

# Learn IEC 61850 Configuration In 30 Minutes

Wei Huang

ABB Inc.

Lake Mary, FL, USA

[Wei.huang@us.abb.com](mailto:Wei.huang@us.abb.com)

**Abstract**— the myth says IEC 61850 is too complicated to use with a steep learning curve. The traditional IEC 61850 learning path is to go through IEC 61850 standard then start IEC 61850 configuration. User spent days to go through massive content of the standard, which includes 10 parts, 27 documents, and more than 4,000 pages. The standard adopts modern communication and computer science technologies like 7-layer communication model, XML (Extensible Markup Language), Unified Model Language (UML), Object Oriented Design (OOD) and others. Many potential users are discouraged with the overwhelming information during the IEC 61850 training. One of IEC 61850 standard's goals is to shorten system engineering time. Learning the know-how presented a challenge with such massive content. It is possible to get a fundamental understanding of standard and be ready for IEC 61850 configuration in 30 minutes. Two basic questions from protection relay engineer's point of view are "Where is the data?" and "How to get the data?" This paper provides an alternate approach to comprehend core components of IEC 61850: Semantic Hierarchical Object Data model and two communication services: Client - Server and Publish - Subscribe. IEC 61850 configuration is demonstrated as preparing the data list following the data model and setting parameters for communication services. This approach has been well received and has provided satisfactory results in recent IEC 61850 configuration training sessions.

**Index Terms**—IEC 61850 Configuration, Semantic Hierarchical Object Data model, Client – Server, Publish – Subscribe.

## I. TRADITIONAL WAY

The traditional way of learning IEC 61850 configuration starts with reviewing IEC 61850 standard. With an unofficial count of 10 parts, 27 documents and more than 4,000 pages[2] – [30], it takes more than 3 weeks to read the full content of the standard with normal reading speed of 2 minutes per page. Being exhausted, little energy is left to practice IEC 61850 configuration on the IED. More than half of potential users in IEC 61850 class would give up or decide to look at it later before the class ends. Those who intend to study IEC 61850 standard later will keep postponing until it is no longer fresh and interesting.

There are differences between IEC 61850 standard and legacy communication protocols. IEC 61850 standard is not just a communication protocol. It is more than a communication protocol. IEC 61850 provides a systemic way to describe the device and system before applying the proper communication services described earlier.

IEC 61850 standard incorporates new achievements of modern computer science and communication technology. Object oriented design is used to design a hierarchical object data mode to describe the power product system, devices and data. Open System Interconnection (OSI) 7 layer mode [31] is used as the base of communication. Client – Server [32] and Publish – Subscribe [33] are the two main communication models adopted by IEC 61850 standard. Unified Modeling Language (UML) [34] is used in the IEC 61850 standard for implementation.

It is a challenge to absorb such large quantities in a few days, hence a new approach is needed.

## II. A NEW APPROACH

After years of IEC 61850 training and system integration experience, we came up a new approach to help learning IEC 61850 configuration more efficiently. Instead of going through enormous contents of IEC 61850 standard in sequence, this new approach start with two basic questions: "Where is the data?" and "How to get the data?", and focuses on core components of the standard: **Semantic Hierarchical Object Data** model, **Client – Server** and **Publish – Subscribe** communication services.

### A. *Semantic Hierarchical Object Data model*

Legacy communication protocols, DNP3 or Modbus, are index or register based. All data points are assigned an index number with the data type. Phase A load current could be located as analog input index 1 in the data point list manual, which will be shared with both relay and SCADA engineers. They have to use the same communication data point list manual. If any modifications or updates are made on the points list on the relay, SCADA configuration needs to be reviewed, or modified at the same time, to match the new list.

IEC 61850 standard adopts a different approach to locate the data. A Semantic Hierarchical Object Data model is used to describe the data points, product device and substation.

1) **Object Data model:** In object oriented design, a system is partitioned into layers and subsystems. A large complex system is divided into a hierarchy of smaller components or objects with lesser complexities. The individual components are of lesser complexity, more comprehensible and manageable. Each component is independent and can be replaced without affecting the whole system. These components or objects are self-contained entity which encapsulates data attributes and operation services.

Adopting the approach of object oriented design, in IEC 61850 standard, each IED (Intelligent Electronic Device) is divided into logical devices, logical nodes and object data points. Every IED contains several logical devices for certain applications. Every logical device contains a group of logical nodes or functions. Logical nodes includes all data objects it needs for the function. IED design is now very flexible by including different logical devices and logical nodes for different protection and control applications.

