



---

TEXAS A&M RELAY CONFERENCE | MARCH 22 - 25, 2021

# **Modernization of power distribution and automation system - A real world experience**

Joe Xavier, Global Product Manager - ANSI, Digital Substation Products & Systems



# Content

- Project overview
- Solution drivers
- Protection and Control architecture
- IEC 61850 Implementation primer
- Lessons learned
- Summary
- Q&A

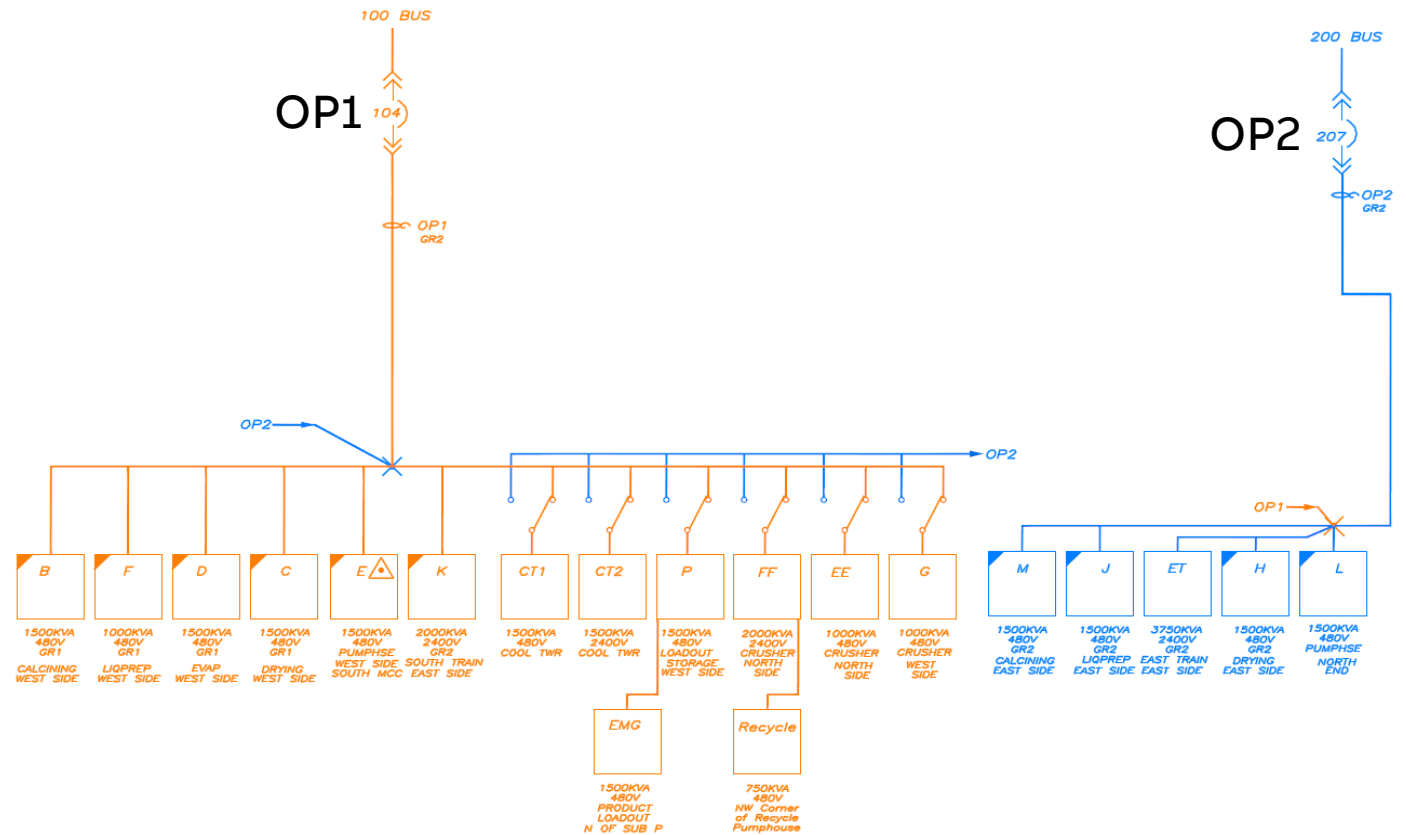
# Existing network

## Large process industry

Large Soda Ash (Trona) mine in Wyoming  
Originally built in 1968

Aging power distribution infrastructure causing  
frequent power interruptions

No integration of power distribution system  
with the plant operations



# Project Drivers

## Problems with the current system

- Over the last 30 years these connections were subjected extreme weather, Trona dust, Soda Ash,
- The 11 distribution locations were installed to be load-break isolation points, but most connections cannot be used as load-break points anymore because of the difficulty in disconnecting and the hazard of reconnecting online
- OP1 and OP2 faults, although short in duration, cause significant prolonged production downtime
- Coordination of the existing protection system allows some feeder faults to travel all the way upstream and trip OP1 or OP2 feeder breakers
- From January 2013 to June 2016, OP1 and OP2 related failures caused more than 28,000 tons for lost SA production
- Equipment damages because of power loss: motors, transformers, PLCs, etc.



