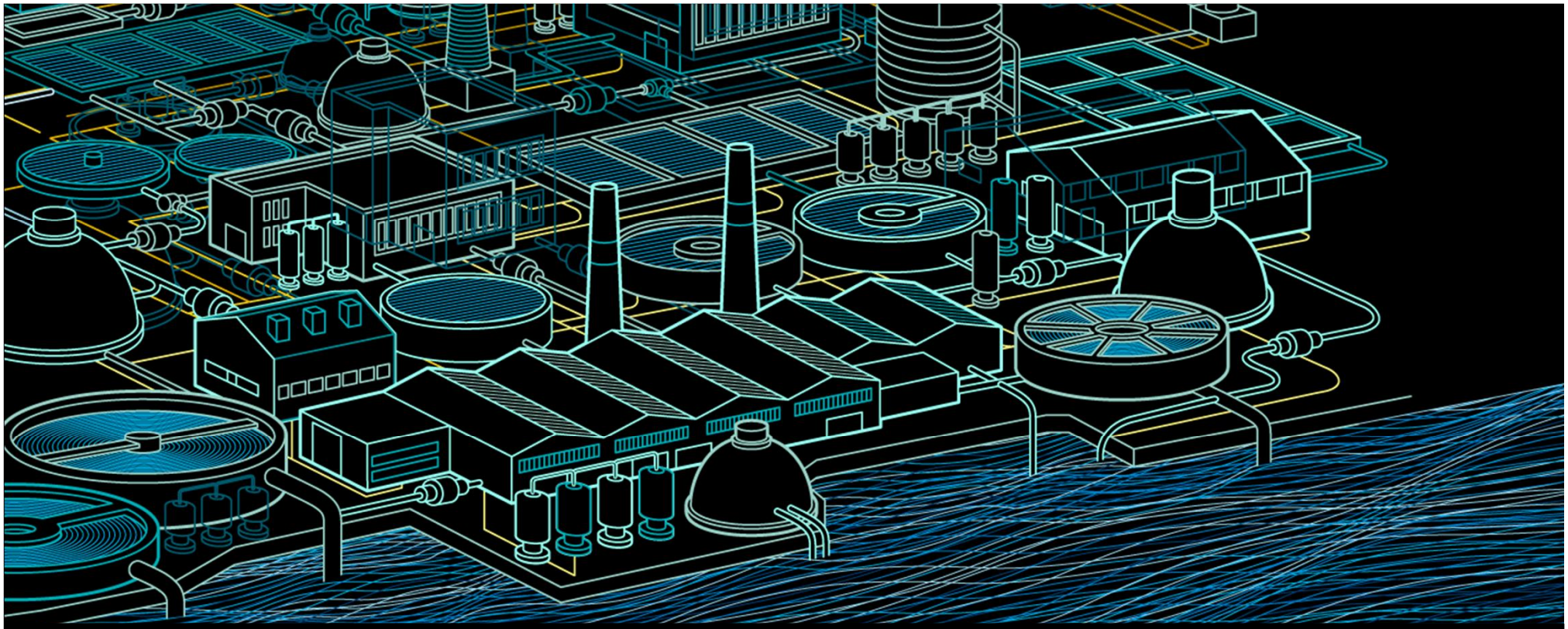


Alfred Wehrle, Market Manager Water Market, MV Drives

ABB drives for the water market
Medium voltage drives for energy savings and life-cycle improvements

3BHT 490 567 R0001 Rev. B

Table of contents

Discrete Automation and Motion, Drives and Controls
VSDs: 0.12 kW up to > 100 MW

Drives and Controls

- **Low voltage AC drives from 0.12 to 5600 kW**
- **Medium voltage drives from 250 kW to more than 100 MW**
- **DC Drives from 4 kW to 15000 kW**
- PLCs, HMIs, and wireless sensors and actuators
- Software tools
- Energy saving tools
- Service

Power Conversion

- Advanced power electronics
- Converter products
- Excitation and synchronizing systems
- High power rectifiers
- Power quality and power protection products, incl. UPS
- Traction converters
- Wind turbine drives
- Solar inverters
- Charging infrastructure for electric vehicles
- Service

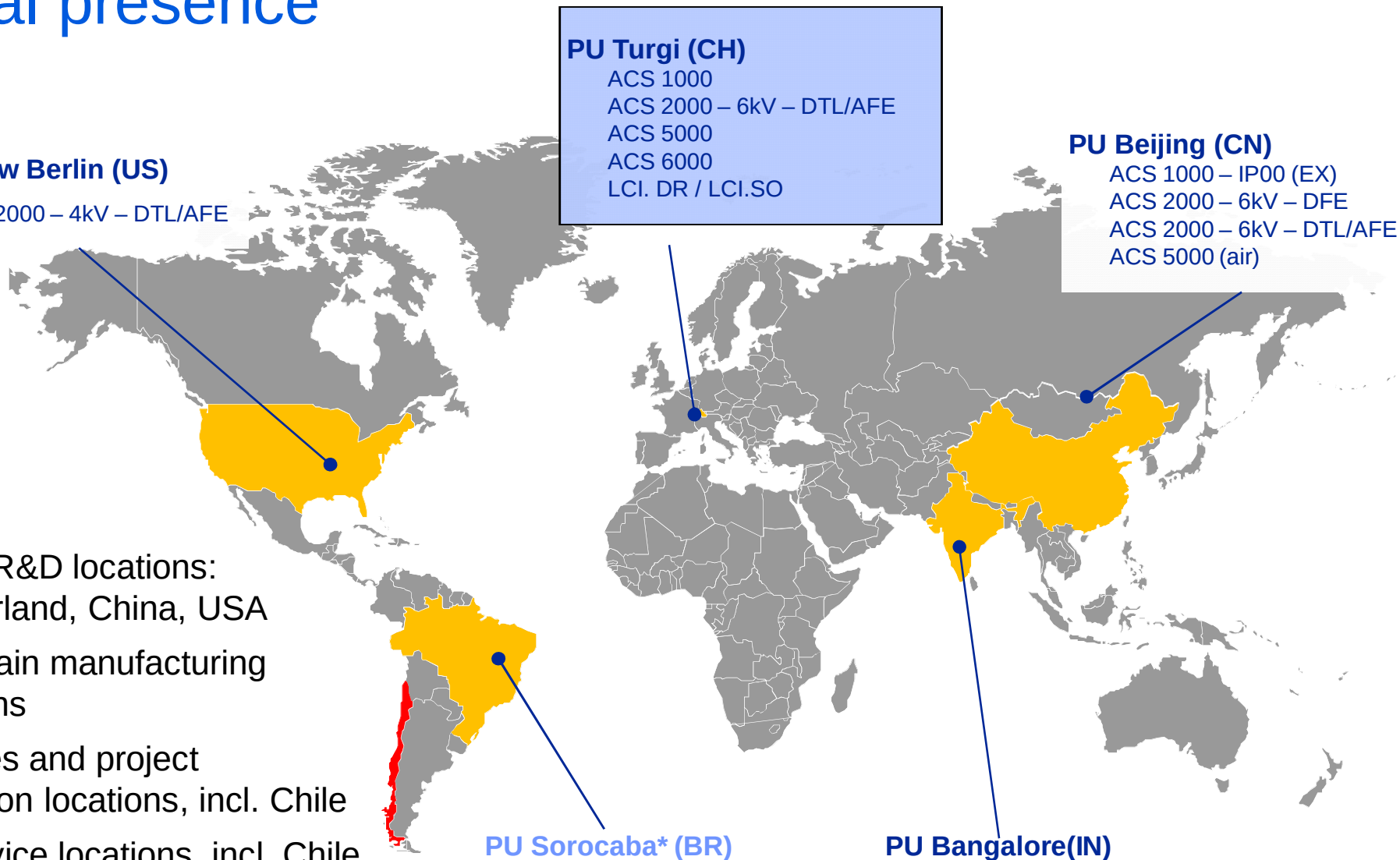
Motors and Generators

- Low voltage motors from 0.25 to 1000 kW
- High voltage motors and generators up to 70 MW
- High speed motors
- Traction motors
- Wind power generators
- Diesel generators
- Gas and steam turbine generators
- Hydro generators, tidal waves, etc
- Service

Robotics

- Industrial robots
- Robot controllers and software
- Industrial software products
- Application equipment and accessories
- Robot applications and automation systems for automotive, foundry, packaging, metal, solar, wood, plastics, etc. industries
- Service

Medium Voltage Drives
Global presence



- Three R&D locations: Switzerland, China, USA
- Five main manufacturing locations
- 40 sales and project execution locations, incl. Chile
- 40 service locations, incl. Chile

Turgi / Switzerand
Center of excellence for Medium Voltage Drives

Global responsibility for:

- Research & Development
- Sales & Marketing
- Engineering & Project Management
- Production
- Service

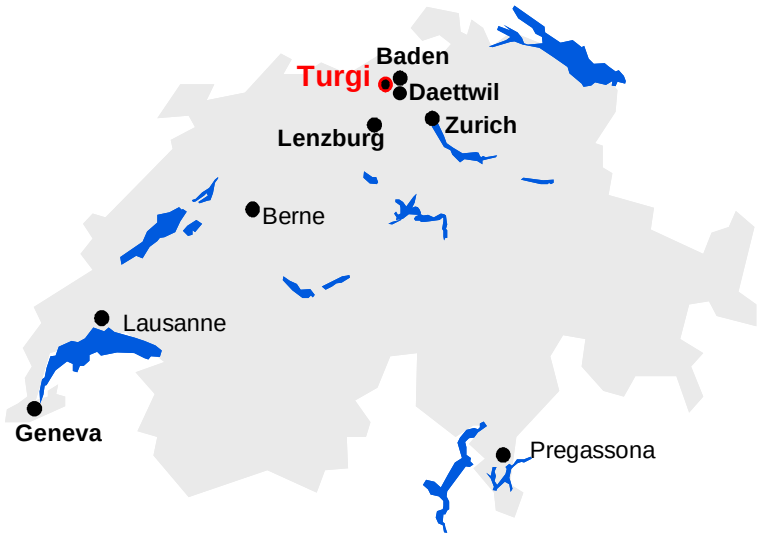


ABB – Pioneering VSD technology since 1969

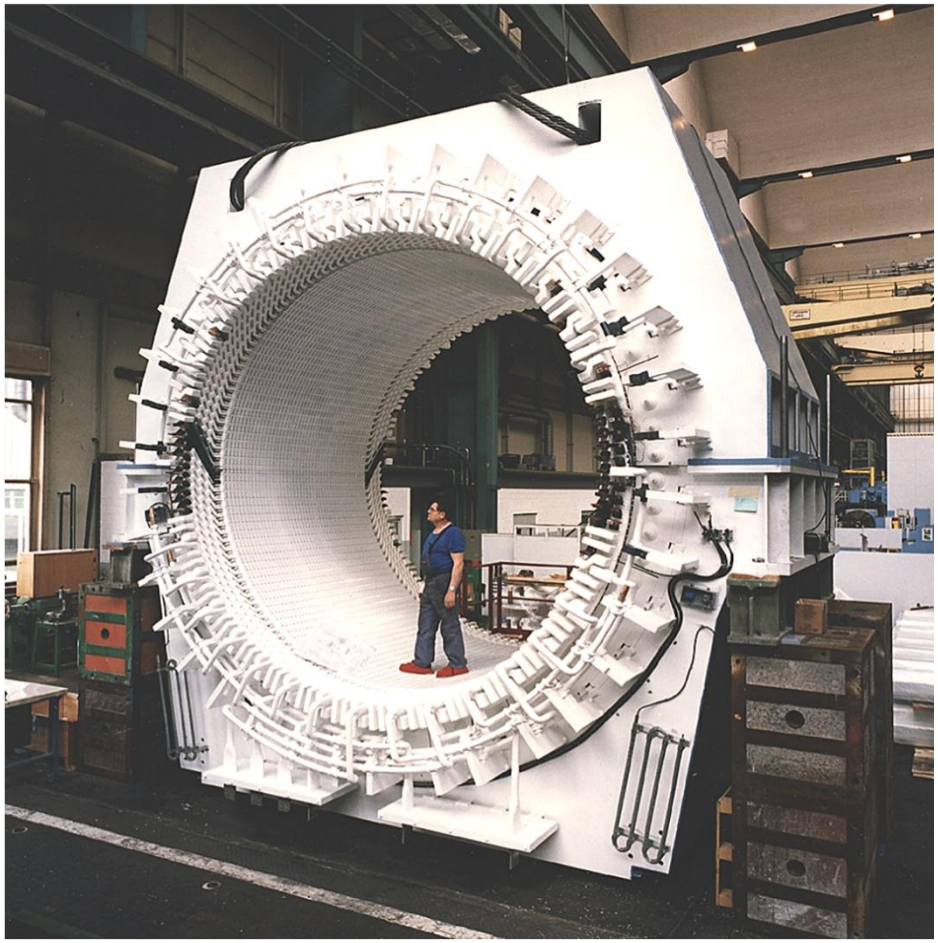
- 44 years experience in developed, design, manufacturing & service
- **The latest innovation:**

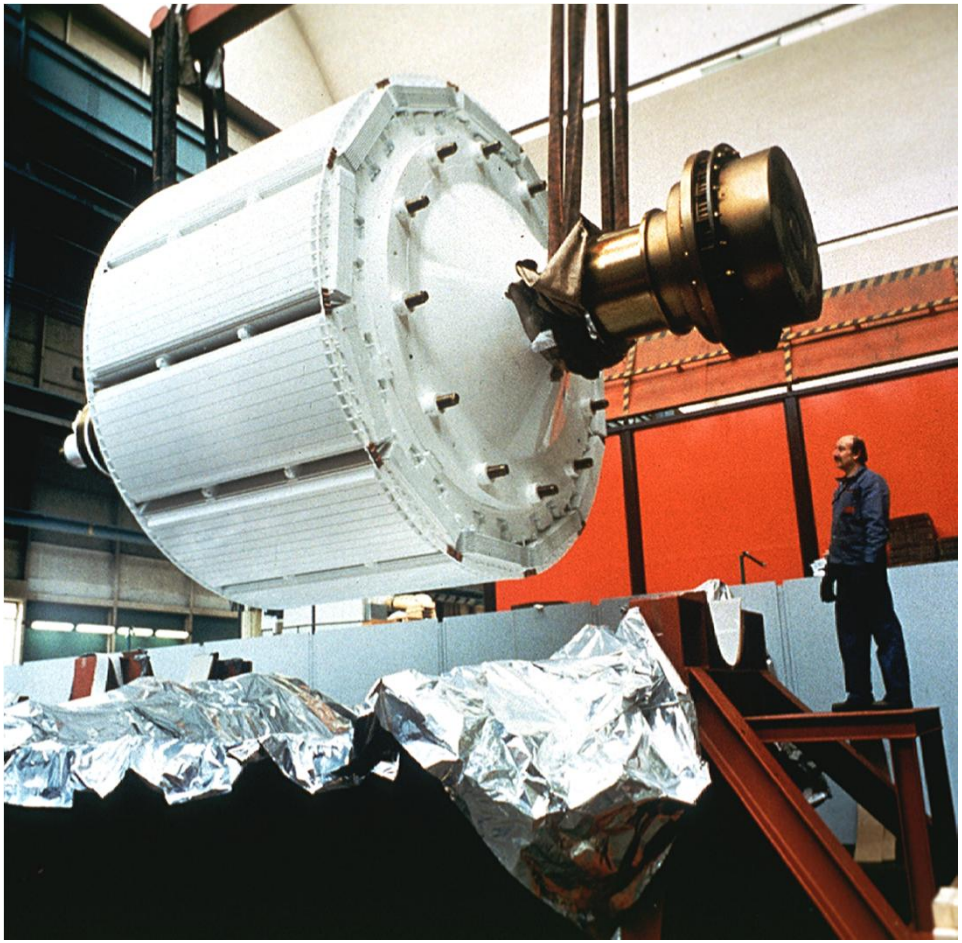
  ACS 2000, the first low harmonic transformer-less general purpose MV drive with VSI topology

Winner of Frost & Sullivan 2010
European Medium Voltage
Drives New Product Innovation Award

Medium voltage drives
High lights – USA NASA wind tunnel

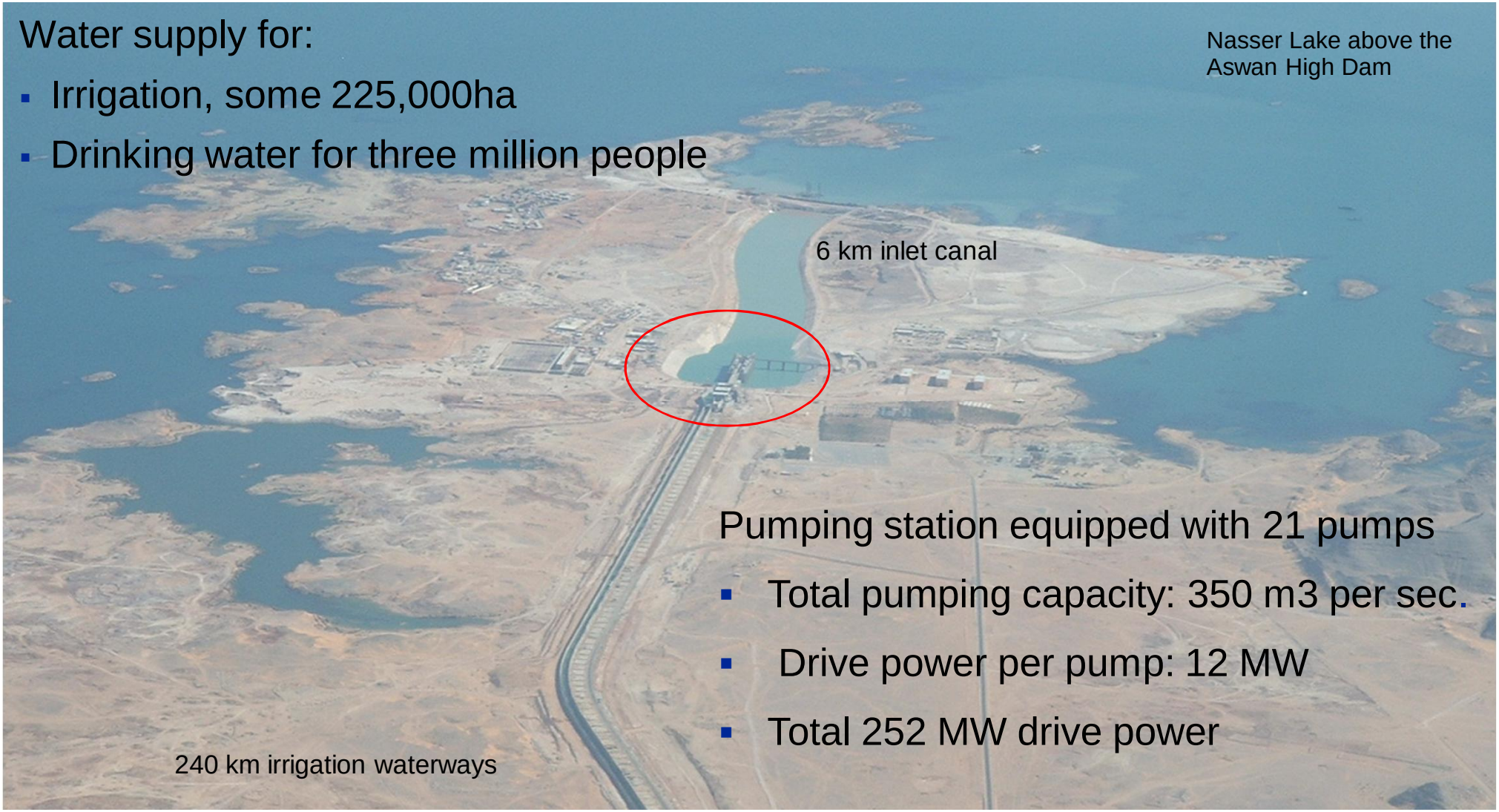
The world largest Variable Speed Drive “101 MW”





- Motor voltage: 2 x 12.5 kV
- Speed range: 360 – 600 rpm

Water market
High lights – Egypt, Aswan pumping station



Water market
High lights – Egypt, Aswan pumping station

- Dimension of the pumping station:
  L 140m / W 40m / H 70m

- Discharge capacity of one pump: 16.7m3/s
- Total discharge capacity (21 pumps): 350 m3/s
- Total head: 57m
- Speed range: 210 – 300 rpm
- Total drive power: 252 MW

3BHT 490 567 R0001 Rev. A

Minerals and Mining
High lights – Largest gearless mill drives (GMD)

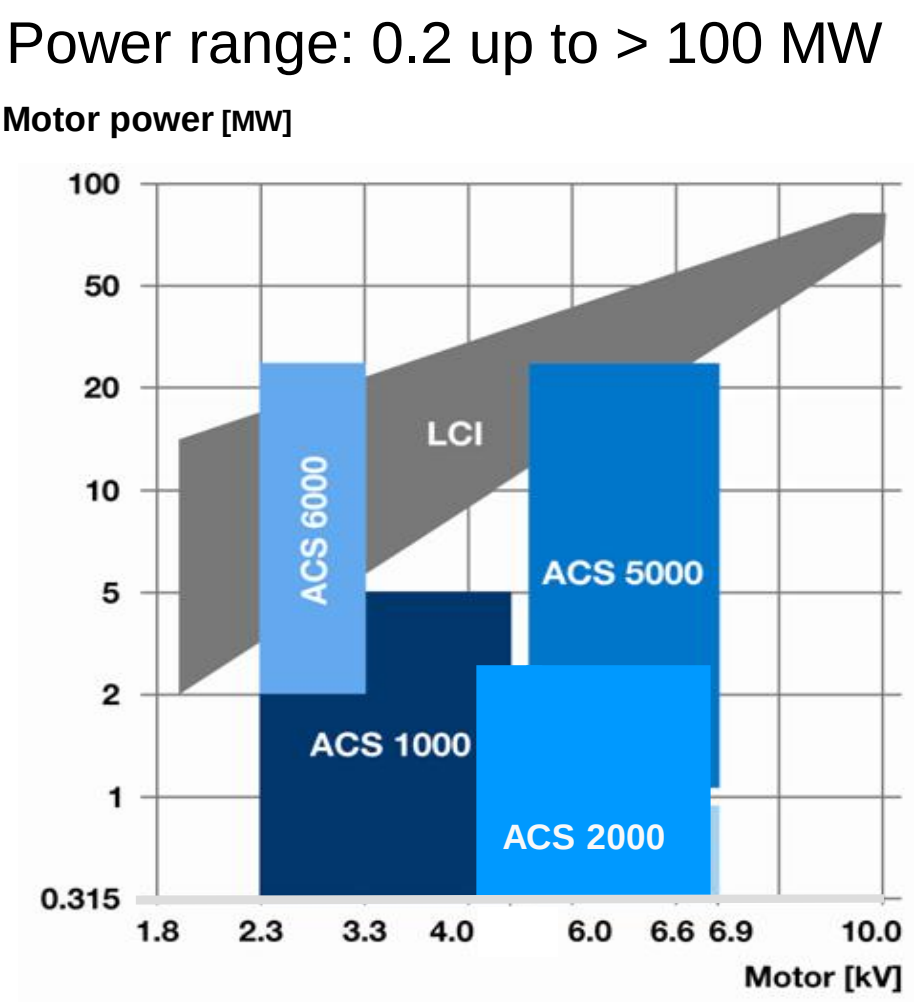
PERU, one of the largest gearless mill drives (for crushing ore), 28 MW drive power

- **Peru / Conga Project**
  - **Rated power:** **28 MW**
  - Diameter: 42 ft (12.8 meter)
  - Rated speed: 8.86 rpm
  - Maximum speed: 10.0 rpm
  - Starting torque: 150%
- **Chile, Examples with Cyclo converters:**
  - **Collahuasi, 1 x 23 MW, 2 x 17.2 MW**
  - **Escondida, 1 x 15.7 MW, 3 x 13.4 MW**,
- **Other projects in Chile:**
  - Sierra Gorda, 3 Drives
  - MMH, 3 Drives
- **Chile, total 13 high power GMD drives**

Status: June 2013

Medium voltage drives
Products and main markets

Power range: 0.2 up to > 100 MW



(ACS) Alternating **C**urrent **S**tandard Converter


Marine


Chemical, Oil & Gas


Metals


Cement, Mining & Minerals


Water


Power


Pulp & Paper


Special applications, e.g. wind tunnels

Medium voltage drives in the water market
VSD and soft starting solutions

Segmentation	Applications	Typical power range
Raw and drinking water	▪ Intake and transmission pumps ▪ Distribution and booster pumps	0.3 - 5.0 MW 0.3 - 1.5 MW
SWRO desalination	▪ Sea water intake and process pumps	0.3 - 4.0 MW
Waste water	▪ Transmission, influent and effluent pumps ▪ Treatment pumps and aeration blowers	0.3 - 5.0 MW 0.3 - 1.5 MW
Domestic	▪ District cooling and heating transfer and distribution pumps	0.3 – 1.5 MW
Industrial	▪ Intake and transmission pumps for cooling/process water	0.3 - 7.0 MW
Lift irrigation and large pumping stations	▪ Intake and transmission pumps	5.0 - 40 MW

Pumping systems
Typical challenges and problems

- Unexpected high energy costs mainly by reason of mechanical flow control methods
- Starting and stopping of motor and pumps
- High regular maintenance costs of the pumping system
- Unexpected maintenance and repair costs (fast wear and tear)
  - Low life time of system components due to high pressure during starting and stopping of the pumps
  - Water leakage in the pumping system due to high pressure during starting/stopping

The result:

- High energy costs
- High maintenance and repair costs
- Low availability of system components

OPEX

High Live Cycle Costs (LCC)

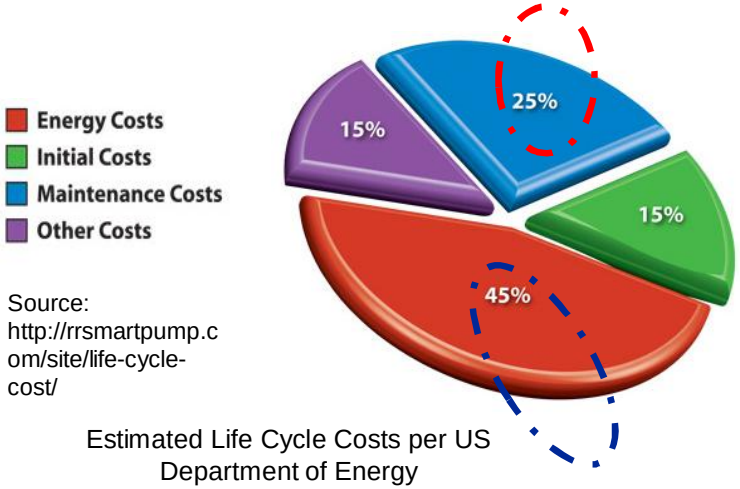
Live cycle costs (LCC) of pumping systems
High energy and maintenance costs

Typical pumping station

Pumping system

Pumping system consisting of:

- Pumps and motors
- Valves (control valves, shut of valves, check valves, etc.)
- Transfer and distribution pipeline



Source: http://rrsmartpump.com/site/life-cycle-cost/

Estimated Life Cycle Costs per US Department of Energy

Typical LCC of a pumping system:

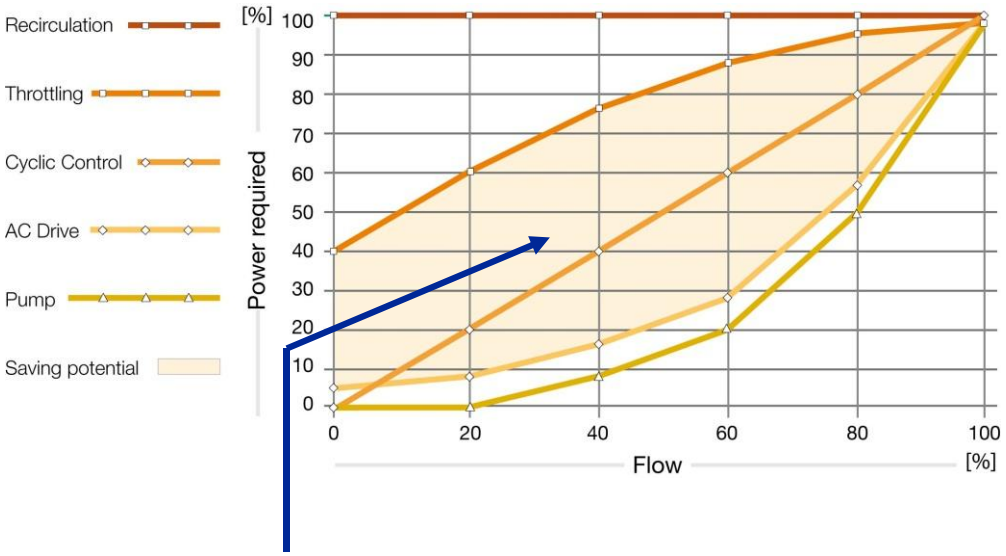
- High energy costs, in this case 45%
- High regular maintenance costs, in this case 25%

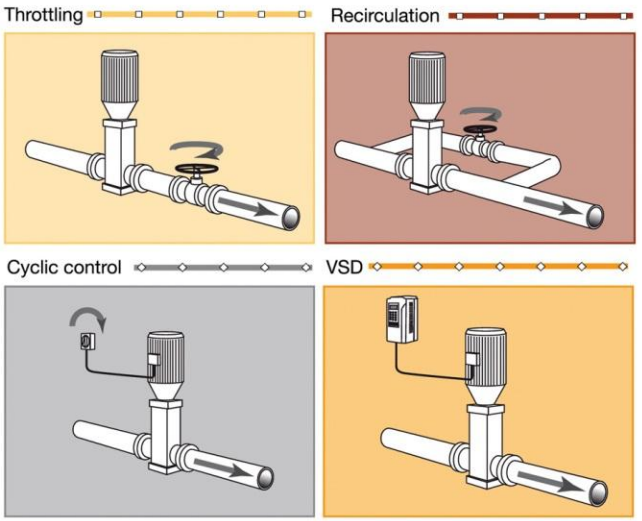
Live cycle costs (LCC) of pumping systems
Reduction of LCC with VSDs

