Development of a Power System Model For Strathfarm

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Power System Model

What is Strathfarm?

Strathfarm is the University of Strathclyde's in-house wind farm modelling software which uses Matlab and Simulink to simulate up to 100 wind turbines in real time. It does this while also modelling changes in component bending moments to a high level of accuracy similar to Bladed (Hur & Leithead 2018).

Motivation for the inclusion of power system model

Previous research in Strathfarm for providing grid support has assumed a static grid model where the response of the wind farm has not been included in the grid modelling. By including this the efficacy of the previously developed dispatch algorithms for droop and inertial response can be tested.

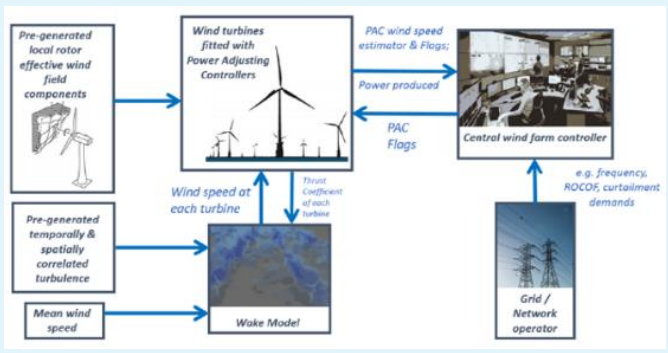

Figure 2: The different attributes modelled in Strathfarm and their interactions.

Wind farm power system circuit solver code

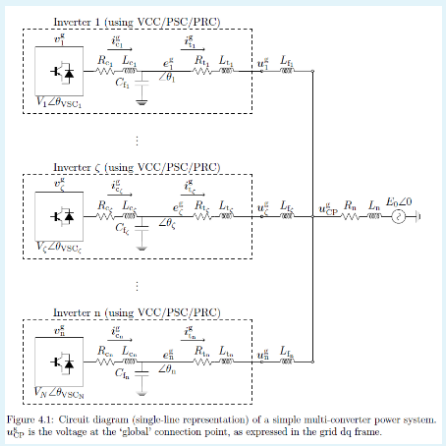

Figure 4.1: Circuit diagram (single-line representation) of a simple multi-converter power system. u_{CP}^{g} is the voltage at the 'global' connection point, as expressed in the grid dq frame.

Figure 1: Offshore Circuit Model from (Giles 2018)

The wind farm circuit model is based on the work from (Giles 2018). This model presents a scalable solution for calculating the current from each wind turbine to the grid.

This is modelled as a 8N by 8N nonlinear matrix equation which can be solved using the Levenburg-Marquardt method.

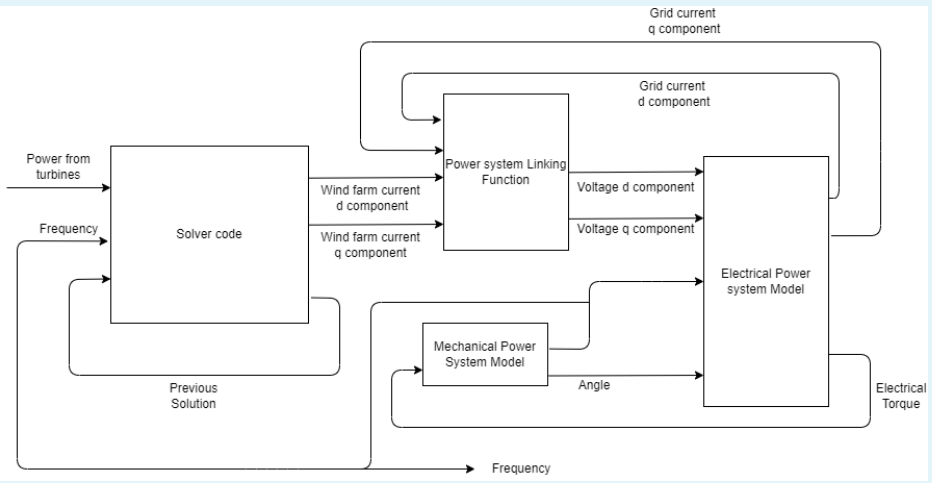

Figure 3: The power system model in Strathfarm

Power system model summary

The power system model has been written as a series of discrete time S-functions in Simulink. The mechanical power system model, the electrical power system model and the power system linking function together model a power system comprised of a single generator, a grid power demand which connect to an AC cable linked to a wind farm represented.by the solver code. As a whole the model takes in the power output of each wind turbine and outputs the frequency of the power system which is then fed to the wind farm controller for use in the dispatch algorithm.

