Power Oscillation Damping from Offshore Wind Farms Connected to HVDC via Diode Rectifiers

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PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 691714.

Offshore Wind Farm Connection to HVDC

Voltage Source Converters (VSCs)

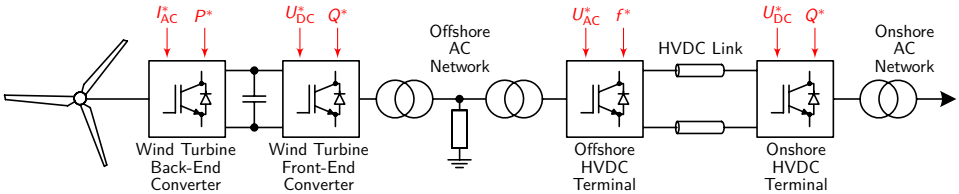


Figure: OWF connection to HVDC via voltage source converters (VSCs)

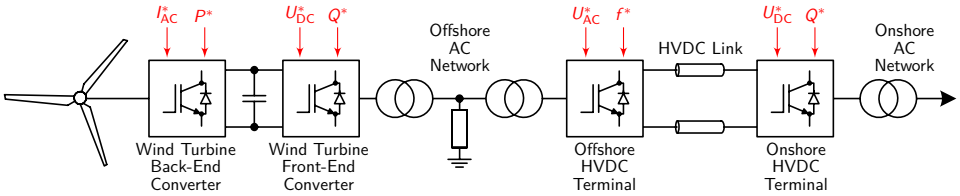
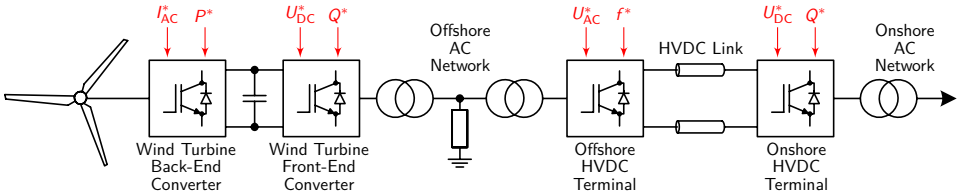


Figure: OWF connection to HVDC via voltage source converters (VSCs)

Figure: Offshore VSC connection platforms (approx. 26 000 tons) [Siemens, 2015]

Offshore Wind Farm Connection to HVDC

Diode Rectifiers (DRs)



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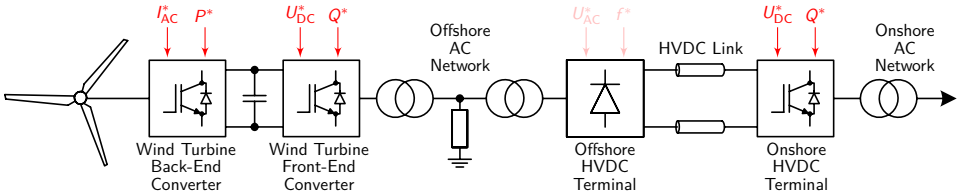

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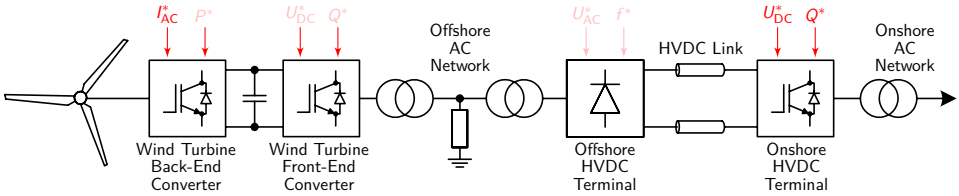
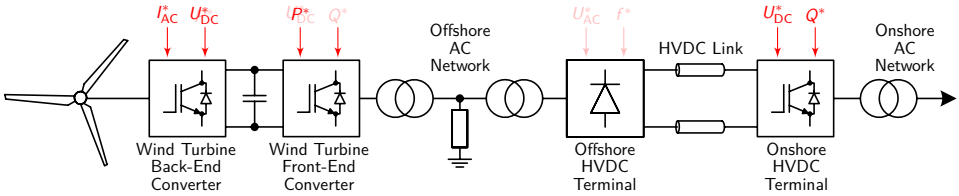


