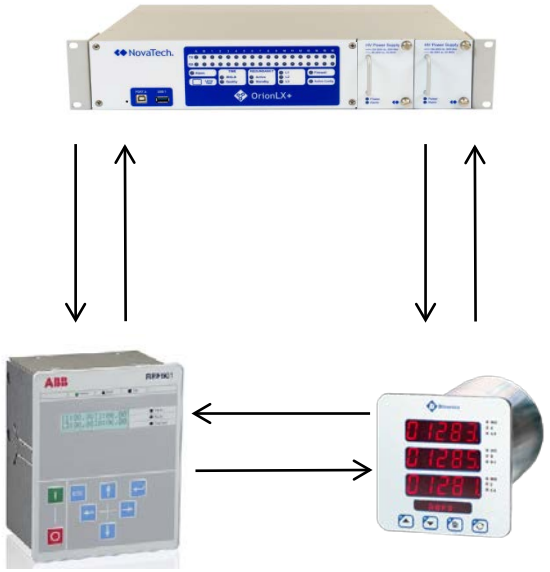
Introduction to IEC 61850 Basics

What is IEC 61850?

IEC 61850 is the international standard for defining devices within substation automation systems and how they interact with one another.



What is the purpose of IEC 61850?

Provide platform for designing, integrating and maintaining substation equipment to do the following:

- Communications
- Protection
- Control
- Automation
- Measurements
- Recording
- Monitoring

Goals of IEC 61850

Standardize

- Design
- Language
- Services
- Protocol
- Configuration
- Substation Information
- Device Information
- Device Services
- Naming Convention
- Fault Records
- Conformance Tests

Features of IEC 61850

- Self description capability (supports Interrogation)
- Fast peer-to-peer communication for tripping, blocking, interlocking
- Reduction of hard-wired connections
- Reporting features

Why should we consider using IEC 61850?

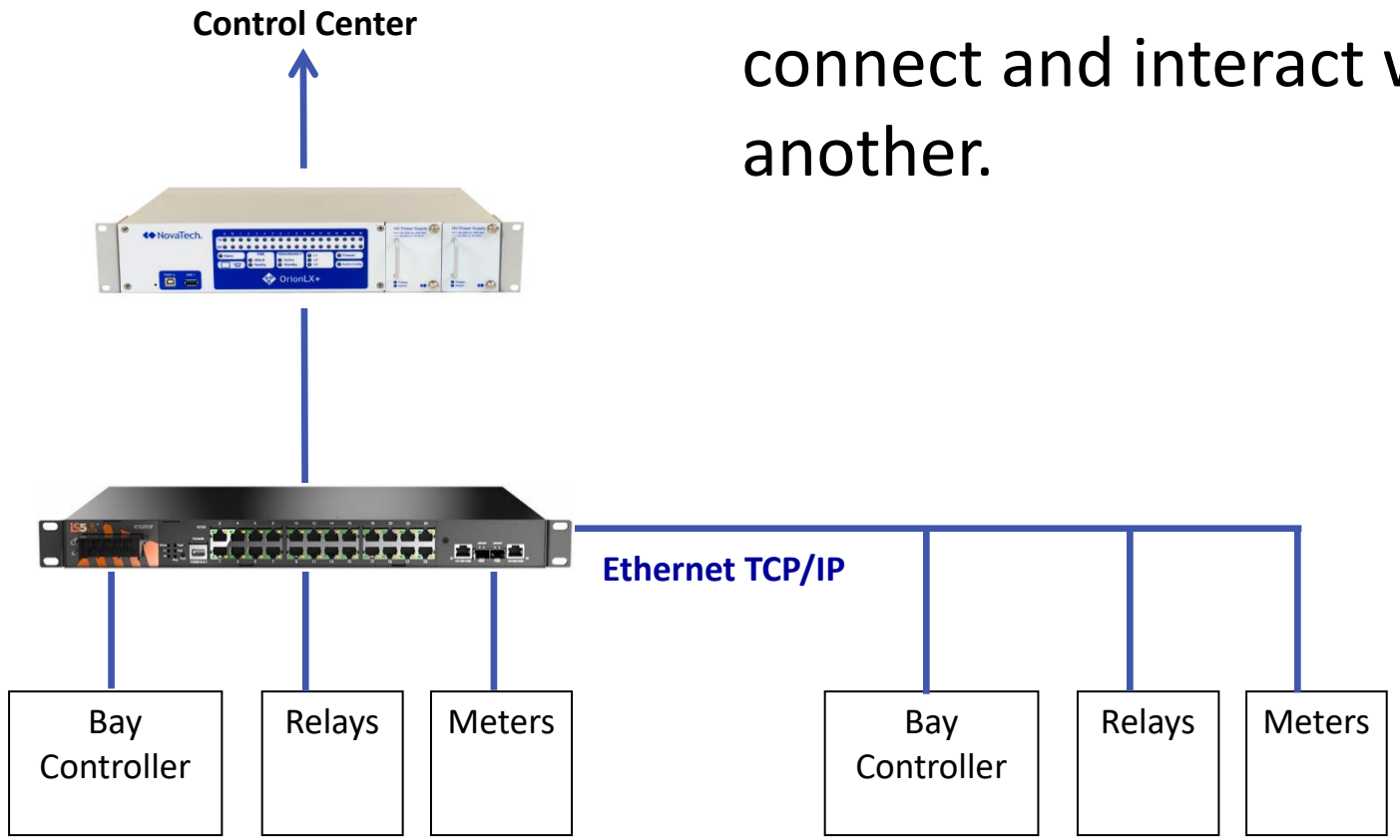
- It could reduce the costs engineering design, installation, commissioning and maintenance
- Allowing adding of new equipment and configuration of new equipment to be easier
- Reduced wiring costs - bay devices communicate using Ethernet not copper wire

IEC 61850 Standard

1. Introduction and Overview
2. Glossary
3. General Requirements
4. System and Project Management
5. Communication Requirements
6. Configuration Language for Communication in Electrical Substations related to IEDs
7. Basic Communication Structure
8. Specific Communication Service Mapping – Mapping to Manufacturing Message Specification
9. Specific Communication Service Mapping - Sample Measured Values
10. Conformance Test

Substation Architecture

IEC 61850 standard has Substation Configuration Language (SCL) that describes how all these components connect and interact with one another.



SCL Applications

- Allow vendors to specify IED capabilities
- Allow users to easily configure IEC 61850 client without having a point list
- Allow export and import of IED configuration to various apps and tools

What are SCL Files?

XML (Extensible Markup Language)based files. The main ones are:

SSD: System Specification Description

- Describes the entire system.

SCD: Substation Configuration Description

- Describes a single substation.

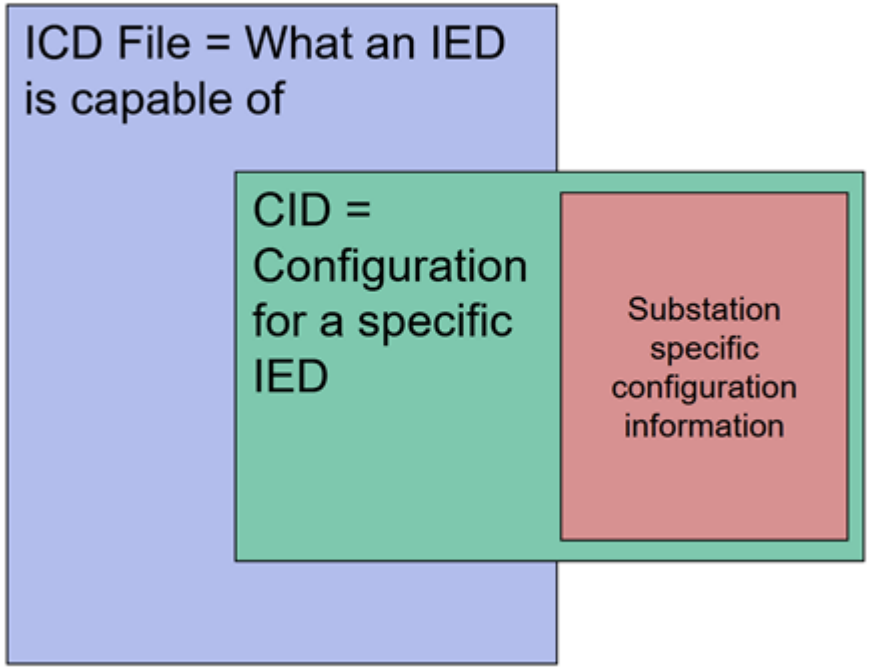
ICD: IED Capability Description.

- Describes complete capabilities supported by an IED.

CID: Configured IED Description

- Configuration for a specific IED.

