

# Advanced Condition Monitoring of Primary Equipment with the Standard Series IEC 61850 AND IEC 61400-25

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**Abstract— This document gives an overview about the application of the new international standard series IEC 61850 and IEC 61400-25 for condition monitoring of primary equipment and monitoring of any process information. It discusses the basic monitoring concepts of IEC 61850 using the many information models (status information and measurements) and communication services for reporting, logging, GOOSE, sampled values, and recording.**

## I. INTRODUCTION

The focus of the globally well accepted and used Standard series IEC 61850 is the provision of interoperability of intelligent electronic devices (IED) and tools for the automation, control, protection, and configuration of substations. Application domains like wind and hydro power plants and other decentralized energy resources (e.g., combined heat and power) have extended the standard information models and communication mappings provided by IEC 61850. The standard for extended information models for wind turbines has been published early 2007 as IEC 61400-25-2 (model extensions of IEC 61850-7-4 for wind turbines).

Most of the information models of the first edition of IEC 61850-7-4 are related to the operation of the power system. During the recent years people have realized that the standard IEC 61850 provides also the basis for the (condition) monitoring of the primary power system equipment – the crucial assets that need best care and attention. Maintenance and asset management can use the new standardized information such as critical vibration, temperature, oil level, gas density et cetera. Such extensions cover the monitoring of equipment in substations (e.g., switchgear, transformers, on-load tap changers, automatic voltage regulation devices, gas compartments, and lines) and on generation sites (e.g., generators, gearboxes, transmission systems, and towers in wind turbines).

Comprehensive input for the extension of the existing standard series IEC 61850 has been provided recently. IEC TC 88 (wind turbines) standardizes IEC 61850 compliant information models for condition monitoring of wind turbines (IEC 61400-25-6) to cover crucial areas of wind turbines.

Condition monitoring is crucial for any kind of power generation plants – especially for huge (offshore) wind parks due

to the weather conditions that heavily impact the maintenance and repair. Myriads of sensors have been and will be installed all over to monitor the conditions of the foundation, tower, rotors, gearbox, generator to name a few. The virtually unlimited amount of monitoring information needs to be managed and communicated efficiently in a standardized fashion. Currently there is a proliferation of vendor-specific solutions that requires high costs for the management, exchange and integration in multi-vendor systems.

An IEC 61850 compliant system for monitoring a high voltage transformer (380/110 kV) has been successfully installed at a substation at RWE (the second biggest German utility) by end of 2007. The monitoring system uses existing and new information models, client-server communication, GOOSE messaging and sampled value information exchange from conventional current and voltage transformers. The objective of the project is to demonstrate the feasibility of the IEC 61850 process bus for protection, control, and equipment monitoring under real high voltage conditions.

The new extensions seem to be a pivotal point for the future electric power system. This paper presents and discusses efforts related to the international standardization. A solution of a comprehensive monitoring system based on IEC 61850 and IEC 61400-25-6 using off the shelf components will be presented. And the benefits and challenges of condition monitoring using standards will be discussed.

Basic knowledge of the modeling approach of IEC 61850 is recommended to fully understand this paper.

## II. THE BASICS OF MONITORING IN IEC 61850

The part IEC 61850-7-2 (ACSI – Abstract communication service interface) defines the basics for information models and services and part IEC 61850-7-4 (Logical Nodes and Data Objects) defines concrete information models (the Data Objects that represent the values to be monitored). It is crucial to understand that the standards IEC 61850 and IEC 61400-25 do not define new process data – the standards assign useful names and types to real-world data. These names are valid internationally!

The ACSI provides the following basic definitions we need for monitoring:

- Logical Nodes are used as containers of any information (Data Objects) to be monitored,
- Data Objects are used to designate useful information to be monitored,
- Retrieval (polling) of the values of Data Objects (GetDataObjectValues),
- Send events from a server device to a client (spontaneous Reporting),
- Store historical values of Data Objects (logging),
- Exchange sampled values (current, voltages and vibration values),
- Exchange simple status information (GOOSE), and
- Recording functions with COMTRADE files as output.

These basic definitions are explained in the following with regard to the use case “monitoring”.

#### A. Logical Nodes

Many Logical Nodes are explicitly defined to represent a set of Data Objects that relate to measurements like temperature, pressure, level, gas density, etc. Many other logical nodes are a mix of controllable Data Objects, objects for settings, protection, and so on.

An example of a Logical Node comprising only monitoring information is the Logical Node “Circuit breaker wear supervision” (SCBR) of the draft edition 2 of IEC 61850-7-4 is shown in Table I (this and the following Logical Node tables are just showing an excerpt of Data Objects).

TABLE I  
CIRCUIT BREAKER WEAR SUPERVISION LOGICAL NODE (SCBR)

Data object	Description
<i>Status information</i>	
Col1Opn	Open command of trip coil 1
Col2Opn	Open command of trip coil 2 (usually as backup protection coil)
AbrAlm	Contact abrasion alarm
AbrWrn	Contact abrasion warning
<i>Measured values</i>	
AccAbr	Cumulated abrasion coefficients
TripA	Current that was interrupted during last open operation
ActAbrCoef	Abrasion coefficient of last open operation
<i>Settings</i>	
AbrAlmLev	Abrasion coefficient sum threshold for alarm state
AbrWrnLev	Abrasion coefficient sum threshold for warning state

Operating a breaker and especially tripping a short circuit causes always some abrasion (or erosion) of the breaker contacts. The supervision relates to a single phase since each phase has its own contact.

The first seven Data Objects can be used for monitoring purposes; the last two are used for settings limits. The communication services applicable are explained below.

#### B. Data Objects

There are several categories of Data Objects that provide various aspects of the monitoring process:

- Status information (single or double point information),
- Measured information (analogue values measured or calculated, and
- Settings (set ratings or limits for monitoring)

The standards related to IEC 61850 define hundreds of Data Objects of these categories.

Some basic aspects with regard to monitoring are explained in the following paragraphs:

*Status information:* In most cases there is a need to provide several details of the status. IEC 61850-7-3 provides these attributes by, e.g., the common data class SPS (single point status as defined in IEC 61850-7-3):

- stVal BOOLEAN
- q Quality
- t TimeStamp

Any change of the value of the status with the standard name “stVal” can be used to trigger a report (comprising the values for stVal, q and t) to be sent to clients or to trigger to log the values of stVal, q and t to one or multiple logs. It is also possible that a client reads these values (stVal, q and t) at any time to get the values of the last change or the current value.

These values may also be used to be sent as content of a GOOSE messages. GOOSE messages are sent by multicast to any IEDs (Intelligent Electronic Device) connected to the same subnetwork. Even a sampled value message may sent the values (stVal, q and t) continuously with the same rate (e.g. 4 kHz) as the current and voltage samples from CTs and VTs.

Independent of the use of reporting, logging, GOOSE, or sampled value exchange, the data to be exchanged has to be specified by a DataSet. A DataSet contains a list of references to Data Objects and parts of it (the so-called functionally constraint data, FCD, or data attributes, FCDA).

