM} = 1.1 \cdot 2I_{STATCOM} = 220\%$$

- SVC = controlled impedance → Reactive power output proportional to the square of the voltage
- SVC cannot be intentionally overloaded
- Higher than nominal power is only possible when the system voltage is over 1 pu

$$Q_{SVC} = \frac{U^2}{Z_{SVC}} = \frac{1^2}{Z_{SVC}} = 100\%$$

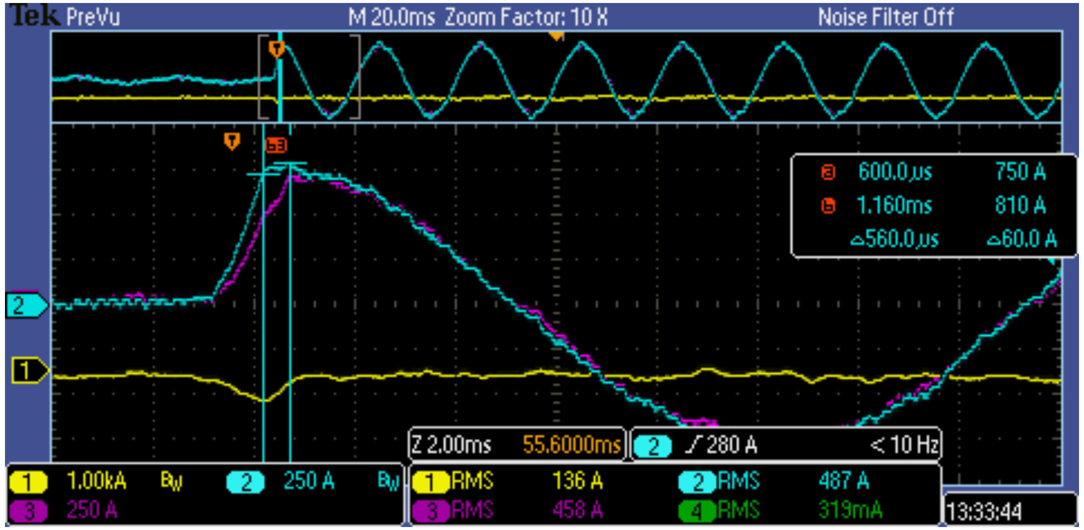
$$Q_{SVC} = \frac{U^2}{Z_{SVC}} = \frac{0.9^2}{Z_{SVC}} = 81\%$$

$$Q_{SVC} = \frac{U^2}{Z_{SVC}} = \frac{1.1^2}{Z_{SVC}} = 121\%$$

STATCOM vs SVC – Response time

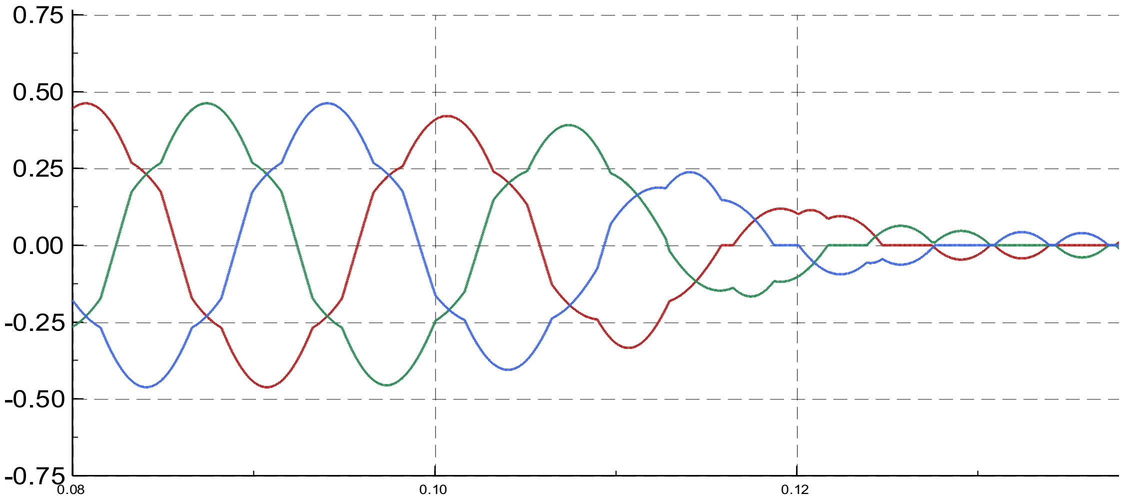
STATCOM

- Response time determined by the control system speed and IGBT switching frequency
- Resoponse time ~600μs
  - Flicker attennuation factor 5



SVC

- Response time determined by the power system frequency
- Response time one cycle (20ms/16.67ms)
  - Flicker attennuation factor 2



STATCOM vs SVC – Redundancy

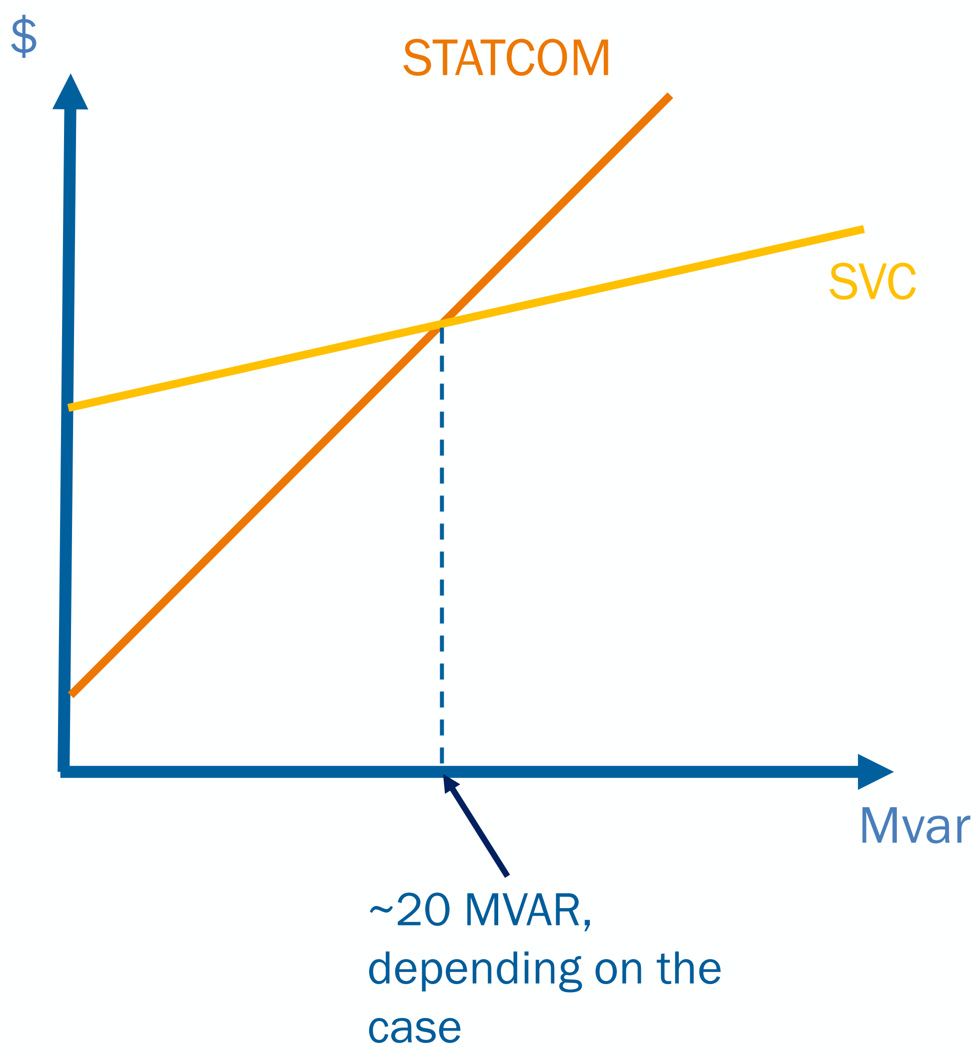
STATCOM

- Stand alone modules
- One module failure does not stop the system
- Each module has independent cooling system
- STATCOM continues to operate if any or all capacitor banks fail

