Engineering and Upscaling of New Floating Renewable Wind Energy Platform

Deliverable D2.3

Integrated monitoring report

Lead Beneficiary	SAITEC S.A.
Delivery date	2022-04-22
Dissemination level	Public
Status	Approved
Version	1.0
Keywords	Integrated Monitoring

This project has received funding by the EMFF programme of the European Union under grant agreement No. 958938

Disclaimer

Any dissemination of results must indicate that it reflects only the author's view and that the Agency is not responsible for any use that may be made of the information it contains.

Document Information

Grant Agreement Number	958938
Project Acronym	SATHScale
Work Package	WP 2
Task(s)	T2.2
Deliverable	D2.3
Title	Integrated monitoring report
Editor	Carlos A. Garrido-Mendoza
Author(s)	Araceli Martínez
File Name	SATHScale_D2.3_Integrated Monitoring Report_20220421_v1.0.docx

Change Record

Revision	Date	Description	Prepared	Reviewed	Approved
0.1	11/04/2022	First draft created – Document structure	CGM		
1.0	21/04/2022	First Deliverable to EC	AM	ACB	CGM

Executive Summary

The monitoring report is broken down into three main sections, each corresponding to a phase of the project: Construction and pre commissioning phase, installation and commissioning phase and operational phase. In each of these phases, the programme is split between Environment and metocean data, Wind turbine, Floating foundation and Mooring system.

In essence, this document provides a high-level overview of the monitoring approach and activities of the project. Specifics of the Condition Monitoring System (CMS) and its component used for the monitoring of the support structure and the electrical connections are described in previous deliverables (D2.1 & D2.2), and therefore, are not described in depth in this document.

Authors

Partner	Name	Phone / Fax / e-mail
Saitec	Carlos Ariel Garrido-Mendoza	Phone: +34 94 464 65 11 e-mail: carlosgarrido@saitec.es
Saitec	Araceli Martínez	Phone: +34 94 464 65 11 e-mail: aracelimartinez@saitec.es
Saitec	Ane Cortina Buron	Phone: +34 94 464 65 11 e-mail: anecortina@saitec.es

Table of Contents

List of Figures

List of Tables

Abbreviations and Acronyms

Term	Description
CMS	Condition Monitoring System
WT	Wind Turbine
O&M	Operation and Maintenance
SATH	Swinging Around Twin Hull

1. INTRODUCTION

1.1 PURPOSE AND SCOPE

This document describes the integrated monitoring approach defined for the DemoSATH prototype. The monitoring programme is divided into three main sections of the monitoring programme: the construction and pre-commissioning phase, the commissioning and installation phase and the operation phase.

The DemoSATH prototype will allow to test and validate the SATH technology in a real-life scenario at all the stages of the project life cycle. Monitoring plays an integral role in the objective of collecting data for further optimization of the technology as well as in ensuring that risks are kept to a minimum during the development of the project. Sensors, data acquisition systems and communications allow to continuously ensure the integrity of the prototype, characterize its construction, installation, and operation, and prevent failures. Moreover, it will allow to compare the behaviour of the structure when subject to complex environmental loads to the simulations and model tests that have been conducted previously to validate the design basis and methodology developed by Saitec.

The monitoring strategy is also closely linked to the O&M activities that are analysed in Task 3 as it provides the necessary input to apply preventive and corrective measures. This document only discusses the monitoring approach, and no reference is done to the expected observations and maintenance strategies that will be discussed in future reports.

This document provides a high-level overview of the monitoring approach and activities of the project. Specifics of the Condition Monitoring System (CMS) and its component used for the monitoring of the support structure and the electrical connections are described in previous deliverables (D2.1 [1] & D2.2 [2]), and therefore, are not described in depth in this document.

For better reference, Figure 1.1 shows an overview scheme of the monitoring system of the floating foundation with the several subsystems that are used. Figure 1.2 shows the monitoring system used in the wind turbine. These monitoring packages have already been described in detail in Deliverable 2.1.

