



Qualification of innovative floating substructures for 10MW wind turbines and water depths greater than 50m

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Definitions & Abbreviations

ALS	Accidental Limit State
CDs	Concept Developers
DLCs	Design Load Cases
EC	Evaluation Committee
FOWT	Floating Offshore Wind Turbine
FLS	Fatigue limit state
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LC	Load Cases
LCOE	Levelized Cost of Energy
O&M	Operation & Maintenance
RNA	Rotor-Nacelle Assembly
SEC	Software Evaluation Committee
SW	Software
TLP	Tension Leg Platform
WTG	Wind Turbine Generator

Executive Summary

This report summarizes the work carried out in subtask 1.3.6 ‘Upscaling procedure’. The aim is to recap the design process followed by the four concept developers in the design of the substructure and the moorings, for the three selected locations.

Each design topic had a specific subtask, like structural design, mooring design, dynamic simulations or WTG controller. The results of the design were collected in three deliverables, restricted to the project consortium:

D1.3 Concepts design. The deliverable summarizes the concepts design, including a design briefs summary, the main dimensions and features of each concept and for each site.

D1.4 Wind turbine controller adapted to each concept. A first section summarizes the reference controller for the WTG and the controller ‘tuning’ workshops hosted by DTU. Then, controller adaptation to each concept is described, to finish with new control strategies proposed by USTUTT.

D1.5 Marine operations. The deliverable compiles the information about concepts manufacturing, installation strategy, O&M and decommissioning for each of the sites.

D1.6 is a public summary of the design activities and design validation carried out in the project. A workshop was scheduled to include, as part of the deliverable, a discussion about the challenges found during the design for a 10 MW WTG, as well as considerations for the design of floating structures for large wind turbines. The workshop was hosted by Politecnico di Milano, taking advantage of the project’s annual meeting, 13th June 2017. All project partners and a member of the external advisory group took part in the discussion, which is summarized in the conclusions section, and aims to provide some highlights to the design of floating structures for 10 MW range WTG.

Tower design and wind turbine control are seen as the main challenges for the design; the collaboration with the wind turbine manufacturer is mandatory for an optimized design.

Same design procedures and modelling used for smaller wind turbines are valid for larger ones.

Logistics for serial production can be a bottleneck as wind turbine size continue growing.

Aspects not considered in detail in LIFES50+, like wind farm layout, turbulence model and power production can significantly influence the floater and moorings design; to be considered when facing detailed design stages.



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1 Introduction

The objective of the present report is to summarize the design stage of the LIFES50+ project, and collect the challenges found in the process, as well as to provide advice of future challenges in the design and industrialization of large floating wind turbines, in the range of 10 MW.

The design was carried out by four concept developers: Iberdrola Ingeniería developing TLPWIND® based on a steel Tension Leg Platform concept, IDEOL based on a barge concept, TECNALIA working on NAUTILUS four-column semi-submersible steel design, and Olav Olsen designing OO-Star three-column semi-submersible concrete concept. All of them had reached at least TRL4 for 5 MW range floating wind turbines.



Figure 1 Offshore wind floating platform concepts considered in LIFES50+

The design was carried out for a 10 MW reference wind turbine developed by DTU, and for three different sites, representative of both potential markets and different environmental conditions and water depths: Golfe de Fos in Marseille area, France; Gulf of Maine in the USA; and West of Barra, in Scotland.



Figure 2 Sites considered for the platform concepts design (Google Earth)

Concepts design was carried out taking into consideration the development of a 500 MW wind farm - 50 positions- for each of the sites. Manufacturing, assembly, transport & installation, O&M and decommissioning stages were considered during the design stage, which was driven by the information required for the concepts evaluation. In this sense, designs were assessed taking into consideration qualitative information -KPIs- and quantitative information -LCOE, LCA, uncertainty and risk analysis figures.

Several evaluation groups were established in order to validate the designs at different stages and carry out the final evaluation:

- Evaluation Committee -EC-. SINTEF Ocean, ORE Catapult, RAMBOLL and DNVGL, led by IREC as WP2 leader, were in charge of the concepts evaluation.
- Software Evaluation Committee –SEC-, with the participation of DTU, RAMBOLL, DNVGL and NREL as advisor. The role of the SEC was to define a procedure to compare the wind turbine models used by the concept developers for the substructure design.
- DNVGL, DTU and RAMBOLL established a group to define the wind turbine functional requirements.

