Hybrid Power Plant Research & Facility

Danish Wind Hybrid Power Plant Forum

DTU Wind Energy
Department of Wind Energy

DTU Fotonik
Department of Photonics Engineering

DTU Elektro
Institut for Elektroteknologi

DTU Energy
Department of Energy Conversion and Storage

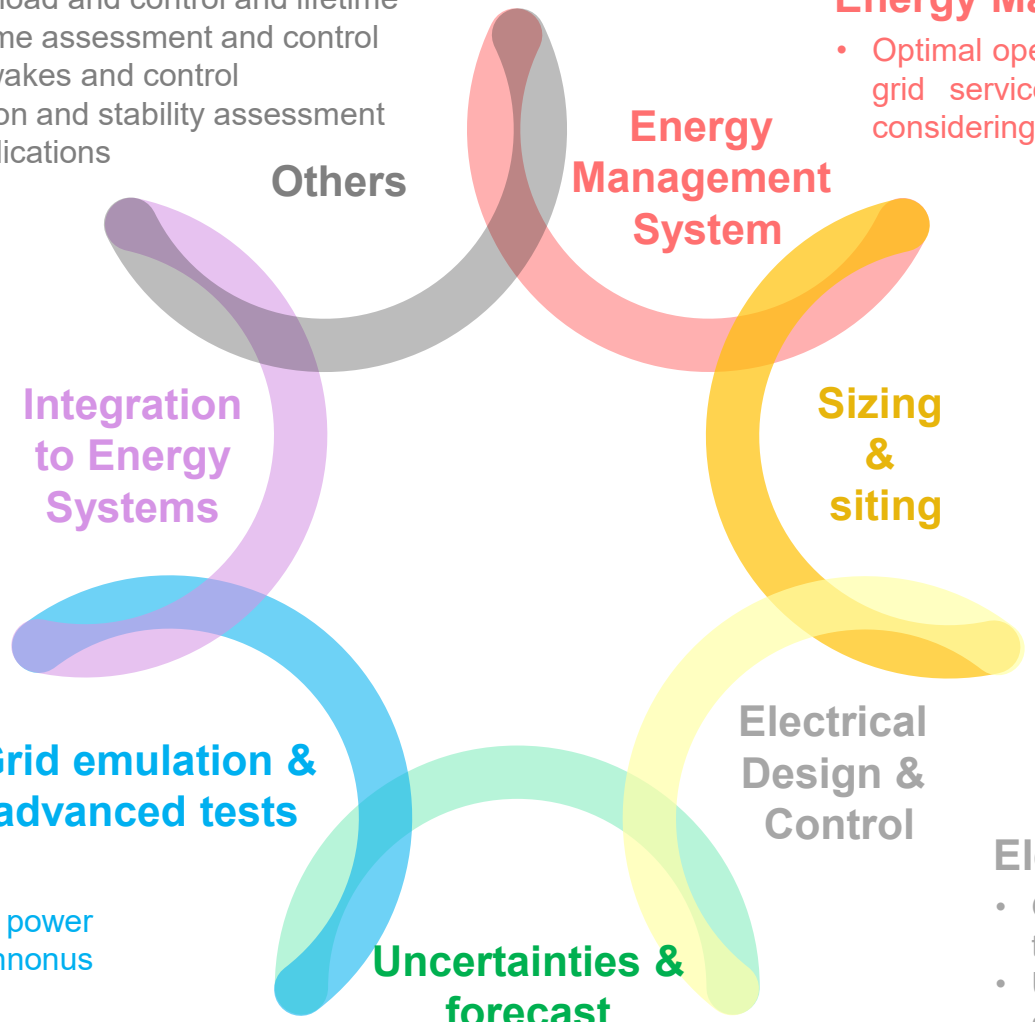
DEPARTMENT OF ENERGY TECHNOLOGY
AALBORG UNIVERSITY

Others

- Wind turbine load and control and lifetime
- Storage lifetime assessment and control
- Wind farms wakes and control
- Grid interaction and stability assessment
- Offshore applications

Energy Management System

- Optimal operation on markets: energy markets, grid service markets and capacity markets considering uncertainties, component lifetime



Integration to Energy Systems

- Co-operation with other energy sectors
- Power2X
- Co-ordinated Control
- Load Balancing

Sizing and siting

- Resource assessment
- Physical Design Optimization
- Selection / hybridization of storage technologies
- Optimal sizing of wind-solar-storage
- Hybridization of existing wind or solar plants

Grid emulation & advanced tests

- Emulation of future converter dominated power systems using CGI and / or synchnonus condenser to emulate grid
- Development of new test methods / grid codes
- Validation of models