- **Energy costs:**
  - **Significant energy savings at reduced motor/pump speed**

Variable speed drives
Higher efficiency and less emissions

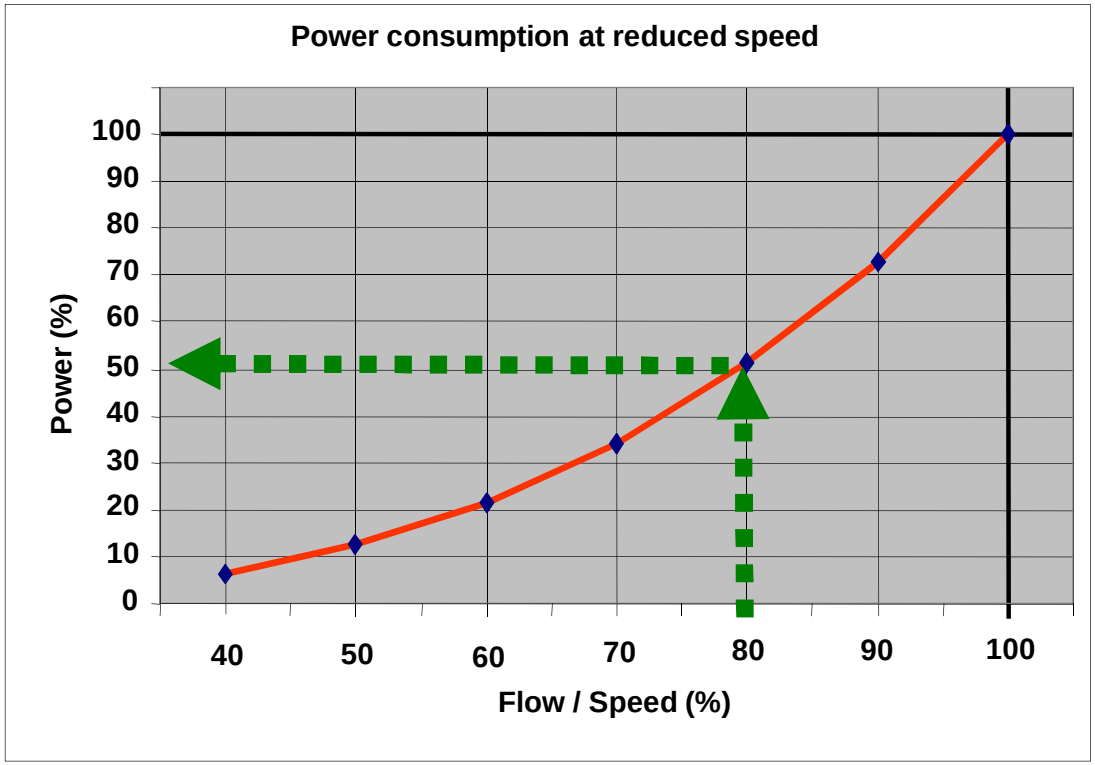
Power consumption for various control methods





- Energy savings potential of VSD Control versus mechanical control methods
- Most pumping systems often run at partial load > huge energy savings can be achieved by controlling the speed with variable speed drives

Power demand of centrifugal pumps



Pump affinity law

Power is proportional to the cube of speed

Example: 4 MW pump drive

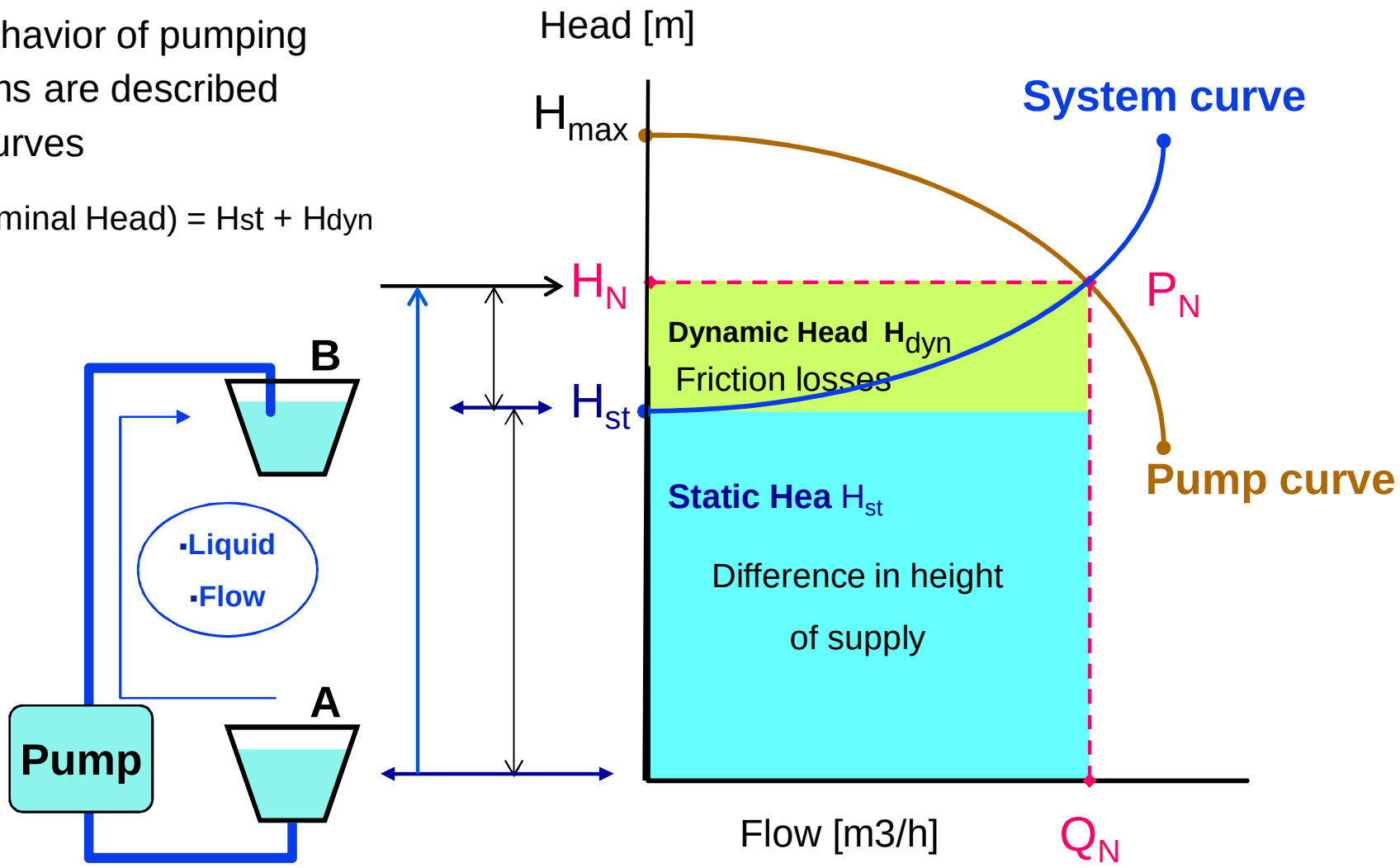
- At 80% seed power consumption is only 51% or 2 MW

Flow / Speed (%)	100	90	80	70	60	50	40	30	20	10
Power (%)	100%	72.9%	51.2%	34.3%	21.6%	12.5%	6.4%	2.7%	0.8%	0.1%
Power (kW)	4'000	2'916	2'048	1'372	864	500	256	108	32	4
Speed (rpm)	1'500	1'350	1'200	1'050	900	750	600	450	300	150

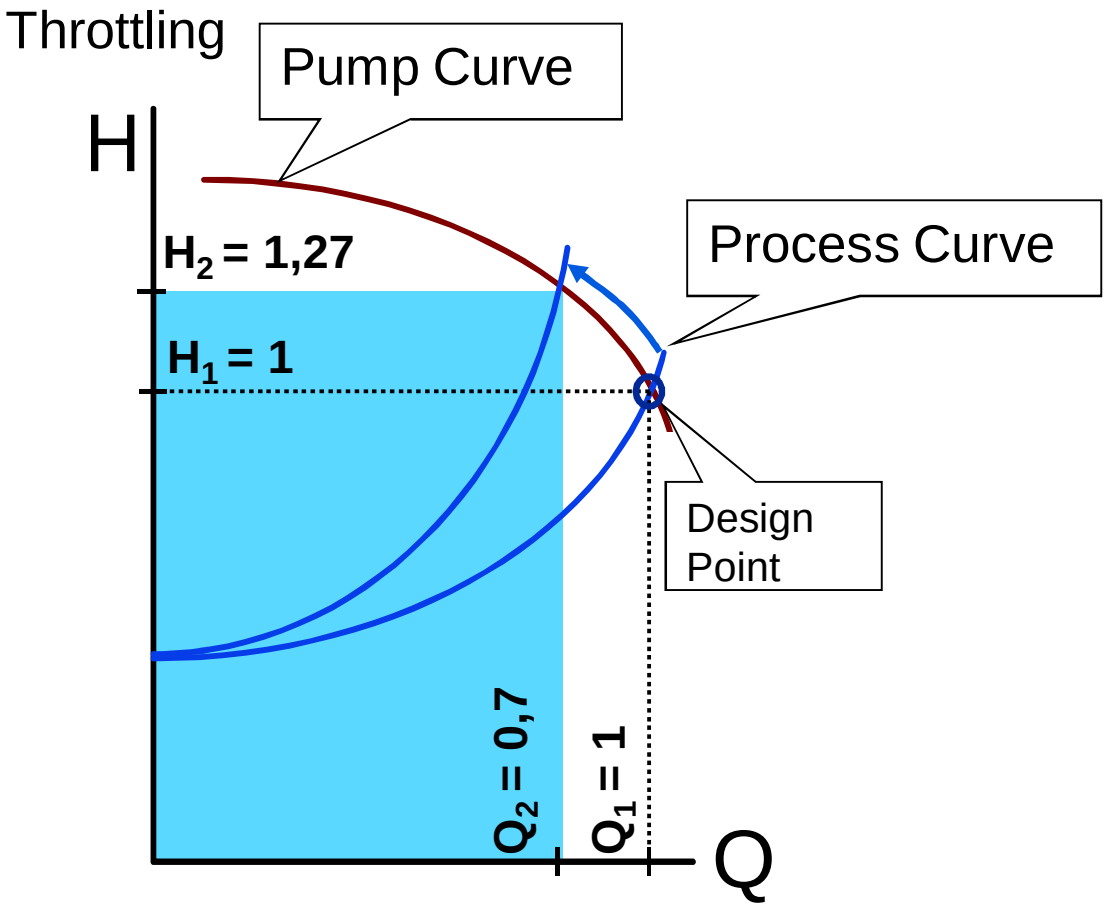
Pump system curve

The behavior of pumping systems are described with curves

H_N (Nominal Head) = H_{st} + H_{dyn}

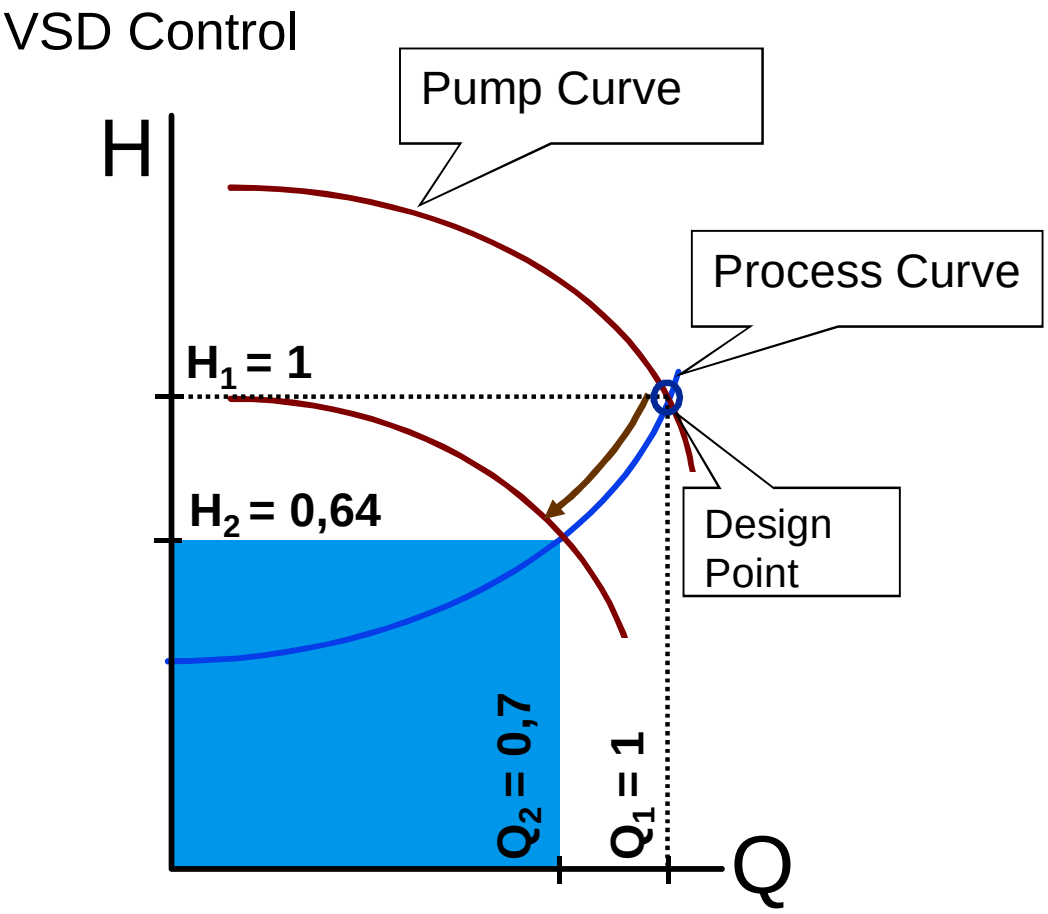


Power demand
Throttling control versus VSD control



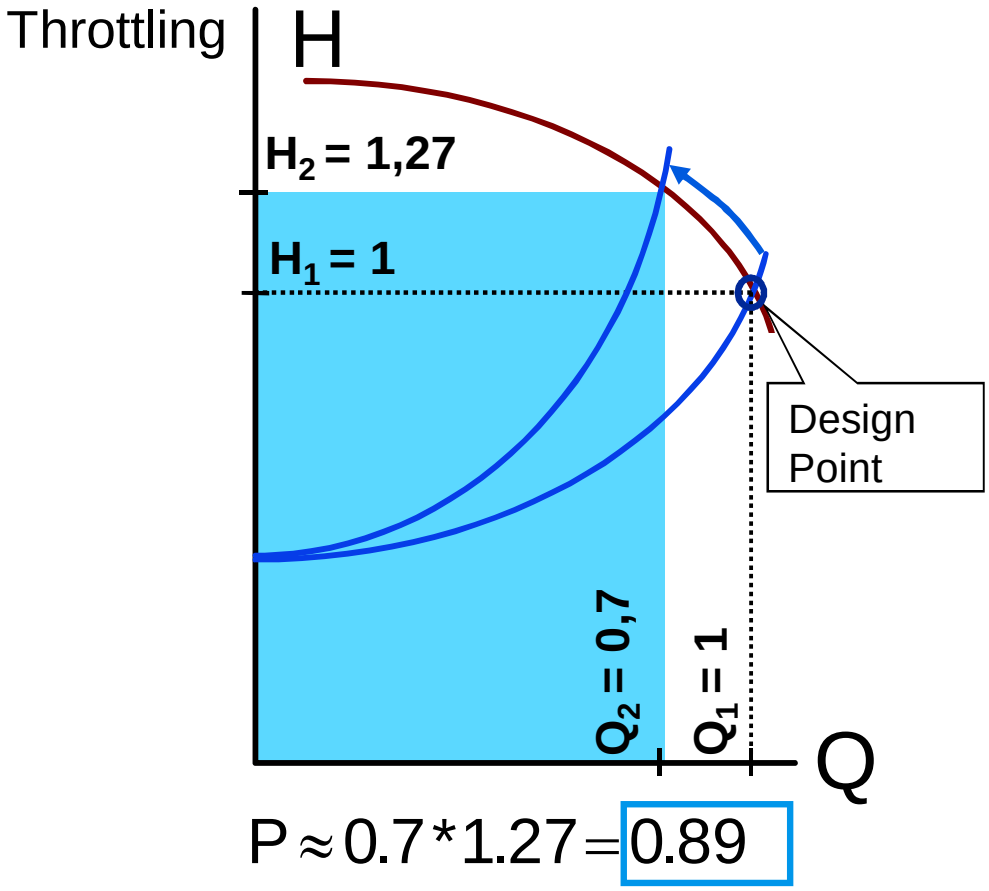
$$P \approx 0.7 * 1.27 = 0.89$$

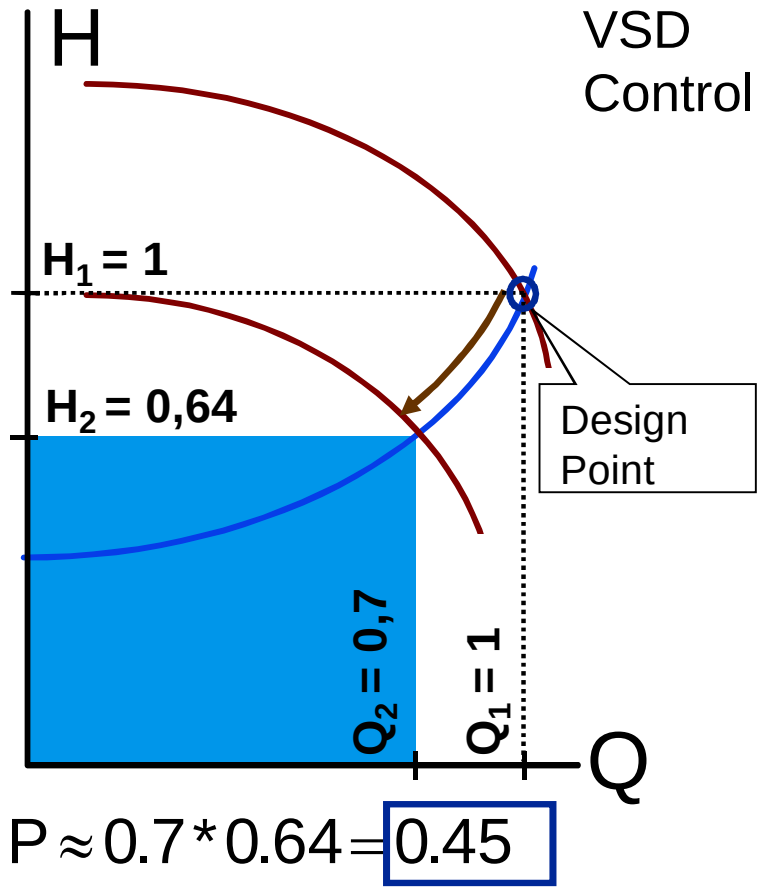
Power demand
Throttling control versus VSD control



$$P \approx 0.7 * 0.64 = \boxed{0.45}$$

Power demand
Throttling control versus VSD control

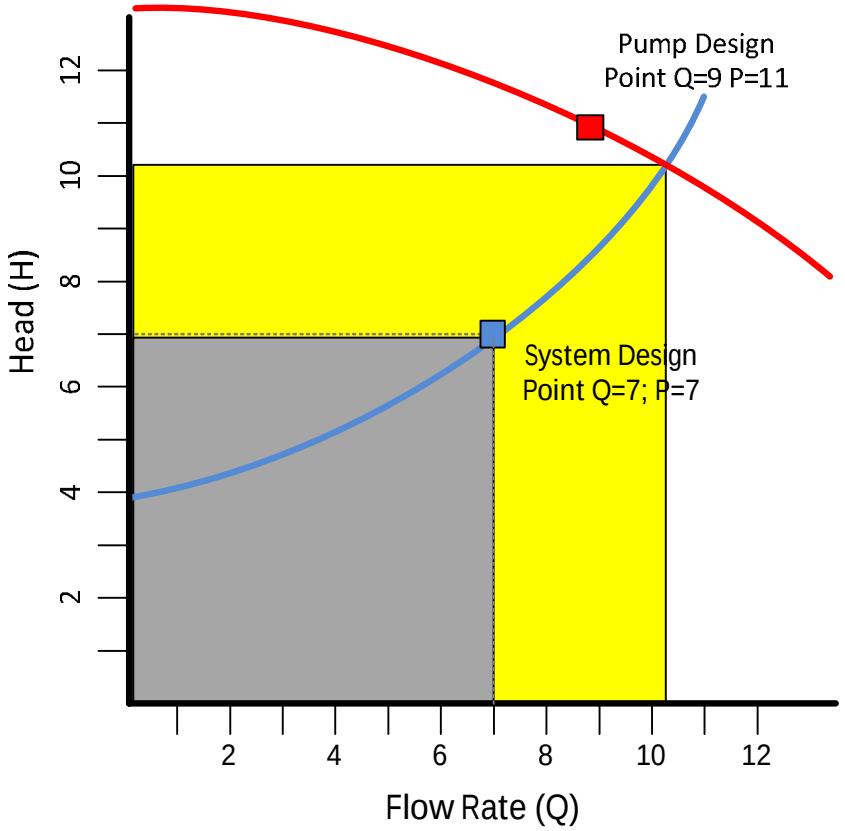




Savings with VSD: 0.44 or approx. 50%

Pump dimensioning
Impact on Energy Efficiency

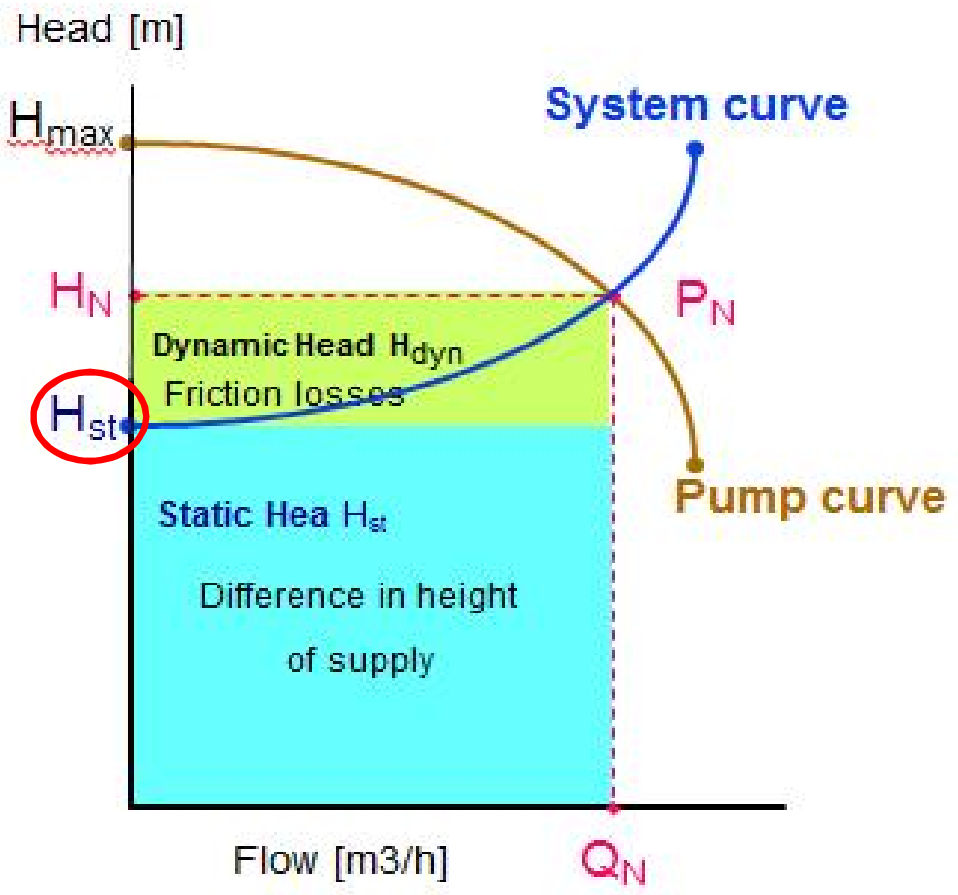
- Oversizing pumps is common practice
- Pumps are sized for maximum flow and head PLUS safety factors
  - Process Engineer
  - Mechanical Engineer
  - Pump Engineer
- Field modifications



- In this situation pump/system is going to provide more flow and head than required.
- Energy consumption also higher

Pumping Systems with high static head
Variable Speed Operation

- **Care must be taken on systems with high static head**
- As pump is slowed down, operating point moves up pump curve
- Eventually reach shut-off point(no flow)
- Pump looses efficiency

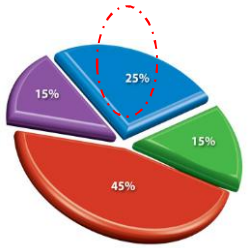


Live cycle costs (LCC) of pumping systems
Reduction of LCC with VSDs

- **Energy costs:**
  - **Significant energy savings at reduced motor/pump speed**
  - **High power factor (0.95 to 1.0)**

- **The benefit:**
  - **Reduced life cycle costs (OPEX) of the pumping**

Live cycle costs (LCC) of pumping systems
Reduction of LCC with VSDs



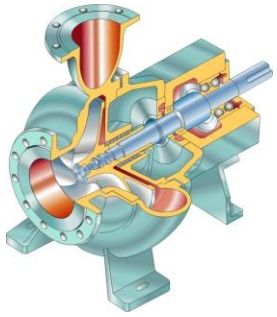
Maintenance and repair costs:

- Reduction of maintenance and repair costs due to LESS pressure at pumping system components during starting, stopping and at operation with reduced motor/pump speed

Live cycle costs (LCC) of pumping systems
High maintenance and repair costs

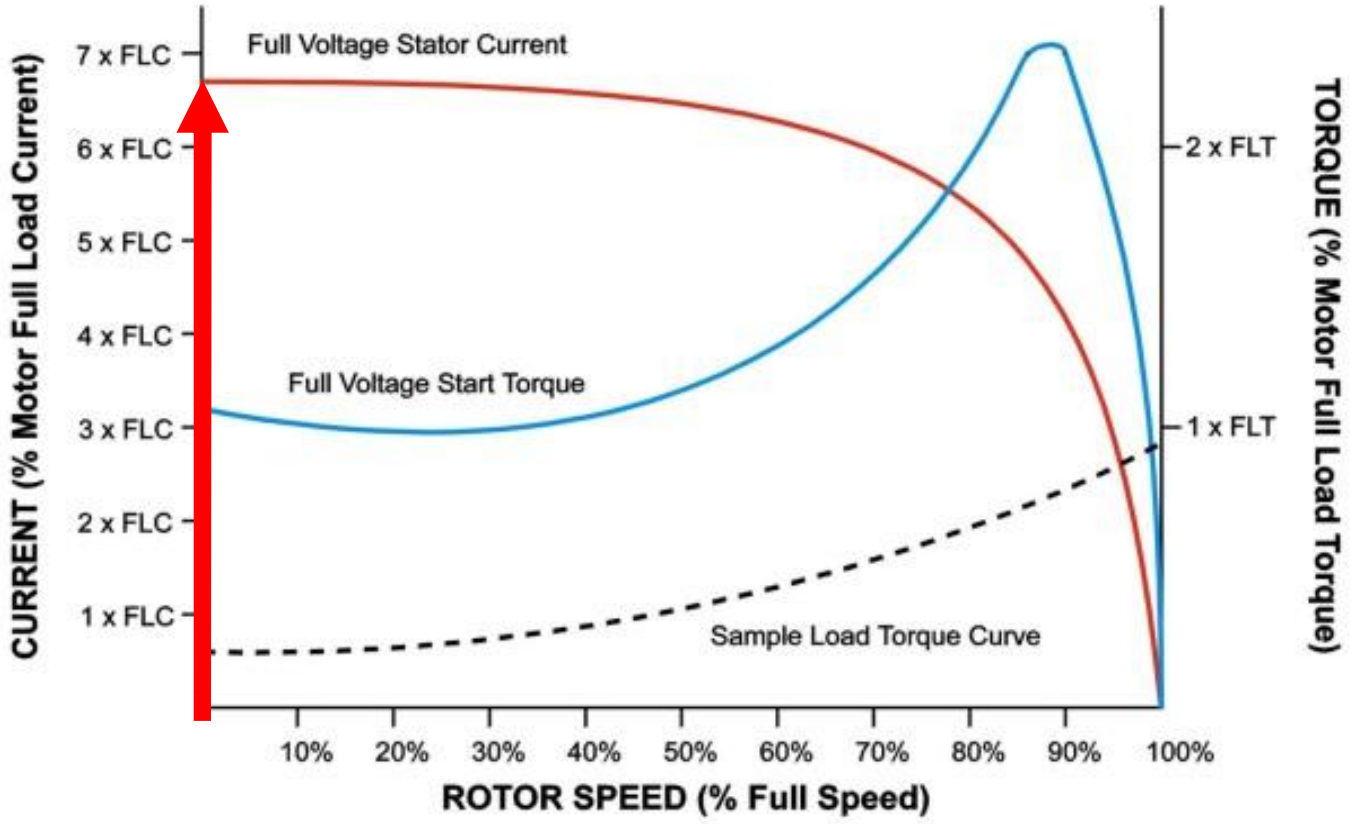
Sensitive wear & tear parts in pumping systems:

- Bearings and gaskets of system components such as motors, pumps, valves, etc.
- Joints and gaskets in the pipeline
- Motor winding and stator cage by DOL start
  Typically DOL starts are limited to max. 3 starts per hour



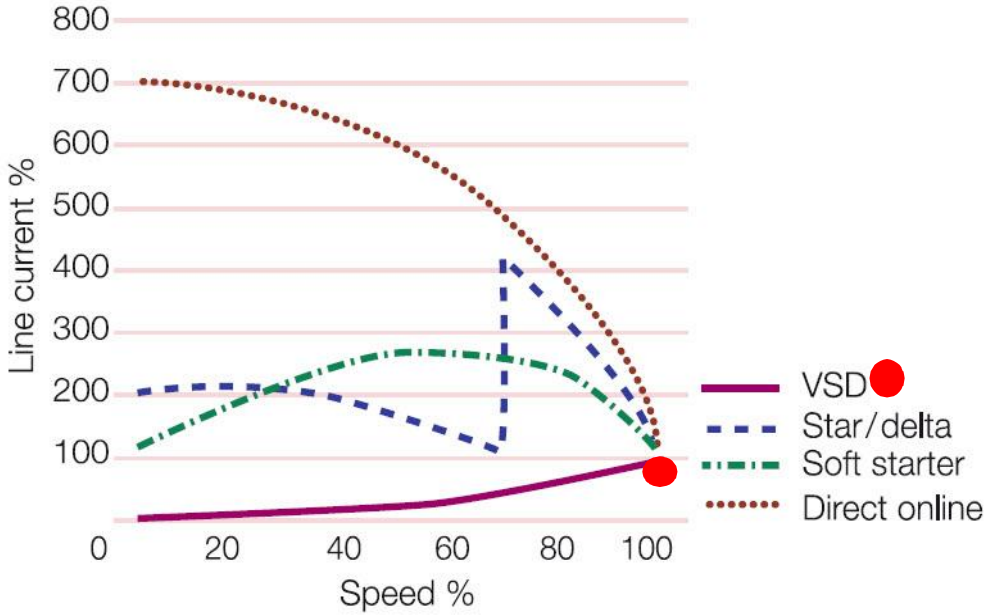
Starting an Induction Motor Direct on Line

- The Motor accelerates up to speed in an uncontrolled way
- Equally when stopping, the rate of deceleration is totally uncontrolled.



