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P & C System Upgrade Based on IEC-61850 and PRP

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Project Owner

- City owned utility in central Alberta, Canada
- Serves over 40,000 customers.
- Primarily an electrical distribution company
- Owns 3x 138-25 KV and 11x 25-4 KV substations

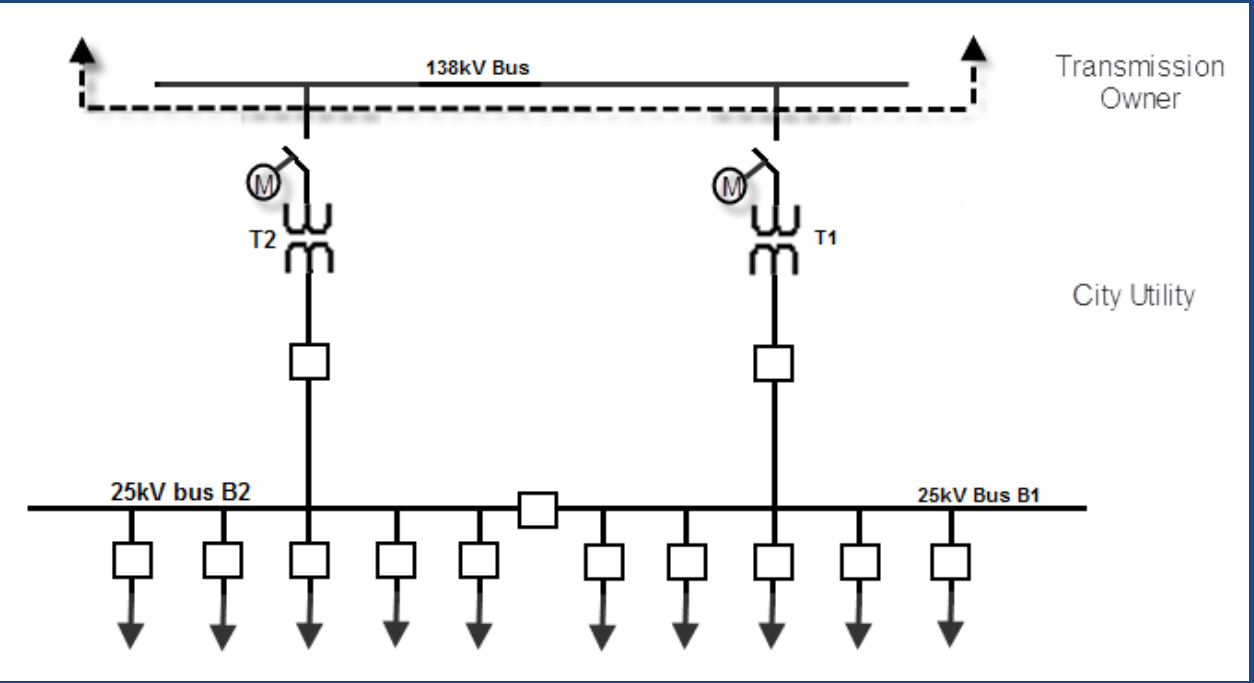
Reasons for Upgrade

- The existing substation required a complete protection & control, and SCADA upgrade.
  - Old electro-mechanical and static protection relays
  - Little or no automation capability. Centralized RTU system.
  - The P&C building was in need of major repairs
  - No centralized control in the substation i.e. HMI
  - In need a modern platform for future distribution automation upgrade

Key Technical Requirements

- All SA communications must comply with IEC 61850, both vertical (MMS) and horizontal (GOOSE)
- The station bus on a redundant network with minimum failover time to ensure dependability and security
- Substation IED's must be GPS time synchronized
- Ethernet switches shall be ruggedized and support priority tagging, VLAN's and RSTP.
- SAS shall include control and monitoring, event and alarm list among other's. DNP link to SCC.
- At the client's request: hard-wired 52CS & 43L/R were still used. External 86 lockout relays and the existing tap-changer controller were maintained