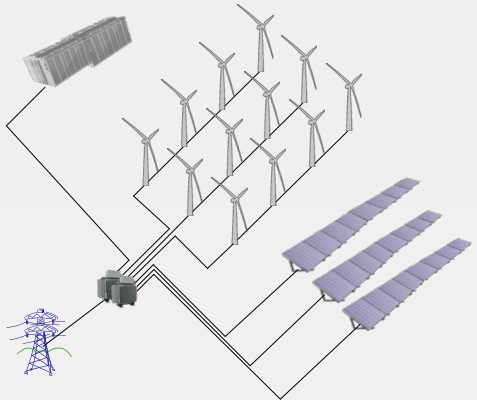
Uncertainties & forecast

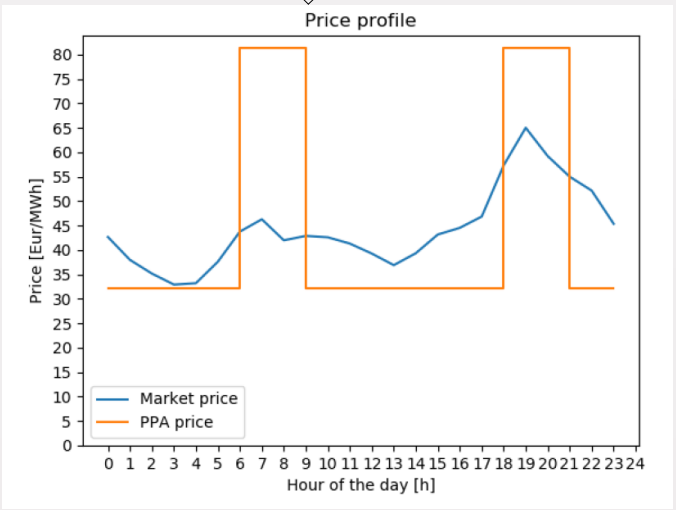
- Variability for combined wind-solar-storage
- Market forecasts
- Hybrid power forecast
- Real time power simulation
- Assessment of flexibility & grid services

Electrical Design and Control

- Optimal electrical design – utilization of wind turbine DC links and inverter
- Use of electrical auxiliaries (supercapacitor, chopper, FACTS)
- Hierarchical control / Distributed control
- Grid services
- Blackstart capability

