Supergen Wind

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Chair 2006 – 2019

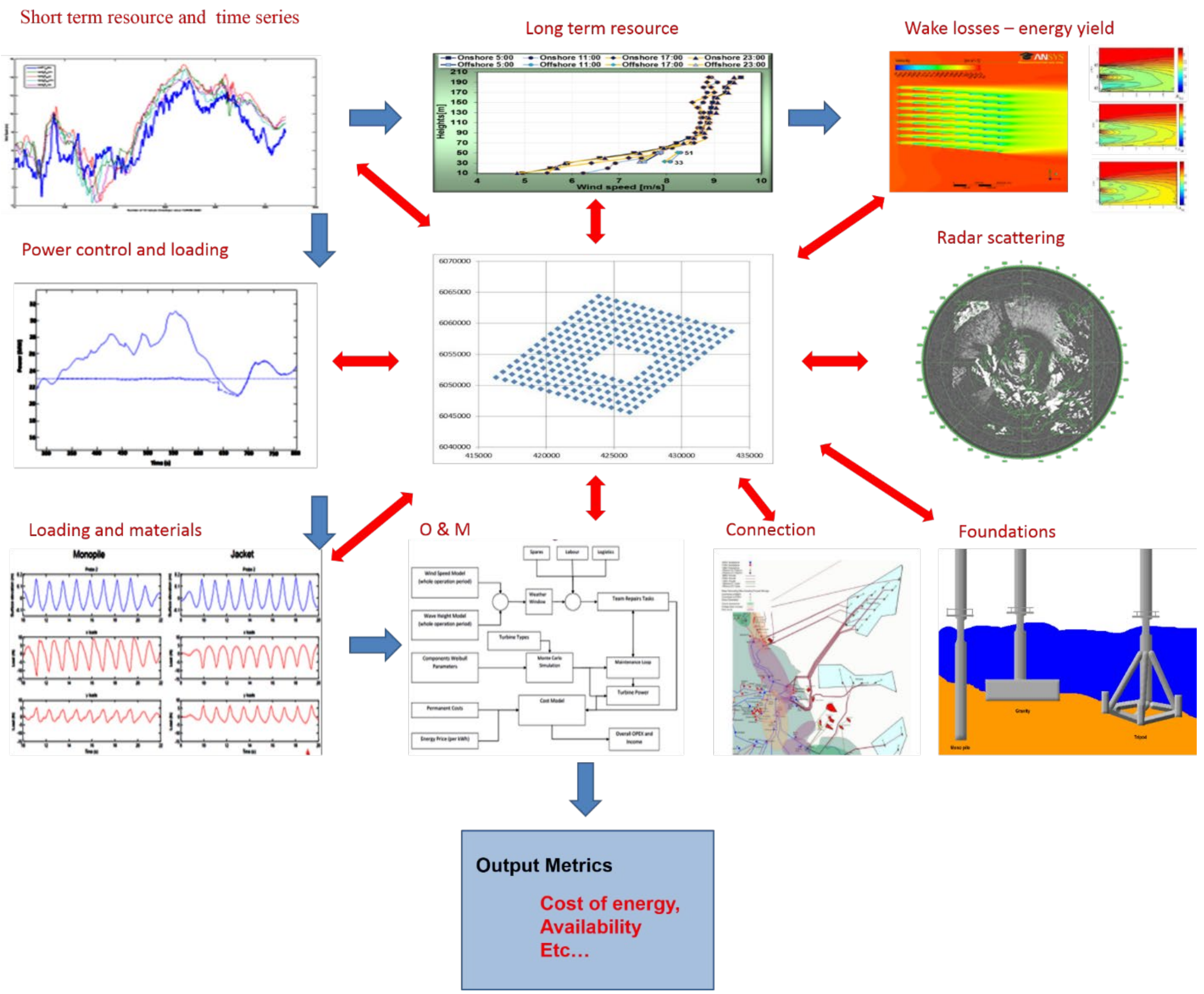
Supergen Wind

Supergen Wind Energy Technologies – Phase 1, 2006 – 2010

Supergen Wind Energy Technologies – Phase 2, 2010 – 2014

Superg Wind Hub, 2014 – 2019

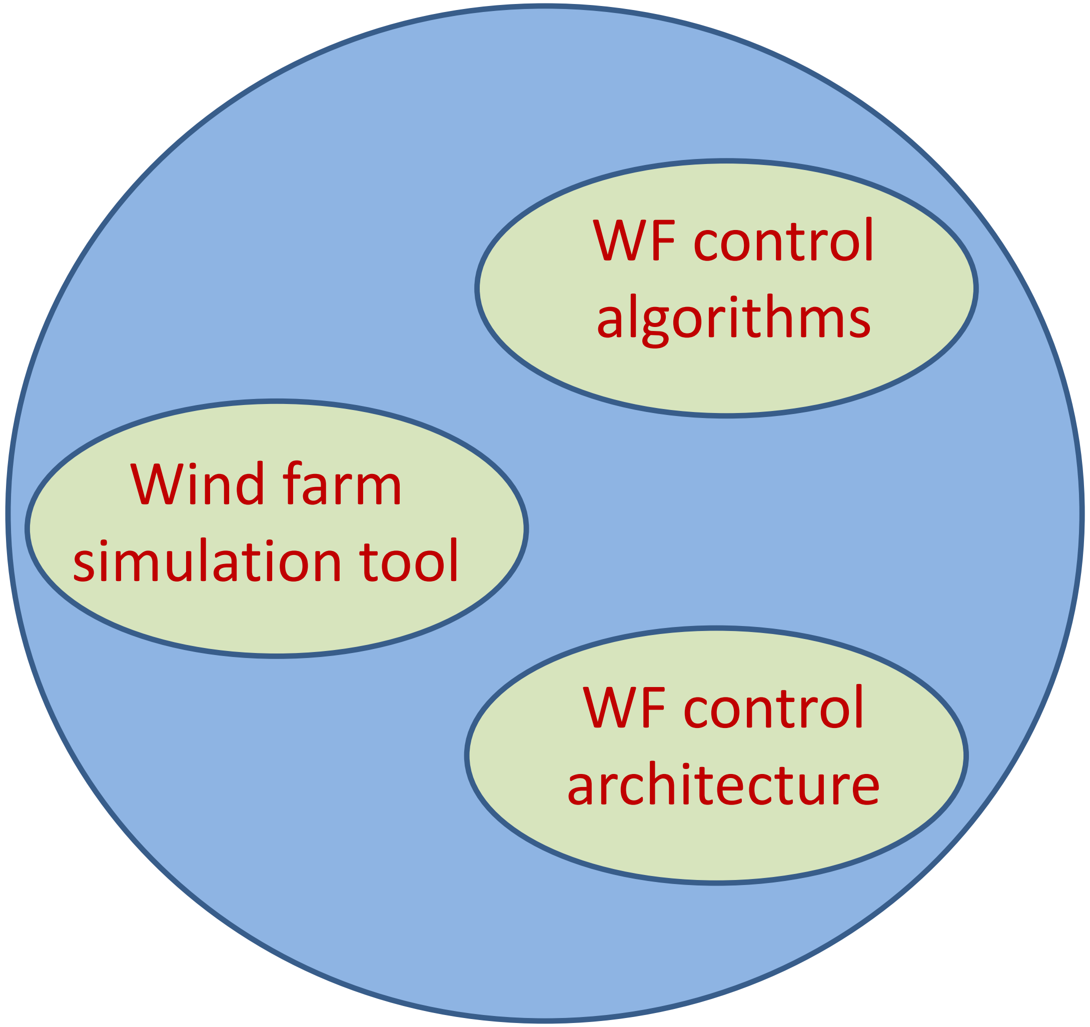
Supergen Wind



Strathclyde Highlight

Wind Farm Control

Wind Farm Control



- EPSRC EP/G037728/1 DTC Wind Energy Systems
- EPSRC EP/H018662/1 Supergen Wind Energy Technologies Phase 2
- EPSRC EP/L016680/1 DTC Wind and Marine Energy Systems
- FP-ENERGY-2013.10.1.6: 609795 IRPWind
- EPSRC EP/L014106/1 Supergen Wind Hub
- EPSRC EP/N006224/1 MAXFARM

