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

- Introduction
- Medium voltage drives, overview and high lights
- Life cycle costs of pumping systems
- Advantages and benefits of variable speed drives
- MV drives in the water market
  Product overview, application and reference examples
<table>
<thead>
<tr>
<th>Drives and Controls</th>
<th>Power Conversion</th>
<th>Motors and Generators</th>
<th>Robotics</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Low voltage AC drives from 0.12 to 5600 kW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Medium voltage drives from 250 kW to more than 100 MW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- DC Drives from 4 kW to 15000 kW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- PLCs, HMs, and wireless sensors and actuators</td>
<td></td>
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</tr>
<tr>
<td>- Software tools</td>
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<tr>
<td>- Energy saving tools</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Service</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Advanced power electronics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Converter products</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Excitation and synchronizing systems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- High power rectifiers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Power quality and power protection products, incl. UPS</td>
<td></td>
<td></td>
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<tr>
<td>- Traction converters</td>
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<tr>
<td>- Wind turbine drives</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>- Solar inverters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Charging infrastructure for electric vehicles</td>
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<td>- Service</td>
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<td></td>
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<tr>
<td>- Low voltage motors from 0.25 to 1000 kW</td>
<td></td>
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<tr>
<td>- High voltage motors and generators up to 70 MW</td>
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<td>- High speed motors</td>
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<td>- Traction motors</td>
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<tr>
<td>- Wind power generators</td>
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<td>- Diesel generators</td>
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<tr>
<td>- Gas and steam turbine generators</td>
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<td>- Hydro generators, tidal waves, etc</td>
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<tr>
<td>- Service</td>
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<tr>
<td>- Industrial robots</td>
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<tr>
<td>- Robot controllers and software</td>
<td></td>
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<tr>
<td>- Industrial software products</td>
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<tr>
<td>- Application equipment and accessories</td>
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<tr>
<td>- Robot applications and automation systems for automotive, foundry, packaging, metal, solar, wood, plastics, etc. industries</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>- Service</td>
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</tbody>
</table>
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
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 supply for:
- Irrigation, some 225,000ha
- Drinking water for three million people

Pumping station equipped with 21 pumps
- Total pumping capacity: 350 m³ per sec.
- Drive power per pump: 12 MW
- Total 252 MW drive power

6 km inlet canal
240 km irrigation waterways

Nasser Lake above the Aswan High Dam
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
Minerals and Mining
High lights – Largest gearless mill drives (GMD)

- **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

Motor power [MW]

Motor [kV]

(ACS) Alternating Current Standard Converter

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June 5, 2013 | Slide 13
### Medium voltage drives in the water market

VSD and soft starting solutions

<table>
<thead>
<tr>
<th>Segmentation</th>
<th>Applications</th>
<th>Typical power range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw and drinking water</td>
<td>- Intake and transmission pumps&lt;br&gt;- Distribution and booster pumps</td>
<td>0.3 - 5.0 MW&lt;br&gt;0.3 - 1.5 MW</td>
</tr>
<tr>
<td>SWRO desalination</td>
<td>- Sea water intake and process pumps</td>
<td>0.3 - 4.0 MW</td>
</tr>
<tr>
<td>Waste water</td>
<td>- Transmission, influent and effluent pumps&lt;br&gt;- Treatment pumps and aeration blowers</td>
<td>0.3 - 5.0 MW&lt;br&gt;0.3 - 1.5 MW</td>
</tr>
<tr>
<td>Domestic</td>
<td>- District cooling and heating transfer and distribution pumps</td>
<td>0.3 – 1.5 MW</td>
</tr>
<tr>
<td>Industrial</td>
<td>- Intake and transmission pumps for cooling/process water</td>
<td>0.3 - 7.0 MW</td>
</tr>
<tr>
<td>Lift irrigation and large pumping stations</td>
<td>- Intake and transmission pumps</td>
<td>5.0 - 40 MW</td>
</tr>
</tbody>
</table>
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

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

Typical LCC of a pumping system:
- High energy costs, in this case 45%
- High regular maintenance costs, in this case 25%

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

- 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% speed power consumption is only 51% or 2 MW

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

The behavior of pumping systems are described with curves

\[ H_N \text{ (Nominal Head)} = H_{st} + H_{dyn} \]
Power demand
Throttling control versus VSD control

\[ H_2 = 1.27 \]

\[ Q_2 = 0.7 \]

\[ H_1 = 1 \]

\[ Q_1 = 1 \]

\[ P \approx 0.7 \times 1.27 = 0.89 \]
Power demand
Throttling control versus VSD control

\[
H_2 = 0.64, \quad Q_2 = 0.7
\]

\[
P \approx 0.7 \times 0.64 = 0.45
\]
Power demand
Throttling control versus VSD control

Throttling

\[ \begin{align*}
H_2 &= 1.27 \\
H_1 &= 1 \\
Q_1 &= 1 \\
Q_2 &= 0.7 \\
P &\approx 0.7 \times 1.27 = 0.89
\end{align*} \]

VSD Control

\[ \begin{align*}
H_1 &= 1 \\
H_2 &= 0.64 \\
Q_1 &= 1 \\
Q_2 &= 0.7 \\
P &\approx 0.7 \times 0.64 = 0.45
\end{align*} \]

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 loses 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
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
Starting methods of induction motors

Overview

<table>
<thead>
<tr>
<th>Starting method</th>
<th>Inrush current in % compared to IN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable speed drive (VSD)</td>
<td>100% (depending on start up requirements)</td>
</tr>
<tr>
<td>Typical soft starter</td>
<td>up to 300%</td>
</tr>
<tr>
<td>Star/delta</td>
<td>up to 400%</td>
</tr>
<tr>
<td>Direct on line (DOL)</td>
<td>up to 700%</td>
</tr>
</tbody>
</table>
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 drop
  - 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

- High maintenance costs and low availability
- Drawbacks
  - High inrush current
  - High pressure/stress at pumping system equipment
- 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
- Less 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

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

- **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

- Tawaelelah 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 km² 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)
Case example
Fresh water distribution

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%.

