Control solutions for Blackstart capability and Islanding operation of Offshore wind power plants

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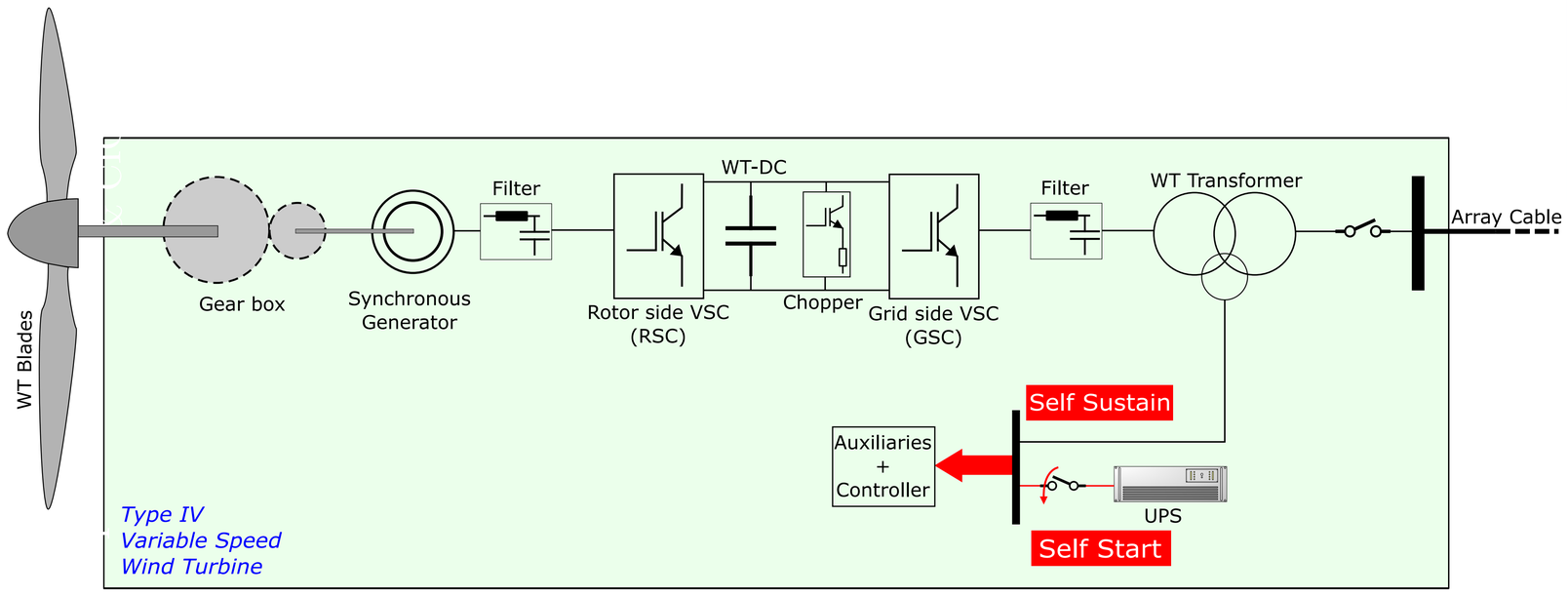
Motivation

Increased risk of wide-area blackouts
High volume integration of RES far from loads
Increased trans-national power exchanges } *Operation closer to dynamic stability limit*
Power electronics converter (PEC) interface }
Stronger network linking

Large OWPPs with modern WTs can address Blackstart requirements targeted conventionally to large thermal plants: ENTSO-E codes
Steady winds far-from-shore, thus *lesser availability-uncertainty*
Fast, fully-controlled, high-power environment-friendly BS capability of VSC-HVDC OWPP
Advanced V,f control functionalities from state-of-art PE interface of modern WTs

Grid forming WT,WPPs
Reduce the overall *impact* of a blackout event
Minimize or totally avoid use of *backup diesel generator* for auxiliary power, thus cost benefits
No wait for completion of network reconstruction; *controlled islanding* to ensure continuity of power supply
Allow DRU / LCC-with-smaller-filter, thus reduce costs, increase efficiency & reliability