SVC

- Redundant
- Thyristor discs
- Valve base control outputs
- Cooling system pumps
- Cooling system fans
- Operation possible without highest order harmonic filter

STATCOM vs SVC – Cost comparison



EAF

Arc furnace

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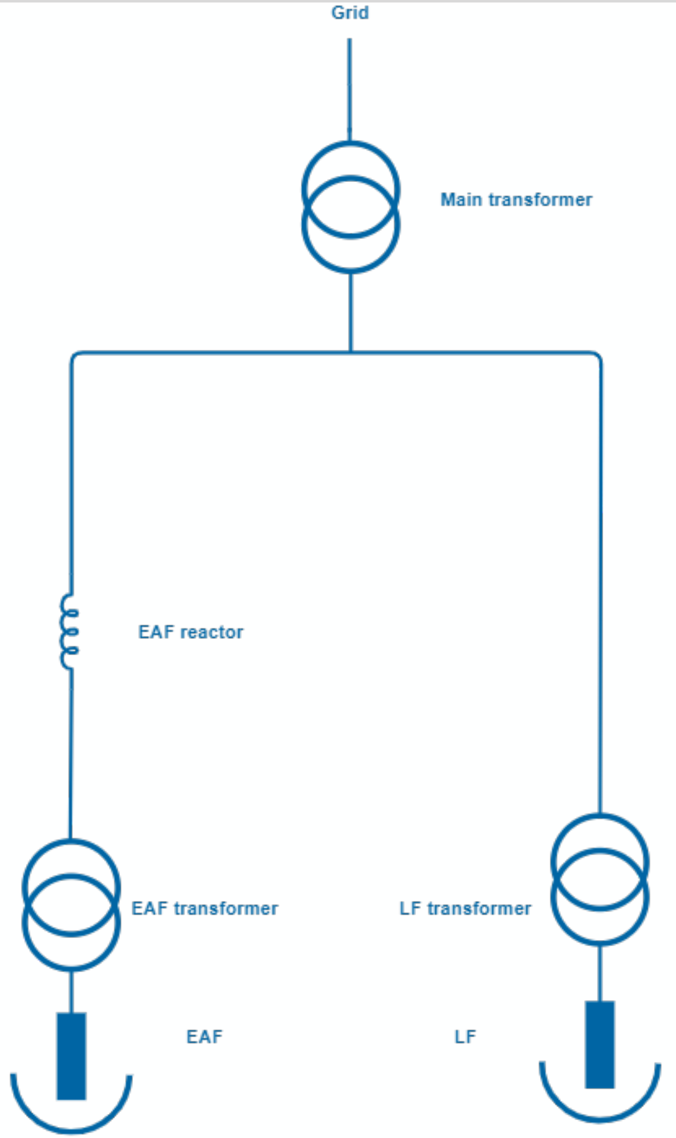
- Uses electric arc to melt metal
- Two main categories
  - AC
  - DC
- AC furnace
  - 3 electrodes
  - Transformer between grid and electrodes
  - Higher flicker severity factor
  - Produces harmonics with wide spectrum
- DC furnace
  - One electrode
  - Large rectifier bridge between the grid and electrode
  - Lower flicker severity factor
  - Produces characteristic harmonics

EAF - Flicker

- Voltage variation is caused by variation in reactive power demand
- An EAF causes rapid variation in reactive power demand
- This creates rapid voltage variations → high flicker

$$\Delta U \approx \frac{\Delta Q_c}{S_k}$$

ΔU = Voltage change
ΔQ_c = Change in reactive power demand
S_k = Fault level



EAF - Flicker

- Hubbell STATCOM or SVC eliminates reactive power demand from the grid → voltage variation due to the reactive power eliminated

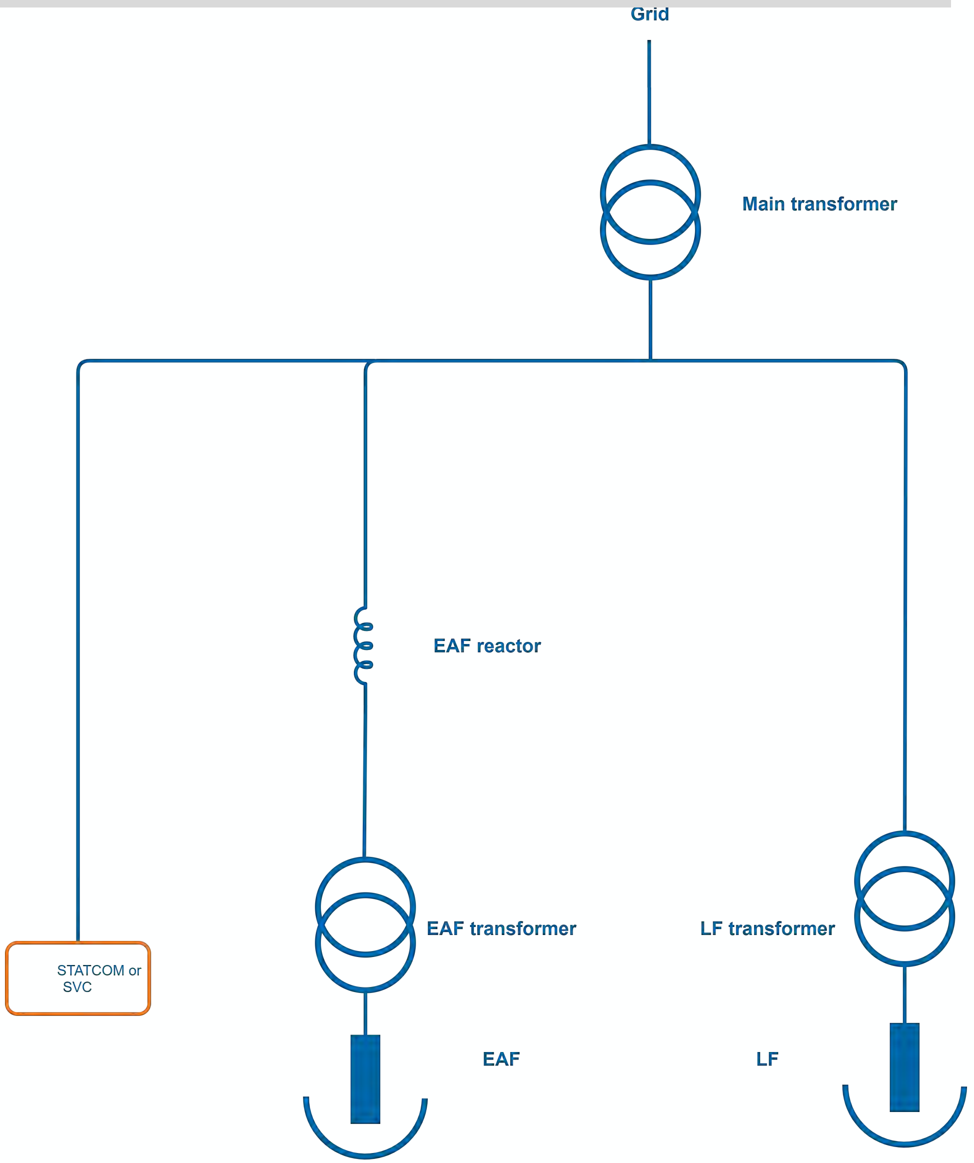
$$\Delta U \approx \frac{\Delta Q_c}{S_k}$$