Sizing of Wind-Solar-Storage Hybrid Power Plant





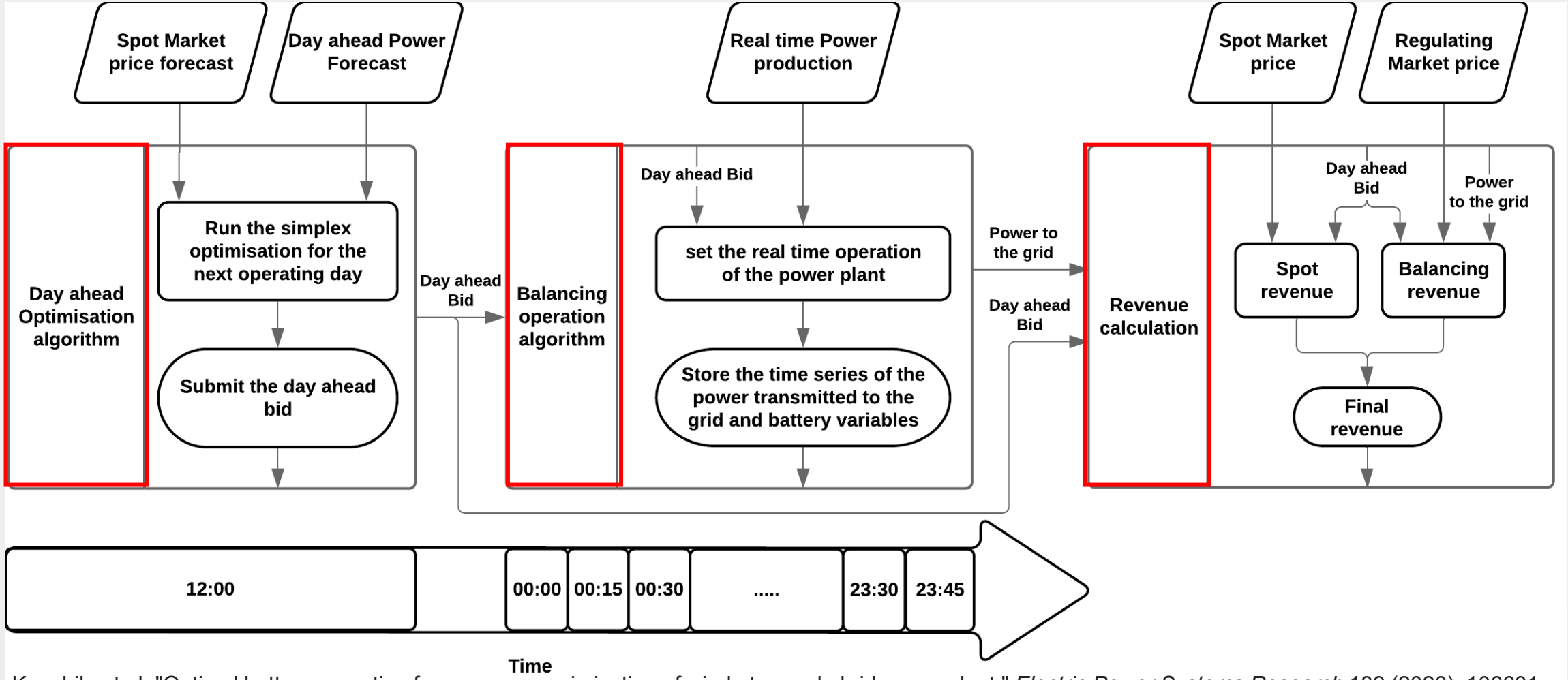
Case Study – Indian Peak Power Plant

Grid Connection (contracted capacity) = 300 MW

	Solar Contracted capacity	Wind Contracted capacity	Wind Solar Optimized	**Optimal Solution**	Unit
Wind	-	300	129	171	MW
Solar	300	-	347	378	MW
Battery energy	-	-	-	271	MWh
Battery power	-	-	-	83	MW
Potential wind-solar energy at nominal capacity	617	775	1047	1219	GWh
HPP Annual energy production	617	775	1026	1199	GWh
Capacity factor	23	29	39	46	%
Full load hours	2057	2584	3421	3997	Hours
Total curtailment	0	0	21	20	GWh
Potential wind-solar energy curtailed	0	0	2	2	%
LCOE	29	38	32	39	EUR/MWh
NPV	37	36	72	82	MEUR

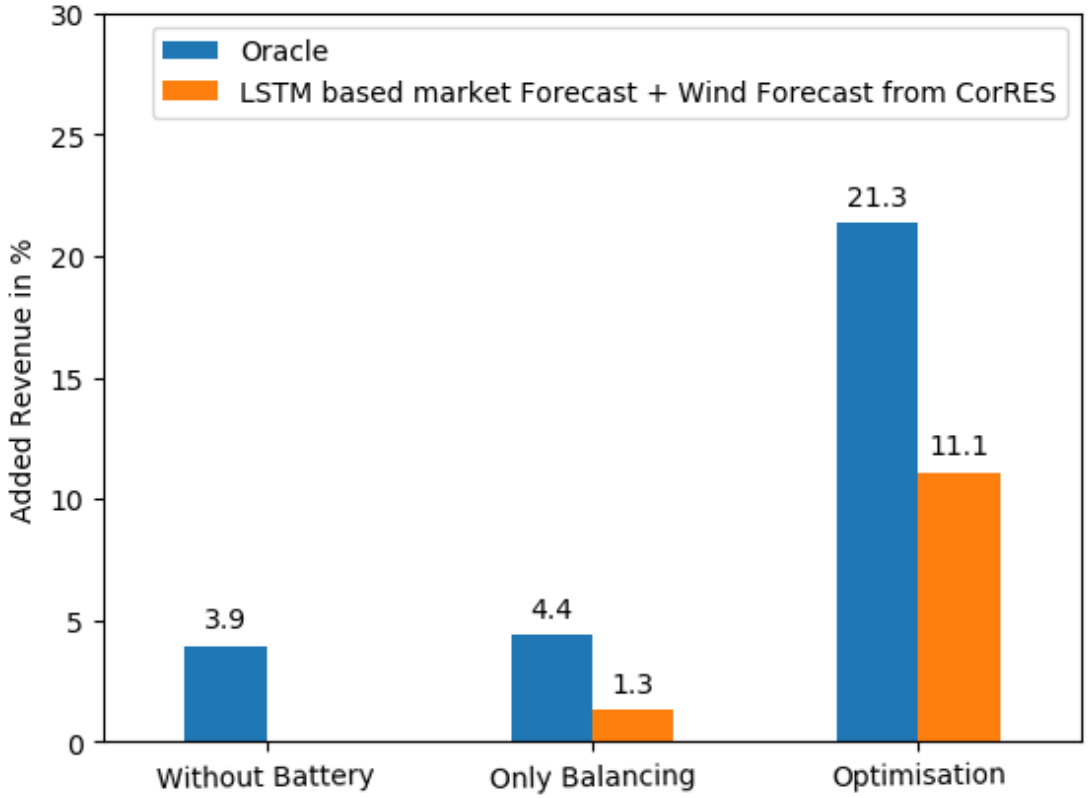
Alessandra Cossu "Optimal sizing of hybrid power plant" *Master Thesis, DTU Wind Energy, 2020*