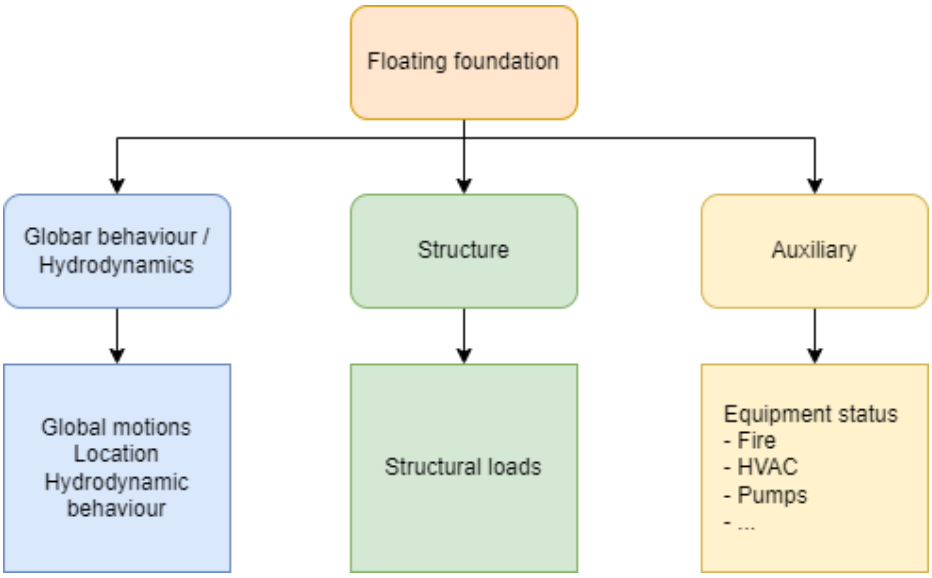

FIGURE 1.1 FLOATING FOUNDATION SUBSYSTEMS

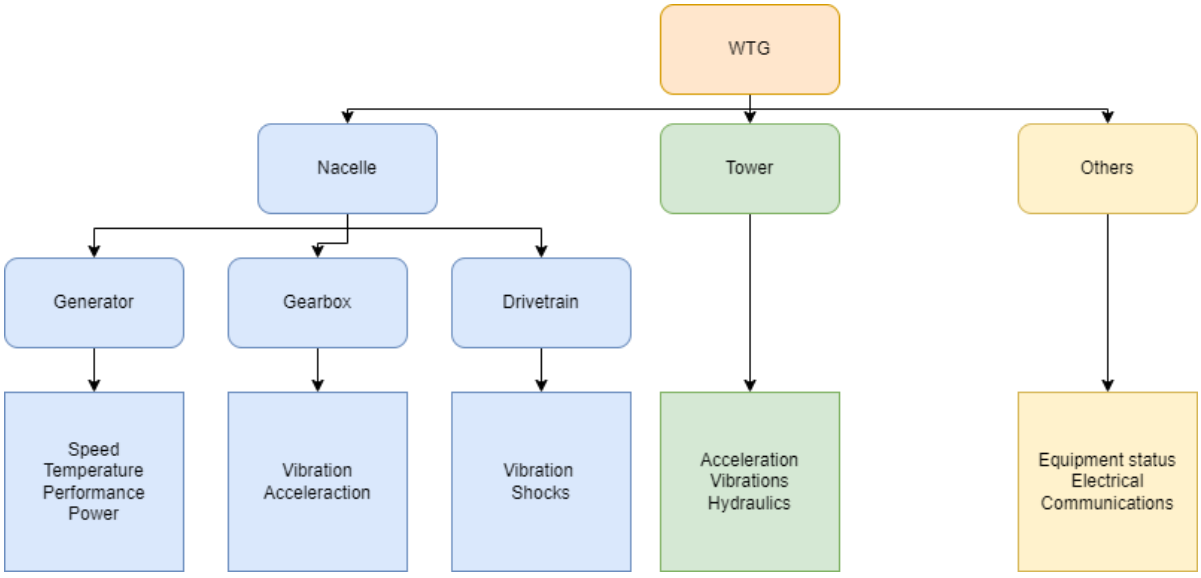

FIGURE 1.2 WIND TURBINE SUBSYSTEMS

1.2 APPLICATION DOCUMENTS

Inputs from the following documents were used as a source of information for preparing this document:

TABLE 1.1: APPLICATION DOCUMENTS

REF	Document
AD-01	Grant Agreement – 958938 - SATHScale
D2.1	Description of the support structure monitoring system
D2.2	Description of the system monitoring of the electrical connection

1.3 DOCUMENT STRUCTURE

This document is structured into three main areas consisting of the three main stages of the project that need to be monitored, that is, construction and pre-commissioning phase, installation and commissioning phase and operation phase. For each of the phases the monitoring approach that has been taken for each of the systems comprising the prototype is explained. The identified subsystems are:

TABLE 1.2 MONITORING SUBSYSTEMS

ID	Subsystem
MET	Environmental and Metocean conditions
MOR	Mooring system
FLO	Floating substructure
WTG	Wind-turbine equipment

2. CONSTRUCTION AND PRECOMMISSIONING PHASE

The monitoring activities during the construction of the floater are aimed at ensuring that the pre-defined quality indicators are maintained at all times. The monitored activities that are comprised at this stage are the construction of the floater and the required sub-structures, the assembly of those structures as well as the pre-commissioning of the auxiliary equipment. It also involves the reception of materials, the performance of quality checks before the assembly of the elements that form the floater and other inspections of the equipment that will be installed in the second stage.

