IEC 61850

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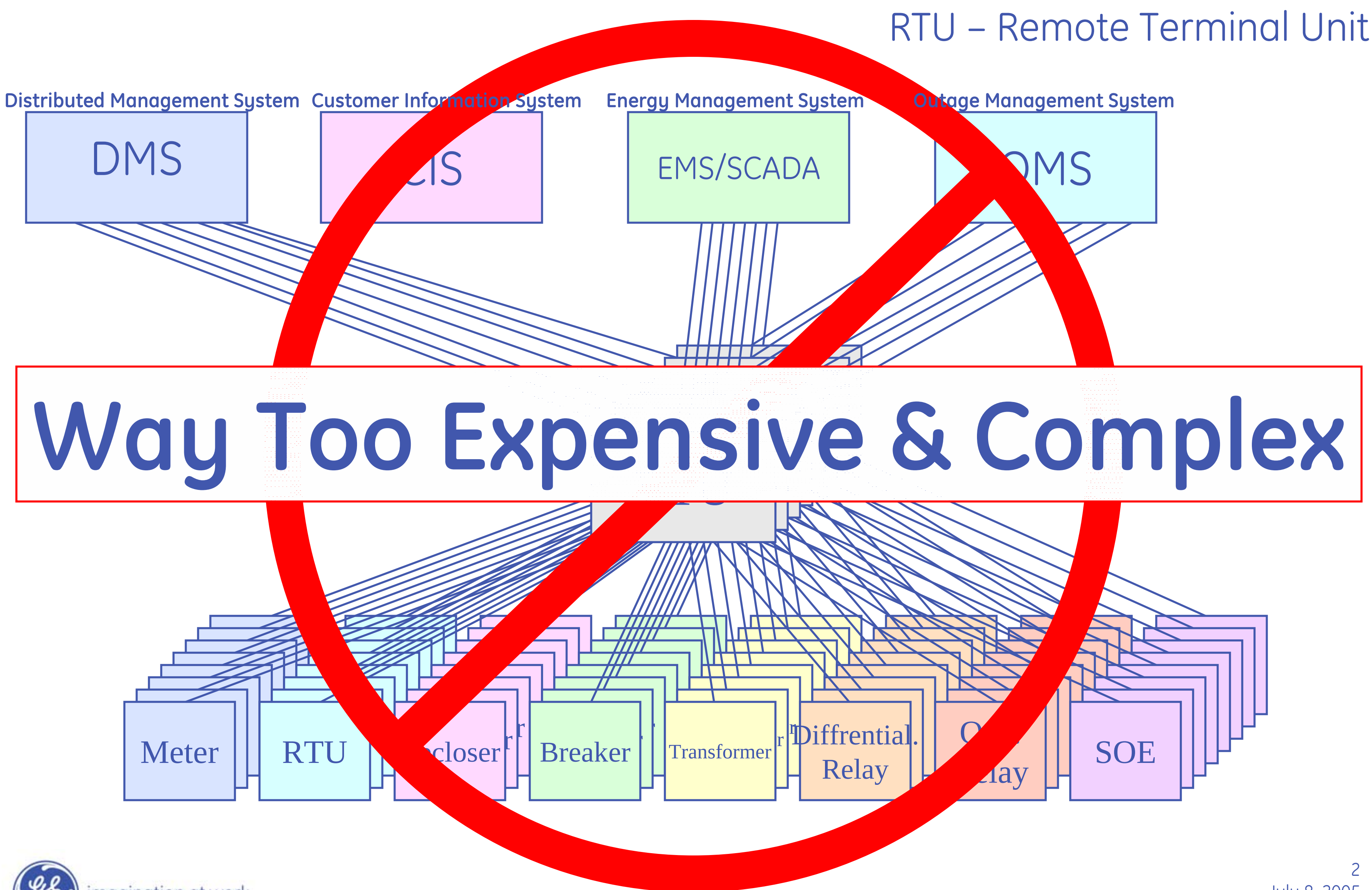
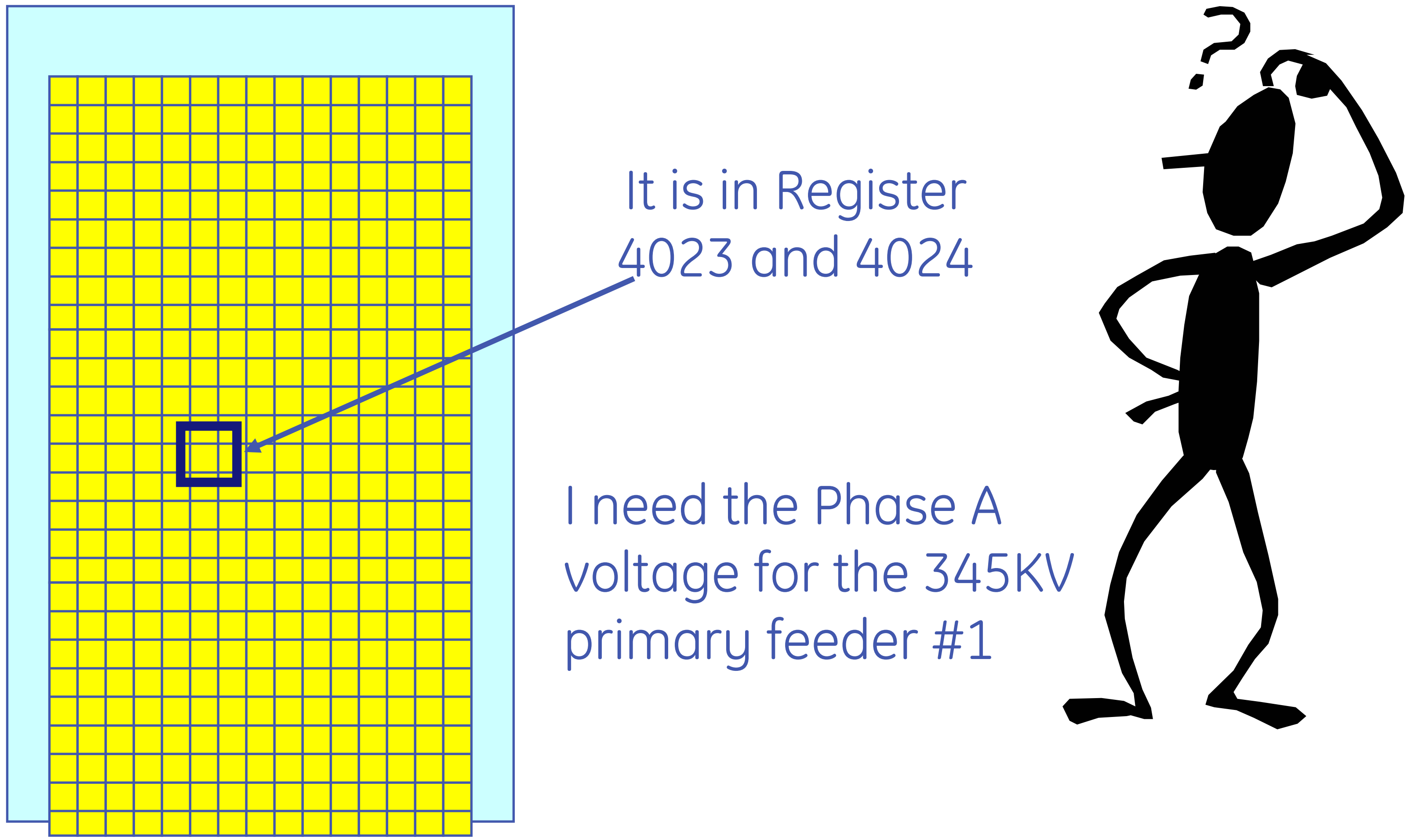
The Interoperability Dilemma



Typical Legacy Protocol Data Model



Traditional Register-based Protocols Carry Significant Configuration Costs & Complexity

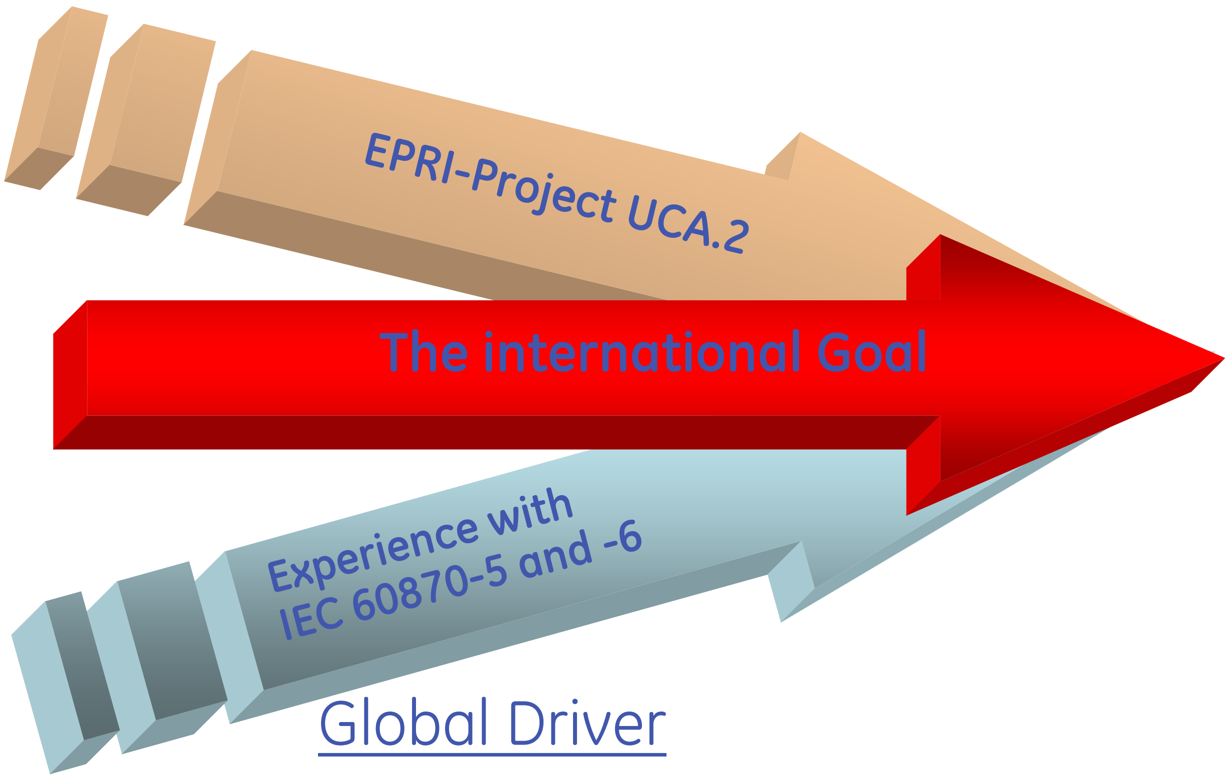
Standards Are Good!

"Standards are great. Everyone should have one."

– Bob Metcalfe,
Co-inventor of Ethernet

Fewer of the Right Standards are Better!!

Where We have Come From…



Communication Networks and Systems in Substations

IEC 61850

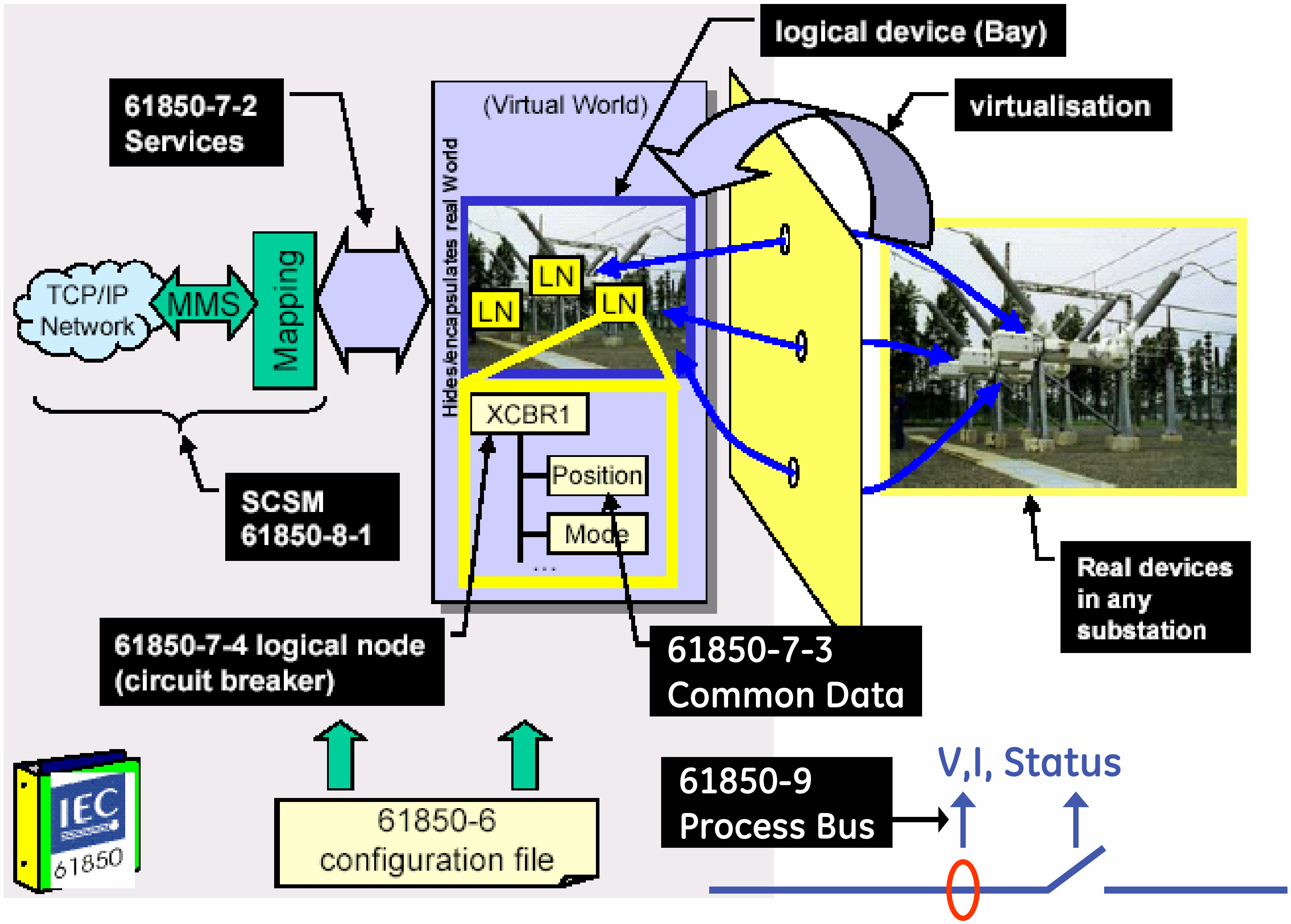
Global Driver

- Necessity to simplify & standardize Substation design, Construction, commissioning, operation and maintenance

