PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

DTU

Prolonged Fault Response of Offshore Wind Power Plants

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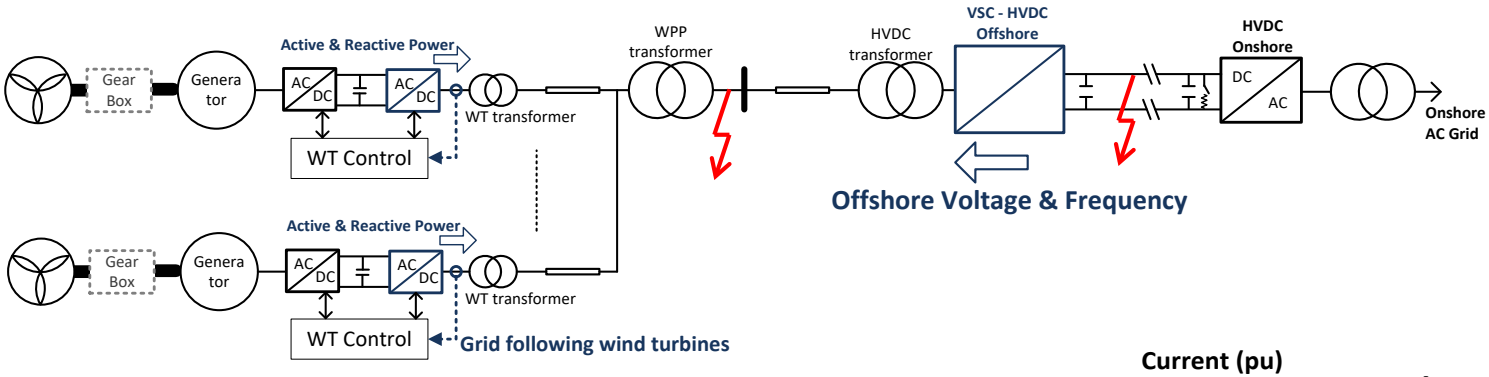
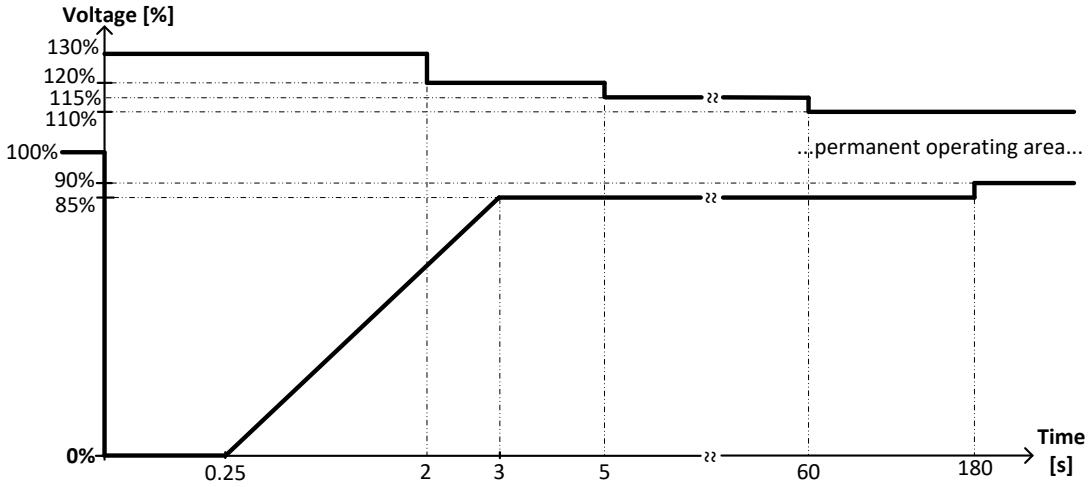
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