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Electrical Power system model

This section contains the electrical component of the generator model used in this power system model. This function takes in the grid voltage, the phase angle and the grid frequency and outputs the current generated in the grid and the electrical torque

Mechanical Power system model

This section contains the swing equation and a governor. This function takes in the electrical torque and outputs a phase angle and the grid frequency

Wind farm dispatch algorithm

The turbine power dispatch algorithm was developed by (Poushpas 2016) and is a scalable dispatch for power change across a wind farm to provide droop and inertial responses based on the grid frequency.

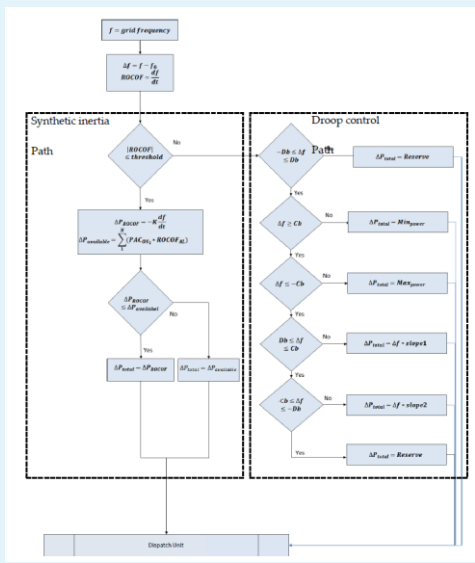

Figure 4: The dispatch algorithm from (Poushpas 2016)

Power system linking function

This section contains the circuit model for the power system model. This function takes in the currents of the wind farm and power grid and outputs a voltage

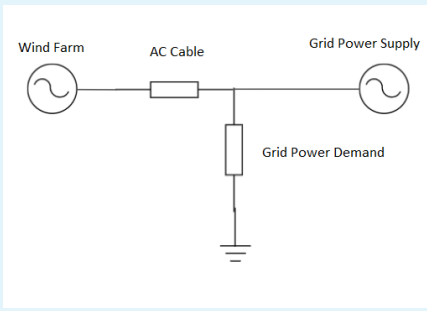

Figure 5: Circuit diagram of the power system model grid

Results

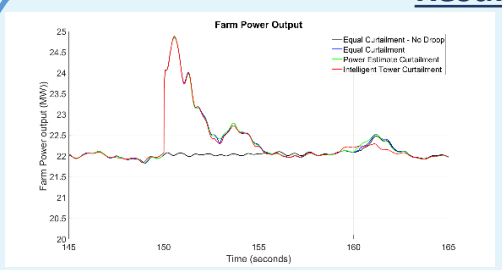

Figure 6: The power output of the wind farm with and without inertial response using a three different curtailment distribution algorithms.

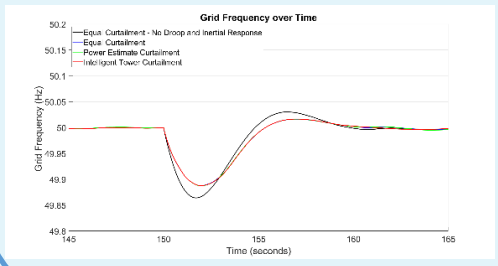

Figure 7: The grid frequency with and without wind farm inertial response.

The results in figure 6 show the power output for a wind farm providing inertial response with three different curtailment distribution algorithms compared with no inertial response.

Figure 7 shows the resulting grid frequency with the increased power output from Figure 6.

The results from the simulation show that when the dispatch algorithm is used and additional power is output from the wind farm there is a reduction in the magnitude of the nadir of an inertial frequency event in the grid.

Future developments

The development of this model opens up several areas of research for future study such as modelling the impact of the AC cable length on the efficacy of both droop and inertial responses and the impact of droop response on wind turbine fatigue.

The model could also be further developed through the inclusion of Virtual Synchronous Machines at the turbine level and by modelling an HVDC link rather than an AC link.

REFERENCES

A. Giles. *State-space modelling of multi-converter power systems.* University of Strathclyde, 2018.

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S H. Hur and W.E. Leithead. Control oriented modelling of a wind turbine and farm. *J. Phys.: Conf. Ser. 1037 062020*, 2018.

Acknowledgements

We would like to thank the Offshore Renewable Energy Catapult and the University of Strathclyde for funding this research.