



HITACHI

ABB

BENEFITS OF USING IEC 61850 MESSAGES FOR TESTING CONVENTIONAL PROTECTION SCHEMES

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Introduction: Relay testing needs and challenges

Protection engineers are challenged to perform

- Thousands of test cases to verify a new design, protection scheme or a relay variant
- Emergency testing to resolve operation issues
- Commissioning tests, new firmware verification tests, etc

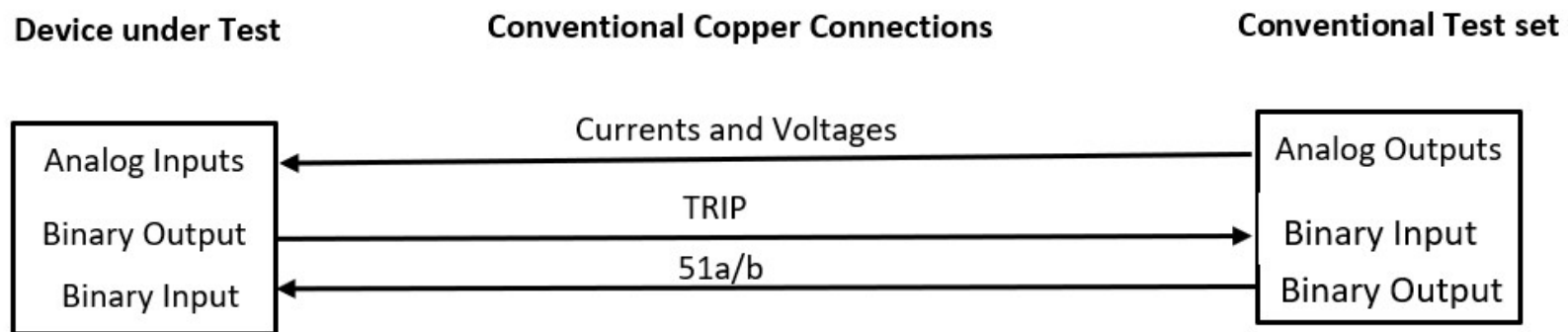
Traditional approaches that use conventional connections
take **enormous time and effort !**

Testing with IEC 61850 messages

- saves precious time
- supports more analog and binary signals
- provides higher visibility of internal relay logic



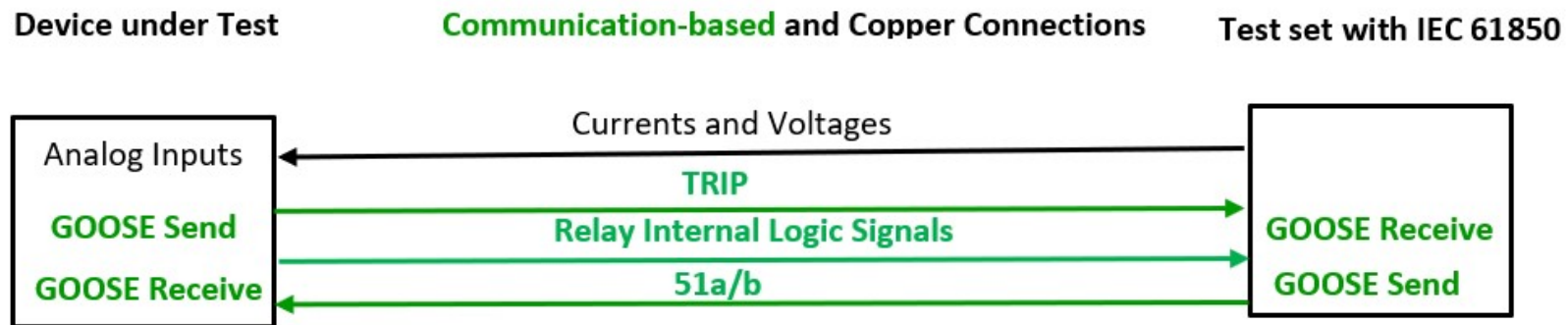
Conventional Relay Testing



Conventional relay testing with traditional copper wire connections typically need

