ROYAL INSTITUTE OF TECHNOLOGY

Lecture #7
Substation Automation with IEC 61850

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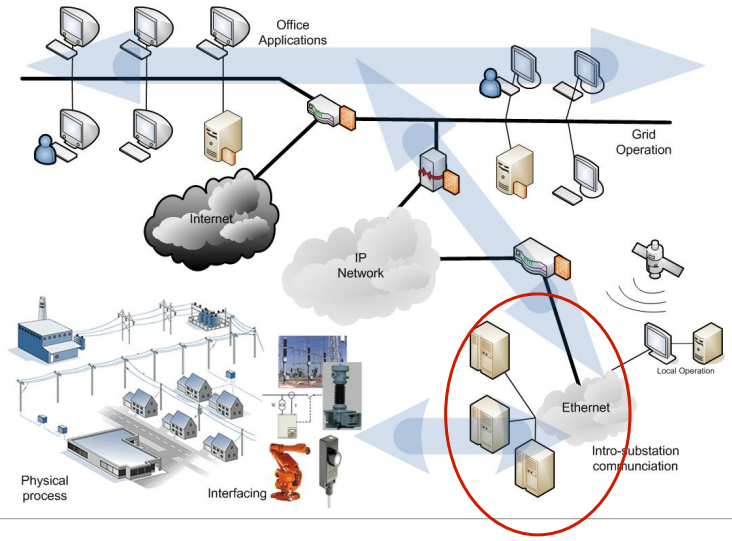
Course map



Outline of the Lecture

- Recap of Substation Configurations
- Recap of Substation Automation Functions
- Recap of modern substation architectures
  - IEC 61850 substation
  - Substation communication
- Some examples of Substation Automation Systems

Recap

Common components

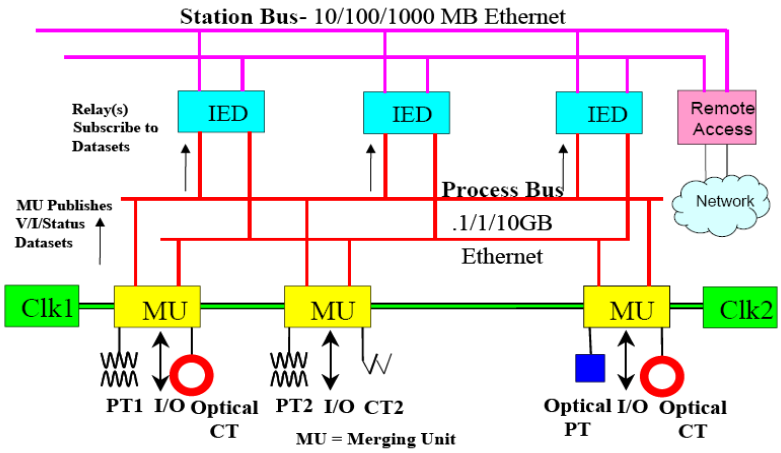
- **Intelligent Electronic Device(s)**
  - Implements functions
- **Bay controller**
  - controls all devices related to a single bay
- **Human Machine Interface**
  - Operator console for local control/configuration
- **Communication bus(es)**
  - Connection between devices
- **Upwards communication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

