Proceedings of the 27th Risø International Symposium
on Materials Science:
Polymer Composite Materials for Wind Power Turbines
Editors: H. Lilholt, B. Madsen, T.L. Andersen,
L.P. Mikkelsen, A. Thygesen
Risø National Laboratory, Roskilde, Denmark, 2006

COMMON ACCESS TO WIND TURBINE DATA FOR CONDITION MONITORING
THE IEC 61400-25 FAMILY OF STANDARDS

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ABSTRACT

As the wind power industry is getting more mature, and as wind farms are taking their place as one of the mainstream options for power generation, the demands to a streamlining of operations are getting larger. In the vein of the IEC 61850 family of standards for communication with (electrical grid) substations, 6 standards for wind turbine communication are in various states of the standardisation process. IEC 61400-25-1 to 5 are dealing with the generic communication with the wind farm, a single turbine and its parts, and is expected to be a final standard some time in 2007. However, for operations not only the usual measurements are important, but also dedicated condition monitoring measurements. For the specific condition monitoring aspects, an extension of the namespace proposed for the general standard is being worked on right now.

Consider the following scenario: a blade monitoring system is developed, based on operating environment exception analysis (of the stress wave activity profile for example). In order to give a meaningful interpretation and intelligent reduction of the very high volume of data, access to generic turbine parameters such as blade angle, rotor frequency, torque and power level is needed. This can either come from the manufacturer-specific turbine control system, or in a manufacturer-independent manner from an IEC-compliant system. The advantage for the supplier is obvious.

But the job is not finished there: further upstream, in the control room of a large wind farm owner, it is also reasonable to have just one utility size SCADA system to acquire all data from the numerous turbines, and to have identical interfaces to the alarm system of all turbines under surveillance. Especially for offshore wind farms, where the accessibility is low and where crane availability for the exchange of large components

is an issue, a condition monitoring system well-integrated into the operations routines of the owner delivers added value.

Here, we describe the philosophy behind the IEC standards, give some examples of condition monitoring systems, and finally will offer the audience to come with input to the ongoing work in the condition monitoring working group, which currently only considers vibration monitoring of bearings, generator and gearbox.

1. INTRODUCTION

The communication between wind farms and control room is so far handled in a manufacturer dependent manner. To illustrate this problem, a few years ago the situation for a large Danish turbine owner was such that the control room needed 7 different and mutually incompatible SCADA applications, some of which could not even be installed on the same computer. To fix that situation, a standardisation effort was started under the auspices of the International Electrotechnical Commission IEC in their Technical Committee TC88 Project Team PT25.

After a longish discussion, the standard is based on similar standards for the communication for substations of the electrical grid, IEC 61 850-7-1 to 4, which exists since 2003. As also the follow-up standard series IEC 62 350 (probably before the final issue renamed to IEC 61 850 Part 7-420) for Communication with Distributed Energy Resources (DER) builds on a similar philosophy. Both the DER and the wind turbine communication standard are in various stages of being approved – there is already a Community Draft for Voting for the wind turbine standard, with a tentative date of final approval in 2007, while currently only a 1st Community Draft exists of the DER standard. The DER standard is so far predominantly about hydropower, with other renewable energy sources also thrown in.

While it is left to the actual implementation to decide whether the IEC conformant communication is used only between wind farm and control room, or also within the wind farm itself, or even within the actual turbine for the communication between the different devices, it is necessary that somewhere, either in the farm or at the control room there is an IEC-conformant interface to the SCADA data. This means that new devices which use the data can access it in a uniform fashion. These devices can be specialised sensors for condition monitoring, e.g. vibration sensors checking for changes in the vibration signature of the gearbox, or data miners along the lines of the CleverFarm® system [*www.CleverFarm.com*].

