Suitable failure statistics as a key for improving availability

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Abstract – Like in most other areas the maintenance optimisation also gains importance in the wind energy sector. A suitable failure statistic can enables a significant reduction of maintenance costs in combination with an improved availability. The findings about necessary data, data base structure and on characteristic reliability indicators as well as an overview about options for improving availability will be presented in this paper. Furthermore, an outlook about gathering and evaluating future operational experiences of offshore wind farms will be given.

I. Introduction

Modern wind turbines achieve a quite high availability of about 95% to 99% [1, 2]. Nevertheless, quite a number of faults cause unscheduled down times up to ten per year, resulting in high maintenance efforts, production losses and costs.
In Figure 1 the mean annual failure rate of WTs in a German national programme [2] depending on the year of operation and the year of production can be seen. Turbines from the first year of production are the first ones of their kind (the first serial production); turbines from subsequent production years were able to benefit from the experience gained from their predecessors.

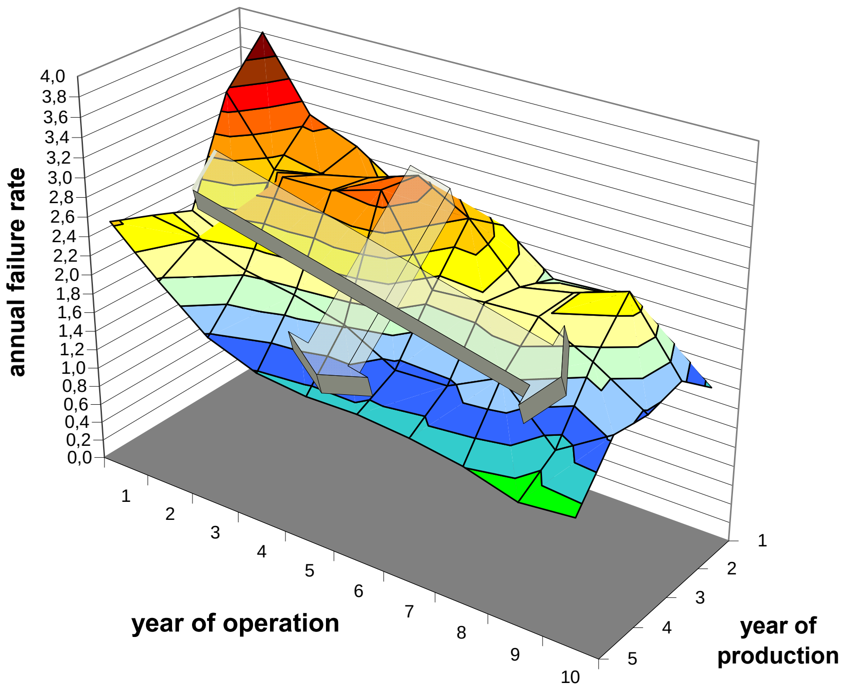

Figure 1: Time dependency of the mean annual failure rate [3]

It can clearly be seen that turbines from the first production year show the highest failure rate in the first operating year. With increasing experience both, in production and in operation, the failure rate decreases and the reliability increases respectively.
However, the common way of documenting faults and maintenance activities is currently not suitable for standardised and automated statistical evaluations. Therefore operational experience can only partly be used to improve design and maintenance procedures.

II. Improving availability

The availability of wind turbines is determined by the sum of downtimes, meaning availability is dependent on failure rates, on downtimes for recovery after failures, as well as on downtimes for planned maintenance measures. Figure 2 shows the possibilities for improving the availability by reducing failure rate and unnecessary downtimes.

