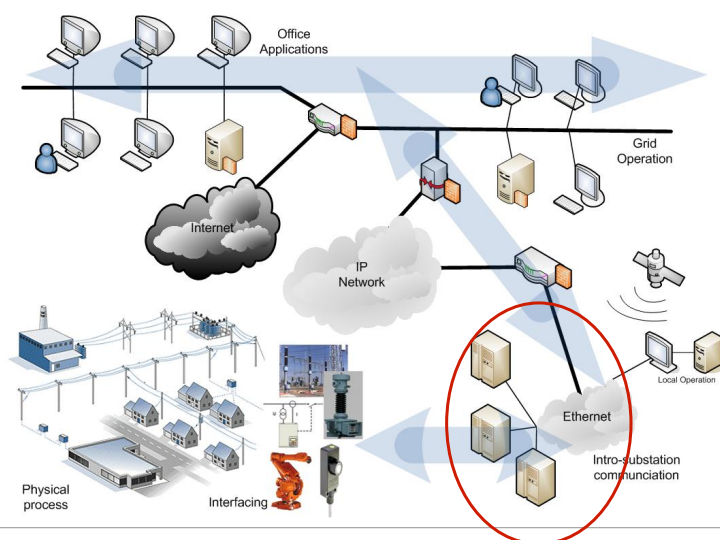




Substation Automation Systems IEC 61850 standard



Course map





Outline of the Lecture

- Recap of modern substation architectures
 - IEC 61850 substation
 - Purpose and scope of IEC 61850
- IEC 61850 Information Model
- Substation communication
 - Introduction
- Specification and configuration



Recap

Common components



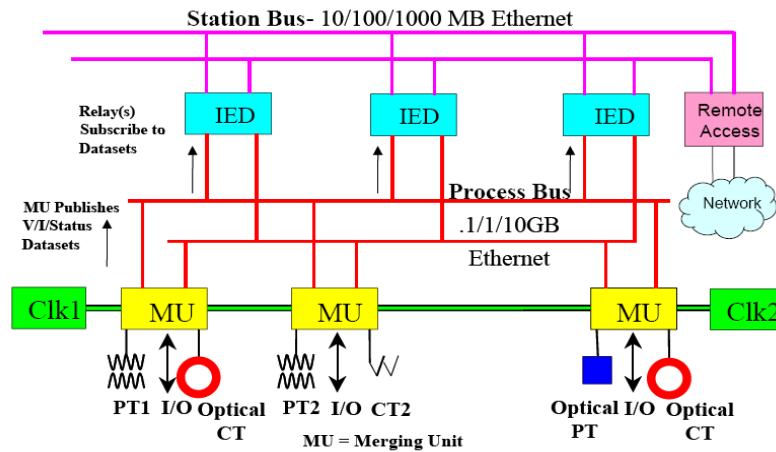
- **Intelligent Electronic Device(s)**
 - Implements functions & protection
- **Bay controller**
 - controls all devices related to a single bay
- **Human Machine Interface**
 - Operator console for local control/configuration
- **Communication bus(es)**
 - Connection between devices
- **Upwards communication interface.**
 - To SCADA
- **Remote Terminal Unit**
 - Telemetry and remote control device



- **Merging Unit**

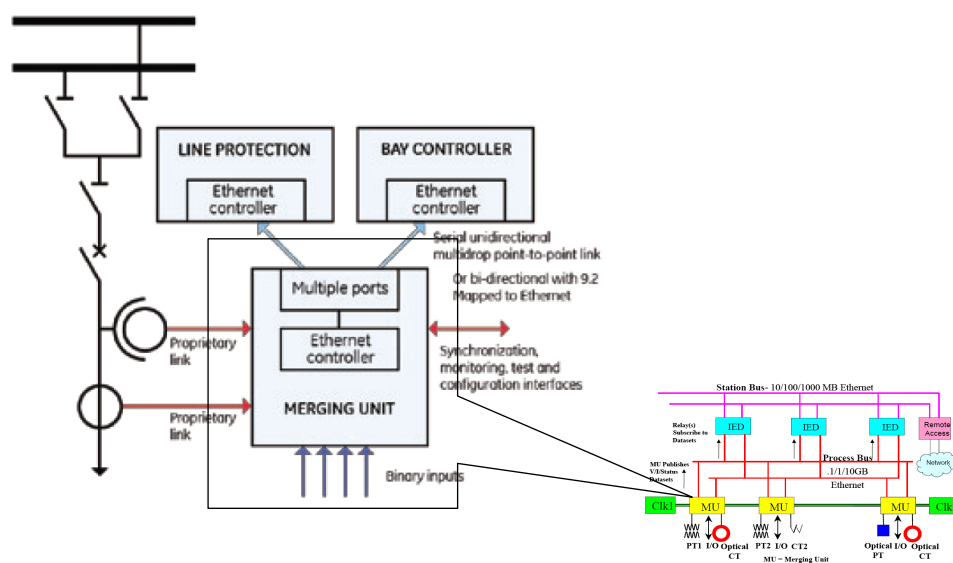
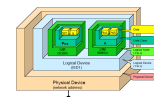
Substation architectures

IEC 61850 substation



Substation architectures

The Merging Unit





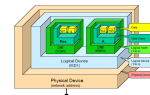
Outline of the Lecture

- Recap of modern substation architectures
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- Specification and configuration



Purpose and Scope of IEC 61850

Objectives



The 61850 standard was developed to:

- Address the need for a **more structured approach** to design of Substation Automation Systems
- **Separate Data model** from method of **communication**
- Utilise new technologies (**Ethernet, TCP/IP**)
- Enable **vendor independence**
- **Simplify** system configuration
- Enable **sharing of measurement** among devices

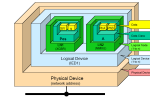
Information Model

Communication



Purpose and Scope of IEC 61850

How is this achieved?



- **Model information about the real world**
 - Status, measurements, settings
 - Configuration of system
 - Single-line diagram
 - Function related information
- **Defines when to exchange values**
 - Configuration of IED
- **Defines how to exchange values**
 - Configuration of IED
- **Describe the recipient of the values**
 - Configuration of IED
- **Describe who to receive values from**
 - Configuration of IED



Outline of the lecture

- Recap of modern substation architectures
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IEC 61850 Information Model

Modelling a substation

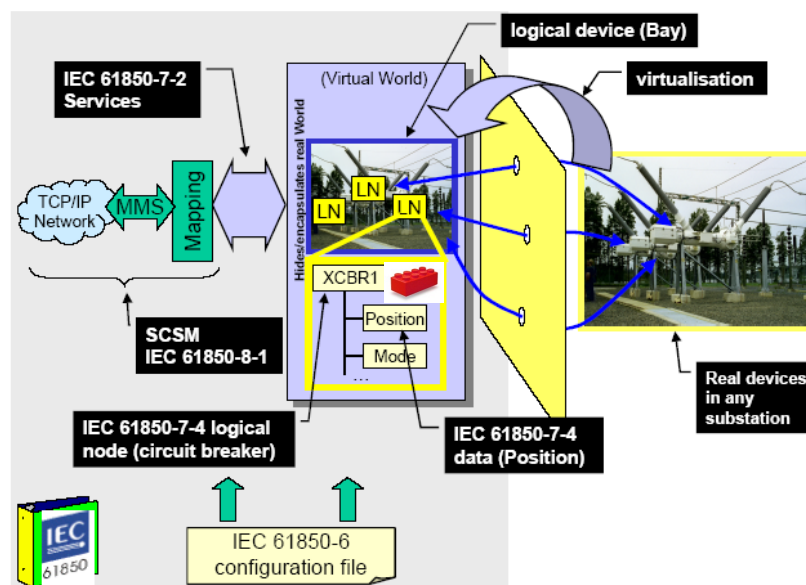


- We would like to have some kind of standardized building-block for functionality
- Enter the Logical Node (LN)...



