IEC61850 Under The Hood for SCADA and Relay Engineers

John Bettler, PE
Kevin Malpede, PE
Vincent Lazzaro
All from Commonwealth Edison Co. Chicago

Abstract

For most Relay & SCADA engineers and technicians in the United States working at a power company that owns and operates substations, IEC61850 is an unknow quantity that is talked about at conferences by consultants or OEM reps for relays, test equipment or software tools. And even for companies that have employed it, many of their folks still have limited knowledge of what is happening "Under the Hood"

The two primary reasons for this are:

1) Day to day job functions consists of calculation, print review, event analysis programming relays/HMI's/Data Concentrator and or field work (Commissioning, Preventive Maintenance or Corrective Maintenance).
2) Limited knowledge base on installing and troubleshooting IP based networked systems & LAN's.

As such, this paper is intended to help the average Relay & SCADA Engineers get a basic understanding of IEC61850, as it applies to GOOSE Messaging, MMS and SV, but do it in a way that is simple and relatable. Note this paper will largely be driven by our experience installing and maintaining 61850 enabled substations.

So what will be covered?

First, we will review the three basic applications of IEC61850: GOOSE, MMS and SV. What is the purpose of each, their modes of operation (Test, Block and Simulation) and how this compares to a standard wired scheme. We will include our opinions about what is and isn't easy, based on our installed substations.

Next we will cover basic network design and layouts. This will include switch types, LAN topologies and some application notes we have picked up from experience.

We then cover setting up each of the three applications in a file called the SCD. This file creates a map between relays sending of information to the relays / SCADA receiving information. This will include a quick breakdown of the IEC61850 data model structure.

We finally finish up with a simple break down of a GOOSE frame structure (what the 1's and 0's are doing) so the readers can see what is being set up and how it actually flows on the network.

1. Introduction

As the use of IEC61850 by utilities to set up protection and control schemes in substations increases, it is critical that Relay and SCADA engineers develop an understanding of IEC61850, have an conceptual idea about implementation and some high level knowledge of what this "digital system" actually looks like on a network.

And although there may seem to be many resources to find out about this, this paper intends to cover material based on the authors experiences in designing and installing IEC61850 systems at their utility and is targeting readers with little knowledge on this subject matter. We were in this position recently and wrote this paper based on concepts we found import to set up these schemes and to clarify items that seemed confusing to us. Basically, we tried to write a paper that we wish we had at the beginning of our Digital Smart Substation (DSS) journey.

So, let's begin. First off, what is IEC61850? Well in broad terms, it is a power system automation standard that defines several communications. It goes beyond the substation to include Distribution Automation, DERs, gas wind and hydro plants. It encompasses IED requirements, data modelling, engineering processes and communication protocols. Currently from the standard, the following three protocols are most commonly used:

1) GOOSE Messaging 2) Sampled Values (SV) 3) MMS

2. IEC61850 Data Basics

Data Set: These three protocols allow us to send information between devices over a Local Area Network (LAN) in the substation. This "information being sent" is defined in a dataset. The standard is word based, so things like like a 51 Trip, current in A Phase, or Clock alarm may be listed there and order in the listing has no real importance. However, items in the dataset must follow the standard's naming convention & structure given below.

Also, the dataset items are device dependent. For instance, a feeder relay would not have an 87L Trip element, and thus it would not be available. Everything that is available for a given relay is found in its ICD File. The device's OEM creates this file. Note it can change over time, so newer ICD files for a device could have additional features.

Although not required, typically you will have independent datasets for GOOSE, SV & MMS for organizational purposes, with the latter probably having multiple datasets. Note some limitations to datasets must be observed:

- GOOSE Datasets have a size limitation. (speed is critical for many GOOSE Application, so size matters)
- SV Datasets must currently contain 4 Currents & 4 Voltages place holders (any number of which could hold no real data because they are not needed)
- Data Attribute count, i.e. the number of "things" in the data set. These "things" are call Data Attributes, which are properties of a Data Object. For example, a 51 TOC Element Data Object would have both a pickup and trip as data attributes. The count limit is also impacted by total number of datasets being used.

Data Model. Items in the dataset must follow a specific IEC61850 format. This format consists of the following:

PhysicalNameLogDevice.prefix_InClass_Instance.Object.Attribute

- *Physical Device*: Your relay/IED. You get to name it. Shorter is better to limit impact to the LAN.
- Logical Device (LD): A grouping of function. For this vender, it falls into 1 of 6 categories:

  - CFG – Configuration
  - PRO – Protection
  - MET – Measurements
  - CON – Control
  - ANN – Annunciator
  - MU01 – Merging Unit

- *Logical Nodes* (LN): Breaking down a logical device into functional areas. Must follow the following naming structure. Some In-Class names in Table 1.
  - A vender chosen Prefix.
  - A 4 character In-Class name, where the first character defines its functionality.
  - End with an instance number.
- *Data Objects*: The actual item you are interested in, like a BF Trip, Digital Variable Status or Port Alarms

G Generic	L System	M Meter	P Protect Element	R Protect Function	X SWR	C Control	Z Power Equip
GGIO	LLNO	MMXU	PTRC	RDIR	XCBR	CSWI	ZBAT
	LPHD	MQSI	PIOC	RDRE			
	LCCH	MDST	PTOC	RFLO			
	LGOS		PDIS	RPSB			

TABLE 1: Logical Node In Class Names

- *Data Attribute*: Specific information about the object. This is what actually gets mapped in the data set. Examples include: .stVal or .general for digital information, .t for time stamp or .q for quality.

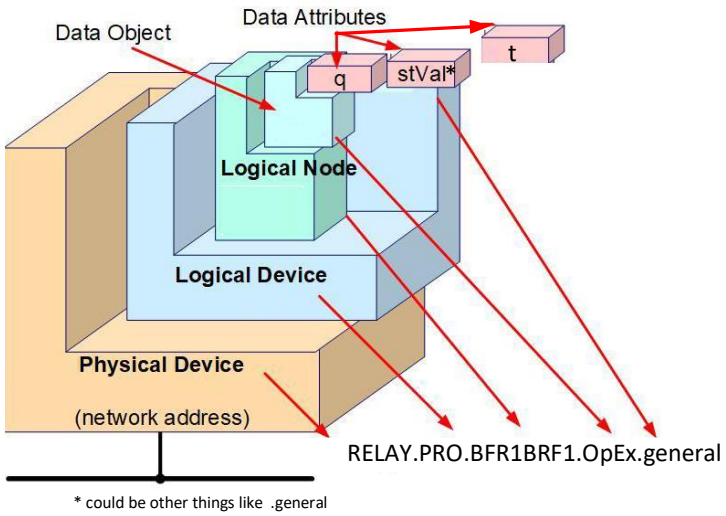


DIAGRAM 1

GOOSE Data Structure

This picture is often used to present a way visualization the IEC61850 data structure discussed above.

