sgurr energy
Sustainable Engineering Worldwide

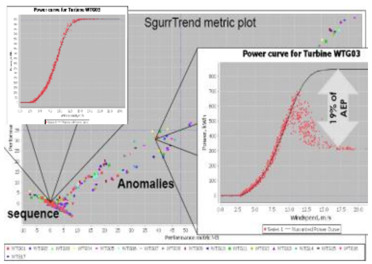
Using Lidar to understand the impact of wind shear on performance

Richard Boddington
Director of Measurement and Analysis
3 July 2012

SgurrEnergy

Products

SgurrTrend



Galion

Wind	Offshore Wind	Wave & Tidal	Solar	Bio-energy	Hydro
					

Overview

To look at the impact of wind flow on an operational power curve on a moderately complex site.

1. Wind characteristics that impact on power curves.
2. A moderately complex site.
3. Wind shear measurement using Galion Lidar.
4. Relationship between wind shear and power curve.
5. Impact on power output.

Underperformance in Operational Wind Farms (wind flow related)

Prediction errors

1. Low hub height wind speeds.
2. Incorrect wind shear extrapolation.
3. Over-estimation of WTG wake recovery.

Performance issues

1. High wind shear.
2. Wind veer.
3. High turbulence levels.
4. Flow inclination.
5. Off-axis WTG alignment.

Case study - Wind Shear

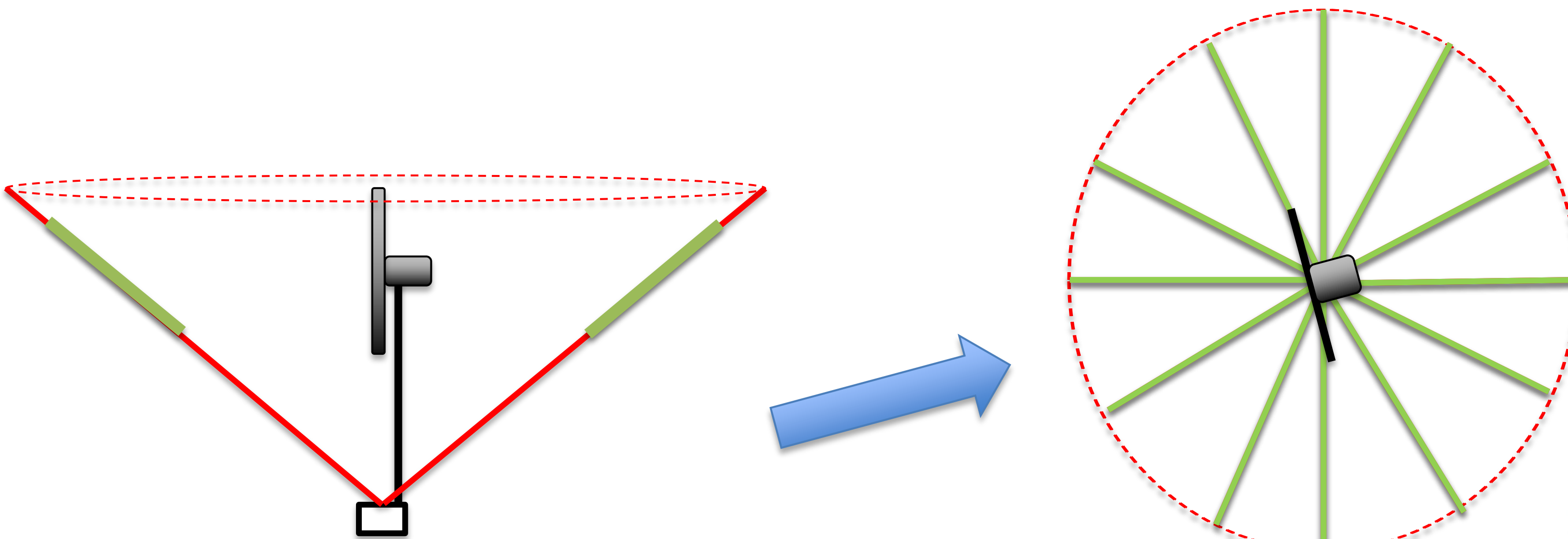
- A WTG was identified with reduced production within a wind farm in a medium complex terrain site in Southern Norway.
- Site reference mast situated at distance of 250m from WTG, elevation difference of approximately 13m.
- Uncertainty in the source of discrepancy between the reference power curve and mast measured power curve; WTG wear and tear or spatial variation of the wind flow.

