ELFORSK

Energimyndigheten

Wind Power Communication – Verification report and recommendation

Elforsk rapport 02:14

Anders Andersson, Claus Bjerge, Peter Christiansen, Martin Heyman Donovan, Arne Hedevang, Anders Johnsson, Niels Raben, Jörgen Svensson

April 2002

Wind Power Communication – Verification report and recommendation

Elforsk rapport 02:14

Anders Andersson, Claus Bjerge, Peter Christiansen, Martin Heyman Donovan, Arne Hedevang, Anders Johnsson, Niels Raben, Jörgen Svensson

April 2002

Wind Power Communication – Verification report and recommendation

Elforsk rapport 02:14

Authors:

Anders Andersson	Vattenfall AB
Claus Bjerge	SEAS Wind Energy Centre
Peter Christiansen	Tech-wise A/S
Martin Heyman Donovan	SEAS Wind Energy Centre
Arne Hedevang	Tech-wise A/S
Anders Johnsson	Vattenfall Utveckling AB
Niels Raben	SEAS Wind Energy Centre
Jörgen Svensson	SYCON Energikonsult

Förord

Föreliggande rapport utgör en komplettering av tidigare utgivna specifikation av funktionella krav för etablering och drift av ett system för datakommunikation mellan kontrollsystemet i ett vindkraftverk och datorer för fjärrövervakning (SCADA), Elforsk rapport 01:25.

Arbetet har, liksom det tidigare projektet, utförts av en dansk-svensk arbetsgrupp med representanter från följande företag: Vattenfall Utveckling AB och Sycon Energikonsult som representanter för Elforsk AB, Sydkraft Vind AB, Tech-wise A/S som representanter för Elsam A/S, SEAS Distribution A.m.b.A som representanter för Energi E2 A/S.

Projektet har genomförts inom ramen för Elforsks vindkraftprogram (projekt 2172). Programmet finansieras av Vattenfall, Sydkraft, Birka Energi, Göteborg Energi, Umeå Energi, Falkenberg Energi, Helsingborg Energi, Varberg Energi, Graninge AB och Energimyndigheten.

Stockholm april 2002

Ulf Arvidsson

Elforsk AB
Programområde El- ooch värmeproduktion

Sammanfattning

Det övergripande syftet med detta dokument är att ge råd och rekommendationer angående användning av IEC 61850/MMS respektive OPC som gränssnitt för vindkraftkommunikation. I rapporten presenteras resultat från två testimplementationer. En version av den preliminära standarden IEC 61850 baserad på kommunikationsprotokollet MMS (ISO 9506) har testats i ett vindkraftverk i Sverige och ett motsvarande projekt med ett OPC-gränssnitt har genomförts i Danmark.

Huvudsyftet med testimplementationerna är att verifiera hur väl de två olika lösningarna uppfyller krav på kommunikationssystem för vindkrafttillämpningar, enligt vad som specificerats i Elforsk rapport 01:25. Utöver praktiska tester omfattar testverksamheten aktiviteter för att utvärdera fördelar och nackdelar med en viss kommunikationslösning. Utvärderingskriteria har satts upp för dokumentation, implementation, installation samt testning. Resultat och slutsatser från dessa utvärderingar presenteras.

Resultat från utvärderingarna visar att implementationerna med MMS resp. OPC båda uppfyller de flesta krav som satts upp för testerna, även om OPC saknar vissa egenskaper. Från ett funktionellt perspektiv erbjuder båda koncepten ett enhetligt sätt för åtkomst och hantering av data. Men de två lösningarna har sina fördelar och nackdelar för olika tillämpningar. De kan också användas samtidigt som kompletterande lösningar.

IEC 61850 omfattar inte enbart en protokollstack (baserad på MMS). Ovanpå denna definieras gemensamma informationsmodeller och tjänster (services). Modelleringsmetoden i IEC 61850 tillhandhåller ett sätt att presentera information i en struktur med datavärden med enhetliga namn och datatyper inom en given lista (namespace). Dessa informationsmodeller och tjänster är separerade från den underliggande protokollstacken. Detta är en viktig egenskap hos IEC 61850 som gör det möjligt att använda olika kommunikationsprotokoll, inte enbart MMS, för att överföra informationen.

Slutsatser har dragits beträffande tre viktiga aspekter, nämligen mognad hos produkter, standardisering och acceptans. Beträffande produktmognad och acceptans ligger OPC definitivt bättre till. Det finns flera OPC produkter på marknaden, vilka används av många företag, numera även inom vindkraftbranschen. Men som beskrivs i rapporten löser den nuvarande versionen av OPC, vilken är baserad på Microsofts DCOM-lösning, inte problemet att finna ett standardiserat leverantörsoberoende gränssnitt till vindkraftverkens styrsystem. OPC Foundations förslag på en ny XML-baserad version av OPC är här en intressant lösning.

För framtiden kommer det pågående standardiseringsarbetet inom IEC TC88 Project team 25 att lösa de flesta av de problem med MMS och OPC som presenteras i rapporten. I likhet med IEC 61850 kommer den framtida kommunikationsstandarden för styrning och övervakning av vindkraftverk separera definitionen av information och tjänster från sk mappning till kommunikationsprotokoll. På så vis kan MMS, OPC och andra lösningar användas för att överföra vindkraftdata.

Summary

The overall purpose of this document is to provide recommendations on do and don’ts regarding the use of IEC 61850/MMS and OPC as solutions for wind power plant communications. The report presents results from two test implementations. A version of the draft standard IEC 61850 based on the communication protocol MMS (ISO 9506) has been implemented and tested at a wind power plant in Sweden and a similar project for an OPC-interface has been conducted in Denmark.

The main purpose of the test activities is to verify to what extent the two different solutions fulfil the requirements on communication systems for wind turbine applications, as defined in the Elforsk report 01:25. In addition to practical tests the verification activities include work to evaluate pros and cons for a particular communication solution. Evaluation criteria have been set up for documentation, implementation, installation, and testing. Results and conclusions from these tests are presented.

Results from the verification activities show that the test implementations with MMS and OPC both meet most of the requirements stated for the tests, although OPC lacks some features. From a functional point-of-view both concepts provide a uniform way to access and manage monitoring and control data. But the two solutions have their pros and cons in different applications. They may also co-exist and could be used a complementary solutions.

IEC 61850 does not only include a protocol stack (based on MMS). On top of that it also includes common information models and services. The modelling method of IEC 61850 provides a way to present information in a structure representing data values with common names (and data types) within a given namespace. These information models and services are separated from the underlying protocol stack. This is an important feature of IEC 61850, which provide the possibility to use various protocol stacks, not only MMS, to exchange the information.

Conclusions are drawn regarding the three important issues product maturity, standardisation, and acceptance. Regarding product maturity and acceptance OPC definitely has a better position since there are today many OPC products available and it is used by many companies, recently also within the wind power industry. However, as described in the report the present version of OPC based on Microsoft DCOM will not solve the problem of getting a standardised vendor-independent interface to the wind turbine control system. The new XML-based version of OPC, proposed by OPC Foundation, is here an interesting solution.

Looking ahead the ongoing standardisation work within IEC TC88 Project Team 25 will solve most of the problems with MMS and OPC presented in the report. Similar to IEC 61850 the future wind power communication standard IEC 61400-25 will use the approach of separating the definition of information and services from the mappings to protocols. Thus, MMS, OPC and other solutions may be used to transfer the data.

Contents

1 INTRODUCTION 1

1.1 GENERAL 1
1.2 PURPOSE 1
1.3 APPLICABLE DOCUMENTS 1
1.4 SELECTION OF PROTOCOLS 2
1.5 VERIFICATION ACTIVITIES 3

2 IEC 61850 (UCA 2.0) BASED ON MMS 4

2.1 DOCUMENTATION 4
2.2 IMPLEMENTATION 6
2.3 INSTALLATION 10
2.4 PRACTICAL TESTS 10
2.5 SOFTWARE PACKAGES 14
2.6 EXPERIENCES 14

3 OPC 17

3.1 DOCUMENTATION 17
3.2 IMPLEMENTATION 18
3.3 INSTALLATION 20
3.4 PRACTICAL TESTS 22
3.5 SOFTWARE PACKAGES 25

4 CONCLUSIONS 26

4.1 IEC 61850/UCA BASED ON MMS 26
4.2 OPC 27
4.3 OVERALL CONCLUSIONS 28

5 REFERENCES 30

Appendices

A COMPARISON OF IEC 60870-5-101/-103/-104 AND IEC 60870-6-TASE.2 WITH IEC 61850

1 Introduction

1.1 General

Elforsk has sponsored a join Swedish-Danish work to find, and to make recommendations on, a common solution for communication with wind power plants. The first stage of the work resulted in the requirement specification Functional requirements on Communication System for Wind Turbine Applications (Elforsk report 01:25) [1]. During the work a number of possible communication solutions were identified. The two most promising solutions have been tested in order to verify to what extent they fulfil the requirements in the specification. A version of the IEC 61850 standard [2] based on the communication protocol MMS [3], [4] has been tested at a wind power plant at Näsudden on Gotland in Sweden and an OPC-interface has been tested at Ny Nøjsomhedsodde at west Lolland in Denmark. This report includes the results of those verification activities together with a recommendation on when and how to use the communication solutions tested.

The experiences gained in this project are of interest for both owners and suppliers of wind power plants. Normally it is the owner who state the requirements on the solution and the supplier who do the implementation, installation and commissioning of the equipment. The recommendations differ depending on the type of project.