Single Line Diagram



- The Substation consists of:
  - The 138kv section is owned by the transmission facility operator. The design specifications for this system maintained traditional hard wired controls, alarms and status with DNP communications to the control center and HMI

Protection Components – Transformers

- A & B Transformer Relay's
  - "A" protection is used for control, such as LTC, circuit breaker and MOD
  - Publishes GOOSE signals to the bus protection to initiate BF and trip re-enforcement
  - Hard wired trips are still maintained

Panel Type	Protection Functions	Control Functions
138kV Transformer	Main Transformer Differential (87T) Restricted Earth Fault (87G) LV Over-current backup (51) LV ground Over-current backup (51N) Auxiliary Trip Lockout Relay	Open/Close of HV MOD and 25kV Main Breaker from IED HMI Open/Close of HV MOD and 25kV Breaker from Selector Switch (52CS) Local/Remote Control Selection (43) Lockout Reset Push Buttons (PB) Lockout Indication

Protection Components – Buses

- Bus Protection Relay
  - Centralized 8-bay Bus and breaker failure protections. Send trip signals via GOOSE to connected IEDs when operated
  - Hardwired trips still maintained

Panel Type	Protection Functions	Control Functions
25kV Bus	Main 3-phase Bus Differential (87B) Breaker Failure Protection for Each Connected Bay (50BF x 7) Trip Re-enforcement Relay for each bay Auxiliary Bus Trip Lockout Relay Auxiliary BF Trip Lockout Relay	Lockout Reset Push Buttons (PB) Lockout Indications

Protection Components – Feeders

- Feeder Protection Relay
  - Publishes GOOSE signals to bus IED to initiate BF and trip re-enforcement
  - Hard wired trips are still maintained

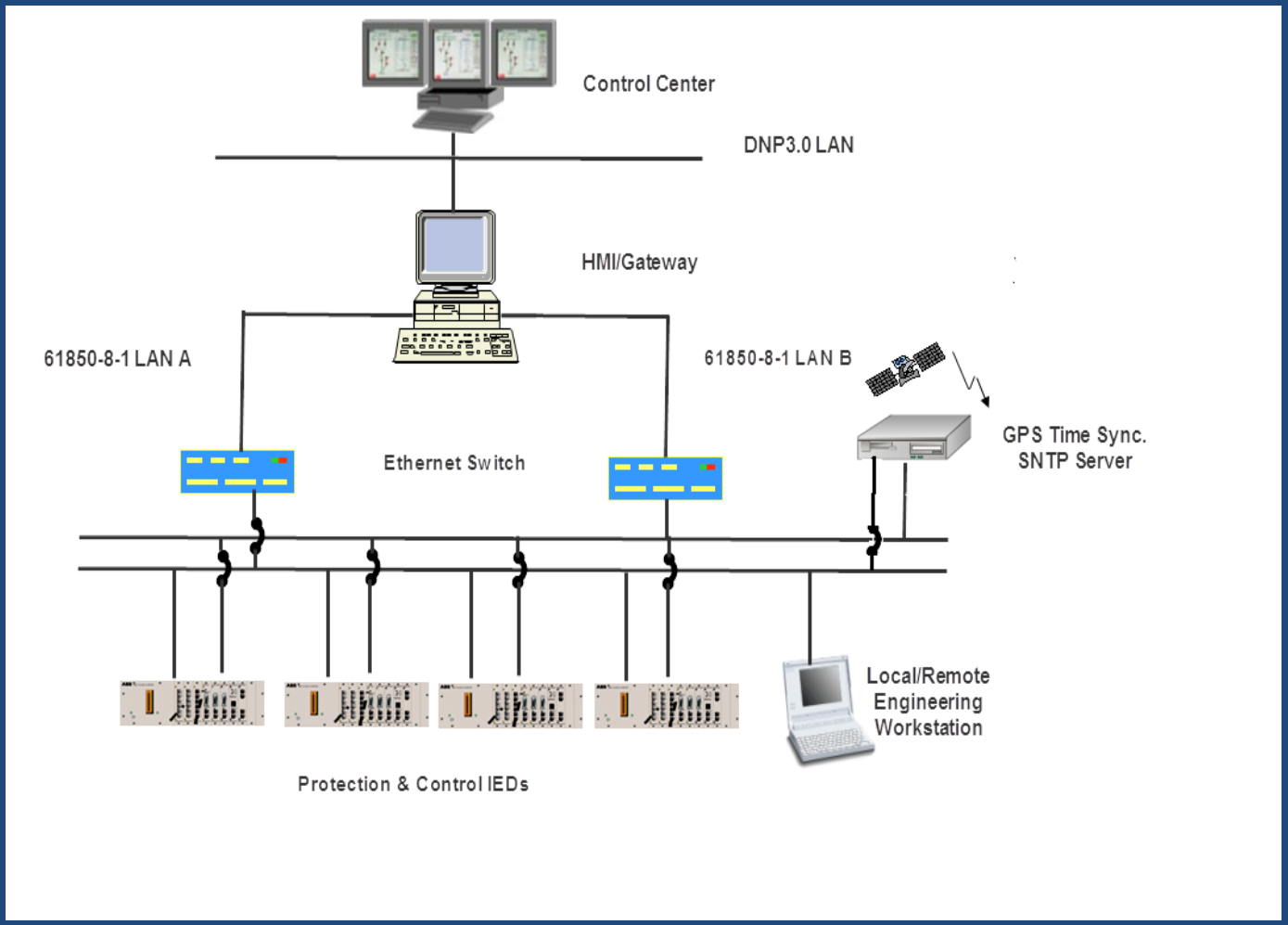
Panel Type	Protection Functions	Control Functions
25kV Feeder	Feeder Over-current Protection (50/51) with alternate, more sensitive, settings in line tagging mode 2-shot auto-reclosing (79) disabled by hot line tagging under-frequency load shedding (81)	Open/Close Feeder Breaker from SLD on IED HMI Open/Close Feeder Breaker from Selector Switch (52CS) On/Off Control of line auto-reclosing via IED HMI On/off Control of line 81 load shedding through IED HMI Local/Remote Control Selection (43) Live Line Tagging Selector Switch