Here it is easy to see how you drill down to a specific attribute for a given device.

Mapping: After creating the dataset of what we want to send out, we then need to map that to a device that want to receive it. Our holiday picture postcard is ready to go, but where? Basically, all three protocols do this in the same way shown graphically below. The only difference between the three is the transmit set up:

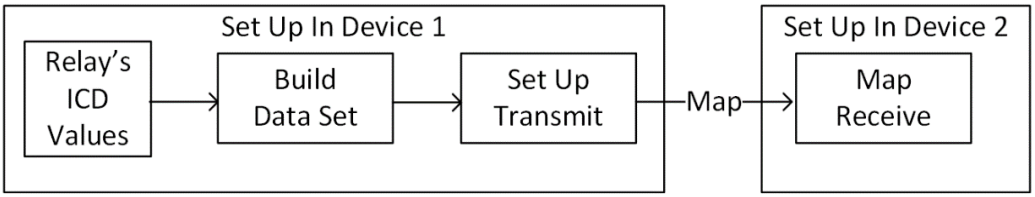


DIAGRAM 2
SCD Set Up Flow
From Sender to Receiver

- GOOSE Transmit Requirement
  - Assigned a Data Set
  - Message Name
  - GOOSE ID
  - Multicast MAC Address form of 01-0C-CD-01-0#-##
  - APP ID
  - VLAN ID & Priority (maybe used by network switches)
- SV Transmit Requirements (Could have two Transmits)
  - Assigned a Data Set
  - Message Name
  - SV ID

A unique Multicast MAC Address and APPID are recommended for sending out of GOOSE & SV messages. These are Layer 2 messages. These plus VLAN ID are used to control message flows in the network and to the relay.

VLAN Priority is used by traditional RSTP Switches to route messages.

- Multicast MAC Address form of 01-0C-CD-04-0#-##
- APP ID
- VLAN ID & Priority (maybe used by network switches)

- MMS Report (Could have multiple Reports)
  - Assigned a Data Set
  - IP Address (Layer 3 activities)
  - Report Name
  - Report ID
  - Report Type
  - Note RTU Polling does NOT follow this model.

Files: All the mapping for a given substation (GOOSE, SV & MMS) takes place in one SCD File. Each relay or IED gets a subset of this file, called the CID file, that specifies what it is sending out, where it's going, what it is receiving and where is it coming from. Note this may be in addition to any normal relay or SCADA settings files the device receives. This is shown Graphically in FIG 1

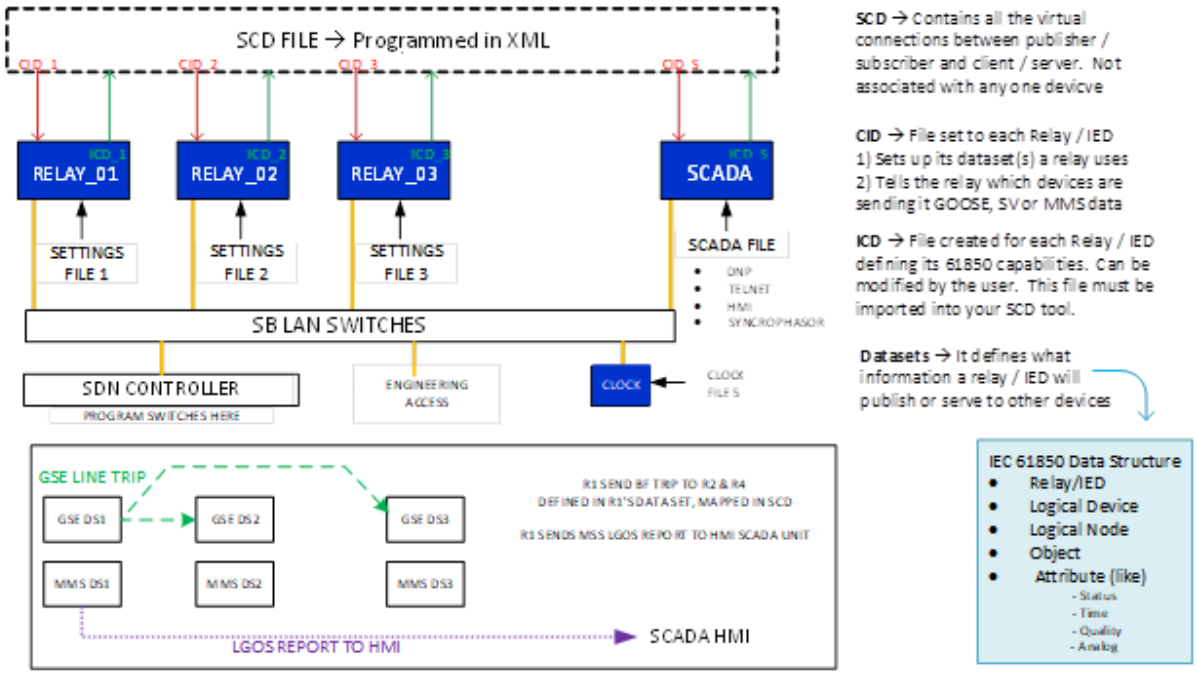


FIG 1: File Used in a IEC61850 Scheme

3. GOOSE Messaging

GOOSE Messaging (Generic Object-Oriented Substation Events): One of the most used aspects of IEC61850 is GOOSE. It basically digitizes the protection schemes contact logic. This new digitized system replaces copper control wires with virtual ones, turns Lock Out Relay (LOR) / Aux Contactors in to digital logic in a relay. FIG 3 show a comparison of a wired vs GOOSE system.. GOOSE properties include:

- Outputs are sent by the Publisher Relay over the Station Bus (SB) Local Area Network (LAN)
- Inputs are received by the Subscribing Relay over the SB LAN
- These virtual connection between the Publishers and Subscribers are created in the SCD File.

