REALTIDE

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Advanced monitoring, simulation and control of tidal devices in unsteady, highly turbulent realistic tide environments

Grant Agreement number: 727689

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Project Title: Advanced monitoring, simulation and control of tidal devices in unsteady, highly turbulent realistic tide environments

Deliverable 1.6
Guidelines for the Development of Tidal Turbines Reliability Databases

WP 1
Increased Reliability of Tidal Rotors

WP Leader: Bureau Veritas

Task Leader: Bureau Veritas

Dissemination level: Public

Summary: This report forms Deliverable 1.6 and details the work of Task 1.6 within WP1 of RealTide. It provides the description of the work carried out on the guidelines for the development of tidal turbines reliability databases. It covers the description of : 1) the requirements for the development of reliability databases recommended by industrial standards, 2) the process developed regarding the database utilisation from pre-data collection to the reliability data reporting including data treatment, recoring and processing; 3) the specifications for the construction of the database (structure, data tables, data relationship and queries…); 4) the reliability formulas to be used t calculate the realibility and maintainability data; 5) the construction of a database demonstrator to simulate the databse functionality with a set of dummy data for demonstrator testing; 6) indication of developments recommended for commercial database versions.

Objectives: The objective of this task is to produce guidelines for the development of a dedicated tidal turbines reliability database based on relevant standards such as IEC 60300-3-2 and ISO 14224 and good practices from existing reliability databases in the industry.
The construction of a demonstrator version of the database is also part of the scope of this task. The database is to be trialed internally by the consortium and will be shared at the REALTIDE Workshop. This demonstrator version will be available for UEDIN to encourage participation from undergraduate and postgraduate researchers to use this database on condition of supplying early feedback.
The final decision on how to incentive the participation of the industry and how to reward the addition of information, in this and other databases resulting from the REALTIDE project will be part of a specific subtask in T6.2 dealing with the exploitation of databases.

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Abbreviations & Definitions

ART	Active Repair Time
BV	Bureau Veritas
BV M&O	Bureau Veritas Marine & Offshore
CAPEX	Capital Expenditure
CMMS	Computerised Maintenance Management System
CTV	Crew Transport Vessel
D	Deliverable
DD	Dangerous Detected (SIS failure)
DU	Dangerous Undetected (SIS failure)
EO	EnerOcean
FMECA	Failure Mode, Effect and Criticality Analysis
FMEA	Failure Mode and Effect Analysis
ID	Identification
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFR	Ifremer (Institut Français pour la Recherche et l'Exploitation de la Mer)
IFREMER	Institut français de recherche pour l'exploitation de la mer
ISO	International Organization for Standardization
ISSA	Ingeteam Power Technology
kW	Kilo Watt
LHS	Left Hand Side
MMH	Mean Man-Hours
MRE	Marine Renewable Energy
MS	Microsoft
MTTF	Mean Time to Failure
MTTR	Mean Time to Repair
MW	Mega Watt
NP	Number of Person
O&G	Oil and Gas
O&M	Operations & maintenance
OPEX	Operational Expenditure
OREDA	Offshore Reliability Database
OSV	Offshore Supply Vessel
PFD	Probability of Failure on Demand
RAM	Reliability, Availability and Maintainability
ROV	Remote Operated Vehicle
SAB	Sabella
SD	Safe Undetected (SIS failure)
SD	Standard Deviation
SU	Safe Undetected (SIS failure)
SIS	Safety Integrity System
SQL	Structured Query Language
T	Task
TT	Tidal turbine
UEDIN	The University of Edinburgh
WP	Work Package
WT	Wind Turbine
1T	1Tech

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Distribution List

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EXECUTIVE SUMMARY

Due to the emerging stage of development of the Marine Renewable Energy (MRE) sector, there is a particular lack of long-term experience at sea on which to build a dedicated failure mode and failure rate database. However, establishing the database structure even at this early stage would enable the collection of future infield data as operators gain experience.

The objective of this task was to produce guidelines for the development of a dedicated tidal turbines reliability database based on relevant standards such as IEC 60300-3-2 [10] and ISO 14224 [14] and good practices from existing reliability databases such as OREDA [3][4]
The construction of a "Demonstrator version" of the Database was also part of the objectives of this task. The database is to be trialed internally by the consortium and will be shared at the REALTIDE Workshop. This "Demonstrator version" will be available for UEDIN to encourage participation from undergraduate and postgraduate researchers to use this database on condition of supplying early feedback.

The final decision on how to incentive the participation of the industry and how to reward the addition of information, in this and other databases resulting from the REALTIDE project will be part of a specific subtask in T6.2 dealing with the exploitation of databases.

This deliverable includes the participation of partners Bureau Veritas, Bureau Veritas Solutions, Ingeteam, EnerOcean and 1-Tech. Deliverable 1.6 describes:

- The database requirements that have been used to elaborate the database guidelines for tidal turbines;
- The database process for data collection, data treatment and processing and reliability databook reporting);
- The database specifications for database structure, data format;
- The construction of a demonstrator database including tests with dummy data;
- Potential development for further versions of an industrial database.

The data requirements covered several aspects of the database. Firstly, the data to be collected are divided into three categories: Equipment data, Failure data and Maintenance data. These three categories of data are to be recorded in the database and are to be used to calculate the reliability data that will be shared with final users.
The second database requirement is the definition of the database applications in terms of:

- equipment covered by the database, which are all equipment installed in tidal turbines;
- the period of data, which are all data related to the useful life of the covered equipment;
- database users, which are stakeholders that are directly or indirectly involved in the designing/engineering, manufacturing, exploitation, maintenance and regulations of tidal turbines;
- database limits, i.e., the database is limited to provide reliability and maintainability data for the covered equipment only (no data related to costs or turbine performance will be covered by the database)
- reliability data exchange, to ensure that the adequate data format is used by all stakeholders and that sensitive and confidential data are made anonymous.

The third requirement is related to the quality of the data. Those requirements define the quality of data (completeness, compliance, accuracy, sampling and adequacy) and how to obtain them. They

drive also the attention of stakeholders of what should be done and checked during all the phases of data collection and recording in the database in order to ensure the quality of the data.
The following requirement is related to the data collection process, where it is specified where data are commonly available in the companied for the data collection (mainly in systems dedicated to the management of the equipment such as CMMS; and engineering documents). From these requirements, the specifications for the data collection are also described (data source identification; data format and transfer in the database, and test of the data collection methodology). The organization is also to be set-up for the data collection phase consisting in defining the responsible for the data collection and the means to ensure the quality of collected data and efficiency and effectiveness of the data collection itself.

The fifth requirement consists in defining the battery limits of the equipment that will be included in the database and setting up the taxonomy recommended to be used in the database divided into 9 levels from industry (level 1) to equipment parts (level 9). However, the most important level to be defined is the equipment level (level 6) because the most relevant data to be collected are related to the equipment. In that requirement, it is also remained that the data to be collected should be referred to the useful life phase of the equipment life cycle where the failure rates are supposed to be constant in time.

The sixth requirement list all data to be collected for the tree categories specified in the first requirement (equipment, failure and maintenance). The minimum data that are necessary to constitute the database are specified as mandatory. The other data are optional because they provide extra information for more completeness database but do not necessarily impact the constitution of a basic reliability database.

Specifications in term of data format are presented in the following requirement. It is recommended to standardize and codify as much as possible the data to ensure consistency of the data record. Extra information in free texts for the collected data are also recommended to provide more details and explanations to ensure the good interpretation and therefore the appropriate recoding in the database.

Finally, the last requirement is for the defining the database structure were it is recommended to divide the database into at least two sections. One to record the data related to the classification of the equipment (such as equipment class, manufacturer, design parameters) which should be collected only one time as long as the equipment or the turbine is not modified. The other section is dedicated to failure and maintenance event data that are to be collected periodically and recorded in the database as failures occurred and maintenance activities are performed on the equipment.
The structure of the database should also provide enough flexibility to include new category of data or structuration in case new configurations or technologies of tidal turbine or equipment arise and to provide the possibility to include new types of data that was not considered in the first versions of the database.

Based on the requirements listed above the consortium elaborated the guidelines for the all phases of database process.
The first step is to designate a database manager belonging to the RealTide Consortium who will be responsible for putting in place all the database process from the constitution of the tidal turbine population and in the data collection; to the elaboration and dissemination of the reliability databook, by assisting the stakeholders on all phases of the datacollection, ensuring the quality of the data and administering the database.

Then a population of tidal turbines needs to be constituted along with operators, owners and maintainers in order to start collecting the data to be included in the database.
The more tidal turbines in quantity but also with different types the more robust the database and the outcoming reliability data will be. As a good practice at least 15 tidal turbines of each type should be selected to have a representative database.

The process of the data collection is presented in the sequence providing the indications of hat should be done to ensure an efficient data collection. Firstly, people should designated as responsible for the data collection in each company that are involved in the database process. The will identify the sources where the data will be collected and will put in place in their organization the adequate means in term of material and people for the data collection. They will control the quality of the data before transferring the data to the database manager. The data related to the turbine and equipment classification will be collected and send first in order to included them in the Turbine/Equipment section of the database. Then, periodically (at least once a year) data related to failures and maintenance will be provided to database manager to include them in the failure and maintenance section of the database. Tables such as presented in the Annex C will be used to assess in the data collection.

Once the data are received, the database manager will treat the data to translate the data into the appropriate format to record them in the database. A data quality check is also performed by the database manager who will request new data set if data are not possible to be exploited in the database.
During the data collection phase, the database manager will also compile all comments and requests from the stakeholders that could be used to enhance the database, its usage and the processes involved.

Once sufficient data are collected, treated, checked and recorded in the database, the reliability data can be calculated either using algorithms in the database or manually by the database manager. The reliability data are recorded in a dedicated reliability data section in the database to provide anonymized data for the elaboration of the reliability databook.
It is recommended to perform the calculations at least once a year. A good practice is to calculate reliability data when at least five failures are recorded for the same equipment class.

The final step in the process is the elaboration of the reliability databook report that will be issued to the market.
An edition should be issued around every 5 years. This period should be enough time to collect sufficient data for most of equipment covered in the database on order to produce robust and confident reliability data.

The reliability data book will present the following main reliability and maintainability data for each sub-assembly and equipment recorded in the database:

- **Reliability data:**
- Number of failures:
  - Per failure consequence
  - Per equipment (for sub-assembly level)
  - Per failure mode (for equipment level);
- Mean failure rates (based on calendar and operating times)
  - Per failure consequence
  - Per equipment (for sub-assembly level)
  - Per failure mode (for equipment level);
- Limits of the 90% uncertainty interval of the failure rates (based on calendar and operating times)
- Number of failures upon request (for equipment, if relevant);
- Probability of failure on demand (for equipment, if relevant);

- **Maintainability data:**
- Mean active repair time and man-hours:
  - Per failure consequence
  - Per equipment
- Maximum and minimum values of the active repair times.

One import issue to be addressed during the database process is the confidentiality of the collected data. This is why a confidentiality agreement between all stakeholders involved in the data acquisition and processing is to be put in place. Moreover a system dedicated to the data transfer such as secured e-mailing or data transfer platform is also to be adequately chosen or developed in order to avoid any loss and leak of data during the data collection phase.

Apart from the guidance for the database process summarized above, the collaborators has also developed all specifications for the database construction in two chapters. The first described the database structure which is divided into three sections:

1) Tidal turbine equipment data section:
   Tidal turbine equipment data section is dedicated to build the taxonomy structure of each tidal turbine from level 1 and level 6 where all data related to the classification of the turbines and their sub-assemblies and equipment will be recorded.
2) Failure and maintenance data section
   Failure and maintenance data section is dedicated to record all data related to failure and maintenance activities that are collected for each equipment included in the tidal turbine equipment data section.
3) Reliability data section:
   Reliability data section is dedicated to record all the reliability and maintainability data calculated from the data stored in the failure and maintenance data section of the database.

For each level of the taxonomy, the details of all the data to be collected for these three sections including which data are mandatory, which ones are optional, and which ones depend on information from another table in the hierarchy are described in this document. Annex C presents the tables summarizing all data to be collected and their definitions.

The second chapter compiles the formulas to be used for the creation of the algorithms and for calculation of the reliability and maintainability data from the data collection which are:

- **For reliability data:**
  - Formula for failure rate of homogeneous equipment sample;
  - 90% uncertainty interval of failure rates of homogeneous equipment sample;
  - Formulas for failure rate of non-homogeneous equipment sample;
  - 90% uncertainty interval of failure rates of non-homogeneous equipment sample.
  - Failure rate estimation when no failure are observed;
  - Estimation of probability of failure on demand.

- **For maintainability data:**
  - Formula for mean active repair time;
  - Formula for Mean Man-hours for repair activity.

Then, a demonstrator database has been constructed to simulate the creation of a functioning database from the developed specification. It goes through determining the end-use of the database, issues around data-entry, issues related to security and commercial sensitivity, and what the data flow should look like to meet the criteria. It was assumed in the simulation that the database service provider would manage data entry. Data will be collected from developers via forms, then manually entered. This process simplifies security related to data entry. Only anonymized data should be presented to the public through an open database service.

Based on feedback from partners within the consortia, the Microsoft Access database engine has been used to build the demonstrator reliability database and to indicate how it should function. To implement the database as an operational system we recommend the use of a more robust and scalable database engine. The decision on which engine to use will depend on the party responsible for hosting and managing the database.

The main goals when constructing a database from complex interrelated data, are to (1) minimise the amount of replicated information within the database, (2) ensure that new information can be added without the need to redesign or rebuild database tables, and (3) ensure that all required relational connections are maintained to meet the end-user requirements.

Based on the specifications developed for the construction of the database, the first step was to identify and define the unique entities in each section of the database structure in order to minimise the amount of replicated information within the database. Then the relational links between entities derived from the specification information was defined to ensure that all required relational connections are maintained to meet the end-user requirements. After that, automatically generated data, copied data from other tables and calculated data are determined. From that point, all database tables, fields and queries was defined and created in the Microsoft Access database engine. For the purpose of the database demonstrator some filters have been created and kept relatively simple, but each can be readily extended to meet operator needs. Finally, field calculations have been implemented to be able to extract the reliability data from the specified calculations.

To test the logical construction for the demonstrator database a set of dummy data where generated using information provided by Ingeteam taken from actual wind farm failure/maintenance data. These data where then modified to represent tidal turbine failure records. Once the operational database had been constructed a query was used to generate a table of anonymised reliability data that would be placed in a public-facing database, and could be queried to generate reliability reports. The fields in the anonymised data were selected to meet the parameter requirements for the reliability data calculations presented in the database specifications.

The database demonstrator is a testing model of the database and it is not intentioned to be commercialized as it is. Some more development still need to be performed and was listed in the last chapter of the document. Some of the recommended development can be implemented for the first version that will be commercialized. Others developed can only be implemented based of the data and feedback got as the database is exploited. The main further developments raised up to now are 1) the creation of a database interface to make data transfer more efficient and secure; 2) development of a web based database for more accessibility to users; 3) creation of filters to potentialize the exploitation of the database for more details and robust reliability analysis; 4) implementation of complementary reliability calculations that could not be implemented in the demonstrator; 5) Continuing to the standardizations and codification of the data recorded in the database; 6) Expand the database taxonomy to bub-unit and part levels for a more detailed and exhaustive database.

1 TERMS AND DEFINITIONS

For the purpose of this document, the following terms and definitions are applied.
Active Repair Time: Part of the maintenance time during which a maintenance action is performed on an item, either automatically or manually, excluding logistic delays.
Aggregate service time (calendar or operating): Cumulated calendar or operating times (surveillance times) between the start date and end date of Reliability/Maintenance data collections of one or several items.
Availability: Ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided.
Boundary: Interface between an item and its surroundings.
Calendar Time: Interval of time (surveillance time) between the start date and end date of Reliability/Maintenance data collection.
Condition Monitoring: the process of monitoring a parameter of condition in machinery (vibration, temperature etc.), in order to identify a significant change which is indicative of a developing fault.
Corrective Maintenance: Maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function.
Critical failure: Immediately loss of production performance.
Degraded failure: Progressive or no loss of production performance.
Equipment Data: Technical, operational and environmental parameters characterizing the design and use of an equipment unit.
Failure Data: Data characterizing the occurrence of a failure event.
Failure mode: Effect by which a failure is observed on the failed item.
Failure Rate: Failure rate is the frequency with which an engineered system or component fails, expressed in failures per unit of time. It is usually denoted by the Greek letter λ (lambda) and is often used in reliability engineering.
Functional Failure: A failure which causes immediate and complete loss of a system capability of providing its output.
Incipient failure: No immediately loss of production performance but could bring critical failure after a period of operation.
Maintainability: Ability of a failed item to have its required function restored under given conditions for a given time interval.
Maintenance Data: Data characterizing a performed maintenance activity.
Mean Time to Repair: Average time required to repair a failed component or device.
Operating Time: Interval of an item operating time (surveillance time) between the start date and end date of Reliability/Maintenance data collection.
Operation Philosophy: Rules describing how the installation is operated including safety, maintenance, spare issues as well as flaring policies.
Population: The total number of items of one particular type in service during the period of the event data surveillance.
Potential Failure: an identifiable condition which indicates that functional failure is either about to occur or in the process of occurring
Preventive maintenance: Maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce probability of failure or the degradation of the functioning of an item (ISO 20815:2008)
Probability of Failure on Demand (PFD): measure of the effectiveness of a safety function. It expresses the likelihood that the safety function does not work when required to.
Reliability: Ability of an item to perform a required function under given conditions for a given time interval.

Service Time: Time interval during which an item is in servicing state.
Severity Classification: Describes effect on operational status and the severity of loss of output from the system. The severity classification is connected to the ability of the item in question to perform its function.
Subunit: Assembly of items that provides a specific function that is required for the equipment unit within the main boundary to achieve its intended performance.
Taxonomy: Systematic classification of items into generic groups based on factors possibly common to several of the items.
Uncertainty Interval: associated confidence level that gives the probability with which the estimated interval will contain the true value of a parameter.

2 INTRODUCTION

Due to the emerging stage of development of the Marine Renewable Energy (MRE) sector, there is a particular lack of long-term experience at sea on which to build a dedicated failure mode and failure rate database. However, establishing the database structure even at this early stage would enable the collection of future infield data as operators gain experience. Therefore, the aim of this task is to produce guidelines for the development of a dedicated tidal turbines reliability database. Particular attention is paid to critical issues such as taxonomy, data storage format, anonymous treatment of confidential data or failure classification. Confidence in the input data (sample, population, collection method...) was also addressed, including how to document conditions related to the recorded failure (location, date, maintenance type,…). Effective and handy processes was investigated to enable operators completing easily the database as they gain field experience. Relevant standards such as IEC 60300-3-2 [10] and ISO 14224 [14] served as a basis for the development of these guidelines. Good practices from existing reliability databases OREDA [3][4] is also highlighted. One of the project participants (UEDIN or BV ideally) could propose to anonymize and treat the data to be sent by all the companies using such technologies. Participants to the project would have access for free to the post-treated data / reports and other companies would be able to buy it the documents. In the future, revenue related to the sales of the reliability data will be injected in the company team in charge of maintaining the reliability database and databook. There is an initial "Demonstrator version" of the Database that is being trialed internally by the consortium before sharing this database at the REALTIDE Workshop. This "Demonstrator version" will be ready with enough time for UEDIN to encourage participation from undergraduate and postgraduate researchers to use this database on condition of supplying early feedback. Some of the data was populated with simulated data (derived from extrapolated data but also from wind turbine real data) for this initial assessment, before significant tidal turbine real data is available. A clear distinction of the origin of the data (extrapolated or real tidal energy data) will be provide. The final decision on how to incentive the participation of the industry and how to reward the addition of information, in this and other databases resulting from the REALTIDE project will be part of a specific subtask in T6.2 dealing with the exploitation of databases.

This document presents the result of the work provided in this task It is described in here the general requirement for a reliability database, general guidelines for all the phases of the database process from Data collection to reliability data book issuance, the specifications required for the database construction and for reliability data calculations, the description of the database demonstrator that was developed and finally recommendations of developments to be provided on commercial versions.

3 DESCRIPTION OF TASK 1.6

3.1 Overview

This deliverable includes the participation of partners Bureau Veritas, Bureau Veritas Solutions, Ingeteam, EnerOcean and 1-Tech. Deliverable 1.6 describes:

- The database requirements that have been used to elaborate the database guidelines for tidal turbines;
- The database process for data collection, data treatment and processing and reliability databook reporting);
- The database specifications for database structure, data format;
- The construction of a demonstrator database including tests with dummy data;
- Potential development for further versions of an industrial database.

3.2 Objectives

The objective of this task was to produce guidelines for the development of a dedicated tidal turbines reliability database based on relevant standards such as IEC 60300-3-2 [10] and ISO 14224 [14] and good practices from existing reliability databases such as OREDA [3][4]

The construction of a demonstrator version of the database was also part of the scope of this task. The database demonstrator is to be trialed internally by the consortium and will be shared at the REALTIDE Workshop. This demonstrator version will be available for UEDIN to encourage participation from undergraduate and postgraduate researchers to use this database on condition of supplying early feedback.

The final decision on how to incentive the participation of the industry and how to reward the addition of information, in this and other databases resulting from the REALTIDE project will be part of a specific subtask in T6.2 dealing with the exploitation of databases.

3.3 Subtasks

The Table 3-1 below presents the sub-tasks developed by the partners for the task 1.6.

Table 3-1. - List of sub-tasks for Tasks T1.2 RAM Assessment

SHORT NAME	SUB TASK DESCRIPTIONS
1. DATABASE GUIDELINE	• Familiarization with database standards and existing industrial databases • Synthesis of reliability requirements • List of all required data to be collected by tidal turbine owner/operators/maintainers at turbine/equipment level and failure & maintenance level • Definition of tidal turbine types and main characteristics (family & configurations) • Definition of tidal turbines taxonomy • Definition of tidal turbine failure modes & codifications • Description of the database structure specifications • Description of data collection procedures • construction of data tables for the database specification • Definition of data treatment and processing (Methodology for Reliability & Maintainability data calculations) • Definition of reliability databook reporting • Describe data base population procedures
2. DATABASE DEMONSTRATOR DEVELOPMENT	**Development of Reliability Data Set** • Construction of database tables and queries • Structuration of database • Construction reliability data calculation codes • Data collection from wind turbine industry for the construction of dummy data • Data treatment and construction of dummy data • Data base trial with dummy data • Database quality check

4 DATABASE REQUIREMENTS

The database has been constructed based on the practices presented in the Standards ISO 14225 [14] and EN 60300-3-2 [10]. The following chapters presents a summary of the basic requirements proposed by these documents in order to build a functional database.

4.1 Data categories

The reliability databases have to include 3 categories of data:

1) Equipment data (inventory data):
    - classification data such as industry, facility, location, system;
    - equipment attributes such as manufacturer data, design specifications;
    - operating data such as operating mode, power and environment.
2) Failure data:
    - Identifying data, for example the failure record number and associated defective equipment;
    - Data characterizing a failure, e.g. date of failure, defective entities, consequence, mode and cause of failure, method of failure detection.
3) Maintenance data
    - Identification data, for example maintenance registration number, associated failure and / or equipment registration;
    - Maintenance data; the parameters characterizing a maintenance operation, for example: date, class, maintenance operation, consequence of the maintenance, entities concerned;
    - Means of maintenance; maintenance in man-hours by discipline and total maintenance, auxiliary equipment / applied resources;
    - Maintenance times; the actual maintenance time, the downtime.

4.2 Applications

Hereafter are defined the main applications of the database in order to drive the development of the structure and the features of database. The applications have also the goal to inform the final users what are the scope and contents of the database and what extent this database can be exploited.

4.2.1 Equipment covered

The database is intended to cover the reliability data for equipment included in the design all types of tidal turbines. The battery limit is limited to equipment that is included in the tidal turbine and excluded all equipment that are in common use with other tidal turbines. For example, manifolds and umbilicals that supply several turbines are not included in the scope of this database.

4.2.2 Period of data

This database applies to data collected during the useful operational life of the tidal turbines including operation, maintenance and potential modifications. The phases of laboratory testing, construction and manufacturing installation, start-up and decommissioning, are not specifically addressed.

4.2.3 Users

These database is dedicated to stakeholders that are directly or indirectly involved in the designing/engineering, manufacturing, exploitation, maintenance and regulations of tidal turbines such as and not limited to tidal turbine owners, manufactures, maintainers, electricity companies, Authorities, regulation organisms, Class societies and subcontractors.

The owners, operators and maintainers have a special role as they are also the ones that will potentially contribute to collect the data that will be used as an input for the reliability database.

4.2.4 Limits

This database is limited to provide reliability and maintainability data of tidal turbines that can be further used in analysis for designing, operating and maintenance. This database will not give any data related to costs, production losses of loss of revenue.

4.2.5 Reliability data exchange

The main objective of the guideline is to enable the exchange of reliability data in a common format, within a company, between different companies, in the industrial sector or in the public sector.

It is also very important to make this data anonymous as confidential and sensitivity data from operators/owners may be used in the process form data collection to the publication of the reliability data to final users.

4.3 Data quality

Here is a summary of the requirements from ISO 14224 [11] related to data quality.
The data collection procedure and the database has been designed following those requirements.

4.3.1 Obtaining quality data

The level of confidence placed in reliability data and, therefore, in analyses using those data, strongly depends on the quality of the data collected. Good quality data is characterized by:

- their completeness in relation to the specifications;
- their compliance with the definitions of reliability parameters, data types and data formats;
- their accuracy of capture, transfer, processing and storage (manual or electronic);
- a sample and an observation period sufficient to provide statistical confidence;
- the adequacy of the data to the needs of the users.

4.3.2 Planning

During the data collection phase, the database manager shall analyse the data source(s) to ensure that relevant data of sufficient quality is available. The sources cover the inventories and technical information relating to the characteristics of the equipment, the associated data on the installations; related to reliability and maintainability events and the associated consequences on the installations.

The taxonomy information is to be previously defined and included in the database for each equipment in order to ensure consistency of the data collected and the equipment that related to these data.

The data manager should identify the date of installation, the population and the period(s) of operation of the equipment where the data can be collected.

The battery limits for each class of equipment should be previously defined, indicating the reliability data to be collected.

A single definition of failures and maintenance activities and a classification method of these is to be applied in order to ensure consistency of the data.

The database manager shall control and verify quality of data and set a priority level for the completeness of the data.

The level of detail of reliability data logged and collected is to be defined so that it is closely related to the importance of the equipment to production and safety.

The data collection process should follow a plan defined by the database manager in order to specify how to collect, record and transfer data from its source to the reliability database.

Then establish a quality assurance plan for the data collection process and its deliverables.

4.3.3 Quality check

During and after collection, data should be analysed to verify consistency, reasonable distribution, code compliance and correct interpretation according to planning measures. This verification of the quality process must be documented and may vary depending on whether the code is for a single installation or for several corporate or industrial installations.

4.3.4 Limits and issues

Related to data format
The use of coded fields is essential to ensure efficient data collection and consistency of collected data (correct coding of a failure mode, for example). Therefore, when describing unexpected or confusing situations, free text should be included in addition to codes. When data is not available, options such as "Other" or "Unknown" is to be applied in order to avoid having fields left in blank, which could be a problem during data processing.

Related to data collection method
Currently, the majority of data required during the data collection is stored in computerized systems (such as Computerized Maintenance Management System (CMMS)). Using state-of-the-art software and conversion algorithms, it is possible to transfer data between multiple databases in (semi) automatic mode, reducing costs.

4.4 Data collection process

Here is a summary of the main requirements related to the data collection process.

4.4.1 Data sources

The main sources related to reliability data are the CMMS used by turbine owners, operators and/or maintainers to manage all preventive and corrective maintenance activities and also to record all maintenance historic since the commissioning of the system. However, some information may not be included in the CMMS such as equipment specifications. In that case the data should be collected from other sources such as drawings, design specification reports, manufacturer manuals etc.

4.4.2 Data collection methodology

The main steps for the data collection are:

- To identify the data source for each required data to be collected;
- To translate the information collected and convert in an suitable format to the reliability database;
- Transfer the data in the database.

The data collection methodology should be tested prior to start using the database. Those tests should ensure that the required data can be properly collected and included in the database. In case of difficulties during the data collection phase, the process, data format or even the database structure should be adapted in consequence.

4.4.3 Organization

For each step of the data collection phase, it is important to identify who will be responsible for the execution of the task. The person in charge should have the adequate knowledge and skill but also the appropriate tools for the execution.

Again, a pilot case should be performed (in a smaller scale for example) before the complete data collection in order to eliminate or mitigate any constraint that could occur during the whole process.

Finally, a system for treatment of deviations and feedback should be put in place to ensure a continuous improvement of the database taking that could take into account any fault or relevant customization raised by the stakeholders to upgrade the database for further versions.

4.5 Battery limits of equipment, taxonomy and time definitions

4.5.1 Description of limit batteries

It is essential to provide a clear description of boundary batteries for the collection, fusion and analysis of reliability data from different industries, facilities or sources.