Consider the following scenario: The manufacturer of a new blade condition monitoring system comes to the market. In order to do the data analysis from his own system, he has to use data on the current power level, wind speed, rotor speed (if not measured self), pitch angle and potentially more data from the turbine control system. Before the standardisation effort, he had to write interfaces to (and sometimes interface in hardware) every single manufacturers turbine control system, which was tedious and often not even possible. Now, only one common point of access is needed, which allows to mostly standardise a platform and to eventually sell it to a broader market, increasing competition among vendors.

Additionally, as Condition Monitoring Systems (CMS) based on vibration measurements of the drive train are getting more and more a standard product, a new working group under the IEC started work in March in Bilbao to consolidate the measurements needed and created by the different vendors in the first enlargement of the communication standard.

The outline of this paper starts with further introduction of the concepts and implementation of both the communication standard for wind turbines and the one for condition monitoring, then leads over to a hypothetical blade monitoring system which could benefit of the standards, and finally gives an outlook to a first actual implementation in the laboratory at Risø.

2. THE IEC 61 400-25 FAMILY OF STANDARDS

The focus of IEC61400-25 is on the communications between wind power plant components such as wind turbines and actors such as SCADA systems. As of the time of writing it consists of five approved parts, while work has begun on a sixth part as the first extension to the standard.

Part 1 (Overall description of principles and models) provides an overview of the standard, defines some of the terminology used in the following parts and outlines the underlying modelling concept. The schematic in Figure 1 illustrates the client-server pattern behind the communication architecture, whose three parts - object model, information exchange model and communication profile mappings - are modularised and modelled separately. This benefits the flexibility and modularity of implementations.

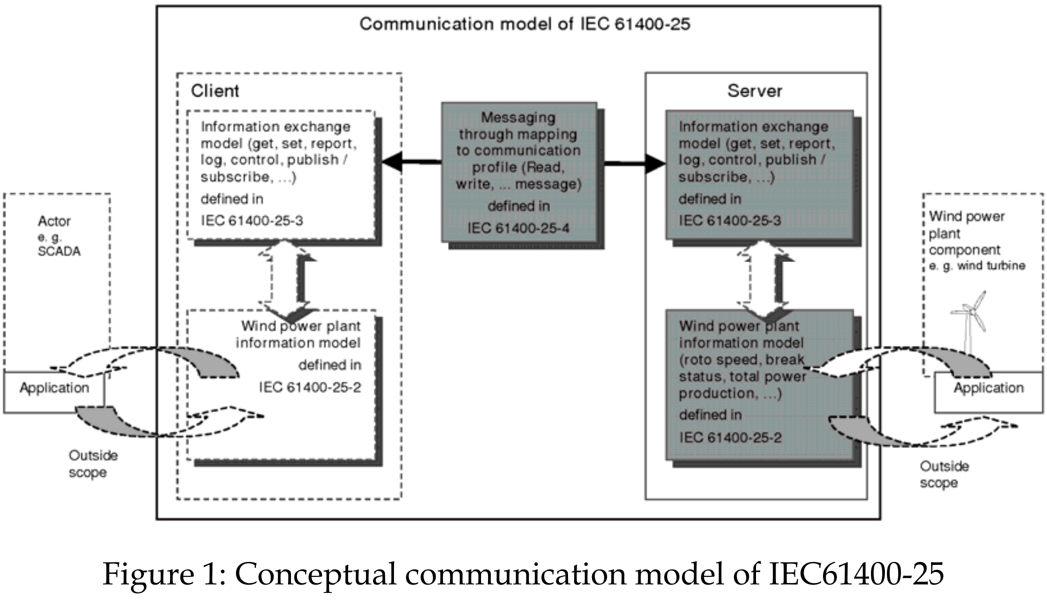

Figure 1: Conceptual communication model of IEC61400-25

Part 2 (Information models) introduces and defines the data objects - referred to as *logical nodes* - specific to wind turbine communication. All data objects and data types are self-describing through embedded meta-data such as scaling and unit information for measured values. This enables e.g. the self-configuration of SCADA systems.