- A relay can publish a message to multiple subscribers → One to Many relationships. For example, the FIG 3 left side Line relay trips both CB1 & CB2 via the Aux Tripping Relay
- A subscriber can receive messages from multiple devices. Again, the FIG 3 left side Line relay receives BF Trips from two different LOR's. These contacts are in parallel.

- What a Publisher sends out as a GOOSE Messages is defined by its GOOSE Data Set. For example, the FIG 3 BF Relay's data set would include both a 52a and a BF Trip. Note:
  - Just because it is in the dataset, doesn't mean it has to be used by the subscribing relay.
  - The GOOSE message size has a max limit, but recommend keeping it small as possible.
- GOOSE messages are not routable yet. Meaning they cannot go thru a firewall and out the door. This will affect substation-to-substation GOOSE network for a RAS or a DTT schemes.
- GOOSE Messages must be very fast to be used for tripping. As such, no handshake logic is used. Instead, the publisher sends out its GOOSE message at a time interval t.
  - If the Subscriber stops getting the publishers heartbeat message, a GOOSE Fail occurs.
  - When GOOSE Message changes state (like as BF Trip), a burst of messages are immediately sent out based on the Min Time until things move back to the heartbeat.
  - FIG 2 shows this below with a Heartbeat time of 1000 mS and a Min Time of 4 mS

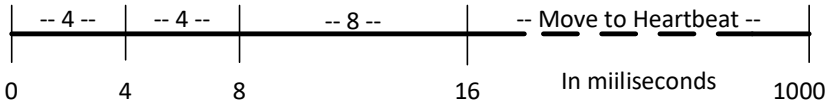


FIG 2: Heartbeat Diagram

- GOOSE Message must follow the IEC61850 digital package format. This allows the messages to be interoperable i.e. a SEL relay can publish a message to a Siemens, GE & ABB relay and they should be able to understand it.

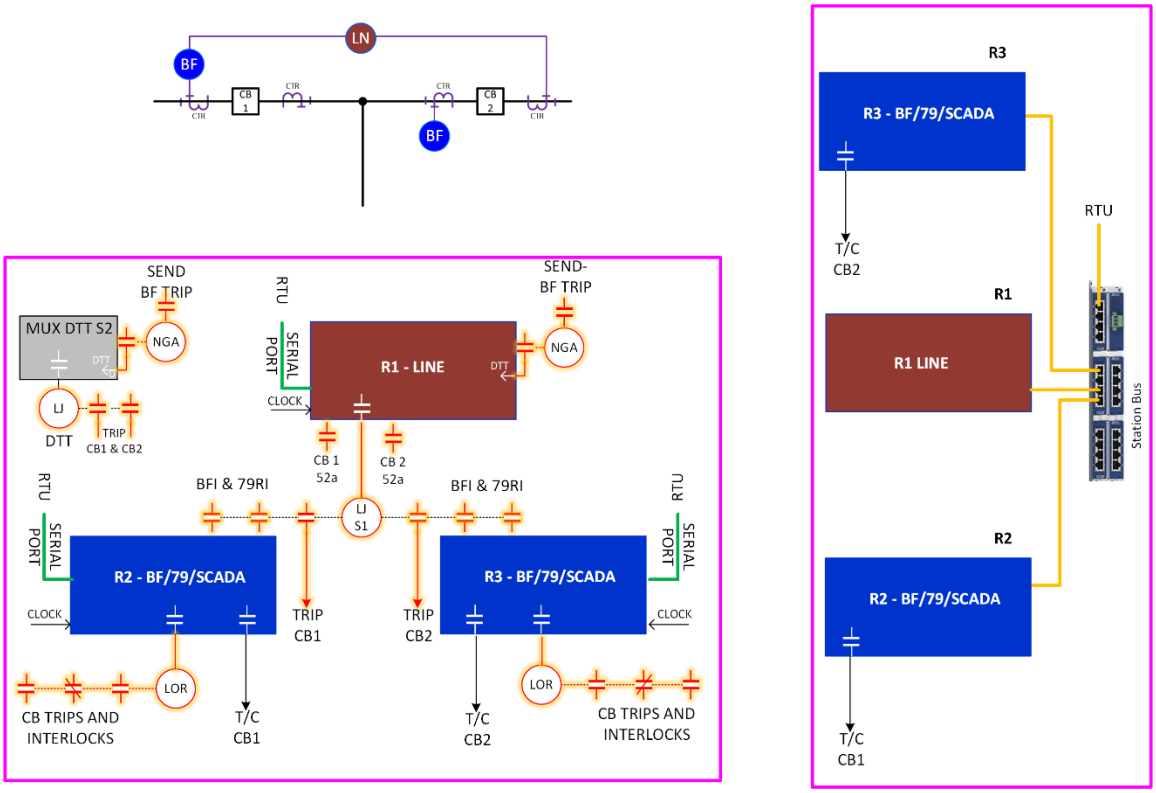


FIG 3: Wired VS IEC61850

4. IEC61850 Modes

IEC61850 Edition 2 relays have three special modes besides typical Operational Mode (Op Mode): Test Mode, Block Mode, and Simulation Mode. IEC61850 Mode and Behaviors MUST be enabled in the Relays Port setting and for each device in the SCD File. These different modes are described below:

- Test Mode: A relay publishes a GOOSE message with a Test Mode Flag = 1. Only Subscriber relays who are also are in Test Mode can process the message. If no relays except the publisher are in Test Mode, nothing will happen if a publisher message is sent.
- Block Mode: Stops any contacts on the relay from changing state. Only used if the relay has any tripping / closing contacts. Note that Block Mode could impact Pilot Relays with DTT if contacts drive any of these functions. Limited use of this mode at ComEd because all of our output contacts have test switches for isolation.
- Simulation Mode: Used to put a Subscribing Relay in Simulation mode. Then a GOOSE / SV simulator kit can be connected to the network at an engineering access port. Load the CID file for the Publishing Relay you want to simulate into your kit and then publish it with its Simulation Flag true. When the message is received by the Subscribing Relay, it stops listening to the normal Publishing Relay and starts listening to the simulated signal. Transferring back to the normal signal requires Simulation Mode be turned off in the Subscribing Relay.

FIG 4 shows the different modes involving Test Mode & Block Mode. With traditional isolation test switches no longer needed, Test Mode becomes critical for the field to isolate a relay or engage in controlled point to point testing. Simulation mode can be used if point to point is not required.

Additionally, a method for putting the relay into one of these modes is required. This could be a Push Button on the relays front panel, an HMI control via MMS or an MMS command by a test kit.

