

D5.11 Base scenario for clusters simulated

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EeFarm-II & FarmFlow Wind farm cabling demonstration (DTC WP5)

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1. Introduction

In this document a demonstration of the ECN toolkit combination FarmFlow - EeFarm-II is performed for use in the EERA DTOC project. The purpose of these simulations is to test the scenarios defined in EERA-DTOC and to show the potential of a combined aerodynamic-electrical tool in quantifying investment cost, electric performance and levelized transport costs given a specific choice of wind farm layout, wind turbine spacing and cable topology.

In the demonstration EeFarm-II makes use of the detailed results of the ECN code FarmFlow that can accurately predict wind farm wake effects and by extension energy yield per year. The computational cases as presented in the present document are based on the so-called near future scenario as defined in EERA-DTOC [3]. This scenario assumes a 1 GW wind farm consisting of 100 turbines with a rated power of 10 MW. The distance between the turbines is chosen to be variable in order to investigate the net wind farm power as function of inter-turbine distance and assess the net wind farm power against the costs for the electrical infrastructure as function of inter-turbine distance.

2. FarmFlow: Wind Farm Flow Simulations

For the accurate calculation of wind turbine wake effects in (large) offshore wind farms, ECN has developed the software tool FarmFlow. FarmFlow calculates the time-averaged flow velocities and turbulence intensities inside a wind farm. The wake model in FarmFlow is a 3D parabolized Navier-Stokes code, using a $k-\varepsilon$ turbulence model to account for turbulent processes in the wake. A boundary layer model is used for the calculation of the free stream wind speed. For the deceleration and expansion of the near wake, FarmFlow uses an axisymmetric vortex wake model to calculate the stream wise pressure gradients, which are prescribed as a source term in the flow equations. Given a year averaged distribution of wind speeds and wind directions the yearly energy yield of a wind farm can be determined.

For a description of the FarmFlow software tool and the validation of FarmFlow against four full scale wind farms see reference [1]. Some typical FarmFlow user interaction windows are shown in Figure 1.

2.1 Wind Turbine Specification

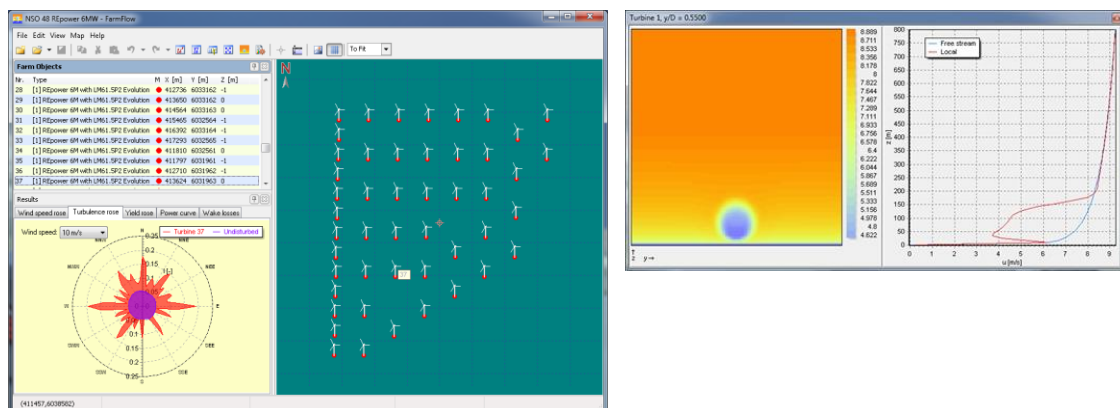


Figure 1 Graphical user interface of FarmFlow.

The 10 MW reference wind turbine from the InnWind.EU project will be used in the FarmFlow simulations to compute the wind farm yearly power yield. Some general data on this wind turbine is given in Table 1. The power performance curve of the reference wind turbine is given in Appendix A.1.

Table 1 DTU 10MW reference wind turbine.

Description	Value	Dimension
Wind Regime	IEC Class 1A	
Rotor Orientation	Clockwise rotation - Upwind	
Control	Variable Speed, Collective Pitch	
Cut in wind speed	4	m/s
Cut out wind speed	25	m/s
Rated wind speed	11.4	m/s
Rated power	10	MW
Number of blades	3	
Rotor Diameter	178.3	m
Hub Diameter	5.6	m
Hub Height	119.0	m

2.2 Wind Farm Layout Specification

For the wind farm a 10 by 10 layout based on the Horns Rev wind farm was chosen. Note that the distance between the turbines is chosen to be variable see section 2.3 and [3]. The location of the corner wind turbines is given in Table 2. A simple cabling layout was selected where 20 parallel strings, each linking 5 wind turbines to the central substation (see Figure 2). Though not investigated here, it is also possible to introduce extra cable links between two parallel strings of wind turbines for redundancy reasons, i.e. between wind turbines 1 and 11, between wind turbines 10 and 20, etc.

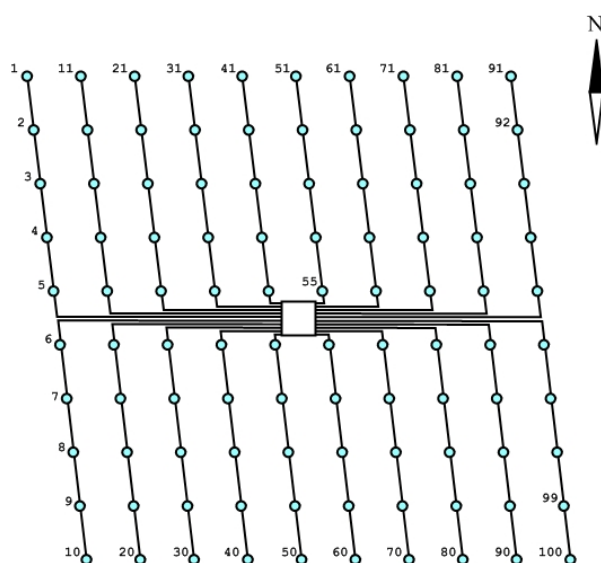


Figure 2 Wind farm 10 MW wind turbine numbering and cabling layout.

Table 2 Wind farm characteristic wind turbine coordinates for 10D turbine spacing.

WT nr	X-coordinate [m]	Y-coordinate [m]
1	-1956	15927
10	0	0
91	14091	15927
100	16047	0

2.3 FarmFlow Results

In FarmFlow the energy production of each of the 100 wind turbines in the wind farm is computed for an array of wind speeds and wind directions where the energy production reducing effects of the wake of the upstream wind turbines on downstream wind turbines are taken into account. The wind speeds in the simulations ranged from 1 m/s to 35 m/s with a 1 m/s step size and the full range of wind directions with a step size of 5 degrees was taken.

The 10 by 10 wind farm was equipped with the same 10MW reference turbine with a rotor diameter of $D=178.3$ m (see Table 1) throughout the simulations in which also the wind farm layout (see Figure 2) was maintained.

Four sets of FarmFlow analyses were performed for wind turbine spacings of 3.65D, 5.10D, 7.29D, and 10.00D. In Figure 3 the velocity distribution in the wind farm as computed by FarmFlow for one particular combination of wind speed and wind direction is shown.

To obtain the yearly energy yield of the wind farm the power production of each wind turbine was weighted with the frequency of the occurrence of the specific wind speed and wind direction. An experimentally determined frequency distribution representative for an offshore location in the North Sea with an average wind speed of 11 m/s and a uniform turbulence intensity of 8% was used and is given in Appendix A. Though not applied in this investigation, it is also possible in FarmFlow to use a non-uniform turbulence intensity distribution.

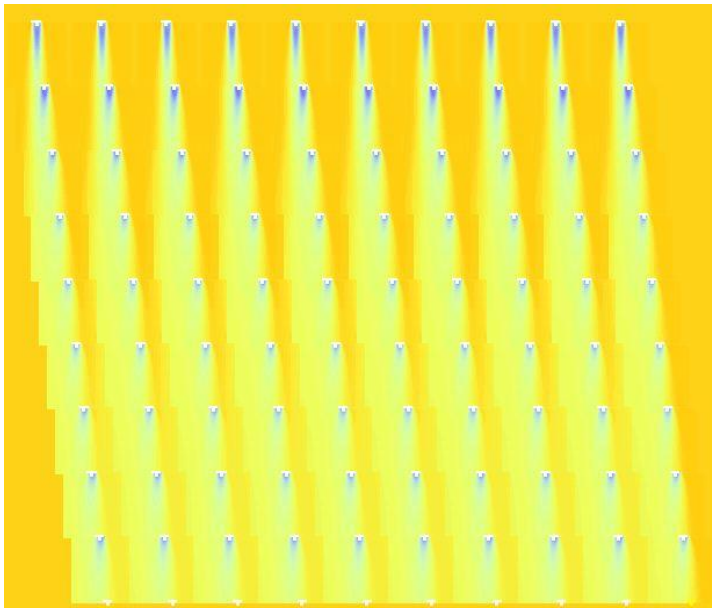


Figure 3 Wind farm wake velocity distribution as determined by FarmFlow.

3. EeFarm-II: Wind Farm Electric Grid Simulations

3.1 EeFarm-II Description

EeFarm-II has been developed to study and optimize the electrical performance of wind farms. The program is used to determine the energy production, electrical losses, component failure losses and the price of the produced electric power of a wind farm. The program consists of a component library, a component data base, and a postprocessor. The component library contains steady state models of turbines, generators, transformers, AC and DC cables, PWM (pulse width modulated) and thyristor converters and of an inductor, statcom and chopper. EeFarm-II is programmed in MATLAB -Simulink. By using a component library, structured component parameters and a single bus signal to connect the different components in a wind farm, it is very easy for the user to build his specific wind farm model. After choosing the wind farm component blocks from the library and connecting the component blocks in Simulink, the parameters of all wind farm components are loaded by preparing a small MATLAB file that calls the database and selects the component data like electrical characteristics, costs, and failure rates, to be fed to individual components. Wind speed and wind direction data generated by a wind farm wake program, for instance Farm-Flow (also developed by ECN), can be fed into the turbine blocks.

EeFarm-II calculates the voltage, current, active and reactive power of the main electrical components in a wind farm. The calculation starts at the turbines and proceeds in the direction of the high voltage grid. The AC component models are the well-known equivalent circuit diagrams for generators (induction, doubly fed and full converter), cables and transformers. For the PWM converter three different models representing the switching and conduction losses can be chosen. EeFarm-II does not solve the load flow in the classical way because this would make it difficult to include DC components or require iteration, which would make the calculations more time consuming. Instead, it calculates an average solution which is sufficiently accurate to determine the losses and the produced power. This is repeated for each wind speed bin of the turbine power curve or each wind speed and wind direction bin if input from a wind farm wake program is used. The average solution is sufficiently accurate due to the small voltage drops and the small voltage angle differences in a wind farm. The results for each wind speed and wind direction bin are combined with its probability to determine the energy production and the price of the produced electric power.

EeFarm-II calculations require component parameters (typically resistances, capacitances and inductances) and budget prices which are stored in a component database. Ideally the parameters and budget prices should be supplied by component manufacturers and should be updated regularly. A database with manufacturer supplied component parameters is included; budget prices however are not included due to confidentiality agreements.

EeFarm-II was originally developed by ECN and Delft University of Technology in MATLAB. To improve user-friendliness, it was completely rebuilt in MATLAB-Simulink, exploiting the advantages of the Simulink graphical user interface and MATLAB data structures. This second version was developed and tested in collaboration with Vattenfall Sweden. Vattenfall was also

the first customer of EeFarm-II. The models comprising the program have been partly validated (only AC components) by comparison to the Vision load flow program.

A detailed description of EeFarm-II can be found in reference [2].

