Przemyslaw Koralewicz, Pieder Jörg, Ester Guidi, ABB Medium Voltage Drives, Switzerland

Power Electronic Grid Simulator
Platform of drives and power quality products for power electronics testing
ACS 6000 focus: Demanding applications

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

- Inverter Unit
  - Pre-defined interfaces for power, cooling & control connections
  - INU 5 – 13MVA

- Active Rectifier
  - ARU 5 – 13MVA

- Inverter Unit
  - INU 1 – 5MVA

- Capacitor Bank
  - CBU

- Diode Rectifier
  - LSU

- Water Cooling
  - WCU
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
Converter topology

- 12-pulse LSU single drive
- 6-pulse ARU single drive

- 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
ACS 6000 grid simulator
Layout possibilities

- 4m – 28m lineups
- U-shape, L-shape, …
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

Specification

- CONTIN POWER: up to 28MVA
  PEAK (several seconds): up to 44MVA
- Isc in normal operation
  Max Scc in case of short circuit
  Out trafo power*20 (i.e. 10MVAX20=200MVA) – ∀ freq –
  NO reactive compensation needed
- THD(v) out < 1%
- 3-ph, 2-ph and 1-ph dips
  (symmetrical and asymmetrical)
- Freq range 45 Hz … 65 Hz
- Fast Dynamic
  V rate of change 0% - 100%, 1msec
ACS 6000 grid simulator
Combined functionality and flexibility

From grid simulator only …

… to fully integrated setup
Overview: Configurations of matching transformer

What is the function of the transformer

- Match the converter voltage to the desired testbus-voltage + tappings
- Sum-up the power (resp. currents) of the different inverters, e.g. of 4 inverters
- Series connection cancels inverter harmonics to improve THDv
- Provide galvanic insulation between DUT and simulator for simpler test-design and protection
ACS 6000 grid simulator

Control hardware overview
ACS 6000 grid simulator
Control hardware features

- **Main controller – AC 800PEC PP D513**
  - Freescale P2020 1.2GHz Dual Core processor
  - FPGA Xilinx Spartan6
  - 36 Optical fiber modules (10MBit)
  - DDCS – DriveBus
  - Communication to the upper control via Anybus-Modules or CEX
    - Profibus-DPV1 Master
    - Modbus-RTU S, -TCP S
    - Profibus-DP S, -DPV1 S
    - EtherCAT S
    - etc..

- **Fast IO – AC 800PEC UA D155**
  - 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)
ACS6000 grid simulator

How is PEGS interfaced by test facility controller?

- PEGS is a controllable/configurable tripple voltage source
- Phasor references
  - Anybus communication interface (1ms)
  - Analogue channels (25us)
  - Optical Powerlink (25us)
- Parametrization interface
  - Anybus communication interface (1ms)
- Allows flexibility in test cases development
Defining dynamics requirements
Dynamics of voltage change - phasor referencing

$\Delta U = 1 \text{P.U.}$

$\Delta \varphi = 4\pi \text{ rad}$

$SR = \frac{\Delta U \ 2\pi}{\Delta \varphi} \left[ \text{P.U.} \right] \left[ \text{cycle} \right]$

Where:
$\Delta U \left[ \text{P.U.} \right]$ - voltage delta
$\Delta \varphi \left[ \text{rad} \right]$ – phase delta

Example:
$SR = \frac{1 \cdot 2\pi}{4\pi} = 0.5 \left[ \text{P.U.} \right] \left[ \text{cycle} \right]$

- Supervisor commands voltage using 3x phasor (Amplitude / Voltage)
Defining dynamics requirements
Dynamics of voltage change – bandwidth definition

\[ y = A(w^{0.25}) \sin(0.25w_1t) \]
\[ y = A(w^{0.5}) \sin(0.5w_1t) \]
\[ y = A(w^2) \sin(2w_1t) \]

\[ SR_u = \frac{1}{2T} = \frac{f}{2} \]

\[ f_b = \frac{SR}{2\pi A} \]

- \( f_b \) – bandwidth
- \( A \) – amplitude

- SR (SlewRate) shall be used to define dynamics of the system as it considers amplitude of the change
ACS 6000 grid simulator
Operating modes – Test cases

- Mode 1) Optimised THD, compromised dynamics
  - Normal operation
  - Power quality tests
- Mode 2) High dynamics, compromised THD
  - LVRT / HVRT tests
  - Harmonic / subharmonic injection
  - HIL operation

Modes can be switched on-line
ACS6000 Grid simulator
Optimized THD mode

Performance specification:
- Very low voltage THD < 1%
- Voltage amplitude accuracy < 1%
- Frequency accuracy < 0.1%
- Symmetrical voltage
- Small dynamics SR < 0.05 [P.U./cycle]
ACS6000 Grid simulator
High dynamics mode

Specification:
- Multilevel PWM
- 17 levels ph-ph waveforms
- Voltage THD < 5%
- Very high dynamics
  - SR < 20 P.U. / cycle
  - 100% voltage drop in <1ms
- Asymmetrical operation – independant phases control
Conclusion

- ABB builds the grid simulators on ACS6000 platform, which is widely used in demanding industrial applications since 1998

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

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

Ester Guidi
Market Manager for Test stand applications
Product Group Medium Voltage Drives

ABB Switzerland Ltd
Austrasse, CH-5300 Turgi, Switzerland
Phone: +41 (0)58 589 24 50
Mobile: +41 (0)79 596 65 17
E-Mail: ester.guidi@ch.abb.com
Power and productivity for a better world™