New

- **Merging Unit**

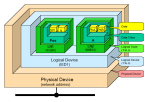
Substation architectures

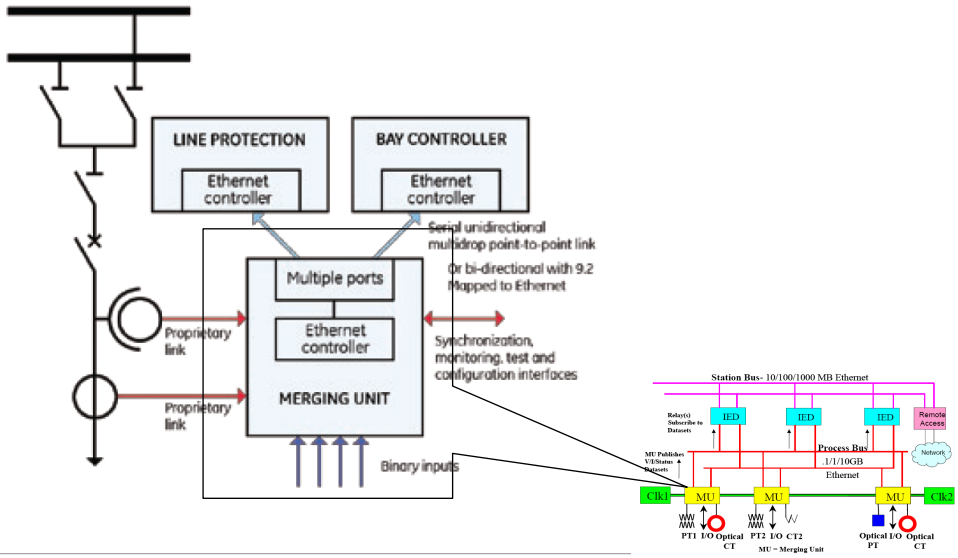
IEC 61850 substation



Substation architectures

The Merging Unit



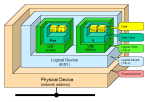


Outline of the Lecture

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

Purpose and Scope of IEC 61850

Objectives

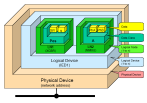


The 61850 standard was developed to:

- 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

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

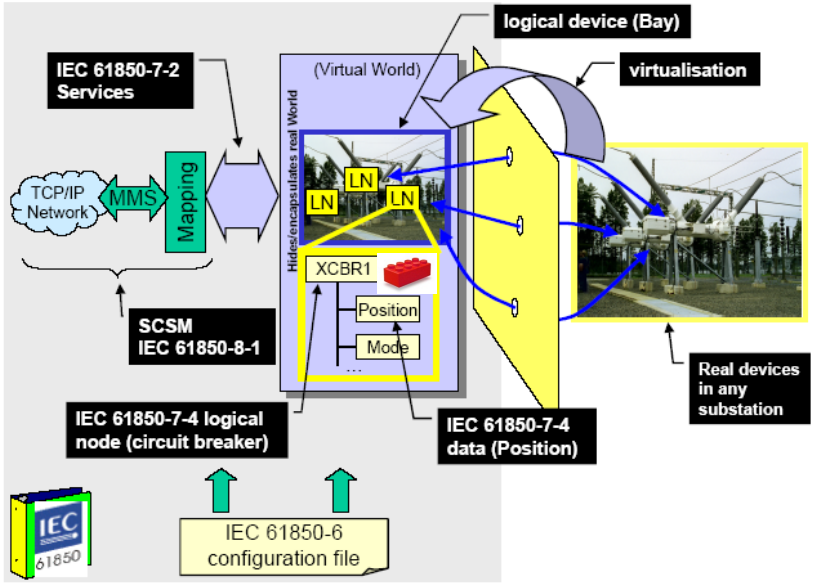
IEC 61850 Information Model

Modelling a substation

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

IEC 61850 Information Model

Modelling a substation



Logical Nodes

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
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

Data Name Common Data Class Mandatory/Optional

Common Data Classes in 61850

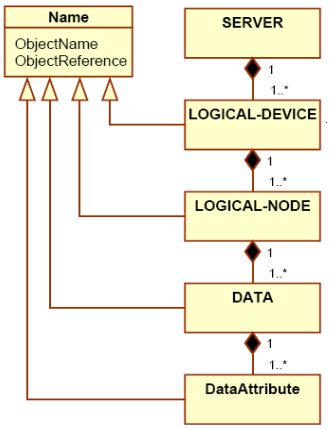
- A common data class is a generic type of infomration that can be found in a substation automation system