Figure: OWF connection to HVDC via diode rectifiers (DRs)

- DRs are inherently devoid of the grid-forming capability of VSCs



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- DRs are inherently devoid of the grid-forming capability of VSCs
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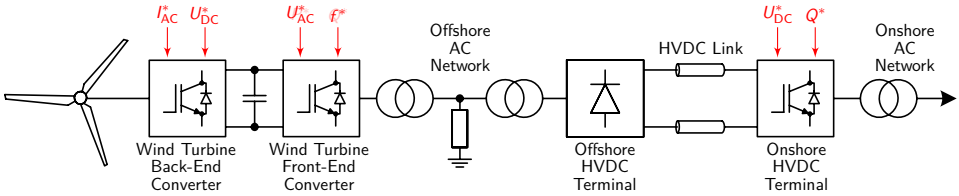

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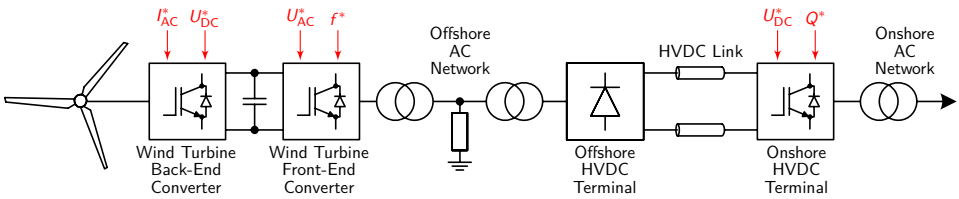

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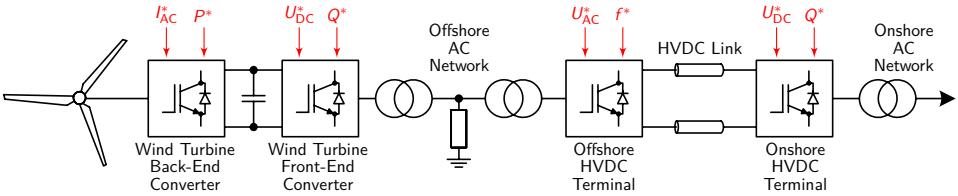
- WTs have been suggested as viable candidates to take over such duty
- Change in WT controls: grid-following units $\rightarrow$ grid-forming units



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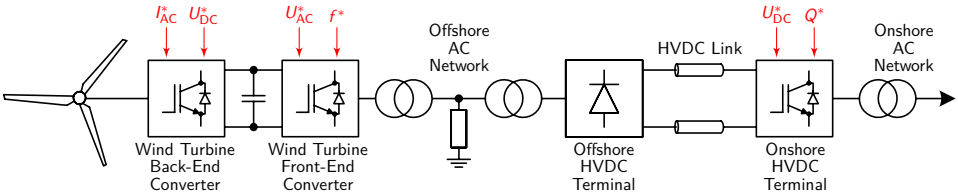

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Figure: New offshore DR connection platform (approx. 9000 tons) [Siemens, 2015]

