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EUROPEAN UNION
European Regional
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TIGER T1.6.6 Deliverable: Summary report on the impact of high fidelity flow data field work and analysis on LCoE of Normandie Hydroliennes tidal project

V0.1

July 2023

Interreg
EUROPEAN UNION
France (Channel Manche) England
European Regional Development Fund

Funding

This work was delivered by the Tidal Stream Industry Energiser project (TIGER) and was co-financed by the European Regional Development Fund through the Interreg France (Channel) England Programme.

Document History

Revision	Date	Description	Originated by	Reviewed by	Approved by
1	July 2023	Final	NH	SA	DB

Disclaimer

Introduction

The “NH-3561-Impact of high-fidelity flow data field work and analysis on LCoE for TIGER T1.6.6” report below provides a summary of the expected impact on Levilised Cost of Energy (LCoE) resulting from the MeyGen array development / optimisation model updates (as reported in MEY-21-2-REP-002-F-Meygen & Raz Blanchard Array Development And Model Optimisation_Rev2”), resulting from high-fidelity flow data field work and data analysis undertaken at the MeyGen site in 2022-2023 (as reported in T1.6.6 - “MEY-21-2-REP-001-F-MeyGen- 2022 Field Work Analysis Report”).

Normandie Hydroliennes (NH) is presently developing a pilot tidal project named NH1 in the Raz Blanchard in France and looking towards future build out to large volume arrays. Turbine array development and optimisation is a topic of great importance to NH and the wider tidal stream sector, particularly in the context of cost of energy, as this is a highly influential factor in the route to tidal energy commercialisation. Under the support of the TIGER project, the work completed in this deliverable has provided valuable input into a global model for project development at multiple levels: from higher accuracy flow predictions that feed reliable resource and engineering design, through to the optimisation of arrays and its impact on cost. Building further confidence in all of these aspects is vital in delivering a dependable financial model which underpins the NH1 business case.

Normandie Hydroliennes hopes, and anticipates, that this publication will assist the whole tidal stream industry as it develops larger-scale arrays.

ACTEUR DE L'ENERGIE FUTURE

NH-3561- Impact of high-fidelity flow data field work and analysis on LCoE for TIGER T1.6.6

July 2023

Purpose

The purpose of this study performed by Normandie Hydroliennes (NH) is to examine the findings of the work carried out in T1.6.6 and to determine what impact, if any, it will have to the projected LCoE for tidal turbine arrays.

This study references two reports that form deliverable for TIGER work package T1.6.6:

- T1.6.6 Technical report on high-fidelity flow data field work and analysis, including vessel-based flow measurements and turbulence measurements at MeyGen, *June 2023*
- T1.6.6 MeyGen array development / optimisation model updates resulting from recent field work and impacts on Raz Blanchard sites, *June 2023*

Summary of key findings from the work

Summary of the key findings from the field work that may have an impact on the LCoE for tidal turbines:

1. The use of 4 beam ADCP leads to overreporting turbulence, specifically, turbine intensity circa 20~25% and kinetic energy by 25~50% .

2. Wake velocity reductions exist slightly further down stream than previously thought at 14-15 rotor diameters rather than 10 rotor diameters.

Impact of reduced levels of turbulence on loads and power

Clearly turbulence has an impact on the mechanical and electrical loading of the tidal turbine.

Proteus Marine Resources (PMR) have studied the loading of the AR1500 turbine at the MeyGen site and have compared the actual loading with the simulated loading produced using tidal bladed with turbulence characteristics from 4 beam ADCP data.

This study was specifically set out to establish the correlation between the actual impact of turbulence and the simulated impact of turbulence.

Figure 1 shows the blade Mx loading from tidal bladed with turbulence commensurate with 4 beam ADCP data is shown in green, and the actuals values are shown in blue. The purple is an alternative simulation package (ttSim) with the turbulence data set to match the actual loading and power as close as possible. The results were achieved by decreasing turbulence intensity by 30% and the length scales by 25-50%. This is similar to the turbulence reductions suggested by the 5 beam ADCP data. The ttSim code was also calibrated against tidal bladed but enabled faster simulations to be performed.