In object oriented design, "Class" is used for the template or definition of a data object. Each object is an instance of the class. Class is the definition of the object. IEC 61850 standard defines the common classes. Vendors of IED implement actual data objects based on the class in the IED.

For example a commonly used class in IEC 61850 is "WYE", which provide information about phase to ground related measured values of a three-phase power system apparatus. Attributes in WYE include phsA, phsB, phsC, neut for phase A, B, C and ground current or voltage measurements. These attributes are of type CMV (complex measured value) and consist of magnitude and phase angle as in any AC measurements. Attributes of CMV are described in Figure 1.

In IEC 61850 standard part 7-3, common data class is defined to describe the data object. Phase A current is not only index 1 of analog input. In IEC 61850, attributes of class CMV "cVal.mag.f" is used for magnitude measurement and "cVal.ang.f" for angle, "q" for quality and "t" for timestamp. Data class SPS (Single point status) is defined for binary data including attribute "stVal" for a Boolean value, "q" for quality, and "t" for timestamp, and some other attributes. In fact all data objects in IEC 61850 have at least three attributes: value, quality and timestamp.

7.4.3 Complex measured value (CMV)

Table 31 defines the common data class "complex measured value".

Table 31 – Complex measured value

CMV class	Type	FC	TrgOp	Value/Value range	M/O/C
Data attribute name					
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute	measured attributes				
instCVal	Vector		MX		O
cVal	Vector		MX	dchg, dupd	M
range	ENUMERATED		MX	dchg	O
rangeAng	ENUMERATED		MX	dchg	O
q	Quality		MX	qchg	M
t	TimeStamp		MX		M

Figure 1: CMV (Complex measured value) defined in IEC 61850 Part 7-3

One important data object DPC (Double Point Control) is defined to describe circuit breaker position and operation. Double point status attribute "stVal" is defined for the breaker position, as 2 bit integer, with bit 0 presents Open position signal, bit 1 presents closed position. So a decimal value 1, as "0 1" in binary, means circuit breaker is Open. Value 2, as "1 0" in binary, means circuit breaker is Closed. Value 0, as "0 0", neither Open or Closed signal is received, breaker position is intermediate. The last possible value 3, as "1 1" in binary, as breaker is not possible both in Open and Closed position, means breaker in fault position. It also includes attribute "q" for quality and "t" for timestamp. As a control data object, it includes a Boolean attribute "ctlVal" for control output. "True" to close and "False" to open. For a data object with name "Pos" of class DPC, when circuit breaker is open, value of Pos.stVal will be 1. When circuit breaker closed, value of Pos.stVal will be 2.

Data object can include other data objects as its attributes. Data object WYE, phase to ground/neutral related measured values of a three-phase system, includes attributes "phsA", "phsB", "phsC", "neut", "net", and "res" with data object type of CMV. Phase IEC 61850 reference of phase A load current will be like "A.phsA.cVal.mag.f" while A is a WYE object. Phase B current will be like "A.phsB.cVal.mag.f".

2) **Hierarchical Structure:** Data structure in IEC 61850 is not flat but a layered hierarchical structure.

Logical node in IEC 61850 is used to define basic functions in the IED as a container of data objects. IEC 61850 part 7-4 defines logical node type, or class. Logical node class CSWI defines data structure of switch controller. One important data object in CSWI is named "Pos" with data type DPC. IEC 61850 reference of circuit break status will be referenced as "CBCSWI1.Pos.stVal" with logical node name "CBCSWI1".

Measurement logical node named CMMXU1, of class MMXU, contains data object A of type WYE for phase currents, data object phsV of type WYE for phase voltage. IEC 61850 reference of phase A current measurement will be "CMMXU1.A.phsA.cVal.mag.f". Phase B current measurement will be "CMMXU1.A.phsA.cVal.mag.f".

In IEC 61850 standard logical node classes are grouped by their functions. All logical node class name consists exact four letters, of which the first letter presents group of the logical node. All logical node of metering and measurement functions begin with "M", like MMXU which contains measurement data objects. Logical node name begin with letter "C" is for control functions. Letter "P" is for protection functions, like PTOC for time over-current. Any IED that supports IEC 61850 consists of a list of logical nodes. To make it more user friendly and better manageable, IEC 61850 standard specify virtual logical device layer. Each logical device is group of logical nodes for a certain application. Logical device CTRL could include all logical node of circuit breaker functions. Logical device LD0 could include all logical node of protection functions, and logical device DR includes all

logical node of disturbance records. IEC 61850 reference of Phase A current will be “LD0.CMMXU1.A.phsA.cVal.mag.f” in full. “CTRL.CBCSWI1.Pos.stVal” presents circuit breaker 1 position.