3.2 EeFarm-II Input Specification

For simplicity of this demonstration only the electrical model is limited to the collection grid, which include:

- Wind turbines, represented by their active power output at 1kV nominal voltage and a fixed reactive power setting of 0MVar.
- Wind turbine transformers: The nominal voltage of the turbine transformers is 1kV/69kV and the power rating is 10 MVA.

Array cables: The wind farm is fitted with a single cable type, which is a 3-core XLPE cable (3x240 mm²), rated for 69 kV, 58.4 MVA.

For the calculation of the Levelized Transport Costs (LTC) within the wind farm the following economical parameters have been used:

- system life time: 12 years,
- nominal interest rate: 7%,
- inflation rate: 1.5%,
- wind farm availability: 90%,

Note: maintenance costs are not included but energy losses due to single cable are included.

3.3 EeFarm-II Simulation Results

In Table 3 investment, energies, and cost at wind farm output is given. Note that with increasing wind turbine spacing distance between the individual wind turbines the rise in total investment costs for cables and cable laying can (at least partially) be offset by an increase in wind farm power production depending on energy prices. For example, the increase in cable costs due to increasing turbine spacing from 3.65D to 10D is earned back in about one and a half years by the increase in energy yield in case of an energy price of € 0.10 per kWh. Some of the EeFarm-II data is plotted as function of wind turbine spacing distance in Figure 4, Figure 5, and Figure 6.

Table 3 Investment, energies and cost at wind farm output for different wind turbine spacing distances.

Dist/D	InvTot	E _{farmnet}	E _{lossCu}	E _{lossCuRel}	E _{fail}	E _{failRel}	LTC
(-)	(M€)	(GWh/y)	(GWh/y)	(-)	(GWh/y)	(-)	(€/kWh)
3.65	88.54	4650.47	25.52	0.00549	10.63	0.00229	0.0015
5.10	112.42	4978.80	31.70	0.00637	12.46	0.00250	0.0018
7.29	148.24	5229.04	41.03	0.00785	14.79	0.00283	0.0023
10.00	192.59	5391.48	52.69	0.00977	17.44	0.00324	0.0028

Figure 6 shows an increasing LTC with increasing wind turbine spacing distance. This is expected as only cable and transformer costs are included of which the cable costs are

dominant and scale more or less directly with cable length, but annual energy production increases slowly with increasing spacing distance. For example doubling the cable length will not be offset by a twice as high energy production of the wind farm. The resulting LTC should be combined with expected electricity market prices to assess which is the preferred option. Note that the LTC are based on investment costs that only include turbine transformers and array cables (including cable laying).

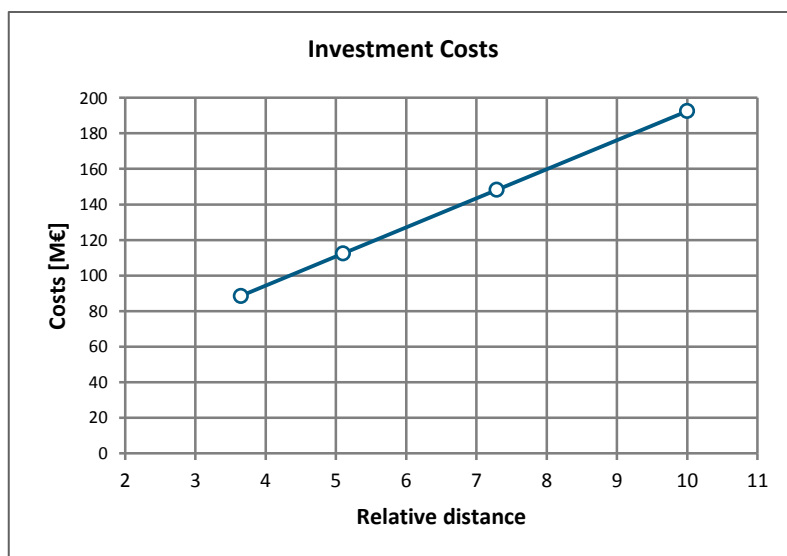


Figure 4 Investment costs as function of wind turbine spacing distance.

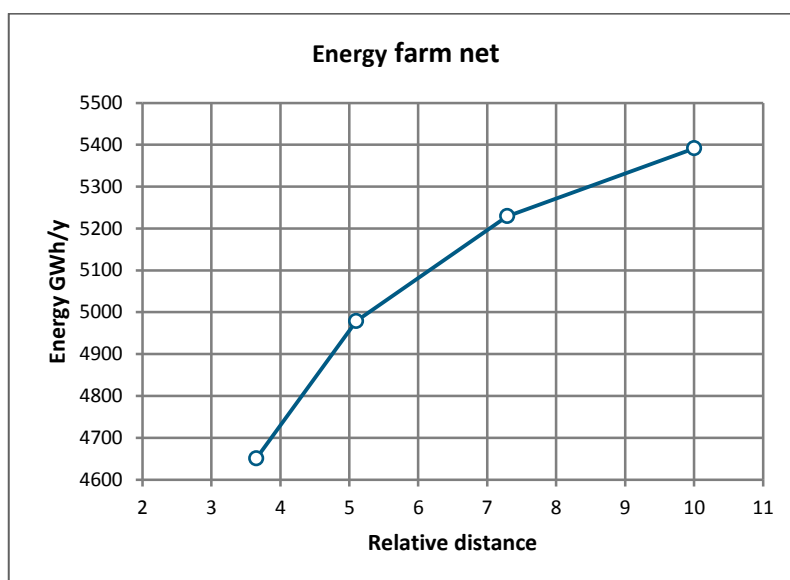


Figure 5 Net wind farm energy yield as function of wind turbine spacing distance.

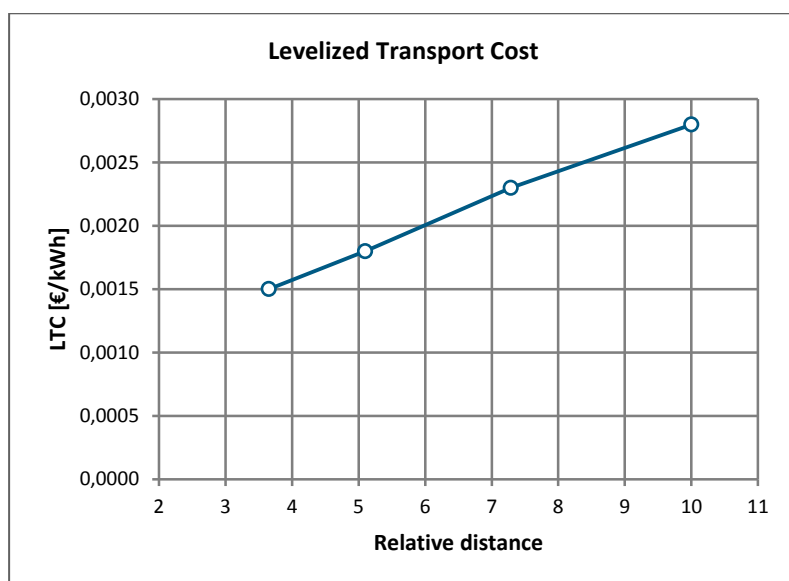


Figure 6 Levelized transport costs as function of wind turbine spacing distance.

In Table 7, Table 8, Table 9, and Table 10 in Appendix C the values at the exit of some specific components (listed from the wind turbine in the direction of the central substation) for two values of power production: maximum and minimum power. This is to study the performance of each component in more detail, for example to check overloading. The selected components are the transformers for wind turbines 1 and 55 (north-west corner and wind park centre respectively), the two rows of wind turbines at the west side of the wind farm, and the complete wind farm itself.

In Figure 7 the net energy yield per year as calculated by EeFarm-II for all 10 rows of wind turbines is plotted. As can be seen, the rows of wind turbines in the middle of the wind farm have a lower energy yield than the rows of wind turbines at the edges of the wind farm. As expected this effect is more pronounced for the wind farm with more closely placed wind turbines.

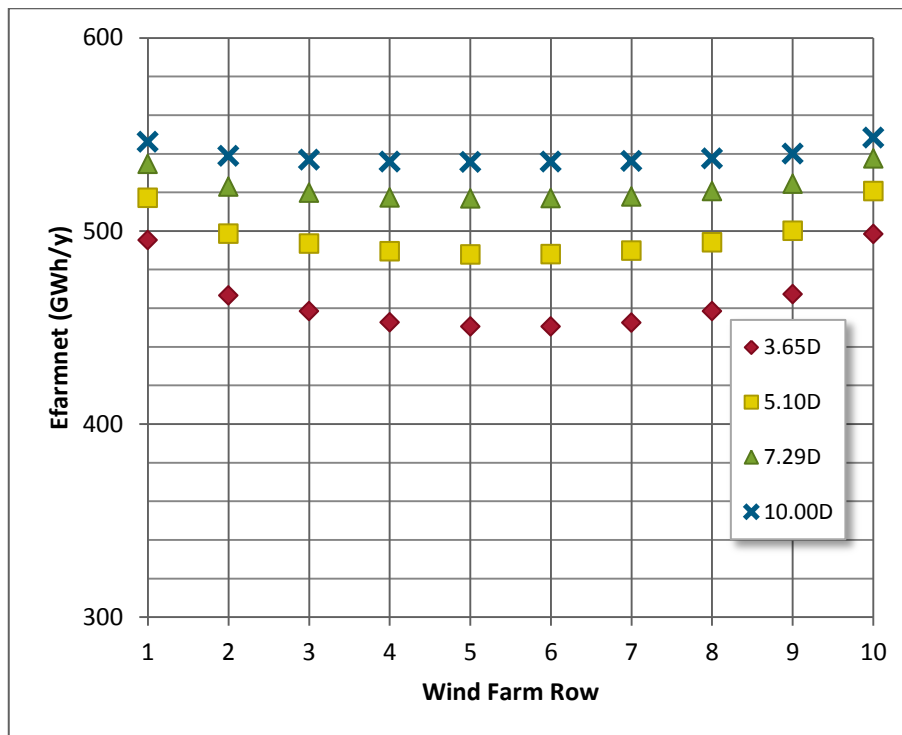


Figure 7 Net energy yield per year for each row of wind turbines for different wind turbine spacing distances.

3.4 EeFarm-II Simulation Results for specific wind conditions

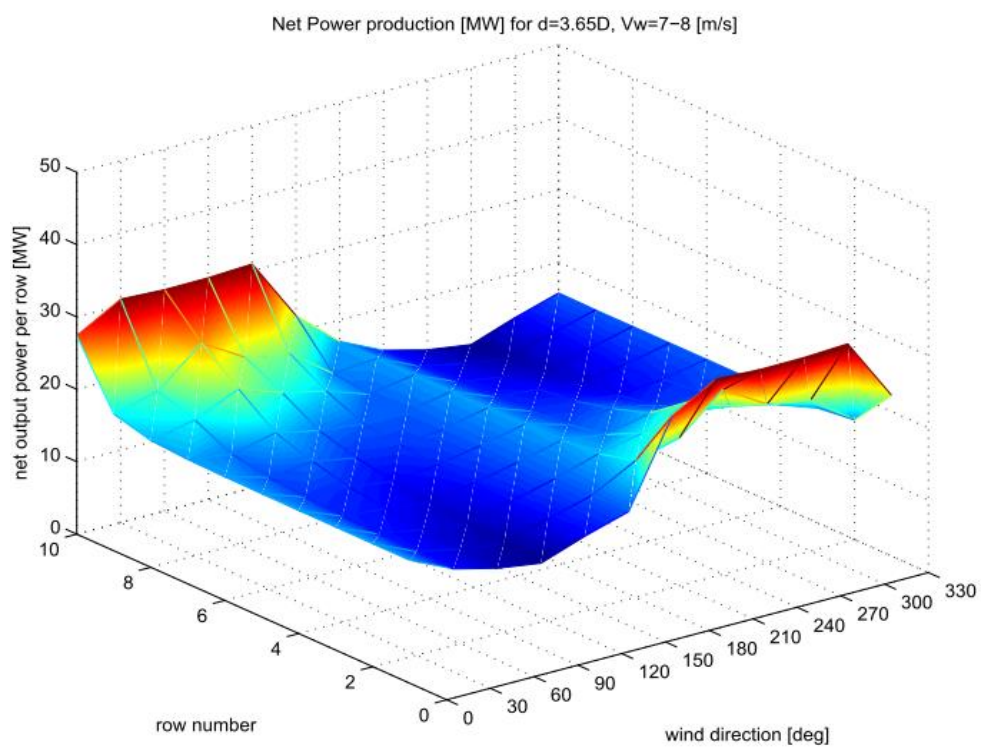
In Figure 7 the generated energy for all occurring wind speeds and wind directions has been accumulated. In order to obtain more insight in on the wake losses the energy contribution for a number specific wind speeds and wind sectors has been presented.