Difference between ICD and CID Files



IEC 61850 File Types

Section	File Type		
	ICD	SCD	CID
	IED Template	Complete Substation	Specific IED
Header	Yes	Yes	Yes
Substation	Optional	Yes	Optional
Comms	One Instance	Yes	One Instance
IED	Yes, values optional	Multiple	Yes, including values
Data Type Templates	As needed	As needed	As needed
Private Data	Unlikely	Must pass through	Probably

IEC 61850 Comparison with DNP3

Read Device/MMXU1.V.phsA.mag.f[MX]

Read AI 27

Return Device/MMXU1.V.phsA.mag.f[MX]

Return AI 27

DNP3 or similar

Master configuration

IP = 192.168.0.120

Phase A voltage = AI 27

Breaker status = DI 59

Comparison

- Addresses must match
- Address assignments are project specific
- Address does not imply ”functionality”
- Address does not enforce restrictions
- Address entry can be time consuming
- Quality bits and time stamps only available if supported by protocol

IEC 61850

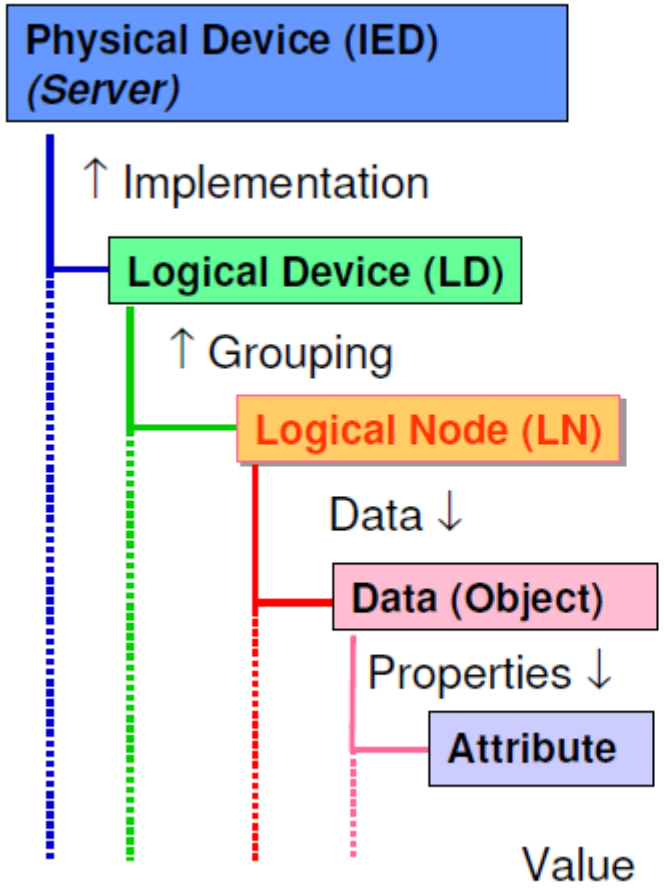
Client configuration

- Read .cid file of ABB relay
- Mapping of Phase A voltage to Device/MMXU1.V.phsA.mag.f[MX] instead of “AI 27”
- Mapping of breaker status to Device/XCBR.Pos.stVal[ST] instead of ”DI 52”

Comparison

- Data exchanged based on functional names and constraints as per .cid file
- The functional names make the mapping self-explanatory
- Quality bits, time stamp, measurement units, and numerous other attributes built-in

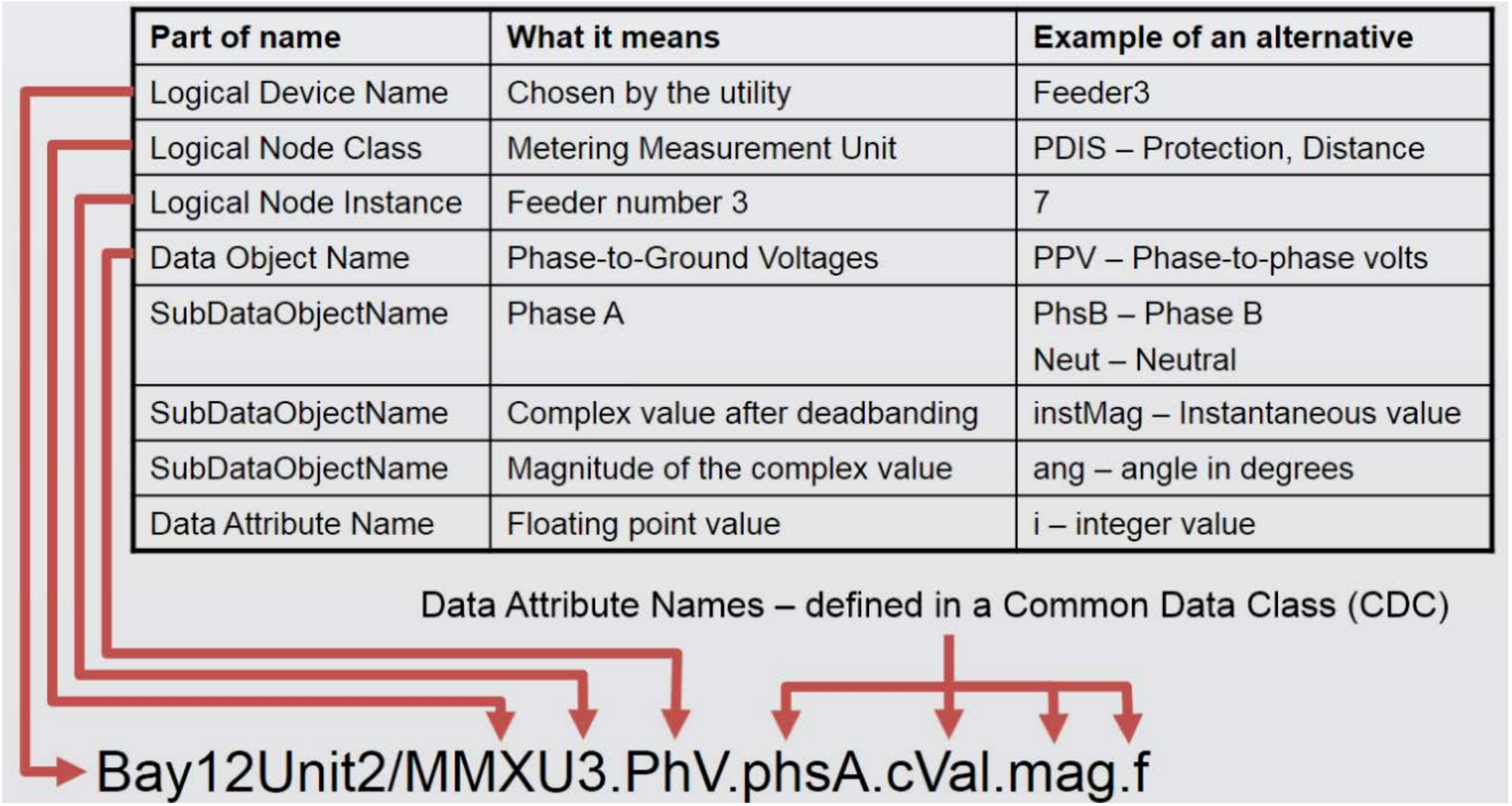
IEC 61850 Information Structure



example	
Bay Unit	**Physical enclosure**
Control	**A physical device has at least one logical device.**
CSWI Switch Control	**Type of node (measurement, circuit breaker, etc.)**
Position	**Switch position**
Control Value *Status Value*	**Position, quality, etc.**
ON/OFF	**Actual value**

