Germanischer Lloyd

Title: **IEC WT 01 vs. IEC 61400-22**
Development of a new standard and innovations in certification of Wind Turbines

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Summary and Conclusion

Certification of wind turbines or components is state-of-the-art and a must in most places around the world. Furthermore certification to harmonised requirements is an active support of export. Therefore it is important for manufacturers, banks and insurances of wind turbines and components to know the different certification processes and guidelines as well as the keystones of their development.

This paper puts focus on IEC WT 01: IEC System for Conformity Testing and Certification of Wind Turbines, Rules and Procedures, 2001-04 [1] and describes the ongoing process of its revision within the Maintenance Team MT 22 of the Technical Committee TC 88 as well as the results of this Maintenance Team for the second edition of IEC WT 01 (or first edition of IEC 61400-22).

Introduction

Certification of wind turbines has a history of thirty years. It has been applied differently in scope, requirements and depth in countries like Denmark or Germany and each on the basis of their own rules. These countries are still leading in the development and application of certification rules, but during recent years a number of other countries as well as many banks realised the necessity of a thorough evaluation and certification of wind turbines and their proposed installation. Among these countries are China, Greece, India, Italy, Spain, Sweden, Japan and the USA. The procedures to obtain Type and Project Certificates are described on the basis of IEC WT 01: IEC System for Conformity Testing and Certification of Wind Turbines, Rules and Procedures, 2001-04, as well as the forthcoming second edition of IEC WT 01 which might be published as a first edition of IEC 61400-22.

International standardisation efforts on wind turbine certification procedures started in 1995 within the International Electrotechnical Commission (IEC) in the Technical Committee TC 88 and resulted in the first issue of IEC WT 01 published by the Certification Assessment Board (CAB) of the IEC in April 2001. TC 88 already started their efforts in 1988 and has so far published standards and technical specifications for the safety of wind turbines, rotor blade tests, power curve, noise and load measurements and power quality under the scope of the IEC 61400 series. A lot of other topics are in preparation (see www.iec.ch for details). At the moment the Maintenance Team MT 22 of TC 88 is preparing the revision of IEC WT 01 including the state-of-the art in certification and the actual knowledge about turbine design.

Certification

According to the European standard EN 45020, certification is the confirmation of compliance of a product or a service with defined requirements (e.g. guidelines, codes and standards). In the field of wind energy the focus lies on complete wind turbines or components such as rotor blades, gearboxes or towers. The scope consists of the examination of structural integrity, safety and compliance with these requirements.

According to the existing IEC WT 01 Type Certification comprises Design Evaluation, Manufacturing Evaluation, Type Testing, Foundation Design Evaluation (optional) and Type Characteristics Measurement (optional). Within the Design Evaluation some items like evaluation of manufacturing plan as well as installation plan and evaluation of personnel safety are necessary for IEC WT 01. The Prototype Testing includes an evaluation of a dynamic blade test and the Manufacturing Evaluation includes an evaluation of the quality system as well as the inspection of the manufacturing.

Project Certification on basis of the existing IEC WT 01 is based on Type Certification and covers the aspects of Site Assessment, Foundation Design Evaluation and Installation Evaluation (optional). These individual modules are concluded with Conformity Statements.

Certificates are issued upon the successful completion of the relevant Type Certification and Project Certification.

Design Evaluation

The evaluation or assessment of the design is generally carried out in two sequential steps. The first part covers all aspects of the safety and control concept as well as the load assumptions and load calculations. The load calculations for wind turbines are to be based on aero elastic codes using stochastic wind fields and modal or finite element analysis techniques [3]. In the case of offshore wind turbines the loads have to contain both the aero elastic behaviour of the wind turbine and the fluid-structure interaction of the submerged part. The latter may have a considerable influence on the structural response for certain types of foundations and/or underwater structures [4]. Applicable codes or standards are listed in Table 1. As the IEC standards do not cover all necessary elements of the Design Evaluation other codes as e. g. the Guideline for the Certification of Wind Turbines, Edition 2003 with Supplement 2004, [2] of Germanischer Lloyd are to be applied.

