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IEC61850 Impact on the Configuration of Protection Functions

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SUMMARY

The IEC61850 communication protocol introduced concepts that not only changed the communication environment but also changed the composition of protection functions in modern protection devices. Output information is for example no longer a pure “binary” signal with a state equal to “on” or “off”. Additional information such as “health” or “test” may be included.

More fundamentally however the “node-structure” introduced by IEC61850 is structurally incorporated in the modern protection device utilizing function groups and stages in a logical hierarchy. The first protection devices to provide IEC61850 based communication had to mirror their information onto the protocol. This can result in gaps where the required information is not available or there is additional information which cannot be exactly mapped onto the protocol. The state of the art device adopts the IEC61850 structure throughout thereby providing consistent use of terminology in the application of the protection functions as well as the related communication.

The paper will show how the modern relay manages to incorporate the innovations introduced by IEC61850 in the combination of protection functions and signal routing.

1 IDENTIFYING THE PROBLEM

The problem addressed in this paper is illustrated by analyzing what is expected of a typical modern protection relay IED. Apart from the protection functions, such a device also provides for control functionality and it serves as the front end for obtaining process information. The large scope of functions and diverse requirements in terms of information demands additional measures to ensure that the volume of information can still be managed.

In figure 1 an extract of the applied function blocks is shown:

- Protection: Time over-current (PTOC).
- Vendor specific indications: GGIO.
- Control: e.g. switch CSWI.
- Measurement: e.g. feeder RMS values (MMXU)
- Process: Circuit breaker (XCBR)

Even though not all functions are shown in the above diagram, the problem of information complexity becomes apparent when taking a closer look. Figure 2 shows the “mapping” of the functions and information in a “conventional” protection IED onto the IEC61850 structure (screenshot of IEC browser on real device). The IEC structure is shown at the right hand side: Device name – Logical

Device – Logical Node – Data object name. The selected data object with this tree definition is: 7SA522 – Protection (PROT) – Dist. Zone Z1 (PDIS1) – Pickup L12 (StrAB -> pickup). Because the information structure in the device (developed before IEC 61850 existed) is very different from that of IEC 61850, the result is a compromise. The structure specified with IEC 61850 is however complied with allowing all the related advantages, the information content in the form of single point signals (well known and understood by the protection engineer) is subjected to a complex structure that appears unnecessary. The optional enhancements are only available to a limited extent.

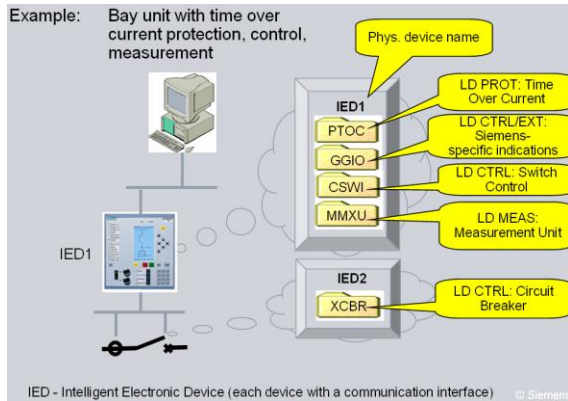


Fig. 1: General structure of functions

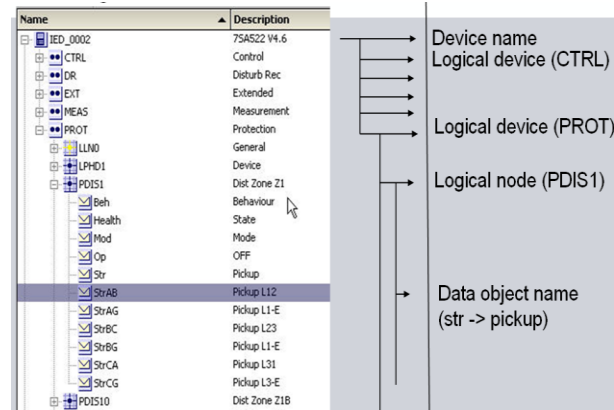


Fig. 2: Mapping of function

A document according to IEC 61850 specification must define this mapping (PIXIT). The general problem that arises is illustrated by taking a closer look at the final element in the tree, e.g. Pickup L12. According to IEC 61850 (StrAB) this information is of class directional protection information (ACD). e.g. direction and phase. A single ACD can contain the pick-up (start) information of a distance protection zone. In this example this was not possible because the contained single point information elements did not allow a meaningful mapping. As “work-around” the data object name was extended with the loop selection “AB”. Now the ACD only applies to this loop – as a consequence a separate object needs to be applied for each loop (6 in total). This inconsistency between the available information elements at lowest level and the model specified for communication can only be overcome by adopting the data model in the design of the device at all levels.

