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ComEd 61850 Implementation Summary

Prepared for: UCA IUG Boot Camp

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IEC 61850: The beginnings at ComEd

- ComEd has been aggressively moving forward with the installation of microprocessor relays and digital communications between IEDs for a long time; at present, almost all of our HV and EHV system has been upgraded to microprocessor relays.
- We have been using point-point communications for automation, local protection, and teleprotection for many years now.
- In 2009, I identified an automation application that required a large number of contact logic statuses into a logic processor. I began looking into what was then for us a very new technology, IEC61850 GOOSE. The technology was tried in a rack in the office and, after a hardware upgrade (the original processor in the device was too slow, and few messages would cause long delays), the technology worked and could seamlessly transfer digital signals. From this, the analogy was inferring the ocean from a drop of water.
- The first substation using this scheme was retrofitted (i.e., a brownfield site) in 2010 - 2011. All off the EM relays were replaced; most were configured to publish/subscribe to GOOSE messages (although most messages were used for oscillography only). The only critical scheme to use GOOSE was the logic scheme mentioned above; and that was configured such that it would still TRIP during a complete network failure (i.e., sufficient status points and outputs were hard-wired to always TRIP via the IEDs); for failure of the GOOSE messaging system, we would lose auto-restoration.

IEC 61850: The beginnings at ComEd

A few features of the system At the first site:

- The network was not redundant and was generally not managed.
- GOOSE failure was monitored, alarmed for, and logged in each relay's SER (Message Quality). Over time we have seen very few major issues even with a network that was designed for "SCADA" quality.
- The LAN was configured using IEEE 1613-compliant switches over fiber. This was a major contribution from Mark Simon (since retired) who was one of the original UCA founders.
- GOOSE documentation was primarily the relay settings, the configuration file (SEL Architect), and a multi-page spreadsheet listing all devices and what messages they published and subscribed to.
- Logic diagrams for the automation scheme were hand-drawn, but at least provided some guidance.
- Training and documentation still left much to be desired, but the scheme works and has been maintained.

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Since the initial site was commissioned, we have successfully retrofitted around a ten additional sites, with the following changes (and comments):

- We have installed redundant LANs, connecting each IED in a failover mode at the relay. The network failover is RSTP.
- We are using VLANs to manage the GOOSE traffic to each IED. We feel that this has decreased the processing overhead that each IED has to perform and has contributed to low Message Quality failure rates
- In addition to the automation functions previously described, we are performing some TRIP functions using GOOSE messages (typically, for remedial distribution load-shed schemes) and are using GOOSE messages for other automation functions (for example, for additional auto-reclosing logic on ring busses and for bus restoration or CLOSE blocking).
- We have implemented a substation-wide autoreclose blocking scheme via GOOSE for a cable-space fire alarm activation (or manually)
- For the initial installations, all of the GOOSE messages that actually perform some function (other than oscillography) are used on distribution voltage system equipment. None of the sites are in CIP scope.
- We have not used MMS or Sampled Values.

IEC 61850: The beginnings at ComEd

- We have installed and commissioned transformer paralleling schemes at several substations that use Beckwith's M-2001D Load Tap Changer Controller relays; the "90" relays themselves publish/subscribe to analog and binary GOOSE messages "under the hood" to share VAR flow information to implement a peer-peer Delta-VAR minimization scheme. Note: the Beckwith "90" relays use internally-generated GOOSE messages but (presently) cannot subscribe to breaker statuses from other devices.
- Using this technology, we have successfully configured and operated a scheme to parallel a "swing" transformer between four ring busses (with two transformers on each ring) at two adjacent but separate substations. Bus tie and transformer secondary breaker statuses are published as GOOSE from hard-wired interface devices; the breaker statuses are then processed in three dedicated SEL RTAC Automation Controllers to provide aggregate breaker statuses to Beckwith M-2001D LTC Controller relays. The LAN that this operates on is connected by fiber between the substations (which is not, by the way, in CIP scope).
- For the first several installations of this scheme, the bus tie and transformer circuit breaker statuses were hard-wired into logic processors that then provided the necessary circuit reduction to the "90" relays either directly via hard-wired contacts or via GOOSE to other controllers (RTACs) that could provide the contact logic to the "90" relays via remote I/O devices (driven by a proprietary protocol).
- For future installations, we will still require a logic processor to provide aggregate substation configuration information to the "90" relays, but the breaker statuses to the logic processors will be provided by locally-connected Process Interface Units via GOOSE.