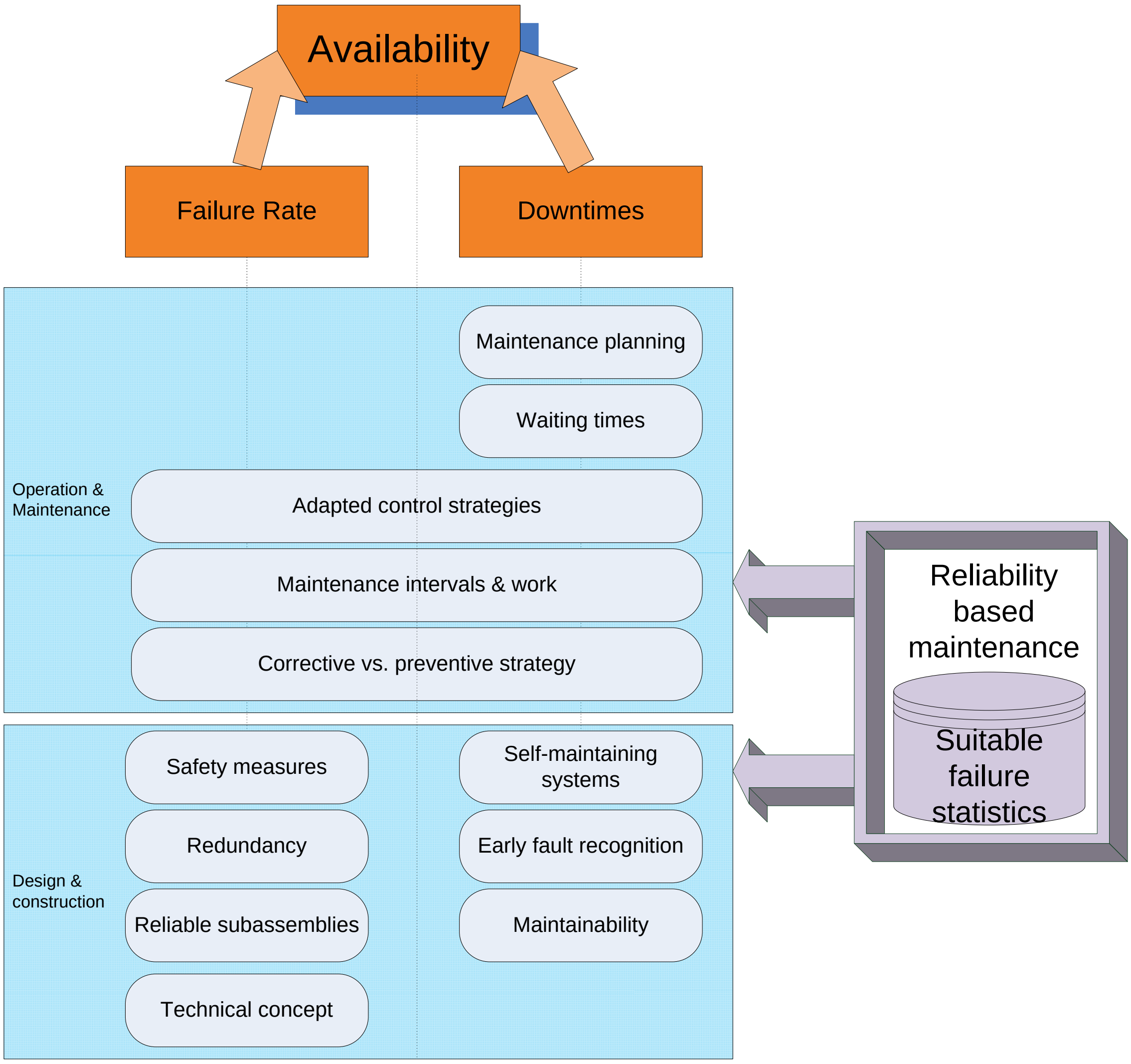

Figure 2: Possibilities for improving availability by applying suitable failure statistics

The different possibilities can be divided into the fields of design & construction and operation & maintenance. The basic idea behind these options and the resultant necessity of a suitable failure statistic is described briefly in the following.

A. Design & construction

An improvement of reliability through design & construction could be achieved by

- Choice of technical concept
- Reliable subassemblies
- Use of redundancy
- Safety measures

In the first instance an appropriate **technical concept has to be chosen**. Most of the wind turbine types show similar development and similar failure rates, but some types are significantly different. Figure 3 shows the annual failure rates of WT subassemblies for different technical concepts [4].