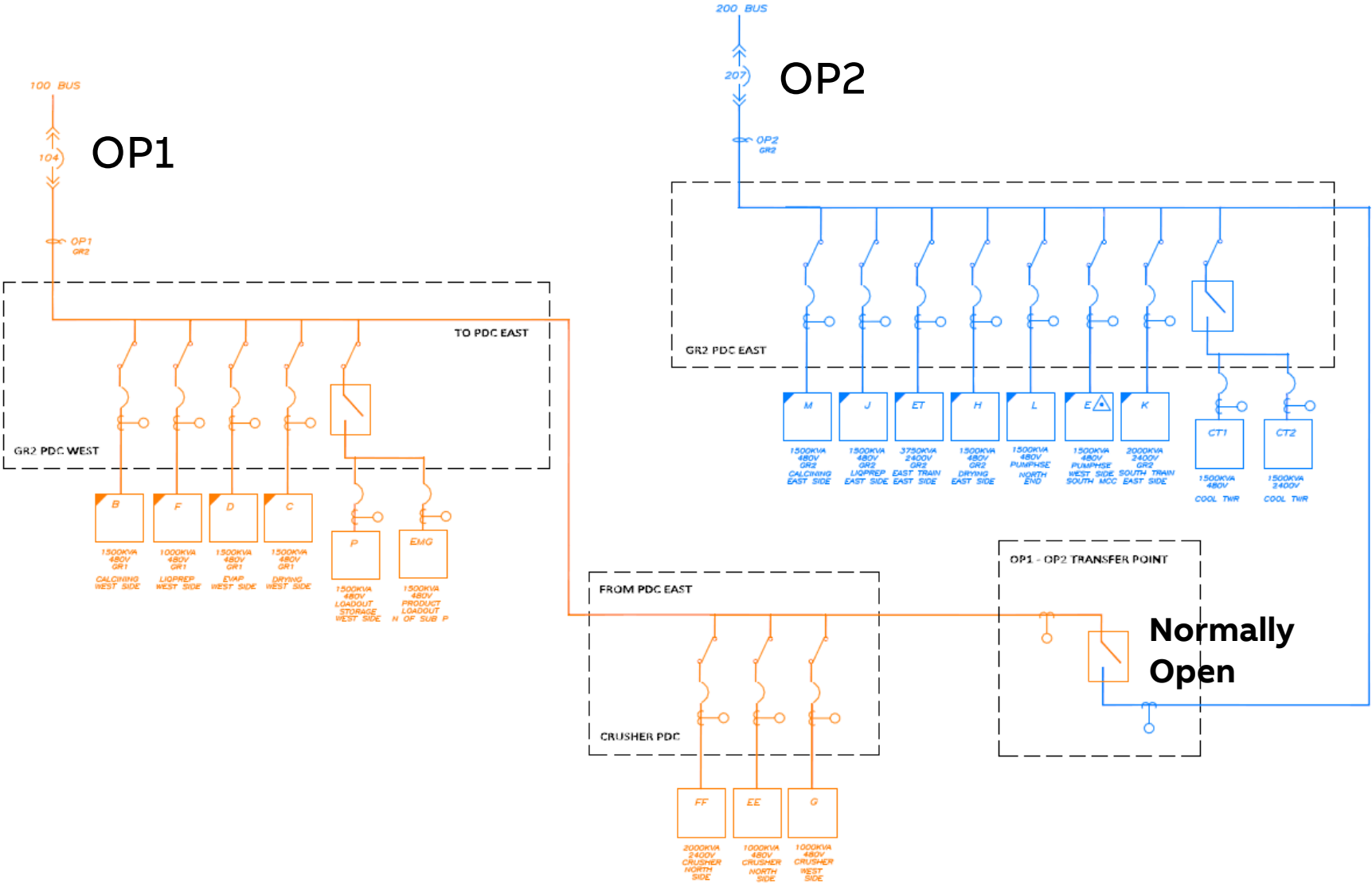
Existing termination points



Plant environmental conditions



# Original Proposed Solution



## Design Review

- Initial discussion with consultants
- Performed a system study to identify possible solutions
- Discussed probable solutions with TATA Consulting Engineers, India, to confirm the solution is the best practice in industry
- Three new power distribution centers (PDC) will feed East GR2, West GR2 and Crusher
- The switchgear will have relays with transformer protection elements, so existing unsafe oil-switches can be eliminated
- The relays communicate to provide faster tripping and better fault segregation

**SAFETY**

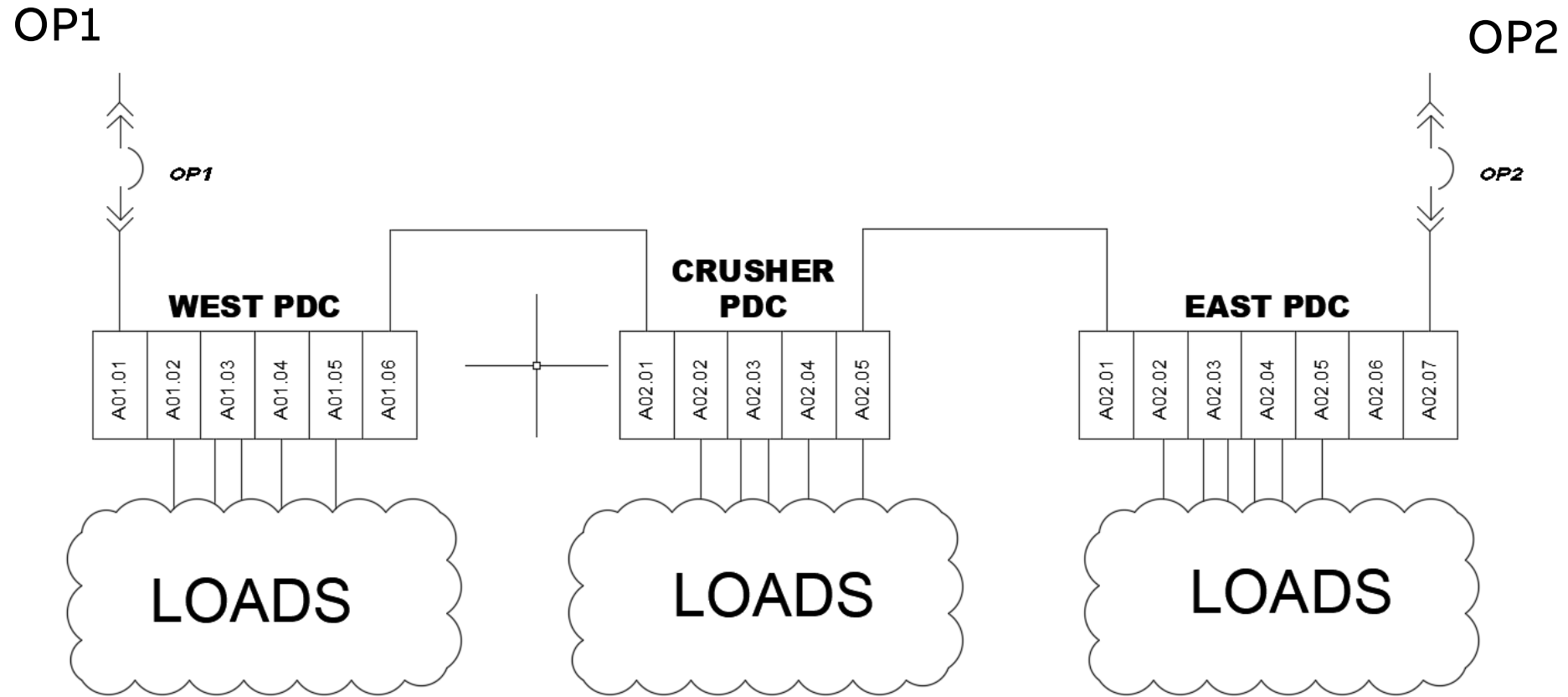
Redundancy

Automation

Efficiency

Integration

# Final Solution



---

# Advantages of New Design

## Safe

- Arc-flash hazard mitigation
- Faster tripping time for high-current faults using Bus Blocking protection scheme
- Feeder relays include distribution transformer protection

