IEC 61850 Digital Substation Tutorial for Novices

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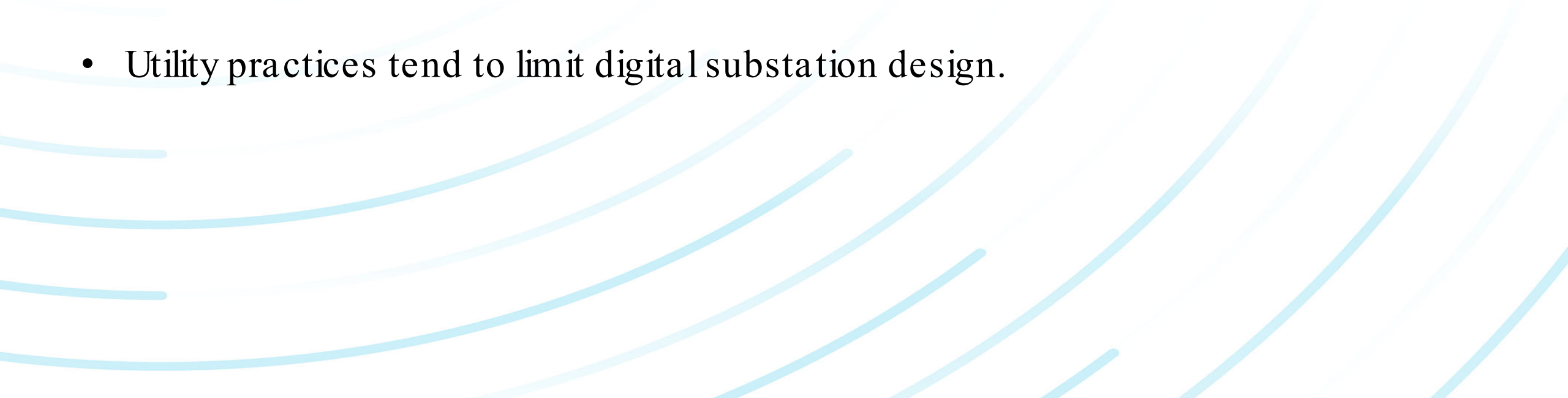
Minnesota Power Systems Conference
Nov 12, 2019

Agenda

- Conceptual Design
- Proper Data Model & Services
- Digital Substation Arcitecture
- Reliability & Redundancy Design
- Time Synchronization
- Network Traffic Segregation

Part #	Title
1	Introduction and Overview
2	Glossary of terms
3	General Requirements
4	System and Project Management
5	Communication Requirements for Functions and Device Models
6	Configuration Description Language for Communication in Electrical Substations Related to IEDs
7	Basic Communication Structure for Substation and Feeder Equipment
7.1	- Principles and Models
7.2	- Abstract Communication Service Interface (ACSI)
7.3	- Common Data Classes (CDC)
7.4	- Compatible logical node classes and data classes
8	Specific Communication Service Mapping (SCSM)
8.1	- Mappings to MMS (ISO/IEC 9506 – Part 1 and Part 2) and to ISO/IEC 8802-3
9	Specific Communication Service Mapping (SCSM)
9.1	- Sampled Values over Serial Unidirectional Multidrop Point-to-Point Link
9.2	- Sampled Values over ISO/IEC 8802-3
10	Conformance Testing

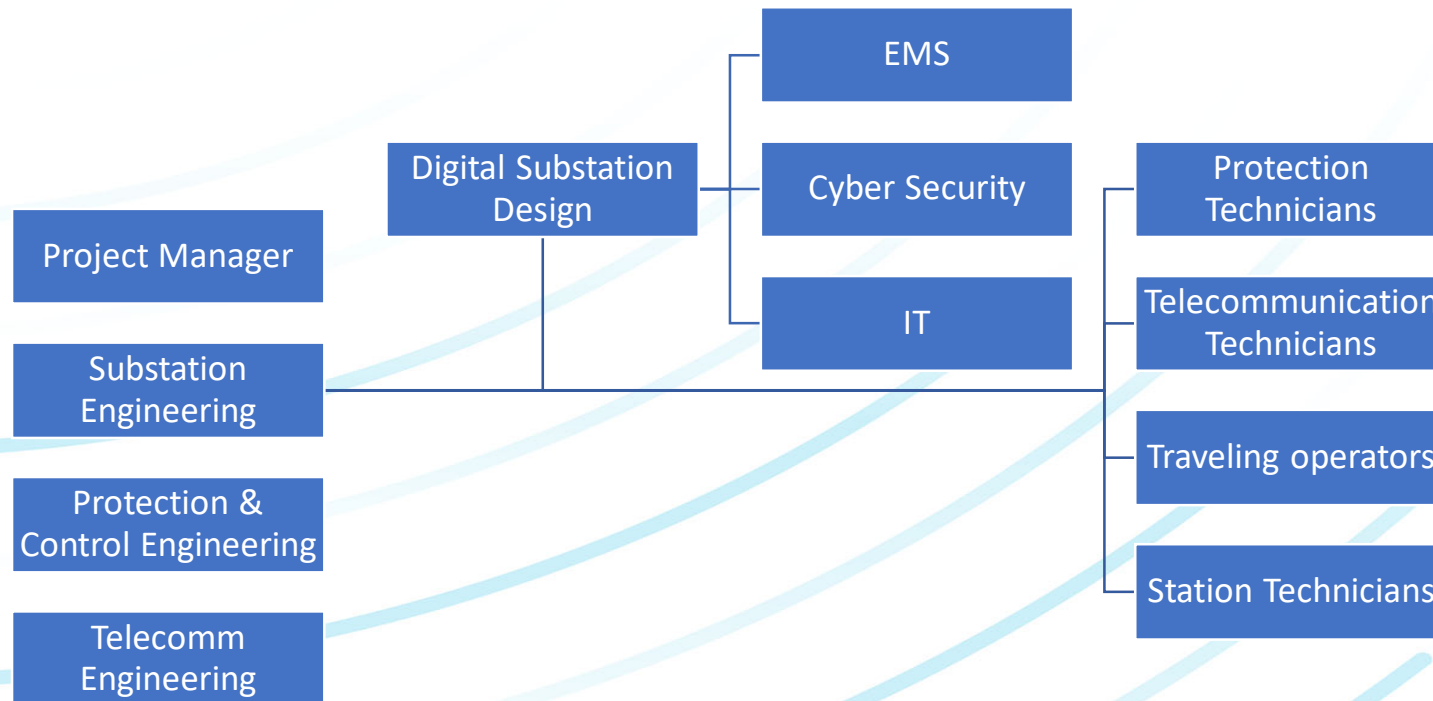| Other	Title
90-4	IEC/TR61850-90-4 Network Engineering Guidelines