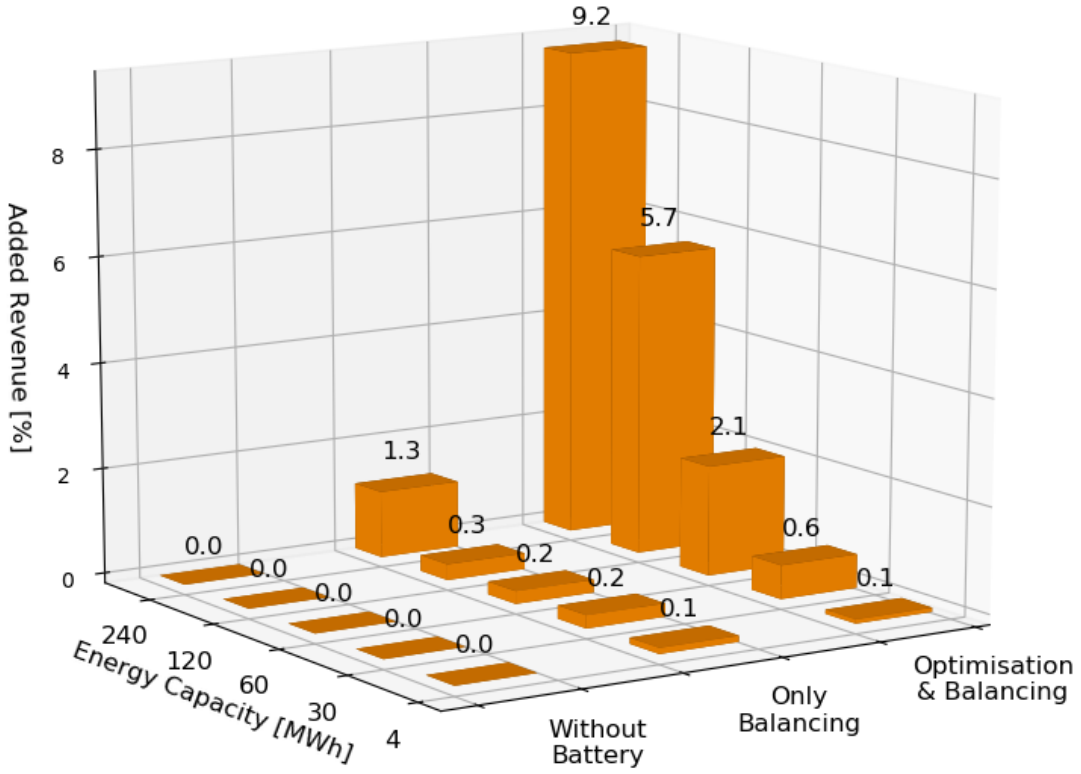
Energy Management System



Das, Kaushik, et al. "Optimal battery operation for revenue maximization of wind-storage hybrid power plant." *Electric Power Systems Research* 189 (2020): 106631.

Study Case - Value of day ahead optimisation



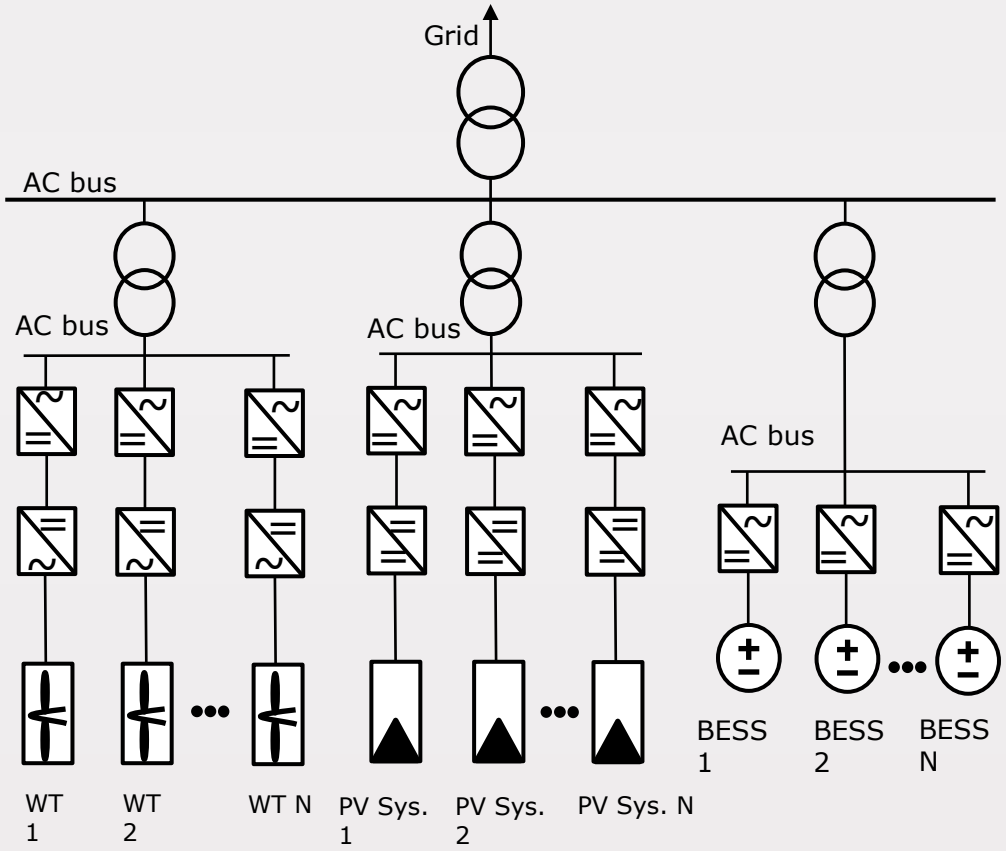


- Storage used only for balancing doesn't add much revenue compared to allowing for day ahead optimization
- Quality of forecast play a major role (revenue up by another 10% as demonstrated by "Oracle" case)

