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ALSTOM

ALSTOM solution
to meet new Grid Codes
for Wind Turbines

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Power Conversion

ALSTOM



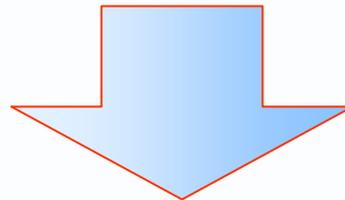
Content

- What is new with Grid Code requirements
- ALSTOM solution for variable speed turbines
- ALSTOM solution for fixed speed turbines
- ALSTOM Converter for wind market application



Why new Grid Connection Regulations?

- Huge growth of wind power in the last years, further increase is expected
- Wind turbines have a significant impact on the grid that cannot be neglected anymore
- Wind turbines have to be included into the stability analysis of the grid



Mains operators demand new Grid Connection Regulations



Our Experience - Your advantage

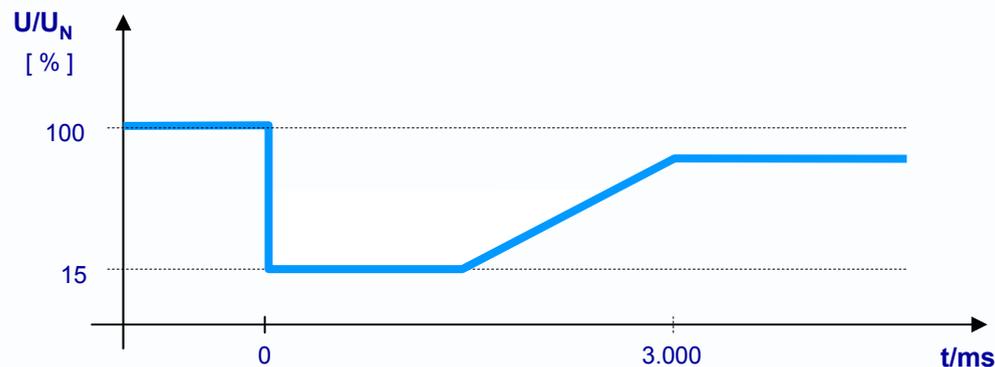
- Experience with industrial drives under rough conditions for decades, e.g. steel mills, offshore platforms
- Experience with converters of all kind and sizes up to 100 MW
- Experience with grid stabilisation and the control of power plants for decades, e.g. Power System Stabiliser (PSS)
- More than 1000 converters for doubly and fully fed generators for wind turbines in operation
- Present in several committees, e.g. FGW, VDN



Example: e.on Grid Code

for the high voltage grid (01.08.2003),
to be observed at the grid connection point

- Frequency range: 47,5 Hz - 51,5 Hz
- Voltage tolerance: +15% / -12%
- Operation with 80 % grid voltage
- Power factor: 0.95 ind. - 0.925 cap.
- Voltage buffering by reactive current ($I_q = I_N$)
- Ride trough capability





Problem definition

for the wind turbines resulting from the grid connection requirements

- 1.** Extended frequency range: 47,5 Hz - [49 Hz - 51 Hz -] 51,5 Hz
- 2.** Extended voltage range: 80 % - [90 % -] 110 %
(for permanent operation)
- 3.** Power factor can be chosen from 100 % active to 100 % reactive current to match the demanded reactive power at the grid connection point [$\cos \varphi = 0,95$]
- 4.** Ride through of voltage dips down to 15 % U_N
[Disconnection at 80 % U_N]



Solution for ProWind

- Point 1 Frequency
- Point 2 Voltage
- Point 3 Reactive power

Solved by new system management and software adaptations!



- Point 4 Voltage dip

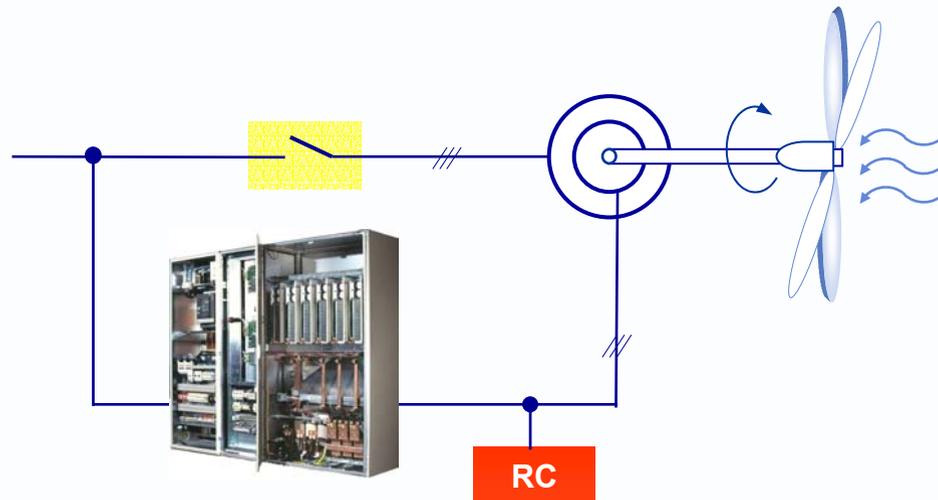
Solved by Hardware adaptations!
Optional, retrofit possible!