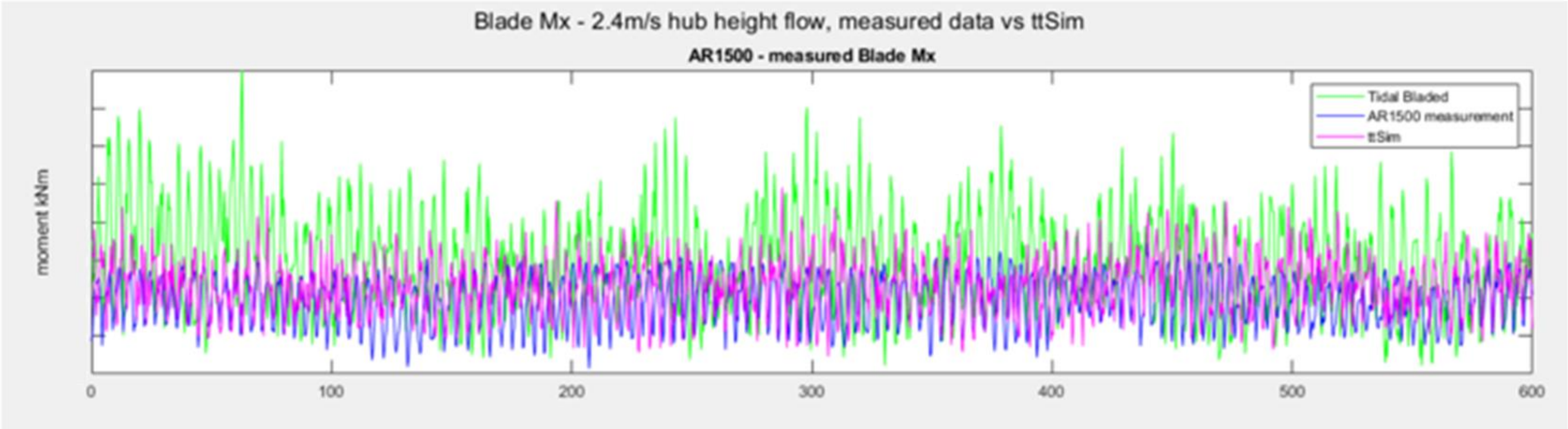

Figure 1: Timeseries of Blade Mx load comparing real vs simulated data

Impact of reduced levels of turbulence on loads and power

Some of the key findings of the study are shown in Table 1 opposite.

The study concluded that:

- The errors in turbulence may lead to over prediction of loads and therefore over-design of components within a tidal turbine system that may increase the LCoE
- Future turbine development should use factored down turbulence values to be more representative to life.

Load metric:		**2.8m/s (no pitching)** new turbulance/old turbulance	**3.2m/s** new turbulance/old turbulance	**3.6m/s** new turbulance/old turbulance
Blade My	Mean	**101%**	**101%**	**101%**
	Max	**91%**	**94%**	**89%**
	SD	**84%**	**73%**	**76%**
Power	Mean	**99%**	**101%**	**99%**
	Max	**83%**	**91%**	**84%**
	SD	**59%**	**64%**	**69%**
Thrust	Mean	**101%**	**101%**	**101%**
	Max	**90%**	**89%**	**91%**
	SD	**61%**	**79%**	**81%**
Tower base Mz	Mean		**99%**	**99%**
	Max		**93%**	**90%**
	SD		**78%**	**85%**

Table 1: Effects of turbulence parameters on loading at different simulated operating conditions

Impact of reduced levels of turbulence on cost

To evaluate the potential impact of lower levels of turbulence to a tidal turbine generator system, each load bearing subsystem of the turbine was considered. Some of the turbine subsystems are design limited by the ultimate loads due to storms or failure cases and the capacity rating of the system. Other aspects are design limited by fatigue loads driven mostly by a combination of turbulence, velocity shear and pylon shadow.

The key findings are that the loading spectrums based on accurate turbulence characterisation leads to significant reductions in cost for some systems, whereas in other systems the effect is insignificant.

The overall estimate is that the turbines cost will be reduced nominally by **3.4%.**

The same process is used for the rest of the cost centres that contribute to the total capital cost of the whole system. The only other contributing subsystems are: the turbine support structure which is driven by fatigue loading, resulting in reductions in material thickness / or tube diameters and less welding; and the converter system, which can be reduced in its capacity as the fluctuations in uncontrollable loads will be lower. (Note, as power conversion systems are sized on nominal standard sizing it is assumed that not all the reduction in peak loading will result in reduced sizing).

The overall reduction in costs are circa **2.6%.**

Note the changes in turbulence do not affect the cost of maintenance, insurance and other operational costs.

Incorporating this into Normandie Hydroliennes financial model, based on the assumption that the annual yield is not affected (see next slide), the impact of the reduced capital cost results in a **2.17% reduction in LCoE**.

Impact to yield on reduced levels of turbulence

A tidal turbine will convert energy from the flow it is subjected to, whether that flow has contributions from the general tidal flow, the waves and the turbulence. It is therefore considered reasonable to assume that some of the energy from the turbulence is converted by the tidal turbine.

It is reasonable then to expect that the annual yield predicted with 4 beam ADCP data will be higher than the actual yield.

However, this is not the case with the AR1500. The AR1500 turbine actual yield from field measurements is nominally 10% greater than the predicted yield as shown in Figure 2.

