UCA and 61850 FOR DUMMIES

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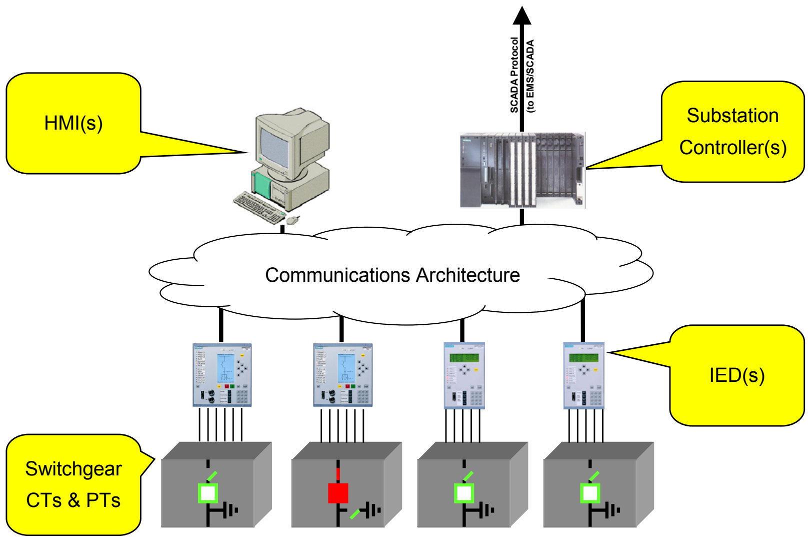
This presentation is intended as a primer for anyone with little or no knowledge of UCA or 61850. As such, it does not examine the protocols in any great depth. Readers interested in learning more about the protocols are encouraged to consult the references on the last slide of this presentation. Some poetic license has been taken with terminology to keep the explanation of concepts as simple as possible.

This presentation makes use of animation on several slides, so readers viewing a hardcopy of this presentation may lose some of the context.

Frame of Reference

Intra-Substation Communications



This architecture will be used extensively throughout the rest of this presentation to discuss concepts. It represents a “typical” SA system:

•Apparatus (switchgear and associated CTs and PTs)

•Intelligent Electronic Devices (IEDs)

•Substation Human Machine Interface (HMI)

•Substation Controller.

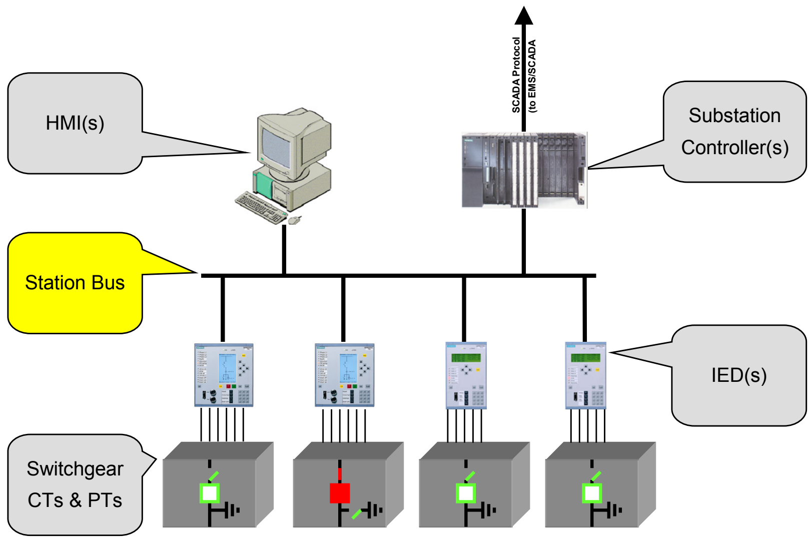
The last two are optional and either, none or both may be present. The Substation Controller may be PC-based (in which case the HMI and Substation Controller may be the same entity), RTU, PLC, Data Concentrator, or a hybrid of the above.

Substation Controller tasks can include collating data from the IEDs, performing system-wide logic, system time synchronization, filtering and pre-processing of data, and presentation of substation data to remote clients (network control center et al). In a truly flat architecture where the above functions are not required, the IEDs may couple directly to the remote client(s). The discussions that follow do not examine that alternative but the concepts we will review are portable to this architecture – just replace the local client with a remote client.

The cloud represents the communications infrastructure that integrates the IEDs into the HMI and/or Substation Controller.

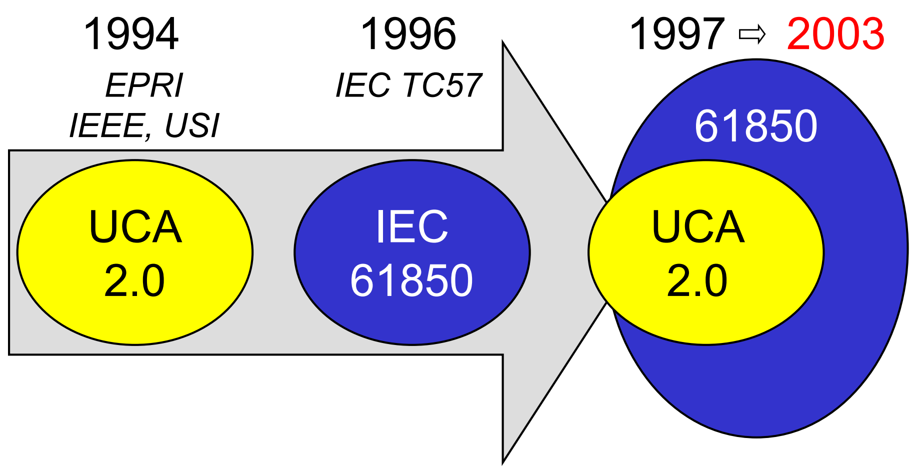
Frame of Reference

Station Bus



The goal for numerous years has been to define a communications infrastructure that will allow seamless integration of the IEDs into higher level devices - an infrastructure that is vendor independent and will allow devices from multiple vendors to be integrated together. The definition of a suitable Station Bus as depicted above has been the focus of standardization efforts on both sides of the Atlantic.

Two Standards Emerge
UCA and 61850



EPRI and the IEEE spear-headed an effort to define an Utility Communications Architecture (UCA) beginning in the early 1990s. The initial focus was inter Control Center communications and Substation to Control Center communications. This culminated in the ICCP specification which was later adopted by the IEC as 61850 TASE.2.

In 1994, EPRI/IEEE started working on the next phase of UCA – namely UCA 2.0, this time focused on the Station Bus.

In 1996, Technical Committee 57 of the IEC began work on IEC 61850 with a similar charter – defining a Station Bus.

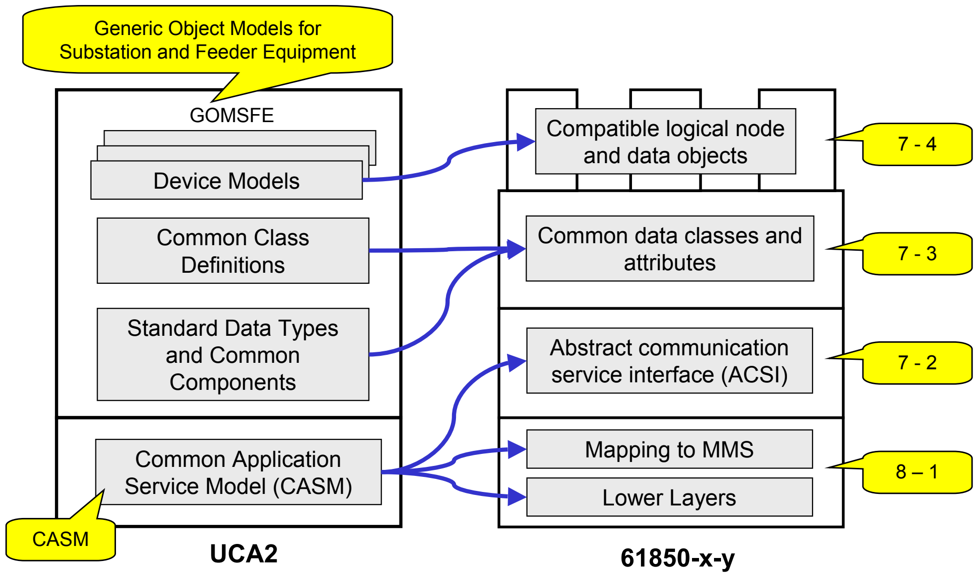
In 1997, the two groups agreed to work together to define a common international standard that would combine the work of both groups. The results of the harmonization efforts are the current IEC 61860 specification.

