

G97 90m Load Validation Campaign Bladed 3.72

Gamesa



Bladed User Conference, 24/09/2014
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G9X Loads & Dynamics Team Leader

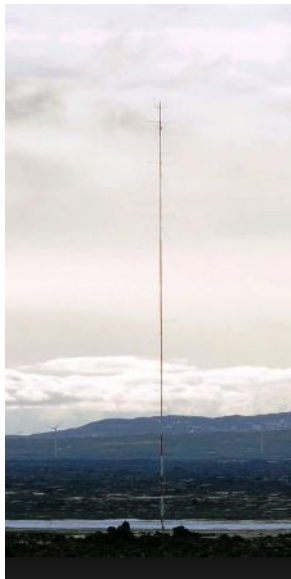
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0.0 INTRODUCTION

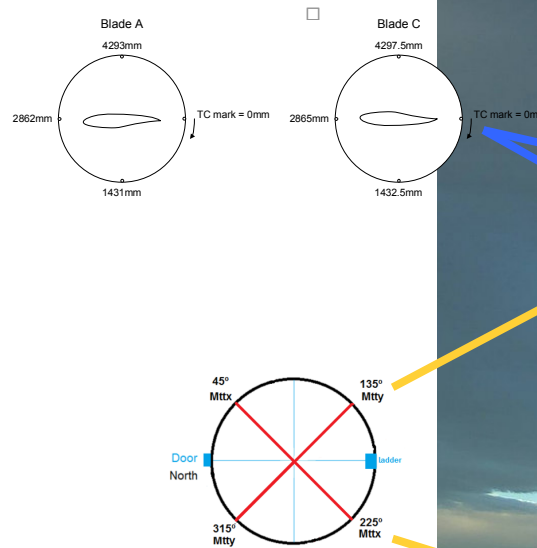
97 90m at NREL NWTC (USA)

Are our models and aeroelastic codes reproducing the dynamic behaviour of the WT? Are the load levels accurate?

→ Met mast



→ Prototype



2

Uncertainties are everywhere

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0.0 INDEX

1.0 Wind Conditions recreation

2.0 Aeroelastic Model adaptation to Prototype

3.0 Power production Simulations and Post Processing

4.0 Comparison measurements vs. simulations: FBM

4.1 Operating parameters

4.2 Extreme and Fatigue Loads

4.3 Frequency Analysis (FFT)

5.0 Conclusion and Future improvements

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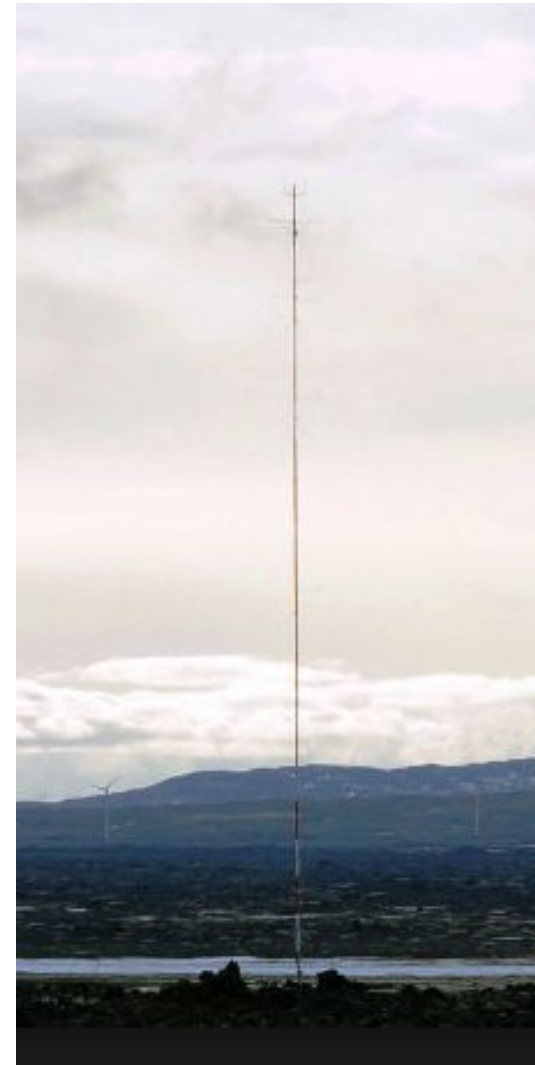
1.0 WIND CONDITIONS RECREATION

→ Necessary wind data for the simulations are measured from the Met Mast: the mean values of

- o Density
- o Wind Shear
- o Wind Direction
- o TI: longitudinal, vertical and lateral
- o Upflow

The screenshot shows the 'Wind' software interface with the 'Time varying wind' tab selected. The 'Turbulent wind file name' is set to 'Y:\ETLACProjects\G97\ETLACProjects\...'. The 'Mean wind speed' is 7.76882 m/s. The 'Height at which speed is defined' is 78.153 m. The 'Turbulence Intensity (longitudinal)' is 6.95215%, 'Turbulence Intensity (lateral)' is 5.56172%, and 'Turbulence Intensity (vertical)' is 5.38177%. The 'Wind direction (from north)' is -6.77491 deg and 'Flow inclination' is 7.03785 deg. The 'Refer wind speed to hub height' checkbox is checked. The 'Additional sinusoidal wind direction transient' section shows 'Amplitude of direction change' as 0 deg, 'Start time for transient' as 0 s, 'Duration of transient' as 0 s, and 'Type of transient (half/full wave)' as Full. The 'Continuous direction change' section shows 'Rate of direction change' as 0 deg/s. The 'Interpolation scheme' is set to Linear. The 'OK' and 'Cancel' buttons are at the bottom.