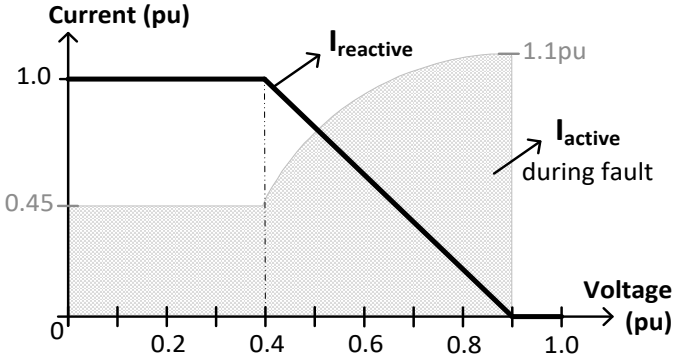
Outline

- Today's FRT requirements
- Today's FRT solutions
- Disconnection-reconnection requirements
- DC fault in meshed HVDC offshore grids
- Next-generation WTs
  - Black-startable / Self-sustaining WTs
- Prolonged FRT case

Today's FRT requirement





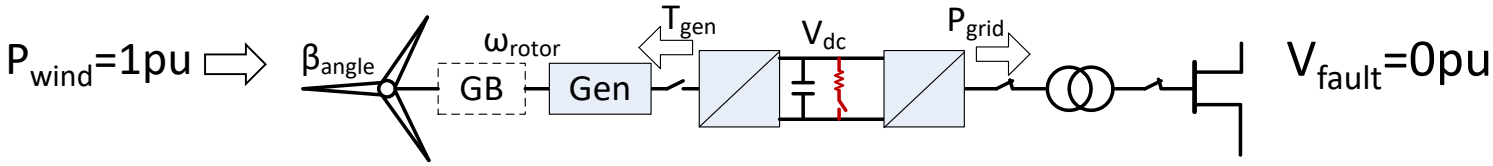


Primarily reactive fault current

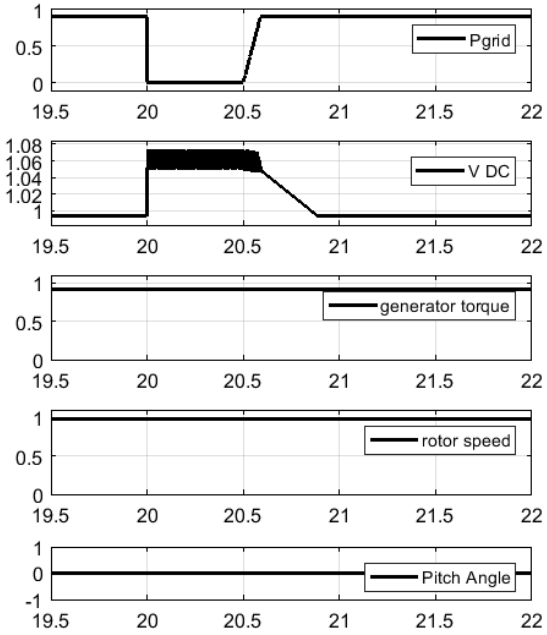