Elevation profile across the prevailing wind direction, marker denotes turbine location.

Galion Placement

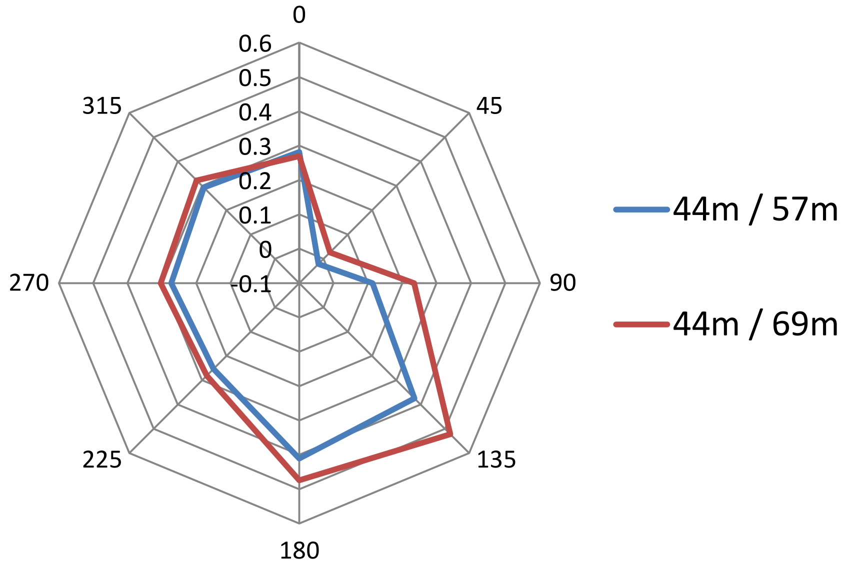
Measurement Campaign

- The scan geometry consists of 12 beams, incremented at 30° intervals in azimuth and elevated to an angle of 25°.
- By convention the Galion's negative doppler shift values denote motion towards the unit.
- Sinusoidal fitting of the Doppler values to obtain upwind flow velocity is then conducted with the four most negative of doppler beams.

