THE ROLE OF IEC 61850 REPORTING IN FAULTS AND DISTURBANCES ANALYSIS

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INTRODUCTION

The August 2003 blackout in the North-East and the European disturbance in 2006 demonstrated that the analysis of different electric power system events is a very important and extremely complex process. It is required in order to determine the cause of the abnormal system condition, to speed-up the restoration of the affected parts of the system, and to evaluate the performance of different protection and control systems. System events and the effect they have on deviations of the supply voltage may result in failure of sensitive equipment with significant economical impact. To better understand the effects of different parameters of the power supplied to sensitive customers, it is necessary to provide engineers with the right tools to allow them to establish the correlation between the combination of certain attributes of the power and the failure of equipment.

The integration of multifunctional intelligent electronic devices (IEDs) from different manufacturers in substation protection, automation and control systems requires a significant effort due to the different formats of the data available from these devices. Measurements, status, event, disturbance, maintenance or configuration data is used at different times by different applications.

One common format that can be used for analysis of event data is IEC 61850. The paper discusses the requirements of fault and disturbance analysis and introduces the IEC 61850 reporting model and how it can be used for analysis purposes.

FAULT AND DISTURBANCE ANALYSIS

The experience from the analysis of wide area disturbances and blackouts shows that they are never the result of a single event, but a sequence of events that may occur over a period of time and involving the operation of protection devices at different stages of the event. That is why the analysis of protective relays operations is one of the main components of fault and disturbance analysis.

The analysis of protective relays operation is based on the different reporting functions in these IEDs. They include:

- Event reports
- Fault records
- Waveform records

In many cases the fault records are included in the event report.

At the same time in order to determine if the relay operated as expected, it is necessary to know what exactly the relay settings at the time of operation were.

The fault location and the distribution of the fault currents and their magnitude at the time of a short circuit fault also have an impact on the operation of protection devices. That is why the analysis needs to consider the electric power system and substation topology at the time of the event.

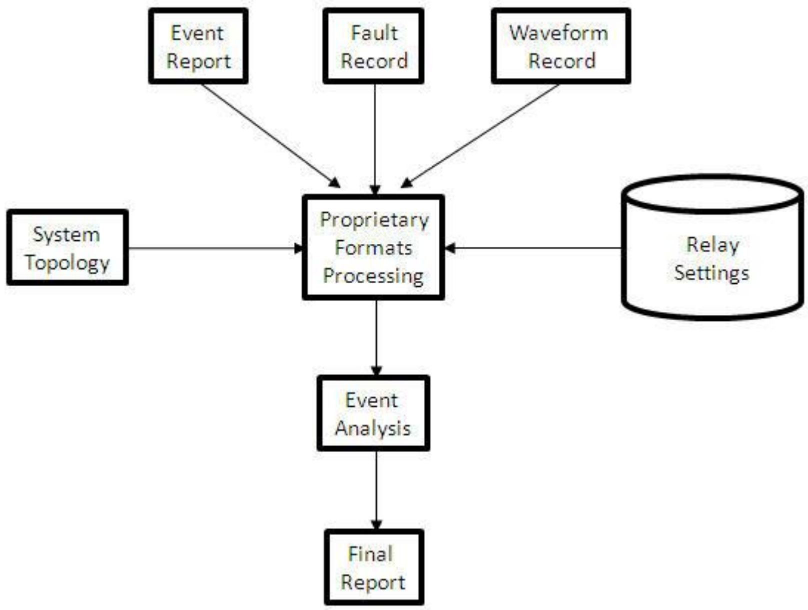

Fig. 1 Protection operation analysis process

The experience from the analysis of many relay operations and system disturbances demonstrates that one of the main problems (other than IEDs that are not time-synchronized) is the fact that all the data available from different devices and tools is in proprietary formats that requires significant effort to convert to a common format in order to perform the analysis. Usually this processing of records and data is done manually, which slows down the process and can also lead to errors that may affect the results from the analysis.

