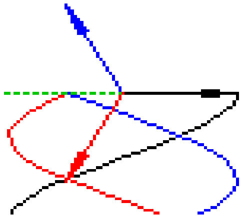
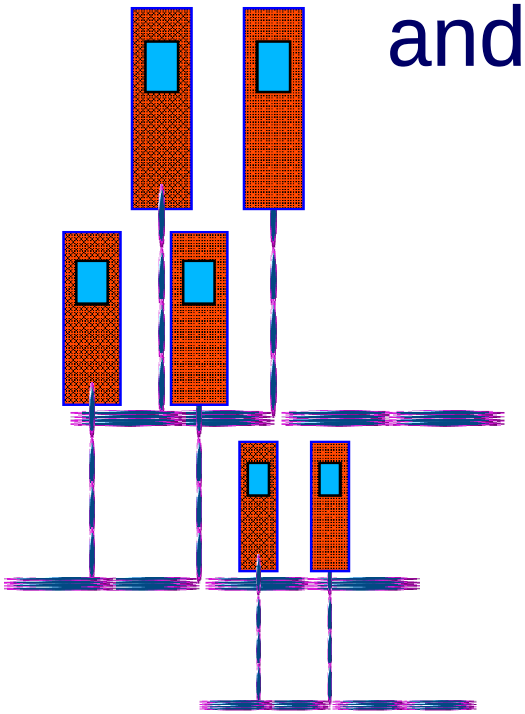


# IEC 61850 ...the Electrical SCADA Standard and Integration with DDCMIS

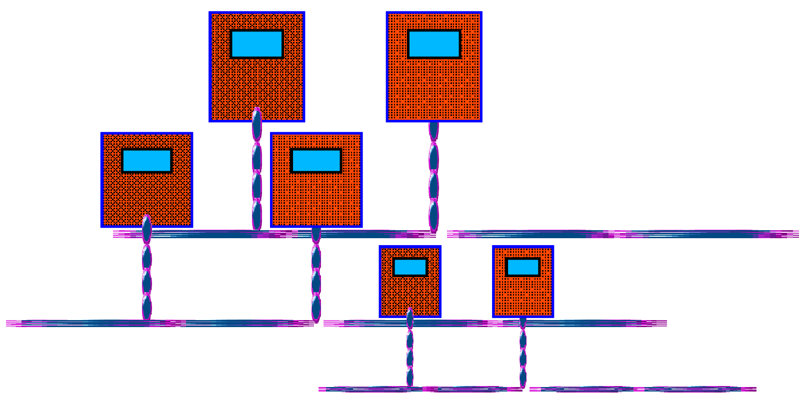


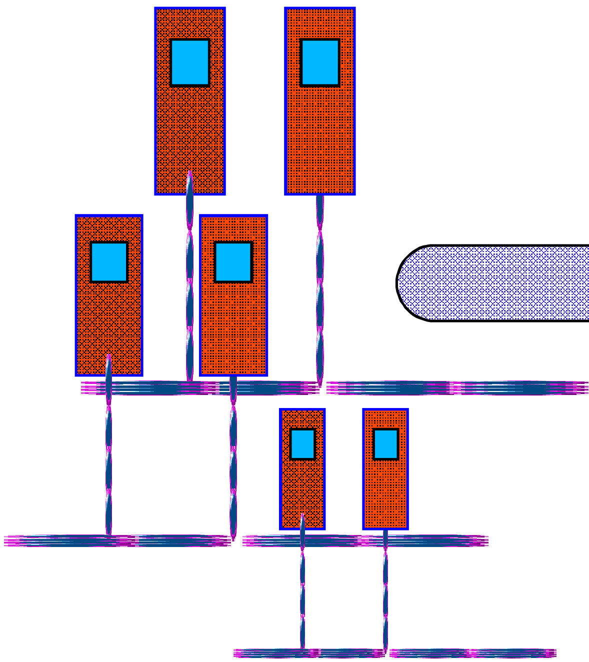
**ISA DELHI 23/01/2015**

**Saroj Chelluri**

**AGM NTPC LTD, INDIA**

- The Concept of IEC 61850
- IEC 62439 ...Standard For Ethernet Redundancy
- Network designing for SCADA And GOOSE Controls
- IEC 61850 Interface with DDCMIS ...OPC or UPC
- Conclusions





# The Concept of IEC 61850

# IEC 61850
# Communication Networks and Systems in Substations

First Time Published in 2004, the IEC 61850 communication standard has gained more and more relevance in the field of Electrical Automation

IEC 61850 has not only taken over the drive of the communication technology of the office networking sector, but it has also adopted the best possible protocols and configurations for high functionality and reliable data transmission. Industrial Ethernet, which has been hardened for substation purposes and provides a speed of 1000 Mbit/s, offers enough bandwidth to ensure reliable information exchange between IEDs (Intelligent Electronic Devices), as well as reliable communication from an IED to a substation controller.

**The definition of an effective process bus offers a standardized way to digitally connect conventional as well as intelligent CTs and VTs to relays.**

More than just a protocol, IEC 61850 also provides benefits in the areas of engineering and maintenance, especially with respect to combining devices from different vendors.

# Key features of IEC 61850

An object-oriented and application-specific data model focused on substation automation

This model includes object types representing nearly all existing equipment and functions in a substation – circuit breakers, protection functions, current and voltage transformers, waveform recordings, and many more Communication services providing multiple methods for information exchange and they  cover reporting and logging of events, control of switches and functions, polling of data model information

**Peer-to-peer communication for fast data exchange between the feeder level devices (protection devices and bay controller) is supported with GOOSE (Generic Object-Oriented Substation Event).**

Support of sampled value exchange and file transfer for disturbance recordings

Communication services to connect primary equipment such as instrument transducers to relays

# Key features of IEC 61850

***Decoupling of data model and communication services from specific communication technologies***.

This technology independence guarantees long-term stability for the data model and opens up the possibility to switch over to successor communication technologies.

Today, the standard uses Industrial Ethernet with the following significant features

- 100/1000 Mbit/s bandwidth
- Non-blocking switching technology
- Priority tagging for important messages
- Time synchronization of 1 ms

A common formal description code, which allows a standardized representation of a system's data model and its links to communication services. **This code, called SCL (Substation Configuration Description Language), covers all communication aspects according to IEC 61850.** Based on XML, this code is an ideal electronic interchange format for configuration data.

A standardized conformance test that ensures interoperability between devices. Devices must pass multiple test cases: positive tests for correctly responding to stimulation telegrams, plus several negative tests for ignoring incorrect information.

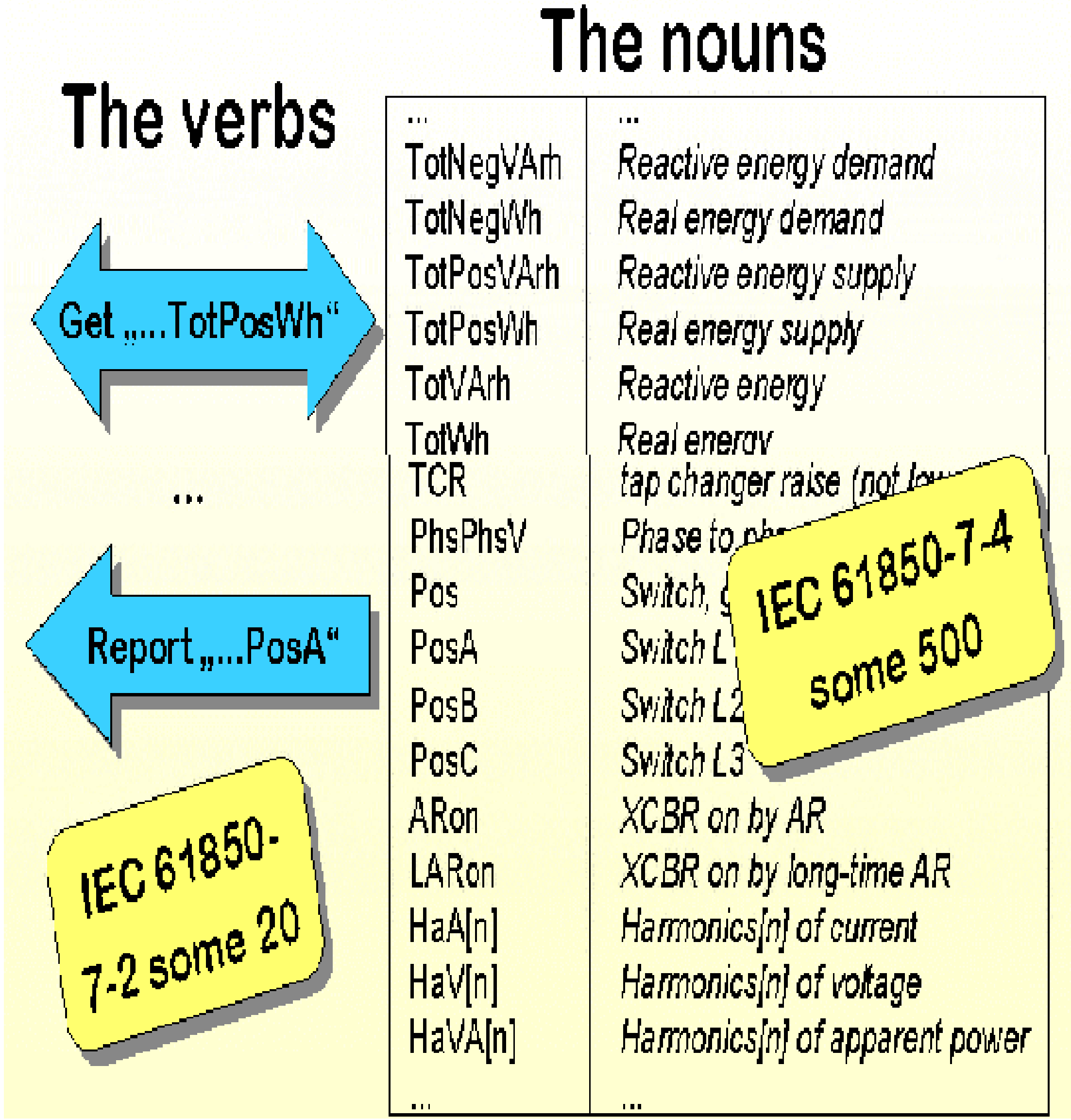
IEC 61850 offers a complete set of specifications covering all communication issues inside a substation.

# IEC 61850 Standard

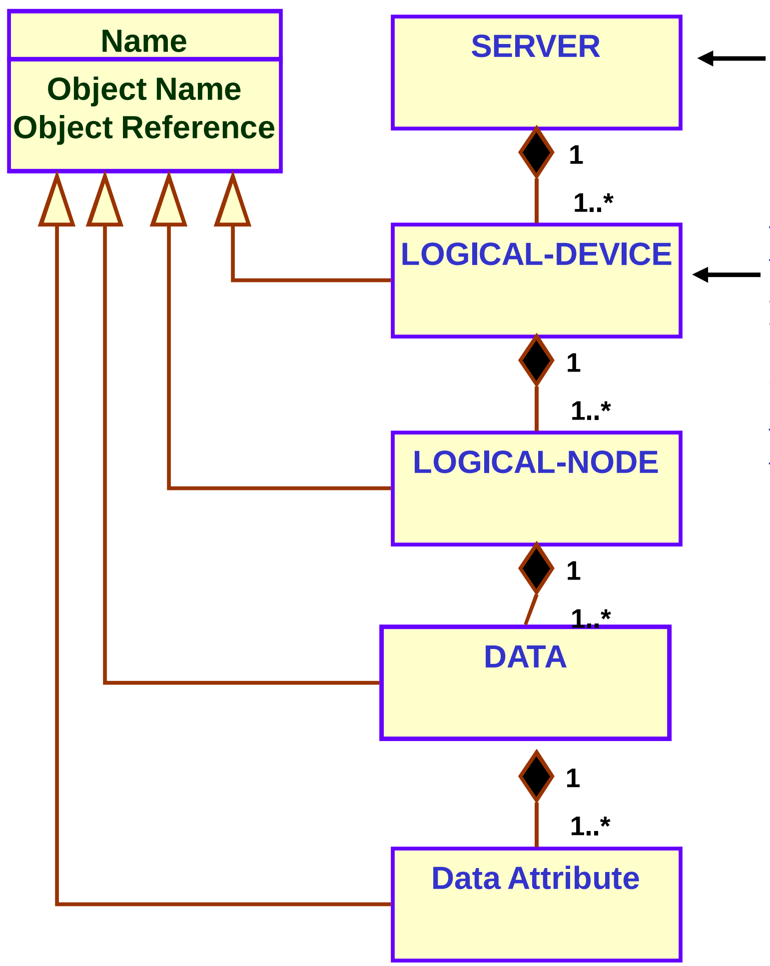
| | |
|---|---|
| Basic principles | Part 1 |
| Glossary | Part 2 |
| General Requirements | Part 3 |
| System and project management | Part 4 |
| Communication requirements | Part 5 |
| Substation Automation System Configuration | Part 6 |
| Basic Communication Structure | Part 7 |
| Mapping to MMS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

# IEC61850 – Primary Parts

- **Part 6-1: Substation Configuration Language (SCL)**
- **Part 7-2: Abstract Communications Service Interface (ACSI) and base types**
- **Part 7-3: Common Data Classes (CDC)**
- **Part 7-4: Logical Nodes**
- **Part 8-1: Specific Communications Service Mappings (SCSM) MMS & Ethernet**
- **Part 9-2: SCSM - Sampled Values over Ethernet**
- **Part 10-1: Conformance Testing**


The verbs
Get „...TotPosWh"
...
Report „...PosA"
IEC 61850-7-2 some 20
The nouns
...
TotNegVArh Reactive energy demand
TotNegWh Real energy demand
TotPosVArh Reactive energy supply
TotPosWh Real energy supply
TotVArh Reactive energy
TotWh Real energy
TCR tap changer raise
PhsPhsV Phase to
Pos Switch,
PosA Switch L
PosB Switch L2
PosC Switch L3
ARon XCBR on by AR
LARon XCBR on by long-time AR
HaA[n] Harmonics[n] of current
HaV[n] Harmonics[n] of voltage
HaVA[n] Harmonics[n] of apparent power
...
IEC 61850-7-4 some 500

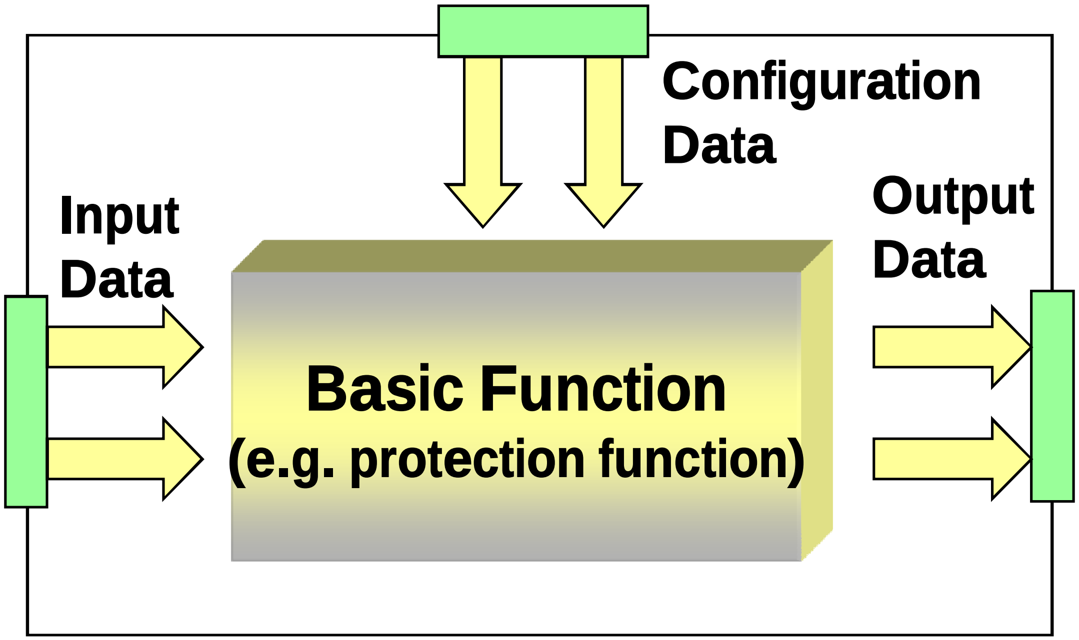
# IEC 61850 Class Model




**Physical Device: access by network address**

**Enables data from multiple devices to be aggregated into a single physical device (data concentrator)**

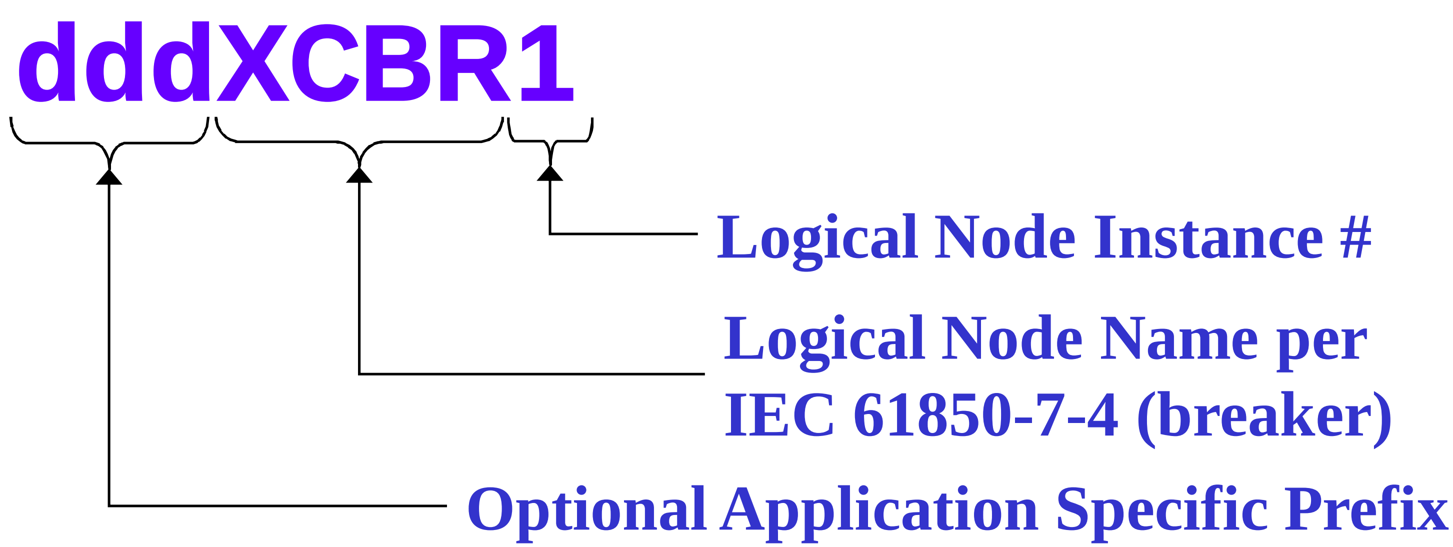
## Concept of a Logical Node




- Functions still remain Vendor Specific
- Data Exchange becomes standardised

# Logical Nodes

A named grouping of data and associated services that is logically related to some power system function.