Two wind speed intervals are chosen 1: between 7 and 8 m/s and between 11 and 12 m/s, which represent a low wind speed and a higher wind speed for which the axial induction is still high. For the wind direction sectors of 30 degrees have been chosen.

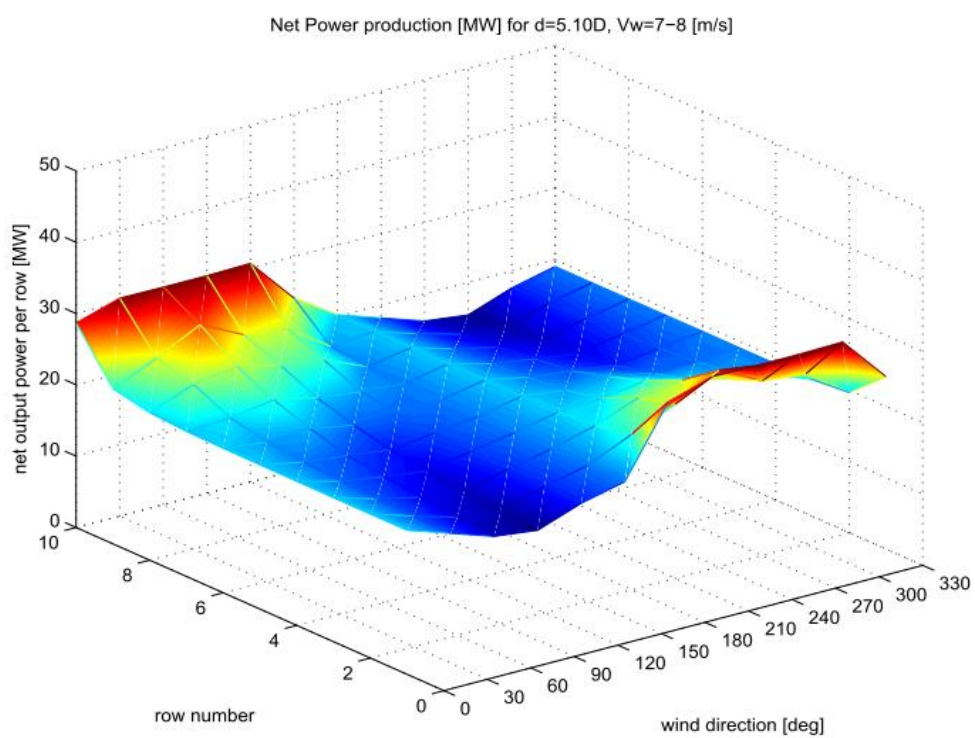
The output power in MW is presented rather than the energy output, i.e. multiplication with the wind rose frequency distribution has not been applied in this analysis.

The maximum power around rated wind speed equals 10 times 10MW, and the maximum output at lower wind speed around 10 times 3MW is also according to expectation. At higher wind speeds the wake losses are higher because of the higher rotor speed while the pitch angle is still small.

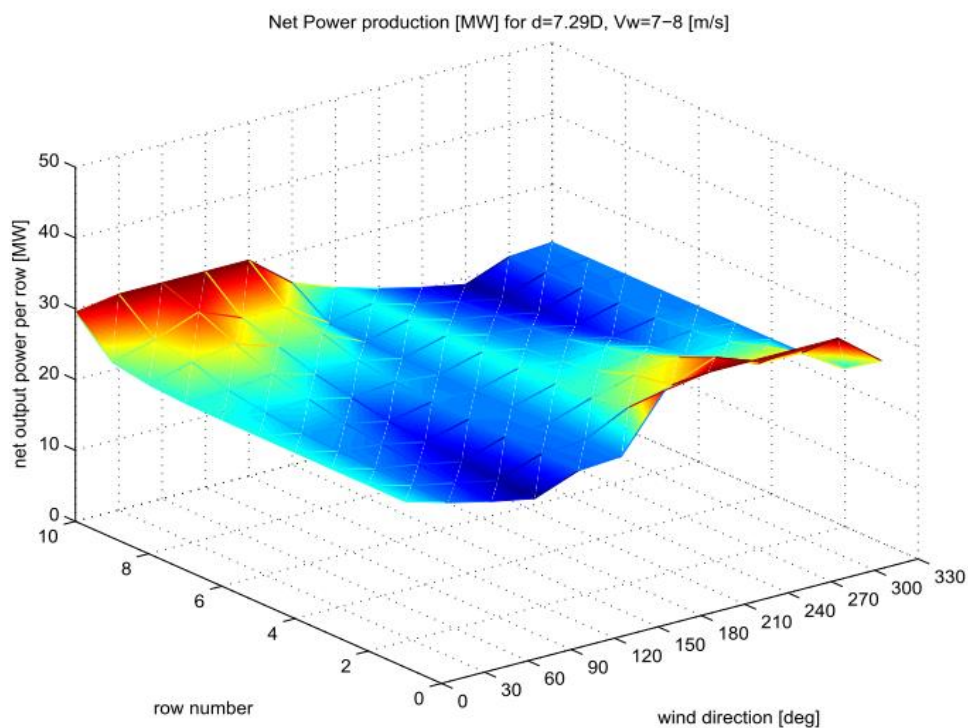
In Figure 10 the power production for each wind sector and the two wind speed ranges have been combined in a polar plot.



a)



b)



c)

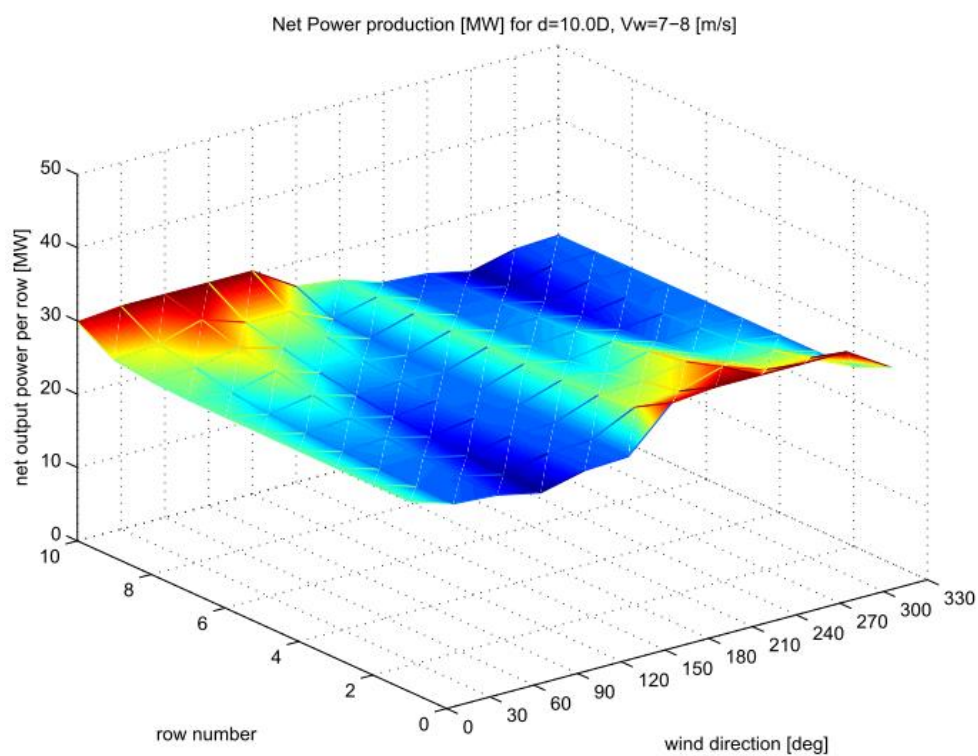
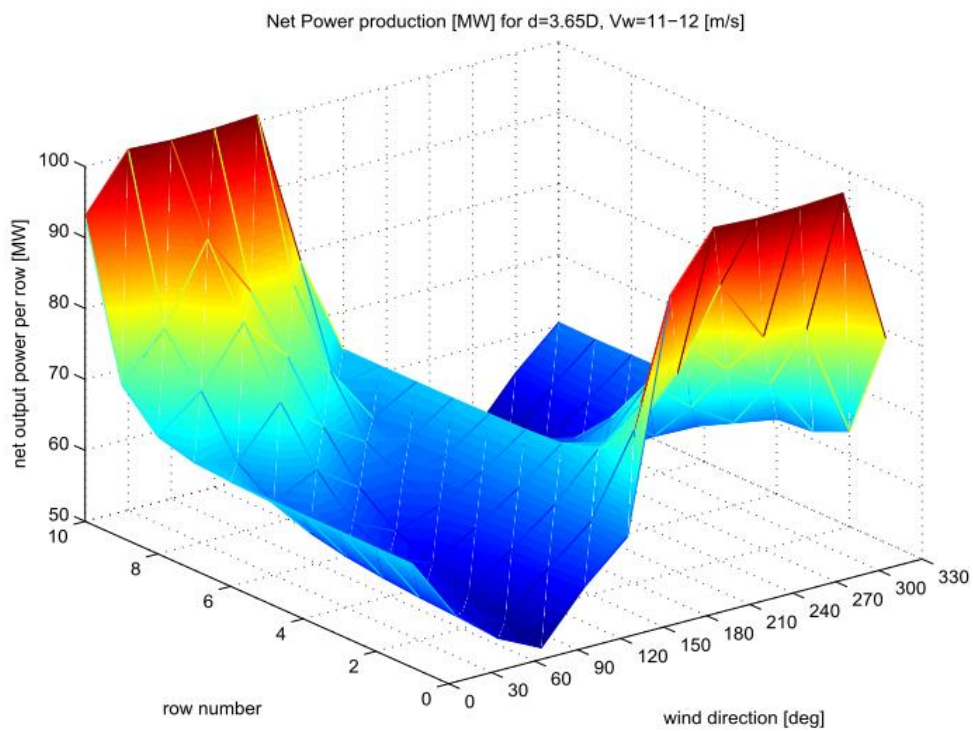
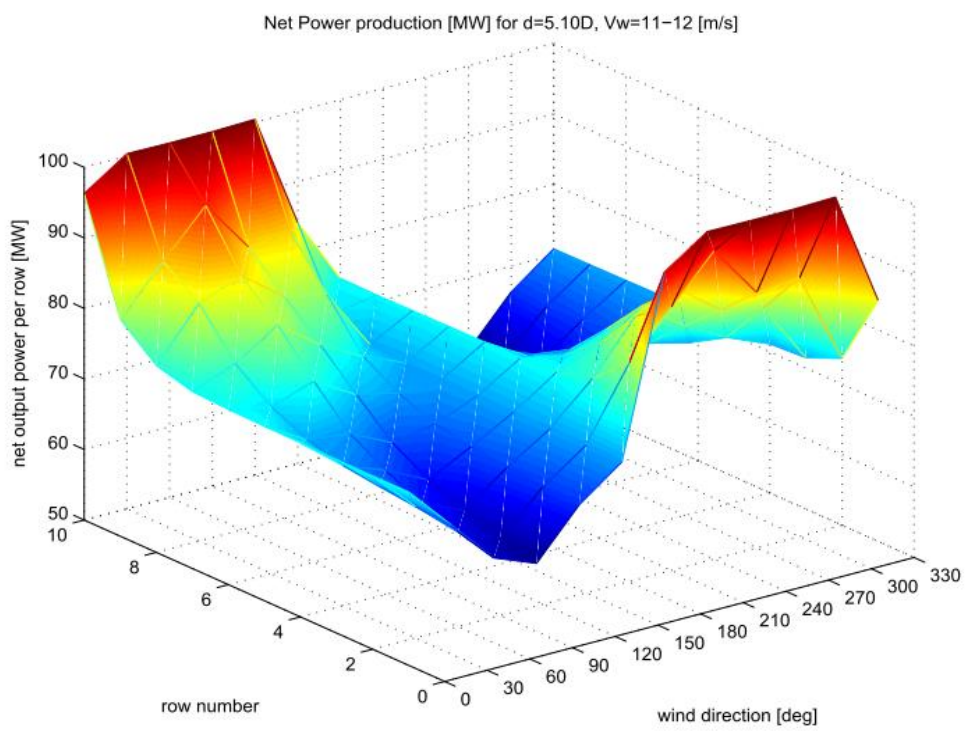