Driven By

- Utilities through UCA & IEC standard committees

IEC 61850 Scope



61850 Addresses All Aspects of Substation Communication and Configuration

IEC61850 Modeling Approach

- Define the Semantics (meaning) of information

- Define the Syntax (structure) of information

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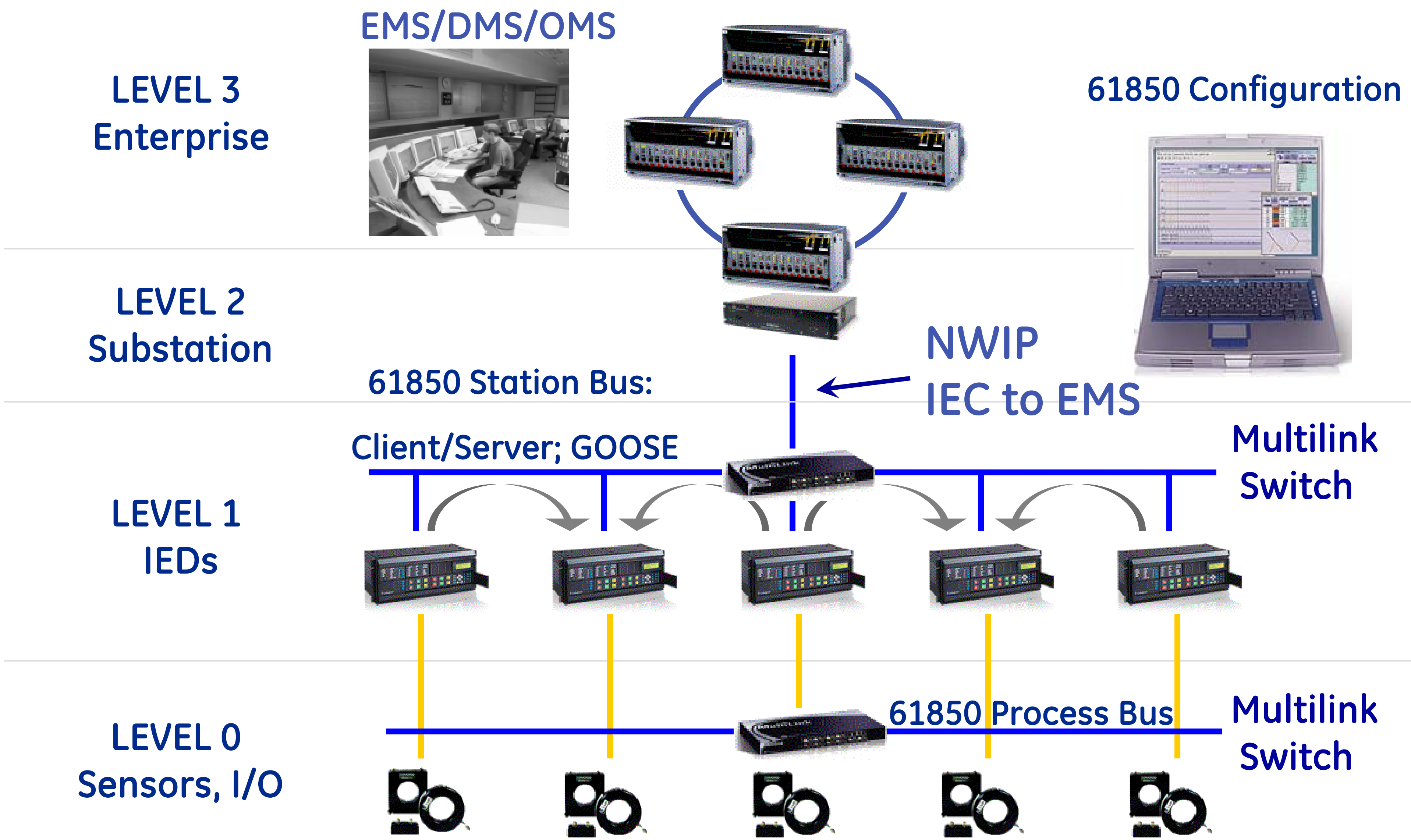
IEC 61850 & The Digital Substation



Some Terms

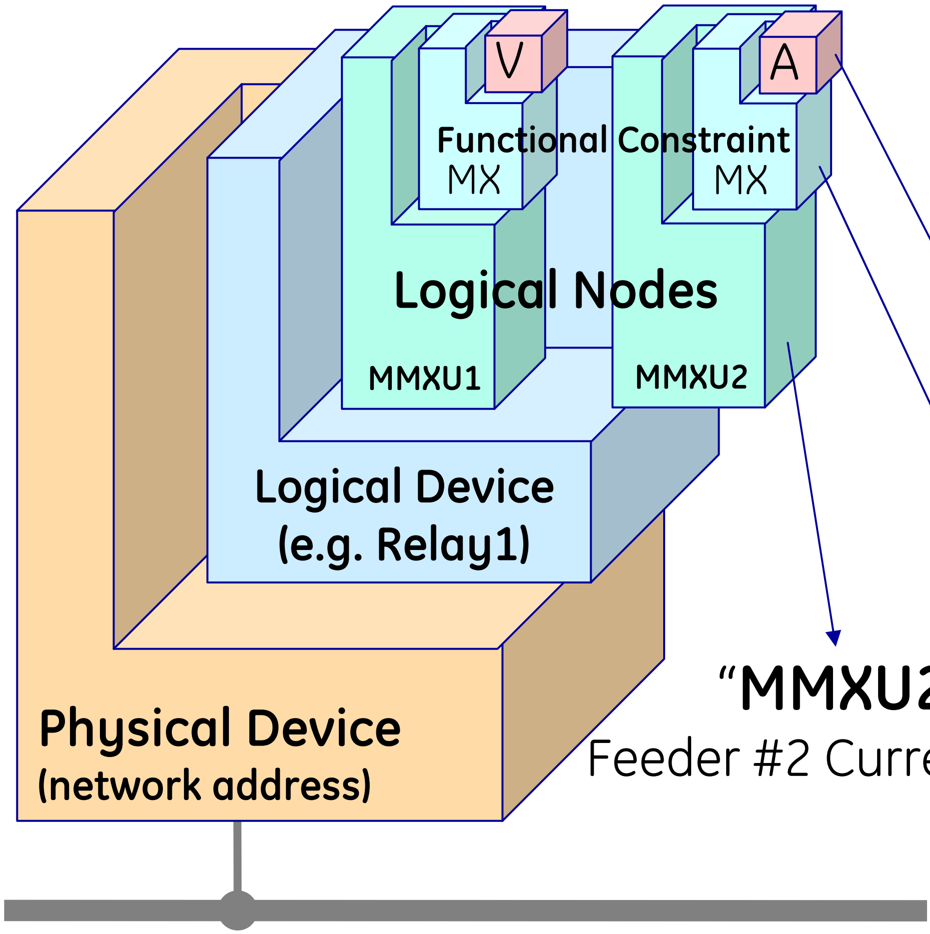
- Master Slave – a master controls slave access to the network (e.g. Modbus).
- Peer-to-peer – any entity may access the network equally
  - Client-Server – defines roles between 2 peers on a network.
  - Publisher-Subscriber – a one to many, connectionless communication architecture

IEC 61850 Standard

Part 1	Basic principles
Part 2	Glossary
Part 3	General Requirements
Part 4	System and project management
Part 5	Communication requirements
Part 6	Substation Automation System Configuration
Part 7	Basic Communication Structure (4 sections)
Part 8	Mapping to MMS and Ethernet
Part 9	Sampled Measured Values; Mapping to Ethernet
Part 10	Conformance testing

Structured Using Extensive Past Experience

Anatomy of an IEC61850 Object Names



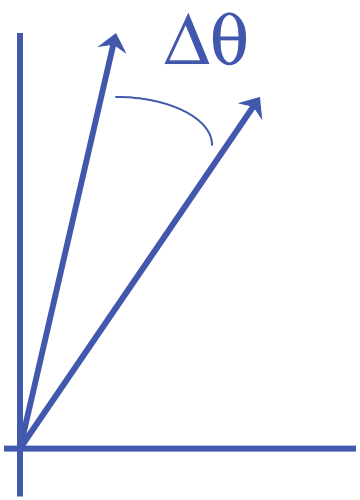
"**MMXU2MXA**" =
Feeder #2 Current Measurements

…Intuitive, Standardized Object Naming

Logical Node

Definition: A Logical Node is an abstract model of a real device or function

XCBR
Circuit Breaker



RSYN
Protection Related

YPTR
Transformer

Logical Node Groups

- **L** System LN (2)
- **P** Protection (28)
- **R** Protection related (10)
- **C** Control (5)
- **G** Generic (3)
- **I** Interfacing and archiving (4)
- **A** Automatic control (4)
- **M** Metering and measurement (8)
- **S** Sensor and monitoring (4)
- **X** Switchgear (2)
- **T** Instrument transformers (2)
- **Y** Power transformers (4)
- **Z** Further power system equipment (15)

Examples:

PDIF: Differential protection

RBRF: Breaker failure

XCBR: Circuit breaker

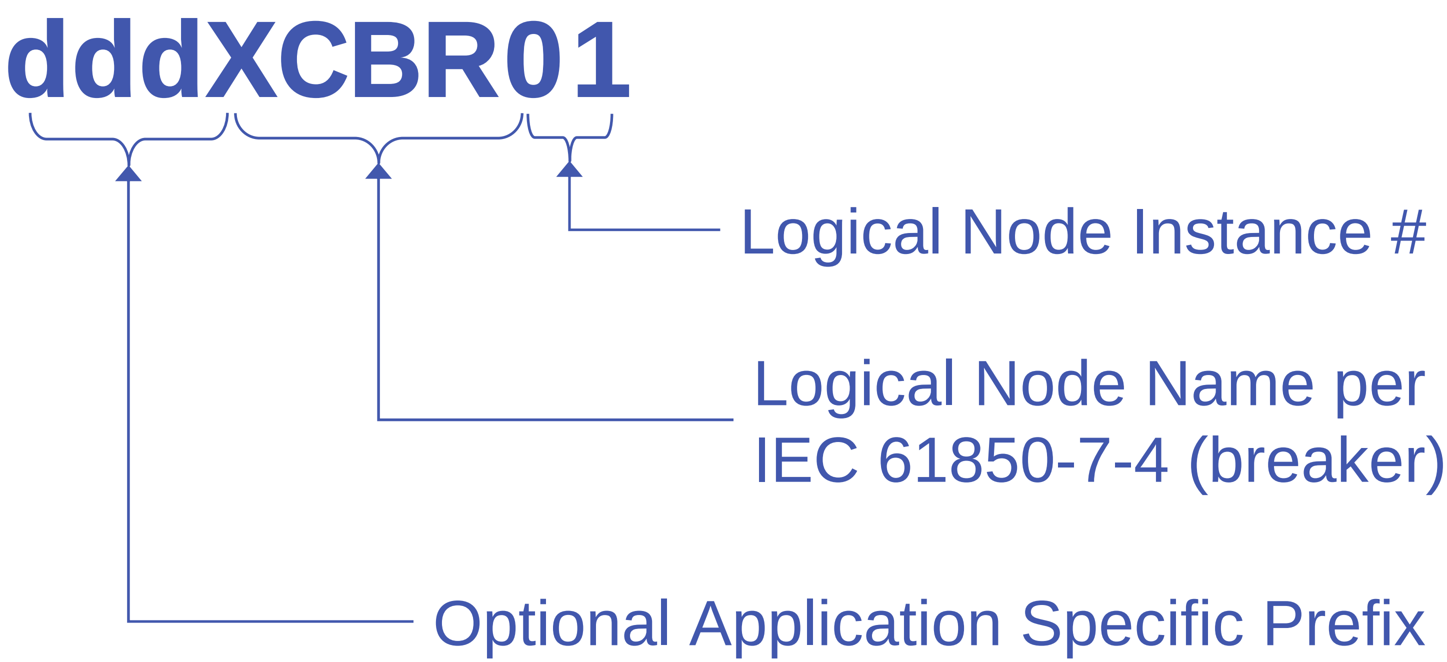
CSWI: Switch controller

MMXU: Measurement unit

YPTR: Power transformer

Logical Node Names

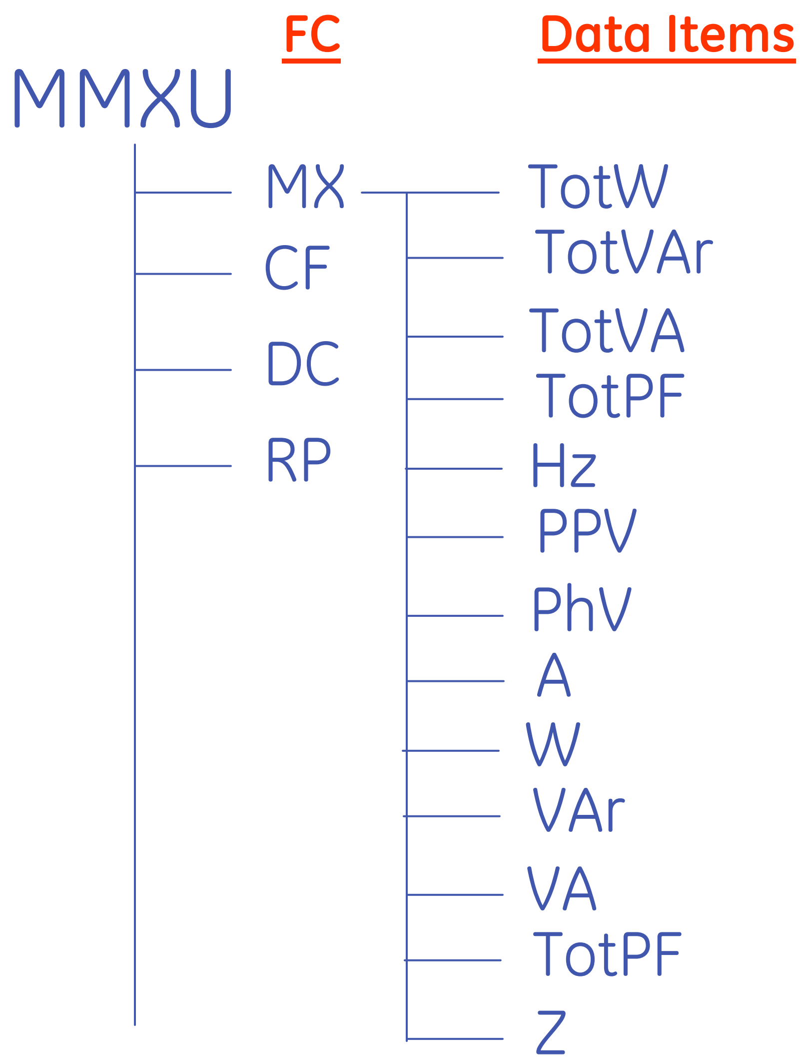
Example for Breaker:



Simple, Structured Naming

Logical Node Tree…

"Tree" View of Measurement Unit

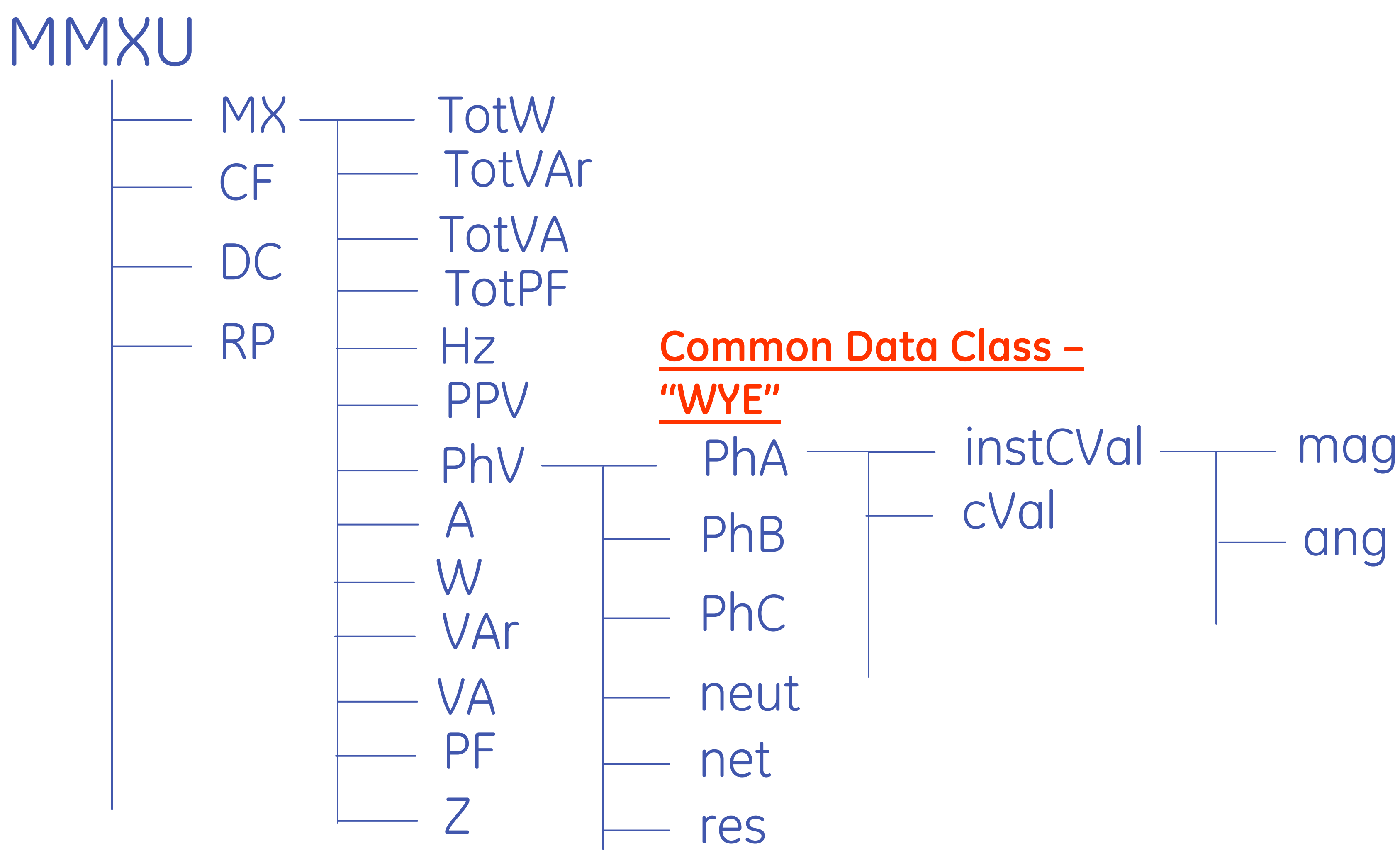


Functional Constraints…

FC Name	Description
ST	Status Information
MX	Measurands (analog values)
CO	Control
SP	Set point
SV	Substitution
CF	Configuration
DC	Description
SG	Setting Group
SE	Setting Group Editable
EX	Extended Definition (naming – read only)
BR	Buffered Report
RP	Unbuffered Report
LG	Logging
GO	GOOSE Control
GS	GSSE Control
MS	Multicast Sampled Value (9-2)
US	Unicast Sampled Value (9-1)
XX	Used as wild card in ACSI

Logical Node Tree…

"Tree" View of Measurement Unit



Common Data Classes (CDC)

Defines structure for common types that are used to describe data objects.

CDC are complex objects built on predefined simple base types organized into functional constraints (FC)

Examples:

- Single point status (SPS) – on/off
- Double point status (DPS) – on/off/transient
- 3 phase measurement (WYE)

Logical Node → FC → Data Items → Common Data Class

Common Data Classes Table

Name	Description
SPS	Single Point Status
DPS	Double Point Status
INS	Integer Status
ACT	Protection Activation
ACD	Directional Protection Activation Info.
SEC	Security Violation Counting
BCR	Binary Counter Reading
MV	Measured Value
CMV	Complex Measured Value
SAV	Sampled Value
WYE	Phase to ground measured values for 3-phase system
DEL	Phase to phase measured values for 3-phase system
SEQ	Sequence
HMV	Harmonic value
HWYE	Harmonic value for WYE
HDEL	Harmonic value for DEL

Common Data Classes Table…

Name	Description
SPC	Controllable Single Point
DPC	Controllable Double Point
INC	Controllable Integer Status
BSC	Binary Controlled Step Position Info.
ISC	Integer Controlled Step Position Info.
APC	Controllable Analogue Set Point Info.
SPG	Single Point Setting
ING	Integer Status Setting
ASG	Analogue Setting
CURVE	Setting Curve
DPL	Device Name Plate
LPL	Logical Node Name Plate
CSD	Curve Shape Description

Common Data Class Example

Single Point Status (SPS)

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				From IEC61850-7-3	
		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

Attribute Name per clause 8 of IEC61850-7-3 — Type — Functional Constraint — Trigger Options — Range of Values — Mandatory/ Optional

Makes Maximum Re-Use of Data Attributes

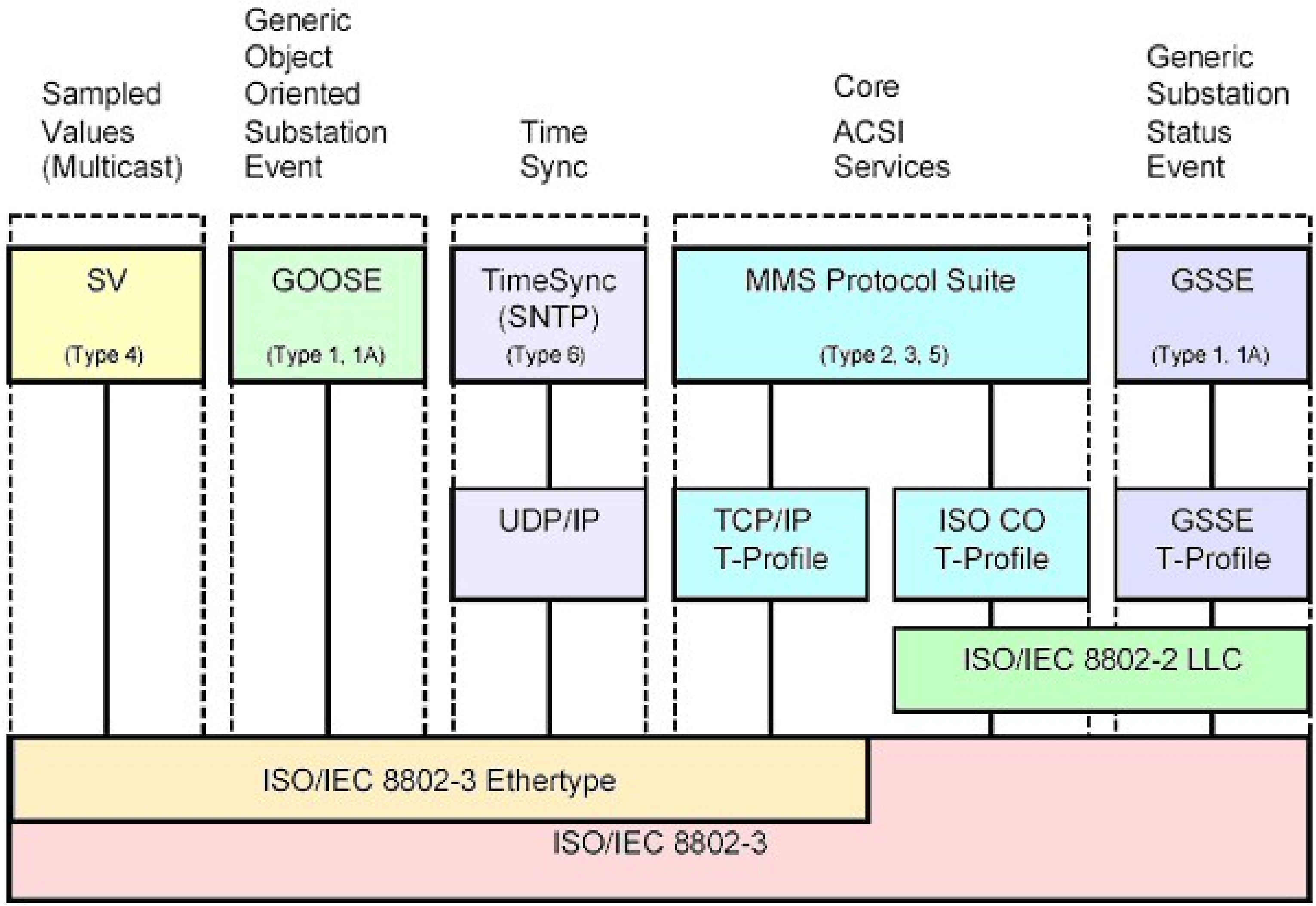
Logical Node Example

Measurement Unit (MMXU) illustration as per Standard

From IEC61850-7-4

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 Profiles



Ethernet – The Foundation of All Future Substation Communications

Abstract **C**ommunications **S**ervice **I**nterface (**ACSI**)

- Defines a set of Abstract Services to manipulate and access data objects
- Defines a base set of data types for describing objects
- Defines the behavior of an Object

Abstraction Makes 61850 “Future Proof “!