Steps of evaluation	**Codes or standards to be applied**
Load Assumptions	GL-Guideline [2]; IEC 61400-1, Second [5] or Third [6] Edition
Safety System and Manuals	GL-Guideline [2]; IEC 61400-1, Second [5] or Third [6] Edition
Rotor Blades	GL-Guideline [2]; IEC TS 61400-23 [7] (for testing)
Machinery Components	GL-Guideline [2]; (IEC 61400-1, Third Edition [6])
Tower (and Foundation)	GL-Guideline [2]
Electrical Equipment and Lightning Protection	GL-Guideline [2]; IEC TR 61400-24 [8], relevant IEC standards
Nacelle Housing and Spinner	GL-Guideline [2]

Table 1: Partial Steps of the Design Evaluation

During the second part of the Design Evaluation all components (e. g. machinery, tower and electrical equipment) are examined on the basis of the previously approved loads and the relevant standards and guidelines. If the dynamic analysis of the system is not part of the general load calculations it will be examined in parallel with the conformity assessment of the components. At the end of the Design Evaluation manuals and procedures for manufacturing, transport, erection, start-up, commissioning, operation and maintenance are checked for suitability, completeness and compliance with the assumptions in the design documentation. In addition to this the evaluation of personnel safety is important. Rotor blade testing [7] forms an integral part of the Type Testing of the blade (see

below). Lightning Protection will be assessed in combination with the electrical equipment. A flow chart of the Design Evaluation is shown in Figure 1.

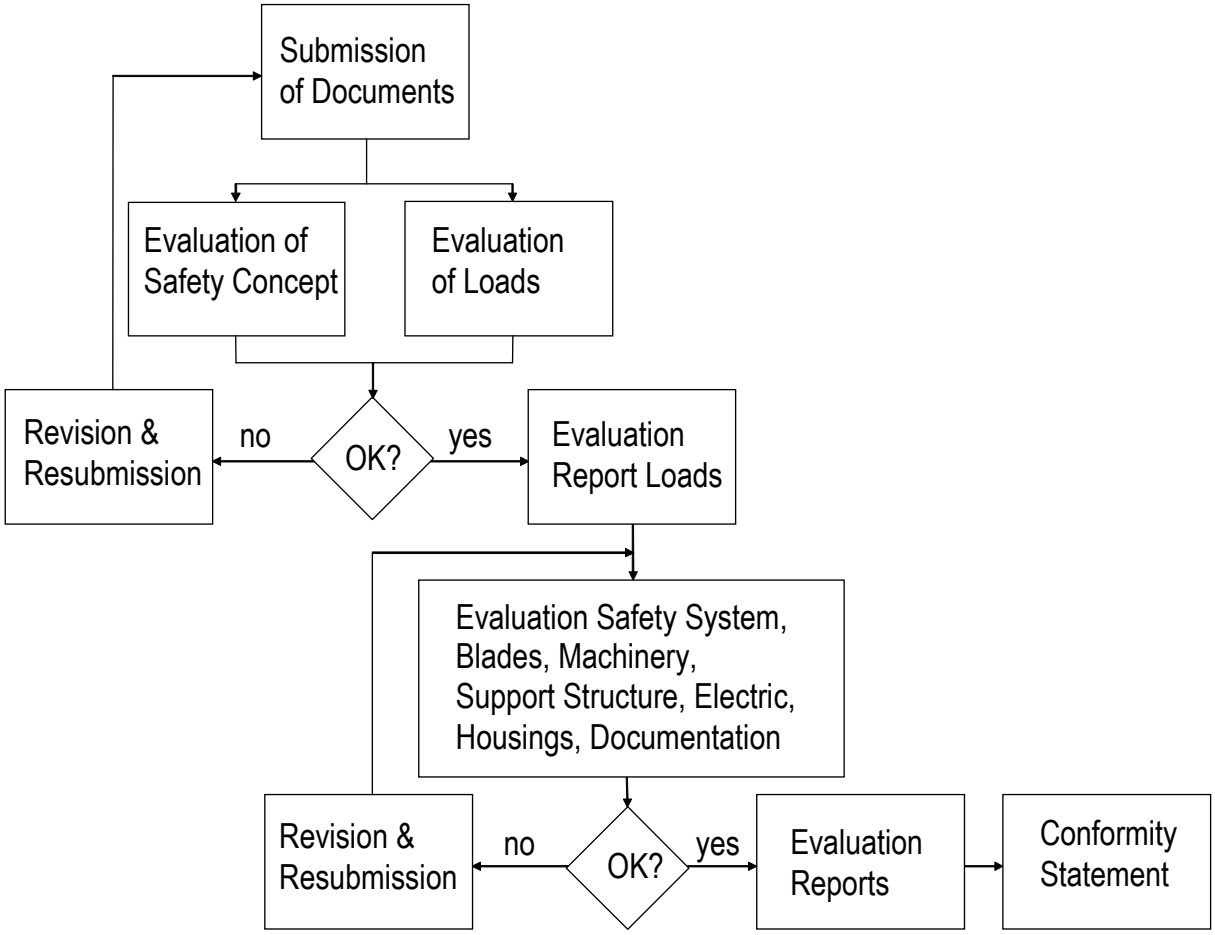

Figure 1: Procedure of the Design Evaluation

Type Certification

To attain the Type Certificate on basis of the existing IEC WT 01, the following steps are necessary (Figure 3):