In order to improve the analysis process and create an environment supporting the development of automatic fault and relay operation analysis tools, the industry has been working for years on the standardization of reporting, recording and configuration data which at this stage is already achieved by the IEC 61850 standard.

IED FUNCTION MODELS

IEC 61850 has made a significant progress in the definition of standard description of the functionality of protection IEDs.

IEC 61850 clearly defines the model hierarchy that can be used for different multifunctional IEDs. If the grouping of functional elements represented by logical nodes in standardized logical devices is accepted by the industry in a way similar to the standardization of logical nodes, it will create the foundation for the development of many applications with a standard interface as required by both users and vendors which can result in the development of tools for automated fault and disturbance analysis.

The model of IEDs in IEC 61850 reflects the functionality of such complex devices and can be done by mapping the different functions supported by the relay to different logical devices. This task is easier to achieve for distribution protection relays due to the fact that they typically are associated with a single breaker, i.e. they interface with a single set of current and voltage inputs. One logical device will represent the primary protection functions. Another will define the Measuring function and a third – the Disturbance recorder. A Fault Locator and a Circuit Breaker Monitor (if available) will be modeled with additional Logical Devices. A simplified block diagram of this model corresponding to its functional hierarchy is shown in Figure 2.

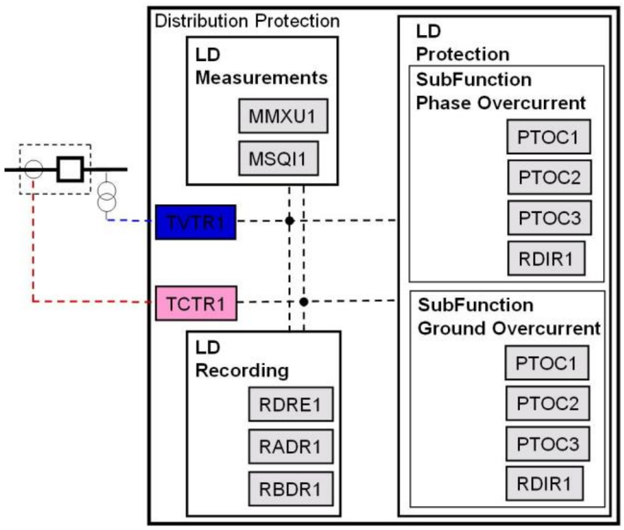

Fig. 2 Feeder protection relay – simplified object model

In order for the logical nodes to interoperate over the substation LAN, it is necessary to standardize the data objects that are included in each of them.

The fact that any protection function element is represented by a logical node (see an example of an overcurrent protection element represented by logical node PTOC in Figure 3) that can have a Started and Operated state, as well as different modes, associated measurements, settings, etc. allows the detailed description of the behavior of a multifunctional protection IED under abnormal system conditions.

The fact that a protection function element Started or Operated, as well as the exact time when it did that plays an important role in the analysis of the operation of a protection IED and the development of an event into a wide area disturbance or even a blackout. That is why the reporting needs to include not only the information about the start or operation of a function element, but also the Time stamp that can be seen in the ACT class in Figure 4.

PTOC 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
OpCntRs	INC	Resetable operation counter		O
Status Information				
Str	ACD	Start		M
Op	ACT	Operate	T	M
TmASt	CSD	Active curve characteristic		O
Settings				
TmACrv	CURVE	Operating Curve Type		O
StrVal	ASG	Start Value		O
TmMult	ASG	Time Dial Multiplier		O
MinOpTmms	ING	Minimum Operate Time		O
MaxOpTmms	ING	Maximum Operate Time		O
OpDlTmms	ING	Operate Delay Time		O
TypRsCrv	ING	Type of Reset Curve		O
RsDlTmms	ING	Reset Delay Time		O
DirMod	ING	Directional Mode		O

Fig. 3 PTOC (Protection Time Overcurrent) logical node

ACT class					
Data attribute name	**Type**	**FC**	**TrgOp**	**Value/Value range**	**M/O/C**
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
		status			
general	BOOLEAN	ST	dchg		M
phsA	BOOLEAN	ST	dchg		O
phsB	BOOLEAN	ST	dchg		O
phsC	BOOLEAN	ST	dchg		O
neut	BOOLEAN	ST	dchg		O
q	Quality	ST	qchg		M
t	TimeStamp	ST			M
originSrc	Originator	ST			O
operTmPhsA	TimeStamp	ST			O
operTmPhsB	TimeStamp	ST			O
operTmPhsC	TimeStamp	ST			O
		configuration, description and extension			
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M
Services					
As defined in Table 18.					