A DataSet may comprise several status information and a few measurements for example.

*Measured values:* IEC 61850-7-3 provides attributes for measured values. The most common class is the common data class MV (measured value) with the following attributes:

- instMag AnalogueValue
- mag AnalogueValue
- range ENUMERATED
- q Quality
- t TimeStamp
- units Unit
- db INT32U
- zeroDb INT32U
- sVC ScaledValueConfig
- rangeC RangeConfig

Any change of the magnitude value (with the standard name “mag”) can be used to trigger a report (of mag, range, q and t) to be sent to clients or to trigger to log these values to one or multiple logs. It is also possible that a client reads these values at any time to get the last change. The values may also be used for other services like GOOSE.

The use of mag (a deadband filtered value) and range in conjunction with reporting and logging is explained below.

The attribute units, db, sVC and rangeC are used to configure the engineering unit (e.g., V for Volt), the multiplier (M for Mega), the deadband value for filtering the analogue value, the scale factor and offset (for integer values) and the range configuration. Those attributes that have an impact on the monitoring of measured value are explained below.

Measurement Data Objects may refer to rms (root mean square) values or just current values, provided at the time when they have been measured. In many applications there is a need to refer also to statistical values of a measurement, e.g.,

maximum value of an hour or 15 minutes interval. The statistical values require some minor extensions of the first edition of IEC 61850-7-x. The standard IEC 61400-25-2 has already published the solution for statistical data.

In many application domains such as wind power plants, it is required to provide additional information of a basic analogue value:

- Statistical information (for example, minimum value calculated for a specified time period, for example, minimum value of last 1 hour)
- Historical statistical information (for example, log of minimum values of the sequence of values calculated above, for example, last 24 hourly values)

This additional information may be derived from the basic analogue values. It may be the only information provided – depending on the application requirements.

The models for the statistical and historical statistical data are explained conceptually in Figure 1.

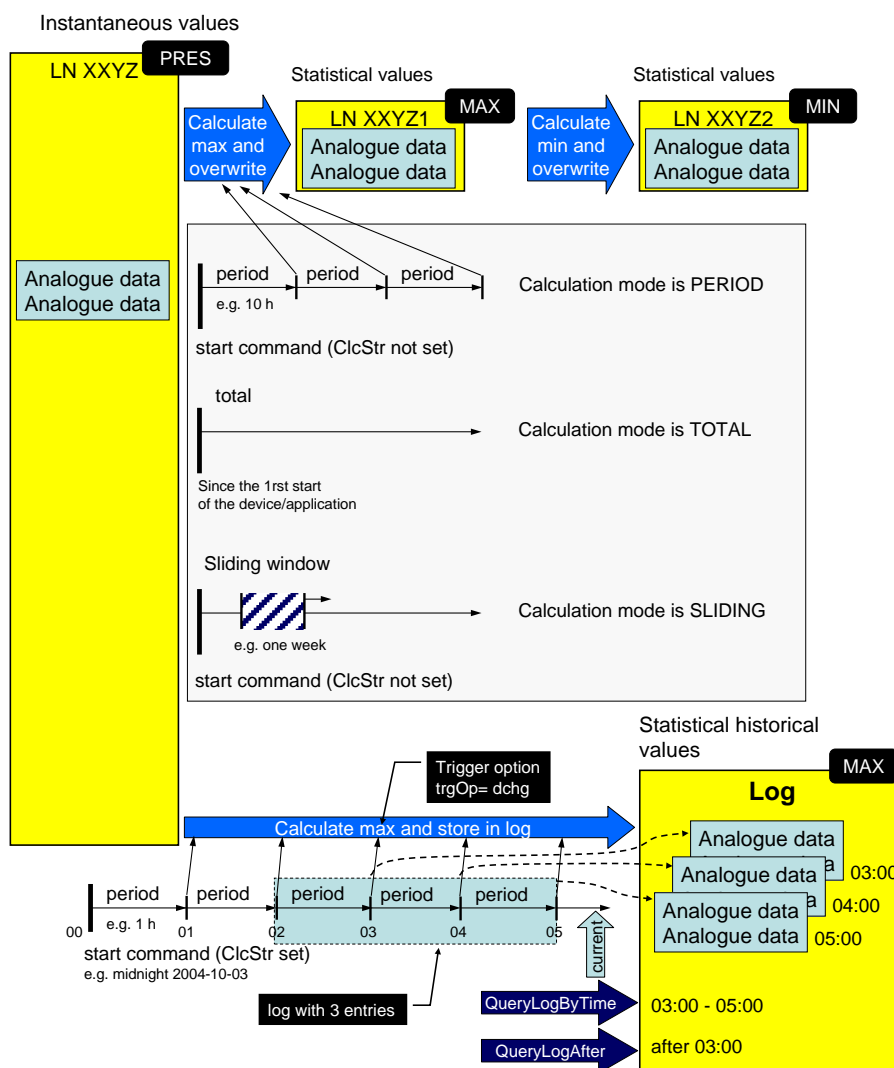


Fig. 1 Statistical and Historical Statistical Data Objects (1)

On the left hand side are the basic data representing the current values (PRES), i.e. some instantaneous analogue (or integer) values that are contained in the logical node instance XXYZ.

The upper half depicts the method defined for statistical values. The first example is the instance XXYZ1 of the logical node class XXYZ. The analogue values represent the calculated maximum values derived from the instance XXYZ. The logical node XXYZ1 has special setting data that indicate that the values are maximum values and that the calculation method is "periodic". The period starts after a start command or by local means. At the end of the period the calculated maximum values of the instance XXYZ1 are overwritten by the new values.

The maximum values can be used to calculate the minimum maximum values in – of course – a much longer period than for the maximum calculation in XXYZ1. The instance XXYZ2 may represent the minimum value of the max value of the last 10 days.

Setting parameters other than PERIOD may be used to specify calculation modes. A calculation mode set to TOTAL means that the calculated maximum values are calculated since the first start of the device or of the involved application. A calculation mode set to SLIDING means that the calculated maximum values are calculated over a sliding window whose width can be set by means of a special interval type setting (e.g. hour, day, week).

The lower part of the figure shows the conceptual model of the historical statistical data. In this model the calculated values (in this case the maximum values with calculation mode set to PERIOD) are stored in sequence in a log. The calculation in the example starts at midnight of 2004-10-03. The interval is 1 h. After that first hour the first log entry is written. After the second hour the second entry contains the value of the second hour. After five (5) hours the log contains the values of the last three hours (intervals 02-03, 03-04, 04-05).

The statistical data model is based on the calculation of analogue values contained in other logical nodes. The top logical node LN XXYZ in Figure 2 refers to three technological logical nodes of the same Type (for example MMXU). The top logical node (LN XXYZ) represents the instantaneous measured values. The second and third logical nodes are the statistical logical nodes, i.e., the logical nodes that represent the calculated values (LN XXYZ1 represents the MIN values, the LN XXYZ2 the MAX values).