- Familiarize yourself with the Standards.
- Read, Read, & Read

Conceptual Design—Read…Learn…

- Understand your current organization's protection and control standards and practices.

- Utility P&C practices exist for a reason.

- As you work through your standards you will find that certain aspects of your current design can be improved or simplified.

- Utility practices tend to limit digital substation design.

- Involve all stakeholders early in your design process.
- Pull everyone involved in a power utility system as they are your customers. Every one has a job function.
- Like every business, know what your customers want, how can you make life more efficient.
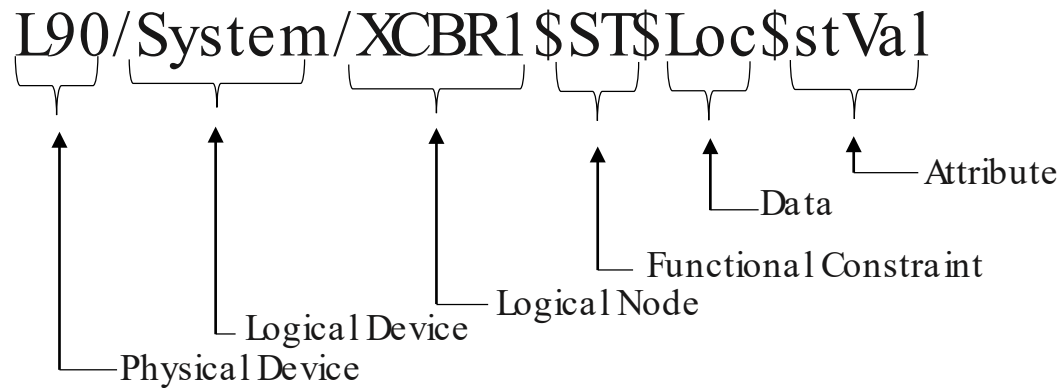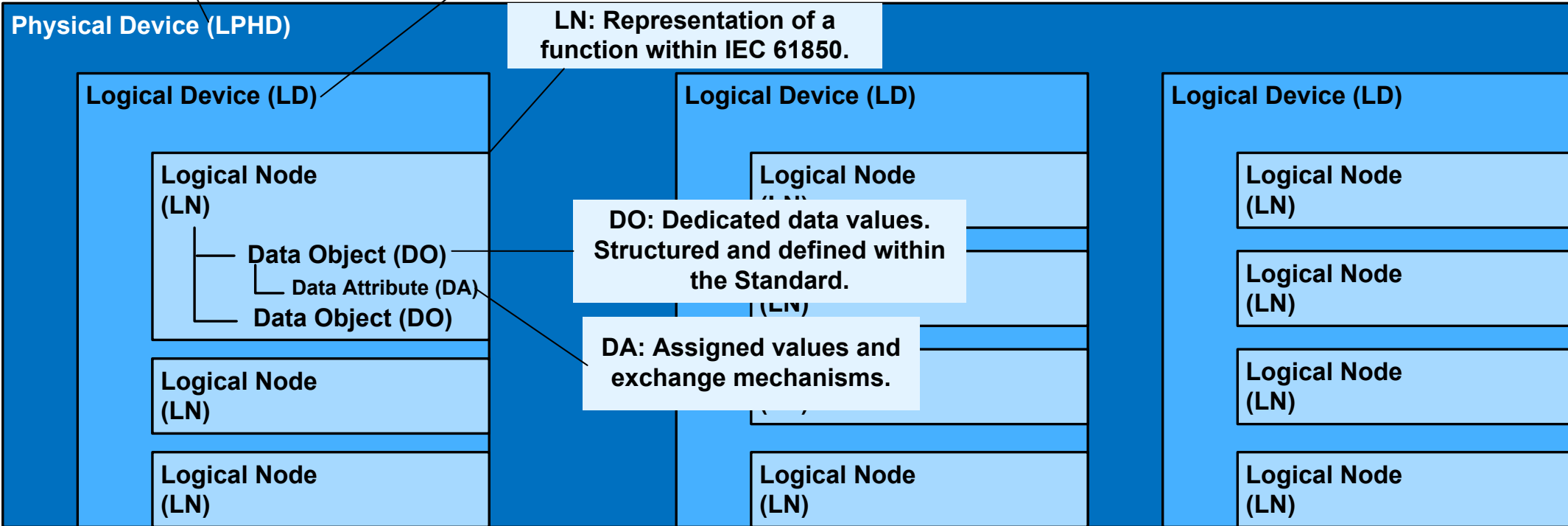- "People fear the future because they do not see their place in it"