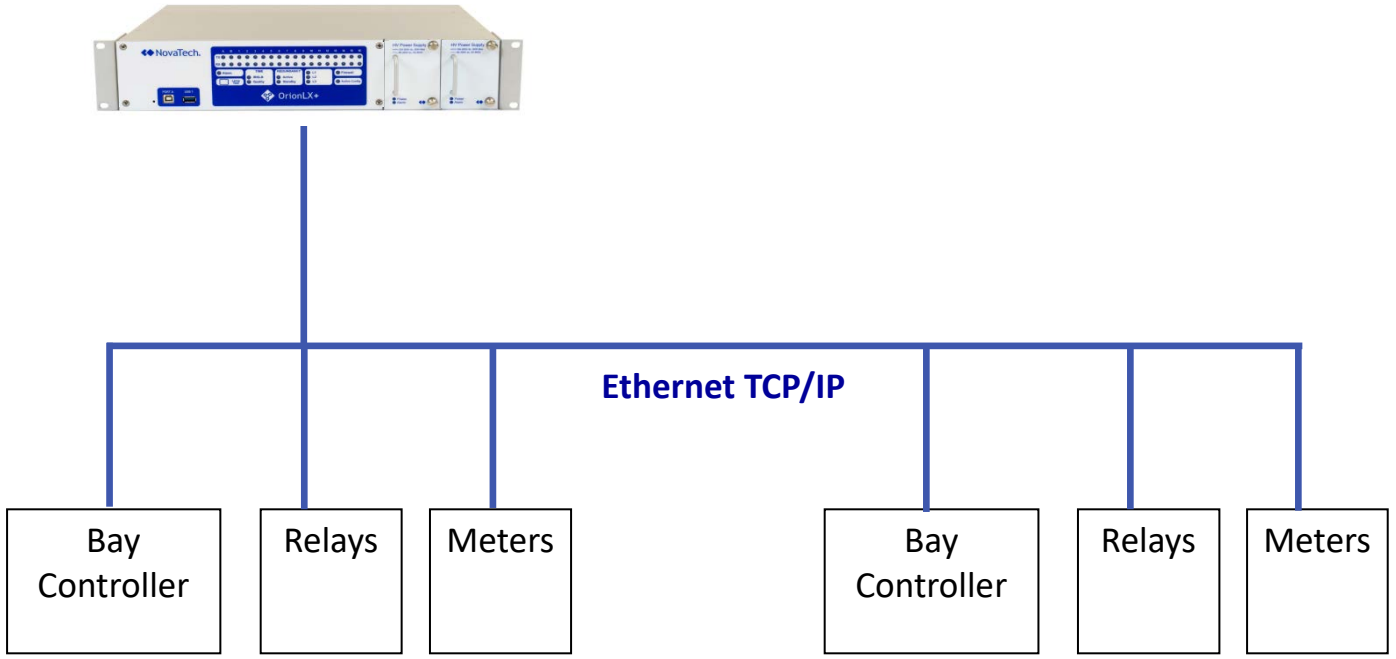
IEC 61850 Information Structure

Part of name	What it means	Example of an alternative
Logical Device Name	Chosen by the utility	Feeder3
Logical Node Class	Metering Measurement Unit	PDIS – Protection, Distance
Logical Node Instance	Feeder number 3	7
Data Object Name	Phase-to-Ground Voltages	PPV – Phase-to-phase volts
SubDataObjectName	Phase A	PhsB – Phase B Neut – Neutral
SubDataObjectName	Complex value after deadbanding	instMag – Instantaneous value
SubDataObjectName	Magnitude of the complex value	ang – angle in degrees
Data Attribute Name	Floating point value	i – integer value



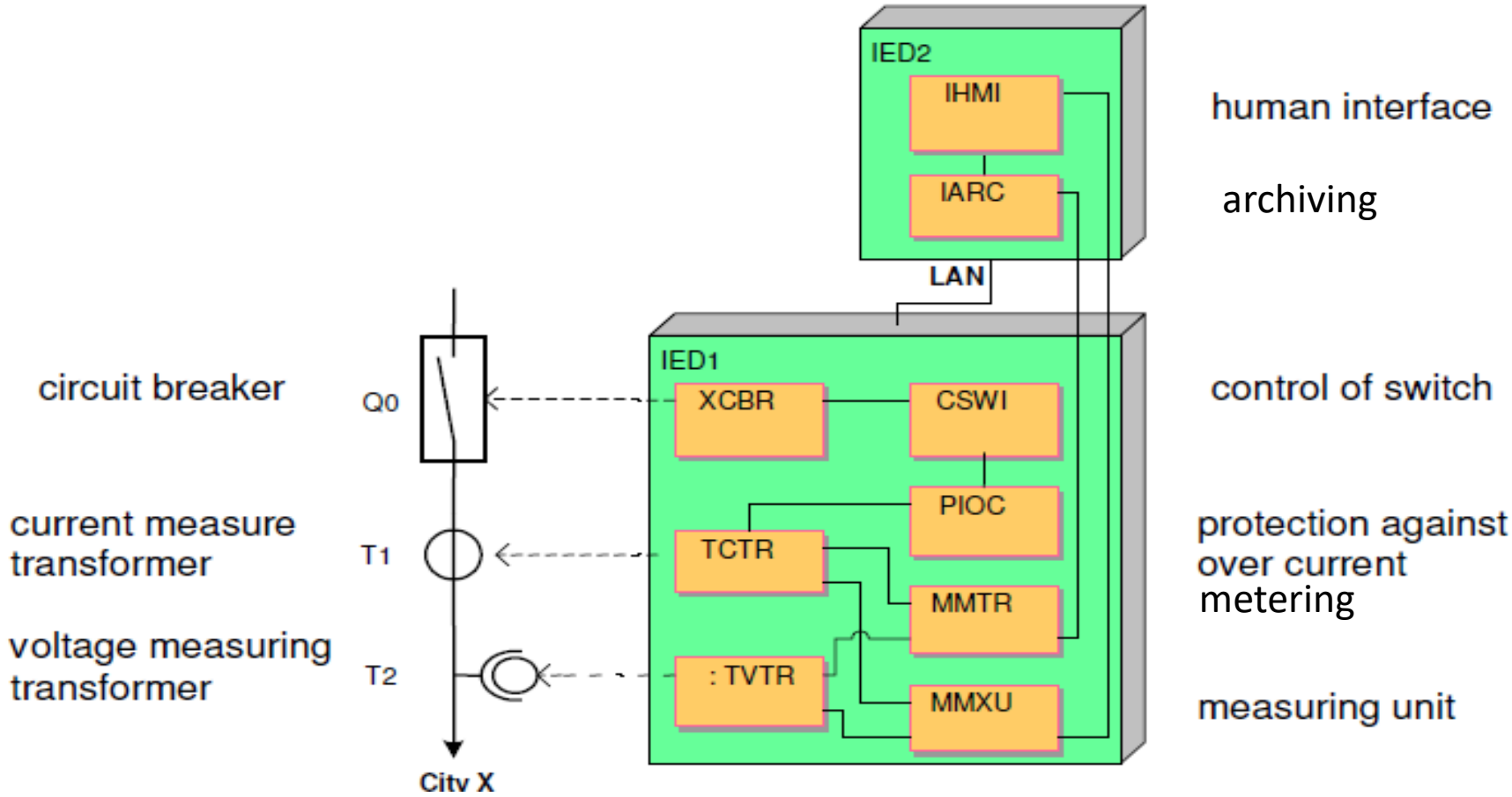
Logical Devices

Each device in a substation is a logical device. In the below diagram the logical devices are the RTU, Bay Controllers, Relays and Meters. When configuring IEC 61850 for a substation, each logical device should have a unique name.



Logical Nodes

Each Logical Device will support various functions. Each function can be categorized into Logical Nodes. Below example, are Logical Nodes break outs for two Logical Devices.



Logical Nodes

Logical Group	Name
L	System LN
P	Protection
R	Protection related
C	Control
G	Generic
I	Interfacing and archiving
A	Automatic control
M	Metering and measurement
S	Sensor and monitoring
X	Switchgear
T	Instrument transformers
Y	Power transformers
Z	Further power system equipment

Logical Node Classes – System LNs

Description	Name
Physical device information	LPHD
Common Logical Node	Common LN
Logical node zero	LLN0
Physical Communication channel Supervision	LCCH
GOOSE subscription	LGOS
Sampled value subscription	LSVS
Time management	LTIM
Time master supervision	LTMS
Service tracking	LTRK

Logical Node Classes – Protection

Differential	PDIF
Direction comparison	PDIR
Distance	PDIS
Directional overpower	PDOP
Directional underpower	PDUP
Rate of change of frequency	PFRC
Harmonic restraint	PHAR
Ground detector	PHIZ
Instantaneous overcurrent	PIOC
Motor restart inhibition	PMRI
Motor starting time supervision	PMSS
Over power factor	POPF
Phase angle measuring	PPAM
Rotor protection	PRTR
Protection scheme	PSCH
Sensitive directional earthfault	PSDE
Transient earth fault	PTEF
Tyristor protection	PTHF
Time overcurrent	PTOC
Overfrequency	PTOF
Overvoltage	PTOV
Protection trip conditioning	PTRC
Thermal overload	PTTR
Undercurrent	PTUC
Underfrequency	PTUF
Undervoltage	PTUV
Underpower factor	PUPF
Voltage controlled time overcurrent	PVOC
Volts per Hz	PVPH
Zero speed or underspeed	PZSU
Rotor protection	PRTR
Thyristor protection	PTHF

Logical Node Classes – Generic

Description	Name
Generic automatic process control	GAPC
Generic process I/O	GGIO
Generic log	GLOG
Generic security application	GSAL

Logical Node Classes – Interfacing and Archiving

Archiving	IARC
Human machine interface	IHMI
Safety alarm function	ISAF
Telecontrol interface	ITCI
Telemonitoring interface	ITMI
Teleprotection communication interfaces	ITPC
Safety alarm function	ISAF

Logical Node Classes – Metering and Measurement

Environmental information	MENV
Flicker Measurement Name	MFLK
Harmonics or interharmonics	MHAI
Non phase related harmonics or interharmonics	MHAN
Hydrological information	MHYD
DC measurement	MMDC
Meteorological information	MMET
Metering	MMTN
Metering	MMTR
Non phase related Measurement	MMXN
Measurement	MMXU
Sequence and imbalance	MSQI
Metering Statistics	MSTA
Environmental information	MENV
Hydrological information	MHYD
DC measurement	MMDC
Meteorological information	MMET
Fuel characteristics	MFUL
Pressure measurements	MPRS
Heat measured values	MHET
Flow measurements	MFLW
Emissions measurements	MENV