Fig. 4 ACT common data class

IED EVENT REPORTS BASED ON IEC 61850

Event reports are available from any multifunctional protection IED and have been used for more than twenty years. They are typically in the form of a record available in the memory of the relay that can be viewed from the front panel or can be extracted locally or remotely using the IED communications capabilities.

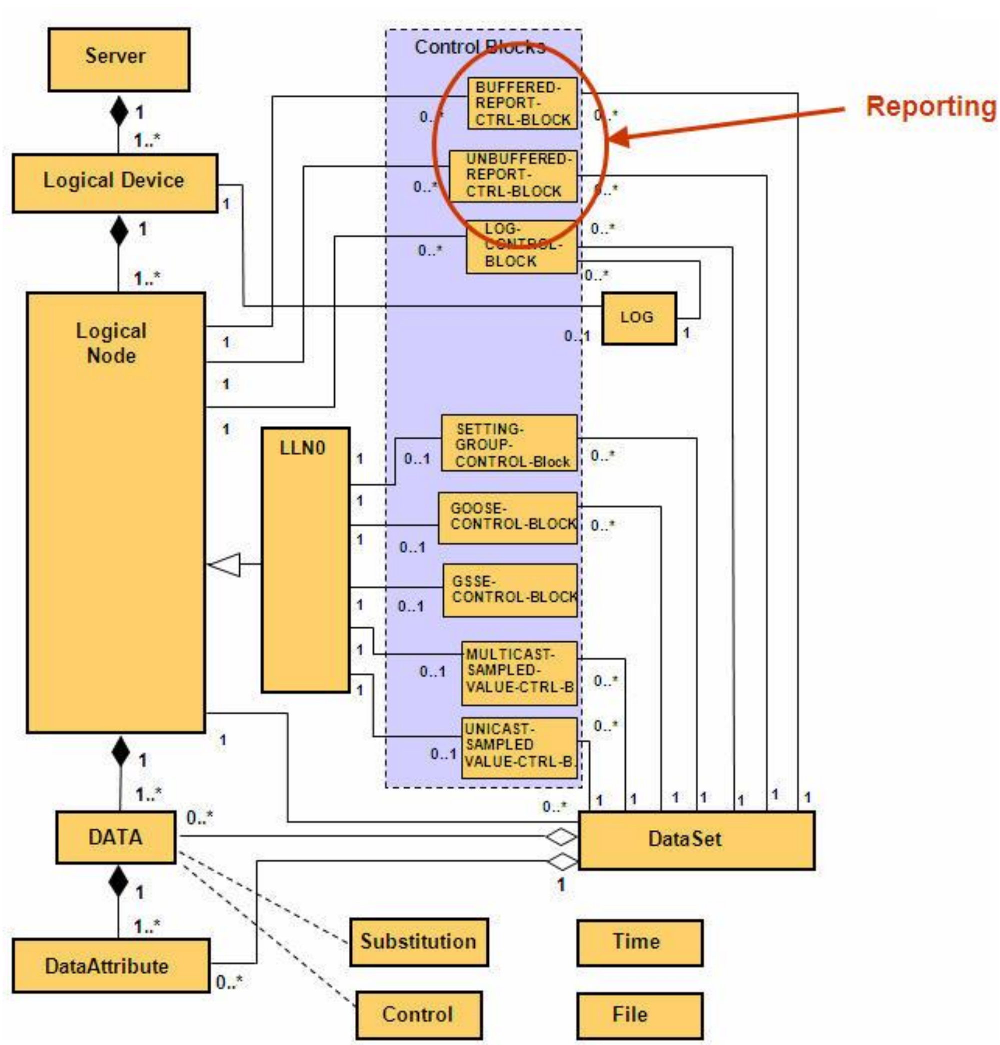

Fig. 5 IEC 61850 reporting services

The format of the event reports are different for the different manufacturers, which makes it difficult to process in automatic fault analysis tools.