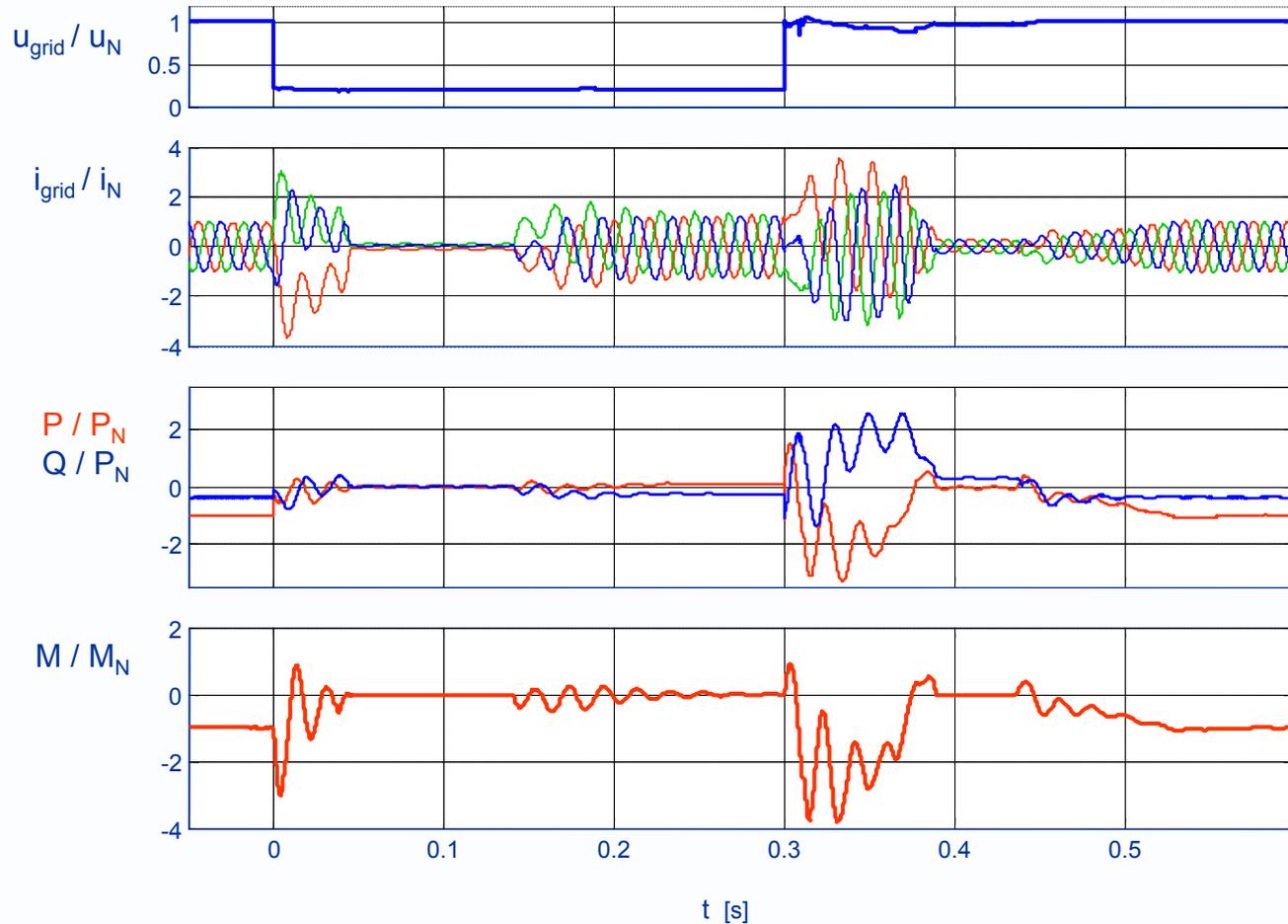
Characteristics

- Voltage dip without triggering of the Rotor Crowbar (RC): controlled operation, low mechanical stress
- **Triggering of the Rotor Crowbar:**
 - Ride through with maximum grid current and fastest possible return to normal operation after the voltage recovery
 - Option: **Disconnection of the stator** and resynchronisation: reduced grid current, low mechanical stress at voltage recovery





