ON-LINE CONDITION MONITORING AND EXPERT SYSTEM FOR POWER TRANSFORMERS - INTEGRATION INTO PROTECTION AND CONTROL SYSTEM BY USING OF IEC 61850

Bartlomiej DOLATA
Alstom Grid – Germany
bartlomiej.dolata@alstom.com

Lutz WAGNER
Alstom Grid – Germany
lutz.wagner@alstom.com

ABSTRACT

The IEC 61850 series of standards for communication in substations has become widespread due to the large worldwide acceptance. The main advantage of the new standard is the interoperability between process control and other equipment in electrical substations. This means that multiple electronic devices can communicate and share information, without detailed knowledge of the equipment or protocols. Based on the standard IEC 61850 a comprehensive modelling of power transformers including advanced on-line monitoring functions is defined and the implementation into the protection and control system is possible.

INTRODUCTION

A power transformer consists of several components, e.g. transformer tank with active part and oil-paper insulation, conservator, cooling system, on-load tap changer and oil impregnated bushings. These components can be fitted with various sensors, which are integrated into the on-line condition monitoring and expert system by means of analogue or digital signals and different protocols e.g. IEC 60870-5-101/104, Modbus, DNP3. The sensor outputs are stored, analysed by means of implemented models and recorded in the IED of the on-line condition monitoring and expert system.

ON-LINE CONDITION MONITORING AND EXPERT SYSTEM

A comprehensive and interactive on-line transformer condition monitoring system integrates all relevant main components of the power transformer within only one system (Fig.1). The database and all algorithms are located on only one IED. Thereby a correlation of all data of the transformer or even of several transformers is possible. The interpretation of the data delivers health information about the transformer and all of its components. The expert system and its diagnosis functions support the user in making right decisions regarding foresighted operation and maintenance of the power transformer.

The concept of the comprehensive on-line monitoring system is based on field bus and process control technology [1], [2]. This approach gives highest flexibility concerning system architecture. This concept allows monitoring of several transformers with only one server. The analogue signals from the sensors are connected to the bus terminals inside the monitoring cubicle at the transformer. The analogue signals are digitalized and transferred to the server via field bus.

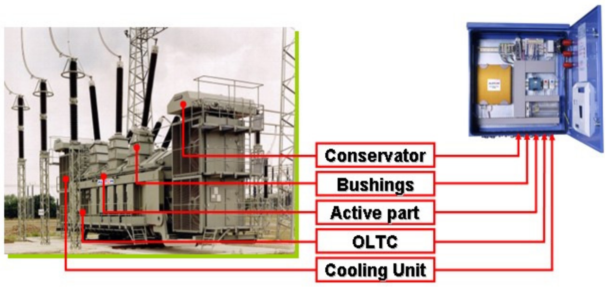


Fig. 1: Main components of power transformer

The Fig. 2 shows the principal architecture of the Alstom MS 3000 comprehensive and interactive condition monitoring system. There are different possibilities for the external communication. It is possible to dial into the system from outside via telephone line. The IED does not only contain the MS 3000 database and models, but acts also as a Web Server, which makes it possible to visualize the MS 3000 system via Ethernet connection in the substation. The server is an Intelligent Electronic Device with flash memory and fan less design and therefore has an extended lifetime. Because of its robustness it can be located in the cubicle at the transformer as well as in the control room or relay room in the substation. Calculation values are derived from the on-line data. The acquisition of the data is time- and event- driven.

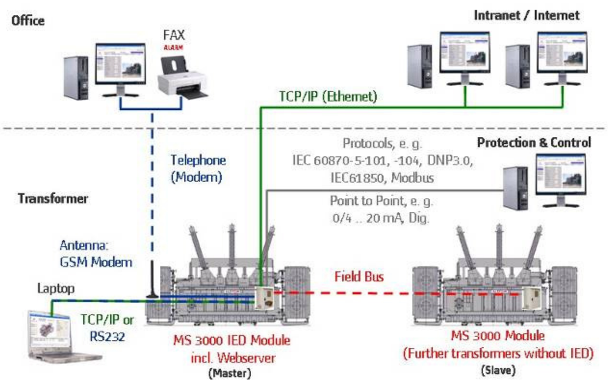


Fig. 2: Principal architecture of the MS 3000 comprehensive and interactive condition monitoring system for power transformers

IMPLEMENTATION INTO PROTECTION AND CONTROL SYSTEM

The implementation of on-line condition monitoring data into the protection and control system can be realized in several stages.

The first implementations were based on the transfer of analogue current signals and potential free contacts into the control system. Setting up system configurations required a substantial effort both on the side of the monitoring system as well as on the side of the control system. The advantage is that also control systems of older design offer the possibility of such data transfer.