IEC 61850 is a superset of UCA 2.0, i.e. it contains almost all of the UCA 2.0 specification, plus offers additional features (more about this later). According to the current schedule, IEC 61850 will be a published, international standard in 2003.

You'll note that the Ven diagram shows 61850 encompassing most, but not all, of UCA 2.0. There are certain features in UCA 2.0 that have been omitted from 61850 (more about this later as well).

Functional Mapping

UCA 2.0 into 61850



This rather daunting looking diagram extracted from the IEC 61850 specification depicts the mapping of the Application layer of UCA 2.0 into 61850.

Without belaboring the technical details or semantic differences between the two, this diagram illustrates how UCA 2.0 has been incorporated into 61850. It may also help as an aid when trying to understand how the functional layers of one maps into the other.

The 61850 specification aims to define three things:

•Which data are available and how are they named and described (IEC 61850-7-4, -7-3, and -7-2),

•How can these data be accessed and exchanged (IEC 61850-7-2), and

•How can devices be connected to communication networks (IEC 61850-8-x and -9-x).

Things to Remember

1 61850 is UCA 2.0 plus…

This presentation aims to reinforce three (relatively) simple ideas; here's the first:

(1) IEC 61850 <u>is</u> UCA 2.0 plus additional functionality.

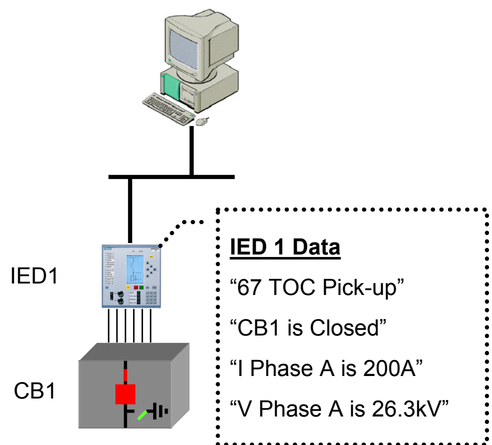
The rest of the presentation will concentrate on 61850 and it's nomenclature. However, with the exception of some differences in terminology, the concepts are equally true.

While our discussions will focus on intra-substation communications, 61850 is intended for other applications as well. The specification states that the standard may also be applied to describe device models and functions for:

- Substation to substation information exchange
- Substation to control centre information exchange
- Power Plant to control centre information exchange
- Information exchange for distributed automation
- Information exchange for metering

Data Communication

In "Human terms" (equates to ASCII protocol)



To explain some communication concepts, we'll use a simplified version of our substation architecture – an HMI connected to one IED.

The IED in question is of the multi-function variety, i.e. it is responsible for the protection, monitoring, metering and control of the associated apparatus (note, that the concepts to follow hold true for simpler, single functions IEDs as well).

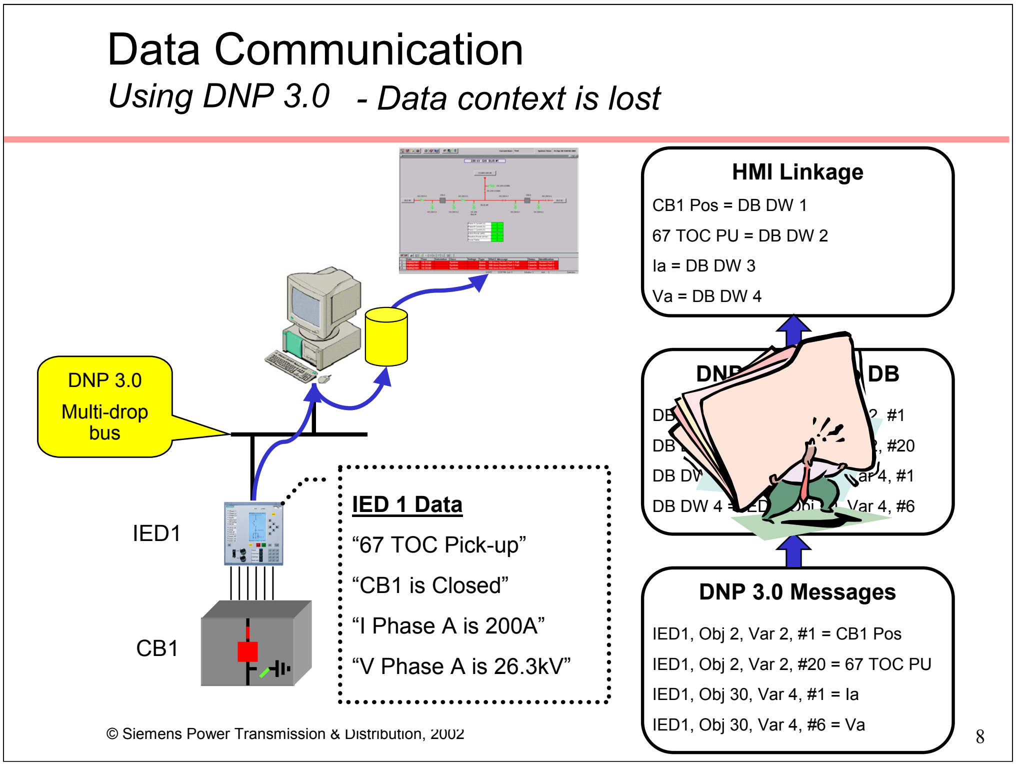
The IED has various data to "share"; in our example that a protection element has picked up, that the CB is closed, that phase A current is 200A, and that phase A voltage is 26.3kV

(multiply the above by several orders of magnitude and you'll have a sense of the data available in modern IEDs)

Communicating this data in human terms is fairly simple; I elected to use English as the "protocol" and conveyed the information in words. However, accomplishing the same data exchange between HMI and IED is a trickier proposition.

Although it is possible to convey information between machines (like our HMI and IED) using "human language" (for example, ASCII protocols), these are normally inefficient, bandwidth intensive, insecure and unsuitable for this type of application.

We have therefore developed communication protocols that map data in a manner that addresses these issues – for example DNP 3.0.