Same as onshore

WTs: allowed to disconnect outside the band

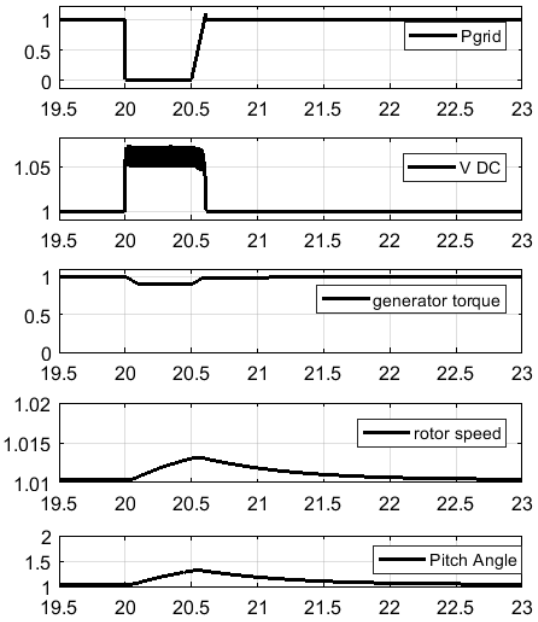
FRT solutions



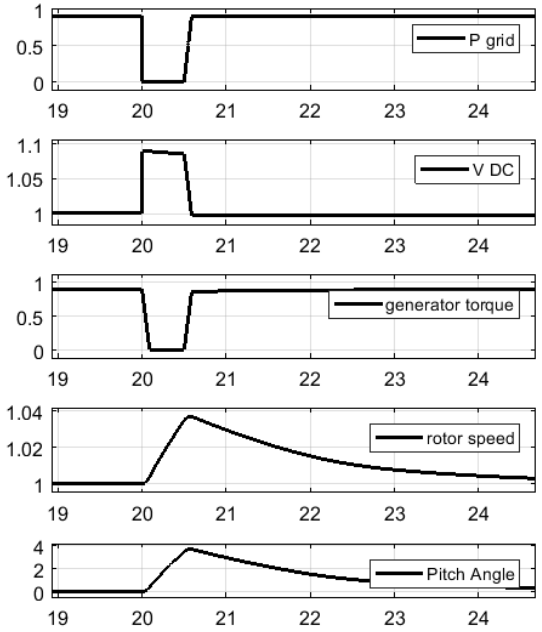
Full Chopper



Partial Chopper

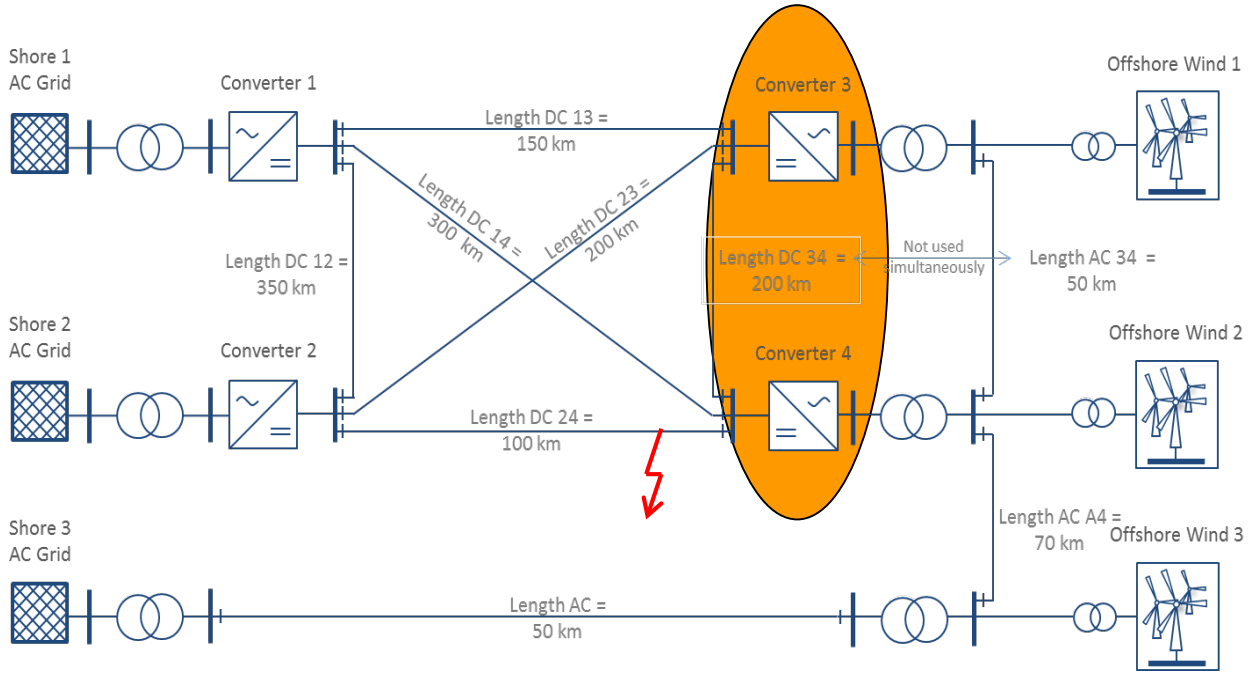


No Chopper



Different design choices by WT OEMs – all proven

DC fault in meshed offshore HVDC grids



Fully-selective DC fault clearing:

DC Circuit Breakers

5-10ms

Non-selective DC fault clearing:

High-Speed DC Switch & AC Circuit Breakers

HVDC Converter Blocking & De-blocking

→ WPP(s) might disconnect due to long outage

[https://www.promotion-offshore.net/fileadmin/PDFs/D4.2_Broad_comparison_of_fault_clearing_strategies_for_DC_grids.pdf]

Reconnection requirements

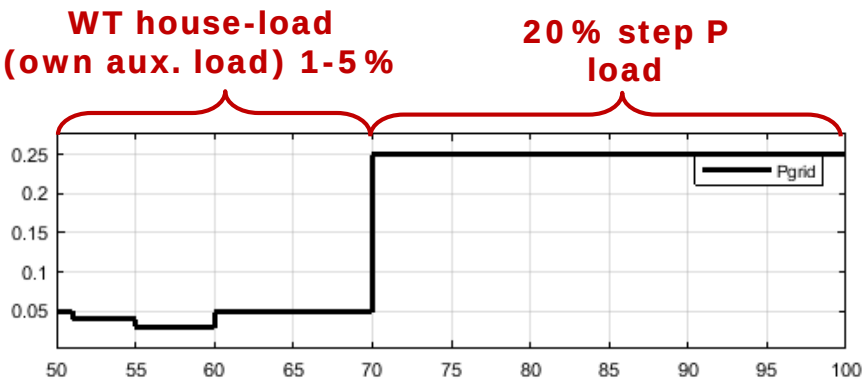
"*HVDC systems, including DC overhead lines, shall be capable of **fast recovery** from transient faults within the HVDC system*"
in article 27 (Fast recovery from DC faults) of **ENTSO-E HVDC code**

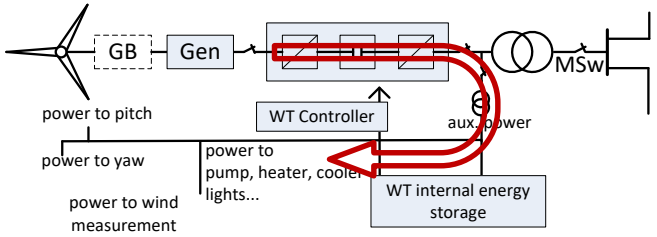
"*after a short-time-interruption **resynchronization** of the plant must take place **within 2 seconds** at the latest. The active power infeed must be increased to the original value with a gradient between 0.1 and 0.2 pu/s***"**
in **TenneT TSO GmbH HV and EHV grid code**

(i) "*in case of disconnection of the power-generating module from the network, the power-generating module shall be capable of **quick re-synchronisation***"
(ii) "*power-generating module with a minimum re-synchronisation time greater than 15 minutes after its disconnection from any external power supply must be designed to **trip to houseload***"
(iii) " *power-generating modules shall be capable of **continuing operation** following tripping to houseload* "
in article 15.5.(c) of **ENTSO-E RfG code**

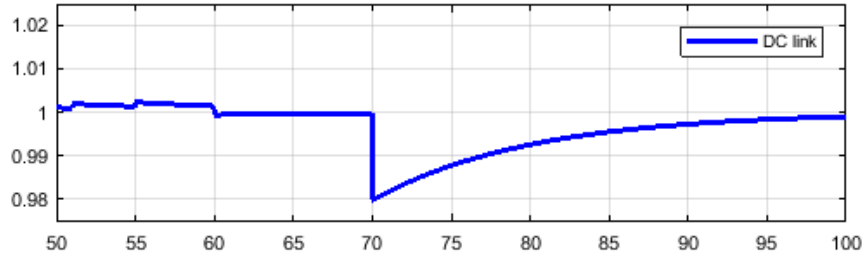
Next Generation:
Self-sustaining (black-startable) wind turbines