The two logical nodes on the left of the bottom in Figure 2 (XXYZ1 and XXYZ2) represent minimum (MIN) and maximum (MAX) values of the analogue data represented in the top logical node (XXYZ). The two logical nodes make use of the setting data ClcSrc (calculation source). The common data class of ClcSrc is ORG, "object reference setting group" and is used to reference the source logical node for the calculation. For both logical nodes, ClcSrc has the value XXYZ. Each logical node with analogue data can be used as a source. Additionally, they have the data ClcStr (calculation start) and ClcExp (calculation expired) and the setting data ClcPerms

(calculation period), ClcSrc (calculation source), and ClcMod (calculation mode).

With the settings ClcMod, ClcMthd, ClcPer and ClcSrc, the behavior of the logical node can be controlled. For periodic calculation, the "event" ClcExp set to TRUE can be used as an event to report the new value (the statistical value) by the report control block or it may be logged as historical statistical data for later retrieval.

The data names of the "Data" in all logical nodes shown in Figure 2 are the same, i.e., in all three logical nodes. The data are contained in different logical node instances (XXYZ, XXYZ1, and XXYZ2). These result in the following references: XXYZ.Data1, XXYZ1.Data1, and XXYZ2.Data1.

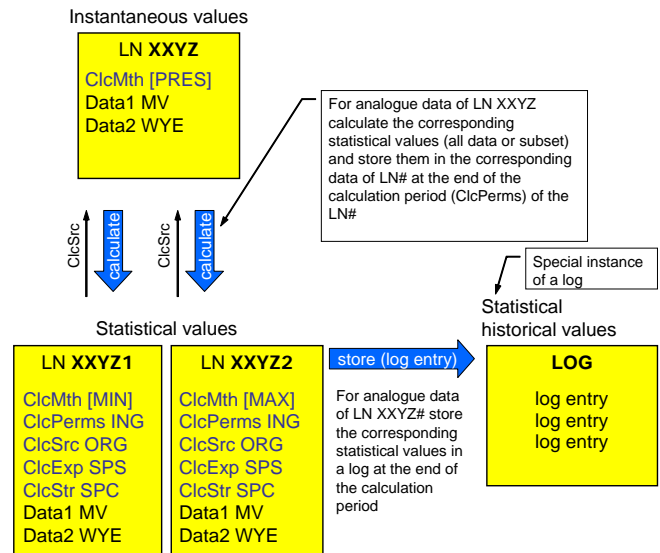


Fig. 2 Statistical and Historical Statistical Data Objects (2)

**Settings:** Setting Data Objects are used to set specific values for limits and other purposes. The purpose is usually defined with the semantic of a Data Object.

In the example of the Logical Node SCBR the two settings are used to monitor when to change status values of the warning AbrWrn and the alarm Data Object AbrAlm. These Data Objects are single point status objects that can be used by the various communication services.

### C. Retrieve (poll) the values of Data Objects

Any Data Object, any part of it and any group of them (optionally through a DataSet) can be read from a client. The corresponding services are GetDataValues and GetDataSetValues.

A DataSet may be defined by the service CreateDataSet (online), during configuration, or it may be built in.

### D. Send events from a server device to a client (spontaneous Reporting)

Reporting is one of the most powerful service models in IEC 61850. It allows to configure the reporting behavior of the server device in a wide range of possibilities.

The basic concept of reporting is that values to be reported are specified by a DataSet object. The DataSet is a list of references to the objects to be reported; each referenced object is

called a member of the DataSet. If a change of a value of one of the members happens the server creates a report message and sends the new value to the corresponding client. The change is also called a trigger – to trigger sending a report.

The trigger options are defined in the Data Objects (in Logical Nodes). There are, for example, two trigger options (data value change and quality value change) defined for each status Data Object derived from the common data class SPS:

SPS (single point status):

- stVal BOOLEAN TrgOp=dchg
- q Quality TrgOp=qchg
- t TimeStamp

The two Data Objects of the Logical Node SCBR (from above) are derived from the common data class SPS:

- AbrAlm Contact abrasion alarm
- AbrWrn Contact abrasion warning

If the cumulated abrasion coefficients AccAbr has reached the value of the AbrWrnLev (as configured by AbrWrnLev - abrasion coefficient sum threshold for warning state) the value of AbrWrn changes and can be reported if the object is a member of the corresponding DataSet.

The principle is explained in figure 3.

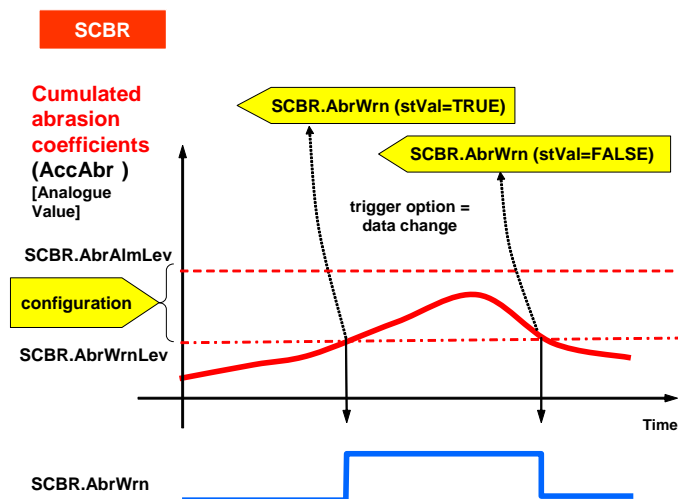


Fig. 3 Monitoring Analog Values

The example has shown that any analog value (measurement or calculated value) can be monitored for limit violations. This approach of defining Data Objects for the analogue value (AccAbr), the limit configurations (AbrWrnLev and AbrAlmLev) and the warning (AbrWrn) and alarm (AbrAlm) is quite often used in the Logical Nodes in edition 2 of IEC 61850-7-4 and in other documents.

The measured value common data class MV contains already some mechanisms to monitor analogue values.

IEC 61850-7-3's common data class MV (measured value) has the following values with regard to reporting:

- mag AnalogueValue TrgOp=dchg
- range ENUMERATED TrgOp=dchg
- q Quality TrgOp=qchg
- t TimeStamp

- db INT32U
- rangeC RangeConfig

The use of the attributes mag and range are shown in figure 4 and figure 5.