4.5.2 Taxonomy

In order to obtain the adequate structural granularity for the database, the taxonomy of the assets should be divided into 5 or 9 levels according to the Figure 4-1. It is recommended that the minimum level for which the data should collected it the equipment level (i.e. level 6).

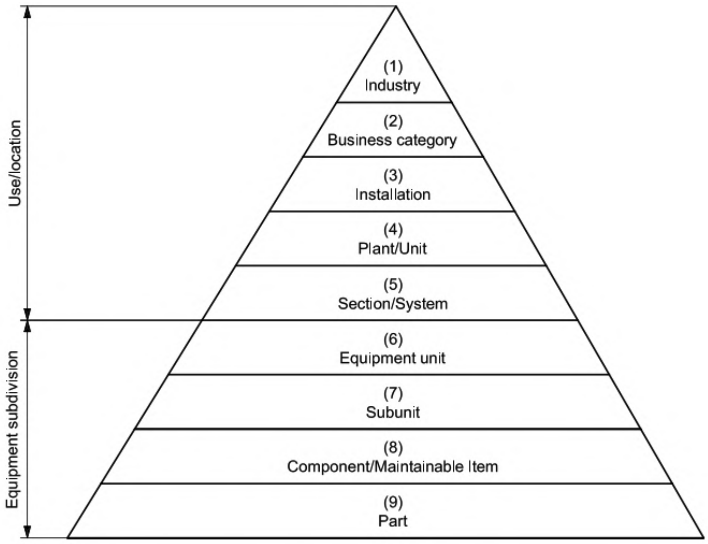


Figure 4-1 - Taxonomy classification as per ISO 14224 [11]

4.5.3 Time issues

Reliability parameters are mostly related to time. Therefore, it is essential to well define for each equipment the following times:

- Operating time,
- non-operating time, and
- unavailability time (programmed or non-programmed)

Moreover, failures must be put into the phase of the equipment's life cycle (burn-in/early failures phase, useful life /intrinsic failure phase, wear-out / deterioration phase).

It is important to note that the database includes essentially reliability data related to failures that occurs during the useful life / intrinsic failures phase of each equipment, where the failure rates is assumed to be constant in time (as presented in Figure 4-2).

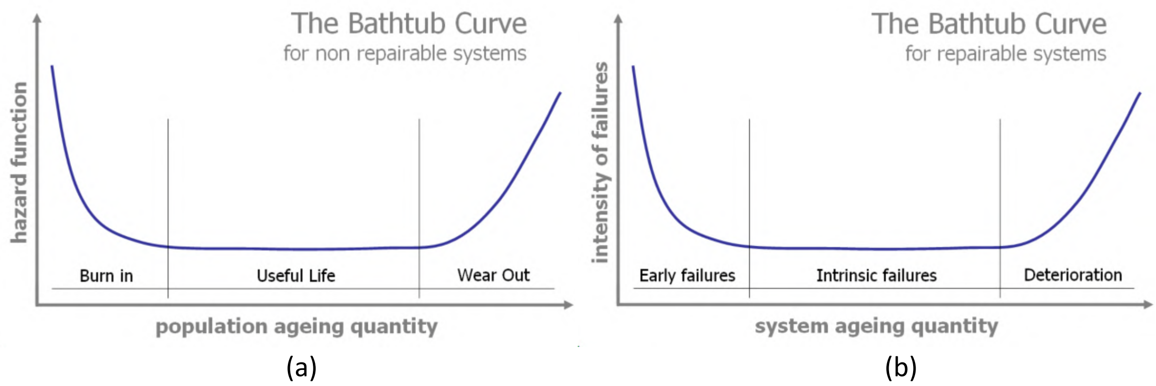


Figure 4-2 - The bathtub curve (a) for non-repairable systems and (b) for repairable systems [26].

4.6 Recommended equipment, failure and maintenance data

Table 4-1, Table 4-2 and Table 4-3 hereafter present the minimum data required for each level of the taxonomy and for each category of data presented in chapter 4.1 (only data relevant or transposable to tidal turbine industry were selected)

Table 4-1 - Equipment data (data common to all classes of equipment) [11]

Data category	Taxonomy level		Data to be recorded
Utilization / Location attributes	Level 1	industry	Industry
	Level 2	Business category	Activity category (*)
	Level 3	Installation	Installation Name or Code (*)
			Geographical location
	Level 4	Plant/Unit	Owner name or code
			Unit/installation category (*)
			Installation name or code (*)
	Level 5	Section/System	Section/System (*)
			Operation category
Equipment attributes	Level 6	Equipment unit	Equipment class (*)
			Equipment type (*)
			Equipment identification or location (ex. Identification number) (*)
			Equipment description (Nomenclature)
			Unique equipment identification number (ex. Serial number)
			Manufacturer name (*)
			Manufacturer model designation
	Levels 6 to 8	Equipment unit / Subunit / Component/Maintainable item	Relevant design data for each class of equipment and sub-unit / component as appropriate(for example capacity, power, speed, pressure, redundancy, applicable standard(s))
Operation (normal use)	Level 6	Equipment unit	Normal functional mode/status (*)
			Initial equipment commissioning date
			Start date of current service (*)
			Observation period (calculated) (*)
			Operating time (measured / calculated)
			Functional parameters appropriate to each class of equipment; for example the external environment, the operating power
	Levels 6 to 8	Equipment unit / Subunit / Component/Maintainable item	Number of requests relating to periodic tests during the observation period, if applicable (*)
			Number of actual (operational) requests during the observation period, if applicable (*)
Additional information	Level 6	Equipment unit	Additional information in free text, if applicable
			Data source, e.g. P & ID, data sheet, maintenance system

(*) Minimum required data

Table 4-2 - Failure data [11]

Data category	Data to be recorded
Identification	Failure recording (*)
	Identification / Location of the equipment (*)
Failure data	Date of failure (*)
	Failure mode
	Consequence of the failure on the safety of the installation (e.g. personnel, environment, property)
	Consequence of the failure on the operation of the installation (e.g. production, intervention)
	Consequence of the failure on the function of the equipment (*)
	Mechanism of failure
	Cause of failure
	Defective subunit
	Defective Component(s) / Maintainable item(s)
	Detection method
	Operating condition during failure (*)
	Operational phase during failure
	Classification of safety instrumented systems failure modes
Remarks	Additional information

(*) Minimum required data

It is essential to have a consistent definition of failures.
A report like that presented in Table 4-2 and Table 4-3 with proper definitions and common to all classes of equipment must be used to record failure data

Table 4-3 - Maintenance data [11]

Data category	Data to be recorded
Identification	Maintenance record identification (*)
	Equipment identification (*)
	Failure record identification (*)
Maintenance data	Maintenance date (*)
	Maintenance category (*) (**)
	Maintenance priority
	Interval (programmed)
	Maintenance activity
	Consequence of maintenance on the operation of the installation
	Subunit subject to maintenance
	Component(s) / Maintainable Item(s) subject to maintenance
	Location of spare parts
Maintenance resources	Maintenance time in man-hours, by discipline
	Maintenance in man-hours, total
	Means necessary for the maintenance of the equipment
Temps de maintenance	Active maintenance time (*)
	Unavailability time (*)
	Maintenance delays / issues
Remarks	Additional Information

(*) Minimum required data

(**) Maintenance categories:

- Corrective maintenance: maintenance aimed at correcting a defective unit;
- Preventive maintenance: maintenance aimed at preventing the failure of an entity.

A report common to all classes of equipment must be used to record maintenance data.
The maintenance category shall be properly identified as only data related to failures that have effectively occurred are taken into account in the reliability data. As preventive maintenance activity aims at preventing or detecting failure but not to correct failure, data for such maintenance should be correctly treated and should not be integrated in the reliability data processing/calculation.

However, it is to be noted that, when performing preventive maintenance operations, incipient failures can be detected and corrected within the scope of this preventive maintenance. In this case, the failure(s) should be recorded like any other failure and followed by the corrective action (corrective maintenance), even if it was the origin of a preventive maintenance type activity.

4.7 Data Format

It is recommended, as far as possible, to standardize and/or code each piece of information. In addition, it should be possible to add a free text in order to provide more details / explanations about the given information. The codification allows ensuring that same information from different sources is recorded in the same way in the database. The free text can be used when there is no standard or code related to the information that is provided (for example, if a failure mode is missing or not coded in the database, the failure can be included in a free text field instead of using a list the code). Moreover, free texts are useful to include additional information to the database manager to ensure the quality and accuracy of the data provided.

4.8 Database structure

The data collected must be structured and linked in a database to facilitate access for updates, queries and analyses. Several structure models can be used to organize the data and are indicated in the standards. One of the logical data structure model proposed consists in dividing the database into two sections as presented in Figure 4-3:

1) Classification/Equipment data section: this section of the database is dedicated to record selected data from Table 4-1, i.e., related to the classification of the installation from Installation/Plant level to Equipment levels. Those data are recorded once and are to be updated only when modifications or component replacements are done on the installation or equipment.
2) Event data section: this section is dedicated to record all selected data from Table 4-2 and Table 4-3, i.e, related to failures and maintenance. This section shall be updated gradually as such events occur on the equipment.

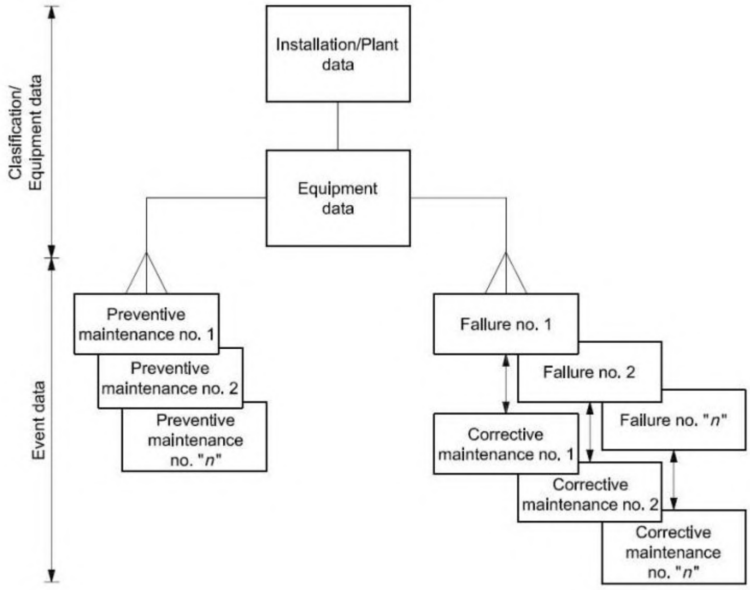


Figure 4-3 - Logical data structure example [11]

4.9 Database expansion

The database structure must provide the possibility to include new data / information which has not been considered in the initial database. For example, if a failure mode has not been considered in the initial database inventory, then the database user must be able to add this failure mode in order to complete the inventory for future versions of the database.
The same for components with new technologies, so the database must allow the user to include these new technologies for further utilization.

5 DATA BASE PROCESS

5.1 Overview

The objective of the database is to provide reliability and maintainability data to the industry regarding tidal turbines. As already highlighted in FMEA and RAM Assessment reports [17][16], the development of a database is of great importance for improving the design and the management of turbines in the future; making this MRE technology more and more efficient end cost effectively for the society as a whole.

So in order to provide that reliability data to final users, data related to equipment, their failures and maintenance (see Table 4-1, Table 4-2 and Table 4-3) are periodically collected from tidal turbine owners, operators and maintainers sources. When significant amount of data is collected, data are treated and translated into standardized way to include in the database where data is processed in order to calculate the final reliability and maintainability data. After a period of time a datebook compiling the reliability data can be issued to the industry. For the operators and maintainers that contribute to the data collection, intermediate and reliability data and reports related to their own turbines may be provided on demand.

This section is dedicated to explain the process to be followed from data collection to the reporting of the reliability data to final user.

The process consists in 4 phases:

1) Constitution of tidal turbine population
2) Data collection
3) Data treatment
4) Data calculation
5) Data base population
6) Reliability data reporting.

The Figure 5-1 below summarises the process from step 2 to step 6.

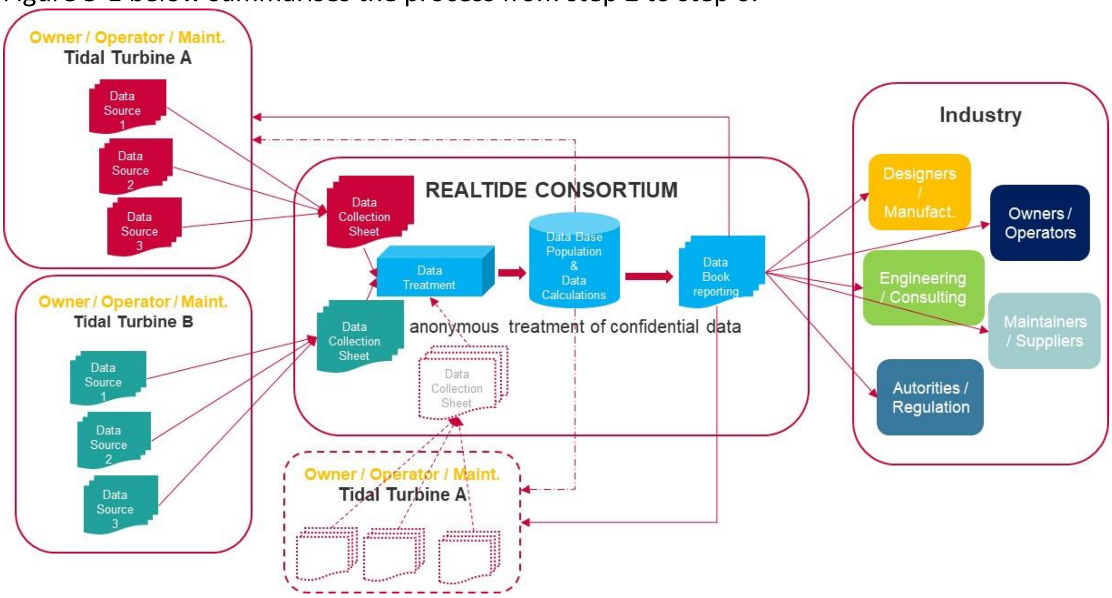


Figure 5-1 - RealTide tidal turbine reliability database process

5.2 Database manager

The RealTide Consortium will designed among its collaborators a database manager who will be in charge of putting in place all the database process. Its main roles will be, but not limited to:

- assist the stakeholders in the constitution of tidal turbine population and in the data collection;
- receive, teat and include the collect data in the database
- assist in the database construction and maintenance;
- provide the specifications for future enhancements on the database and auxiliary features (such as a data collection platform for example) from feedback collected from all database stakeholders;
- elaborate and disseminate the reliability databook;
- ensure that database is secured and that data are the anonymous when provided to final users.

5.3 Constitution of a tidal turbine population

The very first step in the process is to constitute a tidal turbine population from which the data will be collected. A group of stakeholders involving mainly tidal turbine owners, operators and maintainers shall be created in a such way that significant amount of tidal turbines will be used to collect the required data.

As a good practice, the population should be constituted by at least 15 tidal turbines per equipment class in order to have a robust database [25].

Data can be collected from fewer turbines, however it will take longer to cumulate enough data for a robust database. So it is very important to involve the highest number of turbines in order to be able to produce an efficient database in a shorter period of time.
A good quality database should cover a large spectrum of tidal turbine types, but the quantity of turbine of each types is also essential for the quality and robustness of the reliability data.

Moreover, as specified in chapter 4.2.2, tidal turbines selected for the database shall be in their useful operating life phase. To guarantee this requirement, the tidal turbines shall have been running for at least two years since commissioning [25].and should have an age not greater than their design life.

5.4 Data collection

5.4.1 Responsibilities

The data collection is performed by owners, operators and/or maintainers that have access to the data related to equipment, failure and maintenance listed in chapter 5.4.3 for each tidal turbines previously selected for the database collection

Before starting the data collection, a qualified person responsible for the data collection of a turbine or group of turbines must be designated from each entity involved in the data collection process. This person will be in charge of collecting periodically the data to be collected. He will delegate to another colleague or partner the data collection for all data that he cannot collect himself. He will ensure that all required data are complete and in an adequate and understandable format before sending to the consortium database manager.

In case of deviation identified by the database manager (missing data, errors, ambiguous data, etc.) this person will be responsible to correct the deviation, send back corrected data and take action to mitigate the occurrence of such deviations.

5.4.2 Data sources

The main data source to collect the required data are the CMMS. These softwares usually incorporate an asset register where equipment information are recorded and a database including the historic of failures and maintenance activities performed on the turbine.

The asset register will provide most of the data required for the Turbine/Equipment section of the database.

The CMMS database will provide most of the data required for the Failure and Maintenance section of the database related to failure and maintenance data.
In case any data is not available in the CMMS, other sources can be used such as manual manufacture, data books, maintenance files and reports, etc.

5.4.3 Data collection phase

The first set of data to be provided to the database manager is the data related to equipment as described in chapter 6.3. These data will allow the database manager to create the taxonomy of the turbine in the Turbine/Equipment section of the database (see chapter 6.2).
Then, when the structure of turbine is ready, the second phase is to collect the data related failures and maintenance which are listed in chapter 6.4 and to be included in the turbines Failure and Maintenance section of the database (see chapter 6.2).
The data collection for the Failure and Maintenance section of the database must be done periodically; at least once a year and not more than monthly. The recommended interval for data collection is every 3 or 6 months.

Annex C presents a table summarising all the data to be collected for each phase. All mandatory data mentioned in this Annex must be collected.

5.4.4 Data collection completeness

All required data to be collected are listed in chapters 6.3 and 6.4. The tables in Annex C shall be used by owner, operators and maintainers to collect the required data. The mandatory data must be collected, and the other ones are optional. As much as possible, a free text with more information about the data collected is to be included providing more information to the data manager to better interpret the data for treatment and processing before to include them in the database. When data is not available, the data should inform the data manager in order to take into account in the database the fact that the data is not completed or to take action in order to be able to collect these data in the future.

This phase is also the opportunity for owner, operators and/or maintainers to make their request to the database manager to enhance the database to improve the process of data collection or the way to explore the reliability database.

5.5 Data treatment

Once data are collected by owners, operators and/or maintainers, those are sent to the database manager via a data transfer platform (see chapter 5.8.2).

The database manager will be in charge to check the received data and properly include them in the database.

5.5.1 Quality check

The database manager will be responsible to receive the data and perform a quality check of the data received before include them in the database.

The first step is to ensure that all required data have been provided mainly the mandatory data and especially the data required for the reliability data calculation.

Then, the database manager will translate the data in the required format to include them in the database. The database manager will use the additional information eventually provided by owners, operators and/or maintainers during the data collection to interpret the data in case of ambiguity of the data.

The data manager will also ensure the consistency of the data, such as the consistency between the failure mode, the equipment type and the consequence of the failure. Special attention needs also to be driven in the consistency between dates and durations (eg. End dates should also be greater that start dates, durations cannot exceed the difference between end and stat dates, etc…).
In case the database manager has any doubt on the completeness, the accuracy/consistency and the exactitude of the data, the data manager will require new data collection for all missing data and also all data that could not be correctly interpreted.

5.5.2 Data transfer in the database

Once the quality check is finalized, the database manager will translate the data in the required format to include them in the database. The process of transfer of the data in the database is done manually, but in the future an application could be created in order to import the data from a file directly to the database.

5.5.3 Data base upgrading

In case new information is provided by persons that performed the data collection (such as new turbine structure, new technology or new failure modes), the database manager will prepare a report with a compilation of required modifications to be performed in the database in order to take into consideration the new information in further upgrade versions of the database.

It will also be included in the report all relevant request of data base modifications raised by owners/operators/maintainers.

The report will be sent to the database builder to include these modifications in the database. New versions of the database should be issue at least once a year in case any modification is to be made on the database during this period of time.

5.6 Data calculation

After collecting the required data, their treatment and inclusion in the database; the data are processed in order to calculate the reliability data for each tidal turbine equipment class included in the database.

The calculation is performed either by algorithms developed in the database or manually by the database manager (in that case, the results are manually introduced in the database).

The formulas used for the reliability data calculations are presented in chapter 0.

The calculations are performed and therefore the reliability data are updated once sufficient data are collected. A good practice is to collect data from at least 5 failures per equipment class in order to have a robust data for a rigorous analysis [25].

A set of calculation should be performed at least once a year. It is recommended to perform the calculations every 3 to 6 months in order to monitor the trends of the reliability data.

5.7 Reporting data book

Reliability data require that certain number failures to occur on the equipment in order to be calculated. As it is not expected that failures occurs too often, it will be needed to wait several months or even years in order to collect sufficient and representative data to produce relevant reliability data. This is why it is important to monitor periodically the trends of the reliability data that are calculated over time and verify if the reliability data can be published or not.

As already mentioned in the previous section, at least 5 failures per equipment class should be collected in order to have a rigorous analysis [25].
The time to collect sufficient data depends on the number of tidal turbine used to collect the data and how often their equipment fail. Therefore, the greatest the population of tidal turbines the shorter the time needed to issue the reliability data book.

However, as a good practice an edition of the reliability databook should be issued around once every 5 years. This period should be enough time to collect sufficient data for most of equipment covered in the database on order to produce robust and confident reliability data.

The reliability data book will present the following reliability data for each sub-assembly and equipment recorded in the database:

- **Sub-assembly level data:**
  - **Turbine/Sub-assembly data:**
  - Sub-System
  - Assembly
  - Sub-assembly
  - Sub-assembly type
  - Population of subassembly
  - Quantity of turbines
  - Aggregated in service time (based on calendar and operating times);

- **Reliability data:**
- Number of failures:
  - Per failure consequence
  - Per Equipment
- Mean failure rates (based on calendar and operating times)
  - Per failure consequence
  - Per Equipment
- Limits of the 90% uncertainty interval of the failure rates (based on calendar and operating times)

- **Maintainability data:**
- Mean active repair time and man-hours:
  - Per failure consequence
  - Per equipment
- Maximum and minimum values of the active repair times.

- **Equipment level data:**
  - **Turbine/Equipment data:**
  - Sub-System;
  - Assembly;
  - Sub-assembly;
  - Sub-assembly type;
  - Equipment;
  - Equipment type;
  - Population of sub-assembly;
  - Quantity of turbines;
  - Aggregated in service time (based on calendar and operating times);
  - Number of equipment requests (total of operational and test requests) (if any);

  - **Reliability data:**
  - Number of failures:
    - Per failure consequence;
    - Per failure mode;
  - Mean failure rates (based on calendar and operating times):
    - Per failure consequence;
    - Per failure mode;
  - Limits of the 90% uncertainty interval of the failure rates (based on calendar and operating times);
  - Number of failures upon request (if relevant);
  - Probability of failure on demand (if relevant);

  - **Maintainability data:**
  - Mean active repair time and man-hours:
    - Per failure consequence;
    - Per failure mode;
  - Maximum and minimum values of the active repair times.

Table 5-1 and Table 5-2 present example of reporting for sub-assembly and equipment level respectively.

Table 5-1 - Example of reliability data report at sub-assembly level

Sub-Assembly level:

Sub-System	Power take off
Assembly	Drivetrain
Sub-Assembly	Gearbox / high speed shaft
Sub-Assembly type	3 stages

Population	2
Turbines	1
Turbine Types	(Not selected)
Turbine Model	(Not selected)

SubAssembly	**Gearbox / high speed shaft**	**Aggregated in service time (10^6 hours)**						**Active repair hours**			**Repair ManHrs**
SubAssembly type	**3 stages**	**Calendar time**			**Operational time**						
		0,034992			0,02814385						
		Failure rate (failure per 10^6 hrs)									
Failure Modes / Equipment	**Nbr of failure modes**	**Low**	**Mean**	**High**	**Low**	**Mean**	**High**	**Min.**	**Mean**	**Max.**	**Mean**
Critical	**17**	**309,5605**	**485,8253**	**711,6176**	**384,8848**	**604,0396**	**863,4634**	**47,89**	**177,43**	**661,24**	**400,20**
Gearbox Lubrication system	14	241,8821	400,0914	608,0957	300,7384	497,4444	734,3903	47,89	157,52	528,28	380,80
Gears	3	23,36795	85,73388	201,0051	29,054	106,5952	223,7005	58,61	270,34	661,24	490,75
Degraded	**7**	**93,88762**	**200,0457**	**357,1644**	**116,733**	**248,7222**	**420,7809**	**55,69**	**136,54**	**403,38**	**273,08**
Gearbox Lubrication system	7	93,88762	200,0457	357,1644	116,733	248,7222	420,7809	55,69	136,54	403,38	273,08
Incipient	**7**	**93,88762**	**200,0457**	**357,1644**	**116,733**	**248,7222**	**420,7809**	**12,11**	**65,16**	**95,96**	**75,72**
Gearbox Lubrication system	7	93,88762	200,0457	357,1644	116,733	248,7222	420,7809	12,11	65,16	95,96	75,72
Grand Total	**31**	**641,4184**	**885,9168**	**1179,251**	**797,4926**	**1101,484**	**1445,805**	**12,11**	**142,85**	**661,24**	**298,22**

Table 5-2 - Examples of reliability data reports at equipment level

Equipment level:

Sub-System	Power take off
Assembly	Drivetrain
Sub-Assembly	Gearbox / high speed shaft
Sub-Assembly type	3 stages
Equipment	Gearbox Lubrication system
Equipment type	(Not selected)

Population	2
Turbines	1
Turbine Types	(Not selected)
Turbine Model	(Not selected)

Equipment	**Gearbox Lubrication system**	**Aggregated in service time (10^6 hours)**						**Active repair hours**			**Repair ManHrs**
Equipment Type	**(All)**	**Calendar time**			**Operational time**						
		0,034992			0,02814385						
		Failure rate (failure per 10^6 hrs)									
Row Labels	**Count of Failure Mode (Code**	**Low**	**Mean**	**High**	**Low**	**Mean**	**High**	**Min.**	**Mean**	**Max.**	**Mean**
Critical	**14**	**241,8821**	**400,0914**	**608,0957**	**300,7384**	**497,4444**	**734,3903**	**47,89**	**157,52**	**528,28**	**380,80**
External Leakage - utility medium (EXU)	5	56,30286	142,8898	281,1377	70,00284	177,6587	325,2405	60,02	73,58	93,82	129,28
Parameter deviation (PAD)	9	134,18	257,2016	430,7203	166,8296	319,7857	512,8882	47,89	204,16	528,28	520,53
Degraded	**7**	**93,88762**	**200,0457**	**357,1644**	**116,733**	**248,7222**	**420,7809**	**55,69**	**136,54**	**403,38**	**273,08**
External Leakage - utility medium (EXU)	3	23,36795	85,73388	201,0051	29,054	106,5952	223,7005	80,40	100,07	125,07	200,15
Parameter deviation (PAD)	4	39,04659	114,3118	241,7549	48,54767	142,127	275,5009	55,69	163,89	403,38	327,77
Incipient	**7**	**93,88762**	**200,0457**	**357,1644**	**116,733**	**248,7222**	**420,7809**	**12,11**	**65,16**	**95,96**	**75,72**
External Leakage - utility medium (EXU)	7	93,88762	200,0457	357,1644	116,733	248,7222	420,7809	12,11	65,16	95,96	75,72
Grand Total	**28**	**568,7197**	**800,1829**	**1080,586**	**707,1044**	**994,8888**	**1322,995**	**12,11**	**129,19**	**528,28**	**277,60**

Equipment level:

Sub-System	Power take off
Assembly	Drivetrain
Sub-Assembly	Gearbox / high speed shaft
Sub-Assembly type	3 stages
Equipment	Gears
Equipment type	(All)

Population	2
Turbines	1
Turbine Types	(Not selected)
Turbine Model	(Not selected)

Equipment	**Gears**	**Aggregated in service time (10^6 hours)**						**Active repair hours**			**Repair ManHrs**
Equipment Type	**(All)**	**Calendar time**			**Operational time**						
		0,034992			0,02814385						
		Failure rate (failure per 10^6 hrs)									
Failure Modes	**Nbr of failure modes**	**Low**	**Mean**	**High**	**Low**	**Mean**	**High**	**Min.**	**Mean**	**Max.**	**Mean**
Critical	**3**	**23,36795**	**85,73388**	**201,0051**	**29,054**	**106,5952**	**223,7005**	**58,61**	**270,34**	**661,24**	**490,75**
Vibration	3	23,36795	85,73388	201,0051	29,054	106,5952	223,7005	58,61	270,34	661,24	490,75
Grand Total	**3**	**37,51808**	**85,73388**	**201,0051**	**29,054**	**106,5952**	**223,7005**	**58,61**	**270,34**	**661,24**	**490,75**

Reports by turbine type, Assembly type, and Equipment type should be able to be produced in order to be able to get refined data for such level of detail.