1.2 Purpose

The overall purpose of this document is to provide recommendations on do and don’ts regarding the use of IEC 61850/MMS and OPC for wind power plant communications. The recommendations are based on the experiences gained during practical tests. Results and conclusions drawn from these tests are presented. The document may be used during procurement, implementation, testing and commissioning of similar demo installations as well as for real permanent installations. Furthermore, the document states additional activities needed before the tested solutions will be commercially available at a competitive price.

1.3 Applicable documents

The documents within this project are all based on the content of the Elforsk report Functional Requirements on Communication System for Wind Turbine Applications (report no: 01:25). Figure 1 shows the relationships between that report and the documents produced in this project.

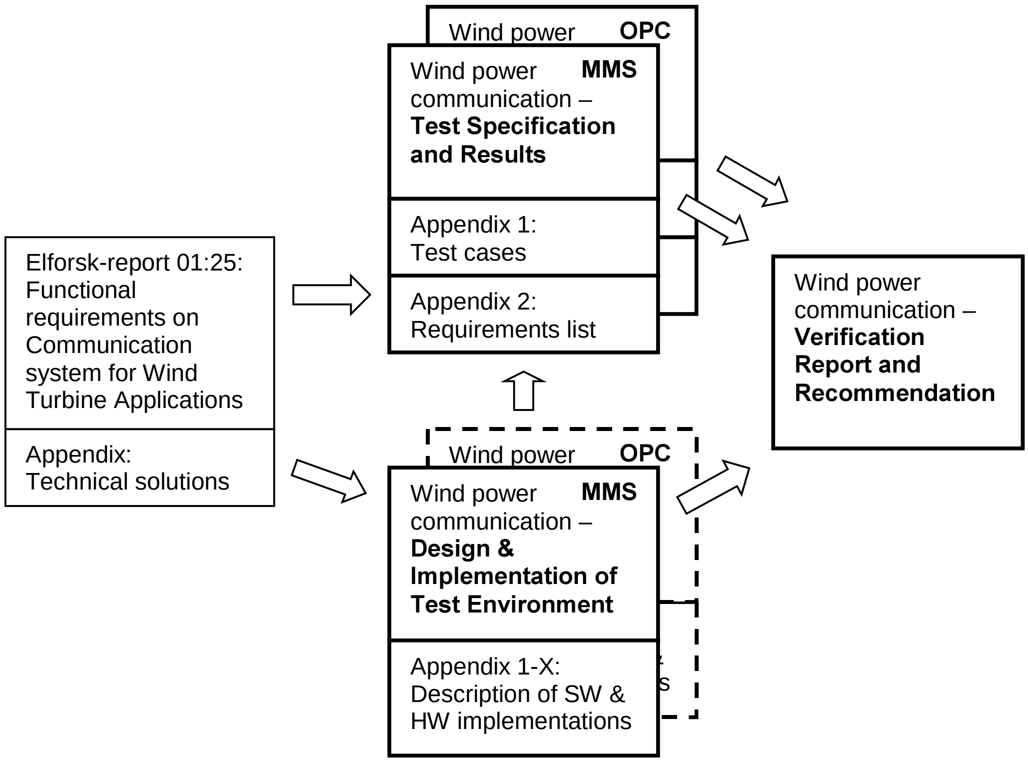

Figure 1 – Applicable documents

The delivery includes the following documents:

- Wind power communication – Verification report and recommendation (this document)
- Wind power communication – Design and Implementation of test environment, with appendices. Includes detailed descriptions of the hardware and software in the implementation but also information on some general design choices regarding server interface issues and software implementation issues.
- Wind power communication – Test specification & Results, with appendices. Includes descriptions of the tests procedures used to verify whether the solutions meet requirements on configuration, security, functionality and performance. Results from practical tests are presented.

1.4 Selection of protocols

In the Elforsk report (01:25) Functional Requirements on a Communication System for Wind Turbine Applications IEC 61850 based on MMS was identified to be one of the most promising solutions for wind power plant communication. The scope of IEC 61850 includes information models, information description method, information exchange methods, and mappings to communication protocols such as MMS. A report from SCC presenting the properties of IEC 61850 in relation to other solutions is included in Appendix A: Comparison of IEC 60870-5-101/-103/-104 and IEC 60870-6-TASE.2 with IEC 61850.

Another interesting solution is the OPC interface. OPC has for instance recently been chosen as the interface to the SCADA system for the new 150 MW wind farm at Horns Rev in Denmark. OPC is also tested at SEAS' test site at Nøjsomheds Odde.

1.5 Verification activities

The requisites for using a particular communication solution include good documentation (available at a reasonable price), good engineering tools and guidelines together with effortless implementation and tools for commissioning. Finally, once in operation, the communication solution shall provide good functionality and performance. The verification activities shall cover all of these areas and include the following:

- Document review
- Implementation
- Installation, and
- Practical tests.

1.5.1 Evaluation criteria

There are different evaluation criteria for the different verification activities.

Document review:

- Existence and quality of documentation

Implementation:

- Existence and quality of guidelines
- Effort needed for implementation

Installation:

- Existence and quality of guidelines.

Practical tests:

- Configuration
- Security
- Functionality
- Performance

2 IEC 61850 (UCA 2.0) based on MMS

2.1 Documentation

2.1.1 General

Documentation is needed to understand and to implement MMS communication.

2.1.1.1 Formal reference documents

The draft standard IEC 61850 is a set of specifications for communication networks and systems in substations developed by IEC TC57 working groups 10, 11 and 12. Until a document reaches status International Standard it is not publicly available. It is only available as a working draft for the members of the working groups or later as a committee draft (CD) for the national committees. However, since the standardisation work is an open process most working groups are willing to distribute their working draft for comments to non working group members.

IEC 61850 ”Communication networks and systems in substations” consists of 14 parts, as shown in Table 1.

Part 1:	Introduction and overview.
Part 2:	Glossary
Part 3:	General requirements
Part 4:	System and project management
Part 5:	Communication requirements for functions and device models
Part 6:	Substation automation system configuration language
Part 7-1:	Basic communication structure for substation and feeder equipment – Principles and models
Part 7-2:	Basic communication structure for substation and feeder equipment – Abstract communication service interface (ACSI)
Part 7-3:	Basic communication structure for substation and feeder equipment – Common data classes
Part 7-4:	Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes
Part 8-1:	Specific communication service mapping (SCSM) – Mapping to MMS(ISO/IEC 9506 Part 1 and Part 2)
Part 9-1:	Specific communication service mapping (SCSM) – Serial unidirectional multidrop point to point link
Part 9-2:	Specific communication service mapping (SCSM) – Mapping on a IEEE 802.3 based process bus
Part 10:	Conformance testing

Table 1: Overview of the different parts of the standard IEC 61850

The correct standard names include the prefix Communication networks and systems in substations. Thus, the full name for part 7-1 is IEC 61850-7-1: Communication networks and systems in substations - Part 7-1 Basic communication structure for substation and feeder equipment – Principles and models.

The parts most relevant to this project are parts 7-1, 7-2, 7-3, 7-4 and 8. Parts 7-1 to 7-4 describes the basic communication structure for substation and feeder equipment, including principles and models, services, common data classes, and logical nodes and data classes. Part 8 describes the mapping of these data objects and services to MMS.

2.1.1.2 Product specific information for application development

Commercially available software packages used when developing an actual system should be well documented and provide good guidance for the developer. The documentation can be either manuals or on-line help.

2.1.2 Results from documentation review

The actual implementation of the server software with the wind power plant information model was done by the subcontractor NettedAutomation GmbH, who produced very good instructions for how to install and start the software. Because of this, there was little need within the project to study manuals in detail. According to the subcontractor the following comments could be made about the documentation.

The source code for MMSd provided by Tamarack was well documented to specify the wind power specific information model and to build the server software. Mainly the following documents from Tamarack have been used for the project:

1. Tamarack Software Overview [5] describing the general architecture, MMS API, and the various software modules.
2. Tamarack Development Environment [6]
3. User's Guide to MMSdPREP [7]. The syntax to specify standardised or specific models (based on a common notation (Bacus Naur)).
4. MMSd Protocol Implementation Conformance Statement [8]. Specifies the supported MMS services and service parameters.

The source code is well structured and provides many comments useful for the porting of the software on various platforms. The source code comes with simple and comprehensive examples that can be used to build specific servers and process data simulations just by modifying the examples.

The information exchange services, the mapping to MMS, and the communication stack is documented in the IEEE TR 1550 (UCA) [9] respective in the various parts of the draft standards IEC 61850.

2.2 Implementation

2.2.1 General

The assessment of a standardised solution like IEC 61850/UCA has crucial impacts on:

(a) the definition of **device models** (that represents the real systems),

(b) how to do **monitoring and control** of devices,

(c) the **configuration and self-description** of devices, and

(d) the support by the communication **protocol stack**

At least the following important aspects have to be taken into account for the assessment:

(1) Information model - The **standard definitions** (in this case parts of IEC 61850/UCA™) and the **Wind Power Plant -WPP** (agreed upon) model itself.

(2) The **implementation of the provisions of 1**, including the communication protocol stack (in this case MMS on TCP/IP [10]{11])

(3) The **implementation of the interface** between the **server and the real application** (process data).

(4) The **implementation of the interface** between the **client and the real application** (HMI, ..., Configuration/Engineering station).

The results of the assessment have to reflect and to differentiate these aspects.

The focus of the project is the application and analysis of the server software and the IEC 61850/UCA standard communication interface. The server contains the information models, the service procedures, the monitoring of data value changes, filtering of data, the services, the communication buffers, and communication links (e.g., TCP/IP).