ΔU = Voltage change

ΔQ_c = Change in reactive power demand

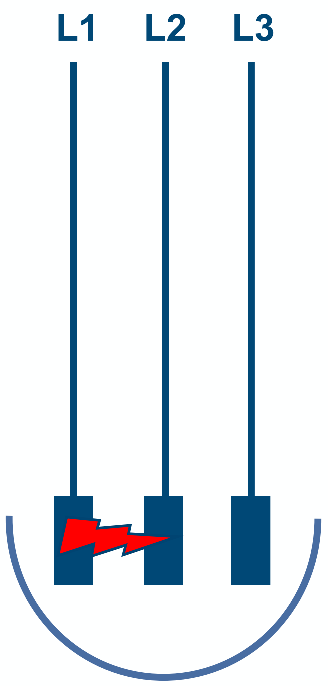
S_k = Fault level

$$Pst = \frac{Pst_0}{Attennuation\ factor}$$



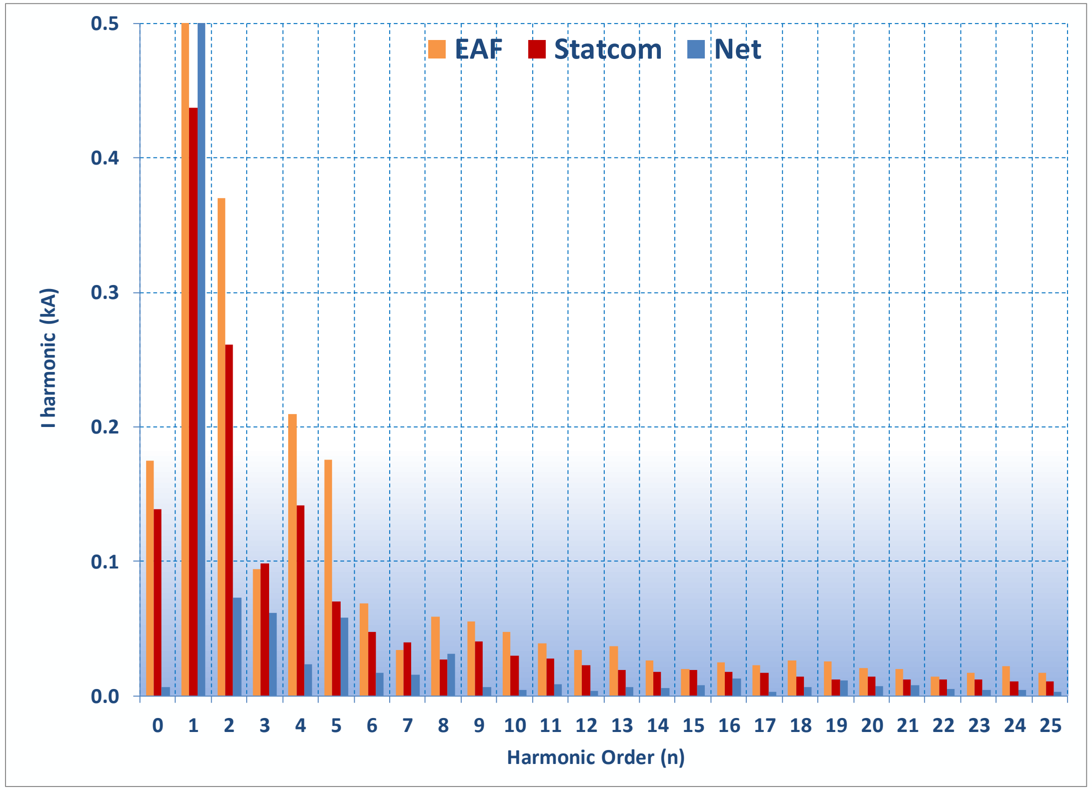
EAF - Unbalance

- An AC EAF has three electrodes
- When two electrodes short circuit the voltage drops significantly in those two phases due to the high reactive power demand
- Asymmetrical voltage drop creates voltage unbalance (negative sequence voltage) in the grid
- A STATCOM or an SVC can compensate asymmetrical reactive power demand → voltage unbalance eliminated



EAF - Harmonics

- AC furnace creates harmonics with wide spectrum
- DC furnace creates harmonics characteristic harmonics
- Harmonic currents create voltage distortion in the supplying grid and inside factory grid
- Harmonic currents also create excess losses
- STATCOM and SVC compensate harmonic from the furnaces