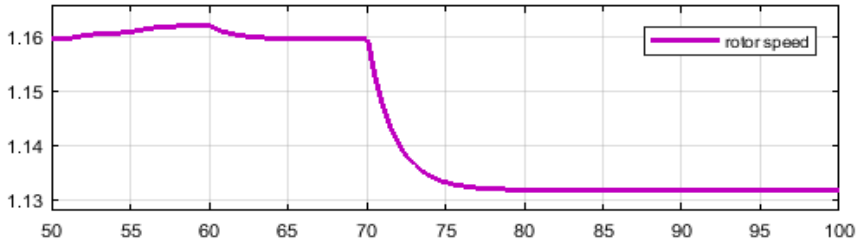
Stand alone (HouseLoad) operation

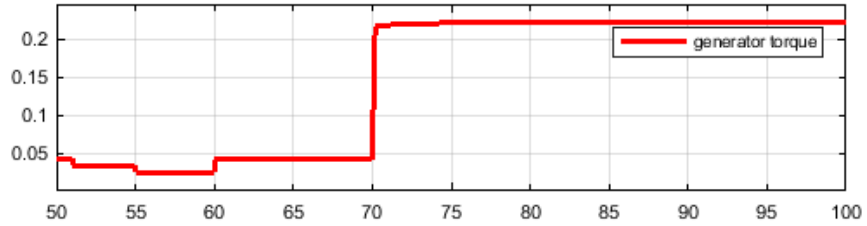


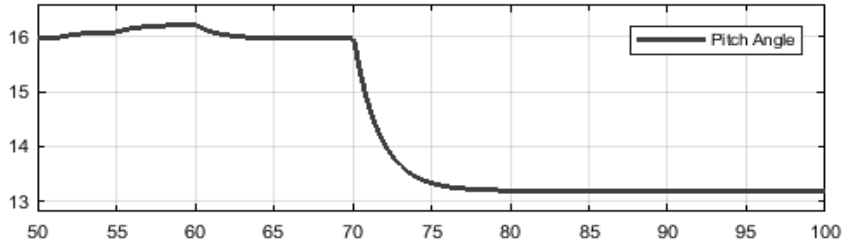


>90% curtailment → idling @ ω_{rated}





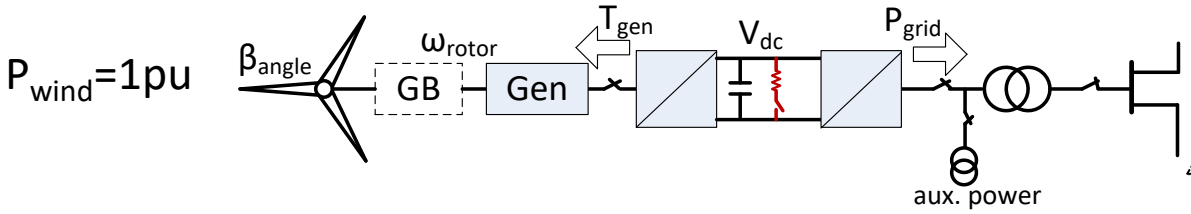