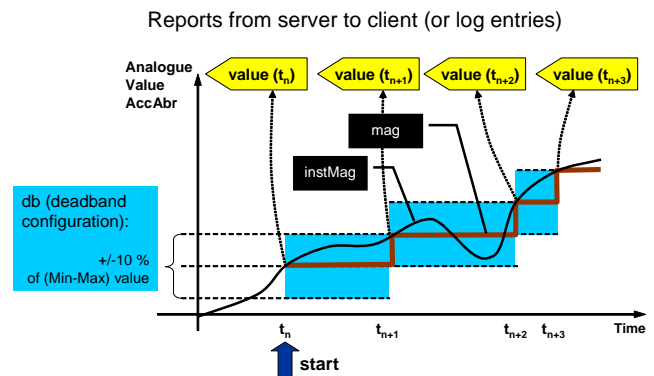


Fig. 4 Deadband Filtering and Reporting (logging)

The analog value AccAbr is monitored for relative changes configured by db (deadband configuration). The deadband configuration specifies a relative change in per cent of the whole value range: Min to Max. In our case the value is 10 per cent. Any change of the value by +/-10 per cent issues a trigger that can be used to report or log the new value.

The deadband configuration value can be configured during engineering, IED configuration, or online with the Set-DataValue service. The smaller the value the more reports may be generated. It is up to the system integrator or operator (later on) to make sure that the whole system is configured in a way that not too many reports are generated. If for thousands of Data Objects the configuration parameter db is very small and the change rate of the values is high then it could happen that the IEDs and the network are flooded. Be aware every-thing is limited!

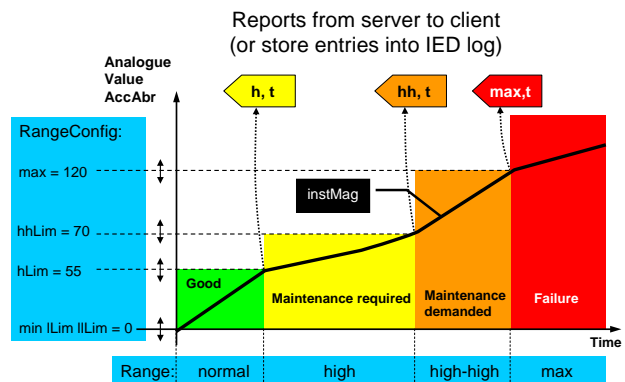


Fig. 5 Range monitoring and reporting (logging)

The range monitoring uses the limits specified by the range configuration values for min, lLim, lLim, hLim, hhLim and max. Each time the analogue value AccAbr crosses one of these

limits a trigger is issued. The triggers can be used to report the analog value with the range value min, low-low, low, normal, high, high-high, and max. In addition to these two values the quality information q and timestamp t can be communicated with the report. Instead or in addition to the report the values may be placed into a log.

The meaning of the range values can be defined by the application. In the example it is defined as good, maintenance required, maintenance demanded, and failure. This approach (which is build-in in each analog value derived from the common data class MV) is different to the approach discussed earlier with the warning and alarm Data Objects and the configuration of the two limits as Data Objects. There is one difference: the Data Objects *AbrAlm* (Contact abrasion alarm) and *AbrWrn* (Contact abrasion warning) represent already a semantic. The two Data Objects can easily be used for GOOSE messaging to trigger an automatic function, e.g. to block operation or to control something in the substation.

A comprehensive modeling approach for monitoring of analog values is expected to be written by IEC TC 57 WG 10. This could be used for modeling monitoring of analog values in future applications.

It is the freedom of the modelers to model the monitoring function one way or the other. All possibilities defined in the various standards today are conformant to IEC 61850 in general.

#### *E. Store historical values of Data Objects (logging)*

The logging of values of members of a DataSet is exactly the same as the reporting – except that the values are stored in a local buffer (the log – a circular buffer) and that clients have to initiate queries to retrieve logged data values.

The query log service is simple and straight forward: A client specifies the log to be queried, a starting time and ending time, a start time, or an ending time. In the first case all values stored between the two times are transmitted, in the second case all values after the start time are provided and in the third case all values before the ending time will be sent to the client.

For different applications it is recommended to think about how to best configure the logging: one log or multiple logs. A DataSet which causes frequent changes that may be logged for a short period (e.g., one day) may use a separate log. Because other Data Objects (not frequently changing) in another DataSet may have to be logged for a year or more. Putting these two streams in one log would cause the low frequent values being overwritten by the high speed values.

Be aware that reporting and especially logging is now migrating from control center SCADA systems down to the IED level. The functions reporting and logging are providing are well known – but usually implemented in SCADA systems; often on top of RTUs (remote terminal units).

#### *F. Exchange sampled values*

The sampled value exchange mechanism has been defined in IEC 61850-7-2 and IEC 61850-9-2 for replacing the many wires carrying analog signals of voltage and current measurements. The samples to be transmitted are defined by a DataSet.

A DataSet may contain analog and any other type of data, e.g., status values.

For the use of sampled value exchange in so-called Merging Units (MU) the UCA IUG (UCA International Users Group) has defined an implementation guide “9-2LE”. This guide provides a set of concrete settings for the DataSet and the control block. The DataSet comprises a fixed set of four currents and four voltages. Two sampling rates are defined: 80 samples/period for protection and 256 samples/period for metering. First Merging Units are available.

The sampled value exchange method can also be used for the high speed transmission of vibration data. Think of a huge hydro power plant with some 50 generators. Each and every set of generator and turbine has a lot of sensors that monitor the turbine, generator, and other components. There is now way to continuously record all samples of vibration sensors. The vibration sensor could trigger a report sent to the maintenance department indicating a warning level. The maintenance people can now start a sampled value control block to send high speed samples from the field up to the office. At the subscriber of the sample stream there could be an analyzing tool that does some online analysis of the sample stream as it arrives. After some time of analysis the publisher may be disabled sending a high frequency stream of samples.

#### *G. Exchange simple status information (GOOSE)*

GOOSE (Generic Object Oriented Substation Event) is used to reliably distribute events very fast in the whole substation (subnetwork). The values to be sent are also specified by a DataSet. The DataSet members may be status information or any other values. After a change of any member of the DataSet the GOOSE message is sent immediately and repeated in a very high frequency. After several repetitions the frequency turns down to a low value (may be every 100 ms). Every 100 ms the receiver (subscriber) can expect new GOOSE message.

If the subscriber does not receive the message after 100 ms, it can expect that the sender (publisher) or the communication network have a serious problem. With that mechanism it is possible to monitor the publisher and communication system continuously. This is not possible in today's wire based exchange of status information.

#### *H. Recording functions with COMTRADE files as output*

The recording functions are defined in IEC 61850-7-4 by a set of Logical Nodes included in the group R – protection related Logical Nodes. They are used to model typical (and well known) recording functions in different devices that have (already!) recording capabilities. The recording mechanisms are NOT defined in IEC 61850.

RDRE is a Logical Node representing the acquisition functions for voltage and current wave forms from the sensors (CTs and VTs), and for position sensors (usually binary inputs). Calculated values such as frequency, power and calculated binary signals can also be recorded. RDRE is used also to define the trigger mode, pre-trigger time, post-trigger time, pre-fault, post-fault, etc. attributes of a disturbance-recording function.

The Logical Node RADR is used to represent a single analog channel, while RBDR is used for the binary channels. Thus the disturbance recording function is modeled as a logical device with as many instances of RADR and RBDR Logical Nodes as there are analog and binary channels of the real recorder function available.