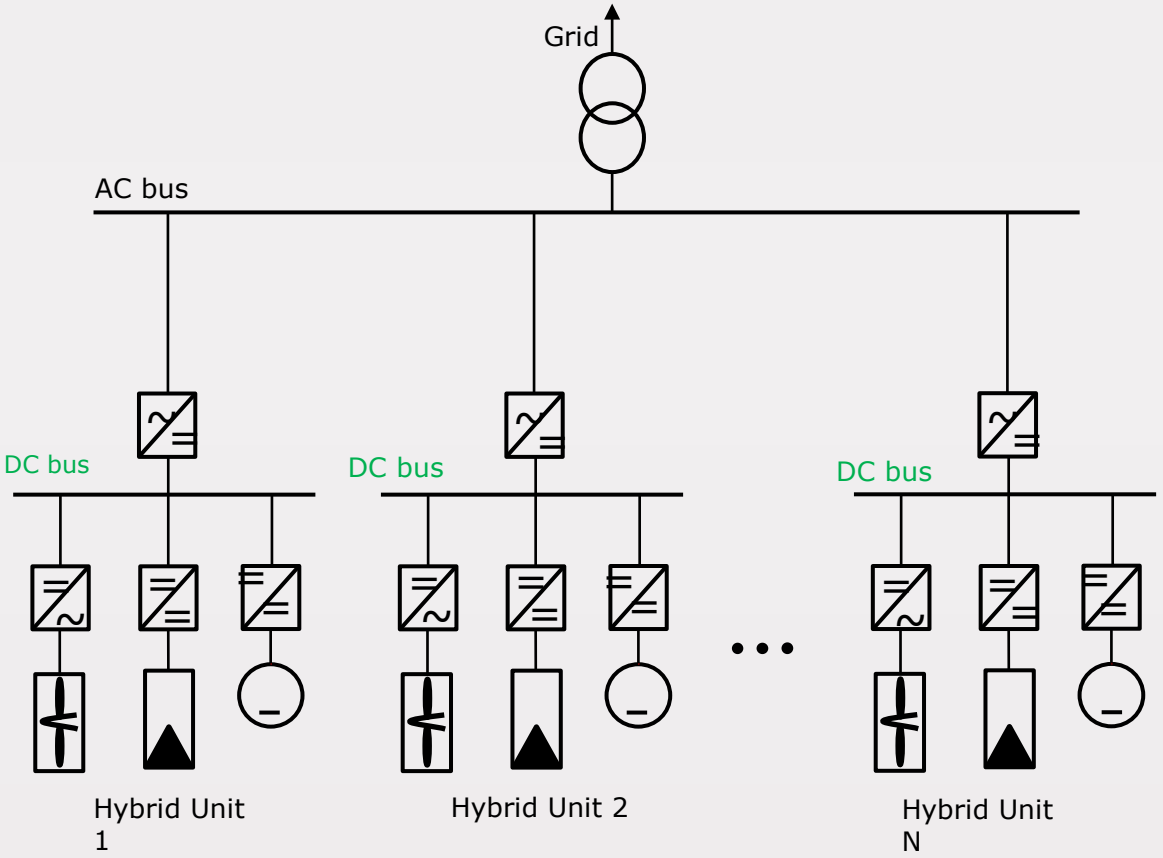
Das, Kaushik, et al. "Optimal battery operation for revenue maximization of wind-storage hybrid power plant." *Electric Power Systems Research* 189 (2020): 106631.