## Robust

- Fault Detection, Isolation, Restoration (FDIR) minimizes downtime
- Distribution equipment is in a controlled indoor environment
- Easier trouble-shooting – all information displayed on Substation HMI

## Future Ready

- Relay and SCADA communications via IEC 61850 protocol

## Cost Conscience

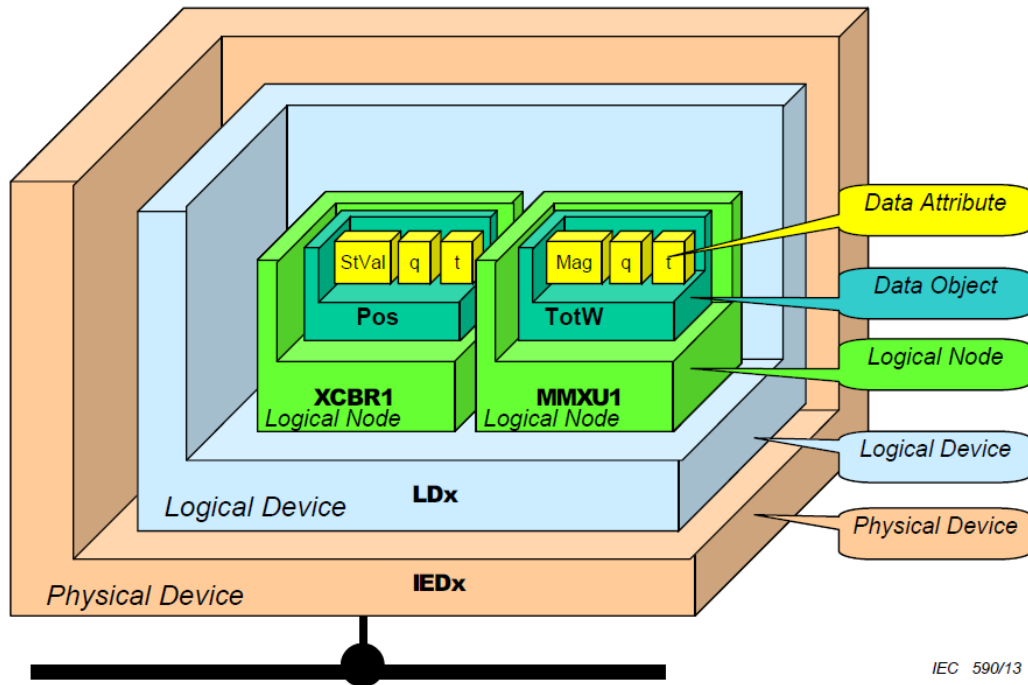
- No time-based maintenance using breakers with magnetic actuators
  - Maintenance on OP1 & OP2 without an outage
  - Reduced cable run distances by almost half
  - Reduced spare parts inventory
-



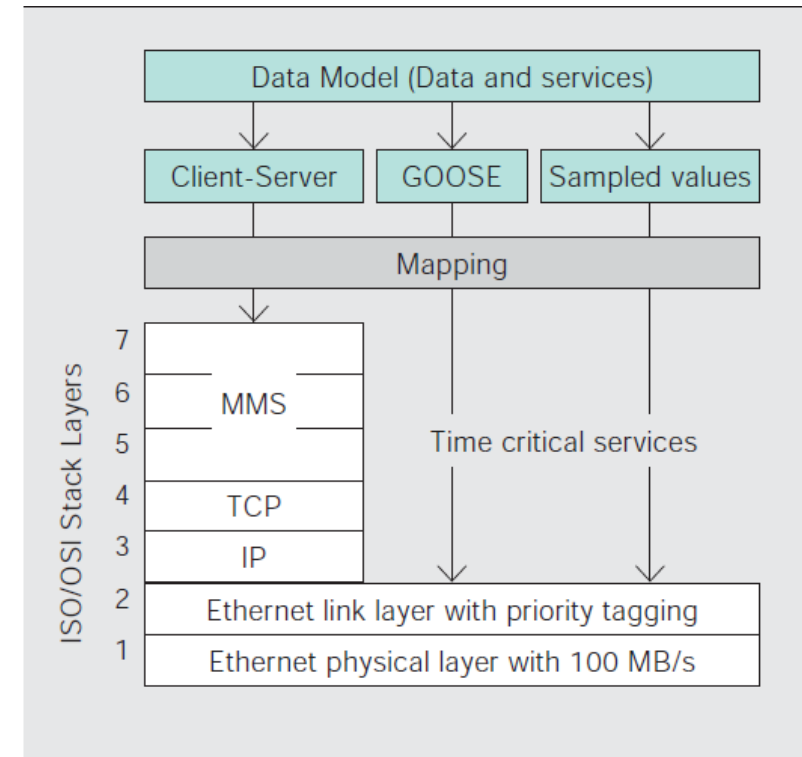
# What is IEC 61850?