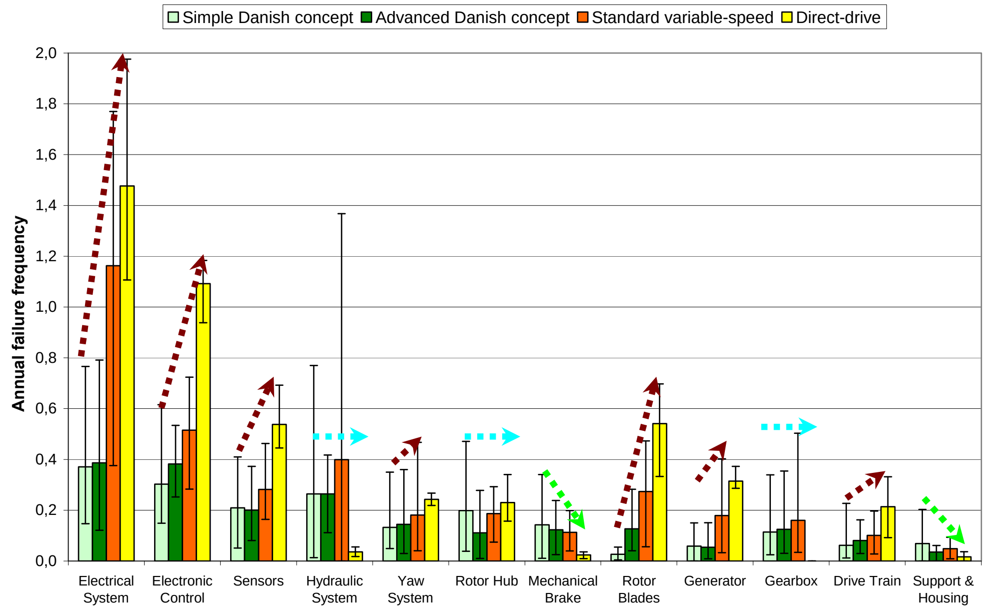

Figure 3: Annual failure rate of WT subassemblies for different technical concepts

Those analyses can be helpful to identify advantages and weak-points of different concepts. The shown example is a more general one. Such a comparison could also be done in a deeper level of detail, e.g. to determine the differences of electric vs. hydraulic pitch systems.

Another influence is the **reliability of the deployed subassemblies**. For optimising design and construction and for the choice of appropriate materials detailed knowledge about the stresses and strains of the subassemblies is mandatory. Weak-point-analyses would be the necessary input for setting priorities which components should be optimised preferentially. Analyses of failure causes and failure modes would be necessary for improving details of component design. An example for a weak-point analysis in combination with failure causes is shown in Figure 4.