The object definitions distinguish between mandatory and optional objects, as well as between mandatory and optional data fields within the individual object. In order to comply with the standard, an implementation must at least provide the functionality of all mandatory fields in each of the mandatory objects.

Figure 2 gives an overview of the available objects and their logical node names. The minimal configuration requires an object model which at least contains information about the rotor, the generator(s), the yawing system, the nacelle and the turbine as a whole.

IEC61400-25 inherits a significant number of data types, as well as some nodes, from its "parent standard" IEC61850, which in turn inherits data types and performance definitions from its predecessor IEC60870 ("Telecontrol equipment and systems").

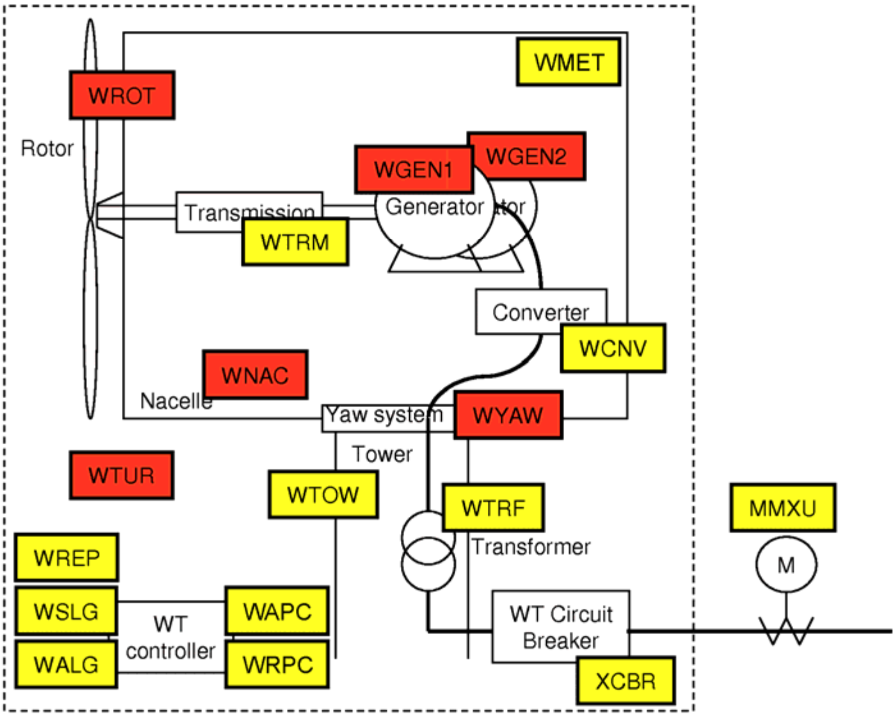

Figure 2: Wind turbine objects (logical nodes). Mandatory nodes marked with a red background, optional nodes in yellow.

Part 3 (Information exchange models) describes the required mechanisms and protocols of data exchange, such as authenticating a client, sending a control command, subscribing to a monitoring data feed or accessing the self-description of a device.

Part 4 (Mapping to communication profiles) defines the message format of the individual data exchange transactions. Several such mappings may be supported by a single implementation, and each mapping specifies which services of the information exchange model will be supported. The current version of the standard defines a mandatory mapping to web services using SOAP, an XML-based protocol. Additional mappings are expected to be defined in the final version. Currently planned mappings are web services, IEC 61850-8-1 MMS, OPC XML DA, IEC 60870-5-104, and DNP3.

Part 5 (Conformance testing) specifies standardised procedures for verifying that a given implementation adheres to the standard, as well as specific measurement techniques to be applied when declaring performance parameters.