Parameter	Value
Turbulent wind file name	Y:\ETLACProjects\G97\ETLACProjects\...
Mean wind speed	7.76882 m/s
Height at which speed is defined	78.153 m
Turbulence Intensity (longitudinal)	6.95215 %
Turbulence Intensity (lateral)	5.56172 %
Turbulence Intensity (vertical)	5.38177 %
Wind direction (from north)	-6.77491 deg
Flow inclination	7.03785 deg
Amplitude of direction change	0 deg
Start time for transient	0 s
Duration of transient	0 s
Type of transient (half/full wave)	Full
Rate of direction change	0 deg/s



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2.0 AEROELASTIC MODEL ADAPTATION TO PROTOTYPE

→ Blade Adaptation:

- o Mean Blade definition from the mounted three blades.
- o Imbalance setting.

→ Drive Train adaptation

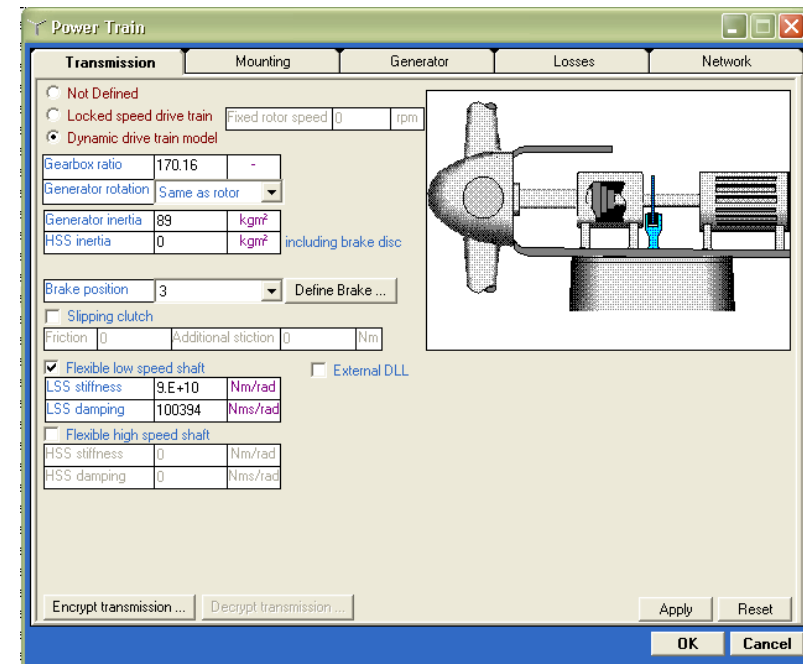
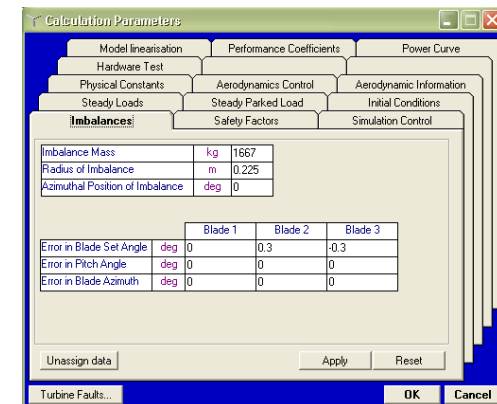
- o Drive Train frequency: the aeroelastic model Drive Train Stiffness can be modified to match the frequency measured in field.

→ Others

- o In other to minimize error sources: pitch TC...

→ Frequency verification

- o The Campbell diagram can be performed to guarantee deviations of the prototype are low.