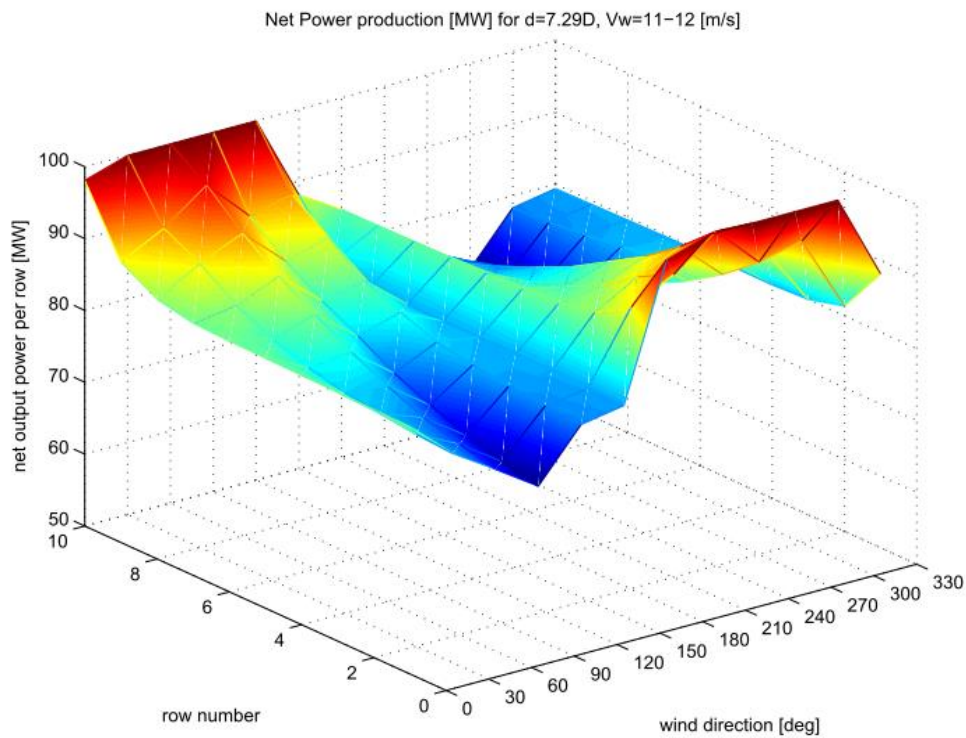
Figure 8 Net energy yield per row and per wind sector, $V_w = 7-8$ m/s and increasing inter-turbine spacing: a) $3.65D$, b) $5.10D$, c) $7.29D$, d) $10.0D$



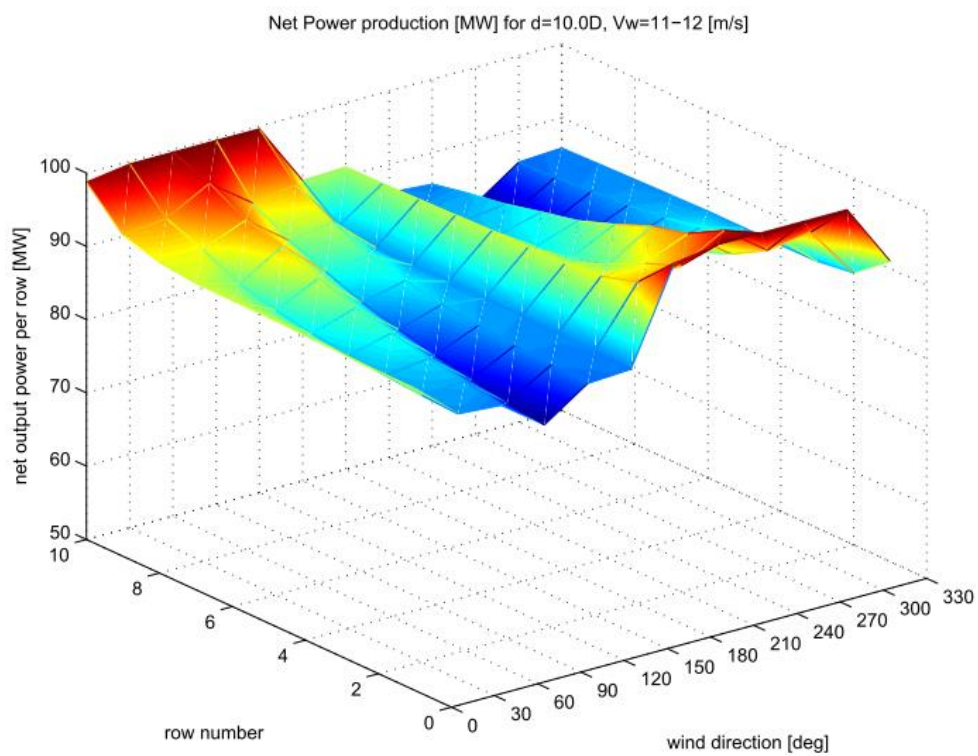
a)



b)

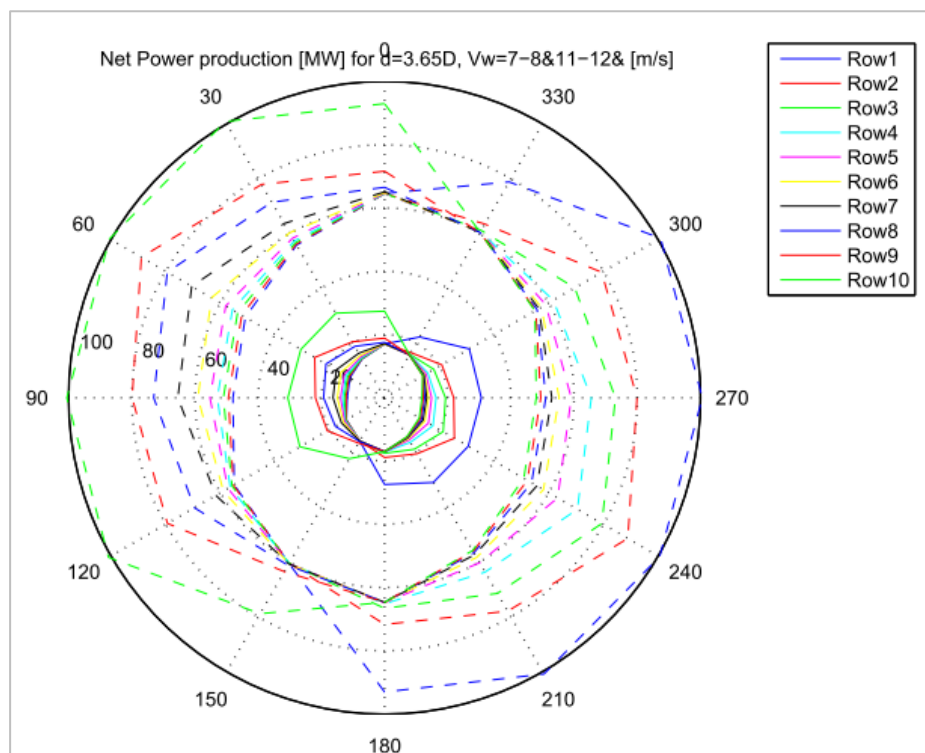


c)

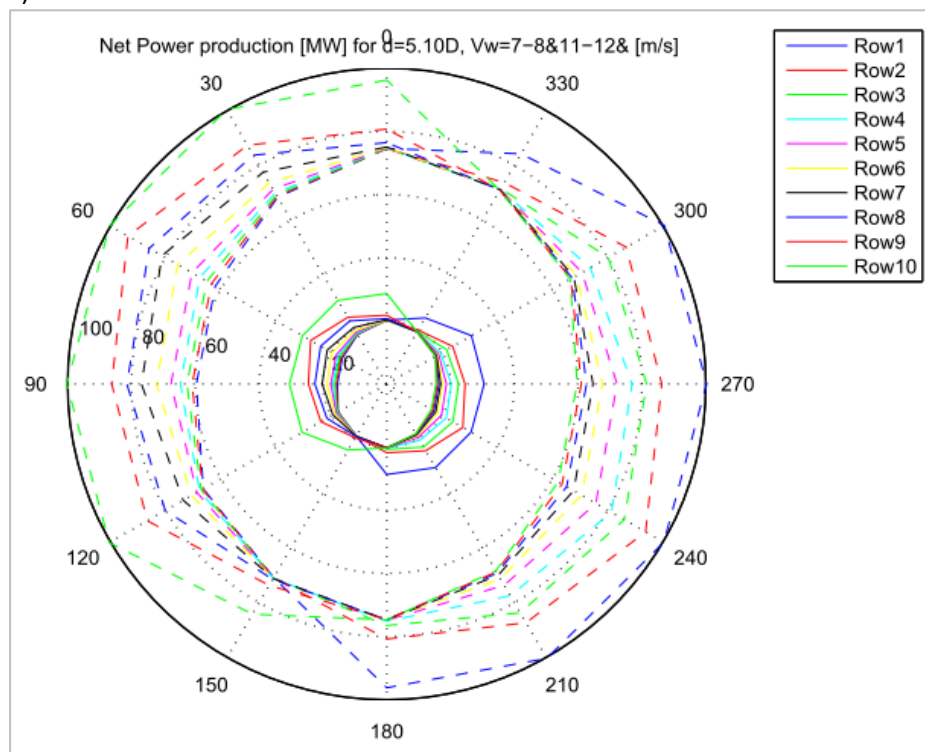


d)