### III. CONDITION MONITORING DATA IN EDITION 2

The edition 2 of IEC 61850-7-4 has many new Logical Nodes and Data Objects that can be used for a variety of monitoring applications.

We have already introduced the Logical Node SCBR for the circuit breaker above. There are mainly the following Logical Nodes that provide a comprehensive list of measured data, status values and configuration data:

- Monitoring and diagnostics for arcs (SARC)
- Circuit breaker wear supervision (SCBR)
- Insulation medium supervision (gas) (SIMG)
- Insulation medium supervision (liquid) (SIML)
- Tap changer Supervision (SLTC)
- Supervision of Operating Mechanism (SOPM)
- Monitoring and diagnostics for partial discharges (SPDC)
- Power Transformer Supervision (SPTR)
- Circuit Switch Supervision (SSWI)
- Temperature supervision (STMP)
- Vibration supervision (SVBR)

Table II shows the list of measured values of the new Logical Node SIML. There are 18 measured values (of common data class MV – inheriting all monitoring methods from deadbanding and range supervision) and more than 10 status Data Objects representing various levels. The levels are not yet configurable by corresponding configuration Data Objects.

TABLE II  
SIML LOGICAL NODE

Data object	Description
<i>Measured values</i>	
Tmp	Insulation liquid temperature
Lev	Insulation liquid level
Pres	Insulation liquid pressure
H2O	Relative saturation of moisture in insulating liquid (in %)
H2OPap	Relative saturation of moisture in insulating paper (in %)
H2OAir	Relative saturation of moisture in air in expansion volume (in %)
H2OTmp	Temperature of insulating liquid at point of H2O measurement
H2ppm	Measurement of Hydrogen (H2 in ppm)
N2ppm	Measurement of N2 in ppm
COppm	Measurement of CO in ppm
CO2ppm	Measurement of CO2 in ppm
CH4ppm	Measurement of CH4 in ppm
C2H2ppm	Measurement of C2H2 in ppm
C2H4ppm	Measurement of C2H4 in ppm

C2H6ppm	Measurement of C2H6 in ppm
O2ppm	Measurement of O2 in ppm
TDCG	Measurement of total dissolved combustable gases (TDCG)
FltGas	Fault gas volume in Buchholz relay

The Power Transformer Supervision Logical Node SPTR represents a couple of Data Objects for measurements and status (see table III).

TABLE III  
SPTR LOGICAL NODE

Data object	Description
<i>Measured values</i>	
AgeRat	Aging rate
BotTmp	Bottom oil temperature
CoreTmp	Core temperature
HPTmpClc	Calculated winding hotspot temperature
<i>Status information</i>	
HPTmpAlm	Winding hotspot temperature alarm
HPTmpOp	Winding hotspot temperature operate
HPTmpTr	Winding hotspot temperature trip
MbrAlm	Leakage supervision alarm of tank conservator membrane
CGAlm	Core ground alarm

Again, as mentioned before: Most of these Data Objects are typed by common data classes SPS and MV. The Data Objects inherit ALL communication services like reporting, logging, GOOSE, sampled value exchange etc. If there is a need for a new Data Object for which the standards do not yet have a definition, it can easily be added to the list of Data Objects. Such new Data Objects are tagged as “EX” (Functional constraint: extended model information).

Due to the fact that the information models in IEC 61850 and IEC 61400-25 are completely independent of the communication services and communication protocols, implementations may add as many Logical Nodes and Data Objects to an IED as they want (as long as the IED has enough memory and processor power). The communication services can be applied to all objects – independent if they are standardized or defined by a vendor or user.

### IV. CONDITION MONITORING DATA FOR WIND TURBINES

Some Data Objects are already defined in the current published standard IEC 61400-25-2. The Logical Node Wind turbine transmission information (WTRM) comprises the Data Objects that represent wind turbine (mechanical) transmission information. The data represent usual transmission topology, consisting of a slow speed shaft, multistage gearbox, a fast shaft and a (hydraulically driven) mechanical brake. In case of a divergent transmission topology (e.g. direct drive, single stage gearbox) or different mounted equipment (e.g. sensors, electromechanical brake), users are free to adapt or extend the data classes. Table IV shows the “regular” Logical Node



WTRM of the standard IEC 61400-25-2 published in January 2007.

TABLE IV  
WTRM LOGICAL NODE

Data object	Description
<i>Status information</i>	
BrkOpMod	Status of shaft brake
LuSt	Status of gearbox lubrication system.
FtrSt	Status of filtration system
CISt	Status of transmission cooling system
HtSt	Status of heating system
OilLevSt	Status of oil level in gearbox sump
OfFltSt	Status of offline filter
InlFltSt	Status of inline filter
<i>Measured values</i>	
TrmTmpShfBrg1	Measured temperature of shaft bearing 1
TrmTmpShfBrg2	Measured temperature of shaft bearing 2
TrmTmpGbxOil	Measured temperature of gearbox oil
TrmTmpShfBrk	Measured temperature of shaft brake (surface)
VibGbx1	Measured gearbox vibration of gearbox 1
VibGbx2	Measured gearbox vibration of gearbox 2
GsLev	Grease level for lubrication of main shaft bearing
GbxOilLev	Oil level in gearbox sump
GbxOilPres	Gear oil pressure
BrkHyPres	Hydraulic pressure for shaft brake
OfFlt	Offline filter contamination
InlFlt	Inline filter contamination

Several other Logical Nodes offer several Data Objects that can be used for monitoring purposes.

The standard IEC 61400-25-6 “Communications for monitoring and control of wind power plants – Logical node classes and data classes for condition monitoring” is intended to provide more sophisticated Data Objects that can be used for higher level diagnosis.

IEC 61400-25 defines information models and information exchange models for monitoring and control of wind power plants. The modeling approach (for information models and information exchange models) of IEC 61400-25-2 and IEC 61400-25-3 uses abstract definitions of classes and services such that the specifications are independent of specific communication protocol stacks, implementations, and operating systems. The mapping of these abstract definitions to specific communication profiles is defined in IEC 61400-25-4. The definitions in parts IEC 61400-25-1 to IEC 61400-25-5 apply also for part 6.

The purpose of part 6 is to define an information model for more specialized condition monitoring information and to define how to use the existing definitions of part IEC 61400-25-2 and to define the required extensions in order to describe and exchange information related to condition monitoring of wind turbines. The models of condition monitoring infor-

mation defined in this standard may represent information provided by sensors or by calculation.

In the context of this standard condition monitoring means a process with the purpose of observing components or structures of a wind turbine or wind power plant for a period of time in order to evaluate the state of the components or structures and any changes to it, in order to detect early signs of impending failure.

Condition monitoring is most frequently used as a Predictive or Condition-Based Maintenance technique (CBM). However, there are other predictive maintenance techniques that can also be used, including the use of the Human Senses (look, listen, feel, smell) or Machine Performance Monitoring techniques. These could be considered to be part of the condition monitoring.