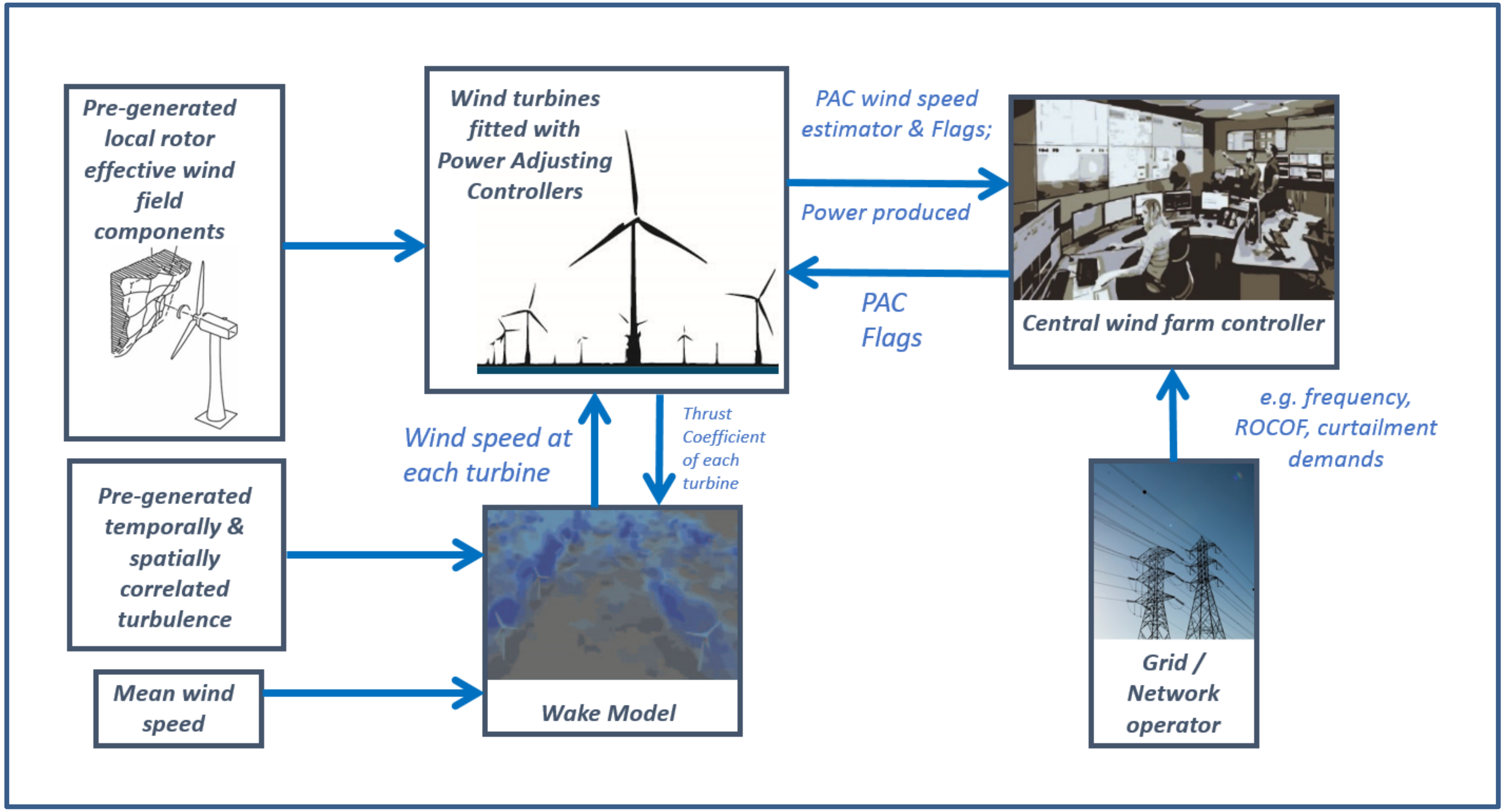
Wind Turbine Simulation Tool

An analysis and design wind farm model and simulation tool is required with the following requirements