Logical Node Classes – Instrument Transformer and Sensor

Angle	TANG
Axial displacement	TAXD
Current transformer	TCTR
Distance	TDST
Liquid flow	TFLW
Frequency	TFRQ
Generic sensor	TGSN
Humidity	THUM
LMedia level	TLVL
Magnetic field	TMGF
Movement senso	TMVM
Position indicator	TPOS
Pressure sensor	TPRS
Rotation transmitter	TRTN
Sound pressure sensor	TSND
Temperature sensor	TTMP
Mechanical tension / stress	TTNS
Vibration sensor	TVBR
Voltage transformer	TVTR
Water acidity	TWPH
Angle sensor	TANG

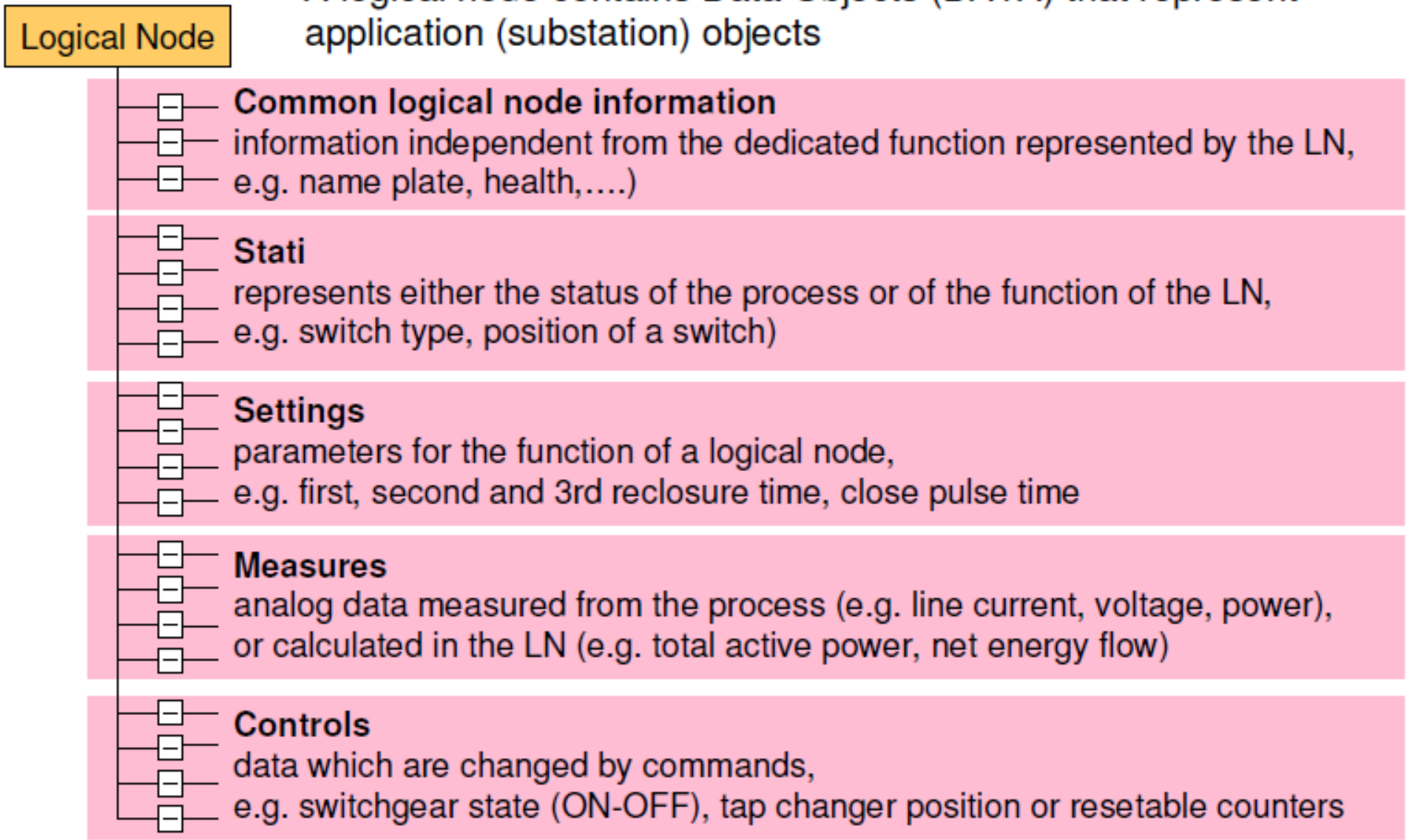
Axial displacement sensor	TAXD
Distance sensor	TDST
Flow sensor	TFLW
Frequency sensor	TFRQ
Humidity sensor	THUM
Level sensor	TLEV
Magnetic field sensor	TMGF
Movement sensor	TMVM
Position indicator	TPOS
Pressure sensor	TPRS
Rotation transmitter	TRTN
Sound pressure sensor	TSND
Temperature sensor	TTMP
Mechanical tension /stress sensor	TTNS
Vibration sensor	TVBR
Water pH sensor	TWPH

Logical Node Classes – Switchgear

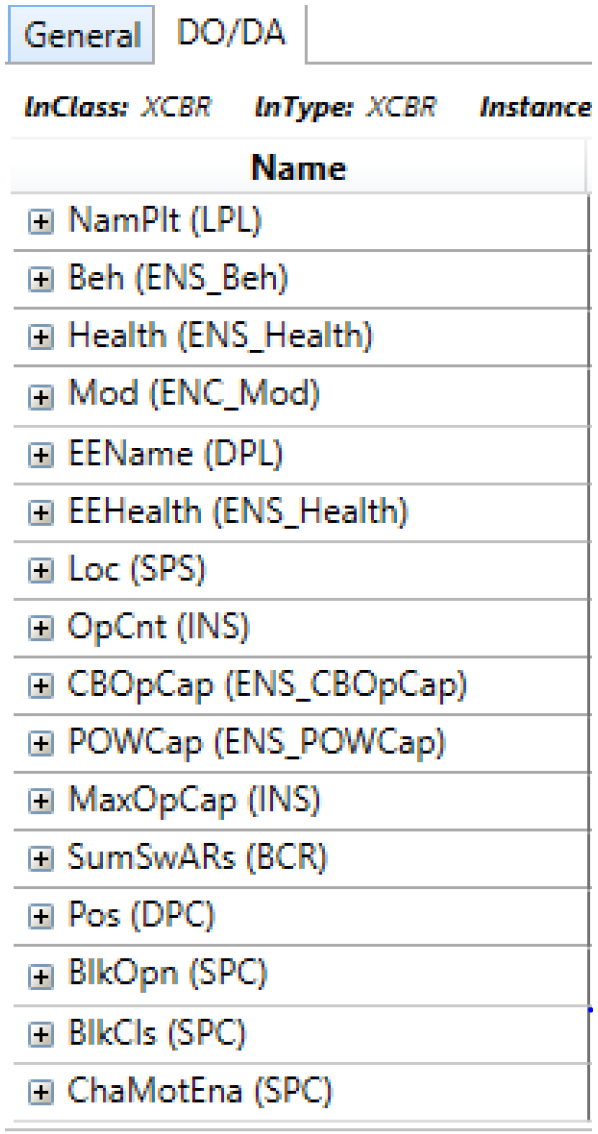
Circuit breaker	XCBR
Circuit switch	XSWI
Fuse	XFUS

Data Objects

A logical node contains Data Objects (DATA) that represent application (substation) objects



Example: Data Objects for XCBR Logical Node



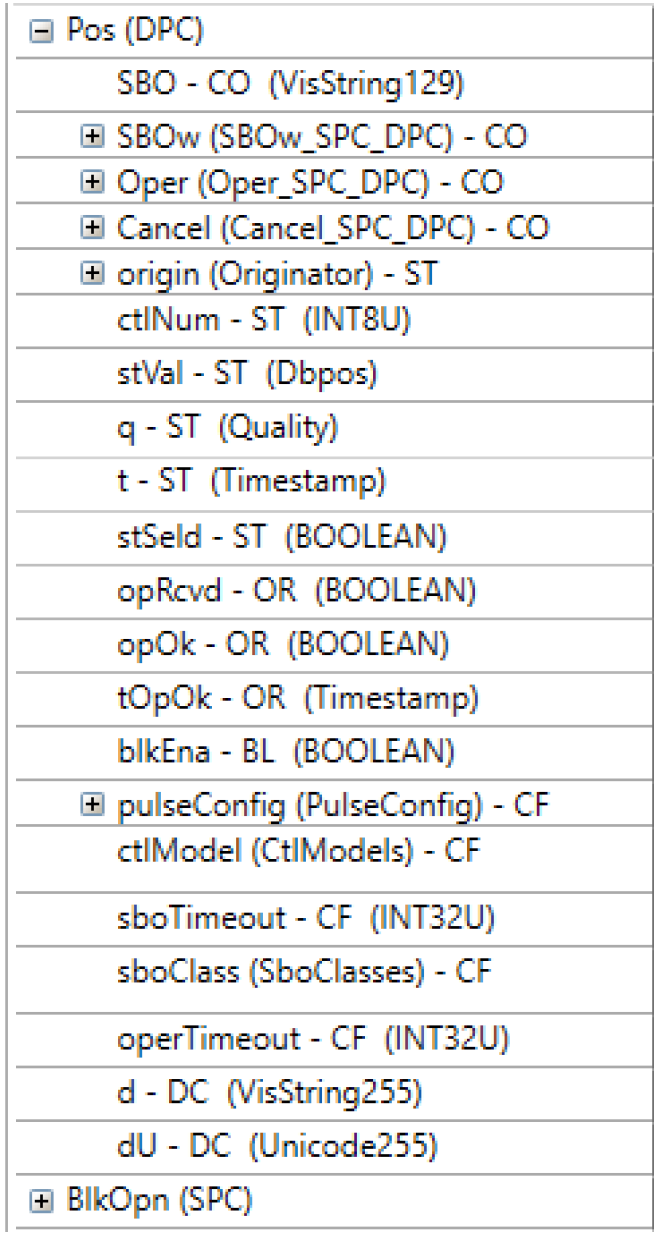
Example: Data Objects for XCBR Logical Node