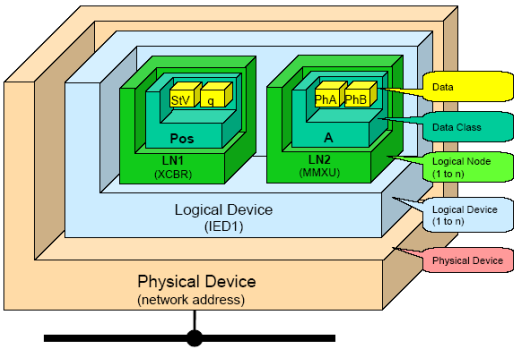
SPS class					
Attribute Name	**Attribute Type**	**FC**	**TrgOp**	**Value/Value Range**	**M/O/C**
DataName	Inherited from Data Class (see IEC 61850-7-2)				
DataAttribute					
status					
stVal	BOOLEAN	ST	dchg	TRUE | FALSE	M
q	Quality	ST	qchg		M
t	TimeStamp	ST			M
substitution					
subEna	BOOLEAN	SV			PICS_SUBST
subVal	BOOLEAN	SV		TRUE | FALSE	PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
configuration, description and extension					
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M

Functional Constraint Mandatory/ Optional

IEC 61850 Information Model

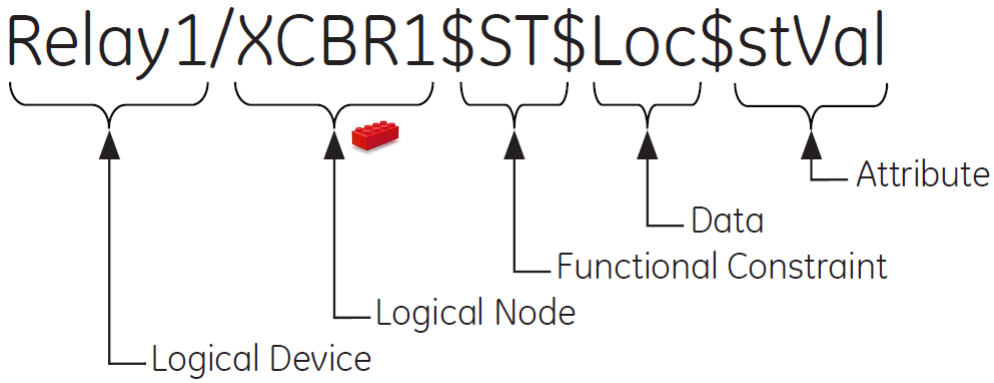
Component hierarchy





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

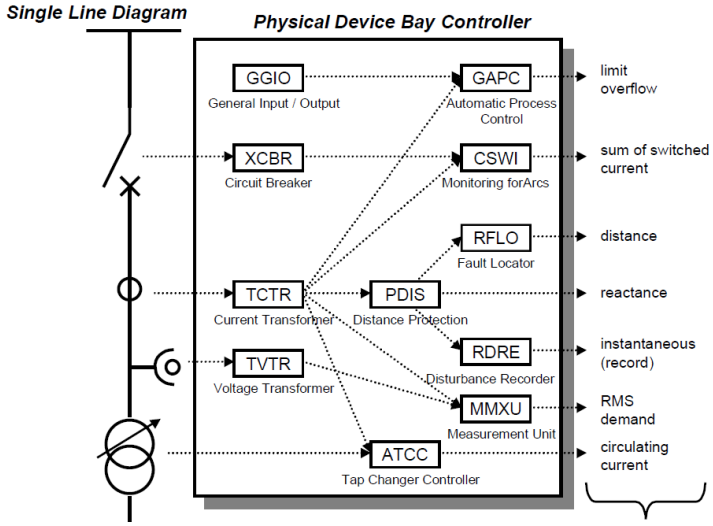
IEC 61850 Information Model

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	Resetable 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
TmDlMod	SPG	Operate Time Delay Mode		O
OpDlTmms	ING	Operate Time Delay		O
PhDlMod	SPG	Operate Time Delay Multiphase Mode		O
PhDlTmms	ING	Operate Time Delay for Multiphase Faults		O
GndDlMod	SPG	Operate Time Delay for Single Phase Ground Mode		O
GndDlTmms	ING	Operate Time Delay for single phase ground faults		O