Part 6 is currently underway in a separate process from parts 1-5. It is called *"Communications for monitoring and control of wind power plants – Logical node classes and data classes for condition monitoring"*. It extends the defined name spaces with logical nodes and possibly new data classes for condition monitoring. Since there are only people involved in vibration monitoring involved in the work, the standard technique of monitoring the drive train with high-frequency (20kHz) vibration sensors is the only one being catered for. People interested in different kinds of condition monitoring, for example monitoring of the gearbox oil quality or the blade monitoring sketched out in chapter 3, are asked to come with their input to the process. Please contact your national IEC contact point or Karl-Heinz Schwarz, the project leader directly [*www.scc-online.de/std/61400/TFCM/*].

The current state is that parts 1, 2, 3 and 5 have received positive votes and can be expected finalised by 2007. No significant changes to the draft are expected, so that companies can plan their implementations. However, part 4 has been referred back to the TC to work on the additional mappings. Part 6 is under discussion, and a first draft is expected after the summer of 2006.

3. BLADE CONDITION MONITORING

Condition monitoring is especially important offshore, where the access to the turbine is more difficult (due to the distance) and partly even not possible due to the weather. Under those conditions, standstill of a turbine is to be avoided if technically possible. While the Wind Energy Department at Risø has worked together with manufacturers of vibration monitoring of the drive train for a number of years, the Materials Department of Risø has undertaken projects aiming to establish the basic technical knowledge to evaluate whether remote surveillance of the rotor blades of large off-shore wind turbines has technical and economical potential (Sørensen et al. 2002). Firstly, a cost-benefit analysis was developed, showing that it is economically attractive to use sensors embedded in the blade. Specific technical requirements were then defined for the sensors capability to detect the most important damage types in wind turbine blades.

Three different sensor types were selected for use in laboratory experiments and independent, full-scale tests of a wind turbine blade developing damage:
1) detection of stress wave emission by acoustic emission,
2) measurement of modal shape changes by accelerometers and
3) measurement of crack opening of adhesive joint by a fibre optics micro-bend displacement transducer that was developed in the project.

All types of sensor approaches were found to work satisfactory. The techniques were found to complement each other: Acoustic emission has the capability of detecting very small damages and can be used for locating the spatial position and size of evolving damages. The fibre optics displacement transducer was found to work well for detecting adhesive failure. Modelling work shows that damage in a wind turbine blade causes a significant change in the modal shape when the damage is in the order of 0.5-1 m. NDT methods (ultrasound scanning and X-ray inspection) were found to be useful for verification of hidden damage.

A follow-up project (McGugan et al. 2006) has developed specific strategies for blade instrumentation and data interpretation, these have been verified in full-scale blade tests conducted by the manufacturers themselves.

Commercially funded retro-fit applications of sensor technology onto operating turbine blades have since been successfully undertaken by Risø National Laboratory, and product development agreements now exist with blade manufacturers to promote new, bespoke products.

At an international level, Risø National Laboratory is tasked within the UPWIND project [*www.upwind.eu*] regarding new CM activities for offshore wind turbines, towers, and blades. One of the work packages is devoted to the integration of new blade condition monitoring and fault prediction approaches into the next generation of wind turbines for offshore wind farms. Especially the use of optical fibres will be evaluated. Input regarding the CM techniques will be given to the standardisation group. This will include the requirements according to calculation power, storage, communication (e.g. IEC 61400-25), digital/analogue conversion, sampling rates, signal conditioning hardware, etc.

It is a key requirement for the rapid development of new CM modules for WT blades, especially when undertaken by independent, specialist technology suppliers, that there are clear guidelines concerning the communication standards expected within the industry.

4. A FULL IMPLEMENTATION

The IEC communication standard is currently being tested in a full scale laboratory set-up. Risø is currently establishing SYSLAB [*www.syslab.dk*], an experimental site for research into intelligent distributed control of distributed energy systems. The setup contains various electrical generation and consumption units which are interconnected through a small grid. Each unit is equipped with its own dedicated computer system to facilitate local control, monitoring and measurements.