XCBR			
Data Object	**Explanation**	**CDC**	**Mandatory**
	Basic LN		
Mod	Mode	INC	M
Beh	Behavior	INS	M
Health	Health	INS	M
NamePlt	Name Plate	LPL	
Loc	Local operation, not remote	SPS	
EEHealth	External equipment health	INS	
EEName	External equipment name plate	DPL	
NamPlt	Name Plate	LPL	
OpCnt	Operation counter	INS	M
	Controls		
Pos	Switch position	DPC	M
BlkOpn	Block opening	SPC	M
BlkCls	Block closing	SPC	M
ChaMotEna	Charger motor enable	SPC	
	Measures		
SumSwARs	Sum of switched amperes, resetable	BCR	
	Status		
CBOpCap	Circuit breaker operating capability	INS	M
POWCap	Point on wave switching capability	INS	
MaxOpCap	Operating capability when fully charged	INS	

common to all logical nodes

Pos is a DATA of Logical Node XCBR

Data Attributes



IEC 61850 Common Data Classes

Many logical nodes have data objects with the same data attributes.

For example, discrete input variables all have the following data attributes

- Value
- Quality
- Timestamp
- Description

IEC 61850 has defined standard groups of data attributes which are called Common Data Classes (CDC).

Each data object of a logical node belongs to a CDC.

IEC 61850 Common Data Classes

Status information

- Single point status information (SPS)
- Double point status (DPS)
- Integer status (ISI)
- Enumerated Status (ENS)**
- Protection activation (ACT)
- Directional protection activation (ACD)
- Security violation counting (SEC)
- Binary counter reading (BCR)
- Histogram (HST)**
- Visible String Status (VSS)**

Measurands

- Measured value (MV)
- Complex measured value (CMV)
- Sampled value (SAV)
- WYE
- Delta (DEL)
- Sequence (SEQ)
- Harmonic Value (HMV)
- Harmonic value for WYE (HWYE)
- Harmonic value for DEL (HDEL)

Controls

- Controllable single point (SPC)
- Controllable double point (DPC)
- Controllable integer status (ISC)
- Controllable enumerated status (ENC)**
- Binary controlled step position (BSC)
- Integer controlled step position (ISC)
- Controllable analogue process value (APC)
- Binary controlled analog process value (BAC)**

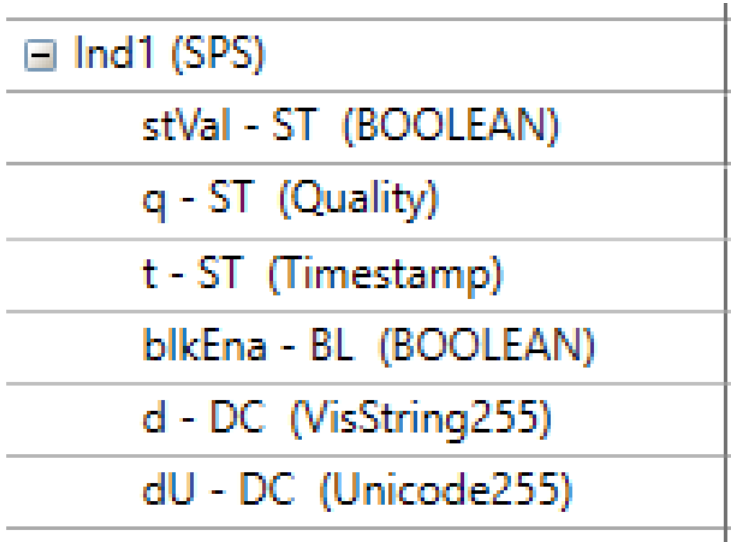
Status settings

- Single point setting (SPG)
- Integer status setting (ISG)
- Enumerated status setting (ENG)**
- Object reference setting (ORG)**
- Time setting group (TSG)**
- Currency setting group (CUG)**
- Visible string setting (VSG)**

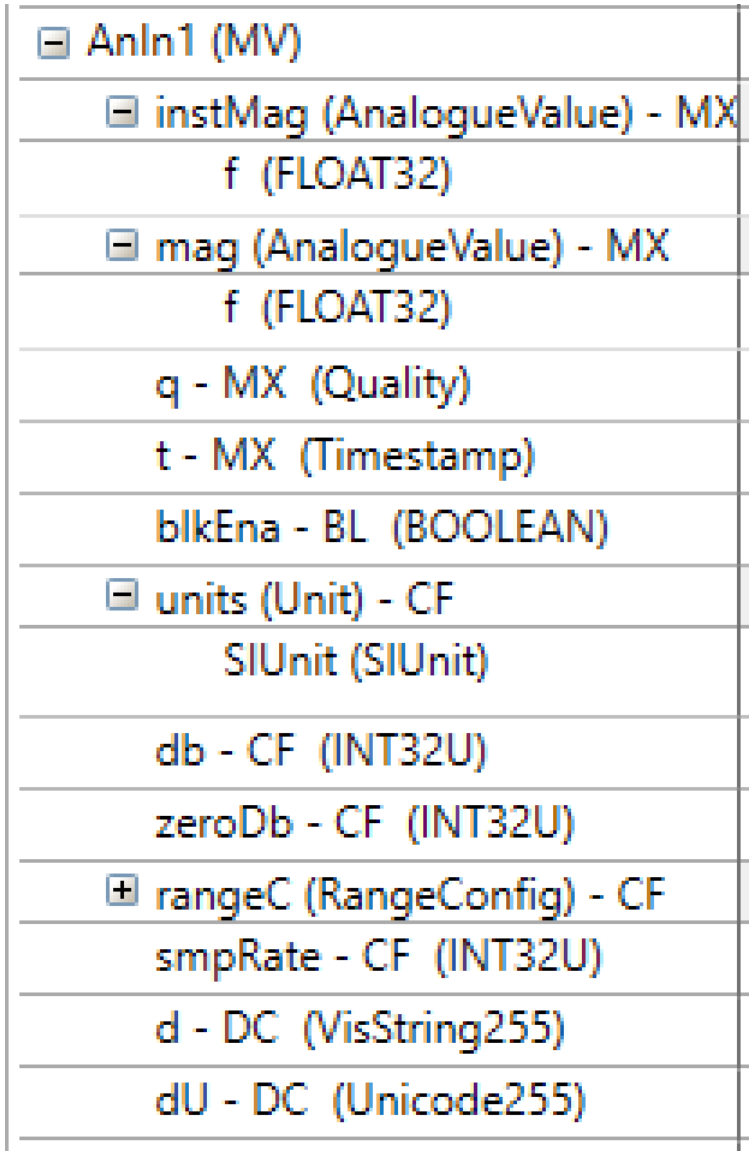
Analogue settings

- Analogue setting (ASG)
- Setting curve (CURVE)
- Curve shape setting group (CUG)**

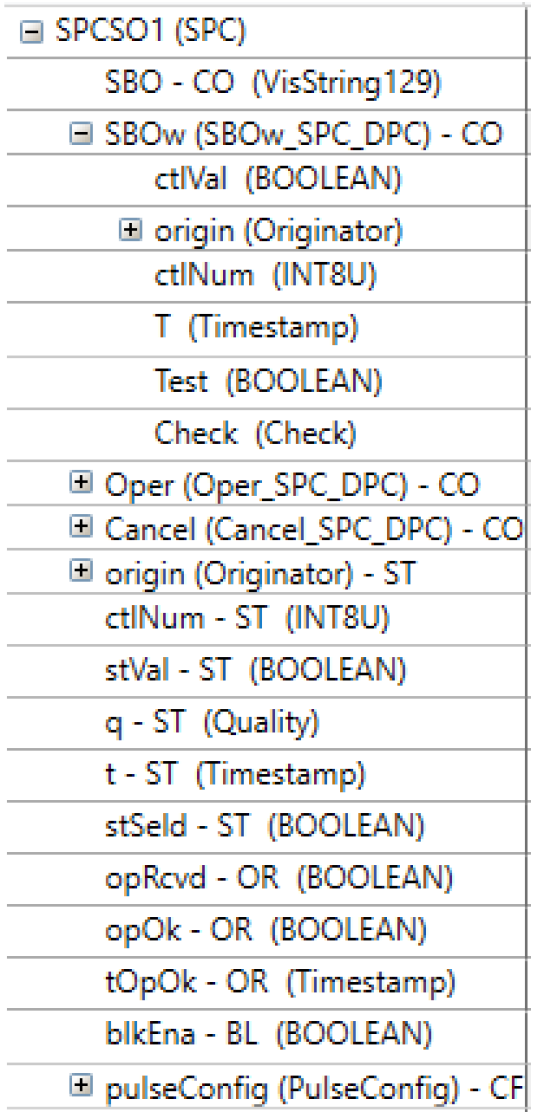
Data Attributes Example for Digital Inputs