Power Oscillation Damping

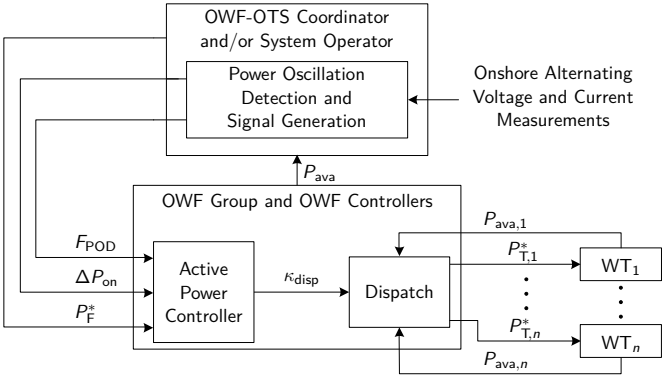
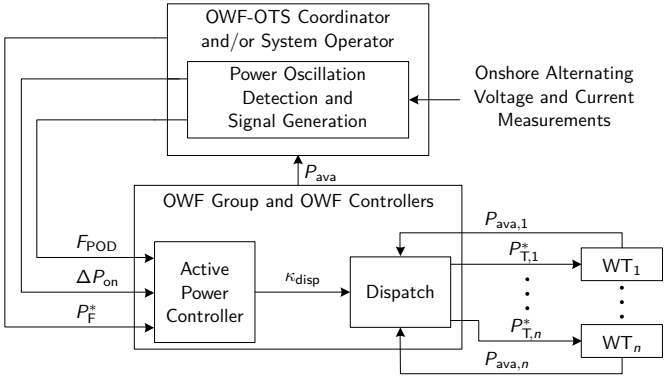


Figure: Simplified block diagram of the functionality for providing power oscillation damping

Power Oscillation Damping

- ΔP_{on} communicated with a delay of 100 ms



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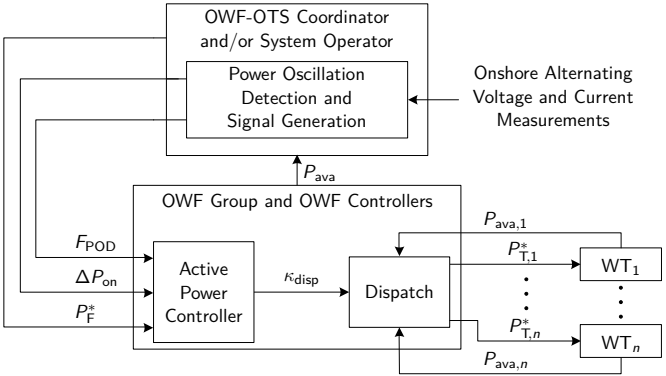
Power Oscillation Damping

- ΔP_{on} communicated with a delay of 100 ms
- Proportional dispatch: $P^*_{\text{T},k} = \kappa_{\text{disp}} P_{\text{ava},k}$



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Modelling and Control
Overview

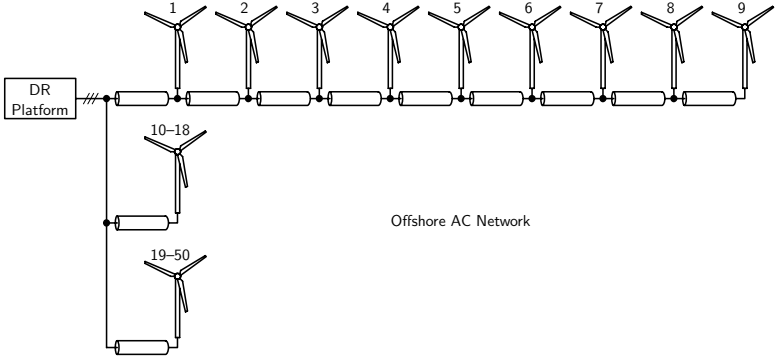
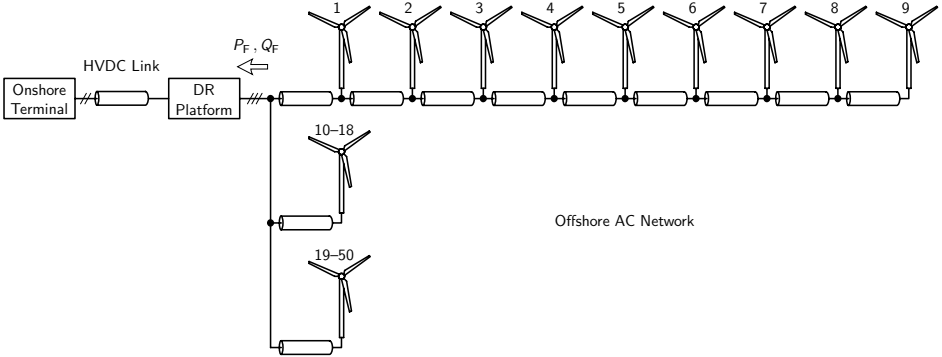