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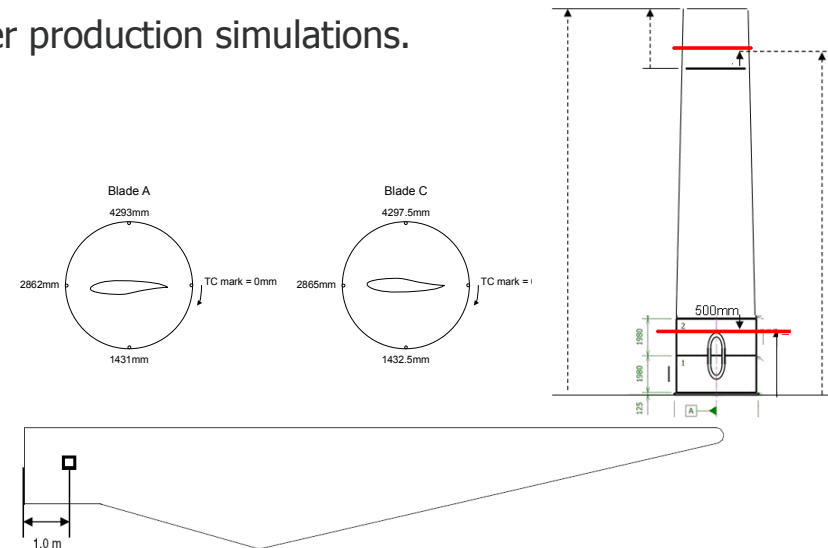
3.0 POWER PRODUCTION SIMULATIONS AND POST PROCESSING

→ Winds and Simulations

- o 585 10min measurements, Capture Matrix Fulfilled!
- o 585x6 seeds = 3510 turbulent winds and power production simulations.

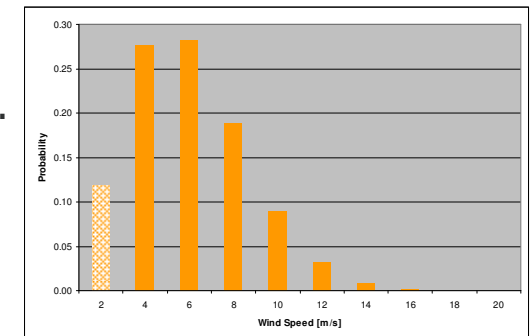
→ Channel Combination

- o Shaft Gauges: MSM_y and MSM_z calculation.
- o Tower and Blade Gauges:
 1. intermediate sections .
 2. Different reference systems (Blade).
 3. Rotation due to gauges positionning.



→ Fatigue Equivalent Load calculation

- o 1Hz Rainflow Cycle Counting for 10min Measurements & Simulations.
- o Representative Equivalent Load per Wind Speed bin.
- o 20 year partial equivalent load.