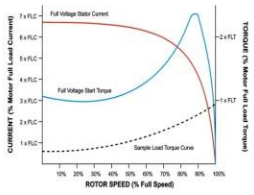
- Soft Start and Soft Stop is not possible

Staring methods of induction motors
Overview

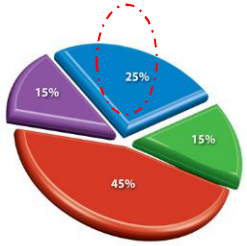


Starting method	Inrush current in % compared to I_N
Variable speed drive (VSD)	100% (depending on start up requirements)
Typical soft starter	up to 300%
Star/delta	up to 400%
Direct on line (DOL)	up to 700%

Starting an induction motor Direct on Line (DOL)
High wear and tear – high maintenance costs



- Negative impact on network
  - High inrush current during starting resulting in voltage trop
    - Typical problems:
      - Other consumers get disturbed
      - Other motors in operation may trip
      - Start of motor maybe not possible at all
- High thermal stress at motor windings
  - Limited number of starts (typically 3 times per hour)



- High mechanical stress at system components such as motor, pump, bearings, gaskets, valves, pipeline, etc.

Starting an induction motor Direct on Line (DOL)
Summary of negative impacts

Direct on line start

Drawbacks

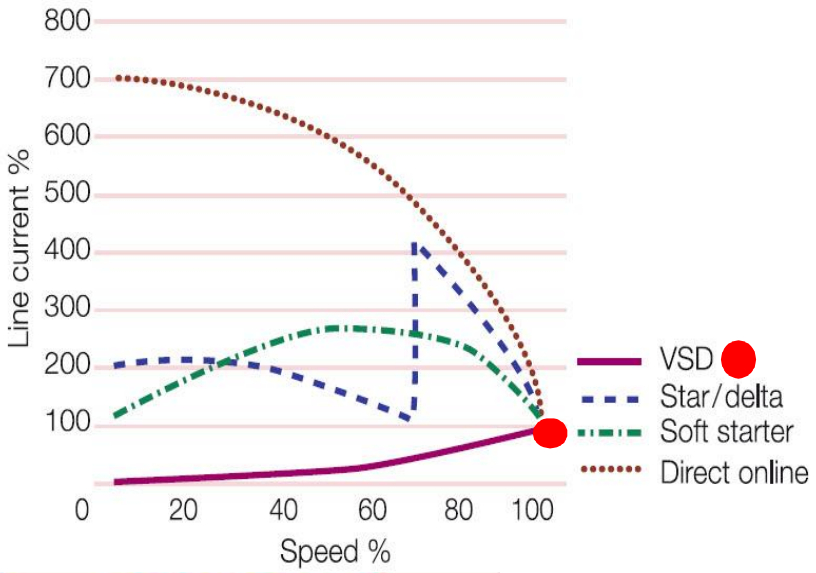
- **High inrush current**
- **High pressure/stress at pumping system equipment**

High maintenance costs and low availability

- **High regular maintenance**
- **High risk for unexpected maintenance**
- **High risk for water hammer**
- **High risk for water leakage**
- **Lower live time of equipment**
- **Loss of process due to network problems**

Starting an induction motor with VSD
Advantages and benefits

VSD provides smooth and controlled acceleration of Motor and Pump



- No inrush current during starting
- No voltage drop in the network
- No thermal stress at Motor windings
- No limitation in number of Starts
- Lees stress at motor and pump
- Less stress at hydraulic system
- Less or no risk for surge (water hammer)
- Less risk for water leakage

- The benefit:
  - Reduced life cycle costs (OPEX) of the pumping system and high availability

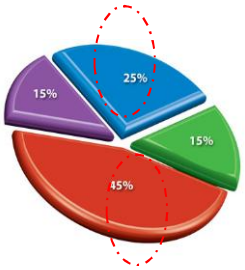
Live cycle costs (LCC) of pumping systems
Reduction of LCC with VSDs - summary

Power is proportional to the cube of speed

- **Less energy costs:**
  - Significant energy savings at reduced motor/pump speed
  - High power factor: 0.95, with ACS 2000 AFE close to 1.0

Pressure is proportional to the square of speed

- **Less maintenance costs:**
  - Reduction of maintenance and repair costs due to LESS pressure at pumping system components during starting, stopping and at operation with reduced motor/pump speed



- **The benefit:**
  - **Reduced life cycle costs (OPEX) of the pumping system and high availability**

Reference: Chile Michilla Pumping Station
Process water for mining

- Converter ACS 1014-W1
- Motor power 2100 kW
- Motor voltage 4 kV
- Motor speed 3000 rpm

Water transmission scheme
Case example - Abu Dhabi

Shuweihat water transmission scheme

- Transfer of fresh water from Shuweihat desalination plant to the city Abu Dhabi
- 250km parallel double pipeline with 1600mm diameter
- Transfer capacity: 100 million gallons a day (682'000m3/d)

Main challenges:

- Precise and accurate pressure control
- Starting and stopping of pumps
- Energy savings

Water transmission scheme
ACS 1000 case example - Abu Dhabi

Pumping stations equipped with ACS 1000 variable speed drives

- Tawaeelah unit 3
  - 7 x 1600 kW
- Mirfa
  - Phase 1: 5 x 4700 kW
  - Phase 2: 3 x 4700 kW
- Shuweihat
  - 4 x 3900 kW

- Liwa project
  - 9 x 710 kW
  - 3 x 2400 kW
- Al Ain PS
  - 8 x 5300 kW
- Fujairah Qidfa
  - 3 x 2450 kW
  - 3 x 3000 kW

- Total 44 x VSDs type ACS 1000
- Total 137 MW drive power

Industrial process water
Sea water intake and transmission pumping station

Qatar - Ras Laffan Industrial City

A 106 km^2 Industrial City to accommodate a large number of gas-based industries

Variable Speed Drives type ACS 6000

Phase 1: 9 x 7050 kW

Drive power: 63.45 MW

Phase 2: 18 x 7500 kW

Drive power: 135 MW

Total 27 drives with 199.45 MW power

Pumping station in construction phase (2003)

© ABB Group
June 5, 2013 | Slide 41

Case example
Fresh water distribution

Case note
ACS 2000 variable speed drive reduces electricity and maintenance costs at Chinese water plant

Reduction of water loss

The use of a variable speed drive provides a soft start which reduces pressure on piping and any subsequent stress on joints or valves. The result is less water loss through leakage. As such the drive mitigates the water leakage along the pipeline saving some 10 percent of water for the severely water-deficient Dagang area.

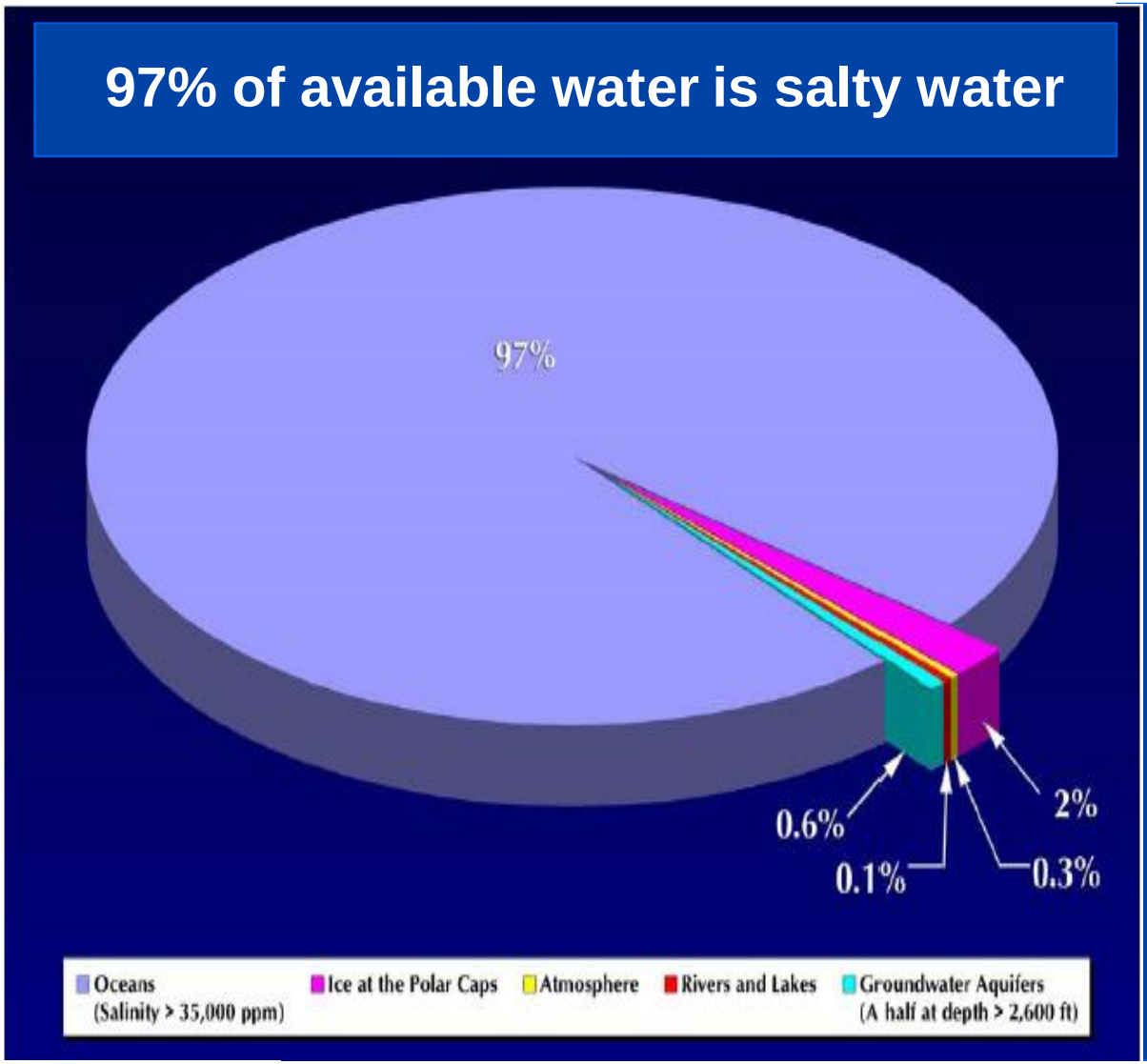
Location:

- Binhai water plant in Tianjin, China
- MV VSD type ACS 2000

Main benefits:

- 30% reduction in energy consumption is achieved with the installation of an ACS 2000 medium voltage drive (315 kW) to replace mechanical throttle control on a pump.
- In addition water losses are reduced by some 10%.

Water Resources on the Earth



The largest source of water supply for:

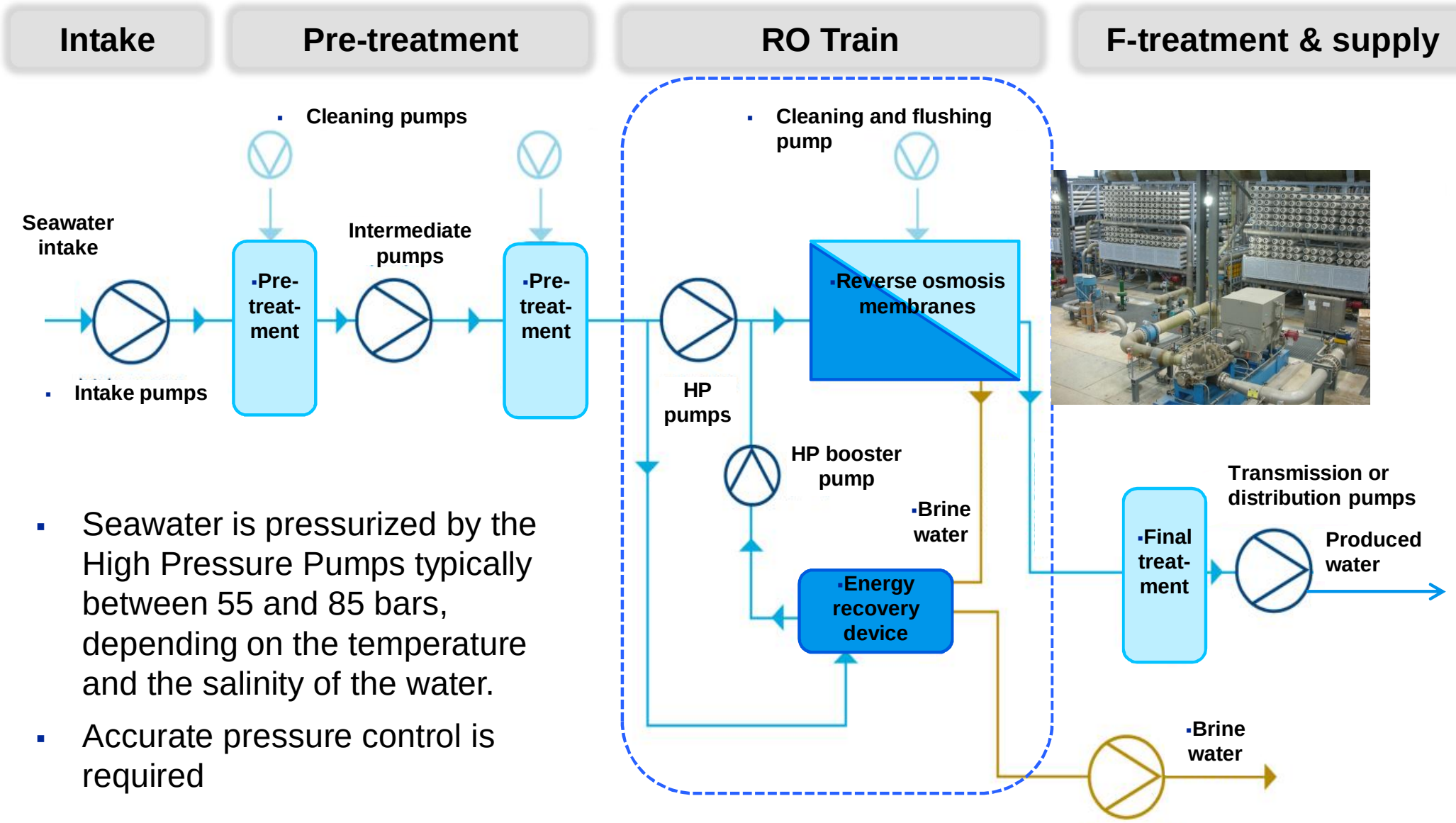
- Drinking water
- Irrigation
- **Industrial process water**

will require

DESALINATION

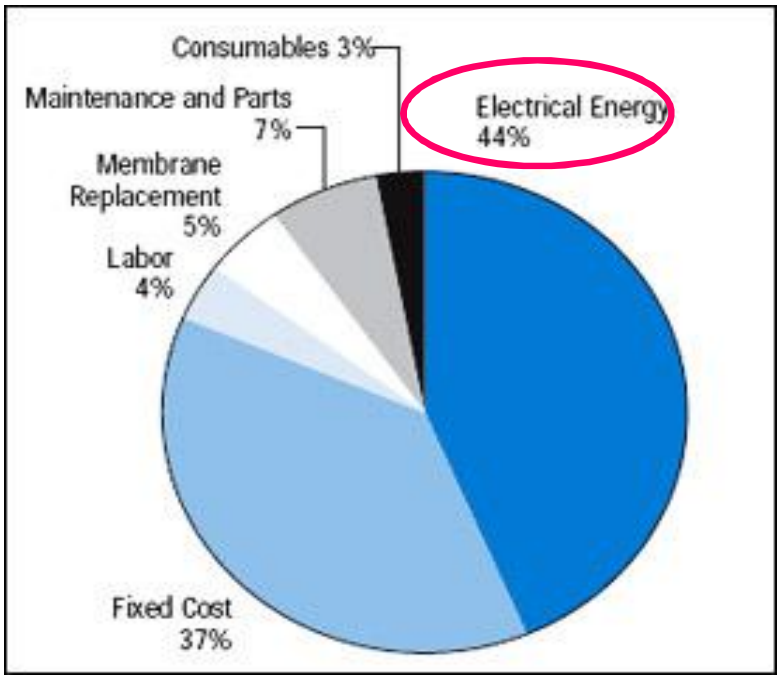
Source: www.idswater.com/Common/Paper/Paper_90/Desali...

Sea Water Reverse Osmosis (SWRO)
Typical process diagram



- Seawater is pressurized by the High Pressure Pumps typically between 55 and 85 bars, depending on the temperature and the salinity of the water.
- Accurate pressure control is required

SWRO desalination
Advantages of Variable Speed Drives



Cost Breakdown of a typical RO Desalination Plant (2006).

Tendency is towards BOO projects

- **Lowest possible operating cost is one of the key factors**

Significant reduction of operation costs

- Significant energy savings
- Accurate and precise pressure control
  - No over/under pressure at RO membranes
  - Pressure is depending on the temperature and the salinity of the sea water
- Protection of process from network fluctuations / save operation down to -25% voltage trop
- Soft starting
  - Less mechanical stress at motor, pump, membrane, hydraulic system, etc.
  - No thermal stress at motor windings

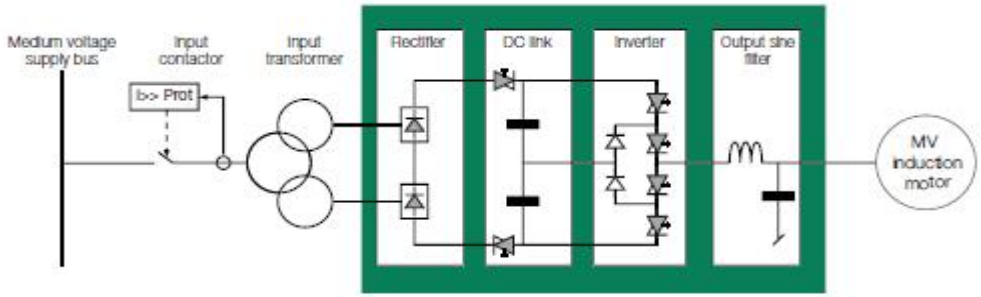
SWRO desalination
Case example / Magtaa, Algeria

Background:

- Capacity of 500,000 m³/day of drinking water to serve about 5 million people
- Magtaa plant in Algeria will be the world's largest seawater desalination plant using reverse osmosis technology
- Production started in 2011

ABB scope of supply:

- Electrical plant system, including a 220 kV outdoor substation
- 33 MVD type ACS 1000 / total drive power: 57.8 MW



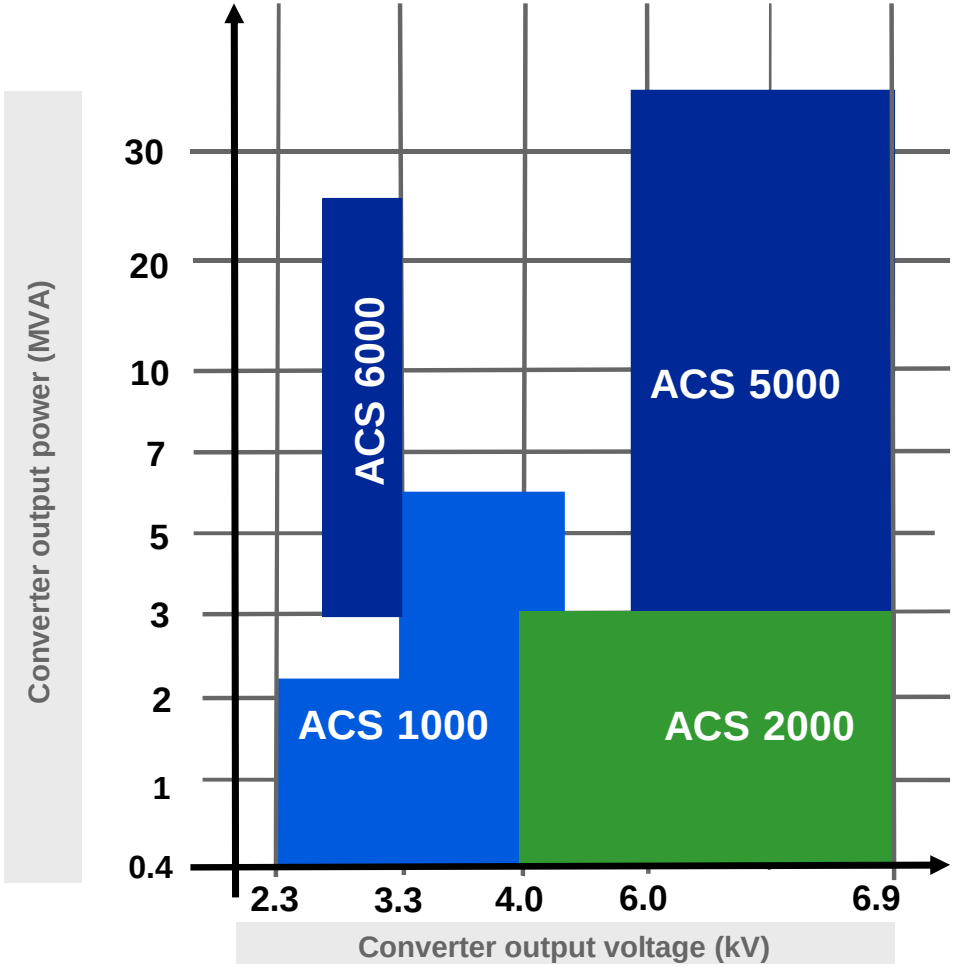
Typical ACS 1000 diagram

- Motor voltage: 3300 V
- Motor power: between 700 and 2000 kW
- 12-pulse
- Air-cooled

SWRO desalination
Overview of some MVD case examples

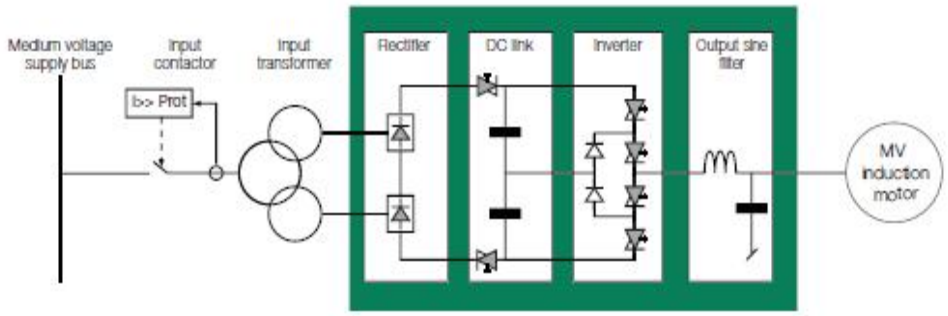
Project name	Installation country	Medium Voltage Drives		
		Quantity	Product	Type
Magataa Desalination Plant	Algeria	33		
		4	ACS 1000	ACS1013-A2
		7	ACS 1000	ACS1013-A3
		22	ACS 1000	ACS1113-A3
Tuas Desalination 70mgd	Singapore	32		
		15	ACS 1000	ACS1013-A2
		17	ACS 1000	ACS1013-A3
Ras Az Zawr	Saudi Arabia	23		
		6	ACS 5000	ACS5060
		17	ACS 2000	ACS2066-1L
Point Lisas Industrial Park	Trinidad	12	ACS 1000	
Salalah Desalination Plant	Oman	10	ACS 1000	
Southern Seawater Desalination (P1)	Australia	9	ACS 1000	ACS1043-A2
Southern Seawater Desalination (P2)	Australia	9	ACS 1000	ACS1043-A2

Medium voltage drives
ACS product family - solutions



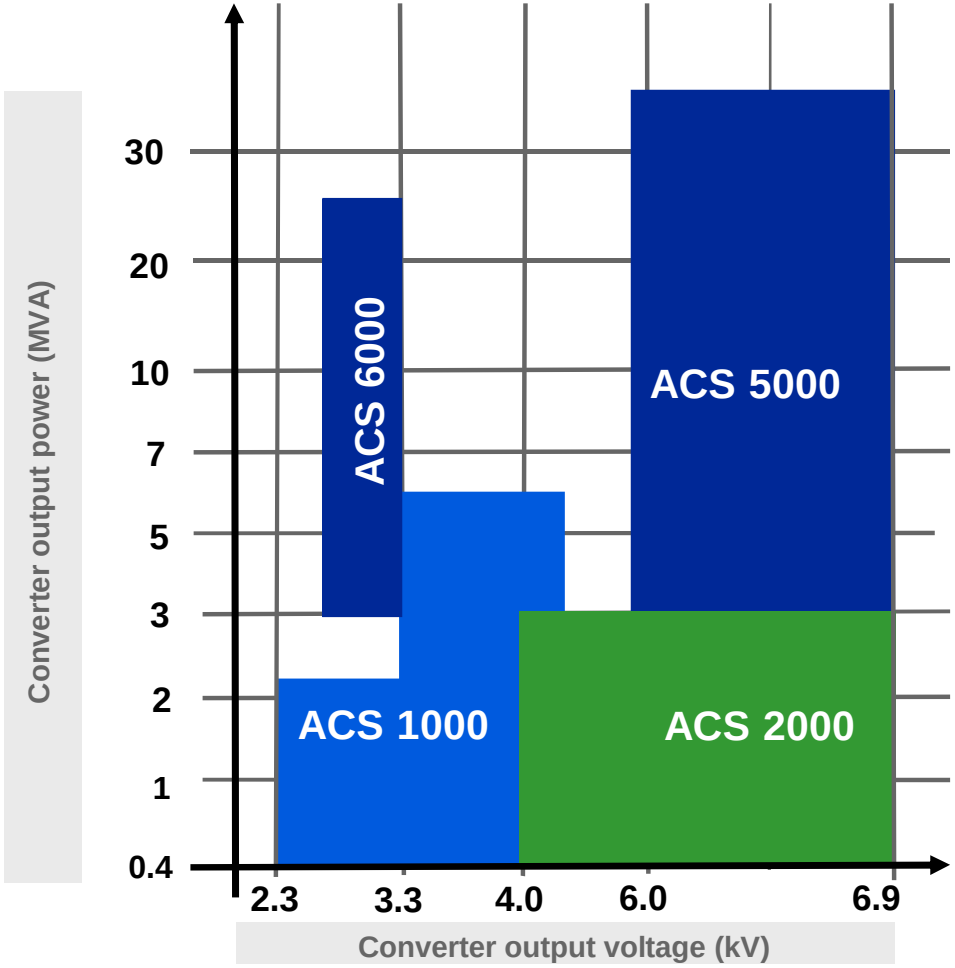
(ACS) **A**lternating **C**urrent **S**tandard Converter

- Variable Speed Drives
- Soft Starting solutions
- Oil immersed input transformer solutions for out-door installation
- Dry type input transformer solutions for in-door door installation
- Integrated transformer solutions
- Transformer less solutions (ACS 2000)