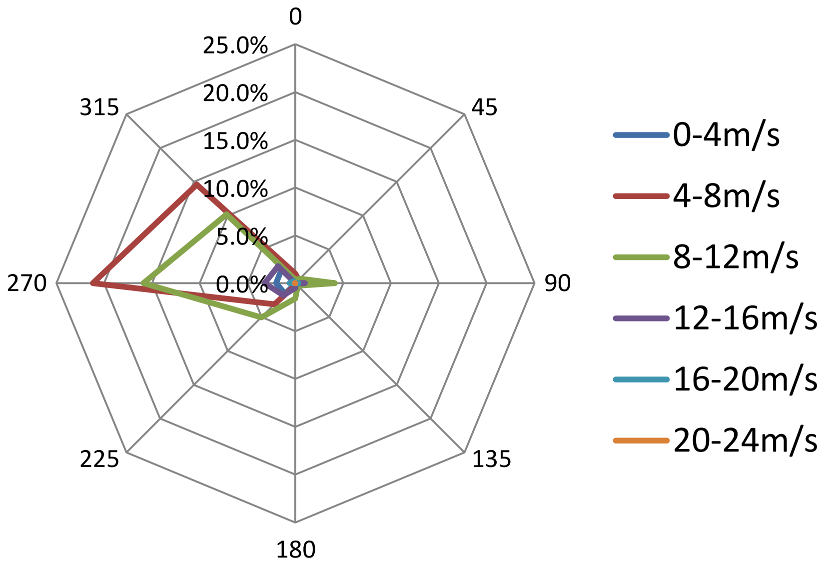


Site Conditions

Wind Shear Rose

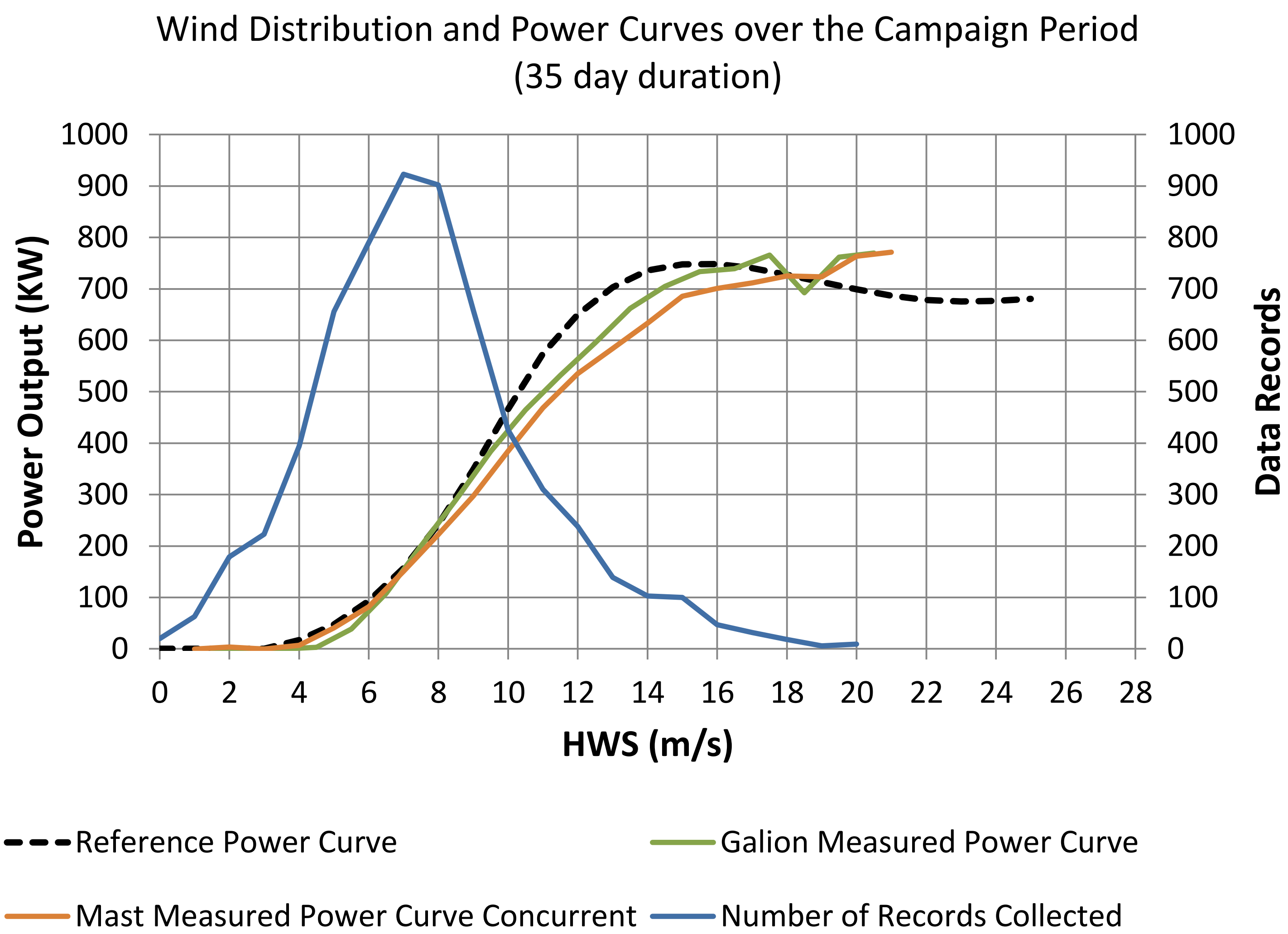


Wind Rose For Campaign Period

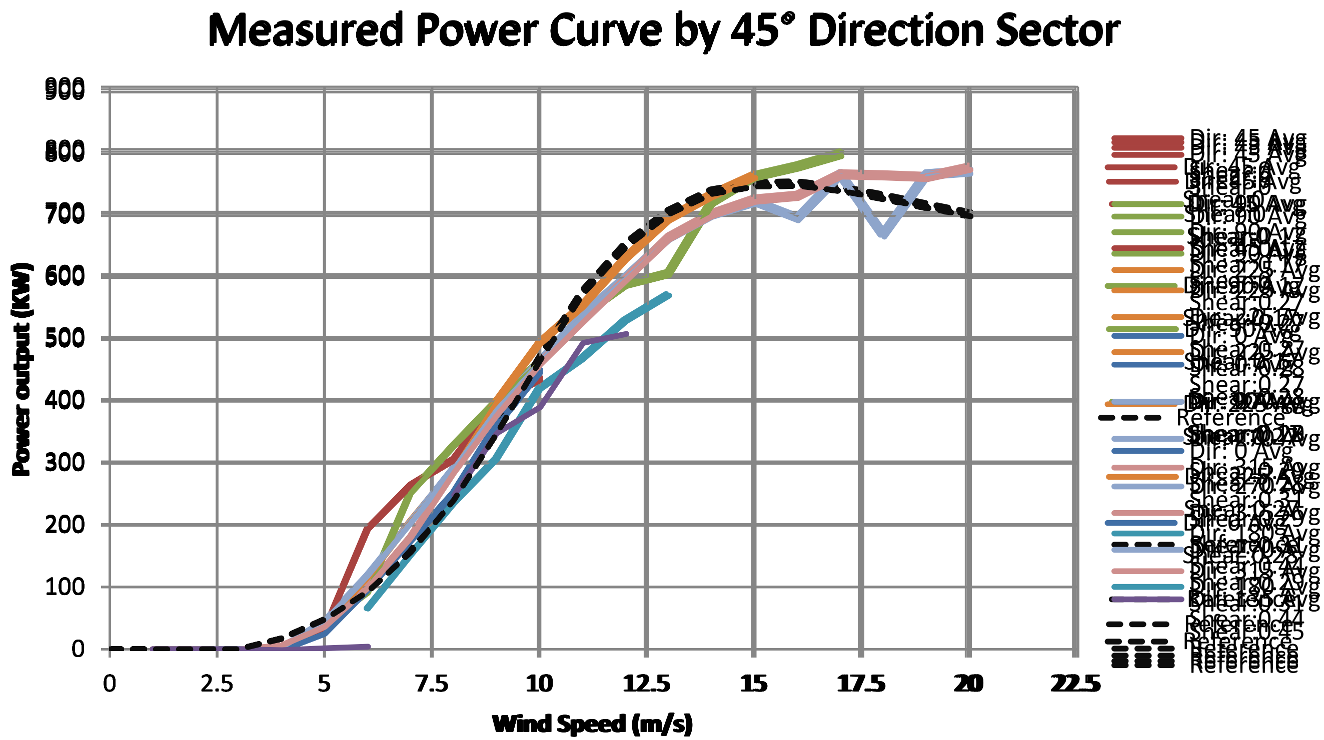


Data Records (10 minute values)		Wind Direction Sector							
		0	45	90	135	180	225	270	315
Wind Speed Bin	0-4m/s	24	12	40	14	2	87	114	116
	4-8m/s	57	29	193	8	11	175	1197	824
	8-12m/s	22	40	233	20	89	285	898	575
	12-16m/s			57	2	27	100	182	144
	16-20m/s			18				34	17
	20-24m/s							3	1