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.
Water Resources on the Earth

97% of available water is salty water

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...
- 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

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 drop
- Soft starting
  - Less mechanical stress at motor, pump, membrane, hydraulic system, etc.
  - No thermal stress at motor windings


Tendency is towards BOO projects
- Lowest possible operating cost is one of the key factors
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

- Motor voltage: 3300 V
- Motor power: between 700 and 2000 kW
- 12-pulse
- Air-cooled
SWRO desalination
Overview of some MVD case examples

<table>
<thead>
<tr>
<th>Project name</th>
<th>Installation country</th>
<th>Medium Voltage Drives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magataa Desalination Plant</td>
<td>Algeria</td>
<td>33 Quantity: 4 ACS 1000, 7 ACS 1000, 22 ACS 1000</td>
</tr>
<tr>
<td>Tuas Desalination 70mgd</td>
<td>Singapore</td>
<td>32 Quantity: 15 ACS 1000, 17 ACS 1000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Product: ACS1013-A2, ACS1013-A3</td>
</tr>
<tr>
<td>Ras Az Zawr</td>
<td>Saudi Arabia</td>
<td>23 Quantity: 6 ACS 5000, 17 ACS 2000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Product: ACS5060, ACS2066-1L</td>
</tr>
<tr>
<td>Point Lisas Industrial Park</td>
<td>Trinidad</td>
<td>12 Quantity: ACS 1000</td>
</tr>
<tr>
<td>Salalah Desalination Plant</td>
<td>Oman</td>
<td>10 Quantity: ACS 1000</td>
</tr>
<tr>
<td>Southern Seawater Desalination (P1)</td>
<td>Australia</td>
<td>9 Quantity: ACS 1000</td>
</tr>
<tr>
<td>Southern Seawater Desalination (P2)</td>
<td>Australia</td>
<td>9 Quantity: ACS 1000</td>
</tr>
</tbody>
</table>
Medium voltage drives
ACS product family - solutions

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

Converter output power (MVA)

Converter output voltage (kV)

ACS 6000
ACS 5000
ACS 2000
ACS 1000

Typical ACS 1000 diagram

(ACS) Alternating Current Standard Converter
Medium voltage drives
ACS product family – 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
- Air and water-cooled solutions
Medium voltage drives
ACS 1000

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

(ACS) Alternating Current Standard Converter

Typical ACS 1000 diagram
ACS 1000 product overview
Air-cooled

- 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

Typical ACS 1000 diagram
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

- 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

- 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

Converter output power (MVA)

Converter output voltage (kV)

ACS 1000
ACS 2000
ACS 5000
ACS 6000

(ACS) Alternating Current Standard Converter

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

```
+V_{DC} \rightarrow \begin{array}{c}
\text{Phase output voltage: } V_{PH} \\
\text{NP} \\
-\text{V}_{DC}
\end{array}
```
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
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
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

- IGCT (semiconductor) protection
- ABB’s fuseless design acts within $25 \mu$s

Fuses disconnect circuits within 100 ms
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

- 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

Oil-filled foil capacitor
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
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
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

Converter output power (MVA)

Converter output voltage (kV)
ACS 2000 low harmonic drive
Overview

- **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

![Diagram of 5-level ANPC VSI topology]

Graph showing phase output voltages:
- $V_{PH}$
- $+V_{DC}$
- $+V_{DC}/2$
- $NP$
- $-V_{DC}/2$
- $-V_{DC}$
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 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 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

(ACS) Alternating Current Standard Converter
Medium voltage drives
ACS 5000

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) Alternating Current Standard Converter
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 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

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
Medium voltage drives
ACS 6000

- 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

Converter output power (MVA)

Converter output voltage (kV)
ACS 6000 water cooled
3 – 27 MW

**Capacitor Bank Unit**
DC capacitors for smoothing the intermediate DC voltage

**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

**Water Cooling Unit**
Supplies the closed cooling system with deionized water for the main power components
ACS 6000
Examples of single drive configurations

6-pulse ARU and Input Filter Unit (IFU)

24-pulse configuration with diode input bridge (LSU)

12-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

24-pulse MultiDrive for two motors

12-pulse MultiDrive for four 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 COLLALHUASI, 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)

- 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

Cabinet dimensions

Length: 830 mm
Depth: 1000 mm
Height: 2360 mm
Weight: 700 kg
Soft starting with VSD and automatic bypass
Example with 6 Motors
Soft starting with VSD and automatic bypass

Functional Description – «Close before Open»

1. MCB
2. MSS1
3. Converter
4. Line Side voltage transformer
5. Motor

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
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 Broncos 1, Michilla, Teniente PDT, Chuquicamata
Live cycle costs (LCC) of pumping systems
Reduction of LCC with VSDs - summary

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

- **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

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™