The second possibility of data implementation into the control system uses various standardized protocols such as IEC 60870-5-104, IEC 60870-5-101, Modbus and others. Again, the implementation was connected on both sides with customizations and configurations effort. The testing of the functionality was usually also significant, as the rather extensive tests could take place only at site in the substation [3].

Today the communication with protection and control system into substation is based usually on the IEC 61850 standards.

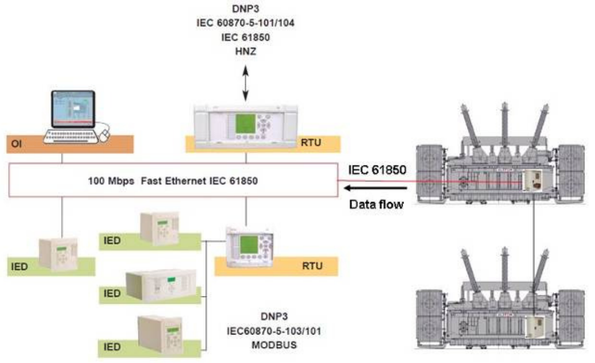


Fig. 3: Implementation of the MS 3000 on/line monitoring system into protection and control system via IEC 61850

The protocol uses TCP/IP as the basic transmission protocol. The monitoring data transmission can be realized as redundant ring architecture by means of 100Mbps fast Ethernet. Fig. 3 shows the implementation of MS 3000 on/line condition and monitoring into protection and control network. The IEC 61850 protocol allows easier implementation of on-line transformer monitoring data into the protection and control system and comprehensive modelling of high voltage equipment in the substation.

The IEC 61850 communication standard has become widespread due to the large worldwide acceptance and many practical experiences. The DKE AK 952.0.2 is involved in definition and optimization of the first edition of IEC 61850 standard in order to provide complete solution for the using in substation automation system. Today the AK 952.0.2 engages in preparation of second edition of IEC 61850 standard, the draft is already available [4].

IEC61850 DATA MODEL

The data structure of the IEC 61850 consists generally of five basic levels of hierarchy. Fig. 4 illustrates the basically coherences of the IEC 61850 data model.

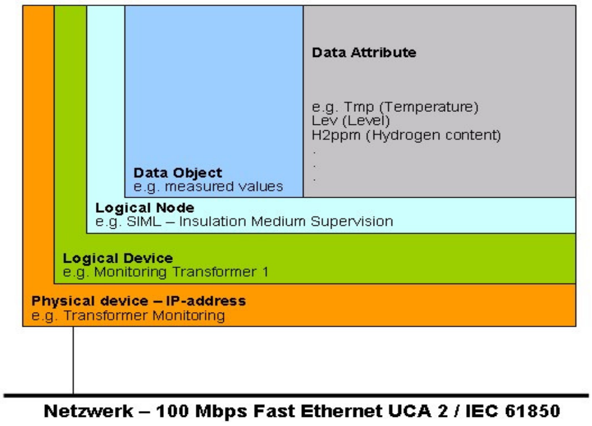


Fig. 4: Data model according to IEC 61850 standard [3]

PHISICAL DEVICE

A physical device (server) is in the top of the hierarchy. The server provides the communication function and has a connection point to the communications system.

LOGICAL DEVICE

In the second hierarchical level, logical device, a physical device is subdivided into multiple, separate logical units e.g. to separate different logical functions of a device from each other.

LOGICAL NODE

The third hierarchy level is the so-called logical nodes. They represent information of all kinds of functions that may be present in the digital substation automation. They are defined in the standard and always consist of a four-letter abbreviation. Fig. 5 illustrates example of logical node SIML (Insulation medium supervision) for transformers.

DATA OBJECT

The fourth level of the hierarchy is the data object corresponding to the logical nodes. There are data objects that are compulsory (mandatory) and must be included in an instance of the logical node and those that must be present only under certain conditions (conditional). The names of the data objects are defined in the standard and consist of acronyms of different lengths.

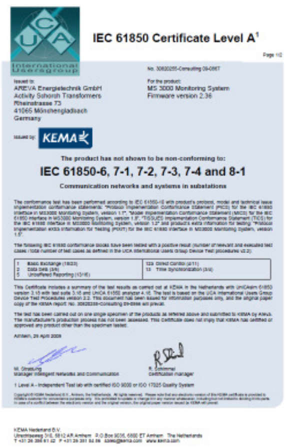
DATA ATTRIBUTES

The fifth and lowest level of the hierarchy is the level of data attributes. They provide detailed information or values such as calculation or measured values of data objects.