2 SOLUTION

The solution to the problem can partly be found in the standard: IEC 61850 Communication networks and systems for power utility automation. This provides a detailed and highly structured description of the functions and associated data models. Wherever information is handled the IEC 61850 can be applied within the context of the protection IED. This is symbolically shown in figure 3.

Naturally the “address” of the information is a key to a successful structure. This follows the structure “tree” mentioned earlier. Here illustrated with the status value of a circuit breaker in the context of controlling the CB (figure 4).

The data object Pos is of data class double point control (DPC) providing more than 20 attributes. The attribute status value (stVal) has type CODED ENUM which can indicate the states: intermediate/ off / on / bad-state. More transparent and less engineering effort is possible by allowing the engineering tools and logging instruments to manage the information at the object layer in stead of having to deal with each attribute separately in the configuration matrix.

It would however not make sense to restrict the implementation of the IEC 61850 structure to the data model. The approach of the IEC 61850 standard series is to break down processes into Logical Nodes (LN). The function (and sub-functions) contained in the LN can then be standardized as far as possible, thereby facilitating the prime objective of the standard which is interoperability. This is illustrated in the following figure 5.

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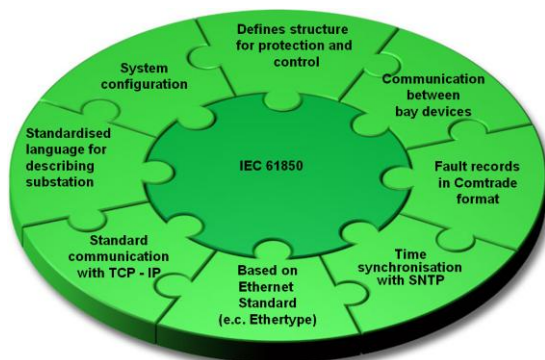


Fig. 3: Standard overview

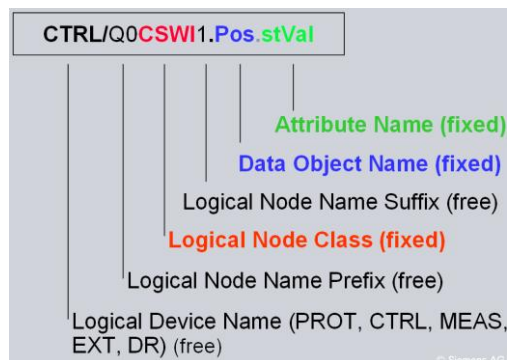


Fig. 4: Structure of LD (control)

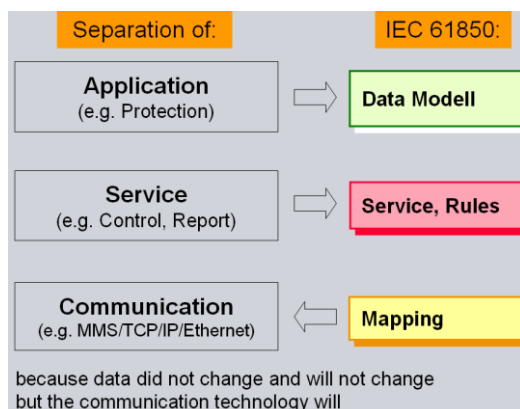


Fig. 5: Separation of functionality in a device

The standard also emphasizes that the combination of functions into physical devices (IED's) is totally flexible and not regimented in any way. This allows the vendor of protection relays a lot of freedom when designing his products. Figure 6 illustrates this:

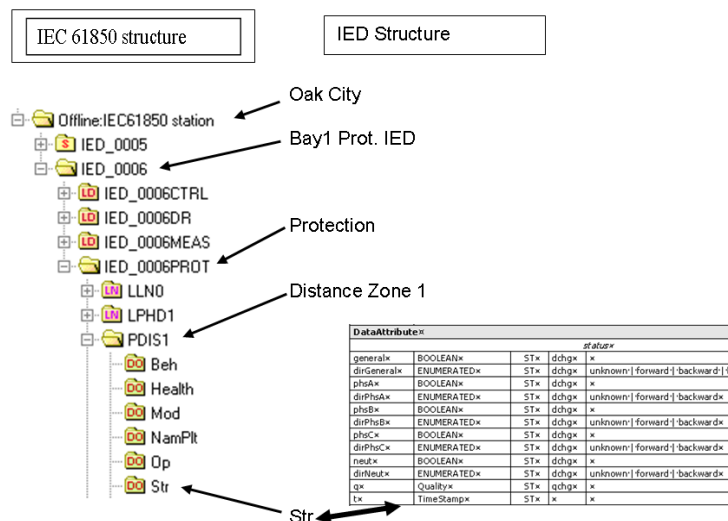


Fig. 6: Structure of a function (e.g. distance protection zone)

The IED structure now matches the structure defined by IEC 61850 and fills out the gaps at the lowest level. All the various clients served by the protection IED can now be optimally served without laboring the application engineer with information and structures that are not needed in his discipline

From the usability point of view different users are involved in the engineering process. The IEC61850 expert knows the terminology and the description. He wants to see a description of information regarding the standard. The following figure 7 shows an extract from IEC61850 configurator. On the left hand side the IEC 61850 structure by using prefix and suffix is shown (e.g. **QUAD** PDIS1). The prefix characterizes the type of characteristic (e.g. QUAD = quadrilateral) and the suffix the instance (e.g. zone 1). The right column shows a clear text description. Icons support a user friendly handling of the configurator. The screwdriver characterizes a setting parameter.

Name	Path
(All...)	(All...)
FG1_Line_FN1_DisGnd1_3pol	21 Distance prot. 1
LLNO	LLNO
GAPC1	Line 1:21 Distance prot. 1:General
PU_GAPC5	Line 1:21 Distance prot. 1:Pickup Z<
DISB_PTRC2	Line 1:21 Distance prot. 1:Group indicat.
QUAD_PDIS1	Line 1:21 Distance prot. 1:Z 1
Mod	Line 1:21 Distance prot. 1:Z 1:Mode (controllable)
Beh	Line 1:21 Distance prot. 1:Z 1:Behavior
Health	Line 1:21 Distance prot. 1:Z 1:Health
NamPlt	Line 1:21 Distance prot. 1:Z 1:Name plate
Str	Line 1:21 Distance prot. 1:Z 1:Pickup
Op	Line 1:21 Distance prot. 1:Z 1:Operate
DirMod	Line 1:21 Distance prot. 1:Z 1:Directional mode
PhDITmms	Line 1:21 Distance prot. 1:Z 1:Operate delay (multi-ph.)
GndDITmms	Line 1:21 Distance prot. 1:Z 1:Operate delay (1-phase)
X1	Line 1:21 Distance prot. 1:Z 1:X reach
RisGndRch	Line 1:21 Distance prot. 1:Z 1:R (ph-g)
RisPhRch	Line 1:21 Distance prot. 1:Z 1:R (ph-ph)
KDFact	Line 1:21 Distance prot. 1:Z 1:KO
KDFactAng	Line 1:21 Distance prot. 1:Z 1:Angle (KO)

Fig. 7: Functional view of protection function in a configurator (edition 2 design)

3 EXAMPLE DISTANCE PROTECTION TRIP

By means of this example the proposed solution will be illustrated. As formulated above, the adopted approach is to achieve an optimal consistency between the structure of the data at the source and the structure used to communicate the data. The core function of protection has not changed; the protection engineer still expects to find the information he is used to.