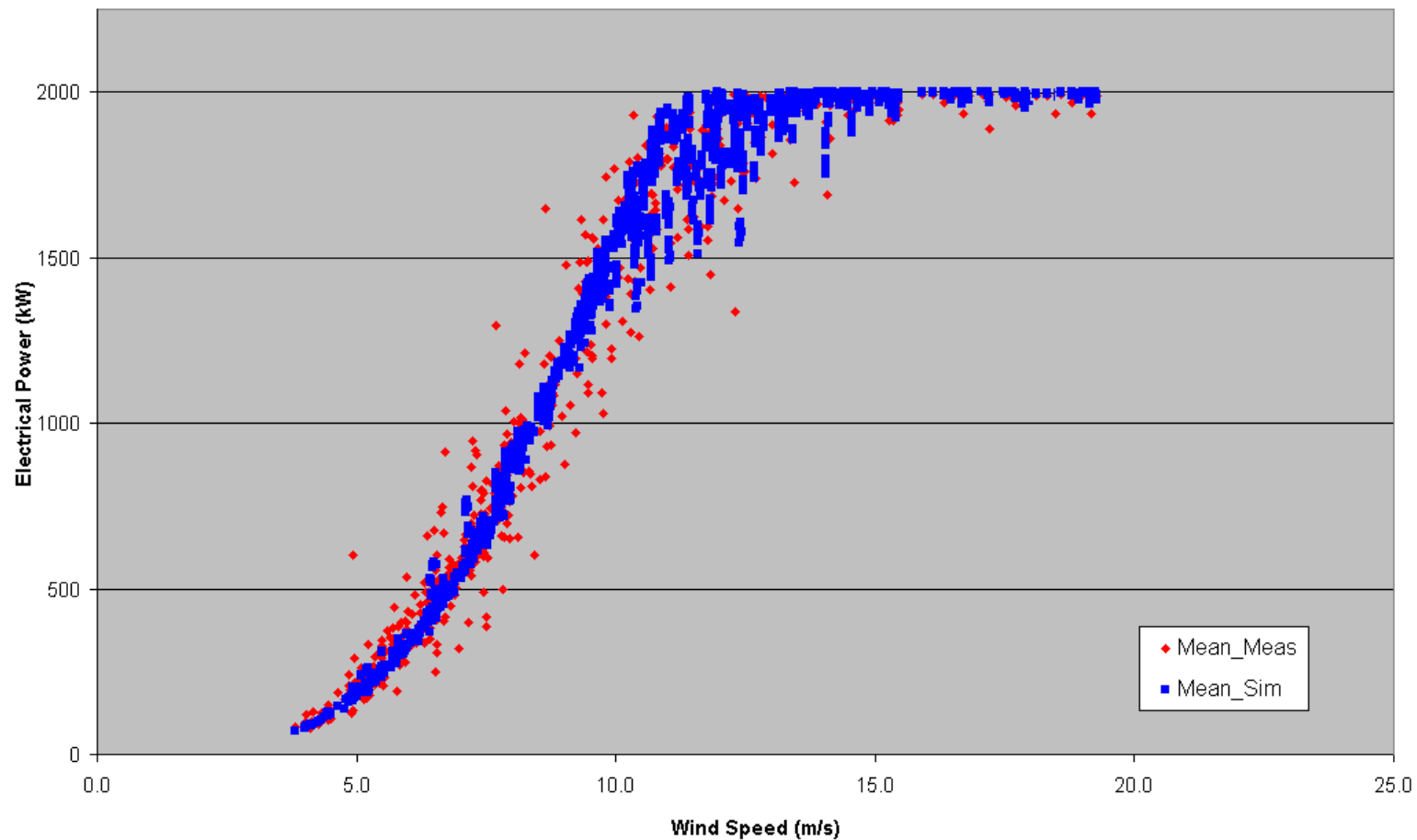


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4.0 COMPARISON MEASUREMENTS VS SIMULATIONS

4.1 OPERATING PARAMETERS

→ Electrical Power vs. Wind Speed

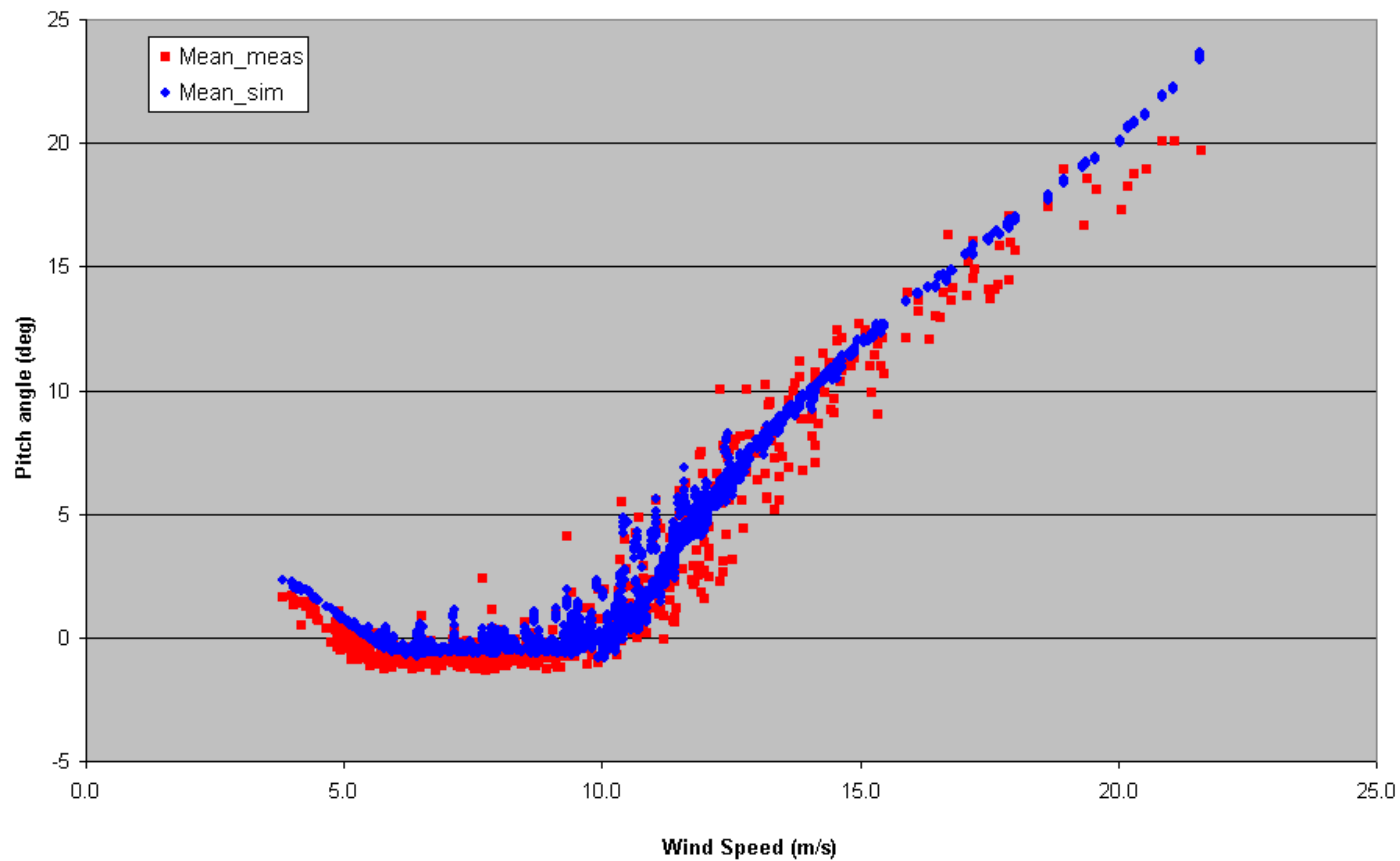


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4.0 COMPARISON MEASUREMENTS VS SIMULATIONS

