Analysis of Wind Turbine Loading during Short-term Overproduction

Müfit Altin, Athanasios Barlas, Anca D. Hansen

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Outline

• What is Synthetic Inertia?

• Short-term Overproduction for Synthetic Inertia

• Impact of Short-term Overproduction on Wind Turbine Loading

• Conclusion
Background

Frequency is the indicator for the balance between generation and consumption.
What is Synthetic Inertia?

‘Synthetic Inertia’ means the facility provided by a power park module or HVDC system to replace the effect of inertia of a synchronous power generating module to a prescribed level of performance.

(ENTSO-E Network Code for Requirements for Grid Connection Applicable to all Generators)
Short-term Overproduction for Synthetic Inertia

$\Delta P_{ov}$ is the overproduction active power step.

$\Delta P_{rec}$ is the drop of the power.

$T_{ov}$ is the overproduction period.

$T_{rec}$ is known also as recovery period.
Dynamic Electrical Model

Wind speed $v$ to Available power $P_{avail}$ to Wind farm controller

Pitch controller $\theta$ to Aerodynamic $P_{aero}$

Aerodynamic $P_{aero}$ to Mechanical model $P_{meas}$

Wind speed $v$ to Pitch controller $\theta$

P, Q meas. $P_{meas}$ to MPPT table $P_{opt}$

Wind farm controller $P_{meas}$ to Selection mode $P_{imposed}$

Selection mode $P_{ref}$ to P control $iP_{cmd}$

P control $Q_{ref}$ to Q control $iQ_{cmd}$

Q control $Q_{meas}$ to Static generator $\omega_{gen_filt}$

Available power $P_{meas}$ to $P_{pref}$

Filter $\omega_{rot}$

$\omega_{gen_filt}$

MPPT $P_{opt}$

Selection mode $P_{imposed}$

P control $iP_{cmd}$

Q control $iQ_{cmd}$

Static generator $\omega_{rot}$

LVRT

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LVRT
Short-term Overproduction Performance

7 m/s

11 m/s
Short-term Overproduction Performance

![Graph showing mechanical and electrical power versus generator speed]

- mech. power for 0.93pu wind speed
- mech. power for 0.6pu wind speed
- elec. power (MPPT table)
Impact of Short-term Overproduction on Wind Turbine Loading

Electrical Model

HAWC2 Aeroelastic Tool
(Horizontal Axis Wind turbine simulation Code 2nd generation)
Impact of Short-term Overproduction on Wind Turbine Loading

Wind Speed = 7 m/s

- Initial power
- $\Delta P_{ov} = 2.5\% - T_{ov} = 30s$
- $\Delta P_{ov} = 10\% - T_{ov} = 9s$
- $\Delta P_{ov} = 30\% - T_{ov} = 4s$

Load channel [-]
Baseline
$\Delta P_{ov} = 2.5\% - T_{ov} = 30s$
$\Delta P_{ov} = 10\% - T_{ov} = 9s$
$\Delta P_{ov} = 30\% - T_{ov} = 4s$
Impact of Short-term Overproduction on Wind Turbine Loading

Wind Speed 7 m/s

Impact of short-term overproduction on wind turbine loading: 
- Initial power
- $\Delta P_{ov} = 20\%$ - $T_{ov} = 18s$
- $\Delta P_{ov} = 40\%$ - $T_{ov} = 9s$
- $\Delta P_{ov} = 100\%$ - $T_{ov} = 4s$

Graph showing generator power and turbine load over time.

DTU Wind Energy, Technical University of Denmark

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Conclusion

• Synthetic inertia can be a future requirement from wind power plants.

• Ramp rates of active power control have a crucial impact on wind turbine loading (also on power system frequency profile)

• Grid code requirements can be tested with the same approach.

• Verification of electrical model with aerodynamic (HAWC2) model is needed in terms of active power and rotational speed deviations.