IEC 61850 Information Model

Modelling a substation





IEC 61850 Information Model

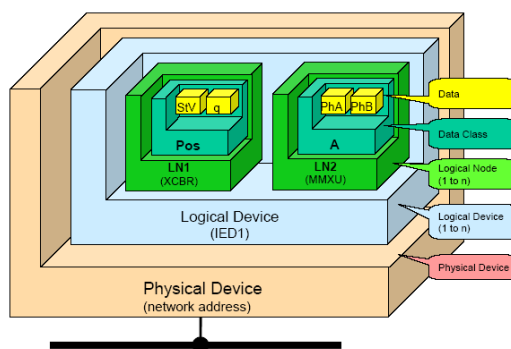
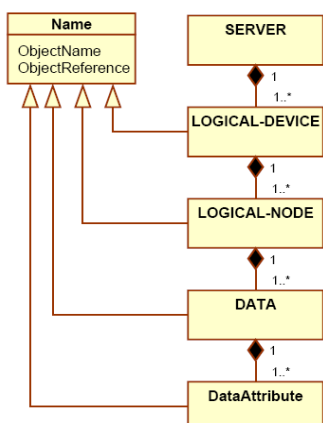


- Modelling a substation
- Component hierarchy
- IEC 61850-8-1 object name
- Logical Node (LN) groups
- Logical Node (LN) examples
- Assigning Logical Nodes



IEC 61850 Information Model

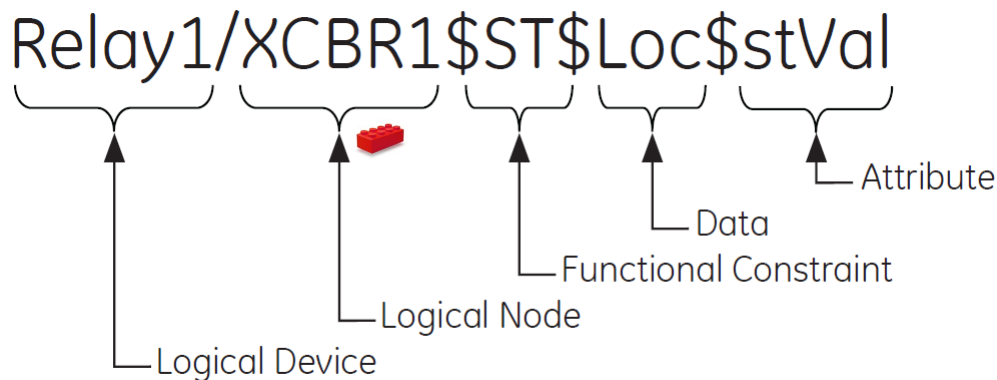
Component hierarchy





IEC 61850 Information Model

IEC 61850-8-1 object name



IEC 61850 Information Model

Logical Nodes - Groups



Name	Description
Axxx	Automatic Control (4). ATCC (tap changer), AVCO (volt. ctrl.), etc.
Cxxx	Supervisory Control (5). CILO (Interlocking), CSWI (switch ctrl), etc.
Gxxx	Generic Functions (3). GGIO (generic I/O), etc.
Ixxx	Interfacing/Archiving (4). IARC (archive), IHMI (HMI), etc.
Lxxx	System Logical Nodes (2). LLN0 (common), LPHD (Physical Device)
Mxxx	Metering & Measurement (8). MMXU (meas.), MMTR (meter.), etc.
Pxxx	Protection (28). PDIF, PIOC, PDIS, PTOV, PTOH, PTOC, etc.
Rxxx	Protection Related (10). RREC (auto reclosing), RDRE (disturbance)..
Sxxx	Sensors, Monitoring (4). SARC (archs), SPDC (partial discharge), etc.
Txxx	Instrument Transformer (2). TCTR (current), TVTR (voltage)
Xxxx	Switchgear (2). XCBR (breaker), XCSW (switch)
Yxxx	Power Transformer (4). YPTR (transformer), YPSH (shunt), etc.
Zxxx	Other Equipment (15). ZCAP (cap ctrl), ZMOT (motor), etc.
Wxxx	Wind (Set aside for other standards)
Oxxx	Solar (Set aside for other standards)
Hxxx	Hydropower (Set aside for other standards)
Nxxx	Power Plant (Set aside for other standards)
Bxxx	Battery (Set aside for other standards)
Fxxx	Fuel Cells (Set aside for other standards)



IEC 61850 Information Model

Logical Nodes – Other examples



-  **TVTR** – Voltage transformer
-  **TCTR** – Current transformer
-  **MMXU** – Measurement
-  **XCBR** – Circuit Breaker
-  **PDIF** – Differential Protection
-  **PDIS** – Distance Protection



IEC 61850 Information Model

Logical Nodes – Example XCBR



XCBR class				
Attribute Name	Attr. Type	Explanation	T	M/O
LNName		Shall be inherited from Logical-Node Class (see IEC 61850-7-2)		
Data				
<i>Common Logical Node Information</i>				
		LN shall inherit all Mandatory Data from Common Logical Node Class		M
Loc	SPS	Local operation (local means without substation automation communication, hardwired direct control)		M
EEHealth	INS	External equipment health		O
EEName	DPL	External equipment name plate		O
OpCnt	INS	Operation counter		M
Controls				
Pos	DPC	Switch position		M
BlkOpn	SPC	Block opening		M
BlkCls	SPC	Block closing		M
ChaMotEna	SPC	Charger motor enabled		O
Metered Values				
SumSwARs	BCR	Sum of Switched Amperes, resetable		O
Status Information				
CBOpCap	INS	Circuit breaker operating capability		M
POWCap	INS	Point On Wave switching capability		O
MaxOpCap	INS	Circuit breaker operating capability when fully charged		O