2.2.2 Interfaces

2.2.2.1 The scope of IEC 61850 - Example interfaces of a real system

To give some guidance in the understanding of the IEC 61850 draft standard, the following discussion with the implementation at Näsudden as an example is intended to show what parts of a real system that the standard covers.

IEC 61850 itself does not constrain any implementation of the information, service models, communication stacks, actions, and application program interfaces (APIs). Any application program interface (API) is outside the scope of the standard.

The information exchange between the wind power plant (WPP) device and supervisory and control systems mainly comprises – according to Figure 2 – a client, a server, several interfaces, and actions.

The server (WPP server) represents the information and information exchange methods. The client (WPP client) represents the complementary to the server. E.g., a service provided by the server can be requested by the client. The client itself is not specified (it provides mainly the complementary roles of the server).

The complete chain from a source of information up to a SCADA visualisation is described (from right to left in the figure):

- The data value source is the real WPP. The exchange of data (raw) values between the real WPP process and the WPP server is realised by the interface 1 (IF1) and (IF2) – these interfaces are implementation specific. How many interfaces are implemented at the server side is implementation specific.
- The WPP server adds useful information to the (raw) process data (e.g., hierarchical name, time stamp, quality, ...). This is defined in the model and the addition of the name etc. is defined as the action 1 (Act1) – this action is implementation specific.
- The model of the information (as it is seem from the network point of view) is defined by the standard – the model realisation is implementation specific.
- Monitoring of value changes of process data values delivered from the real-time data source is represented by (Act1) – implementation specific, but behaviour and services defined in the standard.
- Exchange of data values between WPP server and supervisory and control systems via (IF3) – behaviour and services defined in the standard.
- Exchange of the model description located in the server with another system (IF3) – behaviour and services defined in the standard.
- Exchange of data values between (communication) client and client application (visualisation, HMI) via (IF4) and (Act2) – implementation specific

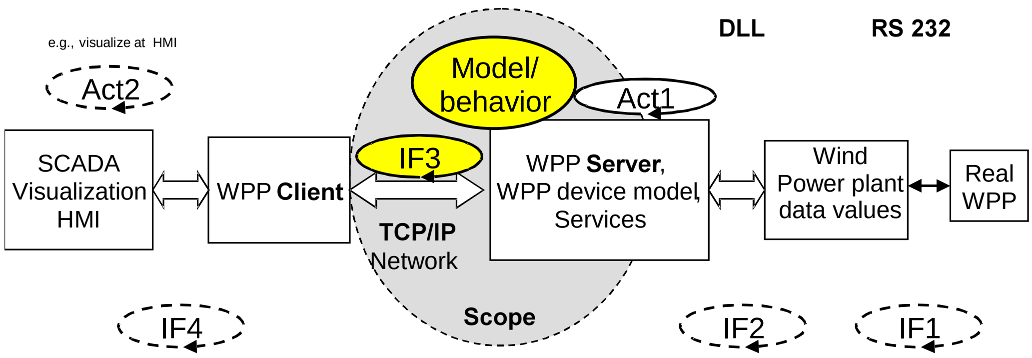

Figure 2 – Implementation issues (example)

Interface (IF3) is the only interface that is defined by the IEC 61850 standard. This interface (IF3) is also the only interface necessary to specify when buying a new wind turbine. The interface is defined by the information that is accessible through this interface and by the messages that carry the service parameters and the values.

2.2.3 Modelling

2.2.3.1 Information Modelling

For the wind power plant used in the tests a grouping of data after physical components (in line with the existing SCADA-system) is applied as the modelling approach in this project. Each data is allocated to one of nine so-called logical nodes. Detailed descriptions of the models can be found in the document Wind Power Communication – Design & Implementation of Test Environment. The concept of logical nodes is defined and described in IEC 61850-5 [2.1].

All process information exchanged between the WPP and the WPP control centre has been modelled with the methods of IEC 61850. Description information (Metadata) has been added to the simple process values (e.g., SI units, scale, and deadband).

The specification of the information model is independent of the information exchange services. Additional models can be specified at any time. After the specification and realisation of the core WPP model there was a requirement to add a “meteorological information model”. This model has been integrated into the existing model without any change of the existing model. Any other model can be defined using the same services.
Adding new logical nodes or data classes for a given logical node requires that the DLL interface and the application have to be modified according top the additional definitions.

2.2.3.2 Information exchange services

The information exchange methods used provide:

- real-time data access and retrieval,
- controlling devices,
- event/alarm reporting and logging,
- self-description of devices,
- data typing and discovery of data types, and
- file transfer

2.2.3.3 Tools to support the engineering and configuration of the server software

The Tamarack pre-processor tool provides a helpful tool (MMSd PREP) to engineer and configure the WPP information model. The MMSd PREP is a tool that processes ASCII based in-formation model input files and produces the required program code source.

2.2.3.4 Interface between application and IEC-61850-compliant software

The selection of the interface between the application and the IEC-61850-compliant software is one of the most crucial issues to be decided when applying communication software. The information model, the service models, and the services are provided as a single DLL. The DLL receives process data from the application for updating the state of the information model implemented in the server.

2.2.4 Communication protocol stack

The Abstract Communication Service Interface (ACSI) in IEC 61850-7-2 [2.2] provide a protocol independent way to describe objects (logical nodes and data) and information exchange services. These data and services are then mapped to different communication protocols that provide the actual means for information exchange.

IEC 61850-8-1 [2.3] specifies a method of exchanging time-critical and non-time-critical data through local-area networks by mapping ACSI to MMS services and protocol operating over full OSI and TCP compliant communications profiles.

2.2.5 Results from implementation

A general comment about the DLL and the Visual basic program is that the DLL has been very stable, even though some halts have occurred. Although it has been developed for the project in a short time the DLL has worked better than expected, which indicates rather extensive testing before delivery. The integration between the DLL and the Visual Basic object went quick and easy.

The basic information and information modelling methods of IEC 61850 meet the requirements defined for the project. The tool MMSd PREP provides a high level means to define any information model and the required services models for reporting and logging. The hierarchical name structure of the data models provide means for getting a good overview of the data. In this case data has been grouped after nine physical objects but that might not be the best way. In any way the modelling tool supports any new model.

The core of the approach applied is the semantic of the models and services of the server. MMS just provides an accepted and widely used syntax for the unified message exchange!

One big advantage of the solution is that the services and local organisation of the MMS variables (logical nodes and data) are independent of each other. Any model can easily be changed/produced.

Regarding the modelling and implementation efforts the original estimation of 5 days has become 15-20 days, counting both time for data modelling and for implementation of data models and the VB interface.

MMS might enable more flexible and innovative automation models than other protocols. A conclusion based on the fact that the implementation has been very time consuming could be that MMS is a complex protocol. However, the time consumption we have seen is something that is mainly outside MMS. The challenges of designing messages that meet automation process requirements and standardising their semantics (logical nodes and data classes) are independent of the syntax (MMS) in which the messages are encoded.

The way the implementation was done at Näsudden no dynamic creations of data sets (selection of measurements, binary signals and mixed data) can be created. Every new data and data sets requires that a new model is described in an xxx.MDL file. New Data Sets are generated with the LIST function. This file then needs to be complied and linked.

2.3 Installation

2.3.1 General

The project activities included an investigation of the efforts needed to install and operate MMS communication.

2.3.2 Results from installation

The Tamarack software is very easy to install. The client software can be started without first going through an installation process. This is true for the Windows 98 environment at least, whereas there were some problems of starting the special Logging client

The Tamarack MMS server software was delivered together with a Visual Basic test program for manually or automatically generated data values. The test program made the implementation much easier because the VB program contained examples of how data should be delivered to the DLL and in what order the DLL functions must be called. A detailed description is documented in Wind Power Communication – Design & Implementation of Test Environment.

2.4 Practical tests

2.4.1 General

2.4.1.1 Verification environment

An overview of the verification environment is presented in Figure 3. The test object, called Sigvards 2, is a 1 MW wind turbine from Nordic Wind Power, NWP. It is located approx. 600 m from the control centre at Näsudden on the island Gotland. The wind turbine control system from Mita-Teknik A/S is connected with the Master-PC and the Test server PC through an RS232 link. The control system uses Mita-Teknik's own protocol to periodically send data packets. A local radio based Ethernet-LAN connects the wind turbine and the control centre at Näsudden. The wind turbine is also equipped with telephone modem. During the tests the wind power plant is in normal operating mode.

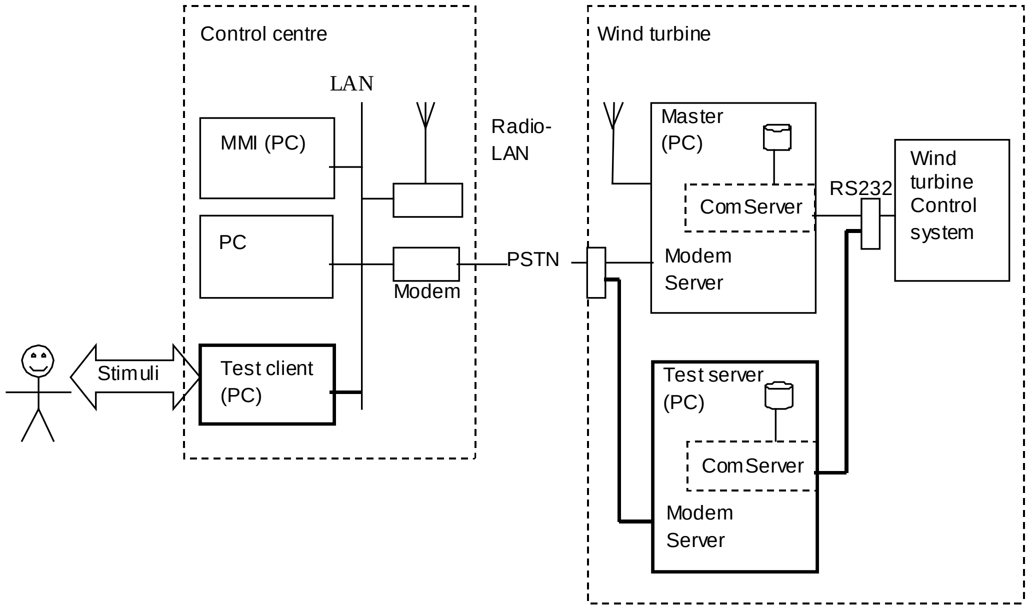

Figure 3: Overview control centre, wind power plants and communication networks.