- Most essential element in the success of implementing a digital substation
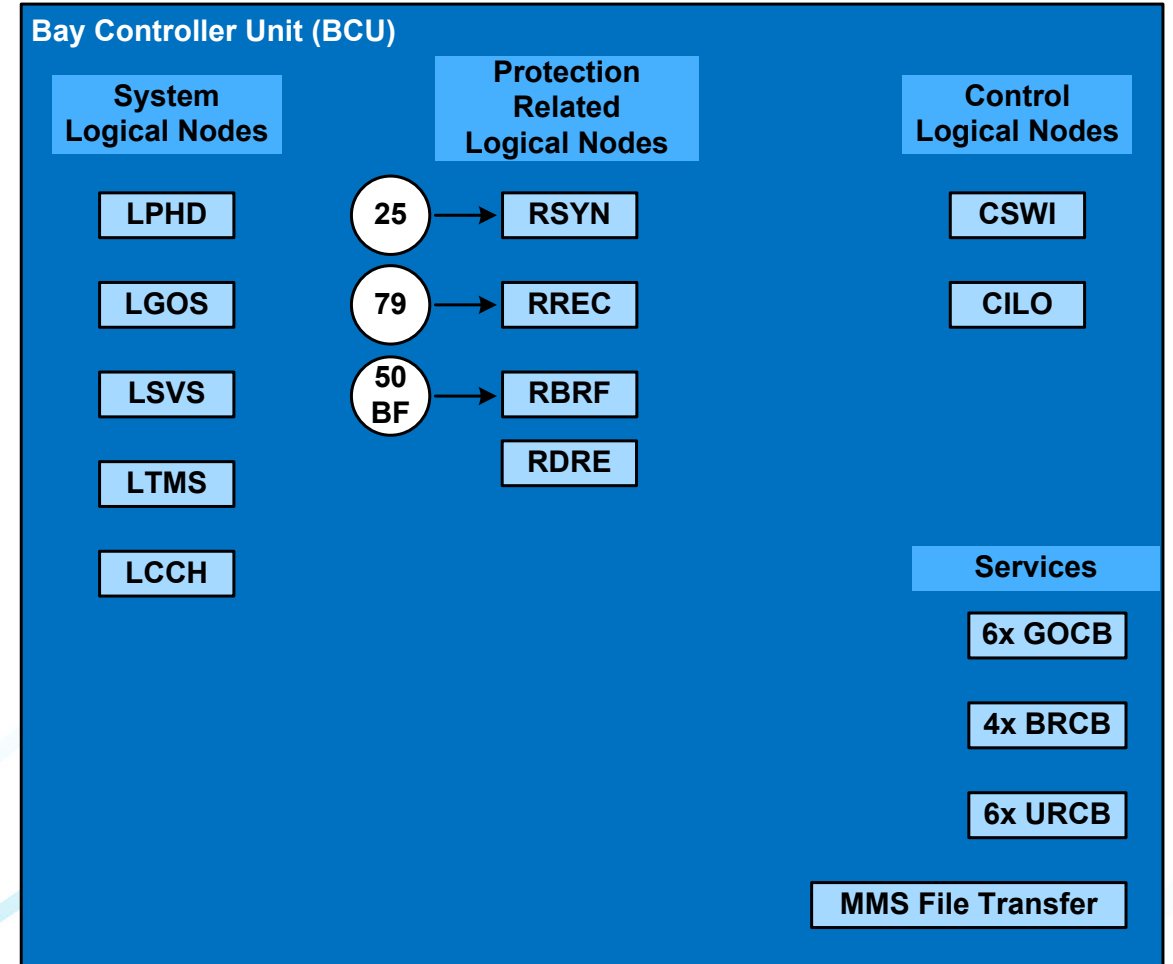- Can be capitalized on projects
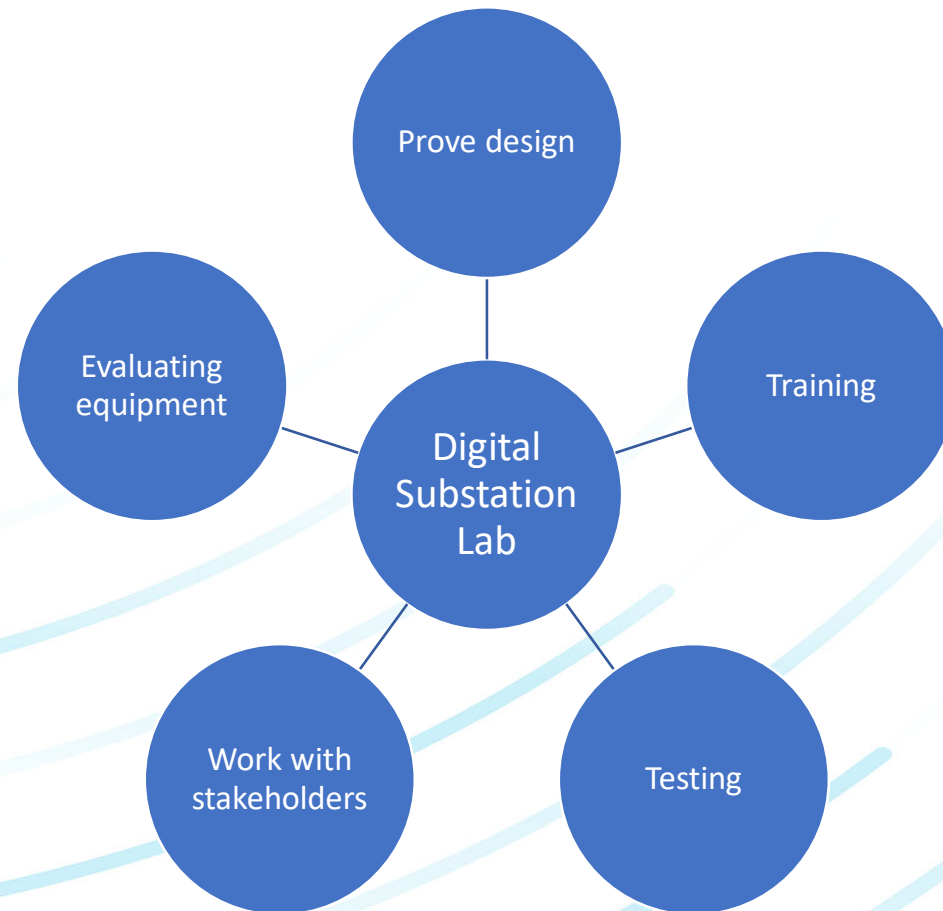
IEC 61850 Data Model