IEC 61850 made the first significant step in the development of data models and services that define standard reporting that can be used in automatic event analysis.

Reporting meets a number of crucial requirements for event-driven information exchange. The data transfer models described in IEC 61850 7-2 provide mechanisms for transferring data values caused by well-defined conditions from a logical node to one.

In contrast to high bandwidth and time-consuming fast reading (polling) of devices for the analysis of extraordinary event occurrences, the reporting provides immediate transmission of events related information.

Reporting is controlled by constraints and its main characteristics are:

– timely reports serve as an indication to clients
– the impact on network bandwidth is minimized
– sending reports only when required (controlled by several attributes)
– low-frequency integrity scan and client-initiated general interrogation

Reporting provides mechanisms to report packed values of instances of a data object immediately or after some buffer time.

Reporting and logging as well as the basic services of the data model provide flexible data retrieval schemas, for example change-of-state notification of clients using immediate reports,

While the IEC 61850 GOOSE is also a form of reporting of some event types, reporting and GOOSE have totally different qualities of services and behaviour. Reporting uses connection-oriented communications and transmits data values once, while GOOSE uses multicast and transmits and retransmits data values with heartbeat.

The principle building blocks and services for reporting are shown in **Error! Reference source not found.**6.

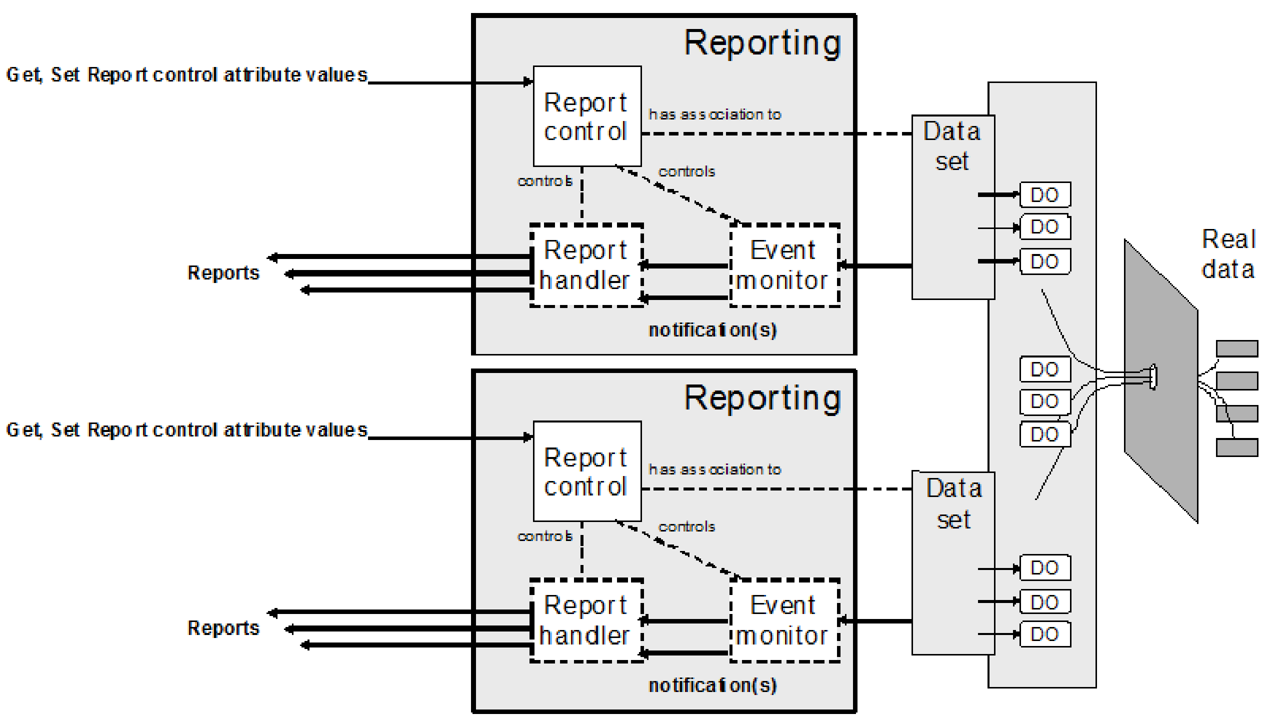

Fig. 6   IEC 61850 reporting basic building blocks

The reporting model is defined in IEC 61850 7-2 and composed of three building blocks together with classes which are defined for the report control.

The DATA-SET (referencing data object) represents the values of data objects. The values are conceptually monitored by the event monitors. An event monitor determines, on the basis of the state of the real data and the attributes of the control class, when to generate a notification to the report handler. This notification includes the data object values and reasons for data inclusion.

The number of values, within a notification, is a local implementation issue. The report handler assigns EntryID(s) and TimeOfEntry(s) to the values contained within a set of notifications. The number of notifications combined into a single EntryID is determined by the RCB control parameters (e.g. BufTm). The value of the EntryID shall be a unique arbitrary OCTETSTRING whose value is unique within the scope of entries for a specific RCB. The value of the TimeOfEntry shall be the timestamp representing the time at which the report handler received the first notification that is used to form an EntryID. The report handler decides when and how to send a report to the subscribed client.