The reasons for this discrepancy is multifaceted. The main reason is that as a supplier the worst case expected system performances are used to predict the power curve and yield. This is used to set the annual yield within the LCoE calculations.

In practice subsystems like generators transformers and power converters perform slightly better than their manufactures worst case levels so the system as a whole performs more efficiently.

The small perceived decrease in yield due to accurate turbulence characterisation is likely to be negligible with respect to the increase in yield due to systems actual performance vs their guaranteed performance. It is therefore assumed that the yield is not affected by the reduced levels of turbulence.

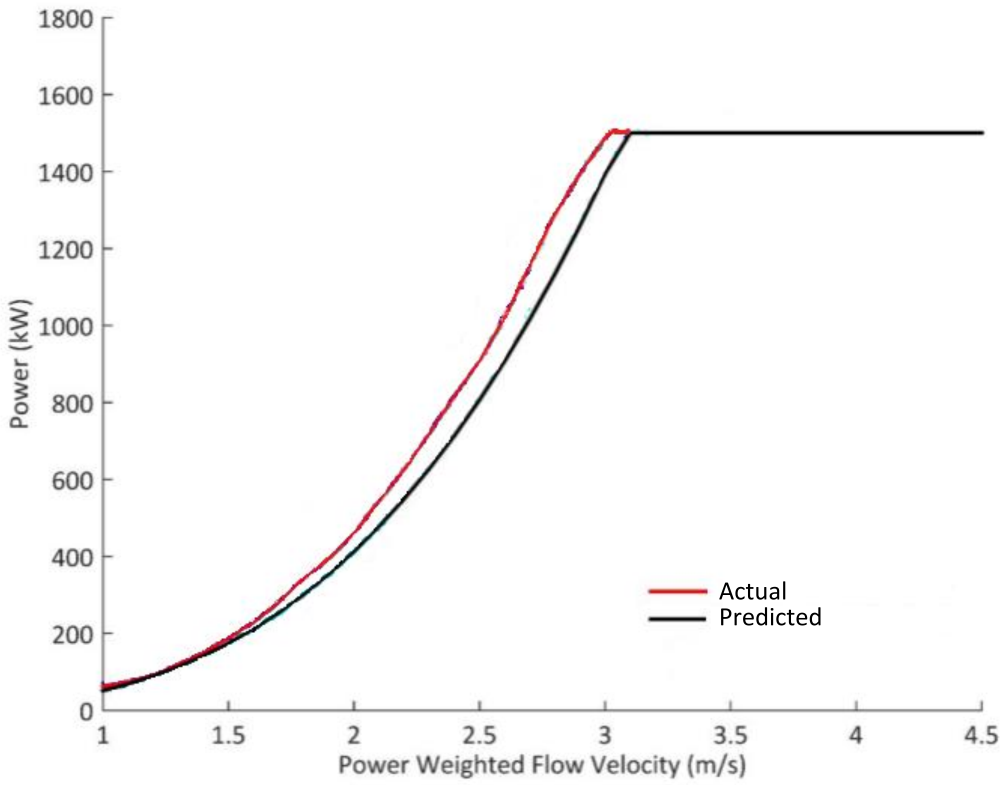

Figure 2: Measured power curve vs Predicted power for the AR1500

Impact of reduced flow due to longer wakes

NH does not consider that there is sufficient data yet on array wakes to understand the likely impact on LCoE.

As arrays get larger the impacts of flow velocity reduction due to wakes and the local velocity increases due to blockage effects will become better understood.

NH's view is that this work is too immature to understand with confidence the impact on LCoE. The local siting of turbines for the NH1 array is such that both wake and blockage effects will be studied.

It is reasonable to assume that developers will want to maximise the return on their investment and therefore could reasonably chose either of the following options depending on energy selling prices.

- To have fewer turbines within a consented area where the LCoE will be optimised but the potential earnings for the project will be lower.
- To have more turbines within a consented area to maximise earnings from the area even if the LCoE is lower due to lower preforming turbines in wakes.

Summary of conclusions

A summary of the key findings from the field work that may have an impact on the LCoE for tidal turbines are:

1. The use of 4 beam ADCP leads to overreporting turbulence, specifically turbine intensity circa 20~25% and kinetic energy by 25~50% .

5 beam ADCP data shows that turbulence has previously been over reported, leading to higher peak and fatigue load predictions. We estimate that accounting for these reduced loads would lead to a reduction of CapEx by 2.6% and LCoE by 2.2%.

2. Wake velocity reductions were measurable between 9 and 10 diameters down stream (depending on ebb or flood) with power-weighted velocity magnitudes reduced by 5% at 14 rotor diameters down stream.

NH are uncertain how the data from this work will impact LCoE as the turbine array spacing will be very site specific and depend on many variables such as site area, energy density, grid connection costs, energy sales pricing etc.

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