LPHD: The actual physical device, accessed by the network address

LD: Collection of Logical Nodes within in one Physical Device.

LN: Representation of a function within IEC 61850.

Physical Device (LPHD)

Logical Device (LD)

Logical Node (LN)

Data Object (DO)

Data Attribute (DA)

Data Object (DO)

DO: Dedicated data values. Structured and defined within the Standard.

DA: Assigned values and exchange mechanisms.

Logical Node (LN)

Logical Node (LN)

Logical Device (LD)

Logical Node (LN)

Logical Node (LN)

Logical Node (LN)

Logical Device (LD)

Logical Node (LN)

Logical Node (LN)

Logical Node (LN)

Logical Node (LN)

L90/System/XCBR1STLoc$stVal

Physical Device

Logical Device

Logical Node

Functional Constraint

Data

Attribute

IEC 61850 Data Model & Services

Distance Relay

System Logical Nodes
- LPHD
- LGOS
- LSVS
- LTMS
- LCCH

Protection Logical Nodes
- 21 → PDIS
- 21N → PDIS
- 67N → PTOC
- RDIR
- 50 → PIOC
- PTRC

Other Logical Nodes
- RFLO
- RDRE
- CSWI

Services
- 6x GOCB
- 4x BRCB
- 6x URCB

MMS File Transfer

Bay Controller Unit (BCU)

System Logical Nodes
- LPHD
- LGOS
- LSVS
- LTMS
- LCCH

Protection Related Logical Nodes
- 25 → RSYN
- 79 → RREC
- 50 BF → RBRF
- RDRE

Control Logical Nodes
- CSWI
- CILO

Services
- 6x GOCB
- 4x BRCB
- 6x URCB

MMS File Transfer

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64 Boolean, DPS, Analog GOOSE Inputs → **LGOS**

8 SV data streams → **LSVS**

64 Boolean, DPS, Analog GOOSE Inputs → **LGOS**

8 SV data streams → **LSVS**

No Standard is Perfect..

Other Missing Info – "BlkOpn", "BlkCls"

CSWI class				
Data object name	**Common data class**	**Explanation**	**T**	**M/O/C**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22.		
Data objects				
Status information				
LocKey	SPS	Local or remote key		O
Loc	SPS	Local control behaviour		O
OpOpn	ACT	Operation "Open switch"	T	O
SelOpn	SPS	Selection "Open switch"		O
OpCls	ACT	Operation "Close switch"	T	O
SelCls	SPS	Selection "Close switch"		O
Controls				
OpCntRs	INC	Resettable operation counter		O
LocSta	SPC	Switching authority at station level		O
Pos	DPC	Switch, general		M
PosA	DPC	Switch L1		O
PosB	DPC	Switch L2		O
PosC	DPC	Switch L3		O