- Model wakes and wake interactions
- Model turbines in sufficient detail that tower, blade and drive-train loads are sufficiently accurate to estimate the impact of turbine and farm controllers on loads.
- Include commercial standard turbine controllers.
- Include wind farm controller and interface to turbine controllers.
- Very fast simulation of large wind farms; run in real time with 100 turbines on a standard PC.
- Flexibility of choice of farm layout, turbines & controllers and wind conditions direction, mean wind speed and turbulence intensity.

All above requirements have been met by StrathFarm

StrathFarm

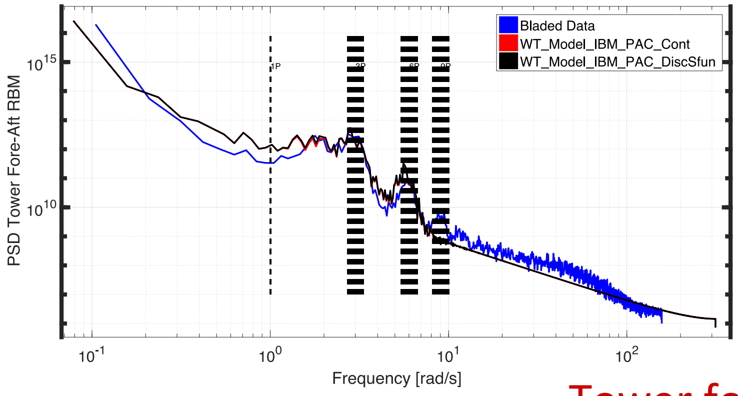


StrathFarm is a medium fidelity model

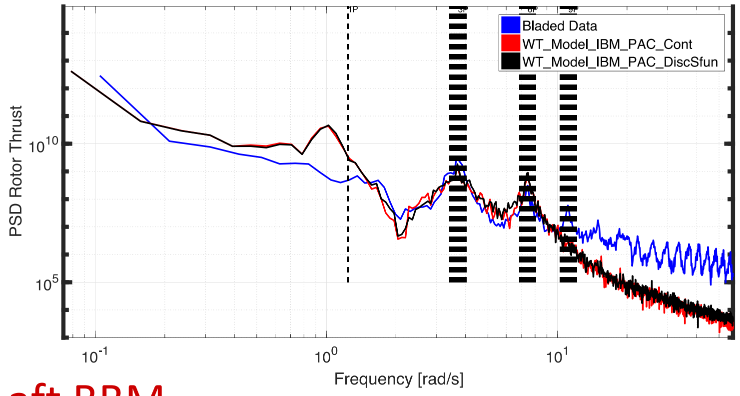
StrathFarm

- Wind turbine model in StrathFarm is **StrathTurb**
- Validated with respect to Bladed
- Comparison is for the Supergen 5MW Exemplar WT