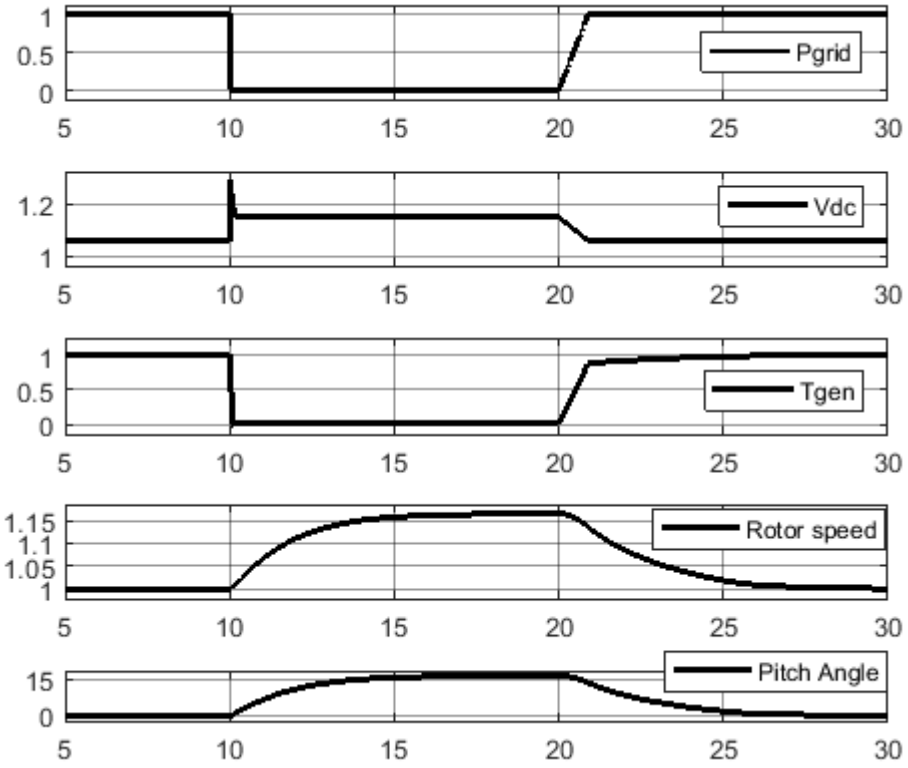
In summary

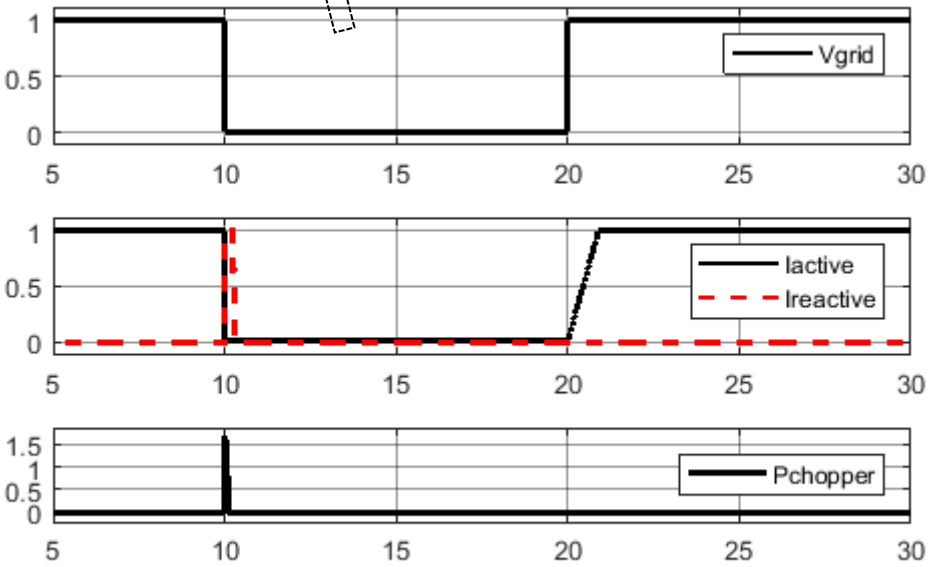
1. Ride-through faults!
2. Ride-through longer, if possible!
3. Otherwise trip to houseload! (possible)
4. Reconnect quickly!