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Examples

Abstract Communications Service Interface

- GetDataValues – Read
- SetDataValues – Write
- GetDataDirectory – Read list of object names

Self-Description Differentiates 61850
From All Other Existing Protocols

Grant County PUD Experience

Substation Modernization Pilot did 2 substations

- DNP3.0 over TCP and UDP
- UCA2.0 (subset of IEC61850)

Time to get DNP3 relay configured and communicating: ~ 2-3 days

Time to get UCA/IEC61850 relay configured and communicating: 2-3 hours

Minimization of Configuration
is a Major Customer Requirement

UR Implemented 61850 Services

Abstract Communications Service Interface

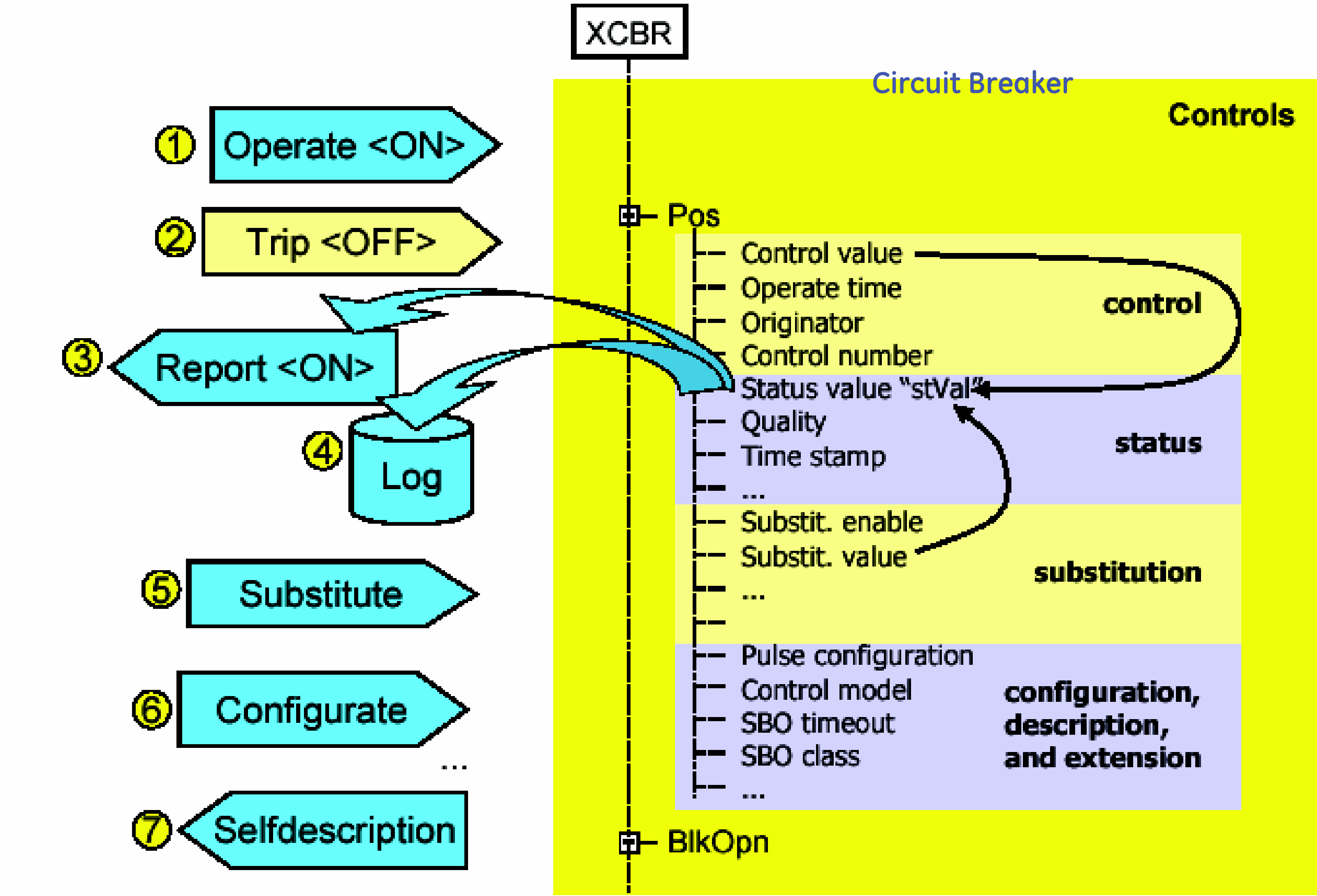
Buffered report control
Unbuffered report control
GOOSE
GSSE (UCA GOOSE)
ServerDirectory
Time (SNTP)
GetFile / GetFileAttributes
Associate
GetDataSetValue
SetDataSetValues
GetDataSetDirectory
GOOSE
GSSE (Generic Substation Status Event)
SBO

Abort
Release
LogicalDeviceDirectory
LogicalNodeDirectory
GetAllDataValues
GetDataValues
SetDataValues
GetDataDirectory
GetDataDefinition
Report (buffered & unbuffered)
- data-change (dchg)

GetBRCBValues
SetBRCBValues

Highlighted Services Enable Self-Description

IEC 61850 Station Bus Transactions



Simplified! Making It All Work Together

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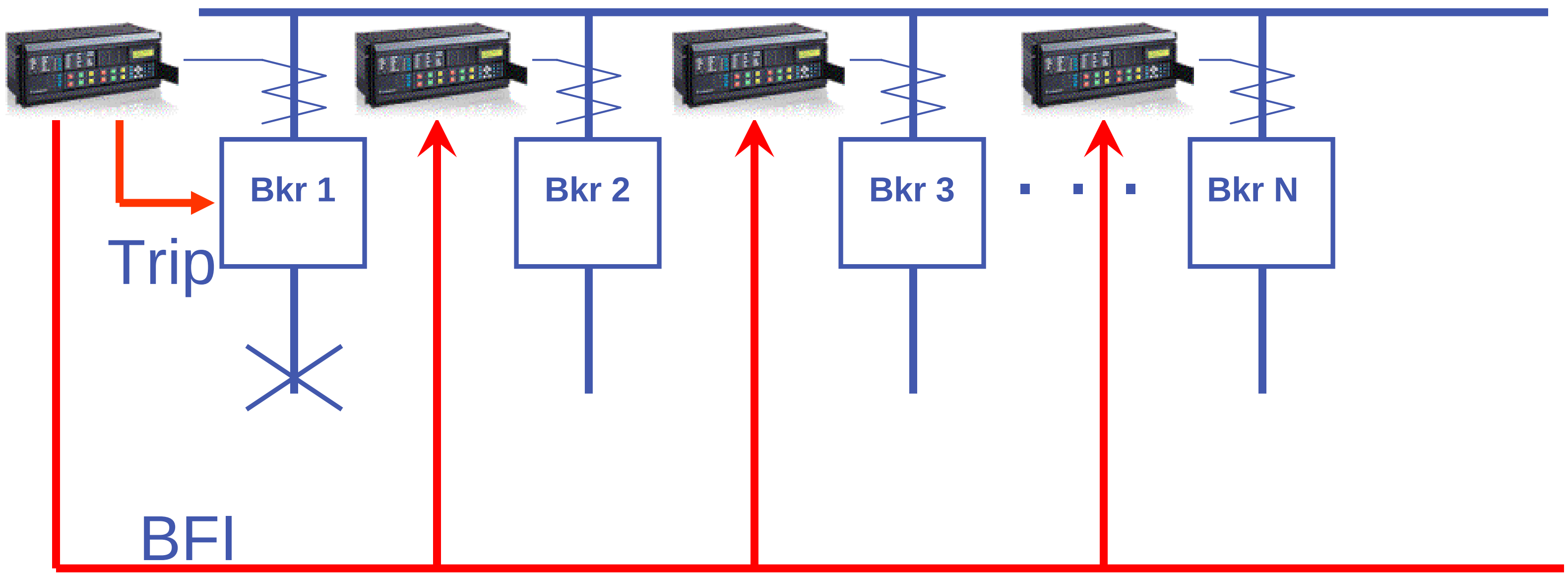
Relay to Relay Communications - Functional Requirements



Requirements:

- Reliable Message delivery from one to multiple other devices - simultaneously
- Fast Delivery (< 4ms)

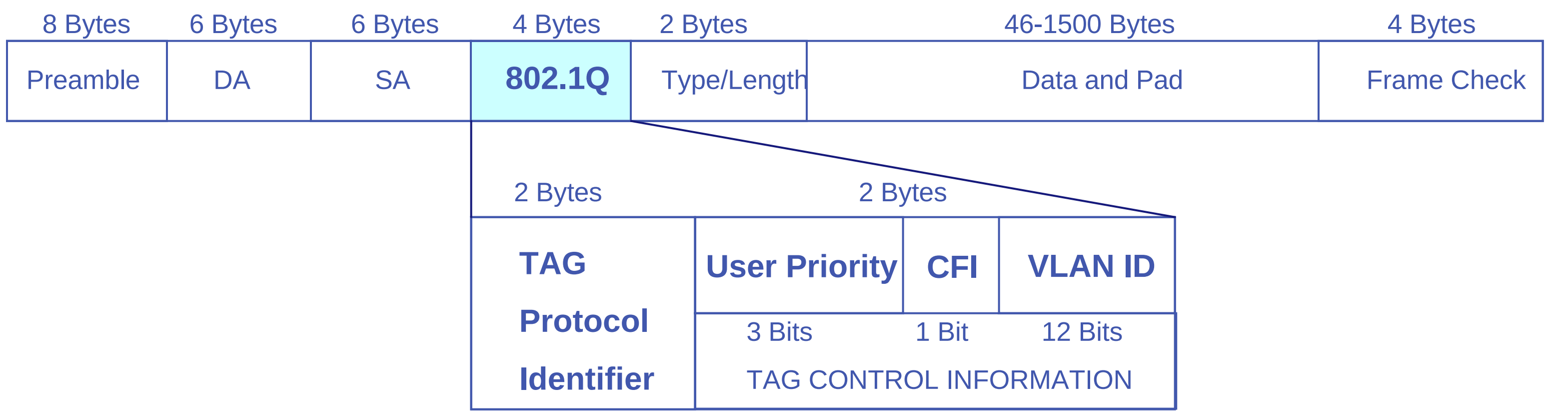
Generic Object Oriented Substation Event (GOOSE)

- **User Dataset sent in Multicast message**
- **Primarily Local but Wide Area possible (and operating!)**
- **Bridgeable but *not* routable**
- **Sent on change of state**
- **Sent periodically for self-test**
- **Reliability by message repeat**

GOOSE Header:
• Multicast Address • Name • Time Until Next GOOSE • Etc.
User-Defined Dataset • Status Information • **Analog Values** • Data Quality • Time

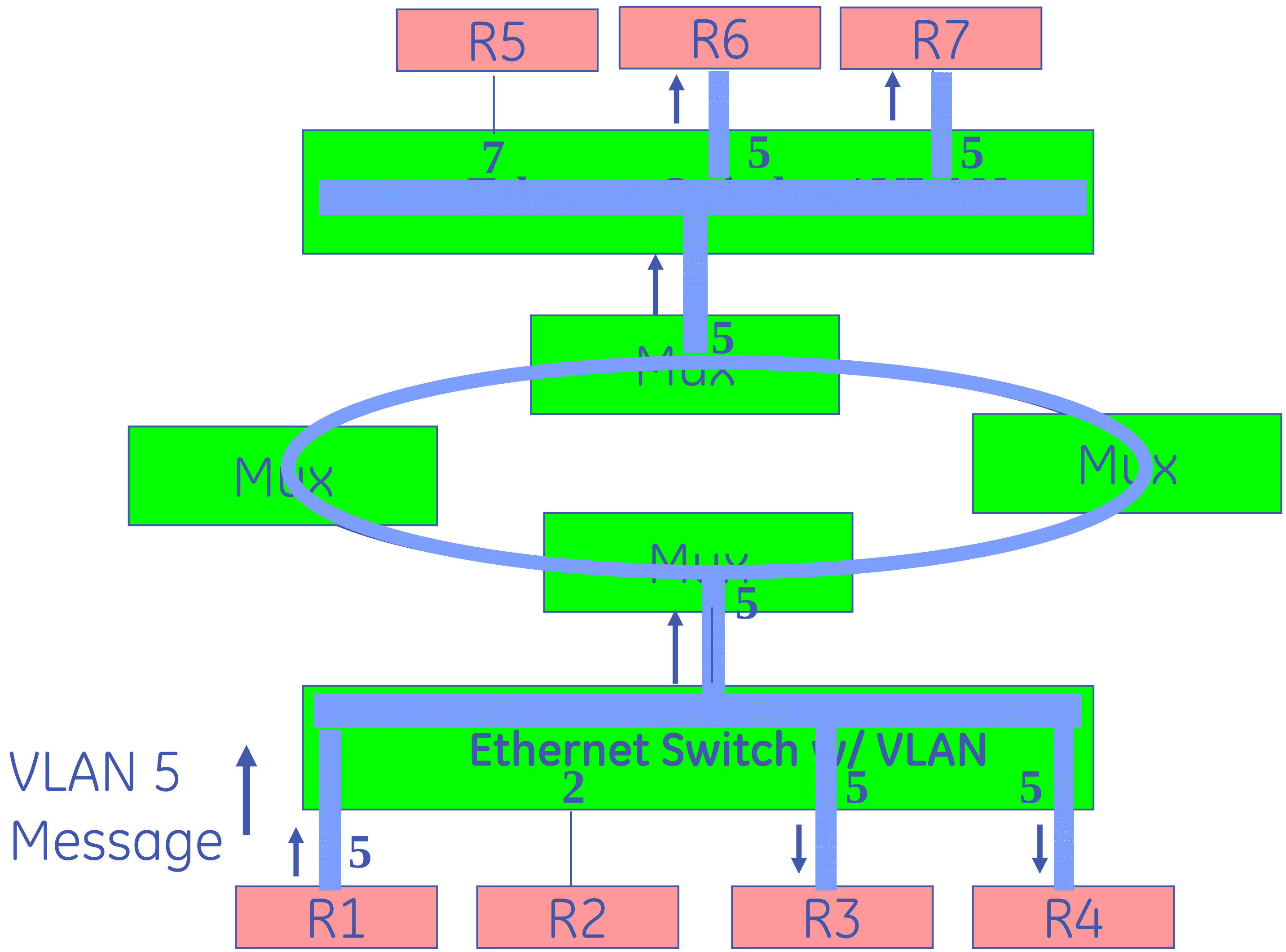
Fast, Reliable, Interoperable
Device to Device Communication