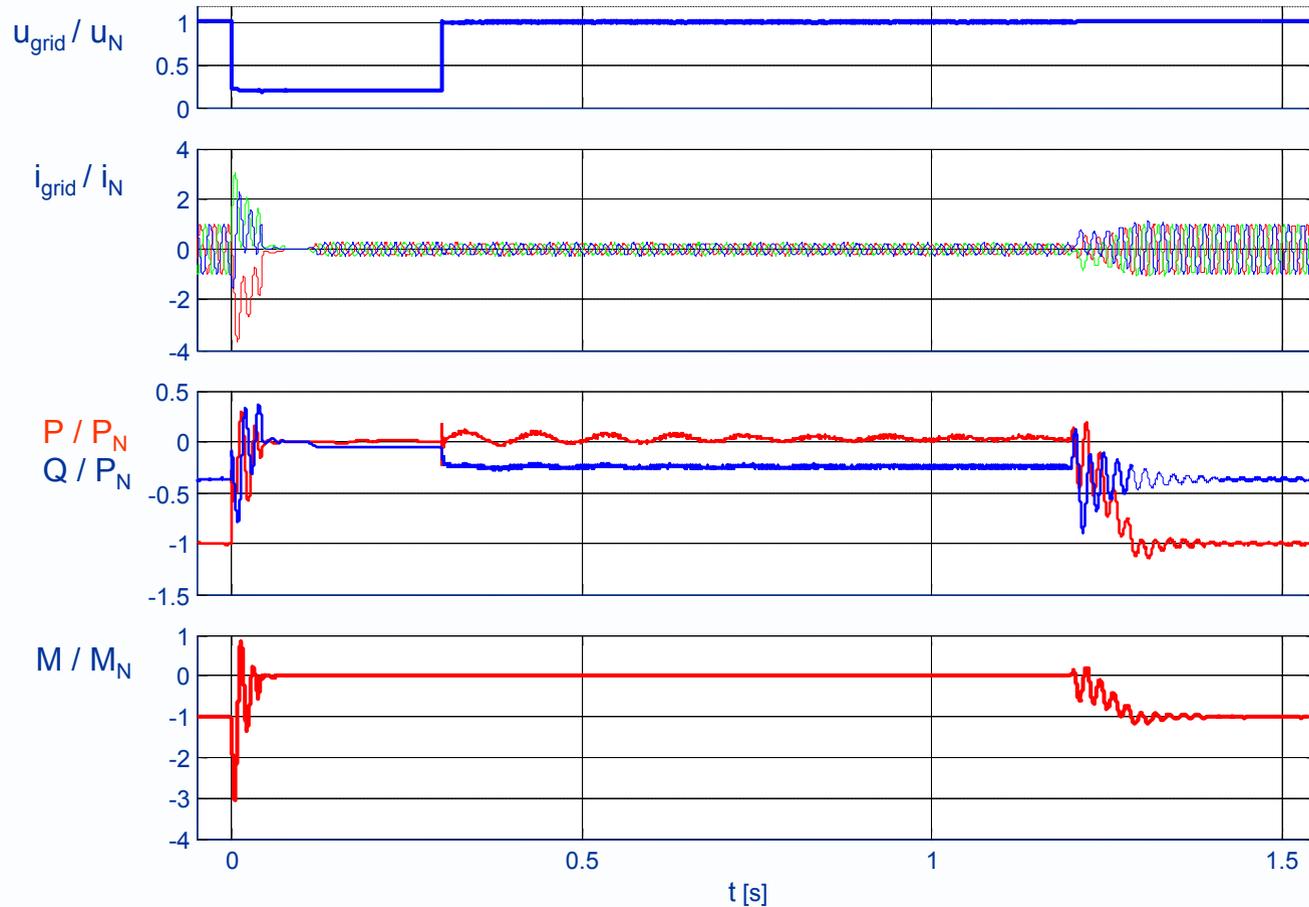
Simulations , without stator disconnection



Voltage dip down to 20 % U_N



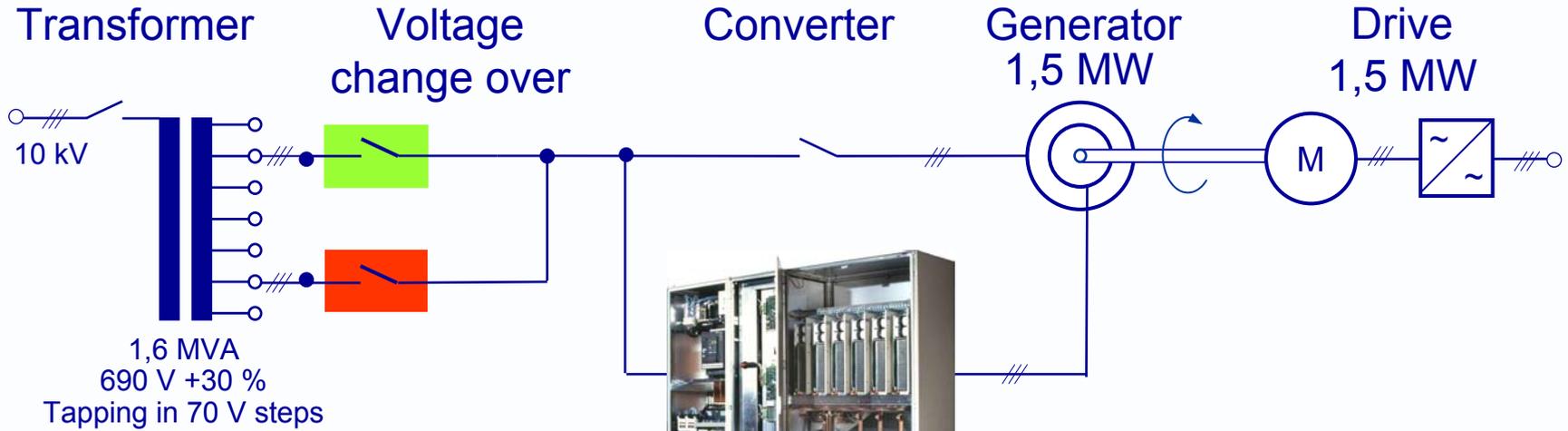
Simulations , with stator disconnection



Voltage dip down to 20 % U_N



Wind Test Bench





Key problem Stall Turbines

- Grid operators expect squirrel cage generator to behave like conventional synchronous generator:
 - no switch-off during voltage dips
 - capacitive power supporting during voltage dips