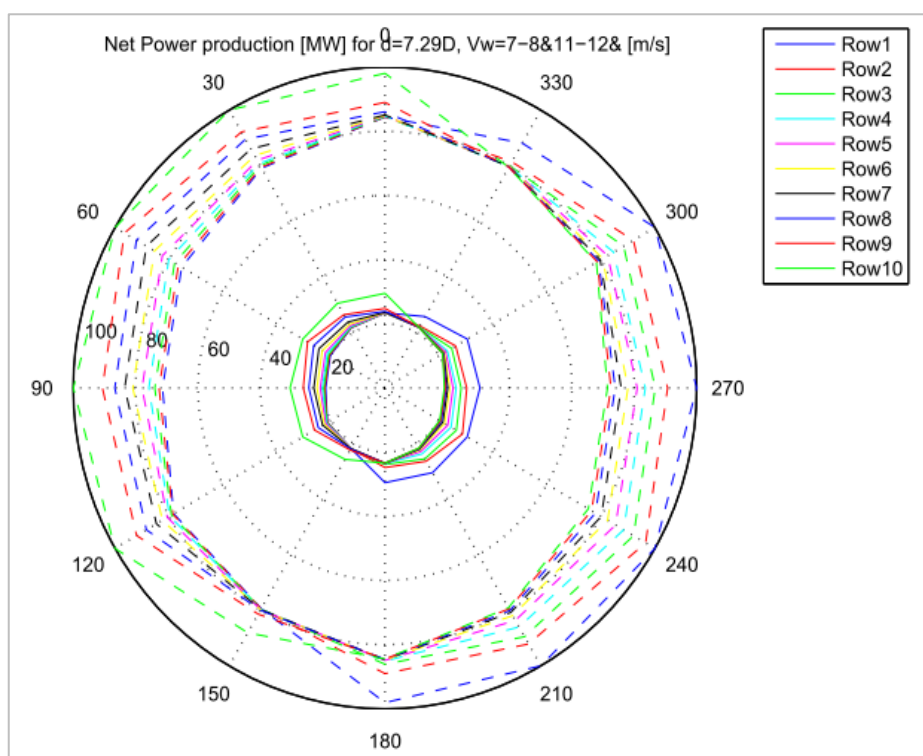
Figure 9 Net energy yield per row and per wind sector, $V_w = 11-12$ m/s and increasing inter-turbine spacing: a) $3.65D$, b) $5.10D$, c) $7.29D$, d) $10.0D$



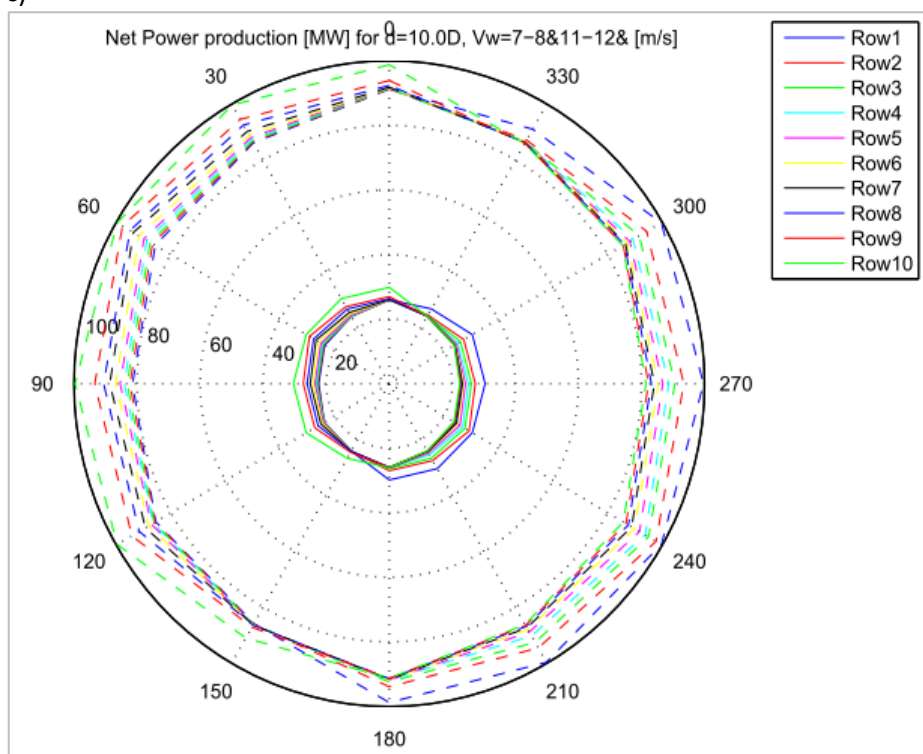
a)



b)



c)



d)

Figure 10 Net power production per row and per wind sector, $V_w = 7-8$ (solid) and $11-12$ m/s (dashed) and increasing inter-turbine spacing: a) $3.65D$, b) $5.10D$, c) $7.29D$, d) $10.0D$

4. Velocity field behind the wind farm

In a further step of EERA-DTOC, clusters of wind farms are considered. It is then important to know the velocity field behind wind farms. This has been studied for the wind farm with spacing $7.29D$. Thereto FarmFlow has calculated the velocity field up to a distance of $100D$ behind the wind farm. The vertical profile of the wind speed is plotted in Figure 11 for different distances behind the farm (note that the distance of $-5D$ denotes the free stream wind speed profile). It can be seen that at the hub height of 119 m , the undisturbed wind speed is 11 m/s in front of the wind farm. At a distance of $20D$ behind the wind farm, the wind speed is reduced to 9.5 m/s , i.e. the wake deficit is still 2.5 m/s . From this point, the wake deficit recovers very slowly. It is then remarkable to see that at a distance of $500D$ behind the farm, the wake deficit at hub height is still 0.7 m/s . An explanation for the slow recovery of this wake velocity is the fact that the recovery at the relatively low hub height should come from the upper layer, i.e. it could be stated that fresh undisturbed air has to ‘travel’ large distances. Consequently the velocity at the upper layer is reduced and figure 11 shows a disturbance of the velocity up to a height of almost 10 rotor diameters (note that the figure only shows heights up to $2.5D$).

It is noted that until now the only FarmFlow validation of the velocity recovery behind wind farms could be done on basis of Horns Rev measurements until a distance of 5000 m . This validation showed good results. A further validation of the velocity recovery at larger distances behind a wind farm will be undertaken on basis of satellite measurements in another EERA-DTOC task.

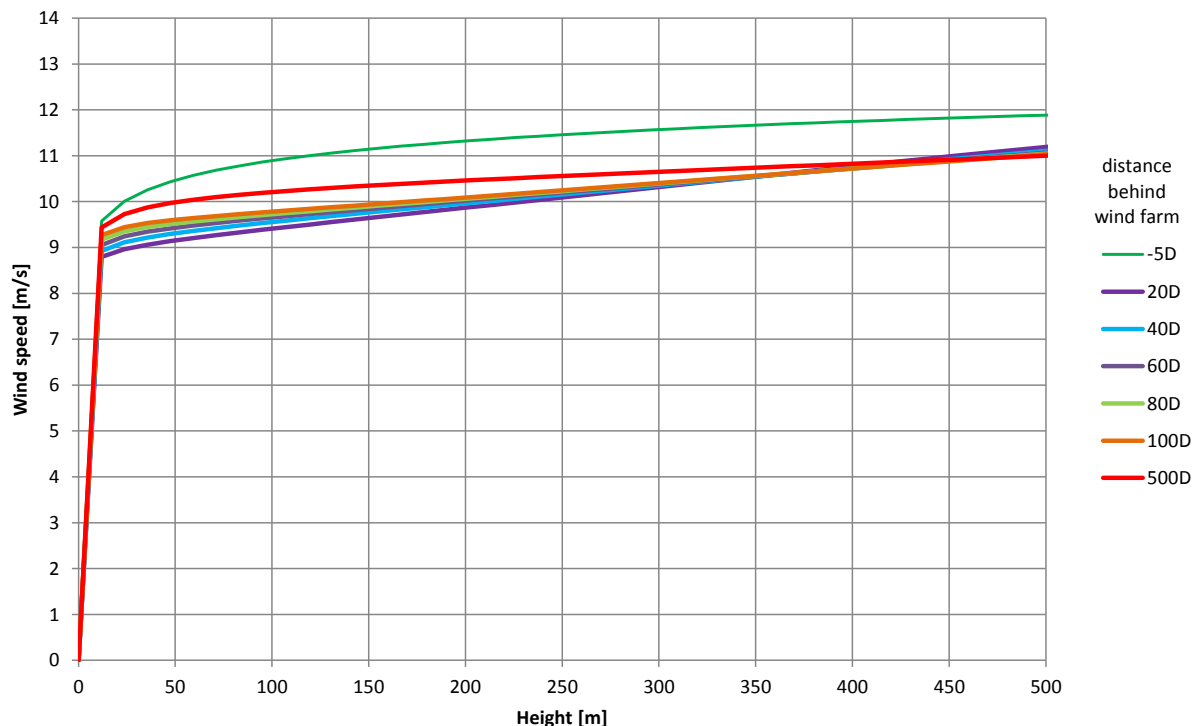


Figure 11 Calculated velocity profiles behind a wind farm with turbine spacing of $7.29D$.

5. References

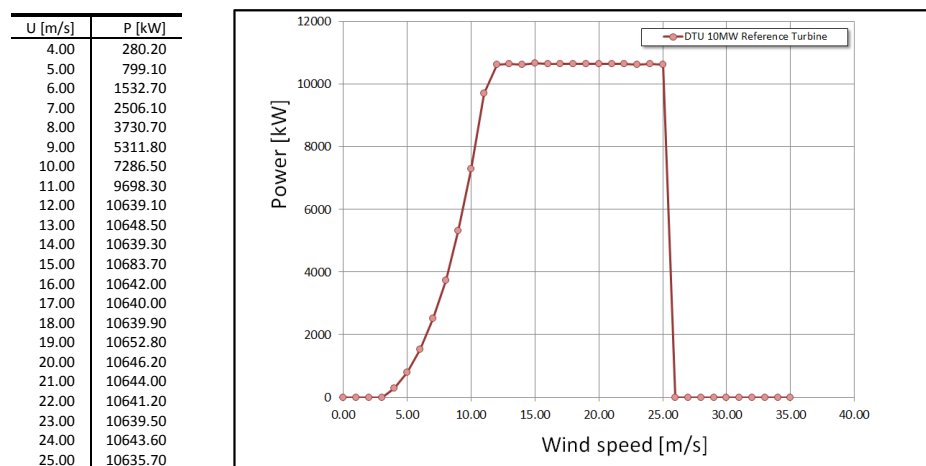
- [1] E.T.G. Bot, *FarmFlow validation against four full scale wind farms*, ECN-E--12-005, 2012.
- [2] J.T.G. Pierik, U. Axelsson, E. Eriksson, D. Salomonsson, *EeFarm II Description, testing and application*, ECN-E--09-051, 2009.
- [3] J.G. Schepers, W. He, C. Bay Hasager, M. Faiella, E.J. Wiggelinkhuizen *EERA DTOC base and near future Scenario*, EERA-DTOC Deliverable 5.2, 2013.

Appendix A FarmFlow input data

A.1 Power performance curve

The power performance curve used for all wind farm turbines in the FarmFlow computations is for the DTU 10MW reference turbine from the InnWind.EU project and is given in Table 4 for wind speeds between cut-in and cut-out.

Table 4 DTU 10MW reference turbine power as function of wind speed.



A.2 Frequency distribution

The frequency distribution of the occurrence of a particular wind speed and wind direction used in the FarmFlow computations is derived from experiments and is given in Table 5 and Table 6 and is representative for an offshore location in the North Sea with an average wind speed of 11 m/s and a turbulence intensity of 8%.