Condition monitoring techniques that generate information to be modeled include, but are not limited to techniques such as:

- Vibration measurements and analysis,
- Oil debris analysis,
- Temperature measurement, and
- Strain gauge measurement.

Components and structures can be monitored by using automatic instrumentation as well as using a manual process.

The condition monitoring functions may be located in different physical devices. Some information may be located in a turbine controller device (TCD) while other information may be located in an additional condition monitoring device (CMD). Various actors may request to ex-change data located in the TCD or CMD. A SCADA device may request the information from a TCD or CMD; a CMD may request information from a TCD and vice versa. The information exchange between any two devices requires the use of information exchange services defined in IEC 61400-25-3 or added in part 6.

The use case of having the condition monitoring functions located in the turbine controller device is a special use case. That use case does not require information exchange services for the information exchange between the condition monitoring functions and the turbine controller functions. The case of having separate devices is the more comprehensive use case. This is used as the typical topology in this part of the standard. The special case of both functions in one device could be derived from the most general use case.

It may also be required to build a hierarchical model of automatic turbine controller and condition monitoring devices/functions. A simple condition monitoring device (CMD; providing measured values and status information and very basic monitoring capabilities). This CMD may retrieve information from the underlying CMD or TCD and may further process and analyze the measured values and status information.

In condition monitoring systems predefined triggers are applied to initiate a sequence of events, for example issuing an alarm to the local SCADA system or sending a message to a monitoring centre in order to prevent further damage on components or structures. In general such messages can be used by a Condition Monitoring Supervision function to generate



actionable information which can be used by a service organization to create work orders and initiate actions. Figure 6 illustrates the information chain of a system using condition monitoring to perform condition based maintenance.

Figure 6 illustrates how data are refined and concentrated through the information chain, ending up with the ultimate goal of condition based maintenance – actions to be performed via issuing work orders to maintenance teams.

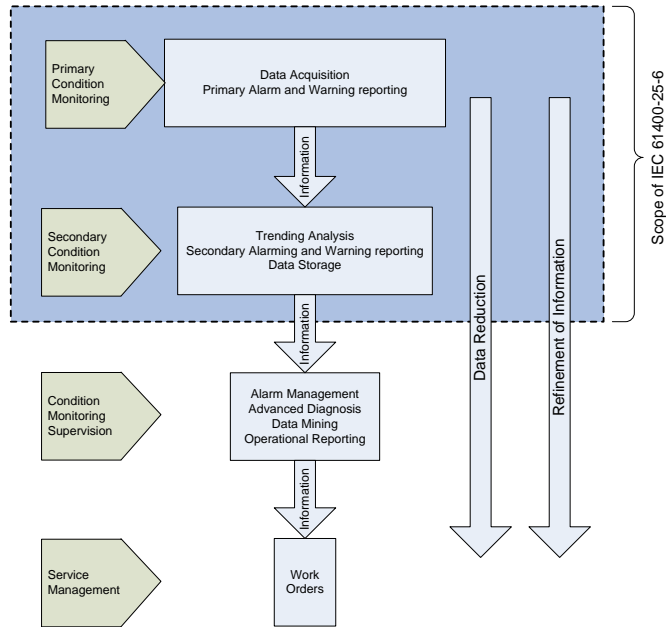


Fig. 6 The information chain of condition based maintenance

Figure 6 shows the scope of IEC 61400-25-6 and the typical information chain of condition monitoring systems. The local (primary) part of the chain could be named as condition monitoring localized in the wind turbine and the wind farm SCADA system, but the local functionality can vary from system to system. The centralized (secondary) data retrieval performed by for example a control centre system is often named as a back-office system. The decreasing sizes of the boxes illustrate the data reduction and the transformation of data into more useful information with an enhanced value.

Table VI shows the gearbox related information.

TABLE V  
GEARBOX RELATED DATA OBJECTS FOR ACCELERATION

Data object	Description
<i>Planetary Stages</i>	
LFRms	Overall Rms, low frequency range (0.1Hz - 10Hz).
HFBP	High Frequency Band pass (1kHz – 10kHz)
TMF	Vibration level at the Tooth Meshing Frequency
2TMF	Vibration level at the 2nd Order Tooth Meshing Frequency
3TMF	Vibration level at the 3rd Order Tooth Mesh-

	ing Frequency
TWF	Time Wave Form
<i>Parallel Stages</i>	
ISORms	Overall Rms according to ISO-10816 standard
HFBP	High Frequency Band pass (1kHz – 10kHz)
TMF	Vibration level at the Tooth Meshing Frequency
2TMF	Vibration level at 2nd Order Tooth Meshing Frequency
3TMF	Vibration level at 3rd Order Tooth Meshing Frequency
1MA	Vibration level at shaft running speed. 1st Order Magnitude
2MA	Vibration level at twice the shaft running speed. 2nd Order Magnitude

The general semantic of Data Objects are depicted in table VII.

TABLE VI  
DATA NAME SEMANTIC

Data object	Description
1MARun	Vibration level at shaft running speed. 1st Order Magnitude
1MA	1st Magnitude
1MASHfRun	Vibration level at shaft running speed. 1st Order Magnitude
1MASHfRot	Vibration level at rotor shaft running speed. 1st Order Magnitude
2MARun	Vibration level at twice the shaft running speed. 2nd Order Magnitude
2MA	2nd Magnitude
2MASHfRun	Vibration level at twice the shaft running speed. 2nd Order Magnitude
2TMF	Vibration level at the 2nd Order Tooth Meshing Frequency
3MA	Vibration level at the blade passing frequency. 3rd Order Magnitude
3TMF	Vibration level at the 3rd Order Tooth Meshing Frequency
HFBP	High Frequency Band pass (1kHz – 10kHz)
HFBP	High Frequency Band pass (1kHz – 10kHz)
ISORms	Overall Rms according to ISO-10816 standard
ISORmsHi	Overall Rms according to the ISO-10816 standard (10Hz -1000Hz)
LFRmsLo	Overall Rms, low frequency range, (0.1Hz - 10Hz)
LFRms	Overall Rms (0.1Hz -10Hz).
TMF	Vibration level at the Tooth Meshing Frequency
TWF	Time Wave Form

The current draft IEC 61400-25-6 (88/316/CDV) is out for comments and ballot until 2008-10-03.



Fig. 7 Transformer T412 in Nehden

## V. THE RWE R&D PROJECT FOR A PROCESS BUS

The RWE Energy AG (second biggest German utility) has launched an Intelligent Switch Bay R&D project to investigate the possibilities of an IEC 61850 compliant Process Bus. The definitions of IEC 61850 go beyond data structures and IED communications (IEC 61850 station bus). They also include Ethernet-based digital transmission of signals from current transformer and voltage transformer (Part IEC 61850-9-2). Merging units capture converter data on the IEC 61850 process bus.

The latest idea is to combine the IEC 61850-9-2 process bus with real time Ethernet, which is a recent development in industrial automation. During the course of this project, RWE plans to stay in close contact with a range of suppliers as it gains experience with process bus communications and interoperability.