NEXT UP: THE SUBSTATION OF THE FUTURE

IEC 61850: The (Near) Future

- A couple of years ago, our senior leadership challenged Engineering and Planning to build on our experience to produce the “Substation of the Future”. In its initial configuration, this substation will have multiple 138kV lines, GIS gear, distribution transformers, incoming cable duct sections, etc.
- We are designing the protection at this site to use 61850 GOOSE for most tripping/closing out to breaker interface devices (proudly stolen as a naming convention from ConEd) and between IEDs; we also plan to use Sampled Values via Process Bus for one system of 138kV bus protection; we will also configure directional comparison schemes on two of the original six 138kV lines (although these will not be configured to trip).
- Almost as soon as this project was approved, we were challenged to design and commission a second GIS substation at 345kV using IEC61850. This one will actually be placed in service before the original planned 138kV site. It will be GOOSE-only (i.e., no Sampled Values). All of the GOOSE messages will co-exist with SCADA traffic on the Station Bus.
- The 138kV (and associated 34kV site will be a greenfield substation known as Elk Grove Village (EGV); the 345kV site will be a bus replacement (and reconfiguration) at Bedford park (BP).

Design Choices:

- All of the relays will be Edition 2; with one exception, all will be single-vendor (SEL).
- For the HV and EHV GIS Local Control Centers, we will install redundant SEL-421-7 relays as Process Interface Units (or Merging Units, although the devices at BP will not be doing Sampled Values). These were chosen because we wanted to perform Breaker Failure protection and Circuit Breaker Reclosing in the same devices (I don't believe the SEL-401 Merging Unit is as flexible). Note: it has not been common practice at ComEd to co-locate Breaker Failure or Reclosing logic in the line protective relays (at transmission voltages). Also, at the time these devices were chosen for these two projects, SEL had not yet released Ed. 2 versions of their non-process bus relays (for example, the SEL-451-5).
- Line relaying schemes will be redundant 87L with step-distance backup at BP, and two lines each of 87L (w. step distance), redundant POTT, and redundant Step Distance on the six 138kV lines at EGV.
- Busses will be protected by redundant low-impedance differential relays
- Trips from the line (and bus) relays will be communicated to the Process Interface Units via GOOSE, where the same signals will initiate Breaker Failure and Reclosing (if appropriate)

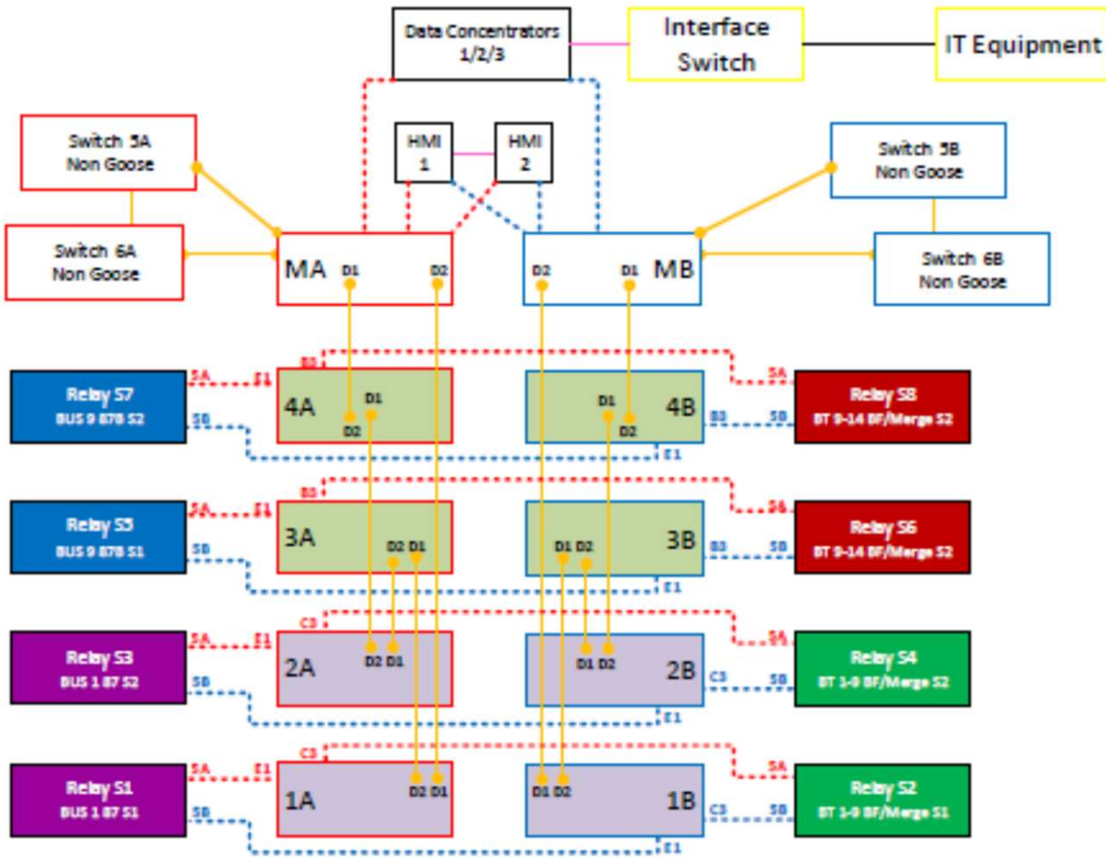
Design Choices (cont.):

