Offshore wind curtailment in future grids

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Abstract

- The open-source Python tool PowerGAMA was used for modelling and analysis.
- The European power system was modelled from openly available data.
- The power system was edited with respect to plausible future scenarios.
- The quantification of offshore wind farm curtailment (i.e. deliberate reduction in output) was measured in amount of energy and number of occurrences.
- The data obtained from simulations were analysed to investigate possible causes of offshore wind farm curtailment.
- Insight on curtailment is needed to better match power generation, power demand and grid capacities

Introduction

"The Horizon Europe WILLOW project aims to extend the lifespan and profitability of offshore wind farms through improved structural health monitoring and wind farm control." Curtailment means a deliberate reduction in output. As done today, curtailment of power output from the turbines have a negative effect on their fatigue life. This implies that the wind farm is both delivering less power than available and potentially damaging the turbines in the process as they operate in off-design conditions. To assess the efficiency of new control algorithms over the farm's lifetime and the impact on levelized cost of energy (LCOE), curtailment must be quantified. This is the goal of this summer project. Figure 1 shows an example of an offshore wind farm being downregulated during simulations.

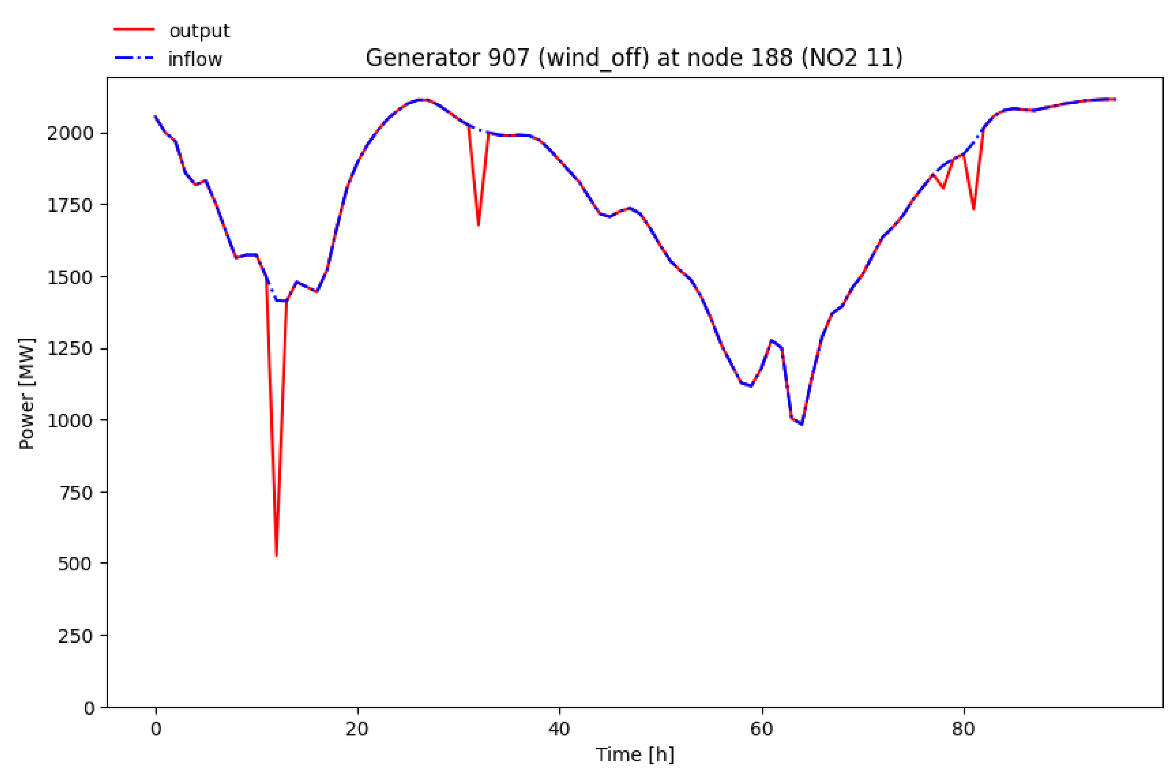

Figure 1: Example of offshore wind farm curtailment in PowerGAMA simulations

PowerGAMA – Power Grid And Market Analysis

"PowerGAMA is a Python-based lightweight simulation tool for high level analyses of renewable energy integration in the large power systems." [1] It performs timestep by timestep optimalisation with the objective of minimizing the total cost of power generation. By modeling the grid, consumers and generation, it is possible to analyze the behavior of the future power system. Figure 2 shows a map of the power grid used in analysis of Scenario A.