3) **Semantic Name Space:** IEC 61850 defines naming convention of logical node. Logical node name must use logical node class name defined in IEC 61850 standard part 7-4, like CSWI, MMXU, or PTOC, as base. Venders are free to add prefix in front of the class name, like CB, C, PHH, and instance number at the end. Logical node name “CBCSWI1” is consisted of prefix “CB”, logical node class CSWI, and instance number 1. “CMMXU1” has prefix “C”, logical node type MMXU, and instance number 1.

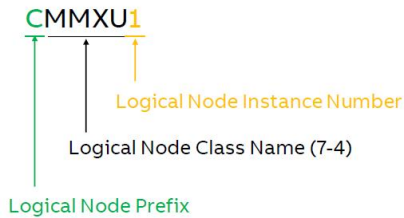


Figure 2 Logical node name includes Prefix, Logical Node Class Name, and Instance

Data object names in logical node are defined in IEC 61850 standard. Circuit breaker status in logical node CSWI is defined as “Pos” of type DPC. Phase current in MMXU is defined as “A” of type WYE.

As a Semantic Hierarchical Data model, IEC 61850 reference has the format of “Logical Device”. “Logic Node”. “Data Object”. “Attribute”. Here are some examples: LD0.CMMXU1.A.phsA.cVal.mag.f for phase A load current and CTRL.CBCSWI1.Pos.stVal for circuit breaker position.

Now the data format is defined, but where is the data in an IED? They are normally prepared and preconfigured in the IED by the vendor. IEC 61850 configuration tool from different vendors have a common function “Export” to export CID (Configuration IED Description) file, which include all logic device, logic nodes and data objects in the IED. CID file’s format is defined by IEC 61850 in XML format. This file can be opened in any XML editor or any web browser. User can browse the hierarchical structure from IED to logical devices, logical node, data object and data attributes.

```

1454 <AccessPoint name="LD0">
1455 <Server>
1456 <Authentication />
1457 <LDevice desc="Protection" inst="LD0">
19008 <LDevice inst="CTRL">
19198 <LDevice desc="Disturbance recorder" inst="DR">
20843 </Server>
20844 </AccessPoint>
20845 </IED>
20846 <DataTypeTemplates>
26338 </SCL>

```

Figure 3 This IED has three logical devices LD0, CTRL and DR

### B. Client – Server Communication Service

IEDs are normally connected with SCADA (Supervisory control and data acquisition) by fast Ethernet connections with speed of 100 megabits per second. Communication protocol MMS (Manufacturing Message Specification) is used in IEC 61850 to implement Client – Server service between IEDs and SCADA. IED runs as a server, contains all the data and is ready to respond to any requests. SCADA, as a client, initiates the communication and sends requests to read data or control command. IED responds to SCADA with the value of the data or result of control operation.

Besides this request - respond polling mechanism, MMS also supports reporting by exception function. When there is no event happens or no data change on the IED, there would be no communication between IED and SCADA. When any critical event happens or data change, IED sends event data to SCADA automatically without requesting. Communication payload is reduced to minimum and SCADA always receives events in time without waiting for the polling.

This reporting by exception communication method is mostly used for communication between IED and SCADA. When communication is first time established between SCADA and IED, SCADA sends numerous requests to IED to read values of all the data. After that, SCADA sends an “enable report” command to IED. IED is now ready to send event report when any data changes. When there is no data change, there is no communication between the SCADA and the IED. Network is quite. Only when data change events happened, IED sends event data to SCADA automatically.

For request - response polling mode, there is no need of any configuration work. Importing CID file exported from IED configuration tool, SCADA receives all IEC 61580 logical devices, logical nodes and data objects about the IED, and is able to send request for any data it is interested.

For event reporting operation, IED need to be configured to create information report data sets to prepare the list of data points for reporting and report control blocks to specify how to send the report. IEC 61850 standard uses information report data set, as a list of data objects to report events. Report control block is used to specify how to send these reports.

Most IED vendors provide default information report data sets and report control blocks. The default information report data sets includes lists of important data objects, like circuit breaker position, protection trip, and measurement with threshold for reporting. Report control blocks are configured to send event reports when data changed or quality changed. It can also be configured to send data to SCADA periodically with or without any data change. IED is ready for communication with SCADA with no configuration work.

When some data points which SCADA requires are not included in the default report data set, users need to update the information report data set to add new data.

For Client - Server MMS communication with SCADA, IEC 61850 configuration work on the IED is minimum.

### C. Publish – Subscribe Communication Service

GOOSE (Generic Object Oriented Substation Event) is the other communication service between IEDs defined in IEC 61850 standard, which is used to replace hardwire connections between binary output contacts of one IED to binary input of another IED or analog connections.