## Data model & communication structure

### Data model

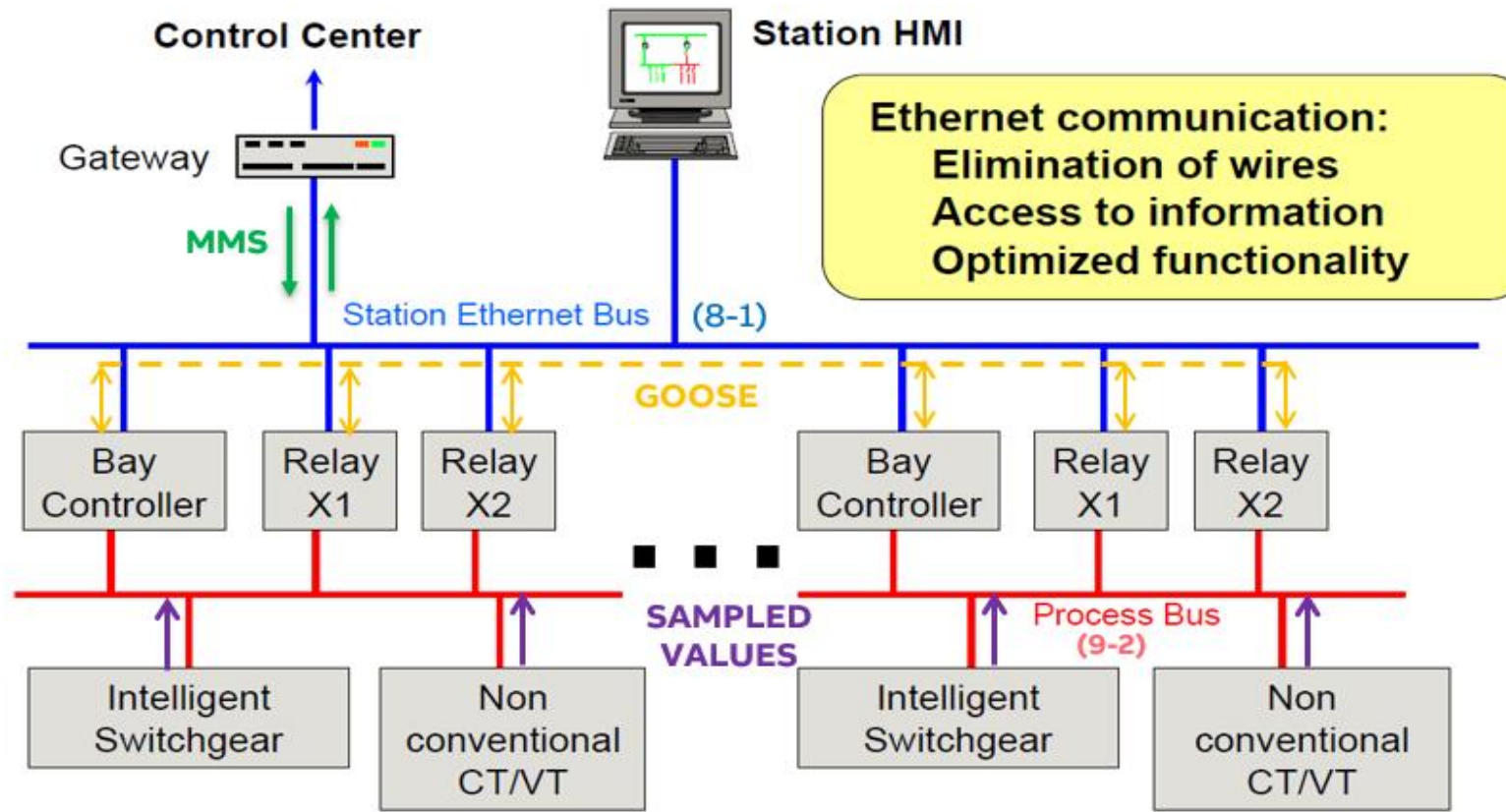


### Communication structure



# What is IEC 61850?

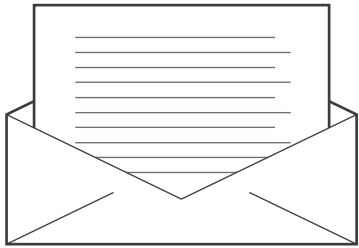
Substation automation system – Station bus & Process bus



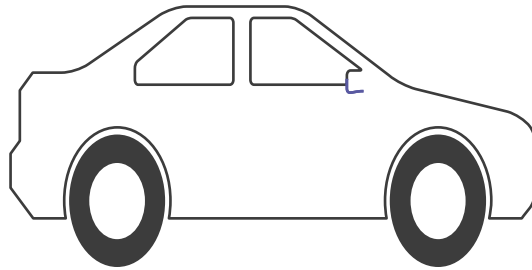
# What is IEC 61850?

