

Wind Turbine Test Site Topographical Testing

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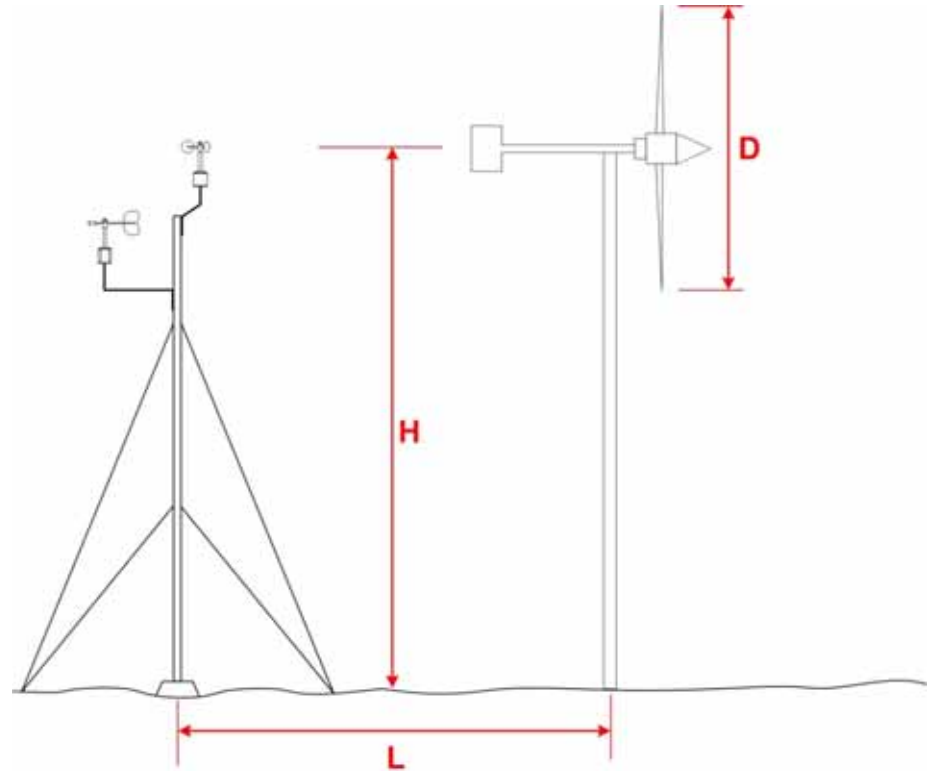


Applicable Standards

- IEC 61400-12-1:2006 Power Performance Measurements of Electricity Producing Wind Turbines
 - Annex B – Assessment of the terrain at the test site
 - Table B.1 – Test site requirements : Topographical Variations
 - Figure B.1 – Illustration of area to be assessed

Reference Variables

- D = Turbine Diameter
- H = Hub Height
- L = Distance Between Turbine & Met Mast
- L is a relationship of the turbine diameter, and must be between $2D$ and $4D$ (ideally $2.5D$)



Measurement Equipment

- Laser Total Station
- Measuring Range min 500m
- Distance, Elevation Change, and Angle Required