2.1 ENVIRONMENTAL CONDITIONS

Existing environmental conditions need to be considered and analysed carefully as they may have a considerable influence in the construction activities, most notably in those related to the manufacturing of the floater. The main environmental parameters that are measured are the ones shown in Table 2.1:

TABLE 2.1 MONITORED ENVIRONMENTAL PARAMETERS (PHASE I)

ID	Description
ENV-I-01	Precipitation
ENV-I-02	Electrical storms
ENV-I-03	Relative humidity
ENV-I-04	Temperature
ENV-I-05	Wind speed
ENV-I-06	Wind direction
ENV-I-07	Wind gust

For this, a weather monitoring station at the construction site is used along with the continuous analysis of weather forecast models for the location of the construction site. This allows to better adequate the building timeline to the existing environmental conditions while ensuring that those conditions do not affect the quality of the construction and that the standards of quality as well as the health and safety standards are met.

2.2 FLOATING STRUCTURE

The manufacturing of the floater is monitored at all stages of the construction to ensure two main objectives:

- **Weight control:** The weight of the structure needs to fall within the defined limits. With this objective in sight, each of the pieces that is assembled in the main floater is weighed and has its centre of gravity calculated. This periodic examination allows to have a continuous estimate of the weight of the prototype and, therefore, reducing the risk of detecting issues further down the road.

- **Shape control:** The shapes and dimensions of the assembled pieces are measured to ensure conformity at all stages of the manufacturing of the prototype. High efforts are focused on topography works to ensure the quality of the dimensions.

Moreover, the quality of the concrete is analysed at different stages of the construction by an independent testing laboratory to ensure that the mechanical property of the concrete remains within the predefined limits. Strength and resistance tests are also routinely conducted.

Structural monitoring equipment needs to be installed at this preliminary stage as it needs to be inside the concrete structure. Monitoring of the loads will be conducted during the operation phase of the testing.

The summary of the monitored variables can be found in Table 2.2

TABLE 2.2 MONITORED FLOATING SUBSTRUCTURE PARAMETERS (PHASE I)

ID	Description
FLO-I-01	Component weight
FLO-I-02	Geometrical tolerances
FLO-I-03	Centre of gravity
FLO-I-04	Concrete density
FLO-I-05	Concrete strength
FLO-I-06	Quality check

Other variables that are monitored during the manufacturing of the floater include:

- Quantities for the reinforcement steel
- Quality check of rest of the elements that composed the floater

2.3 WIND TURBINE

It is important to note that the wind turbine has a monitoring system already installed by default. This system is integrated into the CMS of the prototype. The monitoring activities in this field at the pre-commissioning stage involve ensuring the availability and condition of the installed systems.

Quality inspections are conducted for the ensemble of the turbine systems regarding the condition as well as weight and location of the centre of gravity.

TABLE 2.3 MONITORED WIND-TURBINE PARAMETERS (PHASE I)

ID	Description
WTG-I-01	Component weight
WTG-I-02	Geometrical tolerances
WTG-I-03	Quality parameters
WTG-I-04	Electromechanical components

3. INSTALLATION AND COMMISSIONING PHASE

The installation and commissioning phase forms the second part of the monitoring package. The activities performed at this stage are related to the commissioning of the floater at the dock where all the installation and setup related works are conducted. It involves the testing of all the assembled systems to ensure that no issues arise when the structured is towed out to its mooring place. The final quality and certification steps are also taken at the dock for the floating structure.

With regards to the installation, two separate activities are monitored, firstly the pre-laying of the mooring systems and later the towing and hook-up of the floating structure. Final checks are performed on site before the turbine starts producing.

3.1 ENVIRONMENTAL AND METOCEAN

Environmental conditions play an integral part on the commissioning and installation procedures. Some of the activities that need to be carried out have restrictions in terms of the existing conditions (wind, sea state…). A reliable and tested weather forecast system is used to define, in advance, the timing of the operations and to optimize, as much as possible, the existing resources. As part of the design basis, an allowable weather window was defined in which the towing and hook-up activities are allowed to be conducted. The weather forecast system must ensure that these activities can be fulfilled within the available time.

