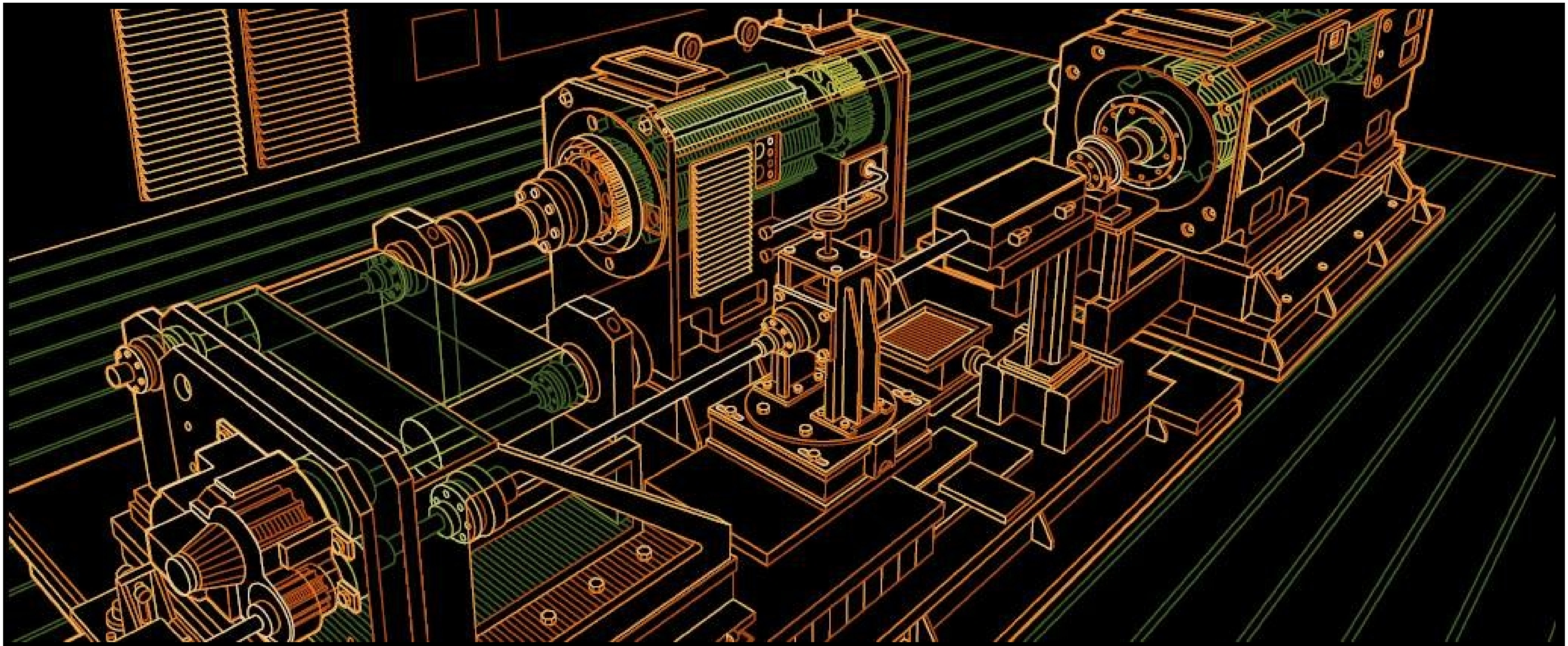


Ester Guidi, Pieder Jörg, ABB Medium Voltage Drives, Switzerland

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

Outline

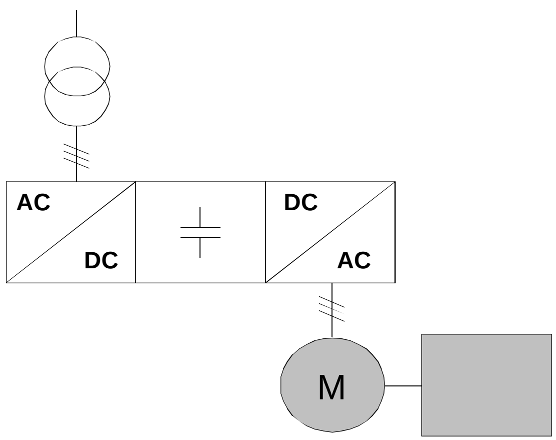
- Teststand applications for drives and power electronics
- Modular drives and power-electronics platform ACS6000
- Power electronic grid simulator based on platform
- Design considerations following windturbine testing requirements