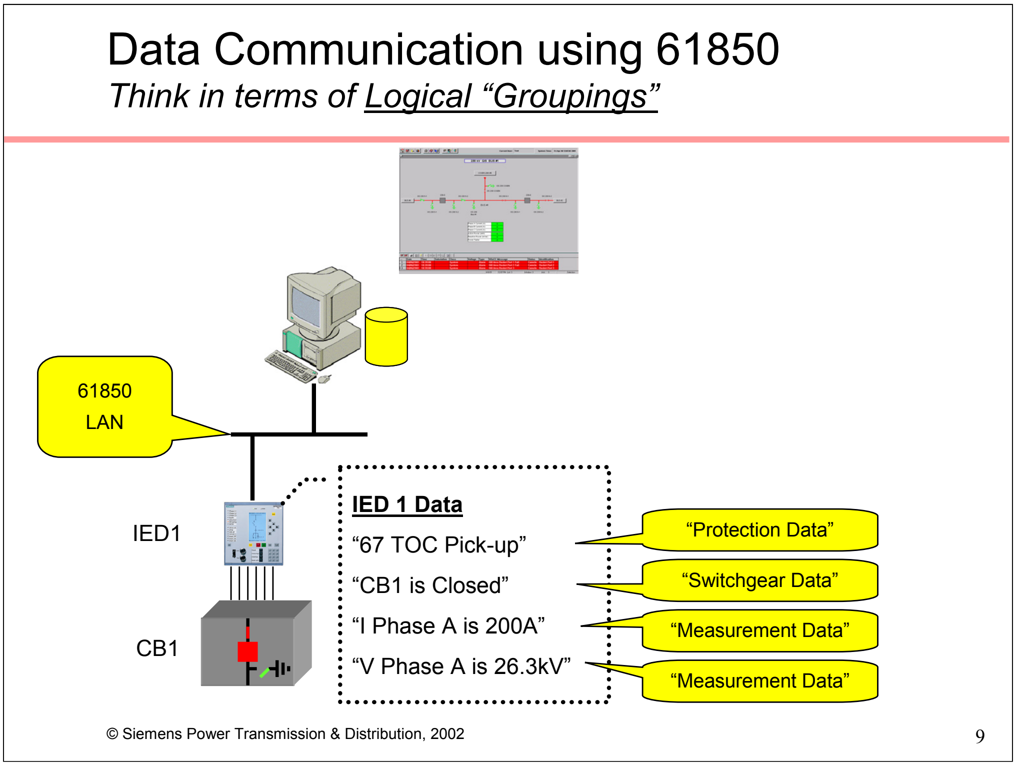
If we use DNP 3.0 as our Station Bus protocol there's a three stage process to getting the data from the source to the destination:

•The IED maps the "actual" data, e.g. "CB1 is Closed" into the appropriate DNP message, in this case, Object 2, Variant 2, Input #1 (Digital Input with time stamp).

•The next time the HMI requests data from this IED, or the IED volunteers data (if unsolicited reporting is supported), this message is transmitted to the HMI where the content, i.e. the value of Obj2, Var2, #1 from IED1 are written into a database.

•The HMI one line diagram contains a circuit breaker symbol, the state of which is being driven by the value in the database.

The problem is that <u>data context has been lost</u>. Unless you record which "actual" data has been mapped into which DNP message, you have no way of regenerating this linkage. This requires the manual transfer of paper or electronic renditions of this mapping to enable the HMI supplier to populate the database and complete the link – which implies additional engineering/configuration time and introduces the possibility of error.



Instead of dividing data into I/O types like Digital Input data, Analog Input data, etc, as is the case with DNP 3.0, IEC 61850 divides data into logical groupings. So in our example above we have:

•protection data (relay has picked up),

•switchgear data (CB is closed) and

•measurement data (values for V and I)

Logical Groupings

There are 13 different groups

Logical Node Groups	Group Designator
System Logical Nodes	**L**
Protection functions	**P**
Protection related functions	**R**
Supervisory control	**C**
Generic References	**G**
Interfacing and Archiving	**I**
Automatic Control	**A**
Metering and Measurement	**M**
Switchgear	**X**
Instrument Transformer	**T**
Power Transformer	**Y**
Further power system equipment	**Z**
Sensors	**S**

61850 defines a total of of 13 different groupings of data. The intent is that all data that could originate in the substation can be assigned to one of these groups.

Logical Nodes

There are 86 Logical Node Classes

Logical Node Groups	Group Designator	Number
System Logical Nodes	**L**	**2**
Protection functions	**P**	**27**
Protection related functions	**R**	**10**
Supervisory control	**C**	**4**
Generic References	**G**	**3**
Interfacing and Archiving	**I**	**4**
Automatic Control	**A**	**4**
Metering and Measurement	**M**	**7**
Switchgear	**X**	**2**
Instrument Transformer	**T**	**2**
Power Transformer	**Y**	**4**
Further power system equipment	**Z**	**14**
Sensors	**S**	**3**
		86

PDIR	Directional element
PHAR	Harmonic restraint
PSCH	Protection Scheme
PTEF	Transient Earth Fault
PZSU	Zero speed or underspeed
PDIS	Distance protection
PVPH	Volts per Hz relay
PTUV	Undervoltage
PDOP	Directional over power
…more	

MMXU	Measuring (Measurand unit)
MMTR	Metering
MSQI	Sequence and Imbalance
MHAI	Harmonics and Inter-harmonics
MDIF	Differential Measurements
…more	

XCBR	Circuit Breaker
XSWI	Circuit Switch

Each of the groups are further subdivided into Logical Nodes. There are 86 different types of Logical Nodes defined. Each of these are composed of data that represent some application specific meaning and are intended to provide separate sub-categories of data (poetic license with terminology applied here). For example,

The Protection Function group comprises 27 different Logical Nodes, some of these are listed above. To map this to the real world, data from a protective relay with 21 and 51 elements would be mapped to PTOC and PDIS logical nodes respectively.

Data

There are 355 Data Classes

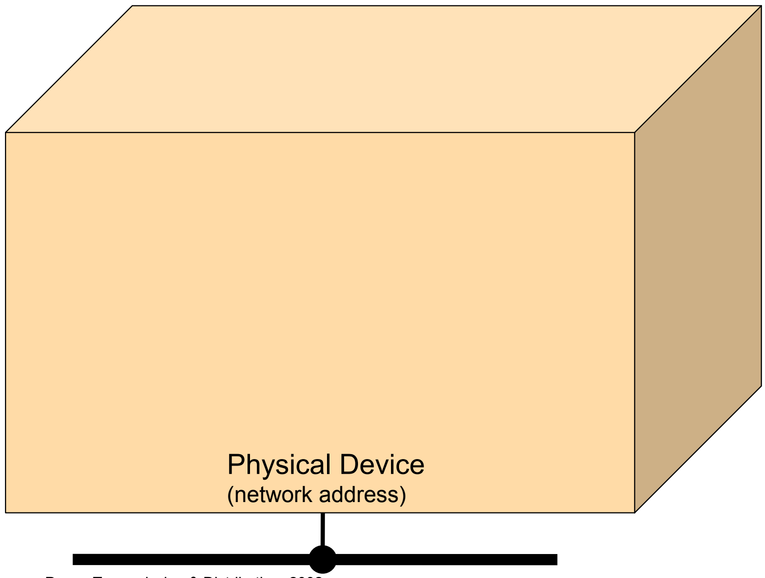
Data Classes	Number
System information	13
Physical device information	11
Measurands	66
Metered values	14
Controllable Data	36
Status information	85
Settings	130
	355

A - Phase to ground amperes for Phases 1, 2, and 3
Amps - Current of a non three phase circuit
Ang - Angle between phase voltage and current
AnIn - Analogue Input used for generic I/O
ChAnVal - Array of analogue channel numbers and actual values at a certain time (time tag)
CircA - Measured circulating current in a transformer paralleling application
CtlV - Voltage on secondary of transformer as used for voltage control.
Den - Density of gas or other insulating Medium
DQ0Seq - Direct, quadrature, and zero axis quantity
ECC - This is the measured current through a Petersen Coil in neutral compensated networks.
FDkm - The distance to a fault in kilometres
FDOhm - The distance to a fault in Ohms
HaRmsA - Current Harmonic RMS (un-normalized THD) for A, B, C, N
HaRmsV - Voltage Harmonic RMS (un-normalized THD) for AB, AN, BC, BN, CA, CN, NG
HaTdA - Current Total Harmonic Distortion
HaTdV - Voltage Total Harmonic Distortion
More…..

There are 355 different classes of data that are used to “construct” Logical Nodes. These data classes are divided amongst the 7 categories detailed above.