SIML class				
Attribute Name	Attr. Type	Explanation	T	M/O
LNName		Shall be inherited from Logical-Node Class (see IEC 61850-7-2)		
Data				
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class		M
EEHealth	INS	External equipment health		O
EEName	DPL	External equipment name plate		O
Measured values				
Tmp	MV	Insulation liquid temperature		O
Lev	MV	Insulation liquid level		O
Pres	MV	Insulation liquid pressure		O
H2O	MV	Relative saturation of moisture in insulating liquid (in %)		O
H2OTmp	MV	Temperature of insulating liquid at point of H2O measurement		O
H2	MV	Measurement of Hydrogen (H_2 in ppm)		O
Status Information				
InsAlm	SPS	Insulation liquid critical (refill isolation medium)		M
InsBlk	SPS	Insulation liquid not safe (block device operation)		O
InsTr	SPS	Insulation liquid dangerous (trip for device isolation)		O
TmpAlm	SPS	Insulation liquid temperature alarm		C
PresTr	SPS	Insulation liquid pressure trip		C
PresAlm	SPS	Insulation liquid pressure alarm		C
GasInsAlm	SPS	Gas in insulation liquid alarm (may be used for Buchholz alarm)		O
GasInsTr	SPS	Gas in insulation liquid trip (may be used for Buchholz trip)		O
GasFlwTr	SPS	Insulation liquid flow trip because of gas (may be used for Buchholz trip)		O
InsLevMax	SPS	Insulation liquid level maximum		O
InsLevMin	SPS	Insulation liquid level minimum		O
H2Alm	SPS	H2 alarm		O
MstAlm	SPS	Moisture sensor alarm		O

Fig. 5: Logical nodes SIML according to IEC 61850-7-4 [5]

The IEC 61850 functionality of MS 3000 on-line condition and expert system for power transformer is certified by KEMA. The certificate is depicted in Fig. 6.


IEC 61850 Certificate Level A[1]

Issued to:
AREVA Energietechnik GmbH
Activity Schorch Transformers
Rheinstrasse 73
41065 Mönchengladbach
Germany

For the product:
MS 3000 Monitoring System
Firmware version 2.36

Issued by: KEMA

The product has not shown to be non-conforming to:

IEC 61850-6, 7-1, 7-2, 7-3, 7-4 and 8-1

Communication networks and systems in substations

Fig. 6: MS 3000 IEC 61850 KEMA certificate

IEC 61850 POWER TRANSFORMER MODEL

In on-line monitoring for power transformer the single data points will be mapped into the data model according to the IEC 61850.

The model for power transformer consists essentially of the following logical nodes:

- YPTR Power Transformer
- SPTR Power Transformer Supervision
- SIML Insulation Medium Supervision
- CCGR Cooling Group Control
- MMXU Measurement
- ZBSH Bushing
- SPDC Monitoring and Diagnostics for Partial Discharges
- YLTC Tap Changer
- SLTC Load Tap Changer Supervision

The logical nodes represent information of monitored data and are defined according to IEC 61850-7-4. For example, the oil temperature, oil level and DGA values can be found in the logical node SIML, the calculated hot spot temperature of transformer in the logical node SPTR and oil temperatures of cooling circuit in the logical node CCGR. The measurement values of current or voltage transducer are mapped in the logical node MMXU. The logical node ZBSH includes information about the bushings. The information about partial discharges is provided in the logical node SPDC. Compared to the previous version, the second edition is supplemented of logical nodes SPTR and SLTC to expand the monitoring of transformers and a tap changer.

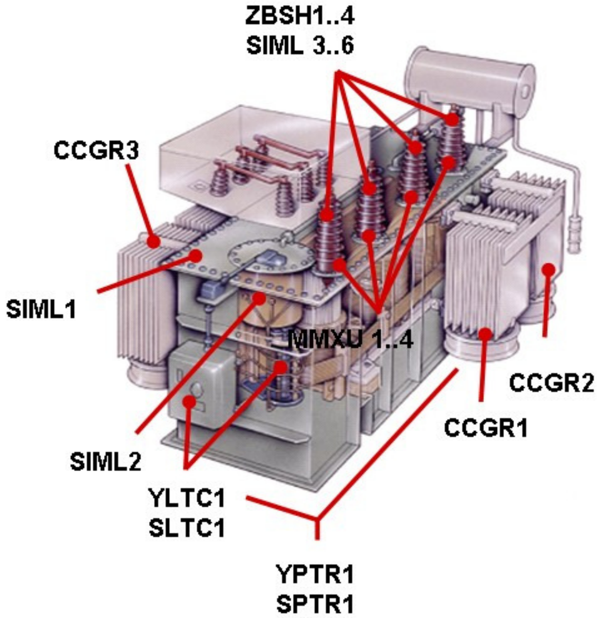


Fig. 7: Logical nodes for power transformer according to IEC 61850 data model

According to the standard the data model can be described by means of an ICD file (**I**ED **C**apability **D**escription). The ICD file comprises customer specified data provided by on-line monitoring system. The created ICD file has to be installed on the MS 3000 server and can be used to pass the available information of the MS 3000 on-line monitoring system to the IEC 61850 server in the protection and control system of a substation.