# IEC61850-7-4 Logical Nodes

| 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) |

# Logical Node Description - 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 |

**Data Name**

**Common Data Class**

**Description**

**Mandatory/Optional**

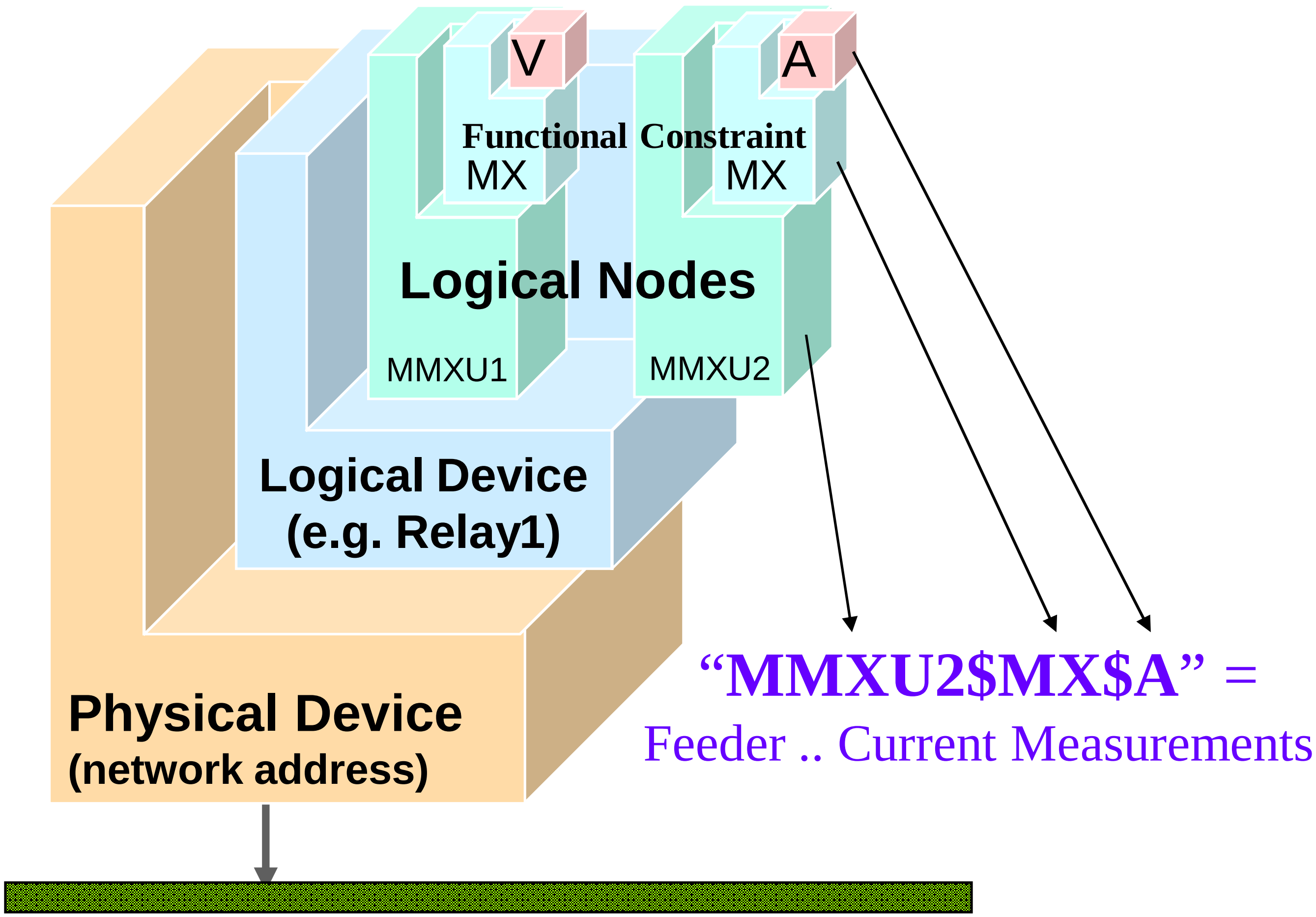
# Single Point Status (SPS) CDC

(e.g. Loc)

| 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 |

**Attribute Name** — **Type** — **Functional Constraint** — **Range of Values** — **Mandatory/ Optional**

# Anatomy of an IEC61850 Object Name



# Object Name Structure

**Relay1/XCBR1$ST$Loc$stVal**

- **Attribute**: $stVal
- **Data**: Loc
- **Functional Constraint**: ST
- **Logical Node**: XCBR1
- **Logical Device**: Relay1

## ACSI Abstract Communications Service Interface

- Defines a set of Objects
- Defines a set of Services to manipulate and access those objects
- Defines a base set of data types for describing objects

# ACSI Objects

| ACSI Object Class (7-2) | MMS Object (8-1) |
|---|---|
| SERVER class | Virtual Manufacturing Device (VMD) |
| LOGICAL DEVICE class | Domain |
| LOGICAL NODE class | Named Variable |
| DATA class | Named Variable |
| DATA-SET class | Named Variable List |
| SETTING-GROUP-CONTROL-BLOCK class | Named Variable |
| REPORT-CONTROL-BLOCK class | Named Variable |
| LOG class | Journal |
| LOG-CONTROL-BLOCK class | Named Variable |
| GOOSE-CONTROL-BLOCK class | Named Variable |
| GSSE-CONTROL-BLOCK class | Named Variable |
| CONTROL class | Named Variable |
| Files | Files |

# ACSI Services

**Enable Self Describing Devices**

| ACSI Services (7-2) | MMS Services (8-1) |
|---|---|
| LogicalDeviceDirectory | GetNameList |
| GetAllDataValues | Read |
| GetDataValues | Read |
| SetDataValues | Write |
| GetDataDirectory | GetNameList |
| GetDataDefinition | GetVariableAccessAttributes |
| GetDataSetValues | Read |
| SetDataSetValues | Write |
| CreateDataSet | CreateNamedVariableList |
| DeleteDataSet | DeleteNamedVariableList |
| GetDataSetDirectory | GetNameList |
| Report (Buffered and Unbuffered) | InformationReport |
| GetBRCBValues/GetURCBValues | Read |
| SetBRCBValues/SetURCBValues | Write |
| GetLCBValues | Read |
| SetLCBValues | Write |
| QueryLogByTime | ReadJournal |
| QueryLogAfter | ReadJournal |
| GetLogStatusValues | GetJournalStatus |
| Select | Read/Write |
| SelectWithValue | Read/Write |
| Cancel | Write |
| Operate | Write |
| Command-Termination | Write |

# Reporting Features

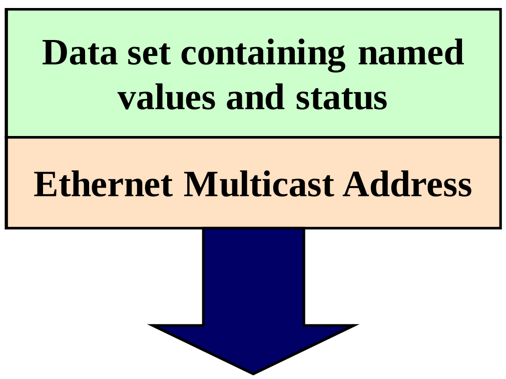
Unbuffered Reporting

Buffered reporting enables the server to retain data if associations are lost enabling the client to retrieve ALL data.

# Relay-Relay Messaging

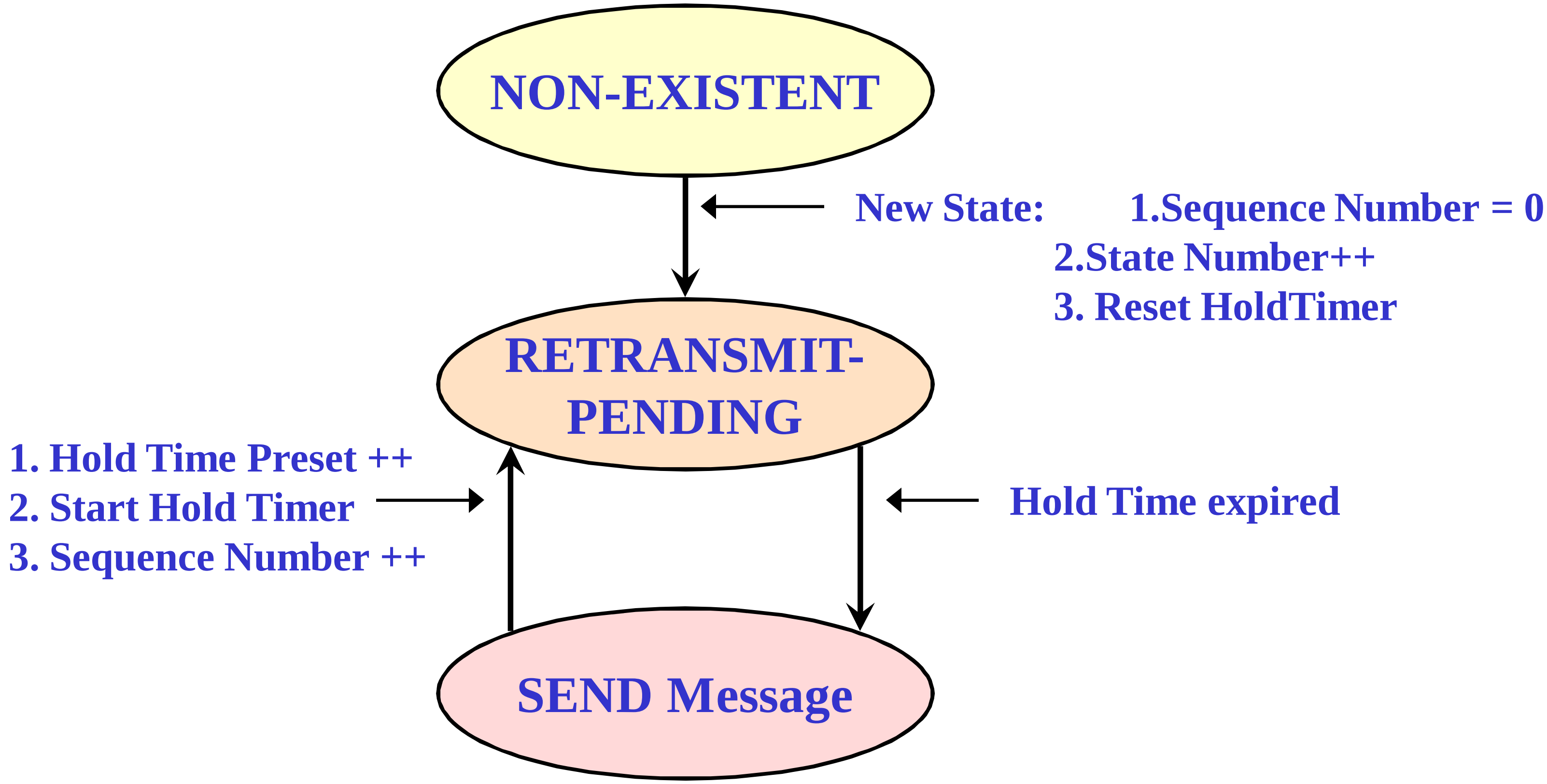
## GOOSE:

**Generic Object Oriented Substation Event**




**Published to all devices subscribed to data on multi-cast address**

# GOOSE/GSSE is Reliable Multicast



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.

XML description of the entire system

**SCD**: Substation Configuration Description

XML description of a single substation

**ICD**: IED Capability Description

XML description of items supported by an IED

**CID**: Configured IED Description

XML configuration for a specific IED

# Sampled Measured Values (SMV)

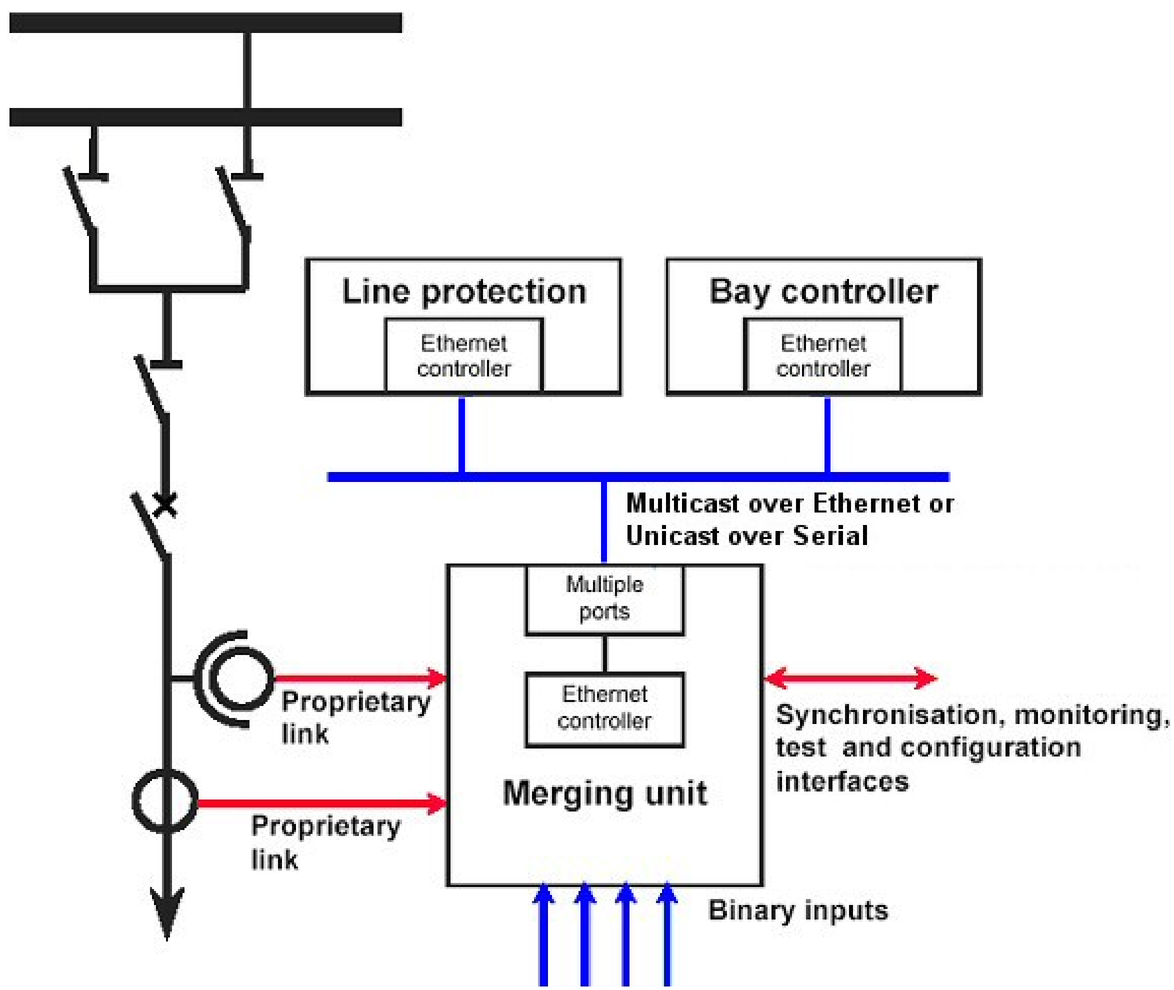
A method for transmitting sampled measurements from transducers such as CTs, VTs, and digital I/O.

Enables sharing of I/O signals among IEDs

Supports 2 transmission methods:

- Multicast service (MSVC) over Ethernet
- Unicast (point-to-point) service (USVC) over serial links.

# SMV Application



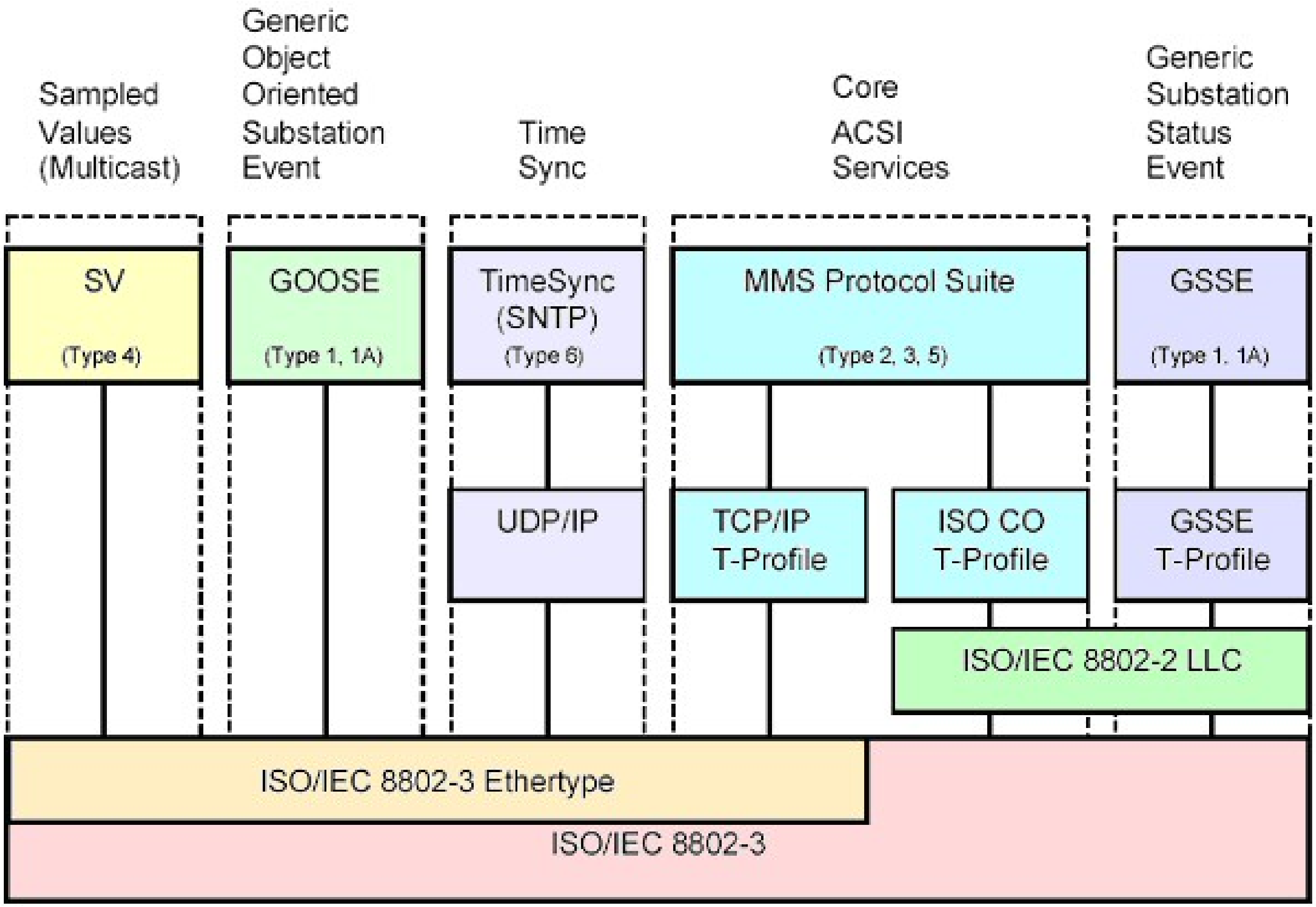
# IEC61850 Controls

## Four Control Models:

- Direct Control with normal security
- SBO Control with normal security
- Direct Control with enhanced security
- SBO Control with enhanced security

Enhanced Security provides validation and supervision of the control action and reporting of status

# IEC61850 Profiles



# IEC61850 is Unique

- Not a recast serial RTU protocol
- Designed specifically for LANs to lower life cycle cost to use a device:
  - Cost to install, configure, and maintain
- Real object-oriented approach for SA:
  - Supports standardized device models using names instead of object/register numbers and indexes.
  - Standardized configuration language (SCL).
  - Feature rich with support for functions difficult to implement otherwise.

# IEC61850 Network Architecture

Data from IEDs available to all applications via network.

Communications unaffected when adding devices or applications.

Standard net. gear provides high perf. & flexibility with environmental protection.

Applications and IEDs share common:

- Protocols
- Data Format and Context
- Data Addressing/naming Conventions
- Configuration Language

# IEC61850 View of Devices

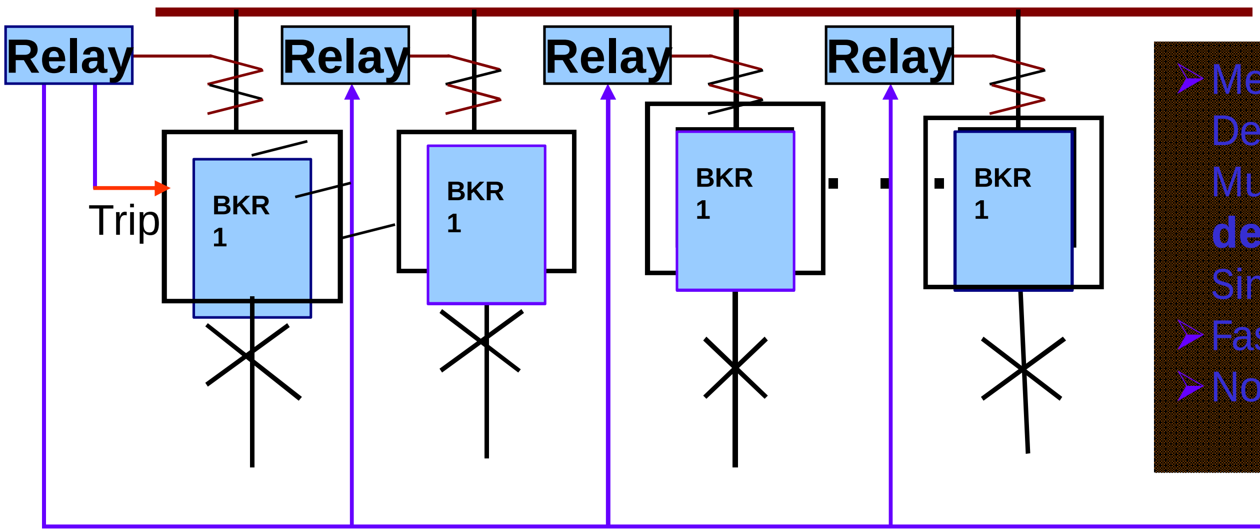
- Only network addressing requires configuration in the remote client.
- Point names portray the meaning and hierarchy of the data.
- Point names can be retrieved from the device automatically without manual intervention.
- All devices share a common naming convention.
- Device configurations can be exchanged using IEC61850-6-1 (SCL) files

# Advent of GOOSE with IEC 61850

# GOOSE WITH IEC 61850

IEC 61850 Ethernet Communication networking has four types of communication modes

- TCP/IP MMS (Client – Server based on connection)
- NTP, SNMP, HTML (Non time critical basic services)
- GOOSE (Multicast, repetition mechanism on Layer 2 )
- Sampled Values (Multicast, data stream directly on Layer 2)