- Both stations will use GNSS redundant clocks, with time distribution via PTP.
- At EGV, we will pilot the use of Fiber Optic CTs for cable section protection (to block reclosing for a cable section fault). This scheme (on two lines) will use GE COSI Optical CTs, paired with ABB SAM600-CT Merging Units and SAM600-TS time synch units (as of the COSI component choice, the COSI MU requires PPS time synch; the SAM600-TS units will provide the PPS signal. The resulting streams will be directed to a SEL-487B-2 relay. This will provide a fairly complex interoperability test at fairly low risk (reclose blocking only for a very short cable section).
- We intend to eliminate control switches and lockout relays; we will implement local controls with front-panel pushbuttons on the relays, and implement lockout logic in chosen IEDs. Since CLOSE operations will normally be performed through the PIUs, blkClose can be implemented there; we will require robust procedural controls to prevent any local manual CLOSE operations if a “virtual lockout” is active (as opposed to 86b contacts).
- For the 34kV switchgear at EGV, inter-cubicle tripping (for example, for a bus fault operation) will be via GOOSE. Intra-cubicle tripping (for example, the 34kV line relays) will be via the relay contacts.
- At present, each voltage level (for example, 138kV & 34kV at EGV) will have its own LAN. Cross-tripping between voltage levels will be via a serial Mirrored Bit connection.

Design Choices (cont.):

- The Station Bus LAN will be via SEL-2740S SDN switches (100Base-FX ports to the IEDs with backbone ports configured as 1000Base-SX. The switches will be configured as two redundant networks to use PRP at the relays.
- The Process Bus LAN will use the SDN switches connected in a ring configuration, with the relays configured for fail-over and doubly-attached to the switches in the ring (note: the relays chosen presently do not support PRP on the process bus ports).
- In previous practice, our SCADA group was responsible for LAN design and switch management. For substations using IEC61850, we are transitioning that responsibility to the Protection engineers. Hopefully, this will mitigate some of the issues that we have had with switch management for traffic control; the downside (upside?) is that Protection Engineers are having to learn at least a bare minimum about being Network Engineers.
- We have also been re-thinking (and improving) the physical fiber system design, including improved overhead fiber tray systems (from Panduit) and beginning to move from 62.5/125 OM1 fiber to 50/125 OM3 fiber.