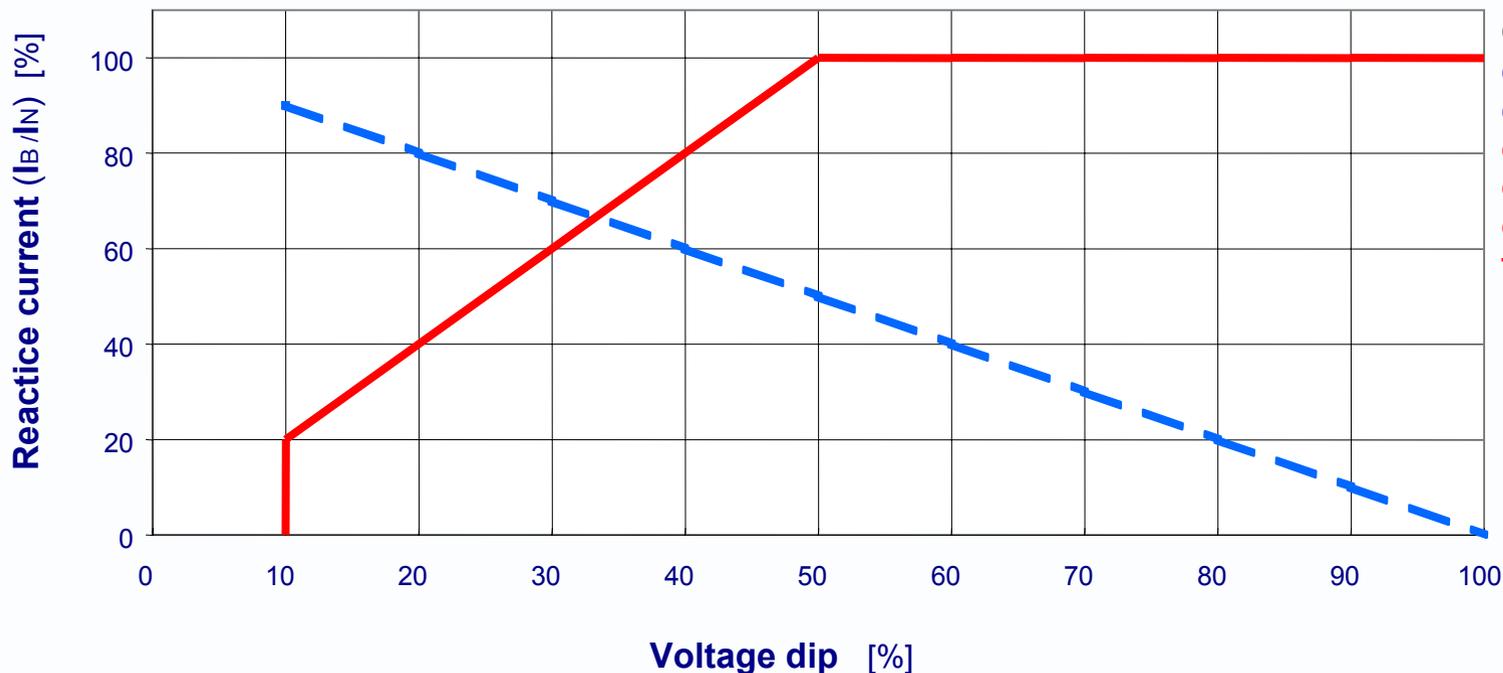
- Disadvantage of conventional compensation systems

Capacitors or conventional dynamic compensation (SVC, with TCR, thyristor controlled reactor) delivers with dipping voltage an correspondingly reduced current



Key task

Reactive current (overexc.) supporting grid
ENE grid codes as per 01.8.2003



Contrary to conventional capacitor can the self-commutated converter follow the desired value