- Message Delivery to Multiple **devices** Simultaneously
- Fast
- No Cu wire

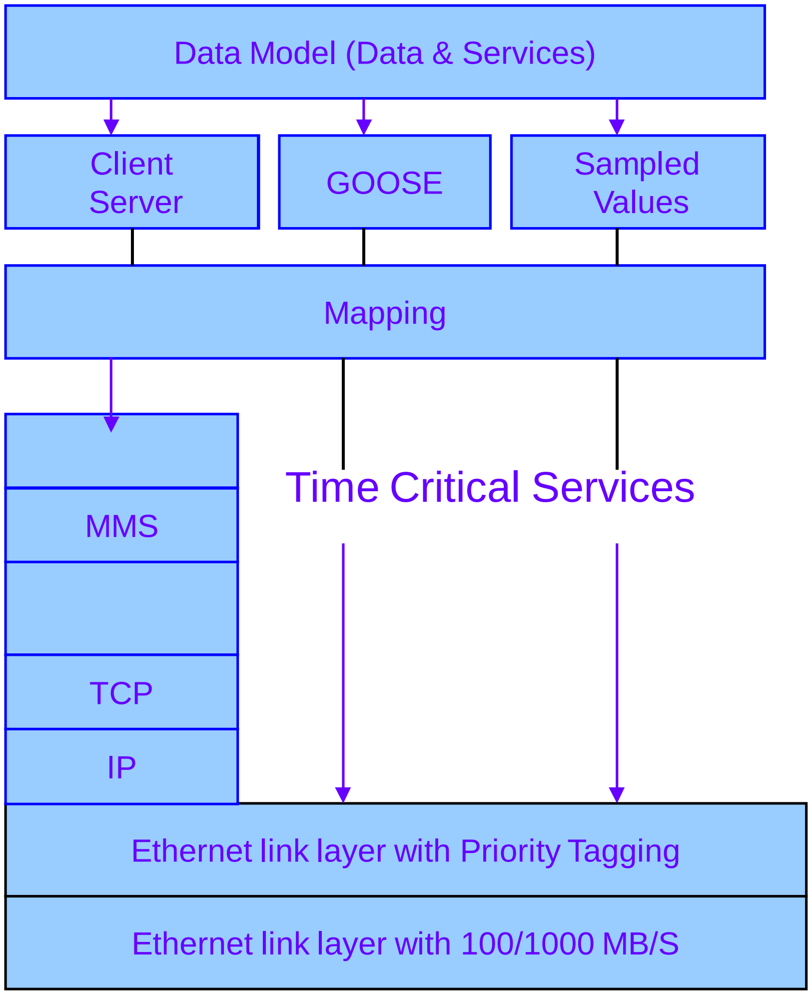
# GOOSE

- Generic Object Oriented Substation Event
- User-defined Dataset (Status / Value)
- Peer-to-Peer Communication
- Publisher – Subscriber Model
- Based on Device MAC Address
- Message initiated on Change of state
- Periodical Repetition
- High Speed Data Exchange – Faster Than Hardwired Signals

# IEC 61850 Communication Services

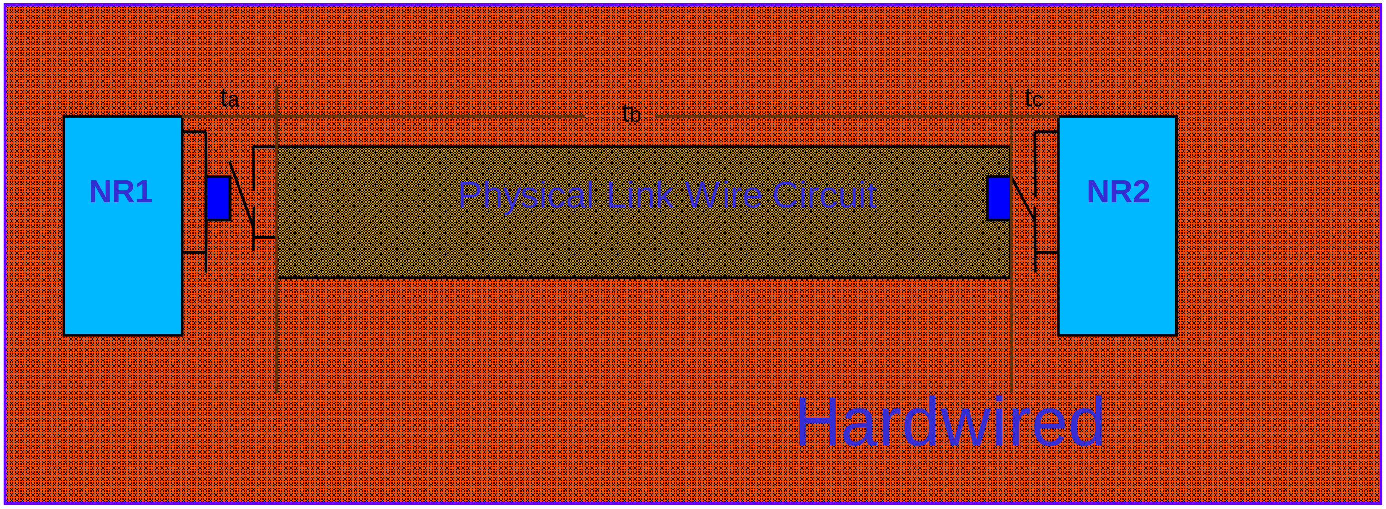
- Un buffered Reports
- Buffered Reports
- Control Operations
- Logging
- Time Synchronization
- File Transfer
- GOOSE
- Sampled Values

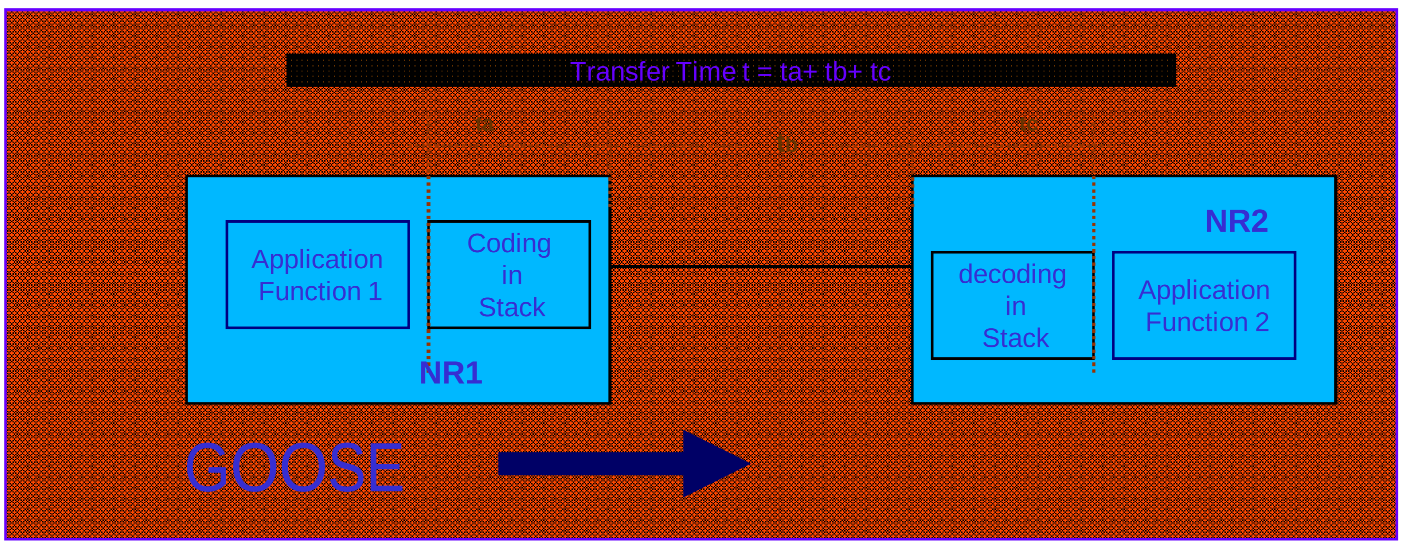
# GOOSE – Mapping to Communication Stack & Performances




| **Type** | **Application** | **Performance Class** | **Requirement (Transmission Time)** |
|---|---|---|---|
| **1 A** | Fast Messages (Trip) | P1<br>**P2/P3** | 10 ms<br>3 ms |
| 1 B | Fast Messages (others) | P1<br>P2/P3 | 100 ms<br>20 ms |
| 2 | Medium Speed | | 100 ms |
| 3 | Low Speed | | 500 ms |
| 4 | Raw Data | P1<br>P2/P3 | 10 ms<br>3 ms |
| 5 | File Transfer | | > 1000 ms |
| 6 | Time Synchronization | | (Accuracy) |

# Hardwired Vs GOOSE



# IEC 61850 Ed. 2

- **Communication Networks & Systems for Power Utility Automation**
- **Broader Scope**
- **Clarifications about gray areas in Edition 1**
- **Improved Interoperability of Devices & Tools**
- **Redundancy in Communication Networks**
- **IEC 62439**

# Benefits of IEC61850

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 config., setup, and maintenance.

Standardized configuration file formats enables exchange of device configuration saving $$$$ in design, specification, config., setup, and maint.

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.

# To Summarize IEC 61850

**IEC 61850 is a global standard for**

**"Communication Networks and Systems in Substations"**

It specifies an expandable **data model and services**

It does not block future development of functions

It specifies **no protection or control functions**

It supports free allocation of functions to devices

It is open for different system philosophies

It provides the Substation Configuration description Language (SCL)

It supports comprehensive consistent system definition and engineering

It uses Ethernet and TCP/IP for communication

Provides the broad range of features of mainstream communication

It is open for future new communication concepts

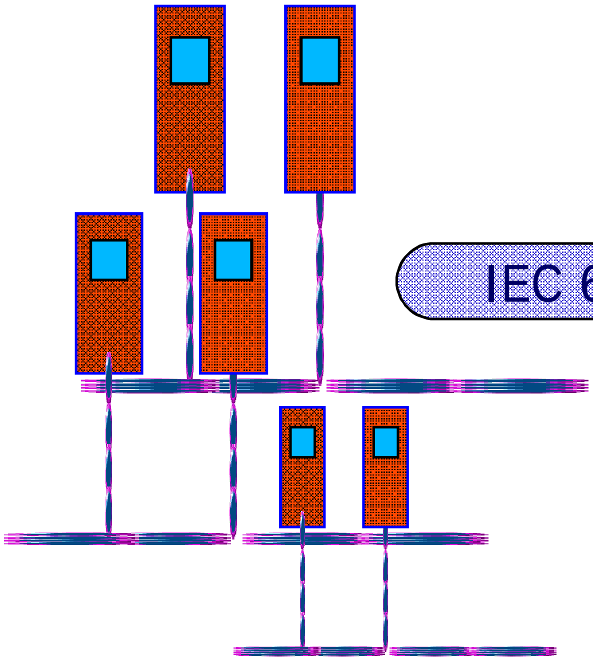
# To Summarize IEC 61850

IEC 61850 standard separates the domain related model for both data and communication services from the protocols, ie, the ISO/OSI seven-layer stack used to code and decode information into bit strings for communication over a serial link

This approach not only accommodates state-of-the-art communication technology, but it also safeguards investments in applications and engineering (based on the object and command communication service model)

Therefore, the standard is future-proof. The mapping of the data model to the communication stack is also standardized in IEC 61850 to ensure interoperable communication

All application functions, including the data interfaces to the primary equipment, are broken down into the smallest feasible pieces, which may communicate with each other and be implemented separately in dedicated IEDs.



# IEC 62439 Standard For Ethernet Redundancy

# IEC 62439 “High Availability Automation Networks”

- Specifies relevant principles for high availability Ethernet networks that basically meet requirements for industrial automation networks
- Application Protocol Independent
- Can be used for both industrial and energy automation applications
- Therefore perfectly applicable to IEC 61850

# Redundancy Methods

Table 2 — Examples of redundancy methods

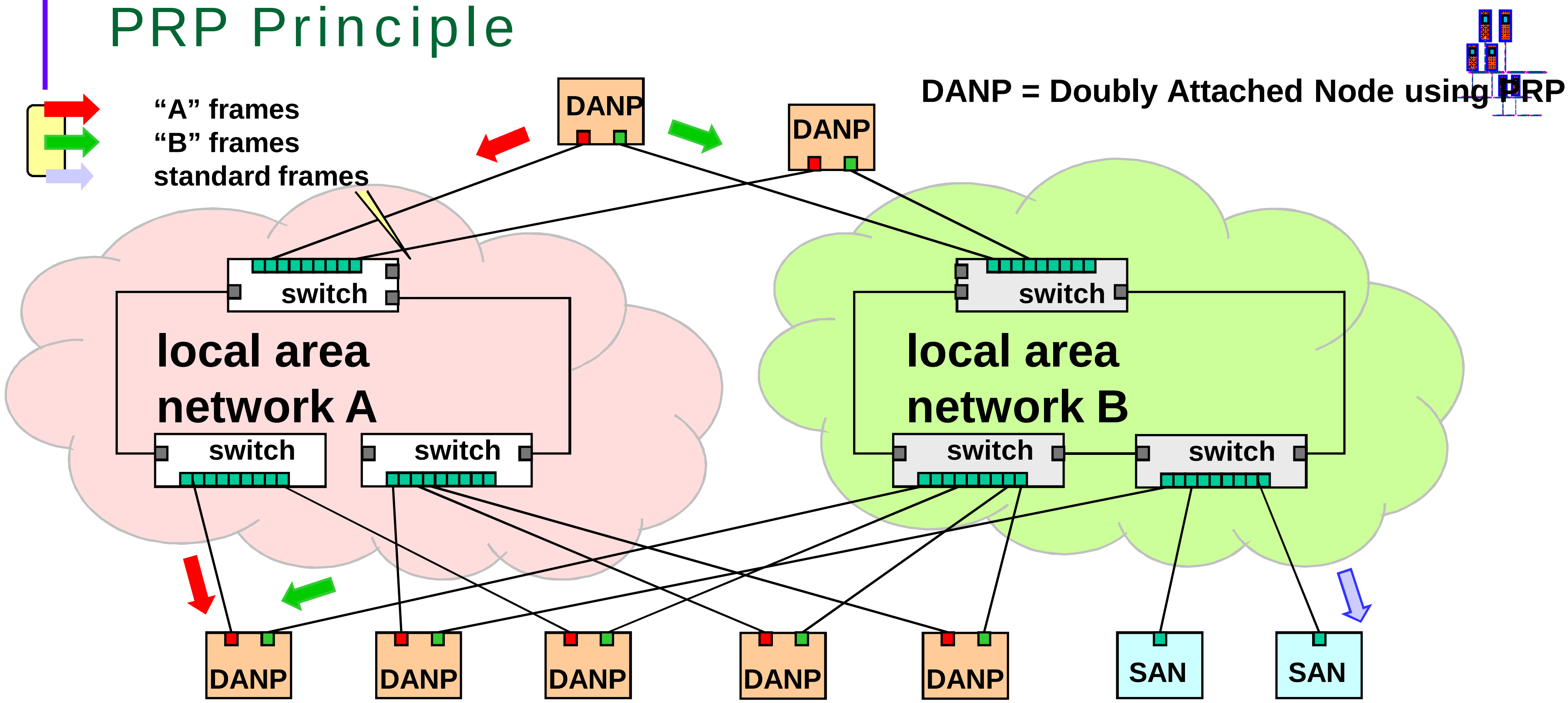
| Protocol | Solution | Frame loss | End node attachment | End node drivers | Network Topology | Recovery time | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Fault | Repair | Reinstatement |
| IP | IP routing | yes | single | standard | single meshed | >30s not deterministic | | |
| STP | IEEE 802.1D-1998 | yes | single | standard | single meshed | >10s not deterministic | | |
| RSTP | IEEE 802.1D-2004 | yes | single | standard | single meshed | >2s not deterministic | >2 s | >20 s for switch, 0 for link |
| MRP | IEC 62439, Clause 5 | yes | single | standard | ring | 500ms-200ms for 50 switches | | |
| CRP | IEC 62439, Clause 7 | yes | double | specific | connected double meshed | 1-2 s for 512 end nodes | | |
| PRP | IEC62439, Clause 6 | no | double | specific | isolated double meshed | 0 | 0 | 0 |

- ** according IEC 62439 (CDV – Committee Draft for Voting) : Digital data communication for measurement and control – High availability automation networks

# Redundancy solutions retained for IEC 61850

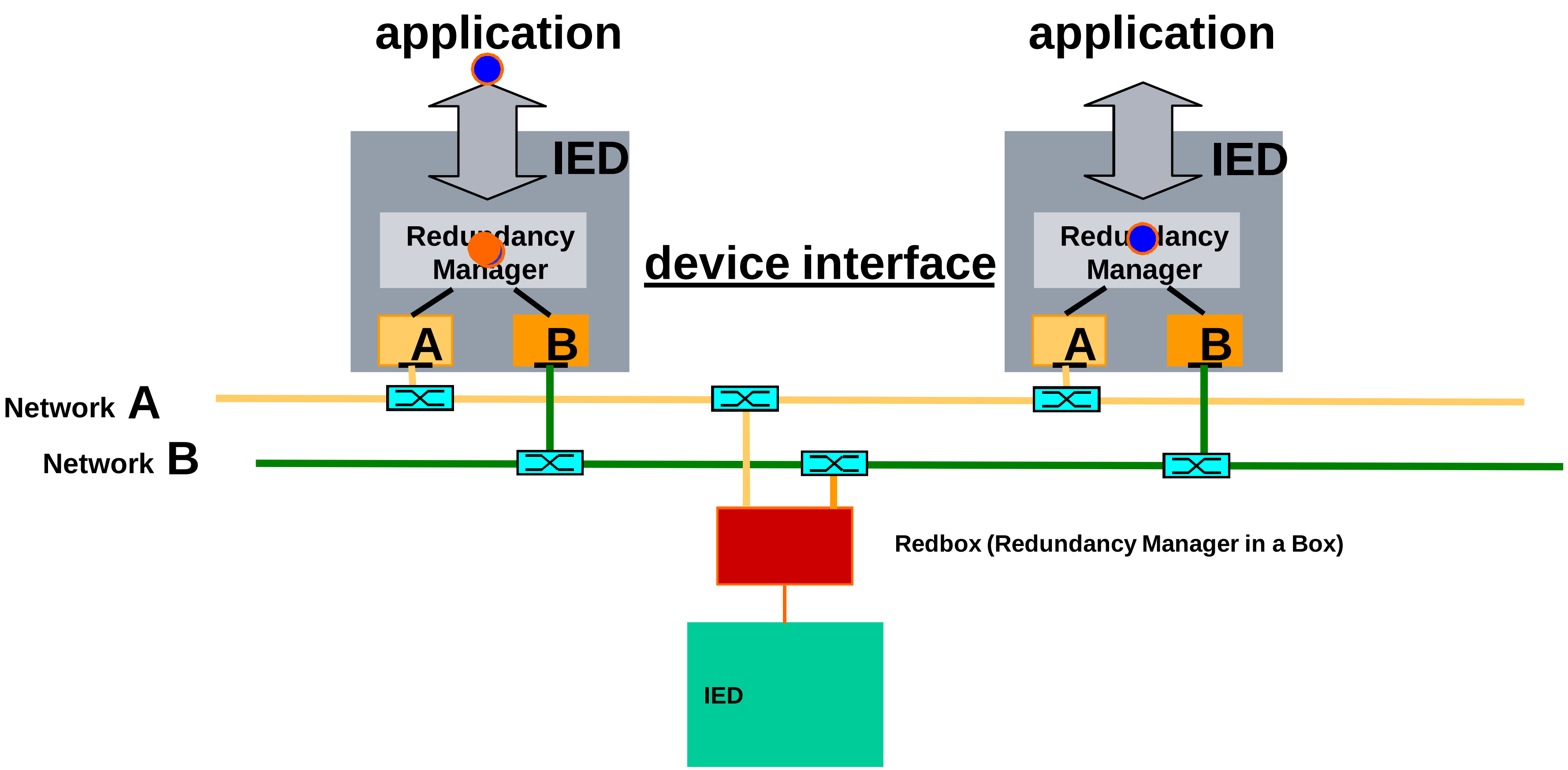
- With “zero” switchover time (seamless)
  - PRP (Parallel Redundancy Protocol)
    IEC 62439-3 Clause 4
  - HSR (High-availability Seamless Redundancy)
    IEC 62439-3 Clause 5
- The recommended application domain of each protocol is explained in IEC 61850-90-4 (Network Engineering Guidelines), to be published.