Table 5 Frequency distribution (in %) of wind speed (1 - 17 m/s) and wind direction (0° - 355°).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	0.3184	0.6478	0.9881	1.1528	1.2407	1.1699	1.5042	1.1858	1.1309	0.9803	0.7246	0.549	0.3843	0.2855	0.1976	0.2086	0.2415
5	0.3673	0.7461	1.1478	1.2167	1.1134	1.2052	1.2626	1.1823	1.1249	0.9642	0.6887	0.6084	0.1951	0.4017	0.2984	0.4132	0.3099
10	0.2778	1.1742	1.6035	1.7803	1.2753	0.947	1.048	1.0995	0.7197	0.5051	0.5556	0.4293	0.404	0.4798	0.3157	0.2399	0.1894
15	0.4662	1.3711	1.6864	1.5082	1.1791	1.0694	1.467	0.9597	0.521	0.3839	0.4113	0.3976	0.4525	0.425	0.4525	0.3702	0.0823
20	0.4204	0.8108	1.0961	1.1862	1.2012	1.021	1.1261	0.976	0.976	1.0811	1.006	0.4354	0.6006	0.4505	0.4655	0.2553	0.2553
25	0.3106	0.7396	1.0945	1.3016	1.065	0.9171	0.8283	0.6804	0.7396	0.7839	0.8283	1.1389	1.0502	0.7691	0.4437	0.355	0.1627
30	0.2095	0.5639	0.9184	1.2084	1.144	0.9667	1.0312	0.854	0.7089	0.9023	0.4028	0.435	0.8862	1.0634	0.6928	0.6928	0.3384
35	0.2705	0.3659	0.9227	1.2728	1.4159	0.9705	0.8089	0.9387	0.8591	0.9068	0.7796	0.7159	0.4932	0.7318	0.8273	0.525	0.3818
40	0.0564	0.4089	0.705	1.0575	1.0998	1.0716	0.8178	0.8742	0.8883	0.9165	0.8319	0.6063	0.7614	0.7191	0.7473	1.0857	0.423
45	0.1129	0.3049	0.6323	0.813	0.8695	0.9824	1.1405	0.9146	0.6888	0.8582	0.7904	0.8017	0.8017	0.9485	0.9033	0.9711	0.734
50	0.1838	0.2872	0.5514	0.10799	0.9305	0.942	0.9535	0.6663	0.6433	0.942	0.5859	0.7697	0.7352	0.919	1.0109	1.2062	0.5974
55	0.0502	0.2308	0.572	0.7526	0.7627	0.8028	0.6924	0.7627	0.9333	0.8329	0.8229	0.843	1.134	1.2042	0.9935	0.7326	0.6322
60	0.0929	0.2973	0.4552	0.5667	0.5853	0.5574	0.5295	0.7618	0.6503	0.7061	0.9383	0.9569	1.152	1.3099	1.1241	0.7618	0.5388
65	0.09	0.2776	0.3677	0.5402	0.6528	0.6753	0.5778	0.7879	0.6453	0.6603	0.8254	0.8254	1.133	1.0955	0.6828	0.7353	0.4952
70	0.1588	0.2382	0.4092	0.4031	0.4581	0.8062	0.5192	0.7268	0.5802	0.6718	0.8001	0.965	1.191	1.1177	0.6596	0.6657	0.7146
75	0.0711	0.2356	0.3689	0.3511	0.3822	0.5244	0.6089	0.6533	0.6978	0.76	0.6533	0.7956	0.9067	1.1289	1.1111	0.8311	1.0044
80	0.0572	0.1868	0.3811	0.4116	0.4726	0.606	0.5793	0.6403	0.7127	0.6403	0.6098	0.8271	1.2197	1.2082	1.2654	1.3492	0.9071
85	0.085	0.2409	0.4204	0.5055	0.5716	0.5716	0.5527	0.7559	0.7795	1.1054	1.1196	0.959	0.9495	0.9023	1.148	0.9495	0.7133
90	0.0948	0.2395	0.3493	0.4442	0.4641	0.4442	0.4991	0.6338	1.0031	0.8484	0.9832	0.9233	0.9632	1.2826	1.2826	1.1129	0.8384
95	0.1229	0.3259	0.3205	0.3365	0.4541	0.4754	0.5182	0.8013	0.7425	1.0791	1.1645	1.1912	1.3782	1.1485	1.0417	0.844	0.5395
100	0.1203	0.2886	0.3307	0.4449	0.475	0.6133	0.6614	0.9019	0.968	1.0281	1.3167	1.2927	1.2386	0.8778	0.6494	0.475	0.3487
105	0.1468	0.2348	0.3229	0.5635	0.4872	0.6575	0.7279	1.1095	0.9921	0.9803	0.9158	0.9803	1.3032	1.0449	0.6868	0.6046	0.5401
110	0.0949	0.2098	0.3098	0.3647	0.3447	0.5695	0.5446	0.7994	0.9243	0.9193	1.1591	1.0092	1.284	1.1091	1.0342	0.6894	0.7644
115	0.106	0.2297	0.3269	0.3092	0.4108	0.614	0.5787	0.7642	0.6936	0.9542	1.2855	1.1309	1.3253	1.0911	1.1025	0.8482	0.645
120	0.0933	0.21	0.3547	0.42	0.532	0.4714	0.5087	0.7234	0.7794	1.1154	1.3628	1.1481	1.1201	1.0501	0.7327	0.7841	0.756
125	0.0876	0.1951	0.4738	0.5176	0.8083	0.4539	0.8083	0.6968	0.7884	0.8203	1.2941	1.33	1.1309	1.2344	0.9357	0.7367	0.6769
130	0.1213	0.3639	0.5132	0.4759	0.5832	0.5598	0.6112	0.5785	0.7278	0.9704	1.1897	1.1803	1.3996	1.129	0.8958	0.9311	0.6298
135	0.1536	0.4224	0.576	0.7679	0.746	0.6912	0.554	0.746	0.9654	1.1629	1.0751	1.1026	1.0916	0.9544	0.7844	0.5101	0.4279
140	0.1753	0.271	0.4463	0.7332	0.6163	0.7598	0.8236	1.1052	0.9404	1.2433	1.1955	1.0573	0.9086	0.6748	0.7385	0.5951	0.3188
145	0.1155	0.4223	0.5578	0.7012	0.5897	0.7968	0.745	1.0239	1.0279	1.1913	1.02	1.0518	0.8128	1	0.7689	0.5418	0.2908
150	0.1302	0.3839	0.44	0.532	0.5522	0.5882	0.7386	0.6622	0.7498	1.0259	1.1404	1.1853	1.0618	0.9114	0.9092	0.7498	0.6667
155	0.1449	0.2457	0.2708	0.6362	0.6425	0.7874	0.844	0.9448	0.8188	1.0771	1.3228	1.2157	0.7937	1.0204	0.8314	0.6551	0.3842
160	0.2247	0.319	0.3334	0.7031	0.7756	0.7829	0.6959	0.8046	1.0583	1.0511	1.0656	1.2033	1.0438	0.8771	0.8264	0.9206	0.4132
165	0.2039	0.4401	0.5367	0.8748	0.703	0.7835	0.9445	0.8318	1.1485	1.2558	1.3953	0.9875	0.7191	0.6333	0.6869	0.6333	0.5152
170	0.2191	0.3817	0.417	0.6927	1.0319	0.6715	0.7987	0.8623	1.0956	1.3095	1.0085	1.1097	0.7351	0.5018	0.6361	0.4048	0.5937
175	0.2012	0.4292	0.57	0.6572	0.8517	0.6975	0.8718	0.9255	0.9858	1.1803	1.1401	1.073	0.6706	0.6103	0.456	0.6572	0.6706
180	0.2288	0.3522	0.5374	0.9005	1.0022	1.1184	1.1002	1.0639	1.2019	1.0712	0.7662	0.8715	0.65	0.512	0.3014	0.3341	0.3377
185	0.2966	0.4201	0.5849	0.8403	1.0462	0.9391	0.8979	1.0462	1.1368	1.3016	0.9885	0.7414	0.7249	0.6343	0.4201	0.346	0.3789
190	0.2303	0.4606	0.4816	0.8375	0.8166	0.7538	1.0748	1.3121	0.9143	1.0329	0.9631	0.8585	0.7607	0.6802	0.4955	0.4467	0.4816
195	0.1942	0.4336	0.589	0.7637	0.9061	0.7831	0.8414	0.9126	1.0614	1.1002	0.8478	0.9514	0.7572	0.6213	0.6025	0.5242	0.4854
200	0.2281	0.4007	0.4315	0.6658	0.8014	0.6596	0.6904	1.1898	1.2761	1.0233	0.9863	0.8692	0.7706	0.8261	0.8322	0.4192	0.4315
205	0.2177	0.3234	0.4478	0.7526	0.821	0.6033	0.821	1.2502	1.2564	0.9827	1.0449	1.0263	0.7961	0.7277	0.5722	0.4229	0.4665
210	0.1622	0.3506	0.628	0.5914	0.7954	0.7169	0.7902	1.2821	0.9943	0.9106	0.9158	0.9681	0.7483	0.6908	0.628	0.5861	0.7326
215	0.152	0.2549	0.5001	0.6373	0.6128	0.755	0.6226	0.9315	0.7942	0.7501	0.8923	1.2256	0.9168	0.8432	0.7354	0.6962	0.7942
220	0.0863	0.259	0.4452	0.5997	0.5679	0.7724	0.8451	0.9132	0.8178	0.7769	0.8587	0.9814	0.8541	0.6978	0.8723	0.6997	0.6406
225	0.1559	0.2167	0.3422	0.5361	0.5323	0.6349	0.6806	0.7794	0.7718	0.8973	0.8593	0.711	0.9391	0.8365	1.0228	0.8897	0.7186
230	0.136	0.2449	0.3469	0.5203	0.5373	0.6768	0.84	0.8026	0.9284	0.7822	0.8434	0.7992	0.8944	0.7856	0.7686	0.8604	0.9182
235	0.1054	0.2255	0.3602	0.4773	0.4773	0.6735	0.7204	0.8014	1.104	0.8931	0.8785	0.94	1.1362	0.8785	0.7986	0.6559	0.7086
240	0.0757	0.2298	0.3131	0.4747	0.563	0.7019	0.6766	0.6665	0.8938	1.0756	0.9569	0.9897	1.0528	0.9392	0.9544	0.8382	0.6514
245	0.0687	0.2331	0.346	0.4957	0.5129	0.6306	0.6797	0.7681	0.7852	1.0748	1.0944	1.1386	0.9276	0.876	0.8466	0.7116	0.5472
250	0.0694	0.1686	0.3248	0.3942	0.4909	0.5727	0.7314	0.662	0.7859	0.9818	0.9744	1.0859	1.1206	0.8553	0.8801	0.7934	0.6372
255	0.0444	0.2147	0.2764	0.4047	0.4862	0.5794	0.7305	0.6762	0.7724	0.881	0.9526	0.9353	1.113	1.0118	0.9921	0.8094	0.6392
260	0.0741	0.1931	0.2354	0.4259	0.4233	0.6111	0.7302	0.7963	0.709	0.8122	1.002	0.9365	1.1217	1.1481	1	0.8836	0.6005
265	0.0885	0.1655	0.2597	0.4452	0.4309	0.625	0.7705	0.8162	0.7762	0.8533	1.1272	1.0302	0.9103	0.9303	0.8818	0.8818	0.7077
270	0.0587	0.2349	0.2261	0.3582	0.4227	0.5813	0.6341	0.7838	0.8367	0.96	1.2741	1.0717	1.0158	0.869	0.7897	0.7222	0.6987
275	0.0846	0.2206	0.2538	0.3082	0.4894	0.6133	0.6798	0.6979	0.6677	0.8973	1.1572	1.1632	0.8913	0.8671	0.997	0.7886	0.6979
280	0.1096	0.1674	0.3501	0.414	0.411	0.6119	0.5389	0.5754	0.7063	0.9316	1.0564	1.0069	0.8799	0.9133	0.7977	0.8251	0.685

Table 6 Frequency distribution (in %) of wind speed (17 - 35 m/s) and wind direction (0° - 355°).