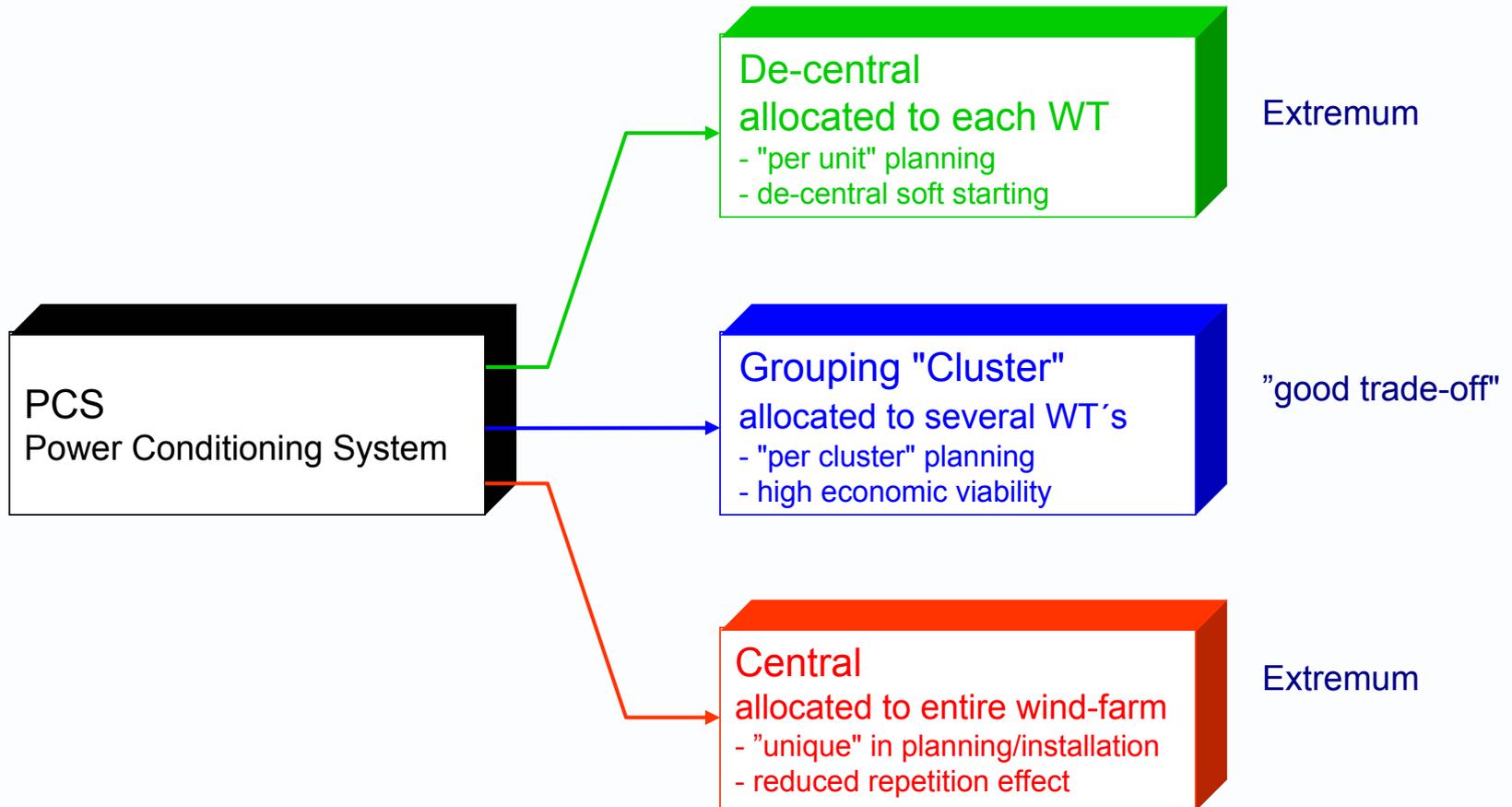


Technical solution for fixed speed application

- Self-commuted converter in PWM-inverter technology
 - Response like a synchronous machine for grid support
 - „*Electronic Synchronous machine (phase-shifter)*“
 - 4-Quadrant inverter PCS: Power Conditioning System
- Advantage of PCS in PWM-inverter technology
 - in spite of voltage dips constant reactive current output
 - grid support during voltage dips with PCS nominal current
- ideal for WT of type „constant speed/Stall control“
 - for new individual WT, for new clusters, for new wind-parks
 - for existing WT / cluster / wind-parks (upgrading)