At the construction site, the monitoring system mentioned in 2.1 is used. For the installation place, the wave buoy (WaveScan) located at the BiMEP Area is used. This buoy collects metocean data by measuring the wave, current, and meteorological parameters at the installation site. More specifically, it provides wave height and wave direction, sea surface temperature, salinity and temperature profiles, surface current speed and direction and other meteorological parameters such as temperature, wind, wind gusts and wind direction.

The use of such a buoy is required to analyse the existing conditions so that the installation and commissioning activities can be done in a safely manner.

TABLE 3.1 MONITORED ENVIRONMENTAL PARAMETERS (PHASE II)

ID	Description
ENV-II-01	Precipitation
ENV-II-02	Electrical storms
ENV-II-03	Relative humidity
ENV-II-04	Temperature
ENV-II-05	Wind speed
ENV-II-06	Wind direction
ENV-II-07	Wind gust
ENV-II-08	Air pressure
ENV-II-09	Current direction
ENV-II-10	Current speed
ENV-II-11	Wave height
ENV-II-12	Wave direction
ENV-II-13	Wave period
ENV-II-14	Water temperature

3.2 MOORING SYSTEM

Regarding the mooring system, monitoring of the conditions of the elements comprising the mooring system is performed at the construction site to ensure that the delivered elements are according to specifications. Parameters measured at this stage include lines stiffness, weight and strength for the various line types used (chain, synthetic).

With regards to the installation of the anchors and pre-laying of the mooring lines monitoring equipment is used to ensure that predefined specifications are always met. These systems are commonly used in the industry and therefore not part of the monitoring definition as they are subcontracted to the company responsible for the marine operations.

The monitoring activities at this stage involve the following:

TABLE 3.2 MONITORED MOORING SYSTEM PARAMETERS (PHASE II)

ID	Description
MOR-II-01	Anchor position
MOR-II-02	Anchor dragging
MOR-II-03	Mooring line tension
MOR-II-04	Mooring line tension dynamic variation
MOR-II-05	Anchor handling vessel motions

3.3 FLOATING FOUNDATION

Monitoring of the floating foundation is mainly aimed at the operation phase. Nevertheless, it also plays an important role at the launching and commissioning phase.

Most of the foundation monitoring systems are installed prior to the launching. Among them, the global motions monitoring equipment allows to record all the motions and displacements during the launching phase. Once floating, the draught and trim of the floater are measured to ensure that the design specifications are met in terms of weight and longitudinal and transversal location of the centre of mass.

The metacentric heights and the vertical position of the centre of gravity are also measured at this stage. Apart from being useful to ensure that the behaviour of the floating structure will be according to the design specifications, the measuring of these variables is also a required certification step.

To do so, several weights are used, which are strategically placed at predefined locations on the structure. The movement of these weight will produce a heel angle on the structure. This angle is measured by the onboard system (CMS) as well as pendulums placed for this inclination experience. A repetition of the weight's movement, with different combinations produces a number of heel angles that can be plotted against the heeling moment created by the weight. The processing of such graph yields the metacentric height of the structure along with the location of the metacentre. This procedure also allows to check the natural periods of the platform and to ensure that the results fall within the expected values.

The rest of the monitoring systems that form the CMS and are explained in Deliverable 2.1 [1] are also installed at this stage.

Once all the systems and equipment are in place with the commissioning fully completed, the tow-out of the foundation is performed. The systems onboard the foundation as well as those in the towing boat are used to monitor the prototype as in the operation phase. The main variables of interest during these operations are related to the dynamics and loads, hence monitoring of the motions of the prototype and the loads of the towing lines is essential.

The variables monitored at this intermediate stage involve the following:

TABLE 3.3 MONITORED FLOATING FOUNDATION PARAMETERS (PHASE II)

ID	Description
FLO-HYD-II-01	Global floater motions
FLO-HYD-II-02	Global floater velocities
FLO-HYD-II-03	Global floater accelerations
FLO-HYD-II-04	Floater position
FLO-HYD-II-05	Hydrodynamic variables
FLO-STR-II-01	Structural loads
FLO-AUX-II-01	Communication system
FLO-AUX-II-02	Electrical system
FLO-AUX-II-03	Firefighting system

3.4 WIND TURBINE

During the installation of the turbine, monitoring systems will be set up and checked. Continuous monitoring activities related to the wind turbine will only start once the protype is installed and operating.

4. OPERATION PHASE

The operation phase covers the duration of the testing of the prototype once it is deployed and fully commissioned at the BiMEP area. During this time of approx. 2 years the monitoring of the platform along with the environmental conditions will allow to correlate the behaviour of the floater with the existing complex conditions. The objective is to validate the design, hypothesis and simulation tests that have been used during the design phases.