4.1 OPERATING PARAMETERS

→ Mean values of the Pitch

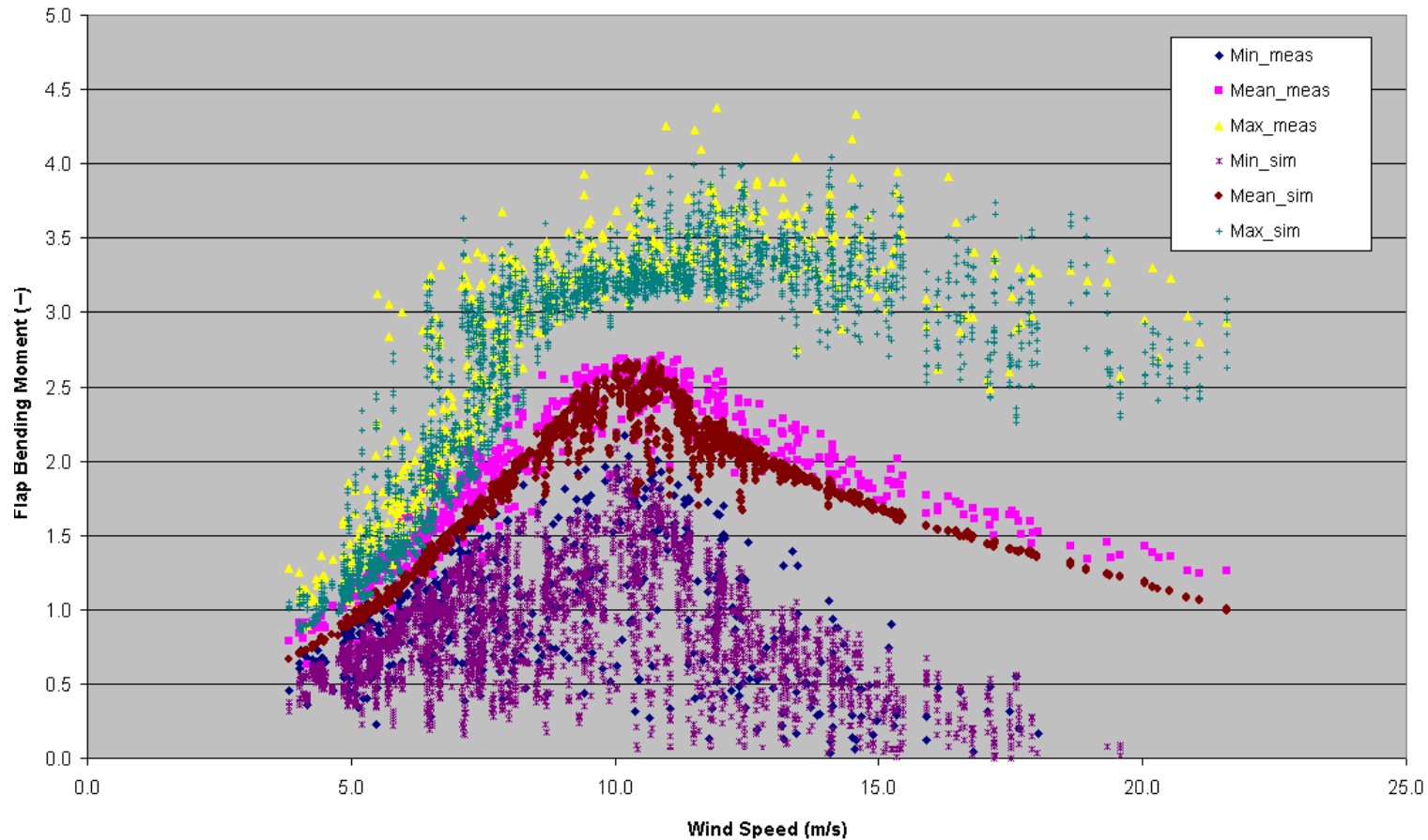


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4.0 COMPARISON MEASUREMENTS VS SIMULATIONS