# PRP Principle

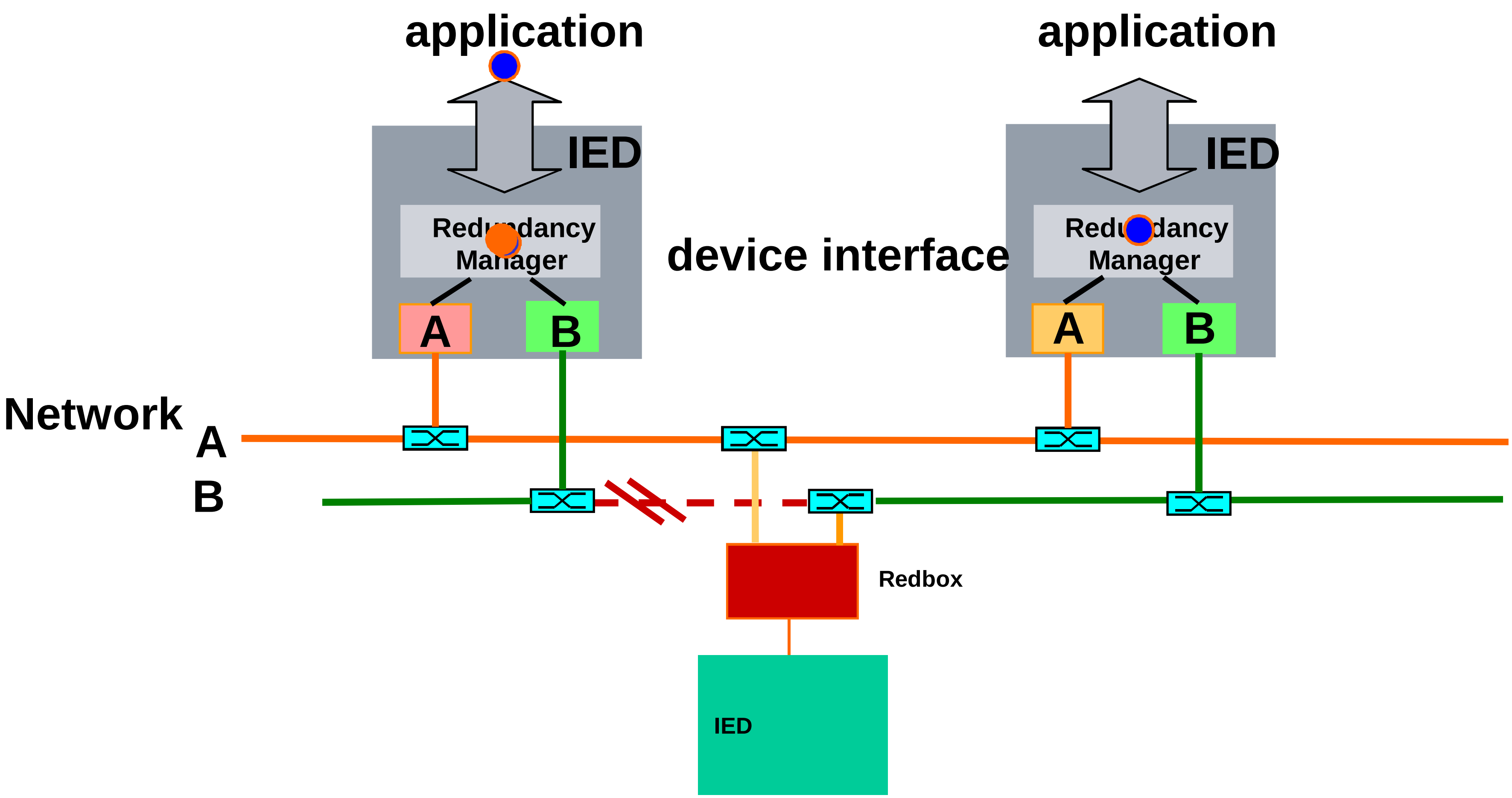



Two Ethernet networks (LANs) of similar topology operate in parallel.
The LANs shall not be connected to each other to ensure fail-independence.
Each node is a doubly attached node with PRP (=DANP) which has an interface for each LAN and sends a frame simultaneously on both LANs.
A receiver receives in normal operation both frames and discards the duplicate.
In case of failure, a receiver keeps on with the frames it receives from the healthy port.
When traffic is reestablished, the receiver resumes processing frames from both channels.

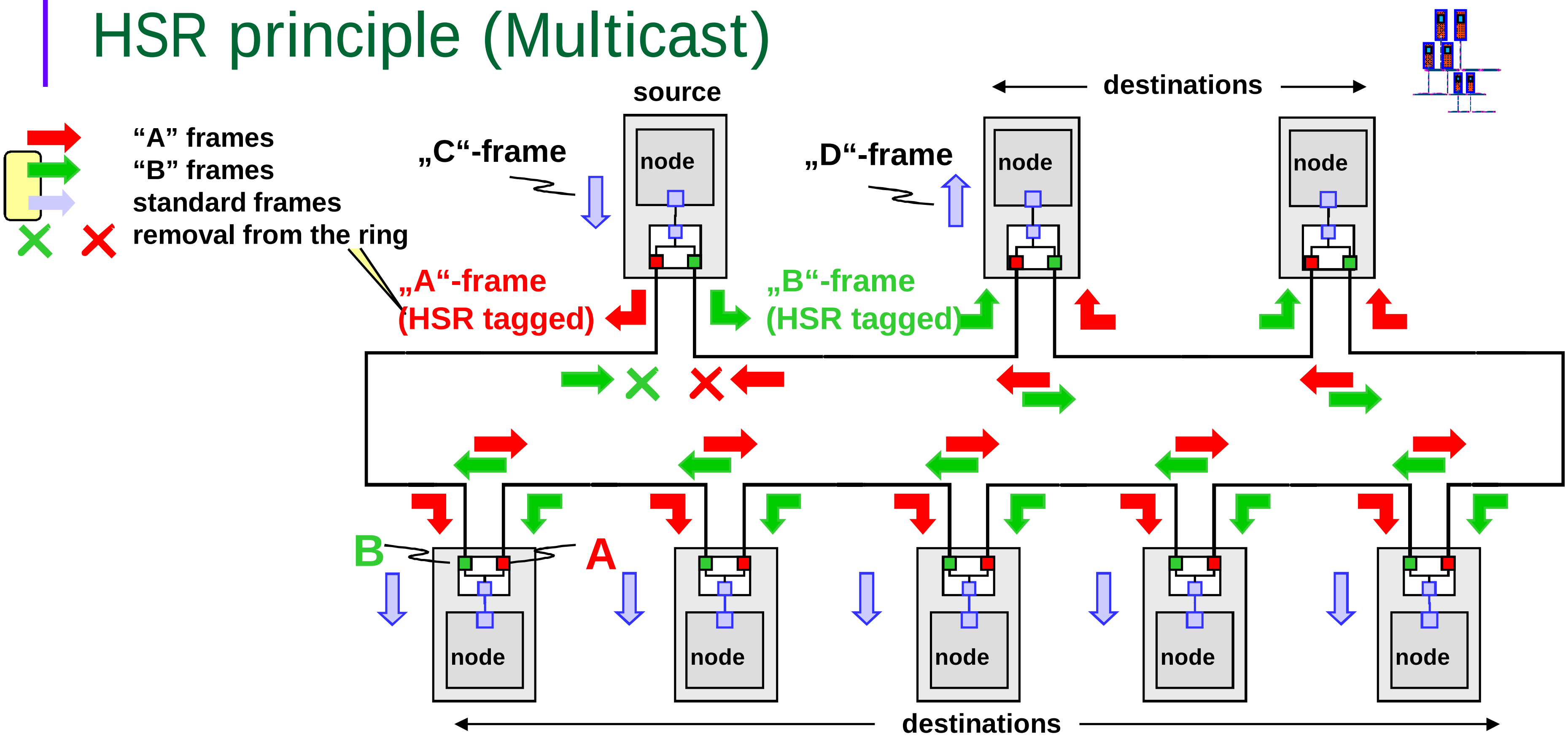
# PRP Normal Operations



# PRP operation with fault



# HSR principle (Multicast)




Nodes are arranged as a ring, each node has two identical interfaces, port A and port B.

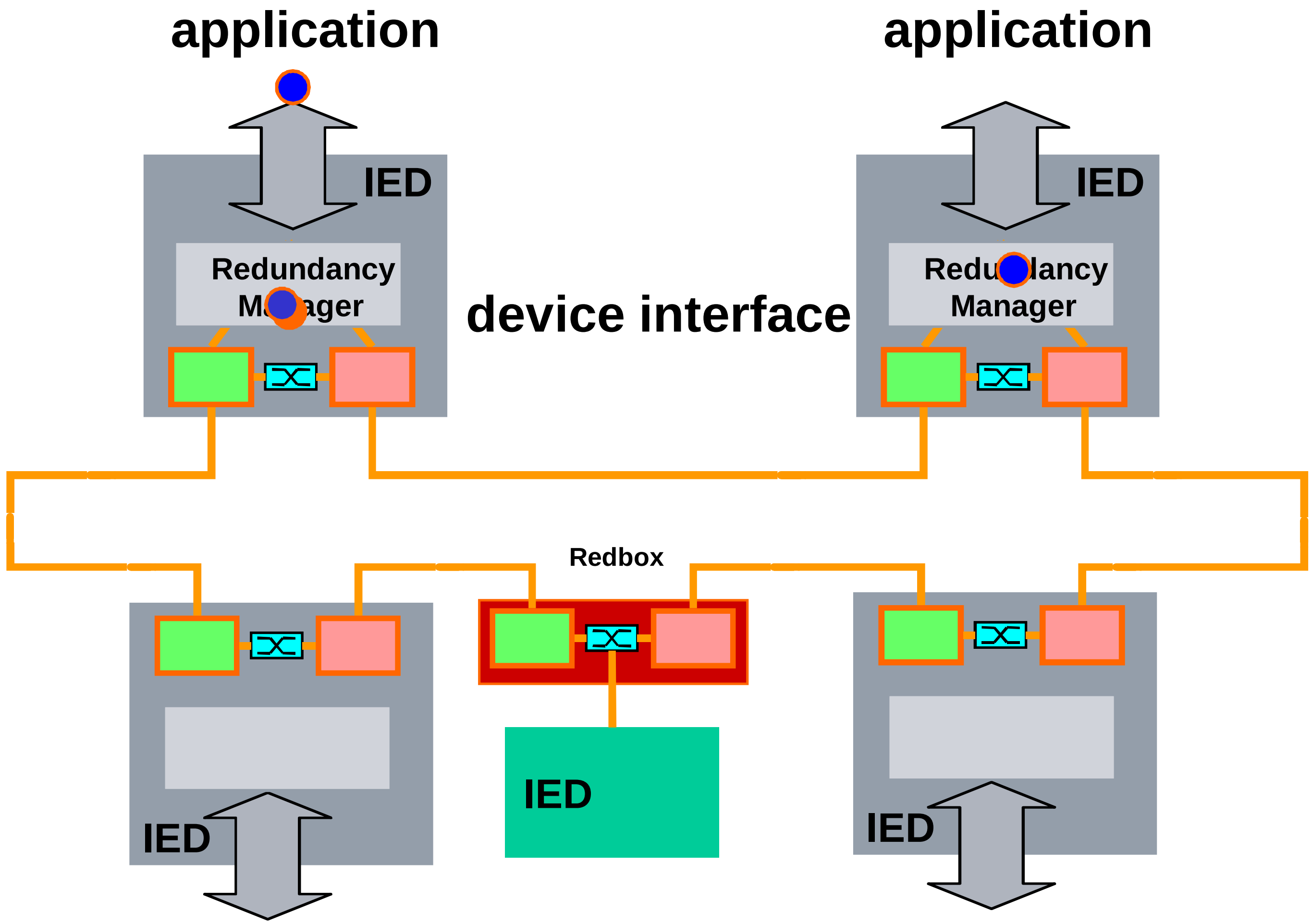
For each frame to send ("C"-frame), the source node sends two copies over port A and B.

Each node relays a frame it receives from port A to port B and vice-versa, except if it already forw it.

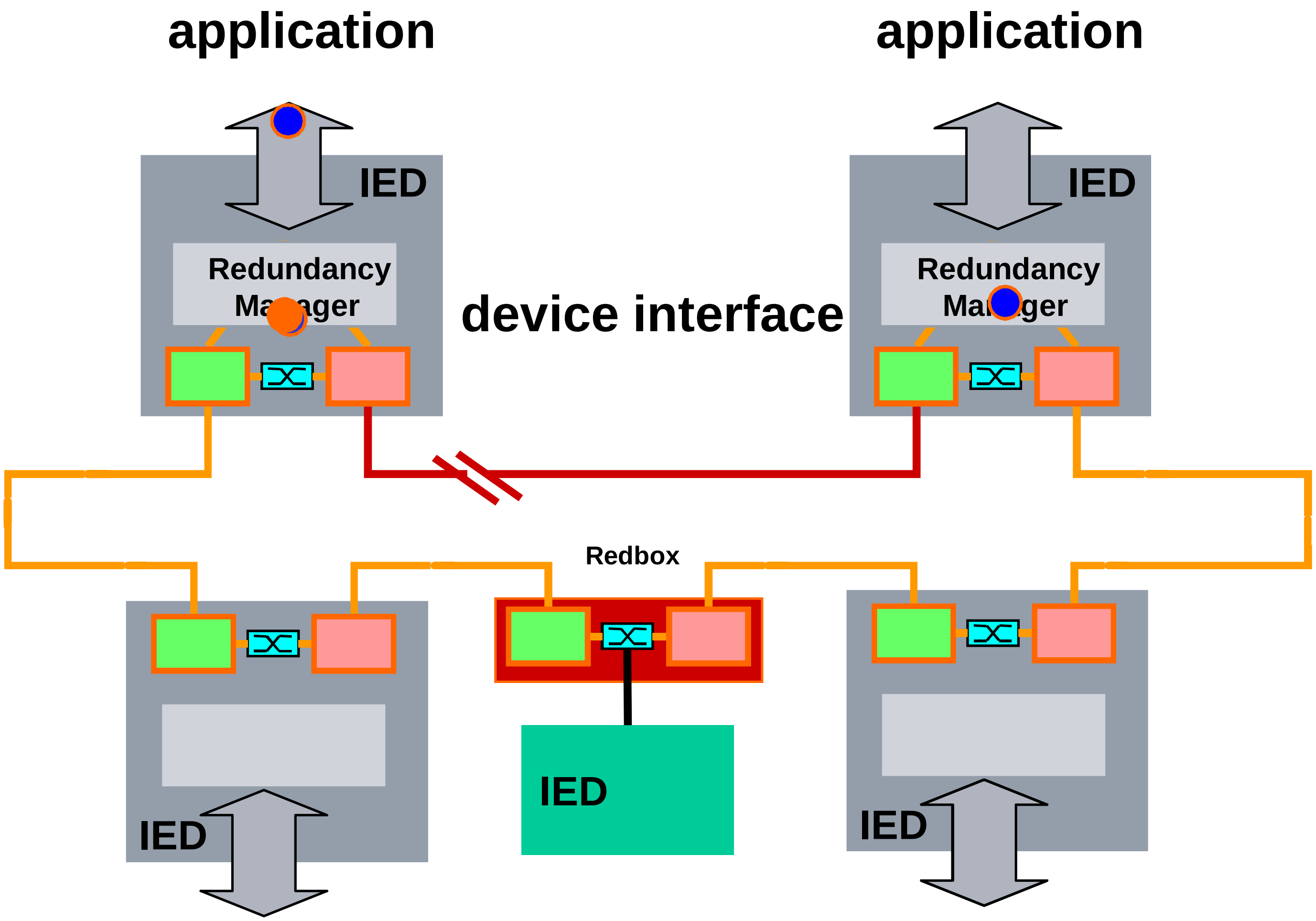
The destination nodes consumes the first frame of a pair and discards the duplicate.

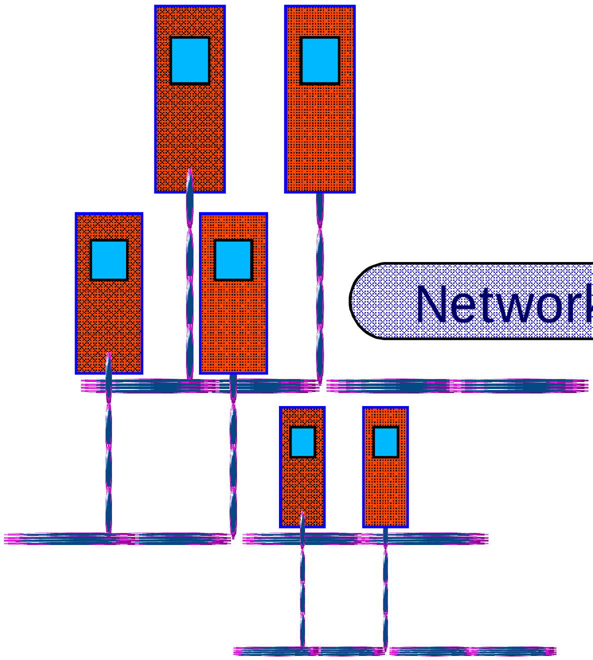
In case of interruption of the ring, frames still continue to be received over the intact path.

# HSR normal operation



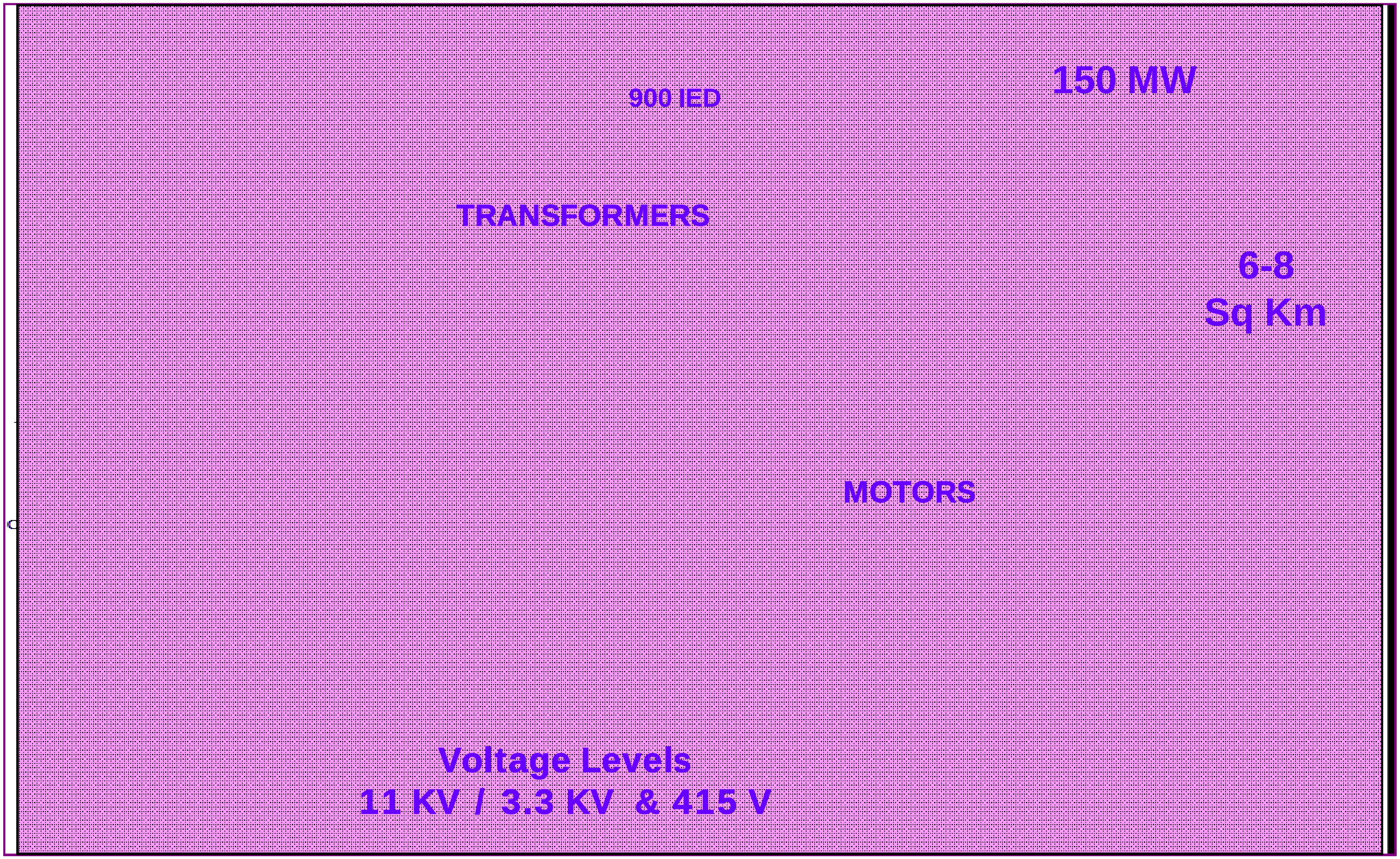
# HSR operation with fault



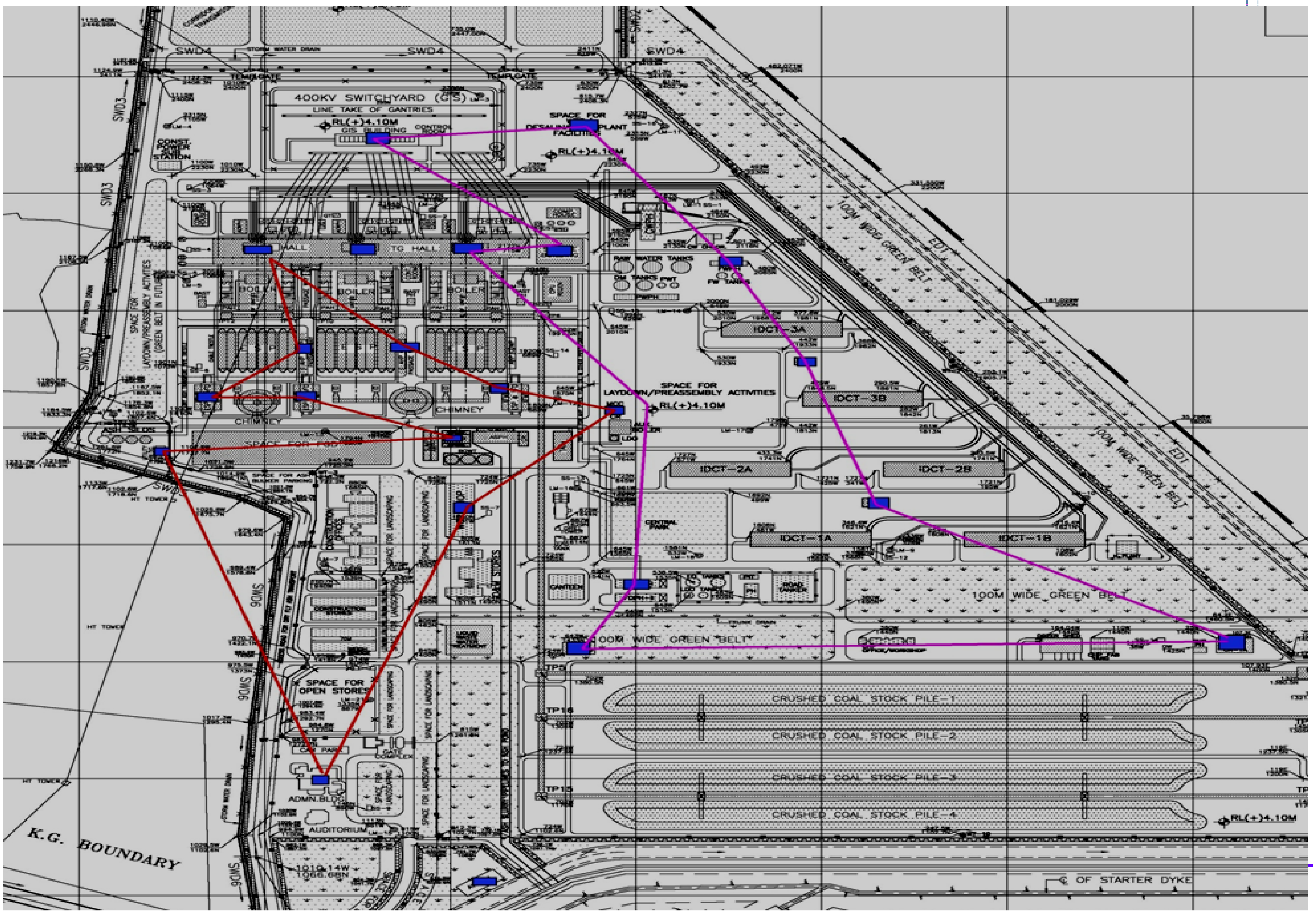


# Network Design For SCADA and GOOSE Controls

# Auxiliary Power Supply for a 3 x 800 MW Power Station



# GLP with FO Loops



# CONTROL SYSTEMS IN A POWER PLANT

Circuit breakers of auxiliary power supply system can be functionally classified into the following categories