Electrical System Design and Control

AC Coupled HPP Topology



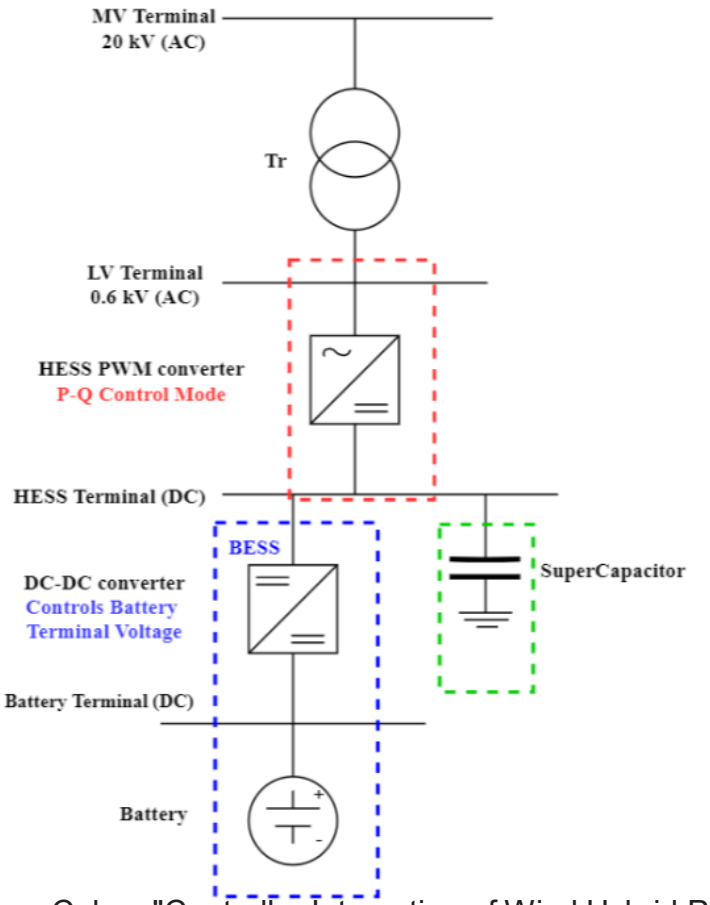
DC Coupled HPP Topology



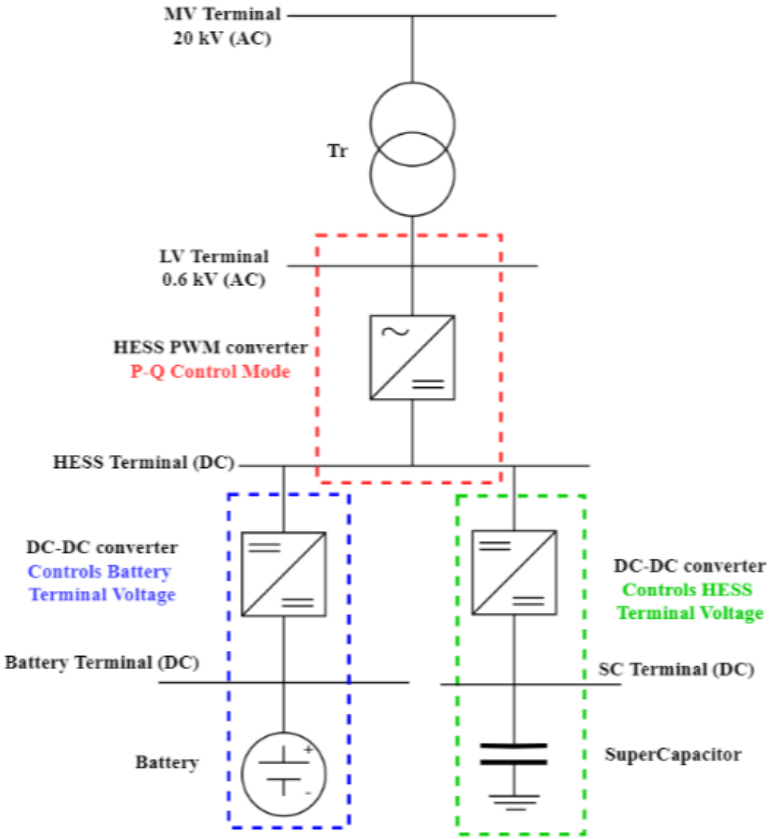
Das, Kaushik et. al. "Dynamic Modelling of Wind-Solar-Storage Based Hybrid Power Plant." 18th Wind Integration Workshop, 2019.