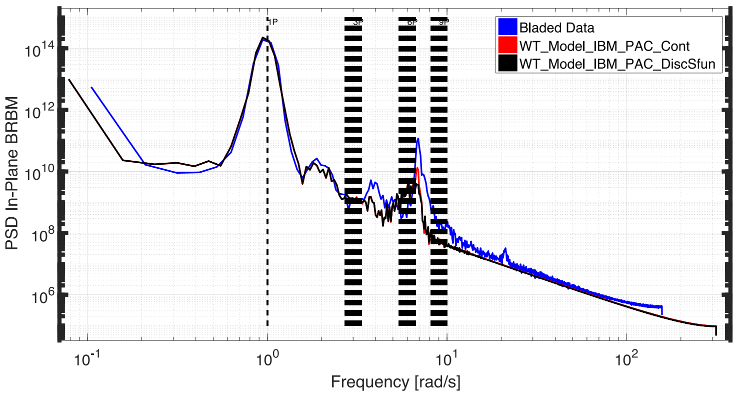
Mean wind speed 8m/s, 10% TI

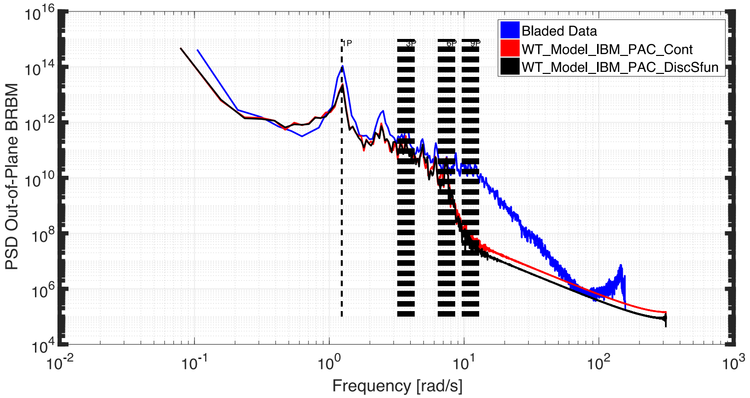


Mean wind speed 15m/s, 10% TI



Tower fore-and-aft BBM





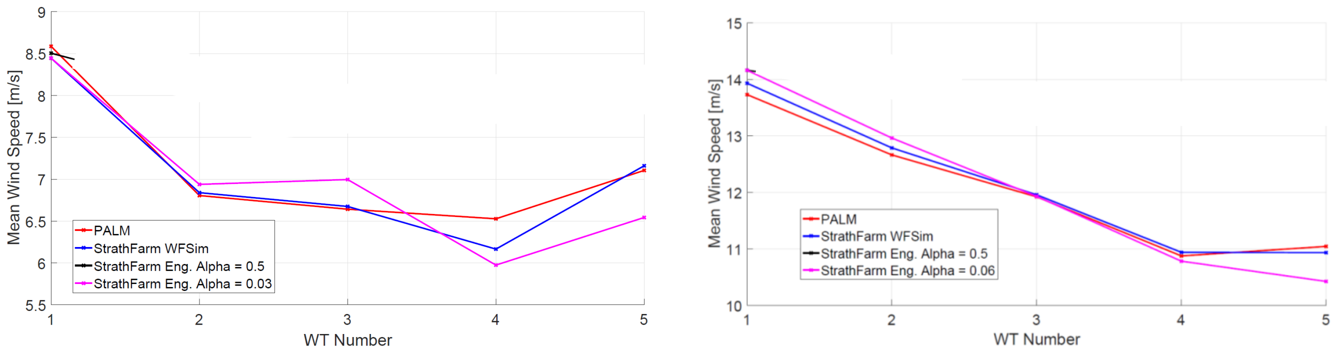
Blade in-plane RBM

StrathFarm

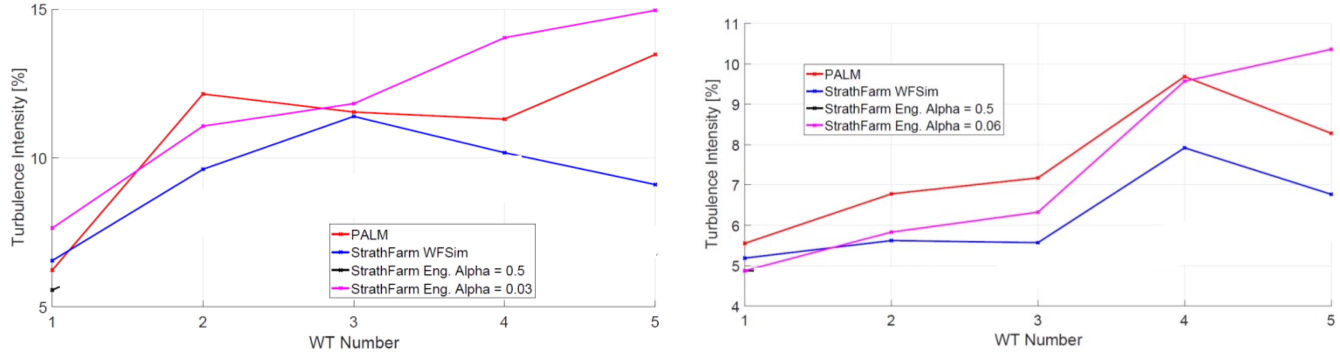
Comparison of StrathFarm wake model to higher fidelity models

