PO.ID 019

Haliade150 - 6mw type certificate validation

N. del Arco, F. Navarro, F.X. Sanz, C. García

Alstom Renovables España S.L.

Abstracts

Increasing the size of the wind turbines is essential for offshore projects since scaling factors achieve economic feasibility despite the cost of substructures. Nevertheless it forces the limits of current designs, and the development of a new generation of larger and more powerful wind turbines is taking place.

Alstom has developed, manufactured, installed and now certified one of the larger wind turbines ever seen. The measurements campaign at the selected site (Le Carnet, Nantes, France) was satisfactory carried out and in December 2014 it has successfully accomplished Type Certificate.

The exhaustive measurement campaign applied on Haliade 150-6MW Prototype is compared with simulations to demonstrate the efficient and robust design. It embraces modal parameters, power curve comparison showing that 100% of annual yield is accomplished, loads not only in normal operation but also in idling and events, and the treatment of the data includes diverse ways of validation (statistics, damage equivalent loads, time series, Operational Modal Analysis, frequency spectrum).

Objectives

The design of a wind turbine is developed with models and methodologies based on knowledge of the company and on standards. A comparison with real results is required in order to validate methodology, codes and models. Usually, this validation is performed by measurement campaign at a prototype.

For Haliade 150-6MW, a deep analysis has been performed exceeding standards requests in order to extensively check its dynamics, performance and reliability.

Following, the most representative analysis performed during validation, including loads, dynamics and power curve performance are presented:

- **wind turbine dynamics validation**: rotor and tower natural frequencies, dampings and mode shapes of first order modes obtained based on the measured responses are compared with the aeroelastic model results.
- **performance validation**: power curve measured and predicted are compared.
- **loads validations**: statistical, rainflow and equivalent loads comparison has been performed, obtaining a good matching between measurements and simulations. The blade has been particularly deeply analysed by comparing load not only at blade root, but at several blade stations.

Methods

- **Wind turbine dynamics validation:**

The measured natural frequencies and damping were extracted from time series in normal operation using the Operational Modal Analysis (OMA) methodology. This method is based on the singular value decomposition (SVD) of the power spectral density matrix. The singular values can be represented as a modal indication function (MIF) curve, where each peak indicates the existence of a mode.

Furthermore, OMA uses an optimization method (Polyreference Least Square Complex Frequency method) to find the natural frequencies, dampings and mode shapes of a theoretical model that better represents the measured power spectral density matrix.

This optimization is carried out for different orders of the model to improve the mode identification. The stable poles resulting of this optimization method indicate the presence of modes or excitants, and are represented together with the MIF curve in the stabilization diagram. The natural frequencies are then extracted by evaluating this stabilization diagram.

- **Power curve comparison**

The HAL150 Power curve measurement is done by an accredited body*(DEWI*) following the IEC 61400-12 standard and using a capture matrix data of more than1800 10-minutes measurements. All these information is compared with the predicted power curve at the same external conditions.

- **Loads comparison:**

The prototype was instrumented with a set of sensors to carry out the certification.

Particularly, blades of Haliade150 includes the Blade Monitoring System (BMS), that has optical strain sensors located at 8m and 16m from the blade root and extrapolates their measurements to calculate the bending moments at the root section of the blade, which are used for the Individual Pitch Control (IPC). These sensors allows Alstom to measure loads at these sections and to perform a deep analysis of blades loads by comparing results at different sections of the blades.

An statistical comparison of measurements and simulations was performed by plotting measurements and simulations with ranges of external conditions representative of the whole capture matrix..

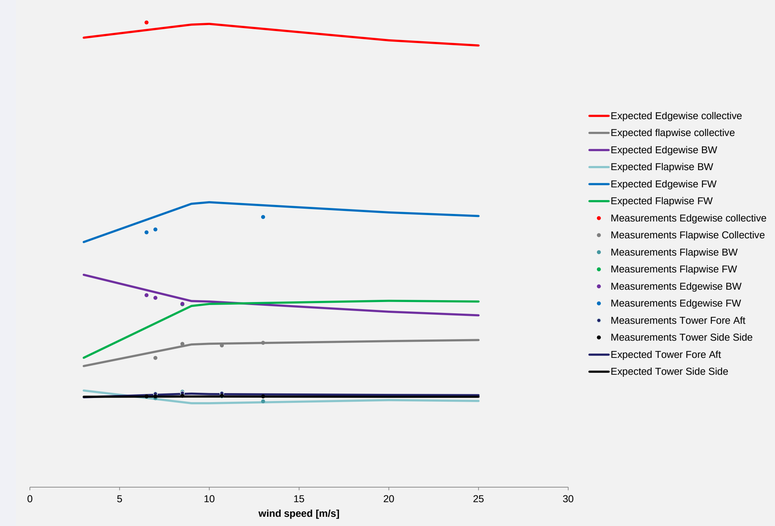
Results

An extract of the comparisons performed is presented here.