Finally, it is recommended that the 61850 Mode status of each relay get mapped to the HMI via MMS.

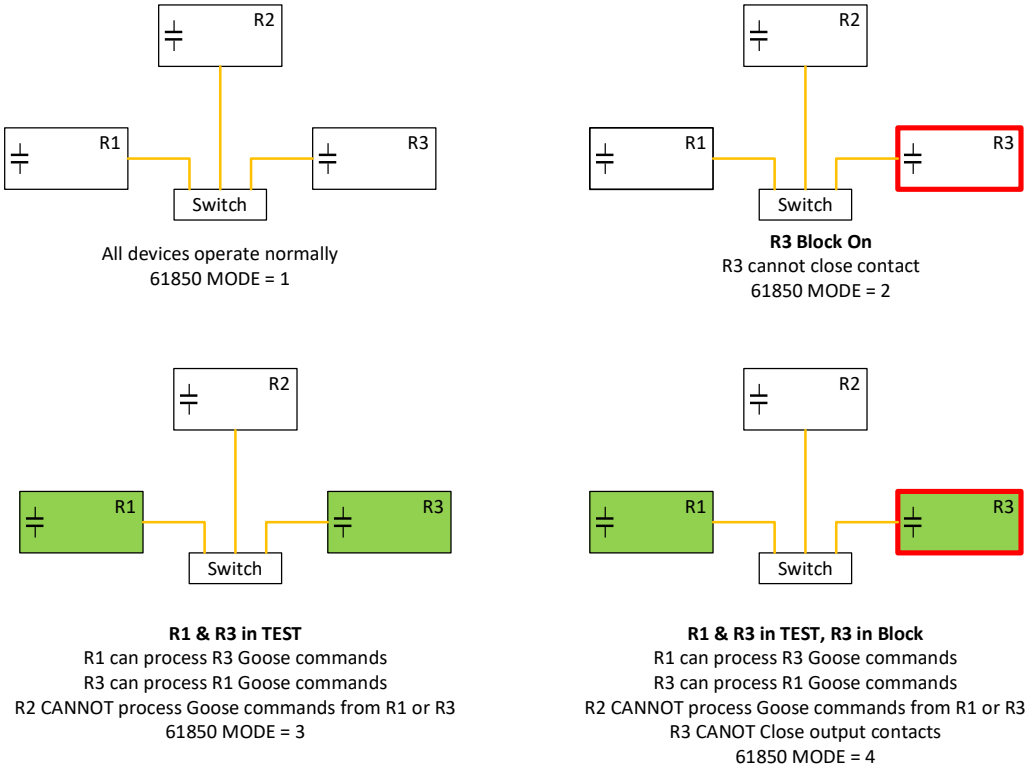


FIG 4: IEC61850 Modes

5. Sampled Vales (SV)

SV are used to send / receive analog quantities on the network. Basic facts include

- CT & PT are wired into a relay. This relay then digitizes these analog quantities, which in turn is then Publishes out to Subscribing relays. This reduces CT /PT cables, CT burden and the likelihood of opening or grounding a CT.
- Publishing units fall into one of three categories:
  - Basic Merging Units → Publish SV and wired to trip / close the CB via GOOSE
  - Intelligent Merging Units → Does everything that Basic unit does, but will have additional features like BF, Reclosing or monitoring logic
  - SAMU → Only publishes out SV
  - Side Note: In a GOOSE only tripping scheme (i.e. no SV), many engineers will refer to the relay that actually trips the CB a Merging Unit. Not technically correct, but it happens.
- SV are typically sent over the Process Bus (PB) LAN. Sample rate is for the relays I have used is 4.8kHz or once sample every 0.208 mS (about 80 samples a cycle). As a result, the PB has a lot of data on its network. So its best to limit other communication session on it.
- Requires a Precision Time Protocol (PTP) Clock signal. This is a highly accurate clock signal sent over the network. To make this happen, you need a clock capable of PTP and switches that have transparent clock capability to accurately transport PTP. Clocks are a critical aspect of SV and should not be taken lightly. Again, advance clock stuff out of scope.
- SV Message must follow the IEC61850 digital package design for interoperability.
- SV has Simulation Mode for testing. For example, if you have a 87B relay, you can simulate sending a current stream into the relay thru a test kit only connected to the network
- Currently the digital package (i.e. data sets) for SV consist of 4 currents and 4 voltages. So, if you only want to send 3 currents (A, B & C phase), you still must leave the other spots blank. So, this take up bandwidth on the PB. This is changing and data sets are being created that allow you to put into up to 8 streams, your choice – 1 to 8 current, 1-8 voltages or any combo. Unused spots do not take up room in the digital package.
- Some venders offer a proprietary version of SV. These systems do not need a PB LAN and the clock signal is handled by the relay. So, it is simple, but it is not interoperable.

6. MMS Basics

MMS (Manufacturing Messaging Specifications)

- Is 61850 SCADA protocol, which is word [object] based (vs. register / row [index] based like DNP).
- Just like for GOOSE & SV, you create an MMS Data set for a relay.
  - The sending / Publishing device (i.e. the relay) is referred to as the Server.
  - The receiving / Subscribing device (i.e. the SCADA unit) is referred to as the Client.
- MMS is sent out to the Client via reports or polling.
  - Reports
    - Reports are set up in the Server device CID File (the relays)
    - Reports are assigned to a data set, which specifies that report's information.
    - Reports are then mapped to a Client.
    - Reports are sent out when triggered by an event (data change, data update, quality change, or periodically).
      - Dead bands are needed by analogs values to trigger a report. If the values change exceeds the dead band range, a report is published. If deadbands areto tight, a high volume of reports could be sent and impact network traffic.
      - Integrity polls get sent out automatically at every time t. They are useful for report that have limited event triggering activities to verification functionality.

        - There are two types of reports:
            - Buffered Report → A buffered report can only be used by one subscribe and data is stored to some amount of time incase comms are lost and are sent when comms are restored. You don't want to make the buffer time to long, as it may affect the relays performance. Buffered reports are useful for things like CB status and other digital variables that could have momentary changes.
            - Unbuffered Report → An unbuffered report can be used multiple subscribers, but data is lost when comms go down. So, things like analog values and non-critical statuses are good candidates for this.