Figure: Overview of the studied system



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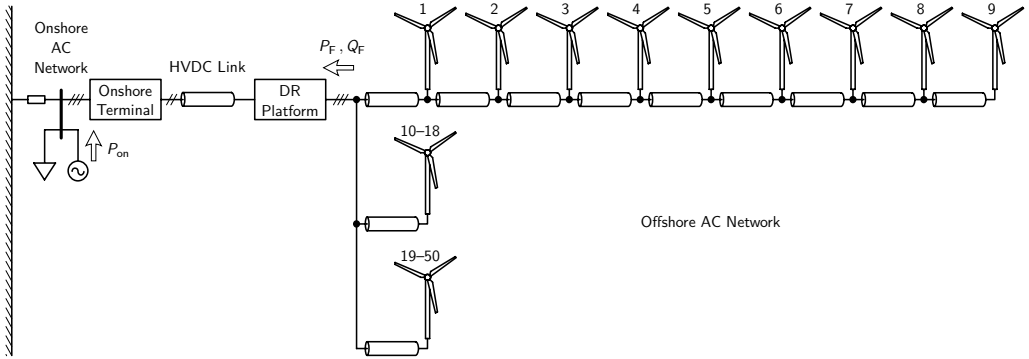

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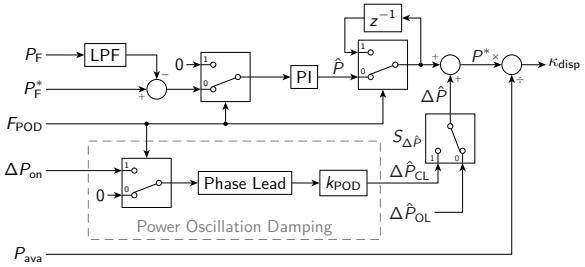
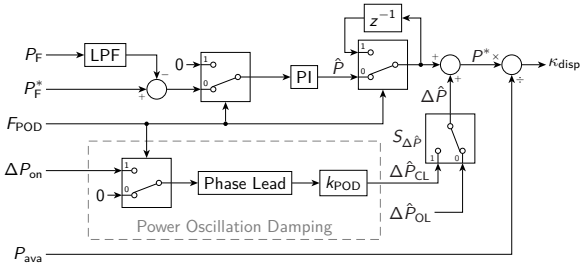


Figure: Wind farm active power control



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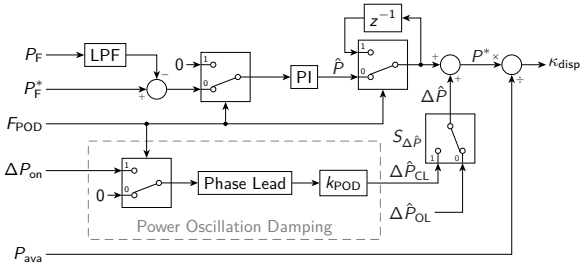
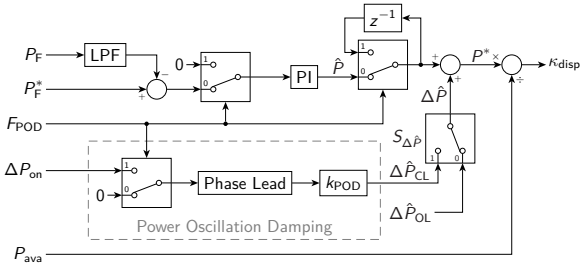


Figure: Wind farm active power control

- F_{POD} activated $\rightarrow$ $\hat{P}$ frozen: $\hat{P}_0$, $P^* = \hat{P}_0 + \Delta\hat{P}$