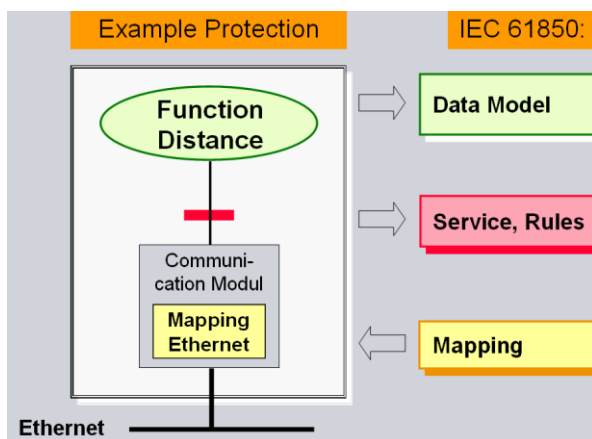


Fig. 8: Device versus IEC61850 structure

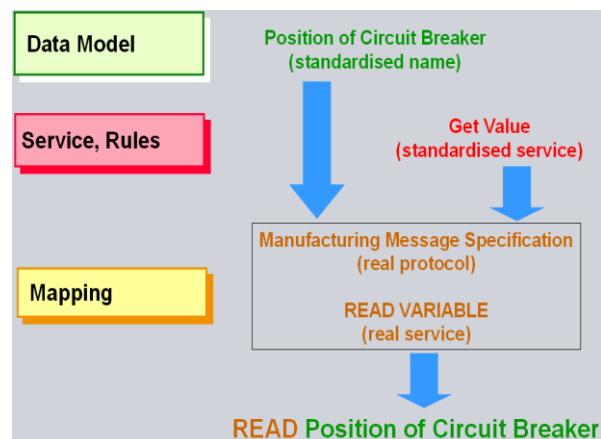


Fig. 9: Defined data model (control CB)

Within the protection IED the user will find the “logical device” protection which can include the function distance protection made up of the “logical nodes” PDISx. These represent the various set

zones. Nothing is really new up to here, however the information from the logical node is provided with the defined Data Model so that standardized services can make use of it (figure 10).

Unless the protection engineer is able to implement the routing of signals for his applications without unnecessary complexity the imposition of the “Data Model” is of no benefit to him.

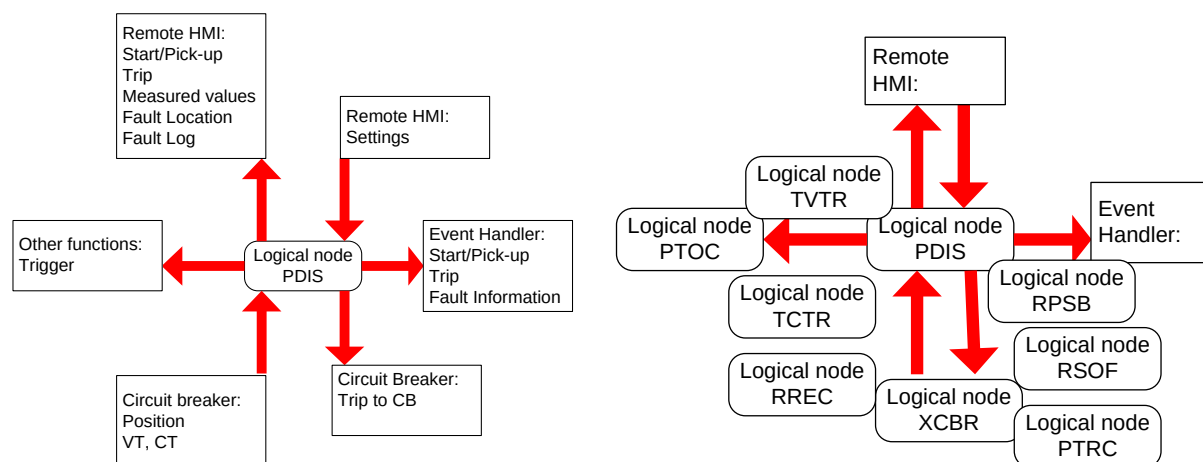


Fig. 10: Interaction of a logical node (left: general overview, right: detailed in IEC61850 view)

As was shown earlier, the breakdown of functions into logical nodes results in a large number of logical nodes within the logical device, protection. The engineering tool must hide this complexity at the application layer where the specific configuration is done.