A client may initiate a general interrogation at any time to receive all values of an application specific set of data object. Using this mechanism, clients can synchronize their databases with the current status of one or more logical nodes.

The REPORT-CONTROL-BLOCK is used to control the procedures that are required for reporting values of data objects from one or more logical node to one client. Instances of report control blocks shall be configured in the server at configuration time.

According to IEC 61850 7-2 a server shall restrict access to an instance of a report control block to one client at a time. That client exclusively “owns” that instance and shall receive reports from that instance of report control blocks.

There are two classes of report control blocks defined, each with a slightly different behaviour.

– BUFFERED-REPORT-CONTROL-BLOCK (BRCB) – internal events (caused by trigger options data-change, quality-change, and data-update) issue immediate sending of reports or buffer the events (to some practical limit) for transmission, such that values of data object are not lost due to transport flow control constraints or loss of connection. BRCB provides the sequence-of-events (SOE) functionality.
– UNBUFFERED-REPORT-CONTROL-BLOCK (URCB) – internal events (caused by trigger options data-change, quality-change, and data-update) issue immediate sending of reports on a “best efforts” basis. If no association exists, or if the transport data flow is not fast enough to support it, events may be lost.

To allow multiple clients to receive the same values of data object, multiple instances of the report control classes shall be made available.

Report control block instances are named. These names must be unique within the scope of a logical node. The number of instances is a local implementation issue and must be appropriately reflected in the configuration provided by the Substation Configuration Language (SCL). Once a report control block is reserved, by a specific client, no other client shall have access rights to set the control block attributes.

Buffered report control blocks are usually configured to be used by a specific client implementing a well-defined functionality, for example, a disturbance or event analysis application running in the substation or at the SCADA master. The client may know the ObjectReference of the BRCB by configuration or by the use of a naming convention.