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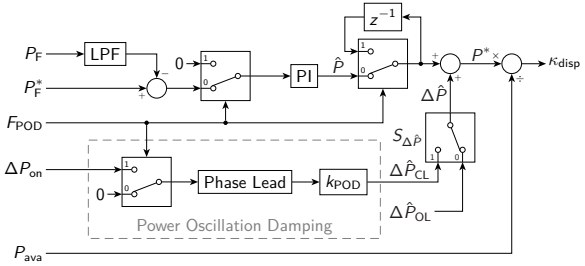

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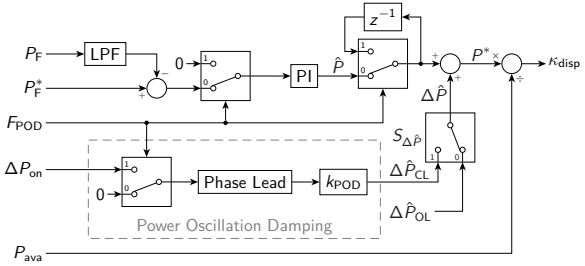

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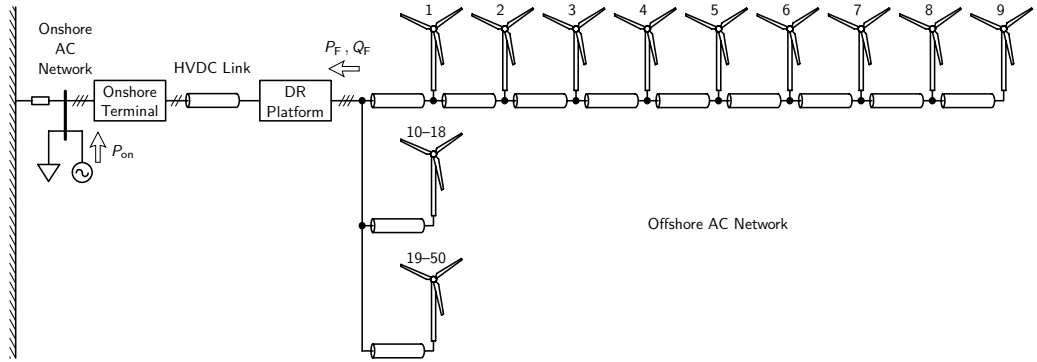
Simulation Results



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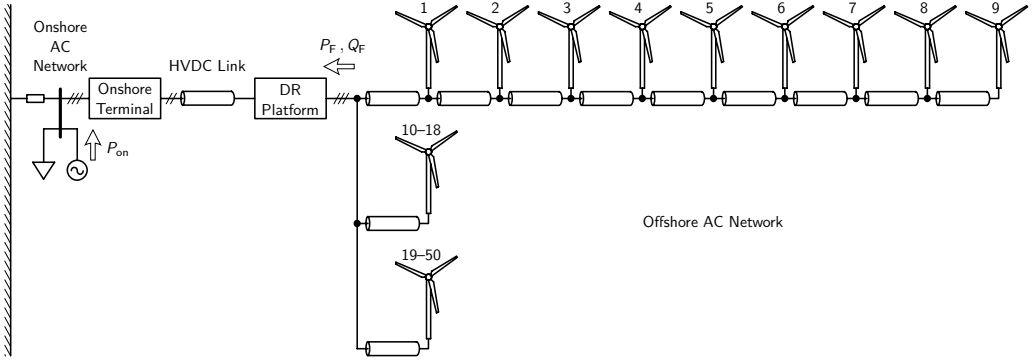

Wind Speed	Aerodynamic power available from the wind [pu]											
	P_{ava}	$P_{ava,1}$	$P_{ava,2}$	$P_{ava,3}$	$P_{ava,4}$	$P_{ava,5}$	$P_{ava,6}$	$P_{ava,7}$	$P_{ava,8}$	$P_{ava,9}$	$P_{ava,10-18}$	$P_{ava,19-50}$
Low	0.100	0.232	0.086	0.105	0.092	0.086	0.080	0.075	0.072	0.072	0.100	0.100
Medium	0.600	0.987	0.564	0.644	0.586	0.562	0.535	0.515	0.504	0.504	0.600	0.600
High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