IEC 61850 Information Model

Logical Nodes – Example MMXU – Measurement



MMXU 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 (external sensor)		O
Measured values				
TotW	MV	Total Active Power (Total P)		O
TotVAr	MV	Total Reactive Power (Total Q)		O
TotVA	MV	Total Apparent Power (Total S)		O
TotPF	MV	Average Power factor (Total PF)		O
Hz	MV	Frequency		O
PPV	DEL	Phase to phase voltages (VL1VL2, ...)		O
PhV	WYE	Phase to ground voltages (VL1ER, ...)		O
A	WYE	Phase currents (IL1, IL2, IL3)		O
W	WYE	Phase active power (P)		O
VAr	WYE	Phase reactive power (Q)		O
VA	WYE	Phase apparent power (S)		O
PF	WYE	Phase power factor		O
Z	WYE	Phase Impedance		O



IEC 61850 Information Model

Logical Nodes – Example TVTR – Voltage Transformer



TVTR 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
EENa	DPL	External equipment name plate		O
OpTmh	INS	Operation time		O
Measured values				
Vol	SAV	Voltage (sampled value)		M
Status Information				
FuFail	SPS	TVTR fuse failure		O
Settings				
VRtg	ASG	Rated Voltage		O
HzRtg	ASG	Rated frequency		O
Rat	ASG	Winding ratio of external voltage transformer (transducer) if applicable		O
Cor	ASG	Voltage phasor magnitude correction of external voltage transformer		O
AngCor	ASG	Voltage phasor angle correction of external voltage transformer		O



IEC 61850 Information Model

Logical Nodes – Example TCTR – Current Transformer



TCTR 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
EENName	DR	External equipment name plate		O
OpTmh	INS	Operation time		O
Measured values				
Amp	SAV	Current (Sampled value)		M
Settings				
ARtg	ASG	Rated Current		O
HzRtg	ASG	Rated Frequency		O
Rat	ASG	Winding ratio of an external current transformer (transducer) if applicable		O
Cor	ASG	Current phasor magnitude correction of an external current transformer		O
AngCor	ASG	Current phasor angle correction of an external current transformer		O



IEC 61850 Information Model

Logical Nodes – Example XCBR – Circuit Breaker



XCBR 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
Loc	SPS	Local operation (local means without substation automation communication, hardwired direct control)		M
EEHealth	INS	External equipment health		O
EENName	DR	External equipment name plate		O
OpCnt	INS	Operation counter		M
Controls				
Pos	SPC	Switch position		M
BlkOpn	SPC	Block opening		M
BlkCls	SPC	Block closing		M
ChaMotEna	SPC	Charger motor enabled		O
Metered values				
SumSwAr	BCR	Sum of Switched Amperes, resettable		O
Status information				
CapCap	INS	Circuit breaker operating capability		M
PonCap	INS	Point On Wave switching capability		O
MaxCap	INS	Circuit breaker operating capability when fully charged		O



IEC 61850 Information Model

Logical Nodes – Example PTOC – Overcurrent Protection



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	Resettable 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
OpDITmms	ING	Operate Delay Time		O
TypRscv	ING	Type of Reset Curve		O
RsdTmms	ING	Reset Delay Time		O
DirMod	ING	Directional Mode		O



IEC 61850 Information Model

Logical Nodes – Example PDIS – Distance Protection

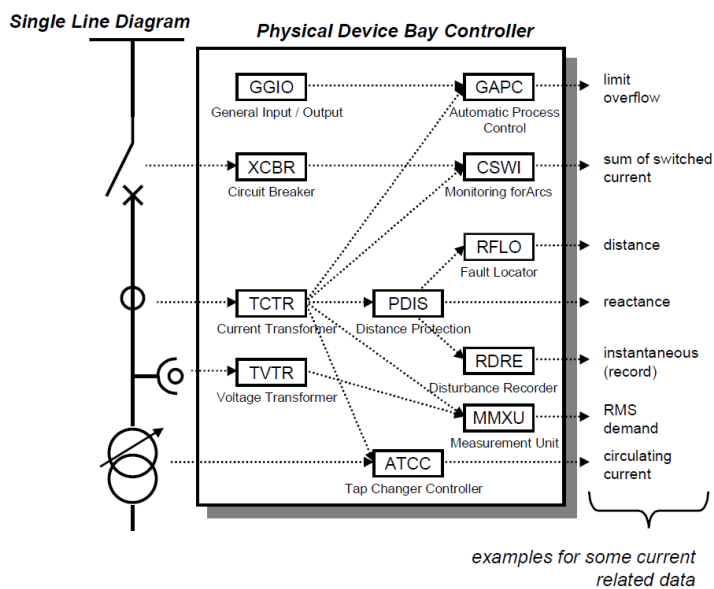


PDIS class				
Attribute Name	Attr. Type	Explanation	T	M/O
LNName		Shall be inherited from Logical-Node Class (see IEC 61850-7-2)		
Data				
Common Logical Node Information				
		LN shall inherit all Mandatory Data from Common Logical Node Class		M
OpCntRs	INC	Resettable operation counter		O
Status Information				
Str	ACD	Start		M
Op	ACT	Operate		T M
Settings				
PoRch	ASG	Polar Reach is the diameter of the Mho diagram		O
PhStr	ASG	Phase Start Value		O
GndStr	ASG	Ground Start Value		O
DirMod	ING	Directional Mode		O
PctRch	ASG	Percent Reach		O
Ofs	ASG	Offset		O
PctOfs	ASG	Percent Offset		O
RisLod	ASG	Resistive reach for load area		O
AngLod	ASG	Angle for load area		O
TmDMod	SPG	Operate Time Delay Mode		O
OpDITmms	ING	Operate Time Delay		O
SPDMod	SPG	Operate Time Delay Multiphase Mode		O
SPDITmms	ING	Operate Time Delay for Multiphase Faults		O
GndDMod	SPG	Operate Time Delay for Single Phase Ground Mode		O
GndDITmms	ING	Operate Time Delay for single phase ground faults		O



IEC 61850 Information Model

Logical Nodes – Example



IEC 61850 Information Model

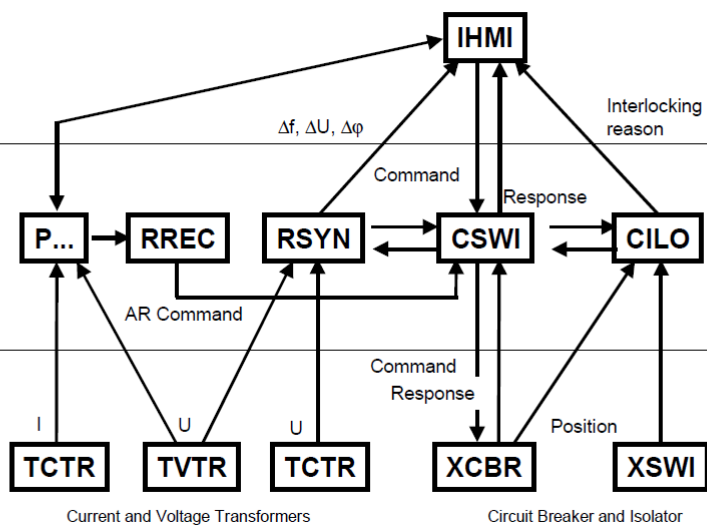
Logical Nodes – Example



LN for station level functions

LN for bay level functions

LN for process images (process equipment)