It is also to bear in mind that owners, operators and maintainers, designers that will contribute to the data collection for the database should have access to the reliability data related to “their turbines”. Therefore, specific reports per turbine, turbine model, grouping and farm but also by owners, operators and maintainers, designers shall be produced for these stakeholders paying attention that data from one stakeholder turbines are not shared to the other stakeholders.

5.8 Confidentiality issues

5.8.1 Agreement

In order to preserve the confidentiality of data that is transferred between owners/operators/maintainers and the database manager, a confidentiality agreement should be put in place with all stakeholders involved in the data collection and data processing. This agreement shall ensure that data from a given stakeholder are not transferred to another stakeholder in any case, and that the reliability data reported to industry are made anonymous for final user.

5.8.2 System

The process from data collection to reporting shall ensure no possible leaks of data to any other stakeholder or user or any public. So the way that data are transferred should be agreed between all stakeholders before starting the data collection. Secured platforms for data transfer and secured emails can be used in that purpose. If required a dedicated platform for data transfer can be further developed by the consortium.

6 DATABASE TABLE SPECIFICATION

6.1 Overview

This chapter describes the specifications of the database to be developed for the tidal turbines industry.

It includes the basis of the database structure and also the specification for data to be included in the database after the treatment of data coming from the data collection phase and for the reliability data that the database is to present after reliability data calculations.

6.2 Database Structure

Tidal turbine reliability database structure consists of three sections:

- Tidal turbine equipment data section
- Failure and maintenance data section
- Reliability data section

Figure 6-1 shows the conceptual hierarchical form for the database where all different data will be recorded.

Tidal turbine equipment data section corresponds to the Classification/Equipment data section according to database structure requirements described in chapter 4.8. This section is dedicated to build the taxonomy structure of each tidal turbine from level 1 and level 6 where all data related to the classification of the turbines and their sub-assemblies and equipment (see chapter 6.3) will be recorded.

Failure and maintenance data section corresponds to Event data section according to database structure requirements described in chapter 4.8. This section is dedicated to record all data related to failure and maintenance activities (see chapter 6.4) that are collected for each equipment included in the tidal turbine equipment data section.

Reliability data section is dedicated to record all the reliability and maintainability data (see chapter 6.5) calculated from the data stored in the failure and maintenance data section of the database.

Each section has their own specifications to be respected which are presented in detail in the chapters below.

The details of which data are mandatory, which ones are optional, and which ones depend on information from another table in the hierarchy is given for each hierarchy level in the following subchapters.

It is to be noted that, the sequence of data to be collected is to be followed as per described in according to 5.4.3. Once a turbine is selected, the turbine taxonomy shall be fully completed in the operation section of the database (following the specification in chapter 6.3) in order to start data collection for the failure section of the database (following the specification in chapter 6.4).

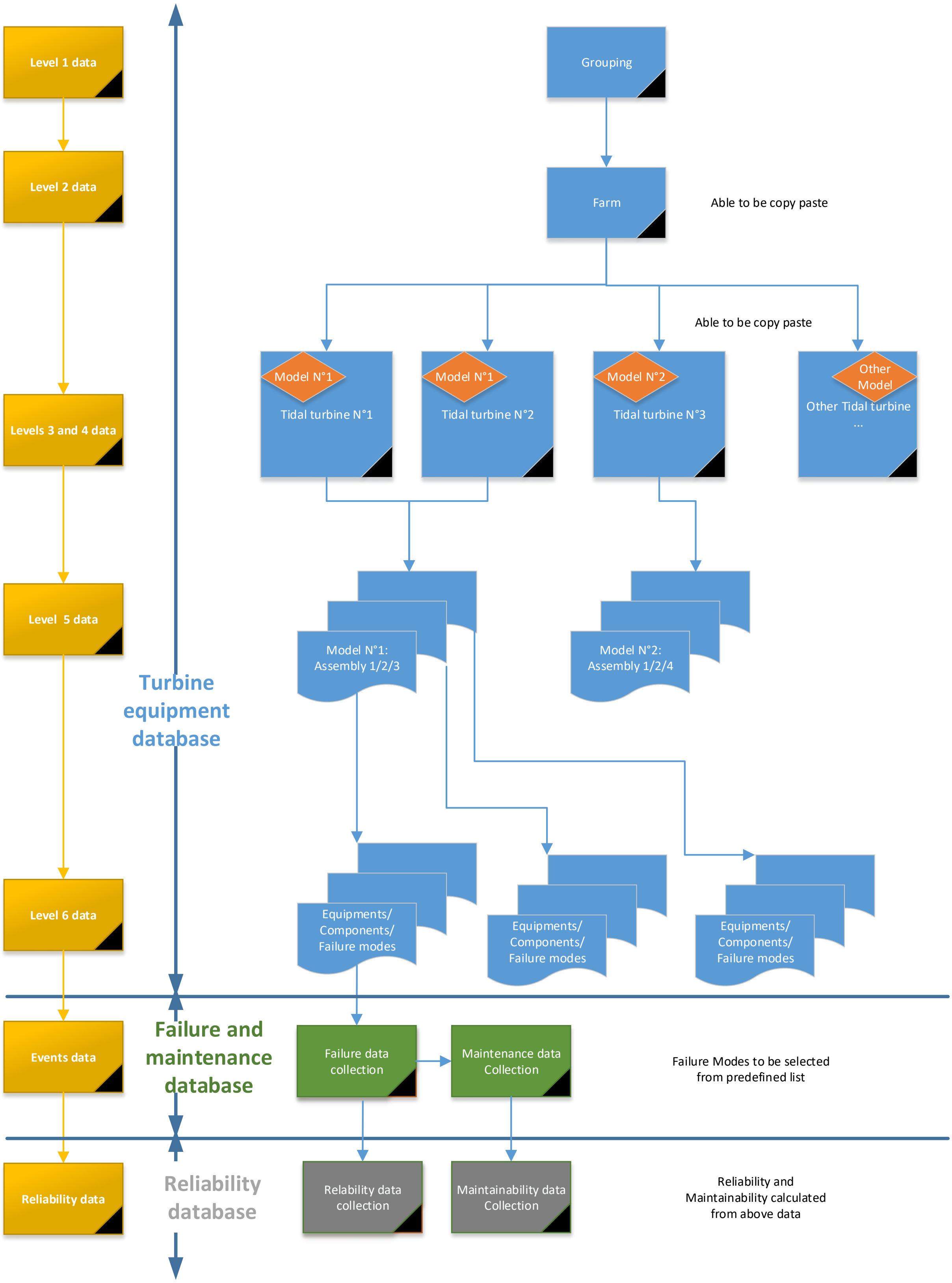


Figure 6-1 - Data Base hierarchy structure

6.3 Database Turbine/Equipment data Table Specifications

6.3.1 Overview

The database hierarchy for the operations data section consists in six identified levels:

1. Grouping
2. Tidal Farm
3. Tidal Turbine
4. Tidal Turbine Model
5. Tidal Turbine Assembly
6. Equipment

Those levels have been adapted in order to meet the taxonomy requirement described in chapter 4.5.2 The specifications for each hierarchy level are described in the subchapters below. The specifications cover ***mandatory data***, automatically ***generated data***, ***optional data*** and ***other specific functions*** (e.g. copy function).

In order to build this data base section, specifications are addressed to each level in below sub-chapters. Specification covers mandatory data, data which need to be generated automatically, not mandatory data and other specific functions (e.g. copy function).

The compilation of the data listed above with their definitions is presented in the ANNEX C.

6.3.2 Level 1 – Grouping data

The compilation of the data to be collected with their definitions is presented in the Table Annex C - 1.

Mandatory data:

- *Grouping name*: Name of the grouping of farms.

Data generated automatically:

- *Grouping ID*: This information shall be generated automatically once « Grouping Name » is entered;
- *Tidal farms quantity*: Tidal Farms shall be counted automatically once Step 2 are recorded (i.e. every time a tidal farm's name is added in step 2, this number shall be recounted automatically).

6.3.3 Level 2 – Tidal Farm data

The compilation of the data to be collected with their definitions is presented in the Table Annex C - 2.

Mandatory data:

- *Tidal farm name*: Tidal farm names shall not be identical;
- *Wiring system type*: 2 types of wiring systems (i.e. DC/AC) shall be predefined;
- *Farm location* : Site / location name of the Farm;
- *Power transmission*: Type of power transmission of the farm.

Data generated automatically:

- *Grouping Name*: Automatically copy the information entered in step 1;
- *Grouping ID*: Automatically copy the information generated in step 1;
- *Farm ID*: Automatically generated once « Farm Name » is entered;
- *Total number of tidal turbine*: Tidal turbine shall be counted automatically once step 3 is completely recorded (i.e. every time a tidal turbine's name is added in step 3, this number shall be updated);
- *Total nominal power*: Cumulated nominal power of the farm (Cumulated nominal power of the farm (in kW)) : Total nominal power shall be counted automatically once step 3 is completely recorded with all the turbines included in the farm.

Other Specification:

- *Copy function*: Database shall provide « copy paste Tidal Farm » function in order to copy not only the information of Farm information, but also all the tidal turbine information (model, family, configuration, assembly, component, etc.).

6.3.4 Level 3 – Tidal Turbine Model data

The compilation of the data to be collected with their definitions is presented in the Table Annex C - 3.

Mandatory data (use predefined list for tidal turbine family and tidal turbine configuration available in Table Annex C – 3):

- *Tidal turbine model name or code*: A list can be provided in order to select a model already created in the database;
- *Tidal turbine model designer*: A list can be provided in order to select a designer already created in the database;
- *Tidal turbine family*: select one type from the tree categories below:
    - Mounting type: Fixed bottom type / Floating type / Hybrid type / Other;
    - Axis type: Horizontal / Vertical / Other;
    - Rotor type: Open / Close / Other.
- *Tidal turbine configuration*: select one type from the tree categories below:
    - *Number of rotors*: 1, 2, 3 or more than 3;
    - *Number of blades per rotor*: 1, 2, 3, 4, 5, 6 or more than 6;
    - *Pitch control type*: Mechanical / Electrical / Other pitch / No Pitch;
    - *Yaw control type*: Passive /Active/ Other yaw / No yaw;
    - *Gearbox type*: 1 stage/ 2 stages/ 3 stages / Other / No gearbox;
    - *Foundation / support structure*: Gravity base / Pile, Suction Anchor / Pretensioned anchor pile / Other.

Data generated automatically:

- *Tidal turbine name*: Automatically copy the information entered in level 4;
- *Tidal turbine ID*: Automatically copy the information generated in level 4.

Not mandatory data:

- *Tidal turbine design power capacities*: unit is kW;
- *Tidal turbine maximum operation power capacities*: unit is kW;
- *Tidal turbine average operation power capacities*: unit is kW;
- *Tidal turbine nominal power capacities*: unit is kW.

6.3.5 Level 4 – Tidal Turbine data

The compilation of the data to be collected with their definitions is presented in the Table Annex C - 4.

Mandatory data:

- *Tidal turbine name*: Tidal turbine names shall not be identical in the same tidal farm;
- *Location latitude coordinates*: Decimal format is selected to be used to present geographical latitude coordinates. North latitude shall be presented as positive value, South latitude shall be presented as negative value. Precision shall be at least 2 number after comma (i.e. precision around 1.1132km);
- *Location longitude coordinates*: Decimal format is selected to be used to present geographical longitude coordinates. East Longitude shall be presented as positive value, West longitude shall be presented as negative value. Precision shall be at least 2 number after comma (i.e. precision around 1.1132km [1]).

Data generated automatically:

- *Farm name*: Automatically copy the information entered in level 2;
- *Farm ID*: Automatically copy the information generated in level 2;
- *Tidal Turbine ID*: Automatically generated once « Tidal Turbine Name » is entered;
- *Mean Water depth/Average tide speed/Wave condition (Hs)/Sea water temperature/Ambient Temperature*: Once location coordinates are selected, this information shall be searched automatically via meteocean data.

Not mandatory data:

- *Assembly Factory/ Constructor/ Owner/ Operator/ Maintainer/ Other associated companies*: Address to be entered. This information is not mandatory;
- *Other environment condition*: To be entered if necessary.

Other Specification:

- *Copy function*: Database shall provide « copy paste Tidal turbine » function in order to create a new similar turbine. The copied information includes not only the information related to the tidal turbine level but also all the other information from other levels (family, configuration, assembly, component, etc.). When paste the tidal turbine, it can be pasted in other tidal farm from the same grouping but not in other grouping in order to avoid confidential information leaks.
- *Library function*: Once all data of one tidal turbine is entered (i.e. tidal turbine model, assembly, equipment, component, failure mode), Library function shall be able to select the tidal turbine as a reference. This reference tidal turbine shall be able to be replied in other tidal farms. Replied reference tidal turbine has following specifications:

  - All information from level 1 to 6 are able to be modified;
  - All information in the failure and maintenance data section shall not be copied to the new tidal turbine;
  - Once modification is done on Reference tidal turbine, other replied reference tidal turbine shall be updated automatically
- *Cancel Library function*: Replied reference tidal turbine can use this function to be able to modify information previously selected. Once this function is applied, modification on reference tidal turbine shall not be synchronized to this tidal turbine.

6.3.6 Level 5 – Tidal Turbine Assembly and Sub-Assembly data

The compilation of the data to be collected with their definitions is presented in the Table Annex C - 5.

Several Tidal turbine assemblies and sub-assemblies are predefined in a list to be selected using Table Annex C – 6 as reference. Once the sub-assembly is selected, the sub-assembly type and designation is to be selected. Assemblies and sub-assemblies shall be predefined in the tool in order to ease the data base construction.

The list of assemblies and sub-assemblies was based on the taxonomy developed during the RealTide Task 1.1 - FMEA for four basic tidal turbine concepts [17].

Then the taxonomy was adapted in order to meet the taxonomy requirement described in chapter 3.5.2. Taking advantage of the similarity between tidal and wind turbines, taxonomy developed in other reliability projects for wind turbine such as Reliawind [25] was also used as a basis to develop the proposed tidal turbine taxonomy in Table Annex C – 6.

Mandatory data

- *Assembly:* the existing assemblies are to be selected from Table Annex C – 6:
  - *Hydrodynamic System / Nacelle Assembly*
  - *Hydrodynamic System / Rotor Assembly*
  - *Hydrodynamic System / Tunnel Assembly*
  - *Hydrodynamic System / Yaw Assembly*
  - *Reaction System / Foundation Assembly*
  - *Reaction System / Support Structure Assembly*
  - *Power take off System / Auxiliaries Assembly*
  - *Power take off System / Drivetrain Assembly*
  - *Power take off System / Control & Communication Assembly*
  - *Power take off System / Electrical Assembly*
  - *Other Assembly: "Other Assembly" is to be selected* if exists other assemblies than listed in in Table Annex C – 6; its identification is to be informed in a comment field.
- *Assembly identification*: identification shall be unique to each assembly;
- *Sub-Assembly:* for each assembly, the existing sub-assemblies are to be selected from Table Annex C – 6. *"Other Sub-Assembly"* is to be selected if exists other sub-assembly than listed in in Table Annex C – 6; its identification is to be informed in a comment field;
- *Sub-assembly type:* "Sub-assembly type" is to be selected from in Table Annex C – 6. If not in the list, the type is to be informed in a comment field;
- *Sub-assembly identification*: identification shall be unique to each sub-assembly.

Data generated automatically:

- *Tidal turbine name*: Automatically copy the information entered in level 4;
- *Tidal turbine ID*: Automatically copy the information generated in level 4.

Other Specification:

  - *Multi-selection*: Assemblies and sub-assemblies can be selected more than one time. For example, turbines with two rotors should have the assembly "Hydrodynamic System / Rotor Assembly" selected twice. However, the identifications of the two Rotor Assemblies" shall be different. The same procedure is to be applied to Sub-Assemblies, when applicable.
- *Copy function*: it shall be possibly to copy an Assemblies or sub-assembly to create a new one with similar data. If this function is applied, the designation of the new assembly or sub-assembly must be changed.

6.3.7 Level 6 – Equipment general data

The compilation of the data to be collected with their definitions is presented in the Table Annex C - 7.

For each Tidal turbine sub-assembly selected in level 5, all equipment included in the corresponding sub-assembly are to be created. Hereafter are the data required for each created equipment:

Mandatory data:

- *Equipment identification*: Designation or identification number in the tidal turbine structure (e.g. pump could be identified as P101A). The equipment identification is unique for each equipment;
- *Equipment class*: to be selected using Table Annex C – 6 as reference. « Other equipment class » could be selected if equipment is not included in the list. A field to inform the new equipment class shall be available;
- *Equipment type*: Type of the equipment inside the equipment class (initially this data is to be included in a free text field. In further versions, a list can be created including all Equipment types previously collected);
- *Equipment manufacturer*: Manufacturer of the equipment (initially this data is to be included in a free text field. In further versions, a list can be created including all Equipment Manufacturer previously collected);
- *Normal function mode*: In function/ Active standby/ Standby with manual activation / Other (in a predefined list). When "Other is selected", a field should be available to inform in a free text the normal function mode;

Data generated automatically:

- *Tidal turbine name*: Automatically copy the information entered in step 4;
- *Tidal turbine ID*: Automatically copy the information generated in step 4;
- *Tidal turbine model ID*: Automatically copy the information generated in step 3;
- *Tidal turbine sub-assembly ID*: Automatically copy the information generated in step 5;

Not mandatory data:

- *Equipment description*: short description of the equipment with additional information to be added, e.g. description of a pump could be: principle pump, transfer pump, bilge pump ….;
- *Unique identification number of component*: serial number (e.g. 123456XL) : free text;
- *Functional parameters*: Operating parameters appropriate to each class of equipment (For example the external environment, the operating power, operating temperature…);
- *Equipment model (manufacturer)*: Model name given by manufacturer;
- *Equipment design data*: i.e. Capacity, power, speed, pressure, temperature, speed, redundancy.
- *Data source*: source where the data come from (eg. CMMS, drawing, operating manual…)
- *Sub-unit*: sub component or group of parts of the equipment
- *Part*: Individual piece of an equipment;
- *Additional information*: any relevant additional information about the equipment;

6.4 Database Failure and Maintenance Table Specifications

6.4.1 Overview

Database requires three connected tables of capture reliability information:

1. Equipment specific data
2. Failure Data
3. Maintenance Data

The specification for these three tables are described in the sub-chapters below. As for the operational tables, the specifications cover ***mandatory data***, automatically ***generated data***, ***optional data*** and ***other specific functions.***

The compilation of the data to be collected with their definitions is presented in the Annex C.2.

6.4.2 Step 1 – Equipment specific data

The compilation of the data to be collected with their definitions is presented in the Table Annex C - 8.

The equipment specific data are complementary to the equipment general data listed in chapter 6.3.7. The data listed hereafter corresponds to the equipment data that should be updated every time that a new data collection is performed.

Mandatory data:

- *Initial equipment service date*: Format: YYYY/MM/DD
- *Observation starting date*: Format: YYYY/MM/DD
- *Observation Ending date*: Format: YYYY/MM/DD;
- *Observation/service duration*: Format : hours;
- *Operational service start time* (at the Observation starting date): Format: hours;
- *Operational service ending time* (at the Observation ending date): Format: hours;
- *Operational service duration*: Format : hours.

Not mandatory data:

- *Number of requests for periodic tests* (during the observation period), if applicable
- *Number of real (operational) requests* (during the observation period), if applicable
- *Additional information* (free text for more details).
- *Data source*

6.4.3 Step 2 – Failure Data

The compilation of the data to be collected with their definitions is presented in the Table Annex C - 9.

The data listed hereafter are related to all failures that occurred during the observation time where data are collected.

Mandatory data:

- *System / Assembly / Sub-Assembly / Equipment*: tree structure could be defined to ease the affection of failure data;
  Attention: Failure data shall only be affected to equipment level;
- Failure record identification (e.g. : Incident report number from CMMS);
- *Date of failure*: Format: YYYY/MM/DD;
- *Service running hours at date of failure* : Format : hours (if available);
- *Failure mode*: Failure mode shall be selected from the Table Annex C - 10: Failure Mode table.
  - If failure mode is not listed, the could select Failure mode as " OTHER" and include in a free text filed the description of the failure mode. All new failure modes will be implemented in the failure mode list in further versions of the database.
- *Failure cause*: The circumstances associated that resulted in failure (generally a physical phenomenon such as corrosion, vibration, wear, overload…);
- *Consequence of the failure on production*: predefined list with option: critical, degraded, or incipient failure.

  Proposed definition:
  - *Critical failure: immediately loss of production performance;*
  - *Degraded failure: progressive or no loss of production performance;*
  - *Incipient failure: No immediately loss of production performance but could bring critical failure after a period of operation;*
  - *Unknown : No identified consequence of failure;*

Data generated automatically:

- *Tidal turbine name*: Automatically copy the information entered in Level 3 of data base construction
- *Tidal turbine ID*: Automatically copy the information generated in Level 3 of data base construction
- *Equipment ID*: Automatically copy the information generated in Level 6 of data base construction
- *Failure mode code*: Automatically displayed once failure mode is selected. Failure mode code shall be predefined at data base construction at level 6
- *Failure record ID*: unique identification of the failure record

Not mandatory data:

- *Operating condition* when the failure occurs: Stopping, starting, working operating, hot redundancy, standby, in cold redundancy, under test
- *Consequence of the failure on the security* of the installation (for example the personnel, the environment, the assets)
- *Failure mechanism*: The physical, chemical or other processes that have caused failure
- *Defective subunit*: Name of defective subunit(s) (could be selected from subunit previously listed for each equipment)
- *Defective part*: Designation of defective part(s) (could be selected from part previously listed for each equipment)
- *Detection method*: How to detect this failure
- *Operation phase during failure*: Type of operation at time of failure
- *Classification of Safety Integrity System (SIS)*: Classify the failure for the specific event:
  - *DU (Dangerous failure Undetected);*
  - *DD (Dangerous failure Detected);*
  - *SU (Safe failure Undetected);*
  - *SD (Safe failure Undetected).*
- *Other information*: client could add additional comments in this field to capture other information about the failure event;
- *Data source*: source where the data is collected.

6.4.4 Step 3 – Maintenance Data

The compilation of the data to be collected with their definitions is presented in the Table Annex C - 11.

Mandatory data:

- *Failure record identification*: (same as for the corresponding failure data);
- *Maintenance record identification* (e.g./ Work Order number form CMMS);
- *Maintenance date*: Date of the maintenance operation or scheduled date (start date) (YYYY/MM/DD);
- *Active repair start date & hour*: Format: YYYY/MM/DD, HH:MM;
- *Active repair end date & hour*: Format: YYYY/MM/DD, HH:MM;
- *Active maintenance duration*: unit: hours;
- *Maintenance category*: predefined list: Corrective or Preventive;
- *Equipment Stop Date & Hour*: Format: YYYY/MM/DD, HH:MM;
- *Equipment Restart Date & Hour*: Format: YYYY/MM/DD, HH:MM;
- *Unavailability / downtime duration*: unit : hours;
- *Number of maintenance persons;*
- *Total Man-hours*: unit : man-hours;

Data generated automatically:

- *Tidal turbine name*: Automatically copy the information entered in level 4 of data base construction;
- *Tidal turbine ID*: Automatically copy the information generated in level 4 of data base construction;
- *Component ID*: Automatically copy the information generated in level 4 of data base construction;
- *Failure mode code*: Automatically displayed once failure mode is selected. Failure mode code shall be predefined at data base construction at level 6;
- *Total man-hours of Maintenance*: active maintenance time x number of maintenance persons.

Not mandatory data:

- *Maintenance delays / issues*: Prolonged causes of unavailability, for example logistics, meteorology, scaffolding, absence of parts spare, delay of the repair team,
- *Maintenance priority*: High, medium or low priority
- *Interval (programmed)*: Schedule or operating interval (not applicable to corrective maintenance)
- *Maintenance activity*: Description of maintenance;
- *Consequence of maintenance on the operation*: None, partial or total (predefined list);
- *Subunit subject to maintenance*: Name of subunit(s) subject to maintenance / repair;
- *Part subject to maintenance*: Name of the part(s) subject to maintenance / repair(may be omitted by preventive maintenance);
- Location of spare parts: Availability of parts (e.g. locally / at distance, at the manufacturer);
- *Maintenance duration in man hours, by discipline*: Maintenance time in man-hours, by discipline (mechanical, electrical, instrument, others)
- *Means necessary for the maintenance of the equipment*: For example heavy lift vessel, CTV, OSV, ROV, etc;
- *Other information*: client could add additional comments in this field to capture other information which could be possible to improve the data base
- *Data source*

6.5 Database Reliability Table Specifications

The section of the database is dedicated to calculate the reliability and maintainability data from the failure and maintenance data section of the database and to record these calculated data in a proper format in the database.

The reliability data are calculated via the formulas described in chapter 0. In this section the following data are to be calculated for each sub-assembly and equipment that will used to include in the databook report (see section 5.7).

Basically, the data to be recorded in the reliability data section are the same as the ones that will be in the databook report for each sub-assemby and each equipment class, which are:

- **Sub-assembly level data:**
  - **Turbine/Sub-assembly data:**
  - Sub-System
  - Assembly
  - Sub-assembly
  - Sub-assembly type
  - Population of subassembly
  - Quantity of turbines
  - Aggregated in service time (based on calendar and operating times);

  - **Reliability data:**
  - Number of failures:
    - Per failure consequence
    - Per Equipment
  - Mean failure rates (based on calendar and operating times)
    - Per failure consequence
    - Per Equipment
  - Limits of the 90% uncertainty interval of the failure rates (based on calendar and operating times)

  - **Maintainability data:**
  - Mean active repair time and man-hours:
    - Per failure consequence
    - Per equipment
  - Maximum and minimum values of the active repair times.

- **Equipment level data:**
  - **Turbine/Sub-assembly data:**
  - Sub-System;
  - Assembly;
  - Sub-assembly;
  - Sub-assembly type;
  - Equipment;
  - Equipment type;
  - Population of sub-assembly;
  - Quantity of turbines;
  - Aggregated in service time (based on calendar and operating times);
  - Number of equipment requests (total of operational and test requests) (if any);

- **Reliability data:**
- Number of failures:
    - Per failure consequence;
    - Per failure mode;
- Mean failure rates (based on calendar and operating times):
    - Per failure consequence;
    - Per failure mode;
- Limits of the 90% uncertainty interval of the failure rates (based on calendar and operating times);
- Number of failures upon request (if relevant);
- Probability of failure on demand (if relevant);

- **Maintainability data:**
- Mean active repair time and man-hours:
    - Per failure consequence;
    - Per failure mode;
- Maximum and minimum values of the active repair times.

It is to be noted that in the process of calculation, that data are processed and stored in such way that reliability data can extracted by:

- Turbine types (families and configurations)
- Sub-assembly
- Sub-assembly type
- Equipment class
- Equipment type

It is also important to make possible to extract the reliability data filtering by turbine, turbine model, grouping and farm but also by owners, operators and maintainers, designers that are contributing to the construction of the database.
It is to bear in mind that these contributors should have access to the reliability data related to "their turbines", but paying attention that their data should not be visible the other stakeholders.

7 RELIABILITY DATA CALCULATION

7.1 Overview

This chapter presents the formulas to be used for the calculations of the reliability and maintainability data based on the data recorded in the tidal turbine equipment and failure and maintenance sections of the database.

The main reliability data are:

- Failure rates (based on calendar and operational times) for each sub-assembly and equipment and their failure modes;
- 90% uncertainty interval for each calculated failure rates;
- Probability of failure on demand estimation for each equipment (when relevant).

The main maintainability data are:

- Mean time to repair for each sub-assembly and equipment and their failure modes;
- Maximum-Minimum interval for each calculated mean repair time;
- Mean repair man-hours.

Those reliability and maintainability data are to be recorded in the failure and maintenance data section of the database.
All formulas are based on [23] which is the reference used in OREDA databook [3][4]; one of the most commonly used reliability database in offshore industry.

7.2 Failure Rate

Failure rate is the frequency with which an engineered system or component fails, expressed in failures per unit of time. It is usually denoted by the Greek letter λ (lambda) and is often used in reliability engineering.

The basic formula for the failure rate (λ) for an item is:

$$\boldsymbol{\lambda}=\frac{Number\ of\ Failure}{Aggregated\ time\ in\ service}=\frac{n}{\tau}$$

Aggregated time in service can be measured either as calendar time or operating time. For operating time, all “unavailable time” shall be excluded as per annex A.

According to OREDA [3][4], the condition to apply failure rate $\boldsymbol{\lambda}$:

1. Failure rate is constant during the observation period
2. Failure time for a specified number of items, with the same failure rate $\boldsymbol{\lambda}$, are available
3. A combination of the two above situation, i.e., there are several items where each item might have several failures.

The failure rate should be calculated for each failure mode of each equipment class and classified by the consequence of the failure on the system (critical, degraded, incipient, or unknown).

From these failure rates, it is possible to calculate equipment class failures rates: global and per consequence.

Then, from the failure rates of each equipment class, it is possible to calculate the failure rates for each sub-assemblies.

An example is presented in Table 5-1 and Table 5-2.