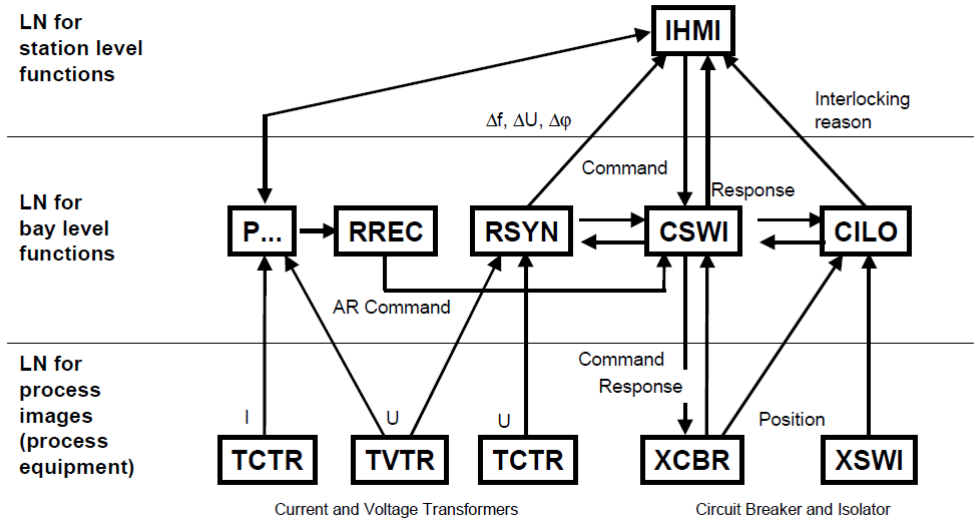
IEC 61850 Information Model

Logical Nodes – Example



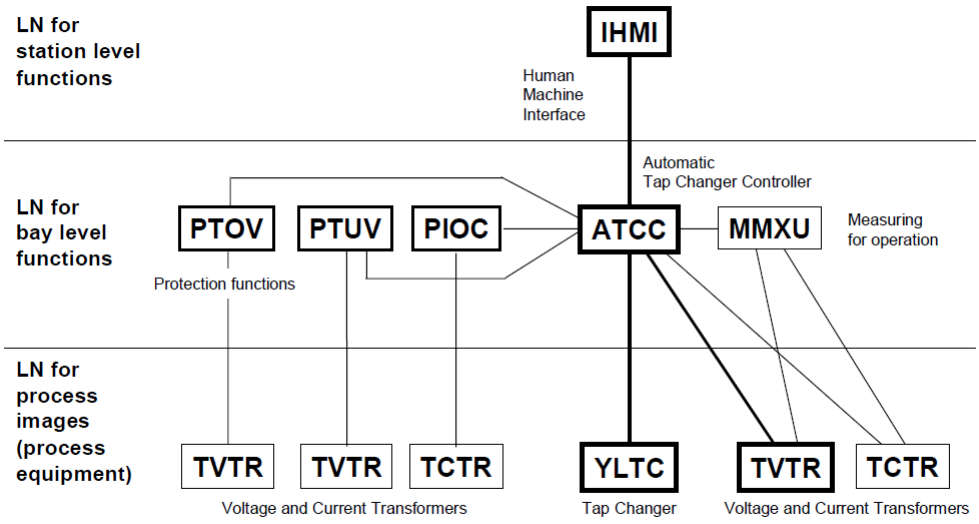
IEC 61850 Information Model

Logical Nodes – Example



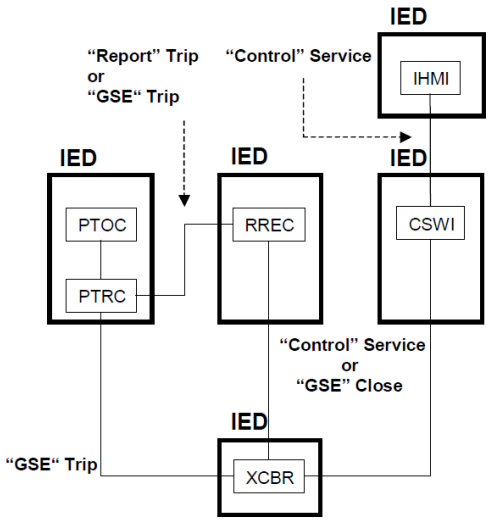
IEC 61850 Information Model

Logical Nodes – Example



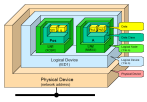
IEC 61850 Information Model

Logical Nodes – Example autoreclosure

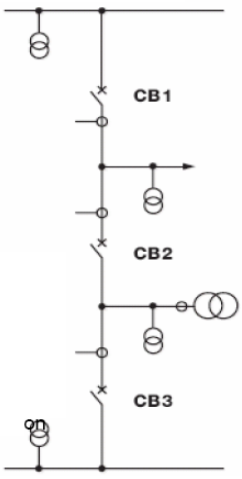


IEC 61850 example

How is this done?