Hybrid Energy Storage System Design in HPP

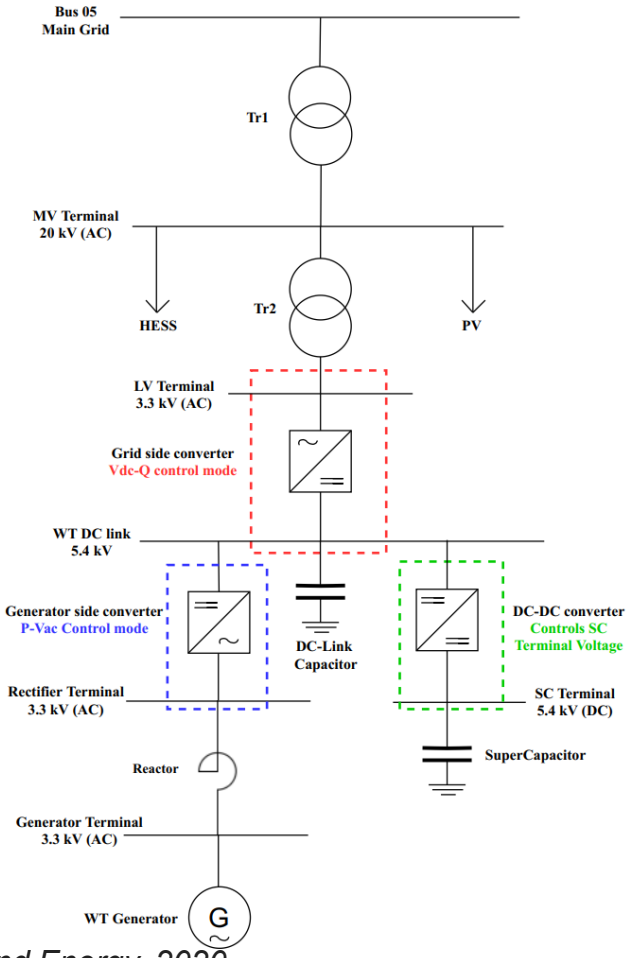
Semi-Active topology



Active topology



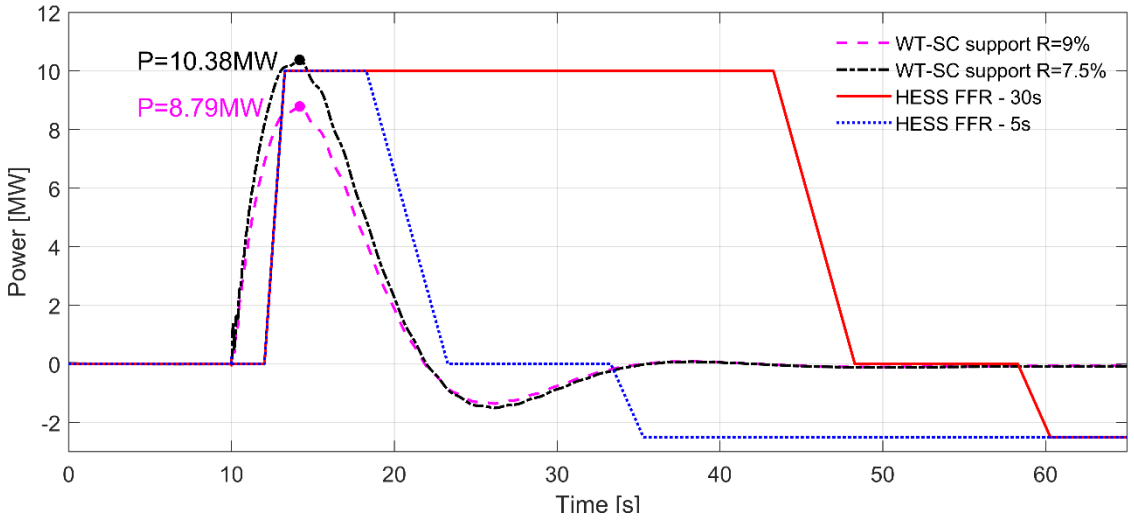
Supercapacitor in WT



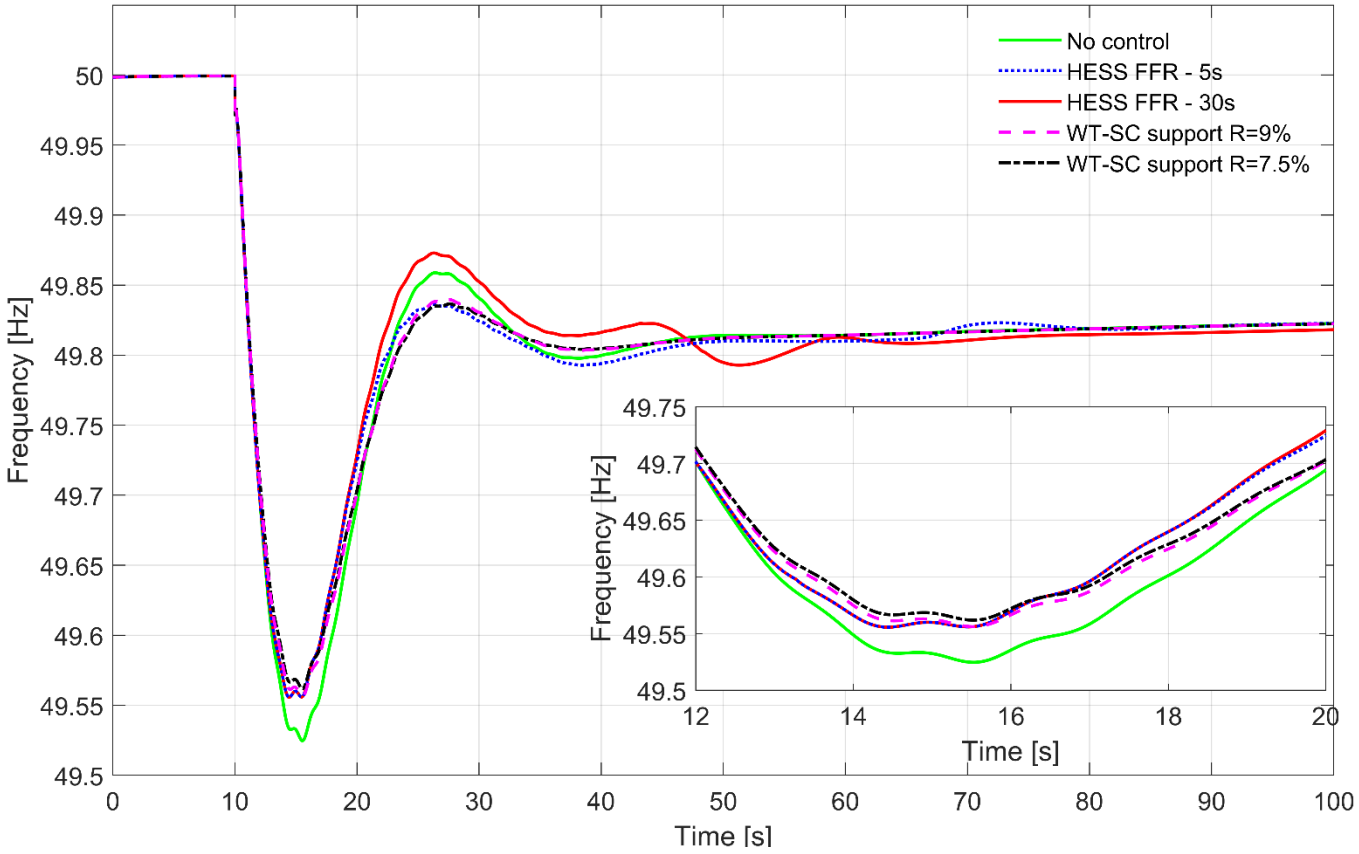
Aivaras Celna, "Controller Interaction of Wind Hybrid Power Plants for providing Ancillary Services" *Master Thesis, DTU Wind Energy, 2020*

Simulation results

Comparison between scenarios with no control, ENTSOE based FFR and droop based FFR.