- **Wind turbine dynamics validation:**

The first rotor and tower natural frequencies comparison is presented.

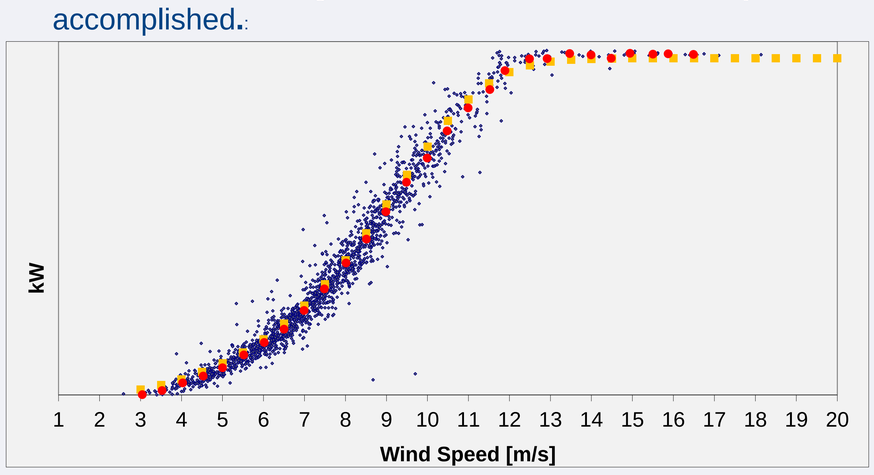
As it can be observed, the natural frequencies obtained with OMA match well with those predicted.



Waterfall diagran in non rotating reference system

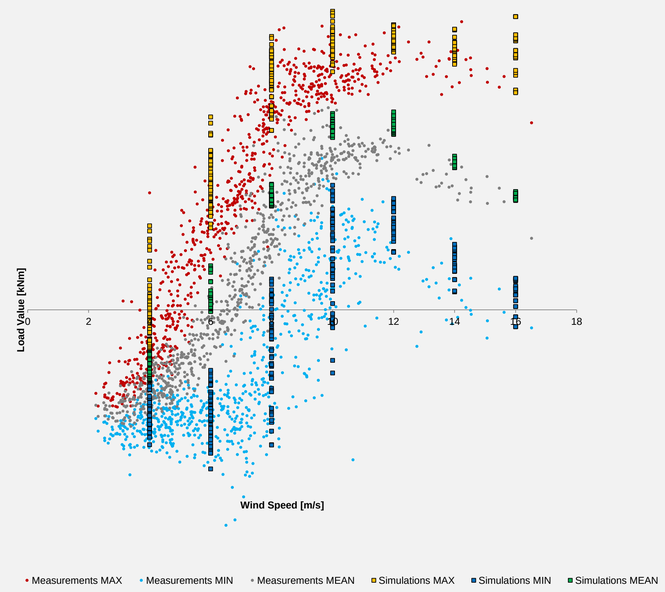
- **performance validation power curve analysis:**

The power curve measured and predicted comparison shows that, following the standards 100% of annual yield is accomplished.:

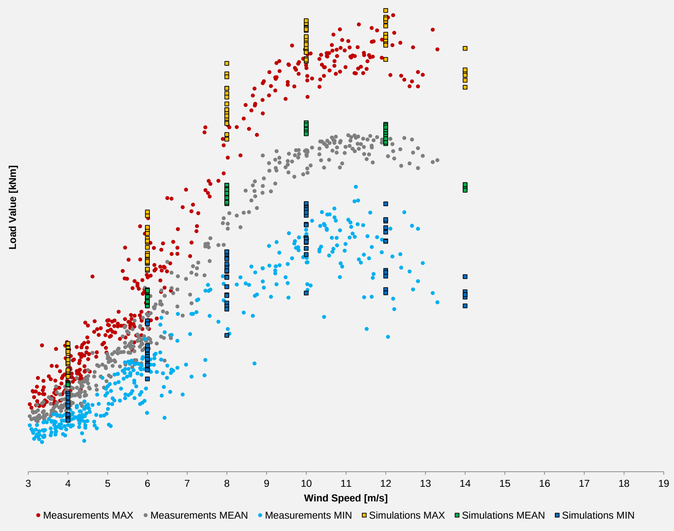


- **loads validations**

The statistics of tower base and flapwise bending moments at 16 m from the root are showed here. The simulations are done with a step of 2 m/s with ranges of external conditions representative of the whole capture matrix and they are superimposed to these measured values.



Tower base normal moment comparison



Blades Flapwise bending moment at 16 m comparison

There is a good agreement between simulations and measurements. These results give an overall validation of the prototype.