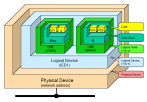


- Given the bay:



IEC 61850 example

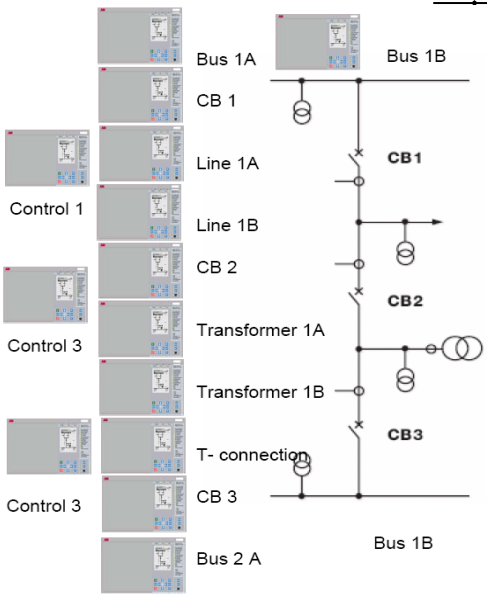
How is this achieved?



Possible LNs

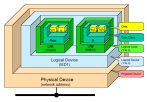
PDIS 21	PDIF HZ	PDIF REF
PDIF 87B	PDIF 87L	PDIF 87T
PIOC 50	PIOC 50N	POCM 51/67
PEFM 51/67N	RBRF 50BF	PUVM 27
POVM 59	PTOF 81	PTUF 81
PVPH 24	PTTR 26	PSCH
RSYN 25	RREC 79	RBRF 50BF
CSWI	MMTR	MMXU

Add IEDs



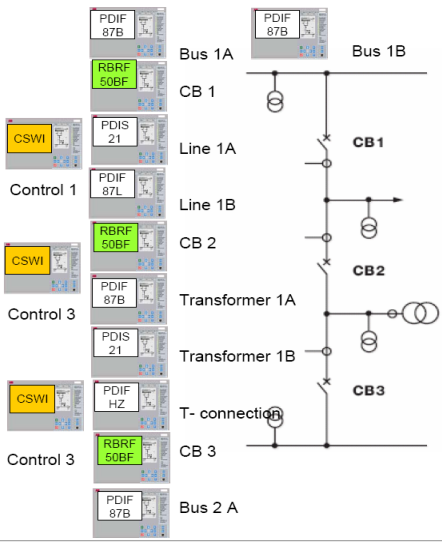
IEC 61850 example

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



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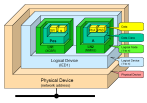
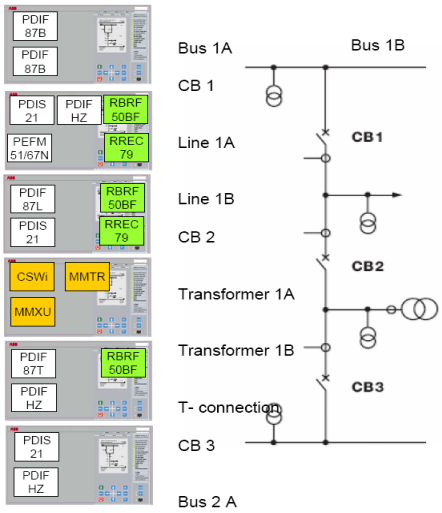
IEC 61850 example

How is this achieved?



- Or like this:

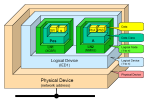


Outline of the lecture

- 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 communicaiton to Controlroom/SCADA.