Once completed the first stage of the project -concepts design and evaluation- the project work will be focused on:

- Testing activities; wave tank and wind tunnel.
- Numerical models development and adjustment based on the wave tank tests results.
- Industrialization of the selected concepts, looking into manufacturing and logistics.
- Risk analysis.

The achievements of all these activities will be implemented in the selected concepts leading to optimized designs. In addition, the process and activities of all work packages related to design questions throughout the entire project will be collected in a set of recommended design practices for the design and qualification of large FOWT substructures

2 Design process summary

The design process of the four concepts involved in LIFES50+ can be summarized in four main steps, as described in [Figure 3](#):

- Definition of the Design Basis: WTG model and Design Load Cases -DLCs- for the three selected locations. Design assumptions and standards. Collection of design representative environmental conditions for each of the sites.
- Validation of the wind turbine model – Software benchmark.
- Review and validation of the Design Briefs.
- Concepts design and validation of the results by the Evaluation Committee.



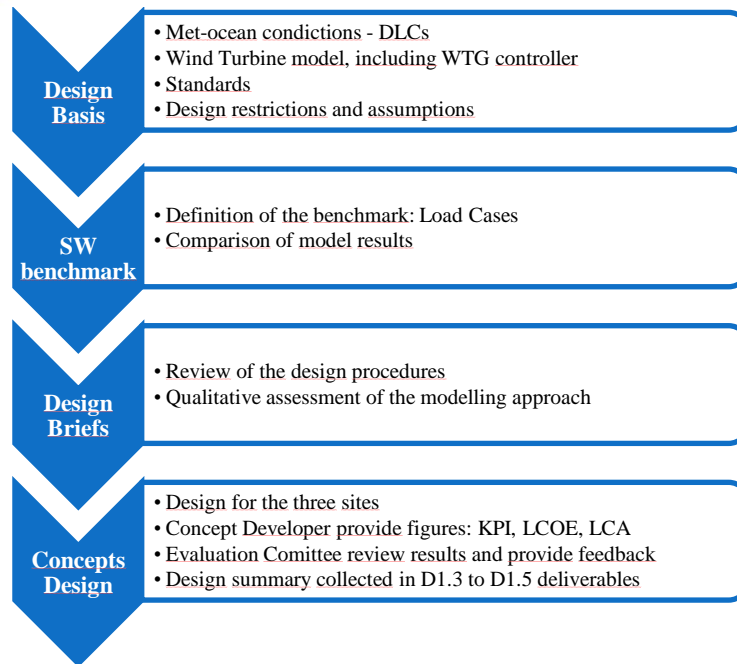


Figure 3 Common design process in LIFES50+

In the following sections, a brief description of each design step is provided.

2.1 Design Basis

The first step of the project was the definition of the design basis. Three different tasks were carried out to define the target locations representative of different met-ocean conditions -and potential markets-, identify the load cases for the design and adapt the wind turbine model to FAST software.

MS1: Design Basis

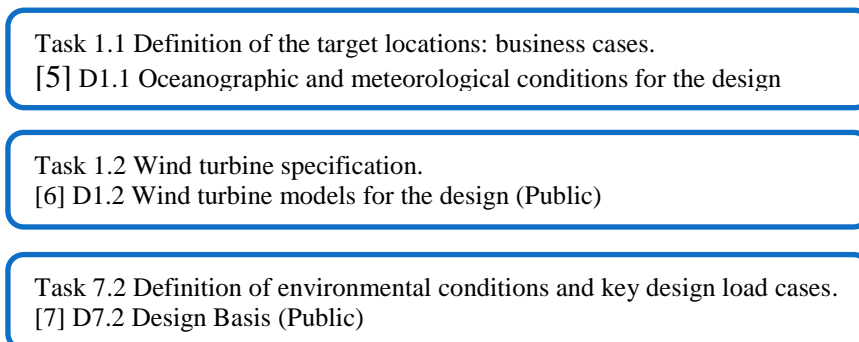


Figure 4 Design basis tasks and deliverables

The information contained in the deliverables was used to design the concepts. In the first tasks, CDs agreed the three target locations:

- Site A (moderate met-ocean conditions), offshore of Golfe de Fos, France
- Site B (medium met-ocean conditions), the Gulf of Maine, USA
- Site C (severe met-ocean conditions), West of the Isle of Barra, Scotland

For those sites, Iberdrola and Tecnalia gathered the available information which is collected in D1.1 and includes:

- Sites location
- Water Depth and Water Levels
- Wind climate, wave climate and wind-wave combined conditions
- Currents Data
- Soil Conditions
- Other Environmental Conditions (ice, sea water characteristics, marine growth etc)

The figure below summarizes the main conditions for each site. It must be noted that some assumptions related to the environmental conditions had to be made for the design, when the required information was not available [1]

	50-year wind at hub height [m/s]	50-year significant wave height [m]	50-year sea-state peak period [s]	50-year current [m/s]	Extreme water level range [m]	Design Depth [m]	Soil Type
Site A	37	7.5	8-11	0.9	1.13	70	Sand/Clay
Site B	44	10.9	9-16	1.13	4.3	130	Sand/Clay
Site C	50	15.6	12-18	1.82	4.2	100	Basalt

Figure 5 Main environmental conditions of the selected sites.

Given the environmental conditions of the sites, four partners -DNVGL, University of Stuttgart, DTU and RAMBOLL- defined a set of DLCs for each of the sites -design references- and established wind turbine restrictions for the design. Those DLCs were a reference for the concept developers, who had to select the most representatives for their specific technology, and run the corresponding simulations and sensitivity analysis. Some 200 DLCs were defined as a reference for each site including operational, ultimate, accidental, serviceability and fatigue states.

In parallel to the definition of the load cases, DTU worked on the wind turbine definition based on their 10 MW reference wind turbine which was originally modelled using HAWC2. A systematic assessment of the FAST model implementation was carried out, to implement a FAST v8.12.00a-bjj numerical model. The steady state performance of the FAST model implementation was compared against HAWC2, with good overall agreement, even though some adjustments [2] were required to compensate the absence of certain modules in FAST.