IEC 61400-12-1 Requirements

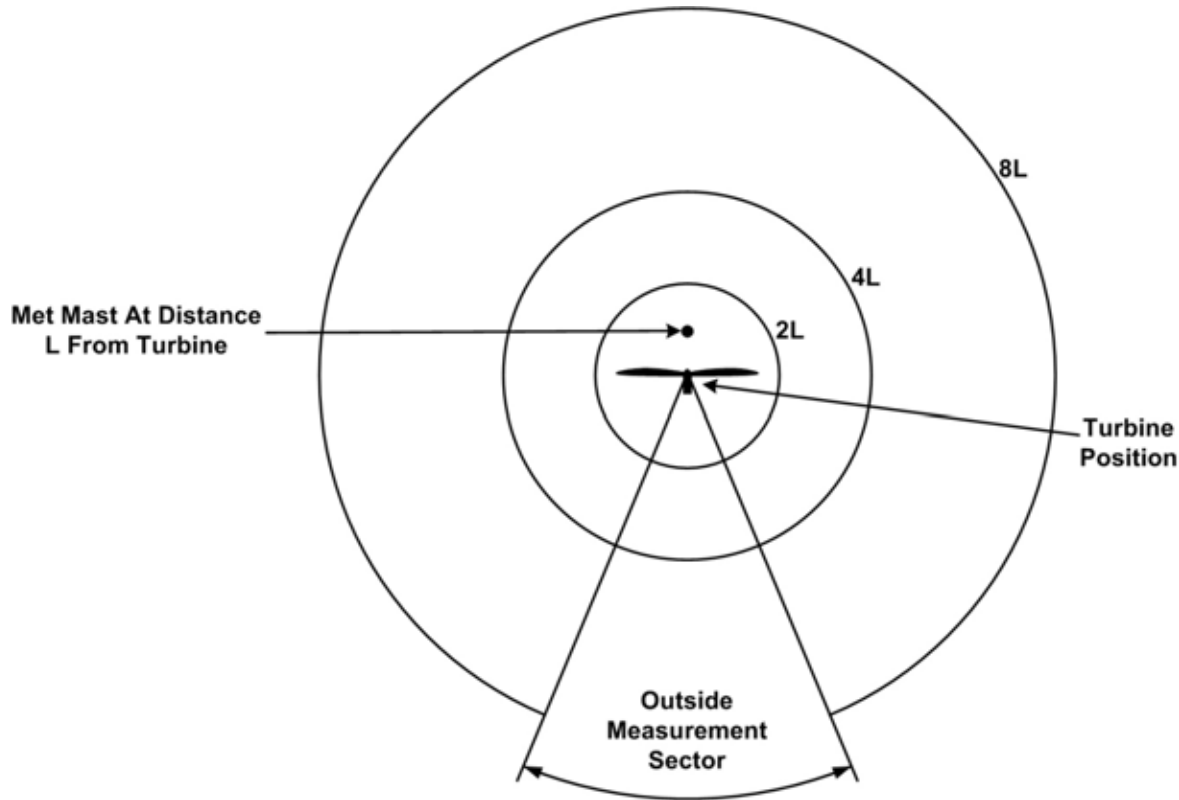


Figure B1 – Illustration Of Area To Be Assessed, Top View

Measurements Required

- Determine Instrument Height, Reflector Height, & North Position
- Establish Measurement Points Required
- Measure Elevation Changes at 2L, 4L, and 8L

Ideal Angle	Actual Angle	8L Distance (m)	8L Variance (m)
10	10.10	111.20	-2.08
20	20.70	113.70	-1.95
30	30.50	113.20	-1.74
40	40.50	114.20	-1.43
50	50.30	112.10	-1.09
60	60.60	111.80	-0.71
70	70.60	111.30	-0.22
80	80.26	112.00	0.27
90	91.30	111.90	0.97
100	100.32	114.10	1.62
110	110.70	111.50	2.22
120	120.80	113.30	2.74
130	130.30	112.50	2.97
140	140.60	112.30	3.16
150	150.70	113.00	2.85
160	158.70	111.40	2.51

IEC 61400-12-1 Requirements

Table B1 – Test Site Requirements : Topographical Variations

Distance	Sector	Maximum Slope %	Maximum Terrain Variation From Plane
<2L	360°	<3*	<0.04*(H+D)
≥2L and <4L	Measurement Sector	<5*	<0.08*(H+D)
≥2L and <4L	Outside Measurement Sector	<10**	N/A
≥4L and <8L	Measurement Sector	<10*	<0.13*(H+D)

* The maximum slope of the plane, which provides the best fit to the sectoral terrain and passes through the tower base