The parameters to calculate the failure rates at the highest level are:

> ***η*** : is the sum of all failure mode occurrences recorded in the database for the population of the same equipment class during the period of observation that led to the same consequence.
>
> ***τ*** : is the sum of the time in service of all of this equipment during the period of observation.
>
> For calendar time, ***τ*** is the sum of the period of observation of each equipment
> For operating time, ***τ*** is the sum of operating times of each equipment.

In the example of Table 5-2, here are the parameters used to calculate the failure rate of an External leakage on a gearbox lubrication system that lead to a critical consequence:

> ***η*** = 8; it means that 8 external leakages occurred on a population of 3 gearboxes;
> ***τ*** (calendar time) = 0,052512x10^6 hours; it corresponds to the sum of calendar service time of the 3 gearboxes;
>
> ***τ*** (operating time) = 0,042172x10^6 hours; it corresponds to the sum of operating service time of the 3 gearboxes (the time id to be from all 3 equipment, even if several equipment has not presented any failure dung this time).

Then, the failure rates for each consequence of failure can be calculated by adding the failure rates of all failure modes that led to the same consequence.
In the example, the failure rate for critical failure modes is the sum of the failures of the External Leakage and Parameter deviation that led to critical consequence (457,0384 = 152,3461 + 304,6923).

Finally, the global the failure rate of an equipment class is the result of the sum of the failure rate of all failure modes of this equipment.

A similar process can be used to define the failure at Sun-Assembly level. Ndeed, the failure rate of a Sub-assembly is the sum of the failure rate of all equipment that is included in this sub-assembly.

7.3 Uncertainty interval for the failure rate

As explained in section 5.6, the more data are collected the more robust are the data in the database. In other words, the higher quantity of data is collected the more confident is the calculated reliability data.
In order to assess the data that is presented in the database, a 90% uncertainty interval is calculate for each failure rate. The more failure data is used for in the failure rate, the more "narrow" is the interval, i.e. the more "accurate" is the calculated failure rate.

The 90% uncertainty interval estimated for λ , will be presented as Pr ($\lambda_L \leq \lambda \leq \lambda_U$) with interval of λ between λ_L and λ_U. It means that the "real" λ has 90% of chance to be between λ_L and λ_U values.

The 90% interval calculation formula is as follows:

$$\left(\frac{1}{2\tau}Z_{0.95,2n},\frac{1}{2\tau}Z_{0.05,2(n+1)}\right)$$

With:

n : number of failures during aggregated time in service ***t*** **,**

t **:** aggregated time in service,

$Z_{0.95,2n}$ and $Z_{0.05,2(n+1)}$ are calculated according Table 7-1 using Chi-square (**c**²) distribution: $Z_{0.95,v}$ and $Z_{0.05,v}$ with ***v*** degree of freedom.

Another way to calculate the 2 values (i.e. : $Z_{0.95,v}$and $Z_{0.05,v}$) is by using function "CHISQ.INV.RT" in excel

Table 7-1 - Percentage point of the Chi-square (²) Distribution Pr(Z>Zα,v) = α

V/α	0.95	0.05
1	0	3.84
2	0.1	5.99
3	0.35	7.81
4	0.71	9.49
5	1.15	11.07
6	1.64	12.59
7	2.17	14.07
8	2.73	15.51
9	3.33	16.92
10	3.94	18.31
….		

Table 5-1 and Table 5-2 present an example of 90% confident interval for the failure rates calculated for gearboxes.

7.4 Multi-Sample calculations

As per OREDA [4]The failure rate mentioned in chapter 7.2 can only be used for the samples which have a homogeneous sample of data. In case different failures (i.e. comes from different installation with different operational and environment condition) needs to be "merged" to present an average failure rate, multi-sample solution shall be used. Following procedure is proposed to calculate average failure rate:

1. Calculate an initial mean failure rate θ1:

   $$\theta 1 = \frac{Total\ no.\ of\ failure}{Total\ time\ in\ service} = \frac{\sum_{i=1}^{k} n_i}{\sum_{i=1}^{k} \tau_i}$$

   Where ***k*** is the total number of equipment.

2. Calculate :

   $S_1 = \sum_{i=1}^{k} \tau_i$

   $S_2 = \sum_{i=1}^{k} \tau_i^2$

   $V = \sum_{i=1}^{k} \frac{(n_i - \theta 1 \tau_i)^2}{\tau_i} = \sum_{i=1}^{k} \frac{{n_i}^2}{\tau_i} - \theta_1^2 S_1$

3. Calculate σ^2, a measure of the variation between samples:

   $\sigma^2 = \frac{V-(k-1)\theta 1}{S1^2 - S2} \times S1$

   In case σ^2 is negative value, then $\sigma^2=0$.

4. Calculate final mean failure rate θ*:

   $$\theta^* = \frac{1}{\sum_{i=1}^{k} \frac{1}{\frac{\theta 1}{\tau i}+\sigma^2}} \times \sum_{i=1}^{k} \left(\frac{1}{\frac{\theta 1}{\tau i}+\sigma^2} \frac{n_i}{\tau_i} \right)$$

5. Calculate uncertainty interval 90% of θ*:

   $\theta^*_{Lower} = \frac{1}{2\beta} Z_{0.95,2\alpha}$

   $\theta^*_{Upper} = \frac{1}{2\beta} Z_{0.05,2\alpha}$

   where :

   $\beta = \frac{\theta *}{\sigma^2}$

   $\alpha = \beta \times \theta^*$

   $Z_{0.95,2\alpha}$, $Z_{0.95,2\alpha}$ can be selected using Table 7-1

Note 1: in case k= 1, Multi-sample solution cannot be used. Failure rate shall be estimated using solution mentioned in chapter 7.2 . Uncertainty interval shall be estimated using method mentioned in chapter 7.3.

Note 2: The calculation of failure for multi-samples has not been developed for the current database demonstrator. However, it is highly recommended to develop those formulas in the next versions of the database.

7.5 Failure rate estimation when no failure are observed

In case no failure is observed for an item, the following approach is used to obtain lower, mean and upper value for "all failure modes":

$$\lambda_0 = \frac{\alpha}{\beta}$$

Where:

$$\alpha = ½, \quad \beta = \frac{1}{2\lambda_p} + \tau,$$

With:

$\boldsymbol{\tau}$ the total time in service(operational or calendar) for the item of interest,
$\boldsymbol{\lambda_p}$ represents the mean failure rate estimate one level up in the taxonomy hierarchy

Besides, 90% uncertainty interval is given by formula below:

$$\left(\frac{1}{2\beta}\, Z_{0.95,2\alpha}\, ,\ \frac{1}{2\beta}\, Z_{0.05,2\alpha}\right) = \left(\frac{0.002}{\beta}, \frac{1.9}{\beta}\right)$$

with standard deviation SD = $\sqrt{\frac{\alpha}{\beta^2}}$

Note: This calculation has not been developed for the current database demonstrator. However, it is highly recommended to develop those formulas in the next versions of the database.

7.6 Probability of Failure on Demand estimation

The Probability of Failure on Demand (PFD) is a specific reliability parameter sued for safety devices, equipment which are in "standby" mode, or occasionally activated (such as alarms or actuated on/off valves).

The PFD is a measure of the effectiveness of such equipment. It expresses the likelihood that the equipment does not work when the equipment is requested to operate (during tests or production).

PFD on demand can be calculated by:

$$\text{PFD} = \frac{n}{d}$$

Where:

n is the number of failure on demand upon equipment request; and
d is the number of demands/requests.

Note: This calculation has not been developped for the current database demonstrator. However, it is highly recommended to develop those formulas in the next versions of the database.

7.7 Mean active repair time

Active Repair Time is the part of the maintenance time during which a maintenance action is performed on an item, either automatically or manually, excluding logistic delays such as presented in Annex A.

Mean time to repair (MTTR) represents the average time required to repair a failed component or device. It is the total corrective maintenance time for failures divided by the total number of corrective maintenance actions for failures during a given period of time.
It generally does not include lead time for parts not readily available or other Administrative or Logistic Downtime.

Therefore, the MTTR is calculated based on the Active Repair Time using the following formula:

$$\text{MTTR} = \frac{\sum_{i=1}^{Total\ no.of\ failure} ART\ (i)}{\text{Total no.of failure}}$$

Where ***ART(i)*** represent active repair time of each failure.

It is to be noted that only active time to perform Corrective Maintenance is to be used to estimate ART and therfrefore in the MTTR calculation.

7.8 Mean Manhours

The mean manhours (MMH) shall take “average of repair time” x “number of involved persons” to perform the repair:

$$\text{MMH} = \frac{\sum_{i=1}^{Total\ no.of\ failure} ART\ (i) \text{ x NP (i)}}{\text{Total no.of failure}}$$

Where **NP(i)** represent number of persons involved to repair each failure.

It is to be noted that only active time to perform Corrective Maintenance is to be used to estimate ART and therefore in the MMH calculation.

8 DEMONSTRATOR DATABASE CONSTRUCTION

8.1 Overview

To construct a functioning database from the specification thought needs to go into determining the end-use of the database, issues around data-entry, issues related to security and commercial sensitivity, and what the data flow should look like to meet the criteria. The demonstrator database has been constructed assuming that the database service provider will manage data entry. Data will be collected from developers via forms, then manually entered. This process simplifies security related to data entry. Only anonymised data should be presented to the public through an open database service. Figure 8-1 provides a conceptual schematic of the data flow to be supported, indicating where separation is required for data security.

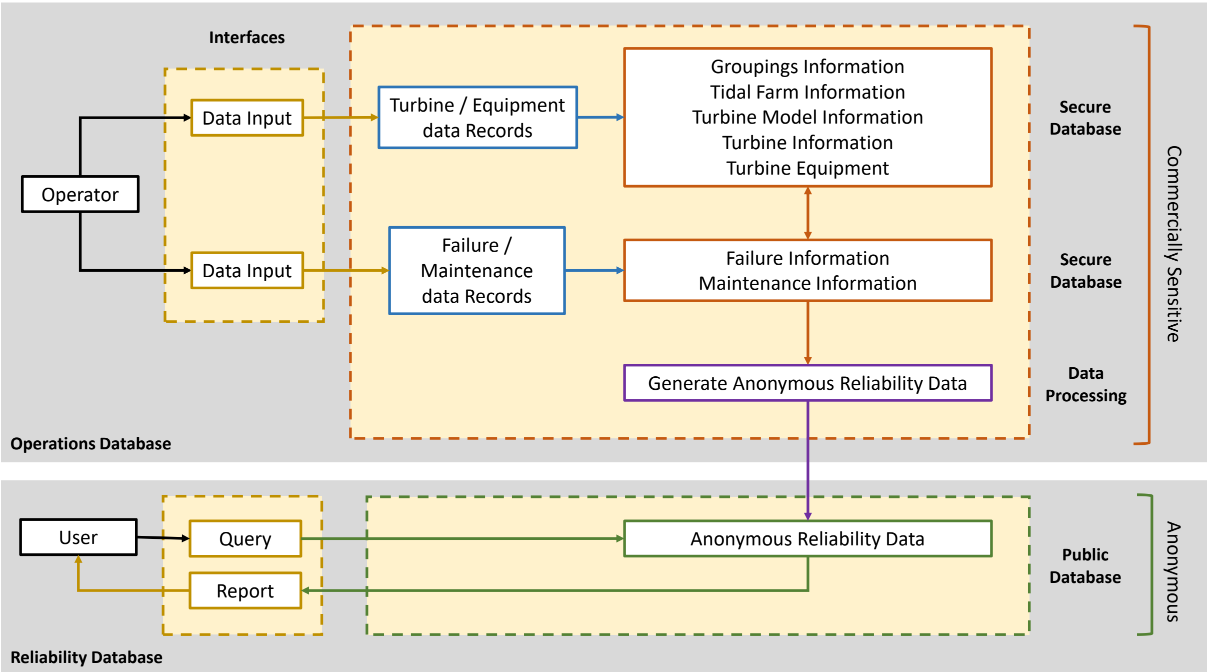


Figure 8-1 - Schematic of reliability database data flow.

The data flow starts with the tidal turbine operators (LHS of upper panel Figure 8-1) who provide the operational and failure data to populate the database. Some form of interface to the database is required for data entry: the form depends on who will manage the data entry. Reliability information is produced by querying the database for a required set of conditions, then processing the returned data to generate reliability information. The reliability information is stored in a public-facing database, with end-user access through some form of managed user interface.

This work package will only provide guidance on how to build the underlying database construct, not how the database is to be served, managed, and interfaced.

8.2 Database Engine

Based on feedback from partners within the consortia, the Microsoft Access database engine has been used to build the demonstrator reliability database and to indicate how it should function. To implement the database as an operational system we recommend the use of a more robust and scalable database engine. The decision on which engine to use will depend on the party responsible for hosting and managing the database.

8.3 Unique Entities, Tables, and Relational Keys

The main goals when constructing a database from complex interrelated data, are to (1) minimise the amount of replicated information within the database, (2) ensure that new information can be added without the need to redesign or rebuild database tables, and (3) ensure that all required relational connections are maintained to meet the end-user requirements. The first two goals are meet by identifying the core entities that make up the database information content. These database entities define the tables that need to be constructed in the database. The third goal is meet by keeping track of the relationships between the entities using relational (or foreign) keys. These keys provide unique identifiers that are used to link records across multiple tables.

8.3.1 Unique Entities

Based on the database specification information provided in Section 0, the initial hierarchy levels provide a first-pass set of entities. Specification requests for replication of information from other tables provide indicators of further refinement of entities and the corresponding relationship. Some of the parameters require predefined lists of options that are generally quite short. Within MS Access these can be integrated with the associated table fields as drop-down list boxes. For the purpose of the demonstrator database this approach has been taken instead of generating separate tables for these lists.

From the database specification, turbine equipment is the central entity that links together the operational data and the failure data. Turbine equipment are related to a particular turbine, which in turn is related to a tidal farm, and the farm is related to a grouping. The turbine equipment are related to a particular sub-assembly, which is related to an assembly, and the assembly to a sub-system. A given turbine within a farm will be of a particular turbine model, so a turbine model needs to be a separate entity. To simplify the creation of specific turbine instances, linked lists of assemblies, sub-assemblies and equipment a required for each turbine model. These turbine model lists are used to auto generate common fields for a specific turbine instance of a turbine model type. The failure records are linked directly to a specific piece of turbine equipment on a specific turbine. For each failure record there will be an associated maintenance record. Table **8**-**1** lists the entities used for constructing the demonstrator database.

Table 8-1 - Identified database entities used to construct demonstrator database.

Entity	Purpose
Groupings	List of tidal farm groupings
Tidal Farms	List of tidal farms with link to a grouping
Sub-systems	List of sub-systems that that make up a turbine
Assemblies	List of assemblies associated with each sub-system
Sub-assemblies	List of sub-assemblies associated with each assembly
Sub-assembly_types	List of separate sub-assembly types used to refine reliability data extraction
Equipment	List of equipment associated with each sub-assembly
Turbine Models	List of generic turbine models

Entity	Purpose
Turbine Model Assemblies	Lists a turbine models assemblies
Turbine Model Sub-assemblies	Lists a turbine models sub-assemblies
Turbine Model Equipment	Lists a turbine models equipment
Turbines	List of individual turbines with links to a turbine model and a turbine farm
Turbine Assemblies	List of all assemblies for a particular turbine based on the turbine model lists
Turbine Sub-assemblies	List of all sub-assemblies for a particular turbine based on the turbine model lists
Turbine Equipment	List of all equipment for a particular turbine based on the turbine model lists
Failure Modes	List of failure modes used to sort failure types for reliability calculations
Failure Records	List of failure records associated with specific turbines and associated equipment
Maintenance Records	List of maintenance records associated with failure records

8.3.2 Entity Relationships

The table specifications include automatically generated unique fields and fields replicated across tables. The table-specific automatically generated fields are the unique records IDs for a given table, and the unique fields copied from other tables are the foreign keys used to form the relational linkage between tables. Based on the table specifications the required entity relationships were determined.

Figure 8-2 shows the relational links between entities derived from the specification information. The arrows point toward an entity from which information is gathered (i.e. a parent entity). To help visualise the structural separation between the operations data tables and the failure/maintenance data tables, the entities have been grouped. MS Access allows drop-down lists to be directly associated with a table field, other engines would require these to be separate entities with their own table. To distinguish the entity tables from embedded drop-down lists, the list tables are represented with a dashed border.

To capture the overall intended operation of the database, a process ("Data Processing") is linked to the "Maintenance Records" table; this link is in essence a query of the database via the maintenance record to extract the field values necessary to calculate the reliability data that is placed in the public-facing database. The intention is to also link this database to the "Environmental Conditions Database" being constructed in WP2: D2.3. For this reason, the linkages to the environmental data have been represented as dashed arrow. A mechanism for linking these databases together is required to capture environmental conditions data.

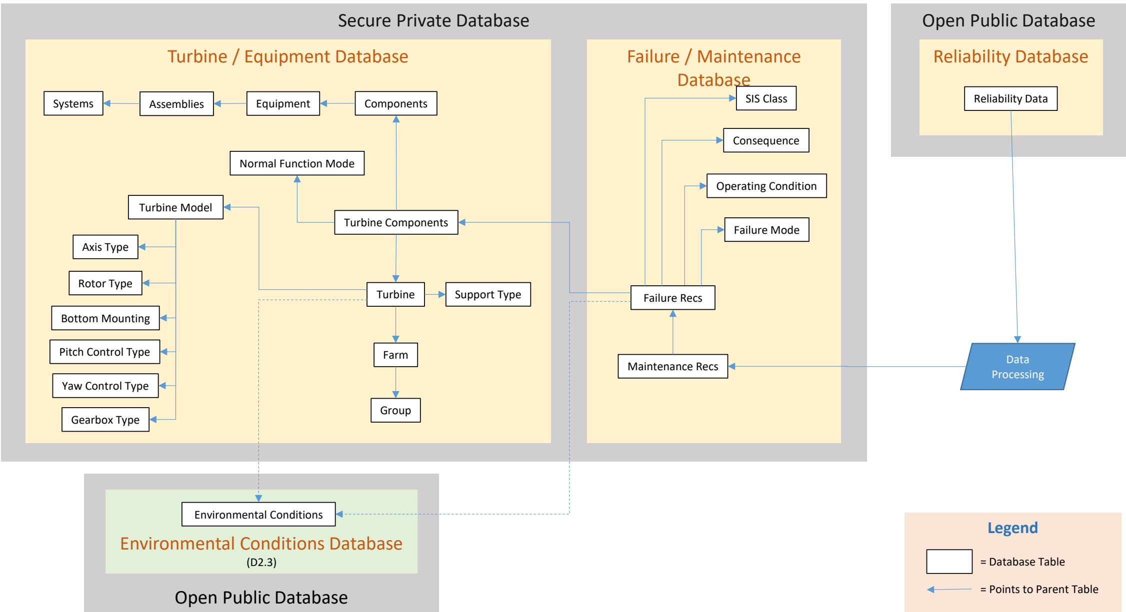


Figure 8-2 - Schematic of database entities, relational links, and processes.

8.3.3 Database Table Fields

In the table specifications, there are a number of fields identified as being "automatically generated" and fields that are "copied" from other tables. The automatically generated fields are the unique records IDs for each table, and the copied fields are the foreign keys used to form the relational linkage between tables. The point of making this separation in the database construct is to ensure that new entity records can be appended without having to rebuild existing tables.

There are two instances of a request to calculate field values from other tables post-population. This is something that is not easily implemented when constructing database tables, and to a certain extent goes against the rationale behind database design. Calculated field values should be generated as part of a query output, all that is required is that the tables contain the necessary fields and the appropriate relational links to perform the calculation. The database tables and fields have been defined so that value for the requested calculated fields can be determined when constructing the anonymised reliability data table and when generating reliability reports from the anonymised data.

8.3.4 Table Data Entry Filters

Given the complex level of relationships between the entities in this database, there has to be some level of control on data entry to ensure that the information being enter is sensible. To achieve this at a basic level, some of the fields that are associated with an extended link list have had a query embedded in the corresponding table field that can be used to pre-filter the list of possible parameters that can be chosen. For the purpose of the database demonstrator these filters have been kept relatively simple, but each can be readily extended to meet operator needs.

Currently there are 11 main data entry filter queries; these are listed in Table **8**-**2**. The SQL query code for each filter is given in Annex E. The tables are connected via their foreign keys using a series of JOIN statements, filtering is achieved using a set of conditional WHERE logic cases, and user control of the filtering is provided via input dialog boxes that are initiated by the embedded query. The default for each input dialog box is a wildcard (*) which effectively selects all values in the conditional field. The conditions are built using LIKE statements so that the user does not need to know the exact field name, but can include wildcards to ease selection.

The three Append queries are used to auto-generate full records sets for a specific turbine, and pre-fill with data available from existing tables. The remaining fields need to be manually entered by the operator. These use the information from the Turbine Model tables to collate and pre-fill the fields. At present these append queries do not check whether the turbine already exists in the table; this is something that will need to be coded to ensure uniqueness of data in the Turbine tables.

Table 8-2 - Implemented data entry queries for data filtering and data record auto-generation

Query	Filter Fields
Query_Select_Assembly	Sub-system
Query_Select_Sub-Assembly	Sub-system, assembly
Query_Select_Sub-Assembly_Type	Sub-system, assembly
Query_Select_Assembly_for_Equipment	Sub-system
Query_Select_Sub-Assembly_for_Turbine_Model	Turbine model, sub-system, assembly
Query_Select_Equipment_for_Turbine_Model	Turbine model, sub-system, assembly
Query_Append_Assemblies_for_Turbine	Turbine name
Query_Append_Sub-Assemblies_for_Turbine	Turbine name

Query	Filter Fields
Query_Append_Equipment_for_Turbines	Turbine name
Query_Select_Turbine_Equipment_for_Failure	Turbine name
Query_Select_Failure_Record_for_Maintenance	Turbine name

8.3.5 Implementation of Field Calculations

As noted in the introduction to this chapter, calculated field values are typically done as part of a query. An example case has been provided that shows how to get the total number of turbines in a tidal farm; this was identified as a calculated field in the database specification. The query takes the following form:

```
SELECT
    [tidal_farms].[farm_name],
    [cnt].[num_turbines]
FROM
    [tidal_farms] LEFT JOIN (SELECT [farm_id], COUNT([farm_id]) AS [num_turbines] FROM
[turbines] GROUP BY [farm_id]) AS [cnt] ON [tidal_farms].[ID] = [cnt].[farm_id]
WHERE
    [tidal_farms].[farm_name] LIKE Nz([Enter Tidal Farm Name:], "*");
```

In this instance the query simply returns the tidal farm name and a count of the number of turbines in that farm. The use of a LEFT JOIN allows for farms that are present in the database that currently have no turbines associated with them; for these cases the field is returned as a NULL. The WHERE condition provides a filter on the tidal farm name, with the default set to the wildcard “*”. There is a wide range of built-in SQL functions that can be used for generating calculated field values as part of an output from a query. These methods for calculating field values are required when extracting field data for the reliability calculations.

8.4 Demonstrator Database Testing

To test the logical construction for the demonstrator database a set of dummy data where generated using information provided by Ingeteam taken from actual wind farm failure/maintenance data (see Annex F.1). These data where then modified to represent tidal turbine failure records. Once the operational database had been constructed a query was used to generate a table of anonymised reliability data that would be placed in a public-facing database, and could be queried to generate reliability reports. The fields in the anonymised data were selected to meet the parameter requirements for the reliability data calculations presented in Chapter 0.

8.4.1 Dummy Data

Four base turbine models have been defined which correspond to the four design concepts chosen for the FMEA analysis carried out in D1.1 (FMEA Report) [17] and D1.2 (RAM Assessment Report) [16]. The associated sub-systems, assemblies, sub-assemblies and equipment where tabulated for these turbine models and manually entered into the database. A list of 28 turbines was generated based on the four turbine models, and sorted into farms and the farms into groups. The base turbine information were generated for all 28 turbines, but only two turbines where select to carry through for generating failure and maintenance records. For these two turbines the remaining required fields where filled in the Turbines table. Then the Turbine Assemblies, Turbine Sub-Assemblies, and Turbine Equipment tables where auto-generated with common fields from the Turbine Model tables. Remaining required fields where manually enter for the two turbine selected. Failure records where generated for the Drivetrain assembly for these tow turbines, focusing on the gearbox. A total of 52 failure and corresponding

maintenance records were generated and manually entered into the Failure Records and Maintenance Records tables. Annex F.2 illustrates the dummy data compilation.
All of the associated queries and relational table linkages were tested and corrected during this data entry process.

8.4.2 Anonymous Reliability Data

The final step of the database construction process is to extract the anonymised failure/maintenance data from the turbine/equipment database into a table that forms the basis of the public-facing reliability database. For the purpose of testing a single flat table has been generated, which can be exported as an MS Excel spreadsheet. This can then be used to generate example Reliability Data Reports.

The fields in the flat Anonymous Reliability Data table have been selected to meet the data requirements of the reliability calculations. The fields selected, and the data type and usage has been tabulated in Table Annex D - 31. The follow query was used to generate this table from the operation database.

```
SELECT
    [tidal_farms].[grouping_id],
    [turbines].[farm_id],
    [turbine_equipment].[turbine_id],
    [turbines].[turbine_model_id],
    [turbine_assemblies].[sub_system_id],
    [turbine_assemblies].[sub_system],
    [turbine_sub-assemblies].[turb_assem_id],
    [turbine_sub-assemblies].[assembly_id],
    [turbine_sub-assemblies].[assembly],
    [turbine_equipment].[turb_sub_assem_id],
    [turbine_sub-assemblies].[sub_assembly_id],
    [turbine_sub-assemblies].[sub_assembly],
    [turbine_equipment].[sub_assembly_type],
    [turbine_equipment].[ID] AS [turb_equip_id],
    [turbine_equipment].[equipment_id],
    [turbine_equipment].[equipment],
    [turbine_equipment].[obs_duration],
    [turbine_equipment].[op_duration],
    [turbine_equipment].[num_periodic_requests],
    [turbine_equipment].[num_operat_requests],
    [failure_modes].[failure_mode],
    [failure_records].[mode] AS [failure_code],
    [failure_records].[failure_time_cal],
    [failure_records].[failure_time_op],
    [failure_records].[consequence],
    [maintenance_records].[category],
    [maintenance_records].[active_repair_time],
    [maintenance_records].[person_hours]
INTO
    anonymous_reliability_data
FROM
    ((((((([failure_records] INNER JOIN [maintenance_records] ON [failure_records].[ID] =
[maintenance_records].[failure_id])
    INNER JOIN [failure_modes] ON [failure_records].[mode_id] = [failure_modes].[ID])
    INNER JOIN [turbine_equipment] ON [failure_records].[turb_equip_id] =
[turbine_equipment].[ID])
    INNER JOIN [turbine_sub-assemblies] ON [turbine_equipment].[turb_sub_assem_id] =
[turbine_sub-assemblies].[ID])
    INNER JOIN [turbine_assemblies] ON [turbine_sub-assemblies].[turb_assem_id] =
[turbine_assemblies].[ID])
    INNER JOIN [turbines] ON [turbine_equipment].[turbine_id] = [turbines].[ID])
    INNER JOIN [tidal_farms] ON [turbines].[farm_id] = [tidal_farms].[ID]
ORDER BY
    tidal_farms.grouping_id,
    turbines.farm_id,
    turbine_equipment.turbine_id;
```

9 DATABASE FURTHER DEVELOPMENT

9.1 Database interface for data collection

In order to ensure correct data collection and ensure proper data transmission to the database manager, a web based data collection platform integrated to the database could be developed. This platform could also be used for better communication between owner/operators/maintainers with the database manager not only to transfer data but also to transmit any question, comment or request regarding the overall process and further development of the database.

9.2 Electronic / web database

For instance, the reliability databook is planned to be issued on paper and PDF formats.
However, web platform including the database could be developed in order to make the access of the database to the users.
Furthermore, functionalities can also be provided such as research function to find reliability data for a specific equipment or assembly for example.
A web database has also the advantage also to provide filters, so the database can provide reliability data to a specific turbine or equipment such as per location of the turbine model, turbine type, equipment type. Examples of filter are presented in section below.
Apart from that a specific access can be provided to owners, operators, maintainers, designers and manufacturers in such way that they can visualize the reliability data for the turbines that are related to. For so, a special access to the database can be setup so the data can be vizualized only for the turbines that are linked to the user For example, a designer will have access to the data related to the turbines that have been designed to them only. Similarly, an operator ill have access to the data of the turbines that they operate only.

9.3 Filters

Users will have access to the reliability database that will compile the data coming from all tidal turbines that has been selected to provide data for this database (see chapter 5.7).
However, if user would like to get more specific reliability data, some filters need to be provided. For example, if the user would like to have data from a specific type of turbine, the database will process the data coming only from this type of turbine.
The following filters for common user will be provided:

- Turbine type
- Turbine model
- Turbine location
- Tidal turbine operating power
- Tidal turbine nominal power
- Environment conditions
- Equipment type
- Equipment manufacturer
- Equipment model
- Equipment design data

Some specific filters to turbine operators/owners could be provided to them so they can analyse the reliability data for their own turbines.