4.2 LOADS

→ FBM STATISTICS: MAX, MEAN & MIN

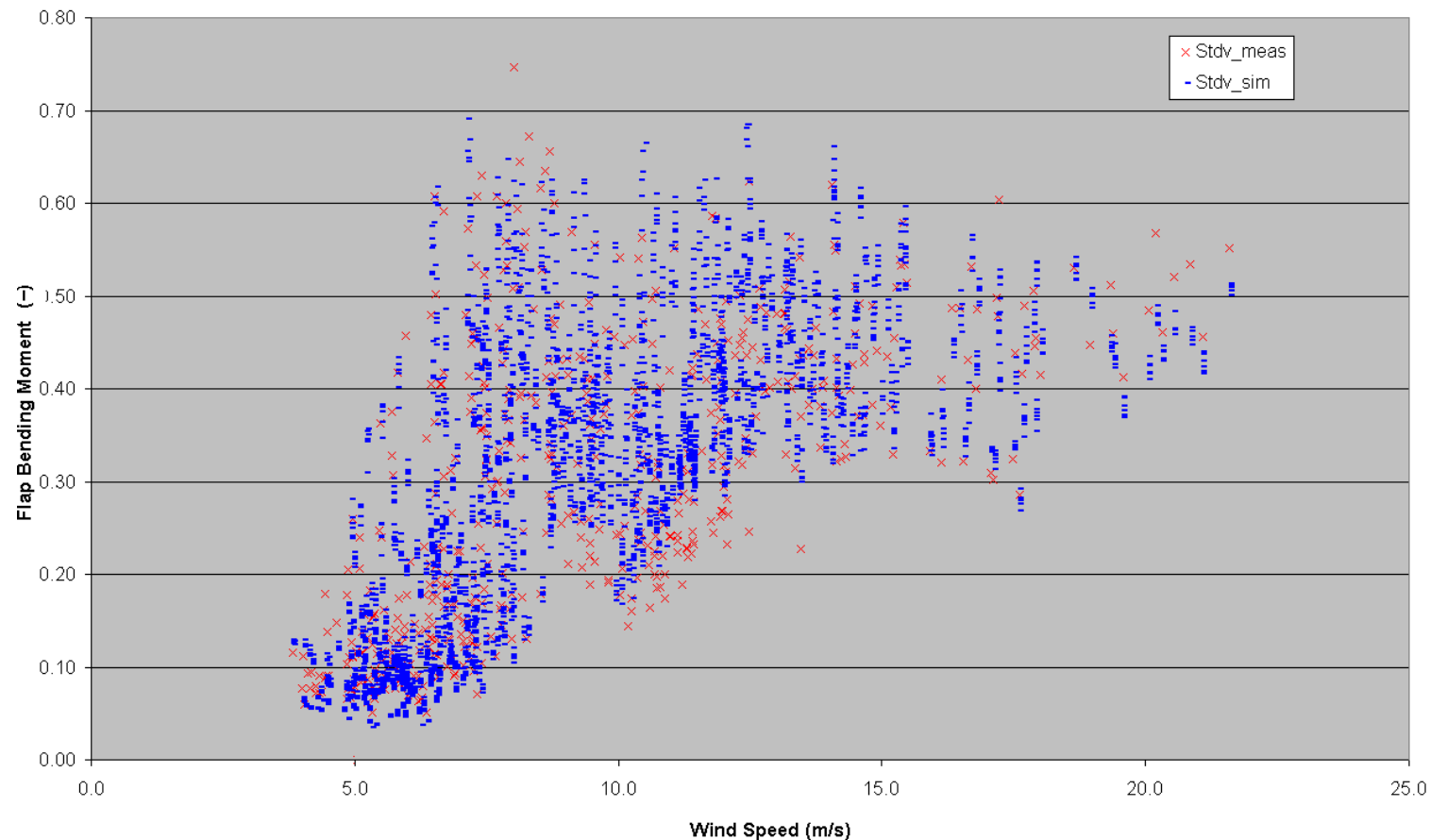


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4.0 COMPARISON MEASUREMENTS VS SIMULATIONS