Communicaiton overview

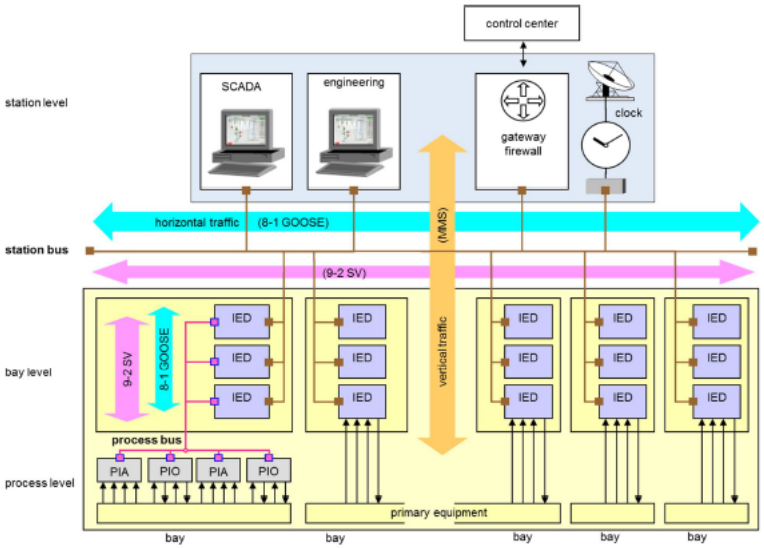
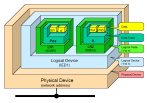
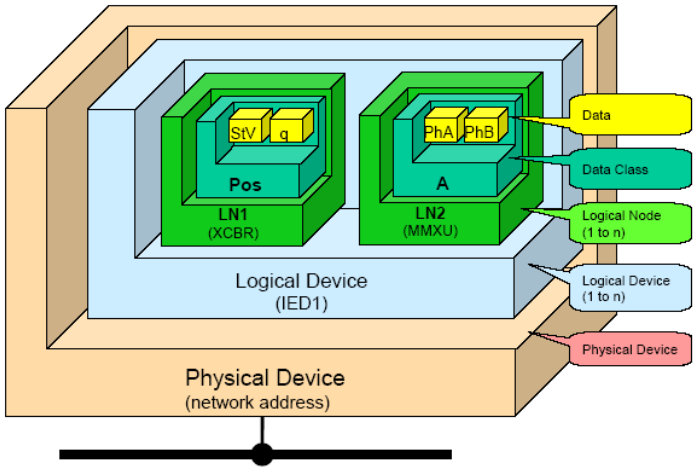