	ROCOF, [mHz/s]	Nadir, [Hz]	Δf of SWING, [mHz]	P_{peak}, [MW]
No Control	102.56	49.524	61.10	-
HESS FFR - 5s	100.15	49.556	43.60	10.00
HESS FFR - 30s	100.15	49.556	59.00	10.00
WT-SC support (R= 9%)	97.13	49.556	36.50	8.79
WT-SC support (R= 7.5%)	95.94	49.561	32.43	10.38



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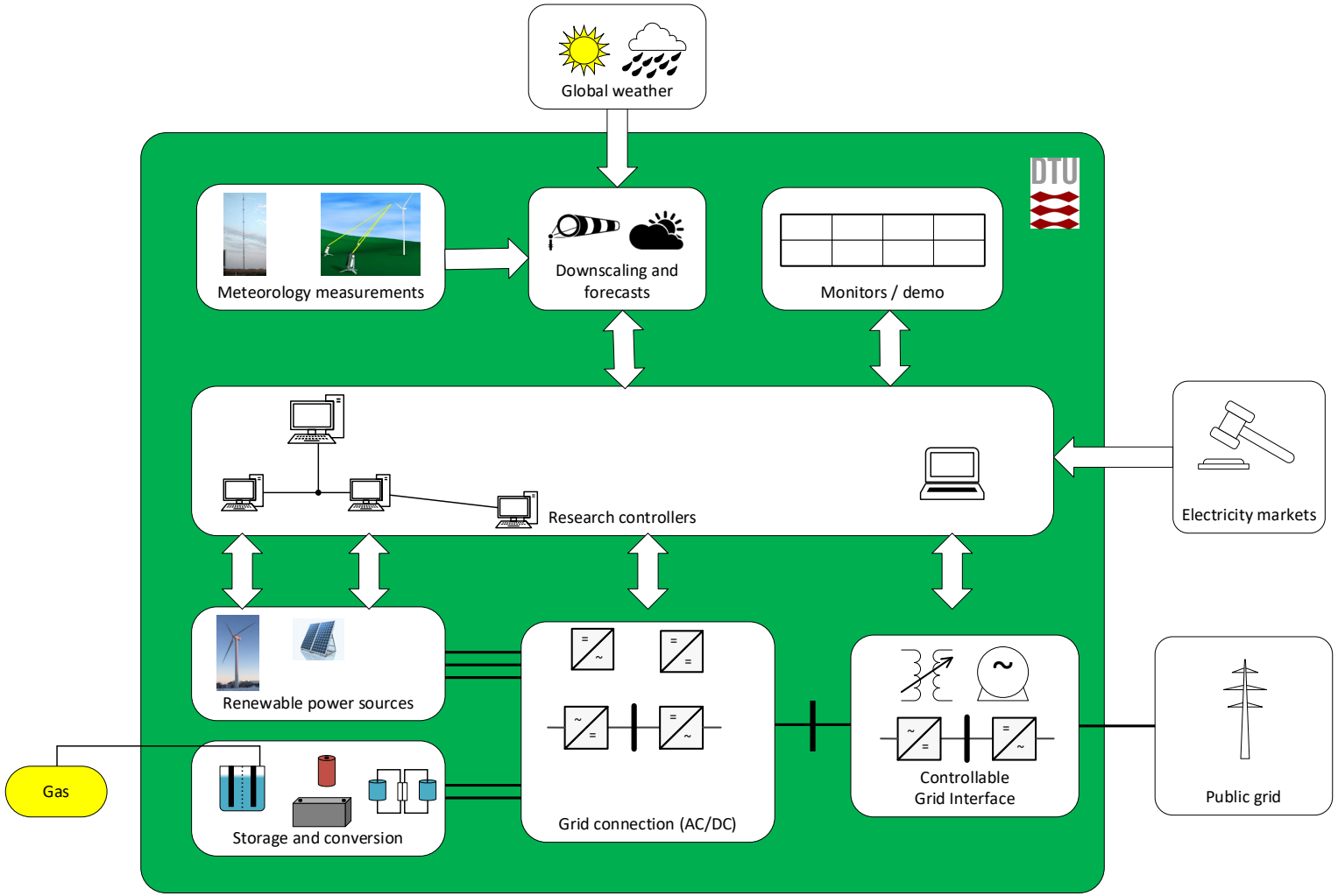
DTU Hybrid Wind Power Plant Facility

- Grid connected wind-hybrid power plant (wind / solar / storage)
- Open research controllers
- Power collection and gird connection (AC / DC)
- Controllable grid interface
- Connection to external information (weather forecasts, markets)



THANK YOU

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