4.1 ENVIRONMENTAL AND METOCEAN

As explained in 3.1 environmental monitoring is key for the characterization of the existing conditions and the loads that the floating structure will need to withstand. The source of these loads is twin fold. One of them are the loads generated by the wind turbine, which need to be assessed. The wind speed, direction, and other characteristics such as gusts, variance, etc. play a major role on it. An anemometer capable of modelling the existing conditions at the wind turbine hub height allows to capture the data.

The second source is related to the monitoring of the wave conditions, using the buoy located at the BiMEP area (see 3.1).

TABLE 4.1 MONITORED ENVIRONMENTAL PARAMETERS (PHASE III)

ID	Description
ENV-III-01	Electrical storms
ENV-III-02	Relative humidity
ENV-III-03	Temperature
ENV-III-04	Wind speed
ENV-III-05	Wind direction
ENV-III-06	Wind gust
ENV-III-07	Air pressure
ENV-III-08	Current direction
ENV-III-09	Current speed
ENV-III-10	Wave height
ENV-III-11	Wave direction
ENV-III-12	Wave period
ENV-III-13	Water temperature

4.2 MOORING SYSTEM

The monitoring of the mooring system during the operation phase of the prototype is aimed at analysing its behaviour in a real-life scenario, as opposed to the tank testing and numerical simulations that have been used during the design process.

The variables that are monitored include:

TABLE 4.2 MONITORED MOORING SYSTEM PARAMETERS (PHASE III)

ID	Description
MOR-III-01	Mooring line tension
MOR-III-02	Mooring line status

4.3 FLOATING FOUNDATION

The characterization of the floating foundation is the main purpose of the monitoring tasks. As explained, the main objective of the monitoring approach is to identify the dynamics of the floater (motions and hydrodynamic properties) as well as the loads that it must withstand (structural loading). From a technical point of view, these two areas constitute the main reason of developing a full-scale prototype and it is expected that the monitorization will contribute to an advance in the technical knowledge.

The floating foundation, however, also features several auxiliary systems that are needed for the successful operation of the prototype. Therefore, they must also be considered as part of the integrated monitoring approach.

The key variables and subsystems that are part of the monitoring package are described in the table below.

TABLE 4.3 MONITORED FLOATING FOUNDATION PARAMETERS (PHASE III)

ID	Description
FLO-HYD-III-01	Global floater motions
FLO-HYD-III-02	Global floater velocities
FLO-HYD-III-03	Global floater accelerations
FLO-HYD-III-04	Floater position
FLO-HYD-III-05	Hydrodynamic variables
FLO-STR-III-01	Structural loads
FLO-AUX-III-02	Communication system
FLO-AUX-III-03	Electrical system
FLO-AUX-II-04	Firefighting system

4.4 WIND TURBINE

Monitorization of the wind turbine is designed per the manufacturer's standards as defined in the wind turbine's user manual. The monitoring approach designed for the DemoSATH project has considered the specifics of having a pre-installed monitoring system in the wind turbine and the monitoring system has been adapted correspondingly.

The areas of the wind turbine that are monitored are as follows:

TABLE 4.4 MONITORED WIND TURBINE PARAMETERS (PHASE III)

ID	Description
WTG-GEN-III-01	Generator speed
WTG-GEN-III-02	Generator temperatures
WTG-GEN-III-03	Generator wear (brushes)
WTG-GEN-III-04	Generator oil pressure
WTG-GEN-III-05	Generator oil level
WTG-GEN-III-06	Generator performance
WTG-GEN-III-07	Blade angle
WTG-GBX-III-01	Gearbox vibration
WTG-GBX-III-02	Gearbox acceleration
WTG-DRT-III-01	Drivetrain vibration
WTG-DRT-III-02	Drivetrain shocks
WTG-TWR-III-01	Tower vibration
WTG-TWR-III-02	Towe acceleration
WTG-TWR-III-03	Tower hydraulics
WTG-OTH-III-01	Temperature at other areas
WTG-OTH-III-02	Nacelle position
WTG-OTH-III-03	Network monitoring
WTG-OTH-III-04	Brake status
WTG-OTH-III-05	Brake wear

5. CONCLUSIONS

This document gathers a high-level analysis of the monitoring strategy that has been used for the DemoSATH Prototype during the different phases of construction, installation, and operation.

6. REFERENCES

[1] «D2.1 Description of the support structure monitoring system, SATHScale,» SAITEC S.A., 2021.

[2] «D2.2 Description of the system monitoring of the electrical connection, SATHScale,» SAITEC S.A., 2021.

[3] «Grant Agreement - 958938 - SATHScale,» 2020.