Figure 11 – Station bus, process bus and traffic example

Substation communication

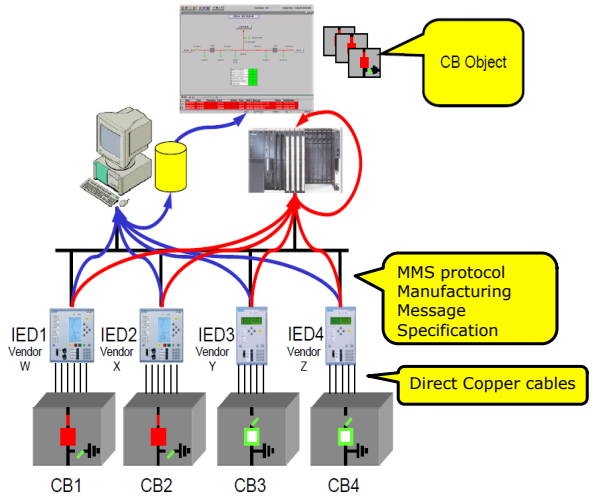
OO information exchange





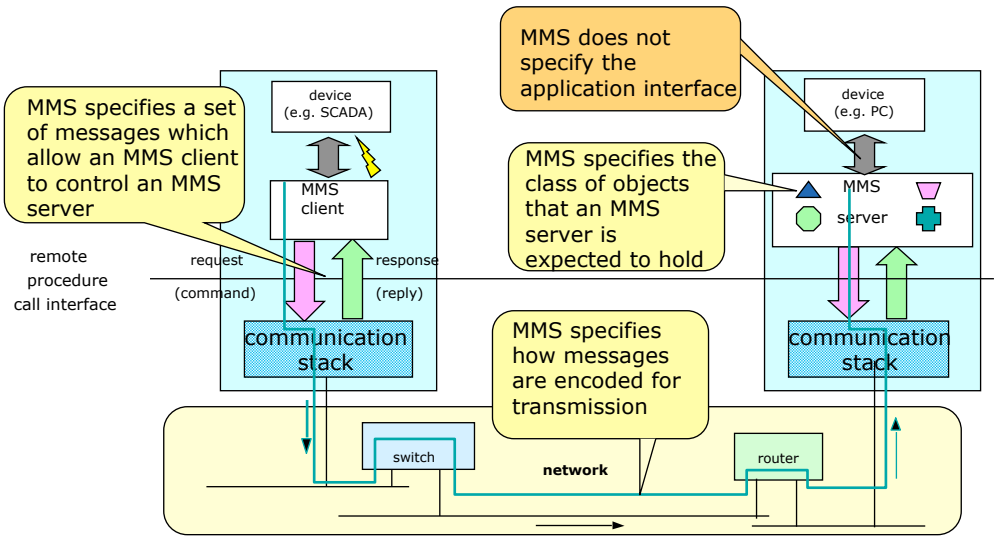
Substation communication

OO information exchange - Vertical



- Server Client model

MMS communication model

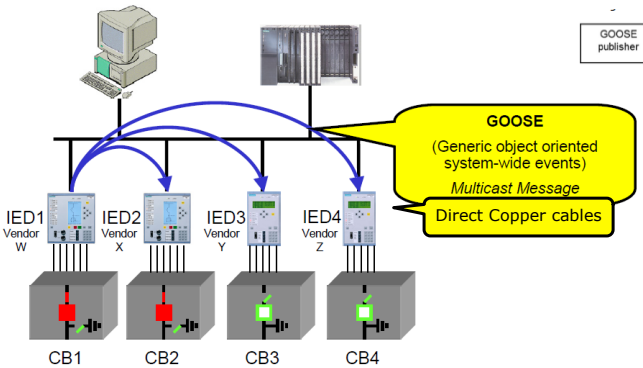


Source: Prof. Dr. H. Kirrmann, ABB Research Center, Baden, Switzerland

Substation communication

OO information exchange - Horizontal

- Publish subscribe model



- Mutlicast
- No confirmation
- Messages sent repeatedly

GOOSE Communication Model

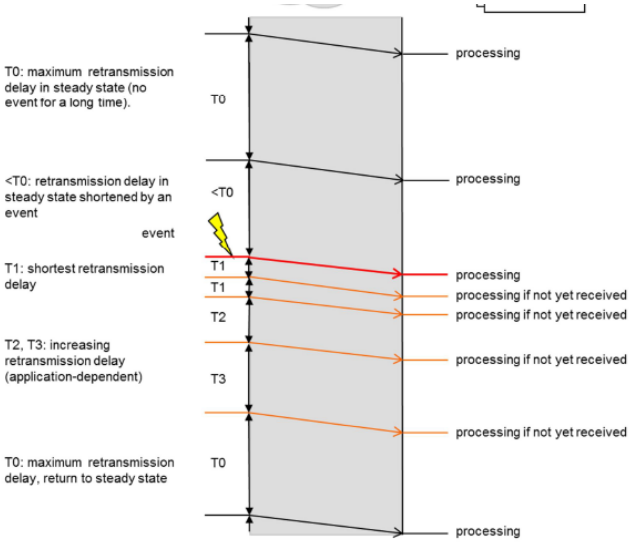


Figure 8 – GOOSE protocol time/distance chart