    - Polling
        - Polling takes place from Client on a fixed time interval.
        - Client requests a data set with a repeating time interval, regardless of any state changes. Higher value for analog data sets, because you can eliminate deadbands and then you have a known traffic flow because analogs can have higher data consumption.
- Map in the SER any MMS points requiring Momentary Change Detect (MCD) or a precision time stamp.
- There are alarms like LGOS that give you statistical info about GOOSE traffic and LSVS for SV traffic. These are not available in DNP. It would be good to run these to the HMI for troubleshooting.
    - Publisher ID
    - State Change Counter → Increments value and resets Sequence Counter when a state changes.
    - Sequence Counter → Counts how many GOOSE message packets have been received after a state change has occurred. It counts the Heartbeats and Min time transmission.
    - Subscription Status -> active or inactive
    - Test Mode, Block Mode or Simulation Mode Status
    - Commissioning Status
    - Error Status
    - Error Counts such as: out-of-sequence, decoding, buffer overflow, total message lost, max message lost, invalid quality, and time-to-live.
        - Time-to-live → Heartbeat TTL is 2X max time
        - Min time (after an event) TTL is 3X
        - This basically says that a message is only valid for this 2X or 3X
    - Downtown and total downtime -> timer to keep track of IED downtime.
- Just like all protocols when everything is set up correctly, they just start talking. In MMS it is critical to keep configuration matching between the publisher and subscriber.
    - Revision number → devices will not communicate if they are on different CID Rev. When modifying the SCD, it will ask if you want to update the REV number.
    - Overall configuration → device will not communicate if there are configuration mismatches. (If you don't use the Rev number and things do not match)
    - Reports/datasets → devices will communicate however data will not be transferred if there are differences in the reports/data sets.

7. Network & LAN

Network & LAN **(**Local Area Network). The transport mechanism for 61850 is a Local Area Network (LAN). The LAN connects all the relays, SCADA boxes and other IED's together. All devices connected this LAN require an IP Address. If this LAN is connected to the substation router and is accessible to the SCADA WAN, these IP address must be provided by IT/OT. If it is not and truly local, intelligent IP address can used

The signals for 61850 are sent on a LAN's. These networks are made up of switches that can connect to devices via CAT 5 or fiber. Since the connection is to an IP port, other types of data are allowed besides GOOSE, SV & MMS. The other data includes: DNP3, Telnet, PTP, SNTP, Synchro phasors.

ARP & Ping commands are also available. ARP occurs when you first plug into a switch, letting it know what port it was connected to. "Hi Mom, I am home in my room". A Ping checks to see if a relay is connected to a network. "John, are you in the kitchen"

There are two 61850 LAN's and a potential third LAN one available

- Station Bus (SB) LAN → Typically carries all communication types except SV
- Process Bus (PB) LAN → Used for SV bust could carry GOOSE & PTP
- An Interface LAN could be created that connects the station to the SCADA WAN. Using this LAN keeps the SB / PB local and prevents any external http services by using the SCADA RTU's as an air gap. It also allows the IP address to be self-generated (no worry of duplicate IP address on the WAN)

The networks can be set up in a lot of different ways.

First there are different types of switches – RSTP vs SDN (Rapid Spanning Tree Protocol vs Software Defined Networks). The switch selection affects both how network reconfiguration takes place and how the flow of data is controlled.

RSTP switches are typically plug and play - data in a port goes out to all other ports. So messages like GOOSE and SV must be controlled using VLAN tagging. Network reconfiguration takes place using RSTP and may not happen at protection speed.

SDN switches are not plug and play. They allow us to engineer both how the GOOSE and SV messages flow on the network and the alternate paths in the event of a network failure. Since fail over is predetermined, it occurs at protection speed. These switches can import your SCD File and auto map your IEC61850 flows.

Also, there are different failure designs: PRP & Fail Over.

Fail-Over uses a single LAN that reconfigures itself during a network fault and the device will switch from its primary to back up port based on link status detected by the relay. Things that should be evaluated.

PRP sends the same message out over two ports of the relay into separate LAN's with a trailer appended to the message. PRP redundancy relies on the expectation that a network reconfiguration will not occur on each network at the same time. The devices simply use the first message in and ignores the duplicate.

My experience suggests that PRP is typically used by folks setting up a 61850 network. That being said, when things are not going as expected, the duplicate paths PRP networks use can make getting to root cause challenging. Carefully evaluate the pros and cons of your network design for cost, commissioning and maintenance of your 61850 system.

Next there are several connection methods: Ring, Meshed, Hub & Spoke, shown below in FIG 5. Your network design may dictate what topology you use. For example, PRP requires a Ring and Fail Over gets a Networked.

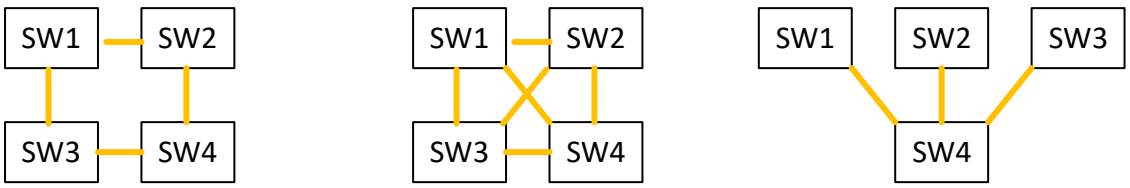


FIG 5: Switch Topologies

A few final comments about networks set up.

- Develop a good fiber plan. Redundant and easy to work on with equipment in service.
- Reserve a Cat 5 engineering access port and make sure it can see all your devices and PTP
- If you are setting up a PB LAN for SV, make sure everything can handle PTP and have a good redundant clock design.

- Note that the NIC Card used as the IP Port connection has a Hardware MAC Address. Every NIC Card has one and they should all be unique. This is different than the unique Multicast MAC Address the user assigned to the device in the GOOSE & SV Transmit tab. This fact is very confusing to new users.

8. Example SCD Development

The best way to put everything together is via an example of creating GOOSE only SCD file for the simple network shown in FIG 3. Note if multi-vender relays are being used, third party software is required to build the overall SCD file and then it gets imported into each manufacture's software. This example is for a single vender relay system and the entire process is described below and shown visually in FIG 6.