Teststand applications for drives and power electronics

Test stand applications

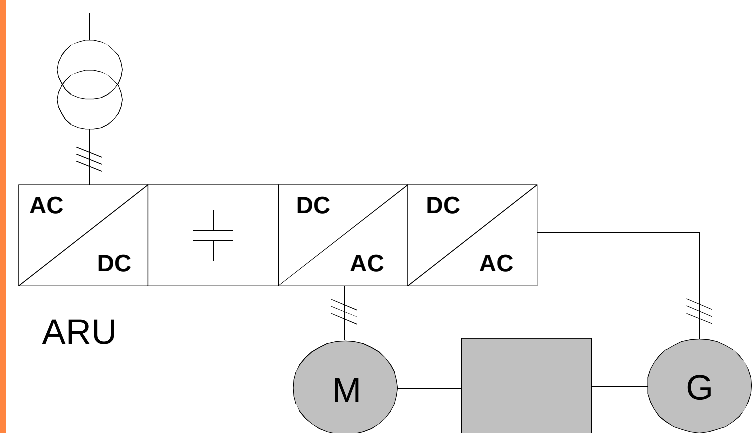
single-drive

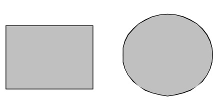
motoring OR generating



multi-drive

motoring AND generating





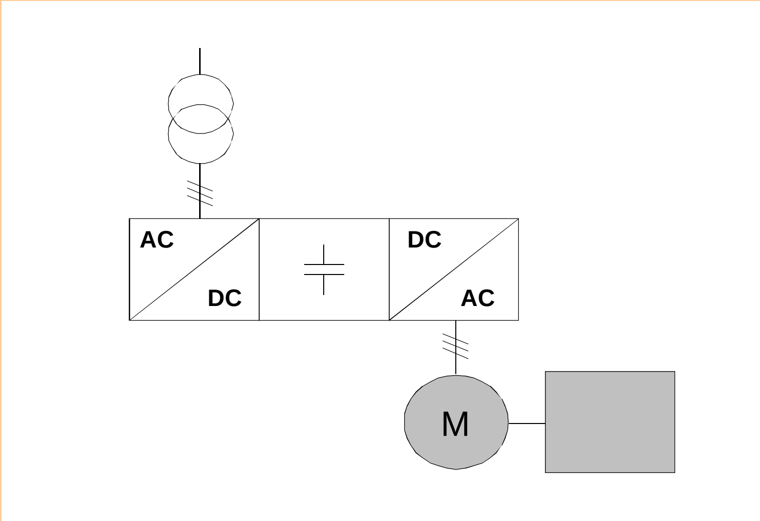
Device under test

Teststand applications for drives and power electronics

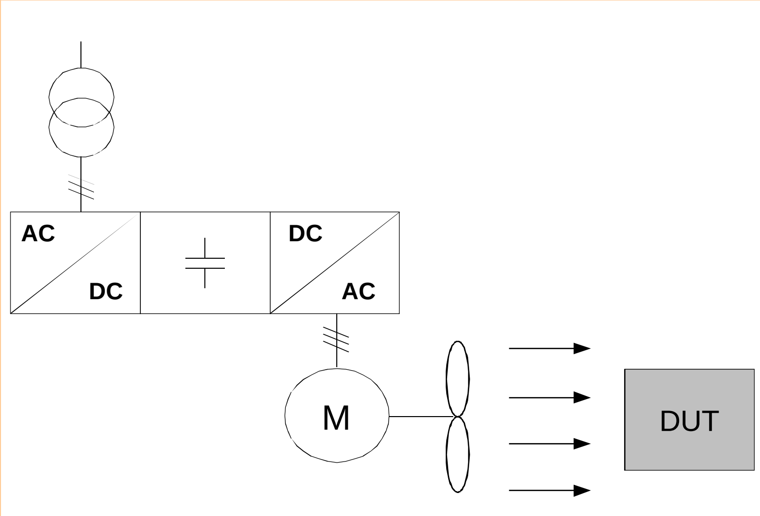
Test stand applications

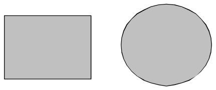
single-drive

motored device testing



fixed installation





Device under test

ABB's areas of activity

Test stand applications

Single drive	Multi drive
Device testing ▪ Compressor & turbo charger ▪ Pump ▪ Balancing plant ▪ Jet engine ▪ Gas Turbines ▪ Motor Generator set, …	▪ Gearbox ▪ Electrical generator ▪ Electrical motor ▪ Grid simulation ▪ Wind turbine ▪ …
Fix installations ▪ Wind tunnel ▪ Human centrifuge (pilot training) ▪ Soft starters for high energy labs	

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

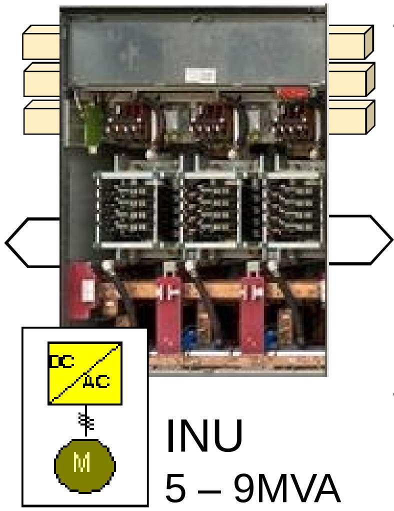

Water


Pulp & Paper


Special applications, e.g. wind tunnels

ACS 6000: Some building blocks

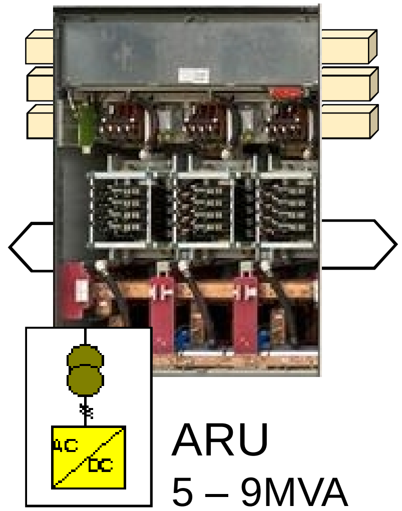
Inverter Unit



Pre-defined interfaces for power, cooling & control connections

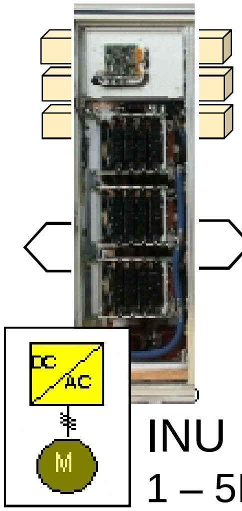
INU
5 – 9MVA

Active Rectifier



ARU
5 – 9MVA

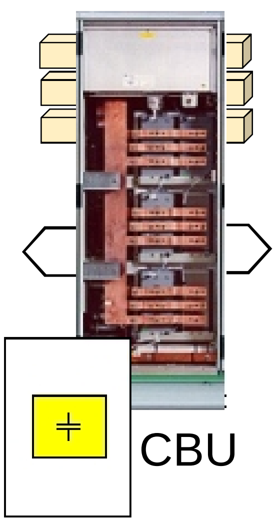
Inverter Unit



INU
1 – 5MVA

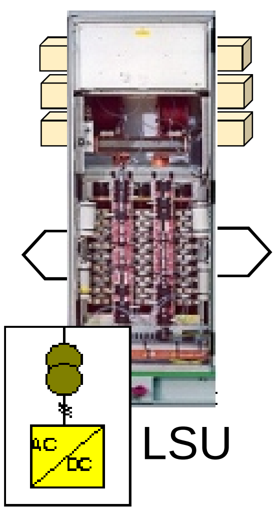
...

Capacitor Bank



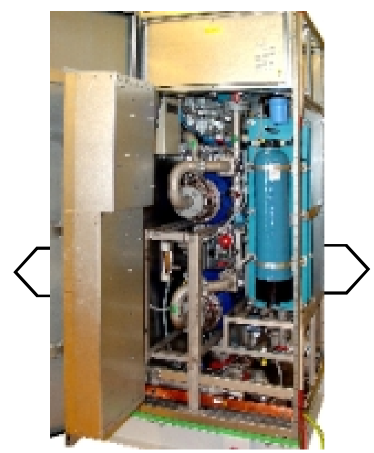
CBU

Diode Rectifier



LSU

Water Cooling



WCU

ABB

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

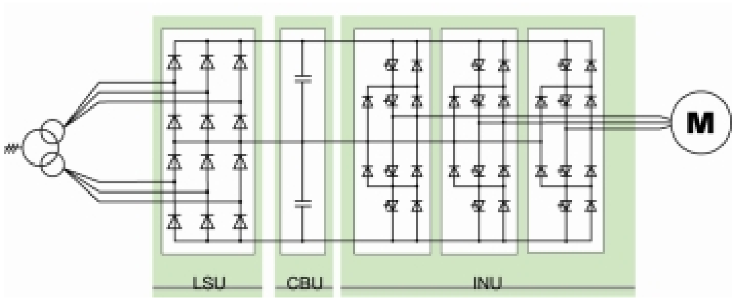
Active Rectifier Unit (ARU)
Self-commutated, 6-pulse, 3-level voltage source inverter with IGCT technology

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

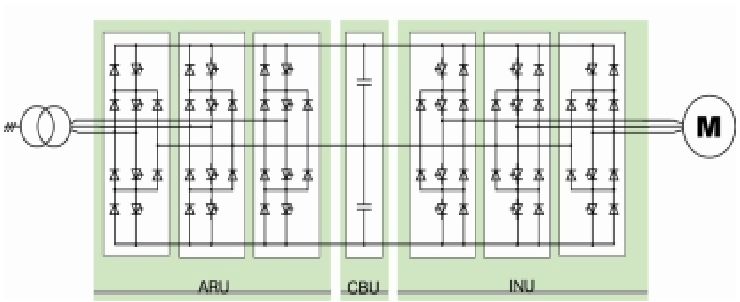
Water Cooling Unit
Supplies the closed cooling system with deionized water for the main power components