EAF - Power increase

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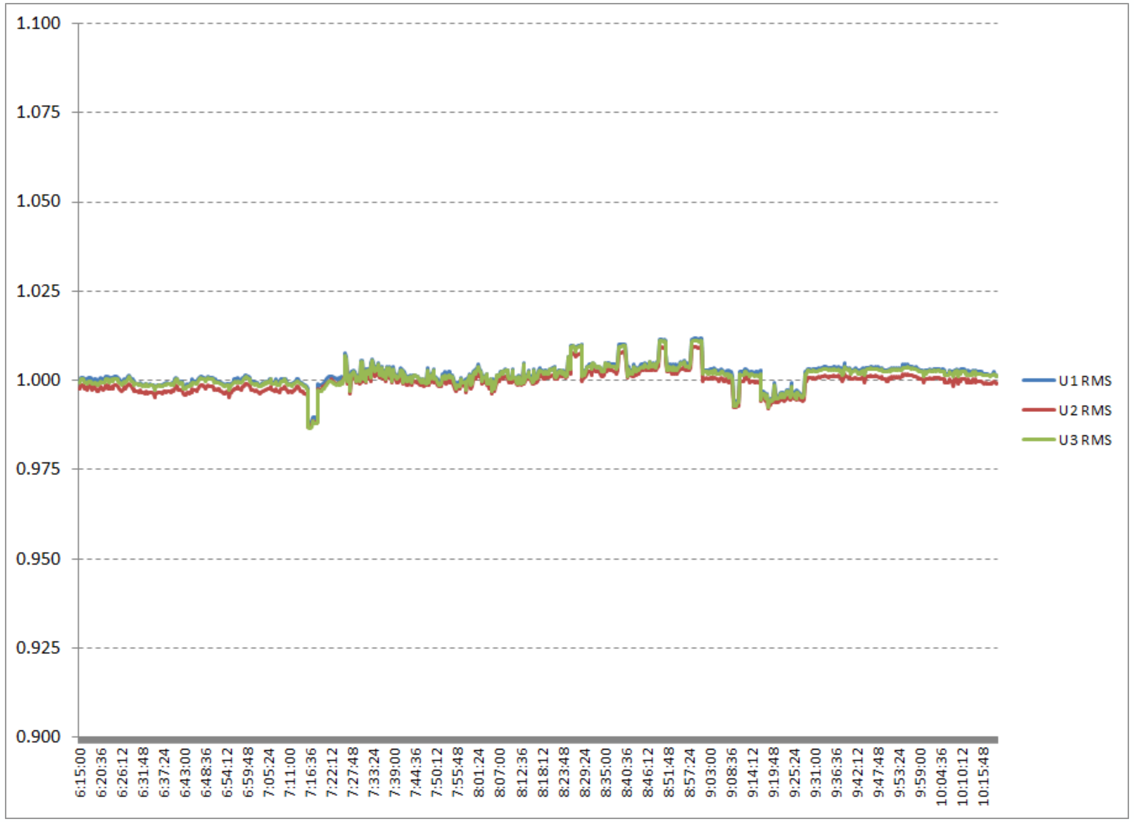
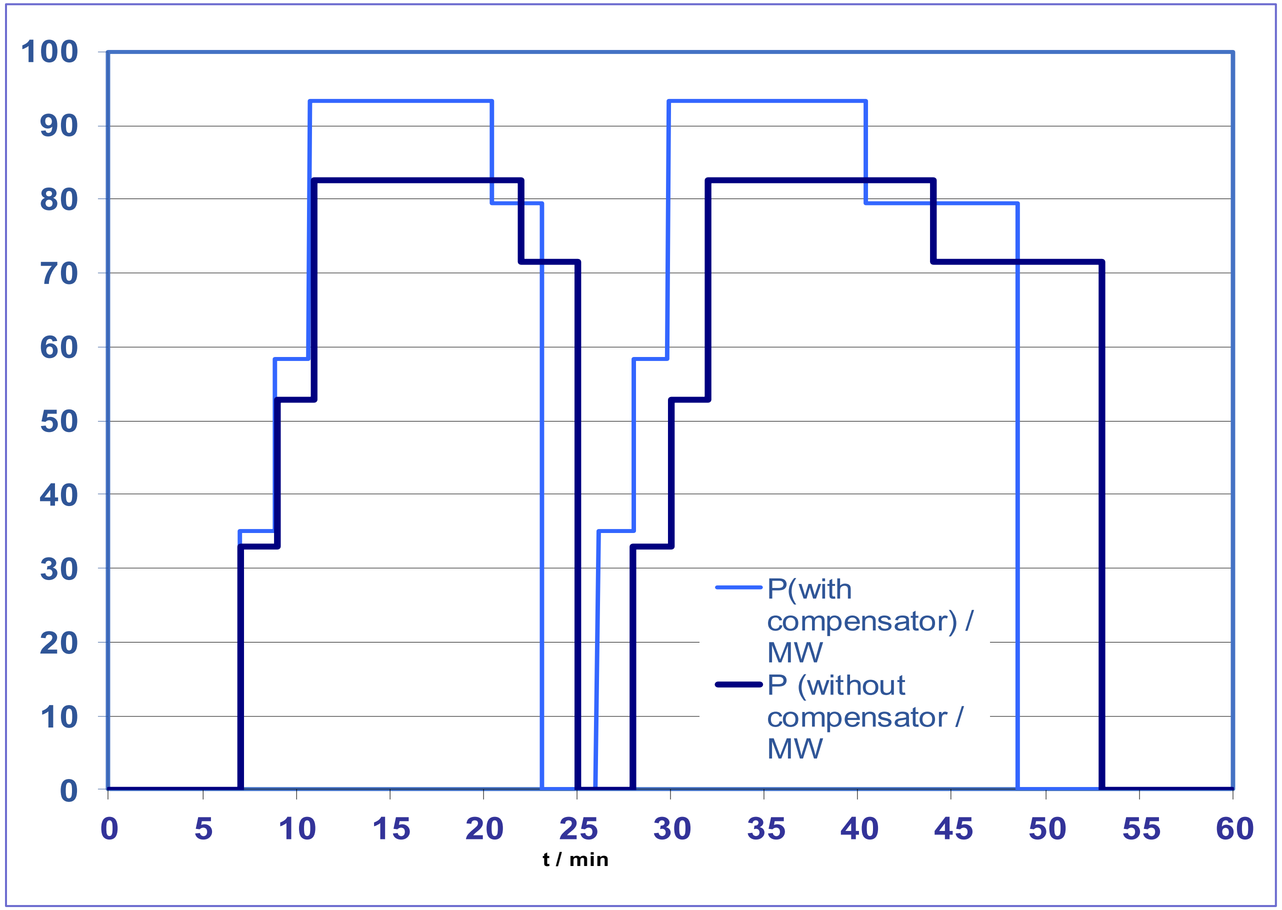
- An arc furnace is an impedance load
  - Power proportional to the square of the voltage
- Hubbell STATCOM or SVC stabilises the voltage
  - Higher average voltage
  - Higher average power
- Power increase for arc furnace

$$P = P_0 \frac{U^2}{U_0^2}$$



EAF – Tap to Tap time reduction

- Melting process requires certain amount of energy/ton
- Energy injected into the material in the furnace is P x t
- With compensator the average power is higher → less time required to achieve same energy output



Payback components example

- Production increase ~8 - 10 %
- Decreased electrode consumption due the more stable arc and reduced tap-to-tap time
  - Estimated electrode saving ~0.18kg / ton
  - Average electrode cost in 2019 €10/kg
- Reduced power losses ~2% in total
  - Main transformer losses
  - Other components in the factory’s power grid
  - Reduction in radiation losses in the furnace
- Typical payback 2 years

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SVC Revamping Concept

SVC active and passive components

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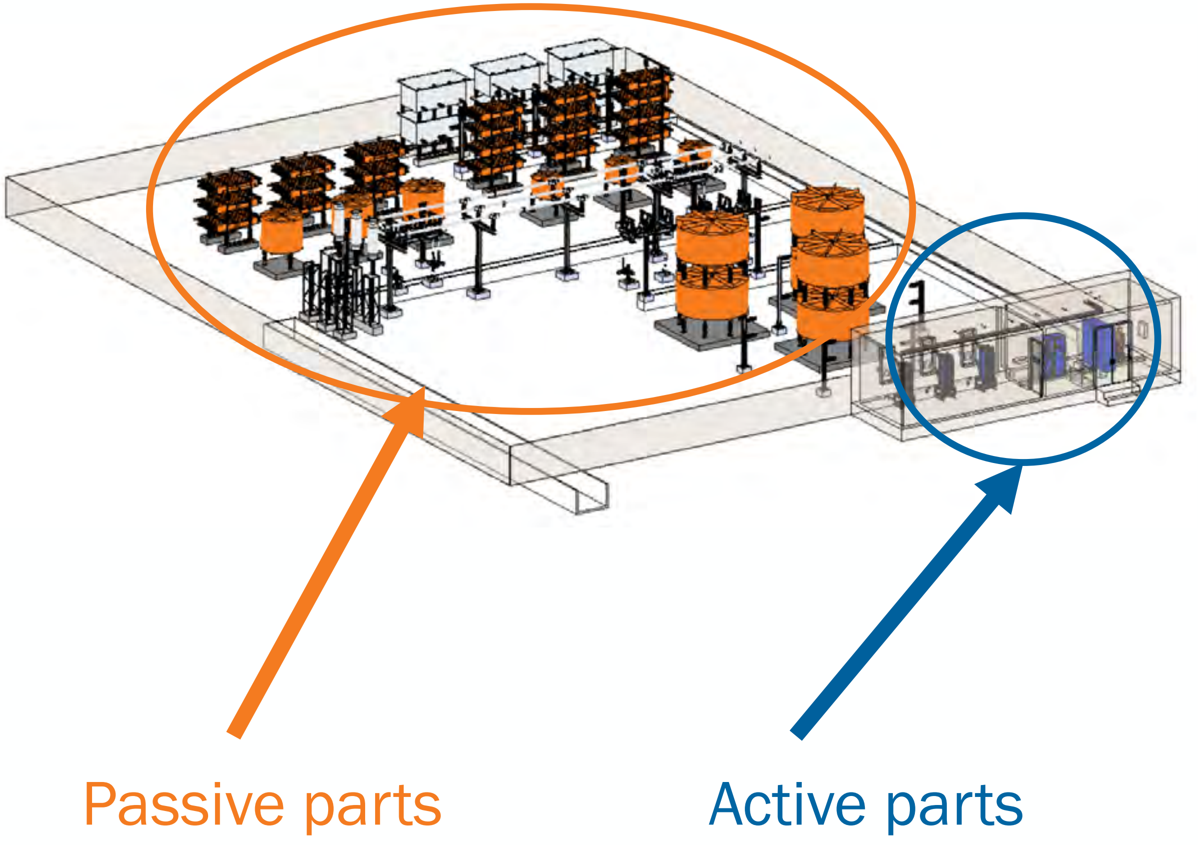
Component	Lifetime (years)
HMI	8-10
Control system	10-15
Cooling system	15-20
Protection system	15-20
Thyristor valves	20-25
TCR reactors	25-35
TSC banks	25-35
Harmonic filters	25-35
Circuit breakers, disconnectors, CTs, VTs and surge arresters	30-35
SVC transformer	30-40
Building for active part	40-50