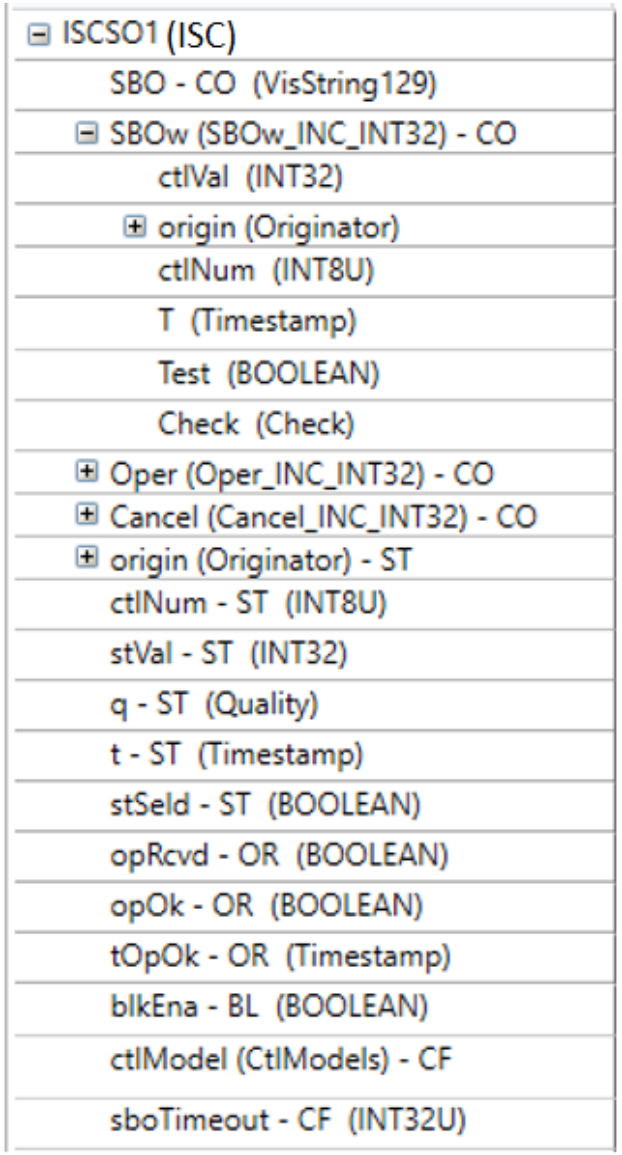
Data Attributes Example for Analog Inputs



Data Attributes Example for Digital Outputs



Data Attributes Example for Analog Outputs

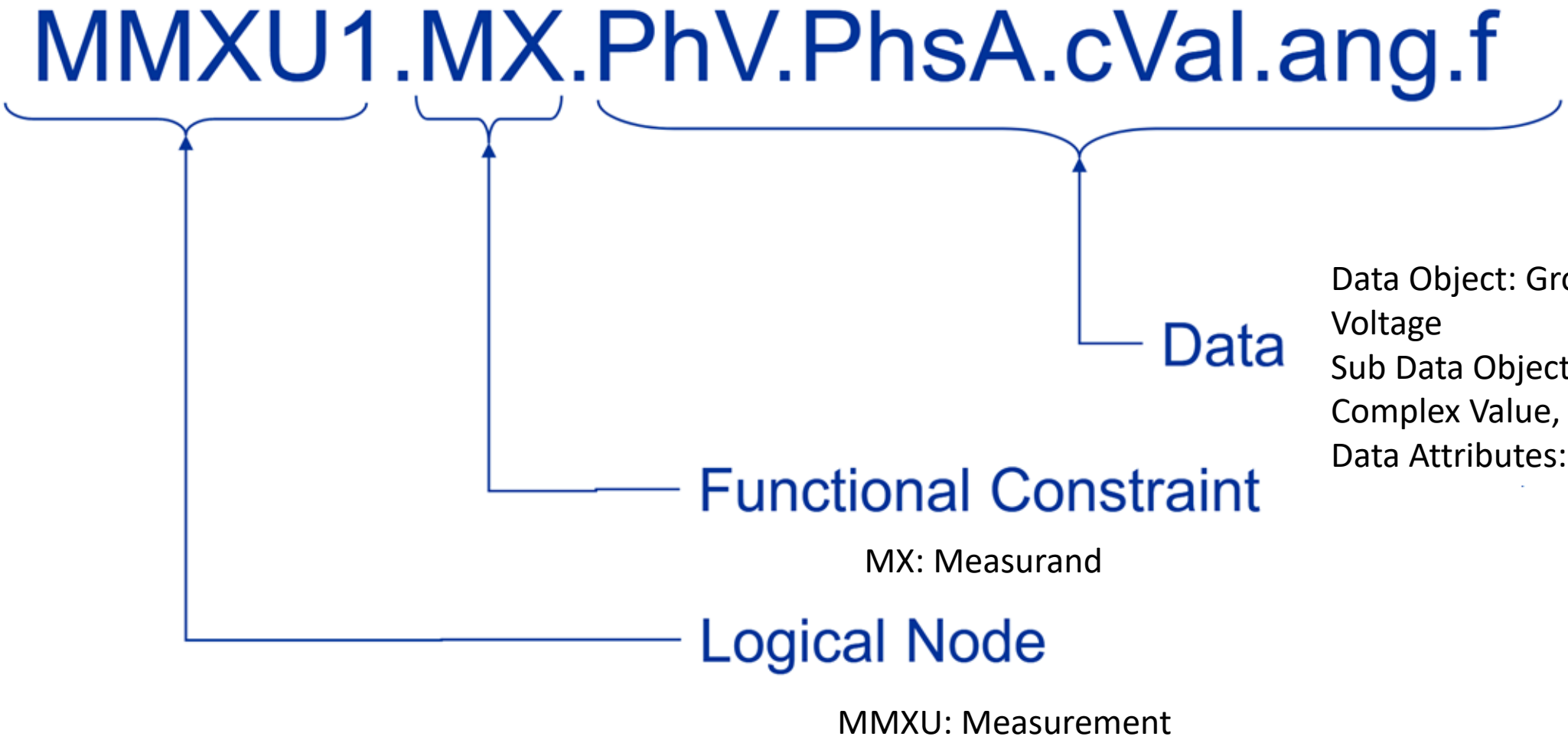


IEC 61850 Functional Constraints

Functional Contraints is a property of a data attribute that characterizes the specific use of the attribute

Functional Constraint	Description	Services
ST MX	Process values: status, measurand	Read, substitute, report, log
CO SP	Process commands: binary, analog (setpoints)	Operate
OR	Operate Received	Operate
CF DC	Configuration, description	Read, write (report, log)
SG SE	Parameters, in settings groups (SG: active value, SE: editable value)	GetSGValue, SetSG Value
CB related	Each CB type	GetxxxCBValues, SetxxxCBValues

IEC 61850 Information Structure Recap



Data Object: Ground to Phase Voltage
Sub Data Objects: Phase A, Complex Value, Angle
Data Attributes: Floating point