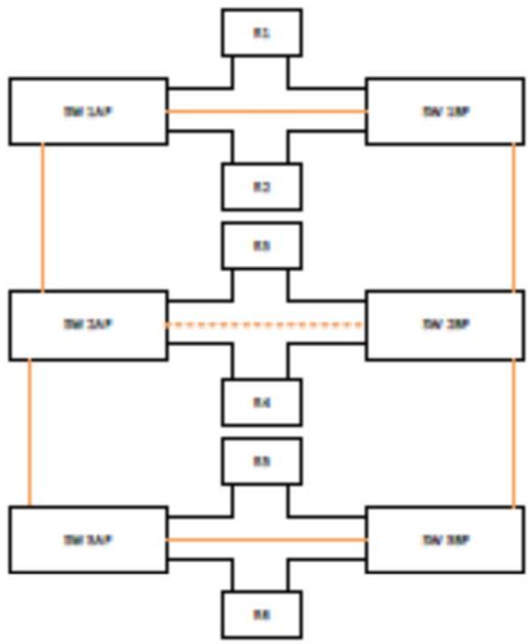
Station Bus



Design of Station Bus / Interface LAN

Slide courtesy J. Bettler

Process Bus



Design of Process Bus LAN (61850 Gen 3 Stations only)

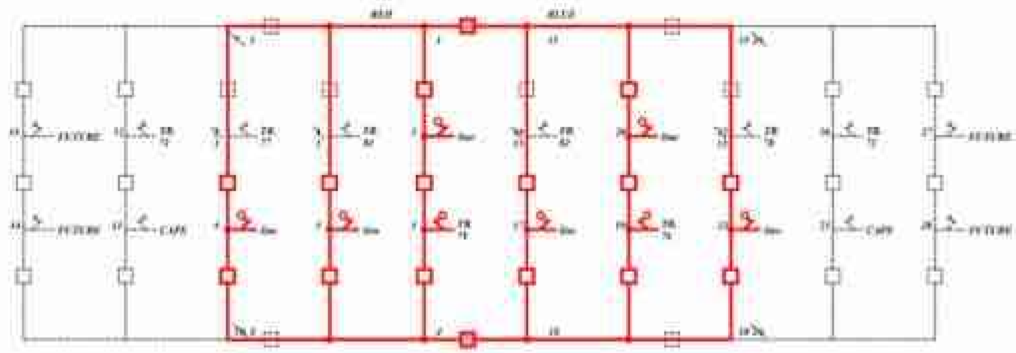
Slide courtesy J. Bettler

Prototyping

Lab Space:

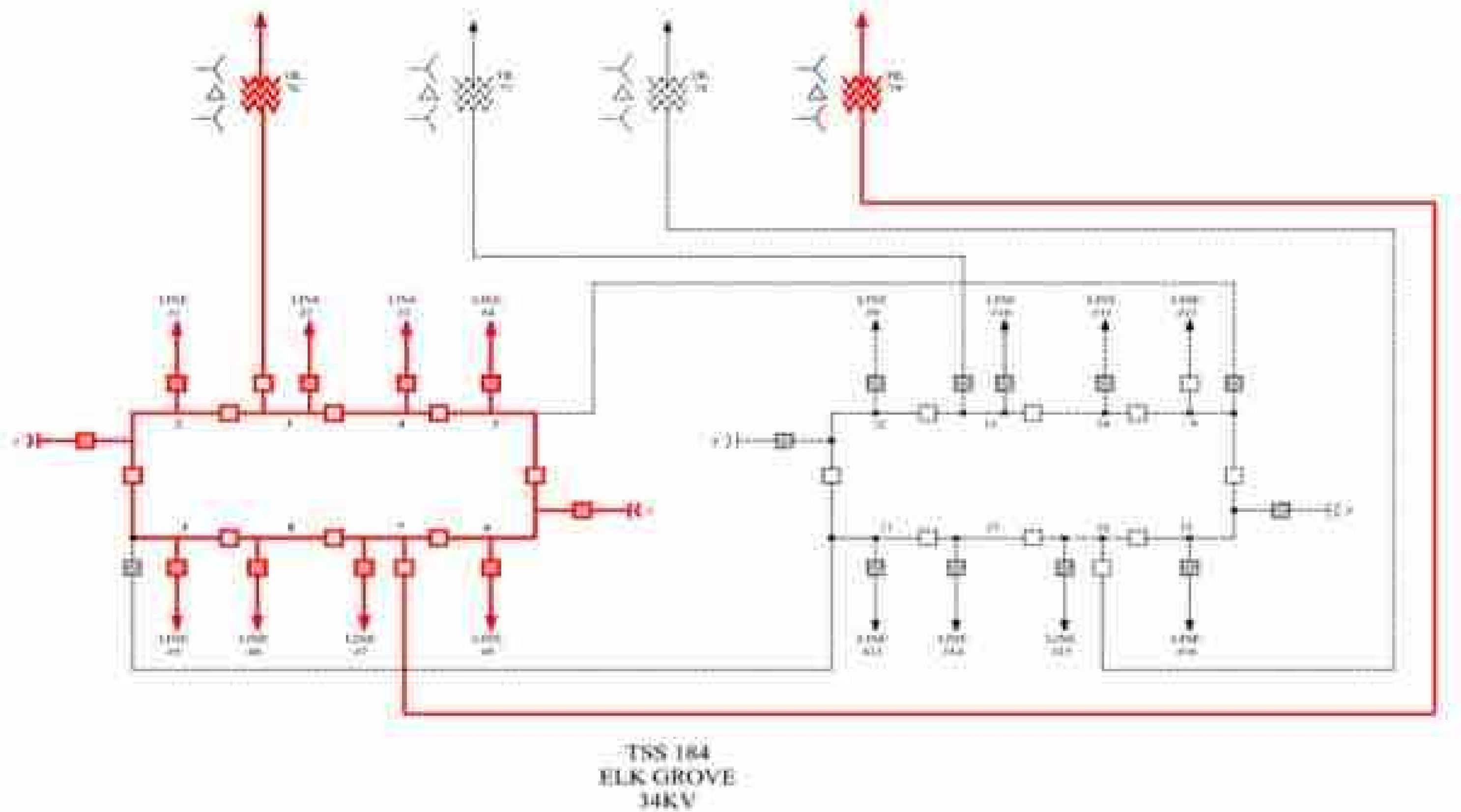
- We presently have a small Lab in the same building as our Protection Engineering office. That lab is functional and is being used to begin to configure the switches for the clock signals, testing merging units, and beginning to test logic.
- We have a larger lab space under construction at ComEd's Tech Center in Maywood, IL. This will be a much larger facility, and will be adjacent to ComEd's "Smart Grid" group's RTDS lab. The Protection lab will have access to the RTDS equipment.