- Incomers / Bus-couplers / Ties (MV)
- Outgoing Transformer Feeders (MV)
- Outgoing Motor Feeders (MV)
- Incomers / Bus-couplers / Ties (LV)

Conventionally, controls, i.e. switching on and off of circuit breakers / contactors, are done by the DDCMIS (Plant Distributed Control and management Information Systems) through hardwired signals

# CONTROL SYSTEMS IN A POWER PLANT

- Motor feeders, being part of the process, are controlled by DDCMIS through various functional groups according to the process requirement
- Other breakers, viz. Incomers, Bus-couplers, Ties, Outgoing and Transformer feeders are controlled by dedicated separate functional group
- The control logic for each individual breaker is split into two parts, one built in the DDCMIS and the other in the IED (Intelligent Electronic Device) of that breaker as below
    - Interlocks related to external systems like upstream and other units' breakers are built in the DDCMIS
    - Interlocks related to the breaker being controlled like synchronism check, No electrical fault (86), Reverse Blocking and breaker schematics are built inside the breaker's IED.
    - Bus transfer logics are also a combination of DDCMIS logics and hardwired interlock
    - Breaker on / off status and electrical fault (86) are the signals that are hardwired to DDCMIS and other important signals are provided to DDCMIS for process displays through OPC

# What is SCADA ?

# SCADA is...

SCADA is an acronym for Supervisory Control and Data Acquisition

SCADA generally refers to an industrial computer system that monitors and controls a process

In the case of the transmission and distribution elements of electrical utilities, SCADA will monitor substations, transformers , switchgears and other electrical assets

SCADA systems are typically used to control geographically dispersed assets that are often scattered over thousands of square kilometres

# Functions Of SCADA

Functions of SCADA systems into four major categories

- Data Acquisition
- Data Communication
- Data Presentation
- Control

# Controls From SCADA

IED's are versatile devices with

- Protection, Metering, Monitoring and Control functions
- High speed and Reliability
- Conform to IEC61850 - internationally accepted standard for substation communication based on high speed Ethernet and Data transmission speeds of up to 1Gbps

The Switchgear SCADA systems are

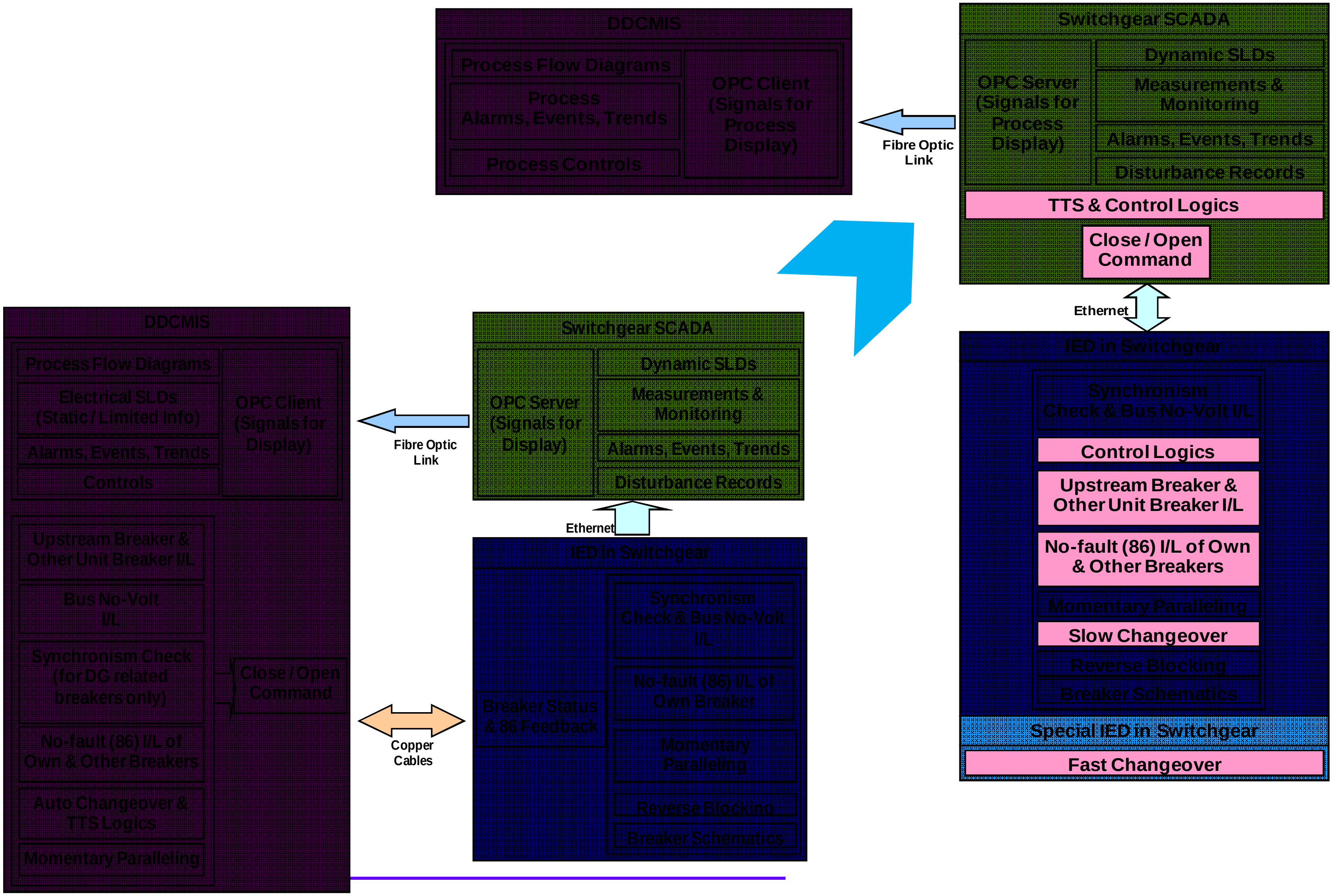
- Highly advanced systems capable of controlling large substations
- Can very be utilized for performing all controls of circuit breakers excluding those of motor feeders
- Faster command processing

# CB Controls From SCADA

Control logic for each individual breaker to be built in the SCADA and the IED of that breaker

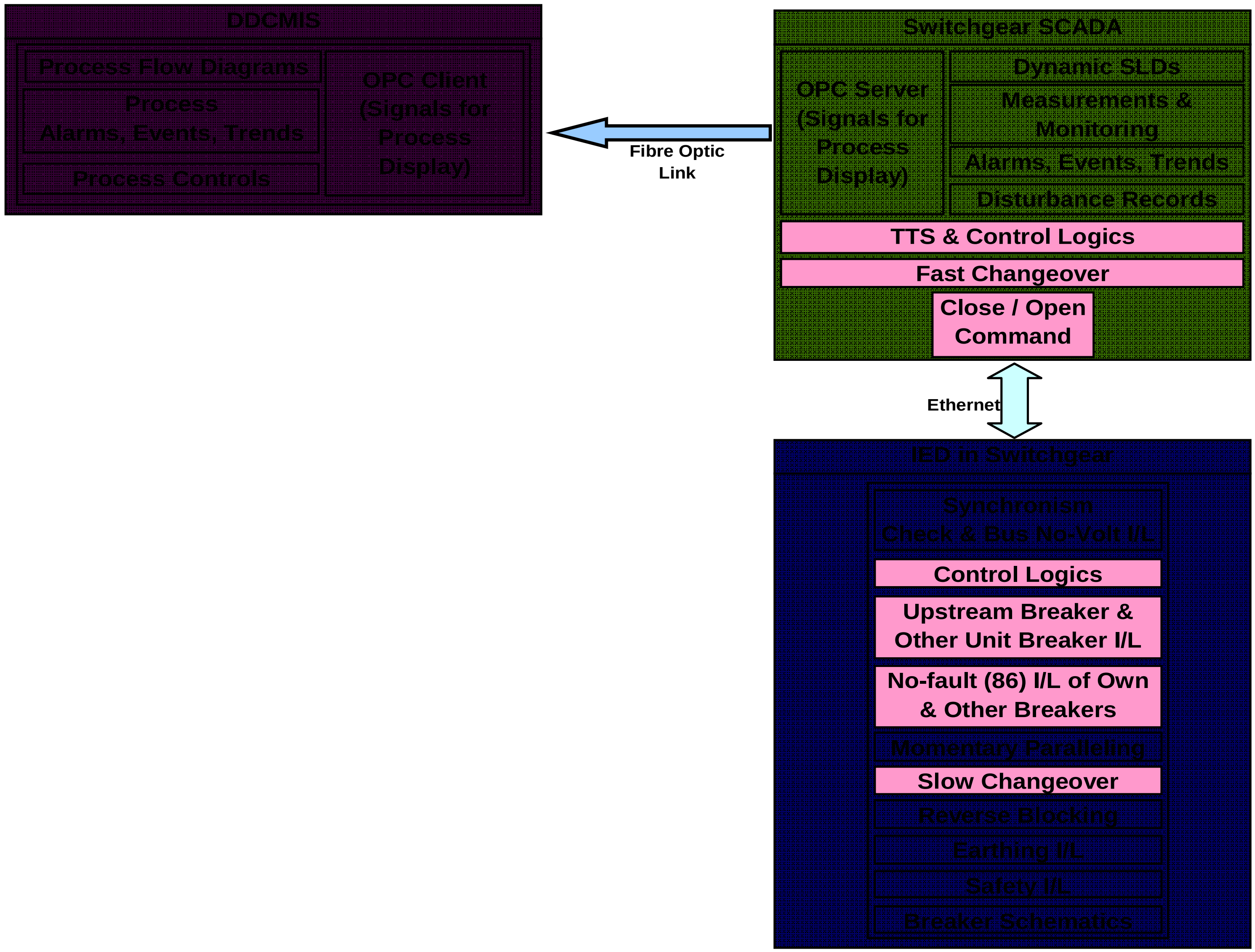
- *Interlocks related to external systems like upstream and other units' breakers to be built in the IED*
- Interlocks related to the breaker being controlled like synchro-check, no electrical fault (86), Reverse Blocking and breaker schematics to be built inside the breaker's IED
- *Bus transfer logics to be built with separate special-purpose IED with hardwired interlocks*
- *No need of hard wiring Breaker on / off status and electrical fault (86) are the signals to DDCMIS*
- Other important signals (about 15 per breaker) to be provided to DDCMIS for process displays through OPC (OLE for Process Control) link – *Only for Motor feeders*

# Migration to SCADA Controls



# CB Controls From SCADA

## Control Philosophy - Incomer / Bus-coupler / Tie (MV)

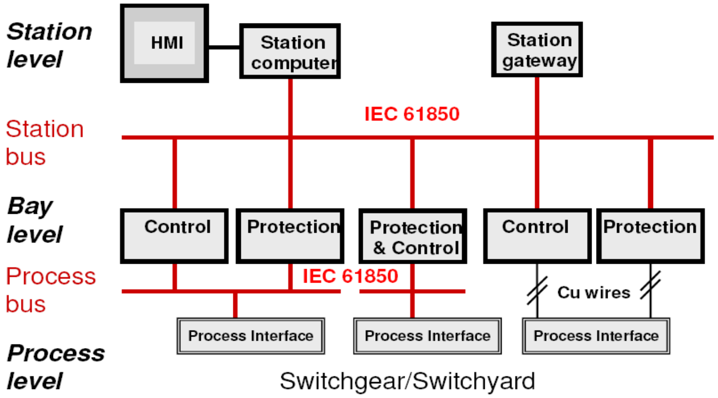


# Advantages Of Electrical SCADA

- No / Negligible Additional Hardware
  - Numerical Relays (IEDs) already part of Switchgears
  - Communication Network already there
    - Network Redundancy to be added
  - Servers with Redundancy already being specified
- No / Minimal Hard-wiring
  - Control commands through Network (FO)
  - No Hardwired feedback
- IEC61850 Platform
  - Ease of Engineering
  - Better coordination
  - Flexibility

# SCADA Network Configurations

# System Design Drivers




Driven by main requirements as ...

- Functionality
- Performance
- Availability
- Single Point of Failure
- Cost

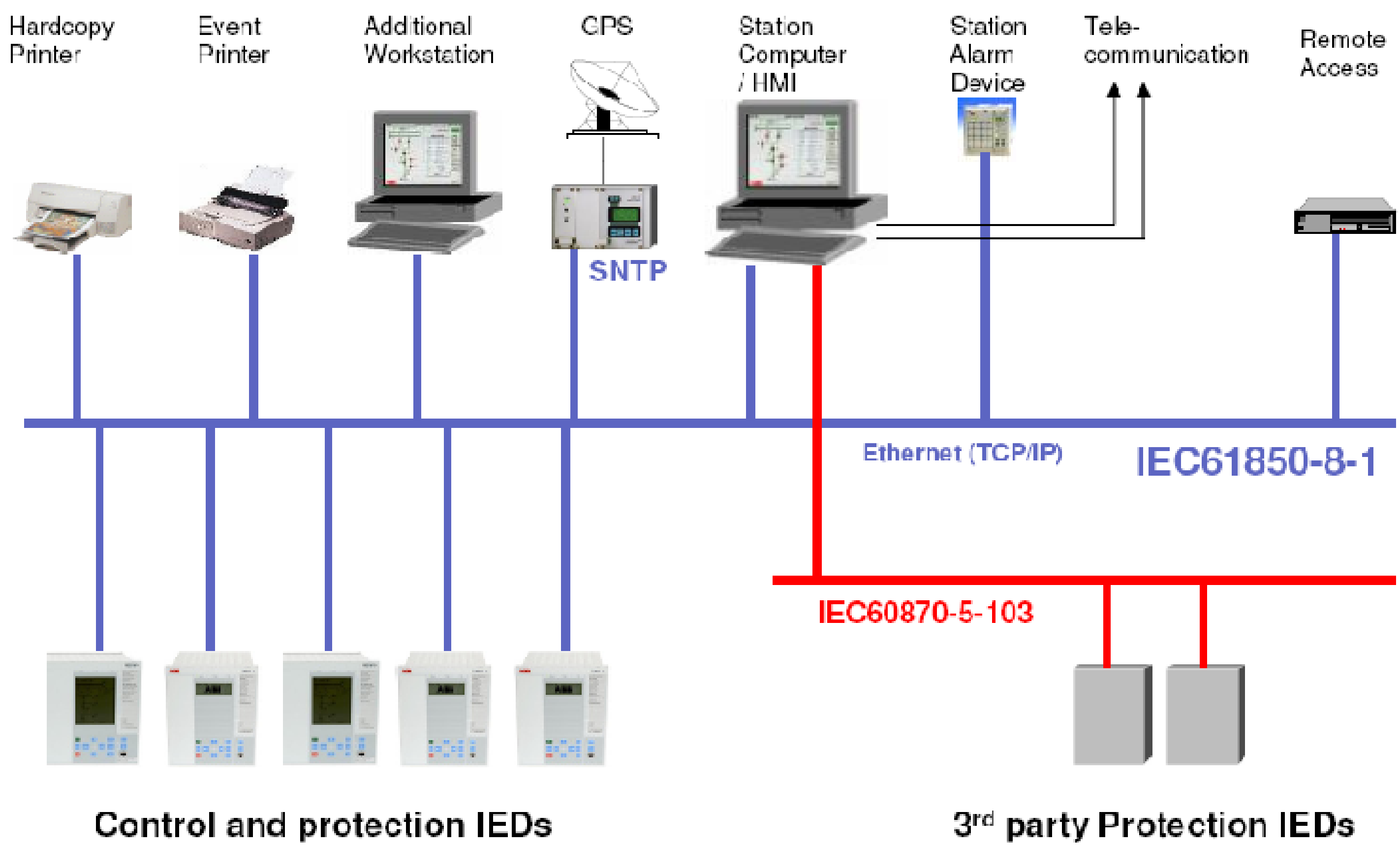
From logical architecture to physical architecture

- Logical architecture provides
  - Functionality
  - Relation between the functions
- Physical architecture provides
  - Assigns functions to devices
  - Real communication technology / network

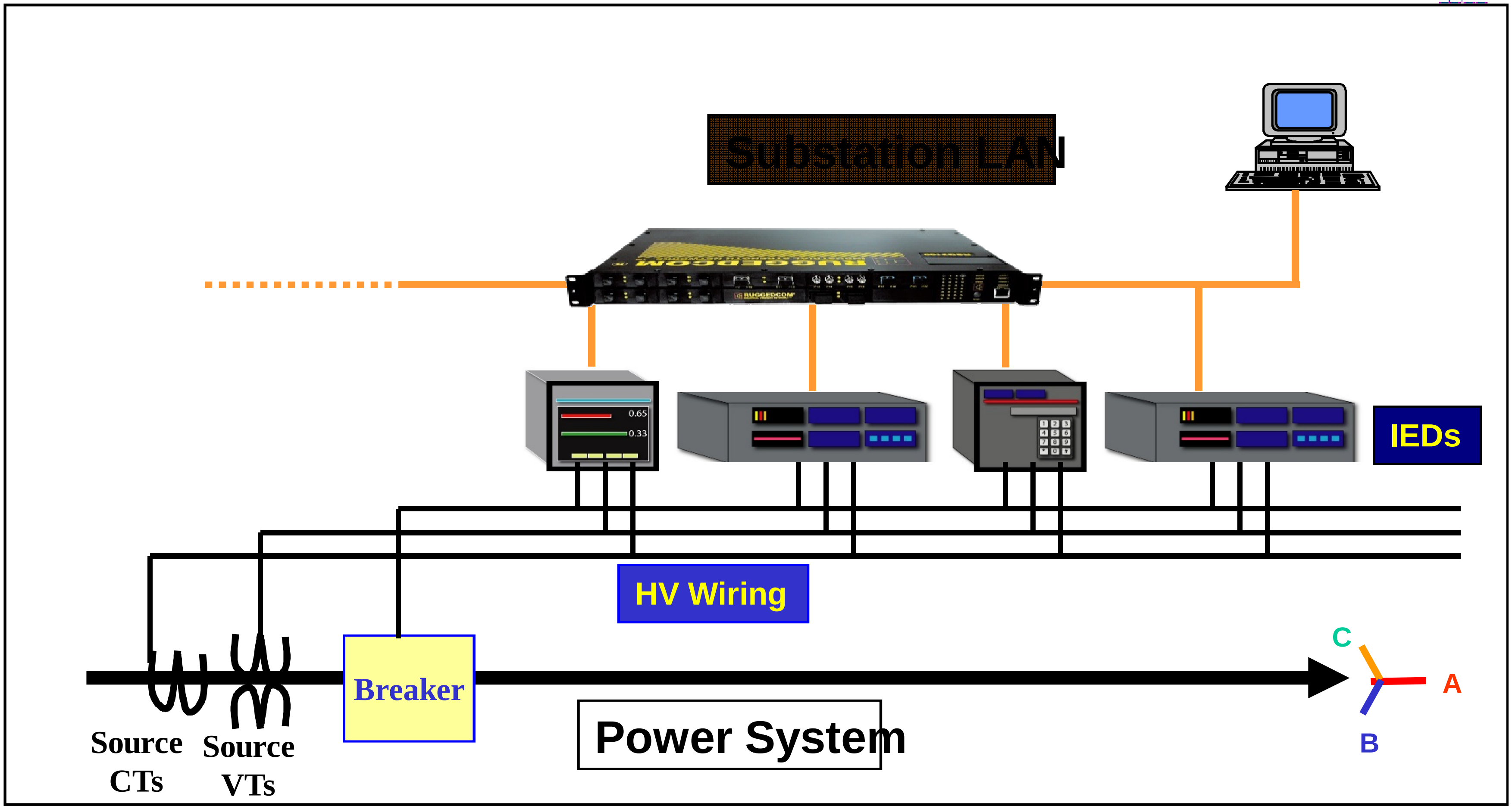
For the design of the communication system, the geography or geometry of the site has to be known e.g.