Inverter topology

12-pulse LSU single drive



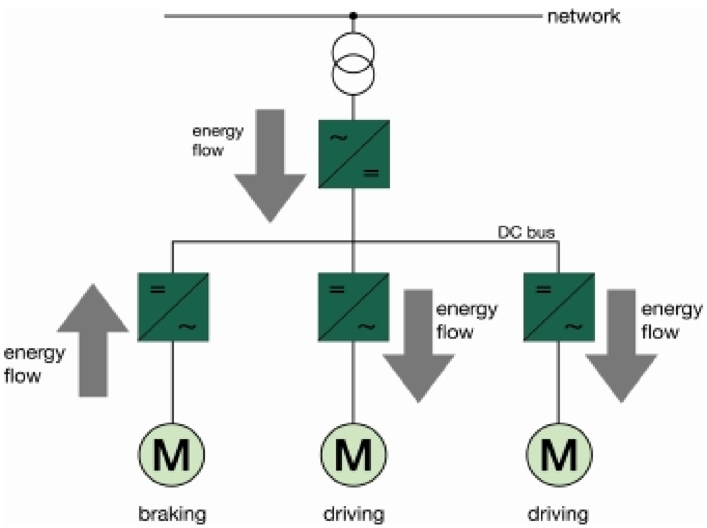
6-pulse ARU single drive



- 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

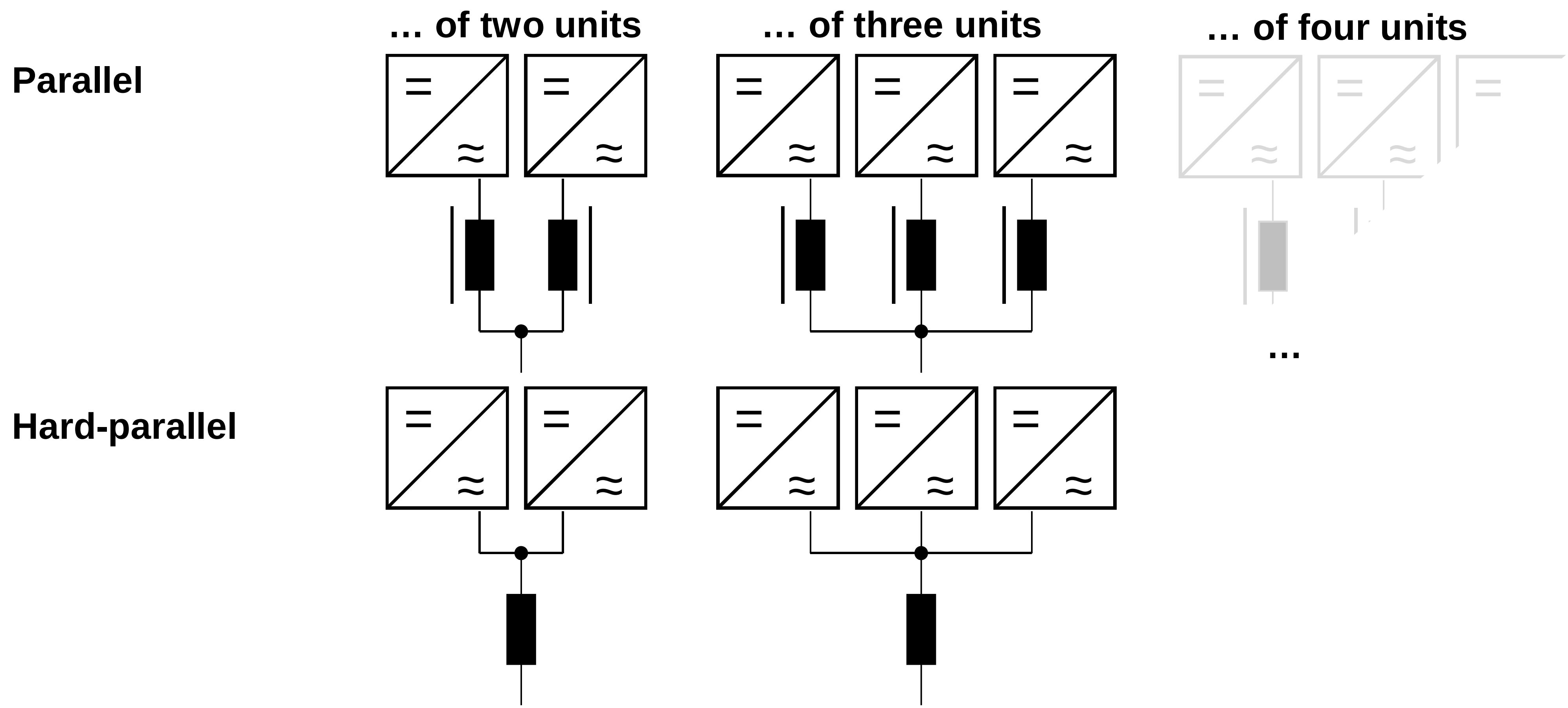
Common DC bus

Optimized energy flow with common DC bus, e.g. cold reversing steel mill



- 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: INU configurations



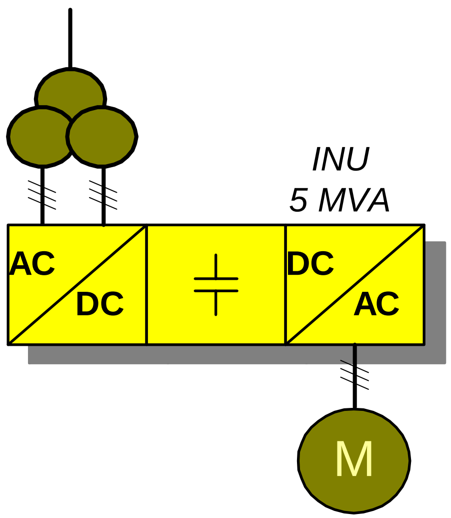
Parallel connection of inverter units:

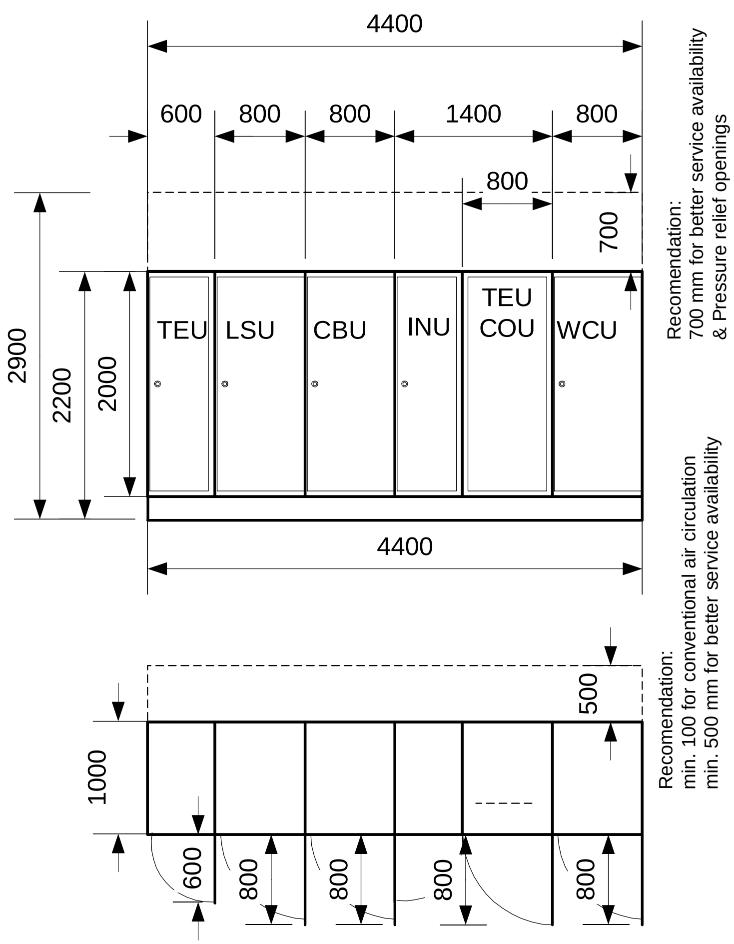
9, 18, 27, 36MVA as standard

e.g. 9MVA unit

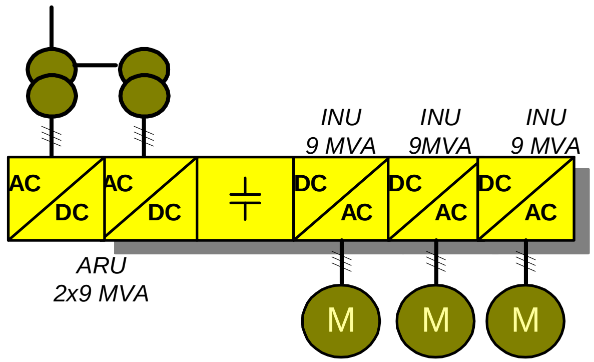
ACS 6000: Flexible solutions from 2Q single ...