Therefore, the data can be provided for a specific turbine or a set of turbine that belongs to the turbine operator/owner.
The confidentiality of data will be preserved, so an owner will not have access to the data coming from turbines that belongs to other operators/owners.

9.4 Complementary reliability calculations

Neither the multi-sample nor the probability of failure on demand calculations described in chapters 7.4 and 7.6 have been developed for the database demonstrator.
It is highly recommended to develop such features on future version of the database in order to get

9.5 Standardizations and codification

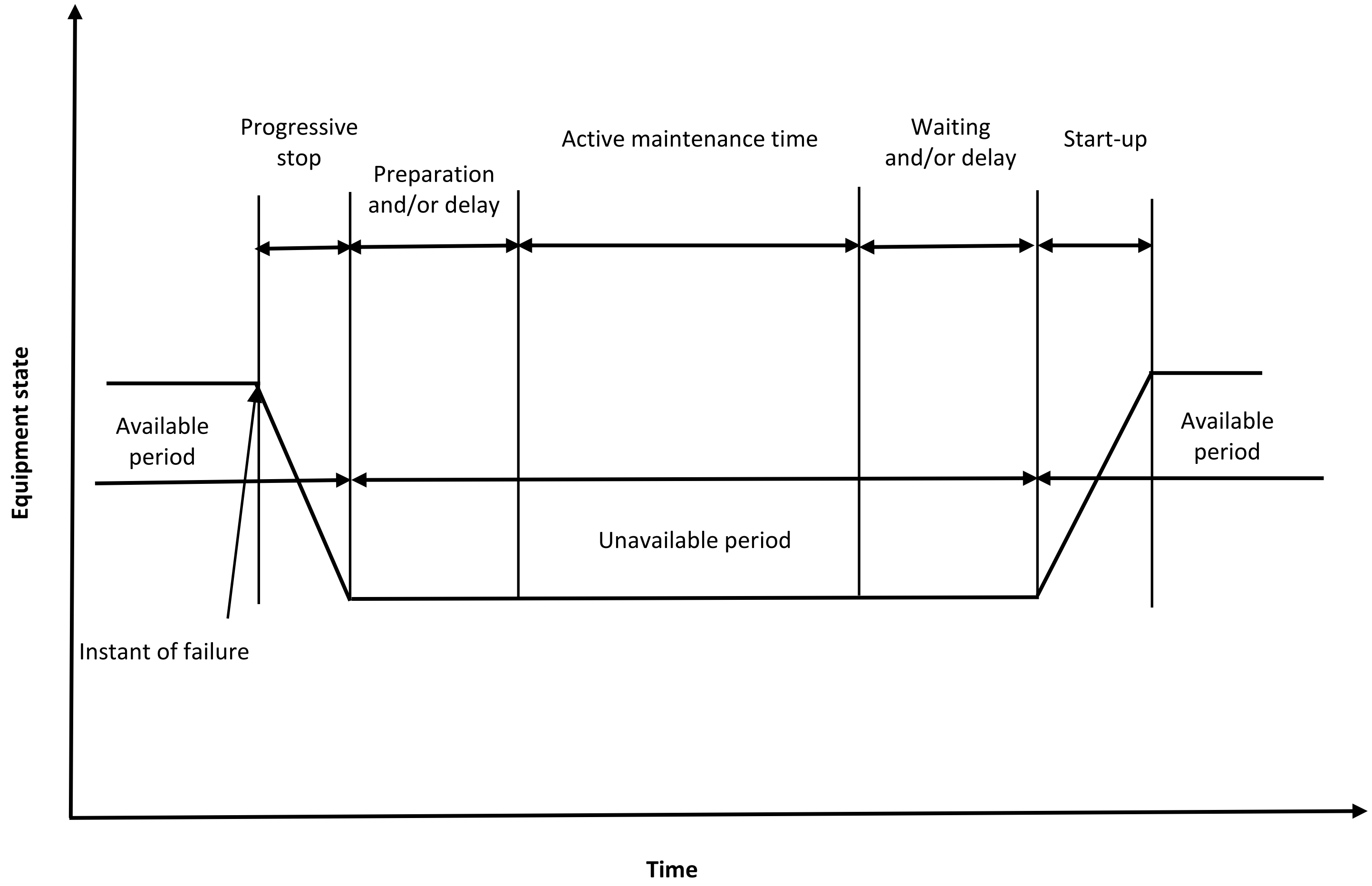
As data is collected time, a list of information such as equipment manufacturers / models / failure causes / equipment sub-units / parts etc… can be progressively developed for each equipment. Each information can be codified in the database and made available in tables and lists to be easier to include this information in the database. This will allow ensuring that the same information is always included in the database in the same way making easier to construction of filters and therefore the exploitation of the database.

9.6 Expand database taxonomy to higher levels

As data is collected in time, a list of sub-unit and parts can be progressively developed for each equipment, so the taxonomy structure of the database can be expanded to level 9 (see 4.5.2). This detail can bring to final users valuable information at sub-unit and part levels and allow them to perform more detailed analysis for their organization.

ANNEX

ANNEX A – MAINTENANCE TIME FIGURE


Progressive stop
Preparation and/or delay
Active maintenance time
Waiting and/or delay
Start-up
Equipment state
Available period
Available period
Unavailable period
Instant of failure
Time

ANNEX B – FAILURE MODE AND ASSOCIATED CODE LIST

Sub System	Assembly	Equipment	Component	Failure mode	Failure mode code	1	2	3	4	BV Comments
Hydrodynamic System	Nacelle	Nacelle shell	Nacelle shell	Structural deficiency	STD	x	x	x	x	
Hydrodynamic System	Nacelle	Nacelle joints	Nacelle joints	Structural deficiency	STD	x	x	x	x	
Hydrodynamic System	Nacelle	Nacelle joints	Nacelle joints	External leak - water ingress	EXW	x	x	x	x	
Hydrodynamic System	Nacelle	Interface with supporting structure	Interface with supporting structure	Structural deficiency	STD	x	x	x	x	
Hydrodynamic System	Nacelle	Penetrations	Penetrations	Structural deficiency	STD	x	x	x	x	
Hydrodynamic System	Nacelle	Lifting points	Lifting points	Structural deficiency	STD	x	x	x	x	
Hydrodynamic System	Nacelle	Seafastening / tug points	Seafastening / tug points	Structural deficiency	STD	x			x	
Hydrodynamic System	Nacelle	Sub-assembly frame	Sub-assembly frame	Structural deficiency	STD	x	x	x	x	
Hydrodynamic System	Nacelle	Lifting equipment / reaction points	Lifting equipment / reaction points	Structural deficiency	STD	x				
Hydrodynamic System	Nacelle	Access into nacelle (hatches)	Access into nacelle (hatches)	Structural deficiency	STD	x	x	x	x	
Hydrodynamic System	Nacelle	Corrosion protection	Coating	Loss of function	LOF	x	x	x	x	"Structural deficiency" which presents loss of function of corrosion protection is not seems a good word. It is proposed to be replaced by "Loss of function". All failure cause such as coating Blistering, surface cracking, coating disbanding from metal surface, erosion and impressed current early failure
Hydrodynamic System	Nacelle	Corrosion protection	Coating	Parameter deviation	PAD	x	x	x	x	Including failure due to excessive marine growth
Hydrodynamic System	Nacelle	Corrosion protection	Impressed current	Loss of function	LOF	x	x	x	x	"Structural deficiency" which presents loss of function of corrosion protection is not seems a good word. It is proposed to be replaced by "Loss of function". All failure cause such as coating Blistering, surface cracking, coating disbanding from metal surface, erosion and impressed current early failure
Hydrodynamic System	Nacelle	Corrosion protection	Impressed current	Parameter deviation	PAD	x	x	x	x	Including failure due to electrical short
Hydrodynamic System	Rotor	Blades	Blades	Structural deficiency	STD	x	x	x	x	All blades components are not studied in details
Hydrodynamic System	Rotor	Blades	Blades	Fouling	FOL	x	x	x	x	
Hydrodynamic System	Rotor	Hub	Hub Shell	Structural deficiency	STD	x	x	x		
Hydrodynamic System	Rotor	Hub	Hub Shell	Vibration	VIB	x	x	x		
Hydrodynamic System	Rotor	Front Bulb	Front Bulb	Structural deficiency	STD	x	x	x		
Hydrodynamic System	Rotor	Front Bulb	Front Bulb	Fouling	FOL	x	x	x		
Hydrodynamic System	Rotor	Pitch System	Pitch System	Spurious stop	SPS	x		x		All "Structural deficiency" related failure modes are in fact spurious stop. Use "Structural deficiency" is not a good word because it could be misunderstood as structure related failure such as: crack, embrittlement. Here, spurious stop would include all stop due to components misalignment, wear, electric motor insulation deterioration and control system failure
Hydrodynamic System	Rotor	Pitch System	Pitch System	External leak - water ingress	EXW	x		x		

Sub System	Assembly	Equipment	Component	Failure mode	Failure mode code	1	2	3	4	BV Comments
Hydrodynamic System	Rotor	Pitch System	Pitch System	Parameter deviation	PAD	x		x		Specially include the degraded failure: Parameter deviation- rotor magnet deterioration, coil fail. May be it would be better to be replace with "low output"
Hydrodynamic System	Rotor	Pitch System	Pitch System	Vibration	VIB	x		x		Including failure cause due to imbalance installation and Structural deficiency - imbalance rotor
Hydrodynamic System	Rotor	Ring	Ring	Structural deficiency	STD				x	
Hydrodynamic System	Tunnel	Tunnel	Tunnel	Structural deficiency	STD				x	
Hydrodynamic System	Yaw system	Yaw shaft (trunnion, crank ring)	Yaw shaft (trunnion, crank ring)	Structural deficiency	STD	x		opt.		
Hydrodynamic System	Yaw system	Yaw Gear	Yaw Gear	Structural deficiency	STD	x		opt.		
Hydrodynamic System	Yaw system	Yawing mechanism power actuator	Yawing mechanism power actuator	Spurious stop	SPS	x		opt.		Including structural deficiency - misalignment, sticking, wear
Hydrodynamic System	Yaw system	Yawing mechanism power actuator	Yawing mechanism power actuator	Structural deficiency	STD	x		opt.		Including structural deficiency - mechanical failure (facture, yield, and cracking)
Hydrodynamic System	Yaw system	Yawing mechanism power actuator	Yawing mechanism power actuator	External leak - water ingress	EXW	x		opt.		
Hydrodynamic System	Yaw system	Yaw locking / brake mechanism	Yaw locking / brake mechanism	Structural deficiency	STD	x		opt.		
Hydrodynamic System	Yaw system	Yaw load bearing	Yaw load bearing	Structural deficiency	STD	x		opt.		
Hydrodynamic System	Yaw system	Yaw load bearing	Yaw load bearing	Vibration	VIB	x		opt.		
Reaction System	Foundation system	Foundation fixation	Foundation fixation	Structural deficiency	STD	x	x	x	x	
Reaction System	Support Structure	Interface with foundation	Interface with foundation (complete)	Structural deficiency	STD		x			Including Structural deficiency due to crack, corrosion, fouling
Reaction System	Support Structure	Interface with foundation	Grouting (piling solution)	Structural deficiency	STD	x				Including Structural deficiency due to breakage, dissolved grouting
Reaction System	Support Structure	Interface with foundation	Grout seal	Structural deficiency	STD	x				
Reaction System	Support Structure	Interface with foundation	Temporary structure (before grouting)	Structural deficiency	STD	x				
Reaction System	Support Structure	Interface with foundation	Mooring line	Structural deficiency	STD			x		Including Mooring line fracture and Displacement greater than expected
Reaction System	Support Structure	Interface with foundation	Turret (Optional, Alternative to Individual Yaw)	Structural deficiency	STD			x		Including Loose or detachment of one mooring line
Reaction System	Support Structure	Interface with foundation	Turret (Optional, Alternative to Individual Yaw)	Noise	NOI			x		
Reaction System	Support Structure	Interface with foundation	Turret (Optional, Alternative to Individual Yaw)	Blockage	BLO			x		

Sub System	Assembly	Equipment	Component	Failure mode	Failure mode code	1	2	3	4	BV Comments
Reaction System	Support Structure	Main Structure (including auxiliary equipment)	Main Structure (including auxiliary equipment)	Structural deficiency	STD	x	x	x	x	
Reaction System	Support Structure	Main Structure (including auxiliary equipment)	Main Structure (including auxiliary equipment)	Fouling	FOL	x	x	x	x	
Reaction System	Support Structure	Main Structure (including auxiliary equipment)	Main Structure (including auxiliary equipment)	Vibration	VIB	x	x	x	x	
Reaction System	Support Structure	Main Structure (including auxiliary equipment)	Main Structure (including auxiliary equipment)	Corrosion	COR	x	x	x	x	
Reaction System	Support Structure	Installation interface	Installation interface	Structural deficiency	STD	x	x		x	
Reaction System	Support Structure	Installation interface	Installation interface	Corrosion	COR	x	x		x	
Reaction System	Support Structure	Interface with turbine support	Interface with turbine support	Structural deficiency	STD	x	x	x	x	
Reaction System	Support Structure	Interface with turbine support	Interface with turbine support	Fouling	FOL	x	x	x	x	
Reaction System	Support Structure	Interface with turbine support	Interface with turbine support	Corrosion	COR	x	x	x	x	
Reaction System	Support Structure	Corrosion protection	Coating	Loss of function	LOF	x	x	x	x	"Structural deficiency" which presents loss of function of corrosion protection is not seems a good word. It is proposed to be replaced by "Loss of function". All failure cause such as coating Blistering, surface cracking, coating disbanding from metal surface, erosion and impressed current early failure
Reaction System	Support Structure	Corrosion protection	Coating	Parameter deviation	PAD	x	x	x	x	Including failure due to excessive marine growth, electrical short
Reaction System	Support Structure	Corrosion protection	Impressed current	Loss of function	LOF	x	x	x	x	"Structural deficiency" which presents loss of function of corrosion protection is not seems a good word. It is proposed to be replaced by "Loss of function". All failure cause such as coating Blistering, surface cracking, coating disbanding from metal surface, erosion and impressed current early failure
Reaction System	Support Structure	Corrosion protection	Impressed current	Parameter deviation	PAD	x	x	x	x	Including failure due to excessive marine growth, electrical short
Power take off	Auxiliaries	Firefighting System	Firefighting System	Fail to function on demand	FTD	x		x		
Power take off	Auxiliaries	Ballast	Ballast	Loss of function	LOF			x	x	Added failure mode
Power take off	Auxiliaries	Ballast	Ballast	Low output	LOP			x	x	Added failure mode
Power take off	Auxiliaries	Ballast	Ballast	Vibration	VIB			x	x	
Power take off	Auxiliaries	Cooling system	Heat exchanger	Insufficient Heat Transfer	IHT	x	x	x	x	

Sub System	Assembly	Equipment	Component	Failure mode	Failure mode code	1	2	3	4	BV Comments
Power take off	Auxiliaries	Cooling system	Heat exchanger	External Leakage - Utility medium	EXU	x	x	x	x	
Power take off	Auxiliaries	Cooling system	Heat exchanger	Internal Leakage	INL	x	x	x	x	
Power take off	Auxiliaries	Cooling system	Heat exchanger	Plugged / choked	PLC	x	x	x	x	
Power take off	Auxiliaries	Cooling system	Heat exchanger	Structural deficiency	STD	x	x	x	x	
Power take off	Auxiliaries	Cooling system	Cooling Pump	External Leakage - Utility medium	EXU	x	x	x	x	
Power take off	Auxiliaries	Cooling system	Cooling Pump	Vibration	VIB	x	x	x	x	
Power take off	Auxiliaries	Cooling system	Cooling Pump	Structural deficiency	STD	x	x	x	x	including impeller breakdown, accelerated components wear and corrosion
Power take off	Auxiliaries	Cooling system	Coolant	Parameter deviation	PAD	x	x	x	x	High Temperature
Power take off	Auxiliaries	Cooling system	Coolant	Contamination	CON	x	x	x	x	
Power take off	Auxiliaries	Cooling system	Cooling system connections	Plugged / choked	PLC	x	x	x	x	Including Heat exchanger insufficient heat transfer, contamination in cooling medium, cooling pump low output
Power take off	Auxiliaries	Cooling system	Cooling system connections	External Leakage - Utility medium	EXU	x	x	x	x	Including Heat exchanger insufficient heat transfer, contamination in cooling medium, cooling pump low output
Power take off	Auxiliaries	Air treatment	Compressor	Loss of function	LOF	x	x	x	x	
Power take off	Auxiliaries	Air treatment	Compressor	Vibration	VIB	x	x	x	x	
Power take off	Auxiliaries	Air treatment	Compressor	Low output	LOP	x	x	x	x	
Power take off	Auxiliaries	Air treatment	Filter	Contamination	CON	x	x	x	x	
Power take off	Drivetrain	Low speed shaft	Low speed shaft	Structural deficiency	STD	x	x	x	x	
Power take off	Drivetrain	Low speed shaft	Low speed shaft	Vibration	VIB	x	x	x	x	
Power take off	Drivetrain	Low speed shaft bearings	Low speed shaft bearings	Structural deficiency	STD	x	x	x	x	
Power take off	Drivetrain	Low speed shaft bearings	Low speed shaft bearings	Vibration	VIB	x	x	x	x	
Power take off	Drivetrain	Low speed shaft dynamic seals	Low speed shaft dynamic seals	Blockage	BLO	x	x	x	x	
Power take off	Drivetrain	Low speed shaft dynamic seals	Low speed shaft dynamic seals	Structural deficiency	STD	x	x	x	x	Including failure cause: dry running, poor lubrication, wear, corrosion
Power take off	Drivetrain	High speed shaft	High speed shaft	Structural deficiency	STD	x		x		
Power take off	Drivetrain	High speed shaft	High speed shaft	Vibration	VIB	x		x		
Power take off	Drivetrain	High speed shaft bearings	High speed shaft bearings	Structural deficiency	STD	x		x		
Power take off	Drivetrain	High speed shaft bearings	High speed shaft bearings	Vibration	VIB	x		x		
Power take off	Drivetrain	Gearbox	Gearbox	Structural deficiency	STD	x		x		
Power take off	Drivetrain	Gearbox	Gearbox	Vibration	VIB	x		x		
Power take off	Drivetrain	Braking system	Braking system	Loss of function	LOF	x	x	x	x	Including failure cause: wear, fracture,
Power take off	Drivetrain	Braking system	Braking system	Blockage	BLO	x	x	x	x	
Power take off	Drivetrain	Couplings	Couplings	Structural deficiency	STD	x		x		
Power take off	Drivetrain	Couplings	Couplings	Vibration	VIB	x		x		

Sub System	Assembly	Equipment	Component	Failure mode	Failure mode code	1	2	3	4	BV Comments
Power take off	Drivetrain	Shaft Lubrication system	Shaft Lubrication system	Loss of Function	LOF	x	x	x		Added, unable to provide lubrication
Power take off	Drivetrain	Shaft Lubrication system	Shaft Lubrication system	Loss of performance	LOP	x	x	x		Including Parameter deviation - viscosity, Contamination, high moisture, high temperature LO
Power take off	Drivetrain	Shaft Lubrication system	Shaft Lubrication system	External Leakage - utility medium	EXU	x	x	x		Added
Power take off	Control & Communication system	Control system	Control sensors	Spurious stop	SPS	x	x	x	x	
Power take off	Control & Communication system	Control system	Control sensors	Parameter deviation	PAD	x	x	x	x	
Power take off	Control & Communication system	Control system	LAN	Spurious stop	SPS	x	x	x	x	LAN includes Network cable and Network interface card
Power take off	Control & Communication system	Control system	LAN	Signal interference	SIN	x	x	x	x	
Power take off	Control & Communication system	Control system	Controller (Software)	Unauthorized access	UAC	x	x	x	x	
Power take off	Control & Communication system	Control system	Controller (Software)	Delayed Operation	DOP	x	x	x	x	
Power take off	Control & Communication system	Control system	Controller (Software)	Spurious stop	SPS	x	x	x	x	
Power take off	Control & Communication system	Control system	Controller (Software)	Buffer Overflow	BUC	x	x	x	x	
Power take off	Control & Communication system	Control system	Controller (Software)	Race Condition	RAC	x	x	x	x	
Power take off	Control & Communication system	Control system	Controller (Hardware)	Spurious stop	SPS	x	x	x	x	Including all material failure (e.g. CPU, memory card)
Power take off	Control & Communication system	Control system	Fiber Optic	Faulty Signal	FAS	x	x	x	x	
Power take off	Control & Communication system	Control system	Fiber Optic	No signal	NSI	x	x	x	x	Including failure due to Laser wear out, Laser instability due to reflections, Whisker formation, Dark line defects, Structural deficiency - cable & jacket fracture

Sub System	Assembly	Equipment	Component	Failure mode	Failure mode code	1	2	3	4	BV Comments
Power take off	Control & Communication system	Control system	Emergency and safety chains	Fail to function on demand	FTD	x	x	x	x	
Power take off	Control & Communication system	Control system	System / component protection sensors	Fail to function on demand	FTD	x	x	x	x	
Power take off	Control & Communication system	Condition monitoring	Condition monitoring Sensor	Parameter deviation	PAD	x	x	x	x	Failure due to nonlinearity / sensor bias, drift error, noise error, environmental error
Power take off	Control & Communication system	Condition monitoring	Condition monitoring Sensor	Spurious stop	SPS	x	x	x	x	including :Structural deficiency - components failure
Power take off	Control & Communication system	Condition monitoring	Hardware	Fail to function on demand	FTD	x	x	x	x	
Power take off	Control & Communication system	Systems cabinets	Power control cabinet	Spurious stop	SPS	x	x	x	x	Including failure due to Overheating or Malfunctioning of one or more control components
Power take off	Control & Communication system	Systems cabinets	Power control cabinet	Signal interference	SIN	x	x	x	x	
Power take off	Control & Communication system	Systems cabinets	Power control cabinet	Spurious stop	SPS	x	x	x	x	Including failure due to Overheating or Malfunctioning of one or more control components
Power take off	Control & Communication system	Systems cabinets	Power control cabinet	Signal interference	SIN	x	x	x	x	
Power take off	Control & Communication system	Systems cabinets	Environmental monitoring cabinet	Spurious stop	SPS	x	x	x	x	Including failure due to Overheating or Malfunctioning of one or more control components
Power take off	Control & Communication system	Systems cabinets	Environmental monitoring cabinet	Signal interference	SIN	x	x	x	x	
Power take off	Control & Communication system	Systems cabinets	Bus communication interfaces	Spurious stop	SPS	x	x	x	x	Including failure due to Overheating or Not all data is sent correctly, Loss of isolation
Power take off	Control & Communication system	Systems cabinets	Bus communication interfaces	Signal interference	SIN	x	x	x	x	
Power take off	Control & Communication system	Systems cabinets	Pitch cabinet	Loss of Control	LOC			x		Including loss of control

Sub System	Assembly	Equipment	Component	Failure mode	Failure mode code	1	2	3	4	BV Comments
Power take off	Electrical system	Generator	Generator	Loss of Function	LOF		x		x	Stator Winding structural deficiency - core fault/ loss of magnetic wedges Rotor Winding: structural deficiency - rotor lead damage Bearings / Bearing housing: Structural deficiency - premature fatigue/ Denting of the bearing raceways and ball Insulator: Loss of isolation - early ageing/ overheating / burst
Power take off	Electrical system	Generator	Generator	Vibration	VIB		x		x	
Power take off	Electrical system	Generator	Generator	Low output	LOP		x		x	Including: Rotor Winding: structural deficiency - winding overstress Slip Ring / Brush: structural deficiency - sticking/Loosening/early wearing Frame: structural deficiency - deformation Bearings / Bearing housing: Structural deficiency - premature fatigue/ Denting of the bearing raceways and ball
Power take off	Electrical system	Generator	Generator	Corrosion	COR		x		x	
Power take off	Electrical system	Power Electronic Converter	Power Electronic Converter	Loss of function	LOF	x	x	x	x	Including: Switch / Switch driver Parameter deviation - overheating, Loss of isolation - insulation breakdown, Corrosion, Structural deficiency - burst IGBT Spurious stop, Fail to start on demand DC Chopper / Crowbar Spurious stop Filter Capacitor tank rupture, Spurious stop
Power take off	Electrical system	Power Electronic Converter	Power Electronic Converter	Low output	LOP	x	x	x	x	IGBT: Parameters degradation - unacceptable vibration/ thermal ageing/ thermomechanical fatigue Heat Management Insufficient heat transfer
Power take off	Electrical system	Transformer(s)	Transformer(s)	Loss of function	LOF	x	x	x	x	Including: Winding distortion Insulator Insufficient efficiency, Bushing failure
Power take off	Electrical system	Transformer(s)	Transformer(s)	Low output	LOP	x	x	x	x	Including: Winding Loss of isolation, Magnetic Core Parameter deviation - overheating Refrigerant Leakage
Power take off	Electrical system	HV switchgear	HV switchgear	Fail to function on demand	FTD	x	x	x		
Power take off	Electrical system	HV switchgear	HV switchgear	Breakdown	BRD	x	x	x		
Power take off	Electrical system	LV switchgear	LV switchgear	Fail to function on demand	FTD	x	x			
Power take off	Electrical system	LV switchgear	LV switchgear	Breakdown	BRD	x	x			
Power take off	Electrical system	Power cabling system	Power cabling system	Spurious stop	SPS	x	x			
Power take off	Electrical system	Power cabling system	Power cabling system	Breakdown	BRD	x	x			

Sub System	Assembly	Equipment	Component	Failure mode	Failure mode code	1	2	3	4	BV Comments
Power take off	Electrical system	Power cabling system	Power cabling system	Faulty transmission	FTT	x	x			
Power take off	Electrical system	Auxiliary Cabling System and Connector	Auxiliary Cabling System and Connector	Spurious stop	SPS	x	x			
Power take off	Electrical system	Auxiliary Cabling System and Connector	Auxiliary Cabling System and Connector	Breakdown	BRD	x	x			
Power take off	Electrical system	Auxiliary Cabling System and Connector	Auxiliary Cabling System and Connector	Faulty transmission	FTT	x	x			
Power take off	Electrical system	UPS systems	Battery	Fail to function on demand	FTD	x	x	x	x	
Power take off	Electrical system	UPS systems	Battery	Breakdown	BRD	x	x	x	x	
Power take off	Electrical system	Subsea cabling system	Subsea cabling system	Breakdown	BRD	x	x	x	x	
Power take off	Electrical system	Dynamic cable	Dynamic cable	Breakdown	BRD			x		
Power take off	Electrical system	Dynamic cable	Dynamic cable	Faulty transmission	FTT			x		
Power take off	Electrical system	Subsea cable joints	Subsea cable joints	Breakdown	BRD	x	x	x	x	
Power take off	Electrical system	Subsea cable joints	Subsea cable joints	Faulty transmission	FTT	x	x	x	x	
Power take off	Electrical system	Lighting Protection	Lighting Protection	Loss of function	LOF			x		
Power take off	Electrical system	Electrical Protection and Safety	Electrical Protection and Safety	Fail to function on demand	FTD	x	x	x	x	

Annex C – DATA COLLECTION TABLES

Annex C.1 Turbine/Equipment data tables (levels 1 to 5)

Table Annex C - 1: Groupings table (Level 1)

Field	Data Type	Mandatory	Definition
Grouping name	Short text	Yes	Name of the group of tidal turbine farms (usually located in nearby areas and connected to the same station)

Table Annex C - 2: Tidal farms table (Level 2)

Field	Data Type	Mandatory	Definition
Farm name	Short text	Yes	Name of the tidal turbine farm (group of tidal turbines located in the same field and connected to the same substation)
Wiring system	Short text	Yes	Type of wiring system of the farm (e.g. DC; AC;…)
Farm location	Short text		Site / location name of the Farm
Power transmission	Short text		Type of power transmission of the farm

Table Annex C - 3: Turbine models table (Level 3)

Field	Data Type	Mandatory	Definition
Model name or code	Short text	Yes	Name or code of the tidal turbine Model from designer
Model version	Short text	Yes	Version of the tidal turbine model
Model designer	Short text	Yes	Designer of the tidal turbine model
Mounting type (*)	List	Yes	Type of tidal turbine mounting (see table Annex C – 3.1 below)
Axis type (*)	List	Yes	Type of tidal turbine axis (see table Annex C – 3.1 below)
Rotor type (*)	List	Yes	Type of tidal turbine rotor (see table Annex C – 3.1 below)