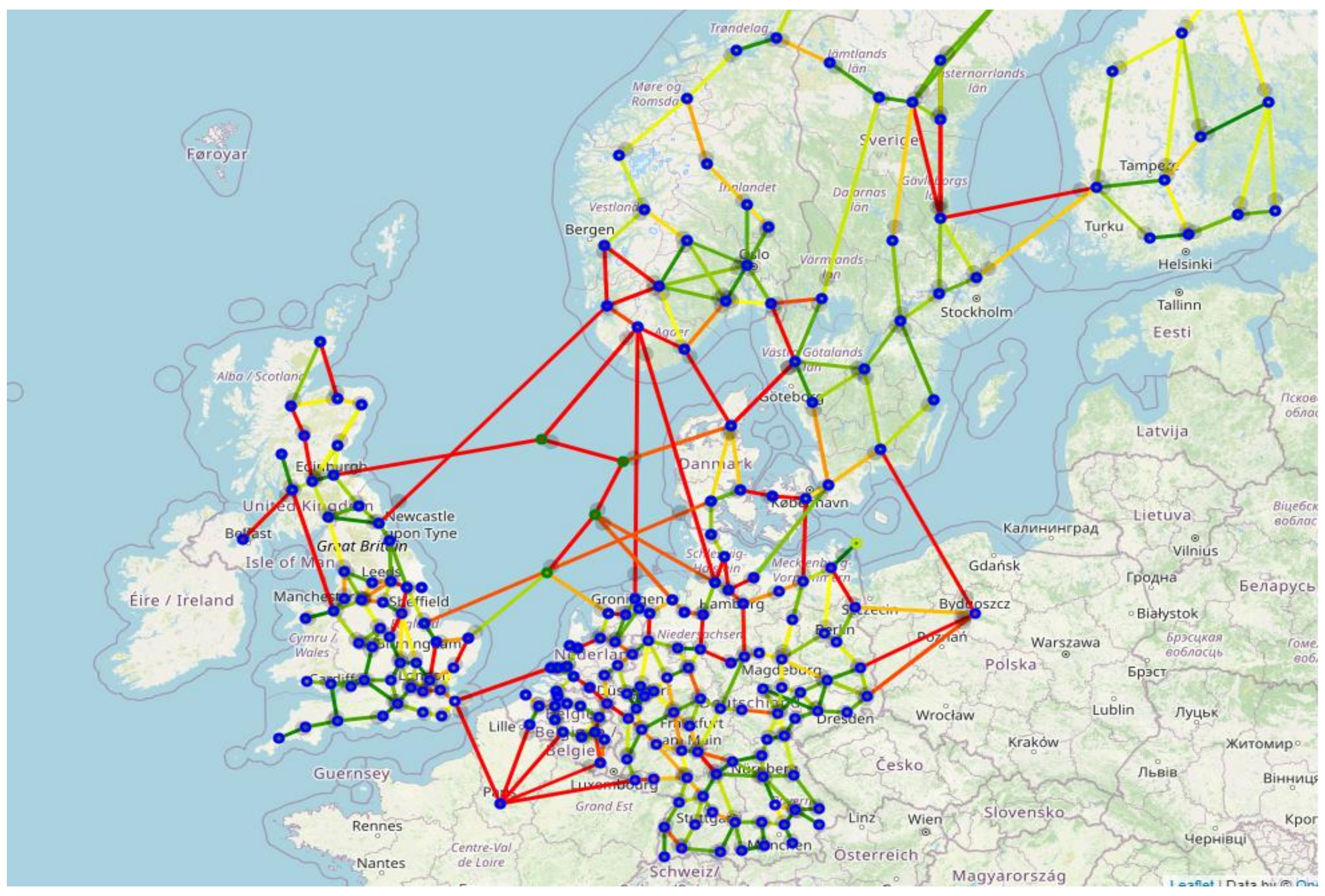

Figure 2: Map of the modelled power grid used in simulations of Scenario A

Method and results

To quantify the occurrence of offshore wind farm curtailment in future grids, several aspects must be considered. The power system is evolving and increasing in complexity. Accurately predicting the power system of the future is very challenging. Considering this, several scenarios of plausible future power systems were designed. By splitting the analysis into said scenarios, one can investigate which factors influence the curtailment of offshore windfarms in future grids. Figure 3 shows an illustration used to visualize how a Scenario A is designed. The number of tiles reflect the emphasis on the category given in the legend.