ACS 6105_L12_1a5

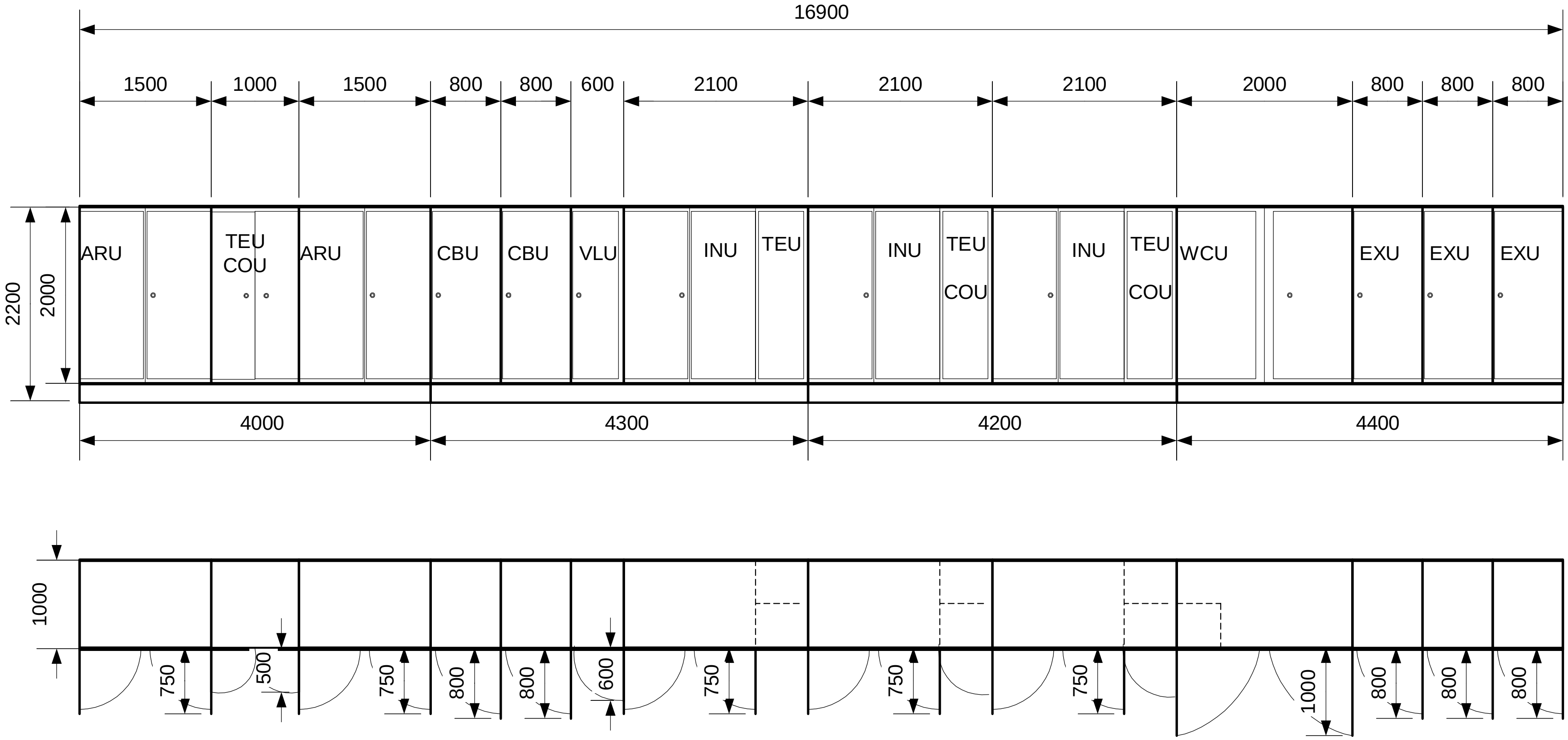




ACS 6000: ... to 4Q multi drive



ACM 6209_A12_1s9_1s9_1s9



Outline

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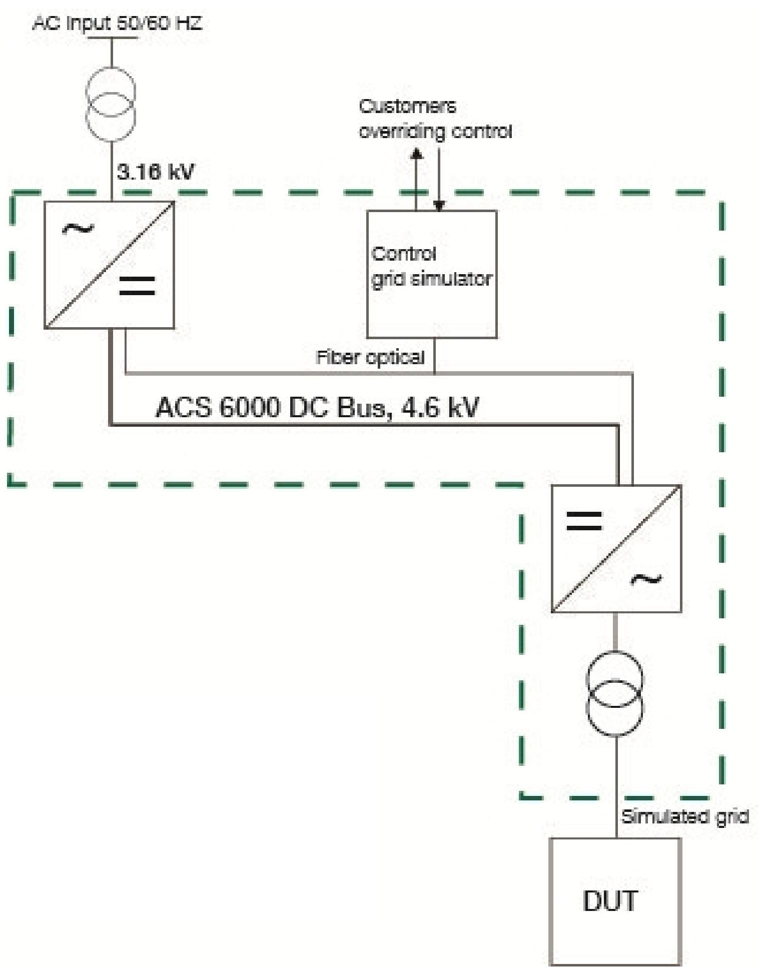
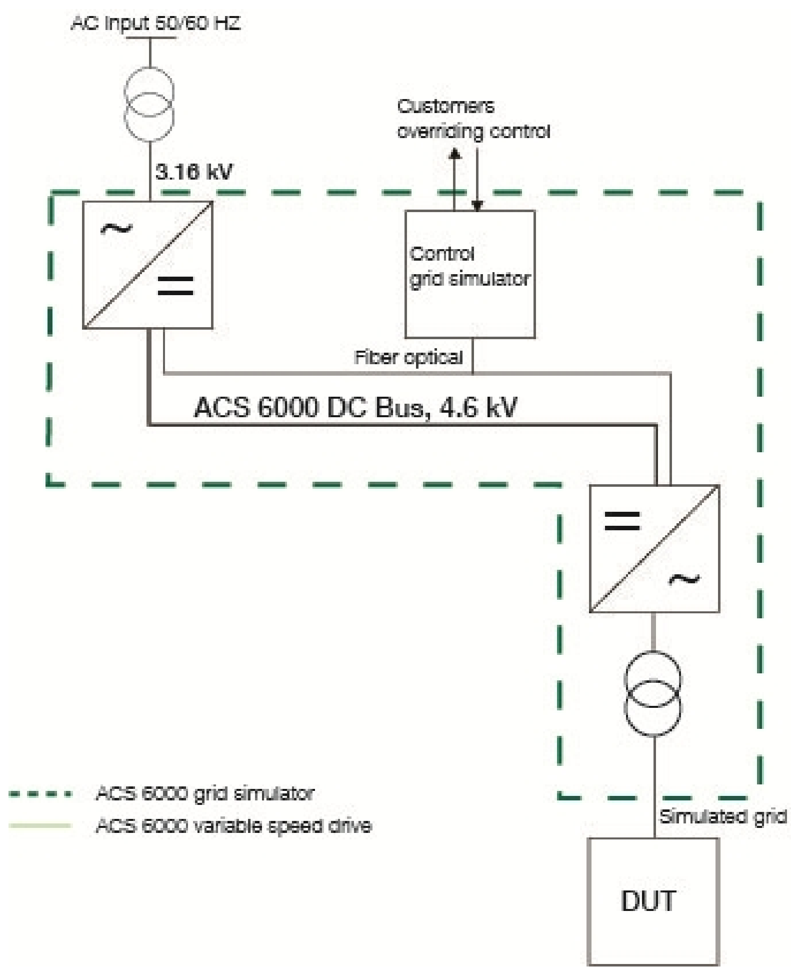
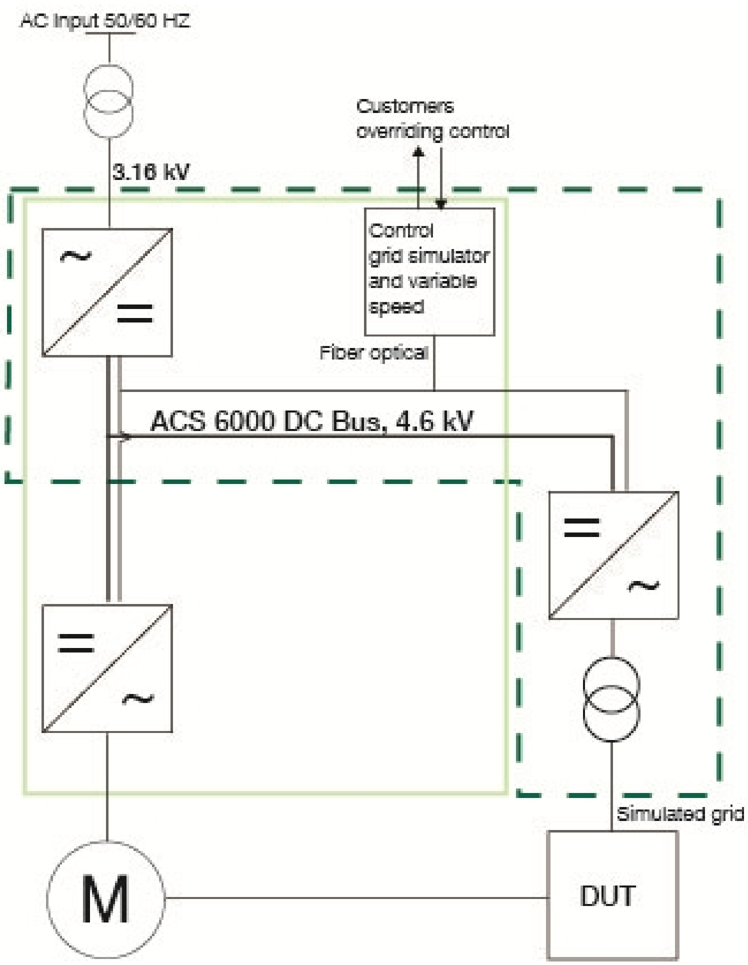
ACS 6000 grid simulator
Overview