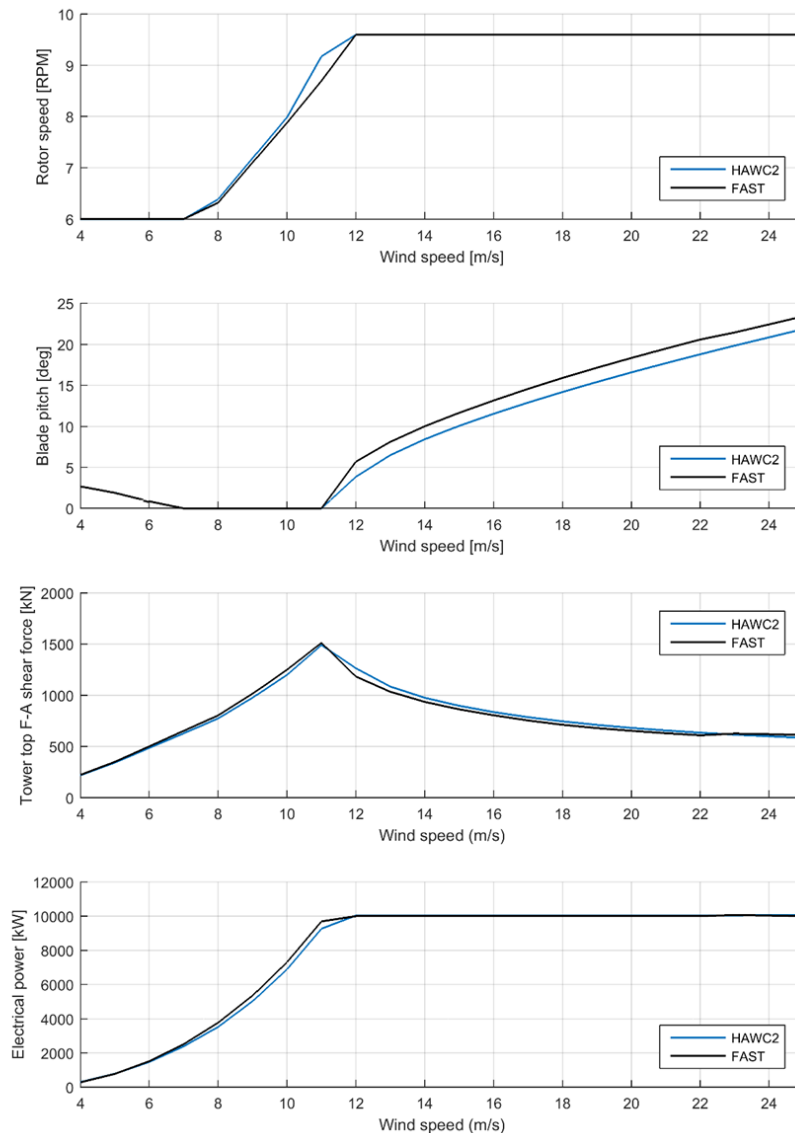


Figure 6 Steady state performance of the FAST model implementation.

DTU finished the WTG model by implementing a generic floater controller. This was used as the starting point for each concept control strategy design -Task 1.3.4, deliverable D1.4-. The base model was tuned to each concept and for each of the three sites. Two workshops were organized and hosted by DTU to support concept developers in the process of understanding and tuning the controller to their design:

1. First workshop took place 25-28 April 2016. The purpose of the first workshop was to present the theoretical background of the controller operation and tuning method, to familiarise the CDs with the practical aspects of using and tuning the controller, and initiate bilateral interactions with DTU on adapting the controller to their concepts.
2. Second workshop took place 8-9 June 2016. The purpose of the second workshop was to facilitate a follow-up with CDs, after allowing the CDs to carry out initial tuning independently. The second workshop included a recap of the tuning method and practical aspects, and focused on hands-on sessions with DTU for further adapting the controller to their concepts to provide CDs with a first general introduction to the wind turbine control, and to guide them on how to tune the control.

A reference tower design was also provided to concept developers, as a starting point for their specific tower designs.

As part of the design basis, it was agreed to design according to the [3] DNV-OS-J103:2013-06 “Design of floating wind turbine structures” and the related standards, e.g. [4] DNV-OS-J101 and [5] DNV-OS-E301. In addition, also IEC standards were considered, e.g. in the definition of the wind environmental conditions according to [6] IEC61400-1.

Finally, a committee formed by DNVGL, RAMBOLL and DTU defined the wind turbine functional requirements, like maximum allowed acceleration in the nacelle, maximum inclination, etc. for operational and survival conditions.

2.2 Validation of the wind turbine model

Three of the concept developers used FAST for the wind turbine model, while another one used 3DFloat. As the wind turbine is the key driver of the floater design, and in order to reduce the uncertainty of the potential differences in the wind turbine models, it was decided to check that the model used in both SWs were comparable. A benchmark of the wind turbine codes was carried out, using an onshore model.

It was decided to establish a Software Evaluation Committee -SEC- with the participation of DTU, RAMBOLL, DNVGL and NREL as advisor. The role of the SEC was to define a procedure and a schedule for the SW benchmark that compared not only the wind turbine models, but also carried out a qualitative assessment of modelling approach chosen for global design analysis.

The procedure proposed by the SEC for the onshore benchmark was:

- SEC proposed a list of onshore benchmark load cases -LCs- to be run by all concept developers, who provided feedback to the LCs list.
- SEC prepared and sent out post-processing scripts.
- Designers performed the LCs simulations.
- Designers generated time series, imported results in post processing scripts and submitted data files and modified scripts to SEC.
- SEC reviewed and compared results and reported to project partners.

After some iterations, all four concept developers got results comparable to HAWC2 model so they got the ‘go’ for using their wind turbine model in the dynamic simulations.

In the process, some improvements were implemented in the reference FAST model provided by DTU.

2.3 Validation of the Design Briefs

As highlighted previously, the conceptual design carried out in LIFES50+ was driven by the information required for the concepts evaluation. At the beginning of the design stage, it was decided to review the design procedures and modelling approach of each concept developer, as it was done for the wind turbine model validation. Again, the idea was to assess that all concept developers were in a similar position to address the design. In other words, it was decided to carry out a qualitative assessment of the modelling approach choice for global design analysis.

Designers provided a description of their modelling approach in the Design Briefs which included, among other design topics, a description of the sizing, structural design, mooring system design, dynamic cable analysis, coupled analysis and outfitting.



The design briefs for each concept is summarized in D1.3 Concepts Design, which is a confidential report internal to LIFES50+ consortium, as it contains a summary of the design process of each of the concept developers.