Prolonged FRT case



V_{fault}=0pu



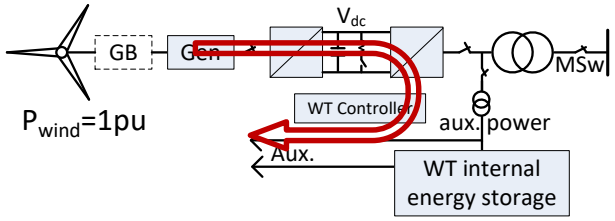


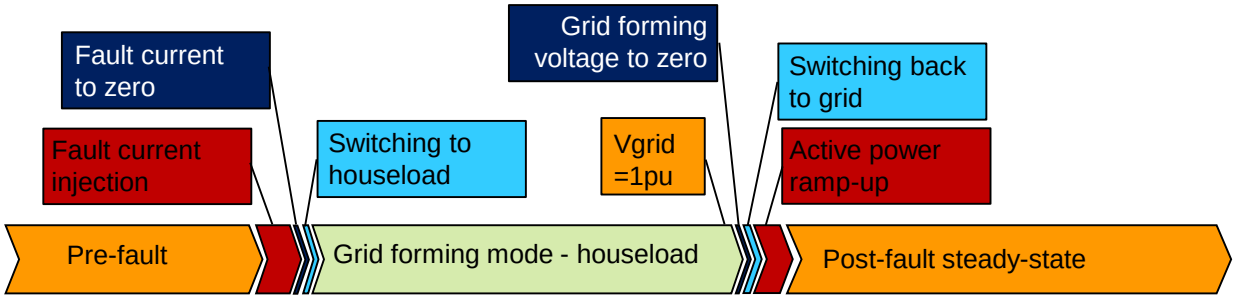
Rotor keeps idling @ω_{rated} → quick reconnection

Vgrid=0, Pgrid=0

→ WT aux. power?