VLAN Packet Structure



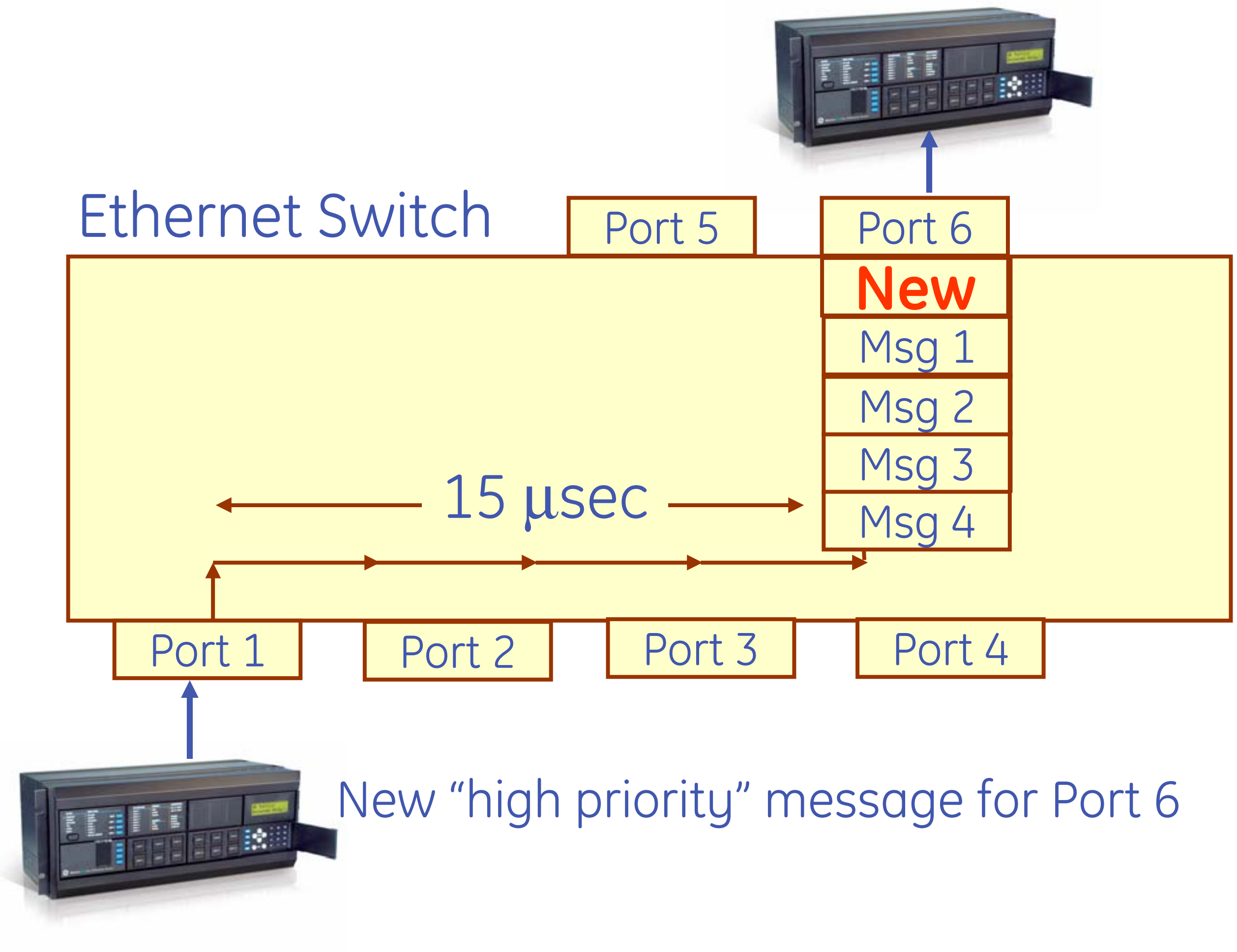
- 4 bytes added to the Ethernet frame
- Tag Protocol Identifier (TPID) set to 8100 hex …identifies an 802.1Q message type
- 12 bits used for VLAN Identifier
- 3 bits used for Priority – 8 levels

Ethernet VLAN



Ethernet Priority

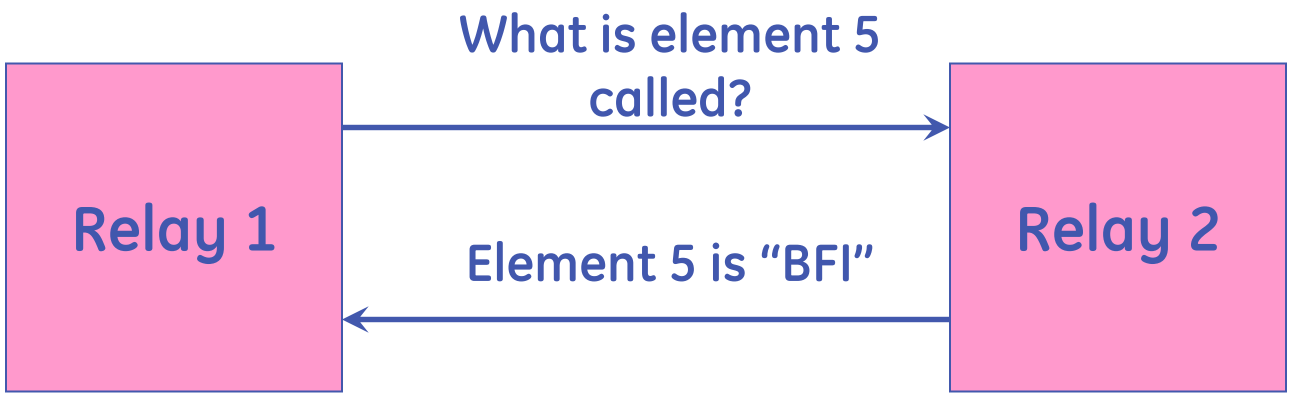
- IEC GOOSE implements the 802.1Q priority setting
- Priority messages moved to the priority queues
- Implemented in many Ethernet switched



Additional Services

GOOSE

- GetGoReference – Retrieve the Data Name for a specific dataset member reference
- GetGOOSEElementNumber– Retrieve the position of a member in a Dataset



Services Enable Virtual Wire Check

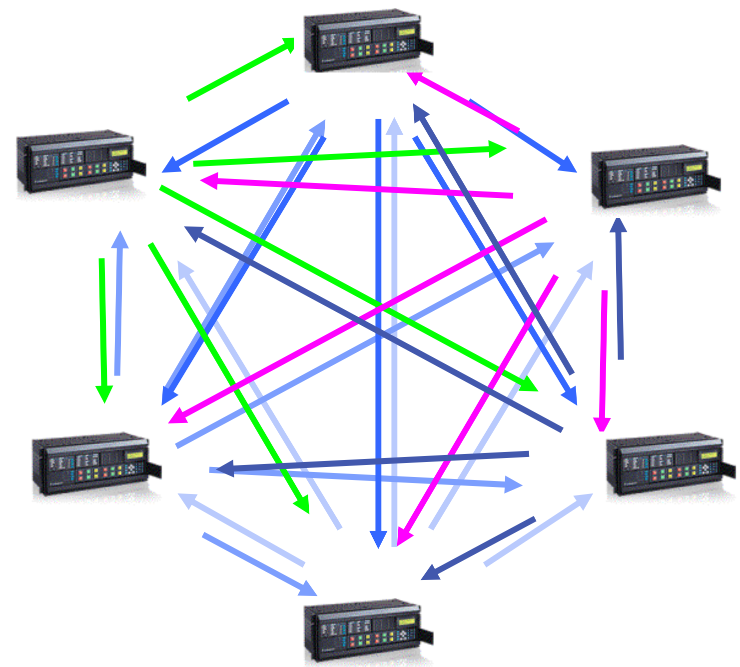
Goose Impact: LAN Interlocking and Tripping

Ideal for interlocking

- Multicasting eliminates multiple connections between devices
- Simplified logic program replaces complex one

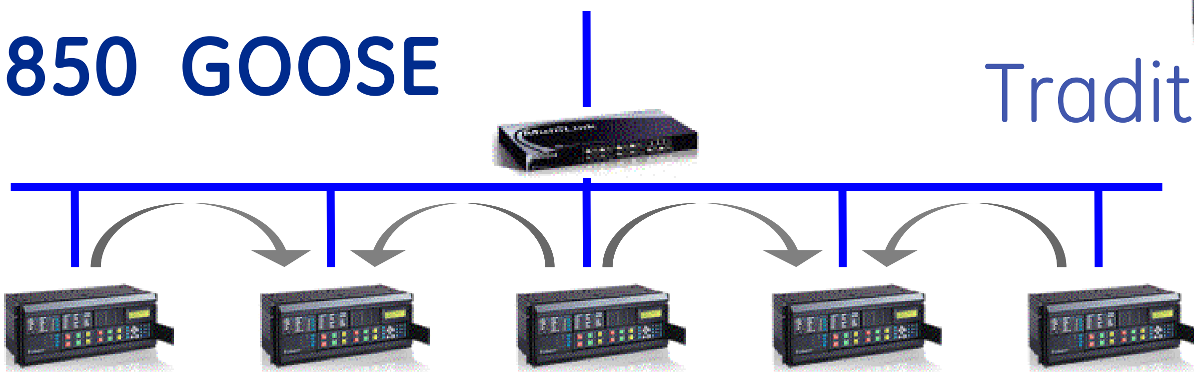
Inter-zone Protective Relaying

- Improved Performance
- Complete Solution Using UR

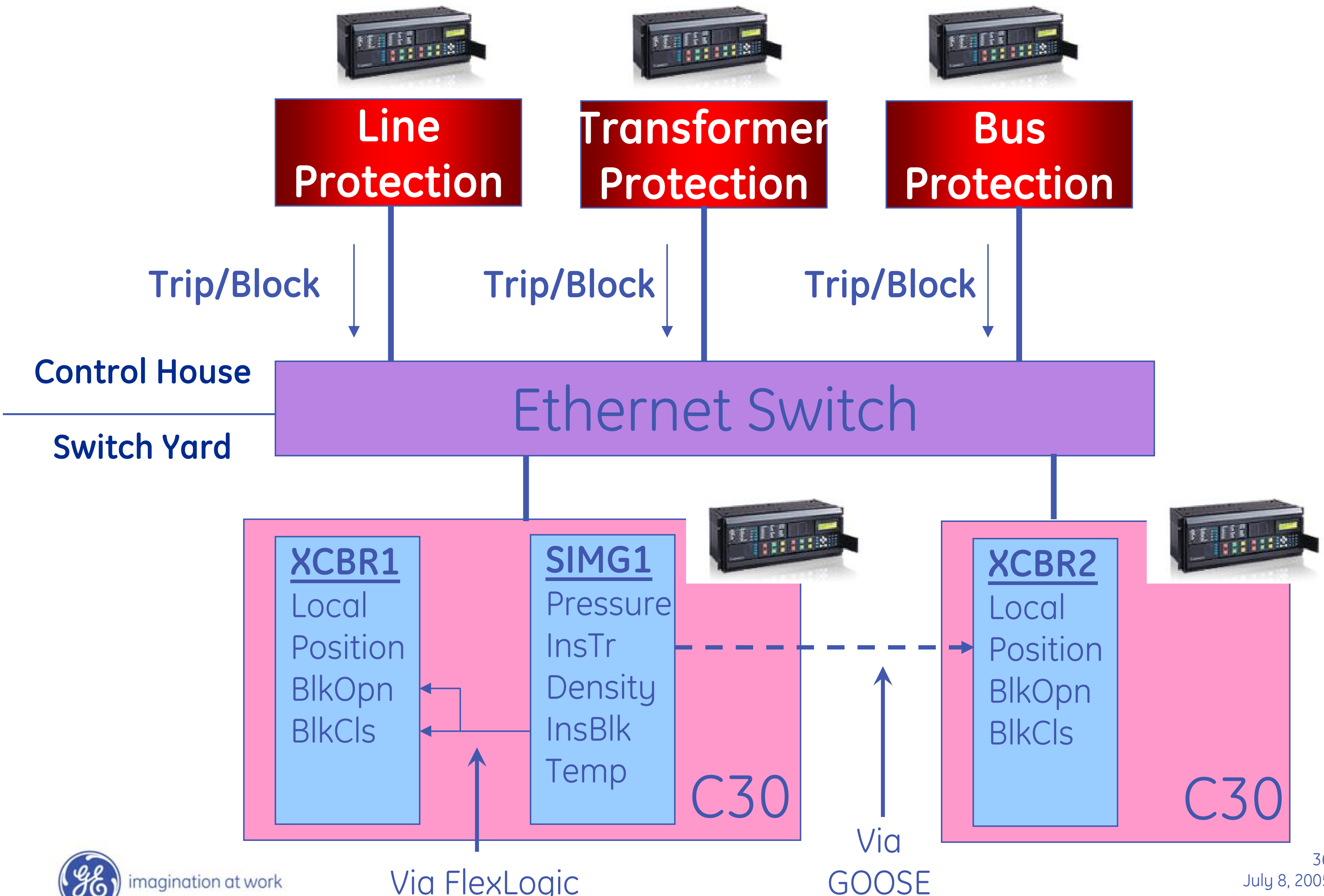


Traditional Wiring

61850 GOOSE



Remote Breaker Control

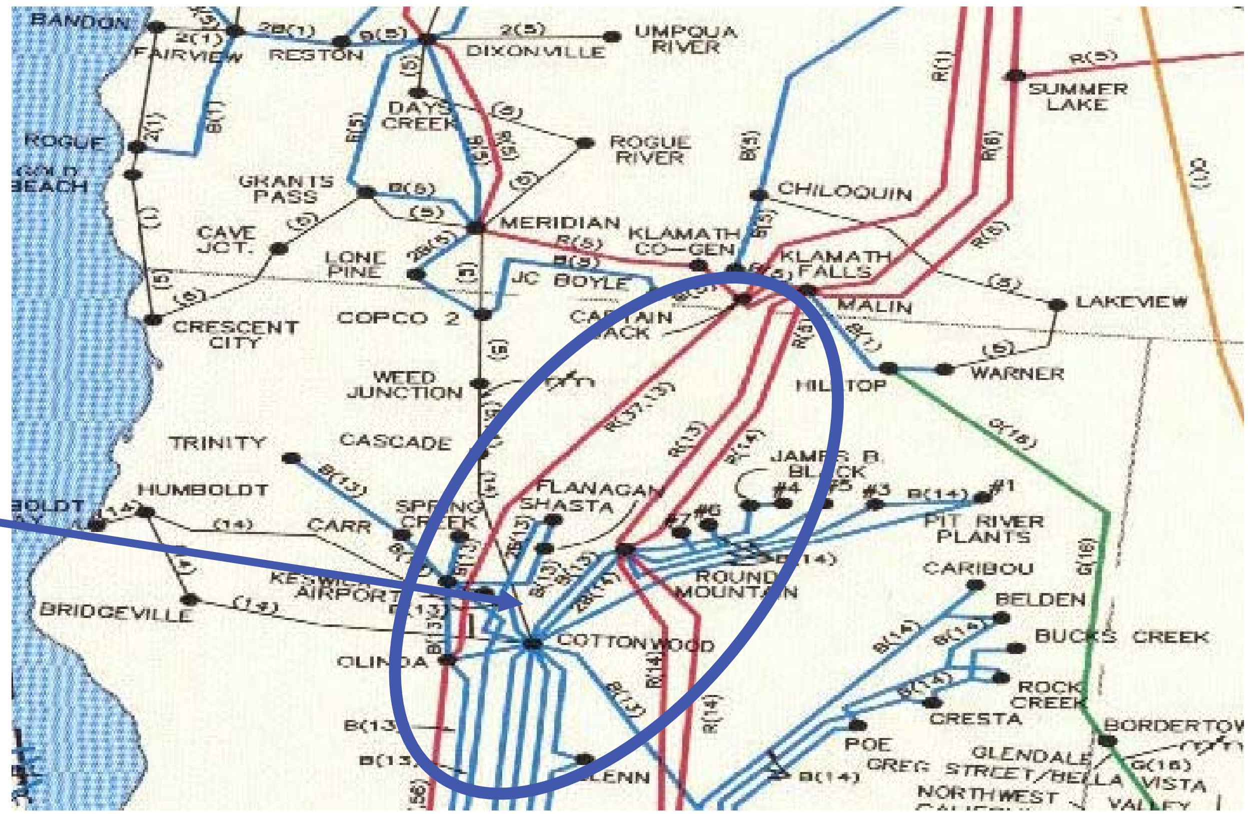


Palo Verde Nuclear Power Plant

The Need For Mitigation?