2.4.1.2 Description of the test system

The data model is implemented with the Tamarack server software and connected to the real time data source under Windows 98. The Tamarack server software and the interface to the data source is implemented as a DLL. The test server provide the following services through the IEC 61850/UCA interface based on the MMS protocol:

- Online services (polling - Get/Read -, reporting, and setting)
- Logging (off-line)
- Identification and self-description of data objects
- Controlling the device (stop, resume, start) is supported but no control data are included in the data model.

During the tests three different MMS-client software were used to connect and exchange data with the server and to present the data to the operator; 1) Tamarack MMS-client, 2) LiveData MMS-client, and 3) SISCO MMS Object Explorer.

The client software from Tamarack support stepwise establishment of transport connection, MMS connection and service initiations. The client software presents the data to the operator through a Windows application.

The LiveData client has a procedure for automatic connection and initiation of MMS services. Thus, at start-up the software gets a list of all variables and starts to poll these values. The LiveData client also provides a DDE interface. It is possible to copy links to MMS values from the LiveData client and paste them in for example an Excel spreadsheet. Furthermore its is possible to write Visual Basic objects that polls values from the LiveData client.

The SISCO MMS Object Explorer provides an interface where the server data can be presented in a hierarchical tree structure.

2.4.1.3 Test procedures

The test procedures include four types of test cases, which corresponds to the four main groups of requirements specified in the report Functional requirements on Communication System for Wind Turbine Applications (Elforsk 01:25). They are configuration, security, functionality, and performance. The test cases are documented in Appendix 1 of the document Wind Power Communication – Test Specification and Results.

Configuration includes test cases for connection establishment, identification of objects and attributes, and configuration management. Security includes test cases for authentication of the calling client. A number of test cases for the functionality have been stated. They include, among others, test cases for retrieving “Online” measurements/analogue data and binary signals/status data and for sending control commands and setpoints. Furthermore, functionality for event logs as well as reporting has been tested. Finally, performance test cases have been set up based on the functionality test cases.

2.4.2 Results from practical tests

2.4.2.1 Configuration

The implementation fulfilled the requirements on start-up and configuration with the exception that it was not possible to define new data sets in the Tamarack server. This is an implementation issue. IEC 61850/UCA2 supports dynamic creation of new data sets.

2.4.2.2 Security

Due to some limitations in the implementation tests on security issues could not be performed.

2.4.2.3 Functionality

The tests show that the IEC 61850/UCA2 solution supports most of the test cases. Some test cases could not be completely performed due to limitations in the implementation of the Tamarack server.

Dynamic implementation of data sets with a selection of measurements, binary signals and mixed data is not possible to create online by a service. The Tamarack server requires these Data Sets to be defined in the data model. However in accordance IEC 61850 dynamic implementation of data sets are possible. The standard 61850 does have this service.

Regarding reports the tests have shown that the Tamarack server only allows one client at a time to receive a certain report. For instance, if a client retrieves the report Sigward/WBrake$MX no other clients can get the report. This is not what we expected since several clients may want the data at the same time.

Something that was not completely verified during the practical tests was how the server acts on interruptions in the communication, especially regarding notification of events. Investigations show that spontaneous data transfer initiated by the server rely on an established connection to the client. If there is no connection the server must wait for the client to establish a connection to the server, using a modem (or any other communication link). Then a new MMS association must be established before the server can send any event data. The reconnection from the client can be automated but for many applications there is a requirement to only connect when there is need to notify an operator or similar about an event or an alarm.

2.4.2.4 Performance

Practical tests show that for the normal operation there are no performance problems. The DLL runs only when it is called by the application. As a consequence of this DLL-typical behaviour, the server DLL processes incoming and outgoing messages as often as the application calls the server DLL. It is therefore important that the servDLL function is called often enough to avoid to long delays. Tests were conducted both with a LAN connection to the server and with a modem connection. In both cases the transfer of data values are fast enough. However, it takes very long time to get Variable lists and associated attributes, especially with a modem connection but also with a LAN connection. In a real SCADA implementation we expect this initial retrieval of data lists is done only once and stored so that this is not necessary at every connection.

Detailed measurements on performance were not done for transfer of operational data and controls. The responses were “immediate”, i.e. less than a second for single data values, and thus fast enough.

2.4.2.5 Client software

Most tests were conducted with client software from Tamarack but a number of tests were also conducted with the LiveData client. The DDE interface of the LiveData client was then used to set up a DDE link to a Visual Basic program where a couple of data values were displayed and continuously updated. This test was conducted to learn more about the functionality of the client software and to demonstrate the possibility to use DDE.

The Tamarack client is built to support test and demonstration of the MMS server functionality but might not be used for real applications since it has no functions for building an MMI for a wind power plant operator. The tests are conducted by manually connecting to a selected server and then manually initiating MMS service requests to the server in order to get variable lists and data. A separate window is used for selecting reports to subscribe (and unsubscribe) to and to continuously displaying the received reports. The Tamarack client contains no functionality for linking data to other applications and for automatic processing and storage of reports.

2.5 Software packages

Vendors now have integrated ICCP clients but there are yet no clients for IEC 61850.

2.5.1 Tamarack

The Tamarack server has been extended with a log model during this project.

2.5.2 Live Data

The LiveData server supports all UCA2 (and most of IEC 61850) services. The client supports basic services only. LiveData's focus is on servers! The LiveData client provides the possibility to include links in an Excel spreadsheet or to make the connection from a VB object using the reference. The client can be connected to several servers at the same time.

2.5.3 SISCO

The SISCO server supports all CASM (and most of IEC 61850) services including log Model. The client supports all CASM (and most of IEC 61850) services including log Model. The log model is mapped to the MMS Journaling model.

2.6 Experiences

2.6.1 Pros and cons

2.6.1.1 Design alternatives

The decision to choose DLL for the tests was based on the assumption that this was the best solution with regard to implementation efforts/costs (low) given the chosen test object and with regard to performance (reasonable high). Some of the advantages and disadvantages with using DDLs are summarised in Table 2.

In addition to a DLL there are also other alternatives for the implementation. Any communication method available under Windows could be used in principle. At this time a certain number is available for the server code:

- Linking the application and MMS server software together (high performant and most compact solution). Requires that the application is written in C code.
- OPC interface between application and MMS server.

Advantages using DLLs	Disadvantages using DLLs
Requirement to easy integrate data into IEC 61850 compliant server (Gateway/Proxy) Requirement to easy visualise the data at client/master Easy to implement Scaleable and flexible (few data to complex models) Easy to use Applicable on standard OS Any Visual Basic and C application can use DLL Easy to integrate into application Standard IEC 61850/UCA/MMS hidden Easy to migrate from any protocol to 61850 Your data can be communicated in a few days	Performance depends on the request from the application Performance is moderate Not for embedded solutions More powerful integrations are possible with other IPCs (inter process communication) and other platforms.

Table 2: Advantages and disadvantages of the DLL solution

2.6.1.2 MMS server development tools

In this project the development of the test server MMS-implementation (DLL) was purchased from a subcontractor. If you were to do the implementation yourselves the following development tools would we be needed:

- First you need the source code.
- If you want to change the DLL interface you need to enhance the source for the DLL services.
- If you want to change the model (e.g. more data to be communicated) there is a tool (Pre processor) from Tamarack available (Backus Naur based). The modelling is independent of the DLL interface!

Comment: IEC TC 57 Working groups 10, 11 and 12 are defining a configuration language (in XML) for IEC 61850. We therefore expect that the models will be described at a very high (abstract) level. This configuration will then automatically be mapped to the server by a configuration tool. That is what big vendors are now developing for IEC 61850.

2.6.1.3 HMI client

The existing HMI (WPC) client does not support all the functionality of the MMS server. However, if that was the case, a DLL based MMS client could be used. I.e. use existing HMI-client and interface with MMS client software. The interface could be a

DLL containing the MMS client and an "HMI-IPC" in the same way as for the server. Then the existing HMI could be used. However, such a DLL based MMS client is not yet available as far as we know. Other possibilities are http, OPC, OLE.

2.6.1.4 Case: Weather station example

As en example, imagine we want to add a meteorological station as a separate new server. The meteorological station is another PC that may be linked to the MMS server via a second RS 232 link or the LAN. The case would include the following steps:

1. Start with a description of the protocol (lets call it Packet type 05)
2. Implement the VB object for delivering the data to the DLL (a VB program providing Packet type 05)
3. Develop the data model. We could define a second logical device "Weather" that contains the weather logical nodes and data. The implementation would be very straightforward if the model uses the same common data classes: MV, SPS, and if the services meet the requirements: mainly Get, Set, and Reporting.
4. Implement (code, compile and link) the MMS server and IPC (as a DLL)
5. Configure the MMS client and HMI
6. Install and run
7. Test (explore, present, etc)

2.6.2 Summary of results

The IEC 61850/UCA2 solution has shown to meet the functional requirements for wind power plant communication. Thus, specifying a wind power specific interface based on IEC 61850/UCA2 will solve the problem of multiple vendor specific interfaces.

