INNOVATIVE TOOLS FOR OFFSHORE WIND AND DC GRIDS

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Blackstart & Islanding Capabilities of HVDC connected Offshore wind power plants

DTU

Motivation

High volume integration of RES far from loads
Increased trans-national power exchanges
Decreased Var reserve due to SG replacement
Power electronics EMT, Inertial decoupling
Uncontrolled Islanding, Protection settings re-design
Complicated grid operation: stability, reliability

→ Increased risk of wide-area blackouts
eg: South Australia 2017, UK 2019

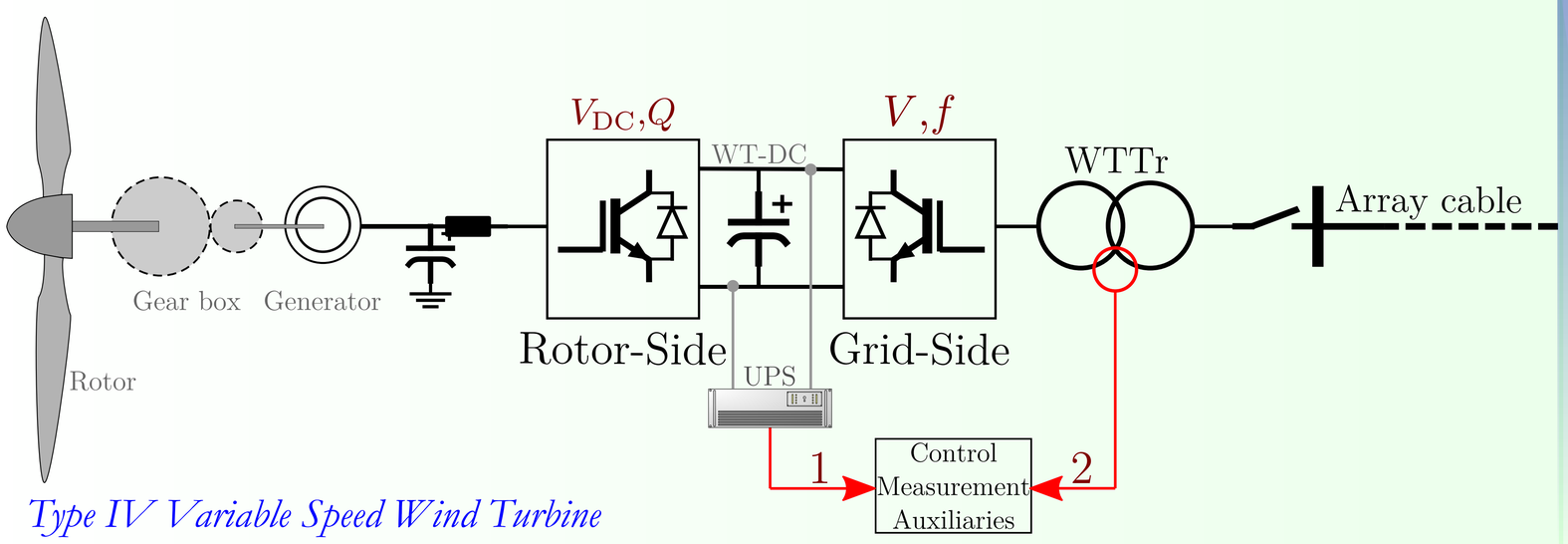
→ TSO → Large OWPPs with modern WTs can address Blackstart requirements targeted conventionally to large thermal plants (ENTSO-E codes)

Steady winds far-from-shore, thus *lesser availability-uncertainty*
Fast, fully-controlled, high-power, green blackstart capability of VSC-HVDC OWPP
Advanced V,f control functionalities from state-of-art PE interface of modern WTs

Grid forming / Blackstart-able WTs → Voltage source rather than traditional current source → WFO

No waiting for end of network reconstruction; *controlled islanding* to ensure continuity of power supply
Reduce the overall impact of a blackout event: *reduced restoration time & unserved load*
Replace *backup offshore diesel generator* for auxiliary power & energization
Cost benefits, reduced shipping downtime, increased reliability & CO2 displacement.