## GOOSE structure

### Data set (information)



### GCB



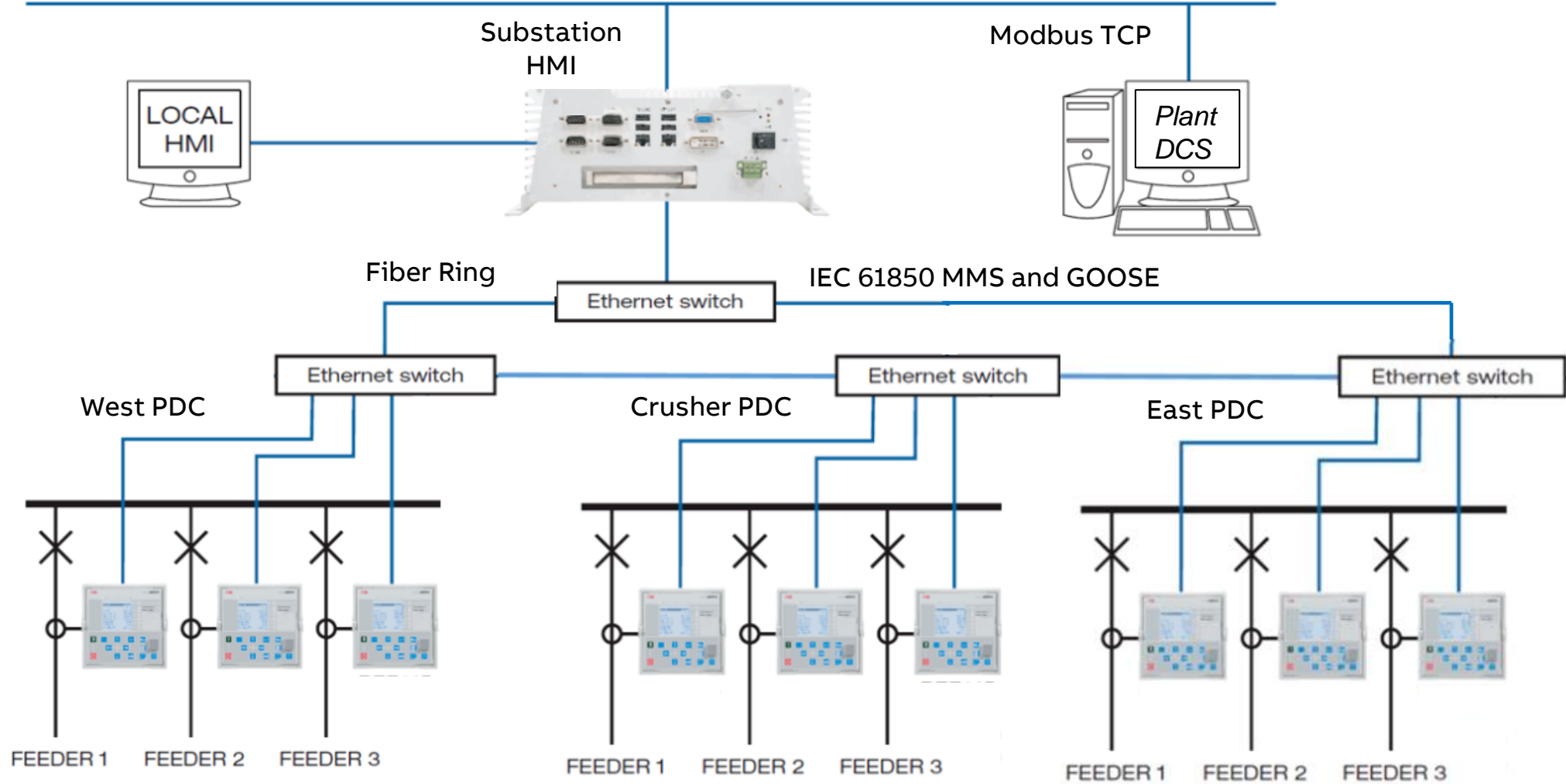
### Network



- GOOSE messages are based on change event
- GOOSE messages include diagnostic functions (a “heartbeat” to all devices subscribed is sent periodically)
- GOOSE messages are managed by GCBs (GOOSE control block) inside IEDs
- GOOSE messages send “data sets” upon changes of state

# Communications Architecture

PLANT TCP/IP



# Protective Relays

Feeder protection relay

## Advanced digital relays with native IEC 61850

- Full complement of feeder protection functions
- Cable Fault Detection (CFD) on the mains
- Fast Bus protection
  - IEC 61850 GOOSE - < 10ms
- Metering and breaker control
- Digital fault recording
- Only 2 relay style variants



Lesson Learned – Plan your Network architecture and nomenclature prior to beginning any relay programming

# Reliable and cost-effective fast bus protection

## Features and benefits

### Overview

- Utilizing directional overcurrent elements of feeder protection relays
- Reliable: operates only against faults on the protected bus
  - All contributing breakers are tripped and block-closed
  - Acceptable operating speed
- Secured: able to distinguish external (through) faults
  - Allows the individual breaker to trip first

### Features

- Flexible to multiple incoming / contributing sources
- Dedicated bus protection relay is not required
- A “master” relay is assigned to perform the bus protection scheme with a “backup” relay automatically assuming the “master” relays operation during relay failure
- High speed communication via IEC61850 GOOSE messaging

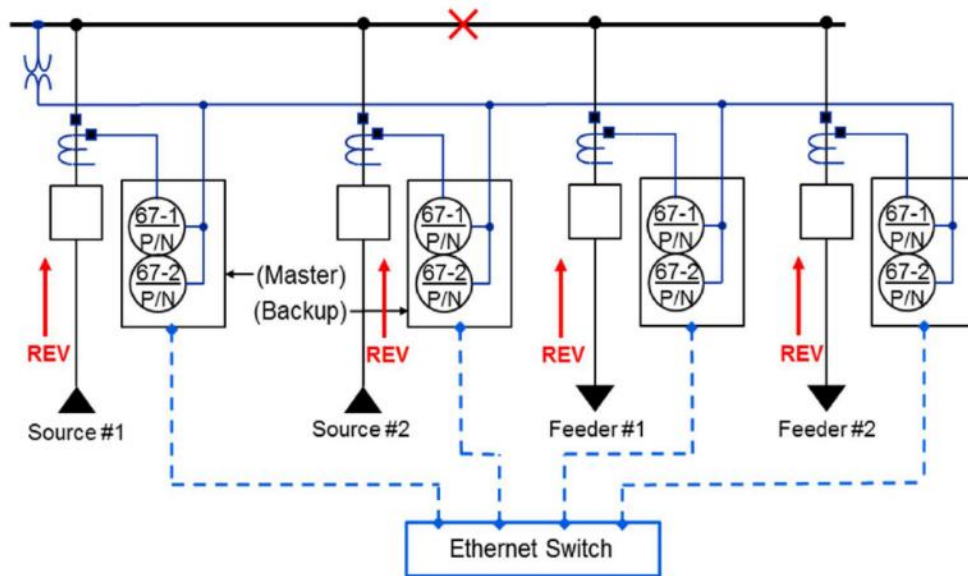
### Benefits

- Adaptable towards increases in system fault levels
- Flexible to new bus additions of loads and sources
- Reduction of wiring versus conventional schemes and potentially removes the requirements for dedicated bus CTs
- Improved scheme security by being immune to the effects of CT saturation
- Communication redundancy

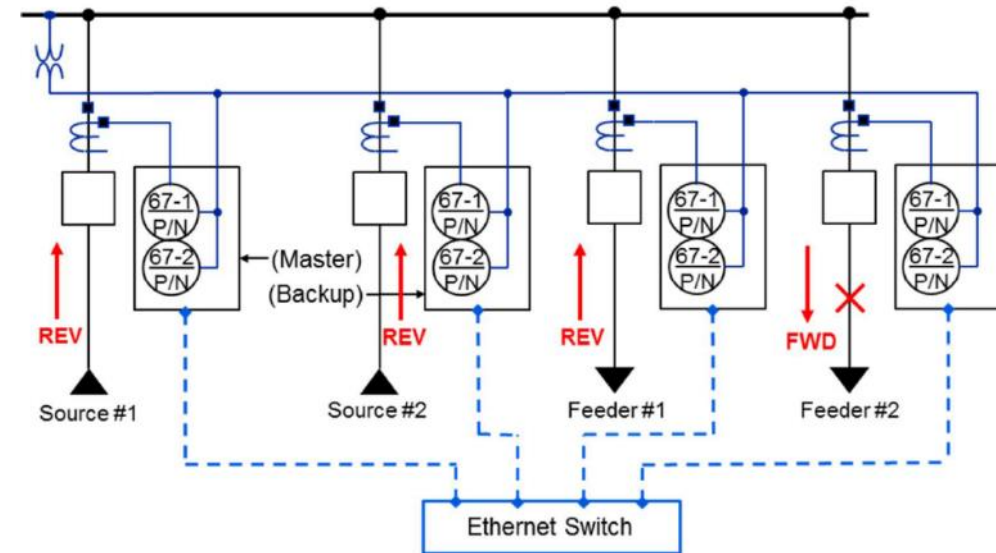
# Fast Bus Protection

## Scheme operation

Operation during internal (bus) fault



Operation during external (feeder) fault



Lesson Learned – Test sample before you program scheme



# GOOSE & MMS Configuration

## Network information

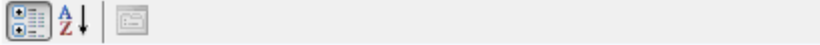
### Device addressing

- IP Address & Subnet
- APP ID, MAC Address
- VLAN ID

### Things to Remember

- Set-up structure in advance of programming
- Test the structure before replication
- Determine what devices are in each Project File
  - One for each Substation/Switchgear