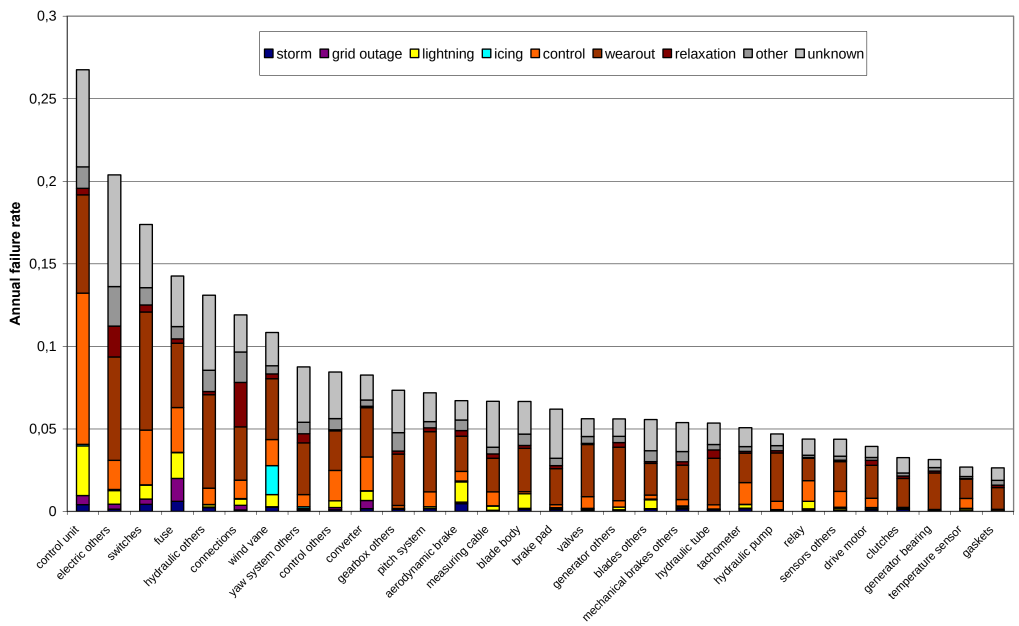

Figure 4: Weak-point analysis for WT subassemblies including failure causes

Despite of improved design and construction, and careful choice of materials some subassemblies are still vulnerable to faults. A possibility for lowering the influence of the reliability of a subassembly on the availability of the whole system is to make **use of redundancy**. Numerous elements in the electric and the control system are already redundant in modern wind turbines. A good example for an efficient use of redundancy can be seen in the wind vane. The annual failure rate of the wind vane has been relatively high as we can see in Figure 4. Modern wind turbines are having two wind vanes instead of overreliance on just one.
The example of the wind vane is also good for explaining the possibility of **safety measures**. Many failures in the wind vane are due to icing effects. This failure rate could be reduced by heating the wind vane in times with low temperatures, what has been realized already for some of WT types.

Besides of lowering the failure rate there are as well possibilities to reduce downtimes through design & maintenance:

- Increasing maintainability
- Early fault recognition
- Self-maintaining systems

B. Operation & Maintenance

In the field of operation & maintenance there are some options affecting both, the failure rate and the downtimes:

- Corrective vs. Preventive strategy
- Maintenance intervals & work
- Adapted control strategies

An optimised maintenance makes use of two control approaches, the **corrective and the preventive strategy**. Under the corrective strategy a subassembly is operated until a failure occurs, accepting unscheduled downtimes. The preventive strategy is established in several variants. One variant would be a cyclic maintenance, aiming at preventing from unscheduled downtimes, but accepting higher efforts and costs. More sophisticated variants would be the condition based and the reliability based one, aiming at balancing maintenance efforts and costs against availability. The general characteristic of the different maintenance strategies is shown in Figure 5.

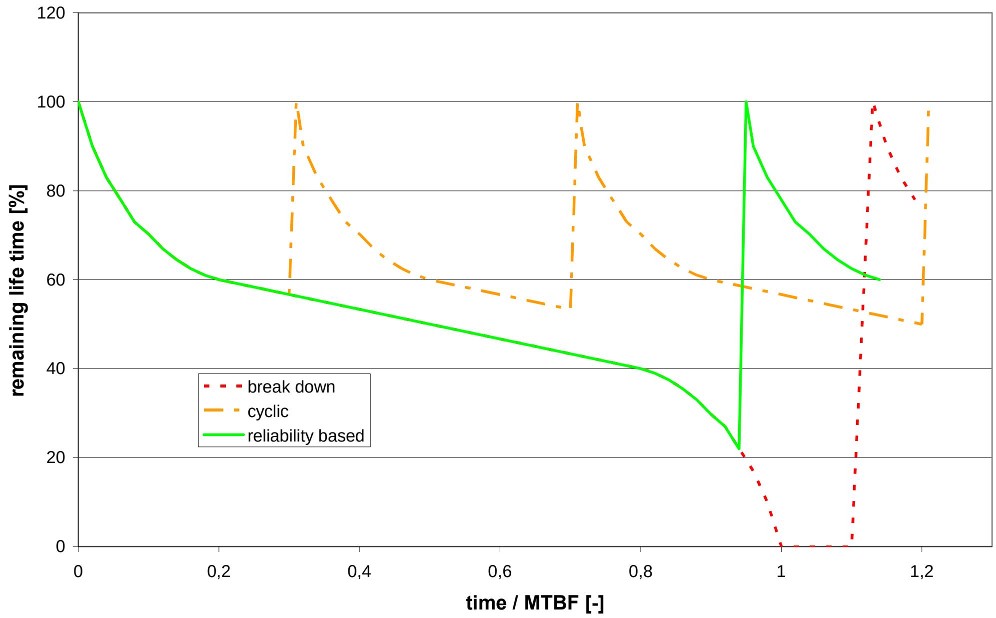

Figure 5: Course of different maintenance strategies through time

The reliability based strategy tries to utilize operational experience already gained from existing plants to estimate the probability of failures for a coming period of time to **optimize maintenance intervals and work**. A detailed documentation of all maintenance measures of a large population of plants and a purposeful structured data base are necessary to extract sound conclusions out of this operational experience.
An option for improving availability, which should not be described in detail, is the use of **adapted control strategies**. The reliability of certain subassemblies may be improved by the change of some control parameters, e.g. using another power curve.

