Power Electronic Grid Simulator
Platform of drives and power quality products for wind-turbine testing

Ester Guidi, Pieder Jörg, ABB Medium Voltage Drives, Switzerland
Outline

- Teststand applications for drives and power electronics
  - Modular drives and power-electronics platform ACS6000
  - Power electronic grid simulator based on platform
  - Design considerations following windturbine testing requirements
Teststand applications for drives and power electronics

Test stand applications

**single-drive**

motoring OR generating

**multi-drive**

motoring AND generating

Device under test
Teststand applications for drives and power electronics

Test stand applications

**single-drive**

**motored device testing**

**fixed installation**

Device under test
## ABB’s areas of activity

### Test stand applications

<table>
<thead>
<tr>
<th>Single drive</th>
<th>Multi drive</th>
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<tbody>
<tr>
<td><strong>Device testing</strong></td>
<td><strong>Gearbox</strong></td>
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<tr>
<td>- Compressor &amp; turbo charger</td>
<td>- Electrical generator</td>
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<tr>
<td>- Pump</td>
<td>- Electrical motor</td>
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<tr>
<td>- Balancing plant</td>
<td>- Grid simulation</td>
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<tr>
<td>- Jet engine</td>
<td>- Wind turbine</td>
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<tr>
<td>- Gas Turbines</td>
<td>- …</td>
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<tr>
<td>- Motor Generator set, …</td>
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<table>
<thead>
<tr>
<th><strong>Fix installations</strong></th>
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</thead>
<tbody>
<tr>
<td>- Wind tunnel</td>
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<tr>
<td>- Human centrifuge (pilot training)</td>
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<tr>
<td>- Soft starters for high energy labs</td>
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Teststand applications
Typical requirements towards electrics/automation

- High dynamic electric motor control over wide speed range
  - capability to control induction and synchronous motors
  - base speed of electrical motor:
    1Hz .. 75Hz / few rpm .. 3600rpm
  - wide field-weakening range (… 1:5)
  - high torque over-loadability (… 275%)
  - air-gap-torque control bandwidth (… 400Hz)
  - flexible automation integration (PLC, FB, fast I/O …)
- Versatile power electronic building blocks
  - load-cycling capable (reliability)
  - parallelable and multi-terminal capable (scalability)
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ACS 6000
Modular drives and power-electronics platform

- Voltage range
  - 2.3…3.3 kV

- Power range
  - 3…27 MVA continuous and 36 MVA short term

- Output frequency range
  - 0…75 Hz (higher on request)

- Field weakening point
  - 3.125…75 Hz (lower / higher on request)

- Field weakening range
  - 1:5
ACS 6000 focus: Demanding applications

- Cement, Mining & Minerals
- Marine
- Metals
- Chemical, Oil & Gas
- Power
- Water
- Pulp & Paper
- Special applications, e.g. wind tunnels
ACS 6000: Some building blocks

Inverter Unit

Active Rectifier

Pre-defined interfaces for power, cooling & control connections

Capacitor Bank

Diode Rectifier

Water Cooling

INU 5 – 9MVA

ARU 5 – 9MVA

INU 1 – 5MVA

AC

DC

M

AC

DC

M

AC

DC

M

AC

DC

M

AC

DC

M

AC

DC

M
ACS 6000 water cooled
3 – 36 MW

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

Capacitor Bank Unit
DC capacitors for smoothing the intermediate DC voltage

Active Rectifier Unit (ARU)
Self-commutated, 6-pulse, 3-level voltage source inverter with IGCT technology

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

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

- 3-level voltage source inverter
- IGCT technology for maximal loadability in combination with minimal part count
- Fuseless design, ACS 6000 uses IGCTs for fast and reliable protection of power components instead of unreliable medium voltage power fuses
Common DC bus

- Several motors (induction and synchronous) can be connected to the same DC bus → optimized energy flow
  - Braking energy generated in one motor can be transferred to other inverters via common DC bus without power consumption from supply network
  - Optimum configuration can be reached by combining different inverter and rectifier modules within one drive
Parallel connection of inverter units:

9, 18, 27, 36MVA as standard

e.g. 9MVA unit
ACS 6000: Flexible solutions from 2Q single ...