Logical Groupings

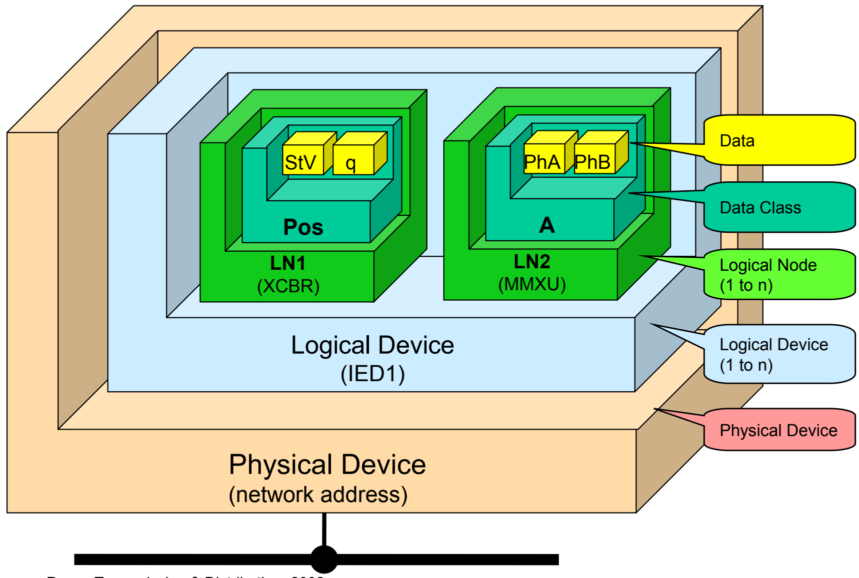
Devices, nodes, classes and data



To illustrate how these device, logical nodes, classes and data concepts map to the real world, imagine an IED as a container.

Logical Groupings

Devices, nodes, classes and data



The container is the Physical Device, it contains

one or more Logical Devices, each of which contains

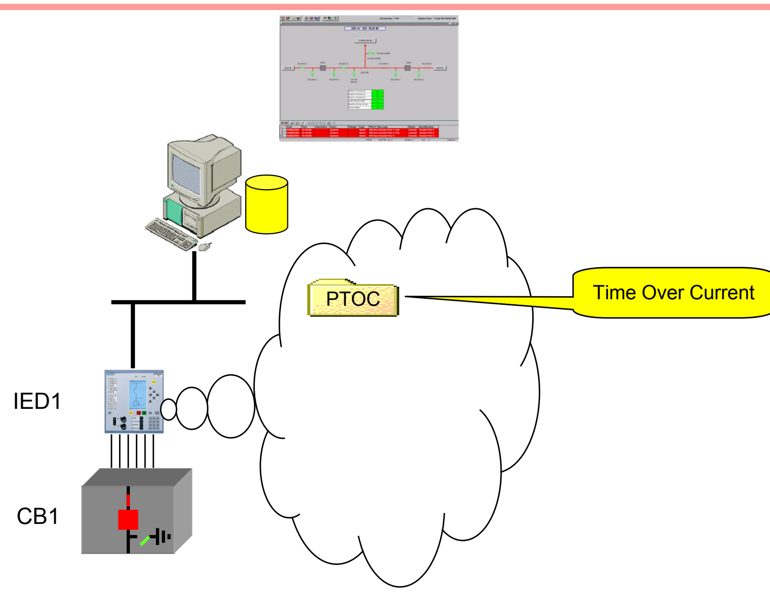
one or more Logical Nodes, each of which contains

a pre-defined set of Data Classes, each of which contains

data.

Defining Devices

Physical Devices breakdown into Logical Nodes

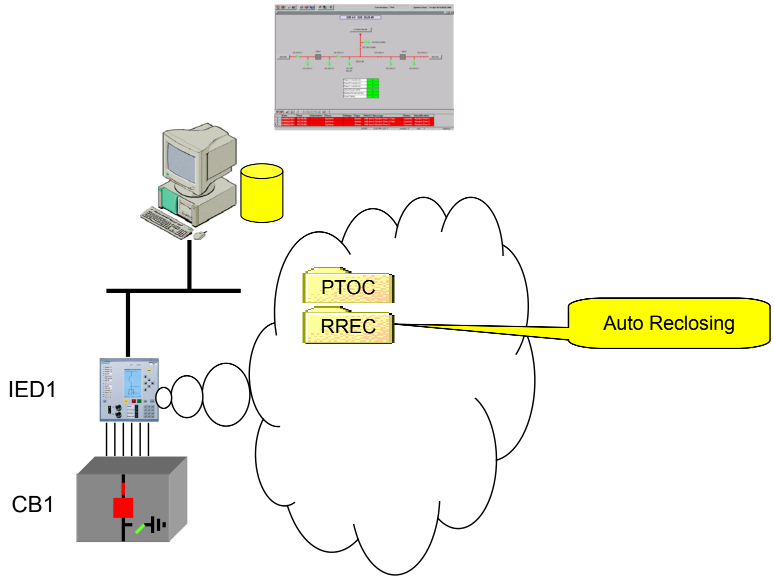


To return to our substation architecture, IED1 is a multi-function IED and supports the following features:

Protection (Time Over Current, 51) PTOC LN

Defining Devices

Physical Devices breakdown into Logical Nodes

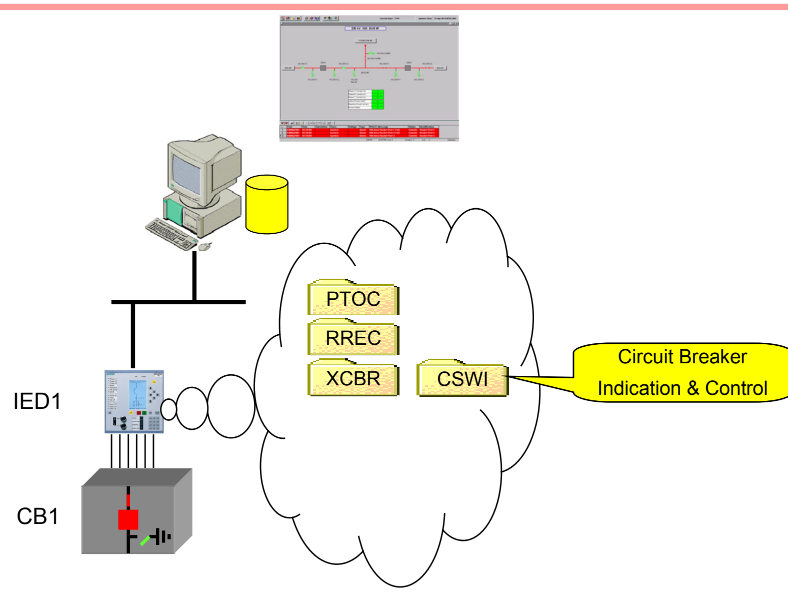


IED1 is a multi-function IED and supports the following features:

Protection (Time Over Current, 51)	PTOC LN
Protection related (Autoreclosing, 79)	RREC LN

Defining Devices

Physical Devices breakdown into Logical Nodes

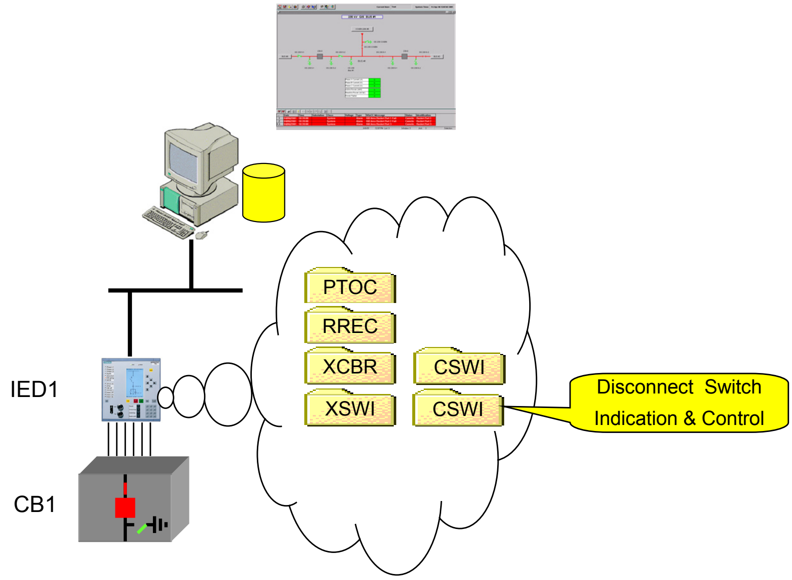


IED1 is a multi-function IED and supports the following features:

Protection (Time Over Current, 51)	PTOC LN
Protection related (Autoreclosing, 79)	RREC LN
Monitoring of CB	XCBR LN
Control of CB	CSWI LN

Defining Devices

Physical Devices breakdown into Logical Nodes



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Protection (Time Over Current, 51)	PTOC LN
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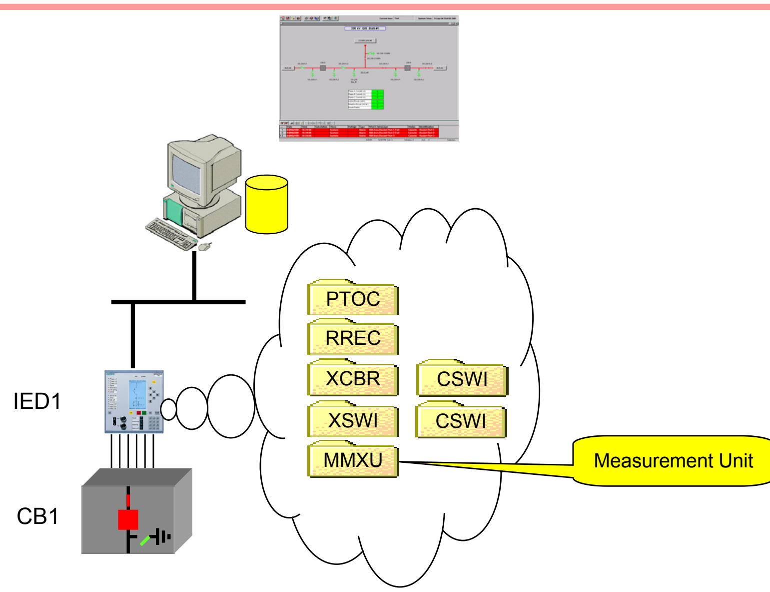
Control of CB	CSWI LN
Monitoring of Disconnect Switch	XSWI LN
Control of Disconnect Switch	CSWI LN

Defining Devices

Physical Devices breakdown into Logical Nodes



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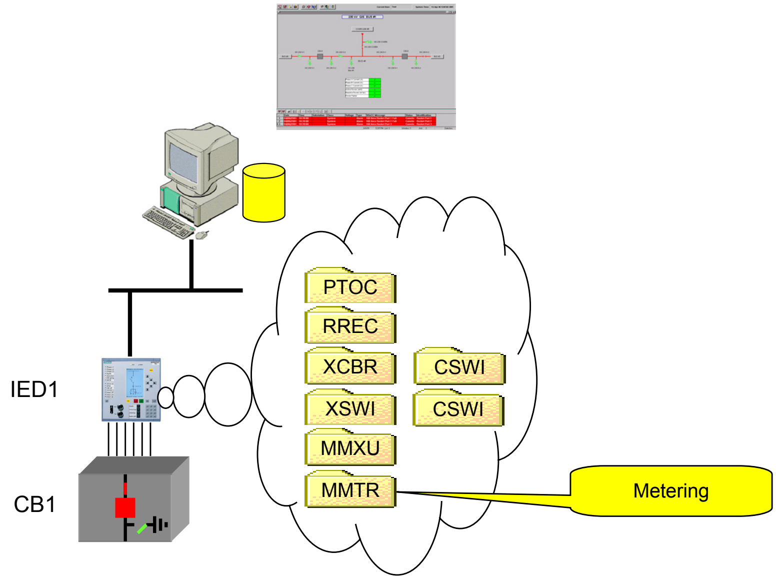
Monitoring of CB	XCBR LN
Control of CB	CSWI LN
Monitoring of Disconnect Switch	XSWI LN
Control of Disconnect Switch	CSWI LN
Measurement (V, A, W, etc)	MMXU LS

Defining Devices

Physical Devices breakdown into Logical Nodes



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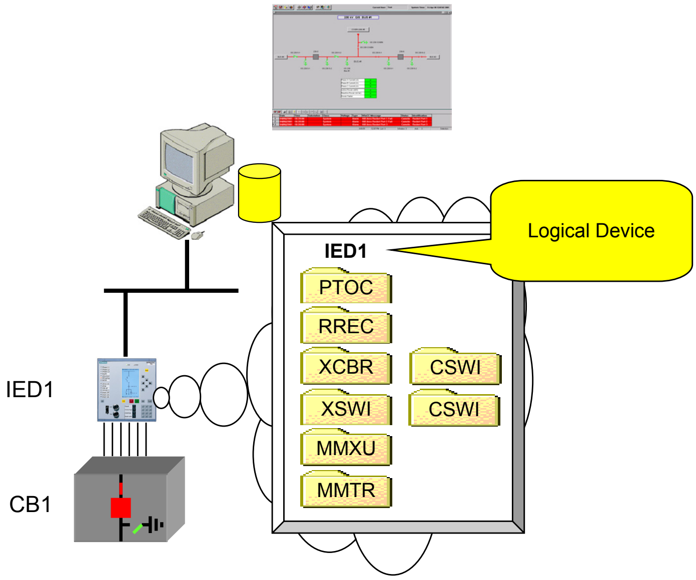
Protection (Time Over Current, 51)	PTOC LN
Protection related (Autoreclosing, 79)	RREC LN
Monitoring of CB	XCBR LN
Control of CB	CSWI LN
Monitoring of Disconnect Switch	XSWI LN
Control of Disconnect Switch	CSWI LN
Measurement (V, A, W, etc)	MMXU LN
Metering (Energy)	MMTR LN

Defining Devices

Logical Nodes are grouped inside a *__Logical Device__*



These eight Logical Nodes are grouped “inside” one Logical Device

Accessing Data

Think Windows Explorer

IED1/XCBR

IED1

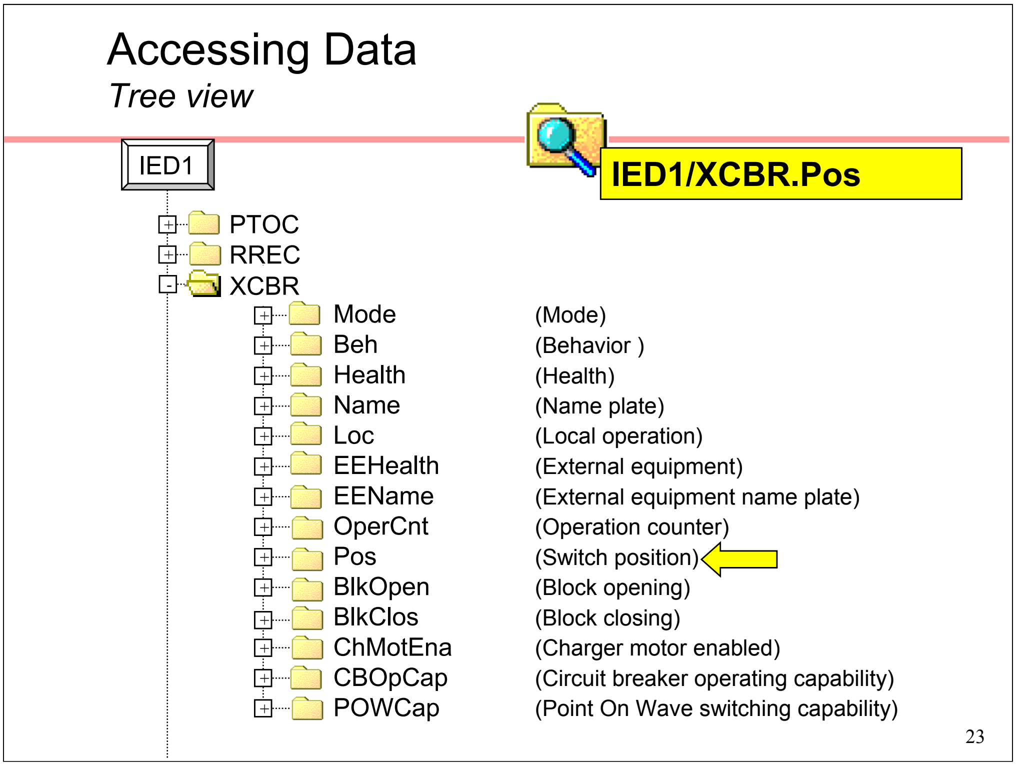
- PTOC (Time Over Current LN)
- RREC (Autorecloser LN)
- XCBR (Switchgear – Circuit Breaker)
- CSWI (Control - Circuit Breaker)
- XSWI (Switchgear – Disconnect)
- CSWI (Control - Disconnect)
- MMXU (Measurement Unit)
- MMTR (Metering)