Additionally there are possibilities for improving availability by reducing downtimes through:

- Minimising waiting times
- Optimise maintenance planning

Especially the second point is getting more and more important for the offshore wind energy use. The restricted site access makes a sensitive **maintenance planning** indispensable. However, an optimisation can only be done when knowing the priority and the duration of measures. Furthermore it is essential to have knowledge about all times spent for logistic operations, travelling and work. The occurring time steps could be described as 'logistic time', 'waiting time due to access restrictions', 'time for travelling' and 'time to repair'. A first definition of different time steps is given in [5]. For the estimation of the optimisation potential as well as for a **minimising of waiting times**, it is requisite to know the average durations of these different steps.

III. Common data base

There are many parameters influencing the reliability characteristics of WTs. For a detailed analysis all these parameters must be taken into account [3].
Figure 6 shows the parameter diversity. One can see that even with a broad data base like the one from the WMEP[1], a national German programme observing 1,500 WTs for more than 10 years each, with a breakdown in different groups a certain point is reached, where the statistical basis is getting insufficient. By the example shown the need for a broader data base is getting clear.

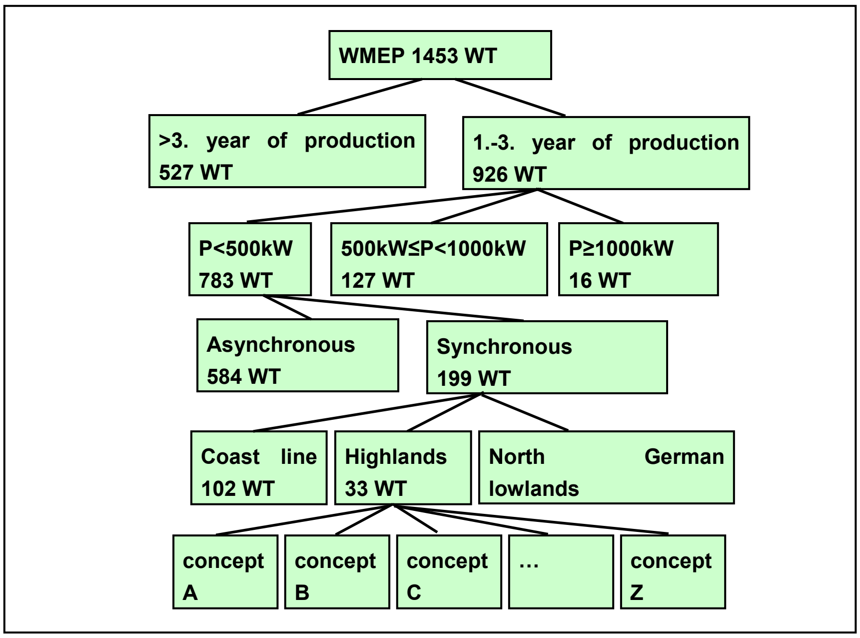

Figure 6: Small basis for statistical analyse due to Parameter diversity

[1] WMEP – Wissenschaftliches Mess- und Evaluierungsprogramm; Scientific Measurement and Evaluation Programme

Empirical experience with as many as possible WTs of similar design running under similar operational conditions should evaluated commonly, to increase the statistical basis.

IV. Failure statistics

For an optimisation of reliability and availability a clear and unambiguous data pool is needed. The principle structure of such a data pool is shown in Figure 7.