2.4 Concepts design

With the information of the Design Basis, the wind turbine model validated and the design procedure reviewed by the Evaluation Committee, concept developers worked on the design for the three locations. The main design topics addressed were:

- Structures sizing for the three sites, including mooring.
- Structural design.
- Mooring design.
- Preparing the coupled models and running the aero-elastic + hydrodynamic simulations for the defined load cases.
- Adaptation and optimization of the wind turbine controller.
- Manufacturing and logistics for the wind farm deployment, including manufacturing, assembly, transport and installation, O&M and decommissioning.

The design work was collected in three deliverables, which were restricted to the project partners to avoid IPR issues:

- D1.3 Concepts design. The deliverable summarizes the concepts design, including a design briefs summary, the main dimensions and features of each concept and for each site.
- D1.4 Wind turbine controller adapted to each concept. A first section summarizes the reference controller for the WTG and the controller ‘tuning’ workshops hosted by DTU. Then, controller adaptation to each concept is described, to finish with new control strategies proposed by USTUTT.
- D1.5 Marine operations. The deliverable compiles the information about concepts manufacturing, installation strategy, O&M and decommissioning, for each of the sites.

During the design stage, concept developers provided information related to previously defined key performance indicators -KPIs- to the Evaluation Committee, as well as LCOE, LCA and risk analysis figures for the three sites. The aim of the KPI assessment was to follow-up the design and validate the figures provided for the LCOE assessment, which was the main driver for the concepts evaluation. Different information submissions were followed by EC feedback, which led to improve concepts design and to have a more homogeneous information for the evaluation. KPIs were defined to collect information about the substructure and moorings dimensions and performance, wind turbine operation, load factors considered and results -plots- of dynamic simulations.

In summary, the design stage has meant not only the design of the floating structures for the reference wind turbine and the three defined locations, but also the validation of procedures, models and results that allowed to face the subsequent evaluation stage.

It must be pointed out that due to the scope of work and the available information, several assumptions were made to move forward with the design. For instance, it was considered a fixed water depth for each of the sites, some of the environmental parameters were estimated for some locations as well as the soil type, it was considered a reference wind farm layout turbulence model and power production. The aim was to put the focus on the floating concepts development, knowing that aspects like the wind farm planning is an important design driver, but it is out of the scope of LIFES50+.



3 Design Workshop

As explained before, the aim of this document is to summarize the design experience of the four concept developers in the design of a 10MW wind turbine. All of them had previously designed their concepts for 5 MW wind turbines, so their experience in the process of scaling their structures for larger WTGs is considered important for the floating wind sector. Even more taking into consideration that VESTAS unveiled its 9.5 MW wind turbine during the last Offshore Wind Conference -London 6-8 June 2017- and SENVION also announced the development of a 10 MW+ wind turbine. Both WTGs are in the same range as the reference wind turbine considered in LIFES50+. The different assessments carried out to the concepts design during the design process, provide a guarantee that the work was done in accordance with the standards and following validated practices.

In order to collect this design experience and provide public information related to the design, it was organized a workshop involving all project partners and a member of the external advisory group: SIEMENS-GAMESA. The workshop was held at Politecnico di Milano premises, 13th June 2017, as part of the project annual meeting.

The workshop begun with a presentation of the Design Basis, by DNVGL -summary of the DLCs- and DTU -wind turbine reference model, including the controller. Some considerations were discussed:

- Severe Sea States seem to be the driving load cases for substructures, and Accidental Limit State is one of the driving load cases for those concepts considering redundant mooring system. Also FLS can be a driving design load case if design assumptions are too conservative.
- It was difficult to get realistic design conditions for the three sites, so it was decided to take assumptions representative of harsh, medium and low conditions. Some of the conditions combinations lead to unrealistic sea states but representative for the concepts design and its evaluation.
- On a real project, typically there will be a greater number of load cases with more combinations of different load types. The concerns of the Client, Classification Society and Turbine Manufacturer must all be addressed in the load case selection.
- Second order wave loads may be important for mooring line design.

Then, concept developers took the lead and presented their experience during the design, highlighting design experience, challenges, future needs. Short presentations were followed by an open discussion with the contribution of all the attendees. To facilitate the discussion and extract conclusions, a script was prepared based on a series of questions.