- Design Evaluation
- Type Testing
- Manufacturing Evaluation
- Foundation Design Evaluation (optional)
- Type Characteristic Measurement (optional)

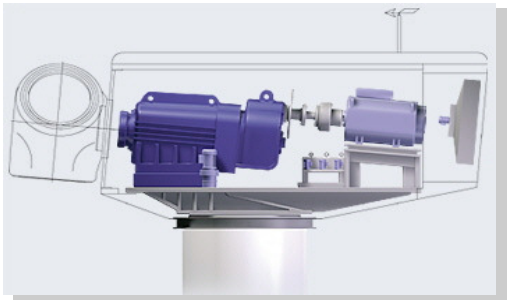

Figure 2: Type of a Wind Turbine

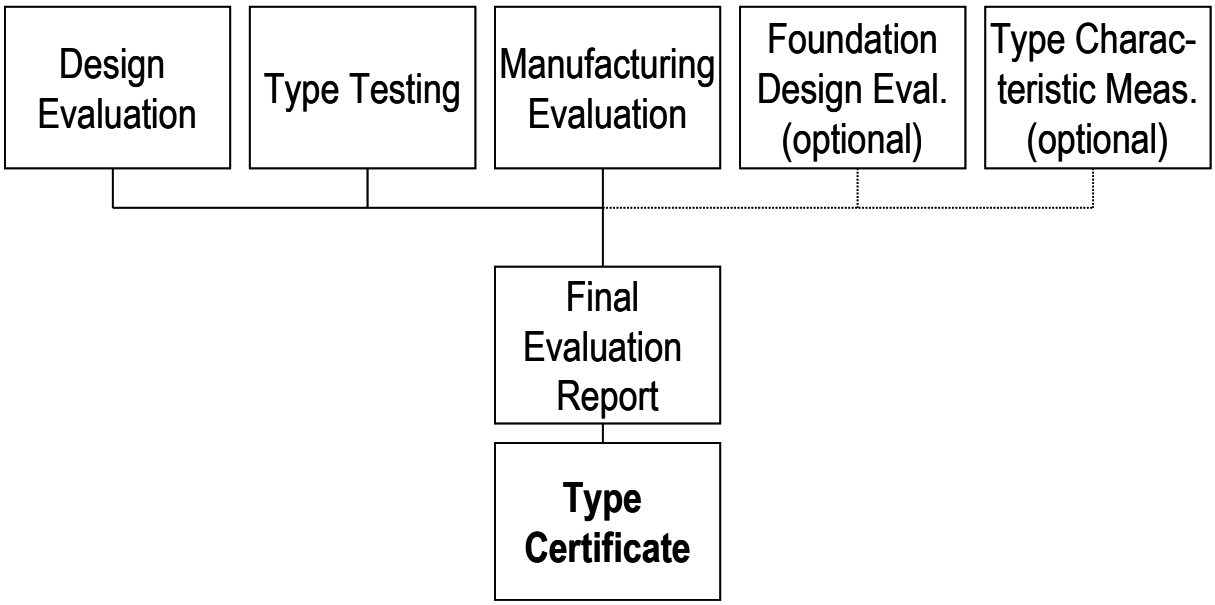

Figure 3: Modules in Type Certification [1]

Conformity Statements for all of these steps as well as the Type Certificate will attest the finalisation of the certification of this type of wind turbine (Figure 4). The Type Certificate has a validity period of up to five years. During the validity period, annual reports are to be sent to the certification body containing deviating operating experience and minor modifications. A re-certification is possible to renew the certificate.

Figure 4: Examples for Evaluation (Certification) Report (left),
Conformity Statement (Statement of Compliance) (middle) and Type Certificate (right)

The most important part of the Type Certification is the assessment of the design documentation, a thorough design review with respect to the requirements defined in the relevant codes and standards as presented above.