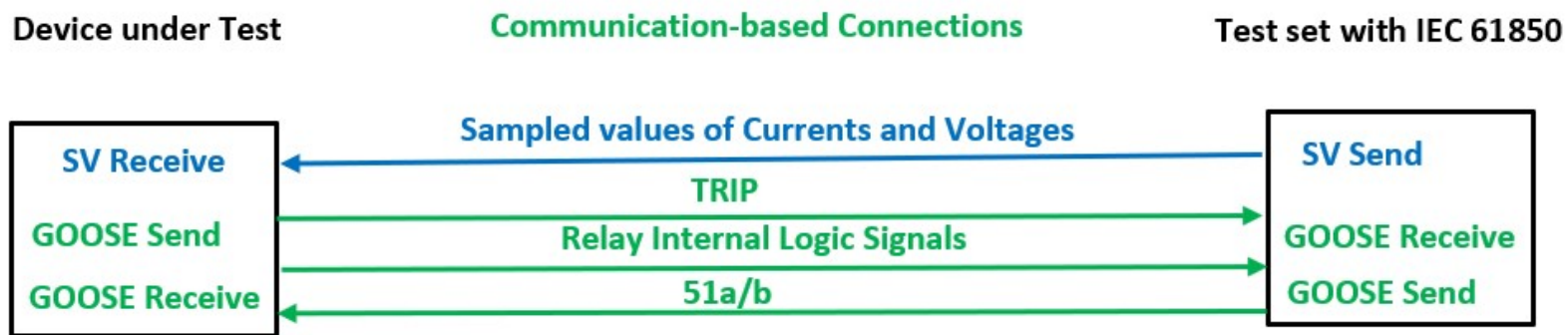
- Analog connections for all required currents and voltages, and
- Binary connections for Trip signals, Breaker status, etc

Converting binary signals to IEC 61850 GOOSE messages



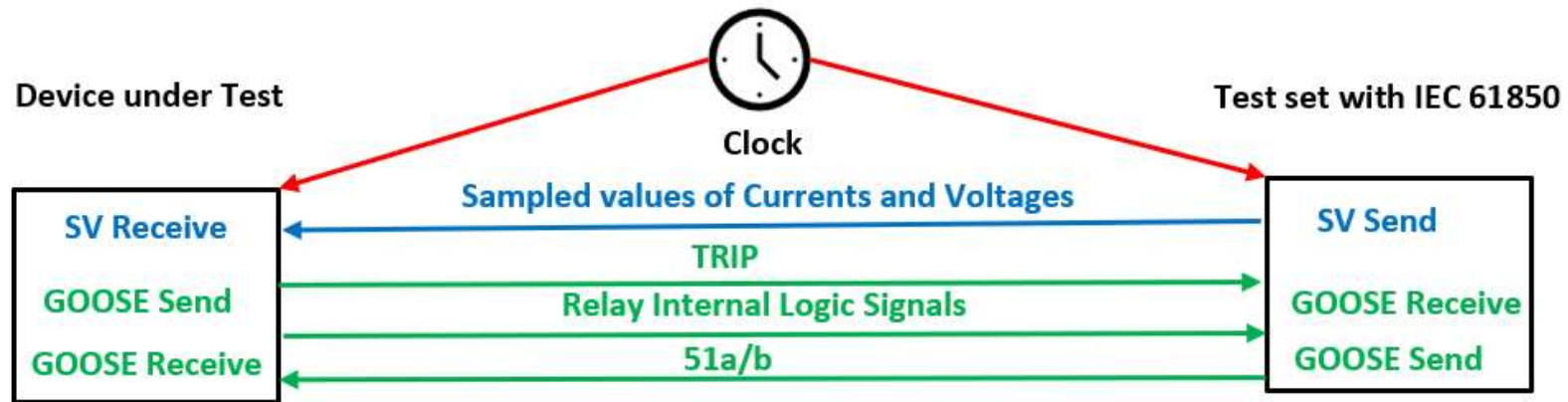
- First step is to convert **binary** copper connections to data bits in Layer 2 Ethernet-based IEC 61850 Generic Object Oriented Substation Event (**GOOSE**) messages
- As the most relays today support IEC 61850 GOOSE messages, this is the most common approach
- **Importantly**, now not only hardware connected binary signals, but also **internal relay logic** can be communicated, as much desired and very useful information