Self-Start & Sustain



Type IV Variable Speed Wind Turbine

1 Initial energization

Control equipment
Measurement units
Yaw & Pitch mechanism
← Onboard backup UPS

2 Rotor oriented to wind

House-load operation;
Prevent rotor over-speeding
← Power curtailment / Idling modes

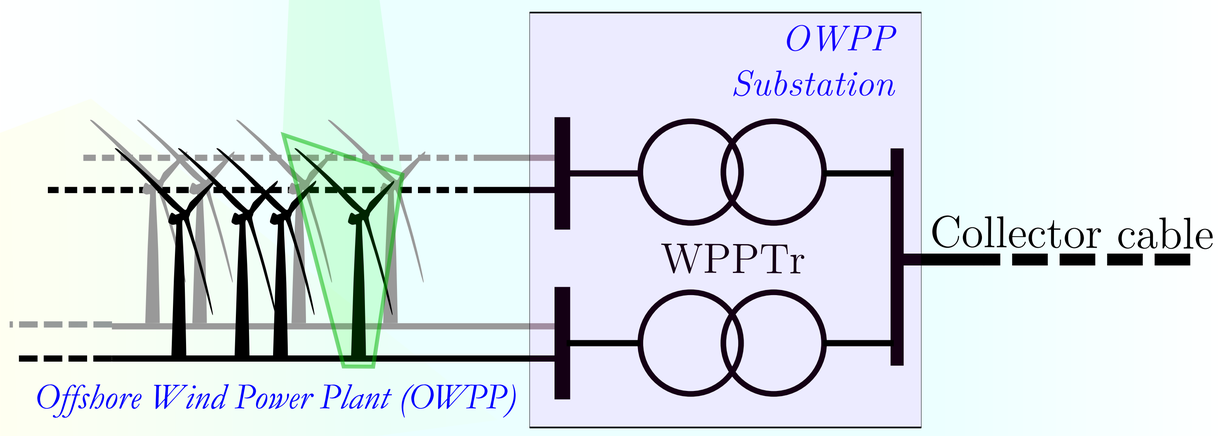
Energize WT DC link, conv & trafo;
Supply auxiliaries & control equipment
← Grid forming GSC

Synchronized Parallel Operation

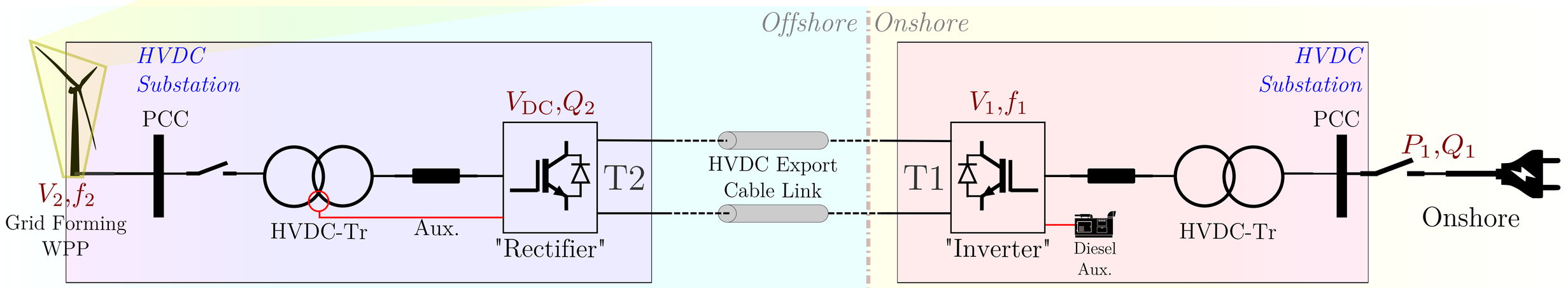
3 Voltage controlled island

Some Grid-forming WTs,
Rest traditional Grid-following WTs
→ Power electronics rich offshore grid

Hierarchical Microgrid based control
Hard switching vs Soft start
PIR, PoWS, Smart energize
→ Synchronization transients
Cable/trafo energization
SOV, TOV, SFO, TRV



Offshore Grid-Forming & Controlled Islanded Operation



4 Offshore Grid Forming

WPP emulates controlled voltage source
Energize trafo, MMC & cables
Sympathetic inrush, Resonance, Controller interactions
Islanded operation with auxiliary load

5 Stable & Robust Islanding

WT connect/disconnect transients
Faults in offshore grid / HVDC cable
Harmonic instabilities
HVDC link resonance issues

6 Grid Point of Connection

Facilitate power system restoration
Trip to Houseload operation
Block load recovery
Grid re-synchronization

Publications

Wind Integration Workshop 2018 (Stockholm) → **Overview**
Defining the Target States
Identifying the technical challenges
Lit. review of potential control solutions

Large-scale Grid Integration of Renewable Energy 2019 (India) → **Functional Requirements**
Identifying the Gap
between Grid codes
and current WT capabilities

Wind Energy Science 2020 (EAWE) → **Grid Forming Controls**
Understanding GFM control structure
Identifying the major different strategies
Compare transient behaviour during energization

Renewable Power Generation 2020 (IET) → **Energization Transients**
Hard switching vs Soft start
HVDC MMC pre-charging transients
Sensitivity Analysis: PIR/PIT, ramp rate

Marie Skłodowska-Curie Actions

https://innodc.org/
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