Adding Forecasts to the IEC 61400-25 Communication Standard

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The IEC standard 61400-25 Wind Turbine Communication is on the way to be implemented in most new wind turbines. Its scope is not only the communication between turbine and control centre, but also the communication within the turbine or between control centres. One widely used technique in turbine management and operations is the use of short-term forecasts, for the next day to improve ones trading position, or for the next week to allow maintenance scheduling. However, in the current standard, there is only one time arrow implemented.

This paper proposes an extension of the IEC 61400-25 standard with classes for the description of forecasted data. The extension is written fairly generically and can thus also be applied quite directly for the various members of the IEC 61850 hierarchy, dealing with Distributed Energy Resources, hydro power plants and other smaller scale generation.

A small demonstration installation of the system at Risø's Syslab is also sketched.

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.

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 61 850 Part 7-420 for Communication with Distributed Energy Resources (DER) builds on a similar philosophy. The wind turbine standard (save the Condition Monitoring extension) is published since December 2006 (the mappings to actual communication profiles came out in August 2008). Amongst other communication profiles, web services with SOAP are described. Another related standard, IEC 61850 Part 7-410, specifies a data model for the communication with hydro power plants.

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].

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.

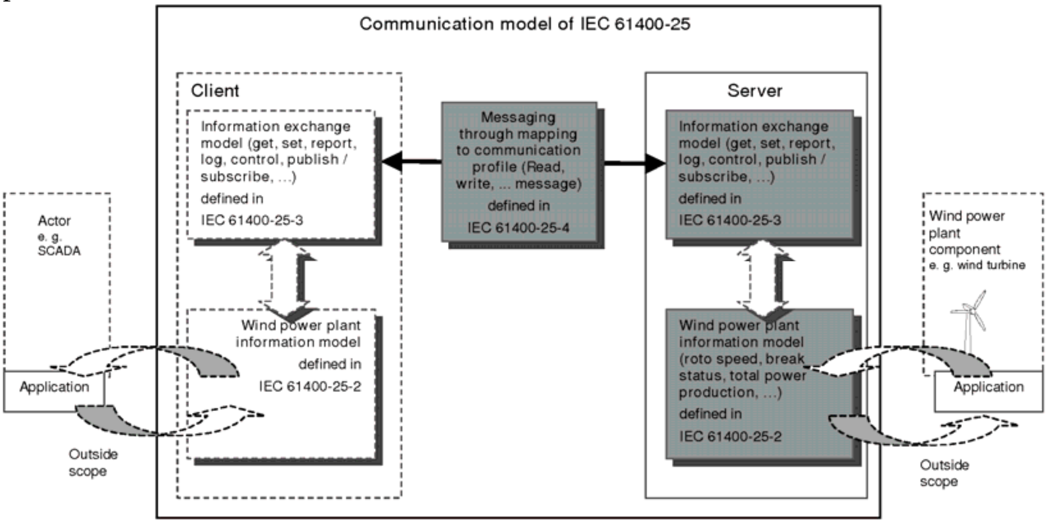

Figure 1: Conceptual communication model of IEC61400-25

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”).

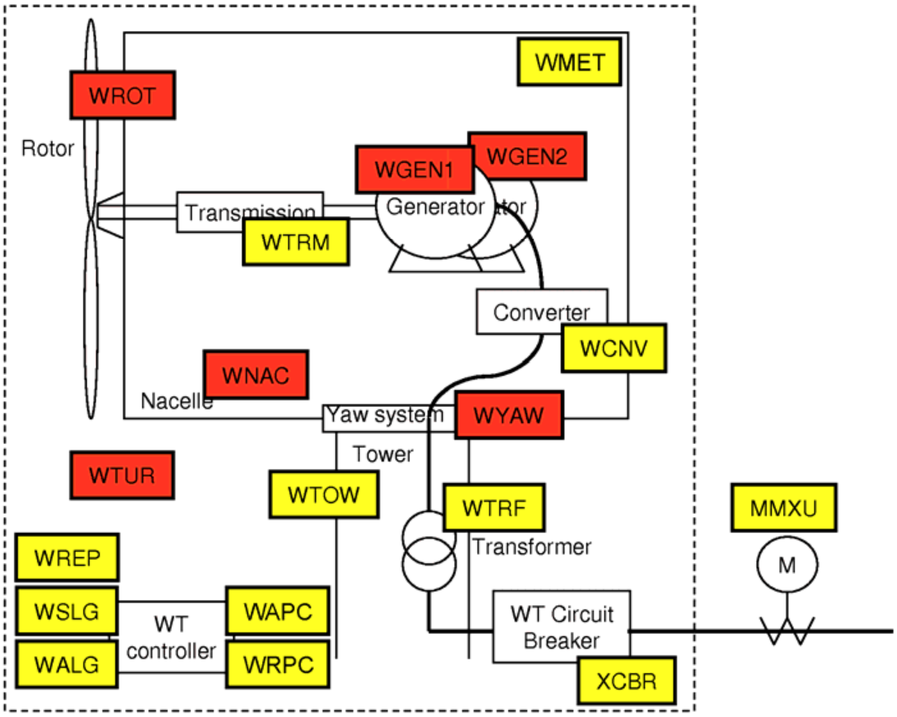

Figure 2: Wind turbine objects (logical nodes). Mandatory nodes marked with a red background, optional nodes in yellow.