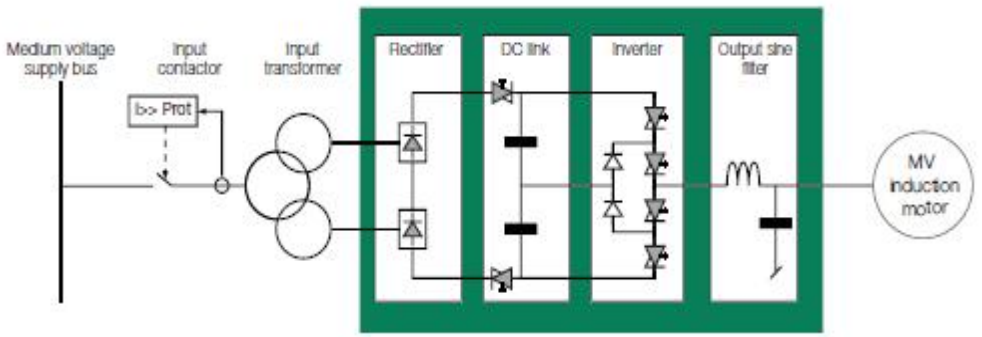
Typical ACS 1000 diagram

Medium voltage drives
ACS product family – main features



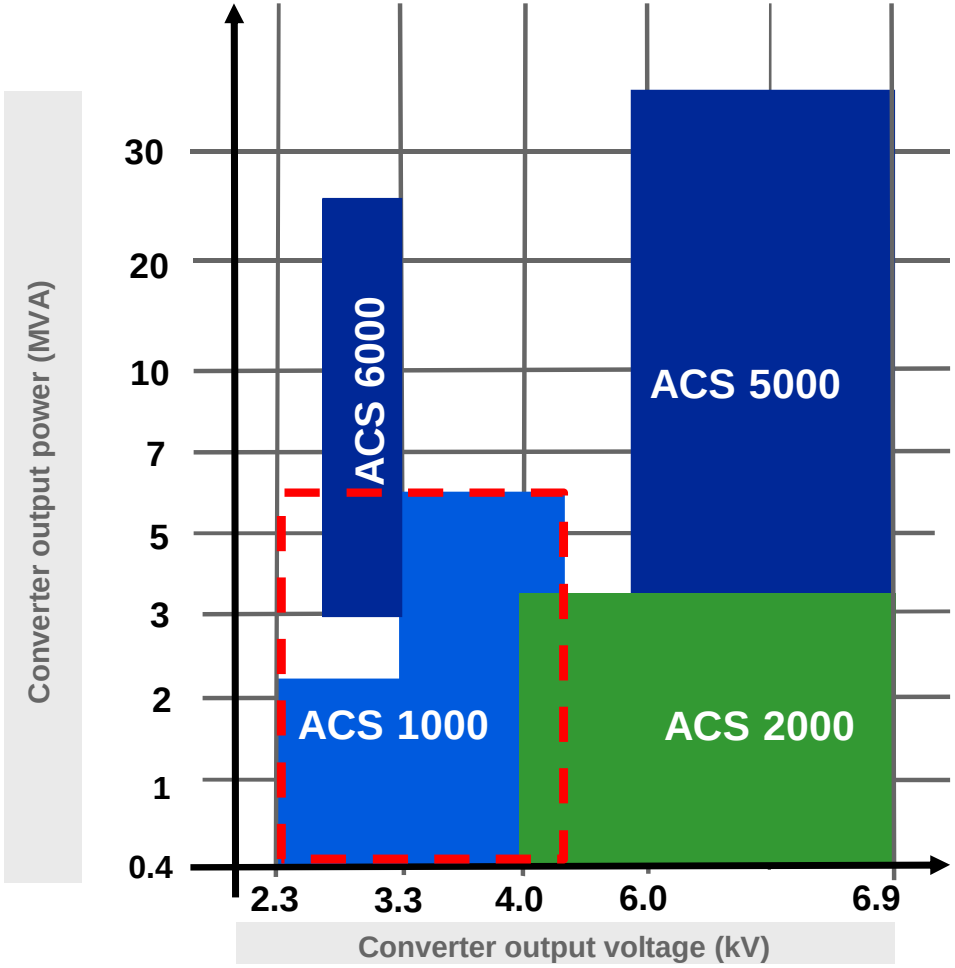
(ACS) **A**lternating **C**urrent **S**tandard Converter

- Robust and simple design
- Fuse lees design in the power part
- Long live time DC-link foil capacitors
- Smooth DC link charging
- Safety grounding switch for DC link capacitors
- Air and water-cooled solutions



Typical ACS 1000 diagram

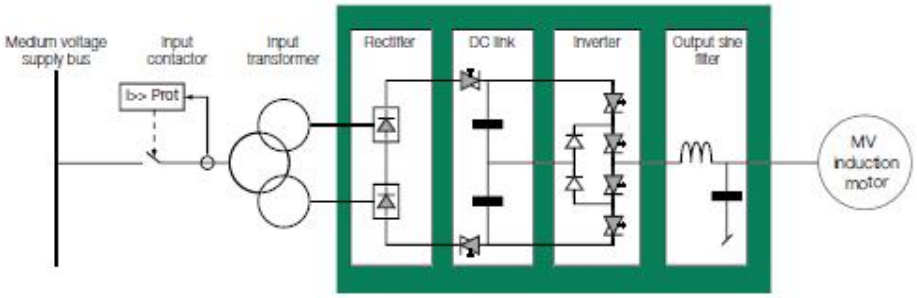
Medium voltage drives
ACS 1000



(ACS) **A**lternating **C**urrent **S**tandard Converter

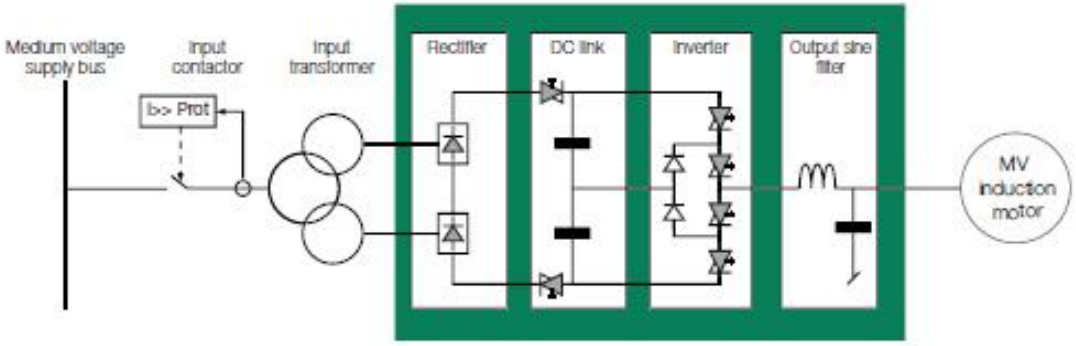
Overview:

- Power range: 0.2 – 5.3MW
- Air-cooled up to 2MW
- Water-cooled up to 5.3MW
- External transformer solutions
- Integrated transformer solutions
- 12 or 24-pulse diode rectifier
- Sine wave output filter



Typical ACS 1000 diagram

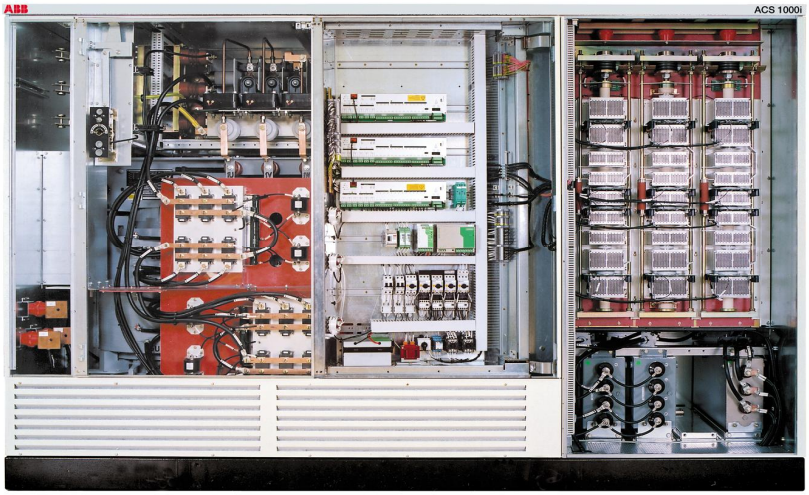
ACS 1000 product overview
Air-cooled



Typical ACS 1000 diagram

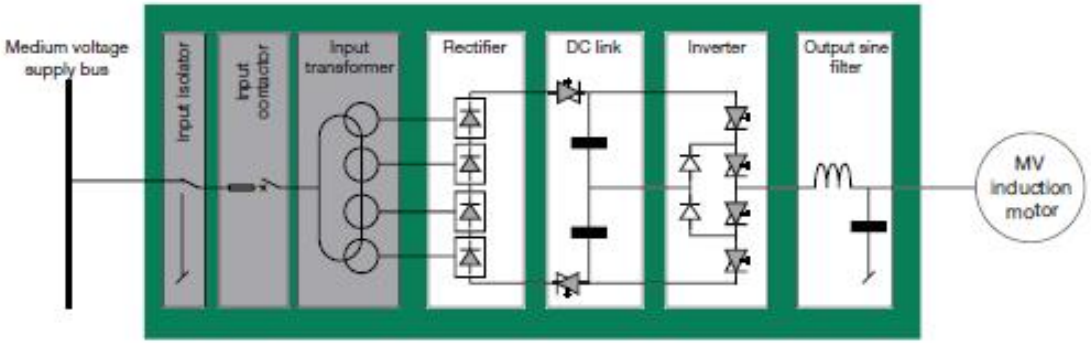
- **Output power: 0.4 up to 2.4 MVA**
- **Output Voltage: 2.3, 3.3 and 4.0 kV**
- Sine wave output filter
- Fuseless design in power part
- Long-life DC-link capacitors
- 12-pulse diode input rectifier
  - 24-pulse as option
- Oil or dry type input transformer

ACS 1000 product overview
Air-cooled with integrated transformer



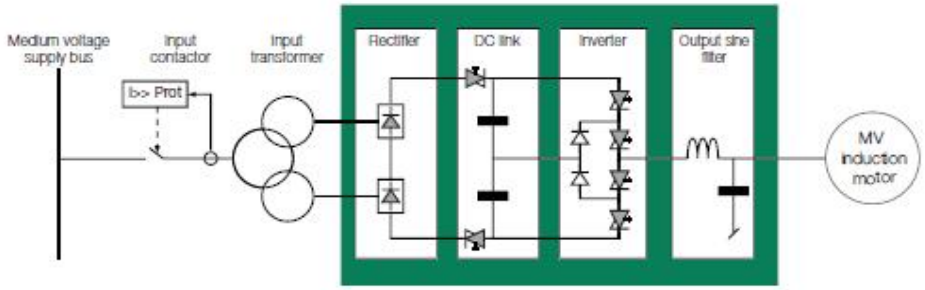
ACS 1000i air-cooled with integrated 24-pulse input transformer

- **Output power: 0.4 up to 2.33 MVA**
- **Output Voltage: 2.3, 3.3 and 4.0 kV**
- Sine wave output filter
- Fuseless design in power part
- Long-life DC-link capacitors



Typical ACS 1000i diagram

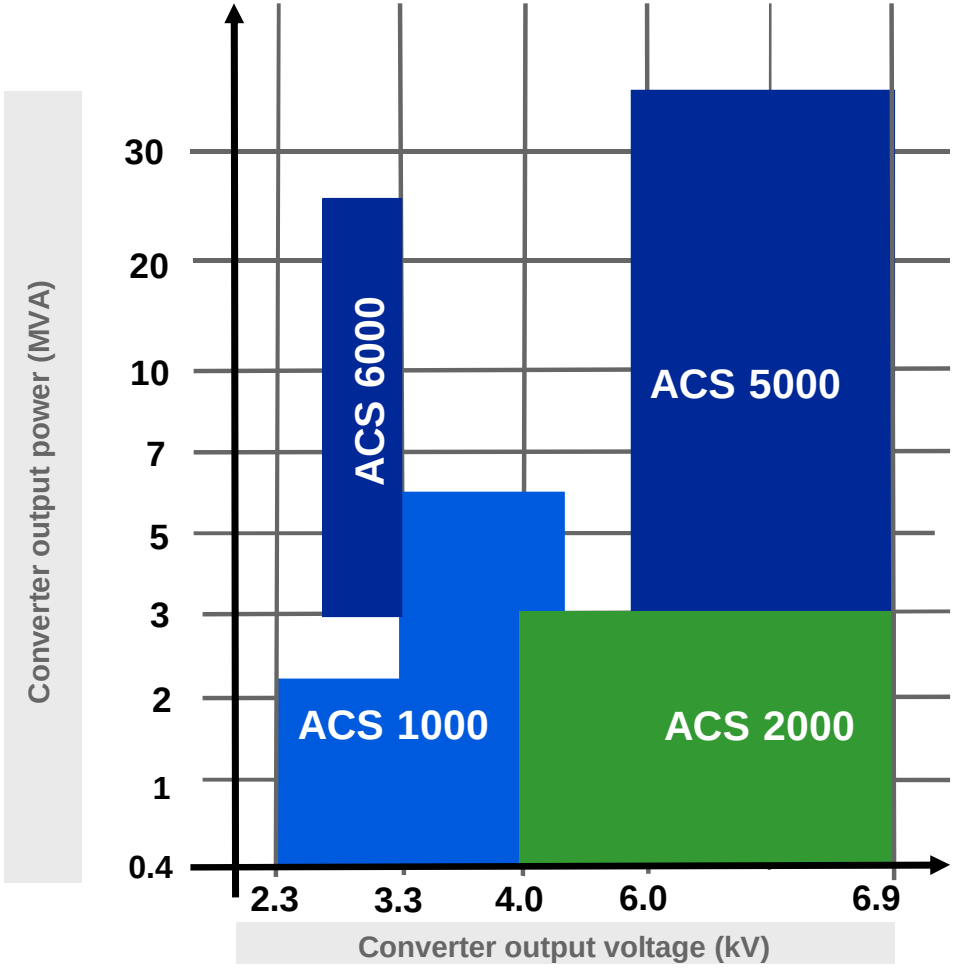
ACS 1000 product overview
Water-cooled



Typical ACS 1000 diagram

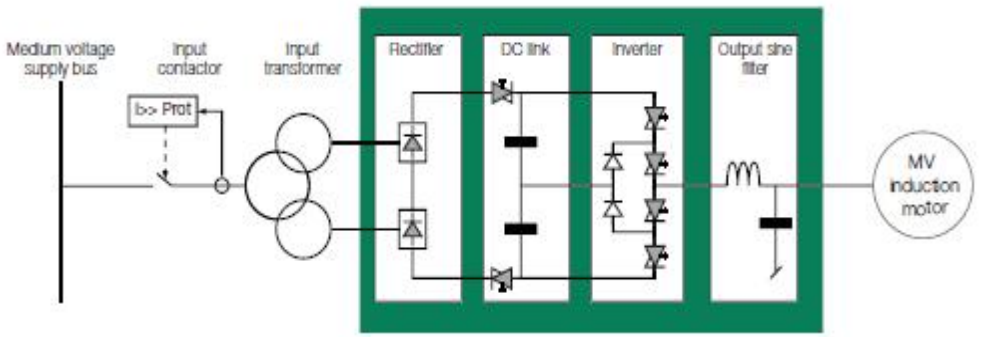
- **Output power: 2.4 up to 6.09 MVA**
- **Output Voltage: 3.3 and 4.0 kV**
- Sine wave output filter
- Fuseless design in power part
- Long-life DC-link capacitors
- 12-pulse diode input rectifier
  - 24-pulse as option
- Oil or dry type input transformer

Medium voltage drives
ACS product family – main features



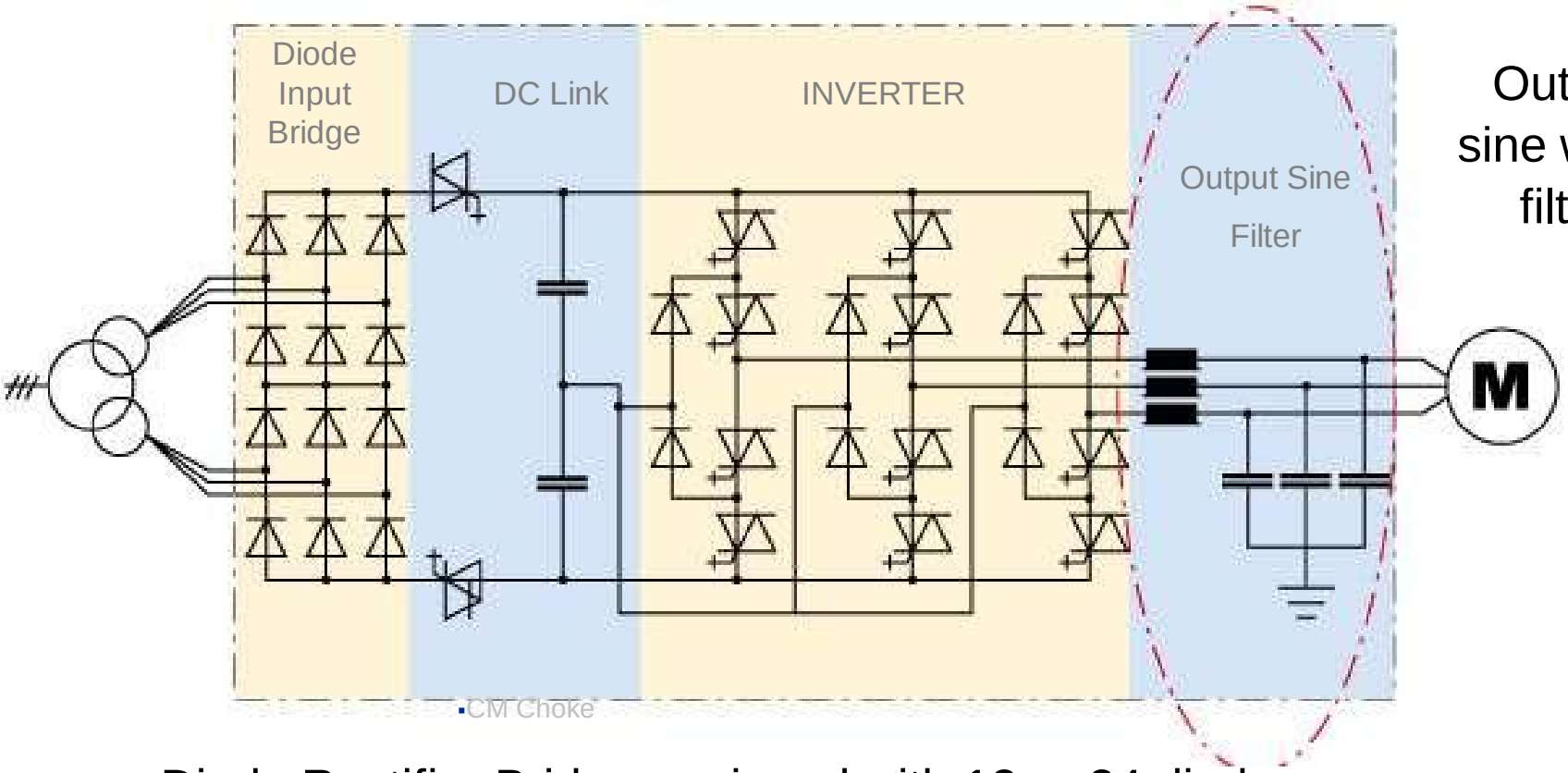
(ACS) **A**lternating **C**urrent **S**tandard Converter

- Robust and simple design
- Fuse lees design in the power part
- Long live time DC-link foil capacitors
- Smooth DC link charging
- Safety grounding switch for DC link capacitors



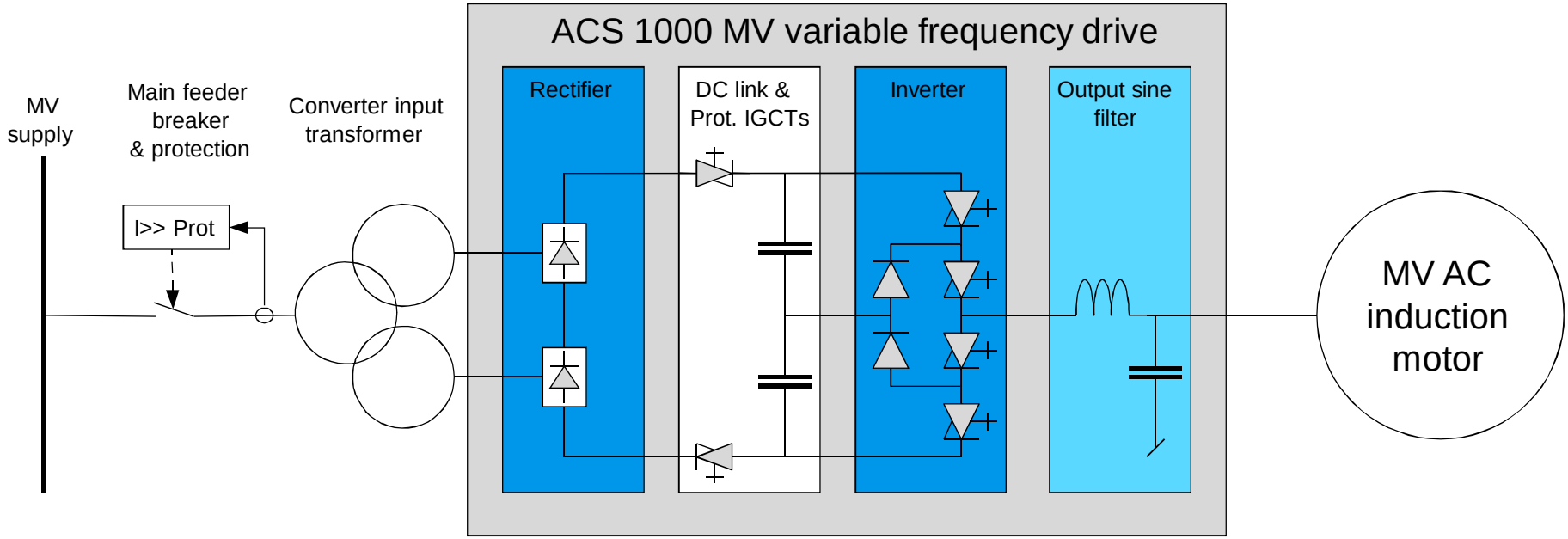
Typical ACS 1000 diagram

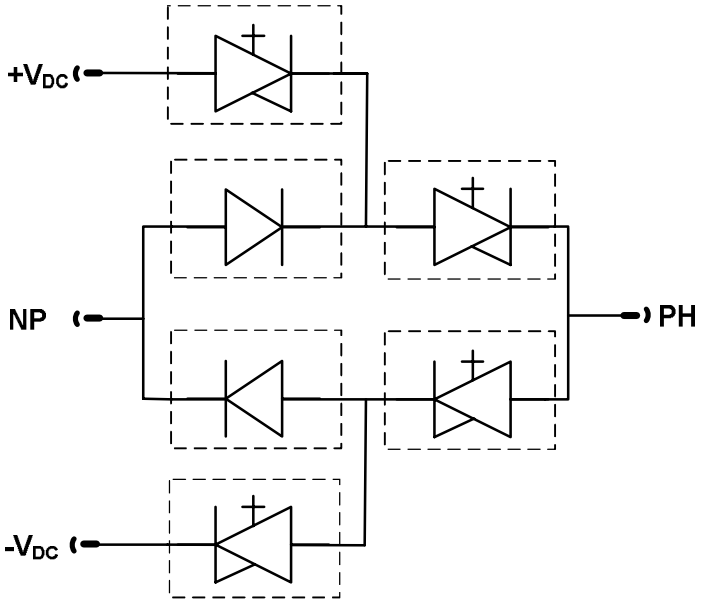
ACS 1000 Topology



- Diode Rectifier Bridge equipped with 12 or 24 diodes
- DC Link Capacitors: 1 max. 5
- Fuse less design – Protection IGCTs
- switch of within 25 μs (100 times faster as fuses)
- Three- level Voltage Source Inverter (VSI) equipped with only 12 IGCTs and 6 diodes

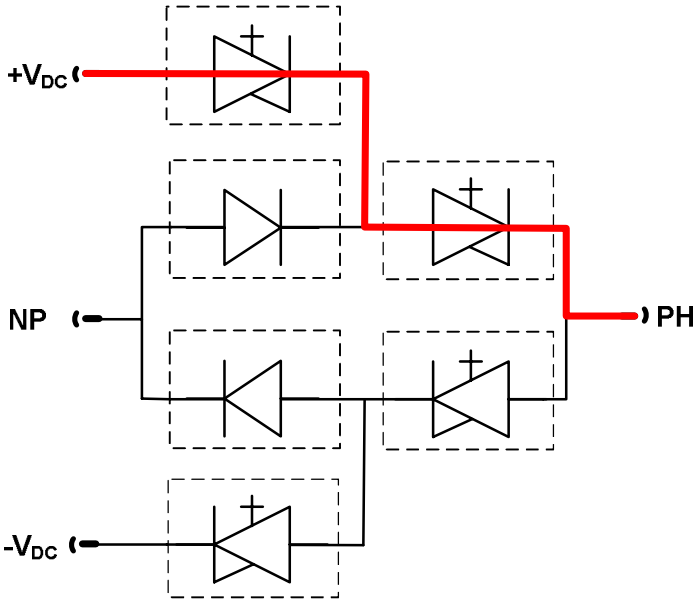
The 3-level VSI topology

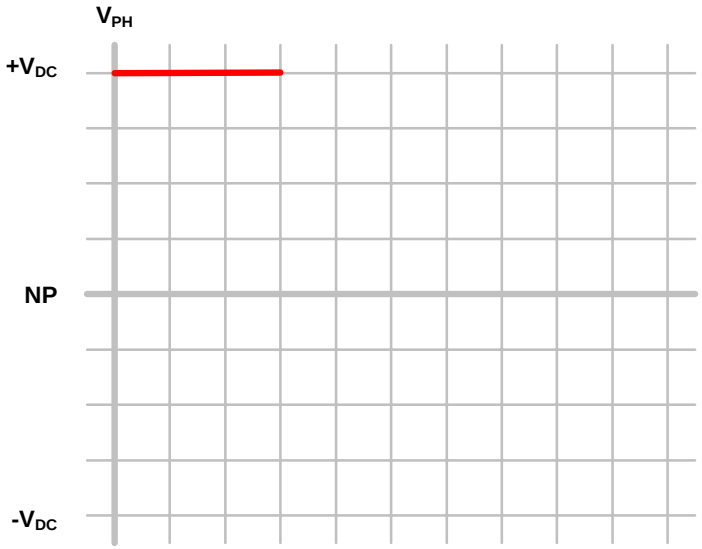




3-level VSI topology

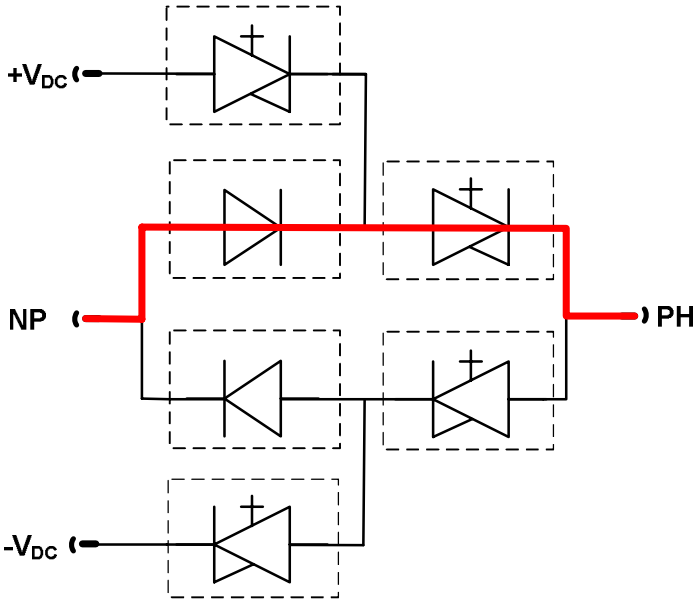
- 3-Level NPC VSI
- Phase output voltage

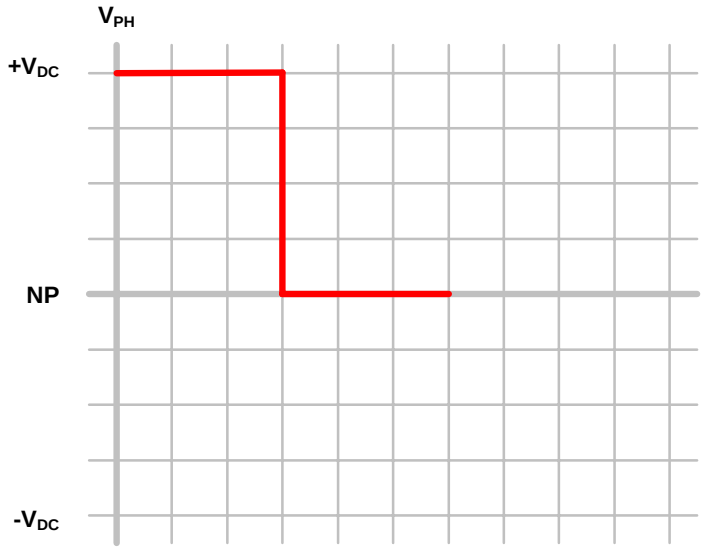




3-level VSI topology

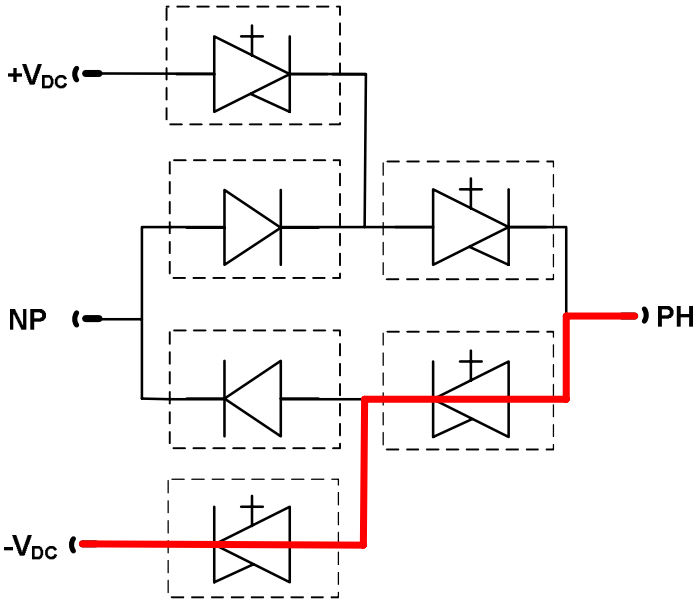
- 3-Level NPC VSI
- Phase output voltage