Was any relevant difference with regard to the design procedure for a 5MW wind turbine?

All four concept developers used the same procedures they used for 5 MW range wind turbines - Design Brief- and all of them do not expect significant changes when facing the design for larger WTG.

Was there any significant difference in the design process for any of the three sites (e.g. more detailed procedures, different numerical tools, new approaches, ...)?

The same design procedure was used for the three sites. Due to the harsh conditions of West of Barra, most of the concept developers had to look in more detail to the design for this site. In general, more detailed environmental data would be required for a site with this type of conditions. For instance, geotechnical information for drilling for the type of seabed considered or wind-wave-currents correlation.



Did any new challenges arise due to new physical behavior of the larger wind turbines?

No challenges from the hydrodynamic behavior point of view. The models provided a good performance, with no significant differences comparing the 10 MW WTG design and previous 5 MW WTG designs.

The main challenge for the design was the wind turbine tower. DTU provided a tower reference design, which was adapted to each of the substructures. Upscaling could possibly increase 3P excitation, and concept designers had to adopt different solutions in order to avoid an overlap with this frequency in the design of the system. Two of the concept developers implemented a stiff-stiff design above the 3P range, while the other two went for a soft-stiff design, between 1P and 3P.

It was agreed that the tower design is a topic that must be carefully addressed for large WTG, taking into consideration the control algorithm and working in collaboration with the wind turbine manufacturer, under a life cycle design approach.

Was there any change with respect to design driving load cases / environmental conditions?

The driving load cases remained the same as those for floaters designed for smaller turbines. Nevertheless, it was identified that some load cases had to be analyzed with more detail, as FLS for Golfe de Fos. For the structures having redundant mooring lines, also ALS is one of the design driving load cases.

Were any new challenges experienced considering constraints from logistics (land transportation, vessels, harbor, etc)? Did concept developers need to implement any modification to their design to adapt it to the logistics?

None of the concept developers needed to adapt their design to accommodate the logistics requirements, although the design for 500 MW wind farm -50 positions each one with a 10 MW wind turbine- means to approach the limits of the available logistics for some deployment stages. It must be kept in mind that the timeframe considered for the manufacturing and installation of the 50 floating wind turbines was 2 years.

Logistics could be a bottleneck as WTG continue growing. On one hand, the size and weight of the wind turbine impose limits to the onshore cranes for the WTG assembly on the substructures: there are only a few cranes with the required capability. On the other hand, the wind farm size -number of units to be deployed- has an important impact on the logistics: number and size of the vessels required, need to develop an on-site manufacturing capabilities, storage needs...

Modularization of the floating structure was highlighted as a key factor in the path for the industrialization -serial manufacturing- of large floating wind turbines and for large wind farms.

VESTAS has just unveiled its 9.5MW WTG that seems to be in the range of LIFES50+ 10MW reference wind turbine in terms of size and weight, supporting the idea that logistics is one of the challenges for the development of large floating wind farms.

There was a lack of information in the project related to the wind turbine components and the associated logistics, that have an important influence on the assembly means, storage required area, etc. Some assumptions were considered in the project, but for a real development, the collaboration with the wind turbine manufacturer is mandatory in order to optimize the design.



Was a different mooring line concept chosen due to increased size / weights of mooring lines (new materials, more lines, different anchors)?

Concept developers used the same mooring system they have adopted for smaller wind turbines. Nevertheless, there's room to improve the mooring design and analyze new configurations, especially for the most severe conditions -West of Barra-

New concepts and configurations can be considered, especially for the most severe environmental conditions and for higher depths, but with the resources available and time constraints, it was not possible to address this topic in the framework of LIFES50+.

All four CDs adopted drilled piles for West of Barra, considering drag embedded anchors or suction piles for the other two sites.

The wind farm layout can be influenced by the mooring system, especially for higher water depths and some types of substructures -TLP is less sensitive to this issue. In LIFES50+ several assumptions were considered but it was agreed that for a real project, wind farm layout and wake effects are important design drivers to be considered at the very beginning of the project, as they may have difference influence for different types of concepts.

In LIFES50+ the design was carried out to a conceptual stage. What about a detailed design?

After the design and evaluation stage, and taking into consideration all the design checks carried out, all concept developers expressed their readiness to face a detailed design for a 10 MW range wind turbine. At this point it was raised again the need to establish a close collaboration with the WTG manufacturer, in order to define the design restrictions and work together in the design of the tower and implement an optimized control strategy.