Results

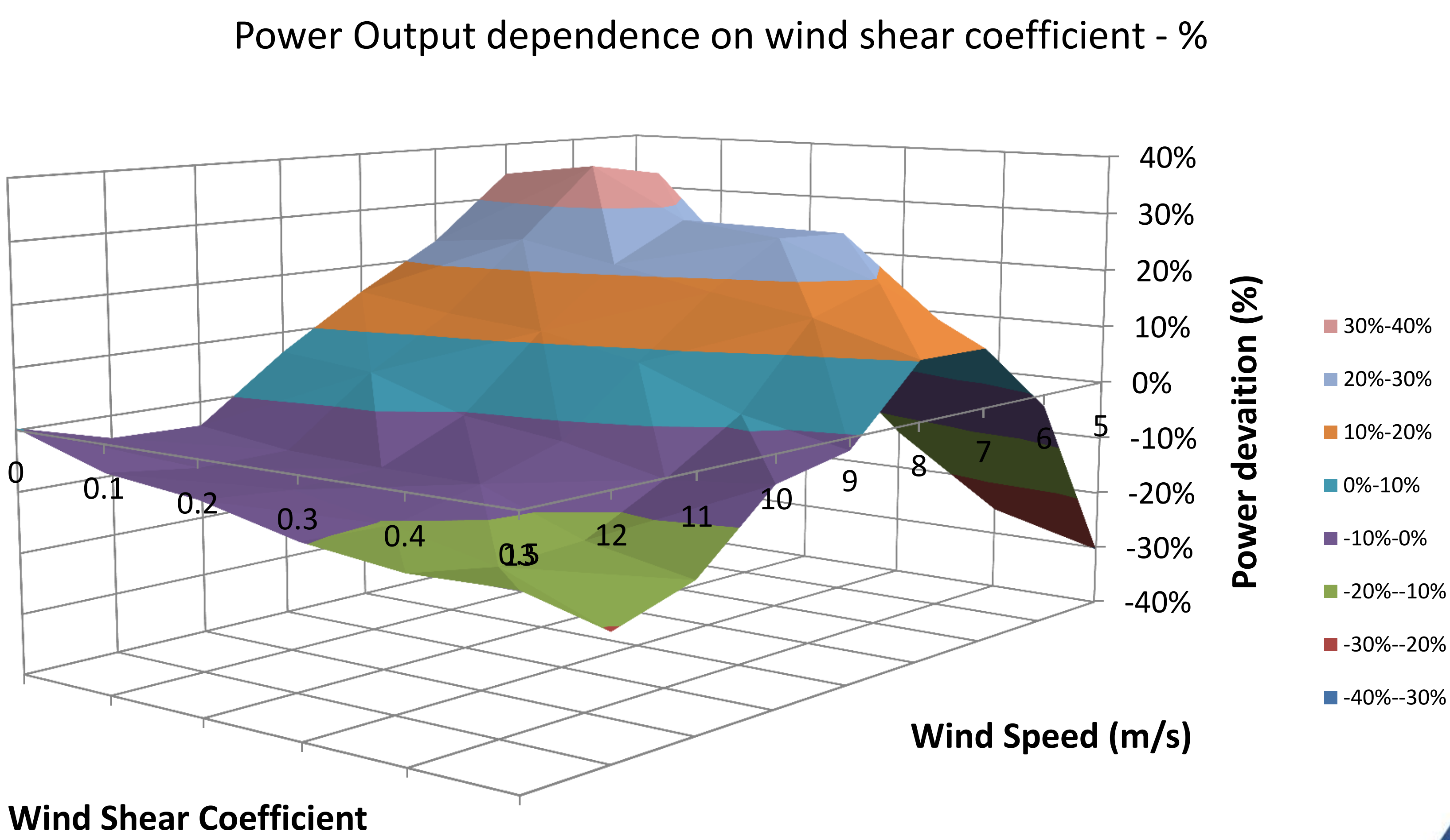

Wind Distribution and Power Curves over the Campaign Period
(35 day duration)
Power Output (KW)
Data Records
HWS (m/s)
0
100
200
300
400
500
600
700
800
900
1000
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
Reference Power Curve
Galion Measured Power Curve
Mast Measured Power Curve Concurrent
Number of Records Collected