The testing of the prototype wind turbine represents the practical aspects of the Type Certification. In order to validate the design calculations, to optimise control, performance and noise behaviour and to verify the performance of the safety and control systems the Type Testing is an integral part of the design and certification process. The topics as indicated in Table 2 are to be verified by measurements which shall be based on the relevant standards mentioned. For the incorporation of measurements in the certification process the measurements shall be performed by independent institutions accredited according to ISO 17025, alternatively witnessing of the calibration and plausibility checks of the measurements by the certification body or by an accredited institute are required. Furthermore the prototype of the gearbox is to be tested on an adequate test bench and on the wind turbine. All measurement results are to be evaluated and documented. The test reports will be checked for plausibility of the measurement results and compared to the assumptions in the design documentation.

Topics for Measurements	**Codes or standards to be applied**
Power Performance Measurements (Power Curve)	IEC 61400-12 [9]
Noise Emissions (other tests)	IEC 61400-11 [10]
Load Measurements	IEC TS 61400-13 [11]
Electrical Characteristics (other tests)	IEC 61400-21 [12]
Blade Tests	IEC TS 61400-23 [7]
Safety and Function Tests / Commissioning	GL-Guideline [2]

Table 2: Testing requirements on the prototype turbine and the respective standards

The evaluation of the manufacturer's QM covers the whole range of activities necessary to confirm the quality of the product. The certification of the manufacturer's QM system according to ISO 9001 (including design) covers a large portion of these requirements. In general the QM system is certified by an accredited certification body. However, the link between quality management and product quality needs to be specially addressed. It shall be ensured that the requirements stipulated in the technical documentation with respect to the components are observed and implemented in production and erection. This is shown to the certification body by the manufacturer of the components and the wind turbine within the Manufacturing Evaluation. Therefore the requirements for conformity assessments of designs, work shops and special fabrication techniques remain a necessary part of the (type) certification procedure.

Project Certification and Site Specific Design Evaluation

Project Certification is carried out for wind turbines having successfully received Type Certification and for locations for which the necessary data are available. Basically Project Certification is intended for projects covering more than one single wind turbine such as wind farms onshore as well as offshore. This certification may include all necessary installations such as measuring masts, power transmission as well as transformer stations and others. Moreover the Project Certification covers the aspects of (Figure 5):

- Type Certificate
- Site Assessment
- Foundation Design Evaluation
- Installation Evaluation including Commissioning (optional)
- OM Surveillance (optional)

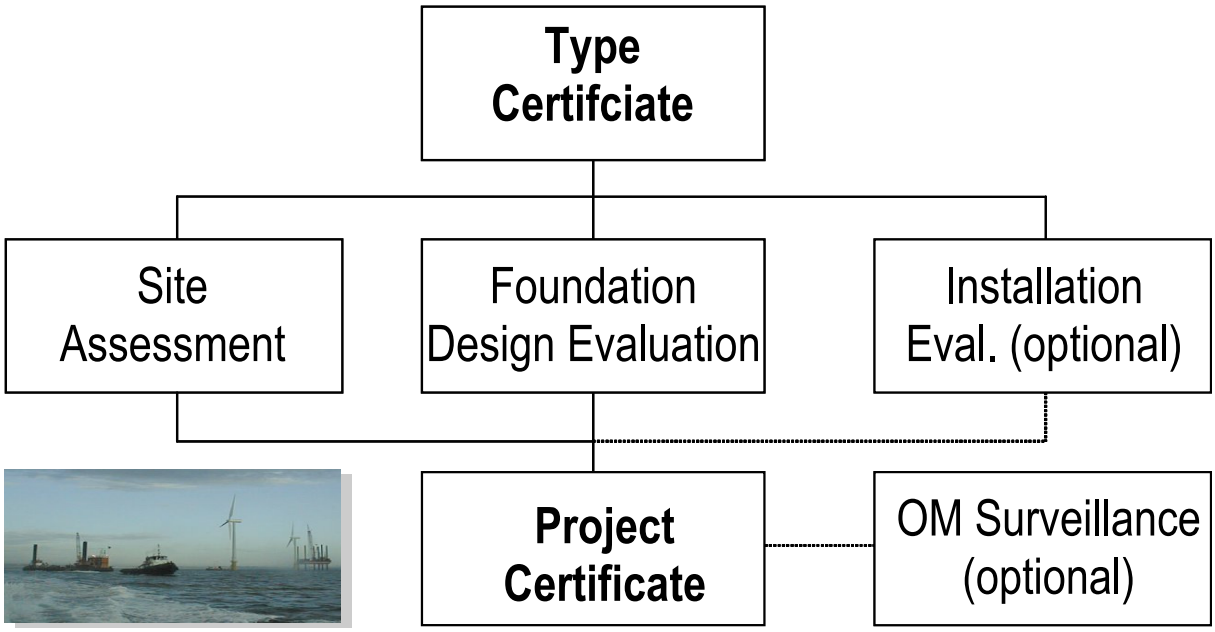

Figure 5: Modules in Project Certification [1] and Offshore Project

Following completion, the Project Certificate is issued by the certification body. It does not expire as long as the Operation and Maintenance Surveillance (OM Surveillance) is carried out at regular intervals. Major modifications, conversions or repairs not approved by the certification body affect the validity of the certificate.