- Decentralized kiosk
- Centralized rooms

# BASIC SAS

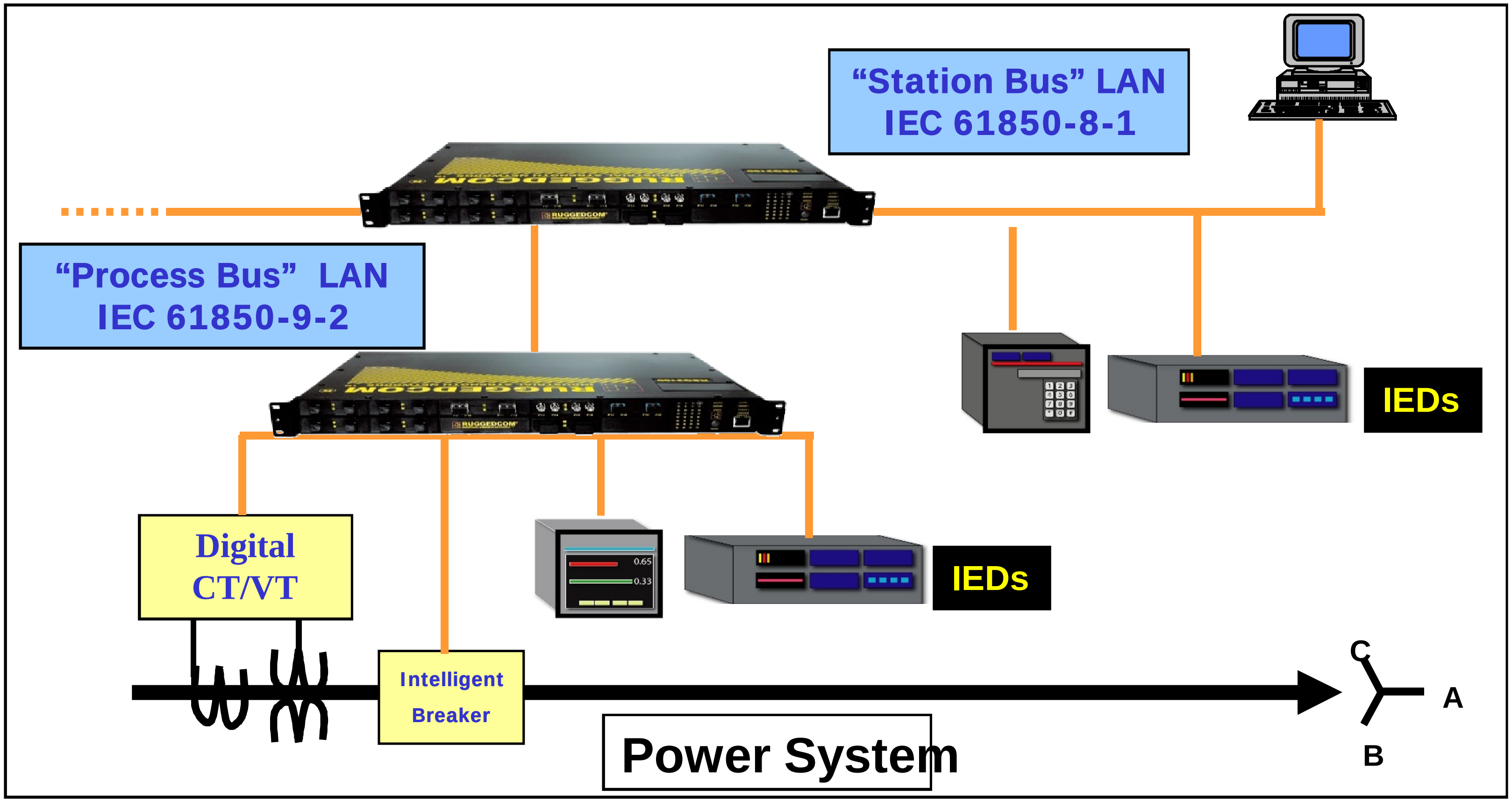

Hardcopy Printer
Event Printer
Additional Workstation
GPS
Station Computer / HMI
Station Alarm Device
Tele-communication
Remote Access
SNTP
Ethernet (TCP/IP)
IEC61850-8-1
IEC60870-5-103
Control and protection IEDs
3rd party Protection IEDs

# Typical Ethernet Substation



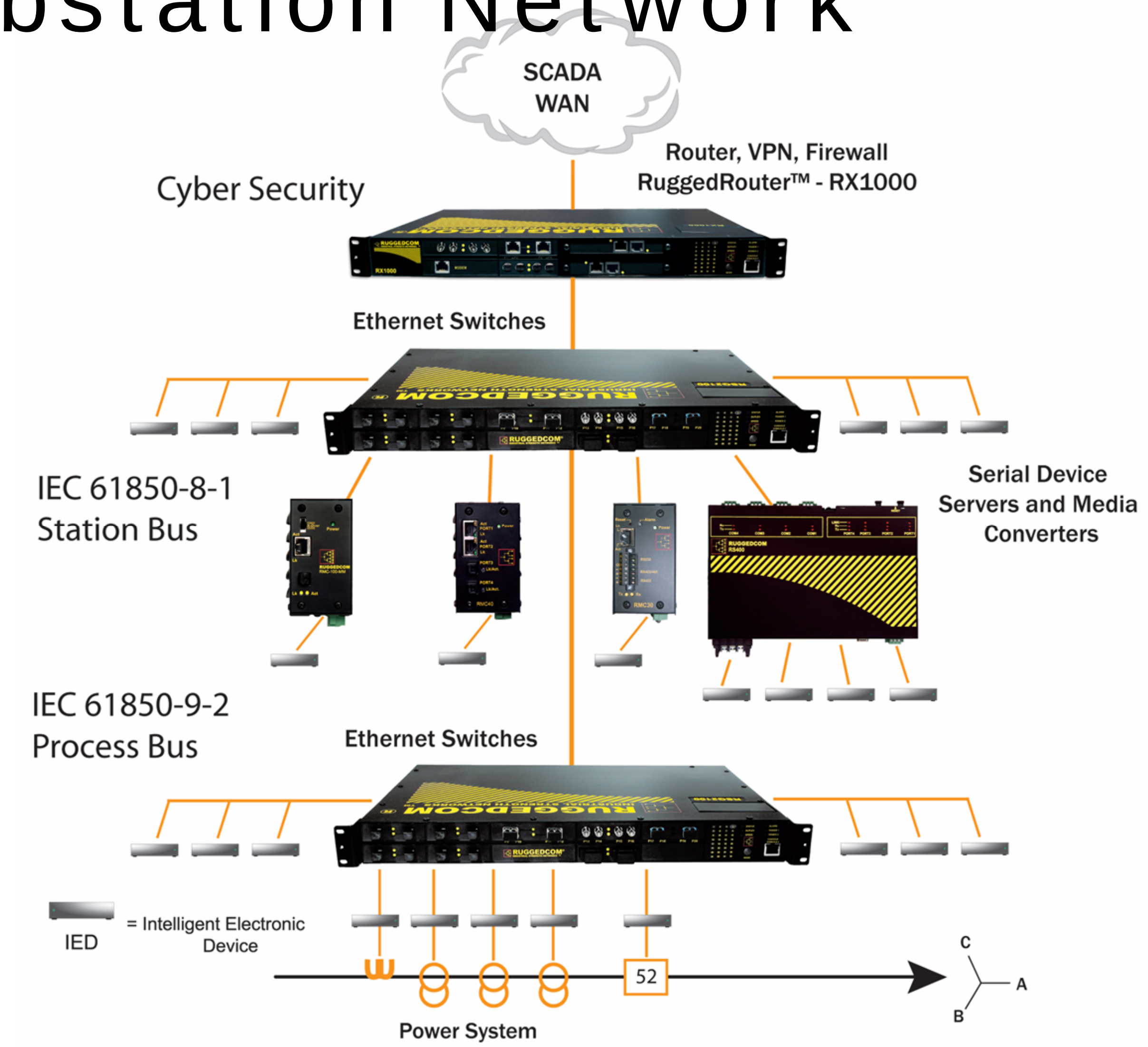

**The Substation LAN provides a high-speed communications bus between a variety of IEDs (e.g. Relays, RTUs, Meters, etc...)**

# IEC 61850 Substation

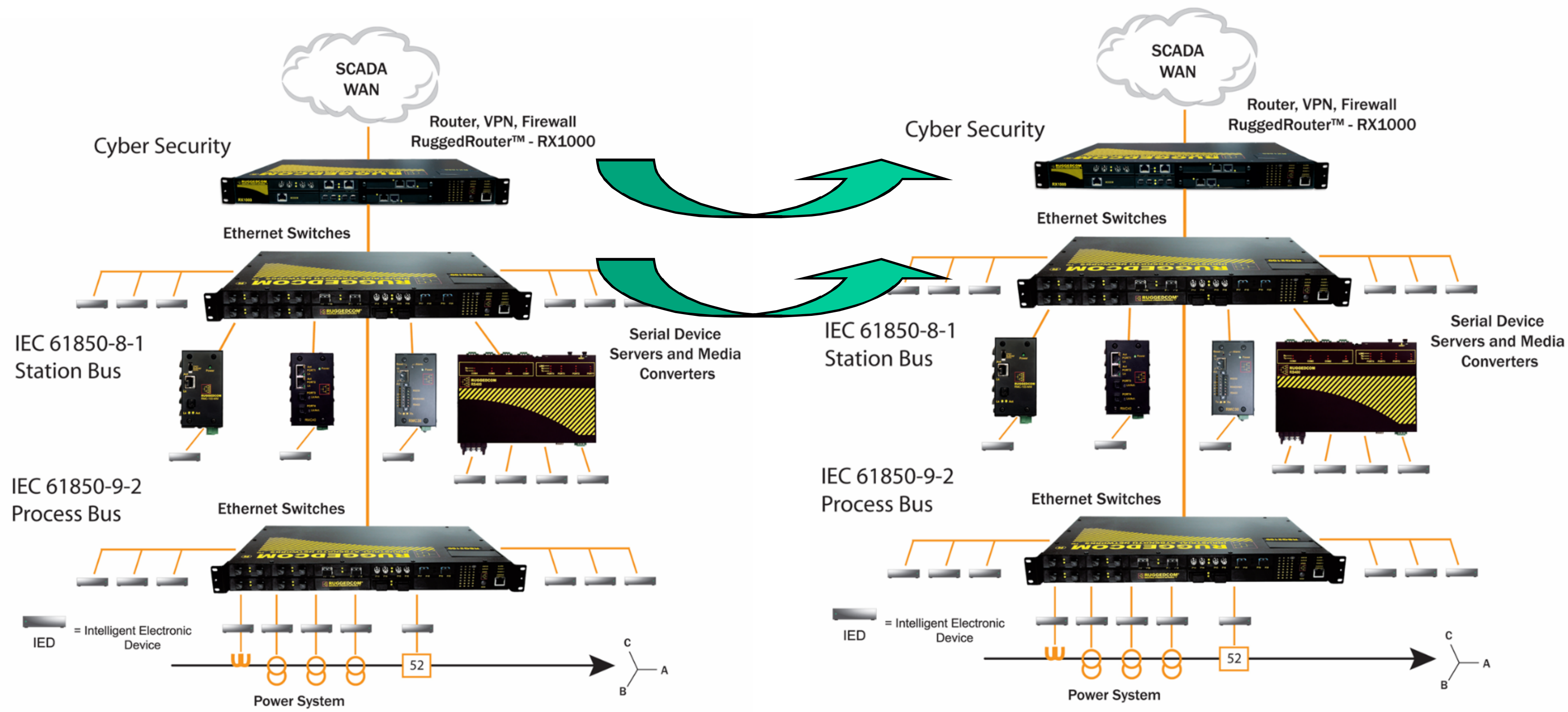



**The "Digital Substation": both power system data and control over the LAN.**

# Substation Network



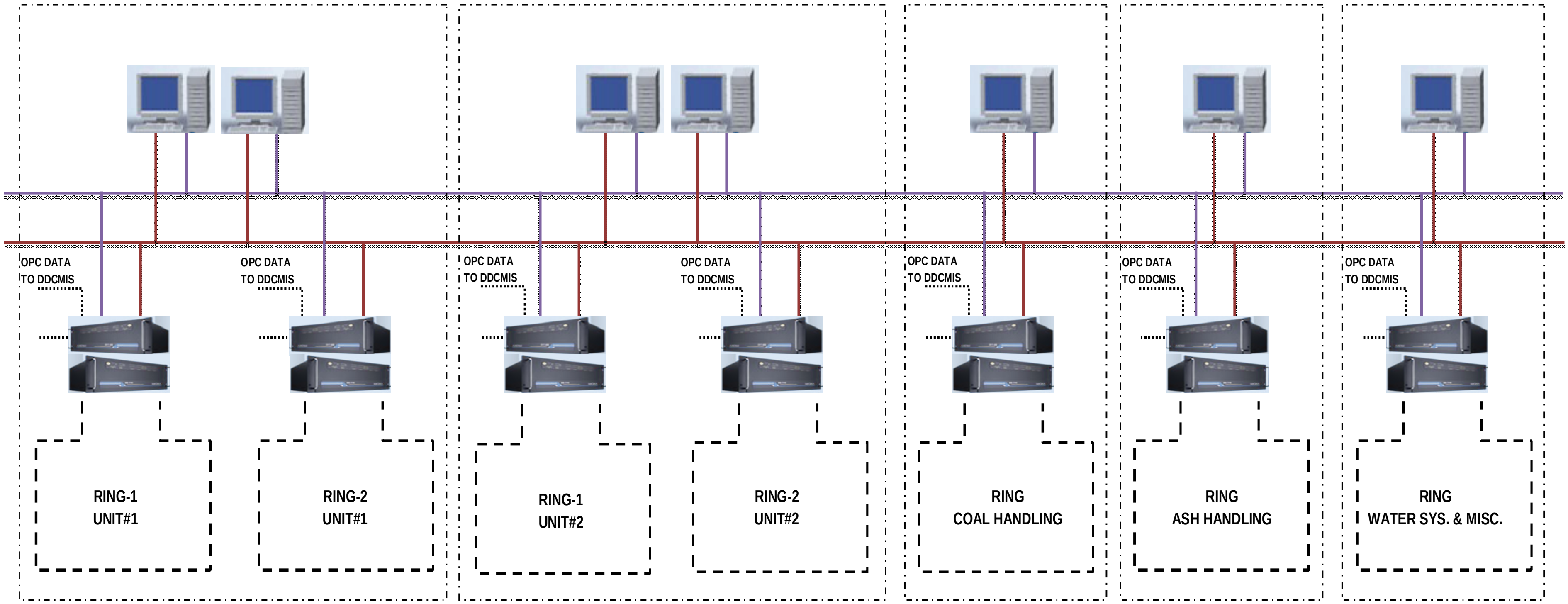
# Substation Network recovery



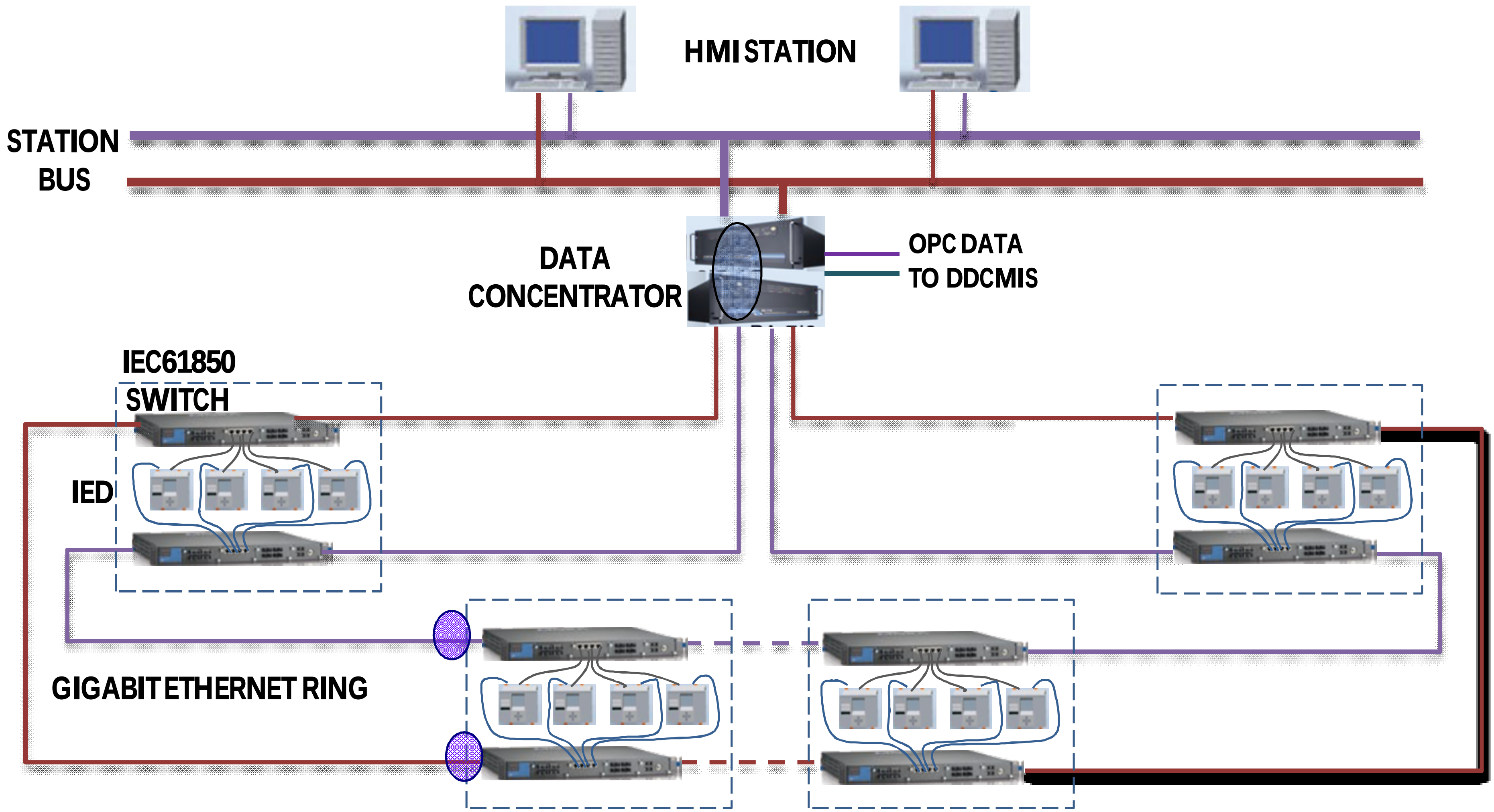
# Design Philosophy

- Decentralized System
  - All Automatic Logics built inside the Relays / BCUs
    - Network-independent Logics
  - HMI for Manual Control & Data Acquisition
  - Main Unit Bus transfers through Fast Bus Transfer Device
  - Critical Interlocks Hardwired