Results

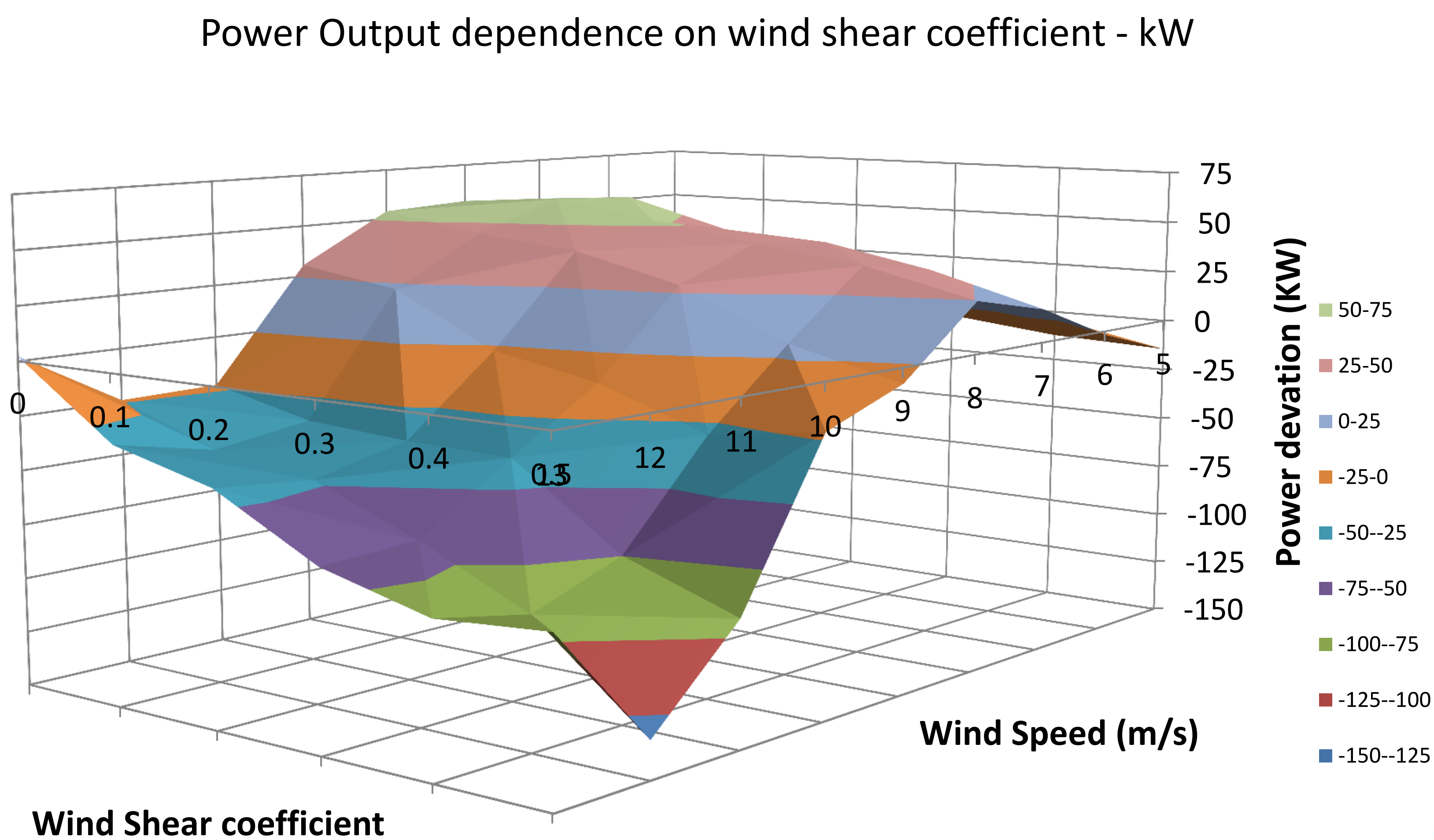


- General trend of decreased power output in the highest shear bins, especially noticeable in direction sectors 180 and 135.