The project has also shown that the interoperability between products from different vendors is very good.

With knowledge in visual basic programming it was quite easy to interface the data source application to the DLL-implementation of the Tamarack MMSd server software. The server is also very easy to install. No specific MMS knowledge was required to install and run the software.

The complete information model and all services have been implemented and tested with the DLL approach. Even though the DLL provides moderate performance due to the basic characteristic of DLLs the implementation meet the performance requirements stated for the project.

The standard IEC 61850 does not specify nor constrain any implementation of the information model, service models, communication stacks, actions, and application program interfaces (APIs).

3 OPC

3.1 Documentation

3.1.1 General

3.1.1.1 Formal reference documents

Reference documents on the OPC interfaces DataAccess 2.0 [12], Alarms & Events 1.0 [13] etc. are available for free for download from www.opcfoundation.org. These documents are the exhaustive and quite readily understood definitions and descriptions of the data models, methods of use and services provided. They mainly comprise data definitions and calling conventions, i.e. subroutine headers with listing of parameters. Besides, brief tutorial introductions are provided.

3.1.1.2 Vendor specific information on products for application development

When developing an actual SCADA system, one will use commercially available software packages; one to make the signals of a process e.g. a wind turbine available in an OPC server and another to utilise the signals in an OPC client. Documentation is vendor specific but typically found in form of readily understood Windows help. When deciding on products to use, useful information of the vendors is found in the Web.

3.1.1.3 Other

In a TCP/IP, MS Windows environment, DCOM [14] set-up is an important aspect to make an OPC-based client-server system run. Documentation is found within MS Windows and at www.microsoft.com.

3.1.2 Results

Little if any documentation is needed to implement a SCADA system based on OPC interface between servers (process) and clients (HMI etc), mainly because OPC DataAccess and Alarms&Events comprise fairly simple, readily understood objects with methods and properties.

When deciding on a strategy for use of the services provided by OPC, it might however be fruitful to skim the reference documents, e.g. when deciding when and how to use other services than those provided by the crude and straightforward DataAccess. The amount of commercially available DataAccess product is large; the somewhat more sophisticated Alarms&Events services is still only efficiently supported by rather few vendors. Hence, important information may be lost if only aiming to find information in brochures and other material of vendor origin.

3.2 Implementation

3.2.1 General

To understand and to implement OPC-communication the developer needs to make himself familiar with the basic concepts of OPC.

The efforts needed to understand and to implement OPC-communication include realising the implications of adopting a MS Windows, TCP/IP, DCOM based environment and platform. Advantages and disadvantages in this respect prevail: Availability, accessibility, developers being familiar with the environment, available hardware etc. Further commenting on this aspect is beyond the scope of this document. Probably, the affinity to the Windows world is a crucial aspect in the decision process on the adoption of OPC.

In the OPC world, there is a tendency to move from DCOM towards XML [15], although not subject to further examination within this project because of the lack of readiness of standards and products.

3.2.2 Information models

To understand and to implement OPC-communication the developer needs to make himself familiar with the hierarchical object models: Groups, branches, tags i.e. signals.

3.2.3 Information exchange services

Different packages of services are defined for OPC. The basic services include the simple DataAccess services for data exchange by the group of tags; read for monitoring, write for issuance of commands. The somewhat more sophisticated Alarms&Events services, provide a condition-subcondition data model, methods for acknowledgement, transparency on user initiated events among several users: tracking events, server-side stored comments related to acking and other. If needed, the other services Historical, Batch etc., not subject to examination within this project

3.2.4 Interfaces

The implementation work includes deciding on products to use for **server** implementation. The typical DataAccess product will provide a database-like interface towards the project, in compliance with the OPC object models where signals of the process are readily stored and retrieved from. Regarding Alarms&Events, protocol converters DataAccess/Alarms&Events are available so that the Alarms&Events specific, additional server side- storage and methods are easily added.

Important aspects when deciding on products to use for **client** implementation include:

- Tools for graphical HMI designs, i.e. symbols with properties such as shape and colour varying at change of data, pushbuttons, menus, hierarchical screens etc.
- Support of both DataAccess and Alarms&Events in the same HMI: Integrated alarm panels, lists etc.

- Availability of an embedded script/programming language such as Microsoft VBA (Visual Basic for Applications), in particular if need for 1) distributed process control with client-side control loop functionality, or 2) code related to client-side procedures such as user access at various levels.
- Availability of interfaces to databases, e.g. the connection/recordset interface of VBA, if aiming to store process history client side, at the top system level.
- Documentation, user friendliness, price, vendor restrictions of use and similar trivial aspects.

3.2.5 Tools

In the Nøjsomhed project, the persons occupied with development of the applications, both server and client, used the approach of hands on directly, without worrying about formal definitions and concepts of OPC. Software packages used were:

- for server purposes: WinTech (WinTech Software Design)
- for client purposes: Genesis (ICONICS) used, BridgeView (National Instruments) also looked at.

The software made clearly all objects, properties and methods directly accessible, easily understood and ready to manipulate by the application developer's interface.

It is expected that other products might turn out to be just as user-friendly.

3.2.6 Communication protocol stack

Regarding DCOM and TCP/IP, i.e. the communications platform, there is some need for skills in network configuration and management and particularly in DCOM set-up. In this project a trial-and-error-approach rather than reading documentation was used during network configuration. Making DCOM work requires many checkboxes to be checked and parameters to be chosen and implications thereof are sometimes deeper buried in Windows functionality than readily understood by the typical, application oriented SCADA engineer. In particular, firewalls and virtual IP addresses may be somewhat cumbersome.

3.2.7 Results

In the project, the use of OPC was a basic decision, not subject to considerations outlined in 3.2.1.

Information exchange services:

1. advantages related to the services and objects being simple: Ease of use and understanding
2. disadvantages related to the services and objects being simple. Almost nothing other than simple data exchange is provided:
3. Security/authentication. Security is basically provided by DCOM set-up of server and client processes with use of Windows login etc., not by OPC. Hence, users will basically have access to all or none of the tags of a server on a network. If there is a need to discriminate efficiently on user access to tags within one server,

workarounds in form of separately developed reduced servers passing parts of the total namespace on are needed. An alternative would be client-side security, however not excluding the possibility of unauthorised browsing and manipulating using other OPC client software than foreseen.

4. Filtering. Filtering is purely project specific, to be implemented client- or server side in code.
5. File transfer, start/stop server computer programmes and other services supported by MMS are not within the scope of OPC but might easily be implemented by other means in a Windows environment.

Other aspects common for most SCADA projects might be mentioned, but no other potential lack was identified within this project.

Regarding the decision on the use of OPC services, the reference documents of www.opcfoundation.org were studied rather carefully. More popular descriptions/tutorials were found in the Web; however, it has been found that turning directly to the basic reference documents is worth the effort. For each family of services, until two types of documents exists: The basic ”custom” i.e. C code interface description and the ”application” interface, i.e. Visual Basic. The ”custom documents” seem to be most exhaustive. One needs to be a little familiar with but not an expert in C programming for Windows to take benefit from them.

The choice of server-side OPC software was basically founded in the ease of access and use in the particular wind turbine controller environment. It supports only DataAccess. To overcome this, a dedicated application for conversion a DataAccess-server into an Alarms&Events one was added.

Basis for the choice of client-side software was a decision of use of all of the said aspects mentioned in 3.2.1. Within one product family (Genesis), tools for all has been found. Only an extensive market analysis has been provided; at least five other vendors might provide similar, mutually compatible and easily accessible products.

3.3 Installation

3.3.1 General

Efforts needed to install and operate OPC communication were in brief:

- <u>Establishing an OPC server</u>: The main effort was the project/turbine controller specific development of code passing data to and from the OPC server software. This required coding at a rather low level, C, XML for server-side network communication between serves and turbine etc.

  The turbines were in advance provided with a common XML based Web server for remote browser access; this software was extended with an OPC add-on. If aiming at an OPC solution from the start rather than adapting to an implemented, proprietary solution, problems might have been less.

The ”back-side” interface of the standard OPC server software was easy to use.

The main challenge has turned out to be a stable and reliable communication between the process and the OPC server. Encountered complications might be expected to prevail no matter which protocol is chosen as the basis for a standard server interface software, being related to proprietary server-side code.

Extending the wind turbine manufacturer’s DataAccess server with an Alarms & Events module implied no obstacles and was accomplished in a few days. This part has worked in a stable and satisfactory manner.

- Developing and configuring an OPC-based HMI has turned out to be an easy task, readily accomplished by an engineer familiar with SCADA user interfaces and general SCADA practice. The complexity is comparable to the design of a Web site using FrontPage, an MS Access database application or the like.

- Establishing communication, DCOM set-up and commissioning. Encountered problems tended more to relate to the implied persons’ lack of experience in IP management and DCOM set-up. After practising, a stable and reliable communications platform has been established.

  However, it is emphasised that the complexity of the test plant is modest: A rather small, closed LAN, remote workstation facilities provided by PCAnywere i.e. client side extension of the PC mouse, screen and keyboard over a telephone line.