Converting analog signals to IEC 61850 sampled values (SV) messages



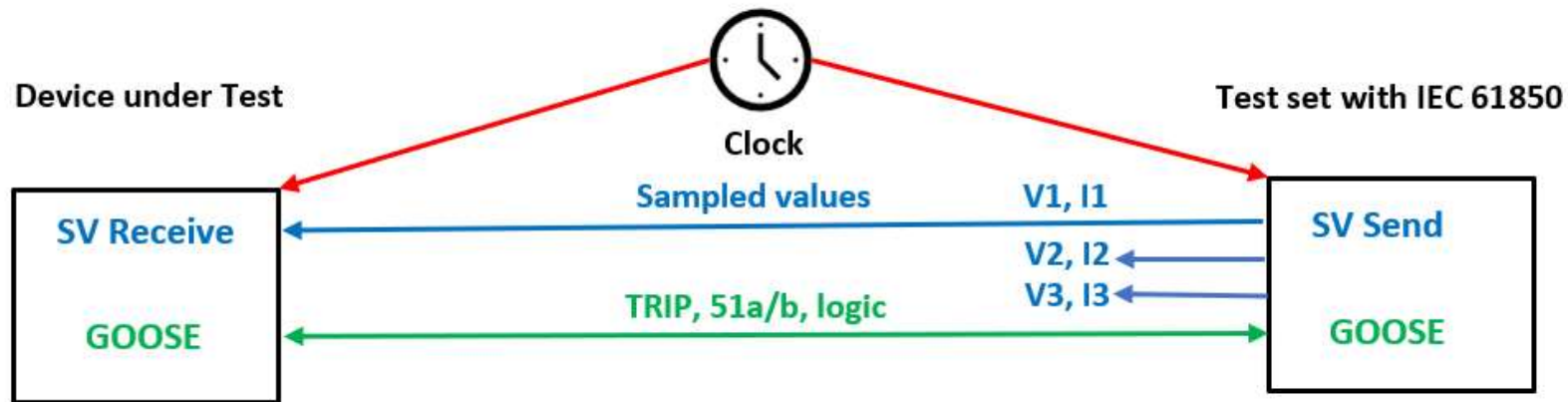
- Second step is to convert **analog** connections to IEC 61850 Sampled Value (**SV**) streams, also consisting of Layer 2 Ethernet messages
- Most commonly relays support **UCA IEC 61850-9-2 LE** (Light Edition) Implementation Agreement with 4 currents (3phases + neutral), 4 voltages (3phases + neutral) per SV stream