1. Define each Relay or IED used in the software
    a. Select device and review the ICD file to determine what Data Objects will use.
    b. Give the device an IP Address
2. Create a Data set for each relay based on what you want to send out. For this example, it is:
    a. BF Relay Send out CB Status and BF Trip
    b. Line Relay sends out Line Trip

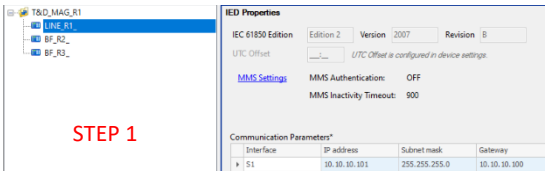
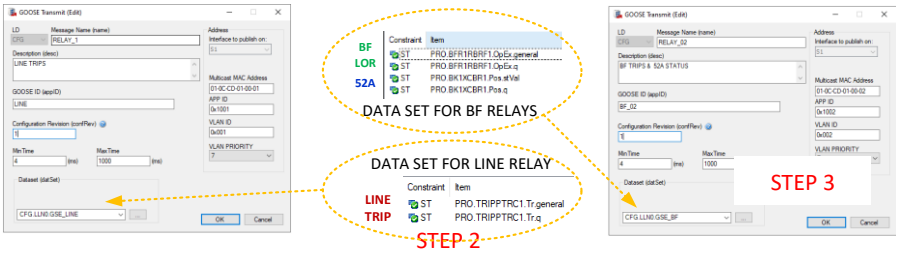


FIG 6a: Building a SCD File

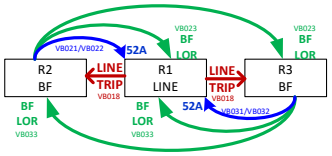
3. Create a GOOSE Transmit for each relay linked to the GOOSE data set. Fill in Message Name, GOOSE ID, Multicast MAC Address, APP ID & VLAN ID (these last three should be unique for each relay). Min & Heartbeat time should be set to 4mS and 1000mS. Set VLAN Priority to 7.
4. Map the data sets from the publishing relay to the subscribing relay. This is the virtual wiring. For this example, assign the publishing relay's dataset elements to a unique Virtual Bits for the subscribing relay. This example reserved VB010-019 for R1, VB020-029 for R2 and VB030-039 for R3. This is not required, but just how we did it.
5. Program the relays to receive these Virtual Bit and respond accordingly. This includes mapping Message Quality Bits from each publish relay to an alarm variable in the subscribing relay for a GOOSE Trouble alarm. (Goes true if publisher heartbeat missing for 3 seconds per our example)
6. Load CID File to each relay
7. Program or otherwise enable TEST & BLOCK Mode in each relay
8. Verify GOOSE Message act as expected



SUB Relay	PUB Desc	PUB VB Mapped	PUB Relay	PUB Message	PUB GSE ID	PUB Data Source (Relay.Log Device.Log Node.Object)	PUB Multicast MAC	PUB APP ID	PUB VLAN ID
LINE_R1_	QB	VB020	BF_R2_	RELAY_02	BF_02	RELAY_02 - message quality	01-0C-CD-01-00-02	1002	2
LINE_R1_	52A	VB021	BF_R2_	RELAY_02	BF_02	RELAY_02.PRO.BK1XCBR1.Pos.stVal - Lo	01-0C-CD-01-00-02	1002	2
LINE_R1_	52B	VB022	BF_R2_	RELAY_02	BF_02	RELAY_02.PRO.BK1XCBR1.Pos.stVal - Hi	01-0C-CD-01-00-02	1002	2
LINE_R1_	BF	VB023	BF_R2_	RELAY_02	BF_02	RELAY_02.PRO.BFR1RBRF1.OpEx.general	01-0C-CD-01-00-02	1002	2
LINE_R1_	QB	VB030	BF_R3_	RELAY_03	BF_03	RELAY_03 - message quality	01-0C-CD-01-00-03	1003	3
LINE_R1_	52A	VB031	BF_R3_	RELAY_03	BF_03	RELAY_03.PRO.BK1XCBR1.Pos.stVal - Lo	01-0C-CD-01-00-03	1003	3
LINE_R1_	52B	VB032	B				01-0C-CD-01-00-03	1003	3
LINE_R1_	BF	VB033	B				01-0C-CD-01-00-03	1003	3
BF_R2_	QB	VB010	L				01-0C-CD-01-00-01	1001	1
BF_R2_	LINE	VB018	LINE_R1_	RELAY_01	LINE	RELAY_1.PRO.TRIPPTRC1.Tr.general	01-0C-CD-01-00-01	1001	1
BF_R2_	QB	VB030	BF_R3_	RELAY_03	BF_03	RELAY_03 - message quality	01-0		3
BF_R2_	BF	VB033	BF_R3_	RELAY_03	BF_03	RELAY_03.PRO.BFR1RBRF1.OpEx.general	01-0		3
BF_R3_	QB	VB010	LINE_R1_	RELAY_01	LINE	RELAY_1 - message quality	01-0		1
BF_R3_	LINE	VB018	LINE_R1_	RELAY_01	LINE	RELAY_1.PRO.TRIPPTRC1.Tr.general	01-0C-CD-01-00-01	1001	1
BF_R3_	QB	VB020	BF_R2_	RELAY_02	BF_02	RELAY_02 - message quality	01-0C-CD-01-00-02	1002	2
BF_R3_	BF	VB023	BF_R2_	RELAY_02	BF_02	RELAY_02.PRO.BFR1RBRF1.OpEx.general	01-0C-CD-01-00-02	1002	2

FIG 6b: Building a SCD File

STEP 4



SUB Relay	Logic Programmed in SUB Relay
BF_R1_	CB_CLSD := (VB021 AND NOT VB022) OR (VB031 AND NOT VB032)
BF_R1_	TRIP := VB023 OR VB033
BF_R1_	GSE_FAIL := VB020 OR VB030
BF_R2_	TRIP := VB018 OR VB033
BF_R2_	GSE_FAIL := VB010 OR VB030
BF_R3_	TRIP := VB018 OR VB023
BF_R3_	GSE_FAIL := VB010 OR VB020

STEP 5

9. GOOSE Frames

These are the discreet digital message sent out into the network in time with the heartbeat (or min time after a state change occurs). GOOSE message both a Header and a Payload. The Header contains most on the information found in the GOOSE Transmit set up. The Payload has the dataset information.

The GOOSE message structure is defined in IEC 61850-8 and it follows well-defined industry standards for ethernet traffic with some caveats described in the standard. Most elements have dedicated "encoding tags" that indicate the type of data that follows that tag as well as that data's length (in bytes).