Accessing data in a 61850 network is analogous to accessing data across a conventional IT network using Windows Explorer, i.e. browse the network until the data source is located, then drill-down into the data source until the data is located.

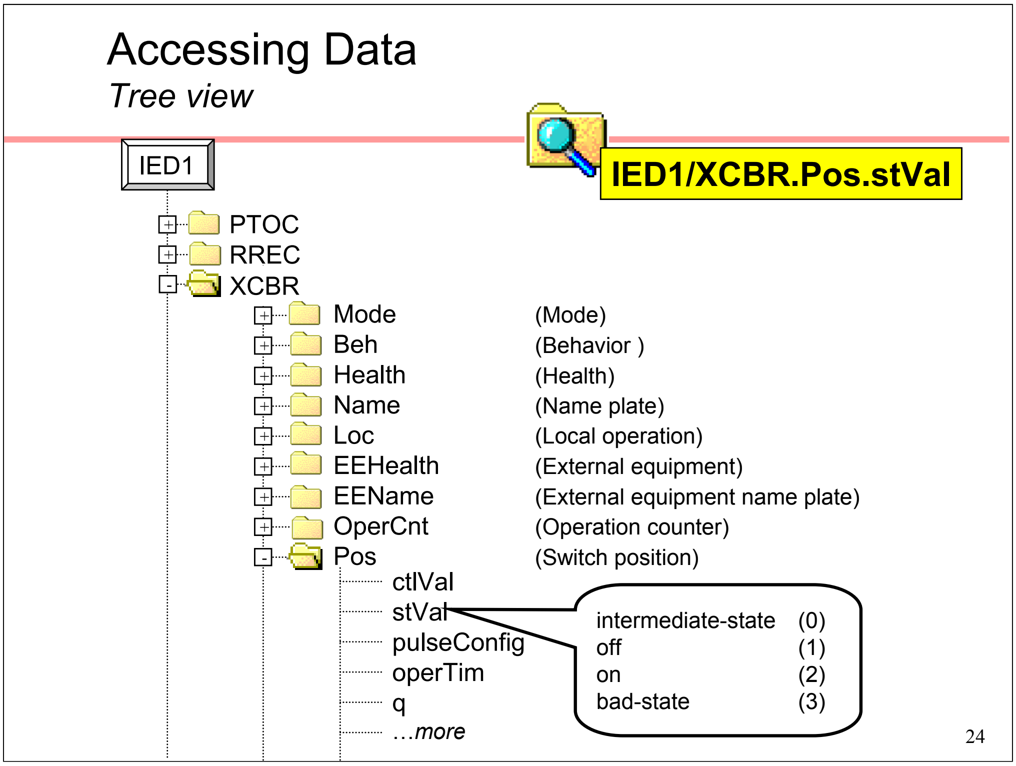
Let’s assume personnel responsible for the HMI wish to animate a CB symbol on a one-line diagram:

•CB1 is being controlled and monitored by IED1, so they would browse the network until this Logical Device was located

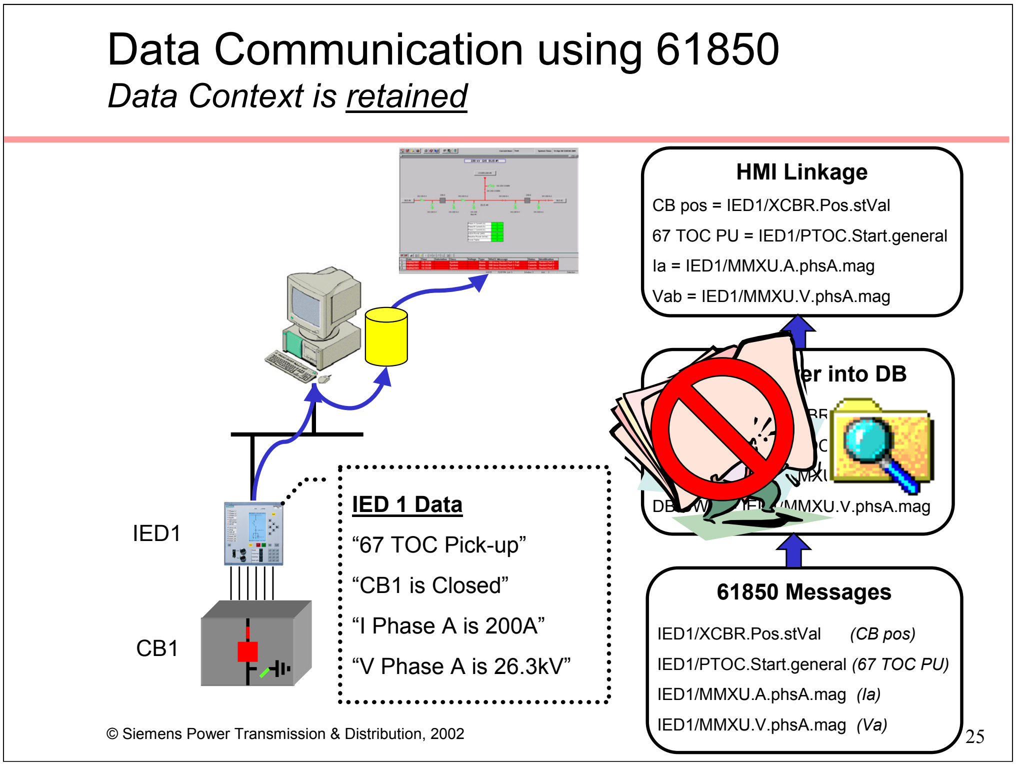
•They would need enough 61850 nomenclature knowledge to know that the XCBR LN is associated with the status of the CB, then drill down into that “folder”



The XCBR LN consists of 14 “folders”. The **Pos** “folder” contains information about switch position, so this would be drilled-down into.



The **Pos** “folder” is of type Controllable Double Point (CDP) data class. The CDP data class consists of 14 data fields (some are mandatory and must always be present, others are optional). The **StVal** field contains the value of the CB.