Samples synchronization between SV sender and SV receiver



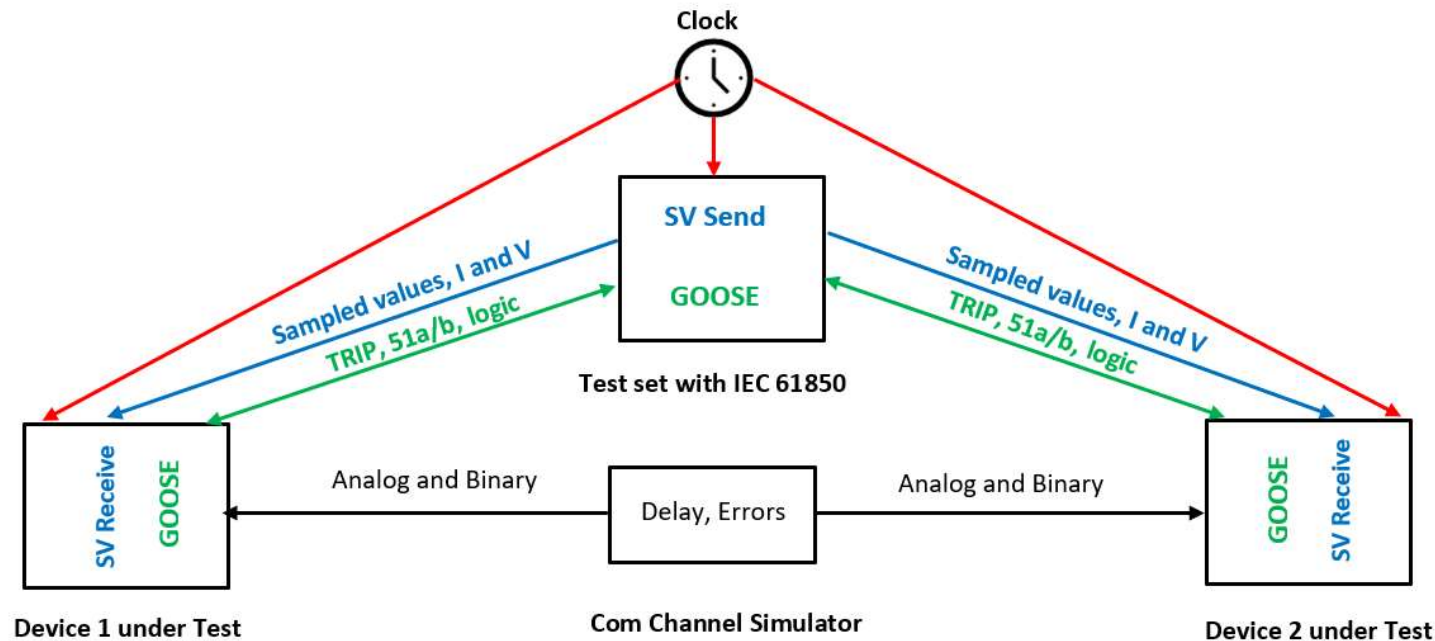
- To correctly obtain, transmit, receive and decode digital samples of analog values, data sampling **needs to be synchronized** between transmitter and receiver
- UCA IEC 61850-2LE specifies **optical 1 pulse per second (PPS)** synchronization, and sample rate of **80 or 256** samples per power cycle
- Newer IEC standards on dynamic merging unit behavior specify other sync methods and sample rates