SA System

Automation Architecture

- The Ethernet switches, IRIG-B clock and Industrial PC (HMI, Gateway and Data concentrator) are installed on the same panel and connected in a dual Star configuration
- PRP provides complete redundancy, through dual 100FX fiber ports on the relays
- The PC has 4 fiber ports and 2 copper ports which can be paired independently for PRP
- The GPS clock sends a SNTP signal over both LAN A & LAN B

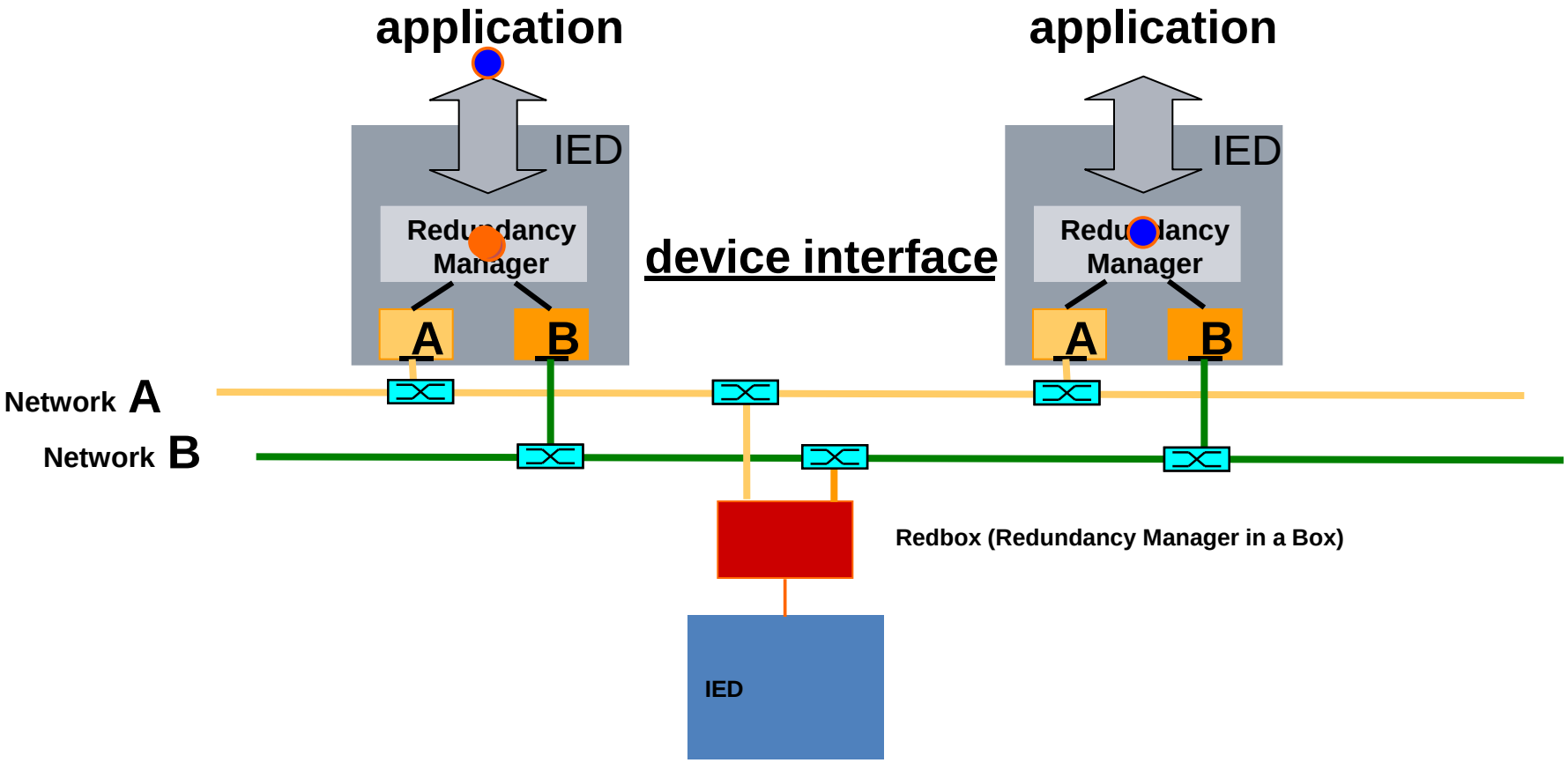