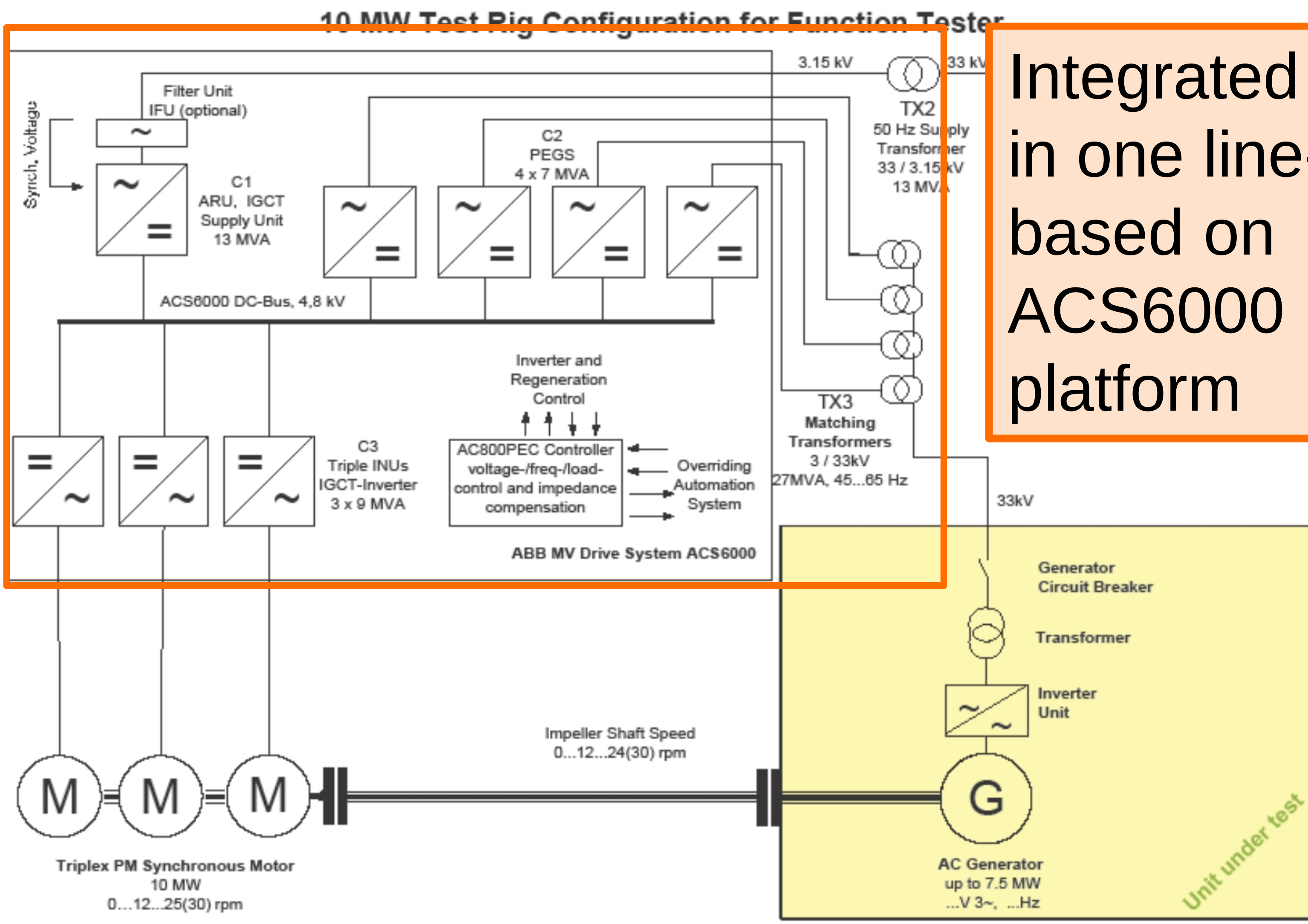
- Main benefit: Enables tests to be carried out off-line in a cost- and time-efficient manner
- Flexibility: suitable for any kind of electrical equipment that needs to be connected to the grid
  - Wind and Tidal Turbines
  - PV systems
  - Solar power
  - Fuel cells
  - Motor Gensets
  - Energy storage systems