Prolonged FRT case – grid forming

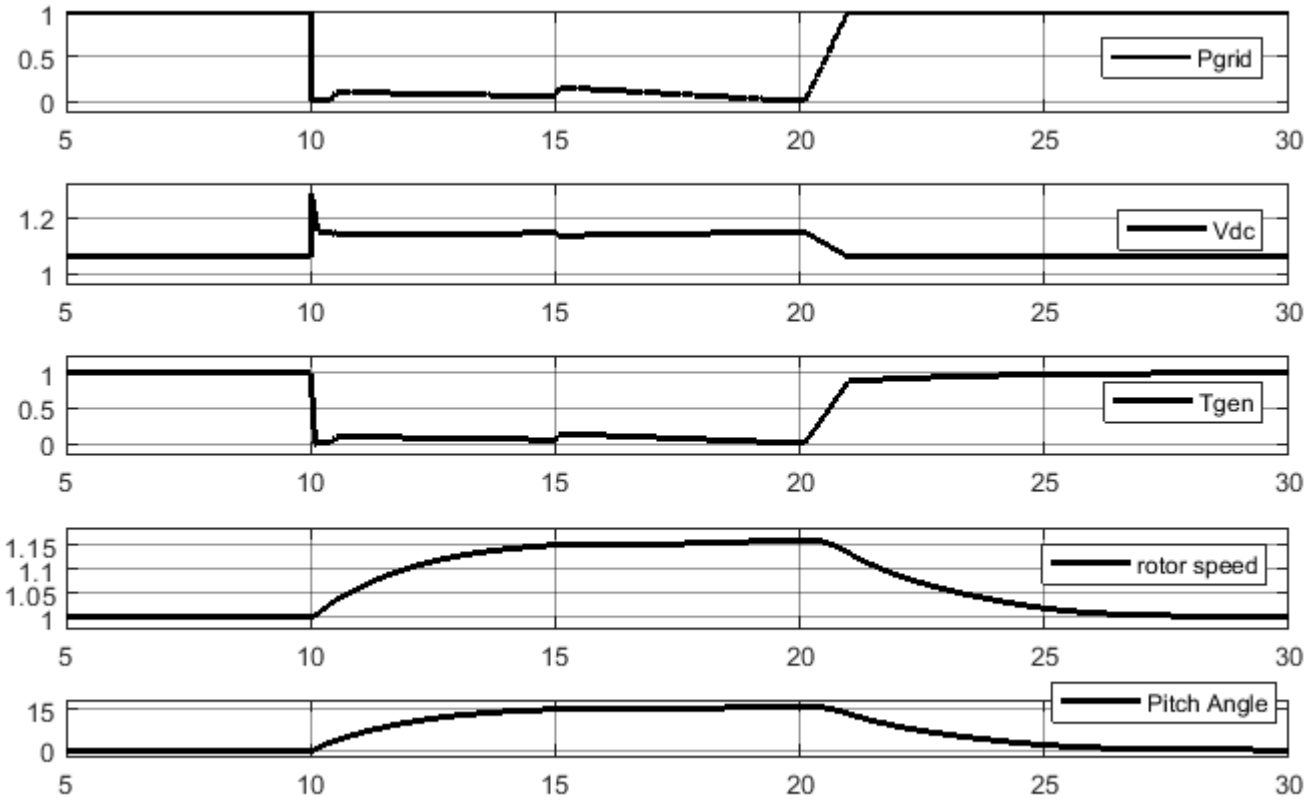




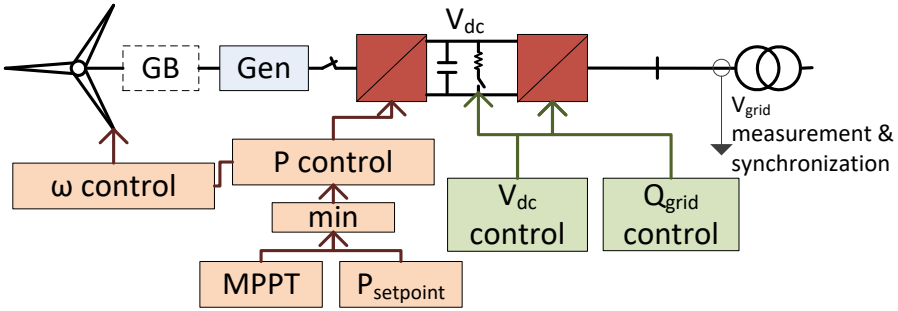
- WT supplies its own auxiliaries during grid outage

(aviation lights, climate conditioners, etc.)

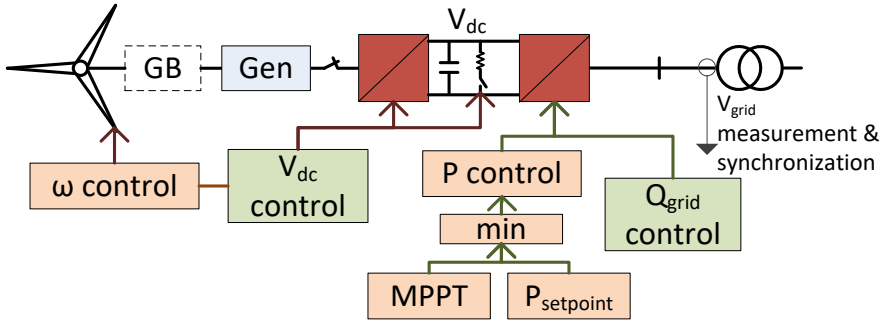
- WT stays ready for quick reconnection



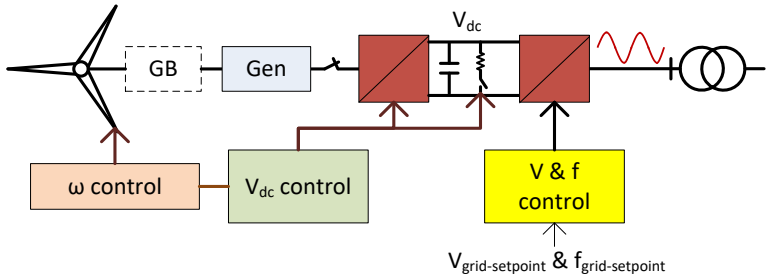
Grid forming WT – stand alone



Grid following WT – option 1



Grid following WT – option 2



Grid forming WT

- Grid side converter behaves as stiff voltage source

Conclusion

- Future WTs are expected to be **stand-alone** active units
    - Grid forming
- **New FRT concepts** for WTs to be developed
- **Quick reconnection** for the sake of power system
- Self-sustaining **houseload** mode for the sake of WT

- Mechanical loads during torque transients – to be investigated
- Aerodynamic during excessive curtailment – to be investigated
- Electrical transients during energization – to be investigated

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