GOOSE timing

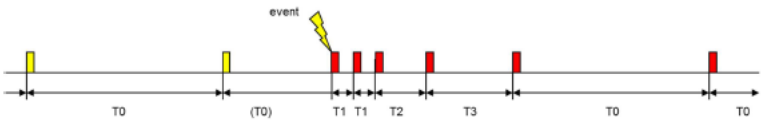
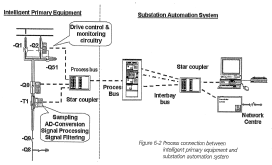
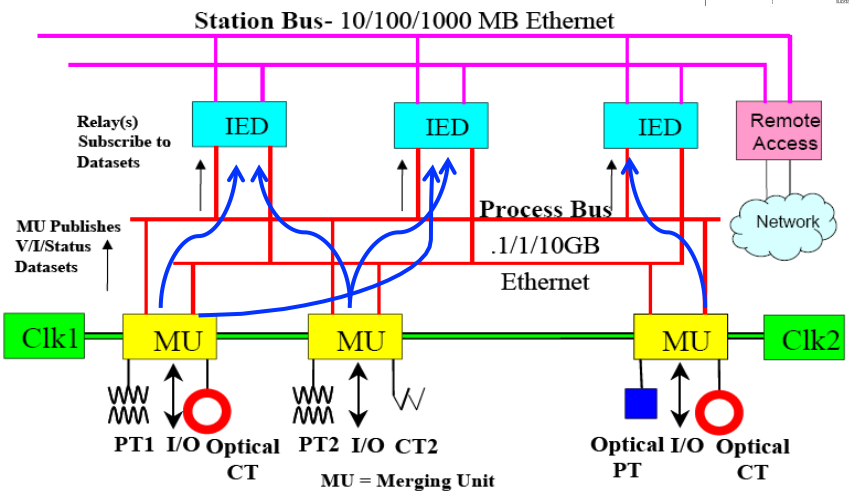


Figure 9 – GOOSE protocol time chart

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.

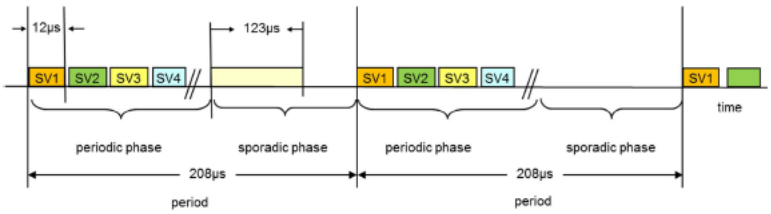


Figure 10 – Example of SV traffic (4800 Hz)

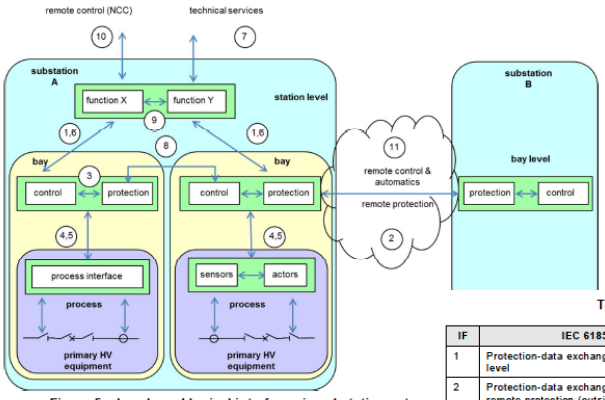


Figure 5 – Levels and logical interfaces in substation autor

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

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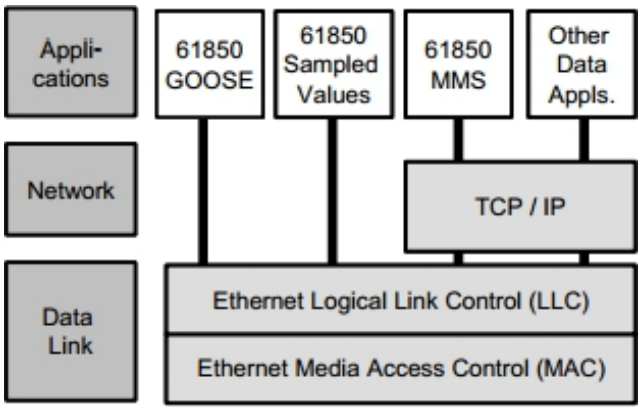
In summary



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

The End