Field	Data Type	Mandatory	Definition
Number of rotors (*)	List	Yes	Quantity of rotors on tidal turbine (see table Annex C – 3.2 below)
Number of blades (*)	List	Yes	Quantity of blades on each tidal turbine rotor (see table Annex C – 3.2 below)
Pitch control type (*)	List	Yes	Type of tidal turbine pitch control (see table Annex C – 3.2 below)
Yaw control type (*)	List	Yes	Type of tidal turbine yaw control (see table Annex C – 3.2 below)
Gearbox type (*)	List	Yes	Type of tidal turbine gearbox (see table Annex C – 3.2 below)
Foundation / support structure (*)	List	Yes	Type of tidal turbine foundation / support structure (see table Annex C – 3.2 below)
Design power	Number		Design power capacity of the tidal turbine (in kW)
Max operating power	Number		Maximum operating power capacity of the tidal turbine (in kW)
Average operating power	Number		Average operating power capacity of the tidal turbine (in kW)
Nominal operating power	Number		Nominal operating power capacity of the tidal turbine (in kW)
Environmental conditions	Text		Environmental conditions of tidal turbine operation (Mean Water depth; Average tide speed ; Wave condition (Hs) ; Sea water temperature; Ambient Temperature etc…)

(*) to be selected from the following tables 3.1 and 3.2 below:

Table Annex C - 3.1: Tidal Turbine Families table

Mounting type	Axis type	Rotor type
Fixed bottom type	Horizontal axis	Open rotor
Floating type	Vertical axis	Close rotor
Hybrid type	Other	Other
Other		

Table Annex C - 3.2: Tidal Turbine Configurations table

Number of rotors	Number of blades	Pitch control type	Yaw control type	Gearbox type	Foundation/ support structure type
1 rotor	2 blades	Mechanical pitch	Passive yaw	1 stage gearbox	Piles
2 rotors	3 blades	Electrical pitch	Active yaw	2 stages gearbox	Gravity base
3 rotors	4 blades	Other pitch system	Other yaw mechanism	3 stages gearbox	Suction anchor
4 rotors	5 blades	No pitch system	No yaw mechanism	Other	Pretensioned anchor pile
> 4 rotors	6 blades			No gearbox (direct drive)	Other
	> 6 blades				

Table Annex C - 4: Turbines table (Level 4)

Field	Data Type	Mandatory	Definition
Turbine name	Short text	Yes	Name of the tidal turbine
Location longitude	Number	Yes	Geographical coordinates of the location longitude of the tidal turbine
Location latitude	Number	Yes	Geographical coordinates of the location latitude of the tidal turbine
Assembly factory	Short text		Name and address of the factory where the tidal turbine was manufactured
Owner	Short text		Name and address of the tidal turbine owner
Operator	Short text		Name and address of the tidal turbine operator
Constructor	Short text		Name and address of the tidal turbine constructor
Maintainer	Short text		Name and address of the tidal turbine maintainer

Table Annex C - 5: Systems / Assemblies / Sub-assemblies table (Level 5)

Field	Data Type	Mandatory	Definition
System (*)	Short text	Yes	Name of the tidal turbine system (see table Annex C – 3.1 below)
Assembly (*)	Short text	Yes	Name of the tidal turbine assembly (see table Annex C – 3.1 below)
Assembly identification	Short text	Yes	Designation or code of the tidal turbine Assembly
Sub – assembly (*)	Short text	Yes	Name of the tidal turbine sub-assembly (see table Annex C – 3.1 below)
Sub – assembly identification	Short text	Yes	Designation or code of the tidal turbine sub-assembly
Sub – assembly type (*)	Short text	Yes	Type of the tidal turbine sub-assembly (see table Annex C – 3.1 below)

(*) Use Table Annex C – 6 as reference

Table Annex C - 6: Taxonomy hierarchy table

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
Hydrodynamic System	**Nacelle**	Nacelle shell	Permanently Closed Openable	Nacelle shell	Provision of watertight compartment
		Nacelle joints	Permanent joint (welded) Openable	Nacelle joints	Hold nacelle parts together Openable, provide maintenance access for big electrical equipment Provide water tightness
		Interface with supporting structure	Detachable Non detachable	Interface with supporting structure	Transfer loads to yaw mechanism or to support structure (see support structure)
		Penetrations	Above water level (for floating type) Subsea	Penetrations	Provide water tightness Provide passage to cables and pipes
		Lifting points		Lifting points	Provide attachment points for transport and handling
		Sub-assembly frame		Sub-assembly frame	Support drivetrain, transferring loads from components of drivetrain to nacelle (brake, gearbox, generator)
		Access into nacelle (hatches)		Access into nacelle (hatches)	Provide access into nacelle
		Access into nacelle (Subsea)		Access into nacelle (Subsea)	Provide access into nacelle

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
		Seafastening / tug points		Seafastening / tug points	Provide attachment points for tugging out of the nacelle (if buoyant nacelle) Provide attachment points to deck of transport ship during transport of nacelle
		Corrosion protection		Material selection	Provide corrosion protection for nacelle
				Coating	
				Impressed current	
				Corrosion Allowance	
	Rotor	Blades	Types 1: Casting, Hollow, Spar and shell, Monocoque, Other types Types 2: Free flooded, Semi-flooded, Non-flooded Air, Foam Types 3 : Buoyant, Non Buoyant Types 4: Serrated trailing edge, Fluted, fin, etc	Blade shell	Capture energy from current via its hydrodynamics profile Capture energy from current Withstand structural loads (normal operating, abnormal, accidental) Withstand fatigue loads Transfer loads to root connection Buoyant blades: rise to surface in case of accidental de-attachment Non-buoyant blades: sink to seabed in case of accidental de-attachment

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
				Blade structural element	Withstand structural loads (normal operating, abnormal, accidental) Withstand fatigue loads Transfer loads to root connection
				Blade coating	Provide protection to the blade against biofouling
				Blade root	Securing the blades to the blade hub
				Blade hydrodynamic features	Increase energy conversion efficiency of the blades
		Hub		Hub shell	Transfer loads from blades to main shaft Resist extreme loads Resist fatigue load
		Front Bulb		Front Bulb	Improve hydrodynamic performance
		Pitch System	Hydraulic-mechanical Electro-mechanical	Pitch Actuator (Hydraulic-mechanical actuator)	Allow pitching of the blades and therefore control of the turbine loading. Provides pitch motion
				Pitch actuator (Electro-mechanical)	Allow pitching of the blades and therefore control of the turbine loading. Provides pitch motion

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
				Pitching load transfer component (shaft, trunnion, crank ring)	Allow pitching of the blades and therefore control of the turbine loading. Provides pitch motion
				Pitch bearing	Support loads in pitch system Allow blade rotation about pitch axis Transfer axial loads and bending moments to hub Resist ultimate loads Resist fatigue loads
				Pitch gear	Transfer motion from pitch actuator to pitching shaft Provide a ratio for power-torque transmission between parts
				Dynamic seals for blades	Provide water tightness and oil leakage
				Control system	
				Electric system	Provide actuators with power
		Corrosion protection		Material selection	Provide corrosion protection for nacelle Provide corrosion protection for metallic part of the rotor
				Coating	
				Impressed current	
				Corrosion Allowance	
		Ring		Ring	Improve blades strenght / stability

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
	Yaw system	Yaw shaft (trunnion, crank ring)		Yaw shaft (trunnion, crank ring)	
		Yaw Gear		Yaw Gear	
		Yawing mechanism power actuator	Hydraulic Electrical	Hydraulic power unit	
				Yaw locking mechanism and turbine attachment mechanism	Provide attachment of nacelle onto substructure Prevents unintended separation of turbine form substructure under yawing operations Possible three conditions to be considered: Open ((for connection during installation), Partially engaged (to allow yaw without releasing vertical transference of permanent loads if part of load path for permanent loads) and Closed (to restrain yaw of the nacelle during operation).
				Guiding mechanism	External power docking station
		Yaw locking / brake mechanism		Yaw locking (clamp, gears, wedges, pins)	

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
				Interface with supporting structure	Provide attachment of nacelle onto substructure Prevents unintended separation of turbine form substructure under yawing operations Possible three conditions to be considered: Open ((for connection during installation), Partially engaged (to allow yaw without releasing vertical transference of permanent loads if part of load path for permanent loads) and Closed (to restrain yaw of the nacelle during operation).
		Cable and pipe management system		Hydraulic connection	
				Guiding mechanism	Manage cables and pipes when yawing, prevent entangling, rubbing of cables when yawing Guide cable connections between nacelle and main structure Align connections with sub structure
				Drag chain	Manage Connection when yawing, prevent entangling, rubbing of cables when yawing
				Slip ring	Provide contact between conducting surface(s) and brushes

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
		Yaw load bearing		Yaw load bearing	
		Yaw load bearing (plain)		Interface with supporting structure	Resist structural loads Resist fatigue loads Transmit load from upper part of joint to lower part of joint Allow rotation about the yaw axis if relevant, transfer bending moments and axial loads to sub-structure or skirt
	Tunnel	Tunnel		Interface with supporting structure	Improve turbine performance by venturing effect
Reaction System	**Foundation system**	Foundation fixation		Interface with supporting structure	Transfer loads from sub-structure to seabed, while complying with requirements for ultimate, fatigue and accidental limit states as well as serviceability aspects such as displacements and natural period
		Gravity base		Interface with supporting structure	Transfer loads from sub-structure to seabed, while complying with requirements for ultimate, fatigue and accidental limit states as well as serviceability aspects such as displacements and natural period

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
		Pretensioned anchor pile		Interface with supporting structure	Transfer loads from sub-structure to seabed, while complying with requirements for ultimate, fatigue and accidental limit states as well as serviceability aspects such as displacements and natural period
		Suction anchor		Interface with supporting structure	
	Support Structure	Interface with foundation		Interface with foundation (complete)	Transfer loads to foundation fixings Resist hydrodynamic loads from substructure
				Grouting (piling solution)	Transfer loads to foundation fixings Resist hydrodynamic loads from substructure
				Grout seal	
				Temporary structure (before grouting)	
				Mooring line	Fixing the turbine on the seabed
				Turret (Optional, Alternative to Individual Yaw)	Anchoring point providing free rotational movement for the turbine

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
		Main Structure (including auxiliary equipment) Main Structure (including auxiliary equipment)-Fixed (concept3)		Interface with supporting structure	Raise turbine height over seabed Resist hydrodynamic loads on the structure Resist fatigue loads Transfer loads to foundation fixings Provide support to umbilical
		Installation interface		Interface with supporting structure	Provide installation/Lifting interface
		Installation interface (Bolt eye)		Interface with supporting structure	Provide installation/Lifting interface
		Interface with turbine support		Interface with supporting structure	Provide safe attachment to turbine Resist hydrodynamic loads on the structure Resist fatigue loads Provide support to umbilical Transfer loads to main structure
		Corrosion protection		Material selection Coating Impressed current Corrosion Allowance	Providing corrosion protection for the support structure parts To provide corrosion protection for the metallic structural part

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
Power take off	**Auxiliaries**	Fire Fighting System		Interface with supporting structure	Provide safety measure in the event of fire hazard
		Cabinets		Interface with supporting structure	Provide enclosure for the auxiliary control system switches and connectors
		Ballast (solid ballast)		Interface with supporting structure	Allow trimming adjustment of nacelle during deployment Allow buoyancy adjustment of nacelle
		Ballast (liquid ballast)		Interface with supporting structure	Allow trimming adjustment of nacelle during deployment Allow buoyancy adjustment of nacelle
		Bilge system		Interface with supporting structure	Empty nacelle if water ingress Oil and water separation
		Air treatment		Compressor	
				Air Filter	
		Cooling system		Heat exchanger	Providing cooling mechanism for the electrical components
				Cooling Pump	Providing circulation mechanism for the heat exchanger coolant
				Coolant	Serving as the cooling working fluid for the electrical system heat management
				Cooling system connections	Providing circulation mechanism for the heat exchanger coolant
		Air treatment		Air filter	Prevent nacelle interior from condensation and salty environment
				Dehumidifier	

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
		Beacon/Lights		Beacon/Lights	To indicate turbine position to the passing vessels
	Drivetrain	Low speed shaft		Low speed shaft	Transfer torque from hub to generator Resist ultimate loads Resist fatigue loads
		Low speed shaft bearings		Low speed shaft bearings	Allow rotation of the shaft Resist misalignment induced loads Resist fatigue loads Transfer thrust and bending moments to nacelle (concept 3&4)
		Low speed shaft dynamic seals		Low speed shaft dynamic seals	Provide water tightness for the nacelle
		High speed shaft		High speed shaft	Transfer torque from gearbox to generator Resist ultimate loads Resist fatigue loads
		High speed shaft bearings		High speed shaft bearings	Allow rotation of high speed shaft Resist misalignment induced loads Resist fatigue loads
		Gearbox / high speed shaft	1 stage 2 stages 3 stages	Coupling	Step up rotation speed of main shaft and support main shaft through bearings Transmission of torque loads into nacelle
				Gears	To transmit torque
				Bearing	Transfer thrust and bending moments to nacelle
				Shaft	To transmit mechanical power
				Casing	To provide enclosure for the gearbox components

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
				Gearbox Lubrication system	Interface between gearbox and sub-frame
		Couplings	Shrink fit couplings Torsionally elastic couplings Tooth couplings Bolted flange couplings Friction flange couplings Torque limiters (Mechanical, hydraulic or magnetic Type)	Couplings	To transmit power
		Braking system		Low speed brake	Providing stopping mechanism for the turbine
		Braking system		Low speed brake (electrical)	Brake the drivetrain from low speed shaft
				Electrical power unit	Provide electrical power to braking mechanism
				Generator rear brake (disk)	Providing stopping mechanism for the turbine
				Parking / Blocking brake	Maintaining turbine on parking position

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
				Braking actuator (electrical)	Provide electrical power to braking mechanism
		Shaft Lubrication system		Shaft Lubrication system	Provide lubrication to the shaft
	Control & Communication system	Control system		Control sensors Data acquisition and processing (concept 4)	Detect events or changes from their measured environment and send feedback to the controller
				LAN	Transmit data from and to sensors and controller in the turbine Providing interface to the controller
				Controllers	Provide logic control system for the turbine
				Fiber Optic	Transmit data from and to the turbine and shore based command center
				Emergency and safety chains	To provide safety mechanism, protect and isolate components failure
				System / component protection sensors	To provide safety mechanism, protect and isolate components failure
		Condition monitoring		Condition monitoring sensors	Monitor defined parameters and send information to condition monitoring system
				Data acquisition hardware	Monitor defined parameters and send information to condition monitoring system

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
		Systems cabinets		Power control cabinet	Send feedback from drive train drive train to PLC controller transmit orders from PLC controller to brake/locking mechanism, drive train Provide enclosure for the control system switches and connectors (concept 3&4)
				Auxiliary cabinet	Send feedback from auxiliary systems to PLC controller Provide enclosure for the auxiliary control system switches and connectors (concept 3&4)
				Environmental monitoring cabinet	Transmit from environmental condition sensors to PLC controller Provide enclosure for the environment monitoring switches and connectors (concept 3&4)
				Bus communication interfaces	Allow communication between cabinets and PLC control system Allow communication with shore Provide enclosure for communication PLC control system components (concept 3&4)

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
				Pitch cabinet	Provide enclosure for pitch control system switches and connectors
	Electrical system	Generator PMSG		Winding	Transform mechanical power into electrical power
				Bearings / Bearing housing	
				Frame	
				Insulator	
		Generator DFIG		Stator Winding	Transform mechanical power into electrical power
				Bearings / Bearing housing	
				Slip Ring / Brush	
				Frame	
				Insulator	
		Generator - Induction Generator		Stator winding	Transform mechanical power into electrical power
				Rotor winding	
				Bearings / Bearing housing	
				Silent blocks	
				Frame	
				Insulator	
		Power Electronic Converter		Switch / Switch driver	To regulate voltage, current, and frequency of the electricity output of the turbine
				DC Bus / Capacitor	To regulate voltage, current, and frequency of the electricity output of the turbine
				IGBT	
				DC Choper / Crowbar	Converts fixed DC input to a variable DC output voltage

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
				Filter	Eliminate electrical noise
				Controller / Sensors	
				Heat Management	to Dissipate heat from the converter
		Transformer(s) - Liquid insulated transformer		Winding	To increase the alternating voltages in order to have efficient export power transmission
				Insulator	
				Magnetic Core	
				Refrigerant	
		Transformer(s) - Dry type transformer		Winding	To increase the alternating voltages in order to have efficient export power transmission
				Insulator	
				Magnetic Core	
		HV switchgear		HV switchgear	To control, protect and isolate electrical equipment. Feed and protect the tidal turbine electrical system
		LV switchgear		LV switchgear	To control, protect and isolate electrical equipment.
		Power cabling system		Power cabling system	Transmit electrical power production
		Auxiliary Cabling System and Connector		Auxiliary Cabling System and Connector	To transmit auxiliary electrical power
		UPS systems		UPS systems	To provide backup auxiliary electrical power (concept 3&4:) Provide back-up power in case of grid loss or internal failure to:

System	Assembly	Sub-Assembly	Sub-Assembly types	Equipment Class	Function
					- Pitch control and power system - Tidal turbine control system - Converter control system - HV switchgear protection relay - Others
				Batteries	
		Dynamic cable		Dynamic cable	Electrical connection of the power equipment and the grid
		Subsea cabling system		Subsea cabling system	To export generated electrical power to the shore
		Subsea cable joints	Internal External	Subsea cable joints	To provide secure connection and removal of subsea cable from the tidal turbine Connect the subsea cabling system the interior of the turbine (Concept 3)
		Lighting Protection		Lighting Protection	Provide protection for floating tidal turbine type
		Electrical Protection and Safety		Electrical Protection and Safety	To provide safety mechanism, protect and isolate electrical equipment failure

Table Annex C - 7: Equipment table (Level 6)

Field	Data Type	Mandatory	Definition
Sub – assembly identification	Short text	Yes	Designation of the sub-assembly where the equipment is installed (to be selected from table Annex C – 5).
Equipment identification	Short text	Yes	Designation or identification number in the tidal turbine structure (Equipment locator) (ex for pumps: duty pump: P101-A; standby pump: P101-B)
Equipment class (*)	Number	Yes	Class of equipment units (eg: Pump)
Equipment type	Short text	Yes	Type of equipment units (eg: Centrifugal Pump)
Description	Long text		Description of the equipment (Main lubrification pump)
Serial number	Short text		Manufacturer unique identification number
Manufacturer	Short text	Yes	Manufacturer name of the equipment
Manufacturer Model			Manufacturer model of the equipment
Design data	Long text		Equipment design data (ex.: capacity, power, speed, pressure, temperature,…
Normal function mode	Short text	Yes	Equipment function mode during normal operation : (In function/ Active standby/ Standby with manual activation / Other)
Functional parameters	Long text		Operating parameters appropriate to each class of equipment (For example the external environment, the operating power, operating temperature…);
Data source	Short text		Source where the data was collected (eg. CMMS, drawing, operating manual…)
Sub unit / Parts	Long text		Sub component or goup of parts of the equipment
Parts	Short text		Individual piece of an equipment
Additional information	Short text		Any relevant additional information about the equipment

(*) Use Table Annex C – 6 as reference

Annex C.2 Failure data tables (levels 1 to 5)

Table Annex C - 8: Equipment table (Level 6)

Field	Data Type	Mandatory	Definition
Group name	Short text	Yes	Name of the group of the tidal turbine farm
Farm name	Short text	Yes	Name of the tidal turbine farm
Turbine name	Short text	Yes	Name of tidal turbine
Equipment identification	Short text	Yes	Designation of the equipment
Initial service time	Date/Time	Yes	Date when the installed equipment started to operate for the first time
Observation starting date	Date/Time	Yes (if Observation time is already provided, this field is not mandatory)	Starting date and time of the data collection
Observation ending date	Date/Time	Yes (if Observation time is already provided, this field is not mandatory)	End date and time of the data collection
Calendar observation/Service duration	Number	Yes	Observation duration = (Observation end time) – (Observation start time) (in hours)
Operational service start time	Number	Yes (if Service operational hours is already provided, this field is not mandatory)	Equipment running hours at the starting date of the data collection (in hours)
Operational service ending time	Number	Yes (if Operational service hours is already provided, this field is not mandatory)	Equipment running hours at the end date of the data collection (in hours)
Operational service duration	Number	Yes	Operational service hours = (Operational service start time) – (Operational service start time) (in hours)
Number of periodic test requests	Number		Number of times a periodic test is performed during the observation period (eg. For safety devices, valves, standby equipment)
Number of operational requests	Number		Number of times an operational request is performed during the observation period (eg. For safety devices, valves, standby equipment)
Additional information	Long text		Any relevant additional information about the observation period
Data source			Source where the data was collected (eg. CMMS, running hour counters, etc)

Table Annex C - 9: Failure records table

Field	Data Type	Mandatory	Definition
Group name	Short text	Yes	Name of the group of the tidal turbine farm
Farm name	Short text	Yes	Name of the tidal turbine farm
Turbine name	Short text	Yes	Name of tidal turbine
Failure record identification	Short text	Yes	Unique failure identification
Failure date	Date/Time	Yes	Date of detection of the failure
Failure mode (*)	Short text	Yes	Manner in which the equipment fails (to be selected from table Annex C – 10).
Failure code (*)	Short text	Yes	Code of the failure mode (to be selected from table Annex C – 10).
Failure cause	Short text	Yes	The circumstances associated that resulted in failure (generally a physical phenomenon such as corrosion, vibration, wear, overload…)
Failure mechanism	Short text		The physical, chemical or other processes that have caused failure
Defective subunit	Short text		Designation of defective the Subunit of the equipment
Defective subunit	Short text		Designation of defective part of the equipment
Detection method	Short text		How the failure was detected
Service operating time	Number	Yes	Service running hours of the equipment at the date of the failure
Consequence on production (**)	Short text	Yes	Consequence/impact of the failure on production (to be selected from table Annex C – 11).
Consequence of the failure on the security	Short text		Consequence of the failure on the security of the installation (for example the personnel injury, the environmental impact, asset damage). The consequence can be quantitative or qualitative data
Operating condition	Long text		Operating condition when the failure occurs: Stopping, starting,

Field	Data Type	Mandatory	Definition
			working operating, hot redundancy, standby, in cold redundancy, under test
Operation phase	Short text		Type of operation at time of failure
SIS class	Short text		SIS Classes to be selected: DU (Dangerous failure Undetected), DD (Dangerous failure Detected), SU (Safe failure Undetected), SD (Safe failure Undetected)
Additional information	Long text		Additional comments to capture other information about the failure
Data source	Short text		Source of collected data

(*) Use Table Annex C – 10 as reference
(**) Use Table Annex C – 11 as reference

Table Annex C - 10: Failure Mode table

Failure mode + code
Structural deficiency (STD)
External leak - water ingress (EXW)
Loss of function (LOF)
Parameter deviation (PAD)
Fouling (FOL)
Vibration (VIB)
Spurious stop (SPS)
Corrosion (COR)
Fail to function on demand (FTD)
Low output (LOP)
External Leakage - utility medium (EXU)
Loss of performance (LOP)
Blockage (BLO)
Delayed operation (DOP)
Faulty signal (FAS)
Unauthorized access (UNA)
Signal interference (SII)
No signal (NSI)
Signal interference (SII)
Breakdown (BRD)
Faulty transmission (FTT)

Table Annex C - 11: Consequence of failure table

Consequence of failure	Definition
Critical	Immediately loss of production performance
Degraded	Progressive or no loss of production performance
Incipient	No immediately loss of production performance but could bring critical failure after a period of operation
Unknown	No identified consequence on production

Table Annex C - 12: Maintenance records table

Field	Data Type	Mandatory	Definition
ID	AutoNumber		
Maintenance record identification			Unique maintenance identification
Failure record identification	Number	Yes	Failure record identification related to the maintenance (same as in table Annex C-8)
Maintenance date	Date/Time	Yes	Date of the maintenance operation or scheduled date
Active repair start date	Date/Time	Yes	Starting date and time of the active repair on the equipment (see in Annex A)
Active repair end date	Date/Time	Yes	Ending date and time of the active repair on the equipment (see in Annex A)
Active repair duration	Number	Yes	Duration of the active repair on the equipment (in hours) (see in Annex A) (Active repair duration) = (Active repair end date) - (Active repair start date)
Equipment Stop Date	Date/Time	Yes	Date and time when the equipment was stopped due to failure or maintenance
Equipment Restart Date	Date/Time	Yes	Date and time when the equipment was back to service after maintenance activity completed
Unavailability / downtime duration			Total downtime duration due to failure and maintenance (in hours) (see in Annex A) (Unavailability / downtime duration) = Equipment Restart Date) – (Equipment Stop Date)
Number of maintenance persons for repair	Number	Yes	Quantity of persons needed to perform the repair activity

Field	Data Type	Mandatory	Definition
Total repair man-hours	Number	Yes	Total man-hours needed to perform the repair activity (in hours) (Total repair man-hours) = (Active repair duration) x (Number of maintenance persons for repair)
Maintenance category	Short text	Yes	Corrective maintenance or preventive maintenance
Interval (programmed maintenance)	Short text		Schedule or operating interval between two programmed maintenance (not applicable to corrective maintenance)
Maintenance activity	Long text		Description of maintenance performed on the equipment
Maintenance delays	Long text		Prolonged causes of unavailability, for example logistics, meteorology, scaffolding, absence of parts spare, delay of the repair team
Maintenance priority	Short text		High, medium or low priority
Consequence of maintenance on the operation	Short text		Consequence / impact of the maintenance on production (None, partial or total (predefined list)
Subunit subject to maintenance	Short text		Designation of the subunit(s) subject to maintenance/repair
Part subject to maintenance	Short text		Designation of the part(s) subject to maintenance/repair
Location of spare parts	Short text		Availability of parts (e.g. locally / at distance, at the manufacturer)
Maintenance duration in man hours, by discipline	Number		Maintenance time in man-hours, by discipline (mechanical, electrical, instrument, others)
Means necessary for the maintenance of the equipment	Short text		For example heavy lift vessel, CTV, OSV, ROV, etc.
Additional information	Long text		Additional comments to capture other information about the equipment maintenance/repair
Data source	Short text		Source of collected data

Annex D – DEMONSTRATOR DATABASE TABLE FIELDS

Table Annex D - 13: Sub-systems table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
sub_system_name	Short text	Yes	

Table Annex D - 14: Assemblies table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
assembly	Short text	Yes	
sub_system_id	Number	Yes	Yes

Table Annex D - 15: Sub-assemblies table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
sub_assemby	Short text	Yes	
sub_assembly_id	Number	Yes	Yes

Table Annex D - 16: Sub-assembly types Table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
turbine_model_id	Number	Yes	
sub_assembly_id	Number	Yes	
sub_assembly_type_id	Number		
number_of	Number	Yes	

Table Annex D - 17: Equipment table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
equipment	Short text	Yes	
sub_assembly_id	Number	Yes	Yes
function	Short text		

Table Annex D - 18: Groupings table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
grouping_name	Short text	Yes	

Table Annex D - 19: Tidal farms table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
farm_name	Short text	Yes	
grouping_id	Number	Yes	Yes
Owner	Short text		
Operator	Short text		
Maintainer	Short text		
wiring_system	Short text	Yes	
power_transmission	Short text		
Total_nominal_power	Number		

Table Annex D - 20: Turbine models table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
Model_name	Short text	Yes	
model_version	Short text		
Design concept	Number		
Axis_type	Short text	Yes	
Rotor_type	Short text	Yes	
Bottom_mounting_type	Short text	Yes	
Number_of_rotors	Number	Yes	
Number_of_blades per rotor	Number	Yes	
Has_pitch_control	Yes/No	Yes	
Pitch_control_type	Short text	Yes	
Has_yaw_control	Yes/No	Yes	
Yaw_control_type	Short text	Yes	
Has_gearbox	Yes/No	Yes	
Gearbox_type	Short text	Yes	
Design_power_kW	Number		
Max_operating_power_kW	Number		
Average_operating_power_kW	Number		
Nominal_operating_power_kW	Number		

Table Annex D - 21: Turbine model assemblies table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
turbine_model_id	Number	Yes	
assembly_id	Number	Yes	
number_of	Number	Yes	

Table Annex D - 22: Turbine model sub-assemblies table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
turbine_model_id	Number	Yes	
sub_assembly_id	Number	Yes	
sub_assembly_type_id	Number		
number_of	Number	Yes	

Table Annex D - 23: Turbine model equipment table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
turbine_model_id	Number	Yes	
equipment_id	Number	Yes	
number_of	Number	Yes	

Table Annex D - 24: Turbines table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
turbine_name	Short text	Yes	
client_turbine_ref	Short text		
turbine_model_id	Number	Yes	Yes
farm_id	Number	Yes	Yes
constructor	Short text		
assembly_factory	Short text		
client_owner_ref	Short text		
other_companies	Long text		
longitude	Number	Yes	
latitude	Number	Yes	
obs_start_date	Date-time	Yes	
obs_end_date	Date-time	Yes	
obs_duration	Number	Yes	
op_time_at_obs_start	Number	Yes	
op_time_at_obs_end	Number	Yes	
op_duration	Number	Yes	
mean_water_depth	Number		
mean_tidal_flow	Number		