Relay Room

CSWI

Switchyard

XCBR

Drawing Update Data Map

P21A-LN6 GE D60 — SBP, 1PBA, 1PBB, 21 PDIS, 21N PDIS, 67N PDEF, CRITICAL FAILURE, TS X-→ FAILURE EMS IND.
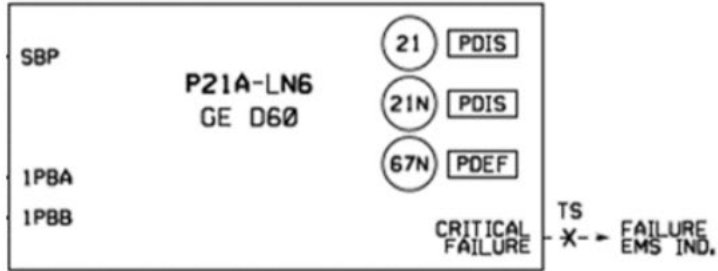
SMV IN	LOGICAL NODE .DO	PUBLISHER
LN6 I Ph. A, B, C	TCTR.AmpSv	MUR60-1
WEST BUS V Ph. A, B, C, N	TVTR.VolSv	MUR60-1
EAST BUS V Ph. A, B, C, N	TVTR.VolSv	MUR30-1

GOOSE OUT	LOGICAL NODE .DO	SUBSCRIBER
LN6 PROT. TRIP (8A1) R60	PTRC.Op	MUR60-1 BC60-1

GOOSE IN	LOGICAL NODE .DO	PUBLISHER
(8A1) R60 STATUS	XCBR.Pos	MUR60-1
43RV-W EMER EAST BUS V	DigEIGAPC4.Op	85A
43RV-E EMER WEST BUS V	DigEIGAPC5.Op	85A

(BC8A1-1) BC60-1 GE C60 — SBP, 1PBA, 1PBB, 79 RREC, 25 RSYN, 50BF RBRF, 86BF CSWI, CRITICAL FAILURE
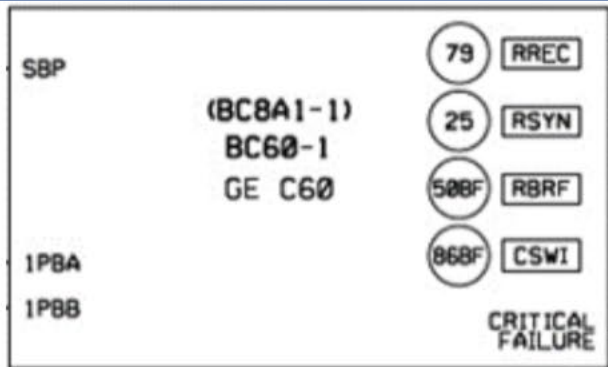
SMV IN	LOGICAL NODE	PUBLISHER
(R925) 10C2 CURRENT Ph A,B,C,N	TCTR.AmpSv	MU10C2-12
LN12 345KV VOLTAGE Ph A,B,C,N	TVTR.VolSv	MU10C2-11
GEN6 345KV VOLTAGE Ph A,B,C,N	TVTR.VolSv	MU10C2-12

GOOSE OUT	LOGICAL NODE	SUBSCRIBER
(R925) 10C2 OPEN COMMAND	CSWI.OpOpN	MU10C2-11
(R925) 10C2 CLOSE COMMAND	CSWI.OpCls	MU10C2-11
(MOD926) 10C2-1 OPEN COMMAND	CSWI.OpOpN	MU10C2-12
(MOD926) 10C2-1 CLOSE COMMAND	CSWI.OpCls	MU10C2-12
(MOD927) 10C2-2 OPEN COMMAND	CSWI.OpOpN	MU10C2-12
(MOD927) 10C2-2 CLOSE COMMAND	CSWI.OpCls	MU10C2-12
(R925) 10C2 RECLOSE	RREC.OpCls	MU10C2-11
(R925) 10C2 BF TRIP/KEY DTT	RBRF.OpEx	MU10C1-11 MU10C1-12 MU10C2-12 MU10C3-11 MU10C3-12 MUG6-11 PR1-LN12
(R925) 10C2 BLOCK CLOSE	CSWI.BlkCls	BC10C1-1 BC10C3-1 MUG6-11

GOOSE IN	LOGICAL NODE	PUBLISHER
PR1-LN12 TRIP	PTRC.Op	PR1-LN12
PR1-SBG6 TRIP	PTRC.Op	PR1-SBG6
(R915) 10C1 BLOCK CLOSE	CSWI.BlkCls	BC10C1-1
(R935) 10C3 BLOCK CLOSE	CSWI.BlkCls	BC10C3-1
G6 LOCK OUT TRIP	CILO.EnaCls	PR1-SBG6
(R925) 10C2 STATUS Ph A,B,C	XCBR.Pos	MU10C2-11
(R925) 10C2 CB HEALTHY	XCBR..EEHEALTHY	MU10C2-11
(R925) 10C2 LOW GAS PRESSURE TRIP	SIMG.InsTr	MU10C2-11
(R925) 10C2 LOW GAS PRESSURE BLK	SIMG.InsBlk	MU10C2-11
(MOD926) 10C2-1 MOD STATUS	XSWI.Pos	MU10C2-12
(MOD927) 10C2-2 MOD STATUS	XSWI.Pos	MU10C2-12
LN12 DTT RECV	PSCH.St	PR1-LN12