In the Frame, the dataset's elements follow the order that they are mapped in the publishing relay. Also, each element in a dataset has its own quality string within the message. This would allow a relay to put individual elements into Test Mode. A relay vender may choose not to do this, and if the relay is put into or taken out of Test Mode, every element in any datasets for that relay will collectively change states.

Below are network traffic captures from a GOOSE message with 10 elements in its dataset.

GOOSE Message Header contains the sender / publisher information, some of the information comes from the GOOSE Transmit tab. Note the Destination MAC is the Multicast MAC address for that GOOSE message defined in the Transmit Tab of the Publisher. The Source MAC is from the Publisher's NIC Card.

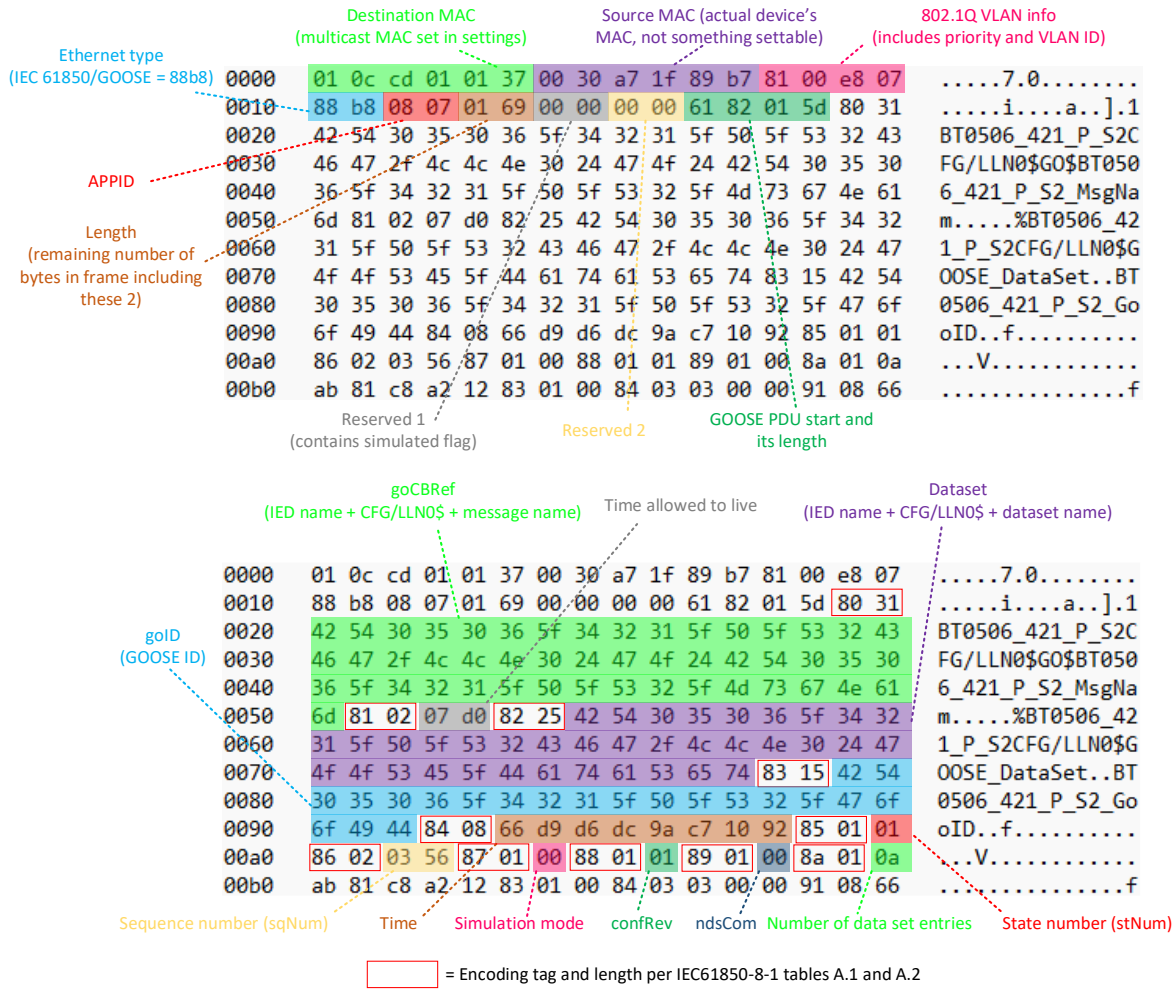


DIAGRAM 3: Packet Capture 1

The following picture is a different view of this same Header information, but in a much simpler format to review. There are many tools out there that can “Sniff the Message” and provide simple visualization as shown here.