- **Palo Verde Unit 2 Was Up-Rated by 121MW.**
- **This Impacted the safe Operation of the California Oregon Intertie**
- **Loss of any 2 Palo Verde Units under full load requires mitigation**

Malin / Round Mountain #1
Malin / Round Mountain #2
Captain Jack / Olinda

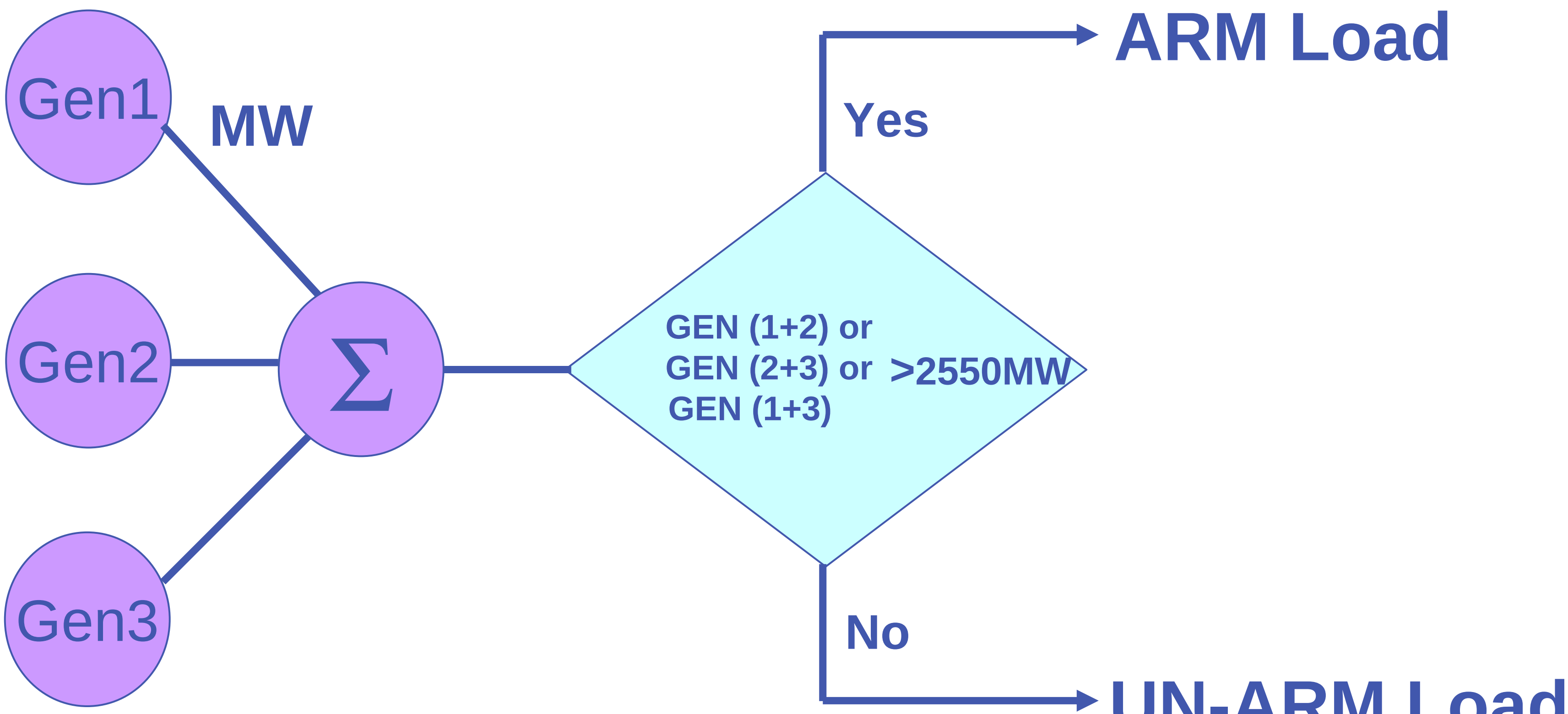


Design Parameters

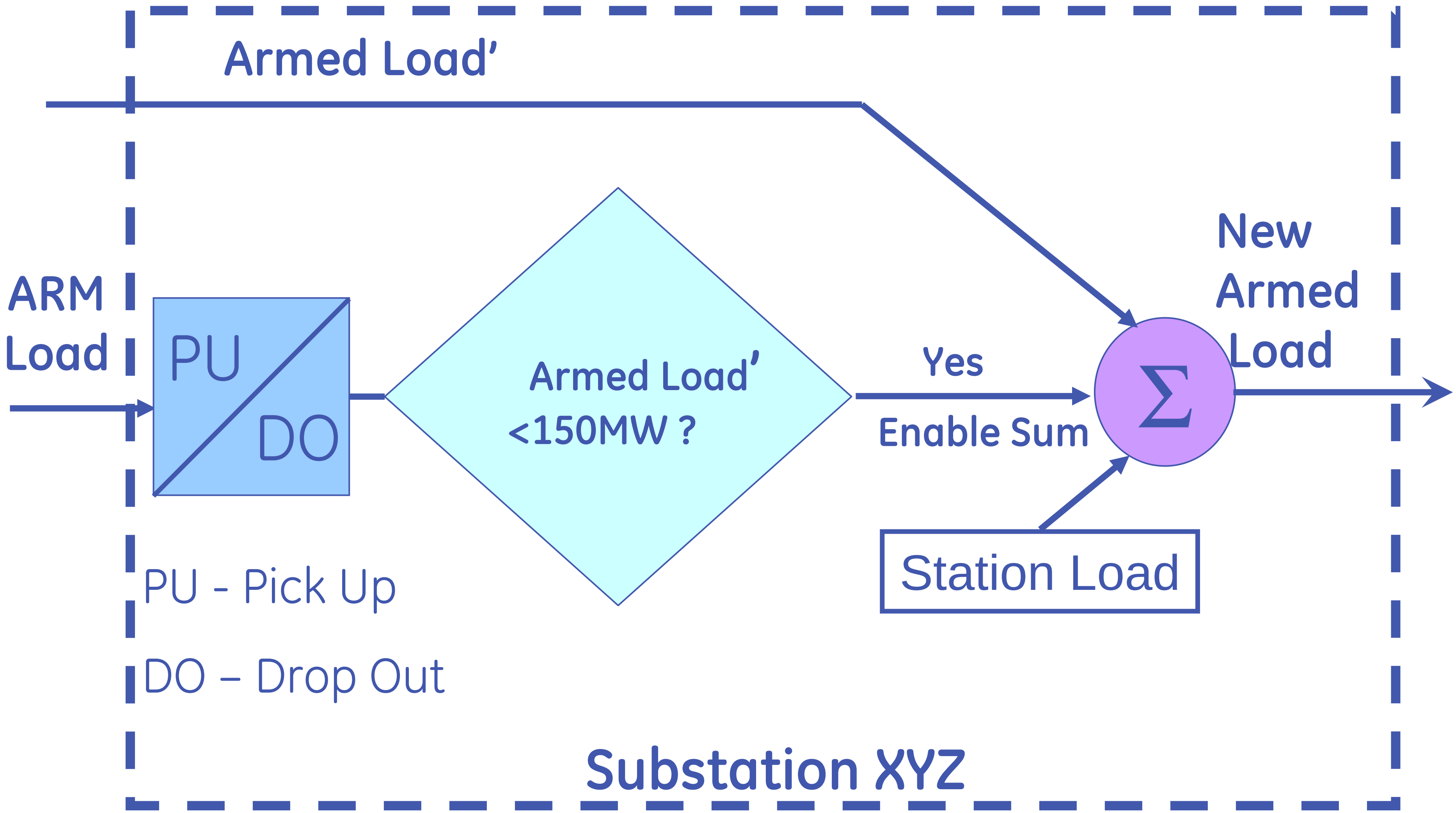
- Shed 120 MW of load upon loss of any 2 units
  - If the sum of any 2 generators exceeds 2574 MW
  - If the 2 units trip within 5 minutes of one another
- Load must be shed within 1 second
- No automatic restoration (Supervisory only)
- Redundant with no common mode failures

And the Solution Is…

Arming Logic

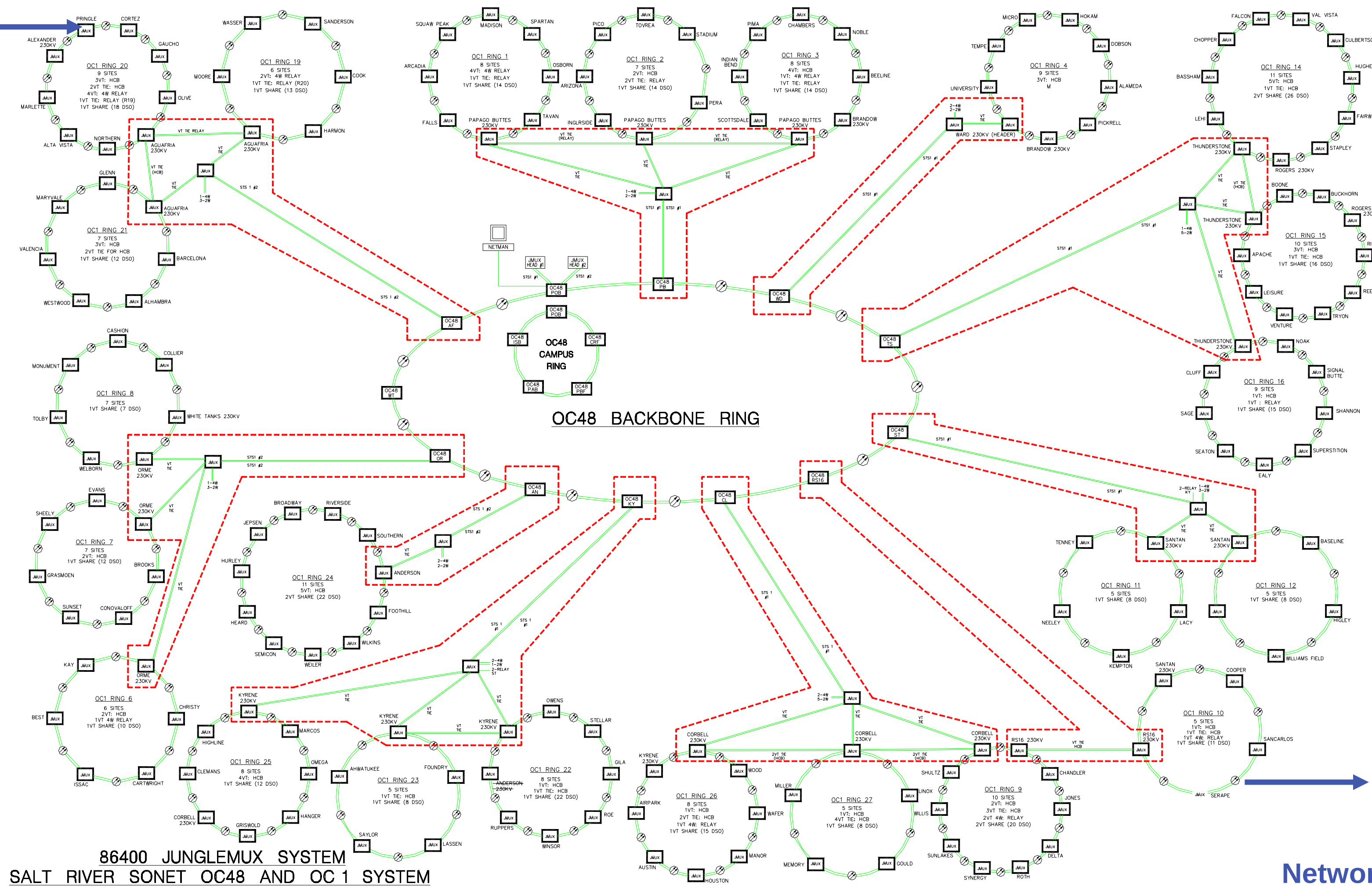


Substation Dynamic Load Aggregation



SRP SONET System

Data In



Data Out

Network elements:
17 OC-48 Nodes
218 MUX Nodes

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Palo Verde ***Round Trip*** Communication Timing

Multicast through fiber

Site	Ethernet	G.703 (Direct I/O)
Gaucho	14ms	11ms
Alameda	14ms	20ms
Indian Bend	14ms	33ms
Buckhorn	14ms	46ms

61850 Provides New Solutions to Complex Power System Issues

SCL – Substation Configuration Language

- Description language for communication in electrical substations related to the IEDs

- XML based language that allows a formal description of
  - Substation automation system and the switchyard and the relation between them
  - IED configuration

SCL File Types

SSD: System Specification Description.

description of the entire system.

SCD: Substation Configuration Description.

description of a single substation.

ICD: IED Capability Description.

description of items supported by an IED.

CID: Configured IED Description.

configuration for a specific IED.