- WFSim: wake model, based on the 2D Navier-Stokes equation partially corrected for the neglected vertical dimension.
- WFSim: validated against higher fidelity models, initially SOWFA, but recently PALM (Parallelized Large-Eddy Simulation Model)
- WFSim: implemented in C in StrathFarm for direct comparison to baseline Wake Model.
- PALM: not practical to implement in StrathFarm, off-line comparison.

5 turbines in a column with 7D spacing



Mean wind speed



Turbulence intensity

Wind Farm Control Architecture

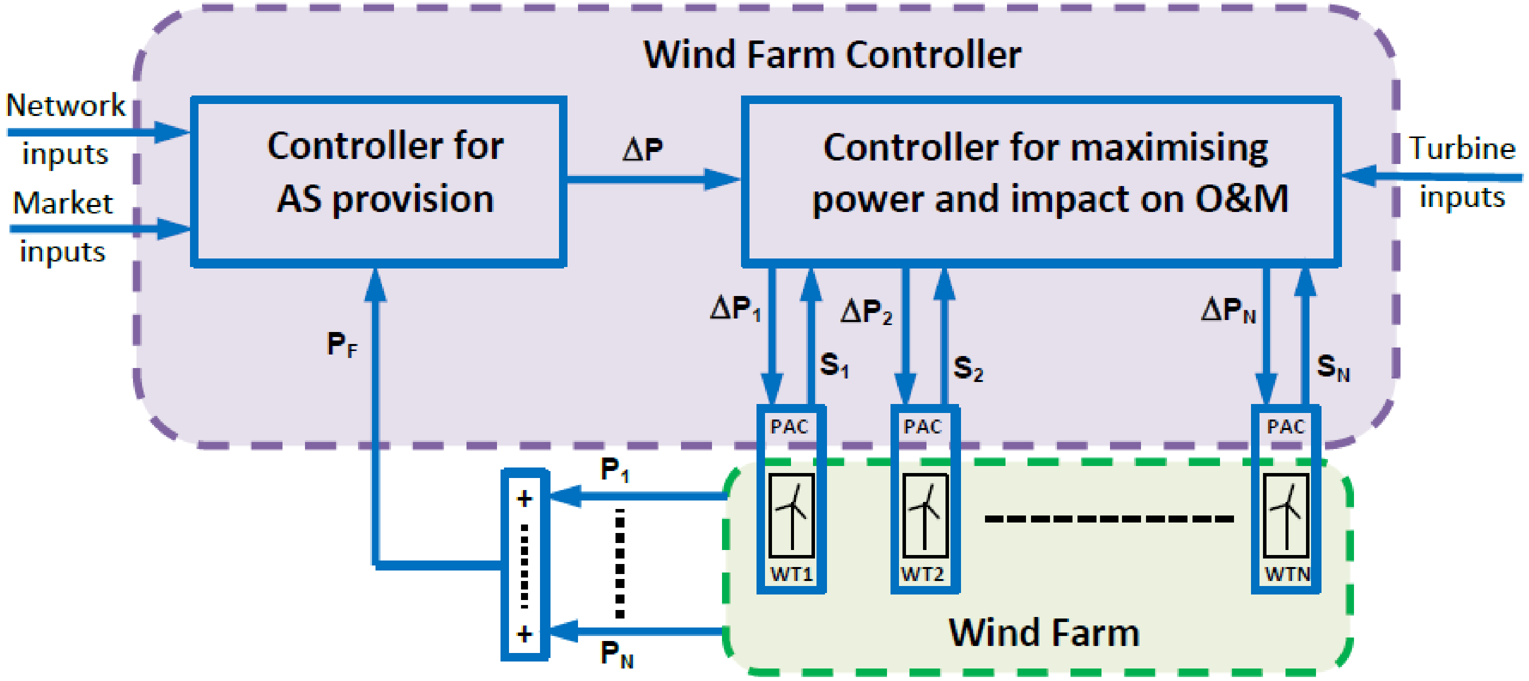
A generic wind farm controller architecture has been adopted with the following attributes.