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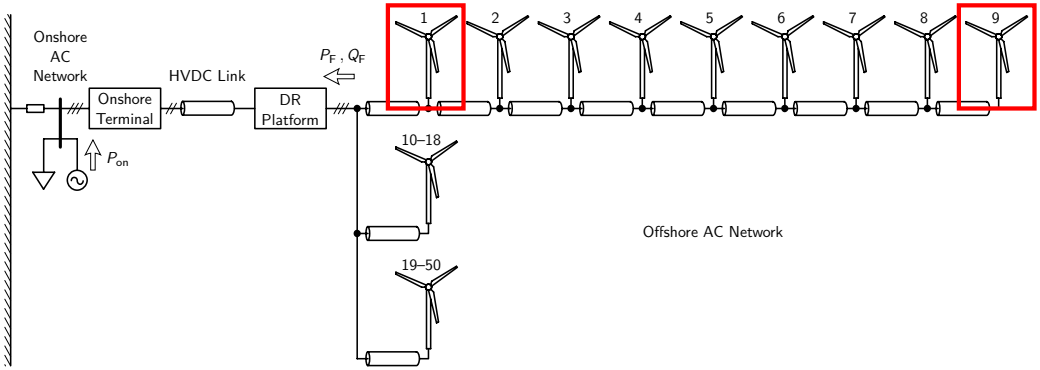

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Simulation Results
Closed-Loop Tests

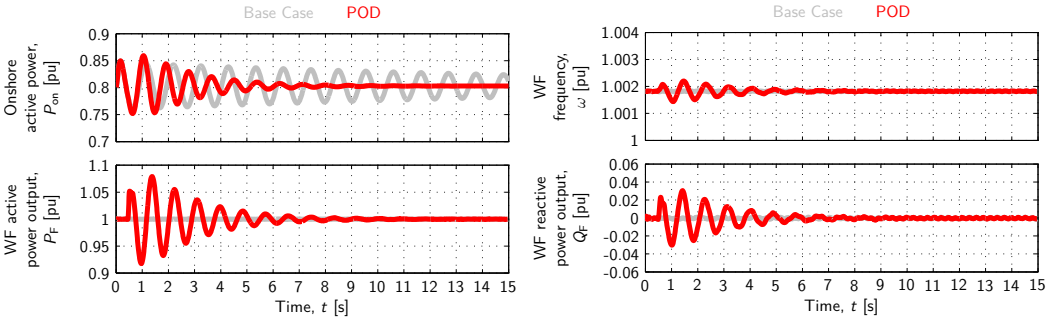
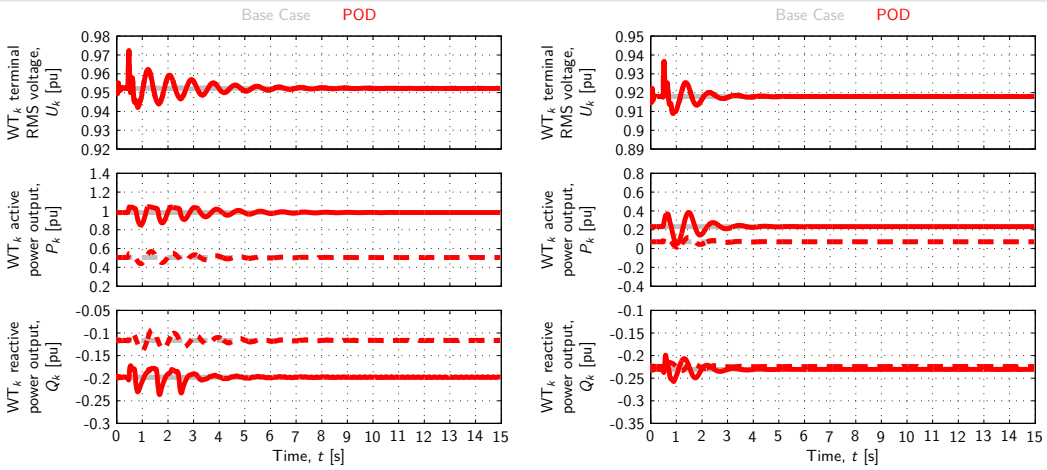