BRCB class			
Attribute name	**Attribute type**	**r/w**	**Value/value range/explanation**
BRCBName	ObjectName		Instance name of an instance of BRCB
BRCBRef	ObjectReference		Path-name of an instance of BRCB
Specific to report handler			
RptID	VISIBLE STRING129	r/w	c1, c2
RptEna	BOOLEAN	r/w	
DatSet	ObjectReference	r/w	c1, c2
ConfRev	INT32U	r	
OptFlds	PACKED LIST	r/w	c2
sequence-number	BOOLEAN		
report-time-stamp	BOOLEAN		
reason-for-inclusion	BOOLEAN		
data-set-name	BOOLEAN		
data-reference	BOOLEAN		
buffer-overflow	BOOLEAN		
entryID	BOOLEAN		
conf-revision	BOOLEAN		
BufTm	INT32U	r/w	c1, c2
SqNum	INT16U	r	
TrgOps	TriggerConditions	r/w	c1, c2
IntgPd	INT32U	r/w	c1, 0.. MAX; 0 implies no integrity report
GI	BOOLEAN	r/w	
PurgeBuf	BOOLEAN	r/w	
EntryID	EntryID	r/w	c2
TimeOfEntry	EntryTime	r	
ResvTms	INT16	r/w	c3
Services Report GetBRCBValues SetBRCBValues			

The behavior of a BRCB instance is as follows:

- disabled: the BRCB is available. No reports shall be issued.
- resync: the BRCB is available. No reports shall be issued.
- enabled: the BRCB shall generate reports for the buffered events and new events as

specified in the BRCB.

These attributes determine the service procedures of the Report service. The impact of the various values is defined in the attribute definitions.

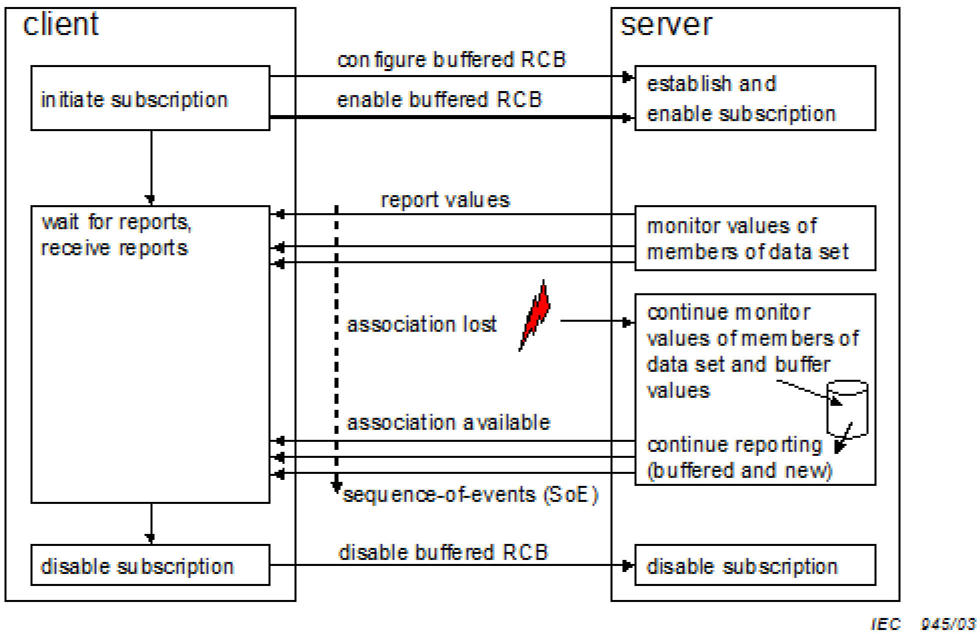

Fig. 7 Basic buffered reporting mechanism

The members of the data set used in the reporting carry the information that can be used for the fault and disturbance analysis.

Since the reporting can be associated with individual logical nodes, the fault and disturbance analysis client will have to subscribe to reports from the specific logical nodes of interest to the analysis of events within or related to the substation protection, automation and control system.

CONCLUSIONS

The use of the reporting model defined in IEC 61850 can support a standardized approach to the analysis of faults and disturbances.

The fact that reports can be associated with individual logical nodes representing specific function elements allows great flexibility in the development of analysis tools.

The standard naming of logical nodes, data objects and data attributes, together with the knowledge of the association of logical nodes with the substation equipment as defined in the substation configuration files and the ongoing work on a standardized model of the functional hierarchy of IEDs create an environment that can help in the development of automated fault and disturbance analysis systems in the future.