IEC 61850 Information Model

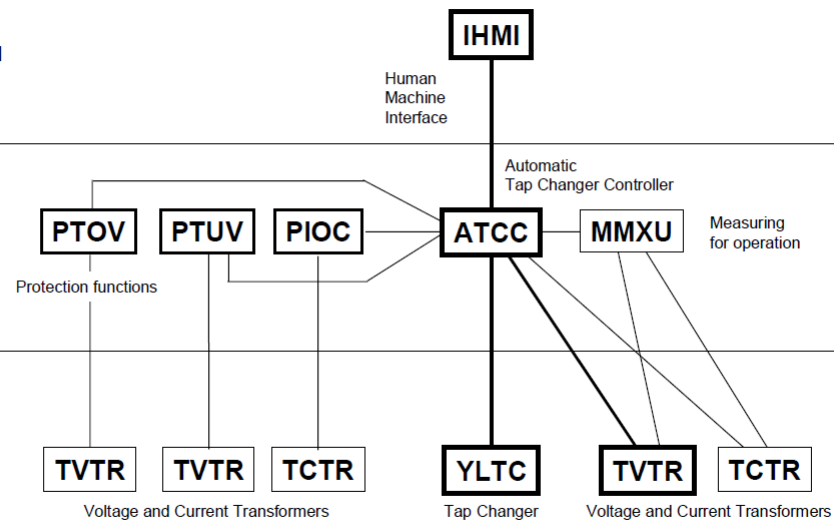
Logical Nodes – Example



LN for
station level
functions

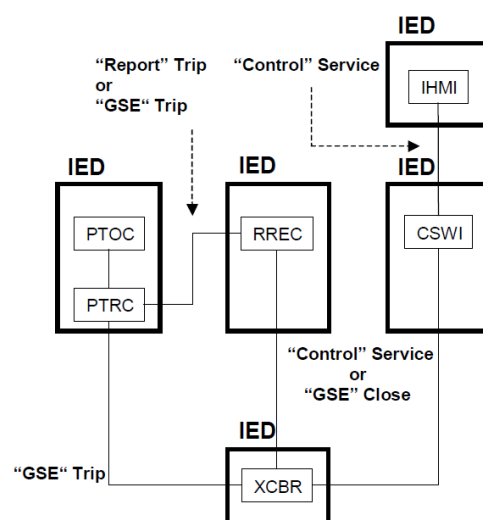
LN for
bay level
functions

LN for
process
images
(process
equipment)



IEC 61850 Information Model

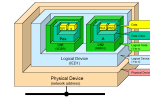
Logical Nodes – Example autoreclosure



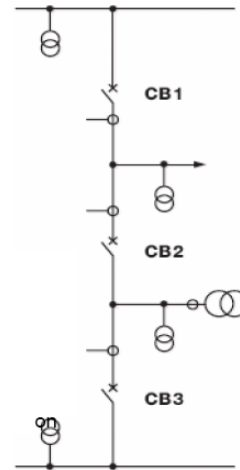


IEC 61850 example

How is this done?

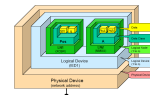


- Given the bay:



IEC 61850 example

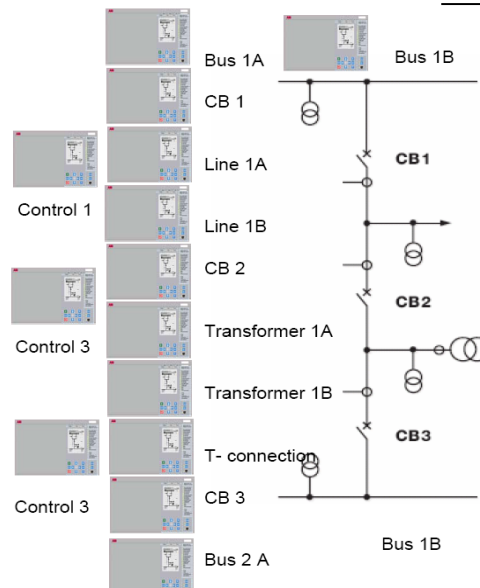
How is this achieved?



Possible LNs

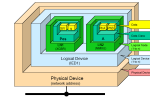
PDIS 21	PDIF HZ	PDIF REF
PDIF 87B	PDIF 87L	PDIF 87T
PIOC 50	PIOC 50N	POCM 51/67
PEFM 51/67N	RBRF 50BF	PUVM 27
POVM 59	PTOF 81	PTUF 81
PVPH 24	PTTR 26	PSCH
RSYN 25	RREC 79	RBRF 50BF
CSWI	MMTR	MMXU

Add IEDs



IEC 61850 example

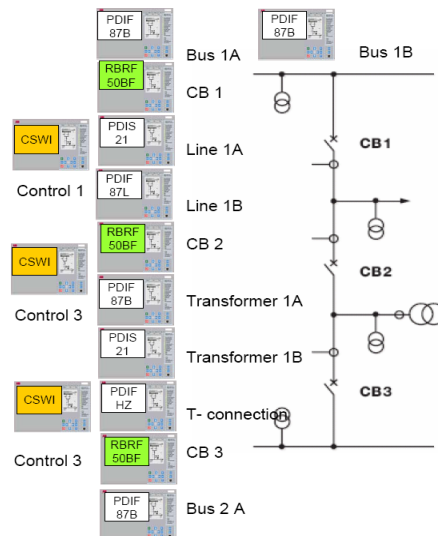
How is this achieved?



- Could allocate like this:

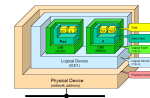
PDIS 21	PDIF HZ	PDIF REF
PDIF 87B	PDIF 87L	PDIF 87T
PIOC 50	PIOC 50N	POCM 51/67
PEFM 51/67N	RBRF 50BF	PUVM 27
POVM 59	PTOF 81	PTUF 81
PVPH 24	PTTR 26	PSCH
RSYN 25	RREC 79	RBRF 50BF
CSWI	MMTR	MMXU

20-Apr-06

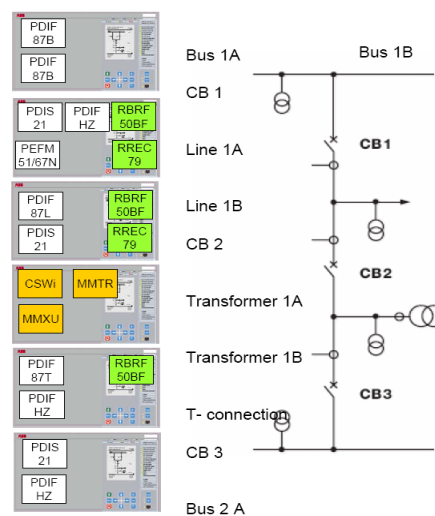


IEC 61850 example

How is this achieved?