Site Assessment can be carried out on the basis of the GL-Guideline [2]. For the selected sites wind (and wave) conditions, other environmental conditions (hot/cold climate, earthquake, corrosion, etc.), electrical network conditions and soil conditions shall be evaluated by measurement or derived from theoretical or other data (e.g. in case of earthquake from standards).

After evaluation of the Site Assessment, the conditions resulting will be checked against those used within the general Design Evaluation as part of the Type Certification. In case the conditions at the site are stronger, additional calculations or modifications of the turbine design are to be carried out to demonstrate the integrity of the design to be suitable for the site in question. The general Design Evaluation can then be enhanced to a Site Specific Design Evaluation which includes the Foundation Design Evaluation as well.

The optional monitoring of Installation Evaluation at the site of erection shall be restricted to the important steps during foundation and erection work. An identification and inspection of components, on site work and installation shall be carried out before start-up of the wind turbine. Commissioning witnessing forms an integral part of the certification process between the building phase and the operation phase. During commissioning, which is performed according to the previously approved procedures all components related to operation and safety are being inspected and/or tested.

The condition of the systems with respect to safety, maintenance and operation shall be inspected by third party at regular intervals within the scope of the optional Operation and Maintenance Surveillance.

Forthcoming revision of IEC WT 01

It was found that there are a lot of topics in preparation related to wind turbines (see www.iec.ch for details; IEC 61400 series), e. g. concerning measurements, gearboxes or offshore specifics. This leads to a wider acceptance of the IEC 61400 series and requires an update of the basis for the certifications – IEC WT 01. Furthermore since the development of the first edition of IEC WT 01 in the end of the last and the beginning of this century there exist

several developments in design and evaluation of wind turbines as well as revisions of standards and guidelines which need to be covered. Therefore the Maintenance Team MT 22 started in March 2005 to review and update the existing rules and procedures with the objective of issuing a second edition.

Up to now nearly all parts of the first edition have been subject to discussions and changes. The procedures of Type and Project Certification have been updated; modules and elements have been revised and explained in more detail. The aim is still to issue a second edition of IEC WT 01 or alternatively a first edition of IEC 61400-22 covering both on- and offshore wind turbines and wind farms.

Within the second edition design evaluations of prototype wind turbines will be integrated including a smaller amount of documentation and evaluation in comparison to the complete design evaluation which can be done later. Furthermore requirements for provisional Type and Project Certificates are under permanent discussion.

In the following examples for different modules are described as intended for the second edition.

Manufacturing Evaluation (Type Certification)

Within the module "Manufacturing Evaluation", which purpose it is to assess if a specific wind turbine type is manufactured in conformity with the documentation design verified during the Design Evaluation, detailed information is provided for the components to be considered for inspection:

- rotor blades
- rotor hub
- rotor shaft
- main, pitch and yaw bearings (pitch and yaw drives)
- main bearing housings
- gear box
- locking devices and mechanical brake
- generator, transformer
- main frame, generator frame
- tower
- foundation (optional)
- bolted connections and
- hub and nacelle assembly (in workshop)

Figure 6: Typical components and manufacturing processes in Manufacturing Evaluation

It shall be ensured that the requirements identified during the Design Evaluation with regard to critical components and critical manufacturing processes, are observed and implemented in production and assembly. The certification body shall verify by inspection that at least one representative specimen is manufactured according to the design under certification (Figure 6).

Such an inspection shall comprise:

- verification that design specifications are properly implemented in workshop
- workshop instructions, purchase specifications and installation instructions
- evaluation of manufacturer´s workshop, if relevant
- verification of fabrication methods, procedures and qualifications of personnel
- review of material certificates
- random checks on effectiveness of procedures for acceptance of purchased components and
- random checks of fabrication processes

Inspection of critical components shall take place at the wind turbine manufacturer unless the manufacturer's incoming goods inspection is insufficient to ensure that the requirements identified during the design evaluation are met.

If a critical component is produced by different component manufacturers, and the components differ significantly in specifications and/or manufacturing processes, all differing components shall be considered for inspection.

Changes in manufacturing processes, which influence the component quality or component properties, shall be reported to the certification body. In the event of major process changes, documentation shall be submitted for renewed evaluation and, if necessary, the inspection shall be repeated.