4.2 LOADS

→ FBM STATISTICS: STD DEVIATION

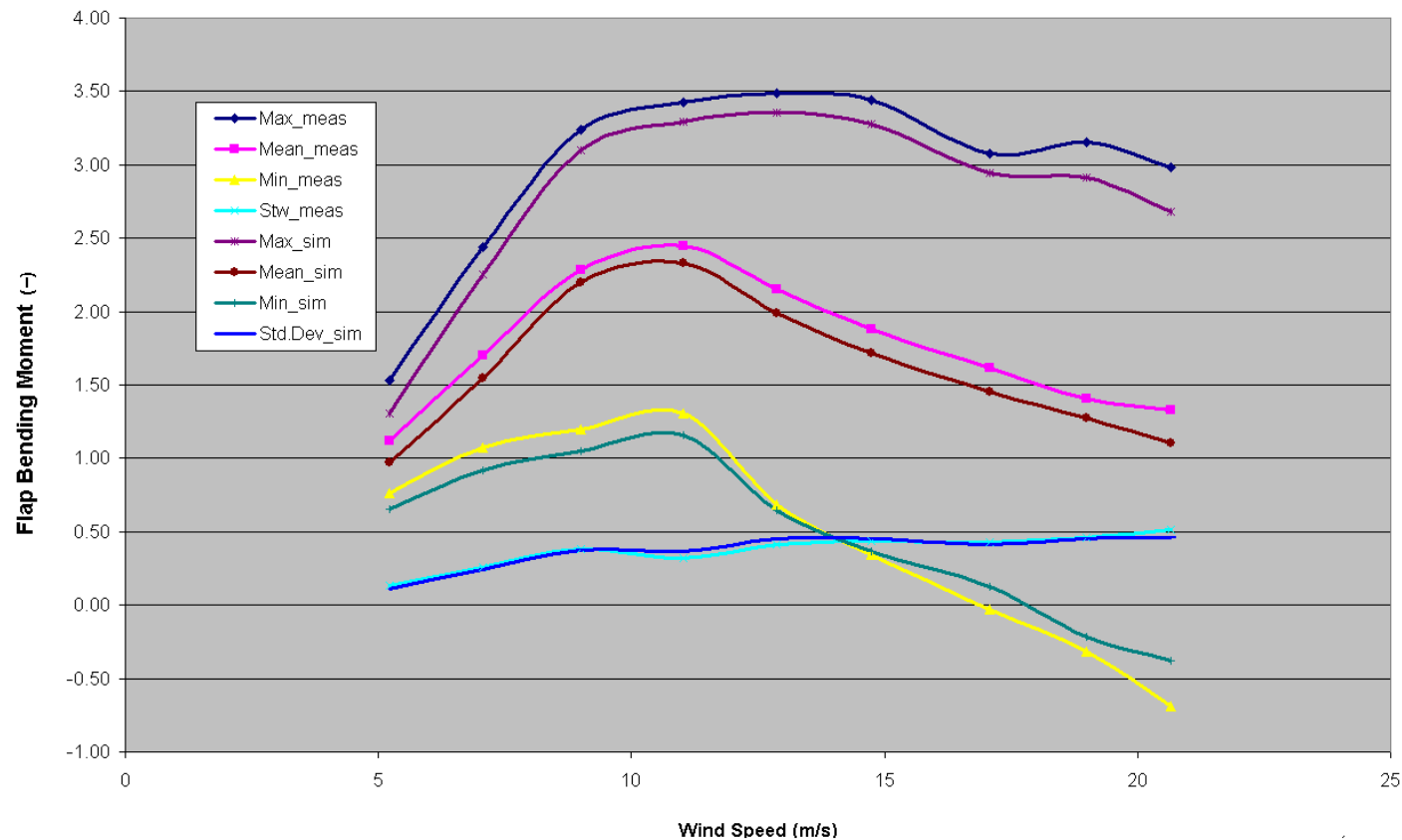


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4.0 COMPARISON MEASUREMENTS VS SIMULATIONS

4.2 LOADS

→ FBM STATISTICS: MEAN VALUES PER BIN



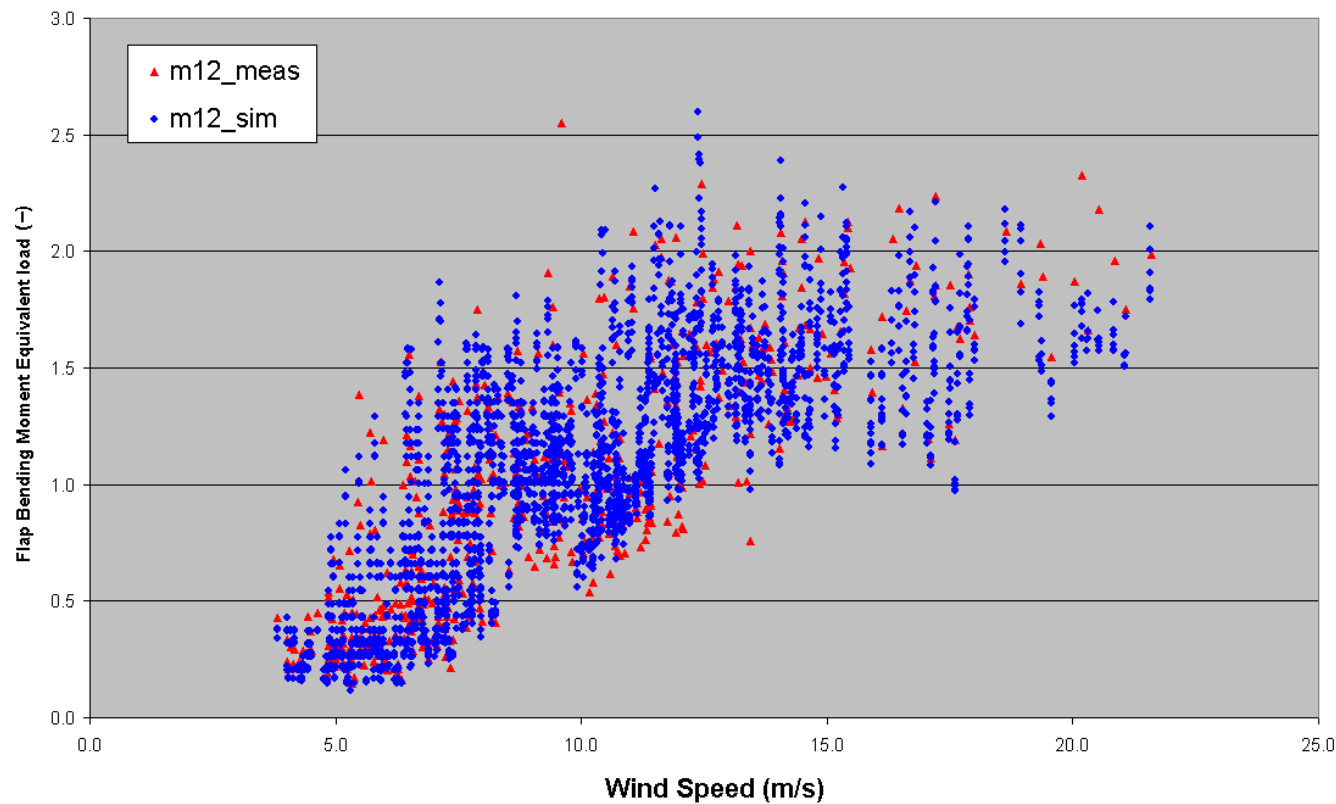
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4.0 COMPARISON MEASUREMENTS VS SIMULATIONS