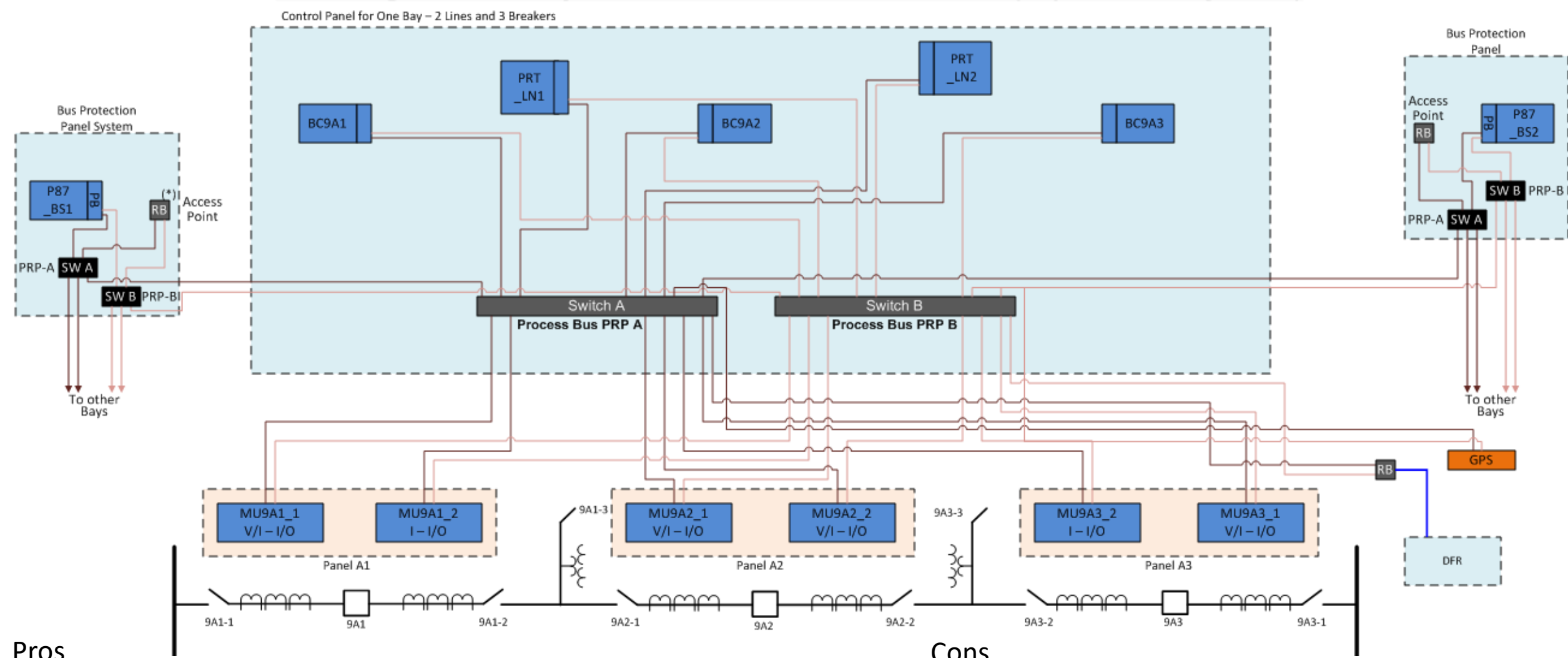# High Availability Seamless Redundancy (HSR)
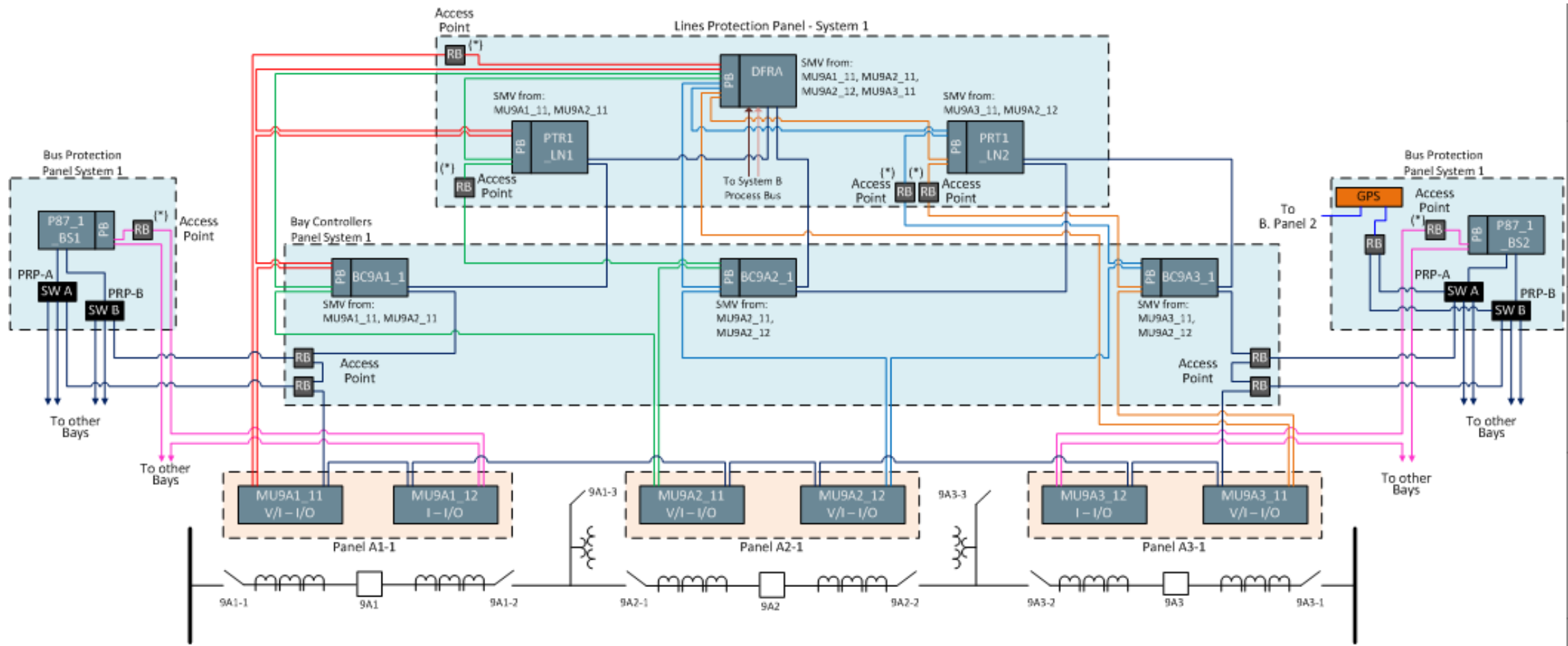
Pros
- No network configuration needed
- Network switches not required, network design less complex