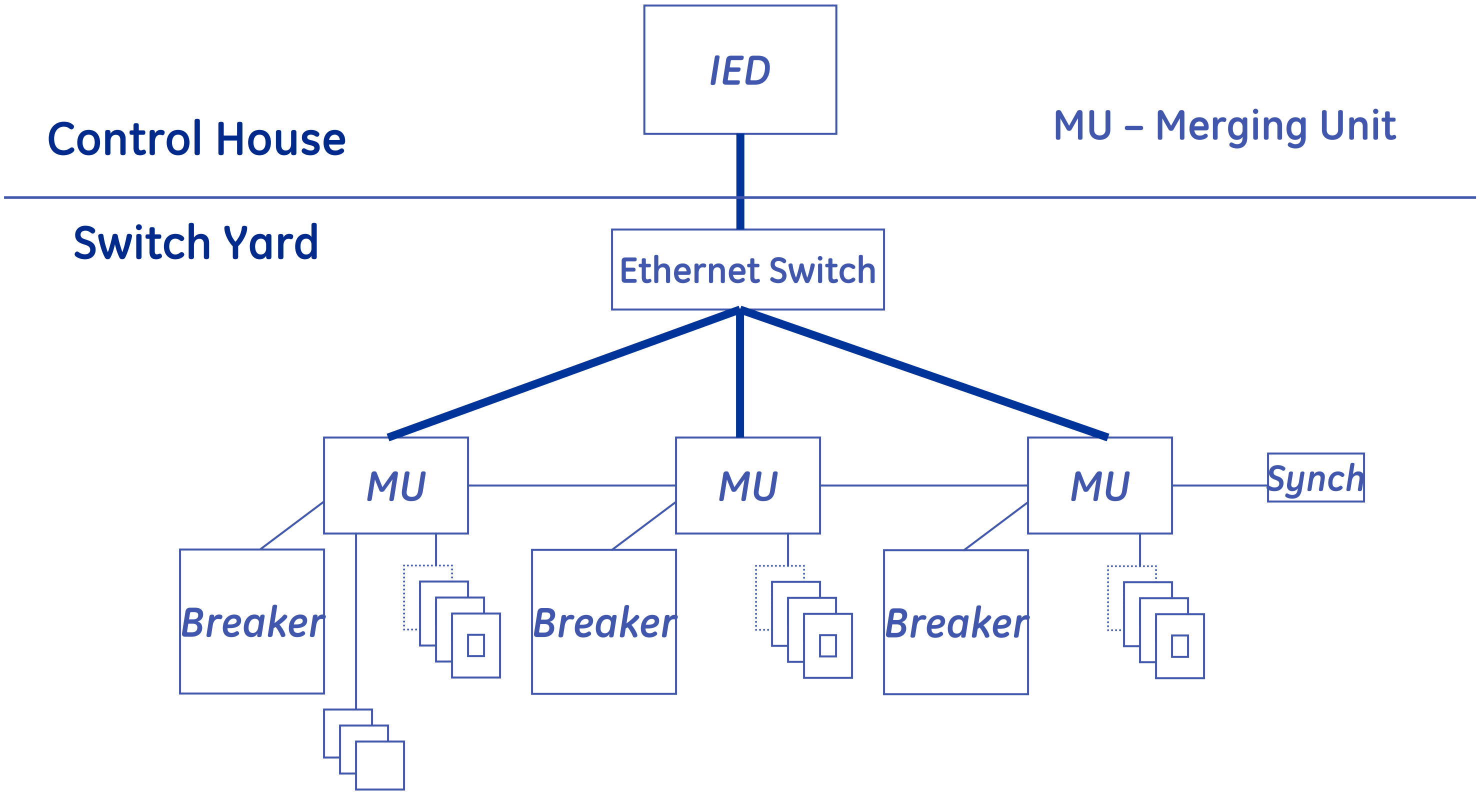
Intended to Address *ALL* Aspects of
Power System Configuration

Example of SCL

```
  <?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 ldInst="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>
```

Easily Readable & Logical Format

61850 Process Bus

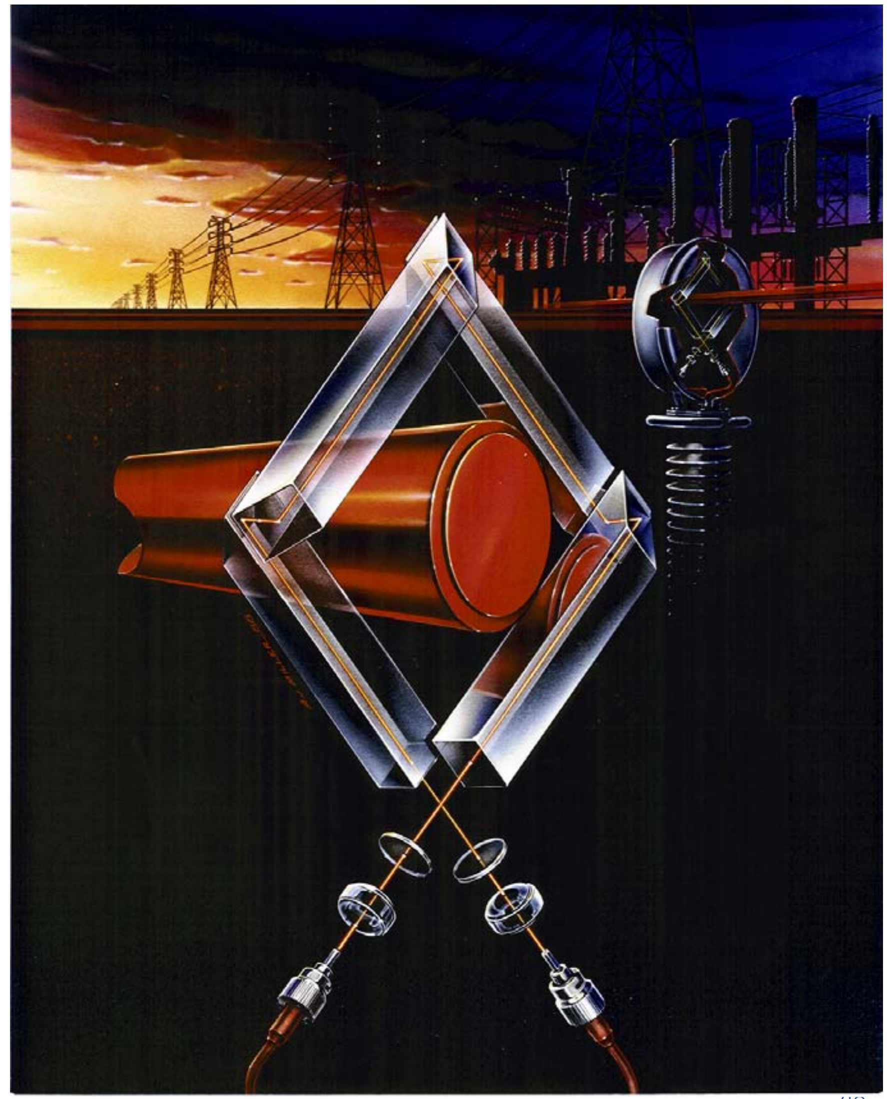


61850 Process Bus

- Synchronous sampling
- Reduction of Point-Point wiring
- Minimization of configuration time
- Elimination of copper wire

Why a Process Bus?

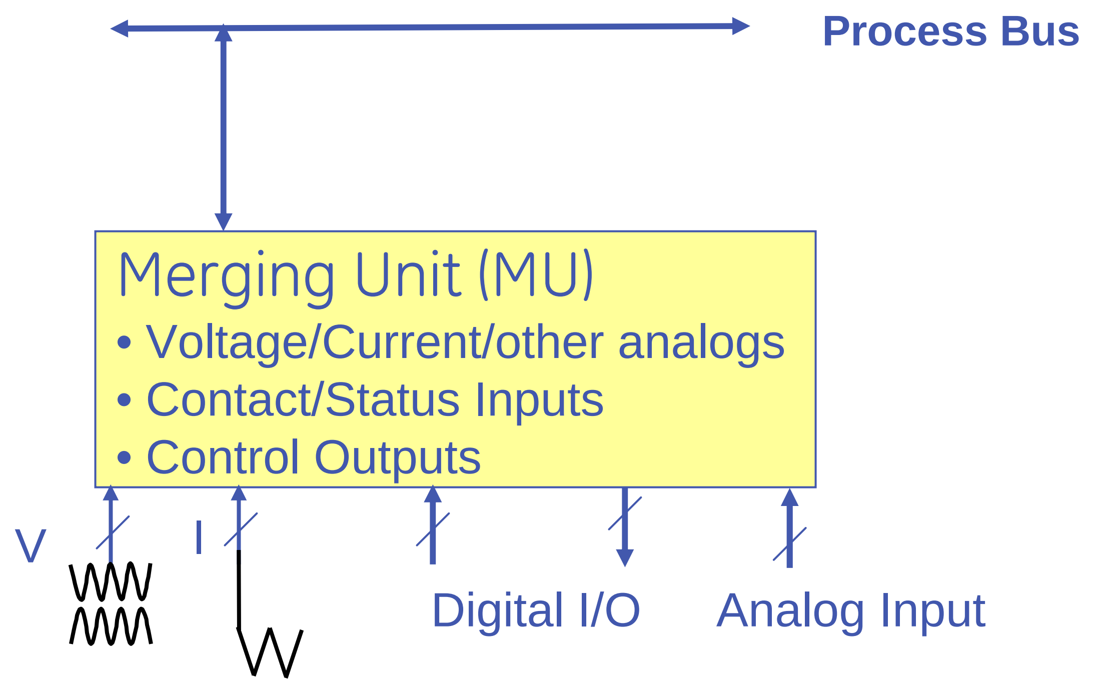
- Need for an interface with optical voltage and current transformers
- Desire to eliminate copper wiring in the field
- Desire to minimize configuration time
- Desire to optimize re-configuration



Process Bus Interface with Conventional CTs and PTs

<u>Implementation Needs:</u>

- Time Sync through the network
- Voltage, Current, Input, Output processing
- Redundant 100BaseFx fiber communication ports
- Redundant Power Supply



Implementation Agreement

IMPLEMENTATION GUIDELINE FOR DIGITAL INTERFACE TO INSTRUMENT TRANSFORMERS USING IEC 61850-9-2

Purpose: to define a subset of IEC 61850-9-2 that shall support a fast market introduction of this standard.