- App ID
  - Must be unique to entire project
  - Limited to 3FFF
- MAC Address
  - Limited to 01-0CCD-01-01-FF

Object Properties	
	
<b>Communication</b>	
Access Point	LD0
App ID	0001
MAC Address	01-0C-CD-01-00-00
Subnetwork	WA1
VLAN ID	000
VLAN Priority	4
<b>Data</b>	
Clients	(Collection)
<b>General</b>	
Application ID	A1CTRL/LLN0.gcbMain1_Control
Config Revision	100
Data Set	Main1_Control
Description	
Max Time	10000
Min Time	4
Name	gcbMain1_Control
Type	GOOSE
<b>Substation</b>	
IED	REF620A_Main1
Logical Device	CTRL
Logical Node	LLN0



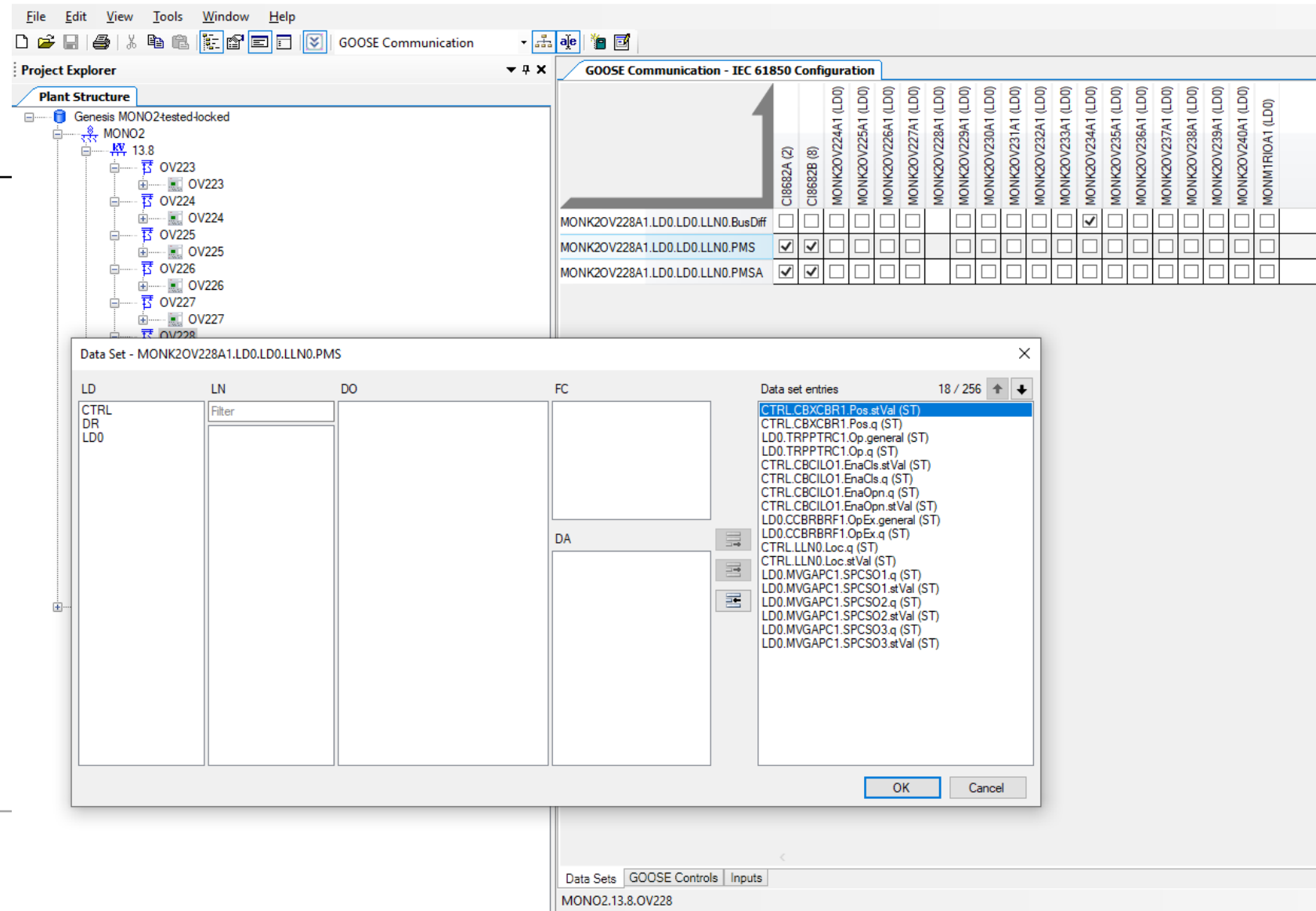
# GOOSE messaging

## Data Sets, GOOSE Control Blocks

### GOOSE Engineering

#### GOOSE DATA SETS

- 20 Elements per Set
- 8 Sets Max
- Digitals in one Data Set
- Analogs in another
  - Minimize Analogs
- Add Value (Val) and Quality (q) to the data