Cons
- Limited Bandwidth
- Redbox required to connect testing equipment
- Addition of new IEDs, Monitoring devices is difficult

Parallel Redundancy Protocol (PRP)

Pros
- No network configuration needed
- Easily able to connect additional IEDs or plug in for testing

Cons
- Multiple network switches required

Time Synchronization

- Process bus requires accurate time synchronization of merging units.
  - Loss of time synchronization leads to undesirable protection system performance
- Can be relative:
  - individual merging units synchronized to a given source, e.g. 1 PPS, individual relays
  - Merging units synchronized to each other in network
- Can be absolute:
  - External time source to synchronize merging units
  - Required for synchrophasors
  - Better than 1 μsec accuracy

| Time synchronization class	Accuracy [μs] Synchronization error	Application
TL	> 10 000	Low time synchronization accuracy – miscellaneous
T0	10 000	Time tagging of events with an accuracy of 10 ms
T1	1 000	Time tagging of events with an accuracy of 1 ms
T2	100	Time tagging of zero crossings and of data for the distributed synchrocheck. Time tags to support point on wave switching
T3	25	Miscellaneous
T4	4	Time tagging of samples respectively synchronized sampling
T5	1	High precision time tagging of samples respectively high synchronized sampling

From IEC 61850-5

- IEEE 1588 -2008
- ~~C37.238-2011~~
- IEC 61850-9-3
- C37.238-2017

- SNTP

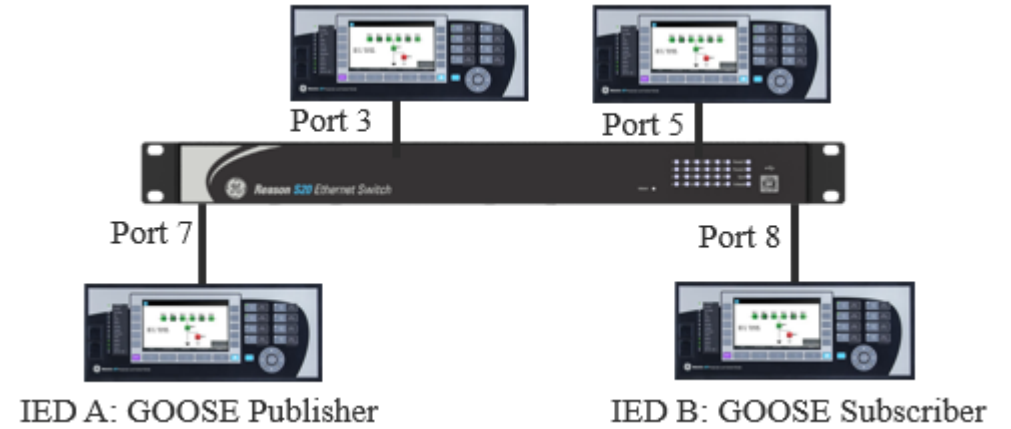| Time-Users (IEDs) Time-User Requirements	1588 PROFILES*		
	C37.238 -2017	61850 -9-3	1588 Annexes F & J.4
Steady State Time Inaccuracy < 1μs	✓	✓	X
Dynamic Time Inaccuracy to determine if time is adequate (e.g. during congestion, power recycling)	✓	X	X
IRIG-B support (per IEEE C37.118), (e.g. for 1588=>IRIG-B Protocol Converters)	✓	X	X
User-configurable clock-source IDs (e.g. for Timing-Island applications)	✓	X	X
…If none of the above needed	✓	✓	✓