Simplified SA System Architecture



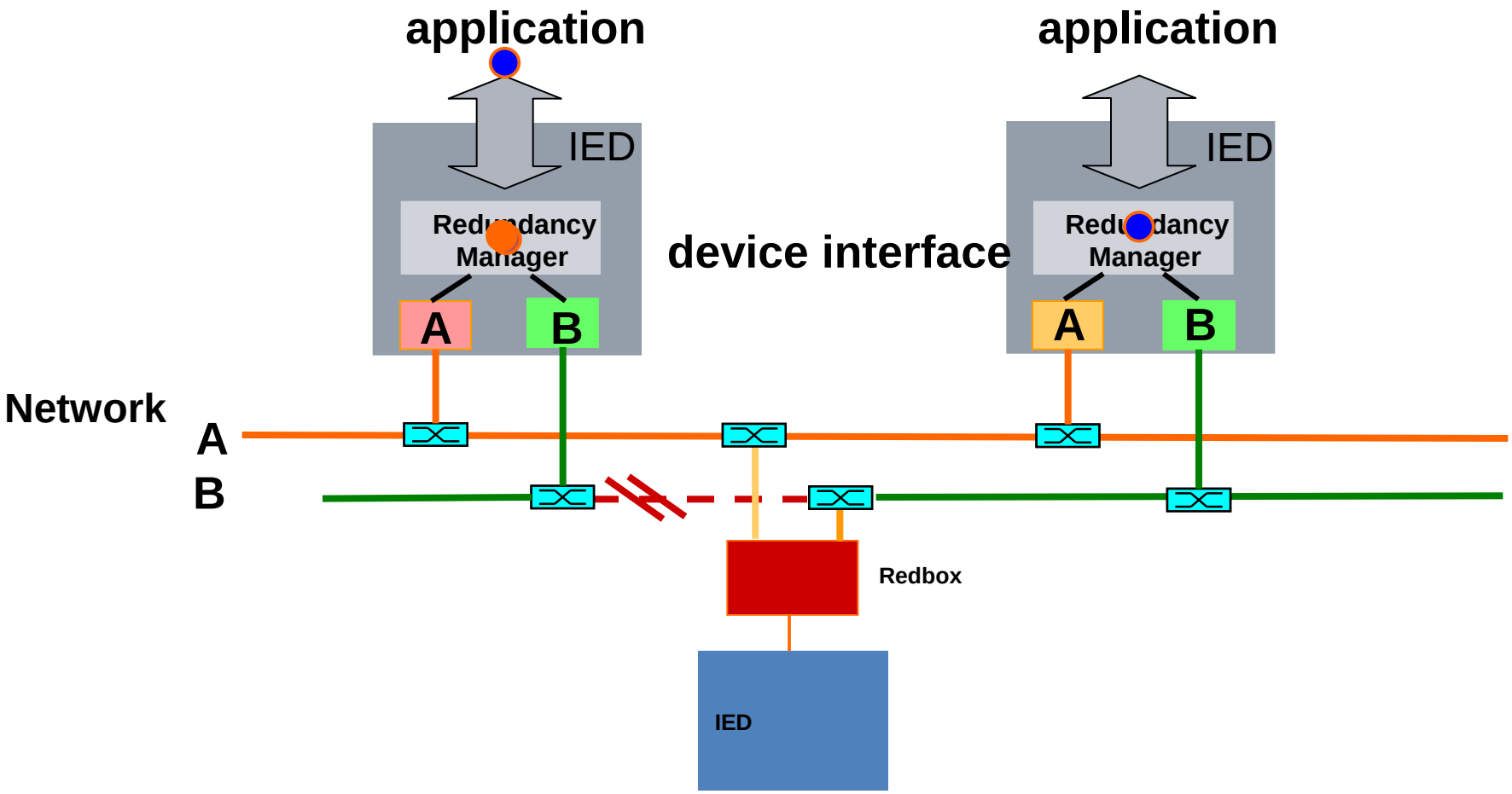
Notes On Parallel Redundancy Protocol (PRP)

- Standardized in IEC-61439 and included in IEC-61850 Ed. 2
- Allows zero network switching time during any single point network communication failure
- Protocol implemented in the end nodes (IEDs)
- Two independent networks required
- PRP end nodes connect via dual Ethernet ports or RED box
- Supports integration with single attached node (non-PRP)
- Network configuration scalable