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 mappings to web services using SOAP, an XML-based protocol, 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 [www.scc-online.de/std/61400/TFCM/].

The Extension for Forecasting

Despite the thousands of pages in the standards for communication for wind turbines, distributed energy resources and other electrical machinery connected to the grid, no reference can be found to data valid at a future date. All SCADA data is thought to be actual or archived. However, for many years short-term forecasting of wind power has been an established technique in the integration of wind power into the grid (see e.g. Giebel 2003). In short, data from the SCADA system and from Numerical Weather Prediction is used to create a forecast of the power production of a wind turbine, farm or region for the next days. This data has currently no representation in the standards. Here, we propose an information model based on the requirements of the application.

Application requirements

Although the forecasting extension is intended to be a remote interface for wind power forecasting data, such an interface should be as generic as possible in order to accommodate other types of forecasting data in the future. Outside of the scope of IEC 61400-25 (but within that of the IEC 61850 family), these may include local forecasts of electrical load calculated by a power consumer or a substation, reservoir level forecasts supplied by a hydroelectric plant, or possibly even contact wear prediction by an intelligent circuit breaker. Furthermore, future intelligent devices may provide more than one type of forecast at the same time.

In practice, a forecast may incorporate output data from more than one run of a forecasting model, either because more than one relevant model exists, or because a model allows parametrisation. Each model run in itself may have produced either one single forecast time series or an ensemble of multiple time series, for example one forecast time series and several quantile time series.

Forecast data may be available in fixed or variable time steps. Because most forecasting models will output data at a fixed time step, this type can be expected to be the most common one. However, some applications may permit a reduction of the amount of data by increasing the reporting time step as the forecasting accuracy decreases towards the end of the forecasting horizon. In other cases, forecast data may be provided for fixed - but not evenly spaced - times of the day.

Data model

Based on the above requirements, design criteria for a data model can be derived as follows:

1. Forecasting is not a structural, but a functional component of a wind turbine, i.e. its physical location within the site is not relevant. It shares this property with existing nodes for control functions, such as e.g. active power control (WAPC) in IEC 61400-25 or interlocking (CILO) in IEC 61850. Similar to these, the forecasting function is best placed within a separate Logical Node (LN). Multiple forecasts of different type can easily be implemented by allowing multiple forecasting nodes to coexist in the same device model.
2. To allow multiple time series - one or several model runs with one or several time series each - within a single forecast, a new container data type is needed in order to efficiently store each time series together with its associated metadata. Metadata in the forecast node can then be limited to the information common to all timeseries within the forecast.
3. Another data container could be imagined for grouping all time series of an ensemble, such that the forecasting LN holds 1...n ensembles, each of which represents a separate model run and in turn holds 1...n time series together with the metadata of the model run. As a simpler alternative, an ensemble ID could be included in the metadata of each timeseries, thus leaving it to the client to reassemble the individual timeseries into groups based on this ID.

4. The model requires a type for storing the actual time series data. Unfortunately, neither IEC 61850 nor any of the derived standards provide a generic data type for storing time series. While IEC 61400-25-6 (condition monitoring of wind turbines) defines a format for transmitting time series, it uses a data format which is specific to condition monitoring, with non-extensible datatype enumerations). IEC 61850-7-3 defines the CSD (curve shape description) data type, which is a generic container for 2D points. Using the CSD type for time series data is not an optimal solution though: it contains redundant data (the xUnit field is not needed), while other information is missing, such as explicit information whether the time series has constant or variable step. Furthermore, CSD exclusively stores 32-bit floating point values for both x- and y coordinates. Specifying absolute time stamps as floating point values is not a good solution, because of the possible lack of precision.

Based on these considerations, we propose the following data model:

1. A new Logical Node for forecasting (FCST) which contains a textual description of the forecast and model, together with 1...n containers for time series data.
2. A new data type for storing a time series together with associated metadata: Forecast Data Container (FDC). The metadata includes an ensemble ID which allows the grouping of forecast time series into ensembles based on a single model run. The latter solution has been chosen over the alternative discussed above in order to keep the data model as flat as possible. Other metadata attributes are:
    - a flag to specify whether a particular time series describes a main forecast or a quantile.
    - a floating point number to specify the quantile, if applicable.
    - a floating point number to specify the time step for fixed-timestep time series.
    - the time stamp of the model run.
    - the time stamp of the start of the time series.
    - a textual description of the time series.
3. Actual time series data is stored in a CSD (curve shape description) object as defined in IEC 61850-7-3. Each CSD object is embedded into one FDC object. In order to overcome the precision issue, data on the time axis is relative to an absolute time stamp in the enclosing data container.

The full text of the model is provided in Annex 1.

A Demonstration Implementation

The IEC communication standard is currently being prepared for testing 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.