# Overall Architecture



# Architecture with Redundancy



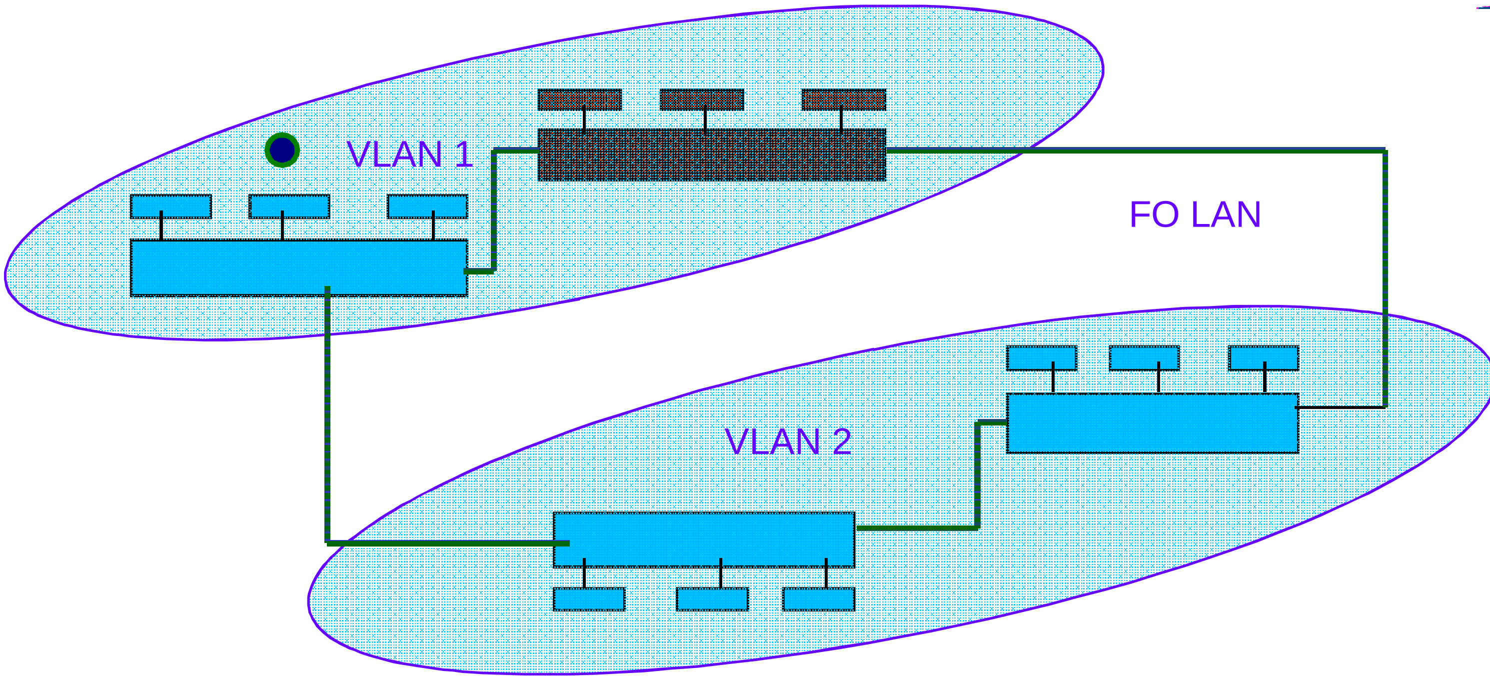
# Hardware Implementation

- Distributed system
- Data concentrators Geographically distributed
  - 2Nos per unit placed in CER
  - 1No each in Water System, Coal & Ash Handling areas (Engineering)
- Numerical Relays & BCUs (wherever required) in Switchgears
- Ethernet Switches with Copper & Fibre ports mounted in Switchgears
- Fibre Optic cable
  - Rings of each data concentrator
  - Station LAN
  - Interconnection with DDCMIS

# Reliability Considerations

- Numerical Relays – Highly reliable
- Replacement and Restoration is very fast
- All network components are tried, tested & certified for harsh environments
- Redundancy at all Levels
  - Server – Hot Standby
  - Ethernet Network – Redundant Rings with PRP
  - IED – Dual Communication Ports with PRP
  - Redundant DC / UPS Power Supply to All Devices
- Separate LV Panels at Extreme ends of MV Switchgears to keep Ethernet Switches & Power Supplies

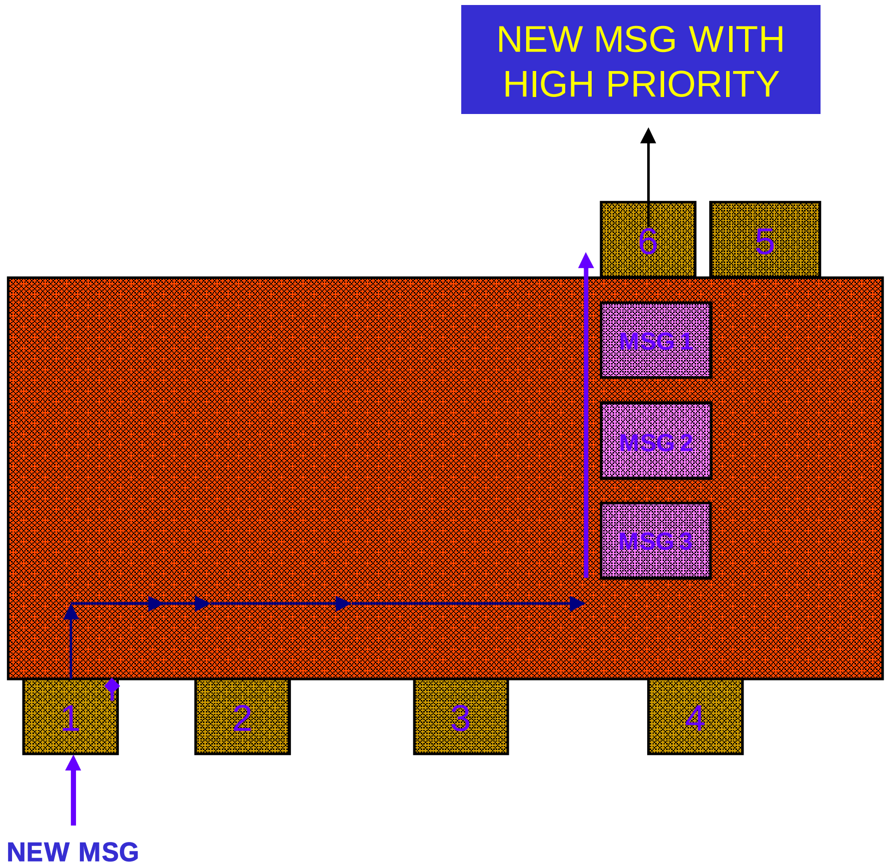
# Implementation of GOOSE Controls ..VLAN

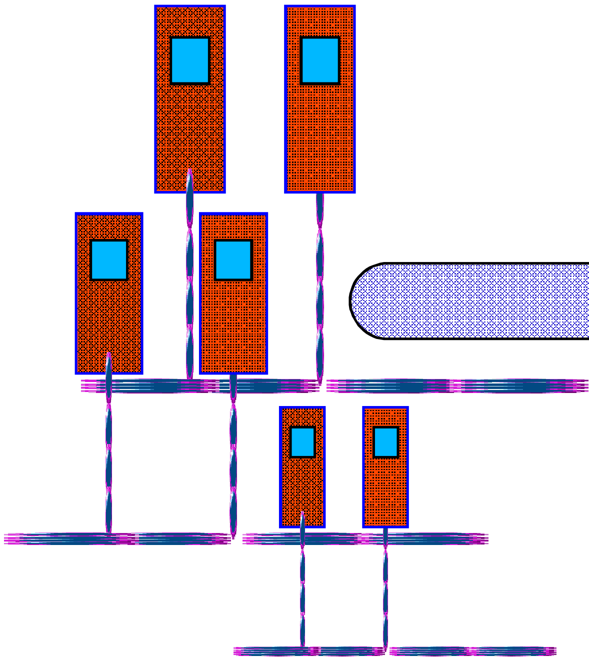



- Use of Virtual Local Area Network (VLAN)
- Group of Ports that form a Broadcast Domain
- Separation of Traffic – Better Bandwidth Usage
- Each Ring having 100 Numerical relays
- VLANS defined as per requirement for optimized Goose Traffic

# Implementation of GOOSE Controls..QoS

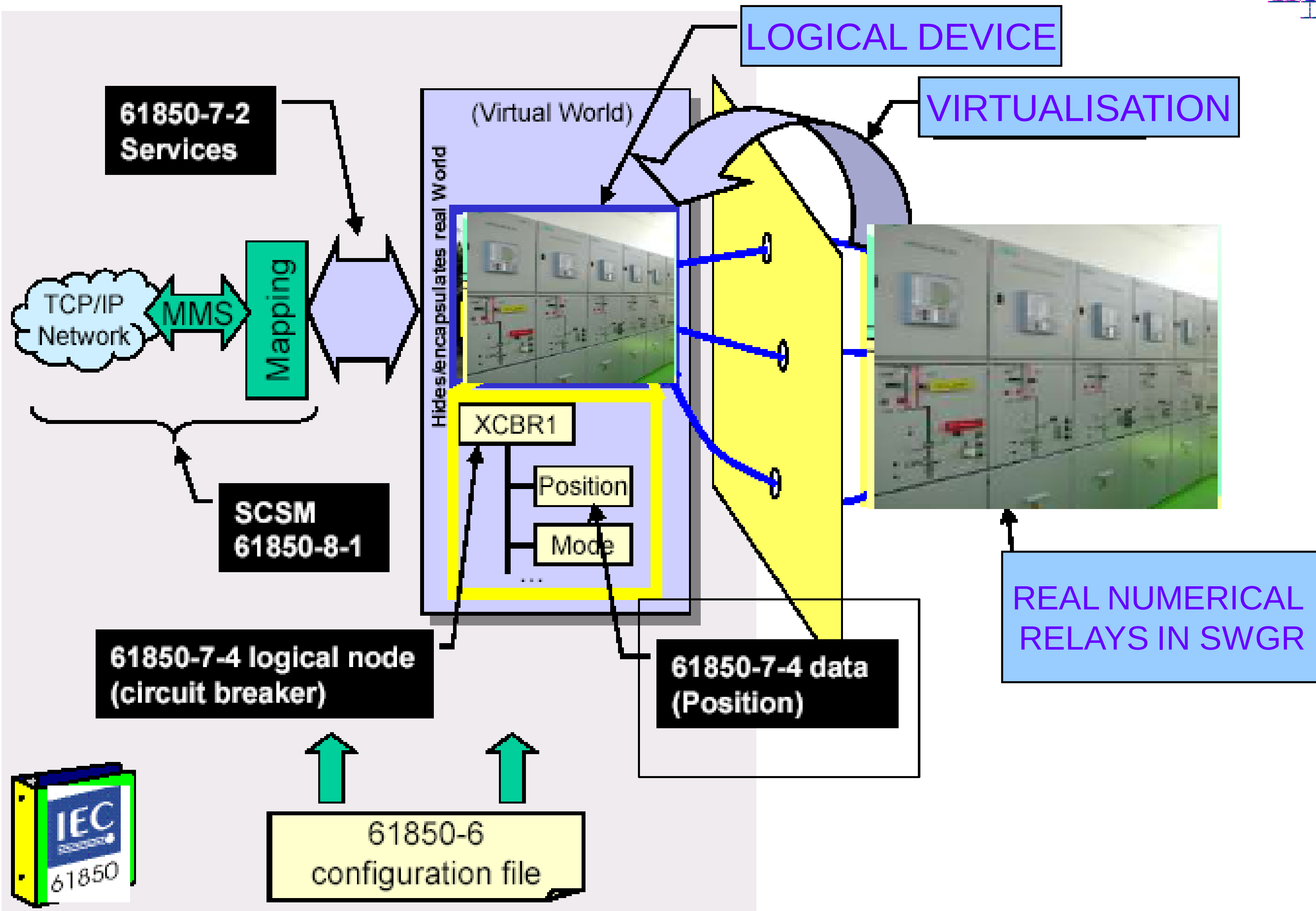
- Use of Quality of Service (QoS)
- Priority attached to each Message
- Priority processing of Message inside the Ethernet Switch
- 8 Levels available





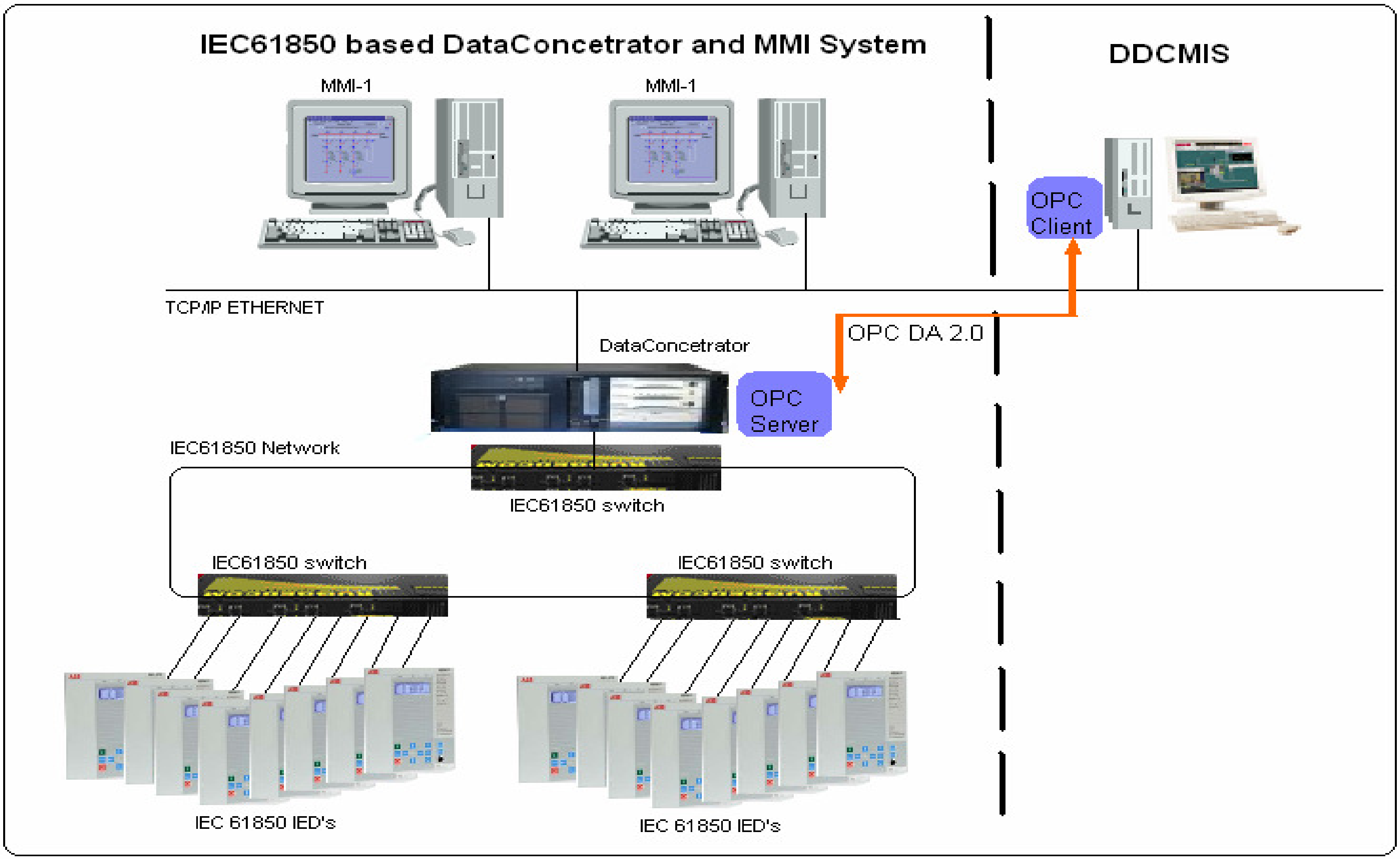
# IEC 61850 Interface with DDCMIS

# 61850 Scope



LOGICAL DEVICE
VIRTUALISATION
61850-7-2
Services
(Virtual World)
Hides/encapsulates real World
TCP/IP
Network
MMS
Mapping
SCSM
61850-8-1
XCBR1
Position
Mode
...
61850-7-4 logical node
(circuit breaker)
61850-7-4 data
(Position)
REAL NUMERICAL
RELAYS IN SWGR
IEC
61850
61850-6
configuration file

# OPC Interface with DDCMIS



## INPUT/OUTPUT SIGNALS for Motor Feeder (Feeder Type - DAX)

| Sr. No. | Input Description | ON State Description | OFF State Description | Signal for DDCIMS |
|---|---|---|---|---|
| | **Status Signals** | | | |
| 1 | Breaker Close Position | Close | Open | ✓ |
| 2 | Breaker Service Position | ON | OFF | ✓ |
| 3 | Breaker Test Position | ON | OFF | ✓ |
| 4 | Reverse Block | Operated | Reset | ✓ |
| 5 | 86 Trip | Operated | Reset | ✓ |
| 6 | Under Voltage trip | Operated | Reset | ✓ |
| 7 | Trip Circuit Healthy | Healthy | Unhealthy | ✓ |
| 8 | Numerical Relay | Healthy | Unhealthy | ✓ |
| 9 | Thermal Overload Alarm/Warning Element | Operated | Reset | ✓ |
| 10 | Thermal Overload Trip Element | Operated | Reset | ✓ |
| | **Analog Inputs** | | | |
| 12 | Current R (Ir) | | | ✓ |
| 13 | Current Y (Iy) | | | ✓ |
| 14 | Current B (Ib) | | | ✓ |
| 15 | Current N (In) | | | ✓ |
| 16 | Active Power (P) | | | ✓ |
| 17 | Reactive Power (Q) | | | ✓ |
| 18 | Energy Kwh | | | ✓ |

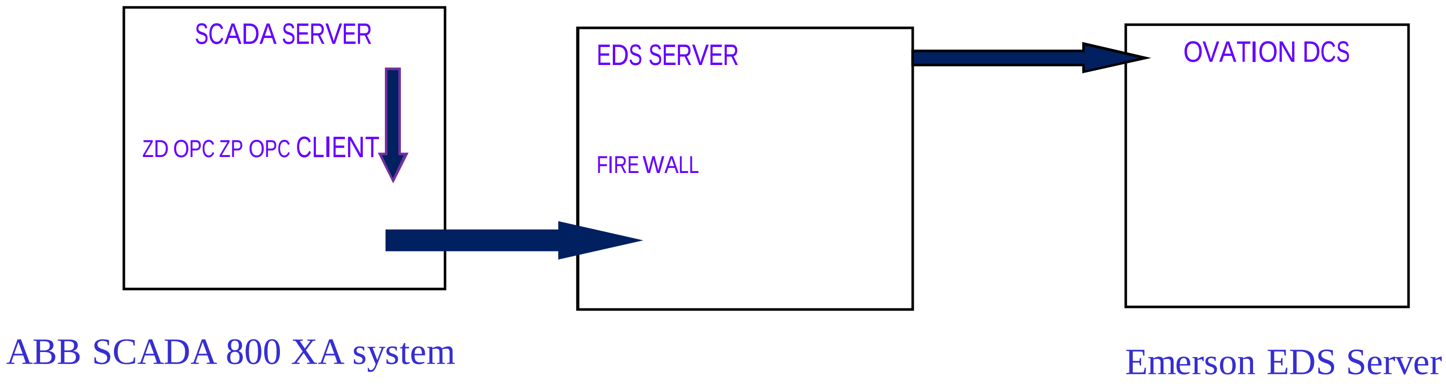
## INPUT/OUTPUT SIGNALS for LT Incomer Feeder (Feeder Type - DAI)

| Sr. No. | Input Description | ON State Description | OFF State Description | Signal for DDCIMS |
|---|---|---|---|---|
| | **Status Signals** | | | |
| 1 | Breaker Status | Close | Open | ✓ |
| 2 | Breaker In Service | ON | OFF | ✓ |
| 3 | Breaker In Test | ON | OFF | ✓ |
| 4 | Realy 86 Opearted (LED-1) | Operated | Reset | ✓ |
| 5 | Trip Circuit Healthy(LED-13) | Operated | Reset | ✓ |
| 6 | 25" in Sync Prem to DDCMIS(LED-14) | Operated | Reset | ✓ |
| 7 | Numerical Relay Healthy | Healthy | UnHealthy | ✓ |
| | **Analog Inputs** | | | |
| 8 | Voltage R-Y (Vry) | | | ✓ |
| 9 | Voltage Y-B (Vyb) | | | ✓ |
| 10 | Voltage B-R (Vbr) | | | ✓ |
| 11 | Current R (Ir) | | | ✓ |
| 12 | Current Y (Iy) | | | ✓ |
| 13 | Current B (Ib) | | | ✓ |
| 14 | Current N (In) | | | ✓ |
| 15 | Active Power (P) | | | ✓ |
| 16 | Reactive Power (Q) | | | ✓ |
| 17 | Power Factor (Pf) | | | ✓ |
| 18 | Frequency (Hz) | | | ✓ |
| 19 | Energy Kwh | | | ✓ |

## INPUT/OUTPUT SIGNALS for Transformer Feeder with Diff (Feeder Type - DBF)

| Sr. No. | Input Description | ON State Description | OFF State Description | Signal for DDCIMS |
|---|---|---|---|---|
| | **Status Signals** | | | |
| 1 | Breaker Status | Close | Open | ✓ |
| 2 | Breaker in Service Position | ON | OFF | ✓ |
| 3 | Breaker in Test Position | ON | OFF | ✓ |
| 4 | Bucholz Trip | Operated | Reset | ✓ |
| 5 | Winding Temp High Trip | Operated | Reset | ✓ |
| 6 | Oil Temp High Trip | Operated | Reset | ✓ |
| 7 | PRV Trip | Operated | Reset | ✓ |
| 8 | (86 Trip (LED-1) | Operated | Reset | ✓ |
| 9 | Numerical Relay Healthy | Healthy | Unhealthy | ✓ |
| 10 | TRF DIFF(87T) | Operated | Reset | ✓ |
| | **Analog Inputs** | | | |
| 11 | Current R (Ir) | | | ✓ |
| 12 | Current Y (Iy) | | | ✓ |
| 13 | Current B (Ib) | | | ✓ |
| 14 | Current N (In) | | | ✓ |
| 15 | Active Power (P) | | | ✓ |
| 16 | Reactive Power (Q) | | | ✓ |
| 17 | Energy Kwh | | | ✓ |