Recomendation:
- min. 100 mm for conventional air circulation
- min. 500 mm for better service availability

INU 5 MVA

ACS 6105_L12_1a5
ACS 6000: ... to 4Q multi drive

ACM 6209_A12_1s9_1s9_1s9
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Main benefit: Enables tests to be carried out off-line in a cost- and time-efficient manner

Flexibility: suitable for any kind of electrical equipment that needs to be connected to the grid

- Wind and Tidal Turbines
- PV systems
- Solar power
- Fuel cells
- Motor Gensets
- Energy storage systems
ACS 6000 grid simulator
Combined functionality
Project example – test stand for wind turbine
Combined functionality drive train and grid simulator

Integrated all in one line-up based on ACS6000 platform
ACS 6000 grid simulator
Example of a layout and dimensions
ACS 6000 grid simulator
Layout possibilities

- U-shape, L-shape, ...
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ACS 6000 based grid simulator
Control and transformer engineered to application

- Grid simulator inverter control and the output transformer are dedicated ("engineered") for the grid simulator application
- Everything else is "off the shelf"
  - Power electronic hardware
  - Hardware protection
  - Mechanical design and cooling
  - Supervisory control and sequencing
  - Supply from public grid
  - ...
ACS 6000 grid simulator
Control hardware overview
ACS 6000 grid simulator
Control hardware features

- **Main controller - PP D113**
  - 36 Optical fiber modules (25us)
  - DDCS (DriveBus Comm)
  - Communication to the upper control via Anybus-Modules or CEX
  - Profibus-DPV1 Master
  - CANopen Slave
  - ControlNet Slave
  - DeviceNet Slave
  - Modbus-RTU S, -TCP S
  - Profibus-DP S, -DPV1 S, EtherCAT S
  - Profinet RTI - IO

- **Fast IO – UA D149**
  - PowerLink (native protocol – 25 us)
  - 32 DI (24V)
  - 16 DO (24V)
  - 12 AI (±10V, ±20mA)
    - Isolated in groups of 3
  - 4 isolated AO (±10V, ±20mA)
ACS 6000 grid simulator
Functional diagram

ACS6000
- ARU
  - DC link control
  - NP balancing
- INU AMC
  - Main state machine
  - Protection
  - RBU control
  - Site control (WCU, etc)

INU INT
- Switching logic & state machine
- Interlock control

Supervisor
- V reference generation – dq
- Tester configuration - parameters

PEC800
- Simulink
  - Communication with supervisor
  - State machine aligned to AMC
  - OPP configuration

- FPGA
  - 4x Modulator (OPP/PWM/…)
  - ASE control
  - Interlocking
  - Zero vector/phase disabling
  - Switching control / clamp interlocking
Overview: Configurations of matching transformer

What is the function of the transformer

- Match the converter voltage to the desired testbus-voltage
- Sum-up the power (resp. currents) of the different inverters, e.g. of 4 inverters
- Cancel inverter harmonics to improve THDv
- Provide galvanic insulation between DUT and simulator for simpler test-design and protection
Overview: Configurations of matching transformer
What works and what not

- What doesn't work
  - 3 winding transformer („12-pulse“) → circulating currents
  - Parallel transformers → circulating currents

- What basically works
  - Series connection of HV winding for summing up
  - Y configuration of LV winding with starpoint to NP
  - Delta configuration of LV winding
  - 3 single phase trafos with H-bridge driven LV winding
Overview: Configurations of matching transformer

**HV side configuration: Series connection**

- Series connection allows summation of voltages with cancellation of harmonic voltages
- This turns the separate inverter units into a multi-level/multi-cell converter
- Tapings are relatively easy to implement
- The star-point is accessible and can be freely treated (hard grounded, soft-grounded)
What you get as result
3 independent floating voltage sources

- Lab setup option 1

- Lab setup option 2

- or any other configuration of 1, 2 or 3 sources
How does the voltage source look like
Potential and achievable short-circuit power

inverter is ideal voltage source with no internal impedance
it can run up to a maximum current

transformer leakage inductance is visible grid impedance during normal operation
minimum is ~5% of rated transformer power

maximum is installed power electronic power

e.g.
3.15kV_{AC,LL} / 2000A
11MVA per unit
44MVA for 4 units

e.g.
16MW cont. rating
5% \rightarrow 320MVA
short-circuit power

e.g.
converter will limit short-circuit at 44MVA
ABB builds the grid simulators on a platform, which is widely used in demanding industrial applications.

The grid simulator is enabled by an application specific control hardware and software, and a dedicated matching transformer.

Compatibility with drives allows setups which include the dynamometer on the same DC-bus, thus isolating it from the local lab supply grid.

The used hardware and its configurations have been (partly widely) used since the launch of ACS 6000 in 1998.

- Dynamometer: High-power rolling-mill drive, direct drive mine-hoist
- Grid simulator: Static VAR compensator, grid-interties (16 2/3 Hz <-> 50Hz) and for large energy storage.
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