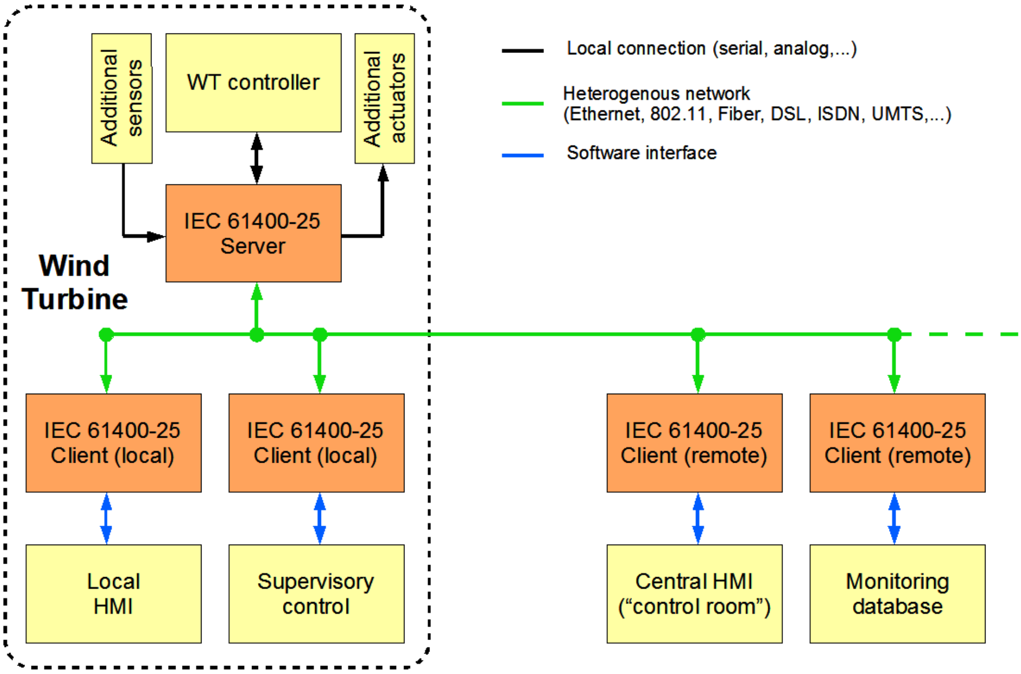

Figure 3: Wind turbine communication in SYSLAB

Figure 4: Gaia wind turbine

SYSLAB uses an 11kW Gaia wind turbine as a test bed for IEC 61400-25 communication (Figure 3). 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.

Risø runs the WRF model (Weather Research and Forecasting) semi-operatively for Denmark. The wind predictions from those runs are taken by Prediktor (see www.Prediktor.dk) and converted to power forecasts for the next 48 hours.

References

Giebel G., Kariniotakis G., Brownsword R.: *The State of the Art in Short-Term Prediction of Wind Power - A Literature Overview*. Position paper for the ANEMOS project, http://www.anemos-project.eu/ (last access: 10.5.2007).

Annex 1: The Proposal in Detail

FCST node (Forecast)			
Attribute name	**Attribute type**	**Explanation**	**M/O**
LNName	inherited from Logical-Node class (IEC 61850-7-2)		
Data			
numTs	INT16U	Number of time series	M
tSeries	ARRAY [1...numTs] of FDC	Time series containers	M
Model	VISIBLE STRING 255	name of the forecast model used	M
nwpModel	VISIBLE STRING 255	description of the data source	M

FDC class (Forecast data container)				
Attribute name	**Attribute type**	**FC**	**Explanation**	**M/O**
DataName	inherited from Data class (IEC 61850-7-2)			
Data				
ensID	VISIBLE STRING 255		Ensemble ID (single timeseries if omitted)	O
tsType	ENUM (???)		0=Forecast, 1=quantile	M
quant	FLOAT32		Quantile	O
tSeries	CSD		Forecast data	M
tStep	FLOAT32		Timestep in s (omitted=variable)	O
modelRun	TimeStamp		Time at which the model was run	M

tsOffset	TimeStamp		Time to which forecast time is relative	M
d	VISIBLE STRING 255	DC	Description of the forecast	M
dU	UNICODE STRING 255	DC	Description of the forecast in Unicode	O

CSD class (Curve shape description, IEC 61850-7-3)				
Attribute name	**Attribute type**	**FC**	**Explanation**	**M/O**
DataName	inherited from Data class (IEC 61850-7-2)			
Data				
xUnit	Unit	DC	Unit on the x axis	M
xD	VISIBLE STRING 255	DC	Description of the x axis	M
yUnit	Unit	DC	Unit on the y axis	M
yD	VISIBLE STRING 255	DC	Description of the y axis	M
numPts	INT16U	DC	Number of data points	M
crvPts	ARRAY[1...numPts] OF Point	DC	Array of data points	M
d	VISIBLE STRING 255	DC	Description of the curve	M
dU	UNICODE STRING 255	DC	Description of the curve in Unicode	O