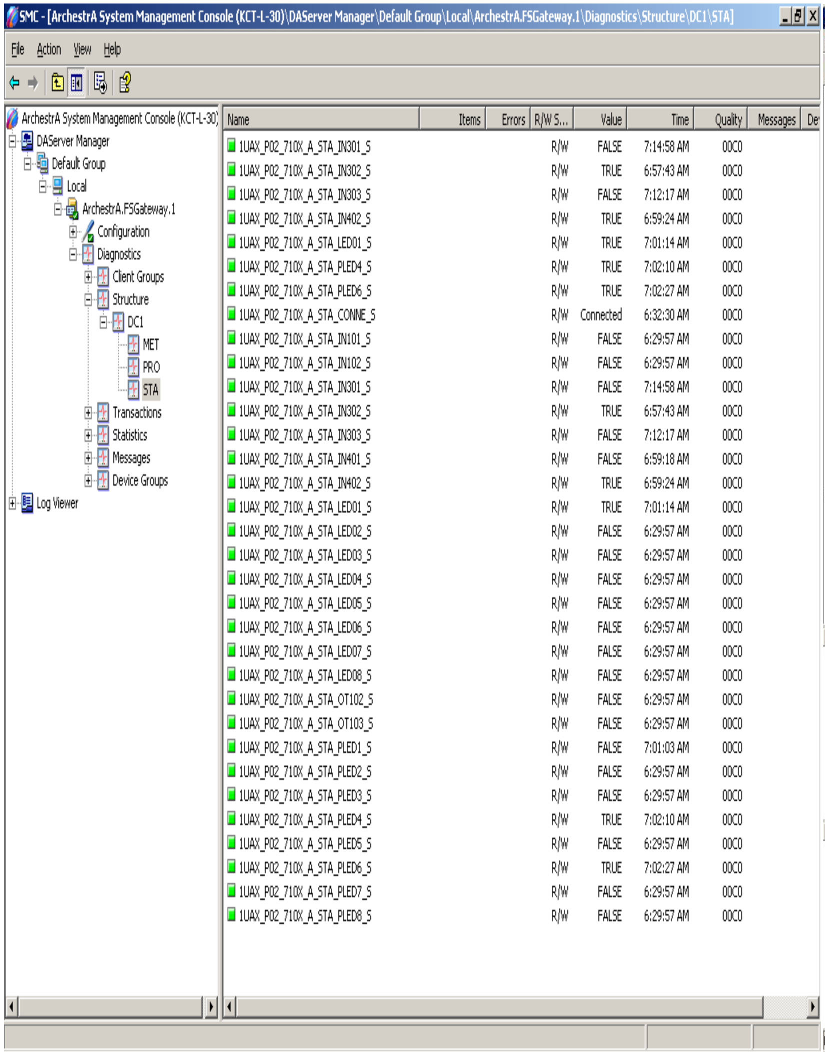
| Sr. No. | Input Description | ON State Description | OFF State Description | Signal for DDCIMS |
|---|---|---|---|---|
| | **Status Signals** | | | |
| 1 | Breaker Status | Close | Open | ✓ |
| 2 | CB in Service Position | ON | OFF | ✓ |
| 3 | CB in Test Position | ON | OFF | ✓ |
| 4 | 3 Ph Inst O/C (LED-2) | Operated | Reset | ✓ |
| 5 | Under Voltage (LED-9) | Operated | Reset | ✓ |
| 6 | Time Between Starts (LED-12) | Operated | Reset | ✓ |
| 7 | Trip Coil Healthy(LED-13) | Healthy | Unhealthy | ✓ |
| 8 | Major Relay Failure (LED-23) | Operated | Reset | ✓ |
| 9 | Thermal Over load alarm/warning element | Operated | Reset | ✓ |
| 10 | Thermal Over load Trip element | Operated | Reset | ✓ |
| | **Analog Inputs** | | | |
| 11 | Current R (Ir) | | | ✓ |
| 12 | Current Y (Iy) | | | ✓ |
| 13 | Current B (Ib) | | | ✓ |
| 14 | Current N (In) | | | ✓ |
| 15 | Active Power (P) | | | ✓ |
| 16 | Reactive Power (Q) | | | ✓ |
| 17 | Energy Kwh | | | ✓ |

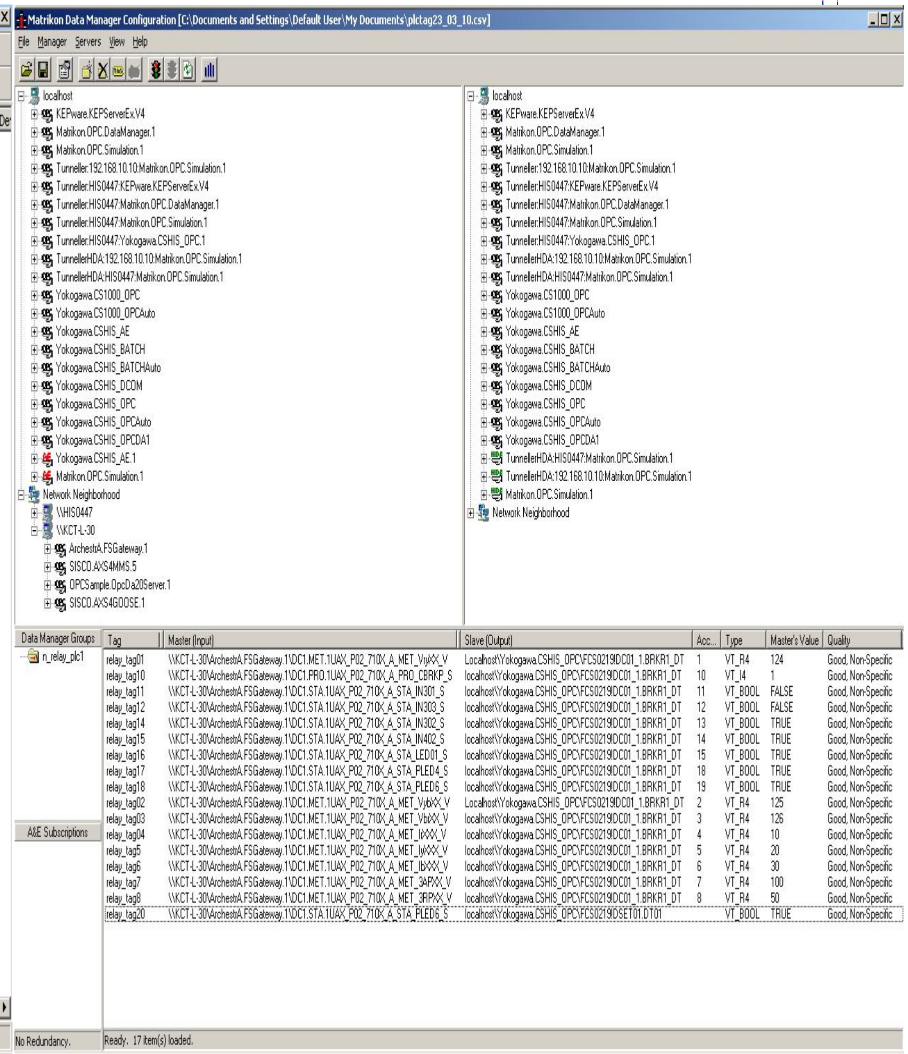



Data connectivity testing during FAT done to ensure the two systems i.e. the electrical SCADA on IEC 61850 and OPC DA and DCS systems are communicating

The ZD OPC ZP OPC client installed in SCADA server acts as a tunneller which feeds the data from the ABB OPC Server and passes it to EDS server through a fire wall

The test results show data connections between ABB 800 XA system and Emerson EDS server


SMC - [ArchestrA System Management Console (KCT-L-30)\DAServer Manager\Default Group\Local\ArchestrA.FSGateway.1\Diagnostics\Structure\DC1\STA]
File Action View Help
ArchestrA System Management Console (KCT-L-30)
DAServer Manager
Default Group
Local
ArchestrA.FSGateway.1
Configuration
Diagnostics
Client Groups
Structure
DC1
MET
PRO
STA
Transactions
Statistics
Messages
Device Groups
Log Viewer
Name Items Errors R/W S... Value Time Quality Messages


Matrikon Data Manager Configuration [C:\Documents and Settings\Default User\My Documents\plctag23_03_10.csv]
File Manager Servers View Help
localhost
Network Neighborhood
Data Manager Groups
A&E Subscriptions
Tag Master (Input) Slave (Output) Acc... Type Master's Value Quality
No Redundancy.
Ready. 17 item(s) loaded.

## Standards for Integration and Data connectivity for Unified Data Models

**In the energy sector the core standards emerging for standardization are**

- **TR 62357: Reference Architecture**
- **IEC 61968/61970: Common Information Model for EMS and DMS**
- **IEC 61850: Intelligent Electronic Device (IED) Communications at Substation level and DER**
- **IEC 62351: Vertical security for the TR 62357**
- **IEC 60870: Telecontrol protocols**
- **IEC 62541: OPC UA – OPC Unified Architecture, Automation Standard**
- **IEC 62325: Market Communications using CIM**

# OPC CLASSIC OR OPC UA

Until now, the data interface between plant DCS system and Electrical SCADA through Classic OPC was considered and implemented only for data exchange of soft data. OPC UA throws a very bigger possibility for automation & electrical engineers to explore & benefit from direct integration with IEC 61850. The mapping of the OPC UA with the IEC 61850 is promising and will open new vistas of collaboration between the plant automation & electrical systems.

Many standardization efforts are going on for creating harmonization and enabling interoperability of systems in terms of communications. IEC TC 57 has identified IEC 61850 and CIM models as core standards which shall play key roles in the seamless integration for smart electrical systems. OPC Unified Architecture, which is also a core standard specifying a server-client-architecture, is also used to harmonize the two mentioned data models based on a common access layer for higher interoperability of Power plant electrical and DCS systems and also for the management of SCADA systems.

## Concept of OPC UA

**Unified Access**: OPC UA integrates existing OPC specifications DA, A&E, HDA, commands, Complex data, and Object Types in one specification and Access via Firewalls and across the Internet OPC UA uses message based security which means messages can be relayed through HTTP, UA TCP port or any other single port available

**Reliability**: OPC UA implements a configurable timeouts, error detection, and communication failure recovery. OPC UA allows redundancy between applications from different vendors to be deployed

**Security OPC UA** is Secure-by-default, encryption enabled, and uses advanced certificate handling

**Platform neutrality OPC UA** is designed to be independent of the platform. Using SOAP/XML over HTTP, OPC UA can be deployed on Linux, Windows XP Embedded, Vx Works, Mac, Windows 7, and Classical Windows platforms

**OPC Unified Architecture** extends the highly successful OPC communication protocol, enabling data acquisition and information modelling and communication between the plant floor and the enterprise reliably and securely

.

**Future-ready and Legacy-friendly**: OPC UA uses binary encoded data; hence the response issue in Classic OPC is expected to be addressed. The scalability offered is tremendous; OPC UA can work on embedded devices which also will address the response issue

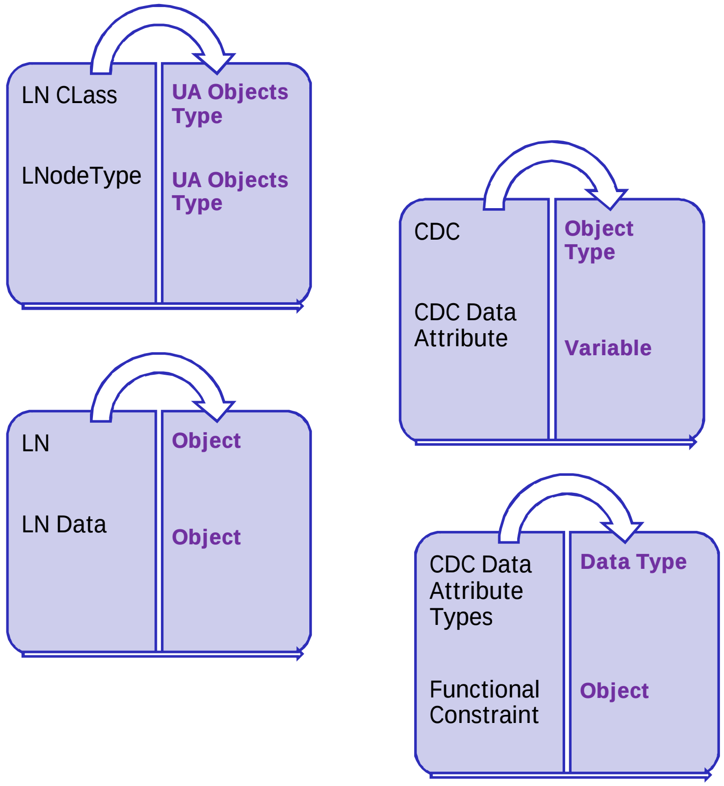
**Easy configuration and maintenance:** As it does not use DCOM, it is fire wall friendly. The OPC client design in case of UA is much simplified since the entire information modelling is done in the UA server

**Higher Performance: Being platform independent**, it is the niche solution as many DCS vendors are also expected to go non-Windows platforms. OPC UA supports redundancy although many of the implementations are yet to add this feature. In addition, mechanisms like failover & heartbeat will make the communication more robust than its classic counterparts.

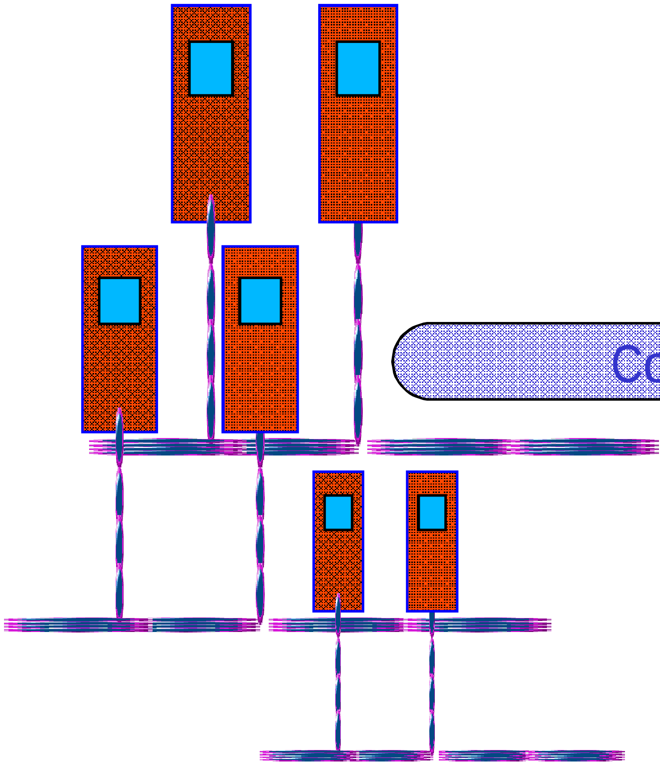
The development of the OPC Unified Architecture (UA) enables a new and very promising opportunity to harmonize data models

The UA specifies an abstract server-client-architecture based on a defined information model and services

The architecture provides that a domain specific information model is used to represent certain objects and hence , a UA-server can be run with an IEC 61850-based model.

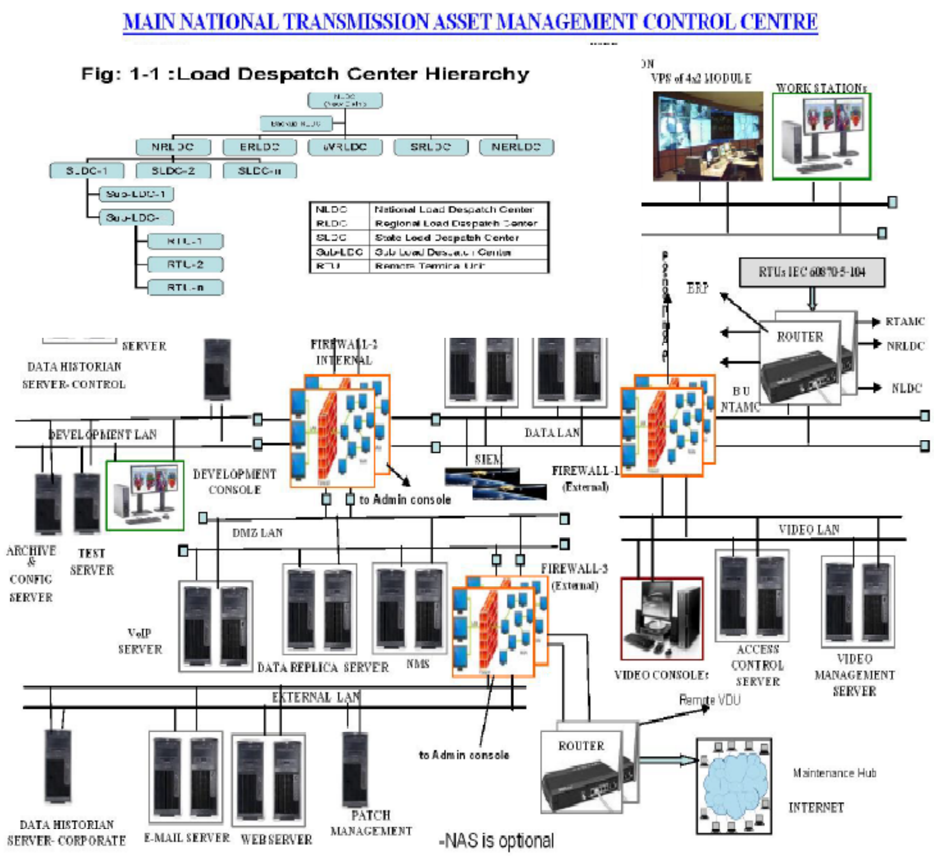



Mapping IEC 61850 data structures onto OPC UA address space



# Conclusions

# NATIONAL TRANSMISSION ASSET MANAGEMENT CENTRE




**Remote Operation and Monitoring of 192 Substations of POWERGRID**

**To Have Unmanned Substations through Automation and SCADA Networks**

# Paradigm Shift In Controls and Information Flow

Fig: 1-1 :Load Despatch Center Hierarchy

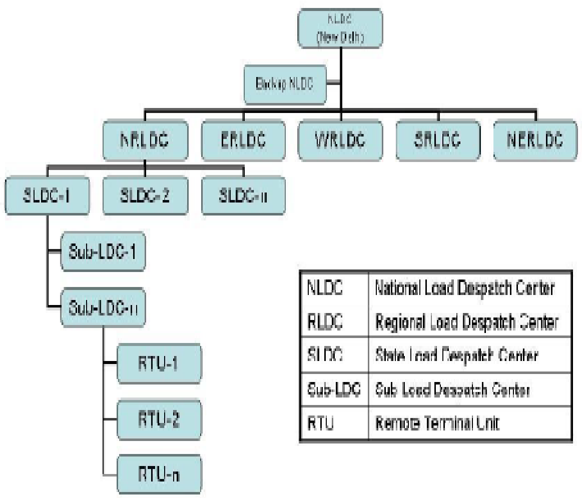
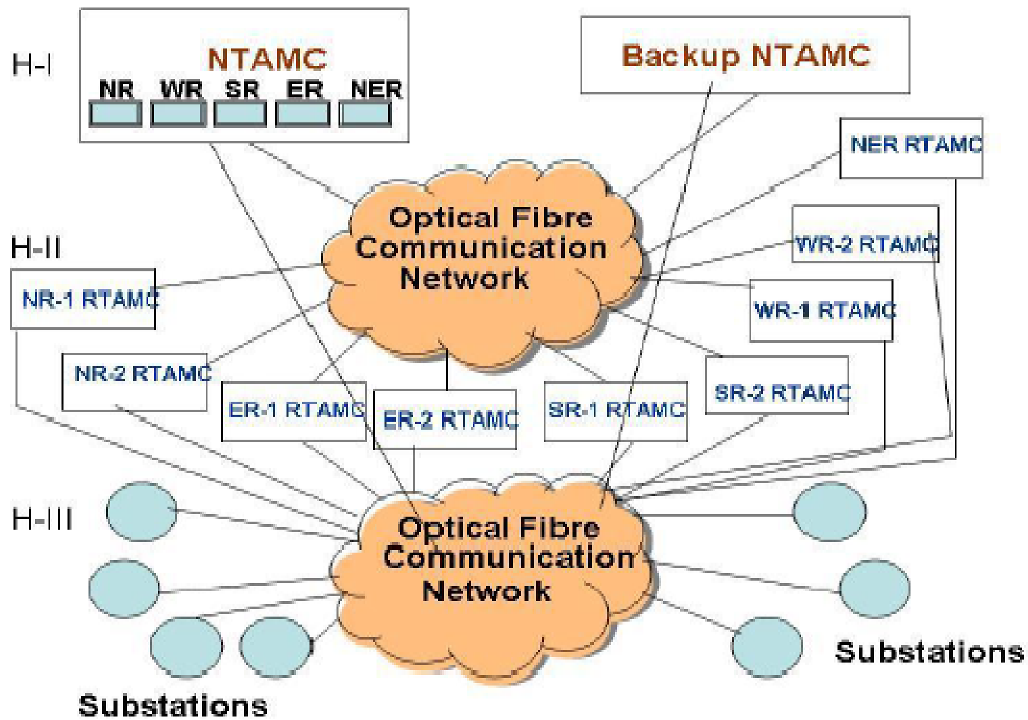



Fig 1-2 : NTAMC Hierarchical Control



- Standardisation of Protocols ...the key for Integrated Controls in Plants and Process Industry
- As Automation levels and complexity are increasing, concept of universal platform for all type of controls shall emerge
- Standardisation of Network configuration a key to Reliable networks and reliable operations

# Thank You

My email csaroj@ntpc.co.in