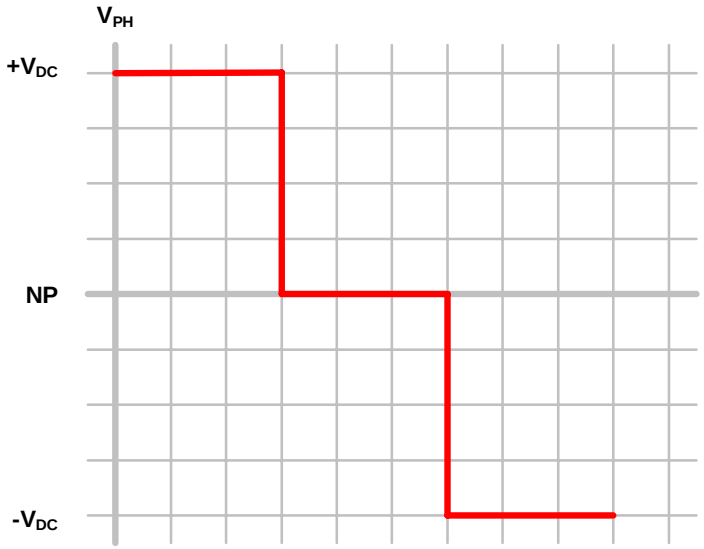




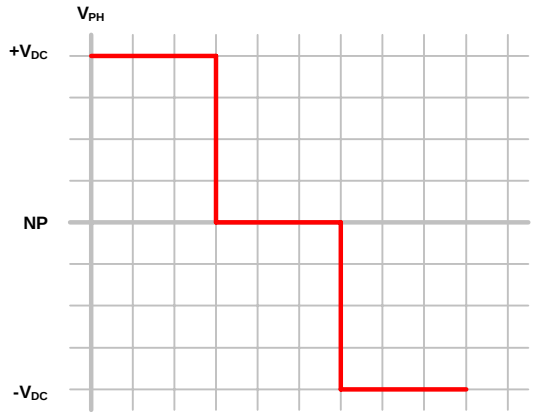
3-level VSI topology

- 3-Level NPC VSI
- Phase output voltage

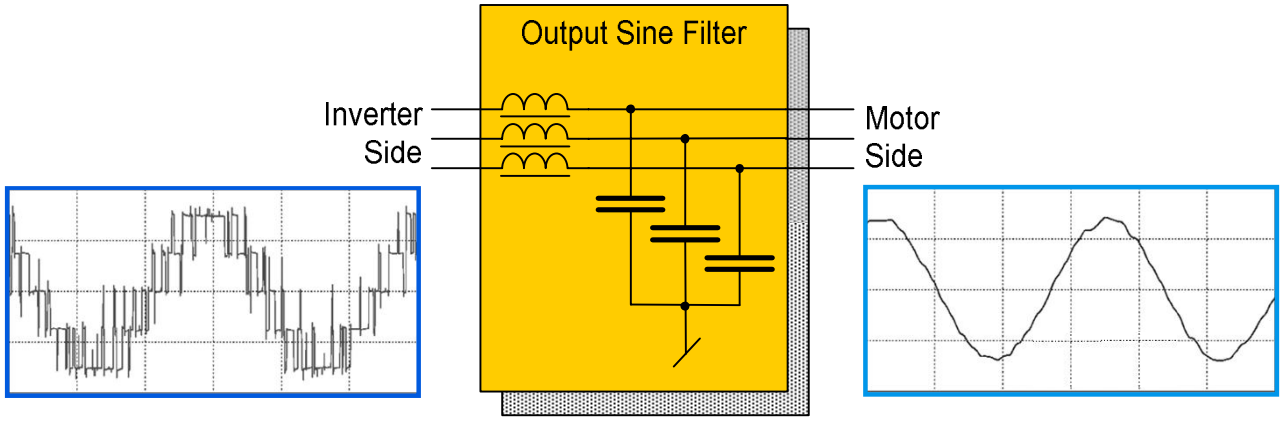




3-level VSI topology



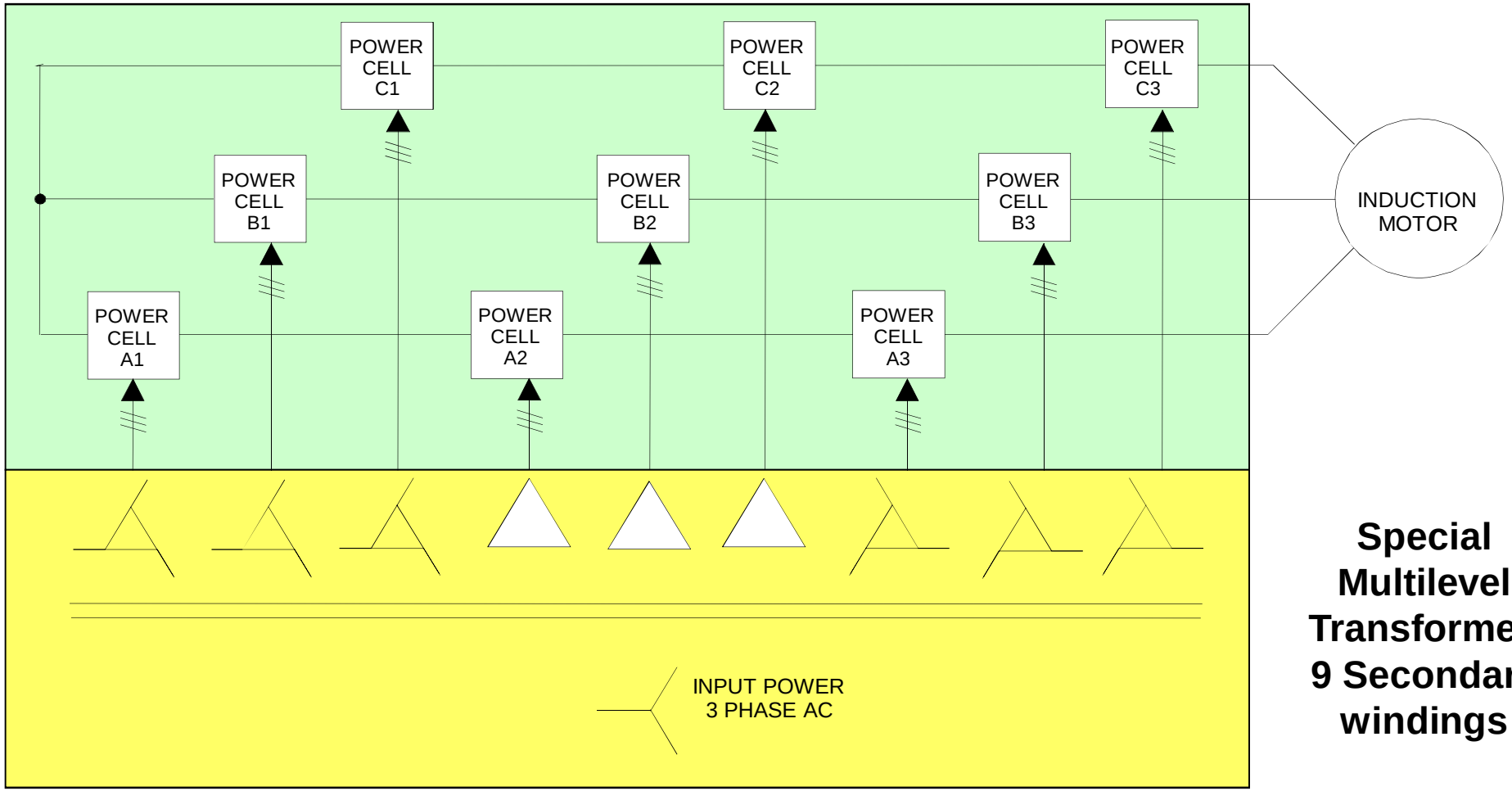
- Inverter phase output voltage
- Without sine wave filter standard motors can not be used



3-level voltage **Output voltage**

Example
Typical multilevel VSI (LV modules series connected)

Motor Power: 3300 V
Power Range: 300hp - 1750hp (315kW - 1400kW)



Special Multilevel Transformer, 9 Secondary windings

Example (3.3kV / 2MW drive)

Typical multilevel VSI (LV Modules series connected)

Large number of LV IGBTs and 54 Diodes

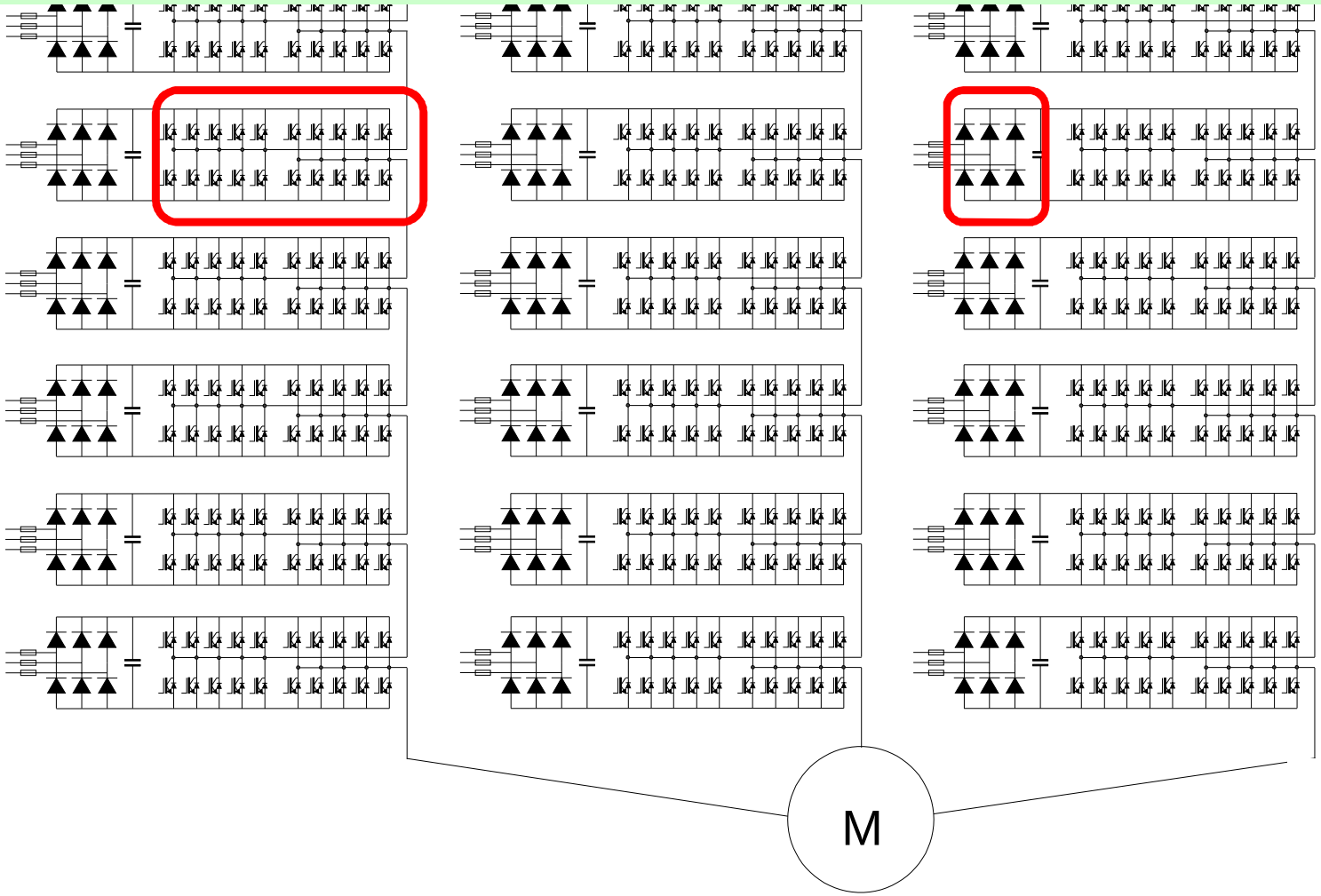
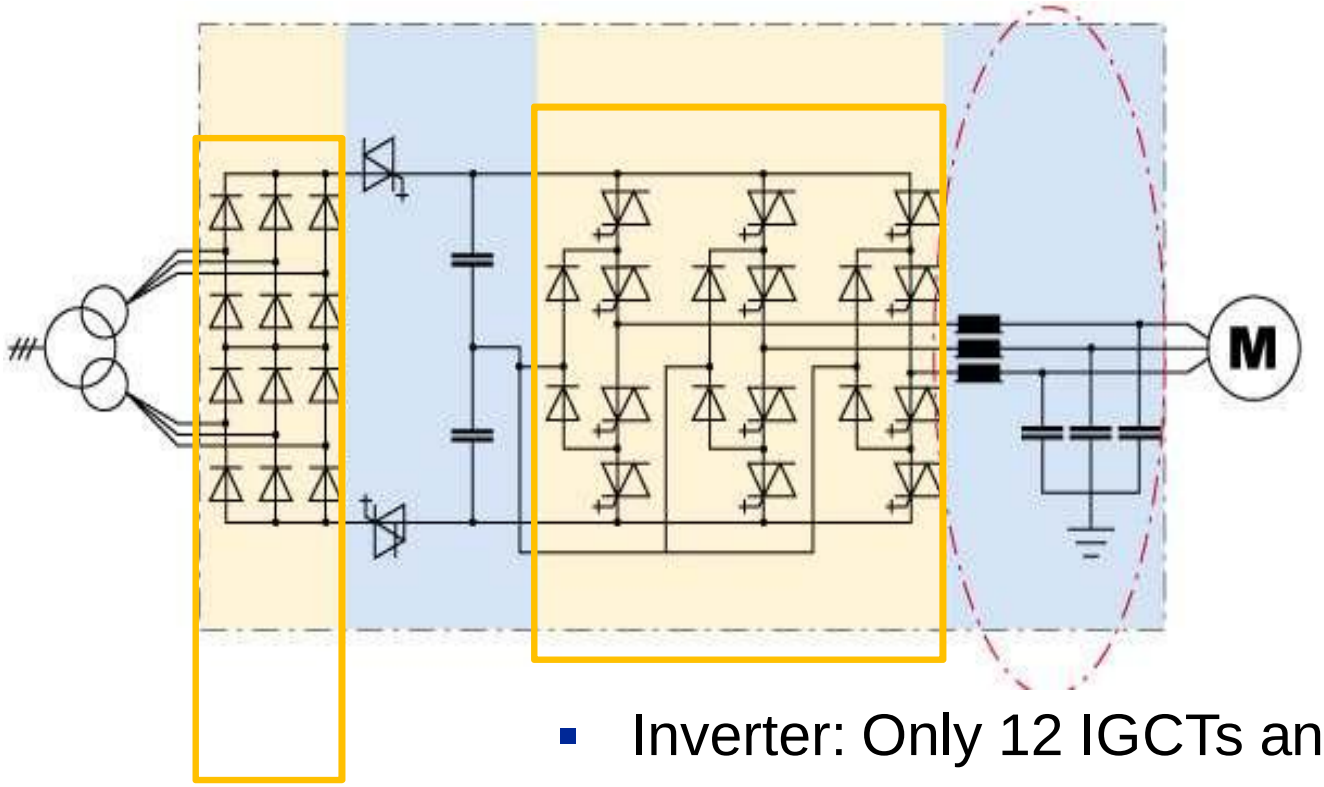


ABB solution – example ACS 1000
Inverter and diode bridge (rectifier)



- Inverter: Only 12 IGCTs and 6 diodes
- Rectifier: 12 or max. 24 Diodes

© ABB Group

Example (3.3kV / 2MW drive)
Typical multilevel VSI (LV Modules series connected)

54 Fuses (27 for power and 27 for control system

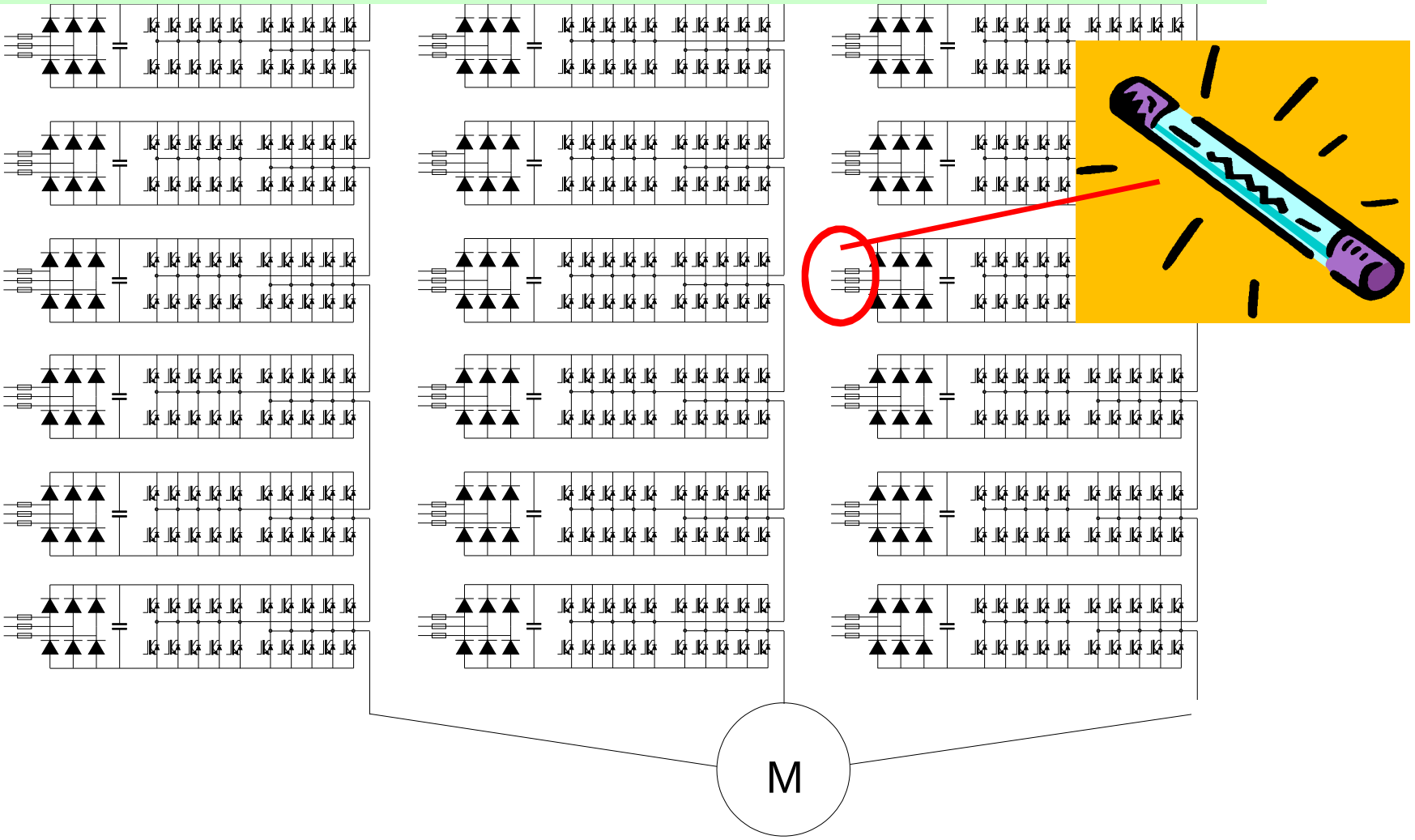
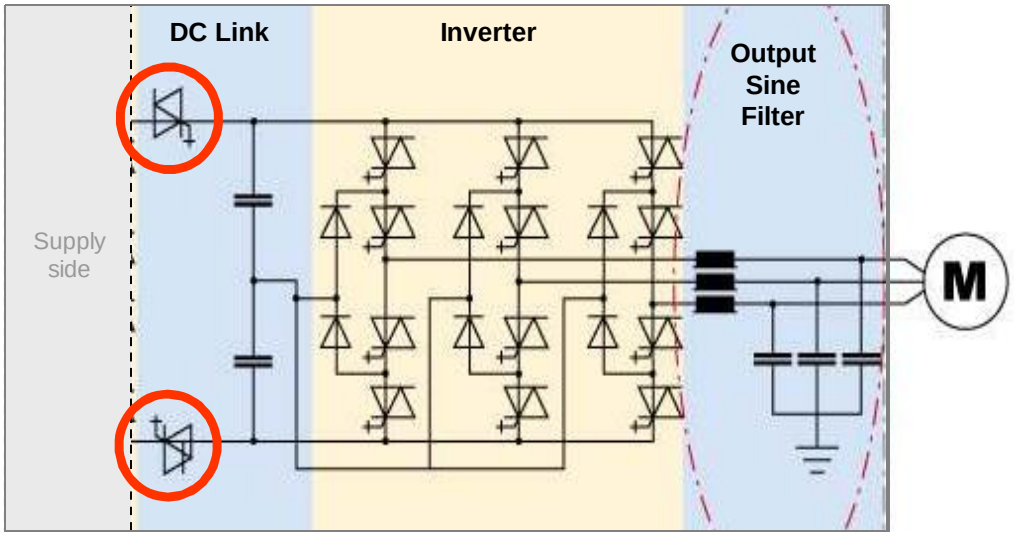
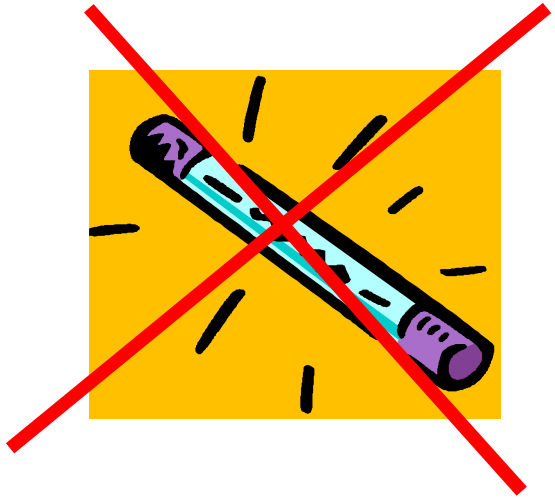


ABB solution - fuseless design
Example: ACS 1000



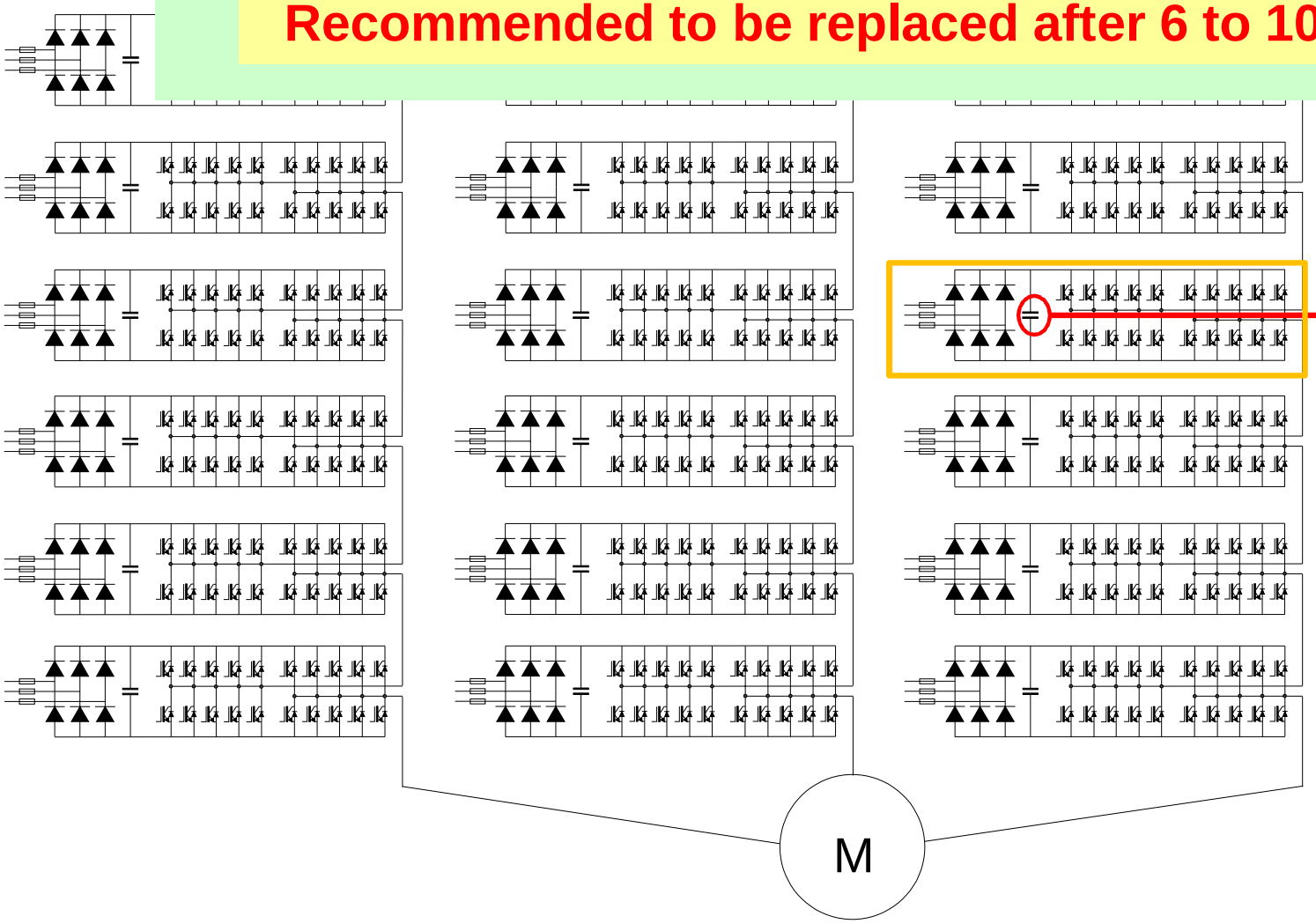


Fuses disconnect circuits within **100 ms**

- IGCT (semiconductor) protection
- ABB's fuseless design acts within **25 µs**

Example (3.3kV / 2MW drive)
Typical multilevel VSI (LV Modules series connected)

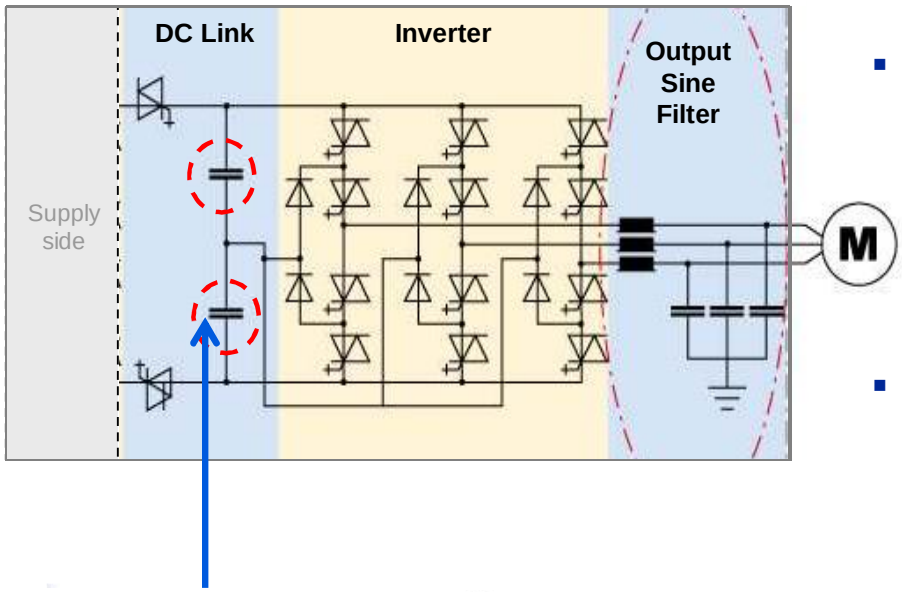
Total 135 DC link Electrolytic Capacitors
Recommended to be replaced after 6 to 10 years



15 x Electrolytic Capacitors per cell

E-caps aging during storage, “formatting” required

ABB solution – example ACS 1000
DC-Link: Oil-filled foil capacitors



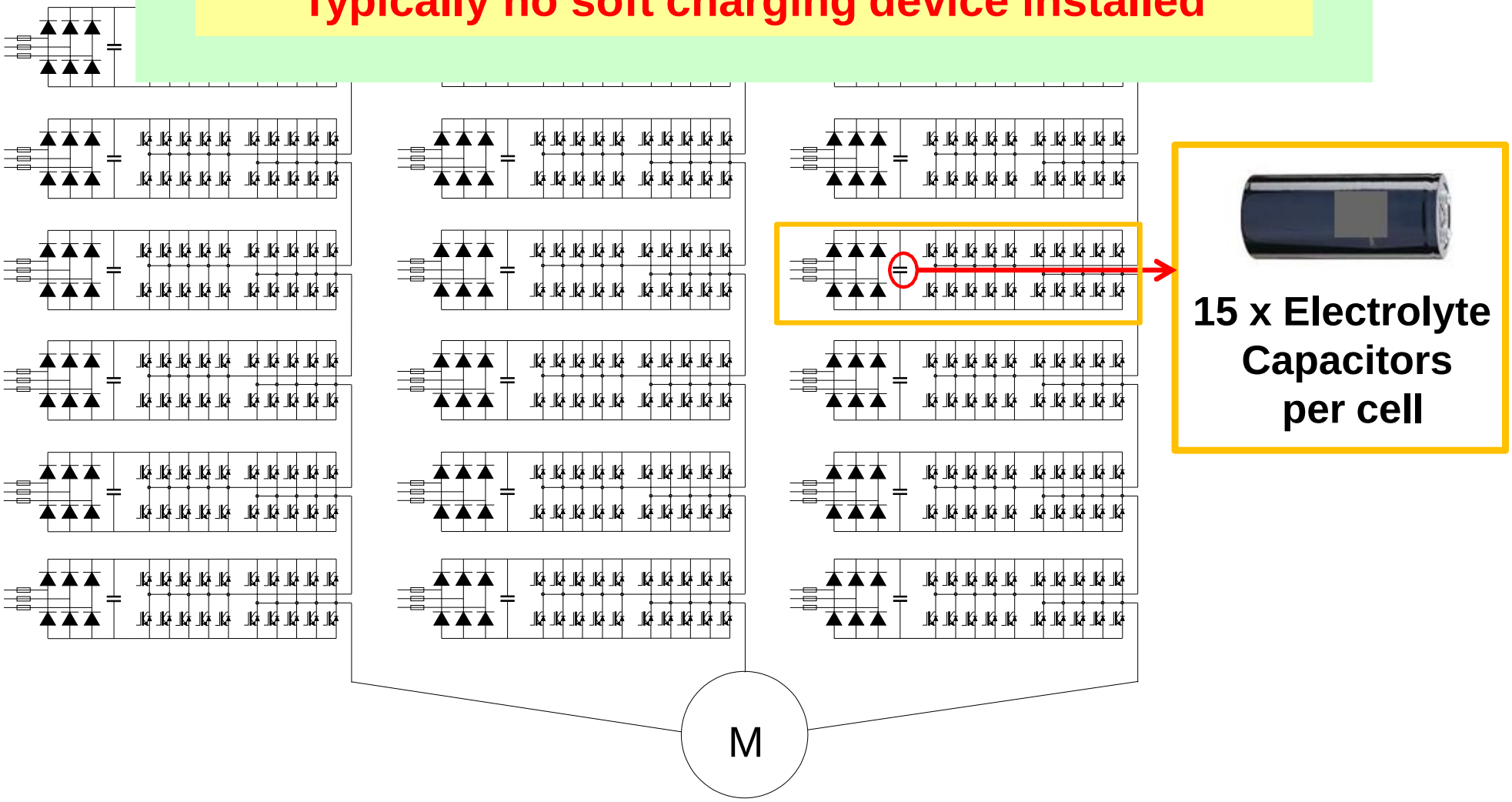
Oil-filled foil capacitor

- Long-life time capacitors
  - Advanced, environmental friendly, natural oil-filled foil capacitors have a substantially longer lifetime than electrolytic capacitors
- Lifetime expectancy
  - under typical operating conditions (30° C ambient) **> 20 years**
  - virtually no aging during storage, no “formatting” (like for electrolytic caps) required