Active part

Passive part

SVC Modernization

Extends the useful lifetime of an SVC for decades



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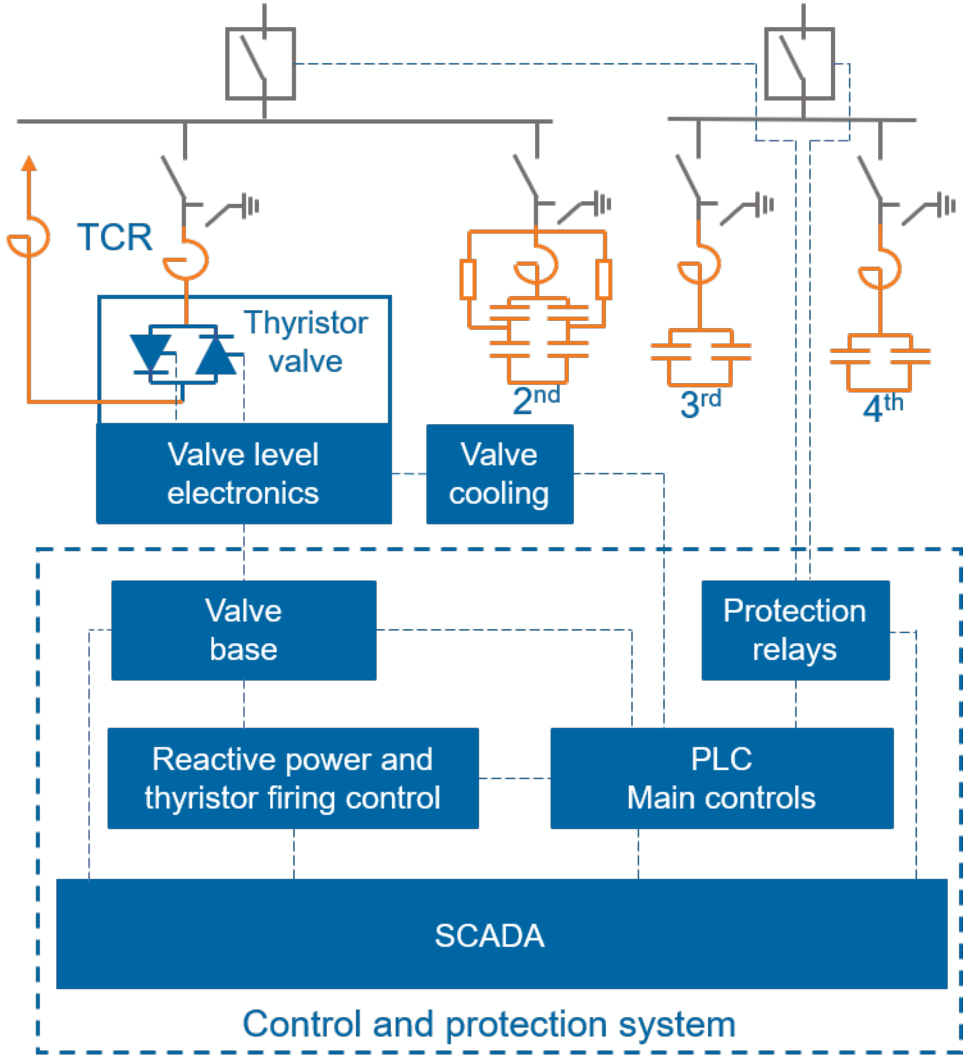
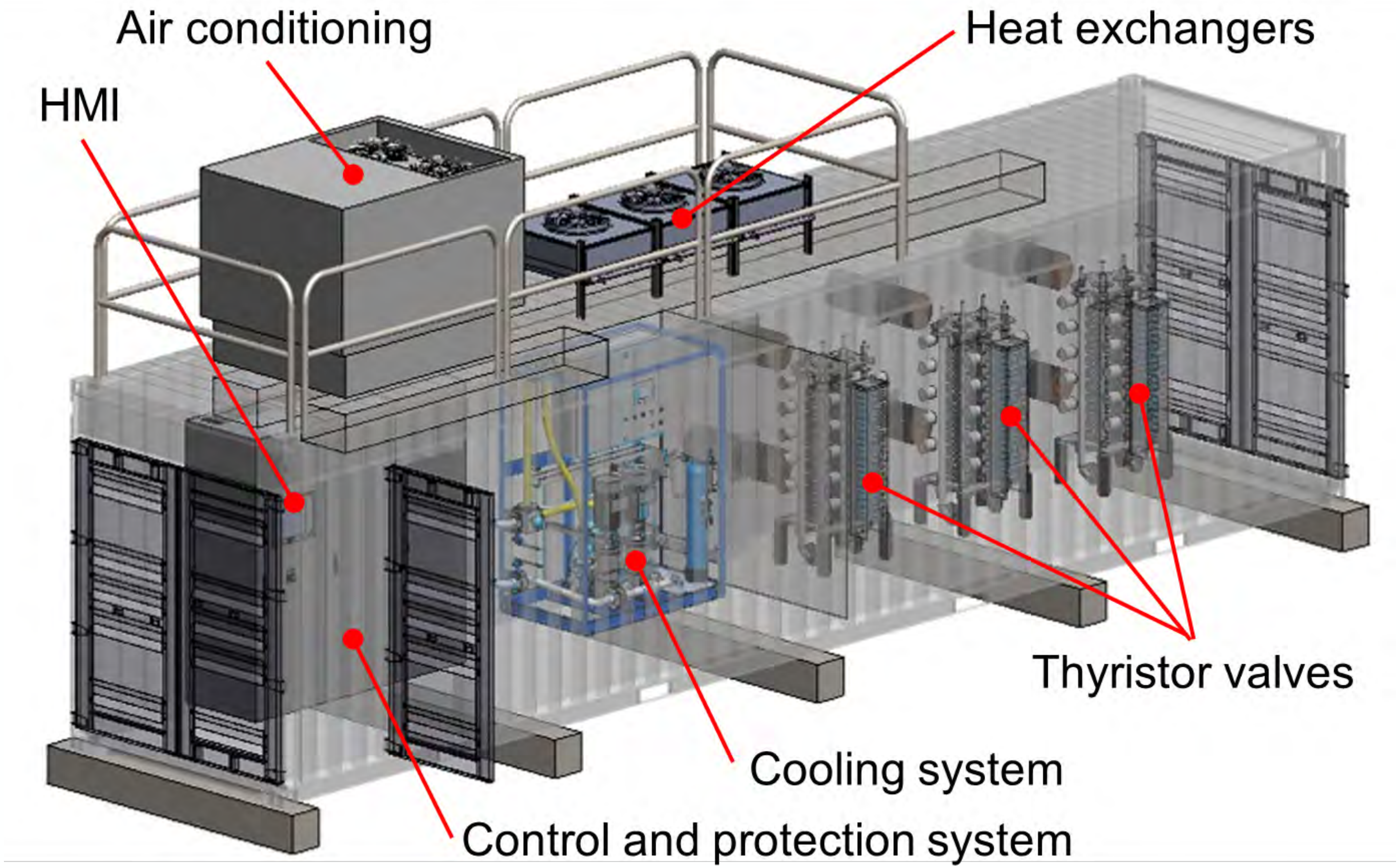
SVC Modernization