- Or like this:





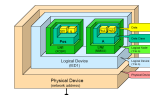
Outline of the lecture

- Recap of modern substation architectures
 - IEC 61850 substation
 - Purpose and scope of IEC 61850
- IEC 61850 Information Model
- Substation communication
 - Introduction
- Specification and configuration



Substation communication

Overview



- OO information exchange
- Levels of communication
 - Vertical
 - Horizontal
 - Process level
- Not counting communication to Controlroom/SCADA.

Communicaiton overview

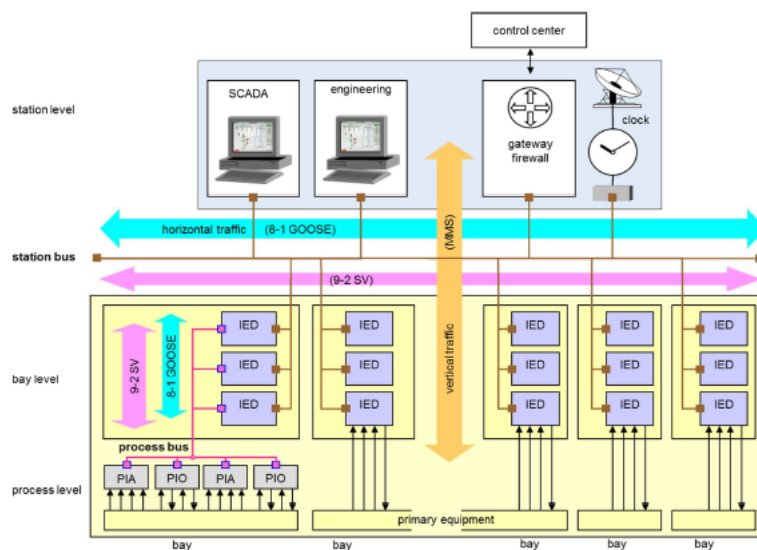
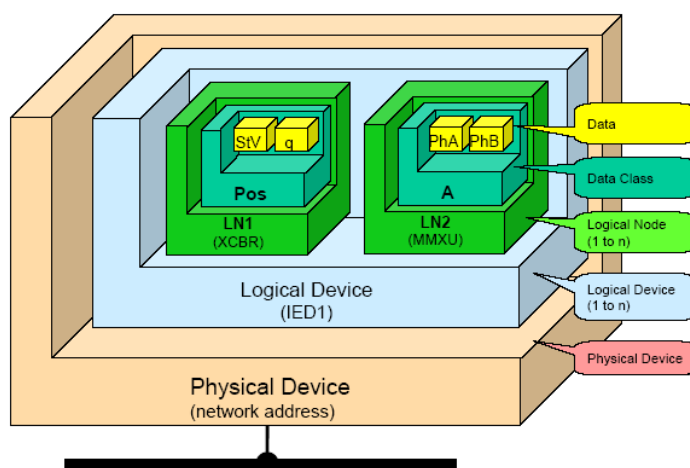
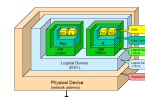