© ABB Group

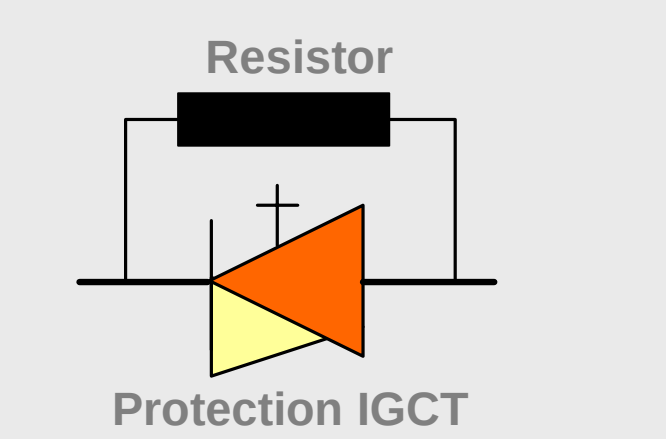
Example (3.3kV / 2MW drive)
Typical multilevel VSI (LV Modules series connected)

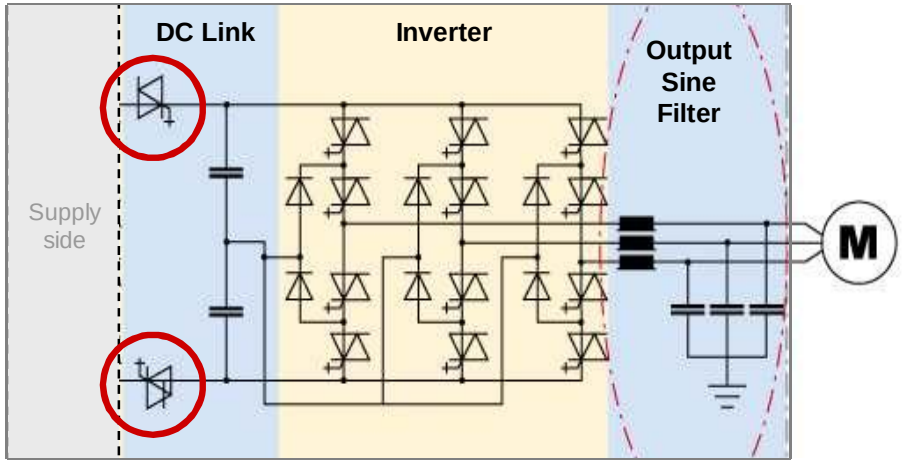
Soft charging of DC Link capacitors
Typically no soft charging device installed



15 x Electrolyte Capacitors per cell

ABB solution - Soft charging of DC link capacitors
Example: ACS 1000



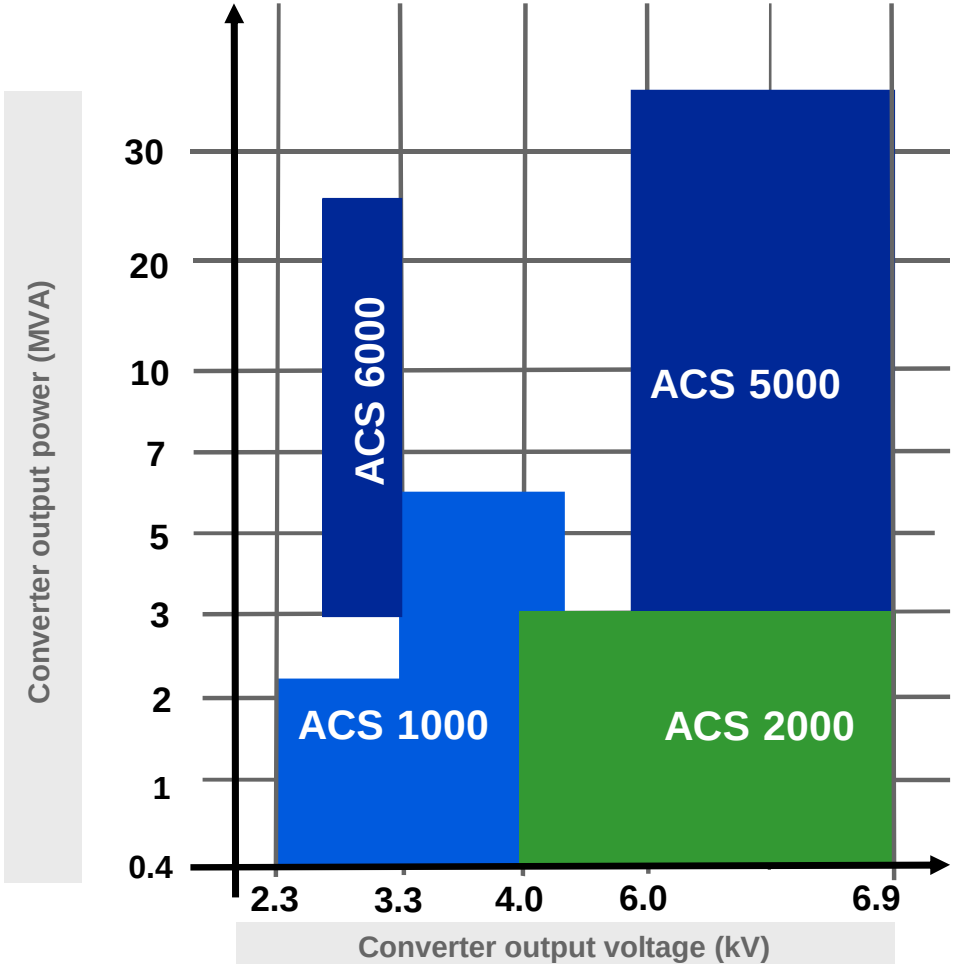


The pre-charge resistors limit the current that flow into the DC link capacitors when power is initially applied.

Soft charging of DC-link capacitors

- Smooth soft charging during start up of the drive, the advantage:
  - No electrical stress at the capacitors
  - No inrush current
  - No stress at input transformer

ABB medium voltage drives
Safety, quality, reliability and energy efficiency



(ACS) Alternating **C**urrent **S**tandard Converter

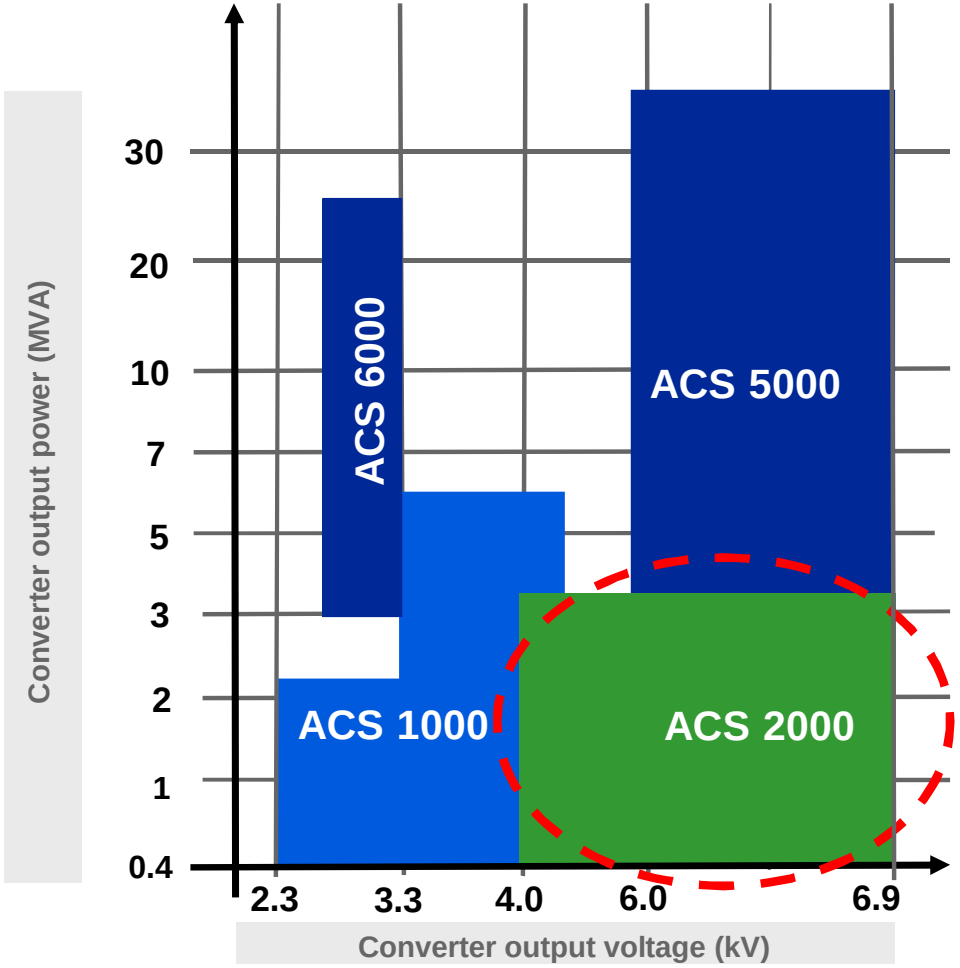
Main features

- Robust and simple design
- Fuse lees design in the power part
- Long live time DC-link foil capacitors
- Smooth DC link charging
- Safety grounding switch for DC link capacitors

Customer benefit:

- High reliability, availability and safety
- High efficiency
- Low live cycle costs

Medium voltage drives
ACS 2000 low harmonic drives



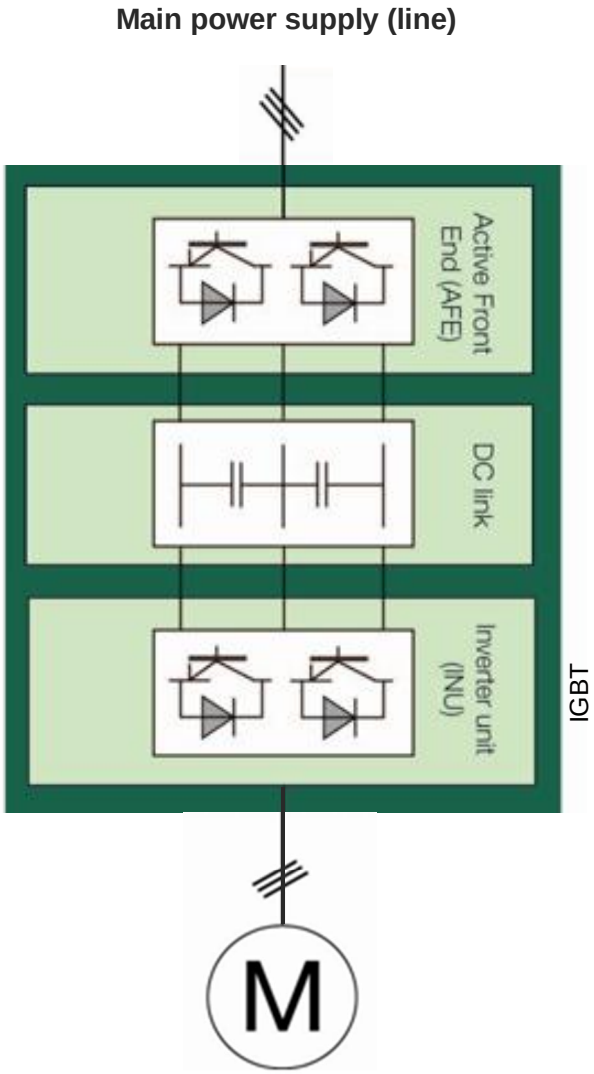
- Power range: 0.3 – 3.0MVA
- Transformer less solution
  - Active rectifier (AFE)
  - Line voltage: 4.16, 6.0 – 6.9kV
  - Motor voltage: 4.16, 6.0 – 6.9kV
- Solution with input transformer (DFE)
  - 24-pulse rectifier
  - Line voltage: flexible
  - Motor voltage: 6.0 – 6.9kV

(ACS) **A**lternating **C**urrent **S**tandard Converter

ACS 2000 low harmonic drive
Overview

ACS 2000
1.0 MVA
with external
transformer

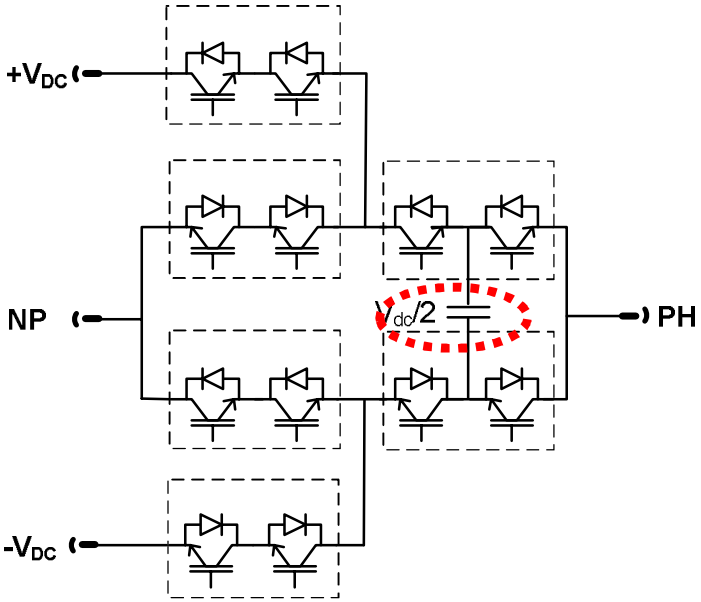
- **Power input section**
  - Active Front End (AFE) phase modules
  - In-built line filter
- **DC-link**
  - Long live time DC-link foil capacitors
- **Power output section**
  - Inverter (INU) phase modules
  - In-built output filter (dv/dt limitation)
- Phase modules are withdrawable and can be replaced within minutes



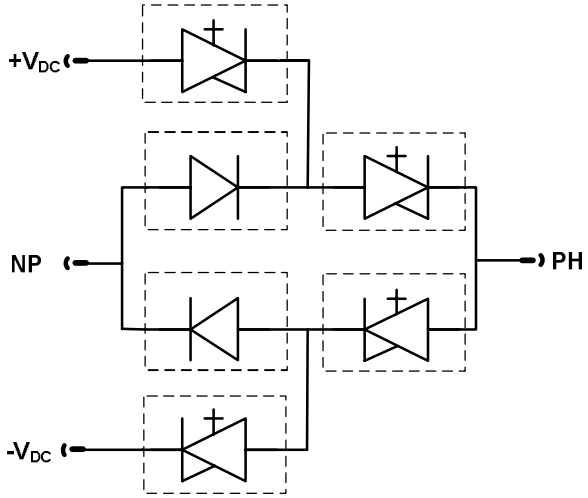
From 3-level to 5-level (multi-level) topology

- 5- level topology
  - Output voltage: 4 – 6.9 kV
  - ABB‘s patented* 5-level topology enabling a multilevel output waveform with a minimum number of components

*Adding a phase capacitor

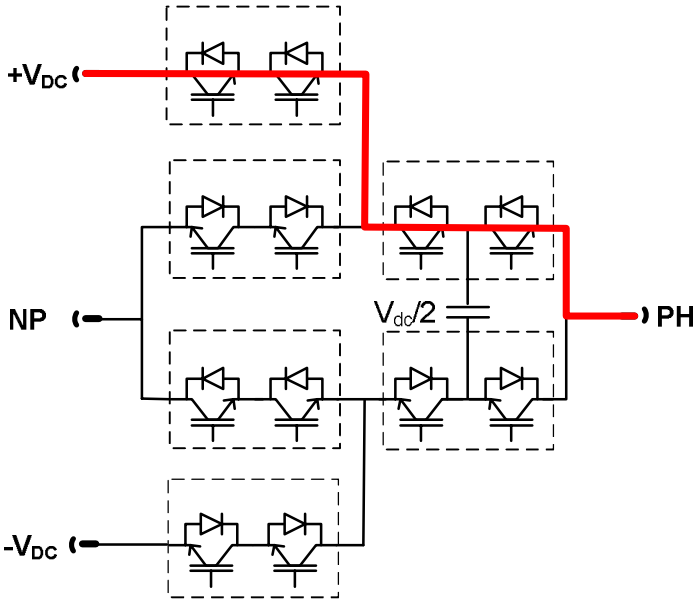


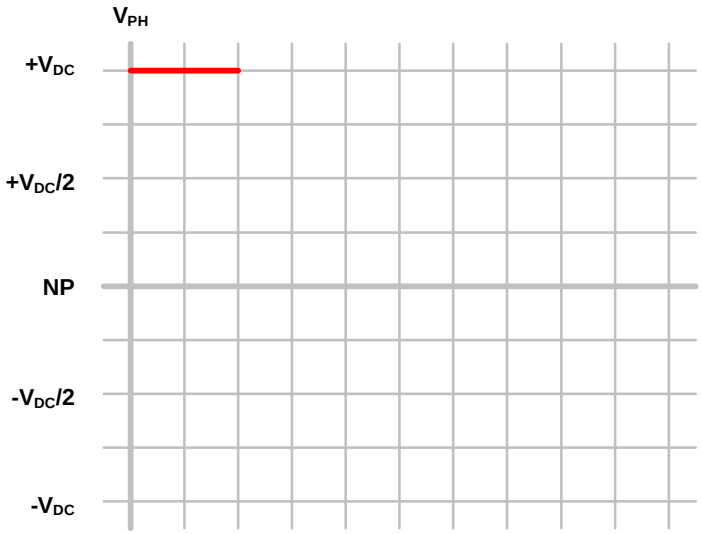
- 3- level topology
  - Output voltage: 2.3 – 4 kV



The 5-level VSI topology
Phase to ground voltage levels

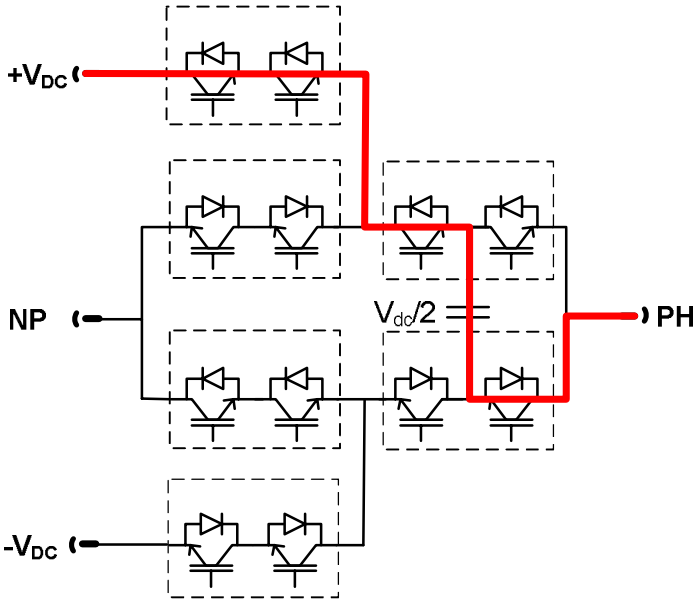
- 5-Level ANPC VSI
- Phase output voltages

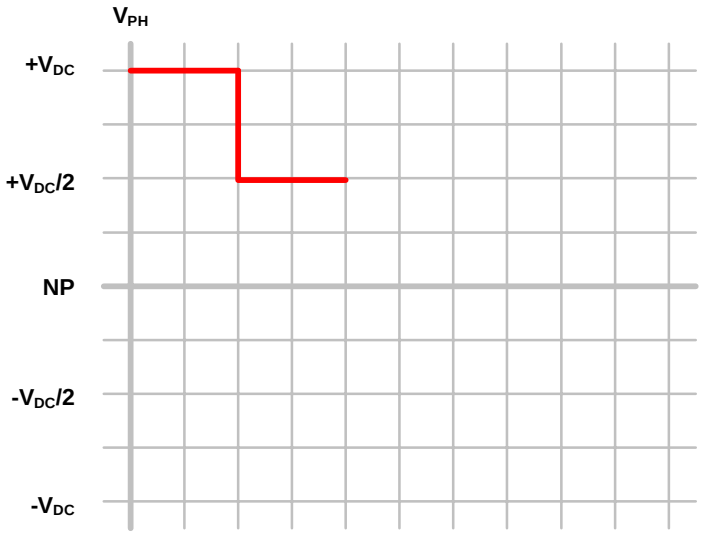




The 5-level VSI topology
Phase to ground voltage levels

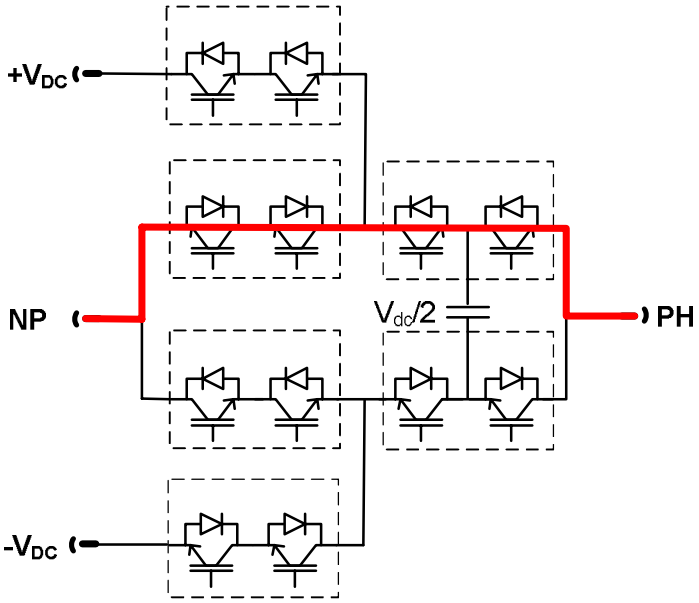
- 5-Level ANPC VSI
- Phase output voltages

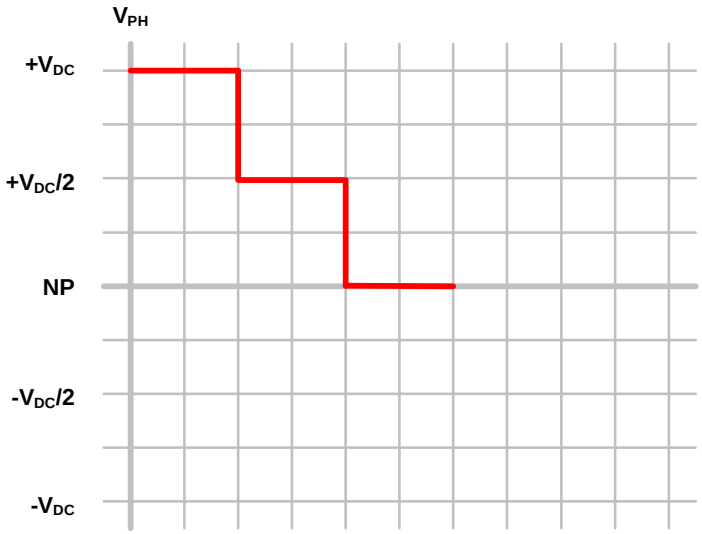




The 5-level VSI topology
Phase to ground voltage levels

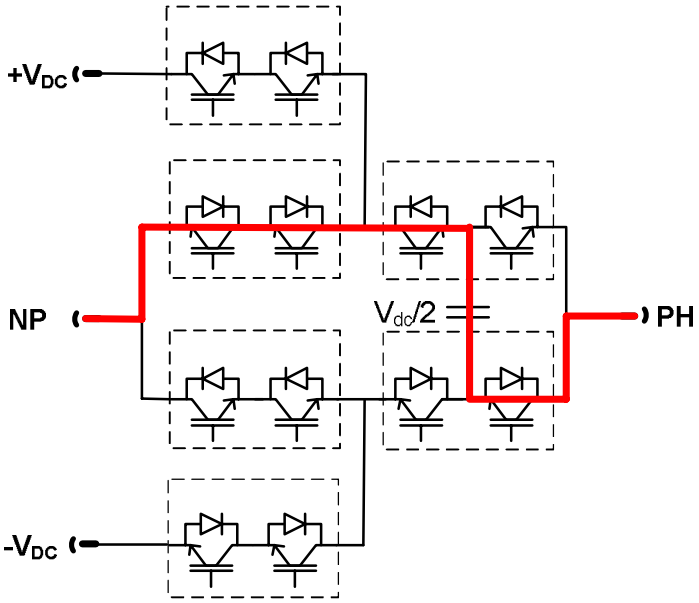
- 5-Level ANPC VSI
- Phase output voltages

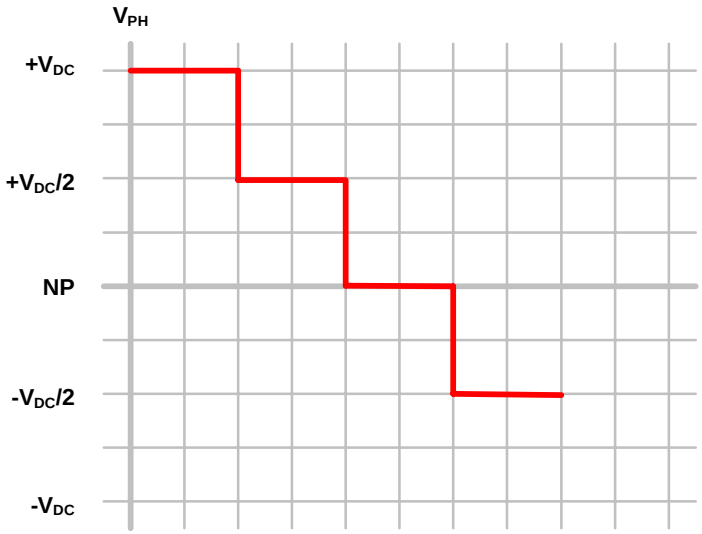




The 5-level VSI topology
Phase to ground voltage levels

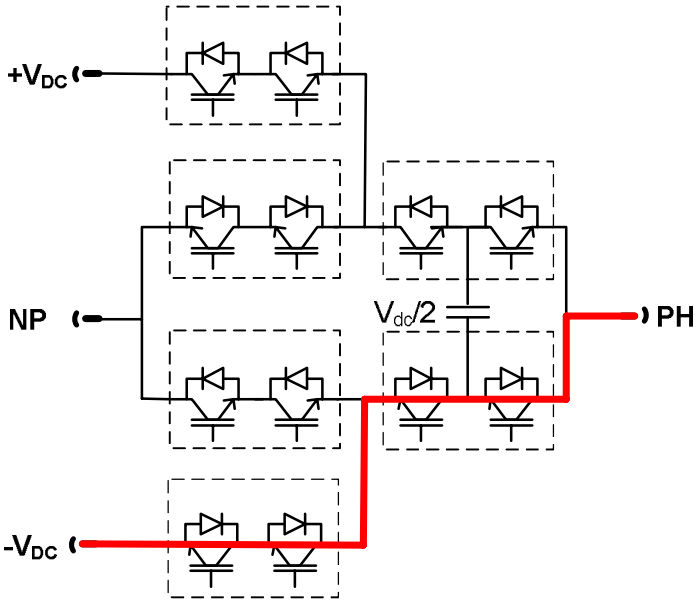
- 5-Level ANPC VSI
- Phase output voltages

