Power Electronic Grid Simulator
Platform of drives and power quality products for power electronics testing
ACS6000
Focus: Demanding applications

- Cement, Mining & Minerals
- Marine
- Metals
- Chemical, Oil & Gas
- Power
- Water
- Pulp & Paper
- Special applications, e.g. teststands
ACS6000
Overview

- Modular MV water-cooled drive
- Versatile control platform with DTC for exceptionally high torque and speed performance or with OPP/PWM for special applications
- Two- or Four-Quadrant Operation
- Voltage range: 0…3.3 kV (w/o trafo)
- Power range: 5…30+ MVA
- Output frequency range: 0…75 Hz (higher on request)
Inverter Unit
Pre-defined interfaces for power, cooling & control connections

Active Rectifier

Capacity Bank
Diode Rectifier
Water Cooling
ACS6000 Water cooled
3 – 36 MW

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

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

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

Water Cooling Unit
Supplies the closed cooling system with deionized water for the main power components
ACS6000
Converter topology - reliability

- 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
ACS6000
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
ACS6000 Special Projects
Not only motors

- ACS6000 as a frequency converter
  - Grid simulator for PE testing
  - Shore-2-ship FC
  - HV electrical insulation testing
- Challenging applications
In special projects inverter control and the output transformer are dedicated ("engineered") for the application.

Everything else is "off the shelf"

- Power electronic hardware
- Hardware protection
- Mechanical design and cooling
- Auxiliary control and sequencing
- Supply from grid
- …
ACS6000 Special Projects
Combined functionality and flexibility

From grid simulator only …

… to fully integrated setup
ACS6000 Grid Simulator

Inverters

- Various inverter units available: 5-13MVA
- 12x NPC phases
- Continuous power = 28MVA
- Short term power overloadability = 44MVA
- Max current = 2721 A
  - DUT of 8MVA -> 600A peak
  - OC margin x4.5

Quad Inverter Unit
ACS6000 Grid Simulator

The function of matching transformer

- Match the converter voltage to the desired testbus-voltage + tappings

  \[ \eta = \frac{U_{PCC}}{2\sqrt{3}U_{inv}} \]
  e.g.: 13kV -> \( \eta = 1.21 \)

- Sum-up the power (resp. currents) of the different inverters, e.g. of 4 inverters

- Special modulation + trafo cancels inverter harmonics to improve THDv

- Provide galvanic insulation between DUT and simulator for simpler test-design, grounding and protection

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ACS6000 Grid Simulator
Grid impedance / short circuit power

- Testing device must be properly oversized so that the grid is not distorted by DUT
- Trafo impedance = 5% @15MVA power level
- Scc = 20*Trafo impedance = 300MVA – For DUT of e.g. 10MVA that is very strong grid (x30) that is unlikely to be distorted
- At controllable frequencies (<2kHz) impedance can be softened by modeling capacitive / inductive virtual impedance
ACS6000 Grid Simulator
High dynamics mode

- Multilevel PWM modulator
- 17 levels ph-ph waveforms
- Very high dynamics
  - 100% voltage drop in <1ms
  - SR < 20.0 [PU/cycle]
  - Controllable bandwidth <2kHz
- Asymmetrical operation – independant phases control
- Voltage THD < 2%
- $f_{SW} = 4800$Hz

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ACS6000 Grid simulator

Optimized THD mode

Performance specification:
- Very low voltage THD < 1%
- Voltage amplitude resolution < 0.1%
- Frequency regulation < 0.01%
- Symmetrical voltage
- Compromised dynamics SR < 0.05 [PU/cycle]
- Modes can be switched online
Defining dynamics requirements
Dynamics of voltage change - phasor referencing

Where:

- \( \Delta U \text{[P.U.]} \) - voltage delta
- \( \Delta \varphi \text{[rad]} \) – phase delta

Example:

\[
SR = \frac{\Delta U \cdot 2\pi}{\Delta \varphi \text{[cycle]}} = 0.5 \text{[P.U.]}\]
Defining dynamics requirements

Dynamics of voltage change – bandwidth definition

- SR (SlewRate) shall be used to define dynamics of the system as it considers amplitude of the change

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

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

\[ y = A(w_{0.12})\sin(0.12w_1t) \]
\[ y = A(w_{0.25})\sin(0.25w_1t) \]
\[ y = A(w_{0.5})\sin(0.5w_1t) \]
\[ y = A(w_2)\sin(2w_1t) \]
ACS6000 Grid Simulator
Bandwidth spec

- 13th harmonic injection @10% amplitude
- Nyquist limitation <2kHz
- Max bandwidth @ amplitude:
  - <2000Hz@1%
  - <2000Hz@2%
  - <2000Hz@5%
  - <1600Hz@10%
  - <800Hz @20%
ACS6000 Grid Simulator

Grid simulator as impedance analyser

Small signal oscillation sweep: 3rd-23rd harmonic @ 10%

Time [s]

Frequency [Hz]

0 1 2 3 4 5 6 7 8 9 10

0 500 1000 1500 2000 2500 3000 3500 4000

-20 0 20 40 60 80
ACS6000 grid simulator
How is PEGS interfaced by test facility controller?

- PEGS is a controllable/configurable 3x AC voltage source
  - 3x Voltage magnitude reference
  - 3x Voltage phase reference
  - 1x Frequency reference
- Communication channels
  - Fieldbus communication interface (1ms)
  - Analogue channels (25us)
  - Optical Powerlink (25us) – Opal-RT or FPGA IP core available
- Parametrization interface - Fieldbus
- Allows flexibility in test cases development
ACS 6000 grid simulator
Specification summary

- CONTIN POWER: up to 28MVA
  PEAK (several seconds): up to 44MVA
- $I_{sc} = 2721 \, A$
- $S_{cc} = \text{trafo power} \times 20$
  (i.e. $10\, \text{MVAr} \times 20 = 200\, \text{MVA}$)
- THD(v) out < 1%
- 3-ph, 2-ph and 1-ph dips
  (symmetrical and asymmetrical)
- Freq range 45 Hz … 66 Hz
- Fast Dynamic
  V rate of change 0% - 100%, 1msec
ACS6000 Grid Simulator
Reference projects

- CENER, Spain – 2007
- NREL, USA – 2013
- IWES-Fraunhofer, Germany - 2015
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