  Some experiments on true, OPC-based client access was initiated but never concluded: Activities were initiated on operating a HMI client in a large office LAN, interconnected with the wind farm LAN over a WAN connection. Test servers in the office LAN could be seen and browsed from the wind farm LAN; unfortunately, the wind farm servers were never seen from the office LAN. More work and higher ambitions might have resulted in success.

- Extending the OPC client with database facilities has been easy. An ODBC (Open DataBase Connectivity) interface and Microsoft MS Access database has been established on the client machine and is manipulated by pure user interface configuration without any need for coding. It works stable.

3.3.2 Results

As indicated in 3.3.1, OPC based products have turned out to provide an easy and reliable platform for a SCADA application.

Development, configuration and commissioning have been simple.

Stability, reliability and availability are satisfactory. The only problems have related to proprietary server-side processes.

Major obstacles with affinity to the choice of the OPC/DCOM/TCP-IP-set-up have been:

- Picking suitable products in a rather complex software market with a wide variety of products
- Lack of experience in IP network configuring and DCOM set-up; not so easy but feasible and, once done, it works

This conclusion goes for a rather simple SCADA application with a modest and uniform amount of signals and without any particular complexity such as distributed control functionality.

3.4 Practical tests

3.4.1 General

3.4.1.1 Verification environment

The wind farm to be tested is situated at Nøjsomheds Odde on the island of Lolland in Denmark. It comprises 21 wind turbines, 1 MW, make Bonus Energy A/S commissioned 2001.

Please refer to Figure 4 below:

- In each turbine, one industrial PC performs signal exchange with one common, centrally situated OPC server. The turbine/server communication is proprietary and XML based.
- PPC01: The said central OPC server provides OPC server functionality as a gateway to OPC clients.
- NODKLIENT: One separate OPC client machine provides all client functionality, HMI, database etc.
- Turbines, OPC server and OPC client are within the same LAN.

Remote control is established by PCAnywhere software, providing remote screen, keyboard and mouse over an ISDN modem connection. I.e., the OPC based SCADA system is purely local and LAN based.

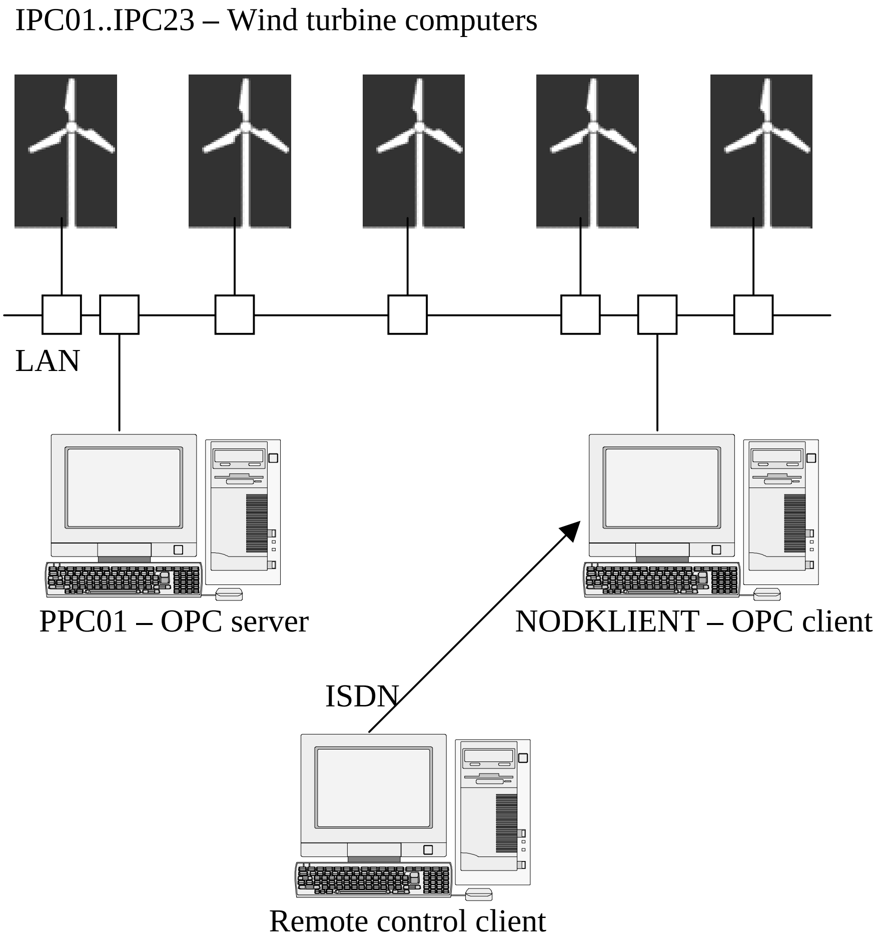

Figure 4: Overview control centre, wind power plants and communication networks.

3.4.1.2 Description of the test system

The test system is mainly identical to the provisions for normal operation. Regarding tests on browsing the server namespace, a product OPC DataSpy, part of the Genesis product family used for the permanent system is used. Furthermore, the DCOM configuration tool in Windows is used for the Security tests. No other dedicated test software has been applied.

By monitoring data values from the OPC server and by changing data values from the OPC client, the reactions in the OPC server and in the OPC client are studied.

3.4.1.3 Test environment

During the test the wind power plant will be in normal operation. The actual data values and alarms on the day of testing will be used in the practical test.

All OPC services such as online read services, logging services, control services and identification of data objects will be in function on the day of testing.

3.4.1.4 Test procedures

The test procedures include four types of test cases:

- Configuration
- Security
- Functionality
- Performance

The test cases corresponds to the four main groups of requirements specified in the report 'Functional requirements on Communication System for Wind Turbine Applications (Elforsk 01:25)'. The cases are documented in Appendix 1 of the document 'Wind Power Communication – Test Specification and Results'.

Configuration includes test cases for connection establishment, identification of objects and attributes and configuration management.

Security includes test cases for authentication of the calling client.

Functionality includes test cases for retrieving online measurements, status information, alarms and binary data as well as test cases for sending control commands and setpoints.

Performance includes test cases based on the functionality test cases.

3.4.2 Results

The following test results were found in the practical tests conducted 05-11-2001 in Nøjsomheds Odde, Denmark.

3.4.2.1 Configuration

The implementation fulfilled the requirements on start-up, configuration and management.

3.4.2.2 Security

The implementation fulfilled the requirements on security. Both the changes in IP-addresses as specified in the requirements but also the OPC specific authentication performed by DCOM configuration were tested.

3.4.2.3 Functionality

The implementation fulfilled most of the requirements on functionality. Online data of analogue and binary nature were monitored in the client. Commands and setpoints were send to the server. Alarms and events were generated and monitored. Trend curves including both real time data and historical data were generated. Transfer of short text messages and file exchange were not tested, as the actual OPC server did not support this.

3.4.2.4 Performance

The performance of the overall system fulfils the requirements. The bottleneck in this system is the update of data values every third second in the OPC server due to a rather low-speed communication from turbine to server. Analogue values, setpoints, binary data, commands and alarms are updated in the OPC client within 0,5 second after the update in the OPC server. The modem tests in the requirements were not performed.

3.4.3 Conclusion

The practical tests shows that the communication between the wind farm and the SCADA control centre fulfils the listed requirements in an acceptable manner.

Both with respect to configuration, security, functionality and performance, the SCADA control centre reacted in a safe, stable and prompt manner.

Some portions of the test programme obviously aimed at demonstrating services and facilities only forming part of MMS, not OPC and where hence not subject to testing the OPC system.

3.5 Software packages

The following software packages were used during the project:

Wind turbines	WPS software package developed for wind turbines from Bonus Energy A/S. XML-based
OPC server	Wintech OPC Server Development Toolkit for development of DA OPC server
OPC client	ICONICS Genesis 32 Enterprise Edition, version 6: • GraphWorX for generation of HMI • AlarmWorX for alarm handling and reporting • TrendWorX for datastoring and reporting • ScriptWorX for scripting
Tools	Tools from ICONICS: • OPC DataSpy for testing and analysing OPC servers • Dr. DCOM for DCOM configuration tests • OPC server simulator for quick test of OPC clients • OPC client simulator for quick test of OPC servers • Universal tag browser for browsing of OPC servers Windows tools: • DCOM configurator for configuration of DCOM

4 Conclusions

The experiences gained in this project are of interest for both owners and suppliers of wind power plants. Normally it is the owner who state the requirements on the solution and the supplier who do the implementation, installation and commissioning of the equipment. The recommendations differ depending on the type of project.

The conclusions focus on the following three important issues regarding the use of communication solutions:

- Product maturity – Are the available products mature enough to be used commercially and do the suppliers provide enough and reliable support for these products?
- Standard – Is the product based on a publicly available standard?
- Acceptance – Will the solution get acceptance and support from the owners, suppliers and developers?

4.1 IEC 61850/UCA based on MMS

4.1.1 The communication software maturity issue

One of the most important conclusions from the project is that the IEC 61850/UCA2 [2][9] solutions meet the needs for communication for wind power plants. Thus, a wind power owner may put down IEC 61850/UCA as a requirement for a wind power plant interface during procurement. But there are some limitations.

The conducted tests within this project must be seen as just experimental tests of the server implementation and the intermediate communication between the server and the client. To complete the chain and to use test installation as a real SCADA application work need to be done on the client/MMI functionality. Then we can state a conclusion whether all wanted functionality is implemented in the server and the client.