Devices underwent lab testing during the course of the project. The project will run until 2009. Devices have already been installed and are running in the substation Nehden (Germany). Following successful completion of the standby operation phase, the devices will be used for live protection and control.

The topology, devices and companies involved are shown in figure 8; the transformer for which the monitoring is discussed is shown in figure 7. With regard to monitoring there is the transformer monitoring IED shown in the red circle.

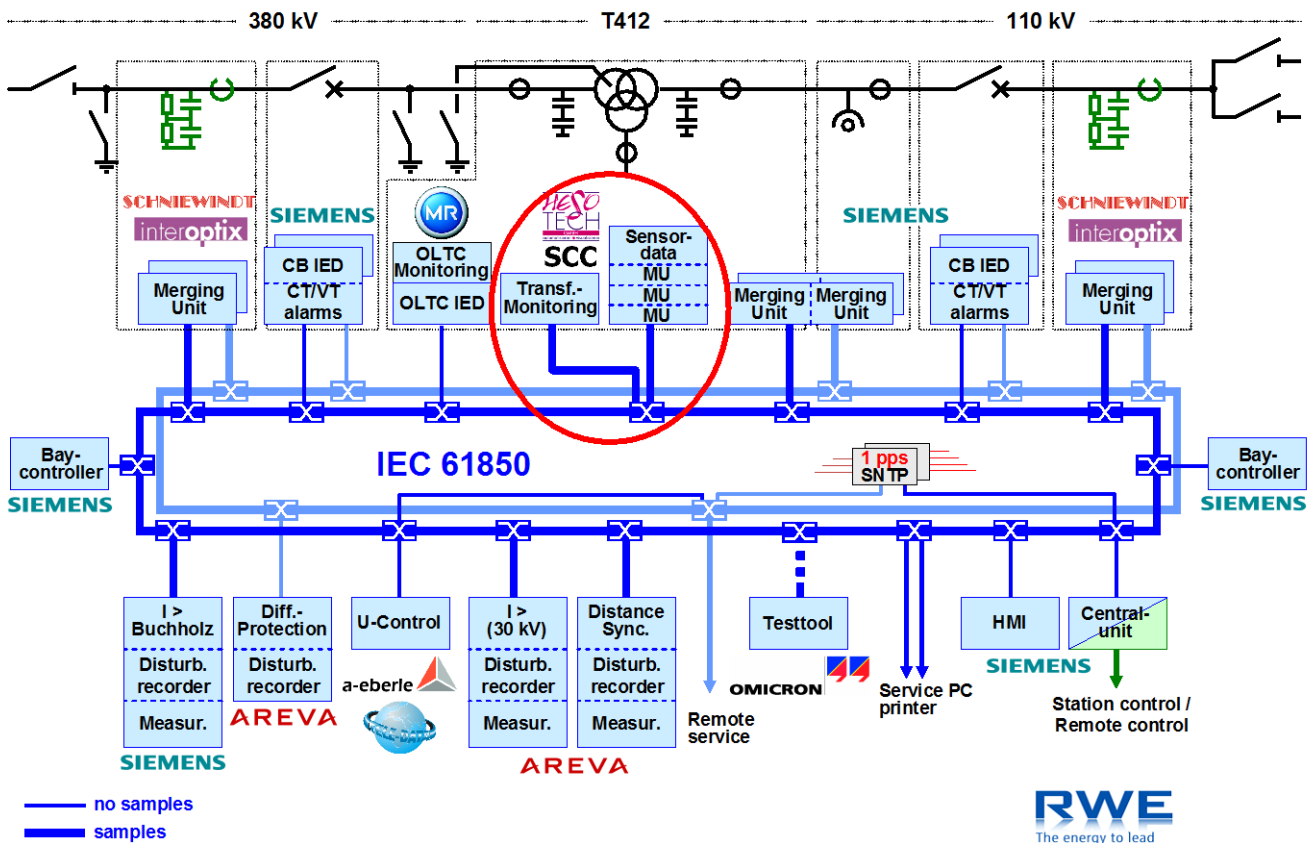


Fig. 8 The information chain of condition based maintenance

The transformer monitoring system comprises the information models shown in figure 9 and figure 11.

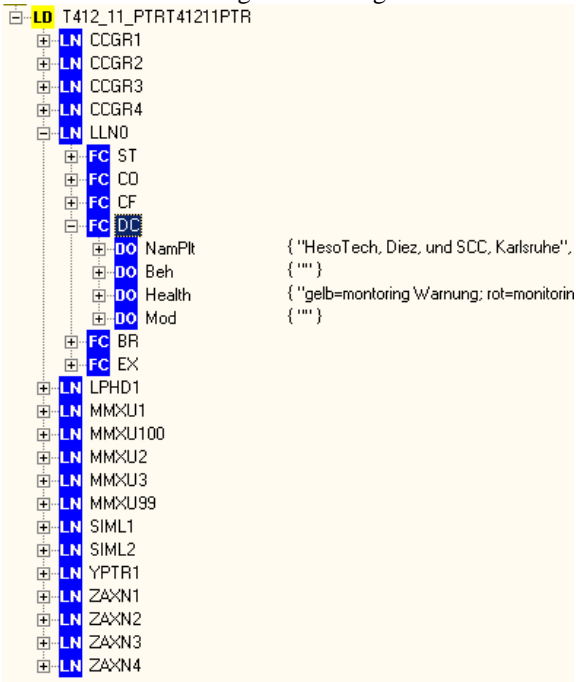


Fig. 9 Transformer monitoring model for RWE R&D project (1)

Details, e.g., implemented in the SIML1 Logical Node are depicted in figure 10.

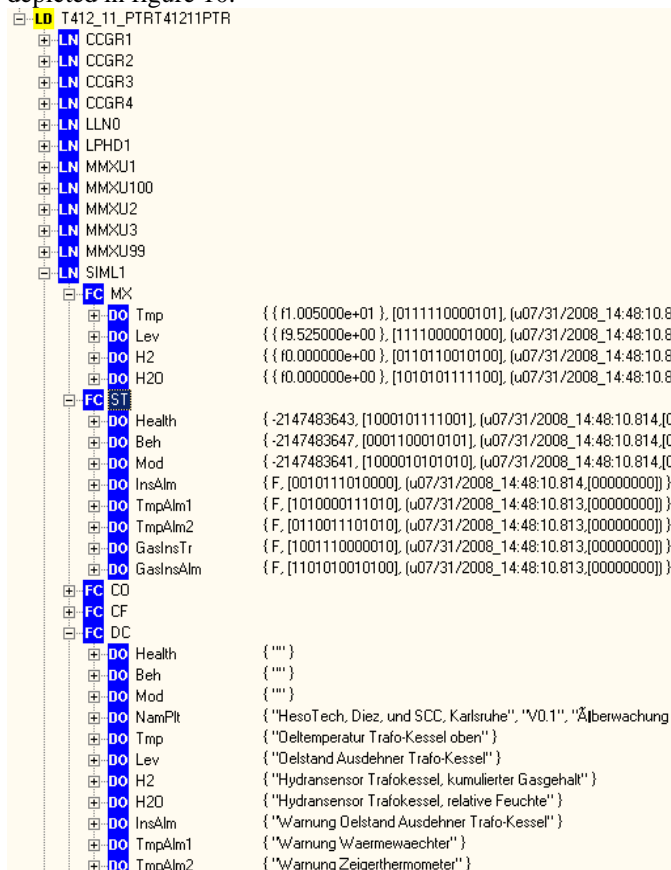


Fig. 10 Transformer monitoring model for RWE R&D project (2)