Elk Grove Village 138kV Substation



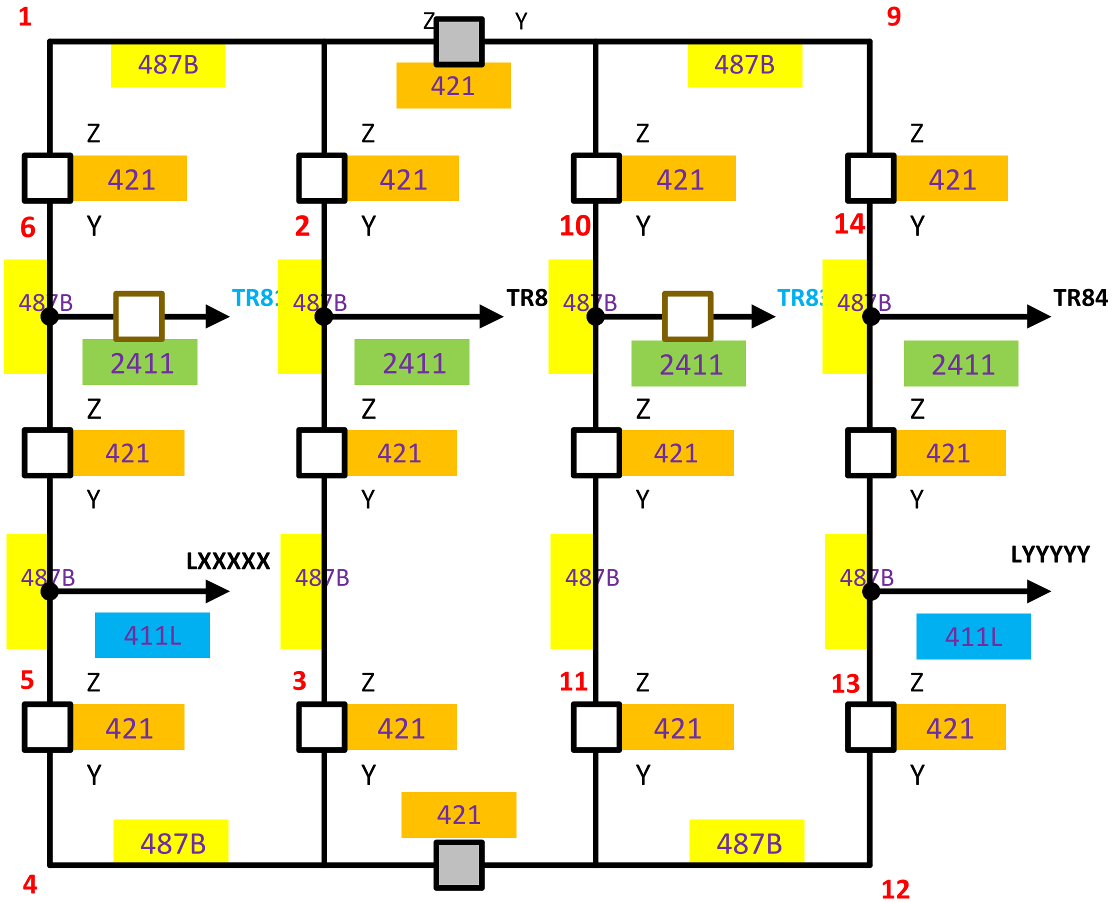
TSS 184
ELK GROVE
138KV

Elk Grove Village 34.5kV Substation



Bedford PK 345kV GIS

Topology for GIS Protection. Using GOOSE tripping. SEL421 relays are the merging units. System 1 and System 2 redundant. No Goose traffic between systems.



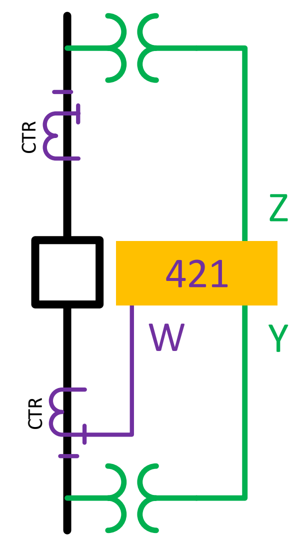
Working with planning to develop CB number's as opposed to Equipment number (like BT1-9, which could change)

LCC DPAC to use Control, Bits to control SW (MOD & GND)

Learning
Send Bus Gas Zone Trips to 487B relays NOT to 421 merging units

Observations
2411 are not currently 61850 V2

Standardized Connection
Standard connection. Note that voltage logic for reclosing may need to be set up in White Board Logic