Figure 11 – Station bus, process bus and traffic example

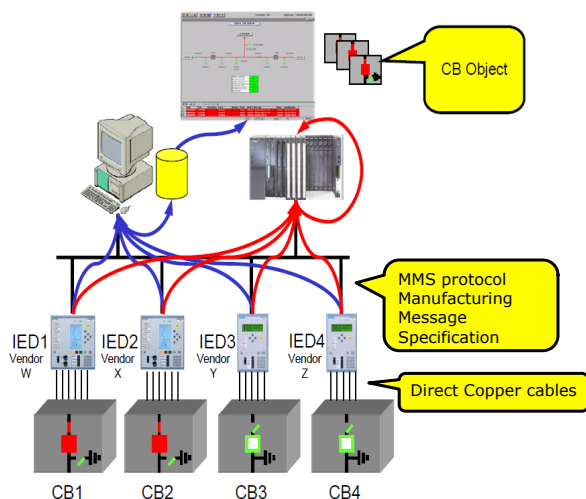
Substation communication

OO information exchange



Substation communication

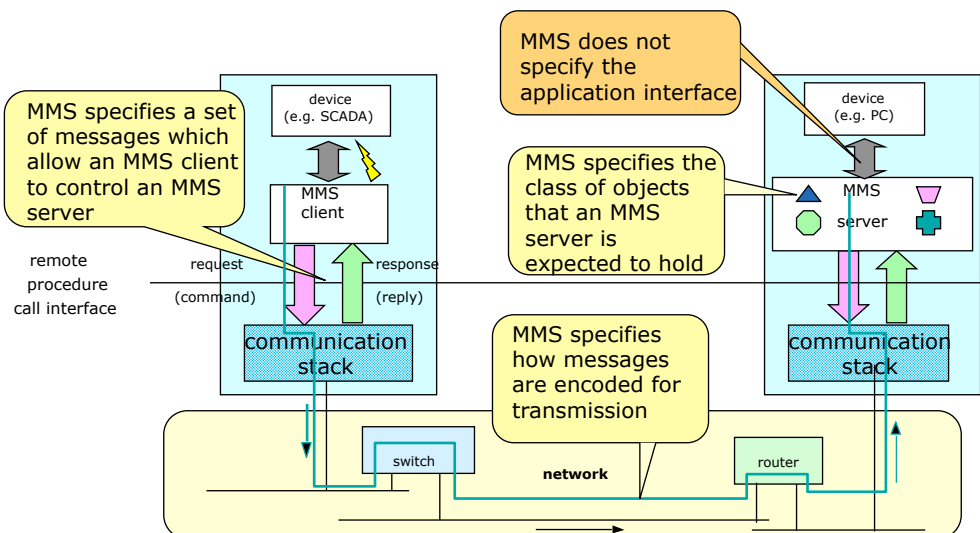
OO information exchange - Vertical



• Server Client model



MMS communication model

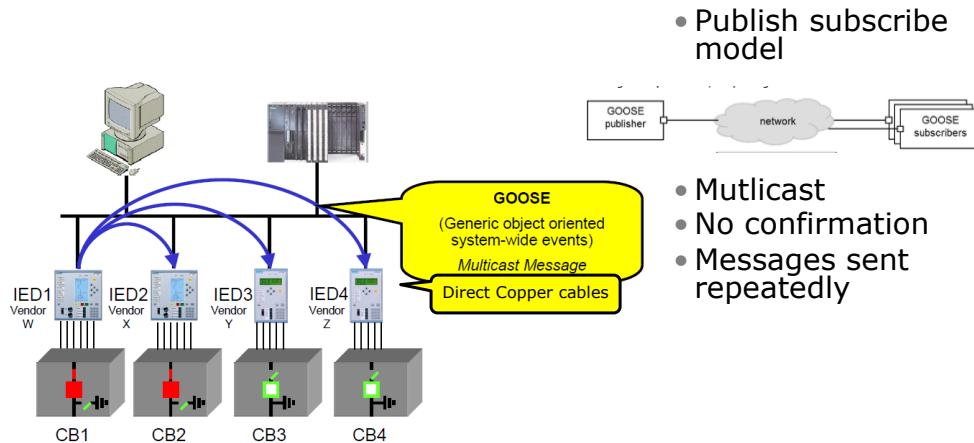


Source: Prof. Dr. H. Kirrmann, ABB Research Center, Baden, Switzerland



Substation communication

OO information exchange - Horizontal



GOOSE Communication Model

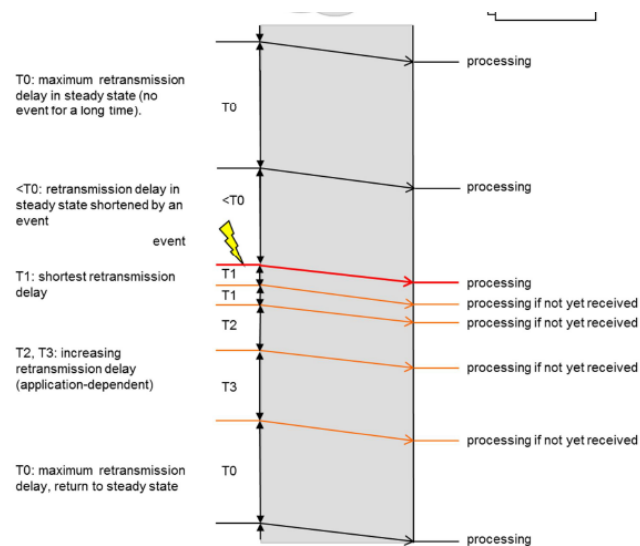


Figure 8 – GOOSE protocol time/distance chart



GOOSE timing

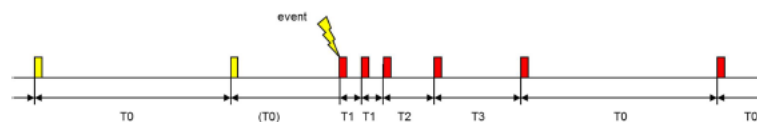
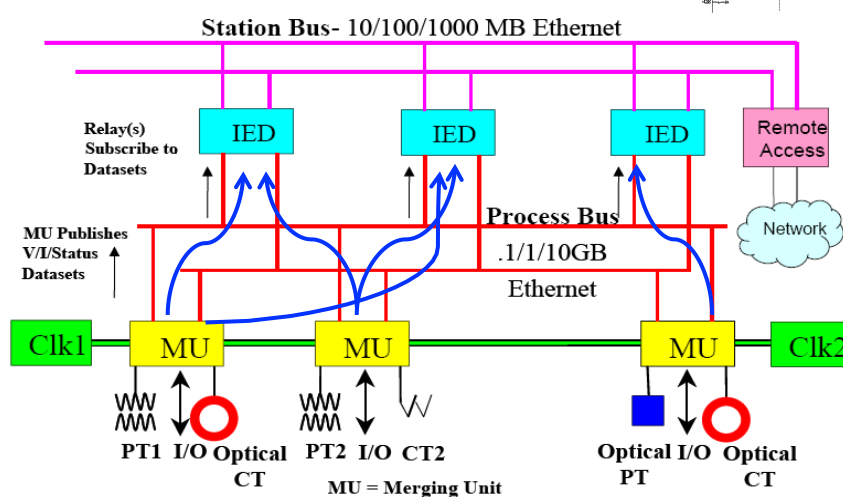
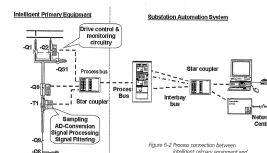


Figure 9 – GOOSE protocol time chart



Substation communication

Process bus communication – Sampled Values





SV communication model

- Sampled Values are transmitted cyclically
- Carries analog measurements
- Sending frequency of 4-5000 values/second.

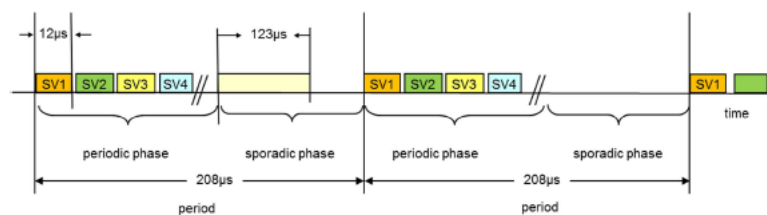


Figure 10 – Example of SV traffic (4800 Hz)

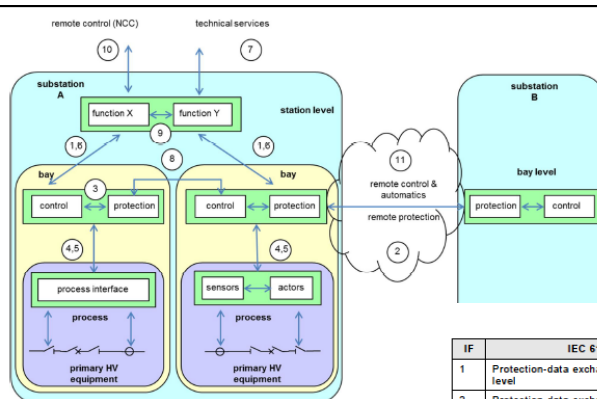


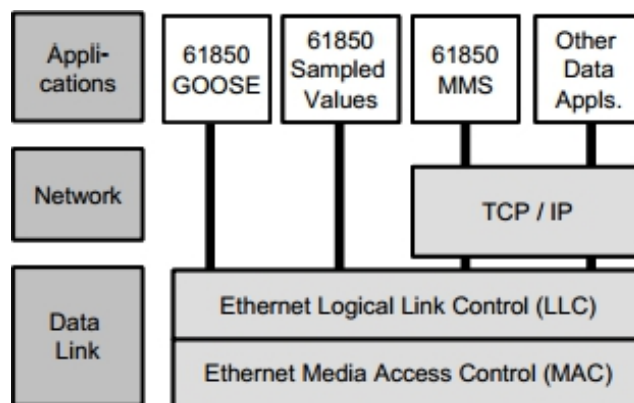
Figure 5 – Levels and logical interfaces in substation automation

Table 1 – IEC 61850-5 interface definitions

IF	IEC 61850-5 Definition	Comment
1	Protection-data exchange between bay and station level	The SCADA Gateway / HMI is not involved in protection functions
2	Protection-data exchange between bay level and remote protection (outside the scope of this part of IEC 61850)	Tunnelled GOOSE defined in IEC/TR 61850-90-1
3	Data exchange within bay level	Relates to station bus
4	CT and VT instantaneous data exchange (especially samples) between primary equipment and bay level	Relates to process bus so are not considered for station bus
5	Control-data exchange between primary equipment and bay level	Relates to process bus so are not considered for station bus
6	Control-data exchange between bay and station level	Station bus to SCADA Gateway / HMI communications
7	Data exchange between substation (level) and a remote engineer's workplace	IED and SCADA Gateway / HMI configuration, monitoring from external like engineering PC
8	Direct data exchange between the bays especially for fast functions such as interlocking	Relates to station bus
9	Data exchange within station level	SCADA GATEWAY / HMI communications
10	Control-data exchange between substation (devices) and a remote control centre (outside the scope of this part of IEC 61850)	SCADA GATEWAY / HMI to control centre communications
11	Control-data exchange between substations, e.g. binary signals for interlocking or other inter-substation automatics	Substation to substation, see IEC/TR 61850-90-1