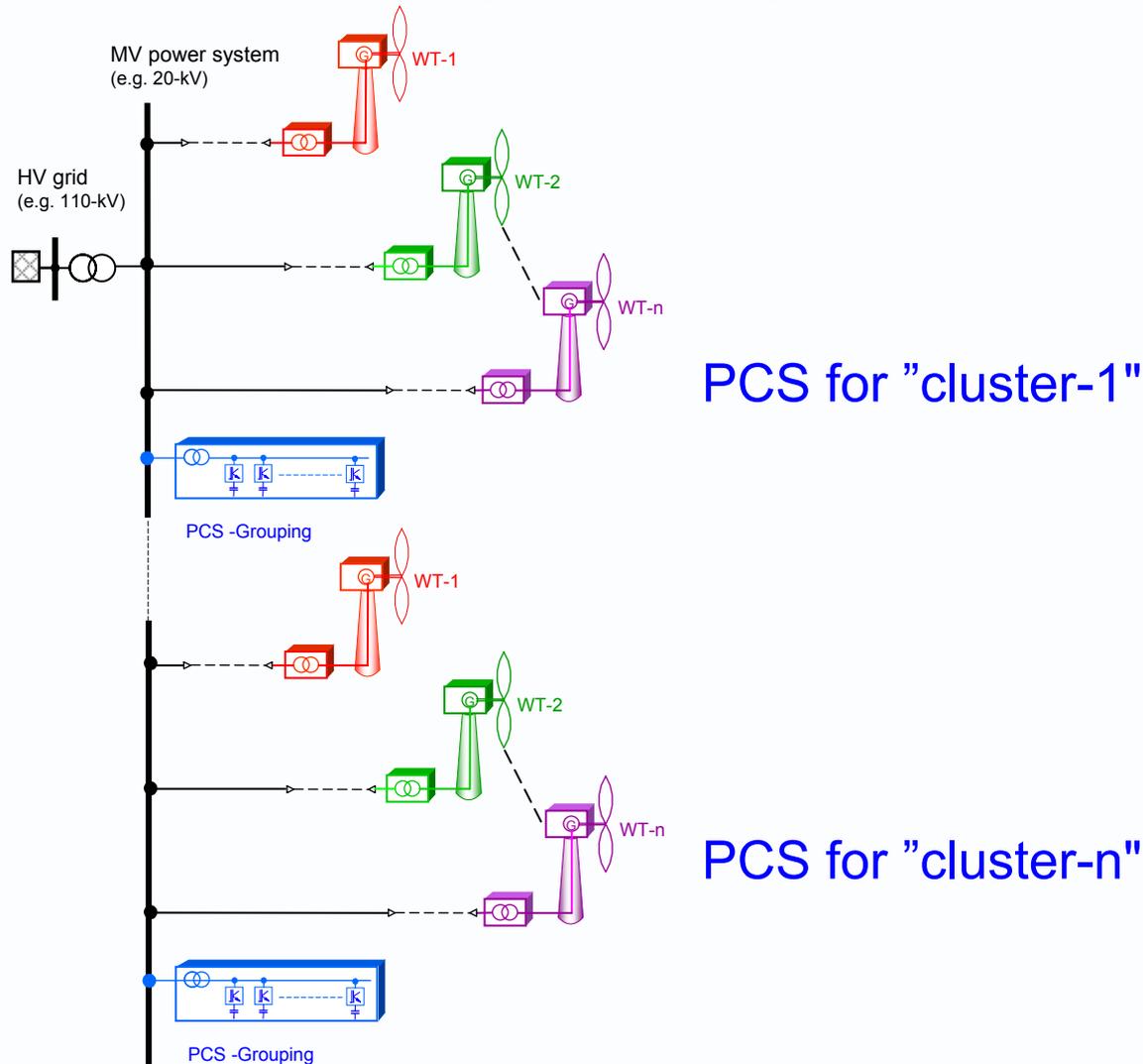


PCS - Flexibility by modularity





PCS - Flexibility by modularity - Economic viable clustering





Advantages of PCS for clustered WTs

- WT diversity in possible groups
 - small, middle and large WT
 - small, middle and large wind-farm
- Project design and engineering
 - Module approach for „typical“, e.g. $\pm 1,5$ Mvar; ± 3 Mvar; ± 6 Mvar
 - „per-cluster“ standard with high repetition effects
 - „n+1“ feature for cluster economically viable
- Delivery, commissioning, project financing
 - shorter delivery times, shorter commissioning, lower risk
 - advantageous cash-flow, lower interest payments/capital bindings
 - simplified and more convenient balance of payments



PCS Mode of operation „Production by windenergy“

- WT „stall-control“ has inductive, load dependent reactive power demand, however
 - Softstart and synchronising of the WT
 - $\cos\varphi$, controllable between 0,95 inductive/capacitive
 - Optional $\cos\varphi$ controllable in wider range
 - Medium voltage (e.g. 20-kV) controllable
 - Reactive power input/output to grid controllable
- Using ALSTOM's Power Conditioning System, the objectives can be met.



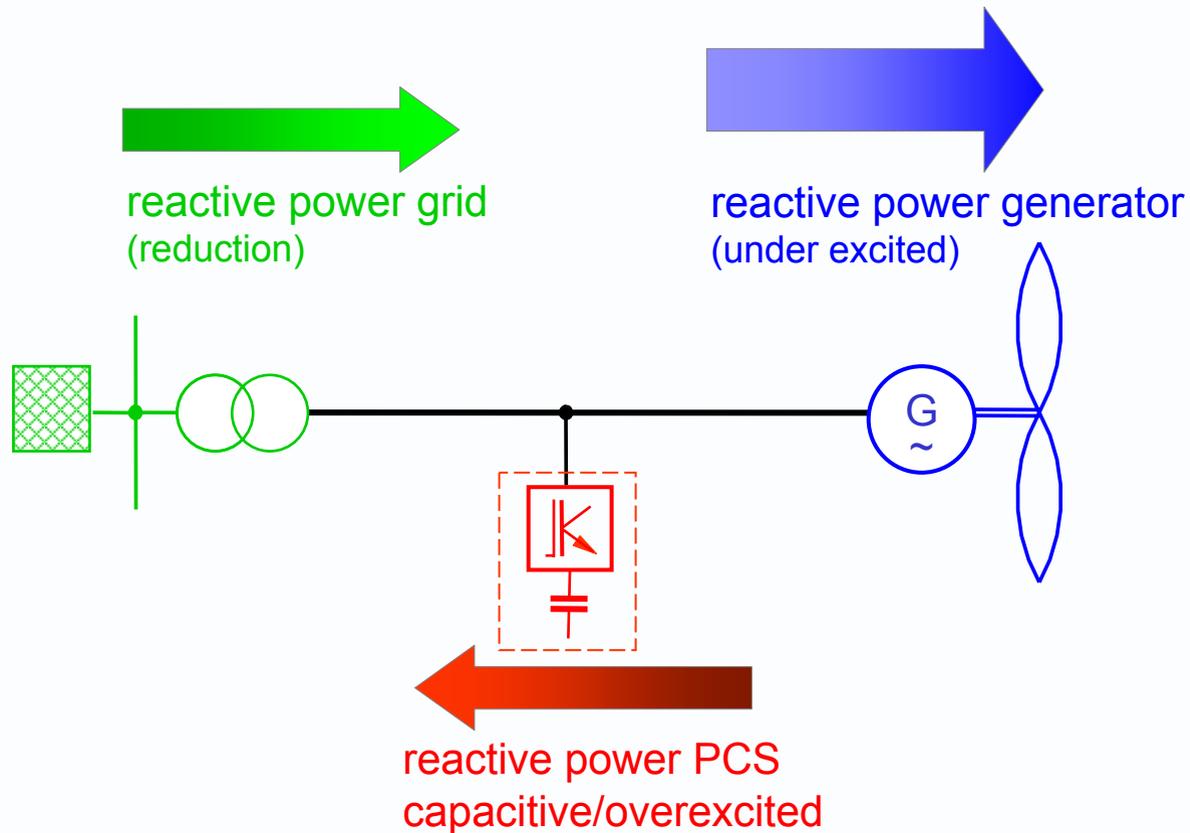
PCS Mode of operation „response to power system faults“