Publish – Subscribe service model is used to reach performance of both high speed and high availability for GOOSE communication. In this model, GOOSE-sending IED sends GOOSE message at low level of communication stack data link layer by broadcasting to all IEDs on the same network. High priority flag is assigned to these GOOSE messages, so these messages will be moved to the front of the queue on Ethernet switch’s communication port to be sent out in front of other messages.

To make sure IEDs receives GOOSE message in 3 milliseconds with any new event, IED sends several GOOSE messages with incrementing sequence numbers at a non-linear rate to ensure at least one message is received. IED keeps sending GOOSE message as a heartbeat mechanism for a fixed rate later, which can be used by GOOSE-receiving IED to detect any communication failure.

While the IED publishes GOOSE message to all IEDs on the network, the subscribed IED retrieves the GOOSE message and get the data.

GOOSE configuration normally involves at least one GOOSE-sending IED and one or more GOOSE-receiving IEDs.

GOOSE configuration consists of three steps: prepare GOOSE data for sending, subscribe, and receive GOOSE data. Similar to MMS configuration, user creates GOOSE data sets, adds data points to the data set, and configures GOOSE control block to specify how to send the GOOSE message for GOOSE-sending IED as the first step.

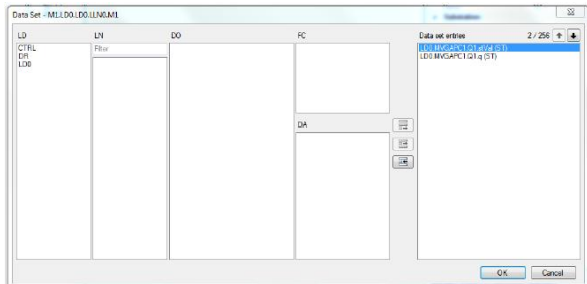


Figure 4 A GOOSE data set with a value and quality

The second step subscribe is to configure which IEDs receive the GOOSE message. It is normally a check box in a table of the configuration tool or any other type of operation in the graphical interface (Fig. 5). The configuration tool will copy all GOOSE data set and control block information to IEDs subscribes to receive the message. It also copies IEC 61850 data structure of sending IED to subscribing IED. After this step, exported CID file from GOOSE-receiving IED includes information of IED, logical device, logical node and data object of its own, it also includes IED, logical device, logical node and data objects of the GOOSE-sending IED.

	F1 (LD0)	F2 (LD0)	F3 (LD0)	M1 (LD0)
F1.LD0.LD0.LLN0.gcbF1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
F2.LD0.LD0.LLN0.gcbF1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
F3.LD0.LD0.LLN0.gcbF1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
M1.LD0.LD0.LLN0.gcbM1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Figure 5 GOOSE Subscribe

The third step is to configure GOOSE receiving IED by mapping the GOOSE data to user logic of the IED. IEDs from different vendors have different ways to map the GOOSE data. Signal matrix is one way of data mapping. In the example above, six GOOSE data from two IEDs (F1, and F2) in the column header are mapped to six GOOSE receiving data object rows in the application logic.

IED	F1, LD0		F2, LD0	
	MVGAFC1	MVGAFC1	MVGAFC1	MVGAFC1
-.F01_CB_CLOSED:GOOSERCV_BIN:0				
.F01_CB_CLOSED:GOOSERCV_BIN:0	IN	X		
.F01_FWD:GOOSERCV_BIN:1			X	
.F01_REV:GOOSERCV_BIN:2				X
.F01_REV:GOOSERCV_BIN:2	IN		X	
-.F02_CB_CLOSED:GOOSERCV_BIN:3				
.F02_CB_CLOSED:GOOSERCV_BIN:3	IN			X
.F02_FWD:GOOSERCV_BIN:4				
.F02_REV:GOOSERCV_BIN:4	IN			X
.F02_REV:GOOSERCV_BIN:5	IN			
.F02_REV:GOOSERCV_BIN:5	IN			X

Figure 6 an example of signal matrix to map GOOSE data to application logic

By these three steps, GOOSE-sending IED is ready to send the data, GOOSE-receiving IEDs are identified and are ready to receive the data.

### III. SUMMARY

Starting with two basic questions: “Where is the data” and “How to get the data”, protection and control engineers should focus on core components of IEC 61850 standard: 1) **Semantic Hierarchical Object Data model**, and 2) communication services: **Client - Server** and **Publish – Subscribe**. Respectively, IEC 61850 configuration includes just two steps: 1) preparing the data following the data model and 2) setting parameters of communication services. There is no myth here.

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