PRP Operation in “normal” condition



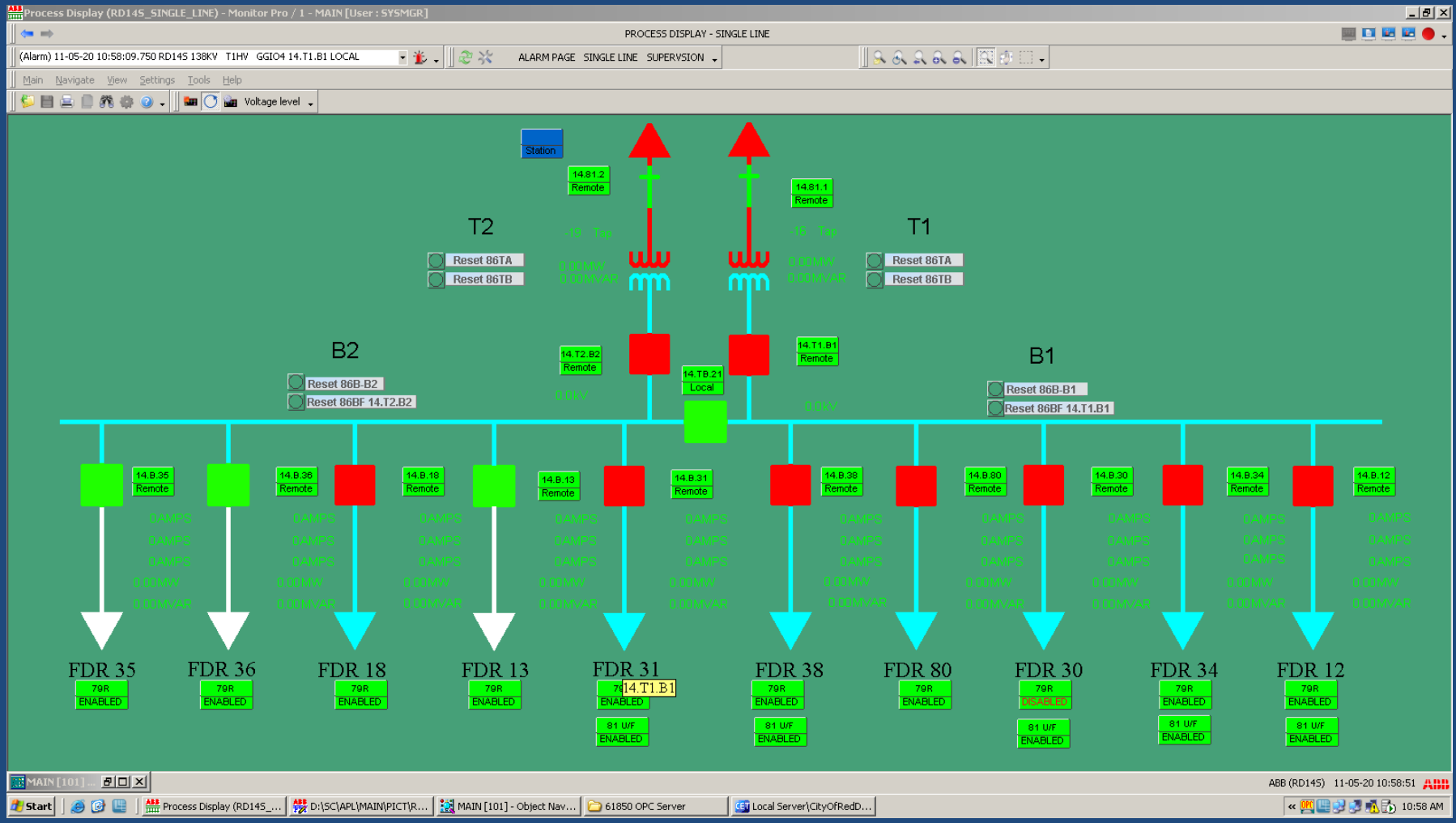
PRP Operation with “faulty” condition



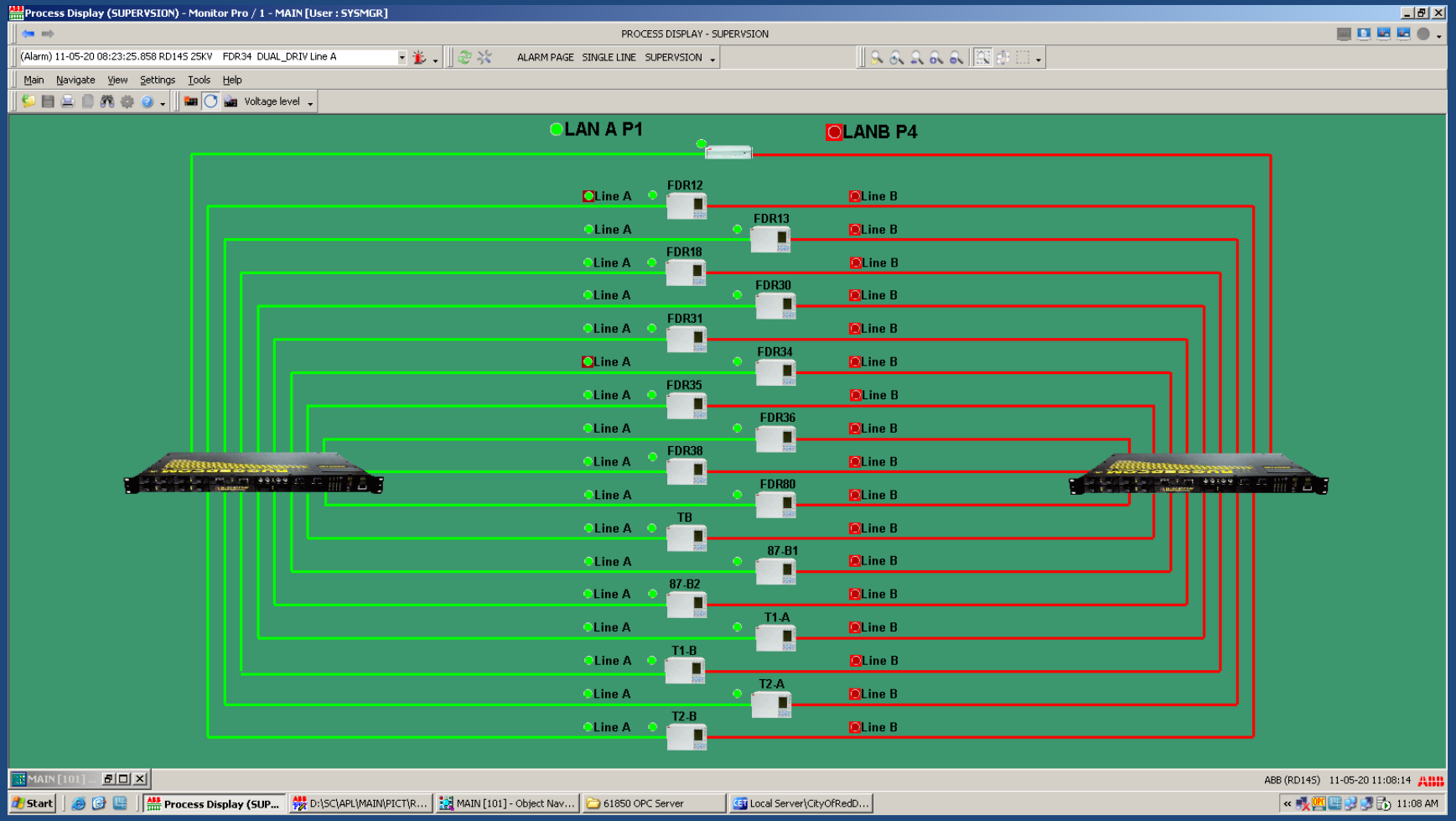
Station Control System

- Data Concentrator/Gateway/HMI
  - A single consolidated device
  - The data concentrator collects/forwards data/commands from/to IEDs using IEC61850 MMS
  - Logic functions are preformed in the device as needed
  - HMI provides: SLD with apparatus positions/control, metering info, selector switch status/control, lockout & tagging status/control, dynamic bus coloring, communication supervision
- DNP Unsolicited reporting to SCADA to reduce traffic
- A fail-over 2nd DNP link was enabled in SCADA