- WT „stall-control“ is to generate reactive current into grid (e.on)
 - with an conventional WT this is not possible
 - with conventional fixed/controllable compensation systems this is practically not possible
- Regenerative reactive current export only possible, if
 - large numbers of additional capacitors have to be installed, which in normal op „Production by wind energy“ are totally useless
 - higher cost at low benefit = economic not viable
- Using ALSTOM's Power Conditioning System, the objectives can be met.



Solution - Reduction of reactive power

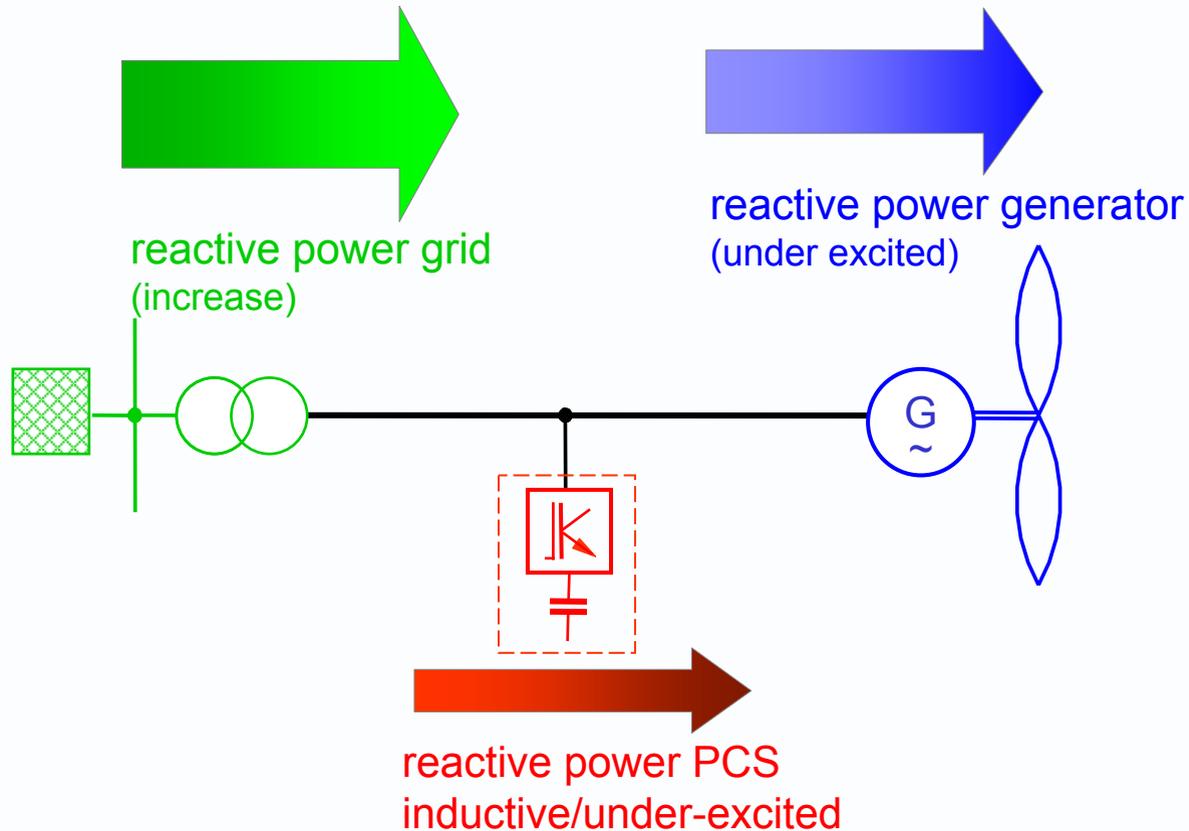
- PCS - capacitive operation





Solution - Increase of reactive power

- PCS - inductive operation





Conclusion

- **ALSTOM Power Conversion** has profound experience with wind turbines and grid stability
- We provide customer oriented solutions from the turbine shaft to the grid connection
- **ProWind** converter:
 - optional solution for new grid connection requirement
 - short-term availability, retrofit possible
 - low mechanical stress



Modular and compact drive converter for wind turbines



- Advanced technology deriving from more than 1000 installed systems
- Flexible design thanks to standardised components and modules
- User-friendly construction and high reliability
- Space reduced by 30 %
- Power range from 0,5 to 5 MW



Design



- Standardised modules for air- or water cooling
- Design meets extreme environmental requirements (-25 °C to +50 °C)
- Protection class up to IP 54
- Optional outdoor containers