Conclusions

The extensive experimental measurement campaign carried out on the Alstom´s Haliade 150-6MW has been satisfactory correlated with the numerical model, providing valuable information in the objective of its design validation, and has culminated with its Type Certification December 2014. The analysis done on the Haliade 150-6MW prototype proves that it is a reliable and efficient product, demostrating its robustness and optimisation. This fact reinforces the technology that Alstom has put in place for the market of new generation of offshore wind turbines.

References

1. D. Tcherniak, S. Chauhan and M.H. Hansen, Applicability Limits of Operational Modal Analysis to Operational Wind Turbines, Proceedings of the IMAC-XXVIII, Jacksonville, Florida, USA, 1–4 February, (2010).
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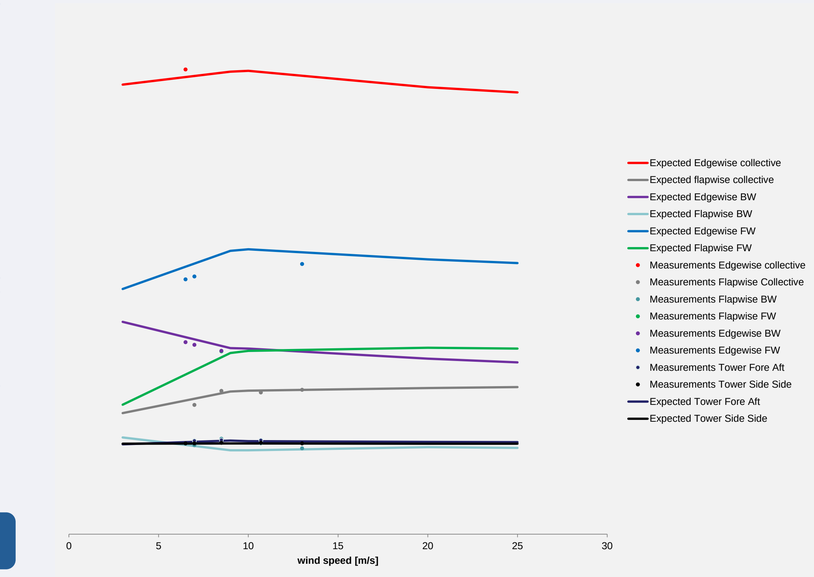

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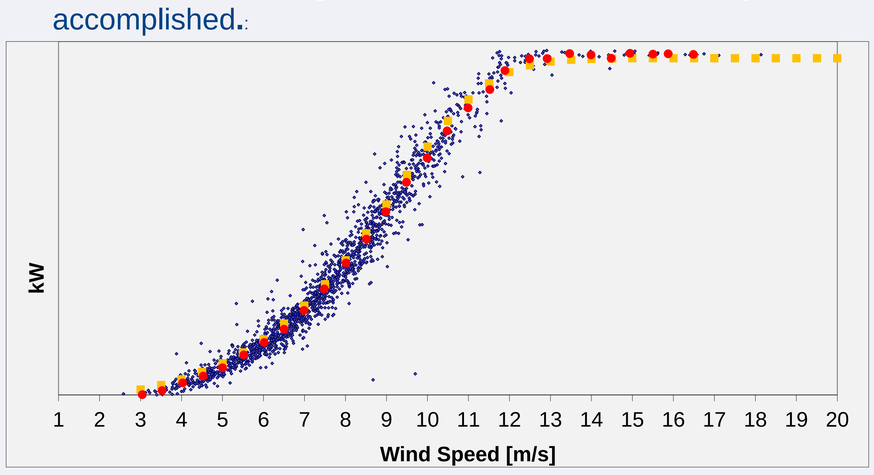

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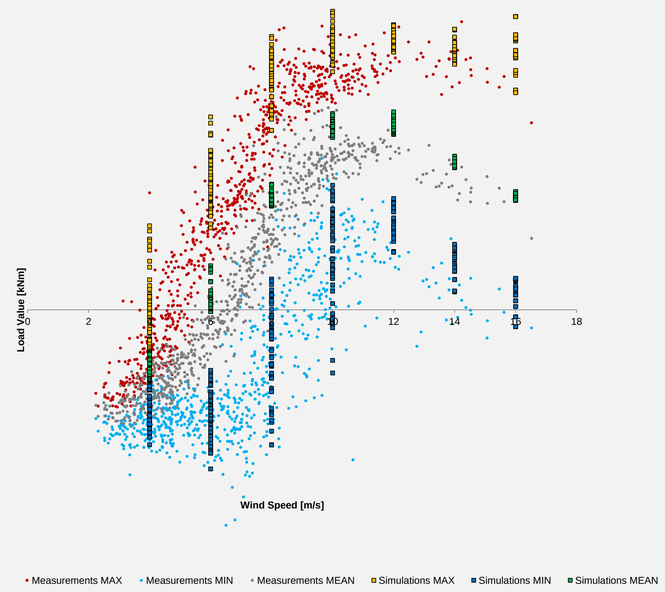

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