For the test system implementation an additional PC that includes the MMS [3][4] server had to be added at the existing wind power plant. This must be considered a temporary solution because the existing wind turbine control systems cannot be extended with this server functionality. The goal for the future is to have the MMS-server implemented by the supplier directly in the control system. There might still however also be a need for MMS servers in separate PC, for example for special solutions for meteorological masts or local historical data storage etc,)

Today the market of development tools is very limited. Only a few small companies have solutions for UCA2 and IEC 61850. The number of people that know the details of the protocols is limited to a few key persons within these companies. This is the situation today but this is expected to change as IEC 61850 come into use.

The possibility for the customer to develop his own server or client software is limited by the fact that the standard is rather complex. Only a few can learn enough about the standard to be able to develop programs. Hopefully this will change in the future as the use of IEC 61850 increases and program modules are available for developers.

4.1.2 Communication standard

This project has been set up to investigate IEC 61850/UCA2.0 as a solution for WPP communication. The discussions presented in this report are based on the assumption that a version of IEC 61850 will be the standard solution for communication with wind power plants. Without a formal standardisation a new solution have difficulties to reach above the critical level as a widely used de facto standard. The suppliers all have their own solutions that they have developed and used for a long time. Recognising the need for a wind power communication standard a new standardisation work has been initiated within IEC TC88 (Wind Turbine Systems).

Many results of this Elforsk project have been used and accepted as major input to the first working draft of the standard with the following title:

WD IEC 61400-25 WIND TURBINE GENERATOR SYSTEMS Part 25: Communications for monitoring and control of wind power plants

The IEC TC88 Project Team 25 (PT 25) has published this first Working Draft (1WD). The working draft can be retrieved from:
http://www.scc-online.de/std/61400/current.html

4.1.3 Acceptance

Good products based on an open publicly available standard have very good chances to get acceptance from the buyers, suppliers and developers. Their acceptance is necessary to reach larger volumes and thereby lower costs. IEC 61850/UCA is a rather new standard that so far has not reached larger volumes.

A big question still remaining is the cost for a SCADA system that supports IEC 61850 and the future IEC61400-25. Such a system must be able to manage existing wind power plants, both with LAN connection and modem connection, as well as new wind power plants delivered with a standard interface already in place.

4.2 OPC

4.2.1 Communication software maturity issue & Acceptance

OPC [12][13] has the following two main advantages:

- The product maturity and acceptance aspects highly tend to favour OPC to a wide extent. Products are easily accessible, readily learned to use and easily implemented. In the demonstration project, no obstacle related directly to products being OPC based.
- Proprietary wind turbine control systems are easily provided with the software overhead needed to make them OPC servers.

A minor drawback is that if strictly requiring compliance with functions and services subject to testing within this project, one will deem OPC to be a little too simple. OPC only aims to communicate status and control data and to facilitate alarm handling, i.e. the basic traditional SCADA services [5].

4.2.2 Communication standard

The major drawback with OPC is that it is not a formal standard. It is a vendor's initiative to ensure compatibility of SCADA software with Microsoft Windows based world of software. Hence, it is hard to envisage OPC to form the basis for a formal standardisation within the framework of an internationally accepted, neutral standardisation body such as IEC, ISO, EN etc. The main driving force behind OPC is Microsoft Windows having become a world wide de-facto standard, users wishing to integrate process data in office applications and developers wishing tools fitting into a Windows environment.

However there is an initiative to develop an OPC interface based on XML [15]. This way OPC will not have to rely on Microsoft DCOM technology [14]. One of the unfortunate things about OPC (DCOM) is it ignores Unix, Linux, Java, and embedded systems. Defining an interface based on XML will enable access from any platform and any language that supports XML, which is almost all of them.

The work has just recently started and there is no publicly available specification of OPC XML. In February 2002 OPC Foundation released Draft version 0.60 of OPC XML-DA. One thing that needs to be investigated is which information exchange methods that can be supported by an XML version. It is expected that OPC XML will be possible to implement directly in the wind turbine control system. The open vendor-independent interface can then be moved from the SCADA to the wind turbine.

4.3 Overall conclusions

Setting up a ”which one is best” –competition between IEC 61850 and OPC is not meaningful.

IEC 61850 does not only include a protocol stack (based on MMS). On top of that it also includes common information models and services. The modelling method of IEC 61850 provides a way to present information in a structure representing data values with common names (and data types) within a given namespace. These information models and services are separated from the underlying protocol stack. See Figure 5. This is an important feature of IEC 61850, which provide the possibility to use various other protocol stacks to exchange the information.

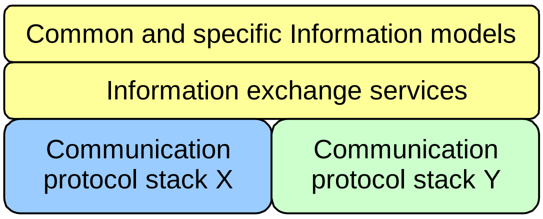

Figure 5. Separation of Information models, Services and Protocol stacks

When comparing MMS with OPC some basic features have to be considered. From a functional point-of-view both concepts provide a uniform way to access and manage monitoring and control data. The test implementations with MMS and OPC both meet most of the requirements stated for the tests, although OPC lacks some features. However, whereas MMS is a protocol that could be implemented in the turbine control systems (embedded solution) for communication with different clients OPC (DCOM) is more of a device driver or an application program interface (API) that typically resides in a SCADA system. The OPC interface was designed as a data-exchange mechanism between programs on the same computer. With OPC the communication interfaces of the wind turbine controllers will still be vendor-specific.

The two solutions may co-exist and could be used a complementary solutions. There are OPC servers available that have a build in IEC 61850/MMS client. This provides the advantages of both: Integration into the higher level SCADA domain with OPC and process information exchange with embedded devices with IEC 61850/MMS.

Regarding product maturity and acceptance OPC definitely has a better position since there are today many OPC products available and it is used by many companies, recently also within the wind power industry.

Looking ahead the standardisation work within IEC TC88 Project Team 25 will solve most of the problems with MMS and OPC presented in this report. Similar to IEC 61850 the future wind power communication standard IEC 61400-25 will use the approach of separating the definition of information and services from the mappings to protocols. Thus, MMS, OPC and many other solutions may be used to access and manage the data.

As described above the present DCOM based version of OPC will not solve the problem of getting a standardised interface to the wind turbine control system. The use of XML for data exchange is here an interesting development. The MMS server product tested in the project provides an XML-interface for reading and writing real-time data and configuration data. The complete information model of the device can be retrieved (via http/XML or MMS) for self-description purpose. And the new OPC-XML solution might be another possible solution to get a vendor-independent interface.

5 References

[1] Bjerge C, et al; ”Functional requirements on Communication System for Wind Turbine Applications”, Report 01:25, Elforsk, Stockholm, June 2001.

[2] IEC TC57, Draft standard “IEC 61850 - Communication networks and systems in substations” – Part 1 to Part 10. For present status see www.iec.ch.

- [2.1] IEC, IEC 61850-5 “Part 5: Communication requirements for functions and device models”
- [2.2] IEC, IEC 61850-7-2 “Part 7-2: Basic communication structure for substations and feeder equipment - Abstract communication service interface (ACSI)”
- [2.3] IEC, IEC 61850-8-1 “Part 8-1: Specific communication service mapping (SCSM) - Mapping to MMS (ISO/IEC 9506 Part 1 and Part 2)”

[3] ISO/IEC 9506-1:1990 Industrial automation systems -- Manufacturing Message Specification -- Part 1: Service definition 1

[4] ISO/IEC 9506-2:1990 Industrial automation systems -- Manufacturing Message Specification -- Part 2: Protocol specification 2

[5] Tamarack Software Overview, <<ARCH.DOC>>

[6] Tamarack Development Environment <<Tools.doc>>

[7] User's Guide to MMSdPREP <<Prep20.doc>>

[8] MMSd Protocol Implementation Conformance Statement <<MMSPICS.doc>>

[9] IEEE “IEEE-SA TR 1550 - IEEE-SA Technical Report on Utility Communications Architecture (UCATM)”, November 1999.

[10] Internet RFC 793 et al., TCP – Transmisson Control Protocol

[11] Internet RFC 791 et al., IP – Internet Protocol

[12] OPC Foundation, “OPC DataAccess 2.0”, 1999, www.opcfoundation.org.

[13] OPC Foundation, “OPC Alarms & Events 1.0”, 1999, www.opcfoundation.org.

[14] Microsoft Corporation, “Distributed Component Object Model (DCOM) ”, http://www.microsoft.com/com/tech/dcom.asp.

[15] W3C- World Wide Web Consortium, “Extensible Markup Language (XML) 1.0”, Feb, 1998, (Second edition Oct 2000), www.w3.org.

Appendices

A Comparison of IEC 60870-5-101/-103/-104 and IEC 60870-6-TASE.2 with IEC 61850

Comparison of IEC 60870-5-101/-103/-104 and IEC 60870-6-TASE.2 with IEC 61850

Edited and drafted by
Karlheinz Schwarz, SCC
schwarz@scc-online.de
www.scc-online.de

1 Objective

Users and vendors of standard compliant power system products ask more frequently why a new International Standard for real-time communication (IEC 61850) will be published soon by IEC TC 57.