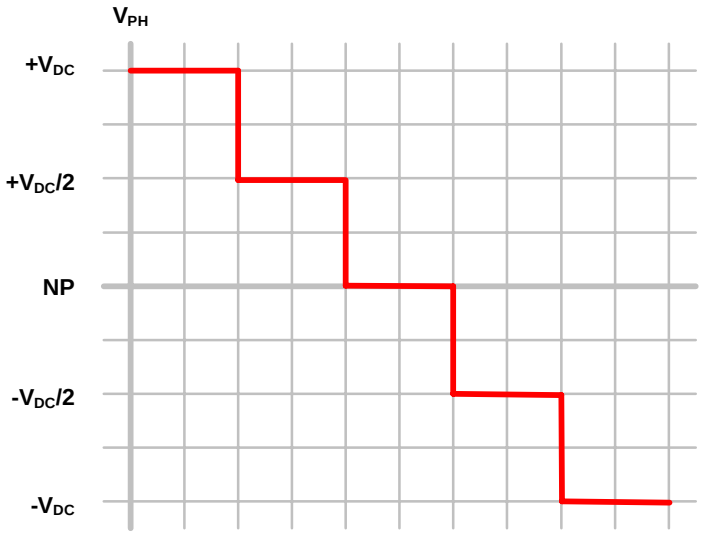




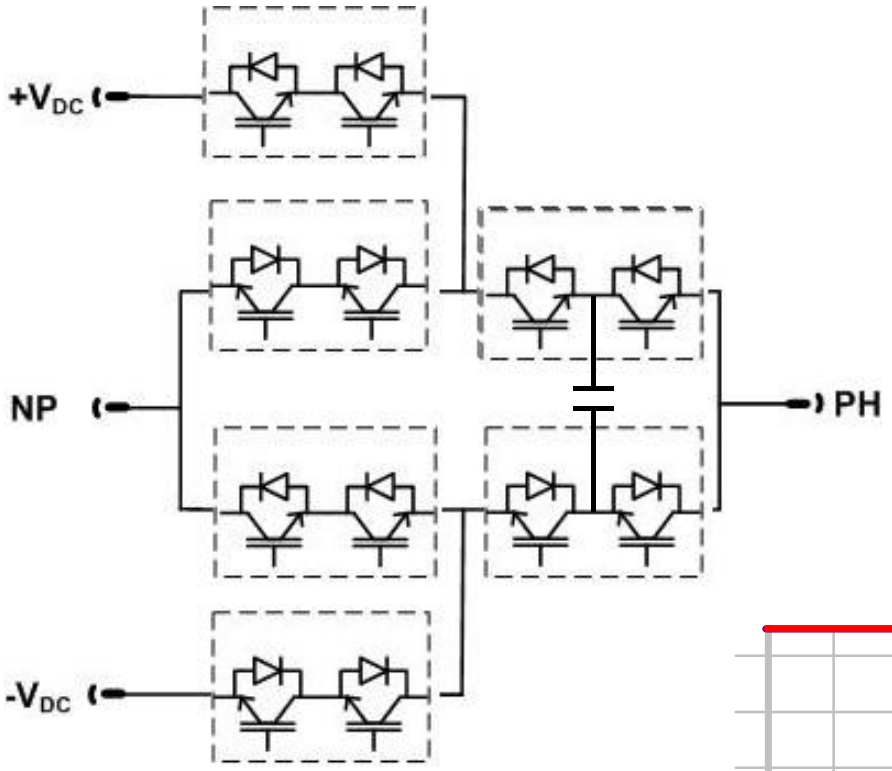
The 5-level VSI topology
Phase to ground voltage levels

- 5-Level ANPC VSI
- Phase output voltages

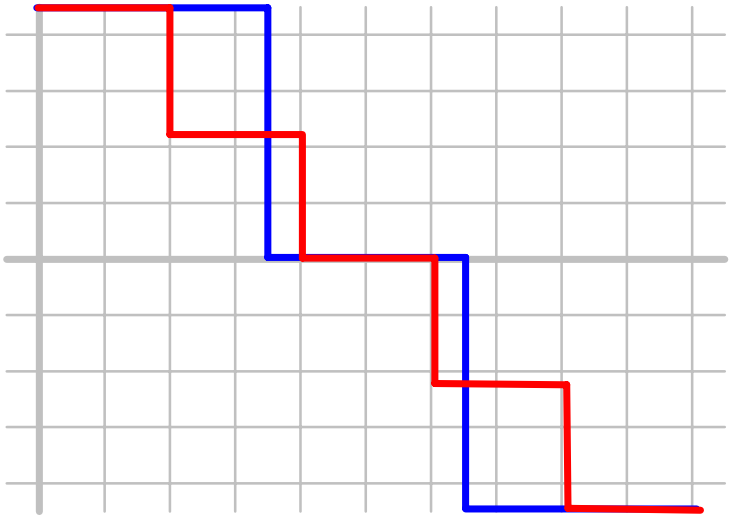




ACS 2000 – The 5-level VSI topology
From 3-level to 5-level topology



- 3-level
- 5-level



ACS 2000 low harmonic drives
Overview

ACS 2000 4kV

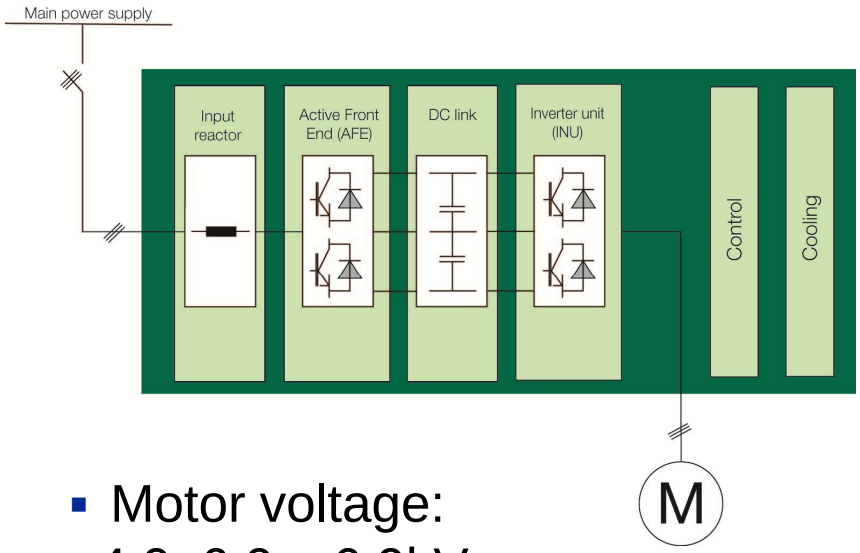
- Cooling: air
- Power range: up to 3 MVA
- Output voltage: 4.0 kV – 4.16 kV
- Available for: direct-to-line connection

ACS 2000 6kV

- Cooling: air
- Power range: up to 3 MVA
- Output voltage: 6.0 – 6.9 kV
- Available for: direct-to-line connection
  connection to a separate two winding transformer
  with an integrated transformer

ACS 2000 low harmonic drive
Direct to Line (DTL) for 4.0 … 6.9 kV line voltage

- Line Voltage: 4.0, 6.0 – 6.9kV



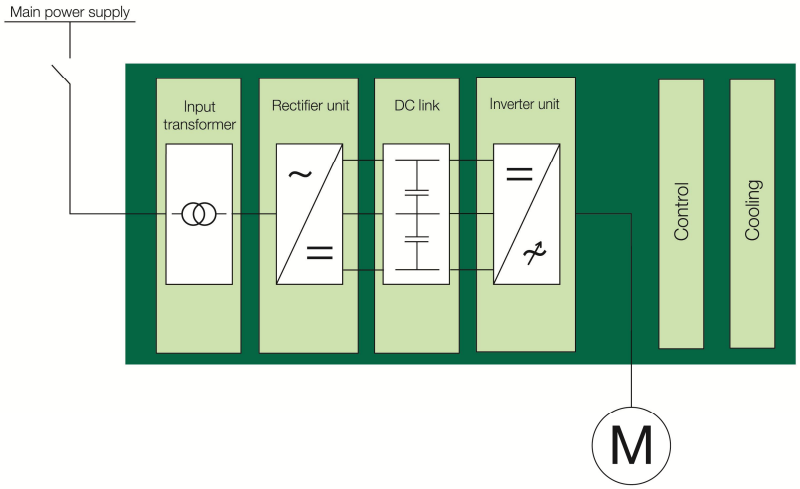
- Motor voltage: 4.0, 6.0 – 6.9kV

Transformer less solution with active front end (AFE)

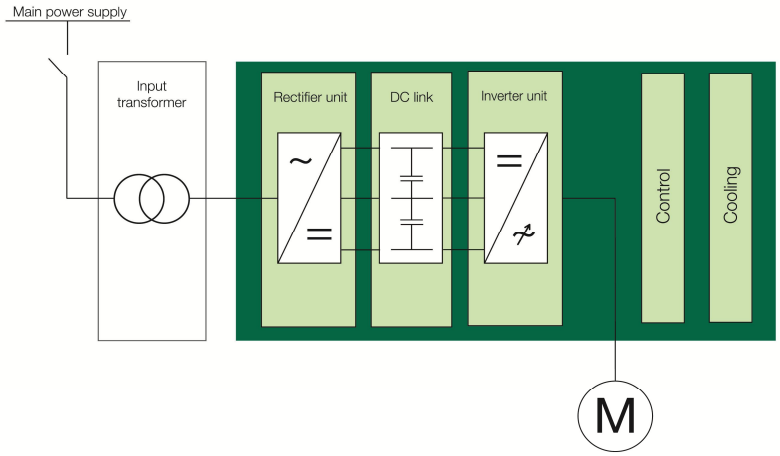
The advantage:

- Lowest harmonics
- Lower investment costs
- Quick and easy installation
- Three cable in, three cable out
- Easy retrofit to fixed-speed motors

ACS 2000 low harmonic drive
With input transformer and diode rectifier (DFE)

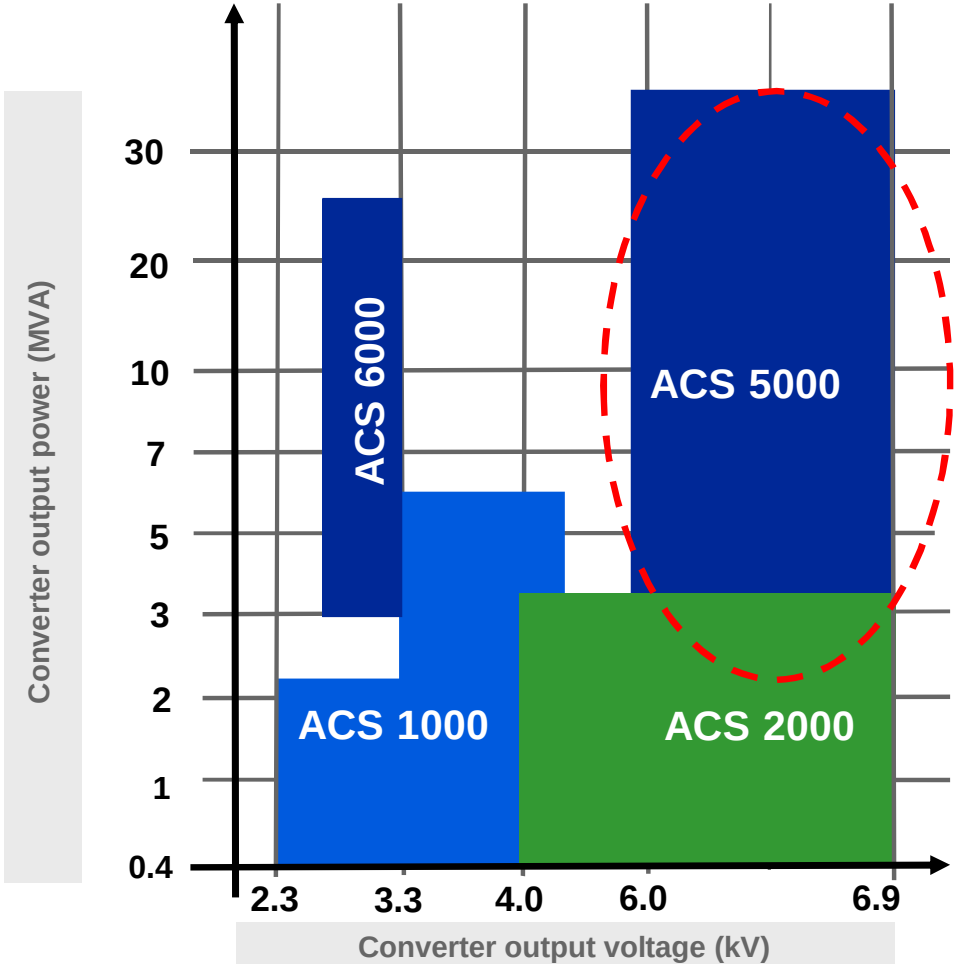


- Integrated 24- pulse dry-type transformer
  - Line voltage: Flexible (input transformer)
  - Motor voltage: 6.0 – 6.9kV



- External transformer
  - Oil transformer for outdoor installation
  - Dry-type transformer indoor installation
  - Line voltage: Flexible (input transformer)
  - Motor voltage: 6.0 – 6.9kV

Medium voltage drives
ACS product family – main features

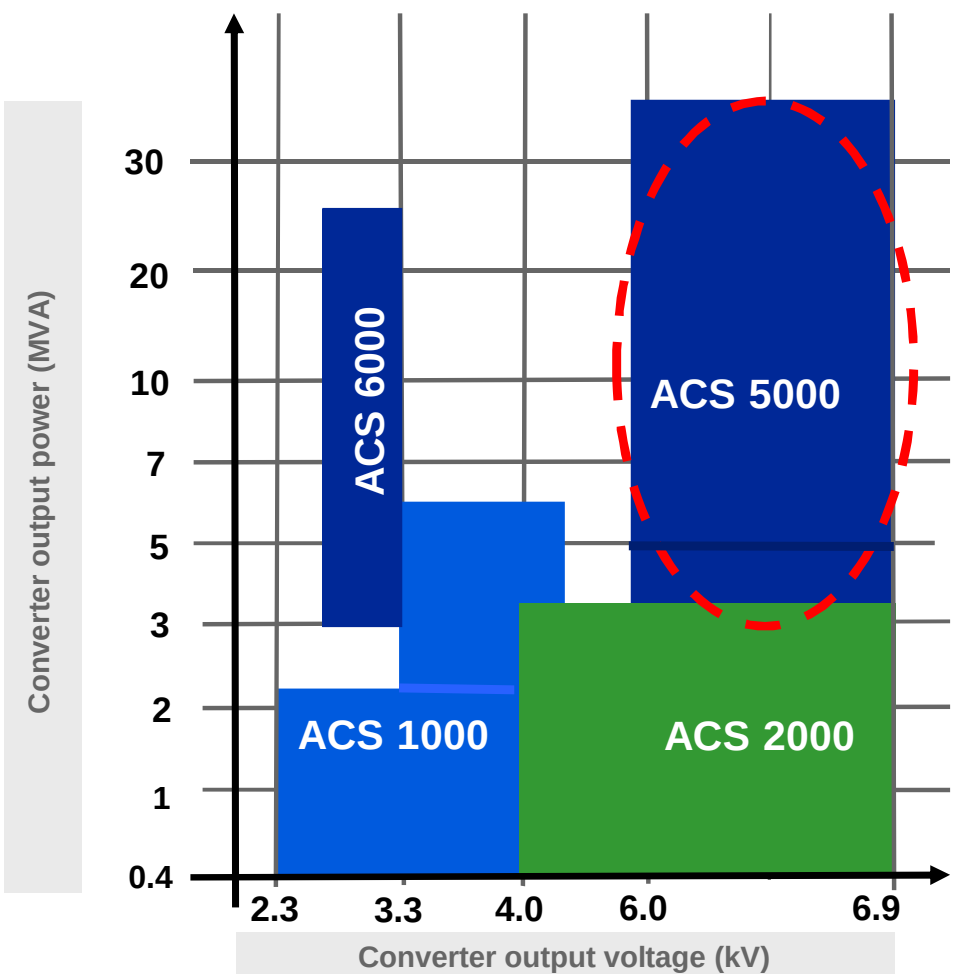


(ACS) **A**lternating **C**urrent **S**tandard Converter

ACS 5000 air and water-cooled

- Output Voltage: 6.0 – 6.9 kV
- Air-cooled up to 7MVA
- Water-cooled up to 32MVA (frame 1 -4)
- Oil or dry type input transformer
- Integrated transformer up to 4.2 MVA
- Optimal network friendliness due to 36-pulse configuration

Medium voltage drives
ACS 5000

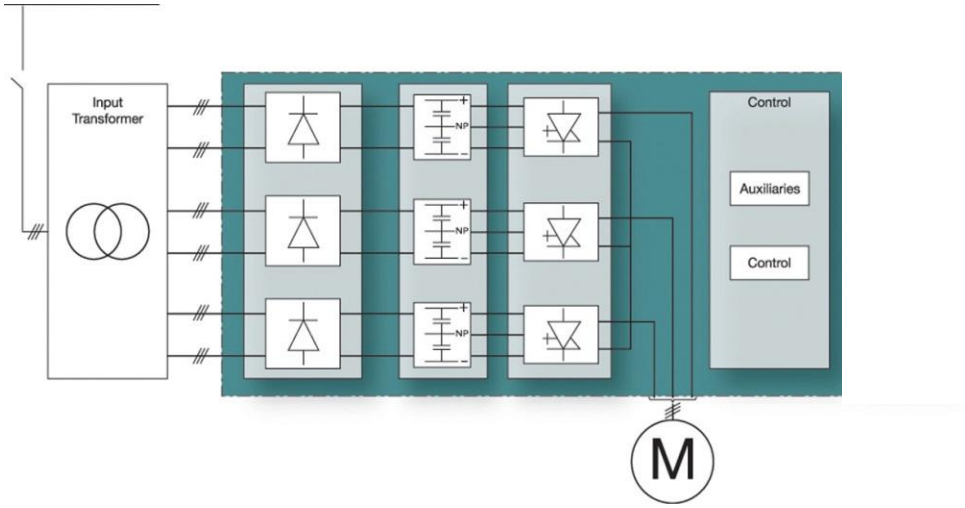


(ACS) **A**lternating **C**urrent **S**tandard Converter

ACS 5000 air and water-cooled

- Output Voltage: 6.0 – 6.9 kV
- Air-cooled up to 7MVA
- Water-cooled up to 32MVA (frame 1 – 4)
- Oil or dry type input transformer
- Integrated transformer for air-cooled types
- Optimal network friendliness due to 36-pulse configuration
- Fuseless design in power part
- Long-life DC-link capacitors

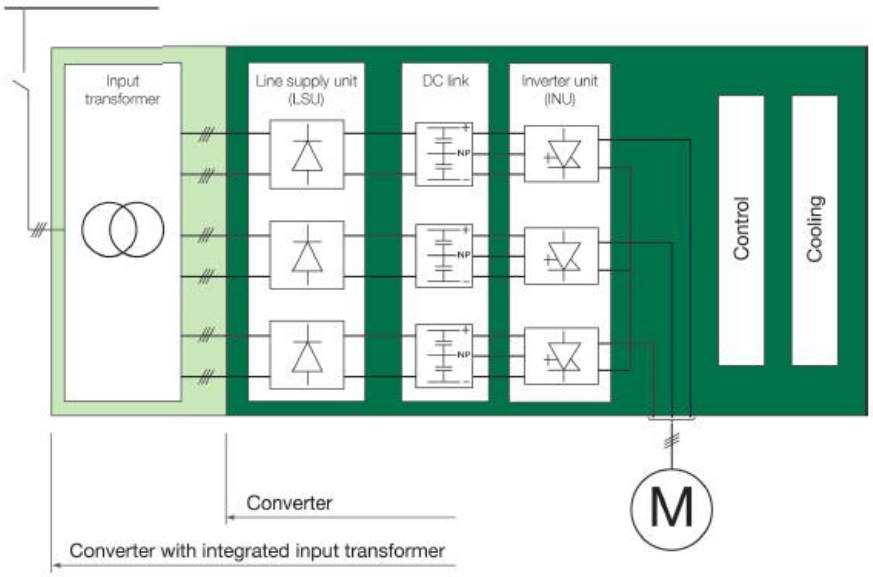
ACS 5000 product overview
Air-cooled range with external transformer



ACS 5000 air-cooled

- **Output power: 1.7 – 7.0 MVA**
- **Output Voltage: 6.0 – 6.9 kV**
- Suitable for standard induction, synchronous and permanent magnet motors up to 6.9 kV
- Optimal network friendliness due to 36-pulse configuration
- Fuseless design in power part
- Long-life DC-link capacitors
- Oil or dry type input transformer

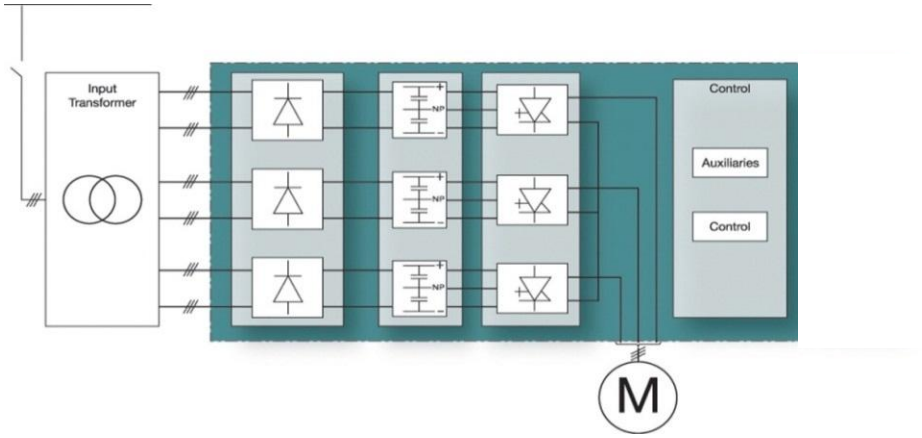
ACS 5000 product overview

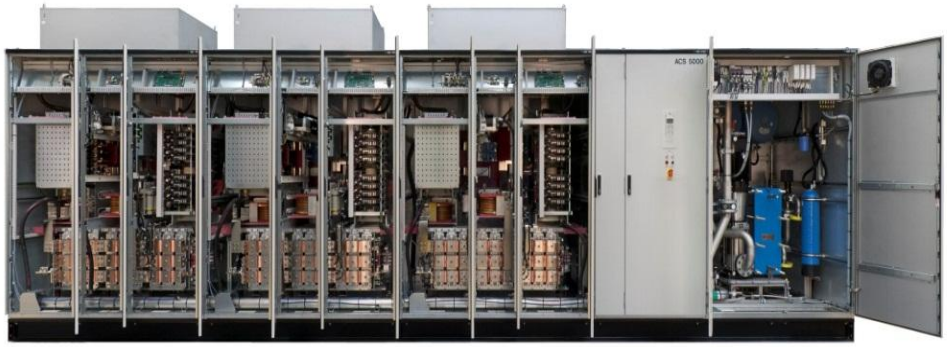


ACS 5000 air-cooled with integrated 36-pulse input transformer

- **Output power: 1.7 – 4.2 MVA**
- **Output Voltage: 6.0 – 6.9 kV**
- Suitable for standard induction, synchronous and permanent magnet motors up to 6.9 kV
- Optimal network friendliness due to 36-pulse configuration
- Fuseless design in power part
- Long-life DC-link capacitors

ACS 5000 product overview
Water- cooled range





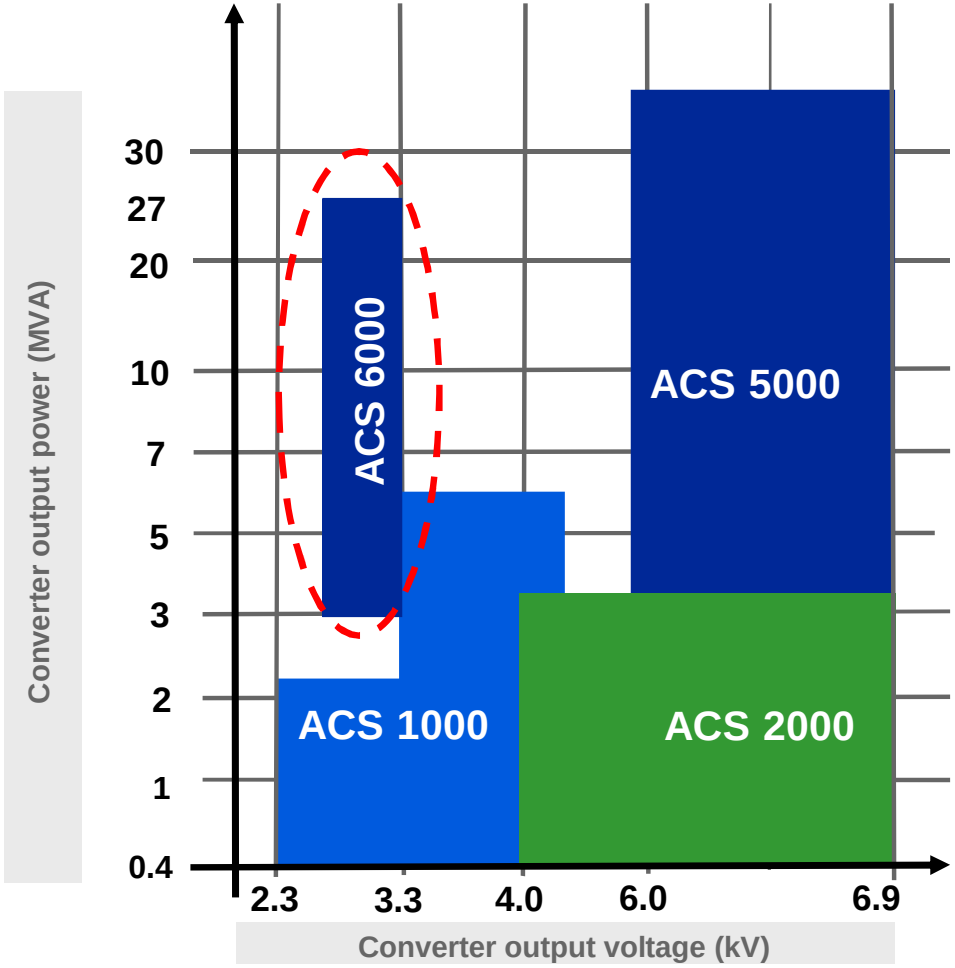
ACS 5000 frame 2
- Output power: 18 MVA
- Dimension: L/W/H: 9.1 / 1.6 / 2.2(2.7)m

ACS 5000 frame 1
- Output power: 12 MVA
- Dimension: L/W/H: 7.1 / 1.6 / 2.2(2.7)m

ACS 5000 water-cooled, frame 1 to 4

- Output power: up to 32 MVA
- Output Voltage: 6.0 – 6.9 kV
- Suitable for standard induction, synchronous and permanent magnet motors up to 6.9 kV
- Optimal network friendliness due to 36-pulse configuration
- Fuseless design in power part
- Long-life DC-link capacitors
- Oil or dry type input transformer

Medium voltage drives
ACS 6000



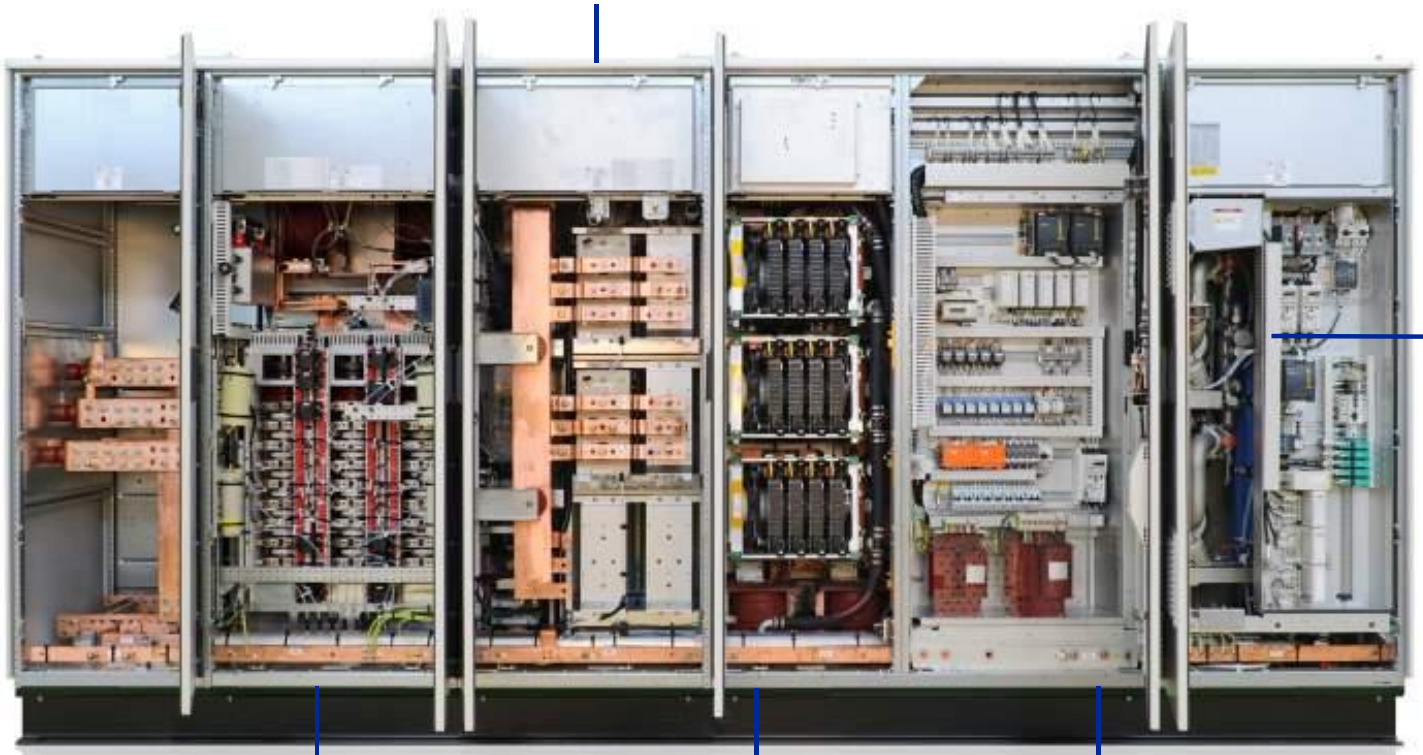
(ACS) Alternating **C**urrent **S**tandard Converter

Single or multi-motor applications, 3 – 27 MW / water-cooled

- For induction, synchronous and/or permanent magnet motors
- Common DC bus for single and multi-motor operation and energy recuperation
- Modular design for optimum configurations
- Line Supply Unit (LSU) for two-quadrant operation with a constant power factor of 0.96 over the whole speed range
- Active Rectifier Unit (ARU) for four-quadrant operation and reduced harmonics, adjustable power factor

ACS 6000 water cooled
3 – 27 MW

Capacitor Bank Unit
DC capacitors for smoothing the intermediate DC voltage



Water Cooling Unit
Supplies the closed cooling system with deionized water for the main power components