Operational reliability is our commitment

- Each ProWind drive is fully factory tested to IEC standards including integrated system testing with the original generator
- Diagnostics and services
 - Spare parts delivery service within 24-hours for most items
 - Field service representatives provide emergency response
 - Tele-service
 - Customised maintenance contracts
- Service-friendly construction
 - Identical components
 - Low weight and compact size
 - User-friendly microprocessor control unit





System solutions for wind energy converters

- Consisting of:
 - Permanent excited generator
 - Frequency converter
 - Transformer
 - Switchgear
- Optimised for offshore applications
- Worlds largest WEC located in Bremerhaven/Germany
- Erection Summer 2004



“MULTIBRID” Wind Energy Converter

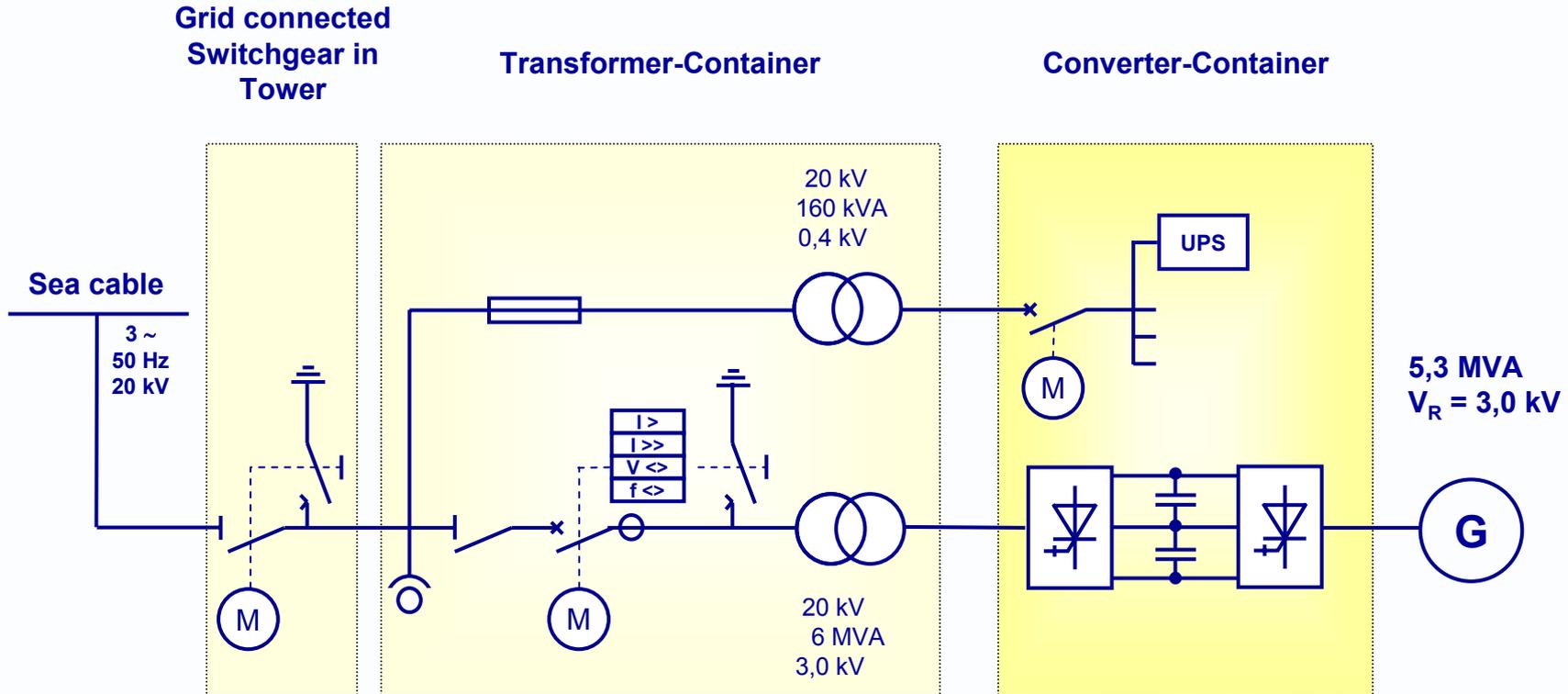


- High power density due to optimised gearbox- and generator concept
- Medium voltage converter and transformer in offshore-container
- Permanent magnets synchronous generator



5 MW Drive System

Overview





Phase leg ALSPA VDM 7000



- Pulse converter GTO
- Liquid cooled
- Machine voltage: 3 kV
- Power: ≥ 5 MW
- Power factor: controllable



Highest availability and reliability

- High operational safety:
 - Redundant ventilation
 - „Worst case“ construction
- Factory tests according to IEC standards including system testing with the original generator
- Resulting in minimised commissioning time
- Easy access and serviceability
- Comprehensive service offerings
- Customised maintenance contracts



Your benefits at a glance

- Tailor made drive solutions for your wind turbine
- Redundancy / high reliability
- Significantly simplified installation and start-up on site due to fully tested drive system
- Easy access and serviceability
- Comprehensive service offerings

The Alstom logo features the word "ALSTOM" in a bold, sans-serif font. The letters "A", "L", "S", "T", and "M" are dark blue, while the "O" is a vibrant red. The "O" is stylized with three concentric, slightly offset circles, creating a sense of motion or a gear. The logo is centered on a white background that is partially framed by a large, thick red arc on the left and top. The background of the entire image consists of vertical blue stripes of varying shades, with some faint white curved lines.

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