The objective of this analysis is to provide a brief comparison of the available standards with the new standard IEC 61850 (see chapter 2 for full titles):

- *IEC 60870-5-101* *Companion standard for basic telecontrol tasks*
- *IEC 60870-5-103* *Companion standard for the informative interface of protection equipment*
- *IEC 60870-5-104* *Network access for IEC 60870-5-101 using standard transport profiles*
- *IEC 60870-6* *Telecontrol equipment and systems - TASE.2*
- *IEC 61850* *Communication networks and systems in substations (UCA™)*

The comparison in chapter 3 shows what the solutions have **in common** and what the **main benefits and advantages** of each solution are. The analysis addresses seven areas of interest:

1. General (Table 1)
2. Process data description (Table 2)
3. Operational services (Table 3)
4. Selfdescription services (Table 4)
5. Online configuration (Table 5)
6. Offline configuration (Table 6)
7. Architecture and communication stacks (Table 7)

Chapter 4 provides a resume.

The analysis is based on the experience and background information of several experts (convenors and other working group members) that are involved in several IEC TC 57 projects and UCA™ for many years. These experts have reviewed this analysis.

IEC 61850 is mainly based on UCA™ (IEEE TR 1550).

2 References

The following documents – among others – have been considered.

- IEC 60870-5-101 Telecontrol equipment and systems - Part 5-101: Transmission protocols - Companion standard for basic telecontrol tasks
- IEC 60870-5-103 Telecontrol equipment and systems - Part 5-103: Transmission protocols - Companion standard for the informative interface of protection equipment
- IEC 60870-5-104 Telecontrol equipment and systems - Part 5-104: Transmission protocols - Network access for IEC 60870-5-101 using standard transport profiles
- IEC 60870-6-503 Telecontrol equipment and systems - Part 6: Telecontrol protocols compatible with ISO standards and ITU-T recommendations - Section 503: TASE.2 Services and protocol
- IEC 60870-6-802 Telecontrol equipment and systems - Part 6: Telecontrol protocols compatible with ISO standards and ITU-T recommendations - Section 802: TASE.2 Object models
- IEC 61850-7-1 Communication networks and systems in substations - Part 7-1: Basic communication structure for substations and feeder equipment - Principles and models
- IEC 61850-7-2 Communication networks and systems in substations - Part 7-2: Basic communication structure for substations and feeder equipment - Abstract communication service interface (ACSI)
- IEC 61850-7-3 Communication networks and systems in substations - Part 7-3: Basic communication structure for substations and feeder equipment - Common data classes
- IEC 61850-7-4 Communication networks and systems in substations - Part 7-4: Basic communication structure for substations and feeder equipment - Compatible logical node and data object addressing
- IEC 61850-8-1 Communication networks and systems in substations - Part 8-1: Specific communication service mapping (SCSM) - Mapping to MMS (ISO/IEC 9506 Part 1 and Part 2)

3 Detailed Analysis

The following tables list the details of the analysis. The yellow fields represent support of a specific feature. The "+" signs indicate a tendency of difference in the quantity : "++" means that this solution provides more (functions, comfort, ...) than the other with "+".

Table 1 General issue

Feature	60870-5-101	60870-5-104	60870-5-103	61850	60870-6-TASE.2
Application domain	**Telecontrol**	**Telecontrol**	**Protection** (informative interface)	**Substation and feeder auto-mation** (open for other domains)	**Control-center to control-center**
Standardisation	**Standard**	**Standard**	**Standard**	**some parts FDIS, other DIS, CDV, CD**	**Standard**
Application specific information models	**A few (3) application specific data** (protection)	**A few (3) application specific data** (protection)	**Some application specific data** (protection)	**some 100 logical nodes**	**some (10) application specific data**
Object-oriented modelling				+	
Common application layer / encoding independent of data definition				+	+
Implementations available	+++	+	+++	+	++
Implementation for embedded devices	+++	+	++	++	+

Feature	60870-5-101	60870-5-104	60870-5-103	61850	60870-6-TASE.2
Market penetration (2000)*	+++	+	+++		+++
Market penetration (2002)*	++	++	++	+	+++
Market penetration (2004)*	+	+	+	+++	++

* estimated

Table 2 Process data description

Feature	60870-5-101	60870-5-104	60870-5-103	61850	60870-6-TASE.2
supported data types	**some fixed**	**some fixed**	**some fixed**	**flexible, easily extentable**	**flexible**
Address/Identification	**Index** (commAddr: 8,16 bits infoObj: 8/16/24 bits)	**Index** (commAddr:16 bits infoObj: 32 bits)	**Index** (commAddr: 8Bits function type: 8 bits infoObj: 8 bits)	**Hierarchical Names** (e.g., AB.E1.Q1 /XCBR4.ST.Pos) **Index for reporting**	**Names** 32/32 characters
Quality	+	+	+	+	+
Timestamp	+	+	+	+	+
Cause of transmission	+	+	+	+	+
> 1 values in one message	**same type** **same COT**	**same type** **same COT**	**same type** **same COT**	**any type** **any reason for inclusion**	**any type**
Semantic of data			**Some** (protection and generic services)	**some 2000 classes** (LN, Data, Data Attr. – for several application domains)	**many**

Feature	60870-5-101	60870-5-104	60870-5-103	61850	60870-6-TASE.2
Selfdescription of data			**limited** (protection and generic services)	**Data name, type, functional characteristic, reporting trigger option, deadband, value range, ... for any data class defined and accessible**	**some**
Open for additional models				**flexible; any new logical node and data class, and common data can be defined for other application areas** (e.g., wind power plants)	

Table 3 Operational services

Feature	60870-5-101	60870-5-104	60870-5-103	61850	60870-6-TASE.2
Cyclic transmission	+	+	+	+	+
Spontaneous transmission	+	+	+	flexible	flexible
Read	single	single	single	many	many
(device) interrogation	+	+	+	+	+
Clock synchronisation	+		+	+	
Control commands	+	+	+	+	+
Exchange integrated totals	+	+	+	+	+
Substitution				+	
Time series data	+	+	+	**any data** (report and logging)	+
Sequence of events	+	+	+	**status data** (report and logging)	
Report data values	+	+	+	**any data** (with filter)	+
Log and retrieve data values (historical)				**any data** (with filter)	
Parameter setting control	**few** (measurands)	**few** (measurands)	**change pre-defined protection setting group only**	**flexible** (define, change, and edit)	

Feature	60870-5-101	60870-5-104	60870-5-103	61850	60870-6-TASE.2
Substation event Exchange (GOOSE, ...)				+	
Sampled value exchange (for CT and VT)				+	
File transfer	+	+	+	+	

Table 4 Selfdescription services

Feature	60870-5-101	60870-5-104	60870-5-103	61850	60870-6-TASE.2
Get Directory of Objects (Names of Data of Logical Node, ...)			**limited** (generic services only)	++	+
Get Definition of operational Objects (Name, Type, range, unit, deadband for reporting, scale, description, ... of process data)			**limited** (generic services only)	++	+
Get Definition of communication service related objects (Report/log control attributes, Control attributes, Setting group attributes, ...)				++	+

Table 5 Online configuration

Feature	60870-5-101	60870-5-104	60870-5-103	61850	60870-6-TASE.2
Define groups of data				+	+
Select data for reporting				+	
Enable/disable communi-cation control objects				+	+
Change reporting/logging behavior				+	

Table 6 Offline configuration

Feature	60870-5-101	60870-5-104	60870-5-103	61850	60870-6-TASE.2
Complete description of device configuration				**XML / XML DTD** (describing the optional information and private information)	

Table 7 Architecture and communication stacks

	60870-5-101	60870-5-104	60870-5-103	61850	60870-6-TASE.2
Data model independent of services				+	+
Services independent of communication networks				+	
Communication system supported	V.24/V.28 or X.24/X.27	TCP/IP over Ethernet 802.3 or X.21	RS 485/Fiber	TCP/IP and OSI over Ethernet 802.3 or X.21serial	TCP/IP and OSI over Ethernet 802.3 or X.21
Routing		IP		IP, OSI NP	IP, OSI NP
Transport protocol		TCP		TCP, OSI TP	TCP, OSI TP
Open for future service systems (CORBA, ...)				+	

4 Resume

The following list gives a brief interpretation of the comparison.

— **All** solutions provide services to exchange the **basic real-time information** (e.g., single point status and control, cyclic and spontaneous reports, interrogation) for SCADA related requirements,

— **One** provides the real-time information exchange for **sampled values** and **trip** commands (61850).

— Most have **fixed functionality** (101, 103, 104, TASE.2), one supports **broad applicability** covering **data modelling, self-description services, configuration service, and advanced communication models and services** (61850),

— Some are **available** in many products and applied all over (101, 103, TASE.2), products are available (104), or **under development** (61850),

— Some use **many main-road technologies** (61850, TASE.2, 104 partly) or use **proven (restricted)** solutions (101, 103, 104 partly),

— **One** will probably become the **preferred IEC solution** within the future seamless Telecontrol Communication Architecture (**61850**), the others will **migrate to 61850** (TC 57 SPAG decision expected in spring 2002).

Additional information:

'Use of the standard IEC 61850 outside the areas of Electrical Utilities'

This article from the same author can be found at:

www.scc-online.de/download/IEC_TC57/UCA-IEC61850_in-non-Utility-areas.zip

Karlheinz Schwarz, M. Sc.
Schwarz Consulting Company, SCC
Im Eichbaeumle 108
D-76139 Karlsruhe
Germany

Phone +49-721-684844
Fax +49-721-679387

Email schwarz@scc-online.de
URL www.scc-online.de
URL www.nettedautomation.com
URL www.dispowergen.com

ELFORSK
SVENSKA ELFÖRETAGENS FORSKNINGS- OCH UTVECKLINGS – ELFORSK – AB
Elforsk AB, 101 53 Stockholm. Besöksadress: Olof Palmes Gata 31
Telefon: 08-677 25 30. Telefax 08-677 25 35
www.elforsk.se