- Majority of SVC suppliers do not deliver partial modernisations or retrofits of existing SVCs
  - Modernisation = renewal of existing equipment
- Hubbell **SVC Core Technology Concept permits the upgrade of only some components in an existing SVC**
  - Hubbell Power delivers new active components to the existing SVC
    - Thyristor valves, C&P system, cooling system and SCADA
  - If needed other companies deliver the passive components, such as filter capacitor banks or Thyristor Controlled Reactors

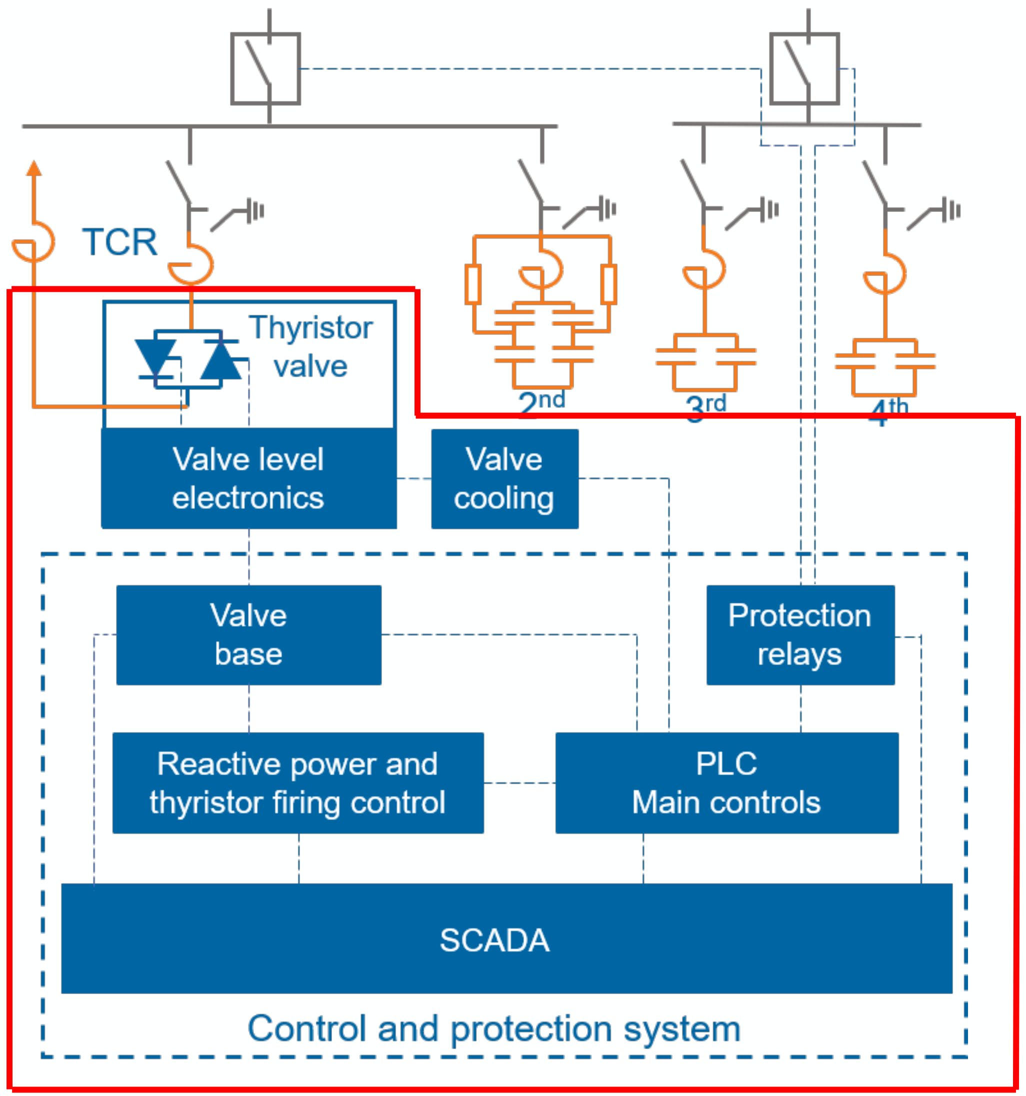


Containerized active part example design



1. Full active part replacement

- Fully updated functionality
- Improvement of SVC performance (response time, flicker reduction, etc.)
- Built from state-of-the-art components with high availability of spare parts
- Remote monitoring and analysis



2. Partial active part replacement

- New power electronics with high reliability, availability of spares and lower losses
- Complete set of valve protections including forward recovery protection (FRP)
- Temperature measurement of each thyristor valve that improves monitoring