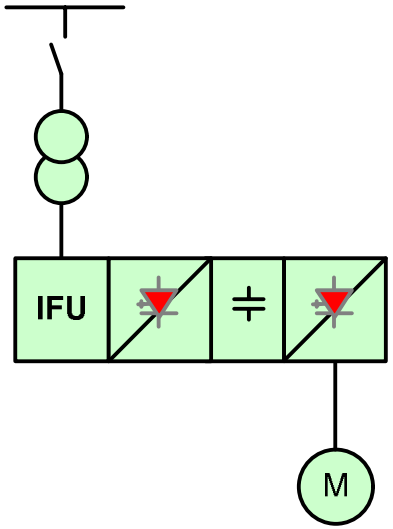
Line Supply Unit
6- or 12-pulse diode rectifier unit

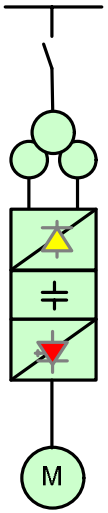
Inverter Unit
Self-commutated, 6-pulse, 3-level voltage source inverter with IGCT technology

Terminal and Control Unit
Contains the power terminals and the control swing frame

ACS 6000
Examples of single drive configurations

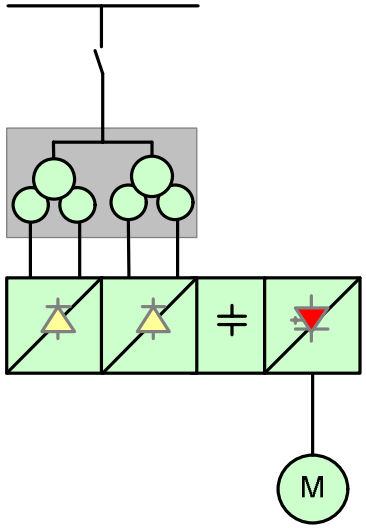
6-pulse ARU and Input Fiter Unit (IFU)

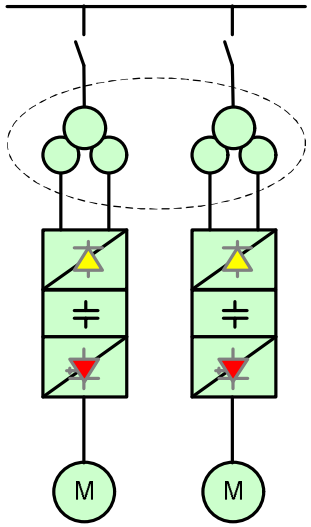




12-pulse configuration with diode input bridge (LSU)

24-pulse configuration with diode input bridge (LSU)

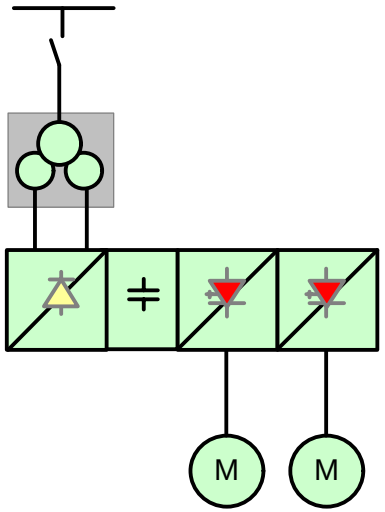


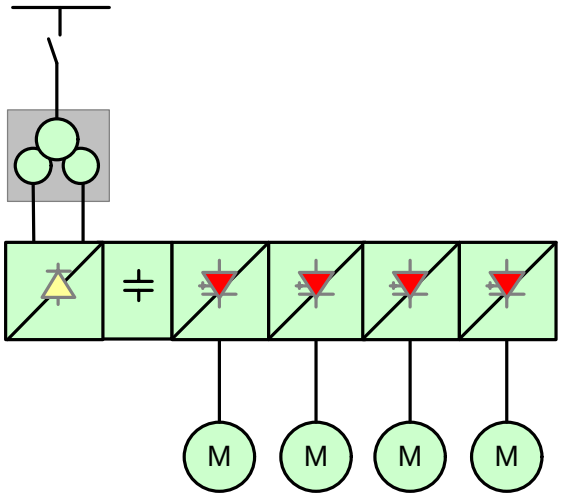


12-pulse configuration with LSU and pseudo 24-pulse transformer configuration

ACS 6000
Examples of MultiDrive configurations

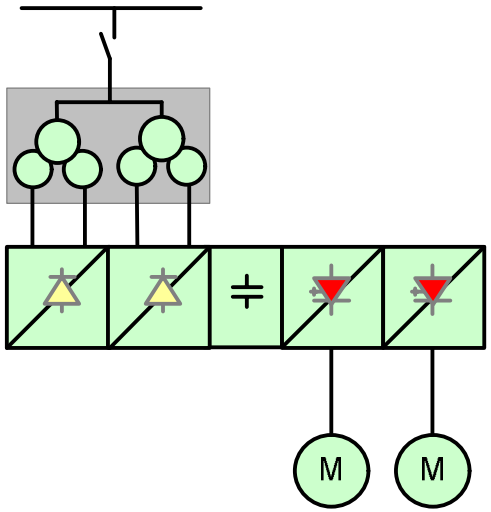
12-pulse MultiDrive for two motors

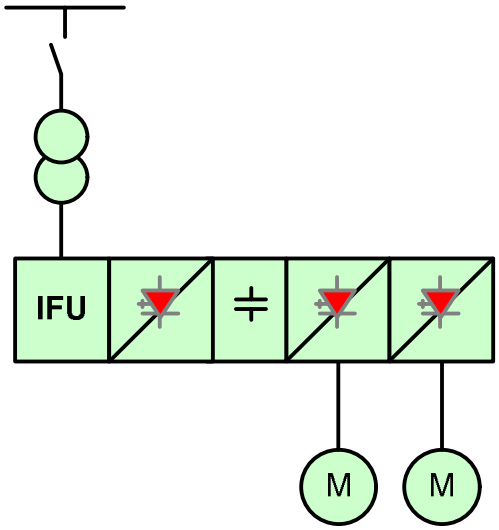




12-pulse MultiDrive for four motors

24-pulse MultiDrive for two motors





6-pulse MultiDrive for two motors

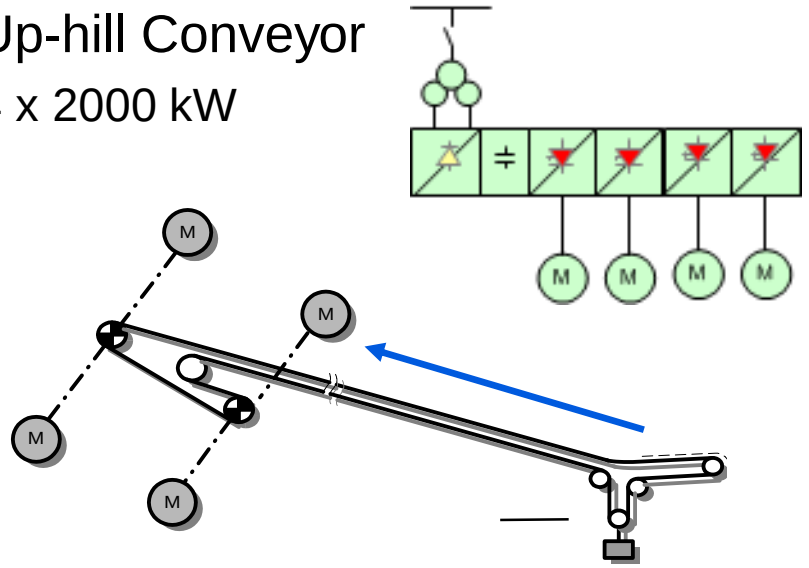
ACS 6000 / Reference installation at 4400 m
Chile COLLAHUASI

Up and down-hill Conveyors

ACS 6000 / Reference installation at 4400 m
Chile COLLAHUASI, total drive power: 20MW

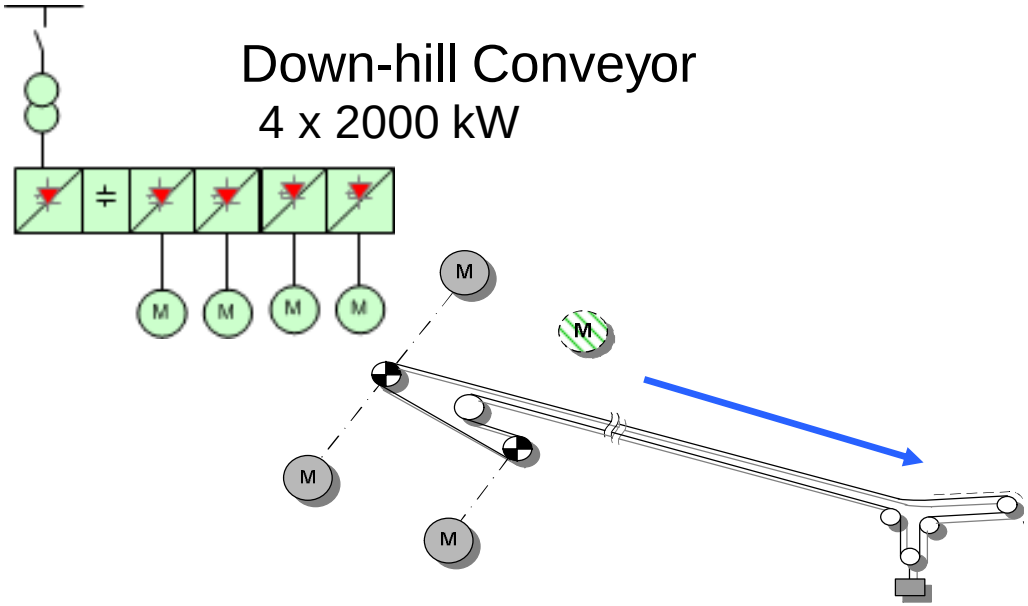
Up-hill Conveyor

4 x 2000 kW



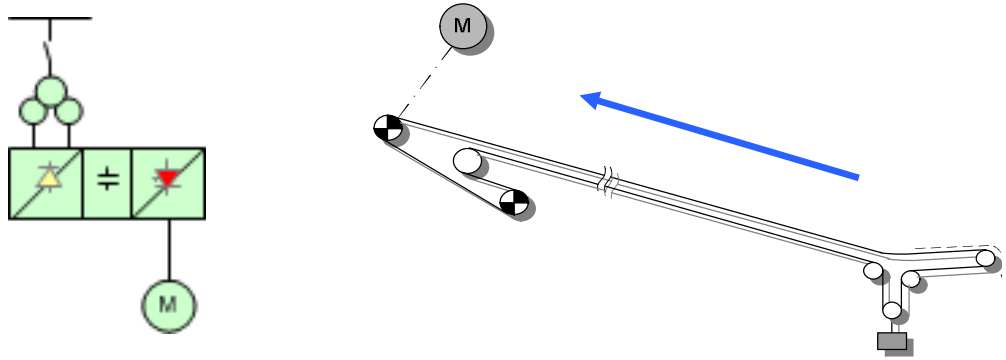
Down-hill Conveyor

4 x 2000 kW



Up-hill Conveyor

1 x 2000 kW



Soft starting with VSD and automatic bypass
Synchronous Bypass Unit (SBU)

Cabinet dimensions

Length:
830 mm;

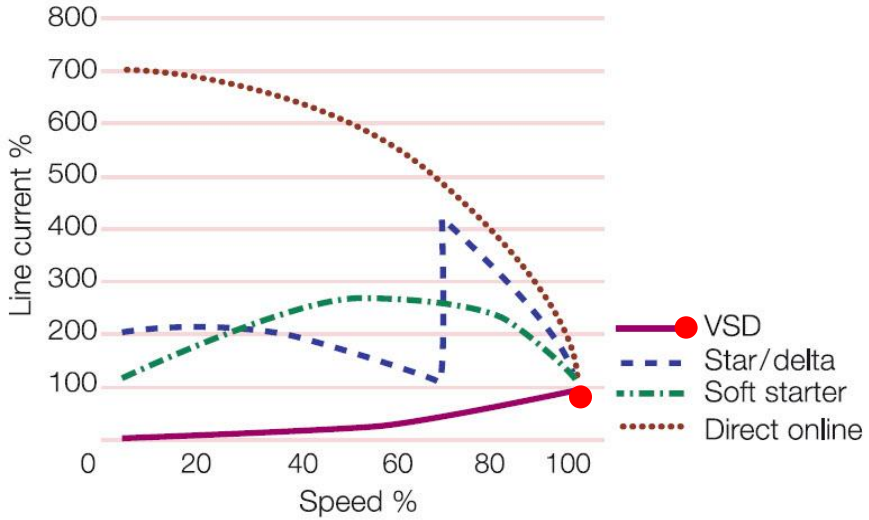
Depth:
1000 mm

Height:
2360 mm

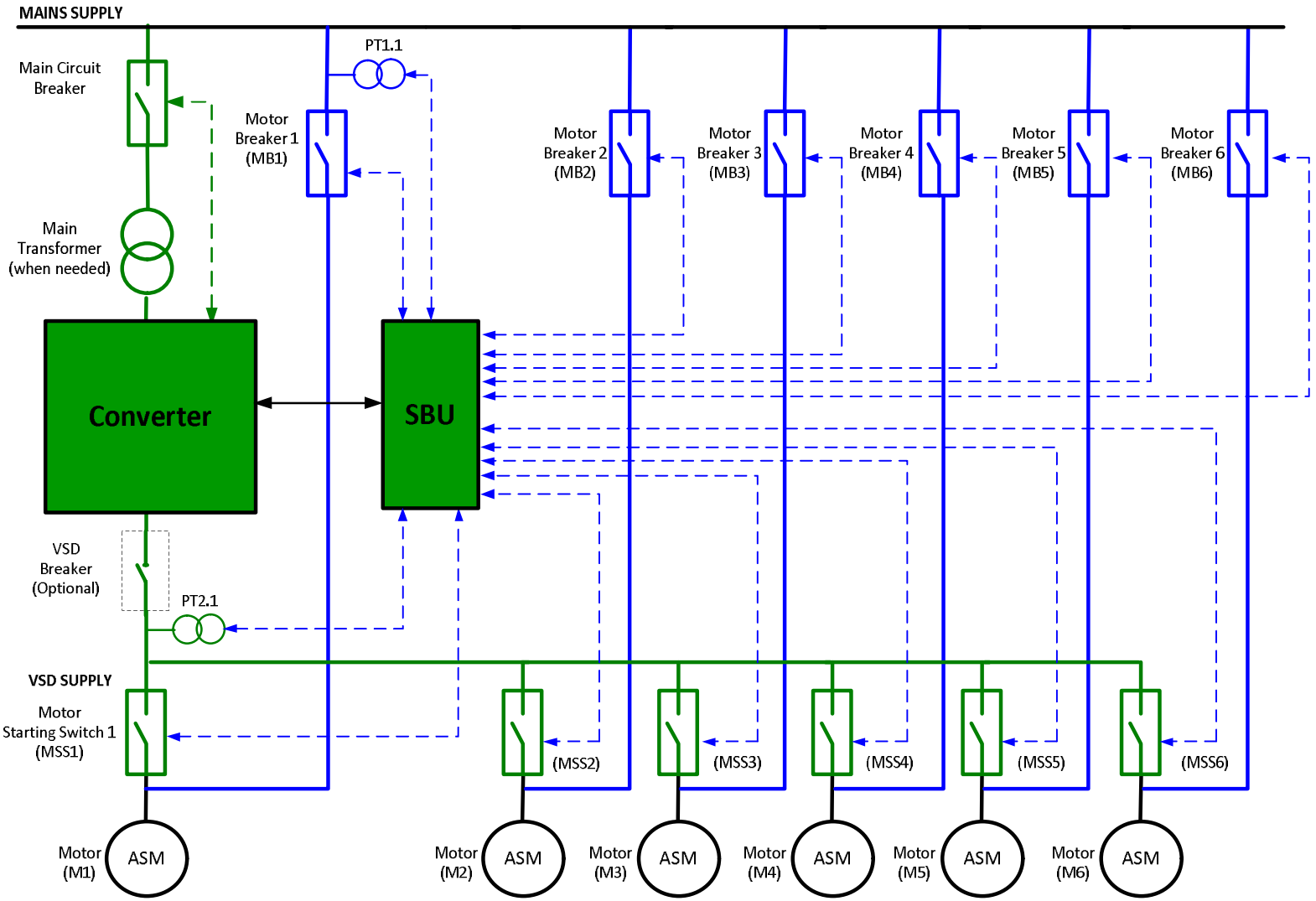
Weight:
700 kg

.

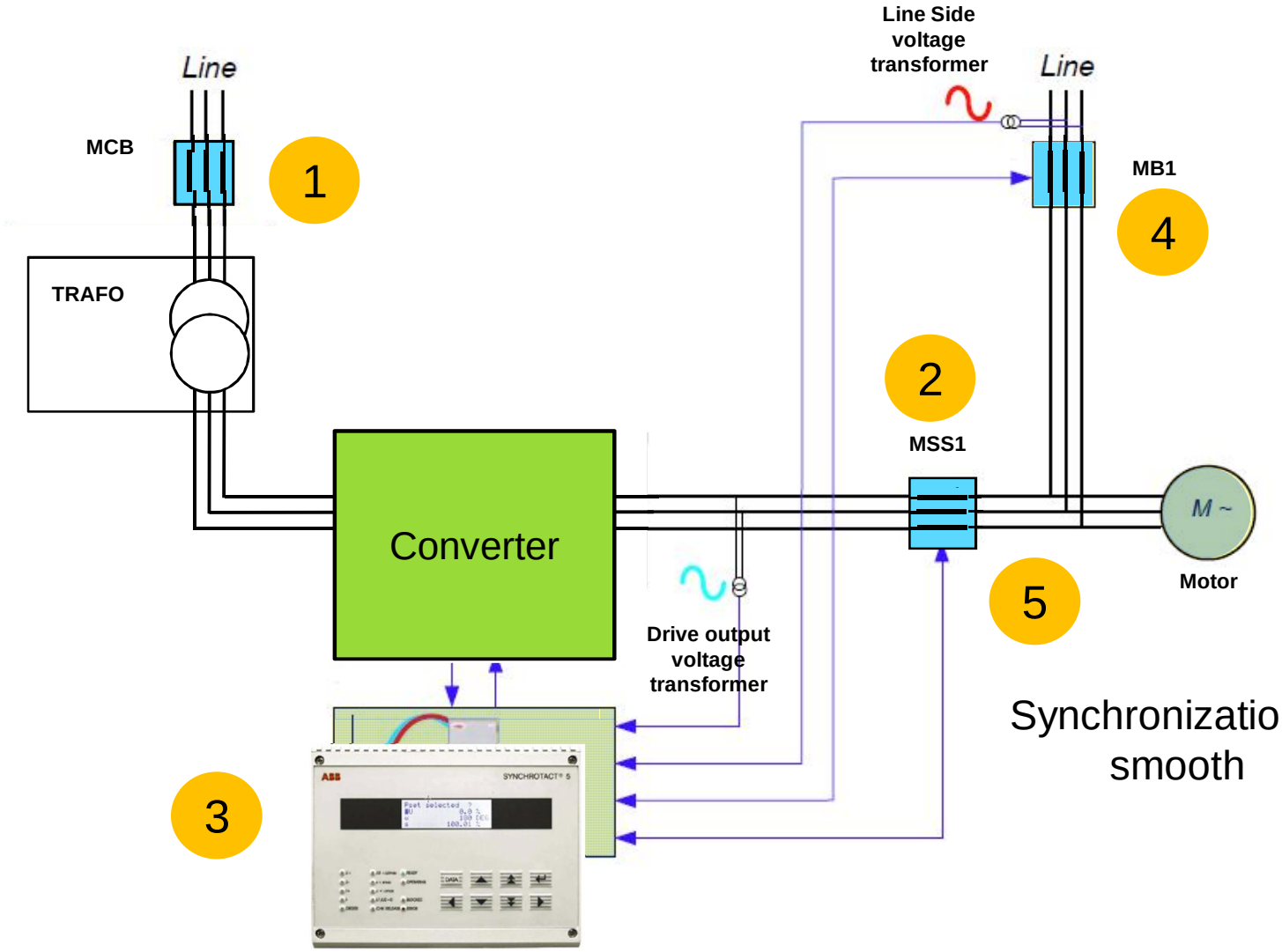
- Synchronous Bypass Control
- Start-up bypass for induction motors
- Start-up bypass for more than 6 motors as engineered option
- Controlled by extra AMC board, using Synchrotact 5



Soft starting with VSD and automatic bypass
Example with 6 Motors



Soft starting with VSD and automatic bypass
Functional Description – «Close before Open»



Synchronization is smooth

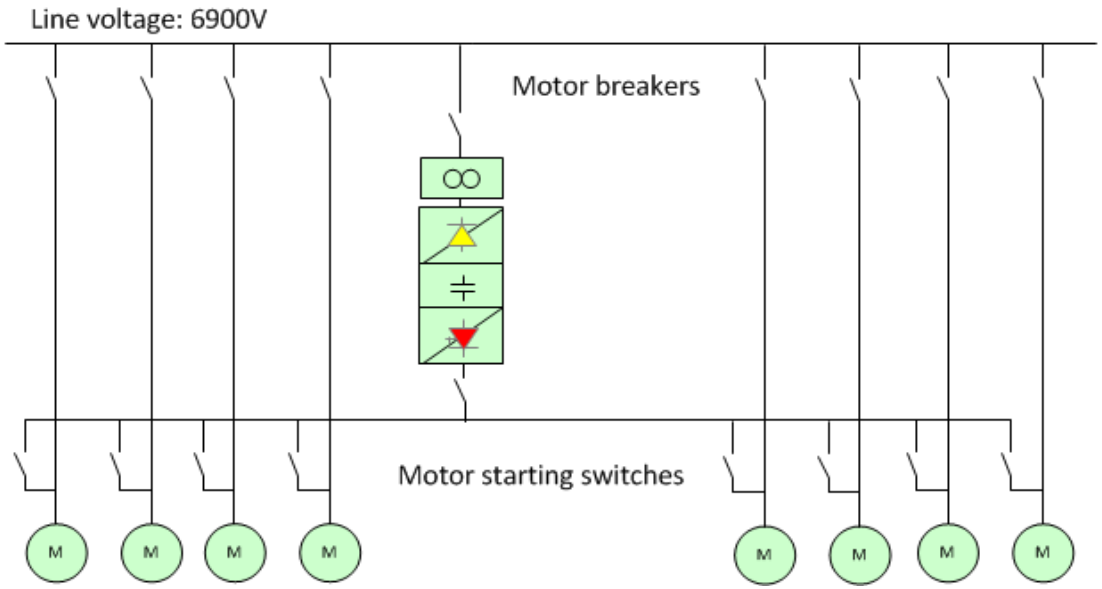
Soft starting with VSD and automatic bypass
Chile, case example - process water supply for mining

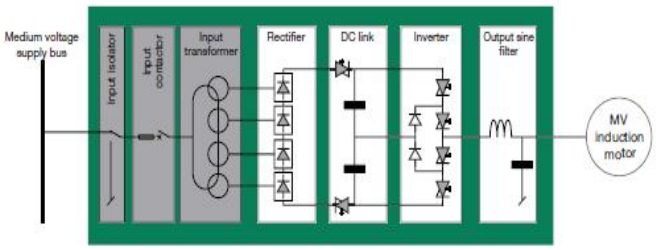
Intake PS,
equipped with 8 pumps

- Motor data: 450 kW / 4000 V
- One ACS 1000i with Auto By-pass

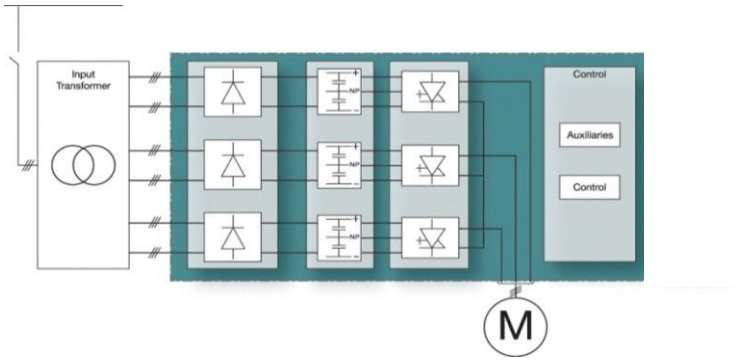
Two Booster PS,
each equipped with total 8

- Motor data: 3200 kW / 6900 V
- Two ACS 5000 with Auto By-pass





Typical ACS 1000i diagram



Soft starting with VSD and automatic bypass
Chile, case example - process water supply for mining

Scope of supply of ABB Process Automation (PA):

Complete e-rooms as turn-key solution including:

- Variable speed drives (ACS 1000 and ACS 5000 with auto bypass)
- MV/LV power distribution (switchgear, MCC)
- Auxiliary power distribution (ACC, UPS, battery charger)
- Distribution transformers
- Instrumentation
- Communication (DCS, SCADA)
- E-room equipment (e.g. fire-fighting, HVAC, lighting)
- Power transformers (distribution and VSD)
- Power factor correction
- Emergency diesel generator
- Heat exchangers for water-cooled equipment (chiller/fin fan)

Medium Voltage Drives
Chile

References: More than 200 medium voltage drives

Applications:

Grinding Mills, conveyors, pumps, roller press, fans, compressors and starter for gas turbine

Markets/Industry

Minerals and Mining, Cement, Oil & Gas, Power Generation, Water Supply

Main customers/projects

Los Colorados, Radomiro Tomic, Escondida, Codelco, El Romeral, Holcim, Los Pelambres, Hierro Atacama, Caserones, Caserones 2, Andina PDA, Esperanza, ACC Horno, Los Bronces 1, Michilla, Teniente PDT, Chuquicamata

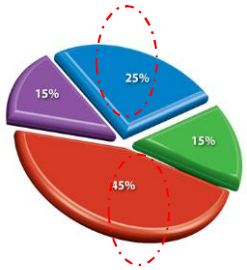
Live cycle costs (LCC) of pumping systems
Reduction of LCC with VSDs - summary

Power is proportional to the cube of speed

- **Less energy costs:**
  - Significant energy savings at reduced motor/pump speed
  - High power factor: 0.95, with ACS 2000 AFE close to 1.0

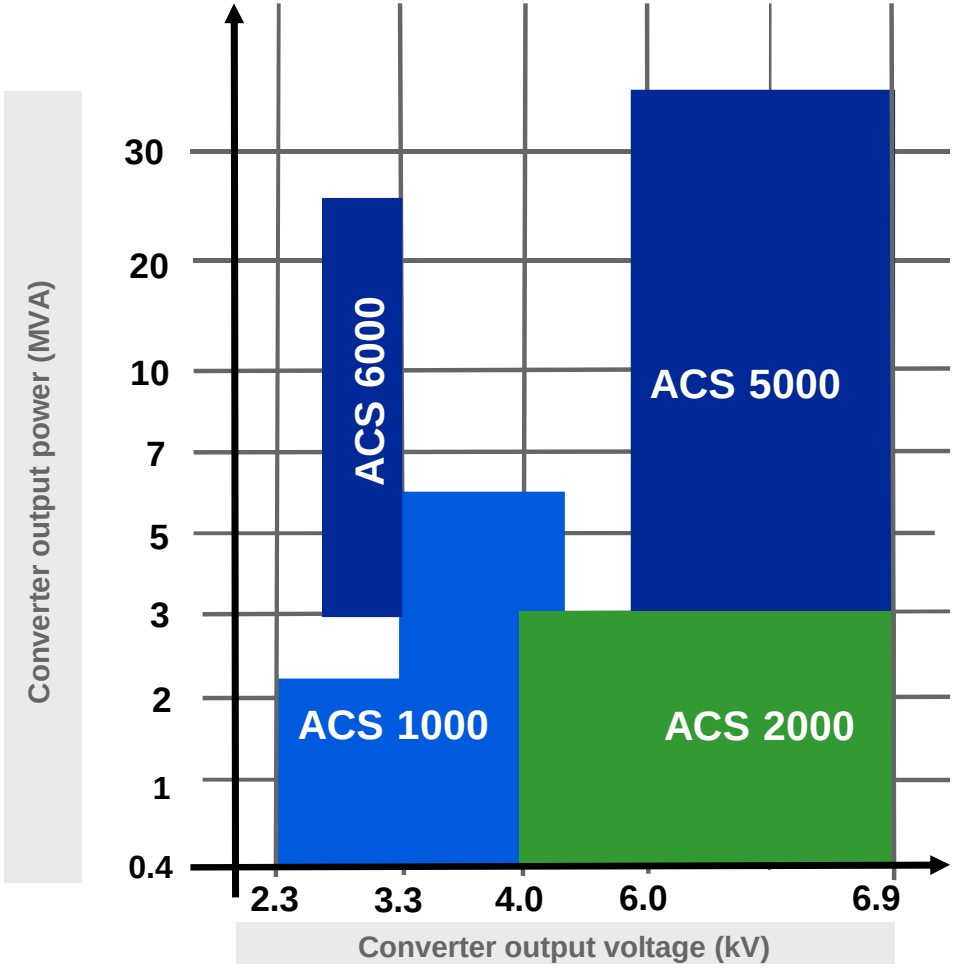
Pressure is proportional to the square of speed

- **Less maintenance costs:**
  - Reduction of maintenance and repair costs due to LESS pressure at pumping system components during starting, stopping and at operation with reduced motor/pump speed



- **The benefit:**
  - **Reduced life cycle costs (OPEX) of the pumping system and high availability**

ABB medium voltage drives
Safety, quality, reliability and energy efficiency



(ACS) **A**lternating **C**urrent **S**tandard Converter

Main features

- Robust and simple design
- Fuse lees design in the power part
- Long live time DC-link foil capacitors
- Smooth DC link charging
- Safety grounding switch for DC link capacitors

Customer benefit:

- High reliability, availability and safety
- High efficiency
- Low live cycle costs

Power and productivity
for a better world™