Table Annex D - 25: Turbine assemblies table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
turbine_id	Number	Yes	Yes
assebmly_id	Number	Yes	Yes
assembly_ref	Short text	Yes	
assembly	Short text	Yes	
sub_system_id	Number	Yes	Yes
sub_system	Short text	Yes	

Table Annex D - 26: Turbine sub-assemblies table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
turbine_id	Number	Yes	Yes
sub_assembly_id	Number	Yes	Yes
sub_assembly_ref	Short text		
sub_assembly_type_id	Number		Yes
sub_assembly_type	Short text		
turb_assem_id	Number	Yes	Yes
assembly_id	Number	Yes	Yes
assembly_ref	Short text		
sub_system_id	Number	Yes	Yes

Table Annex D - 27: Turbine equipment table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
turbine_id	Number	Yes	Yes
equipment_id	Number	Yes	Yes
equipment_ref	Short text		
equipment	Short text	Yes	
turb_sub_assem_id	Number	Yes	Yes
sub_assembly_ref	Short text		
sub_assembly	Short text	Yes	
sub_assembly_type	Short text		
equipment_type	Short text		
description	Long text		
serial_number	Number		
manufacturer	Short text		
Model	Short text		
design_data	Long text		
normal_function_mode	Short text		
initial_service_date	Date/time	Yes	
initial_start_date	Date/time	Yes	
obs_start_date	Date/time	Yes	
obs_end_date	Date/time	Yes	

Field	Data Type	Mandatory	Foreign Key
obs_duration	Date/time	Yes	
op_time_at_obs_start	Number	Yes	
op_time_at_obs_end	Number	Yes	
op_duration	Number	Yes	
num_periodic_requests	Number		
num_operat_requests	Number		
functional_parameters	Short text		
additional_info	Long text		
data_source	Short text		
Components	Short text		
sub-components	Short text		

Table Annex D - 28: Failure modes table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
Failure_mode	Short text	Yes	
Failure_code	Short text	Yes	

Table Annex D - 29: Failure records table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
turbine_id	Number	Yes	Yes
turb_equip_id	Number	Yes	Yes
reference	Short text		
failure_date	Date/Time	Yes	
failure_time_cal	Number	Yes	
failure_time_op	Number	Yes	
report	Short text		
cause	Short text		
failure_start_time	Date/Time	Yes	
mode_id	Number	Yes	Yes
mode	Short text	Yes	
consequence	Short text	Yes	

Table Annex D - 30: Maintenance records table

Field	Data Type	Mandatory	Foreign Key
ID	AutoNumber		
failure_id	Number	Yes	Yes
reference	Short text		
report	Short text		
category	Short text	Yes	
comments	Long text		
start_date	Date/Time	Yes	

Field	Data Type	Mandatory	Foreign Key
end_date	Date/Time	Yes	
active_repair_time	Number	Yes	
num_persons	Number	Yes	
person_hours	Number	Yes	
restart_date	Date/Time	Yes	
unavailability	Number	Yes	
delays-issues	Long text		
priority	Short text		
impact	Short text		

Table Annex D - 31: Anonymous reliability data table

Field	Data Type	Use
ID	AutoNumber	Unique record identifier
grouping_id	Number	Grouping identifier, calculate the number of unique groupings
farm_id	Number	Tidal farm identifier, calculate the number of unique farms
turbine_id	Number	Turbine identifier, calculate the number of unique turbines
turbine_model_id	Number	Turbine model identifier, calculate the number of or filter by model type
sub_system	Short text	Human-readable sys-system name
turb_assem_id	Number	Turbine Assembly identifier, calculate the number of unique assembly instances
assembly_id	Number	Assembly identifier, filter by assembly
assembly	Short text	Human-readable assembly name
turb_sub_assem_id	Number	Turbine sub-assembly identifier, calculate the number of unique sub-assembly instances
sub_assembly_id	Number	Sub-assembly identifier, filter by sub-assembly
sub_assembly	Short text	Human-readable sub-assembly name
sub_assembly_type	Short text	Human-readable sub-assembly type, filter by sub-assembly type
turb_equipment_id	Number	Turbine equipment identifier, calculate the number of unique equipment instances
equipment_id	Number	Equipment identifier, filter by equipment
equipment	Short text	Human-readable equipment name
obs_duration	Number	Observation duration, calculation of failure rate data
op_duration	Number	Operational duration, calculation of failure rate data
num_periodic_requests	Number	?
num_operat_requests	Number	?
failure_mode	Short text	Failure mode, description of mode for reporting
failure_code	Short text	Failure code, 3 letter failure mode code for reporting
failure_time_cal	Number	?
failure_time_op	Number	?
consequence	Short text	Consequence of failure, filtering and counting failures
category	Short text	Maintenance category, filtering and counting failures
active_repair_time	Number	Active repair time, calculating repair time statistics
person_hours	Number	Person hours, calculating repair person hours statistics

ANNEX E – DEMONSTRATOR DATABASE SQL QUERIES

Annex E.1 Select assembly

```
SELECT
    [assemblies].[ID],
    [assemblies].[assembly],
    [sub-systems].[sub_system]
FROM
    [sub-systems] INNER JOIN assemblies ON assemblies.[sub_system_id]=[sub-systems].ID
WHERE
    [sub_system] Like Nz([Enter sub-system name:],"*");
```

Annex E.2 Select sub-assembly

```
SELECT
    [sub-assemblies].[ID],
    [sub-assemblies].[sub_assembly],
    [assemblies].[assembly],
    [sub-systems].[sub_system]
FROM
    ([assemblies] INNER JOIN [sub-assemblies] ON [sub-assemblies].[assembly_id] =
[assemblies].[ID])
    INNER JOIN [sub-systems] ON [assemblies].[sub_system_id] = [sub-systems].[ID]
WHERE
    ([sub-systems].[sub_system] LIKE Nz([Enter sub-system name:], "*")) AND
    ([assemblies].[assembly] LIKE Nz([Enter assembly name:], "*"))
ORDER BY
    [sub-systems].[sub_system],
    [assemblies].[assembly],
    [sub-assemblies].[sub_assembly];
```

Annex E.3 Select sub-assembly type

```
SELECT
    [sub-assembly-types].[ID],
    [sub-assembly-types].[type],
    [sub-assemblies].[sub_assembly],
    [assemblies].[assembly],
    [sub-systems].[sub_system]
FROM
    (([assemblies] INNER JOIN [sub-assemblies] ON [sub-assemblies].[assembly_id] =
[assemblies].[ID])
    INNER JOIN [sub-systems] ON [assemblies].[sub_system_id] = [sub-systems].[ID])
    INNER JOIN [sub-assembly-types] ON [sub-assemblies].[ID] = [sub-assembly-
types].[sub_assembly_id]
WHERE
    ([sub-systems].[sub_system] LIKE Nz([Enter sub-system name:], "*")) AND
    ([assemblies].[assembly] LIKE Nz([Enter assembly name:], "*"));
```

Annex E.4 Select assembly for equipment

```
SELECT
    [assemblies].[ID],
    [assemblies].[assembly],
    [sub-systems].[sub_system]
FROM
    [sub-systems] INNER JOIN assemblies ON assemblies.[sub_system_id]=[sub-systems].ID
WHERE
    [sub_system] LIKE Nz([Enter sub-system name:],"*");
```

Annex E.5 Select sub-assembly for turbine model

```
SELECT
    [sub-assemblies].[ID],
    [turbine_models].[model_name],
    [sub-assemblies].[sub_assembly],
    [assemblies].[assembly],
    [sub-systems].[sub_system]
FROM
    ((([assemblies] INNER JOIN [sub-assemblies] ON [sub-assemblies].[assembly_id] =
[assemblies].[ID])
    INNER JOIN [sub-systems] ON [assemblies].[sub_system_id] = [sub-systems].[ID])
    INNER JOIN [turbine_model_assemblies] ON [assemblies].[ID] =
[turbine_model_assemblies].[assembly_id])
    INNER JOIN [turbine_models] ON [turbine_model_assemblies].[turbine_model_id] =
[turbine_models].[ID]
WHERE
    ([turbine_models].[model_name] LIKE Nz([Enter turbine model name:], "*")) AND
    ([sub-systems].[sub_system] LIKE Nz([Enter sub-system name:], "*")) AND
    ([assemblies].[assembly] LIKE Nz([Enter assembly name:], "*"))
ORDER BY
    [turbine_models].[model_name],
    [sub-systems].[sub_system],
    [assemblies].[assembly],
    [sub-assemblies].[sub_assembly];
```

Annex E.6 Select equipment for turbine model

```
SELECT
    [equipment].[ID],
    [turbine_models].[model_name],
    [turbine_model_assemblies].[number_of]*[turbine_model_sub-assemblies].[number_of] AS
[number of],
    [equipment].[equipment],
    [sub-assemblies].[sub_assembly],
    [assemblies].[assembly],
    [sub-systems].[sub_system]
FROM
    (((([sub-systems] INNER JOIN assemblies ON [sub-systems].[ID] =
[assemblies].[sub_system_id])
    INNER JOIN [sub-assemblies] ON [sub-assemblies].[assembly_id] = [assemblies].[ID])
    INNER JOIN [equipment] ON [equipment].[sub_assembly_id] = [sub-assemblies].[ID])
    INNER JOIN [turbine_model_sub-assemblies] ON [sub-assemblies].[ID] = [turbine_model_sub-
assemblies].[sub_assembly_id])
    INNER JOIN [turbine_models] ON [turbine_model_sub-assemblies].[turbine_model_id] =
[turbine_models].[ID])
    INNER JOIN [turbine_model_assemblies] ON ([turbine_models].[ID] =
[turbine_model_assemblies].[turbine_model_id]) AND ([turbine_model_assemblies].[assembly_id] =
[assemblies].[ID])
WHERE
    ([turbine_models].[model_name] LIKE Nz([Enter turbine model name:], "*")) AND
    ([sub-systems].[sub_system] LIKE Nz([Enter sub-system name:], "*")) AND
    ([assemblies].[assembly] LIKE Nz([Enter assembly name:], "*"))
ORDER BY
    [turbine_models].[model_name],
    [sub-systems].[sub_system],
    [assemblies].[assembly],
    [sub-assemblies].[sub_assembly];
```

Annex E.7 Append assemblies for turbines

```
INSERT INTO
    [turbine_assemblies] ( turbine_id, assembly_id, assembly, sub_system_id, sub_system )
SELECT
    [turbines].[ID] AS [turbine_id],
    [assemblies].[ID] AS [assembly_id],
    [assemblies].[assembly],
    [assemblies].[sub_system_id],
    [sub-systems].[sub_system]
FROM
    (((([turbines] INNER JOIN [turbine_models] ON [turbines].[turbine_model_id] =
[turbine_models].[ID])
    INNER JOIN [turbine_model_assemblies] ON [turbine_models].[ID] =
[turbine_model_assemblies].[turbine_model_id])
    INNER JOIN [assemblies] ON [turbine_model_assemblies].[assembly_id] = [assemblies].[ID])
    INNER JOIN [sub-systems] ON [assemblies].[sub_system_id] = [sub-systems].[ID])
    INNER JOIN [numbers] ON [numbers].[n] <= [turbine_model_assemblies].[number_of]
WHERE
    (((turbines.turbine_name) LIKE Nz([Enter turbine name:],"*")));
```

Annex E.8 Append sub-assemblies for turbines

```
INSERT INTO
    [turbine_sub-assemblies] ( turbine_id, sub_assembly_id, sub_assembly, sub_assembly_ref,
sub_assembly_type_id, sub_assembly_type, turb_assem_id, assembly_id, assembly_ref, assembly,
sub_system_id )
SELECT
    [turbines].[ID] AS [turbine_id],
    [turbine_model_sub-assemblies].[sub_assembly_id],
    [sub-assemblies].[sub_assembly],
    [turbine_assemblies].[assembly_ref] AS [sub_assembly_ref],
    [turbine_model_sub-assemblies].[sub_assembly_type_id],
    [sub-assembly-types].[type], [turbine_assemblies].[ID] AS [turb_assem_id],
    [turbine_assemblies].[assembly_id],
    [turbine_assemblies].[assembly_ref],
    [assemblies].[assembly],
    [turbine_assemblies].[sub_system_id]
FROM
    (((((([turbines] INNER JOIN [turbine_models] ON [turbines].[turbine_model_id] =
[turbine_models].[ID])
    INNER JOIN [turbine_assemblies] ON [turbines].[ID] = [turbine_assemblies].[turbine_id])
    INNER JOIN [assemblies] ON [turbine_assemblies].[assembly_id] = [assemblies].[ID])
    INNER JOIN [sub-assemblies] ON [assemblies].[ID] = [sub-assemblies].[assembly_id])
    INNER JOIN [turbine_model_sub-assemblies] ON (turbine_models.[ID] = [turbine_model_sub-
assemblies].[turbine_model_id]) AND ([sub-assemblies].[ID] = [turbine_model_sub-
assemblies].[sub_assembly_id]))
    LEFT JOIN [sub-assembly-types] ON [turbine_model_sub-assemblies].[sub_assembly_type_id] =
[sub-assembly-types].[ID])
    INNER JOIN numbers ON [numbers].[n] <= [turbine_model_sub-assemblies].[number_of]
WHERE
    ((([turbines].[turbine_name]) LIKE Nz([Enter turbine name:],"*")));
```

Annex E.9 Append equipment for turbines

```
INSERT INTO
    [turbine_equipment] ( turbine_id, equipment_id, equipment_ref, equipment,
turb_sub_assem_id, sub_assembly_ref, sub_assembly, sub_assembly_type )
SELECT
    [turbine_sub-assemblies].[turbine_id],
    [turbine_model_equipment].[equipment_id],
    [turbine_sub-assemblies].[sub_assembly_ref] AS [equipment_ref],
    [equipment].[equipment],
    [turbine_sub-assemblies].[ID] AS [turb_sub_assem_id],
    [turbine_sub-assemblies].[sub_assembly_ref],
    [turbine_sub-assemblies].[sub_assembly],
    [turbine_sub-assemblies].[sub_assembly_type]
FROM
    (((((([turbines] INNER JOIN [turbine_models] ON [turbines].[turbine_model_id] =
[turbine_models].[ID])
    INNER JOIN [turbine_sub-assemblies] ON [turbines].[ID] = [turbine_sub-
assemblies].[turbine_id])
    INNER JOIN [sub-assemblies] ON [turbine_sub-assemblies].[sub_assembly_id] = [sub-
assemblies].[ID])
    INNER JOIN [equipment] ON [equipment].[sub_assembly_id] = [sub-assemblies].[ID])
    INNER JOIN [turbine_model_equipment] ON ([turbine_models].[ID] =
[turbine_model_equipment].[model_id]) AND ([equipment].[ID] =
[turbine_model_equipment].[equipment_id]))
    INNER JOIN [numbers] ON [numbers].[n] <= [turbine_model_equipment].[number_of]
WHERE
    ((([turbines].[turbine_name]) LIKE Nz([Enter turbine name:],"*")));
```

Annex E.10 Select turbine equipment for failure

```
SELECT
    [turbine_equipment].[ID] AS [ID],
    [turbines].[turbine_name] AS [turbine],
    [turbine_equipment].[equipment_ref],
    [turbine_equipment].[equipment],
    [turbine_equipment].[sub_assembly],
    [turbine_sub-assemblies].[assembly],
    [turbine_assemblies].[sub_system]
FROM
    (([turbines] INNER JOIN [turbine_equipment] ON [turbines].[ID] =
[turbine_equipment].[turbine_id])
    INNER JOIN [turbine_sub-assemblies] ON [turbine_sub-assemblies].[ID] =
[turbine_equipment].[turb_sub_assem_id])
    INNER JOIN [turbine_assemblies] ON [turbine_assemblies].[ID] = [turbine_sub-
assemblies].[turb_assem_id]
WHERE
    [turbines].[turbine_name] LIKE Nz([Enter turbine name:], "*")
ORDER BY
    [turbines].[turbine_name],
    [turbine_assemblies].[sub_system],
    [turbine_sub-assemblies].[assembly],
    [turbine_equipment].[sub_assembly];
```

Annex E.11 Select failure record for maintenance

```
SELECT
    [failure_records].[ID] AS [failure ID],
    [turbines].[turbine_name] AS [turbine],
    [failure_records].[reference]
FROM
    [failure_records] INNER JOIN [turbines] ON [failure_records].[turbine_id] =
[turbines].[ID]
WHERE
    [turbines].[turbine_name] LIKE Nz([Enter turbine name:],"*")
ORDER BY
    [failure_records].[ID];
```

ANNEX F – DUMMY DATA TABLES

Annex F.1 Ingeteam wind farm failure/maintenance sampling data

Event	idGrouping	idProject	idFarm	Farm	set	idSubset	idSubset	subset	hoursBase	kwAcumulate	hoursAcumulate	numberOT
321	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	72265	28030923	61893	16028157131
445	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	72958	28271913	62459	16038668631
460	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	73024	28302214	62522	16038698331
667	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	74173	28803522	63562	160510253331
923	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	75240	29093462	69440	160713291131
1511	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	78101	29992698	66754	161123521031
7240	6717822	16217	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	78249	30040235	86874	161124301531
8229	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	78555	30152289	67141	161224509431
8230	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	78555	30152289	67141	161224509531
8248	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	78635	30156747	67188	161224553931
8323	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	78946	30198841	67407	161224854031
8333	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	79012	30214184	67443	161224951431
8339	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	79018	30214189	67443	161225031331
8344	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	79049	30214821	67451	161225035231
8350	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	79058	30215116	67452	170125036431
8358	6717822	750	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	79092	30217574	67473	170125101431
8451	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	79821	30518039	68107	170225534931
8520	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	80170	30645411	68387	170225919631
8610	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	80539	30803703	68686	170326080231
9539	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	84822	32264049	72240	170932332831
9577	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	84984	32298738	72364	170932719331
9591	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	85024	32304999	72392	170933561331
9612	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	85123	32312987	72452	171033691431
9766	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	85765	32457867	72926	171134910631
9810	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	85914	32498880	73045	171135046831
10407	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	89249	33987436	45877	180444834431
10766	6717822	753	6718323	WindFarm	WT08	6725524	929825	MULTIG1 - MULTIPLICADORA	90306	34321488	76747	180549085831

(Cont.)

Event	numberOT	dateCreate	idDefect	defect	idCause	cause
321	16028157131	2016-04-12 10:42:16	3897529	Parada por excesiva temperatura del ace	2867727	FALLO VÁLVULA
445	16038668631	2016-04-22 12:58:53	3895429	Nivel bajo de aceite en multiplicadora;	2860927	FALLO NIVEL
460	16038698331	2016-04-29 07:53:18	0		0	
667	160510253331	2016-06-17 07:35:18	3895429	Nivel bajo de aceite en multiplicadora;	2860927	FALLO NIVEL
923	160713291131	2016-08-05 09:12:40	3895429	Nivel bajo de aceite en multiplicadora;	2868427	FUGA ACEITE
1511	161123521031	2016-12-15 08:36:39	3890629	Parada Manual;	2860827	FALLO MULTIPLICADORA
7240	161124301531	2017-01-19 17:18:44	0		0	
8229	161224509431	2017-01-03 17:02:30	3895429	Nivel bajo de aceite en multiplicadora;	2868427	FUGA ACEITE
8230	161224509531	2017-01-03 17:02:52	3895429	Nivel bajo de aceite en multiplicadora;	2868427	FUGA ACEITE
8248	161224553931	2017-01-10 10:31:32	3895429	Nivel bajo de aceite en multiplicadora;	2860927	FALLO NIVEL
8323	161224854031	2017-01-28 08:28:47	3895429	Nivel bajo de aceite en multiplicadora;	2860927	FALLO NIVEL
8333	161224951431	2017-01-30 07:31:22	3895429	Nivel bajo de aceite en multiplicadora;	2860927	FALLO NIVEL
8339	161225031331	2017-01-31 07:36:27	3895429	Nivel bajo de aceite en multiplicadora;	2860927	FALLO NIVEL
8344	161225035231	2017-02-01 10:00:42	3895429	Nivel bajo de aceite en multiplicadora;	2868427	FUGA ACEITE
8350	170125036431	2017-02-02 09:51:00	3895429	Nivel bajo de aceite en multiplicadora;	2860927	FALLO NIVEL
8358	170125101431	2017-02-04 13:18:10	3895429	Nivel bajo de aceite en multiplicadora;	2868427	FUGA ACEITE
8451	170225534931	2017-03-06 17:57:45	3895429	Nivel bajo de aceite en multiplicadora;	2860927	FALLO NIVEL
8520	170225919631	2017-03-21 13:48:58	3895429	Nivel bajo de aceite en multiplicadora;	2860927	FALLO NIVEL
8610	170326080231	2017-04-10 12:43:24	3895429	Nivel bajo de aceite en multiplicadora;	2868427	FUGA ACEITE
9539	170932332831	2017-10-18 15:21:03	3895429	NIVEL BAJO DE ACEITE EN MULTIPLICADORA;	2868427	FUGA ACEITE
9577	170932719331	2017-10-26 13:20:51	3890629	PARADA MANUAL;	33561627	ACEITE EN MAL ESTADO
9591	170933561331	2017-10-28 17:16:37	23516029	DEFECTO MULTIPLICADORA	33561627	ACEITE EN MAL ESTADO
9612	171033691431	2017-11-03 14:01:47	3890629	PARADA MANUAL;	2868427	FUGA ACEITE
9766	171134910631	2017-12-03 14:18:57	0		0	
9810	171135046831	2017-12-10 10:14:34	3890629	PARADA MANUAL;	2860827	FALLO MULTIPLICADORA
10407	180444834431	2018-05-07 12:49:39	0		0	
10766	180549085831	2018-06-24 14:49:12	0		0	

(Cont.)

Event	numberOT	idAction	action	reasonIntervention	classWork	dateSubmission	dateHandOperation
321	16028157131	2876628	CAMBIO VÁLVULA	Thermostatic valve of the gearbox is changed	CORRECTIVE	2016-04-12 10:41:26	2016-03-17 00:00:00
445	16038668631	2878528	REARME MÁQUINA LOCAL (BLOQUEO: TARJET	LOCAL RESET	CORRECTIVE	2016-04-22 12:37:51	2016-04-21 00:00:00
460	16038698331	0		THE OIL LEVEL OF THE GEARBOX IS CHECKED. FOAM IS FOUND, IT IS LEFT TO REST AND 8 LITERS OF OIL 320	PREDICTIVE	2016-04-24 10:24:53	2016-04-24 00:00:00
667	160510253331	2879328	REPOSICIÓN Y MARCHA	The oil level of the gearbox is checked. It is correct (just above the maximum). Leave the machine in manual speed for 30 minutes to dissipate the oil foam.	CORRECTIVE	2016-06-17 07:33:43	2016-06-14 00:00:00
923	160713291131	2878928	RELLENAR ACEITE	1.- Limit it to 900 revolutions and inform Cecovi that the machine will be running in 30 minutes. 2.- Fill the gearbox with 10 liters of 320 oil.	CORRECTIVE	2016-08-05 10:40:09	2016-08-03 00:00:00
1511	161123521031	2870528	ACCIÓN SIN CODIFICAR	Collect sample of oil from the gearbox.	CORRECTIVE	2016-12-15 08:37:32	2016-12-12 00:00:00
7240	161124301531	0		A VIDEOSCOPY OF THE gearbox IS MADE.	PREDICTIVE	2016-12-19 17:23:13	2016-12-19 00:00:00
8229	161224509431	2878928	RELLENAR ACEITE	OIL LEVEL IS FILLED AND CLEANED.	CORRECTIVE	2017-01-03 17:03:48	
8230	161224509531	2878928	RELLENAR ACEITE	OIL LEVEL IS FILLED AND CLEANED.	CORRECTIVE	2017-01-03 17:05:07	2017-01-03 00:00:00
8248	161224553931	2878528	REARME MÁQUINA LOCAL (BLOQUEO: TARJET	Checking for leaks and local reset	CORRECTIVE	2017-01-10 10:35:25	2017-01-09 00:00:00
8323	161224854031	2878528	REARME MÁQUINA LOCAL (BLOQUEO: TARJET	It is put in manual mode at 900 turns as the oil temperature is 39º.	CORRECTIVE	2017-01-28 08:49:00	2017-01-24 00:00:00
8333	161224951431	2878528	REARME MÁQUINA LOCAL (BLOQUEO: TARJET	Local reset. It is put in manual mode at 900 rpm.	CORRECTIVE	2017-01-30 09:17:50	2017-01-29 00:00:00
8339	161225031331	2878528	REARME MÁQUINA LOCAL (BLOQUEO: TARJET	Set the machine to 900 rpm.	CORRECTIVE	2017-01-31 08:23:34	2017-01-30 00:00:00
8344	161225035231	2878528	REARME MÁQUINA LOCAL (BLOQUEO: TARJET	Local reset and check for possible leakage	CORRECTIVE	2017-02-01 10:48:05	2017-02-01 00:00:00
8350	170125036431	2878528	REARME MÁQUINA LOCAL (BLOQUEO: TARJET	Local reset and check for possible leaks	CORRECTIVE	2017-02-02 10:25:46	2017-02-02 00:00:00
8358	170125101431	2878928	RELLENAR ACEITE	The gearbox (5.l) is filled, emptied and the tray is cleaned from the surplus of the gearbox. All the platforms are cleaned.	CORRECTIVE	2017-02-04 13:16:30	2017-02-04 00:00:00
8451	170225534931	2878528	REARME MÁQUINA LOCAL (BLOQUEO: TARJET	LOCAL RESET	CORRECTIVE	2017-03-06 18:10:54	2017-03-05 00:00:00
8520	170225919631	2878928	RELLENAR ACEITE	YOU CAN SEE A LOT OF FOAM IN THE gearbox, BUT THE OIL LEVEL IS AT ITS MAXIMUM. THERE IS OIL LEAKAGE ON THE MAIN BEARING	CORRECTIVE	2017-03-21 13:51:56	2017-03-21 00:00:00
8610	170326080231	2878928	RELLENAR ACEITE	gearbox oil filling (Oil S4 Omala 320). The anemo and vane heaters are wired according to engineering. Luminaire is placed on the ground. Clean the tower and sections (oil leakage)	CORRECTIVE	2017-04-10 12:44:02	2017-04-10 00:00:00
9539	170932332831	2878928	RELLENAR ACEITE	Turn in manual to check operation. It is filled with 7 liters of oil. Start up	CORRECTIVE	2017-10-18 15:21:43	2017-10-18 00:00:00
9577	170932719331	33561828	CAMBIO ACEITE	Additive gearbox with 15 liters of kluber summit varnasolv HV for oil change Place bottle in the oil pan of the gearbox	CORRECTIVE	2017-10-26 13:22:10	2017-10-26 00:00:00
9591	170933561331	33561828	CAMBIO ACEITE	3-Manual stop. Change gearbox oil, oil and air filter. gearbox OIL DEFECTIVE. gearbox OIL CHANGE. Possible preventive task.	CORRECTIVE	2017-10-28 17:18:19	2017-10-28 00:00:00

Event	numberOT	idAction	action	reasonIntervention	classWork	dateSubmission	dateHandOperation
9612	171033691431	2877528	LIMPIAR ACEITE	The oil level of the gearbox is checked. Check the interior and take pictures. Put on cardan shaft protection plates and clean tubes and platforms.	CORRECTIVE	2017-11-03 14:01:56	2017-11-03 00:00:00
9766	171134910631	0		Check gearbox. No leaks are observed.	PREDICTIVE	2017-12-03 14:48:33	2017-12-03 00:00:00
9810	171135046831	42016628	REVISION MULTIPLICADORA	Gearbox oil sample collected.	CORRECTIVE	2017-12-10 10:14:45	2017-12-10 00:00:00
10407	180444834431	0		oil sample is collected	PREDICTIVE	2018-05-07 12:58:32	2018-05-07 00:00:00
10766	180549085831	0		gearbox videoscopy is performed, slip ring is checked and cleaned, gearbox pump is changed, shaft seal is broken	PREDICTIVE	2018-06-24 15:00:43	2018-06-24 00:00:00