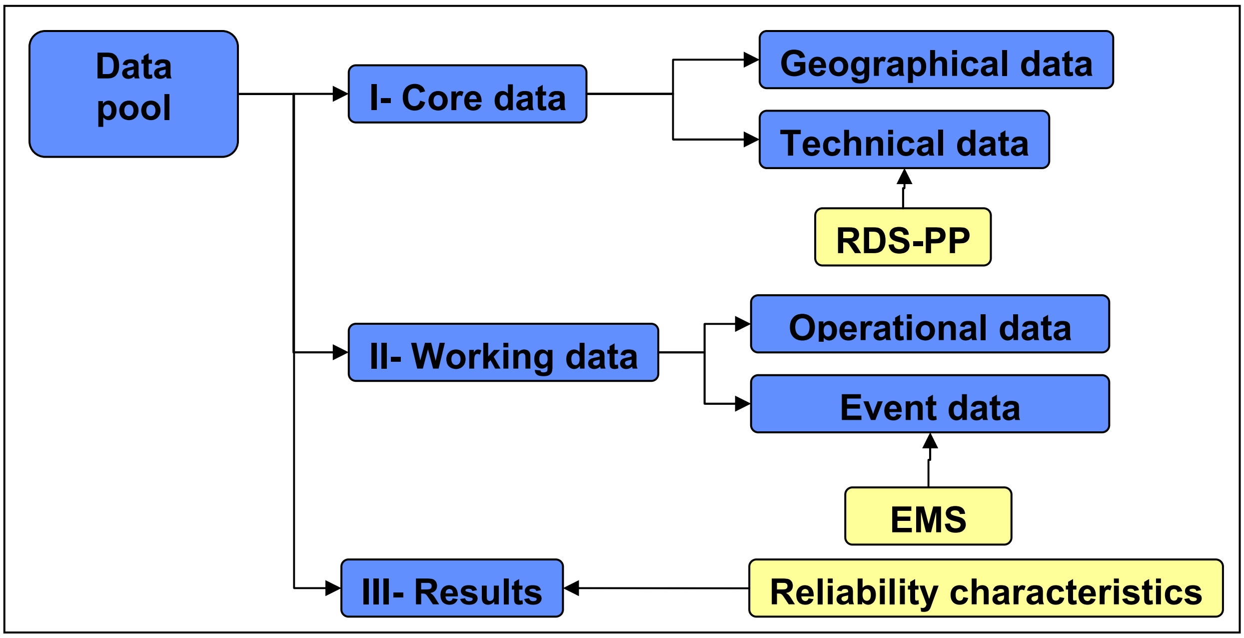

Figure 7: Data structure

The data set consists of three groups: core data, event data and result data. These groups are described in the following.

A. Core data

The set of core data contains general information about the wind farm and the turbine. Besides basic data of the machine as capacity, diameter and height, also information about operating conditions, geographical aspects, technical concept, etc. are covered by these data.
Additionally all wind turbine components have to be designated and structured by all players in a standardised way to correctly identify the component affected. A ‘Reference Designation System for Power Plants’ (RDS-PP), which is commonly used by operators of conventional plants, is going to be adopted by wind turbine operators. This guideline from the German association VGB Power Tech enables a uniform indication of all objects of a system. For this assignment the turbine is divided into groups of functional coherences and structured in several layers [6, 7]. There are for example the groups ‘wind turbine system’ ‘generator system’, or ‘transmission of electrical energy’, while ‘wind turbine system’ consists of the subassemblies ‘blade adjustment’, ‘drive train’, and ‘yaw gear box’.
The wind farm, the turbine and the infrastructure form the first layer, the systems and the subsystems of the turbine as well as of the transformer station form the second layer. Subassemblies like the generator are identified in a third layer.
The set of core data later on enables analyses of reliabilities of wind turbine types, subassemblies or components considering different technical concepts, different operational conditions or even considering the position of a turbine in a large wind farm.

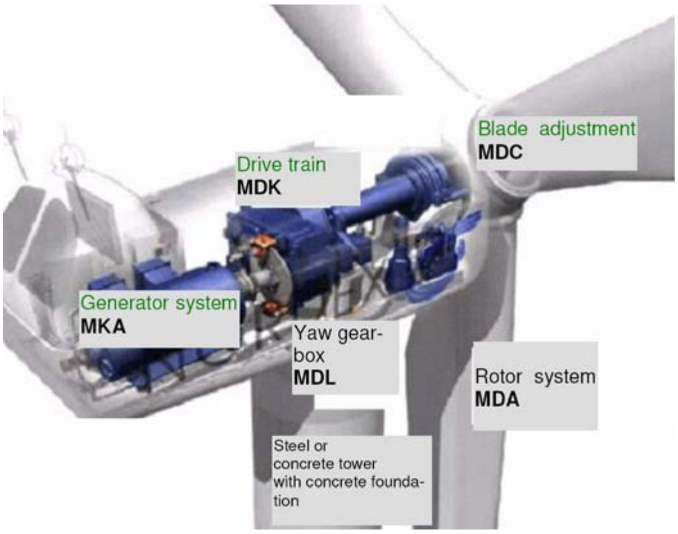

Figure 8: 'Reference Designation System for Power Plants' (RDS-PP) [6, 7]

B. Working data

Working data form the second group of important information.