Relay lab testing with multiple SV streams: transformer differential protection



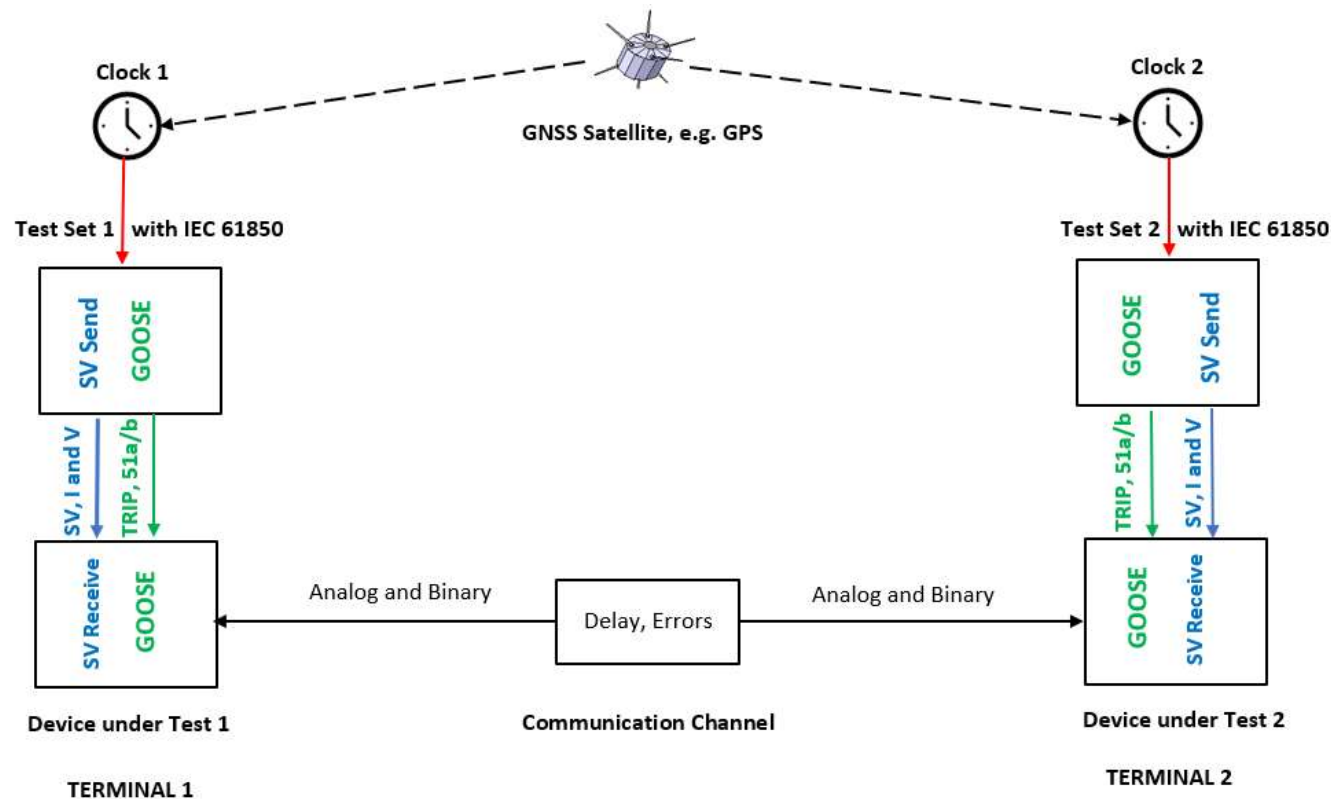
- Using SV streams instead of copper connections allows testing with **many more analog signals** than conventional test sets can typically support
- For example, transformer protection can be tested with **five (5) 3-phase** current streams
- Some relays can subscribe to **up to eight (8) SV streams**