Figure: Wind farm response to onshore (active) power oscillations at high wind speed



(a) Medium wind speed

(b) Low wind speed

Figure: WT$_k$ response to onshore (active) power oscillations; solid: $k = 1$, dashed: $k = 9$

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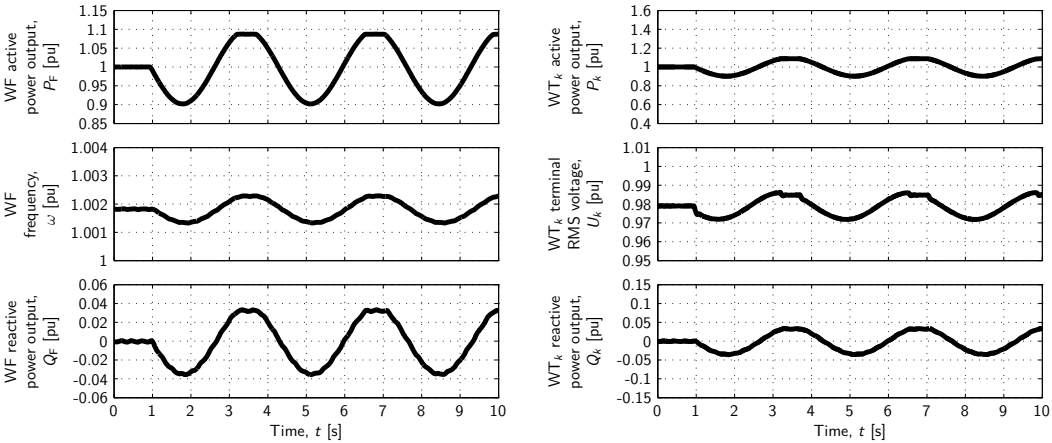
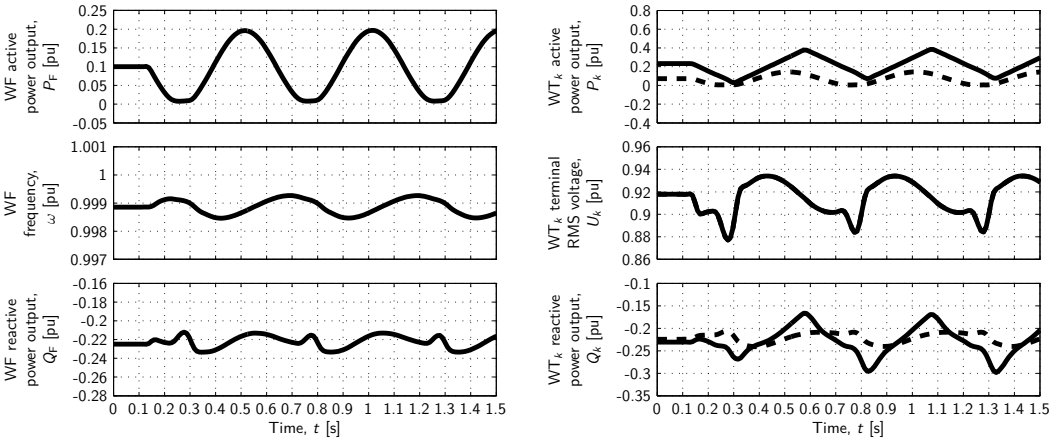


(a) Offshore wind farm

(b) kth wind turbine; solid: $k = 1$, dashed: $k = 9$

Figure: Open-loop response at high wind speed; $\Delta\hat{P}_{\mathrm{OL}} = (0.1\,\mathrm{pu})\cos\left[2\pi\,(0.3\,\mathrm{Hz})\,t\right]$