The manufacturing evaluation presupposes that the manufacturer of the wind turbine and the main components operates a quality system. It requires manufacturing of at least one representative specimen.

Site Conditions Evaluation (Project Certification)

The purpose of the module "Site Conditions Evaluation" within Project Certification is to examine whether the environmental, electrical and soil properties at a site conform to the parameter values defined in the design documentation.

The certification body shall evaluate whether the external conditions at the site have been adequately obtained and documented. The conditions are classified in the following categories:

- wind conditions
- wake effects
- other environmental conditions
- earthquake conditions
- electrical power network conditions and
- geotechnical conditions
- marine conditions, if relevant
- weather windows and weather downtime, if relevant

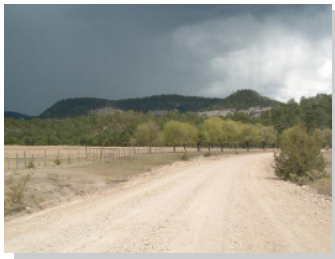

Figure 7: Typical Site

The site conditions provided may be derived from site-specific measurements and/or applicable standards or methods valid for the installation site. Site-specific measurements shall normally be correlated with data from a nearby location for which long term measurements exist. The monitoring period for the site-specific measurements shall be sufficient to obtain reliable data. Measurements of the external conditions of the site shall be carried out by a testing laboratory accredited to ISO 17025, or the certification body shall verify the satisfactory quality and reliability of the measurements. The verification shall include evaluation of:

- test and calibration methods
- equipment
- measurement traceability
- assurance of the quality of test and calibration results and
- reporting of the results

Design Basis Evaluation (Project Certification)

The purpose of the module "Design Basis Evaluation" within Project Certification is to examine that the design basis is properly documented and sufficient for a safe design and execution of the project.

The design basis shall identify and include:

- design parameters for the external conditions
- design methodologies and principles
- codes and standards which form the basis for the project
- other relevant statutory requirements (e.g. embarkation, rescue and decommissioning)
- requirements for manufacturing, transportation, installation and commissioning
- requirements for operation and maintenance
- requirements for grid connection including a layout diagram of the cable routing together with grid operators' requirements and
- other project requirements, e.g. from the owner

The design basis shall include all relevant overall design aspects and parameters to be applied in the calculations regarding the site external conditions, loads, design load cases, partial safety factors applied on loads and materials, geometric tolerances, corrosion allowance growth etc.

The design basis shall describe the design principles and methodology, including how the following has been established:

- codes and standards
- external design parameters
- design load cases
- load factors and load reduction factors
- duration of simulation as well as number of simulations and
- extreme and fatigue design loads/response analyses

The design basis shall include relevant manufacturing, transportation, installation and commissioning requirements such as:

- codes and standards
- quality management system
- environmental conditions relevant for installation and
- requirements for the manufacturing, transportation, installation and commissioning manuals

The design basis shall include relevant operation and maintenance requirements such as:

- codes and standards
- quality management system
- inspection scope and frequency
- target lifetime of components, systems and structures
- requirements for service and maintenance manuals
- requirements for conditioning monitoring systems and
- requirements with respect to personnel safety

A comparable module has been drafted for Type Certification.

Figure 8: Guideline [2]

Integrated Load Analysis (Project Certification)

The purpose of the module “Integrated Load Analysis” is to examine whether the site-specific loads and load effects on the integrated wind turbine structure, including the rotor-nacelle assembly plus the support structure and supporting soils, are derived in conformity with the design basis.

If the conditions and requirements in the design basis regarding loads and load effects are more benign than assumed for the Type Certification and the wind turbine characteristics are identical, no further load analysis needs to be made.

If further load analyses are to be carried out, these calculations shall be performed taking due account of complete structural dynamics. Full documentation of the load calculation and a comparison with the loads assumed for the Type Certificate shall be provided.

The certification body shall evaluate:

- the combination of external conditions and design situations (e.g. normal, fault, transport, installation)
- the respective partial load safety factors
- the calculation methods, e.g. simulation procedure, number of simulations and combinations of wind and wave loads
- the design driving load cases defined with reference to the site conditions and the operation and safety system of the wind turbine and
- any difference between the site specific loads and the loads assumed for the Type Certificate

In addition to the revision of elements and modules following flow charts have been developed to describe the different processes.