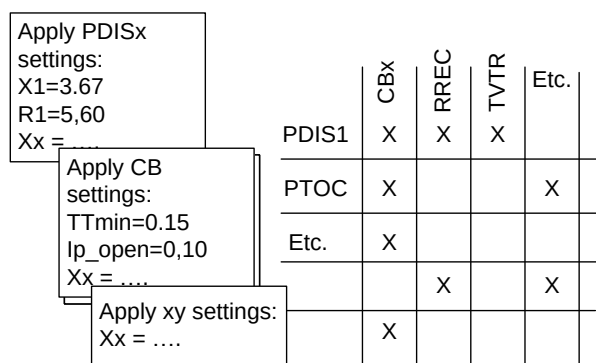


Fig. 11: Simplification via engineering tool

Clear entry and visualization of protection settings with setting windows must be provided. Depending on the applied protection functions, all the relevant inter-function connections must be settable in tabular form. The scope of this table must be interactive depending on the available functions.

The assignment to a physical interface (binary input/ output and LED) as well as the routing of signals to sequence of event logs will be done with the proven “matrix” approach. Due to the vast amount of information in numerous different data classes the intelligent presentation of signals in the matrix is essential. The clear separation of functions ensures that all “subscribers” to an information e.g. circuit breaker position can obtain this information at a single source. The provider of the information has well defined rules for the presentation of the information so that all subscribers can get exactly what they require.

Getting back to the example of the distance protection trip, this is handled as follows. The distance protection function is selected and configured with the provided application software. This is done for the protection IED which will also be configured with measuring points, circuit breaker and other power system data. The application software will identify meaningful information flow between the applied functions and allow selection of active links by means of a table. The distance protection trip must therefore be routed (linked) to the relevant circuit breaker by means of this table. The final

connection from the protection IED to the circuit breaker is via the physical interface and is configured with the matrix. Here all further destinations of the trip signal are also set (LED, Trip Log etc.). As this final connection of the trip signal is done for the circuit breaker logical node (XCBR), it automatically applies for all other protection functions.

The single selection applied by the application engineer associates the distance protection with a particular circuit breaker. The actual association has numerous facets that are automatically done in the background. For example the line closure detection required for the switch on to fault function will utilize the breaker status information of this circuit breaker without the need of further selection. The same applies to the weak in-feed logic associated with the distance protection.

Real benefit will only be seen in the future

On the surface the discussion above appears to be a lot of complexity to achieve something that could be a lot simpler if the typical case is considered: one distance protection and one circuit breaker in a single logical device. It is however foreseeable that the circuit breaker function and measuring functions will not always be located in the same physical device. When this is the case the structures of the IEC 61850 standard must be adopted. The closer the real protection data structure is to the standard the better the quality of the overall system will be.

Tele-protection via IEC 61850

The distance protection is a significant part of a selective system protection arrangement. With widely applied tele-protection supplements the quality of the protection is further improved. The option of routing the protection signals for tele-protection via the IEC 61850 infrastructure is a viable option. To eliminate any fear that congestion of the Ethernet during faults may create problems for the signaling, the substation to substation connection can be done via a dedicated sub-net. In this case it is even possible to achieve complete physical separation of this connection from the remaining communication structure. On the other hand if these doubts do not exist, the communication infrastructure can also be shared.

4 COMBINING AND CONNECTION FUNCTIONS

In the example above the focus was primarily on the distance protection and how it interfaces with other functions to route the trip signal to the circuit breaker. Here some other functions will be described to show how the combination of functions using the logical node concept allows for high flexibility without undue complexity.

Example breaker fail

The breaker fail protection can be applied in the same IED as the main protection functions e.g. distance and differential protection. In this case the trip signals from the main protection must be routed internally to the breaker fail for initiation. On the other hand, the breaker fail function could be located in a different physical device. The application should also provide for simple configuration of the breaker fail in this case.

The start signals can be separated into two categories: Trip by function based on fault current and trip by function without current criteria. These two types must be managed separately by the breaker fail. The source of the start (trip) signal could be internal (other protection functions in the same IED) or external via binary input or GOOSE. In this case the start may be dual channel for additional security.