Challenges expected for a detail design.

Considering the information available for the conceptual stage and the assumptions made, some challenges were identified:

- Installation and fabrication tolerances will need more detailed consideration as they could lead to a design change.
- Need to optimize wind turbine controller and establish design requirements, in collaboration with the WTG manufacturer.
- Wind farm layout optimization.
- Lifting capacities for the RNA.

Lack of information to address a detailed design.

- Better environmental data, including joint probability distributions, would be needed for further studies compared to the data available in the project. This would lead to less conservative Load Cases and optimized designs, especially for the mooring system.
- Geotechnical information for the design of anchors, mooring system and power cable.
- WTG functional requirements like tilt, acceleration, maximum inclination -operation and extreme conditions. Although those considered in the project are considered reasonable, it is only the wind turbine manufacturer who will be able to provide these figures.
- Wind farm functional requirements (maximum FOWT excursion, minimum airgaps, etc.) and wind farm layout detailed definition.



Concept developers do not expect significant changes in the design process after the first stage of the project.

Their design procedures were not influenced by the achievements of LIFES50+ first stage, except for considering fatigue checks at the first phases of the design.

During the discussion, it was also highlighted the availability of the wind turbine and its relation to the type of vessels that need to be considered for O&M procedures. It is a cost compromise consideration: the better the vessels, the more availability, but also more costs. For an R&D project like LIFES50+ a 95% availability could be considered a conservative value.

Finally, wind farm layout as well as wake effects are considered of high importance in general, but were considered outside the scope of the first stage of LIFES50+. Several assumptions and simplifications were made, as well as for the offshore substation and the export cable.

4 Conclusions

In the first stage of LIFES50+ it was addressed the design of four different floating concepts for a 10 MW reference wind turbine, and for three different sites, representative of severe, medium and low environmental conditions. The design was faced taking into consideration the manufacturing and logistics for the deployment of a 500 MW wind farm for each site in two years' time, excluding the offshore substation.

The design activities were carried out by the four concept developers and the procedures, models and results were evaluated and validated by different committees established in the consortium. This allowed evaluate and validate the design from a common basis.

Once the design and concepts evaluation stage was finished, it was organized a workshop to discuss and share design experience, challenges found and lessons learnt in the design of 10 MW-range floating wind turbines. All the project partners took part in the workshop, including SIEMENS-GAMESA as part of the external advisory group. The main findings can be summarized in these highlights:

- The **design methodology** for performing the design of a 10 MW-range floating wind platform **did not require any important modification** with respect to the design methodology of a 5 MW scale conceptual design.
- The **main challenge** arisen by the four concept developers is related **to tower natural frequencies** and the challenge to avoid coupling with the 3P frequency of the WTG.
- Working in **direct collaboration with a turbine manufacturer is critical** for the optimum design of a floating structure for offshore wind: definition of turbine functional requirements, controller optimization and tower design. Control has been highlighted by all partners as a very important part of the design that might need additional attention.
- **Logistics can be a bottleneck** for the deployment of large wind farms, using next generation of large wind turbines. **Working with the industry is very important** for reaching a concept design that keeps on 'standard' industry elements (installation means, auxiliary systems' components, manufacturing facilities capabilities...)
- A **global vision of the whole wind farm may be critical** for reaching the optimum design. Aspects like wind farm layout, wake effects, power production or O&M strategy may influence the substructure and moorings design. Although most of these aspects were out of LIFES50+ scope, they must be considered for a realistic project.



5 Bibliography

- [1] “LIFES50+ Deliverable 7.2 Design Basis”.
 - [2] “LIFES50+ Deliverable 1.2 Wind turbine models for the design”.
 - [3] “DNV-OS-J103:2013-06, Design of Floating Wind Turbine Structures”.
 - [4] “DNV-OS-J101:2014-05, Design of Offshore Wind Turbine Structures”.
 - [5] “DNVGL-OS-E301:2015-07, Position Mooring”.
 - [6] “IEC 61400-1:2005, Wind turbines – Part 1: Design Requirements, incl. Amendment:2010”.
 - [7] “LIFES50+ Deliverable 1.1 Oceanographic and meteorological conditions for the design”.
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