Type Certification

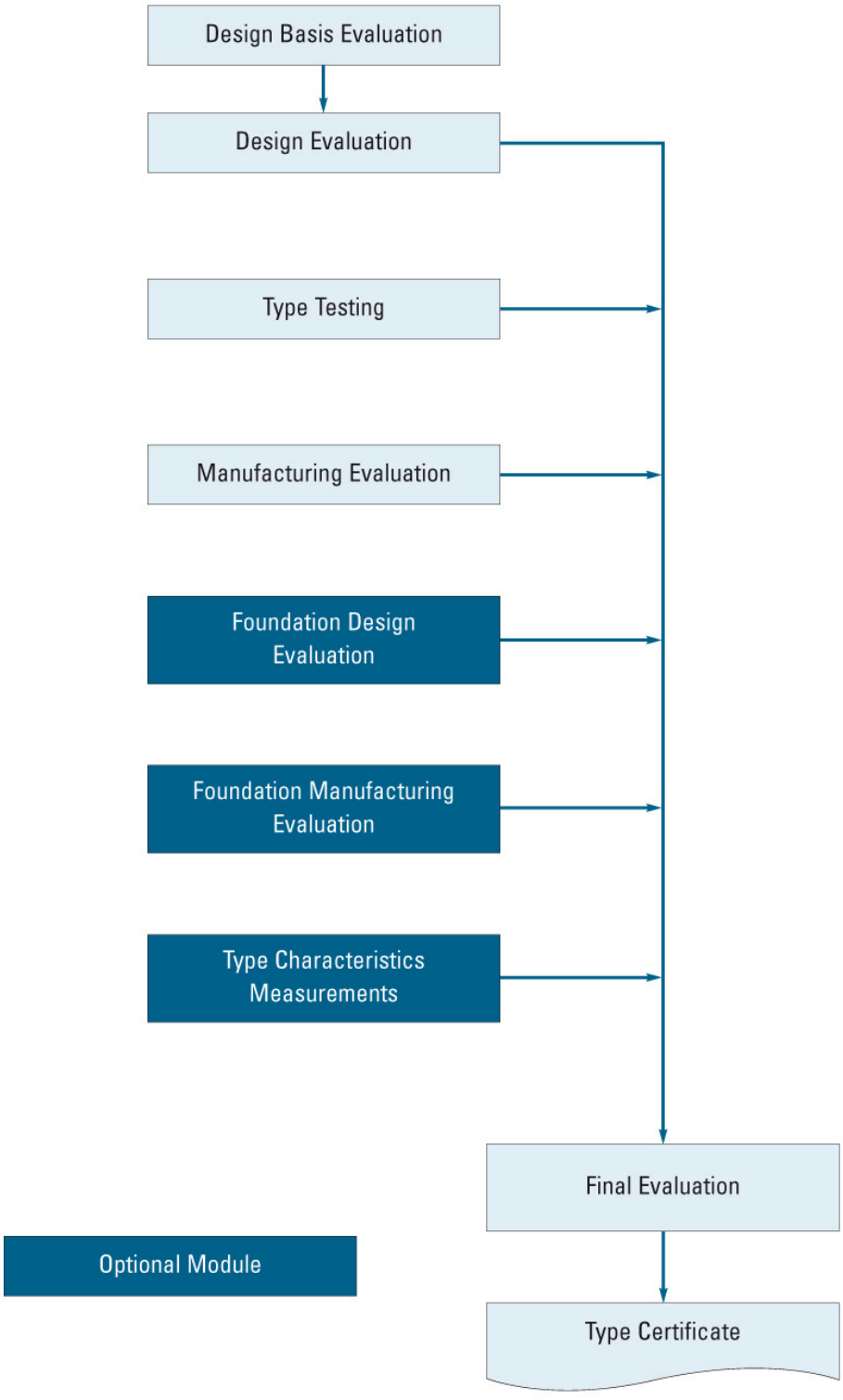

Figure 9: Modules in Type Certification based on [14]