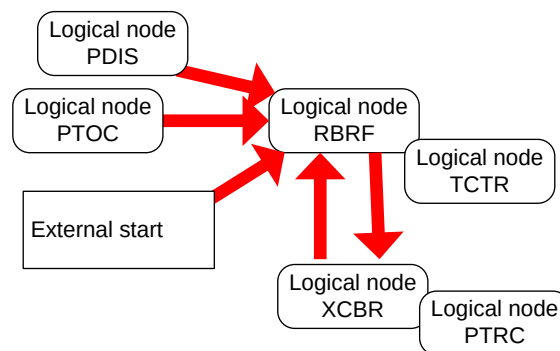


Fig. 12: Structure of breaker failure function and interactions

For the application engineer the selection must consist of a simple “X” in the relevant position to link the desired functions.

Example auto re-closure

The auto re-close function incorporates several signals that need to be exchanged with the associated protection functions: fault detection and phase selective operate signals from the protection function and zone release signals from the re-close function to the protection.

The auto re-close function also requires information from the associated circuit breaker: auxiliary contact status and CB ready indication.

Operating mode may also be changed via external or internal selection: e.g. 1&3 pole or 1pole only.

For the application engineer it is important that he can apply the association between the recloser function and circuit breaker, protection function, control selection, sync check and so on without having to configure individual signals such as start and trip. Figure 13 shows how the interaction can be solved by a matrix. With few clicks (routed crosses) the interaction is configured. The figure shows which functions and signals start the automatic reclosing as well as the breaker failure protection (CB failure).

▼ Circuit-breaker interaction					
Protection group	Circuit breaker 1				
	Start automatic reclosing	Block automatic...	Trip	Start CB failure ...	
REL_(All...)	REL_(All...)	REL_(All...)	REL_(All...)	REL_(All...)	REL_(All...)
49 Th.overl. 1			X		
▼ 21 Distance prot. 1	*		X		X
Z 1	X		X		X
Z 2			X		X
Z 3			X		X
Z 4			X		X
▶ 85-21Perm.overr.			X		
▼ 87 Line diff. prot.	X		X		X
General	X		X		X
▼ 50/51 OC-3phase 1	X		X		X
Definite-T 1	X		X		X
Definite-T 2	X		X		X
Inverse-T 1	X		X		X

Fig. 13: Configuration of interaction between functions

Operational and fault log

Also in the context of reporting the data model must be considered. When an information element such as “distance protection zone 1 pick-up” is routed to a fault log, the application engineer does not want to consider each phase separately, nor the selection of forward or reverse direction. The logs should therefore be capable of listing the details of a “distance pick-up” without the need to select each eventuality separately. Figure 14 shows an example. The pick-up signal is routed in the fault log (F). Only the ACD type is used.

5 CONCLUSION

If the structures introduced by IEC 61850 are adopted and applied to the development and design of a protection IED, it is essential to also provide comprehensive application tools to assist during setting and configuration. A protection system based on this structure will provide enhanced flexibility and cost saving in the near term. The real benefit however is in the future where such a system will be extremely well positioned for enhancements in the area of substation automation and smart grid.

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30 May – 3 June 2011, Saint Petersburg

Information			Source			Destination		
Signals	Number	Type	▼ F	GOOSE	CFC	▼ BO	▼ LED	Fault records
								Recorder
REL_(All...)	REL_(All...)	...						REL_(All...)
▼ 21 Distance prot. 1	21.901					*		*
▶ Z ph-g	21.901.2310.	WYE						
▶ Z ph-ph	21.901.2310.	DEL						
▶ Group indicat.	21.901.4501							
▶ General	21.901.2310							
▼ Z 1	21.901.3571					*		*
▶ >Block stage	21.901.3571.	SPS						
▶ >Block ph-g loops	21.901.3571.	SPS						
▶ >Block ph-ph loops	21.901.3571.	SPS						
▶ Inactive	21.901.3571.	SPS						X
▶ Behavior	21.901.3571.	ENS						X
▶ Health	21.901.3571.	ENS						X
▼ Pickup	21.901.3571.	ACD				*		X
▶ general		SPS				*		
▶ phs A		SPS				*		
▶ phs B		SPS				*		
▶ phs C		SPS				*		
▶ gnd		SPS				*		

Fig. 14: Routing of signals into the logs

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