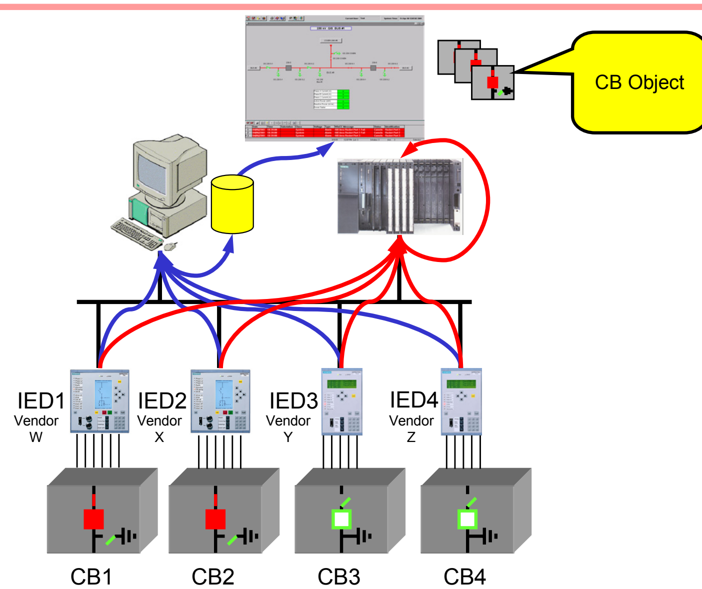


In our earlier DNP example HMI personnel had to cross-reference data against protocol address information to know which data points to connect to which objects on the one-line. There was a commensurate increase in engineering effort and the possibility of error.

In our 61850 example however, HMI personnel browse the devices directly and subscribe to the data they require – there is no need for an intermediate cross-reference of data.

Data Communication using 61850

Devices are self describing



The remainder of the system is configured in the same fashion. Data from the other IEDs are available to the HMI and Substation Controller for incorporation into one-lines, historical archives, control sequences, logic programs, automation applications, etc.

Things to Remember

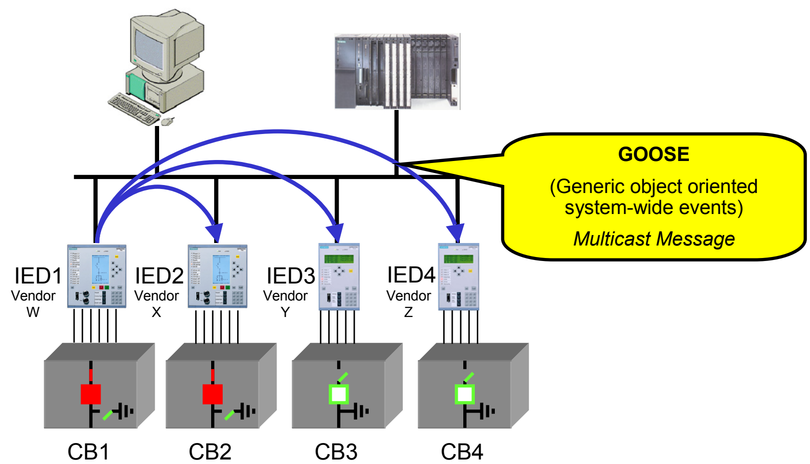
1. 61850 is UCA 2.0 plus…
2. Self description

Here's the second of the three concept this presentation aims to convey
(2) IEC 61850 supports self description

You can see what data a device has by communicating with it and browsing its contents.

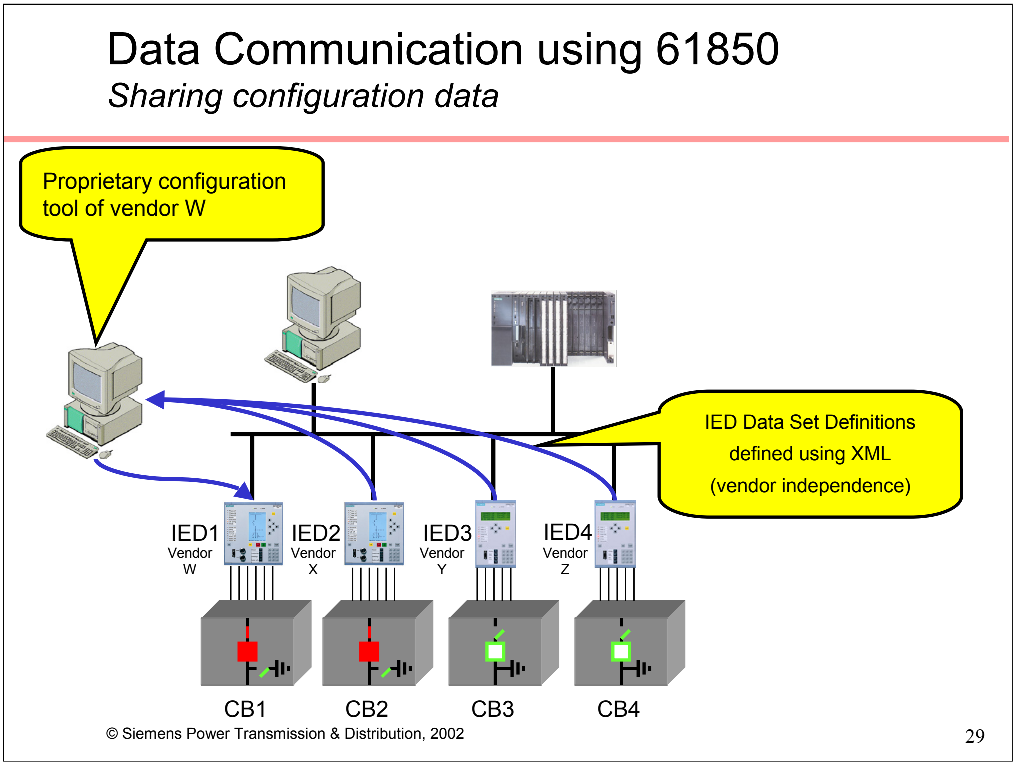
Data Communication using 61850

Peer-to-peer communications are possible



GOOSE is an acronym for Generic Object Orientated System-wide Events. It aims to replace the conventional hardwired logic necessary for intra-relay coordination with station-bus communications. Upon detecting an event, the IED(s) use a multi-cast transmission to notify those devices that have registered to receive the data. The performance requirements are stringent – no more than 4ms is allowed to elapse from the time an event occurs to the time of message transmission.

The number of IEDs, the network topology and the type of event will all contribute to the amount of data that will be generated after an event. Collisions are quite possible in an Ethernet network in this scenario, so the GOOSE messages are re-transmitted multiple times by each IED. Three LAN configurations (10 MB switched hub, 100 MB shared hub, and 100 MB switched hub) are able to deliver 100 messages within 4 milliseconds.



GOOSE requires peer-to-peer communications between relays, quite possibly from different vendors. Configuring the requisite Publisher/Subscriber model could be a very daunting task, especially when each vendor will have their own “proprietary” configuration program.

61850 has an elegant solution to that challenge. IED vendors are required to provide a descriptor file for their IEDs in XML format. Extensible Markup Language (XML) provides many of the same features as HTML with the important distinction that it not only presents data, but also provides instructions on how the data should be interpreted.

The eventual goal is for the devices to transmit their configuration in XML upon request. The use of XML and the substation configuration language defined by 61850 will provide visibility into the data available from any vendor. This will allow dynamic configuration of the GOOSE communications as shown above. The Configuration tool of Vendor W is used to read the IED Data Set Definitions of IED2, IED3 and IED4 from vendors X, Y and Z respectively. The subsets of data that IED1 require from the others (to be used in logic programs or for blocking) are identified and downloaded into IED1. The same procedure would be followed using the configuration tools of the other IEDs.

Until the IEDs are themselves able to produce the XML data, it will be made available by each vendor and delivered along with the IEDs in some electronic format. While not allowing dynamic configuration, this interim step will still minimize configuration effort considerably.

Things to Remember

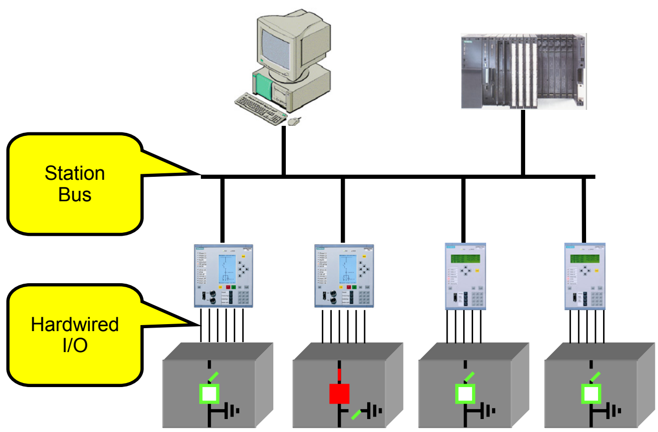
1. 61850 is UCA 2.0 plus…
2. Self description
3. Client-Server and Peer-to-peer communications

And here's the last of the three concept this presentation aims to convey

(3) IEC 61850 supports both Client-Server and Peer-to-Peer communications. It is the peer-to-peer communications ability that is used to exchange GOOSE messages between IEDs.