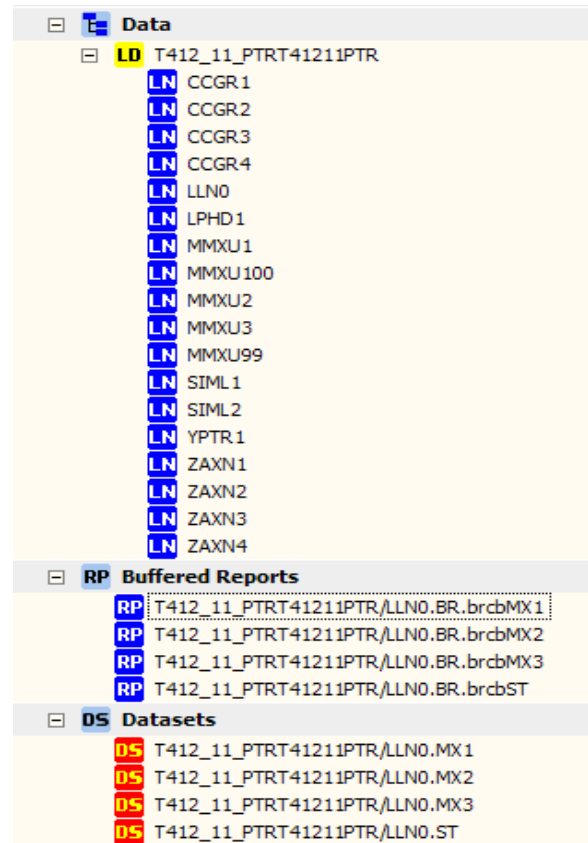


Fig. 11 Transformer monitoring model for RWE R&D project (3)

The Transformer monitoring system is provided by the company HesoTech GmbH ([www.hesotech.com](http://www.hesotech.com)) with the support of SCC. The server for the transformer monitoring and the merging unit for the current and voltage samples of the transformer measurements are implemented in a standard PLC.



Fig. 12 Transformer monitoring and merging unit IEDs

The whole transformer monitoring system is configured through an SCL file defining all needed objects, services, and the binding of the model to the real data of the monitor. The real data values are contained in a database. The binding of the model to the database is accomplished by the so-called sAddr attribute in SCL. The binding is automatically done by an interpreter in the IEC 61850 server software.

```

<IED name="T412_11_PTR" manufacturer="Hesotech" type="PTR-Monitoring for RWE Nehden">
+ <Services>
- <AccessPoint name="HesoTechSCC-IED">
- <Server>
- <Authentication />
- <LD device inst="T41211PTR">
- <LN0 lnType="HSS_LN0" inst="" lnClass="LLN0">
- <DataSet name="ST">
- <FCDA fc="ST" lnClass="LLN0" prefix="" ldInst="T41211PTR" doName="Mod" />
- <FCDA fc="ST" lnClass="LLN0" prefix="" ldInst="T41211PTR" doName="Health" />
</DataSet>
- <DataSet name="MX1">
- <FCDA fc="MX" lnClass="MMXU1" prefix="" ldInst="T41211PTR" doName="TotVar" />
- <FCDA fc="MX" lnClass="MMXU1" prefix="" ldInst="T41211PTR" doName="PhV" />
- <FCDA fc="MX" lnClass="MMXU1" prefix="" ldInst="T41211PTR" doName="A" />
- <FCDA fc="MX" lnClass="MMXU1" prefix="" ldInst="T41211PTR" doName="TotVA" />
- <FCDA fc="MX" lnClass="MMXU1" prefix="" ldInst="T41211PTR" doName="TotPF" />
</DataSet>
+ <DataSet name="MX2">
+ <DataSet name="MX3">
- <ReportControl name="brcbST" dataSet="ST" intgPd="0" buffered="true" bufTime="0"
confRev="1" rptID="">
<TrgOps dchg="true" dupd="true" qchg="true" />
<OptFields dataSet="true" reasonCode="true" seqNum="true" timeStamp="true" />
<RptEnabled />
</ReportControl>
+ <ReportControl name="brcbMX1" dataSet="MX1" intgPd="0" buffered="true" bufTime="0"
confRev="1" rptID="">
+ <ReportControl name="brcbMX2" dataSet="MX2" intgPd="0" buffered="true" bufTime="0"
confRev="1" rptID="">
+ <ReportControl name="brcbMX3" dataSet="MX3" intgPd="0" buffered="true" bufTime="0"
confRev="1" rptID="">
- <DOI desc="Mode" name="Mod">
- <DAI name="ctlModel" valKind="RO">
- <Val>direct-with-normal-security</Val>
</DAI>
</DOI>
<DOI desc="Behaviour" name="Beh" />
<DOI desc="Health" name="Health">
- <DAI name="d">
- <Val>gelb=monitoring Warnung; rot=monitoring Stoerung</Val>
</DAI>
</DOI>

```

Fig. 13 Transformer monitoring model SCL File

Once the pilot project is fully functional and protecting, controlling, and monitoring the substation it may be the first time where a comprehensive process bus is installed and operating.

## VI. CONCLUSIONS

In highly automated substations and power plants, almost no limitations exist with regard to make the information from the process (status values, measurements, events on limit violations, any monitoring data) available to any entity that needs the information for controlling, monitoring, service, diagnosis, network analyzing, testing, or asset management. The acquisition of any needed process information increases the stability of the system because any failure or trend that may lead to a failure can be made visible.

The electric power delivery system is using IEC 61850, IEC 61400-25, and its extensions in substations, in power quality monitoring applications, for the control and monitoring of wind power plants, control and monitoring of distributed energy resources (DER), and the control and monitoring of hydro power plants.

The condition monitoring possibilities rely on four aspects:

- Standard Data Objects for values to be monitored,
- Standard communication services,
- Fast and reliable communication protocols, and
- Standard configuration language to specify or document the huge amount of information

IEC 61850 and IEC 61850 provide already today a rich set of the first three and a comprehensive XML schema for the system configuration.

It is very likely that especially the monitoring applications will be the focus for the next couple of years. Protection and automation of substations is well understood, implemented and used. Many physical aspects are not yet sensed by advanced or even simple sensors.

The standards are ready to include more and more condition monitoring Data Objects.

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