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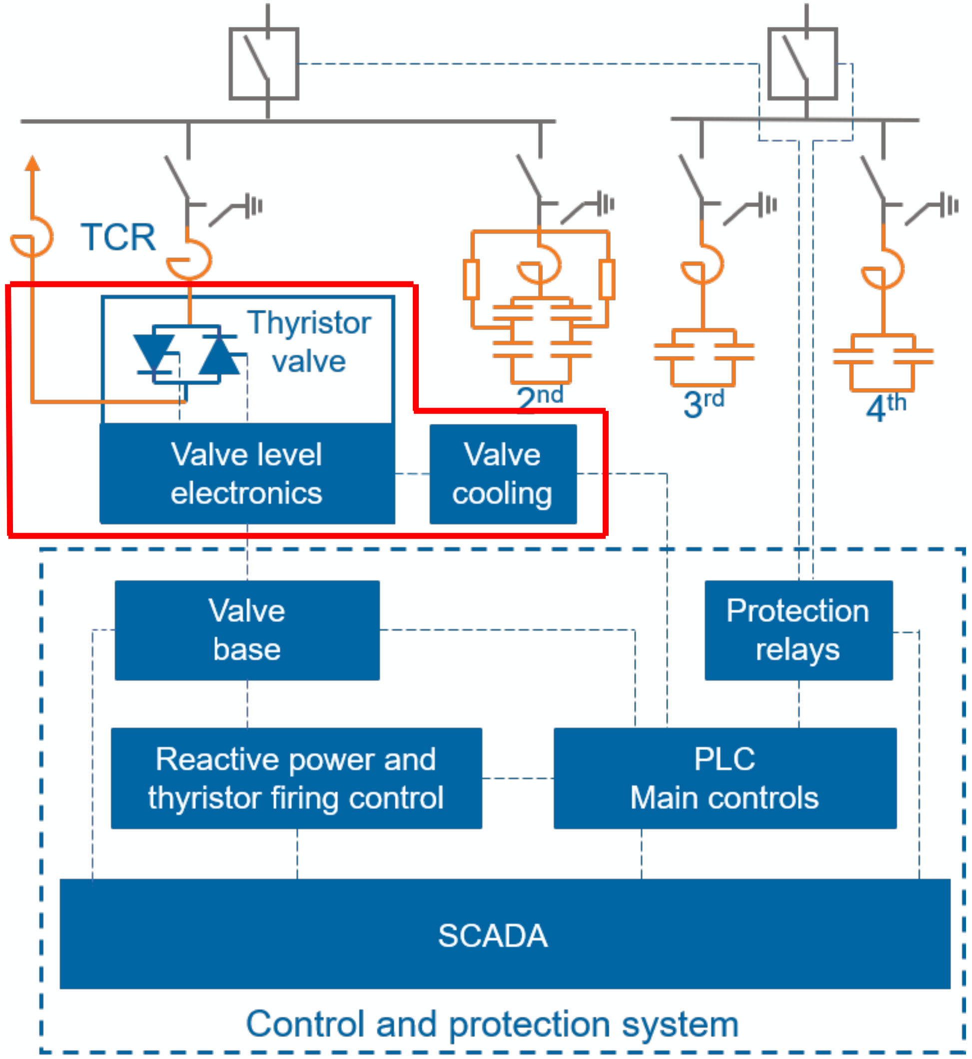
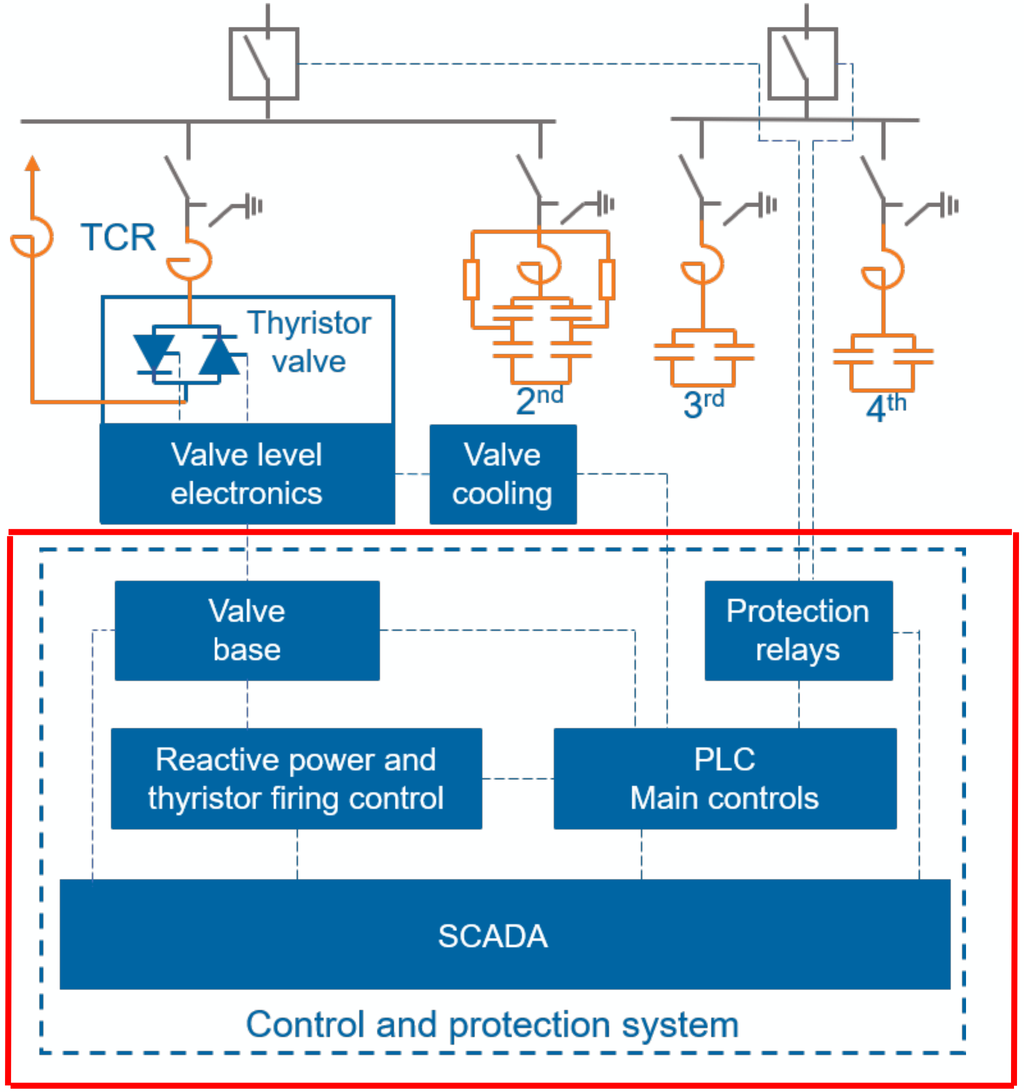


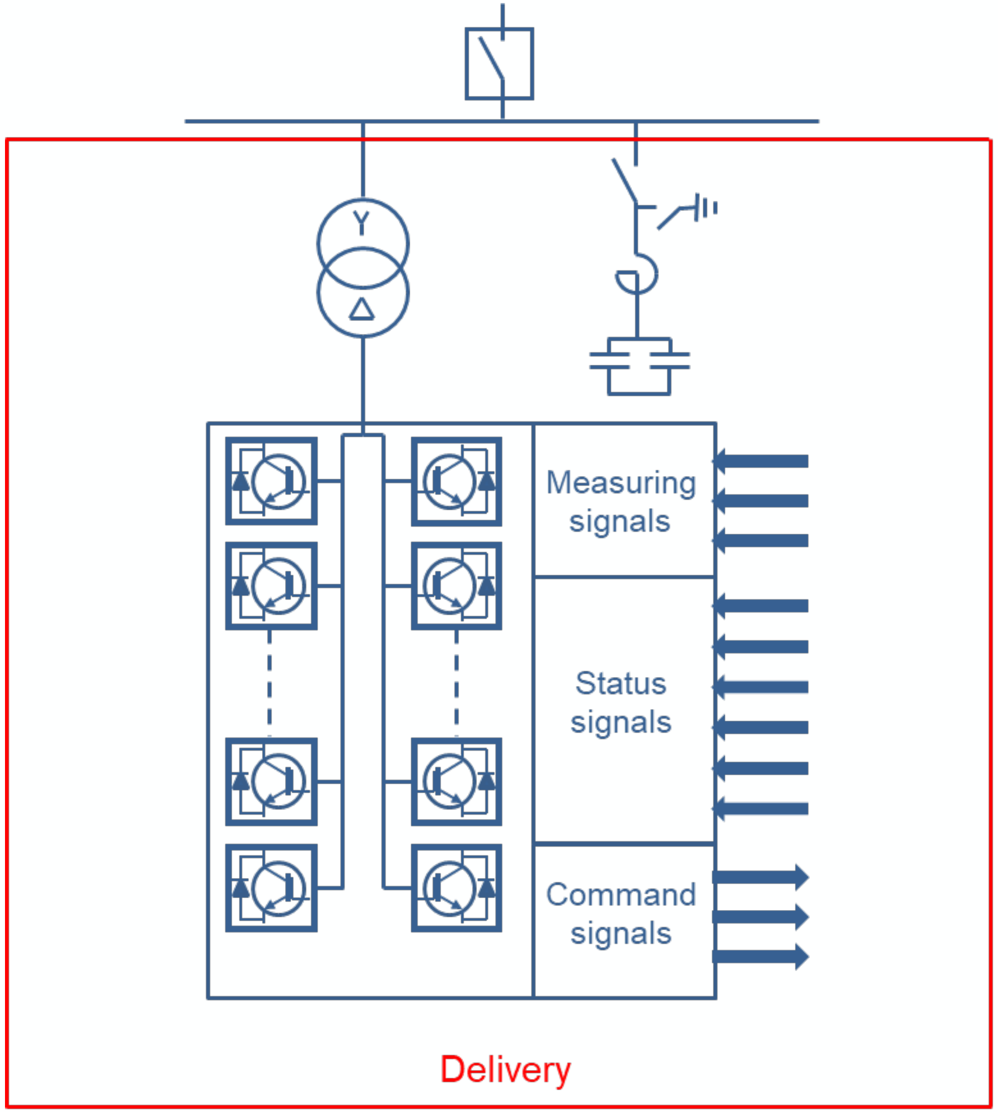
3. C&P & HMI replacement

- Improvement of SVC performance (response time, flicker reduction, etc.)
- Built from state-of-the-art components with high availability of spare parts
- Remote monitoring and analysis



