

## Study Committee C4

PS3 Challenges and advances in power system dynamics

Paper ID\_10696

# Experimental validation of a grid-following wind turbine connected to weak grids

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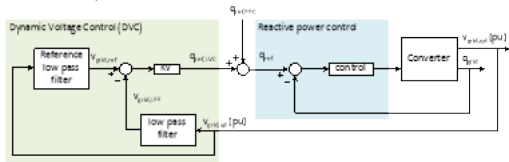
Vestas Wind Systems A/S

## Motivation

- A significant part of the future converter based energy sources will be grid following converters operating in weak grids.
- A general solution enabling a grid following based Wind Turbine Generator (WTG) to operate properly in weak grid conditions down to a Short Circuit Ratio (SCR) level at 1.5.

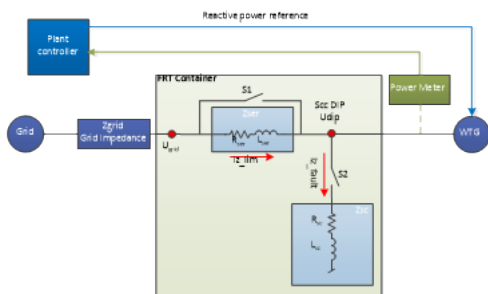
## Method/Approach

- The weak grid control is based on the standard two-axis control of a grid converter with the addition of the Dynamic Voltage Controller (DVC).
- The DVC provides fast disturbance rejection for voltage disturbances with a soft transition toward the steady state condition.



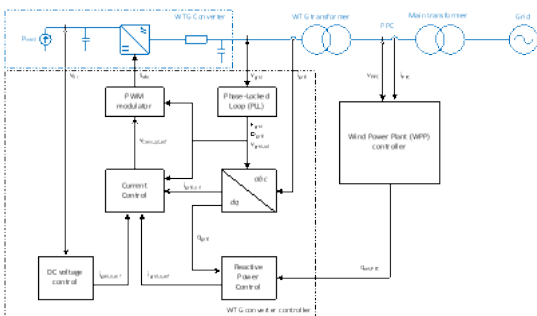
## Experimental setup

- Weak grid conditions are obtained by a Fault-Ride-Through (FRT) container, and three types of test are conducted: Voltage setpoint control, Change of SCR, and FRT tests.
- The pictures show the FRT container.



## Objects of investigation

- The grid control of the full-scale type 4 grid-following wind turbine is enhanced to operate under weak grid conditions.
- The WTG is connected to a PPC at the Point of Common Coupling (PCC).



## Discussion

- Test is only conducted with new control structure as WTGs without the DVC are not expected to survive at the investigated low SCR levels.

## Conclusion

- A general solution for operating of the grid-following based wind turbines under weak conditions.
- The proposed weak grid control can handle voltage setpoint control, can withstand abrupt changes in the SCR level, and it shows to ride through voltage dips.
- The combination of the dynamic voltage control of the WTG and the centralised voltage control of the WPP enables the grid-following based WTG to operate properly at low SCR levels.
- Experimental results of a WTG in a real weak grid supports the validity of the selected approach to enhance the operational SCR range down to 1.5.

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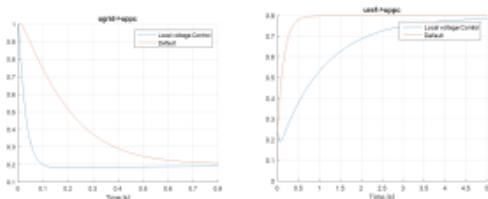
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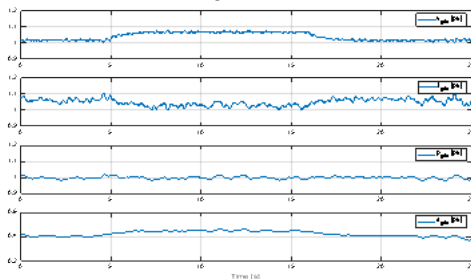
### Weak grid design

- The DVC acts fast on sudden disturbances of the WTG voltage and the voltage setpoint response is slowed
- The centralised PPC handles the steady state operating points.



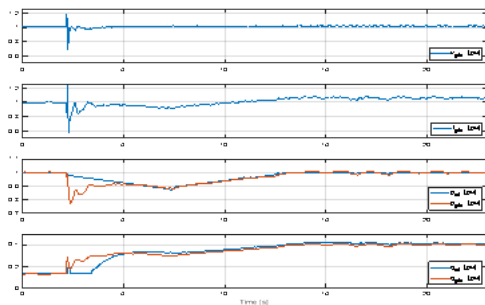
### Field setup of the FRT container

- WTG response during a voltage reference change at SCR=1.5.
- The voltage reference is increased with 5% at t=5s, and this is removed again after t=15s.



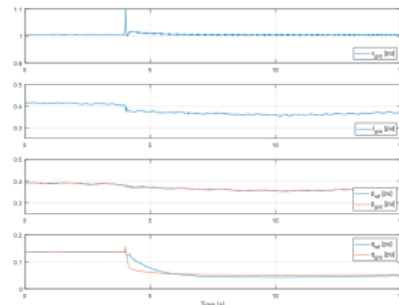
### Test of step change of SCR level

- The figure shows performance for a step change in SCR level at full load.
- At t=2s the SCR is changed from 20 to 1.5.



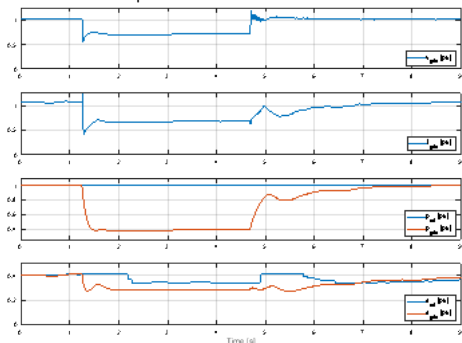
### Test of step change of SCR level

- WTG response during a step change in the SCR level at partial load.
- At t=2s the SCR is changed from 20 to 1.5.



### FRT test at full load

- WTG response during a three phase 55% voltage dip at full load power and a SCR=1.5.



### FRT test at partial load

- WTG response during a three phase 55% voltage dip at partial load power and a SCR=1.5.