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
0	0.1427	0.1318	0.1208	0.1066	0.1318	0.1208	0.1537	0.0549	0.011	0.022	0	0	0	0	0	0	0	0
5	0.1033	0.1033	0.1148	0.0574	0.1263	0.0689	0.0459	0.0115	0.0115	0	0	0	0	0	0	0	0	0
10	0.1515	0.1515	0.0631	0.0631	0.101	0.2146	0.0505	0.0379	0.0126	0	0	0	0	0	0	0	0	0
15	0.0823	0.1234	0.0823	0.1097	0.1097	0.0411	0.0548	0	0.0548	0.0137	0.0137	0	0	0	0	0	0	0
20	0.1051	0.03	0.0901	0.1652	0.0751	0.015	0.015	0	0	0	0	0	0	0	0	0	0	0
25	0.074	0.0296	0.1331	0.1331	0.1923	0.0807	0	0.0148	0	0	0	0	0	0	0	0	0	0
30	0.1933	0.1933	0.1772	0.1289	0.145	0.0322	0	0	0	0	0	0	0	0	0	0	0	0
35	0.1909	0.0955	0.0795	0.0318	0.0636	0.0318	0.0159	0.0795	0.0159	0	0	0	0	0	0	0	0	0
40	0.2397	0.0423	0.1551	0.1128	0.1128	0.0705	0	0	0.0564	0	0	0	0	0	0	0	0	0
45	0.2484	0.0452	0.0452	0.0565	0.0678	0.0339	0.0226	0.0339	0.0339	0.0339	0	0	0	0	0	0	0	0
50	0.2872	0.1149	0.0919	0.046	0.0919	0.0574	0.046	0.0345	0.0115	0.023	0.0689	0.0115	0	0	0	0	0	0
55	0.3914	0.2308	0.2007	0.0803	0.0702	0.0502	0.0903	0	0.01	0.0401	0	0	0	0	0	0	0	0
60	0.288	0.3902	0.3809	0.1672	0.0557	0.1115	0.1951	0.1208	0.0372	0.0279	0.1022	0.0186	0	0	0	0	0	0
65	0.3602	0.2101	0.1951	0.2701	0.4052	0.3977	0.4577	0.1951	0.1351	0.0825	0.075	0.0375	0	0	0	0	0	0
70	0.5314	0.226	0.2993	0.3054	0.5192	0.3359	0.1283	0.1222	0.0366	0.0183	0.0794	0.0916	0.0855	0.0183	0.0061	0	0	0
75	0.68	0.4978	0.3644	0.3644	0.2578	0.1156	0.0667	0.0222	0.0044	0.04	0.0711	0.1333	0.1556	0.0267	0	0	0	0
80	0.5603	0.4497	0.4269	0.2134	0.061	0.0457	0.0343	0.0152	0	0	0.0038	0	0	0.0038	0	0	0	0
85	0.685	0.3354	0.1984	0.0898	0.0803	0.0898	0.0472	0.0236	0	0.0047	0	0	0	0	0	0	0	0
90	0.5589	0.3394	0.2695	0.0699	0.0848	0.0798	0.0349	0.0299	0.005	0	0	0	0	0	0	0	0	0
95	0.2938	0.3632	0.3686	0.1603	0.0908	0.0427	0.0427	0.0267	0.0107	0	0	0	0	0	0	0	0	0
100	0.3427	0.493	0.3066	0.2946	0.1383	0.1323	0.0722	0.0601	0.018	0	0	0	0	0	0	0	0	0
105	0.3698	0.3522	0.2407	0.2465	0.1702	0.0998	0.0587	0.0411	0.0117	0	0	0	0	0	0	0	0	0
110	0.5745	0.3797	0.3397	0.2448	0.05	0.05	0.04	0.025	0.035	0	0.005	0.005	0	0.005	0	0	0	0
115	0.3076	0.3887	0.2695	0.2076	0.1237	0.0972	0.0353	0.0133	0.0088	0	0.0044	0	0	0	0	0	0	0
120	0.4667	0.3594	0.294	0.252	0.182	0.1073	0.0233	0.0327	0.0093	0	0	0	0	0	0	0	0	0
125	0.3424	0.2668	0.1911	0.1314	0.1553	0.0637	0.008	0.0398	0.008	0	0	0	0	0	0	0	0	0
130	0.4385	0.2426	0.0653	0.126	0.042	0.0373	0.0233	0.0327	0.028	0	0	0	0	0	0	0	0	0
135	0.4333	0.2194	0.2139	0.1371	0.0540	0.0274	0.0329	0.011	0.0165	0	0	0	0	0	0	0	0	0
140	0.34	0.3507	0.3135	0.1807	0.0691	0.0053	0.0213	0.0053	0	0	0	0	0	0	0	0	0	0
145	0.3267	0.3745	0.2151	0.1275	0.1514	0.0239	0.004	0.004	0	0	0	0	0	0	0	0	0	0
150	0.6667	0.4018	0.1571	0.1212	0.0539	0.018	0.0157	0.0067	0.0022	0	0	0	0	0	0	0	0	0
155	0.3527	0.2897	0.2394	0.2079	0.063	0.0441	0.0063	0.0252	0.0063	0	0	0	0	0	0	0	0	0
160	0.2972	0.1377	0.1087	0.0797	0.0797	0.0435	0.0072	0	0.0072	0	0	0	0	0	0	0	0	0
165	0.2093	0.102	0.0966	0.0859	0.0268	0.0161	0.0215	0.0107	0.0054	0.0107	0	0	0	0	0	0	0	0
170	0.3746	0.2615	0.1979	0.1908	0.0707	0.0141	0.0777	0.0283	0.0424	0	0	0	0	0	0	0	0	0
175	0.4896	0.2615	0.1744	0.1341	0.0671	0.0335	0.0335	0.0134	0.0201	0.0067	0	0	0	0	0	0	0	0
180	0.4466	0.3667	0.2905	0.2179	0.1017	0.0508	0.0182	0.0145	0.0036	0	0.0036	0	0	0	0	0	0	0
185	0.3954	0.2307	0.173	0.14	0.0824	0.0577	0.033	0.0082	0	0	0	0	0	0	0	0	0	0
190	0.4327	0.1675	0.2024	0.1675	0.1605	0.1535	0.0489	0.014	0.007	0	0	0	0	0	0	0	0	0
195	0.4013	0.2977	0.1747	0.22	0.1812	0.0906	0.0259	0.0129	0.0129	0	0	0	0	0	0	0	0	0
200	0.3267	0.2959	0.2404	0.1911	0.1726	0.1171	0.0247	0.0123	0.0062	0	0	0	0	0	0	0	0	0
205	0.3048	0.3421	0.2799	0.1368	0.1368	0.056	0.0311	0.0311	0	0.0124	0.0187	0	0	0	0	0	0	0
210	0.5757	0.2826	0.1413	0.1256	0.0994	0.068	0.0262	0.0157	0.0052	0.0157	0.0052	0.0157	0.0105	0	0	0	0	0
215	0.6569	0.5442	0.2059	0.152	0.0882	0.0294	0.0196	0.0098	0.0147	0.0196	0.0147	0.0098	0.0049	0	0.0049	0	0	0
220	0.577	0.3907	0.4134	0.2726	0.1136	0.0954	0.0454	0.05	0.0045	0.0091	0.0091	0.0136	0	0	0.0091	0.0045	0.0136	0
225	0.6349	0.4753	0.3308	0.3954	0.2357	0.0874	0.057	0.0494	0.0342	0.0266	0.0076	0.0038	0.0038	0.0076	0	0.0114	0.0038	0
230	0.755	0.4727	0.2789	0.2177	0.1666	0.0986	0.0238	0.0408	0.0306	0.017	0.0102	0.0102	0.0204	0.017	0.0306	0.0068	0.0034	0
235	0.5212	0.4305	0.3573	0.2313	0.1435	0.1083	0.0586	0.0293	0.0351	0.0264	0.0059	0.0029	0.0029	0.0088	0.0117	0.0088	0	0
240	0.462	0.3535	0.3408	0.1969	0.1313	0.0833	0.0757	0.0707	0.0429	0.0126	0.0202	0.0126	0.0101	0.0076	0.0025	0.0076	0.0025	0
245	0.5227	0.373	0.373	0.2429	0.1988	0.1521	0.1153	0.0687	0.0491	0.0319	0.0123	0.0049	0.0049	0	0.0025	0	0	0
250	0.5958	0.4066	0.2273	0.2528	0.2554	0.176	0.1537	0.0942	0.0694	0.0545	0.0298	0.0074	0.0099	0.005	0	0	0	0
255	0.464	0.3455	0.3554	0.2517	0.2147	0.1802	0.2073	0.1308	0.0987	0.0592	0.0222	0.0222	0.0049	0.0074	0	0	0	0
260	0.4524	0.2593	0.2989	0.3333	0.1878	0.1481	0.1534	0.1111	0.0873	0.0397	0.0238	0.0053	0	0.0026	0	0	0	0
265	0.5365	0.4109	0.3995	0.2854	0.2055	0.1341	0.0656	0.0542	0.0428	0.0342	0.0143	0	0	0	0	0	0	0
270	0.5754	0.4961	0.3934	0.2789	0.229	0.1761	0.0939	0.0969	0.0528	0.0323	0.0117	0.0059	0.0058	0	0	0	0	0
275	0.5408	0.4169	0.281	0.2266	0.2508	0.1602	0.0937	0.1541	0.1178	0.0544	0.0725	0.0181	0.0091	0.006	0	0	0	0
280	0.5389	0.5724	0.3866	0.3166	0.2892	0.2162	0.1705	0.1248	0.0792	0.0639	0.0426	0.0244	0	0	0	0	0	0
285	0.5313	0.5732	0.5474	0.38	0.2705	0.2802	0.1191	0.058	0.0322	0.0322	0.0193	0.0032	0.0097	0.0032	0	0	0	0
290	0.6012	0.6263	0.4115	0.3149	0.2255	0.161	0.0966	0.0322	0.0286	0.0322	0.0036	0.0036	0.0072	0	0	0	0	0
295	0.5565	0.5605	0.326	0.2743	0.1749	0.1193	0.0755	0.0318	0.0159	0.0477	0.0239	0	0.0239	0	0	0	0	0
300	0.4515	0.3669	0.2963	0.1646	0.2022	0.1505	0.0847	0.0705	0.0753	0.0047	0.0094	0.0141	0	0	0	0	0	0
305	0.5799	0.415	0.2331	0.1706	0.1706	0.1364	0.1364	0.0853	0.0682	0.0682	0.0398	0.0114	0.0114	0	0.0057	0	0	0
310	0.3084	0.2952	0.1837	0.2296	0.2362	0.105	0.105	0.0459	0.0394	0.0656	0.0197	0.0066	0	0.0066	0.0066	0	0	0
315	0.3317	0.24	0.3035	0.1694	0.0706	0.0847	0.1129	0.0353	0.0141	0	0.0071	0.0071	0	0.0212	0	0	0	0
320	0.3895	0.316	0.2278	0.1837	0.1396	0.0661	0.0735	0.1102	0.0735	0.0147	0.022	0.022	0	0.0073	0.0073	0	0	0
325	0.3941	0.2082	0.171	0.2528	0.1413	0.0892	0.1413	0.0892	0.052	0.0149	0.0074	0.0297	0.0074	0	0	0	0	0
330	0.3311	0.2365	0.1576	0.1655	0.1218	0.0709	0.0788	0.0473	0.0473	0	0.0079	0.0236	0.0079	0	0	0	0	0
335	0.3072	0.3819	0.4151	0.3653	0.1162	0.1162	0.0996	0.0996	0.0415	0.0083	0	0	0	0	0	0	0	0
340	0.474	0.2618	0.3679	0.2264	0.2193	0.191	0.1344	0.0566	0.0283	0.0071	0.0142	0.0142	0	0	0	0	0	0
345	0.3298	0.2425	0.2522	0.17														