CID Example

SEL_487E.CID - Notepad

File Edit Format View Help

```
        </DataSet>
        <DataSet desc="Terminal S Meter" name="DSet08">
          <FCDA ldInst="MET" prefix="METS" lnClass="MMXU" lnInst="1" doName="TotW" fc="MX" />
          <FCDA ldInst="MET" prefix="METS" lnClass="MMXU" lnInst="1" doName="TotVAr" fc="MX" />
          <FCDA ldInst="MET" prefix="METS" lnClass="MMXU" lnInst="1" doName="TotVA" fc="MX" />
          <FCDA ldInst="MET" prefix="METS" lnClass="MMXU" lnInst="1" doName="TotPF" fc="MX" />
          <FCDA ldInst="MET" prefix="METS" lnClass="MMXU" lnInst="1" doName="Hz" fc="MX" />
          <FCDA ldInst="MET" prefix="METS" lnClass="MMXU" lnInst="1" doName="PhV1" fc="MX" />
          <FCDA ldInst="MET" prefix="METS" lnClass="MMXU" lnInst="1" doName="PhV2" fc="MX" />
          <FCDA ldInst="MET" prefix="METS" lnClass="MMXU" lnInst="1" doName="PPV1" fc="MX" />
          <FCDA ldInst="MET" prefix="METS" lnClass="MMXU" lnInst="1" doName="PPV2" fc="MX" />
          <FCDA ldInst="MET" prefix="METS" lnClass="MMXU" lnInst="1" doName="A1" fc="MX" />
          <FCDA ldInst="MET" prefix="METS" lnClass="MMXU" lnInst="1" doName="W" fc="MX" />
          <FCDA ldInst="MET" prefix="METS" lnClass="MMXU" lnInst="1" doName="VAr" fc="MX" />
          <FCDA ldInst="MET" prefix="METS" lnClass="MMXU" lnInst="1" doName="VA" fc="MX" />
          <FCDA ldInst="MET" prefix="METS" lnClass="MMXU" lnInst="1" doName="PF" fc="MX" />
        </DataSet>
        <ReportControl desc="Predefined Buffered Report 05" name="BRep05" datSet="DSet05" rptID="DSet05" confRev="1" buffered="true" bufTime="500">
          <TrgOps dchg="true" qchg="true" period="true" />
          <OptFields seqNum="true" timeStamp="true" dataSet="true" reasonCode="true" entryID="true" />
        </ReportControl>
        <ReportControl desc="Predefined Unbuffered Report 01" name="URep01" datSet="DSet08" rptID="DSet08" confRev="1" bufTime="250">
          <TrgOps dchg="true" qchg="true" period="true" />
          <OptFields seqNum="true" timeStamp="true" dataSet="true" reasonCode="true" />
        </ReportControl>
        <DOI name="Mod">
          <DAI esel:datasrc="db:EN?5:1" name="stVal" />
          <DAI esel:datasrc="db:EN" name="q" />
          <DAI esel:datasrc="imm" name="ctlModel">
            <Val>status-only</Val>
          </DAI>
        </DOI>
        <DOI name="Health">
          <DAI esel:datasrc="db:EN?3:1" name="stVal" />
          <DAI esel:datasrc="db:EN" name="q" />
        </DOI>
```

MMS and GOOSE Protocol within IEC 61850

MMS:

- Manufacturing Message Specification
- International standard dealing with messaging systems for transferring real-time process data and supervisory control information
- Similar to standard DNP3 Master polling DNP3 Slave for real-time data

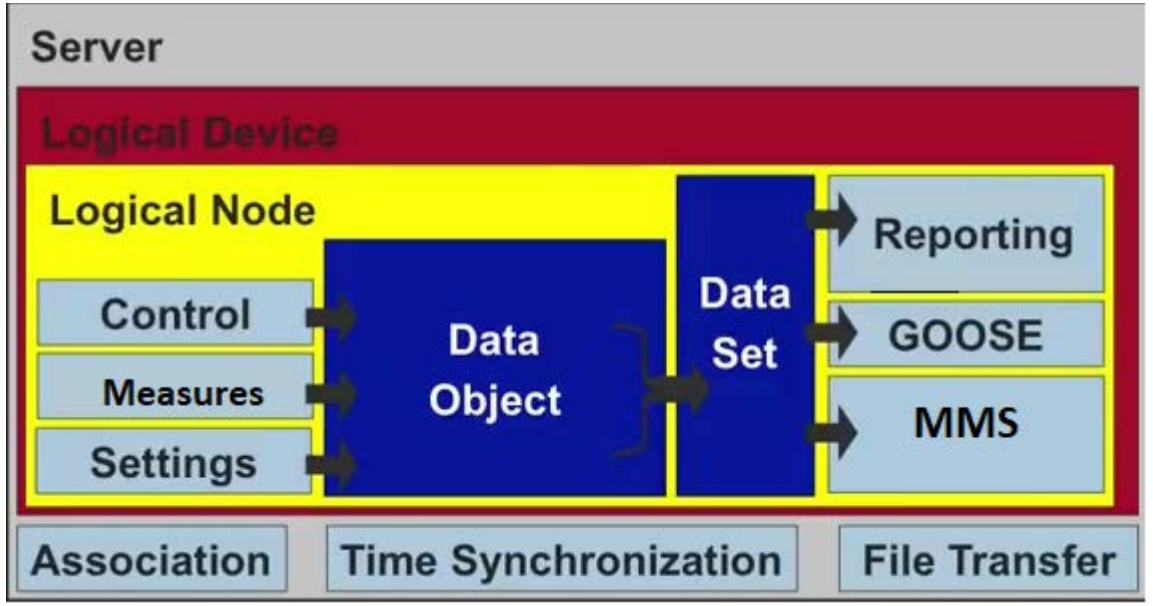
GOOSE:

- Generic Object Oriented Substation Events
- data is directly embedded into Ethernet data packets and works on a subscription mechanism on multicast or broadcast MAC addresses
- uses VLAN and priority tagging to have separate virtual network within the same physical network and sets appropriate message priority level
- Enhanced retransmission mechanisms - The same GOOSE message is retransmitted with varying and increasing re-transmission intervals.

IEC 61850 Data Set

Data set

- A data set in IEC 61850 is a list of variables that can be observed and transmitted together in a more efficient manner.
- Data sets are used to define variables that can be transferred via MMS read and write services, reporting (mapped to MMS information reports) or GOOSE.