4.2 LOADS

→ FBM FATIGUE LOADS

		Blade_My		
		Leq4	Leq8	Leq12
Sims	EqL 20 Years 1Hz	0.913	1.117	1.214
Measured	EqL 20 Years 1Hz	0.895	1.134	1.251
		2.0%	-1.5%	-3.0%



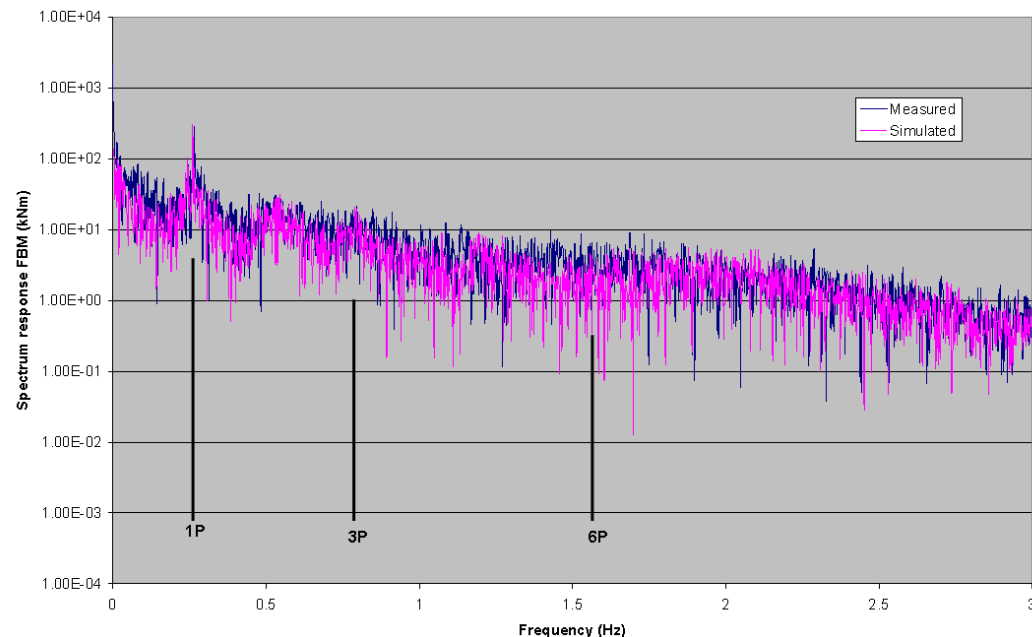
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4.0 COMPARISON MEASUREMENTS VS SIMULATIONS

4.3 FREQUENCY ANALYSIS

→ FBM FFT analysis

- o A 10min measurement time series is selected ($V=15\text{m/s} > V_{\text{rated}}$) → a power production simulation is created with the same wind conditions.
- o An FFT analysis is performed for all the variables involved in the comparison with both time series, measurements and simulations.
- o Response Spectra are compared in order to identify dynamic discrepancies.



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5.0 CONCLUSIONS AND IMPROVEMENTS

→ Conclusions

- o Despite all the uncertainties involved in the process, good agreement is observed in general.
- o Strong interaction with the instrumentation entity is essential to find the sources of discrepancies.
- o The selection of the Wind Site for the prototype is important (avoid Complex Terrain).
- o A lot of data involved in measurements and, specially, in simulations → a good data management (preprocessing, filtering, post processing...) is essential for efficiency.
- o A lot of useful information gathered → Maximise its use!

14

→ Improvements

- o Grow the possibilities of the simulations (wind shear, wind direction, input different blades...).
- o Quantify the uncertainties in order to have a better idea of where we really are.



G97 90m Load Validation Campaign ACKNOWLEDGEMENTS AND QUESTIONS

→ **Aknowledgements**

- o G9X Loads and Dynamics Team, especially Jesús Javier Guerrero and Roberto Santivañez.

→ **Thank you very much for your attention**

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