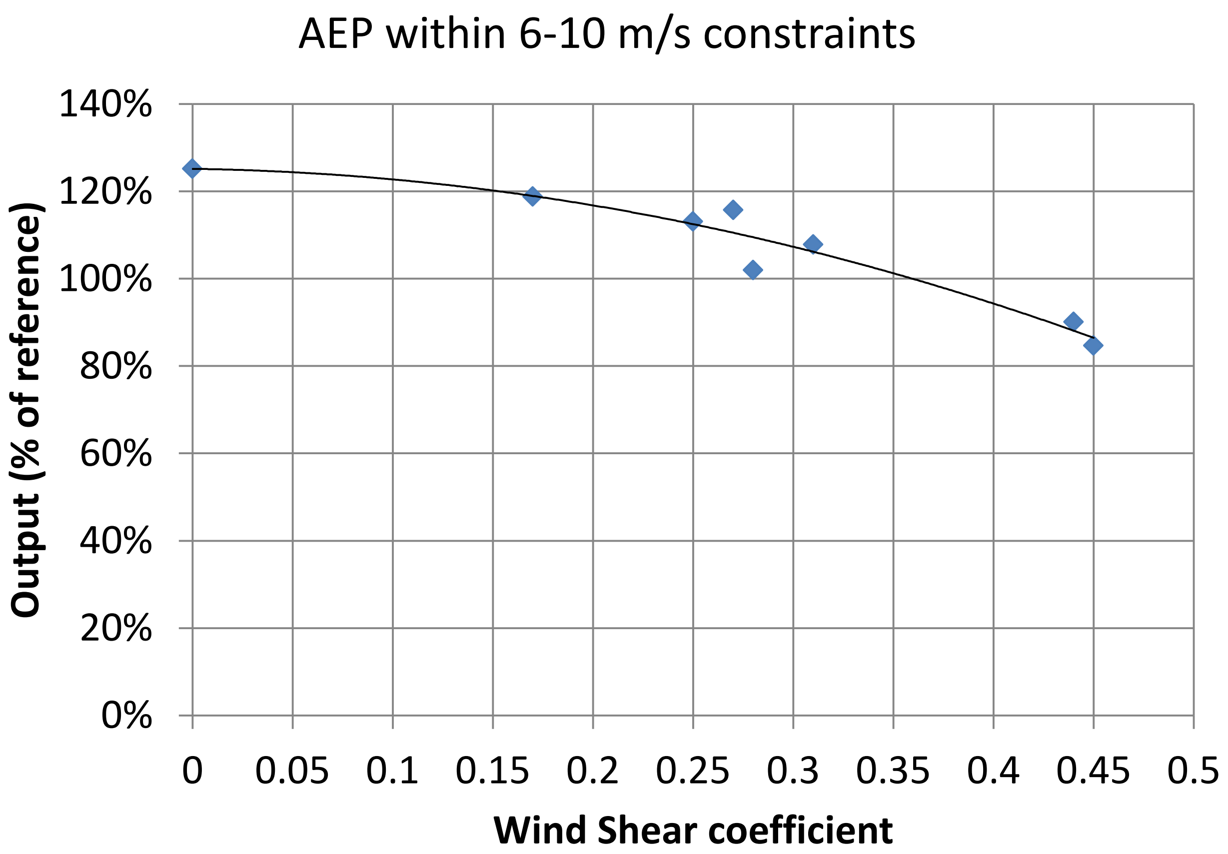
Results


Power Output dependence on wind shear coefficient - %
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
Power devaition (%)
0
0.1
0.2
0.3
0.4
0.5
13
12
11
10
9
8
7
6
5
Wind Speed (m/s)
Wind Shear Coefficient
30%-40%
20%-30%
10%-20%
0%-10%
-10%-0%
-20%--10%
-30%--20%
-40%--30%

Results


Power Output dependence on wind shear coefficient - kW
75
50
25
0
-25
-50
-75
-100
-125
-150
Power devation (KW)
0
0.1
0.2
0.3
0.4
0.5
13
12
11
10
9
8
7
6
5
Wind Speed (m/s)
Wind Shear coefficient
50-75
25-50
0-25
-25-0
-50--25
-75--50
-100--75
-125--100
-150--125

Results



- Difference between actual power output compared with reference power curve.
- Decreasing expected power production for increasing wind shear.

Conclusions

- There is a clear trend between increased wind shear and power curve "smoothing".
- In direction sectors with high wind shear (>0.4), this can result in performance reductions of more than 10% in AEP (conservative estimate!)
- Use of Galion Lidar allows measurement of wind shear across the entire vertical extent of the rotor, not just to hub height.
- Flexible scan geometry allows free stream wind measurements in all directions.
- Better understanding of real site performance allows better asset management and wind farm forecasting.
- Thank you to our colleagues at Agder Energi who made these measurements

sgurr energy

Thank you

Any Questions?

richard.boddington@sgurrenergy.com
+44 141 227 1700
www.sgurrenergy.com