All periods of time when wind turbines are not in standard operation mode have to be considered as 'event' and must get documented. The data set shall record items like date and time of occurrence, counter readings, time of restart, all efforts, as well as a set attributes describing the kind of event. Current work is aiming at adapting an existing designation system for event attributes from VGB PowerTech (EMS – Ereignis-Merkmal-Schlüsselsystem) to the necessities of wind energy use. The set consists of items like kind of work, failure cause, the kinds of faults, the necessity for further measures etc. [8].

Furthermore, the subassemblies and components affected have to be noted using the RDS-PP code mentioned above. Gathering all these data will cause some additional effort, but there are possibilities of electronic aid, which not only enables the service staff noting attributes, but also helps them finding appropriate descriptions by offering lists of standardized items.

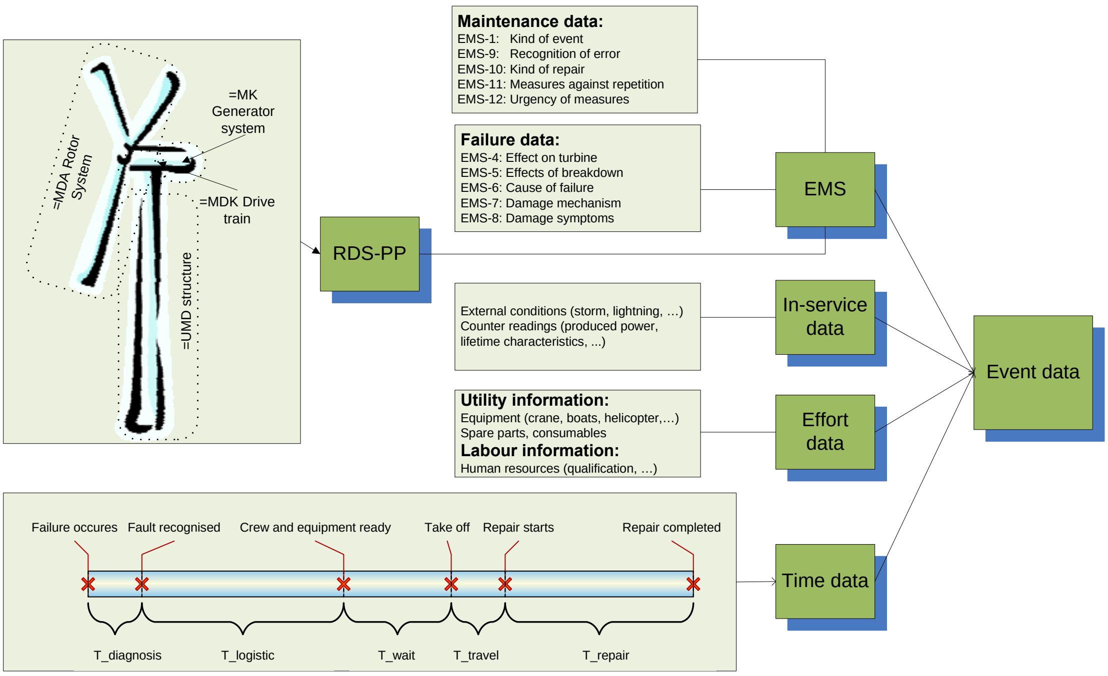

Figure 9: Event data needed

C. Data base structur

The final data base will contain a lot of data from different sources, so it needs a purposeful, but complex structure. The main table will be a large list of working data, containing information on all events of the assets observed. A second table contains all the core data. In this table the data of all real components, as serial number, manufacturer, date of manufacture, start-up date, etc. are stored. A third central table, consisting of all RDS-PP codes, designating all existing subassemblies and components of all types of wind turbines, connects the event data with the real component affected as well as with the group of functional coherence.