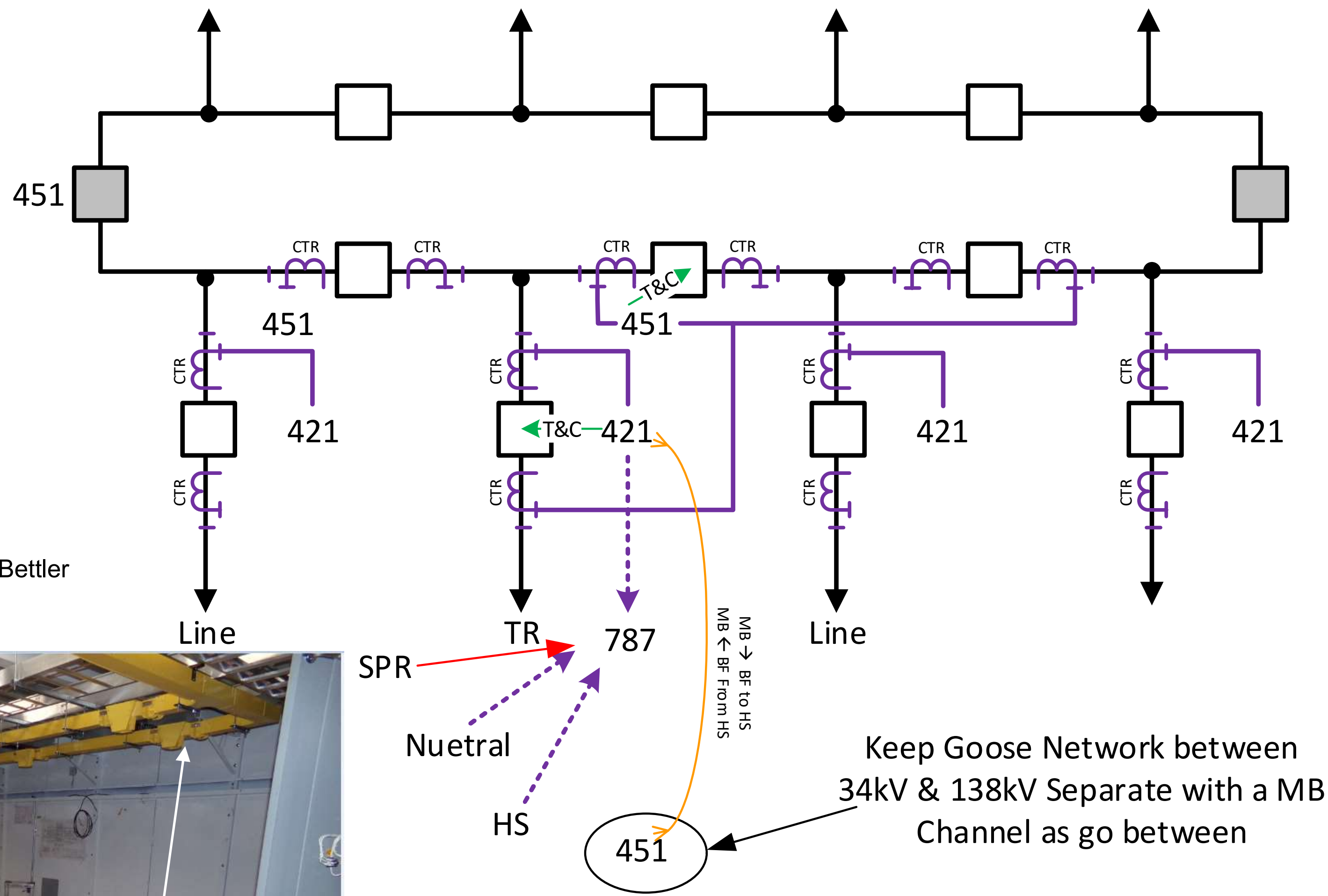


Slide courtesy J. Bettler

Additional Projects

- 12kV Substation Revision – Chicago - GOOSE
- 34kV Indoor Switchgear replacement - GOOSE