ACS 6000 grid simulator
Combined functionality





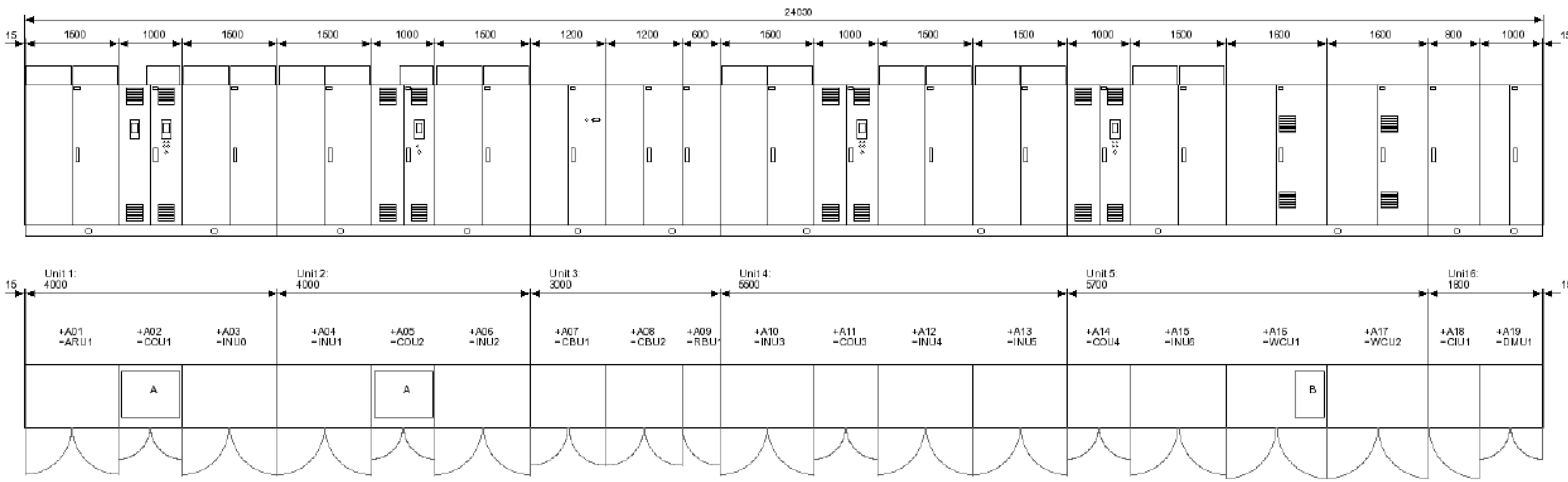
Project example – test stand for wind turbine
Combined functionality drive train and grid simulator



Integrated all in one line-up based on ACS6000 platform

ACS 6000 grid simulator
Example of a layout and dimensions

Layout drawing / Converter line up



ACS 6000 grid simulator
Layout possibilies

- U-shape, L-shape, …

Outline

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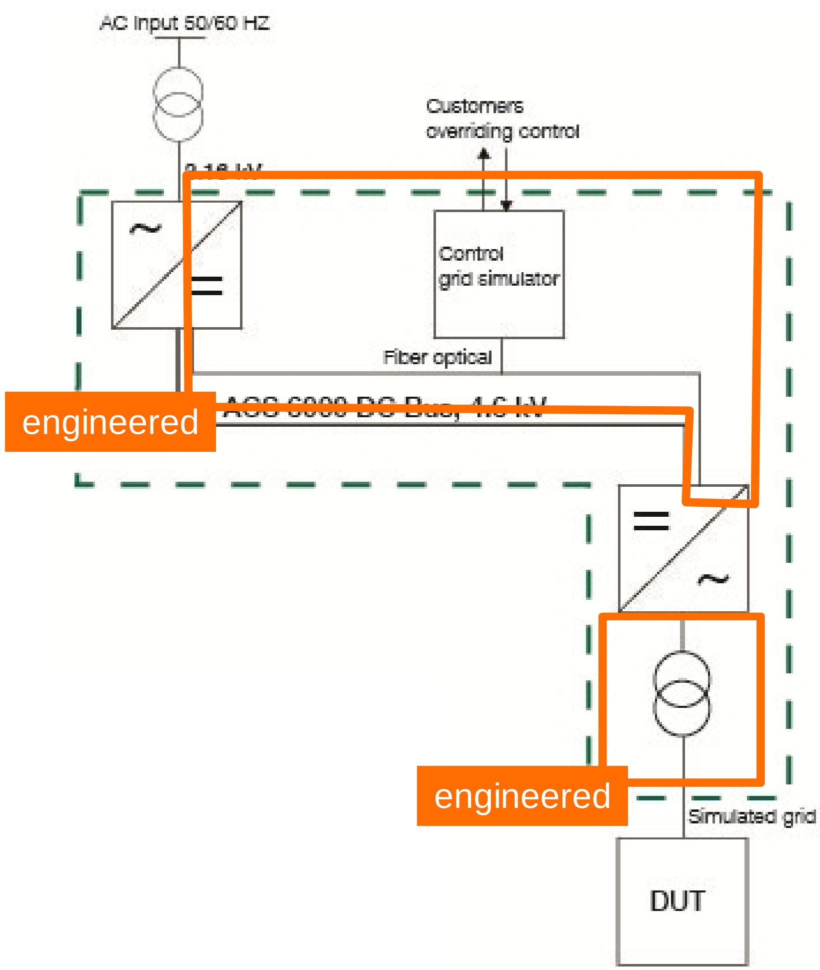
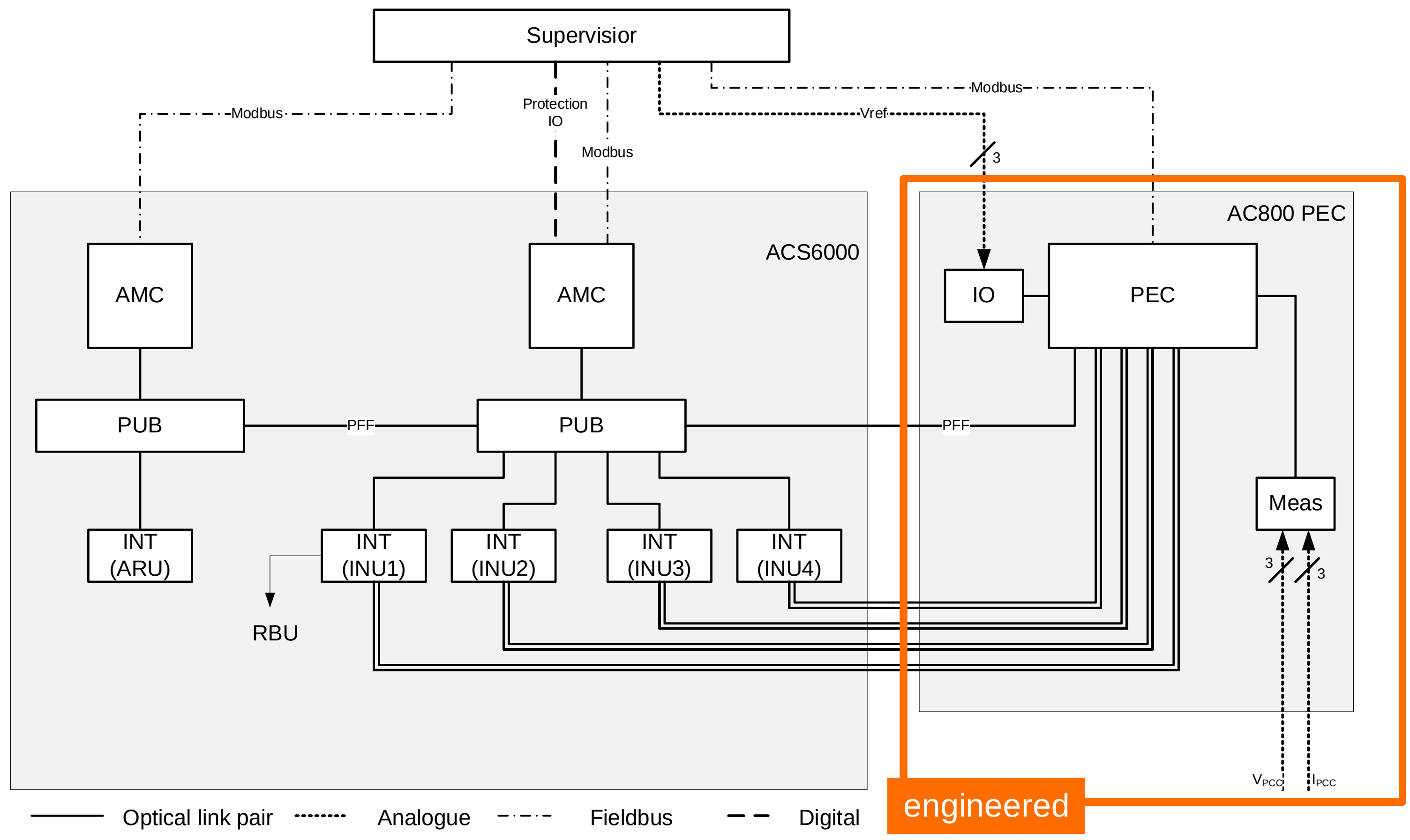
ACS 6000 based grid simulator
Control and transformer engineered to application