Project Certification

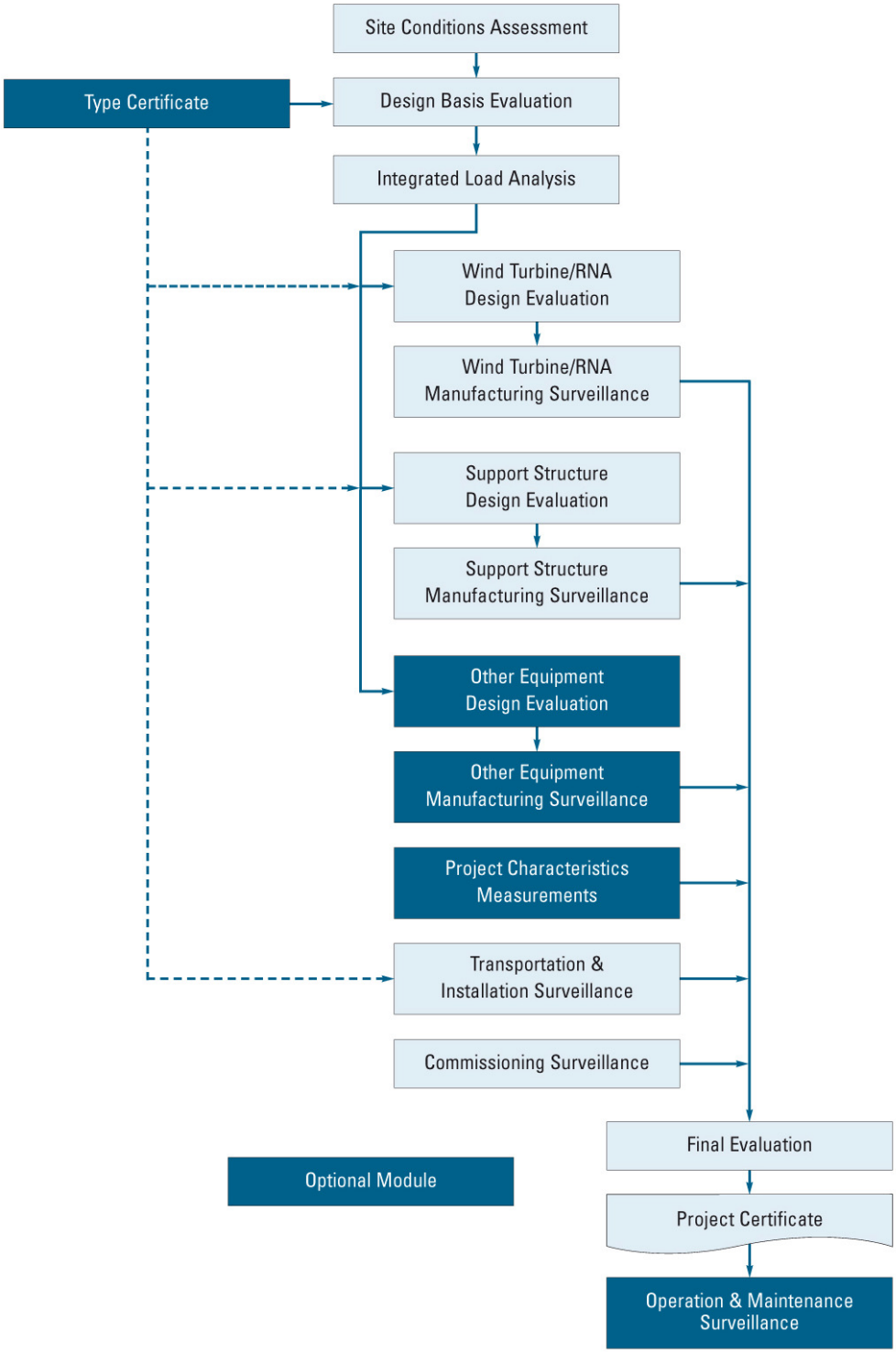

Figure 10: Modules in Project Certification based on [14]

The Certification Body

Germanischer Lloyd (GL) is an internationally operating certification body for wind turbines and leads the world in this field. GL carries out examinations, certifications and expertises and is actively involved in the development of national and international standards (e.g. TC 88). GL offers the complete range of services for certifying wind energy products and projects. Certification of wind turbines is carried out on the basis of the GL-Guideline for the Certification of Wind Turbines (Edition 2003 with Supplement 2004) and the GL-Guideline for the Certification of Offshore Wind Turbines (Edition 2005). Furthermore, GL is accredited to carry out certification in accordance with all relevant standards in the field of wind energy (e.g. IEC 61400 series, national and international standards, guidelines and regulations).

Conclusion

The rapid growth of the wind energy industry and the growing size of wind turbines itself enforce financing banks and insurance companies as well as authorities to require reliability and safety assessments of these projects. The assessments are carried out within the certification of the individual turbines or the projects such as wind farms, onshore and offshore. Within the framework of the certification of wind turbines, reliability, safety, strength and fatigue are evaluated in order to guarantee safe operation for building authorities, financing institutions, manufacturers and operators as well as insurance companies. The work of Maintenance Team MT 22 will lead to a second edition of IEC WT 01 (or first edition of IEC 61400-22) covering all aspects of state-of-the-art certification procedures.

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