(a) Offshore wind farm (b) kth wind turbine; solid: $k = 1$, dashed: $k = 9$

Figure: Open-loop response at low wind speed; $\Delta\hat{P}_{\mathrm{OL}} = (0.1\,\mathrm{pu})\cos[2\pi\,(2\,\mathrm{Hz})\,t]$

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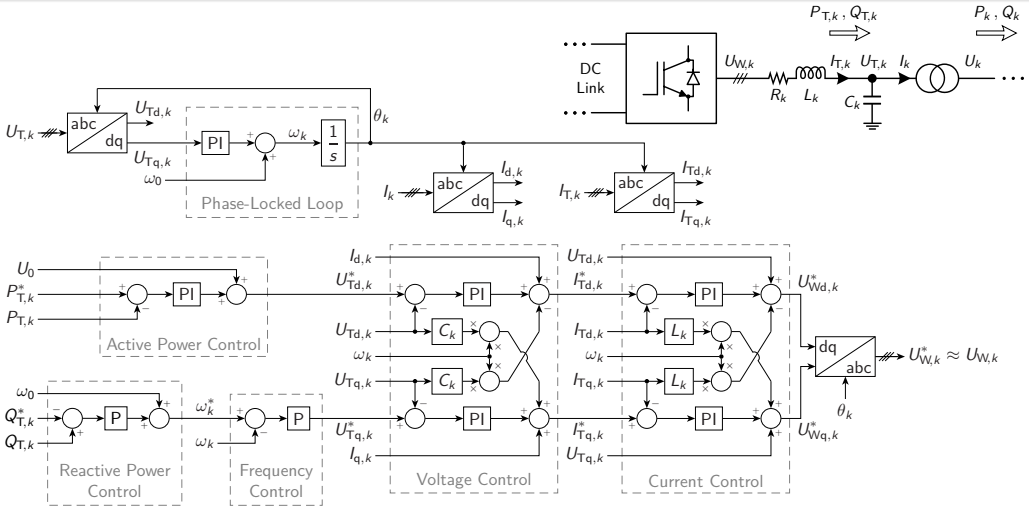
Wind Turbine Front-End (Grid-/Line-Side) Converter Controls



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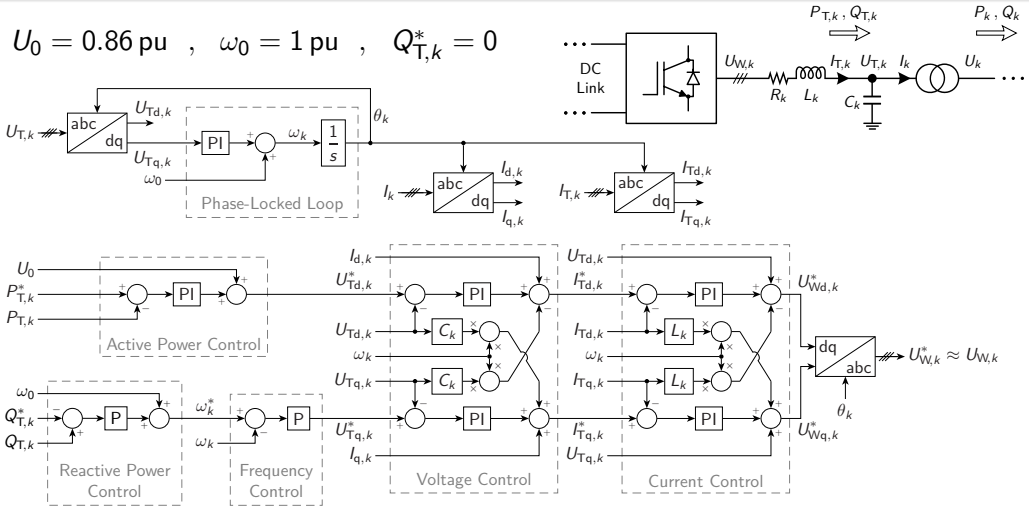

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