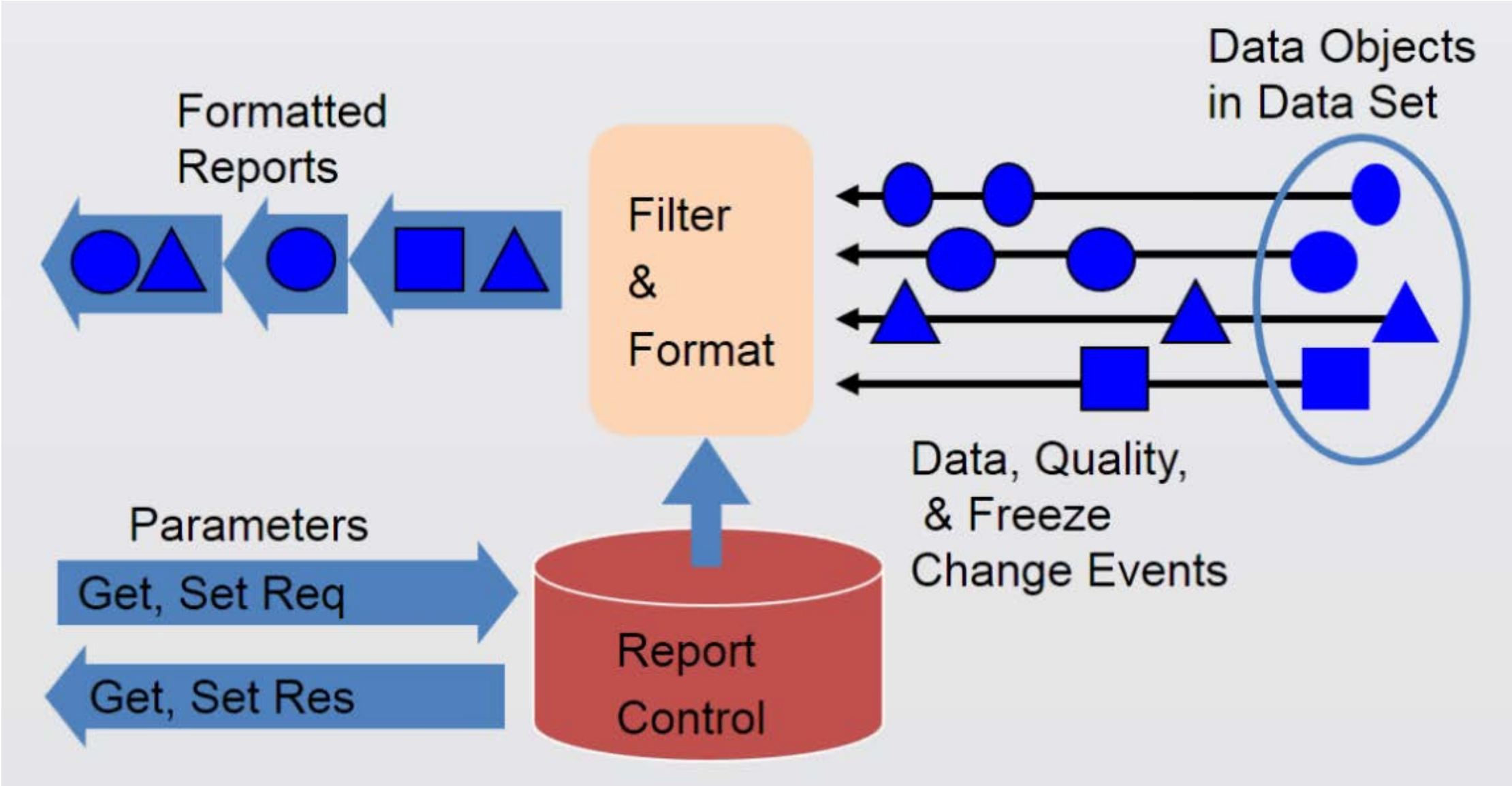


IEC 61850 Report Control Blocks

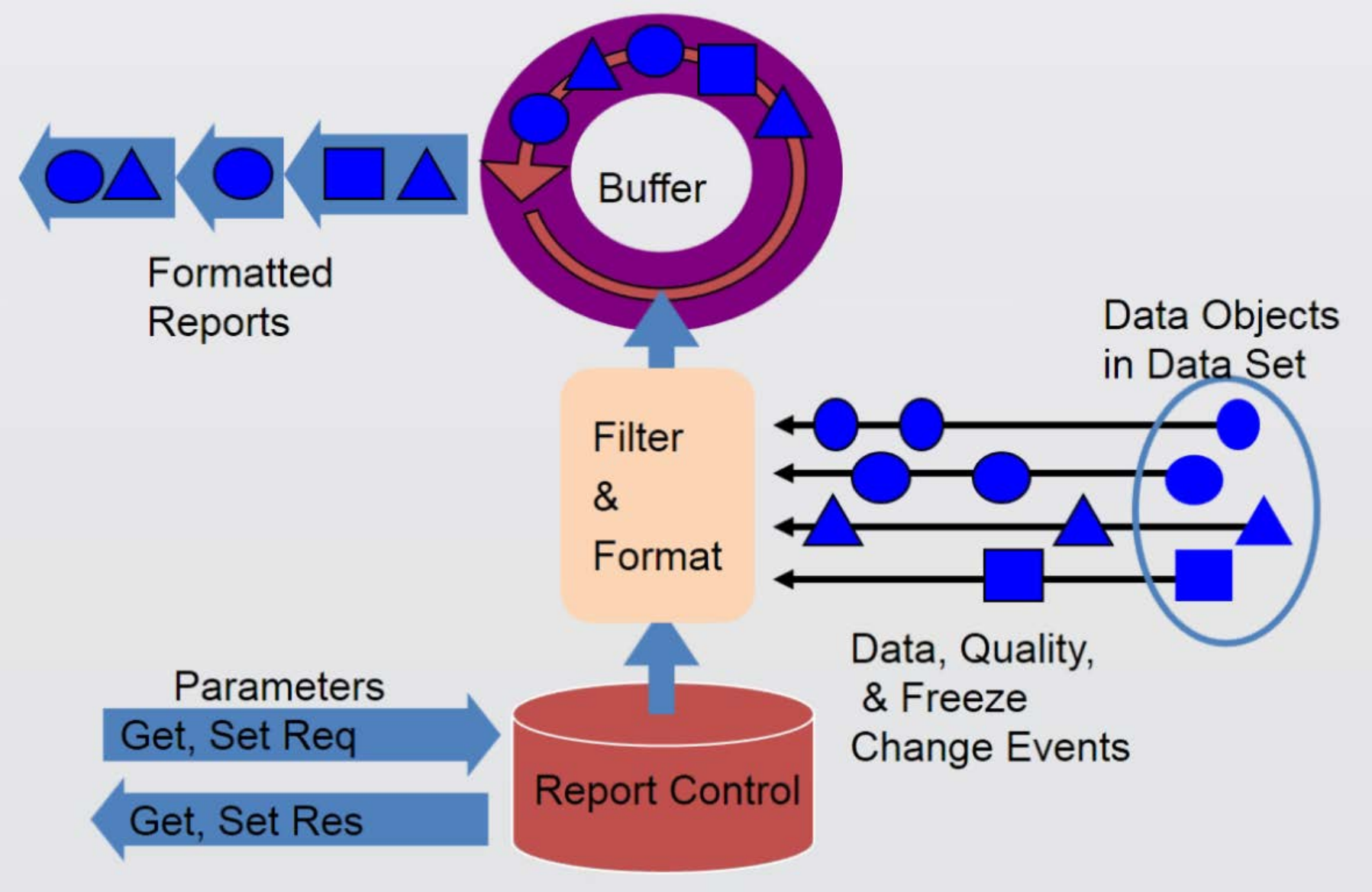
Reports

- Reports are unsolicited data messages sent by the server.
- The sending of reports is triggered by preconfigured events.
- Triggers can e.g.be if the value or quality of a variable in the monitored data set changes.
- In unbuffered reporting, events will not be logged and reported if the associated client for the unbuffered report control block is not connected.
- In buffered reporting, events will be logged for a specific amount of time and sent later when the client is connected again.

IEC 61850 Unbuffered Reporting – Sent only once, lost if client is down

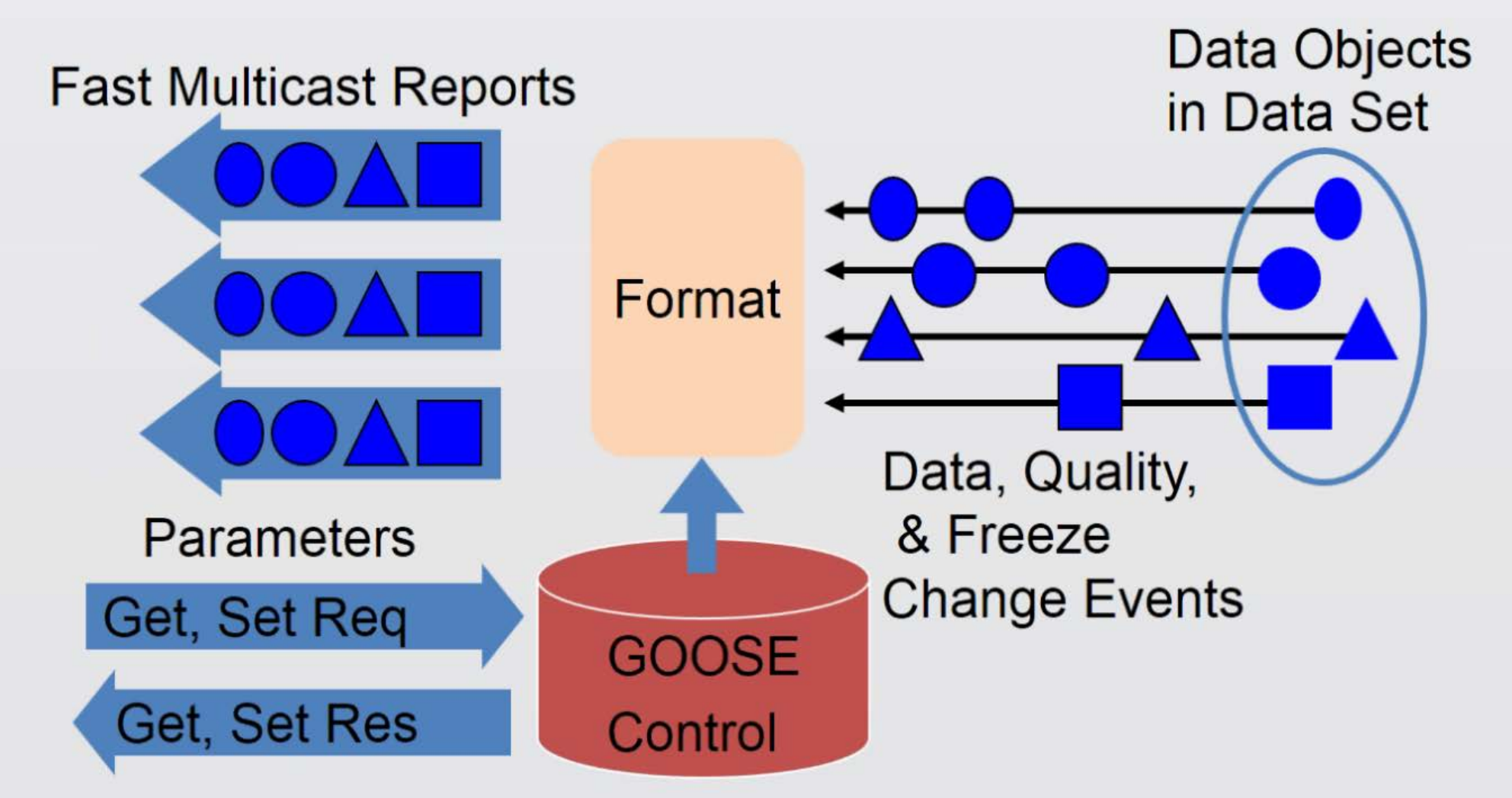


IEC 61850 Buffered Reporting – Stored until client sends acknowledgement



IEC 61850 GOOSE Reporting – Publisher sends to multiple Subscribers

- Intended to replace relay-to-relay wiring
- Reduces wiring
- High speed <4ms
- High reliability by automatic retransmission
- Ideal for interlocking



IEC 61850 Comparison – Data Exchange Types

Feature	Modbus	DNP3	IEC 61850
Polling	Yes	Yes	Yes
Report by exception (initiated by slave/server)	No	Yes ”Unsolicited”	Yes “Buffered RCB” “Unbuffered RCB”
Data broadcast to multiple recipients	No	No	Yes “GOOSE” messages from “Publisher” to “Subscribers”
Quality bits	No	Yes	Yes, multiple • Overflow • Out of range • Failure • Old data • Inaccurate
Timestamp	No	Yes	Yes

Thank you, Questions?

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