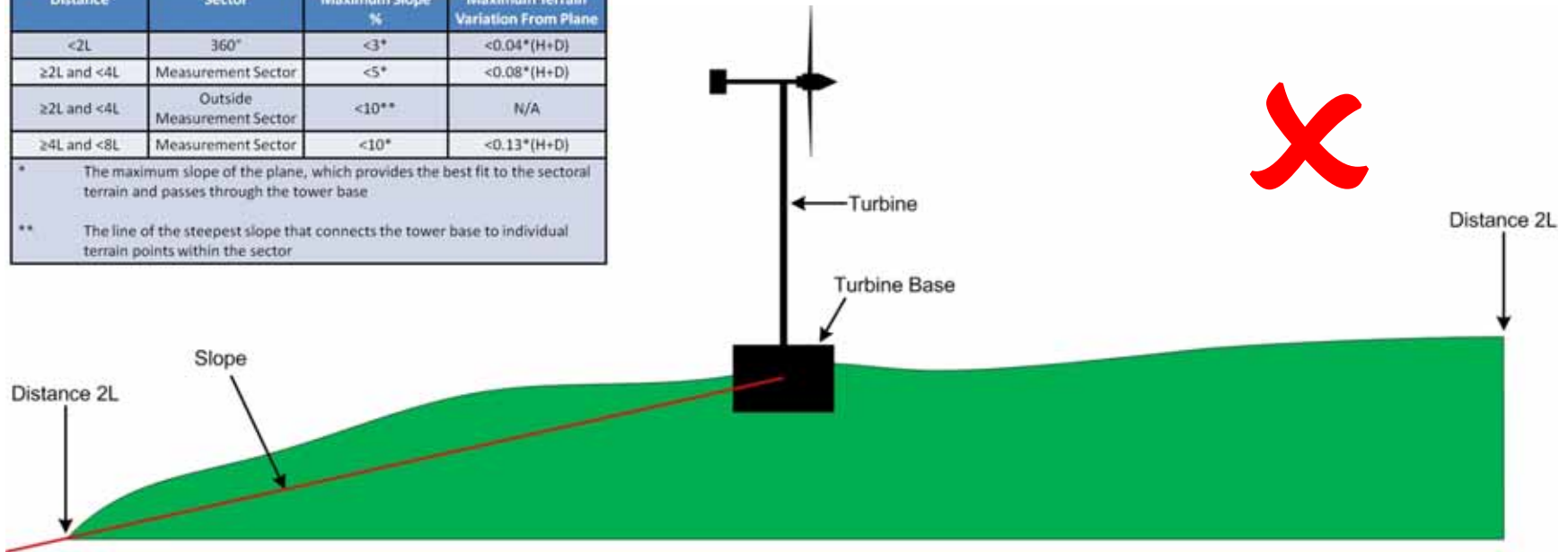
** The line of the steepest slope that connects the tower base to individual terrain points within the sector

Slope Measurement

Distance	Sector	Maximum Slope %	Maximum Terrain Variation From Plane
<2L	360°	<3°	<0.04*(H+D)
≥2L and <4L	Measurement Sector	<5°	<0.08*(H+D)
≥2L and <4L	Outside Measurement Sector	<10**	N/A
≥4L and <8L	Measurement Sector	<10*	<0.13*(H+D)

* The maximum slope of the plane, which provides the best fit to the sectoral terrain and passes through the tower base

** The line of the steepest slope that connects the tower base to individual terrain points within the sector



Slope is from tower base as point of origin rather than through the base, and therefore does not include land slope on the opposite side