# GOOSE messaging

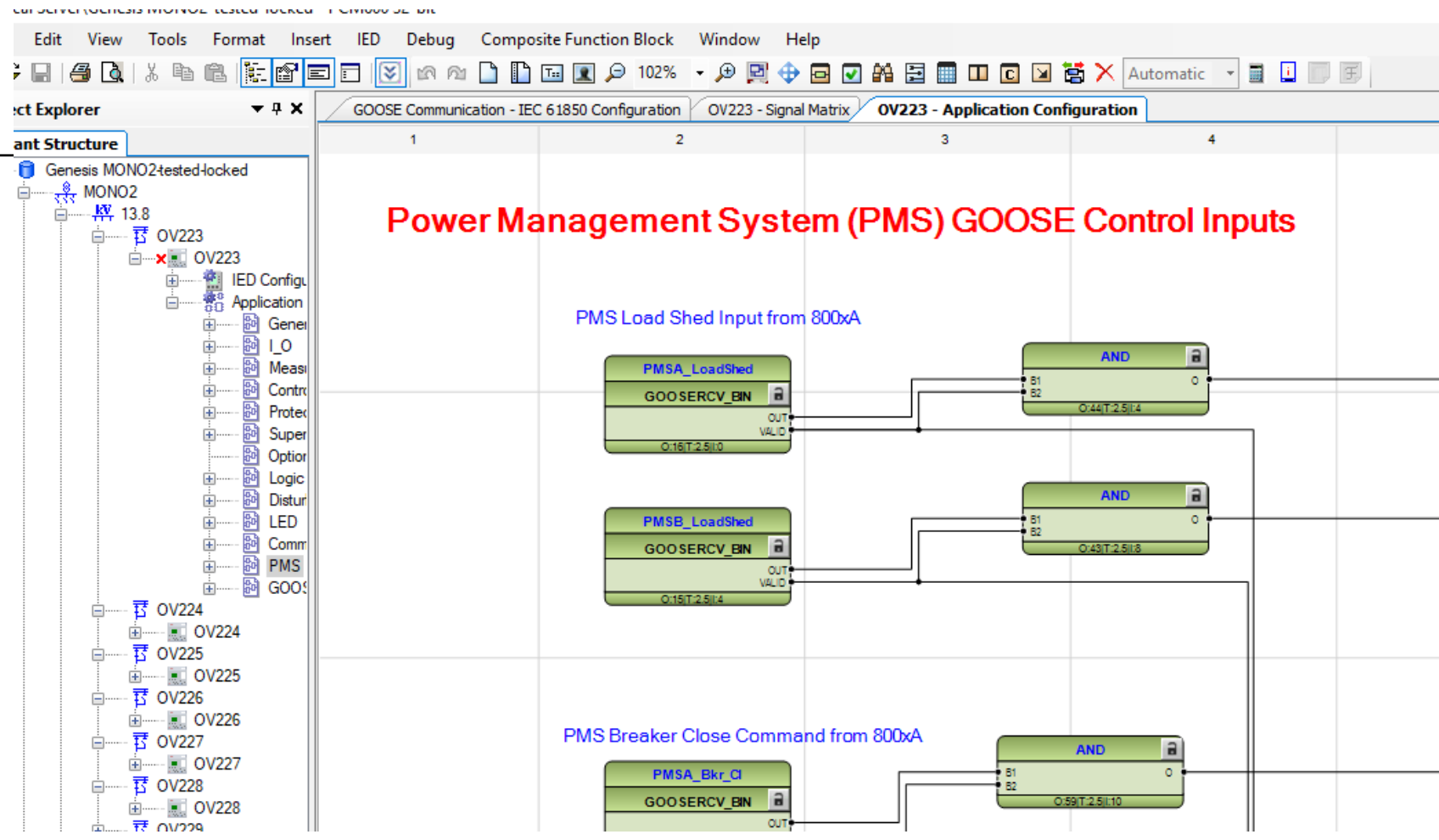
Bring signals to the logic blocks

## Application Configuration

- Insert GOOSE Receive function blocks
- Tie Signals to Relay logic

## Things to Remember

- Be thoughtful with structure
  - Logic Design
  - Tabs
- *Naming is Everything!*
- *Test before you replicate*



# GOOSE messaging

Create connections

## Tie up the signals

### Signal Matrix

- Connect GOOSE Signals to
- GOOSE Receive function blocks

### Things to Remember

- Naming is Everything
  - Relays
  - Other devices
- Test before you replicate
- **No Room for Error here!**

The screenshot displays the 'Signal Matrix' window for device 'CI8682A, LD0'. The window is divided into three main sections: a left-hand tree view, a top header area, and a central data table.

**Left-hand Tree View:** Shows a hierarchical structure of the configuration. The 'GOOSE' section is expanded, showing several GOOSE objects (OV223, OV224, OV225, OV226) and their associated function blocks (IED Config, Application, General, I/O, Meas, Contr, Protec, Super, Option, Logic, Distur, LED, Comm, PMS, GOOS).

**Top Header Area:** Contains the title 'GOOSE Communication - IEC 61850 Configuration' and the specific configuration name 'OV223 - Signal Matrix'. It also includes a 'Logical Device' label with a large arrow pointing to the device name 'CI8682A, LD0'.

**Central Data Table:** This table maps GOOSE signals to specific data objects and attributes. The columns are organized as follows:

- Signal Name:** The name of the GOOSE signal (e.g., BB\_Trip, PMSA\_Bkr\_Cl).
- Data Object:** The IED data object (e.g., GOOSERCV\_BIN:3).
- Data Attribute:** The specific attribute (e.g., IN).
- SPCSO1 stVal:** Status value for SPC SO1.
- SPCSO2 stVal:** Status value for SPC SO2.
- SPCSO3 stVal:** Status value for SPC SO3.
- SPCSO4 stVal:** Status value for SPC SO4.
- SPCSO5 stVal:** Status value for SPC SO5.
- Tr4 general:** General status for Tr4.

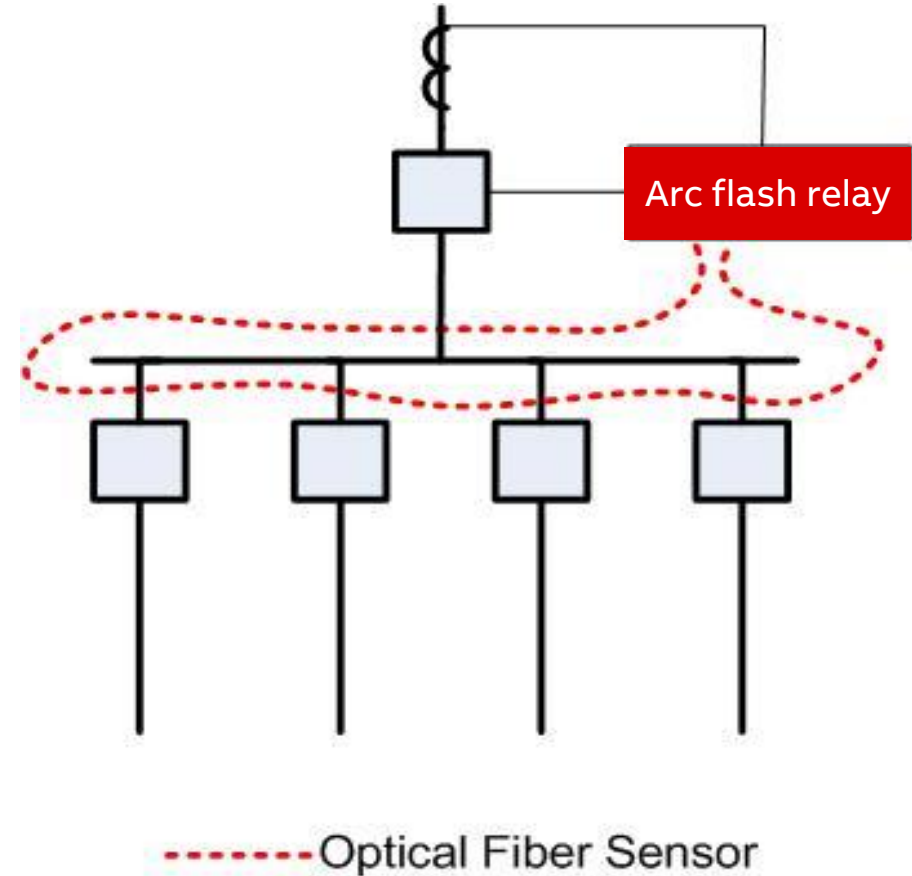
The table contains the following data rows:

Signal Name	Data Object	Data Attribute	SPCSO1 stVal	SPCSO2 stVal	SPCSO3 stVal	SPCSO4 stVal	SPCSO5 stVal	Tr4 general
- BB_Trip;GOOSERCV_BIN:3	BB_Trip;GOOSERCV_BIN:3	IN						
- PMSA_Bkr_Cl;GOOSERCV_BIN:1	PMSA_Bkr_Cl;GOOSERCV_BIN:1	IN	X					
- PMSA_Bkr_Opn;GOOSERCV_BIN:2	PMSA_Bkr_Opn;GOOSERCV_BIN:2	IN		X				
- PMSA_LoadShed;GOOSERCV_BIN:0	PMSA_LoadShed;GOOSERCV_BIN:0	IN						X
- PMSB_Bkr_Cl;GOOSERCV_BIN:5	PMSB_Bkr_Cl;GOOSERCV_BIN:5	IN						
- PMSB_Bkr_Opn;GOOSERCV_BIN:6	PMSB_Bkr_Opn;GOOSERCV_BIN:6	IN						
- PMSB_LoadShed;GOOSERCV_BIN:4	PMSB_LoadShed;GOOSERCV_BIN:4	IN						

# Arc Flash Detection

Enhancing safety

- Fully independent of feeder protection protection
- ~ 2.5ms arc flash detection
- ~ 50ms total (incl breaker opening) clearing time
- Current arming to prevent nuisance trips



Lesson Learned – Plan for more fiber loops than you think

# Substation HMI

## Grid Automation Controller

### IEC 61850 Communications Protocol

- GOOSE Control
- MMS Metering

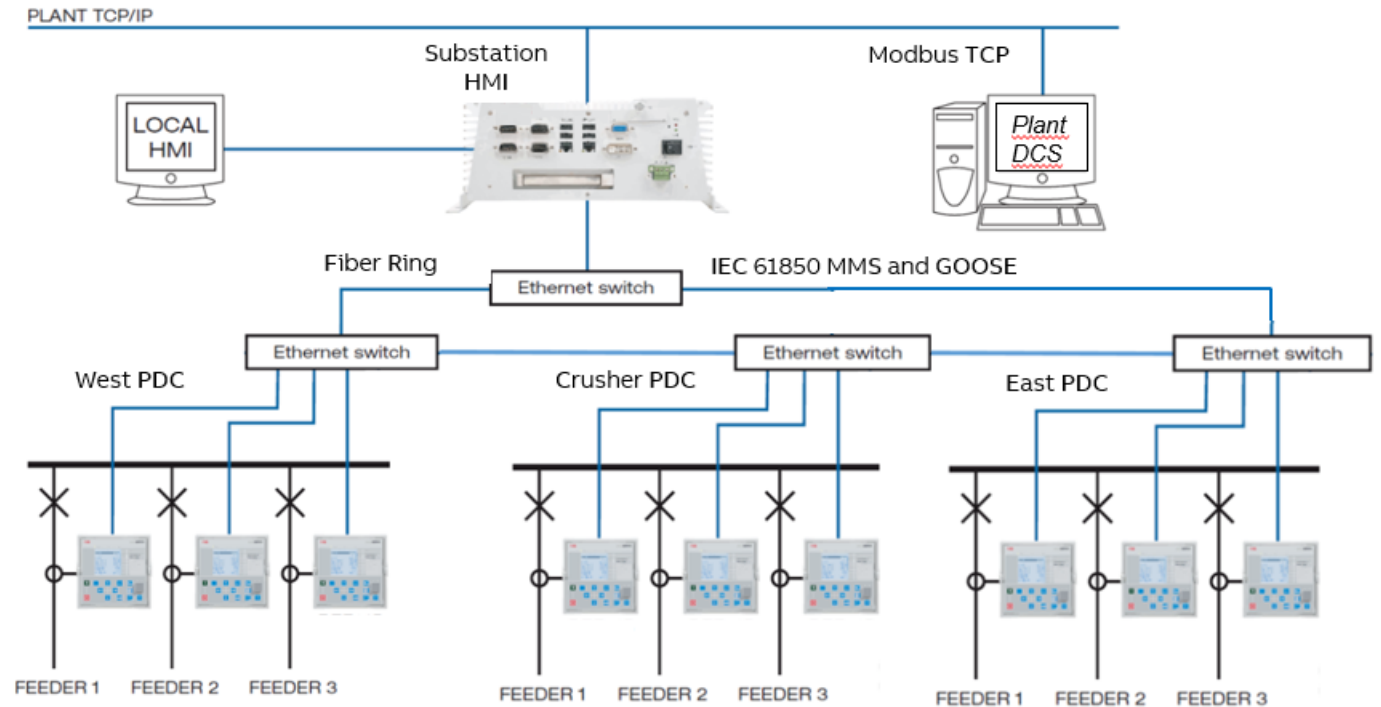
### Fault Detection, Isolation, and Restoration (FDIR)

- < 2 second transfer using 61850 GOOSE

Full relay information available via IEC 61850 MMS

Integration with Plant DCS via MODBUS

Web Interface – monitor and control from anywhere with access to network



Lesson Learned - Use a GOOSE Network Analyzer

---

# Distribution protection and automation solution: A real world experience

Lessons learned from an actual project – Concept, Design, Implementation

## Summary

---

### Network design benefits

Redesigning the radial system to ring network to enable automatic fault detection, fault isolation and service restoration brought in substantial benefit to operations by reducing down time

### IEC 61850 control efficiencies

IEC61850-based protection schemes helped to reduce overall cost, increase safety, and improve efficiency of operations

### Plan in advance

The lessons learned from this modernization project around engineering, testing and commissioning is a valuable asset in future implementations

—  
**Thanks for your attention!**

**QUESTIONS?**