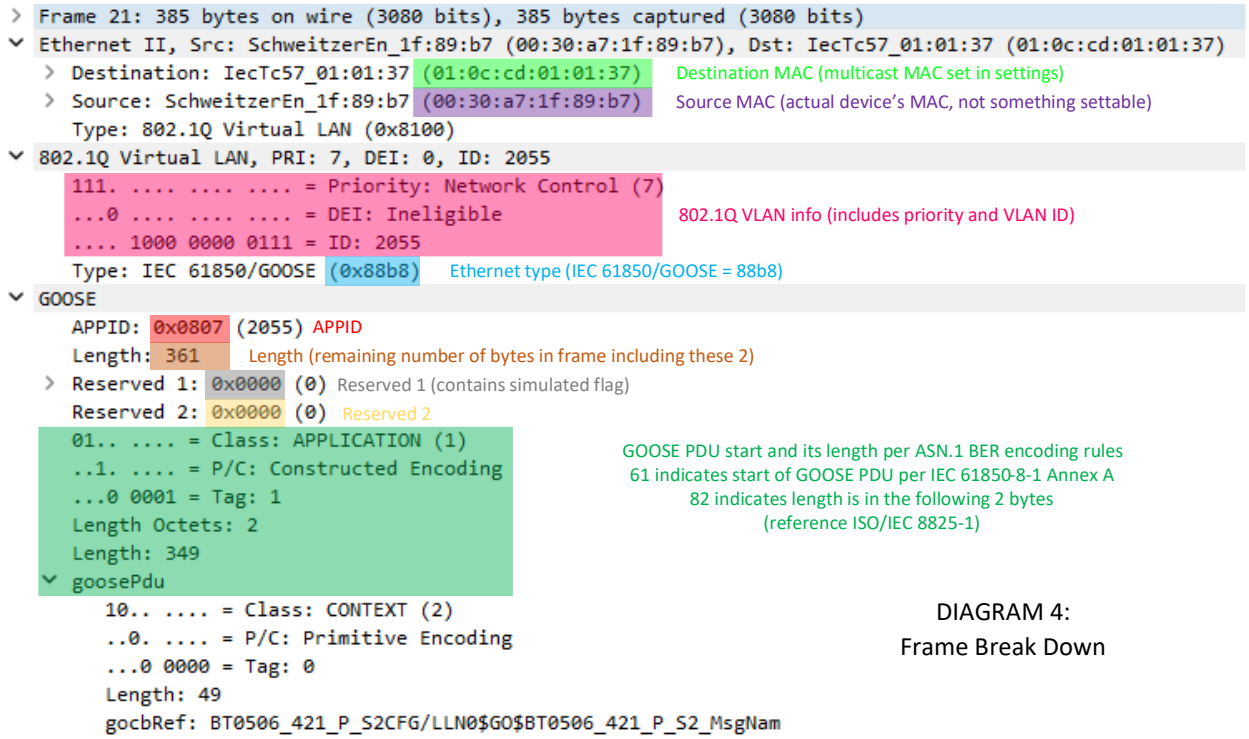


DIAGRAM 4:
Frame Break Down

The Payload is shown below and is part of the overall frame/packet capture. Each element has its stVal, quality and timestamp included in the dataset. StVal is either a 1 or a 0, the quality is encoded into 2 bytes (16 bits) and the timestamp is per section 8.1.3.7 in IEC 61850-8-1. For the quality string, table 44 in IEC 61850-8-1 shows the use of each bit in the quality string. Bit 11 in the quality string corresponds to the test mode flag. Assuming the validity is good and all other elements in the quality string are false when the message is sent, a quality string equal to 0x0010 (0b0000 0000 0001 0000) means that element is in test mode (0x0000 is op mode).

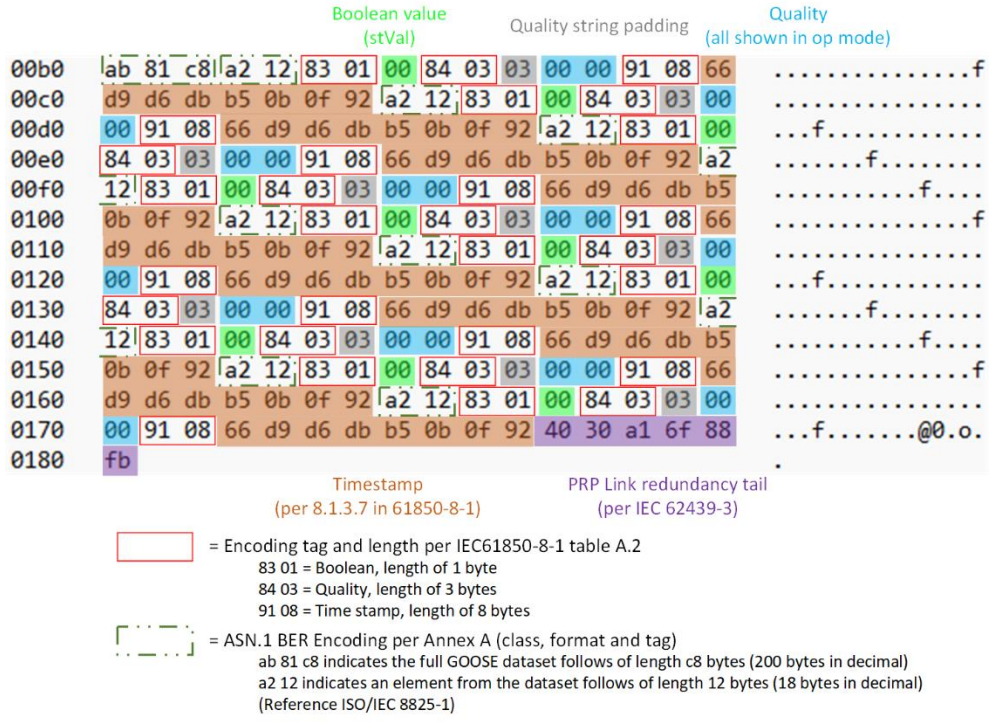


DIAGRAM 5:
Packet Capture 2

10. Conclusion

In Conclusion, the IEC61850 standard is a very effective tool to reduce physical assets in a station and replace them with virtual ones. We can use GOOSE and SV to replace wired contact logic and CT/PT cables. We can then use MMS as a word-based SCADA Protocol that is self-tagging and has IEC61850 alarm points available.

The foundation of 61850 is creating a Dataset from the devices ICD file, setting up a standards-based transmission to send this dataset, and finally, mapping this dataset to a receiving device (Relays being Subscribers and RTU's being Clients). This all takes place in a file called the SCD, which contains all the information for all the relays / IED / SCADA boxes. A chunk of the SCD file is sent to all the devices, letting each know what it is sends, receiving and where this information is coming or going.

These new communication systems work over a local area network system using redundant network switching schemes. A simple example was provided to show the readers the real steps needed to build one of these systems.

Finally, we looked at an actual GOOSE frame to break down what is actually in a GOOSE message.

References

1. IEC 61850-8-1 "Communication networks and systems for power utility automation – Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3", Edition 2.1, 2020-02

Biographies

John Bettler has a BSEE from Iowa State University of Science and Technology and an MSEE from Illinois Institute of Technology (IIT). John has worked at Commonwealth Edison Company (ComEd), a power company in the Chicago area, for 29 years. He has experience as a field engineer and protection engineer. Currently, he is the principal engineer for ComEd's relay division. His team's purview includes 4 kV and 12 kV feeders up to 765 kV transmission lines and all transmission and distribution equipment in between (e.g., transformers, buses, cap, and inductors). John's team also reviews interconnections, independent power producers, and distribution generation projects. John is also adjunct faculty at IIT and University of Wisconsin- Madison teaching power and protection classes. He is a PE in Illinois.

Kevin Malpede, B.S. degree in Electrical Engineering from Purdue University. He has worked in the power industry in various roles since graduating in 2014. Started off with print design and moved into a relay settings engineer role at ComEd. Kevin has been working in ComEd's relay and protection group since 2018, gaining experience with various T&D protection schemes , their settings and utilizing IEC61850.

Vincent Lazzaro, bachelor's degree in electrical engineering from Iowa State University with the focuses of Power Systems and Controls. He has been working in the power industry for 4 years now at ComEd under the SCADA Engineering group.