Annex F.3 Dummy data compilation

idGrouping	Grouping	idFarm	Farm	idTurbine	Turbine	Assembly	idSubAssembly	SubAssembly identification	SubAssembly	SubAssembly type	Equipment	Equipment identification	Equipment type	Failure record ID	Failure date	Failure Calendar Time (hours)	Failure Operating Time (hours)	Failure record	cause	Failure Mode (Code)	Consequence of failure	Maintenance activity	Maintenance Report	Maintenance ID	Maintenance category	Maintenance starting date	Maintenance Ending date	Active repair Time (hours)	Man power	Total Man-hours	Restarting date	Unavailability time (hours)	Maintenance delays / issues
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	16028157131	2016-03-17 00:00:00	72265	61893	Parada por excesiva temperatura del ace	FALLO VÁLVULA	Parameter deviation (PAD)	Critical	16028157131	CAMBIO VÁLVULA	Thermostatic valve of the gearbox is changed	CORRECTIVE	2016-03-24 08:00:26	2016-04-10 00:01:17	352,0143333	3	1056,0	2016-04-12 10:41:26	587	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	16038668631	2016-04-21 00:00:00	72958	62459	Nivel bajo de aceite en multiplicadora;	FALLO NIVEL	Parameter deviation (PAD)	Critical	16038668631	REARME MÁQUINA LOCAL (BLOQUEO: TARJET	LOCAL RESET	CORRECTIVE	2016-04-21 10:59:21	2016-04-22 08:58:04	21,9785	2	44,0	2016-04-22 12:37:51	37	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage		(*Unknown)	(*Unknown)	16038698331	2016-04-24 00:00:00	73024	62522				Unknown	16038698331		THE OIL LEVEL OF THE GEARBOX IS CHECKED. FOAM IS FOUND, IT IS LEFT TO REST AND 8 LITERS OF OIL 320	PREDICTIVE	2016-04-24 03:07:28	2016-04-24 09:22:24	6,248833333			2016-04-24 10:24:53	10	
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	160510253331	2016-06-14 00:00:00	74173	63562	Nivel bajo de aceite en multiplicadora;	FALLO NIVEL	Parameter deviation (PAD)	Degraded	160510253331	REPOSICIÓN Y MARCHA	The oil level of the gearbox is checked. It is correct (just above the maximum). Leave the machine in manual speed for 30 minutes to dissipate the oil foam.	CORRECTIVE	2016-06-14 23:52:07	2016-06-16 23:36:21	47,73716667	2	95,5	2016-06-17 07:33:43	80	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	160713291131	2016-08-03 00:00:00	75240	69440	Nivel bajo de aceite en multiplicadora;	FUGA ACEITE	External Leakage - utility medium (EXU)	Degraded	160713291131	RELLENAR ACEITE	1.- Limit it to 900 revolutions and inform Cecovi that the machine will be running in 30 minutes. 2.- Fill the gearbox with 10 liters of 320 oil.	CORRECTIVE	2016-08-03 17:36:03	2016-08-05 04:48:08	35,2015	2	70,4	2016-08-05 10:40:09	59	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage	Gears	(*Unknown)	(*Unknown)	161123521031	2016-12-12 00:00:00	78101	66754	Parada Manual;	FALLO MULTIPLICADORA	Vibration	Critical	161123521031	ACCIÓN SIN CODIFICAR	Collect sample of oil from the gearbox.	CORRECTIVE	2016-12-13 00:11:16	2016-12-15 00:33:47	48,37533333	2	96,8	2016-12-15 08:37:32	81	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage		(*Unknown)	(*Unknown)	161124301531	2016-12-19 00:00:00	78249	86874				Unknown	161124301531		A VIDEOSCOPY OF THE gearbox IS MADE.	PREDICTIVE	2016-12-19 05:12:58	2016-12-19 15:38:54	10,43216667			2016-12-19 17:23:13	17	
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	161224509531	2017-01-03 00:00:00	78555	67141	Nivel bajo de aceite en multiplicadora;	FUGA ACEITE	External Leakage - utility medium (EXU)	Incipient	161224509531	RELLENAR ACEITE	OIL LEVEL IS FILLED AND CLEANED.	CORRECTIVE	2017-01-03 05:07:32	2017-01-03 15:22:36	10,25116667	1	10,3	2017-01-03 17:05:07	17	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	161224553931	2017-01-09 00:00:00	78635	67188	Nivel bajo de aceite en multiplicadora;	FALLO NIVEL	Parameter deviation (PAD)	Critical	161224553931	REARME MÁQUINA LOCAL (BLOQUEO: TARJET	Checking for leaks and local reset	CORRECTIVE	2017-01-09 10:22:37	2017-01-10 07:07:52	20,75416667	2	41,5	2017-01-10 10:35:25	35	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	161224854031	2017-01-24 00:00:00	78946	67407	Nivel bajo de aceite en multiplicadora;	FALLO NIVEL	Parameter deviation (PAD)	Critical	161224854031	REARME MÁQUINA LOCAL (BLOQUEO: TARJET	It is put in manual mode at 900 turns as the oil temperature is 39º.	CORRECTIVE	2017-01-25 07:26:42	2017-01-27 22:20:06	62,89	4	251,6	2017-01-28 08:49:00	105	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	161224951431	2017-01-29 00:00:00	79012	67443	Nivel bajo de aceite en multiplicadora;	FALLO NIVEL	Parameter deviation (PAD)	Critical	161224951431	REARME MÁQUINA LOCAL (BLOQUEO: TARJET	Local reset. It is put in manual mode at 900 rpm.	CORRECTIVE	2017-01-29 09:59:21	2017-01-30 05:58:03	19,97833333	2	40,0	2017-01-30 09:17:50	33	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	161225031331	2017-01-30 00:00:00	79018	67443	Nivel bajo de aceite en multiplicadora;	FALLO NIVEL	Parameter deviation (PAD)	Degraded	161225031331	REARME MÁQUINA LOCAL (BLOQUEO: TARJET	Set the machine to 900 rpm.	CORRECTIVE	2017-01-30 09:43:04	2017-01-31 05:09:13	19,43566667	2	38,9	2017-01-31 08:23:34	32	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	161225035231	2017-02-01 00:00:00	79049	67451	Nivel bajo de aceite en multiplicadora;	FUGA ACEITE	External Leakage - utility medium (EXU)	Critical	161225035231	REARME MÁQUINA LOCAL (BLOQUEO: TARJET	Local reset and check for possible leakage	CORRECTIVE	2017-02-01 03:14:26	2017-02-01 09:43:16	6,480833333	1	6,5	2017-02-01 10:48:05	11	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	170125036431	2017-02-02 00:00:00	79058	67452	Nivel bajo de aceite en multiplicadora;	FALLO NIVEL	Parameter deviation (PAD)	Critical	170125036431	REARME MÁQUINA LOCAL (BLOQUEO: TARJET	Local reset and check for possible leaks	CORRECTIVE	2017-02-02 03:07:44	2017-02-02 09:23:11	6,257666667	1	6,3	2017-02-02 10:25:46	10	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	170125101431	2017-02-04 00:00:00	79092	67473	Nivel bajo de aceite en multiplicadora;	FUGA ACEITE	External Leakage - utility medium (EXU)	Incipient	170125101431	RELLENAR ACEITE	The gearbox (5.l) is filled, emptied and the tray is cleaned from the surplus of the gearbox. All the platforms are cleaned.	CORRECTIVE	2017-02-04 03:58:57	2017-02-04 11:56:51	7,965	1	8,0	2017-02-04 13:16:30	13	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	170225534931	2017-03-05 00:00:00	79821	68107	Nivel bajo de aceite en multiplicadora;	FALLO NIVEL	Parameter deviation (PAD)	Critical	170225534931	REARME MÁQUINA LOCAL (BLOQUEO: TARJET	LOCAL RESET	CORRECTIVE	2017-03-05 12:39:16	2017-03-06 13:57:49	25,309	3	75,9	2017-03-06 18:10:54	42	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	170225919631	2017-03-21 00:00:00	80170	68387	Nivel bajo de aceite en multiplicadora;	FALLO NIVEL	External Leakage - utility medium (EXU)	Incipient	170225919631	RELLENAR ACEITE	YOU CAN SEE A LOT OF FOAM IN THE gearbox, BUT THE OIL LEVEL IS AT ITS MAXIMUM. THERE IS OIL LEAKAGE ON THE MAIN BEARING	CORRECTIVE	2017-03-21 04:09:35	2017-03-21 12:28:44	8,319333333	1	8,3	2017-03-21 13:51:56	14	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADORA	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	170326080231	2017-04-10 00:00:00	80539	68686	Nivel bajo de aceite en multiplicadora;	FUGA ACEITE	External Leakage - utility	Incipient	170326080231	RELLENAR ACEITE	gearbox oil filling (Oil S4 Omala 320). The anemo and vane heaters are wired according to engineering.	CORRECTIVE	2017-04-10 03:49:13	2017-04-10 11:27:38	7,640333333	1	7,6	2017-04-10 12:44:02	13	(*Unknown)

idGrouping	Grouping	idFarm	Farm	idTurbine	Turbine	Assembly	idSubAssembly	SubAssembly identification	SubAssembly	SubAssembly type	Equipment	Equipment identification	Equipment type	Failure record ID	Failure date	Failure Calendar Time (hours)	Failure Operating Time (hours)	Failure record	cause	Failure Mode (Code)	Consequence of failure	Maintenance activity	Maintenance Report	Maintenance ID	Maintenance category	Maintenance starting date	Maintenance Ending date	Active repair Time (hours)	Manpower	Total Man-hours	Restarting date	Unavailability time (hours)	Maintenance delays / issues
																				medium (EXU)				Luminaire is placed on the ground. Clean the tower and sections (oil leakage)									
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADOR A	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	170932332831	2017-10-18 00:00:00	84822	72240	NIVEL BAJO DE ACEITE EN MULTIPLICADOR A;	FUGA ACEITE	External Leakage - utility medium (EXU)	Degraded	170932332831	RELLENAR ACEITE	Turn in manual to check operation. It is filled with 7 liters of oil. Start up	CORRECTIVE	2017-10-18 04:36:31	2017-10-18 13:49:33	9,217166667	2	18,4	2017-10-18 15:21:43	15	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADOR A	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	170932719331	2017-10-26 00:00:00	84984	72364	PARADA MANUAL;	ACEITE EN MAL ESTADO	External Leakage - utility medium (EXU)	Critical	170932719331	CAMBIO ACEITE	Additive gearbox with 15 liters of kluber summit varnasolv HV for oil change Place bottle in the oil pan of the gearbox	CORRECTIVE	2017-10-26 04:00:39	2017-10-26 12:01:57	8,021666667	1	8,0	2017-10-26 13:22:10	13	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADOR A	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	170933561331	2017-10-28 00:00:00	85024	72392	DEFECTO MULTIPLICADOR A	ACEITE EN MAL ESTADO	External Leakage - utility medium (EXU)	Incipient	170933561331	CAMBIO ACEITE	3-Manual stop. Change gearbox oil, oil and air filter. C0000-gearbox OIL DEFECTIVE. A0000-gearbox OIL CHANGE. Possible preventive task.	CORRECTIVE	2017-10-28 05:11:30	2017-10-28 15:34:29	10,38316667	2	20,8	2017-10-28 17:18:19	17	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADOR A	Gearbox / high speed shaft	1 stage	Gearbox Lubrication system	(*Unknown)	(*Unknown)	171033691431	2017-11-03 00:00:00	85123	72452	PARADA MANUAL;	FUGA ACEITE	External Leakage - utility medium (EXU)	Critical	171033691431	LIMPIAR ACEITE	The oil level of the gearbox is checked. Check the interior and take pictures. Put on cardan shaft protection plates and clean tubes and platforms.	CORRECTIVE	2017-11-03 04:12:35	2017-11-03 12:37:44	8,419333333	2	16,8	2017-11-03 14:01:56	14	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADOR A	Gearbox / high speed shaft	1 stage		(*Unknown)	(*Unknown)	171134910631	2017-12-03 00:00:00	85765	72926				Unknown	171134910631		Check gearbox. No leaks are observed.	PREDICTIVE	2017-12-03 04:26:34	2017-12-03 13:19:42	8,8855			2017-12-03 14:48:33	15	
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADOR A	Gearbox / high speed shaft	1 stage	Gears	(*Unknown)	(*Unknown)	171135046831	2017-12-10 00:00:00	85914	73045	PARADA MANUAL;	FALLO MULTIPLICADOR A	Vibration	Critical	171135046831	REVISION MULTIPLICADOR A	Gearbox oil sample collected.	CORRECTIVE	2017-12-10 03:04:25	2017-12-10 09:13:16	6,1475	1	6,1	2017-12-10 10:14:45	10	(*Unknown)
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADOR A	Gearbox / high speed shaft	1 stage		(*Unknown)	(*Unknown)	180444834431	2018-05-07 00:00:00	89249	45877				Unknown	180444834431		oil sample is collected	PREDICTIVE	2018-05-07 03:53:34	2018-05-07 11:40:41	7,785333333			2018-05-07 12:58:32	13	
6717822	A	6718323	A1	6725524	WT8	Drivetrain	929825	MULTIG1 - MULTIPLICADOR A	Gearbox / high speed shaft	1 stage		(*Unknown)	(*Unknown)	180549085831	2018-06-24 00:00:00	90306	76747				Unknown	180549085831		gearbox videoscopy is performed, slip ring is checked and cleaned, gearbox pump is changed, shaft seal is broken	PREDICTIVE	2018-06-24 04:30:13	2018-06-24 13:30:39	9,007166667			2018-06-24 15:00:43	15	
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain A - Gearbox / high speed shaft - coupling	(*Unknown)	IR1	2017-03-21 00:00:00	72265	61893	(*unknown)	(*unknown)	Parameter deviation (PAD)	Critical	(*unknown)	(*unknown)	WO1	CORRECTIVE	2017-03-28 20:40:21	2017-04-19 20:57:22	528,2833889	3	1584,9	2017-04-21 10:41:26	755	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages			(*Unknown)	IR2	2017-04-28 00:00:00	73024	62522				Unknown		(*unknown)	WO2	PREDICTIVE	2017-04-29 08:36:13	2017-05-03 03:53:38	91,29030556			2017-05-03 10:24:53	130	
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain A - Gearbox / high speed shaft - coupling	(*Unknown)	IR3	2017-06-18 00:00:00	74173	63562	(*unknown)	(*unknown)	Parameter deviation (PAD)	Degraded	(*unknown)	(*unknown)	WO3	CORRECTIVE	2017-06-18 19:53:26	2017-06-21 03:35:02	55,69336111	2	111,4	2017-06-21 07:33:43	80	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain A - Gearbox / high speed shaft - coupling	(*Unknown)	IR4	2017-08-07 00:00:00	75240	69440	(*unknown)	(*unknown)	External Leakage - utility medium (EXU)	Degraded	(*unknown)	(*unknown)	WO4	CORRECTIVE	2017-08-08 20:40:02	2017-08-14 01:44:09	125,0684167	2	250,1	2017-08-14 10:40:09	179	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gears	Drivetrain A - Gearbox / high speed shaft - gears	(*Unknown)	IR5	2017-12-16 00:00:00	78101	66754	(*unknown)	(*unknown)	Vibration	Critical	(*unknown)	(*unknown)	WO5	CORRECTIVE	2017-12-25 20:09:23	2018-01-22 09:23:39	661,2378889	2	1322,5	2018-01-24 08:37:32	945	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain A - Gearbox / high speed shaft - coupling	(*Unknown)	IR6	2018-01-07 00:00:00	78555	67141	(*unknown)	(*unknown)	External Leakage - utility medium (EXU)	Incipient	(*unknown)	(*unknown)	WO6	CORRECTIVE	2018-01-08 10:16:17	2018-01-12 10:13:52	95,95969444	1	96,0	2018-01-12 17:05:07	137	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain A - Gearbox / high speed shaft - coupling	(*Unknown)	IR7	2018-01-13 00:00:00	78635	67188	(*unknown)	(*unknown)	Parameter deviation (PAD)	Critical	(*unknown)	(*unknown)	WO7	CORRECTIVE	2018-01-14 14:38:51	2018-01-19 02:51:39	108,2131944	2	216,4	2018-01-19 10:35:25	155	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain A - Gearbox / high speed shaft - coupling	(*Unknown)	IR8	2018-01-25 00:00:00	78946	67407	(*unknown)	(*unknown)	Parameter deviation (PAD)	Critical	(*unknown)	(*unknown)	WO8	CORRECTIVE	2018-01-27 02:12:15	2018-02-01 22:46:33	140,5716667	4	562,3	2018-02-02 08:49:00	201	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain A - Gearbox / high speed shaft - coupling	(*Unknown)	IR9	2018-02-02 00:00:00	79012	67443	(*unknown)	(*unknown)	Parameter deviation (PAD)	Critical	(*unknown)	(*unknown)	WO9	CORRECTIVE	2018-02-03 14:19:27	2018-02-08 01:37:56	107,3080556	2	214,6	2018-02-08 09:17:50	153	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain A - Gearbox / high speed shaft - coupling	(*Unknown)	IR10	2018-02-03 00:00:00	79018	67443	(*unknown)	(*unknown)	Parameter deviation (PAD)	Degraded	(*unknown)	(*unknown)	WO10	CORRECTIVE	2018-02-04 14:05:53	2018-02-09 00:46:23	106,6749444	2	213,3	2018-02-09 08:23:34	152	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain A - Gearbox / high speed shaft - coupling	(*Unknown)	IR11	2018-02-05 00:00:00	79049	67451	(*unknown)	(*unknown)	External Leakage - utility medium (EXU)	Critical	(*unknown)	(*unknown)	WO11	CORRECTIVE	2018-02-06 08:42:01	2018-02-10 04:15:41	91,56097222	1	91,6	2018-02-10 10:48:05	131	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain A - Gearbox / high speed shaft - coupling	(*Unknown)	IR12	2018-02-06 00:00:00	79058	67452	(*unknown)	(*unknown)	Parameter deviation (PAD)	Critical	(*unknown)	(*unknown)	WO12	CORRECTIVE	2018-02-07 08:36:26	2018-02-11 03:54:29	91,30061111	1	91,3	2018-02-11 10:25:46	130	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain A - Gearbox / high speed shaft - coupling	(*Unknown)	IR13	2018-02-08 00:00:00	79092	67473	(*unknown)	(*unknown)	External Leakage - utility medium (EXU)	Incipient	(*unknown)	(*unknown)	WO13	CORRECTIVE	2018-02-09 09:19:07	2018-02-13 06:36:40	93,2925	1	93,3	2018-02-13 13:16:30	133	(*Unknown)

idGrouping	Grouping	idFarm	Farm	idTurbine	Turbine	Assembly	idSubAssembly	SubAssembly identification	SubAssembly	SubAssembly type	Equipment	Equipment identification	Equipment type	Failure record ID	Failure date	Failure Calendar Time (hours)	Failure Operating Time (hours)	Failure record	cause	Failure Mode (Code)	Consequence of failure	Maintenance activity	Maintenance Report	Maintenance ID	Maintenance category	Maintenance starting date	Maintenance Ending date	Active repair Time (hours)	Man power	Total Man-hours	Restarting date	Unavailability time (hours)	Maintenance delays / issues
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain A - Gearbox / high speed shaft - coupling	(*Unknown)	IR14	2018-04-14 00:00:00	80539	68686	(*unknown)	(*unknown)	External Leakage - utility medium (EXU)	Incipient	(*unknown)	(*unknown)	WO14	CORRECTIVE	2018-04-15 09:11:00	2018-04-19 06:05:50	92,91372222	1	92,9	2018-04-19 12:44:02	133	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain A - Gearbox / high speed shaft - coupling	(*Unknown)	IR15	2018-10-22 00:00:00	84822	72240	(*unknown)	(*unknown)	External Leakage - utility medium (EXU)	Degraded	(*unknown)	(*unknown)	WO15	CORRECTIVE	2018-10-23 09:50:26	2018-10-27 08:35:38	94,75336111	2	189,5	2018-10-27 15:21:43	135	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain A - Gearbox / high speed shaft - coupling	(*Unknown)	IR16	2018-11-02 00:00:00	85024	72392	(*unknown)	(*unknown)	External Leakage - utility medium (EXU)	Incipient	(*unknown)	(*unknown)	WO16	CORRECTIVE	2018-11-02 04:19:35	2018-11-02 16:26:24	12,11369444	2	24,2	2018-11-02 17:18:19	17	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain A - Gearbox / high speed shaft - coupling	(*Unknown)	IR17	2018-11-07 00:00:00	85123	72452	(*unknown)	(*unknown)	External Leakage - utility medium (EXU)	Critical	(*unknown)	(*unknown)	WO17	CORRECTIVE	2018-11-08 09:30:29	2018-11-12 07:19:50	93,82255556	2	187,6	2018-11-12 14:01:56	134	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages			(*Unknown)	IR18	2018-12-07 00:00:00	85765	72926				Unknown		(*unknown)	WO18	PREDICTIVE	2018-12-08 09:42:08	2018-12-12 08:04:07	94,36641667			2018-12-12 14:48:33	135	
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain A - Gearbox / high speed shaft	Drivetrain A - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gears	Drivetrain A - Gearbox / high speed shaft - gears	(*Unknown)	IR19	2018-12-14 00:00:00	85914	73045	(*unknown)	(*unknown)	Vibration	Critical	(*unknown)	(*unknown)	WO19	CORRECTIVE	2018-12-15 08:33:41	2018-12-19 03:44:01	91,17208333	1	91,2	2018-12-19 10:14:45	130	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain B - Gearbox / high speed shaft	Drivetrain B - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain B - Gearbox / high speed shaft - Gearbox Lubrication system	(*Unknown)	IR20	2017-01-11 00:00:00	72265	61893	(*unknown)	(*unknown)	Parameter deviation (PAD)	Critical	(*unknown)	(*unknown)	WO20	CORRECTIVE	2017-01-22 00:08:30	2017-02-05 03:45:09	339,61075	3	1018,8	2017-02-11 10:41:26	755	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain B - Gearbox / high speed shaft	Drivetrain B - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain B - Gearbox / high speed shaft - Gearbox Lubrication system	(*Unknown)	IR21	2017-02-15 00:00:00	72958	62459	(*unknown)	(*unknown)	Parameter deviation (PAD)	Critical	(*unknown)	(*unknown)	WO21	CORRECTIVE	2017-02-17 06:49:15	2017-02-20 05:18:17	70,483875	2	141,0	2017-02-21 12:37:51	157	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain B - Gearbox / high speed shaft	Drivetrain B - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages			(*Unknown)	IR22	2017-02-18 00:00:00	73024	62522				Unknown		(*unknown)	WO22	PREDICTIVE	2017-02-19 21:38:43	2017-02-22 08:19:54	58,686625			2017-02-23 10:24:53	130	
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain B - Gearbox / high speed shaft	Drivetrain B - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain B - Gearbox / high speed shaft - Gearbox Lubrication system	(*Unknown)	IR23	2017-04-08 00:00:00	74173	63562	(*unknown)	(*unknown)	Parameter deviation (PAD)	Degraded	(*unknown)	(*unknown)	WO23	CORRECTIVE	2017-04-10 21:50:48	2017-04-14 15:38:58	89,802875	2	179,6	2017-04-16 07:33:43	200	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain B - Gearbox / high speed shaft	Drivetrain B - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain B - Gearbox / high speed shaft - Gearbox Lubrication system	(*Unknown)	IR24	2017-05-28 00:00:00	75240	69440	(*unknown)	(*unknown)	External Leakage - utility medium (EXU)	Degraded	(*unknown)	(*unknown)	WO24	CORRECTIVE	2017-05-30 14:32:03	2017-06-02 22:56:07	80,401125	2	160,8	2017-06-04 10:40:09	179	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain B - Gearbox / high speed shaft	Drivetrain B - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain B - Gearbox / high speed shaft - Gearbox Lubrication system	(*Unknown)	IR25	2017-10-28 00:00:00	78555	67141	(*unknown)	(*unknown)	External Leakage - utility medium (EXU)	Incipient	(*unknown)	(*unknown)	WO25	CORRECTIVE	2017-10-29 23:58:47	2017-11-01 13:40:06	61,688375	1	61,7	2017-11-02 17:05:07	137	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain B - Gearbox / high speed shaft	Drivetrain B - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain B - Gearbox / high speed shaft - Gearbox Lubrication system	(*Unknown)	IR26	2017-10-23 00:00:00	79012	67443	(*unknown)	(*unknown)	Parameter deviation (PAD)	Critical	(*unknown)	(*unknown)	WO26	CORRECTIVE	2017-11-05 02:03:14	2017-11-21 21:50:16	403,78375	2	807,6	2017-11-29 09:17:50	897	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain B - Gearbox / high speed shaft	Drivetrain B - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain B - Gearbox / high speed shaft - Gearbox Lubrication system	(*Unknown)	IR27	2017-10-24 00:00:00	79018	67443	(*unknown)	(*unknown)	Parameter deviation (PAD)	Degraded	(*unknown)	(*unknown)	WO27	CORRECTIVE	2017-11-06 01:44:15	2017-11-22 21:06:51	403,37675	2	806,8	2017-11-30 08:23:34	896	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain B - Gearbox / high speed shaft	Drivetrain B - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain B - Gearbox / high speed shaft - Gearbox Lubrication system	(*Unknown)	IR28	2017-11-27 00:00:00	79058	67452	(*unknown)	(*unknown)	Parameter deviation (PAD)	Critical	(*unknown)	(*unknown)	WO28	CORRECTIVE	2017-11-28 13:15:01	2017-11-30 13:08:37	47,89325	1	47,9	2017-12-01 10:25:46	106	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain B - Gearbox / high speed shaft	Drivetrain B - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain B - Gearbox / high speed shaft - Gearbox Lubrication system	(*Unknown)	IR29	2017-11-30 00:00:00	79092	67473	(*unknown)	(*unknown)	External Leakage - utility medium (EXU)	Incipient	(*unknown)	(*unknown)	WO29	CORRECTIVE	2017-12-01 05:50:46	2017-12-02 20:13:12	38,37375	1	38,4	2017-12-03 13:16:30	85	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain B - Gearbox / high speed shaft	Drivetrain B - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain B - Gearbox / high speed shaft - Gearbox Lubrication system	(*Unknown)	IR30	2017-12-31 00:00:00	79821	68107	(*unknown)	(*unknown)	External Leakage - utility medium (EXU)	Critical	(*unknown)	(*unknown)	WO30	CORRECTIVE	2018-01-02 00:21:49	2018-01-04 14:32:43	62,18175	3	186,5	2018-01-05 18:10:54	138	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain B - Gearbox /	Drivetrain B - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain B - Gearbox / high speed	(*Unknown)	IR31	2018-08-20	84984	72364	(*unknown)	(*unknown)	External Leakage - utility	Critical	(*unknown)	(*unknown)	WO31	CORRECTIVE	2018-08-21 22:40:46	2018-08-24 10:41:44	60,01625	1	60,0	2018-08-25 13:22:10	133	(*Unknown)

idGrouping	Grouping	idFarm	Farm	idTurbine	Turbine	Assembly	idSubAssembly	SubAssembly identification	SubAssembly	SubAssembly type	Equipment	Equipment identification	Equipment type	Failure record ID	Failure date	Failure Calendar Time (hours)	Failure Operating Time (hours)	Failure record	cause	Failure Mode (Code)	Consequence of failure	Maintenance activity	Maintenance Report	Maintenance ID	Maintenance category	Maintenance starting date	Maintenance Ending date	Active repair Time (hours)	Manpower	Total Man-hours	Restarting date	Unavailability time (hours)	Maintenance delays / issues
							high speed shaft					shaft - Gearbox Lubrication system			00:00:00					medium (EXU)													
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain B - Gearbox / high speed shaft	Drivetrain B - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain B - Gearbox / high speed shaft - Gearbox Lubrication system	(*Unknown)	IR32	2018-08-22 00:00:00	85024	72392	(*unknown)	(*unknown)	External Leakage - utility medium (EXU)	Incipient	(*unknown)	(*unknown)	WO32	CORRECTIVE	2018-08-24 00:03:25	2018-08-26 13:50:39	61,787375	2	123,6	2018-08-27 17:18:19	137	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain B - Gearbox / high speed shaft	Drivetrain B - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gearbox Lubrication system	Drivetrain B - Gearbox / high speed shaft - Gearbox Lubrication system	(*Unknown)	IR33	2018-08-28 00:00:00	85123	72452	(*unknown)	(*unknown)	External Leakage - utility medium (EXU)	Critical	(*unknown)	(*unknown)	WO33	CORRECTIVE	2018-08-29 22:54:41	2018-09-01 11:13:33	60,3145	2	120,6	2018-09-02 14:01:56	134	(*Unknown)
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain B - Gearbox / high speed shaft	Drivetrain B - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages			(*Unknown)	IR34	2018-09-29 00:00:00	85765	72926				Unknown		(*unknown)	WO34	PREDICTIVE	2018-09-30 06:23:00	2018-10-01 21:26:50	39,064125			2018-10-02 14:48:33	87	
id Grouping B	B	id Farm B1	B1	id Turbine 10	10	Drivetrain	id Drivetrain B - Gearbox / high speed shaft	Drivetrain B - Gearbox / high speed shaft	Gearbox / high speed shaft	3 stages	Gears	Drivetrain B - Gearbox / high speed shaft - gears	(*Unknown)	IR35	2018-10-04 00:00:00	85914	73045	(*unknown)	(*unknown)	Vibration	Critical	(*unknown)	(*unknown)	WO35	CORRECTIVE	2018-10-05 21:35:10	2018-10-08 08:11:48	58,610625	1	58,6	2018-10-09 10:14:45	130	(*Unknown)