Thus, different important analysis can get conducted. For example, the reliability of identical components in different turbines may be evaluated as well as the reliability of a wind turbine type equipped with subassemblies from different sub-contractors. Since the core data also contain information about the site, also a dependency of the wind turbines reliabilities on the operational conditions may get evaluated.

D. Library of reliability characteristics

Having gathered core data of the whole asset and working data about a longer period of time, the operator becomes able to extract the information on the weak-points of his assets and also efforts and cost connected to it. Applying the reliability centred maintenance, the operator then will set up a new part of the data base, namely a library of characteristic values. Typical characteristics will be ‘mean time between failure’ or ‘mean time to repair’ (MTBF, MTTR) and reliability functions. But he will also derive individual values to improve his maintenance strategies for sub-assemblies and components.

V. Conclusion

It is obvious that reliability of WTs and subassemblies needs to get improved. Otherwise, availability, especially for offshore application, will not reach suitable results [9]. Improvements have to be achieved in the design of turbines as well as in the organisation of maintenance.

Although wind energy use has been established well during the recent years, still common standards for the documentation of O&M measures as well as for a uniform structure of data bases are missing. Thus, a working group of the ‘Foerdergesellschaft Windenergie’ (German association supporting the development of technical standards for wind energy use) is working on appropriate standards for the O&M of wind power plants.

Single WT operators will possibly not be able to achieve a suitable statistical basis for thorough analyses. Even with a broad data base like the one from the WMEP, the breakdown in concept groups, power classes, site conditions, etc., lead to a point, where the statistical basis was getting insufficient. The necessity for a broader data base and for an appropriate data structure is obvious. A joint approach of operators, firstly agreeing on standards and secondly on requirements, promises being most successful.

VI. Outlook

Joint activities on standardising O&M measures, documentation and data structure have been launched on a national German basis for onshore wind energy application [10, 11].

First steps have been made also for offshore wind energy use. A group of planners and operators have confirmed to support a new German programme for monitoring the development of offshore wind energy use as well as improving availability of offshore wind farms. This new project is named ‘Offshore-WMEP’ (OWMEP) following the former German monitoring programme for onshore turbines [12].

The principal concept of collecting data in a data pool, driven by a neutral and independent institution, is shown in Figure 10.

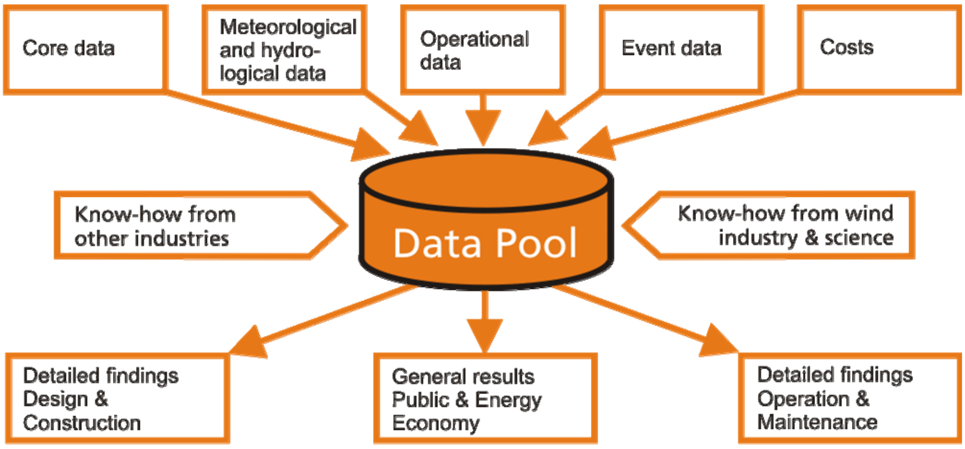

Figure 10: Concept of the Offshore~WMEP

This project is currently running in a concept phase and is designated to start operation together with the first German offshore wind farms. It will enhance the data base, already existing for onshore application.
However, operators of wind farms have started to document assets, maintenance measures and failures using standardised structures. Thus, future analysis of failure rates, downtimes and causes can be based on much more detailed information and on an enhanced statistical basis.

VII. Acknowledgements

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VIII. References

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