Substation Architecture
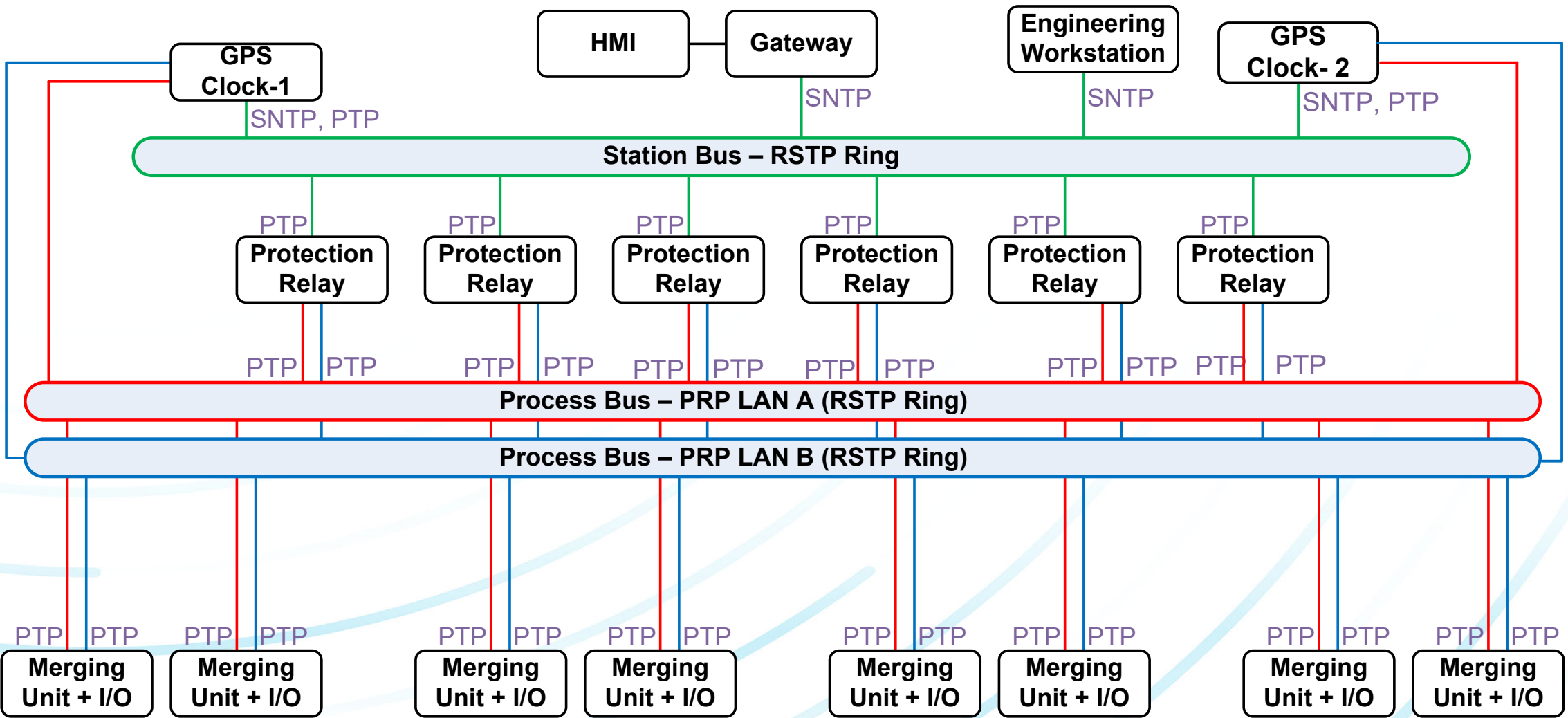
Network Traffic Segregation

Traffic Segregation is important
- MAC Filtering
- VLANs
- ACL

Port 3   Port 5

Port 7   Port 8

IED A: GOOSE Publisher   IED B: GOOSE Subscriber

Static MAC Table Configuration

			Port Members													
Delete	VLAN ID	MAC Address	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Delete	1	01-0C-CD-01-00-02	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐

			Port Members											
Delete	VLAN ID	VLAN Name	1	2	3	4	5	6	7	8	9	10	11	12
☐	1	default	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
☐	2	GOOSE2	☐	☐	☐	☐	☐	☐	☑	☑	☐	☐	☐	☐

SETTING	PARAMETER
TxGOOSE1 MODE	GOOSE
TxGOOSE1 GoCB name	L90_GoCB01
TxGOOSE1 GoID	L90_TxGOOSE1
TxGOOSE1 DatSet	TT6DataSet1
TxGOOSE1 DST MAC	01-0C-CD-01-00-02
TxGOOSE1 VLAN PRIORITY	4
TxGOOSE1 VLAN ID	2

IED A: GOOSE Publishing Parameters

Ingress Port	Policy / Bitmask	Frame Type	Action	Rate Limiter	Port Redirect
Port 8	Any	EType- 0x88b8	Deny	Disabled	Disabled

Thank You

Questions?