The capability to exchange data in real time between different parts of the system is an essential precondition for distributed control and monitoring. Each unit's data must be accessible for other units, supervisory controllers, the monitoring system as well as through one or more human-machine interfaces (HMIs), which do not need to be physically located in the same part of the system.

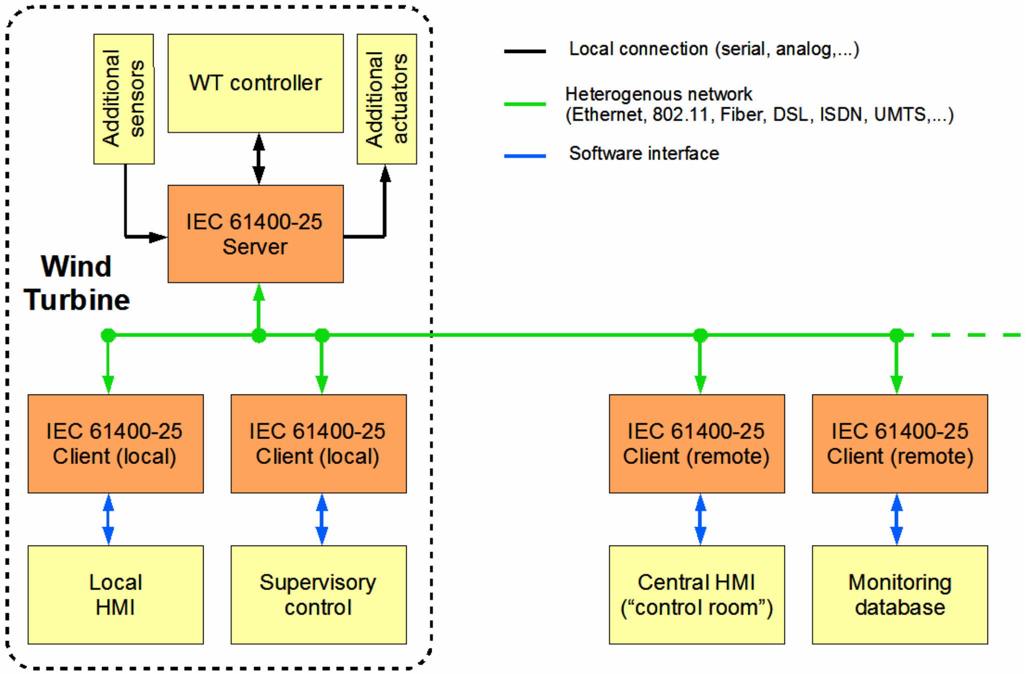

Figure 3: Wind turbine communication in SYSLAB

Figure 4: Gaia wind turbine

SYSLAB uses IEC 61400-25 for the data communication needs of an 11kW Gaia wind turbine (Figure 3). The server communicates locally with the wind turbine controller using the manufacturer's proprietary interface, augments the controller data with measurements from additional sensors and maintains a single object model.

Clients and server communicate using standard TCP/IP networking, which offers independence of the physical medium: An operator panel located in the tower base, connected via wired LAN, accesses the server in the exact same way as a park controller on a wireless or switched fiber-optic network, or a remote monitoring system using the Internet for transport.

Due to its small size and simplified design (passive yawing, passive stall, directly connected single generator) the Gaia turbine lacks much of the complexity found in current megawatt-class turbines and can serve as a good example for a minimal implementation of the standard. Should one decide to use the turbine for tests of CMS equipment, the basic parameters of the turbine would be readily available.

5. CONCLUSIONS

A new standard for the communication with wind turbines is close to be finalised by the IEC. This standard allows vendor-independent data access to and command of the wind farm via remote links, but also for additional equipment in the wind farm itself. This equipment could be condition monitoring sensors and evaluation software. A subset of such techniques is the condition monitoring of the drive train based on vibration sensors. For this case, the first extension of the communication standard is currently in the works. Please come with input to the standardisation process regarding other forms of CMS systems now. Finally, one of the first working implementations of the standard is presented.

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