In summary



And we will get back to how these protocol stacks work in detail in Part#2 of the course



The End



Outline of the lecture

- Recap of modern substation architectures
 - IEC 61850 substation
 - Purpose and scope of IEC 61850
- IEC 61850 Information Model
- **Specification and configuration**
- Substation communication
 - Very brief introduction (more coming next week)



Specification and Configuration

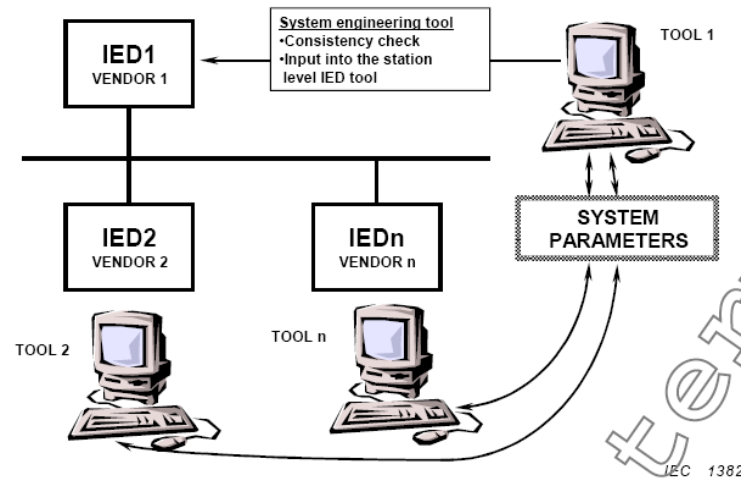


- Integration and configuration process
- Substation Configuration Language (SCL)
- Design - System Specification Description (SSD)
- Specification – Substation Configuration Description (SCD)



Specification and Configuration

IEC 61850 configuration process



Specification and Configuration

Substation Configuration Language



- SCL is Part 6 of the 61850 standard
- Formal description of:
 - Substation automation system and
 - The switchyard
 - The relation between them
 - IED configuration



Specification and Configuration

Substation Configuration Language



- **SSD**: System Specification Description
 - Entire system
- **SCD**: Substation Configuration Description
 - Single substation
- **ICD**: IED Capability Description
 - Items supported by an IED
- **CID**: Configured IED Description
 - Specific IED

- XML files 



XML

eXtensible Markup Language



- Set of rules for encoding documents in a machine-readable form
- Hundreds of XML-based languages exist
- Human-readable data serialization
 - converting to a storable format
- Main concepts:
 - Character
 - Processor (parser) and Application
 - Markup and Content
 - Tag
 - Element
 - Attribute
 - XML declaration

```
<?xml version="1.0"?>
<quiz>
  <question>
    Who was the forty-second
    president of the U.S.A.?
  </question>
  <answer>
    William Jefferson Clinton
  </answer>
  <!-- Note: We need to add
  more questions later.-->
</quiz>
```

XML

```
<?xml version="1.0" encoding="UTF-8" ?>
```



Databases and XML

eXtensible Markup Language



```
<?xml version="1.0" encoding="UTF-8" ?>
- <SCL xmlns="http://www.iec.ch/61850/2003/SCL" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.iec.ch/61850/2003/SCL SCL.xsd">
  <Header id="SISCO_IED1_Complete" version="1" revision="2" toolID="xml spy" nameStructure="IEDName" />
- <Communication>
- <SubNetwork name="Subnetz1" type="8-MMS/TCP">
  <Text />
  <BitRate unit="b/s" multiplier="M">100</BitRate>
  <ConnectedAP iedName="SISCO_IED1" apName="AXS4MMS_CIGRE">
  - <Address>
    <P type="IP" xsi:type="tp_IP">192.168.2.11</P>
    <P type="IP-SUBNET" xsi:type="tp_IP-SUBNET">255.255.255.0</P>
  </Address>
  <GSE IdInst="CTRL" cbName="Control_DataSet1">
  - <Address>
    <P type="VLAN-ID" xsi:type="tp_VLAN-ID">001</P>
    <P type="VLAN-PRIORITY" xsi:type="tp_VLAN-PRIORITY">4</P>
    <P type="MAC-Address" xsi:type="tp_MAC-Address">01-0C-CD-01-F1-04</P>
    <P type="APPID" xsi:type="tp_APPID">0000</P>
  </Address>
    <MinTime unit="s" multiplier="m">10</MinTime>
    <MaxTime unit="s" multiplier="m">2000</MaxTime>
  </GSE>
  </ConnectedAP>
</SubNetwork>
</Communication>
```



Specification and Configuration

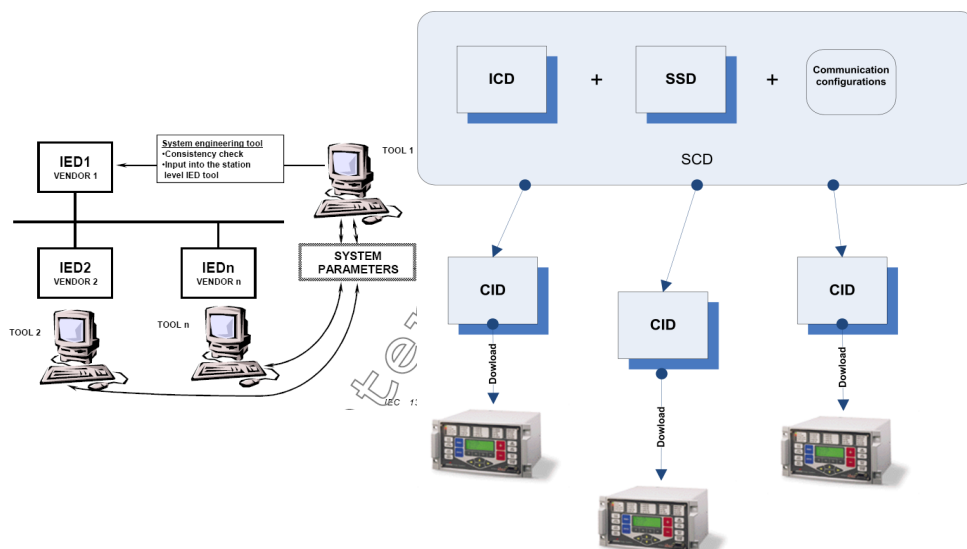
Substation Configuration Language



```
<?xml version="1.0" encoding="UTF-8" ?>
- <SCL xmlns="http://www.iec.ch/61850/2003/SCL" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.iec.ch/61850/2003/SCL SCL.xsd">
  <Header id="SISCO_IED1_Complete" version="1" revision="2" toolID="xml spy" nameStructure="IEDName" />
- <Communication>
- <SubNetwork name="Subnetz1" type="8-MMS/TCP">
  <Text />
  <BitRate unit="b/s" multiplier="M">100</BitRate>
  <ConnectedAP iedName="SISCO_IED1" apName="AXS4MMS_CIGRE">
  - <Address>
    <P type="IP" xsi:type="tp_IP">192.168.2.11</P>
    <P type="IP-SUBNET" xsi:type="tp_IP-SUBNET">255.255.255.0</P>
  </Address>
  <GSE IdInst="CTRL" cbName="Control_DataSet1">
  - <Address>
    <P type="VLAN-ID" xsi:type="tp_VLAN-ID">001</P>
    <P type="VLAN-PRIORITY" xsi:type="tp_VLAN-PRIORITY">4</P>
    <P type="MAC-Address" xsi:type="tp_MAC-Address">01-0C-CD-01-F1-04</P>
    <P type="APPID" xsi:type="tp_APPID">0000</P>
  </Address>
    <MinTime unit="s" multiplier="m">10</MinTime>
    <MaxTime unit="s" multiplier="m">2000</MaxTime>
  </GSE>
  </ConnectedAP>
</SubNetwork>
</Communication>
```