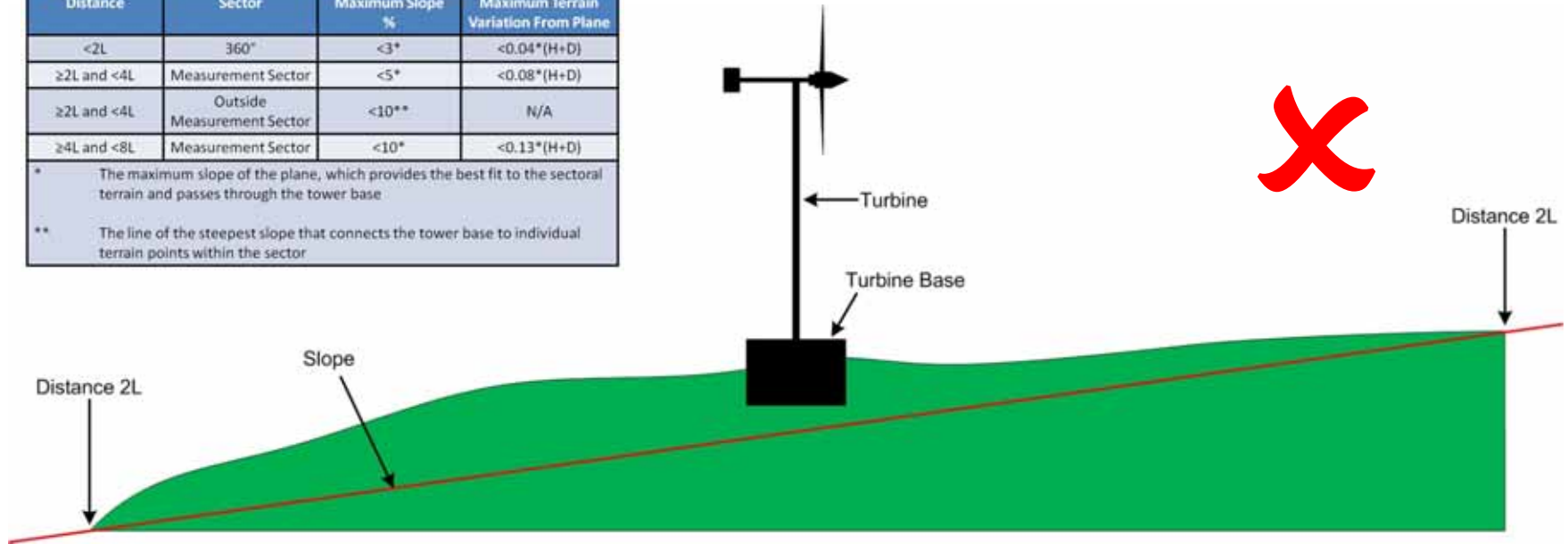
However this is the correct method of measuring the steepest slope for areas outside of the measurement sector

Slope Measurement

Distance	Sector	Maximum Slope %	Maximum Terrain Variation From Plane
<2L	360°	<3°	<0.04*(H+D)
≥2L and <4L	Measurement Sector	<5°	<0.08*(H+D)
≥2L and <4L	Outside Measurement Sector	<10**	N/A
≥4L and <8L	Measurement Sector	<10°	<0.13*(H+D)

* The maximum slope of the plane, which provides the best fit to the sectoral terrain and passes through the tower base

** The line of the steepest slope that connects the tower base to individual terrain points within the sector



The slope between these two measurement points is direct, and therefore not a best fit to the sectoral terrain, nor does it pass through the tower base

Slope Measurement

Distance	Sector	Maximum Slope %	Maximum Terrain Variation From Plane
<2L	360°	<3°	<0.04*(H+D)
≥2L and <4L	Measurement Sector	<5°	<0.08*(H+D)
≥2L and <4L	Outside Measurement Sector	<10**	N/A
≥4L and <8L	Measurement Sector	<10°	<0.13*(H+D)

* The maximum slope of the plane, which provides the best fit to the sectoral terrain and passes through the tower base