- It is hierarchical, decentralised and scalable.
- Top layer responds to grid requirements to determine an adjustment in the power output from the wind farm.
- It may operate open-loop, eg to reduce the power output by a fixed amount, or closed-loop, e.g to curtail the output from the farm to a fixed power level. The latter feedback is based on feedback of the total farm output.
- Second layer determines change in power required from each turbine.
- Bottom layer is a generic interface to each turbine, the PAC.
- The only feedback permitted from each turbine to the first and second layers are flags containing information on the state of the turbines and an estimate of the local wind speed.

Wind Farm Control Architecture

Hierarchical structure ensures turbine controllers are not compromised

- Wind speed estimation is sufficiently good to be independent of turbine state
- Using flags avoids feedbacks based on the state of the turbine
- Farm level feedback acting on the total power introduces feedback round a single turbine but it is very weak



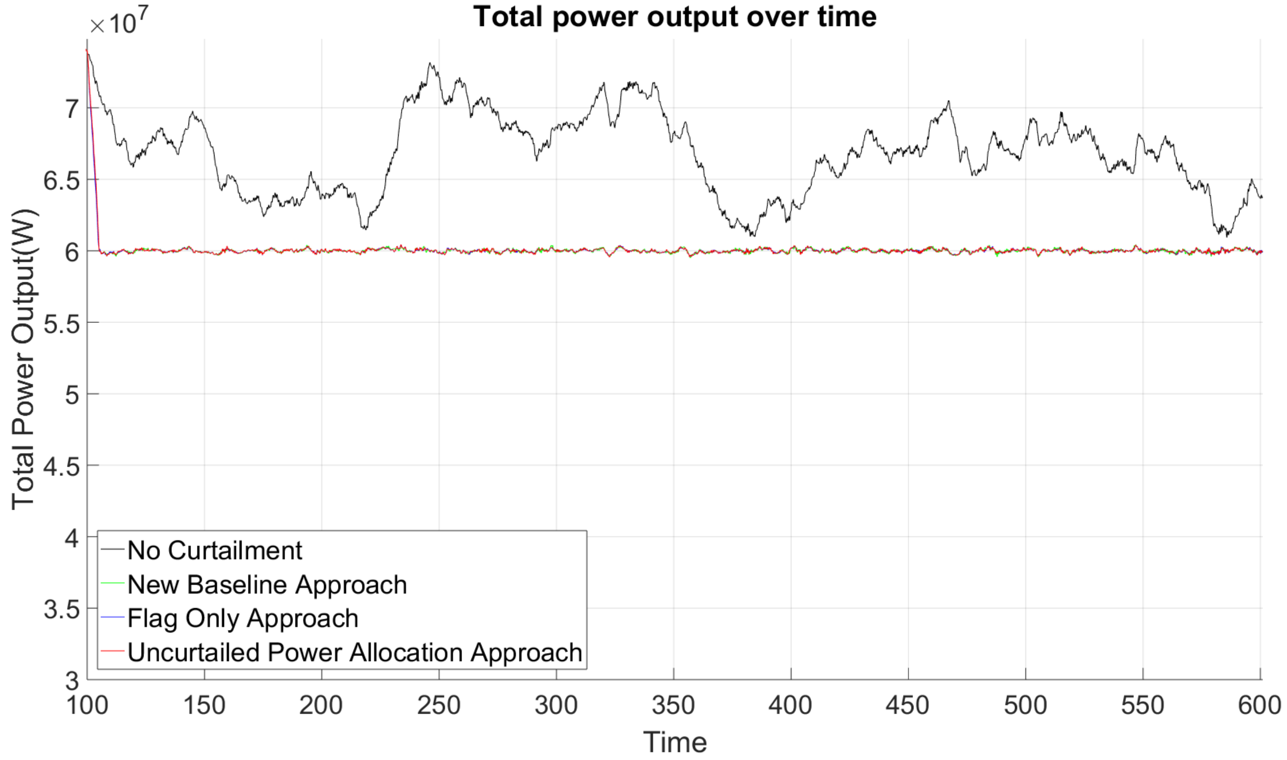
Tight control at the wind farm level can, thus, be achieved with very weak control of each turbine.