Specification and Configuration

IEC 61850 configuration process



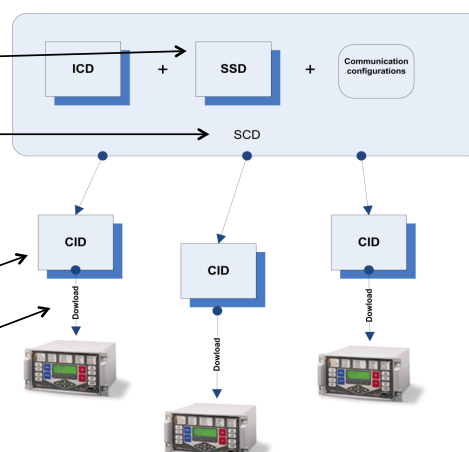
Specification and Configuration

IEC 61850 configuration process



Design Sequence:

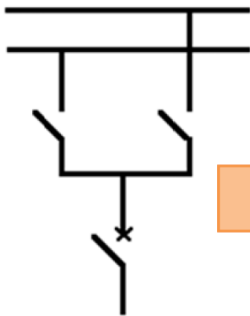
1. Design SSD
2. Create SCD = integrate SSD with manufacturer provided ICDs and add communication configuration
3. Generate IED specific CID for each IED
4. Download CIDs into IEDs





Specification and Configuration

Design - System Specification Description (SSD)



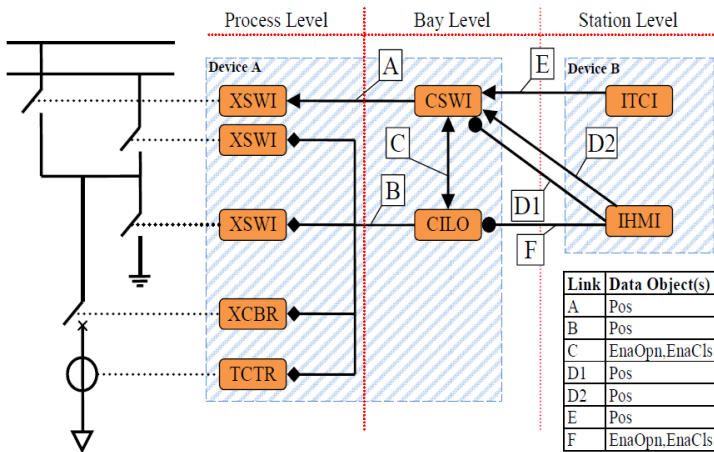
```
<scl:Substation desc="25/10 kV substation" name="ABC">
  <scl:VoltageLevel desc="25kV sectie" name="K1">
    <scl:Voltage multiplier="k" unit="V">25</scl:Voltage>
    <scl:Bay desc="25kVLinefeeder" name="Q8">
      <scl:ConductingEquipment desc="Disconnector" name="QB1" type="DIS">
        <scl:Terminal bayName="Q8" cNodeName="CN1" connectivityNode="#CN1">
          <scl:Terminal bayName="Q8" cNodeName="CN2" connectivityNode="#CN2">
        </scl:ConductingEquipment>
      <scl:ConductingEquipment desc="Disconnector" name="QB2" type="DIS">
        <scl:Terminal bayName="Q8" cNodeName="CN3" connectivityNode="#CN3">
          <scl:Terminal bayName="Q8" cNodeName="CN2" connectivityNode="#CN2">
        </scl:ConductingEquipment>
      <scl:ConductingEquipment desc="Breaker" name="QA1" type="CBR">
        <scl:Terminal bayName="Q8" cNodeName="CN2" connectivityNode="#CN2">
          <scl:Terminal bayName="Q8" cNodeName="CN5" connectivityNode="#CN5">
        </scl:ConductingEquipment>
    </scl:Bay>
  </scl:VoltageLevel>
</scl:Substation>
```

- Single-line diagram represented as SSD file



Specification and Configuration

Specification – Substation Configuration Description (SCD)



Legend				
Link	Data Object(s)	Data Attribute(s)	Msg. type	PC
A	Pos	[control structure]	7	P2(TT2)
B	Pos	stVal/q/t	1B	P2(TT4)
C	EnaOpn.EnaCls	stVal/q/t, stVal/q/t	2	P1(TT3)
D1	Pos	stVal/q/t	2	P1(TT3)
D2	Pos	[control structure]	7	P2(TT2)
E	Pos	[control structure]	7	P2(TT2)
F	EnaOpn.EnaCls	stVal/q/t, stVal/q/t	2	P1(TT3)



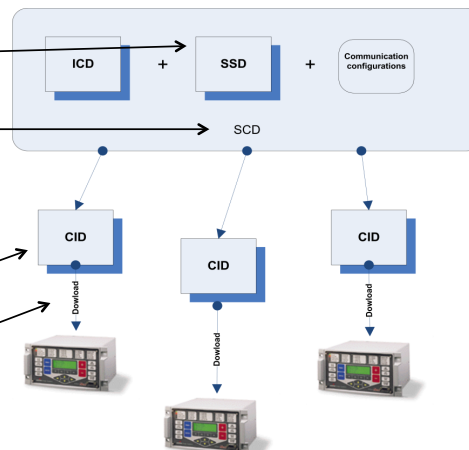
Specification and Configuration

IEC 61850 configuration process



Design Sequence:

1. Design SSD
2. Create SCD = integrate SSD with manufacturer provided ICDs and add communication configuration
3. Generate IED specific CID for each IED
4. Download CIDs into IEDs



Specification and Configuration

IEC 61850 substation