** The line of the steepest slope that connects the tower base to individual terrain points within the sector

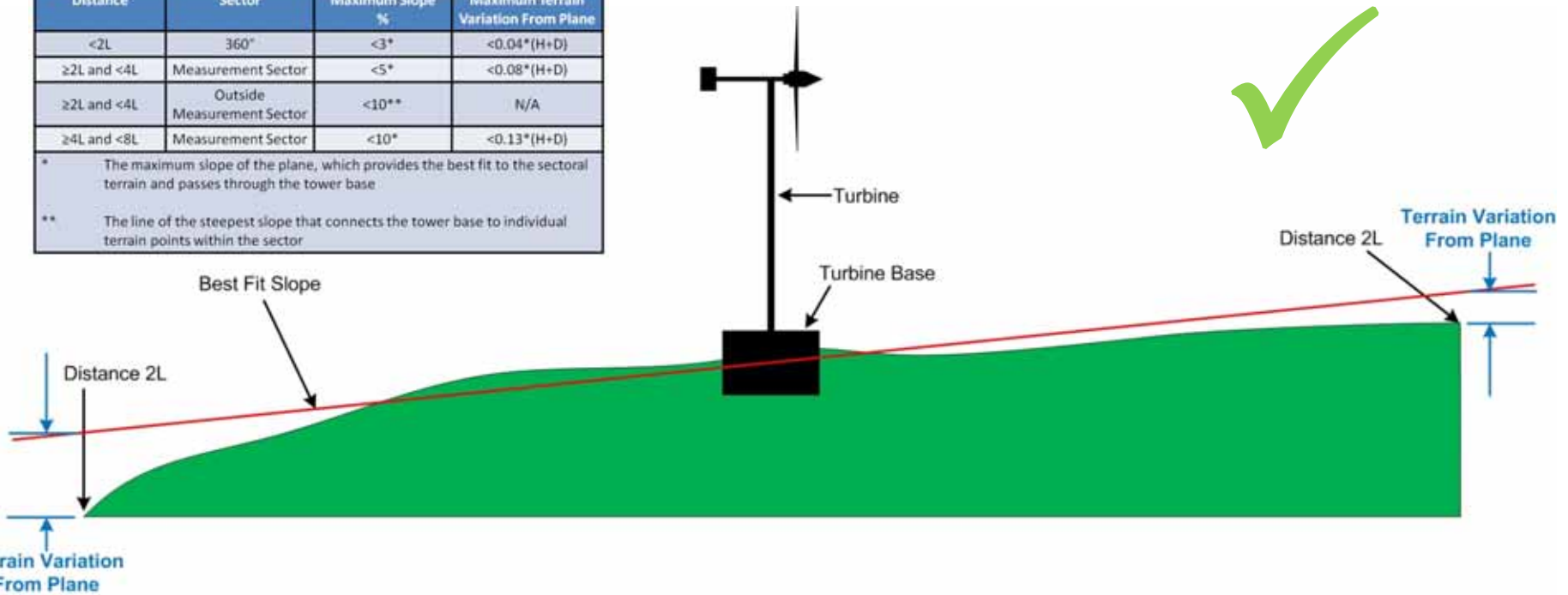


Table B1 - * The maximum slope of the plane, which provides the best fit to the sectoral terrain and passes through the tower base.

Assessment Of Data

- Resulting data can be assessed using 3D modelling of terrain data, with known upper and lower bounds
- Alternative to use spreadsheet calculating best line fit across each opposite compass point

	8L Distance						
Bearing Angle	X Values	Y Values	Best Fit Slope	Best Fit Y Value	Deviation	Maximum Terrain Deviation Limit	Pass/Fail
10	-111.20	-2.08	0.94%	-1.05	1.03	2.70	Pass
190	112.20	0.03		1.06	1.03	2.70	Pass
20	-113.70	-1.95	0.38%	-0.44	1.51	2.70	Pass
200	112.34	-1.10		0.43	1.53	2.70	Pass
30	-113.20	-1.74	-0.12%	0.14	1.88	2.70	Pass
210	113.90	-2.00		-0.14	1.86	2.70	Pass
40	-114.20	-1.43	-0.58%	0.67	2.10	2.70	Pass
220	113.10	-2.78		-0.66	2.12	2.70	Pass
50	-112.10	-1.09	-0.91%	1.03	2.12	2.70	Pass
230	111.20	-3.15		-1.02	2.13	2.70	Pass
60	-111.80	-0.71	-1.27%	1.42	2.13	2.70	Pass
240	113.10	-3.54		-1.44	2.10	2.70	Pass

Outside Requirements?

- If terrain does not comply with the requirements, then a site calibration is required
- Site calibration involves locating a met mast at the turbine position as well as the met mast in its intended position
- Wind speed is then measured and grouped in 10 degree increments, and a table of correction factors produced according to direction, to be used for future power performance test regime

Thank You For Your Attention