Process Bus Dataset & Common Data Class

LN LLN0

PhsMeas1
IATCTR.Amp
IBTCTR.Amp
ICTCTR.Amp
Inm/cTCTR.Amp

UATVTR.Vol
UBTVTR.Vol
UCTVTR.Vol
Unm/cTVTR.Vol

MSVCB01
DatSet = PhsMeas1
MsvID = MSVCB01
SmpRate = 80
NoASDU = 1

Attribute Name	Attribute Type
instMag.i	INT32
q	Quality
sVC	ScaledValueConfig

sVC.offset = 0
sVC.scaleFactor = 0.001

sVC.offset = 0
sVC.scaleFactor = 0.01

Defined per the Implementation Agreement

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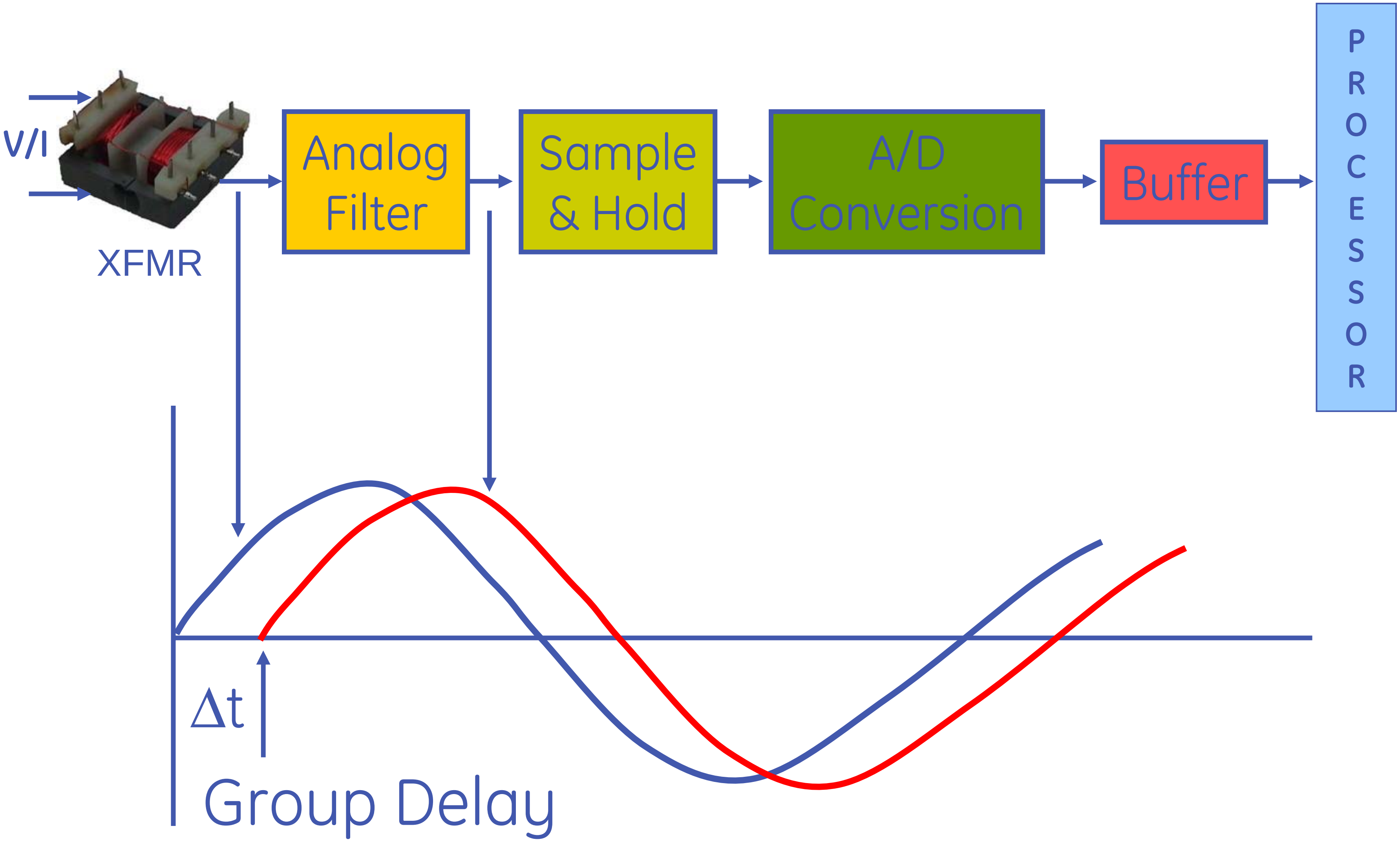
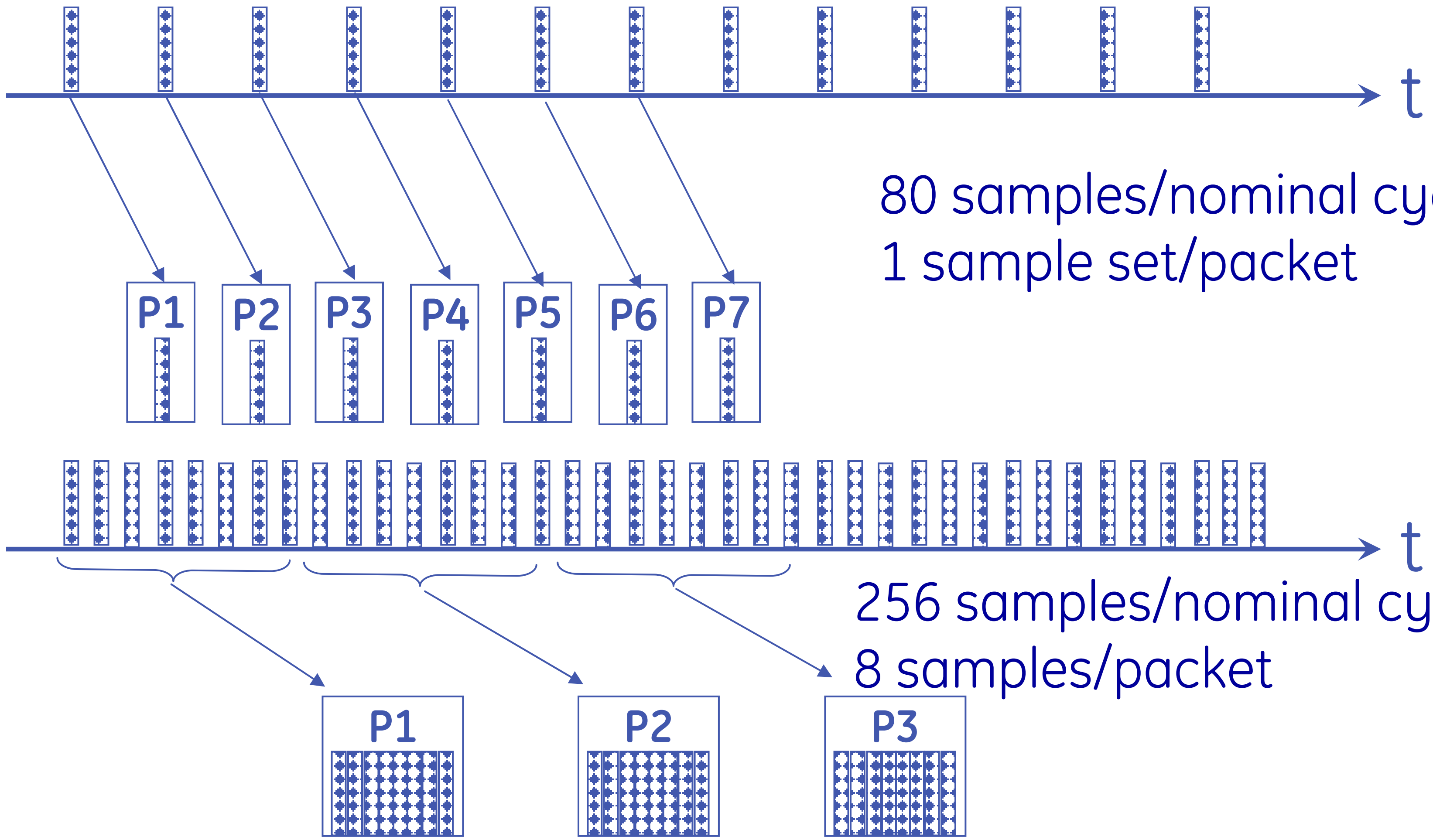
Analog Filter Compensation



Provides Compensated Sample Time Stamping

Sample Sets: Single or Aggregated

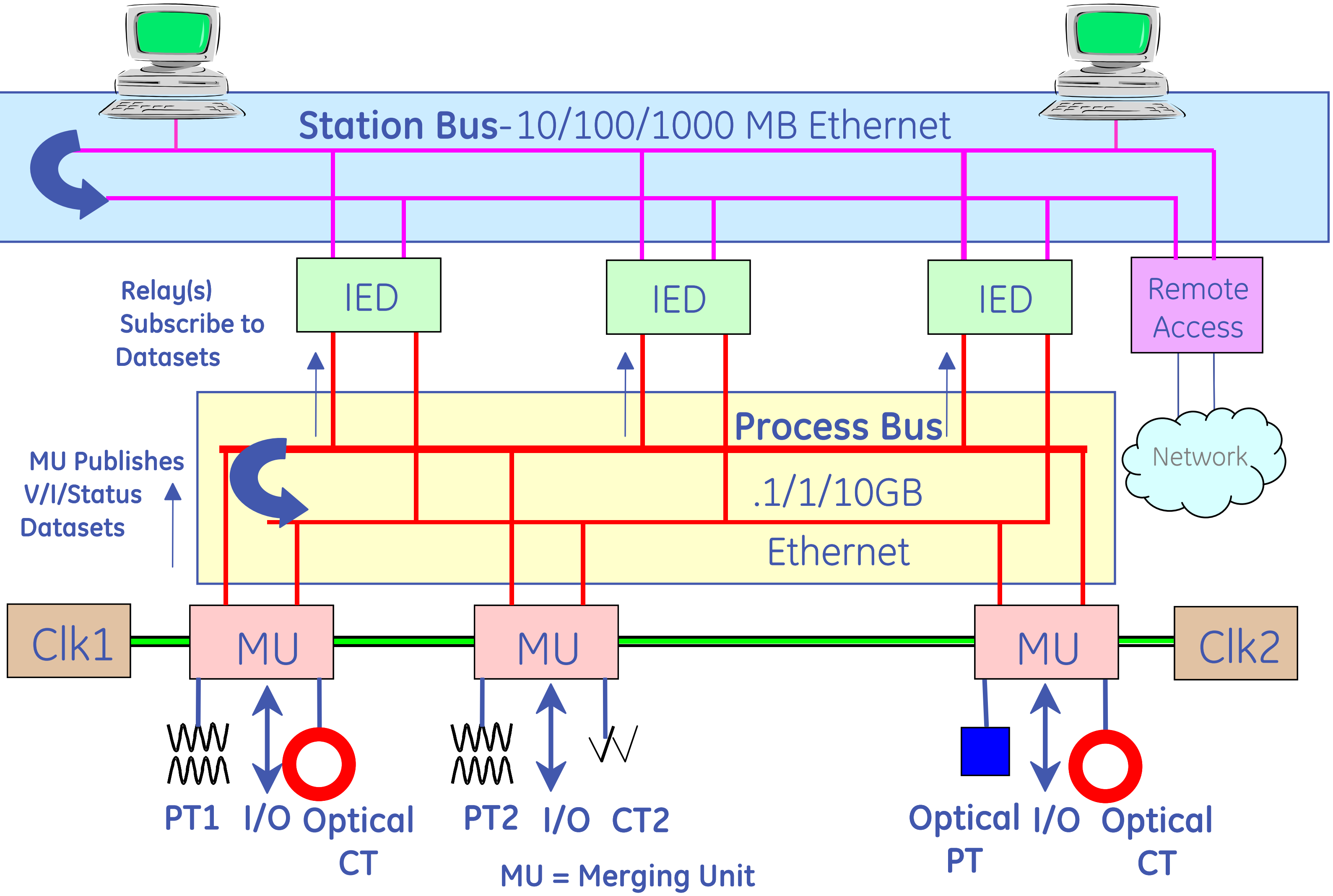


80 samples/nominal cycle
1 sample set/packet

256 samples/nominal cycle
8 samples/packet

Sampling Capability for Now and the Future

IEC61850 Substation Architecture

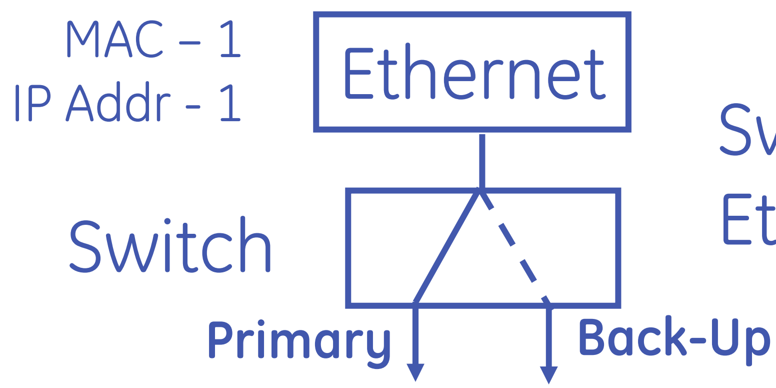


Simplified Architecture… Positioned for the Future

Redundancy Implementations

Redundant Port: 2 independent Ethernet ports with 2 different addresses

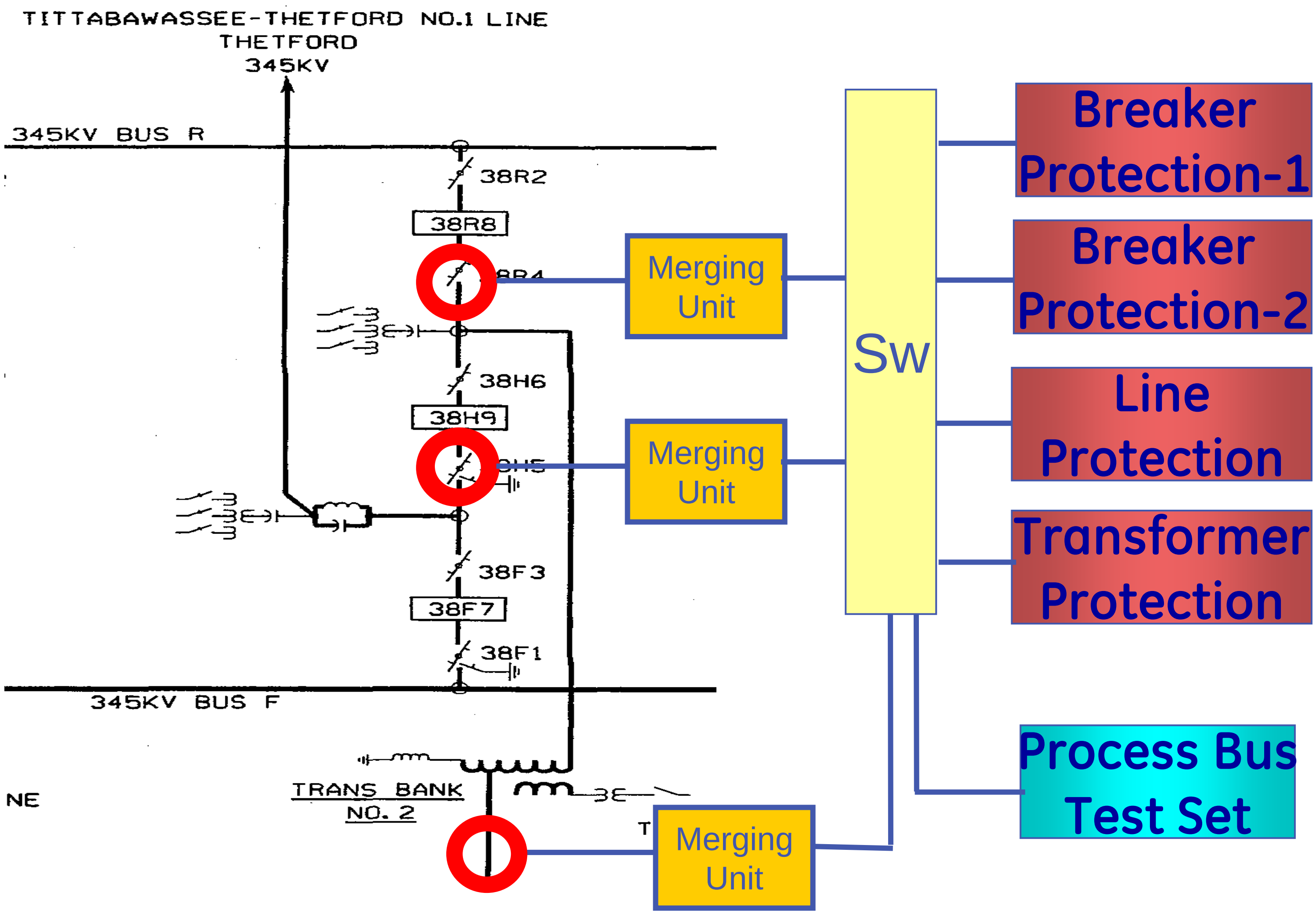
Redundant Media: 1 Ethernet port with switched media



Switches on loss of Ethernet link pulses

Easy to Configure for Redundancy

Process Bus System Implementation



Swift & Economical Test Capabilities

IEC61850 Benefits - 1

- High-level services enable self-describing devices & automatic object discovery saving $$$$$ in configuration, setup and maintenance.
- Standardized naming conventions with power system context eliminates device dependencies and tag mapping saving $$$$ in configuration, setup, and maintenance.
- Standardized configuration file formats enables exchange of device configuration saving $$$$ in design, specification, configuration, setup, and maintenance.

IEC61850 Benefits - 2

- Higher performance multi-cast messaging for inter-relay communications enables functions not possible with hard wires and save $$$$ in wiring and maintenance.

- Multi-cast messaging enables sharing of transducer (CT/PT) signals saving $$$$ by reducing transducers and calibration costs.