Station Bus vs Process Bus

61850-8 vs 61850-9

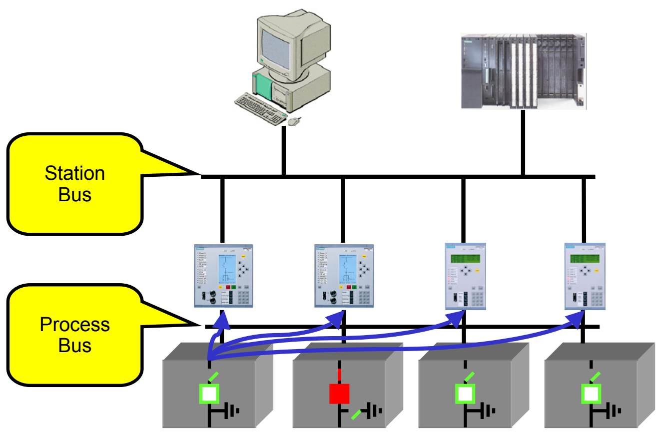


To date we have focused our attention on the Station-Bus, i.e. upstream of the IEDs.

Communications downstream of the IEDs with the apparatus has traditionally been accomplished by hardwired I/O used to monitor CTs and PTs and control CBs and Switches. However, 61850 details a Process Bus that aims to change that.

Station Bus vs Process Bus

61850-8 vs 61850-9

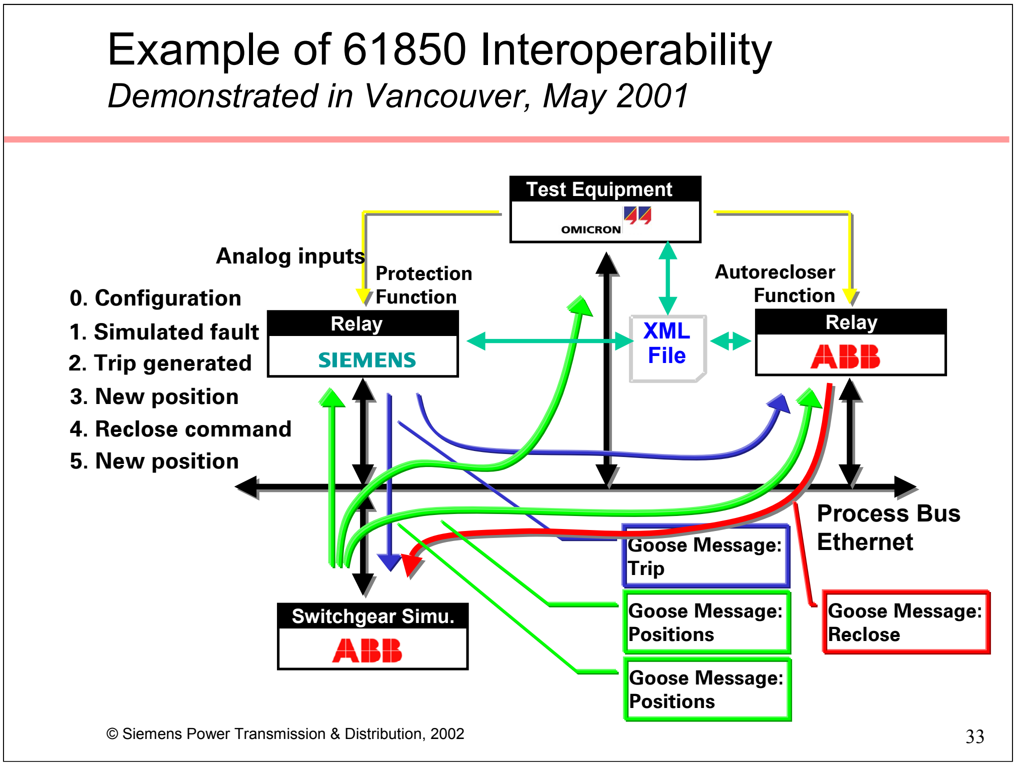


The Process Bus replaces hard wired connections with communication lines. “Smart” CTs, PTs and switchgear continuously transmit data over the process bus and any upstream devices that wish to use the data for protection, measurements, metering or monitoring do so by monitoring the communications.

There are two flavors of 61850-9:

9-1, Serial unidirectional multidrop point to point link
9-2, IEEE 802.3 based process bus, i.e. Ethernet

Although still under development, process bus definitely appears viable. Siemens and ABB successfully demonstrated interoperability using a combination Substation and Process bus architecture in May 2001 at the Utility Substation Initiative meeting in Vancouver.



The above diagram illustrates how 61850 is used in a “real world” example in a recent interoperability demonstration.

The example consists of two protective relays from different vendors, one with protection functions and the other with recloser functions, a test set which is simulating CT and PT inputs, and a 61850-enabled Switchgear simulator

•Pertinent configuration information is shared between the two protective relays and the test set using XML data

•Test set simulates a fault

•Relay with protection functions detects the fault and issues a trip message via GOOSE

•Switchgear simulator trips the breaker and issues a GOOSE messages containing the new status of the breaker

•Relay with recloser function detects breaker has tripped and issues Reclose command via GOOSE

•Switchgear closes breaker and issues a GOOSE messages containing the new status

61850 is UCA 2.0 plus…

- Different terminology (Logical Nodes vs Bricks)
- Expanded GOOSE
- Different control model
- Process bus
- Conformance test defined
- General device requirements defined
- Communications requirements defined
- XML-based Engineering Language

As mentioned earlier there are some differences between 61850 and UCA. These include:

•Although the models are very similar, UCA uses different terminology, i.e. Logical Nodes are referred to as Bricks.

•The GOOSE message structure has been expanded in 61850 to provide greater flexibility in the type of data transported.

•61850 has a different control model. The UCA control model includes features used in the water and gas industries. The 61850 control model contains only features required for the electrical utility industry.

•UCA makes no provision for the process bus.

•61850 defines conformance tests against which devices can be tested and certified for conformance to the specification.

•61850 defines general device requirements like temperature range devices need to adhere to, etc.

•61850 defines communication requirements that devices have to comply with like required behavior after communications are interrupted, etc.

•61850 defines a XML-based engineering language

•UCA defines more communication stacks, including a short stack intended for simple implementations over low speed communications. At present 61850 does not cater for this application.

61850 Components

System Aspects

Part 1: Introduction and Overview

Part 2: Glossary

Part 3: General Requirements
Part 4: System and Project Management

Part 5: Comm Requirements for Functions and Device Models

Configuration

Part 6: Configuration Language for electrical Substation IEDs

Data Models

Part 7-4: Compatible Logical Node Classes and Data Classes
Part 7-3: Common Data Classes

Abstract Communication Services

Part 7-2: Abstract Communication Services (ACSI)
Part 7-1: Principles and Models

Mapping to real Comm. Networks (SCSM)

Part 8-1: Mapping to MMS

Part 9-1: Serial Unidirectional Multidrop Point-to-Point link

Part 9-2: Mapping on IEEE 802.3 based Process Bus

Testing

Part 10: Conformance Testing

61850 consists of several parts – these are shown above.

Useful Links

http://www.ucausersgroup.org/IEC61850docs.htm
http://www.nettedautomation.com/index.html

Questions?