Appendix B EeFarm-II parameter list 10D

Parameter list for the wind farm with 10D spacing between the wind turbines.

```

--- turb
--- turb
-- Uamp : 1000
-- Urad : 0
----- Q : 0
0

--- trafo
----- Name : 'Siemens-Pauwels MM02293 2.6KVA '
----- L11_orig : 2.41916e-05
----- L12_orig : 0.165025
----- M_orig : 28.3446
----- R1_orig : 0.0008
----- R2_orig : 5.6061
----- Ploss_orig : 26810.2
----- Ploss_orig_Re1R : 0.00883854
----- Ploss_orig_Re1fe : 0.00147309
----- Ploss_orig_Re1 : 0.0103116
----- Lin : 2.63691e-05
----- Lm : 0.187036
----- Rin : 0
----- Lout : 1.31333e-05
----- Rout : 0.000446154
----- Rfelo : 67.8845
----- Ulo : 1000
----- Uhi : 69000
----- Srated : 1e+07
----- Uin_ph_zero : 577.35
----- Iin : 5773.5
----- Uout_ph_zero : 39837.2
----- Iout : 83.674
----- TR : 82.9146
----- PlossRinRout : 88385.4
----- Ifelo : 8.50489
----- PlossRfe : 14730.9
----- PlossRe1R : 0.00883854
----- PlossRe1fe : 0.00147309
----- PlossRe1 : 0.0103116
----- Invcost : ---
----- notavail : 0.0017
----- Sredun : 0
----- typeindex : [1x37 Array]
0

--- cable
----- type : ' Prysmian, XLPE 3x240 '
----- Ref : ' Sea '
----- IncludeNexans : [ ]
----- nr : 26
----- kVeffpp : 69
----- I : 620
----- SMVA : 58.4
----- area : 240
----- Rac20 : 0.0754
----- Rac90 : 0.0966703
----- Rdc20 : 0
----- Rdc90 : 0
----- L : 0
----- C : 1.97e-07
----- Wd : 0.4
----- tandelta : 0.00407256
----- kEurokmInvest : ---
----- notavail_km : 0.000138082
----- Tandelta : 0.00407256
----- Rkm : 0.0754
----- Ckm : 1.97e-07
----- Lkm : 0
----- fail_peryr_perkm : 0.0008
----- repairtimehr : 1512
----- kEurokmLaying : ---
----- Invcost_km : ---
----- Sredun : 0
----- Length : 1.833
----- typeindex : [1x37 Array]
0

--- cable1
----- type : ' Prysmian, XLPE 3x240 '
----- Length : 1.833
0

--- cable2
----- type : ' Prysmian, XLPE 3x240 '
----- Length : 3.616
0

--- cable3
----- type : ' Prysmian, XLPE 3x240 '
----- Length : 5.399
0

--- cable4
----- type : ' Prysmian, XLPE 3x240 '
----- Length : 7.182
0

--- cable5
----- type : ' Prysmian, XLPE 3x240 '
----- Length : 8.965
0

----- WT_D : 0.1783
----- WT_nD : 10
----- WT_Htower : 0.05

```

Appendix C EeFarm-II output data

Table 7 Wind farm 3.65D component values at maximum and minimum power.

Node	U	I	Pout	Qout	sumPloss	sumPfail
3.65D	(kV)	(A)	(MW)	(MVA)	(MW)	(MW)
Wftrafo1						
maxP	69.26	89.13	10.67	-0.74	0.02	0.02
minP	69.00	1.73	-0.02	0.21	0.02	0.00
Wftrafo55						
maxP	69.20	445.49	53.27	-3.68	0.15	0.11
minP	69.00	8.65	-0.08	1.03	0.08	0.00
WFrow1						
maxP	69.01	889.93	106.24	-5.40	0.60	0.26
minP	69.00	33.56	-0.16	4.01	0.16	0.00
WFrow2						
maxP	69.05	890.12	106.30	-5.78	0.54	0.25
minP	69.00	30.36	-0.16	3.62	0.16	0.00
WFrow3						
maxP	69.09	890.15	106.34	-6.17	0.48	0.24
minP	69.00	27.15	-0.16	3.24	0.16	0.00
WFrow4						
maxP	69.13	890.39	106.40	-6.55	0.42	0.23
minP	69.00	23.95	-0.16	2.86	0.16	0.00
WFrow5						
maxP	69.16	890.52	106.45	-6.93	0.36	0.22
minP	69.00	20.75	-0.16	2.48	0.16	0.00
WFrow6						
maxP	69.16	890.52	106.45	-6.93	0.36	0.22
minP	69.00	20.75	-0.16	2.48	0.16	0.00
WFrow7						
maxP	69.13	890.39	106.40	-6.55	0.42	0.23
minP	69.00	23.95	-0.16	2.86	0.16	0.00
WFrow8						
maxP	69.09	890.15	106.34	-6.17	0.48	0.24
minP	69.00	27.15	-0.16	3.24	0.16	0.00
WFrow9						
maxP	69.05	890.12	106.30	-5.78	0.54	0.25
minP	69.00	30.36	-0.16	3.62	0.16	0.00
WFrow10						
maxP	69.01	889.93	106.24	-5.40	0.60	0.26
minP	69.00	33.56	-0.16	4.01	0.16	0.00
WF						
maxP	69.08	8892.53	1062.15	-61.44	4.77	2.41
minP	69.00	271.54	-1.61	32.41	1.60	0.00

Table 8 Wind farm 5.10D component values at maximum and minimum power.

Node	U	I	Pout	Qout	sumPloss	sumPfail
5.10D	(kV)	(A)	(MW)	(MVA)	(MW)	(MW)
WFtrafo1						
maxP	69.26	89.08	10.67	-0.66	0.02	0.02
minP	69.00	2.37	-0.02	0.28	0.02	0.00
WFtrafo55						
maxP	69.18	445.21	53.24	-3.29	0.17	0.11
minP	69.00	11.85	-0.08	1.41	0.08	0.00
WFrow1						
maxP	68.91	889.21	106.06	-3.87	0.77	0.29
minP	69.00	46.37	-0.17	5.54	0.17	0.00
WFrow2						
maxP	68.96	889.41	106.15	-4.40	0.69	0.28
minP	69.00	41.89	-0.17	5.00	0.17	0.00
WFrow3						
maxP	69.02	889.62	106.23	-4.94	0.60	0.26
minP	69.00	37.40	-0.17	4.47	0.17	0.00
WFrow4						
maxP	69.07	889.85	106.32	-5.48	0.52	0.25
minP	69.00	32.92	-0.16	3.93	0.16	0.00
WFrow5						
maxP	69.12	890.10	106.40	-6.01	0.44	0.24
minP	69.00	28.43	-0.16	3.39	0.16	0.00
WFrow6						
maxP	69.12	890.10	106.40	-6.01	0.44	0.24
minP	69.00	28.43	-0.16	3.39	0.16	0.00
WFrow7						
maxP	69.07	889.85	106.32	-5.48	0.52	0.25
minP	69.00	32.92	-0.16	3.93	0.16	0.00
WFrow8						
maxP	69.02	889.62	106.23	-4.94	0.60	0.26
minP	69.00	37.40	-0.17	4.47	0.17	0.00
WFrow9						
maxP	68.96	889.41	106.15	-4.40	0.69	0.28
minP	69.00	41.89	-0.17	5.00	0.17	0.00
WFrow10						
maxP	68.91	889.21	106.07	-3.87	0.77	0.29
minP	69.00	46.37	-0.17	5.54	0.17	0.00
WF						
maxP	69.00	8892.88	1061.68	-49.28	6.03	2.64
minP	69.00	374.02	-1.66	44.67	1.66	0.00

Table 9 Wind farm 7.29D component values at maximum and minimum power.

Node	U	I	Pout	Qout	sumPloss	sumPfail
7.29D	(kV)	(A)	(MW)	(MVA)	(MW)	(MW)
WFtrafo1						
maxP	69.25	89.03	10.66	-0.54	0.02	0.02
minP	69.00	3.33	-0.02	0.40	0.02	0.00
WFtrafo55						
maxP	69.14	444.83	53.20	-2.71	0.21	0.12
minP	69.00	16.66	-0.08	1.99	0.08	0.00
WFrow1						
maxP	68.76	888.45	105.80	-1.57	1.03	0.34
minP	69.00	65.60	-0.18	7.84	0.18	0.00
WFrow2						
maxP	68.84	888.60	105.92	-2.33	0.91	0.32
minP	69.00	59.19	-0.18	7.07	0.18	0.00
WFrow3						
maxP	68.91	888.79	106.04	-3.10	0.79	0.30
minP	69.00	52.78	-0.17	6.31	0.17	0.00
WFrow4						
maxP	68.99	888.94	106.15	-3.86	0.67	0.28
minP	69.00	46.37	-0.17	5.54	0.17	0.00
WFrow5						
maxP	69.06	889.14	106.26	-4.62	0.55	0.26
minP	69.00	39.97	-0.17	4.77	0.17	0.00
WFrow6						
maxP	69.06	889.14	106.26	-4.62	0.55	0.26
minP	69.00	39.97	-0.17	4.77	0.17	0.00
WFrow7						
maxP	68.99	888.95	106.15	-3.86	0.67	0.28
minP	69.00	46.37	-0.17	5.54	0.17	0.00
WFrow8						
maxP	68.91	888.79	106.04	-3.10	0.79	0.30
minP	69.00	52.78	-0.17	6.31	0.17	0.00
WFrow9						
maxP	68.84	888.60	105.92	-2.33	0.91	0.32
minP	69.00	59.19	-0.18	7.07	0.18	0.00
WFrow10						
maxP	68.76	888.45	105.80	-1.57	1.03	0.34
minP	69.00	65.60	-0.18	7.84	0.18	0.00
WF						
maxP	68.89	8885.75	1059.81	-30.86	7.91	2.98
minP	69.00	527.81	-1.74	63.06	1.74	0.00

Table 10 Wind farm 10.00D component values at maximum and minimum power.

Node	U	I	Pout	Qout	Pfail	sumPfail
10.00D	(kV)	(A)	(MW)	(MVA)	(MW)	(MW)
WFtrafo1						
maxP	69.25	88.97	10.66	-0.40	0.02	0.02
minP	69.00	4.52	-0.02	0.54	0.02	0.00
WFtrafo55						
maxP	69.10	444.44	53.15	-2.00	0.26	0.13
minP	69.00	22.61	-0.09	2.70	0.08	0.00
WFrow1						
maxP	68.58	888.11	105.48	1.26	1.35	0.39
minP	69.00	89.41	-0.20	10.68	0.20	0.00
WFrow2						
maxP	68.68	888.09	105.65	0.22	1.19	0.37
minP	69.00	80.62	-0.19	9.63	0.19	0.00
WFrow3						
maxP	68.78	888.15	105.81	-0.82	1.02	0.34
minP	69.00	71.83	-0.19	8.58	0.18	0.00
WFrow4						
maxP	68.89	888.27	105.97	-1.86	0.86	0.31
minP	69.00	63.04	-0.18	7.53	0.18	0.00
WFrow5						
maxP	68.99	888.55	106.14	-2.91	0.70	0.29
minP	69.00	54.25	-0.17	6.48	0.17	0.00
WFrow6						
maxP	68.99	888.55	106.14	-2.91	0.70	0.29
minP	69.00	54.25	-0.17	6.48	0.17	0.00
WFrow7						
maxP	68.89	888.27	105.97	-1.86	0.86	0.31
minP	69.00	63.04	-0.18	7.53	0.18	0.00
WFrow8						
maxP	68.78	888.15	105.81	-0.82	1.02	0.34
minP	69.00	71.83	-0.19	8.58	0.18	0.00
WFrow9						
maxP	68.68	888.09	105.65	0.22	1.19	0.37
minP	69.00	80.62	-0.19	9.63	0.19	0.00
WFrow10						
maxP	68.58	888.11	105.48	1.26	1.35	0.39
minP	69.00	89.41	-0.20	10.68	0.20	0.00
WF						
maxP	68.75	8883.92	1057.88	-8.19	10.24	3.41
minP	69.00	718.31	-1.85	85.83	1.85	0.01