Such solution of implementation of IEC 61850 protocol communication in a substation is already successful realised in various projects. Fig. 8 shows a visualisation platform used in control and protection system for 315MVA and 800MVA transformers and 60MVAR shunt reactors (Fig. 9) equipped with MS 3000 on-line condition monitoring and expert system. The following monitoring data can be provided by means of the IEC 61850:

- Transformer status
- Ambient, top oil and hot spot temperatures
- Loading
- Water content in oil
- Moisture of insulation paper
- Ageing rate
- Oil level – Main tank
- Oil level – OLTC
- OLTC position and number of operation
- Gas in oil content (DGA)

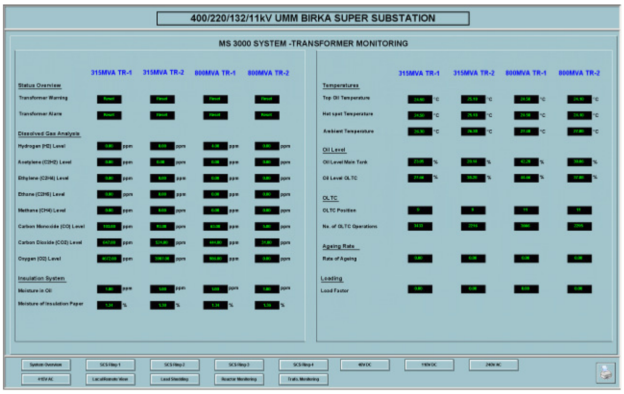


Fig. 8: Control and protection system visualisation platform by using of IEC 61850 for transformers

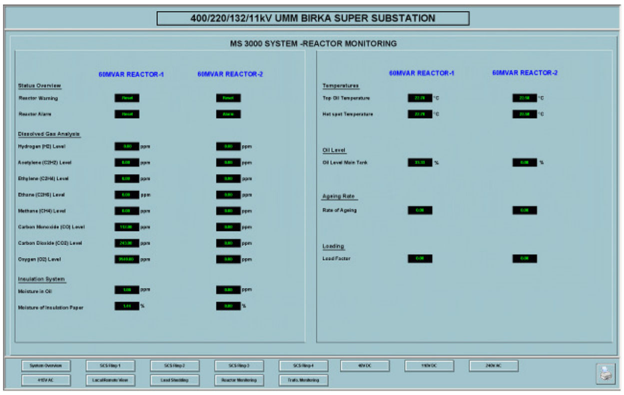


Fig. 9: Control and protection system visualisation platform by using of IEC 61850 for shunt reactors

CONCLUSIONS

The MS 3000 comprehensive and interactive on-line monitoring for power transformers leads to early recognition of incipient faults and to a much better knowledge of the transformer condition.

Its user interface is based on Web technology and allows a quick and accurate overview of the transformers. The modern on-line transformer condition monitoring and expert system provides central data storage (IED incl. WEB server) and visualisation of acquired and analysed data for all transformers of the substation.

By integration of on-line condition monitoring and expert system into substation protection and control system by means of IEC 61850 an additional visualisation platform of selected information available within the logical nodes can be performed.

Based on the standard IEC 61850 a comprehensive modelling of power transformers including advanced on-line monitoring functions is defined and the implementation into the protection and control system is possible.

Thus using of on-line condition monitoring and expert systems and IEC 61850 protocol communication allows a safer, more reliable and optimized operation of the power transformers.

REFERENCES

[1] T. Stirl, R. Skrzypek, S. Tenbohlen and R. Vilaithong, 2006, "On-line condition monitoring and diagnosis for power transformers their bushings, tap changer and insulation system", *CMD2006 Conference*, Changwong, Korea

[2] T. Stirl et al., 2006, "Umfassendes On-line Monitoring – Praktische Betriebserfahrungen", *Stuttgarter Hochspannungssymposium*

[3] M. Rösner, R. Skrzypek, T. Stirl, 2008, "Praxiserfahrung mit IEC 61850 – Einbindung des Transformator Monitoringsystems MS 3000 in die Leittechnik", *Stuttgarter Hochspannungssymposium*

[4] DKE Arbeitskreis 952.2.0, 2008, "IEC 61850 für die prozessnahe Kommunikation in Schaltanlagen", *ew,*Jg. 107, Heft 25-26, 72-77.

[5] International Standard, First Edition 2003-05, "IEC 61850-7-4 Communication networks and systems in substations - Basic communication structure for substation and feeder equipment - Compatible logical node classes and data classes"