Self-Start & Sustain



1 Initial energization
Control equipment
Measurement units
Yaw & Pitch mechanism
← *Onboard backup UPS*

2 Rotor oriented to wind
Insufficient load;
Prevent rotor over-speeding
← *Power curtailment / Idling modes*

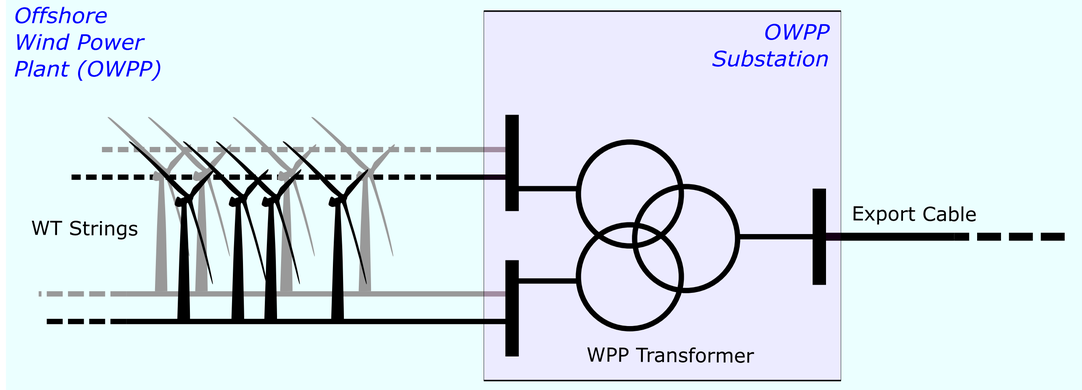
Energize WT transformer & DC link;
Supply auxiliaries & control equipment
← *Grid forming GSC*

Parallel Operation

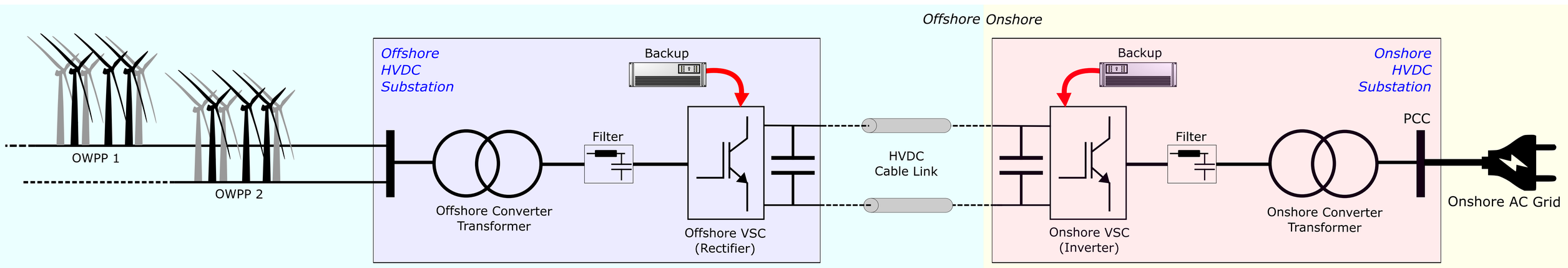
3 Coordinated parallel operation

Some BS-capable Grid-forming WTs, Rest Grid-following WTs
Multiple PEC-interfaced WTs in a WPP

Adapt microgrid control strategies
Voltage controlled island
Energize Array cables, WPP transformer & Export cable



Offshore Grid-forming & Controlled Islanded Operation



4 Offshore collector-grid forming
Multiple WPPs in a Cluster
Emulate stiff & controlled Voltage source
Energize Converter transformer
VSC & HVDC link energization
Load sharing

5 V,f-Stability & Robust Islanding
Large load-pickups
WT connection/disconnection transients
Faults in offshore & DC grids
Harmonic instabilities
HVDC link resonance issues

6 Final aim: Grid synchronization
Facilitate onshore grid restoration
Block-load recovery

Challenges

Technical
Magnetic inrush currents: transformers
Initial charging currents: long unloaded cables, filter banks } *Non-linear loading*
Starting transients: LCC/DRU
Dynamic VAR control for steady-state & transient voltage issues
Risk of operation of protection, that can trigger a re-blackout

Resource-based
Inherent fluctuating nature of wind energy resource

Control Strategies

Distributed Grid-forming V,f control
Phasor-control / Synchronous-machine emulating mode
3-level hierarchical Micro-grid control structure
Multi-Master Operation
VAR-compensation STATCOM mode

Down-regulated operation with set-point control
Capability assessment for Grid synchronization

INNOVATIVE TOOLS FOR OFFSHORE WIND AND DC GRIDS

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