Wind Farm Control Algorithms

Wind farm curtailment

4 curtailment algorithms compared

- No curtailment
- Same curtailment for each turbine when allowed by Flags (flag only approach)
- Curtailed according power output from each turbine (uncurtailed power allocation approach)
- Curtailed according to loading on each turbine (new baseline approach)



Conditions: mean wind speed= 9m/s; TI=10%, 20 turbines

Wind Farm Control Algorithms

Farm Layout:

20 turbines in 1 rows

Allocation	40 MW	45 MW	50 MW
New Baseline Allocation	17.67%	13.11%	6.67%
Flag Based Allocation	2.15 %	2.23%	-3.11%
Uncurtailed power based allocation	18.82%	16.52%	5.70%

Fore-aft Tower BBM: Change in DEL

Conditions:

mean wind speed= 9m/s; TI=10%

Allocation	40 MW	45 MW	50 MW
New Baseline Allocation	28.51%	25.82%	12.68%
Flag Based Allocation	9.90 %	5.30%	-2.32%
Uncurtailed power based allocation	21.66%	16.49%	4.43%

Out-of-plane Blade RBM: Change in DEL

Wind Farm Control Algorithms

Allocation	55 MW	60 MW	65 MW
New Baseline	14.9669 %	10.9634%	0.0807%
Flag Based	4.1174%	0.7643%	-3.4875 %
Uncurtailed power based	14.1510%	7.8221%	-1.1447%

Fore-aft Tower BBM: Change in DEL

Farm Layout:

20 turbines in 2 rows

Conditions:

mean wind speed= 10m/s; TI=10%

Allocation	55 MW	60 MW	65 MW
New Baseline	23.2143 %	16.7617%	2.7853%
Flag Based	4.3062%	-0.0380%	-3.2246 %
Uncurtailed power based	15.8376%	8.6528%	-0.2661%

Out-of-plane Blade RBM: Change in DEL

Wind Farm Control Algorithms

Farm Layout:

20 turbines in 2 rows

Conditions:

mean wind speed= 12m/s; TI=10%

Allocation	75 MW	80 MW	90 MW	95MW
New Baseline	39.0714 %	37.0105 %	30.8308%	25.5851%
Flag Based	26.9845 %	22.7368 %	10.8973%	-1.3208%
Uncurtailed power based	26.2650 %	21.9763 %	10.4311%	-1.1002%

Fore-aft Tower BBM: Change in DEL

Allocation	75 MW	80 MW	90 MW	95MW
New Baseline	29.8090 %	28.2637 %	24.2163%	21.3699%
Flag Based	19.1523 %	15.8531 %	7.1148%	-2.0382%
Uncurtailed power based	19.2559 %	15.7853 %	6.9554%	-0.6282%

Out-of-plane Blade RBM: Change in DEL

Wind Farm Control Algorithms

- Wind farm control has much to offer in reducing CoE
- To assess performance need data for all mean wind speeds, turbulence intensities and directions
- StrathFarm is a medium fidelity simulation tool sufficiently fast to cover all operating conditions
- It enables many issues to be addressed

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