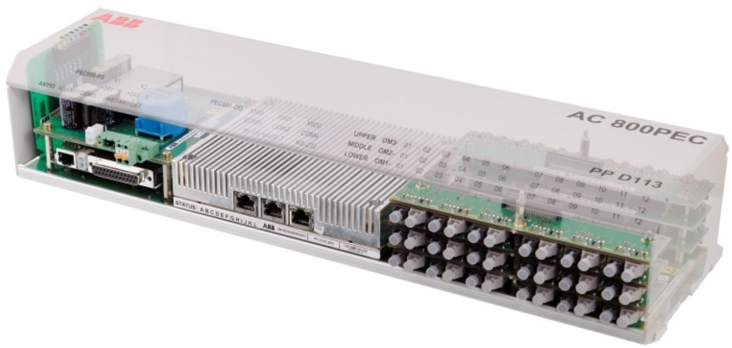
- Grid simulator inverter control and the output transformer are dedicated ("engineered") for the grid simulator application
- Everything else is "off the shelf"
  - Power electronic hardware
  - Hardware protection
  - Mechanical design and cooling
  - Supervisory control and sequencing
  - Supply from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



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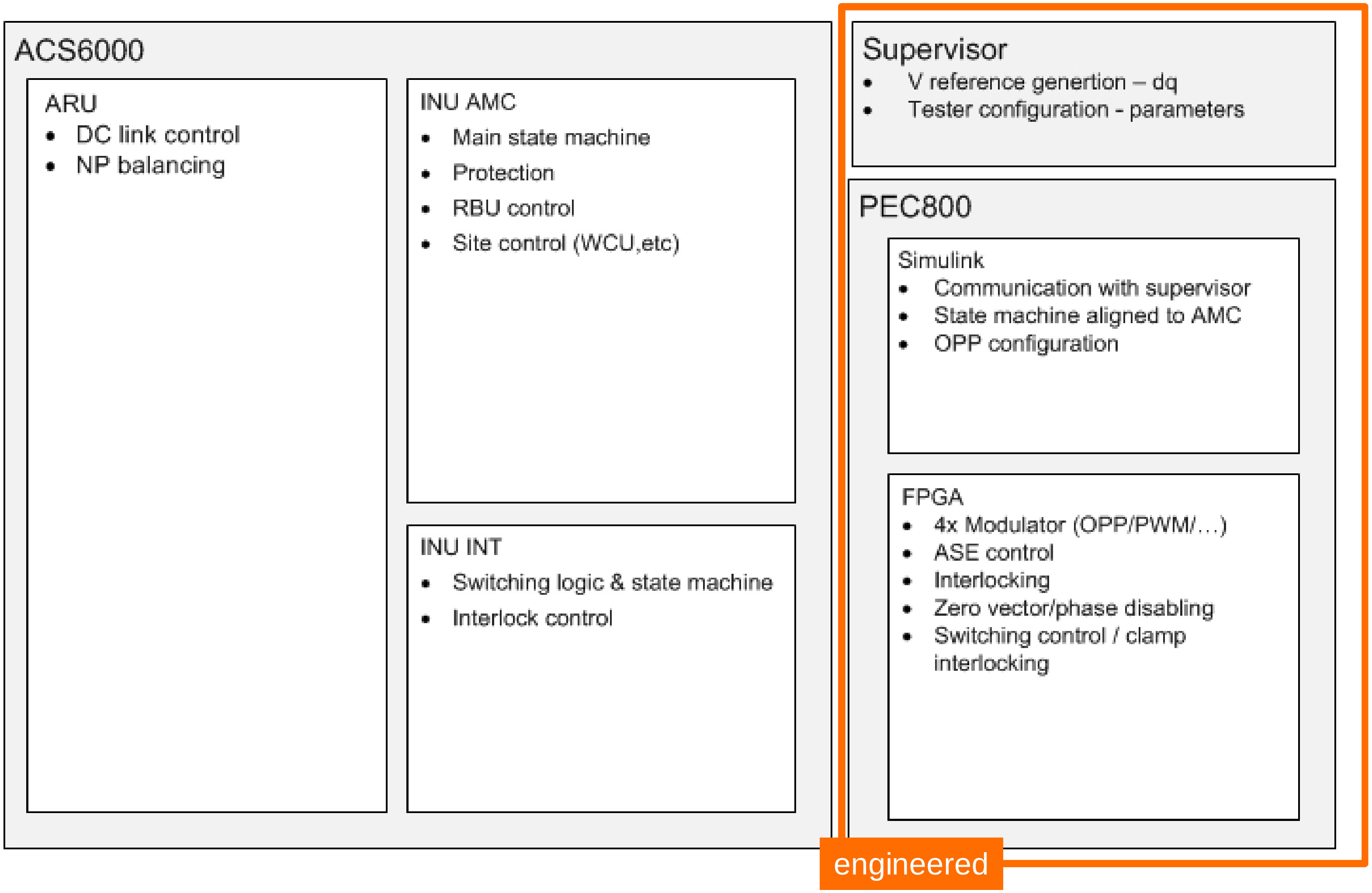
ACS 6000 grid simulator
Functional diagram