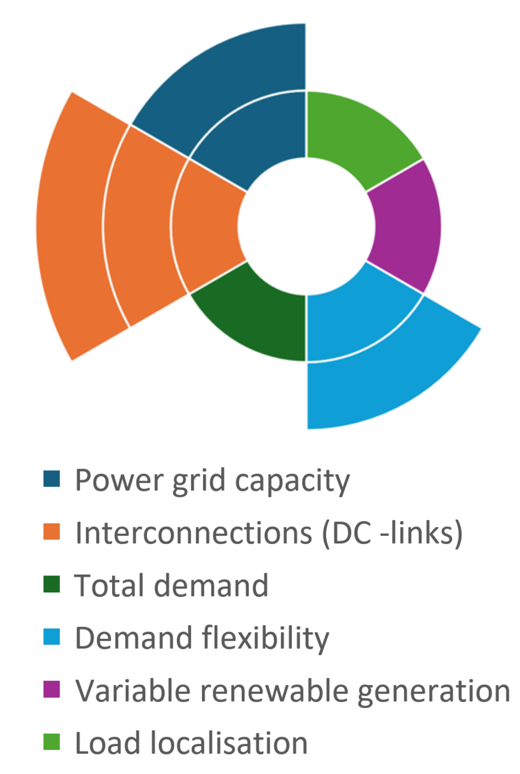

Figure 3: Visualisation of Scenario A

The results mainly consist of two variables; Spillage hours and number of spillage occurrences during a year. The spillage hours is in this context the total amount of energy spilled divided by the capacity of the farm. In extension, other relevant data was retrieved from the simulations, allowing for further analysis of the causes of curtailment. This data includes timeseries values of generator output, generator spillage, demand and power line utilisation. Figure 4 shows a correlation analysis plotted as a heatmap. Here, the spillage timeseries values from a single wind farm have been analysed against relevant operational conditions in the grid, such as branch utilisation (flow/capacity) and load at landfall (local demand). This could help paint a picture of the circumstances around spillage.

Table 1: Total spillage and number of occurrences of some offshore windfarms in the model, simulated over a one-year period

	Spillage hours [h]	Nr. of occurrences
Sørvest F.2 (NO)	3115.22	3963
Sørvest F.1 (NO)	2669.60	3531
DE1 51 (DE)	2264.67	4178
DK_hub (DK)	2246.88	2914
Sørvest B.1 (NO)	2185.17	3064
GB0 15 (GB)	2119.75	5867
Vestavind F.1 (NO)	1723.31	2708
Vestavind F.0 (NO)	1533.89	2554
Vestavind E.1 (NO)	1514.31	2507
NL1 12 (NL)	1234.90	3114
HornsRev1 (DK)	947.52	1164
DK_west0 (DK)	940.66	1244
NL1 7 (NL)	729.59	1725
DK_west2 (DK)	639.46	895
GB0 6 (GB)	615.40	1627
Sørvest B.2 (NO)	593.69	2306

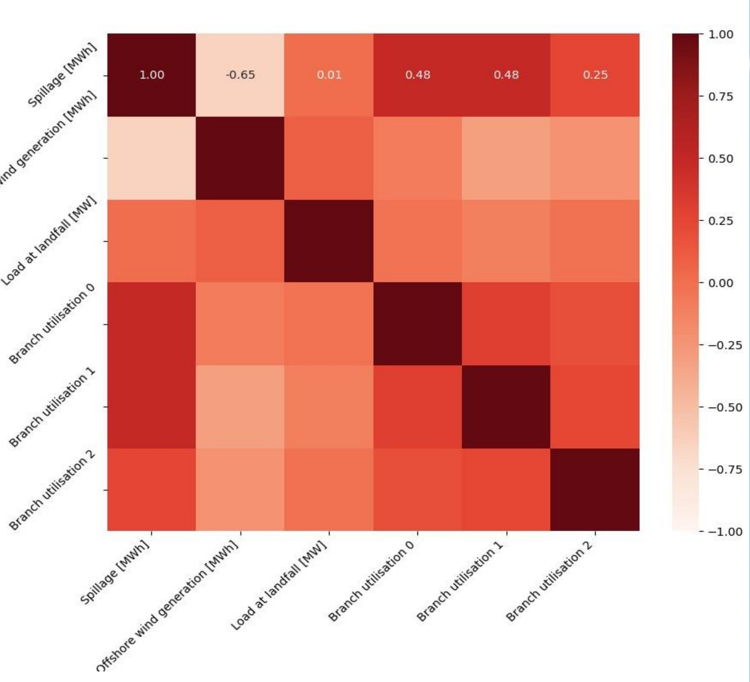

Figure 4: Heatmap showing correlations in timeseries values of a single offshore wind farm

Discussions and conclusions

The results and scripts obtained during this summer project has laid the groundwork to allow for further investigation of offshore wind curtailment. PowerGAMA has the necessary tools to quantify the extent of curtailment.

Discussions and further work

- Spillage is here used as a proxy for curtailment. In reality, intra-day power market mechanisms are made to mitigate spillage and will alter this direct relationship.
- The power system and market are greatly simplified to allow for efficient study of many hypothetical scenarios
- The design of scenarios have a high degree of uncertainty
- Participation in power reserve, real-time balancing markets and frequency restoration ancillary services are other sources of curtailment that are not quantified here.

Acknowledgement

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[1] Svendsen, Harald G., and Ole Chr Spro. "PowerGAMA: A new simplified modelling approach for analyses of large interconnected power systems, applied to a 2030 Western Mediterranean case study." Journal of Renewable and Sustainable Energy 8.5 (2016).