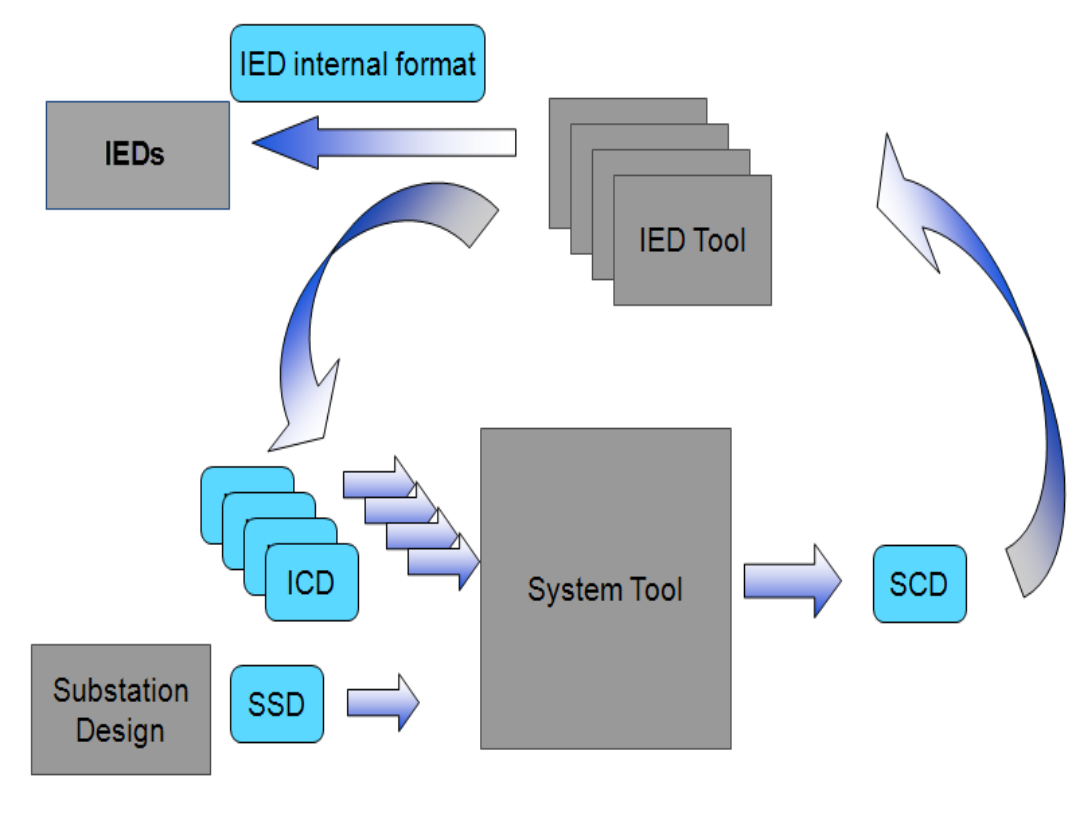
HMI Single Line



Communication Supervision



IEC 61850 Engineering



- IED engineering (IED configuration tool)
- Communication engineering (System Integration Tool)
- HMI engineering
- Gateway engineering

Factory Acceptance

- Performed at Engineer's integration shop
- Panel wiring verified
- The complete SA system was connected as in the substation
- HMI indication and control functionality and inter-panel GOOSE tested and verified
- 61850 GOOSE Testing Tools
- Reduce time and labor onsite for commissioning

Site Commissioning

- Inter-IED and HMI-IED functionality already verified
- Cursory random system tests after installed on-site (eg. BF operations, apparatus status, events, alarms)
- Control cable installation and wiring termination to primary equipment
- Testing of indications/control functionality to/from SCADA
- Additional functional implementations/modifications
- SA system commissioning lasts only 3 - 4 weeks

Lessons Learned

- Thorough planning of IED functionality prior to beginning system integration to avoid repetitive work
- Develop documentation standards for GOOSE messages to aid proper device isolation during maintenance
- Training/education to operators/maintenance crew to gain confidence and experience on virtual control functionality of modern IEDs and HMIs
- GGIO used in some instances instead of standard IEC 61850 data attributes

Conclusions

- IEC 61850 works as claimed
- Initial learning curves on the standards, Ethernet, multiple configuration tools, and testing methods
- Education and training required for engineers, operators and maintenance team
- Reduction of inter-panel wiring and labor
- FAT further reduces time spent on-site
- Efficient testing tools for GOOSE messages are commercially available from third party vendors
- Scalability and expandability for future similar projects

QUESTIONS?