34kV Indoor SWGR

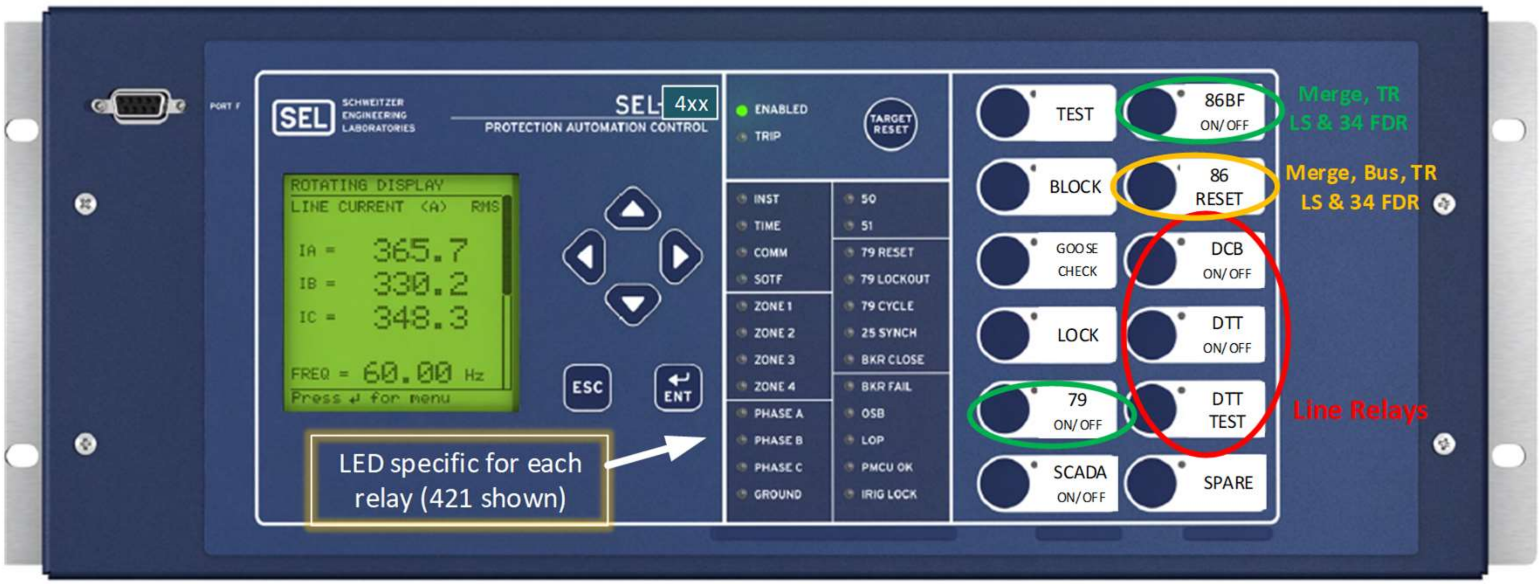


Slide courtesy J. Bettler

HS CB Device Status passed thru the interface device.
Autoclose for a HS or LS TR Open

400 Series PB

Slide courtesy J. Bettler



Pulse in RB4 Only resets, set by BF

	SCADA	HMI	Bit On	Bit Off	PB On	PB Off	VTS	Com SW
Trip / Close	Y	Y	OC	CC	NA	NA	N	
79 On / Off	Y	Y	RB1	RB2	PB5	Toggle	N	
86B or 86T On/Off	N	N	NA	NA	NA	NA	Y	
86 Reset	N	Y	NA	RB4	PB8	Toggle	N	
Blast On/Off	N	Y	RB5	RB6	NA	NA	N	
86BF On/Off	Y	Y	RB7	PB8	PB7	Toggle	Y	
87L/DCB/POTT On/Off	Y	Y	RB9	RB10	PB9	Toggle	Y	Y
DTT On/Off	Y	Y	RB11	RB12	PB10	Toggle	Y	Y
DTT Test	N	N			PB11	Toggle		Y
Local SCADA On/Off	N	N			PB6	Toggle		
Test Mode	N	N			PB1	Toggle		
Block Mode	N	N			PB2	Toggle		
Goose Check	N	N			PB3	Toggle		
Lock w/ time out	N	N			PB4	Toggle		

VB Lay Out

Using this prescribed VB layout, a consistent, predictable relationship is created between the publishing relay and the subscribing relay

Device X	VB0X0	**Goose Check***
Device X	VB0X1	52a
Device X	VB0X2	Trip
Device X	VB0X3	BF Trip
Device X	VB0X4	886B Trip
Device X	VB0X5	86T Trip
Device X	VB0X6	TPT - 1
Device X	VB0X7	TOR
Device X	VB0X8	**Spare***
Device X	VB0X9	**Spare***

* Every Relay Publish and Subscribes

NA	Device Quality Bits	VB001 - VB009
Device 1	421 Merge	VB010 - VB019
Device 2	421 Merge	VB020 - VB029
Device 3	421 Merge	VB030 - VB039
Device 4	421 Merge	VB040 - VB049
Device 5	487B or 451	VB050 - VB059
Device 6	487B or 451	VB060 - VB069
Device 7	Line Relay	VB070 - VB079
Device 8	TR 87 Relay	VB080 - VB089
Device 9	Interface (2411)	VB090 - VB099

Using this makes it easy to set up standard White Board logic in the relay:

RCV BF_Trip → PSVx := VB013 OR VB023 OR VB033 OR VB043

RCV Bus LOR → PSVy := VB054 OR VB064

QB Alarm → PSVz := VB001 OR VB002 OR VB003 OR VB004 OR VB005 OR VB006 OR VB007 OR VB008 OR VB009

Goose Check is used to establish the relationship between the Publisher Relay and the Subscriber Relays. Press it and all relays subscribing to that relay should give a visual indication.

Slide courtesy J. Bettler