Overview: Configurations of matching transformer
What is the function of the transformer

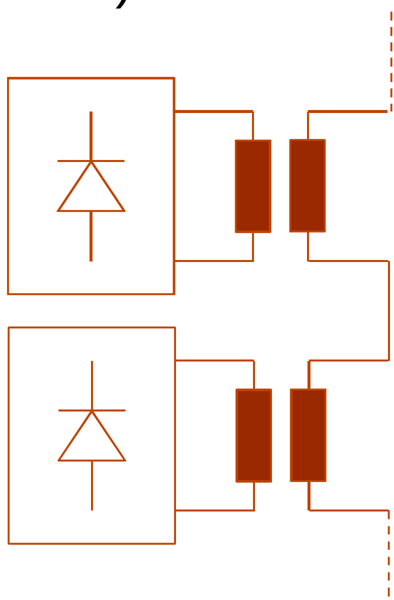
- Match the converter voltage to the desired testbus-voltage
- Sum-up the power (resp. currents) of the different inverters, e.g. of 4 inverters
- Cancel inverter harmonics to improve THDv
- Provide galvanic insulation between DUT and simulator for simpler test-design and protection

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

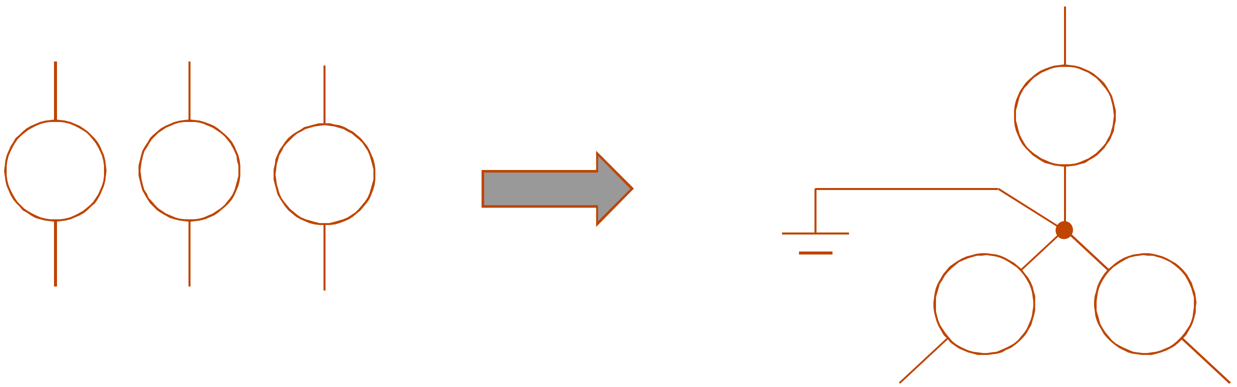
Overview: Configurations of matching transformer
HV side configuration: Series connection

- 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)

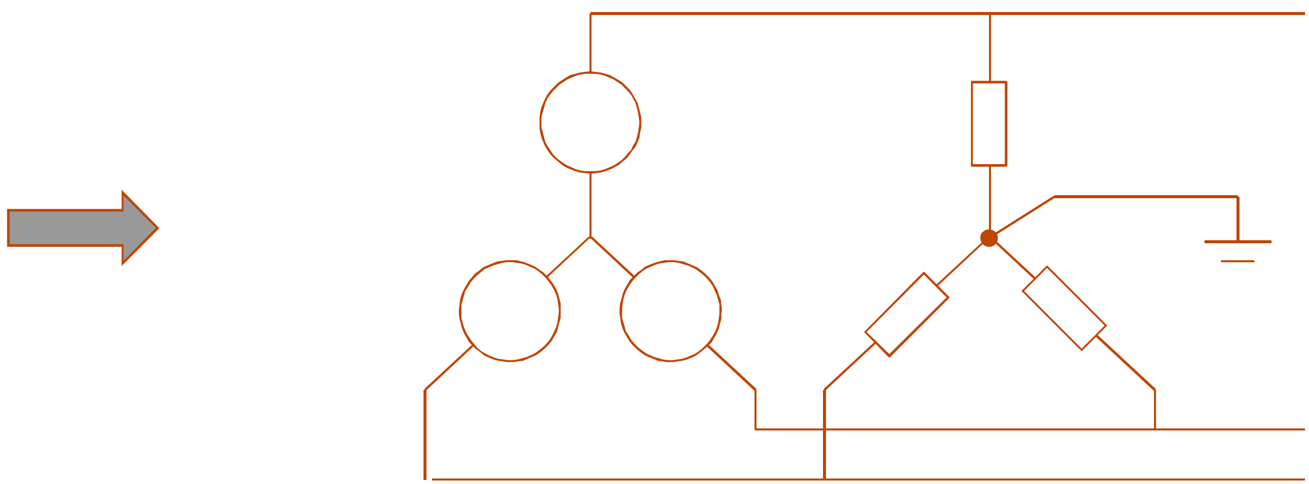


What you get as result
3 independent floating voltage sources

- Lab setup option 1

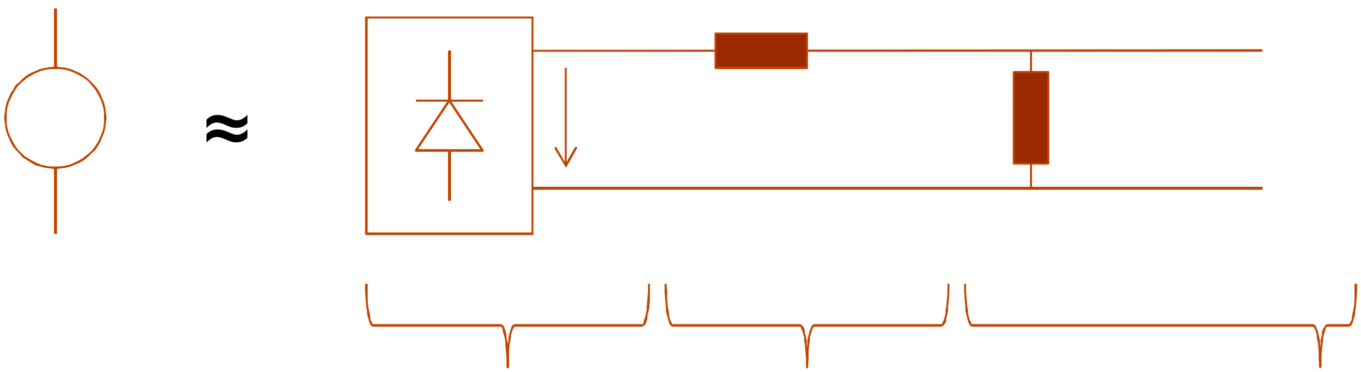


- Lab setup option 2



- 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

e.g.
3.15kV$_{AC_LL}$ / 2000A
11MVA per unit
44MVA for 4 units

transformer leakage inductance is visible grid impedance during normal operation

minimum is ~5% of rated transformer power

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

transformer thermal rating defines the short-circuit currents, that the grid simulator can really sink or source

maximum is installed power electronic power

e.g.
converter will limit short-circuit at 44MVA

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Conclusion

- 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

Power and productivity
for a better world™

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