4. SVC replacement by STATCOM

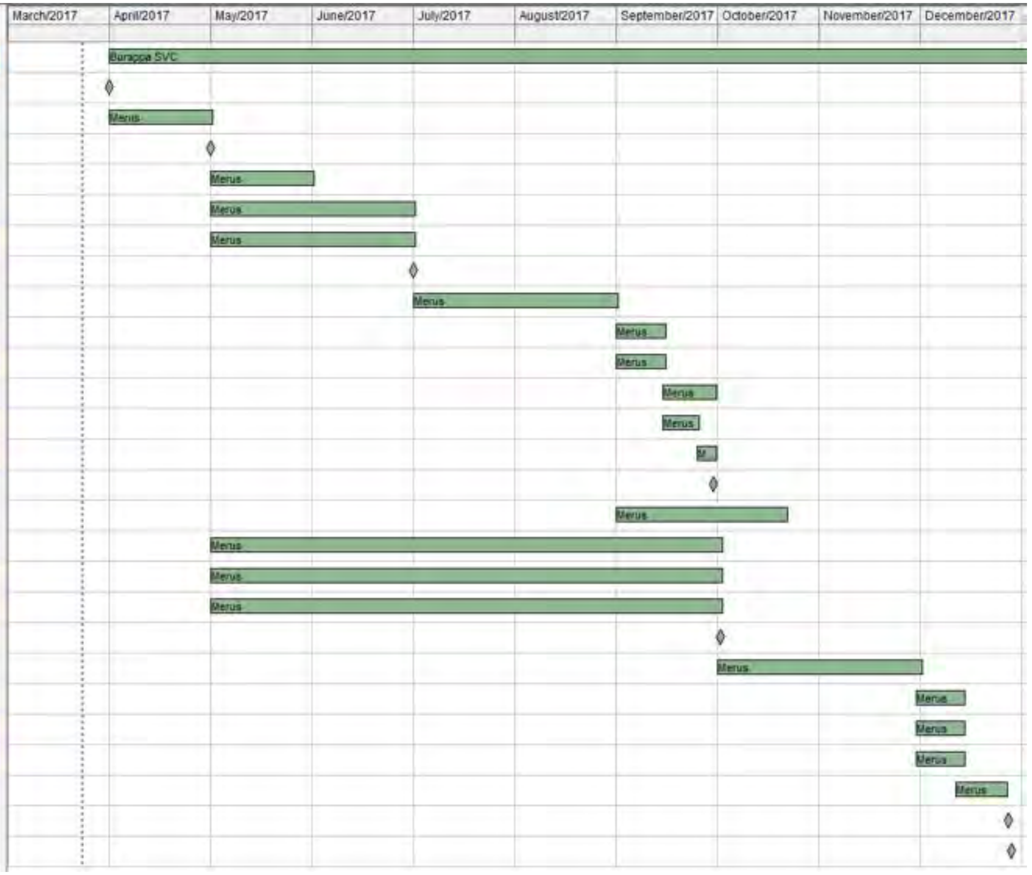
- Cost efficient transfer to STATCOM level dynamic performance
- Superior flicker reduction performance
- Smaller footprint
- It may be possible to use existing SVC harmonic filter banks to extend the control range of the STATCOM system
- Availability of spare parts
- Remote monitoring and analysis



Delivery times

- Inspection and system study 2-4 days
- Modernization project 6-9 months
- SVC downtime 6-14 days

Id	Name	Start	End	Project	Status
PR024	Burappa SVC	01/04/2017	30/11/2018	PR024	Active
CONTRACT	Merus	01/04/2017	01/04/2017	PR024	Active
BASIC ENGINEERING	Merus	01/04/2017	01/05/2017	PR024	Active
ENGINEERING FIXED	Merus	01/05/2017	01/05/2017	PR024	Active
PURCHASING	Merus	01/05/2017	01/06/2017	PR024	Active
MANUFACTURING	Merus	01/05/2017	01/07/2017	PR024	Active
C&P SYSTEM	Merus	01/05/2017	01/07/2017	PR024	Active
EQUIPMENT READY EXW	Merus	01/07/2017	01/07/2017	PR024	Active
SHIPMENT	Merus	01/07/2017	01/09/2017	PR024	Active
INSTALLATION	Merus	01/09/2017	15/09/2017	PR024	Active
C&P SYSTEM INS.	Merus	01/09/2017	15/09/2017	PR024	Active
COMMISSIONING	Merus	15/09/2017	30/09/2017	PR024	Active
COLD COMMISSIONING	Merus	15/09/2017	25/09/2017	PR024	Active
HOT COMMISSIONING	Merus	25/09/2017	30/09/2017	PR024	Active
TAKE INTO OPERATION	Customer	30/09/2017	30/09/2017	PR024	Active
SITE PREPARATION	Merus	01/09/2017	22/10/2017	PR024	Active
MANUFACTURING 2	Merus	01/05/2017	02/10/2017	PR024	Active
REACTORS	Merus	01/05/2017	02/10/2017	PR024	Active
CAPACITOR BANK	Merus	01/05/2017	02/10/2017	PR024	Active
EQUIPMENT 2 READYEXW	Merus	02/10/2017	02/10/2017	PR024	Active
SHIPMENT 2	Merus	01/10/2017	01/12/2017	PR024	Active
INSTALLATION 2	Merus	30/11/2017	14/12/2017	PR024	Active
REACTOR INS.	Merus	30/11/2017	14/12/2017	PR024	Active
CAPACITOR BANK INS.	Merus	30/11/2017	14/12/2017	PR024	Active
COMMISSIONING 2	Merus	12/12/2017	27/12/2017	PR024	Active
TAKE INTO OPERATION2	Customer	28/12/2017	28/12/2017	PR024	Active
WARRANTY	WARRANTY	29/12/2017	29/12/2017	PR024	Active



Hubbell's Power's scope

- New systems
  - System study and report
  - Project management
  - Equipment delivery
  - Installation supervision
  - Commissioning

- Modernisation
  - Site survey
  - Measurements and report
  - Project management
  - Equipment delivery
  - Installation supervision
  - Commissioning

Key takeaways

- EAF are demanding loads for the grid → only SVC or STATCOM can guarantee sufficient performance
- SVC or STATCOM sizing
  - With simulations if new installation
  - With measurements if existing installation
- SVC generally for higher powers
- STATCOM for lower powers and cases where flicker attenuation greater than >2 needed
- SVC modernisation for cases where existing SVC has problems and/or poor spare part availability

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