Relay lab testing with multiple SV streams: line differential protection



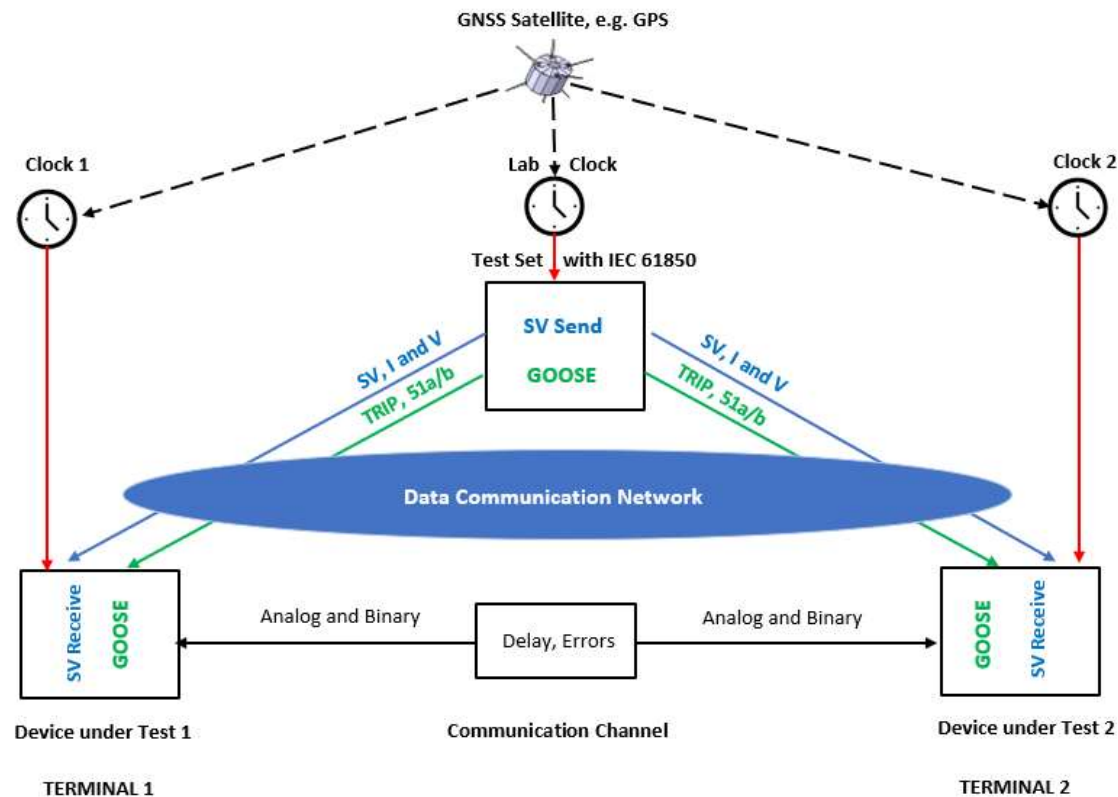
- Multiple SV streams are also necessary for testing multi-terminal line protection schemes
- In a lab setup SV streams for all terminals can be generated **by the same test equipment**, eliminating the need to use and synchronize multiple test sets
- Communication Channel Simulator can emulate channel delay and inject channel errors as required

Relay field testing for two-terminal line protection



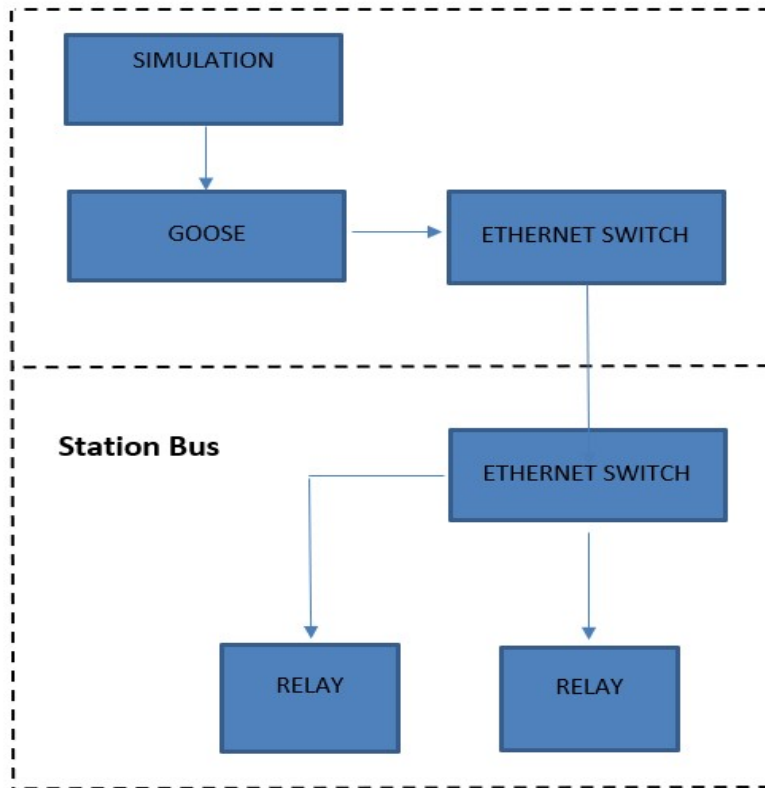
For field testing copper connections can be replaced by communication bits, but **a new test setup** and **testing personnel** will be required at each line terminal

Remote relay testing idea for two-terminal line protection



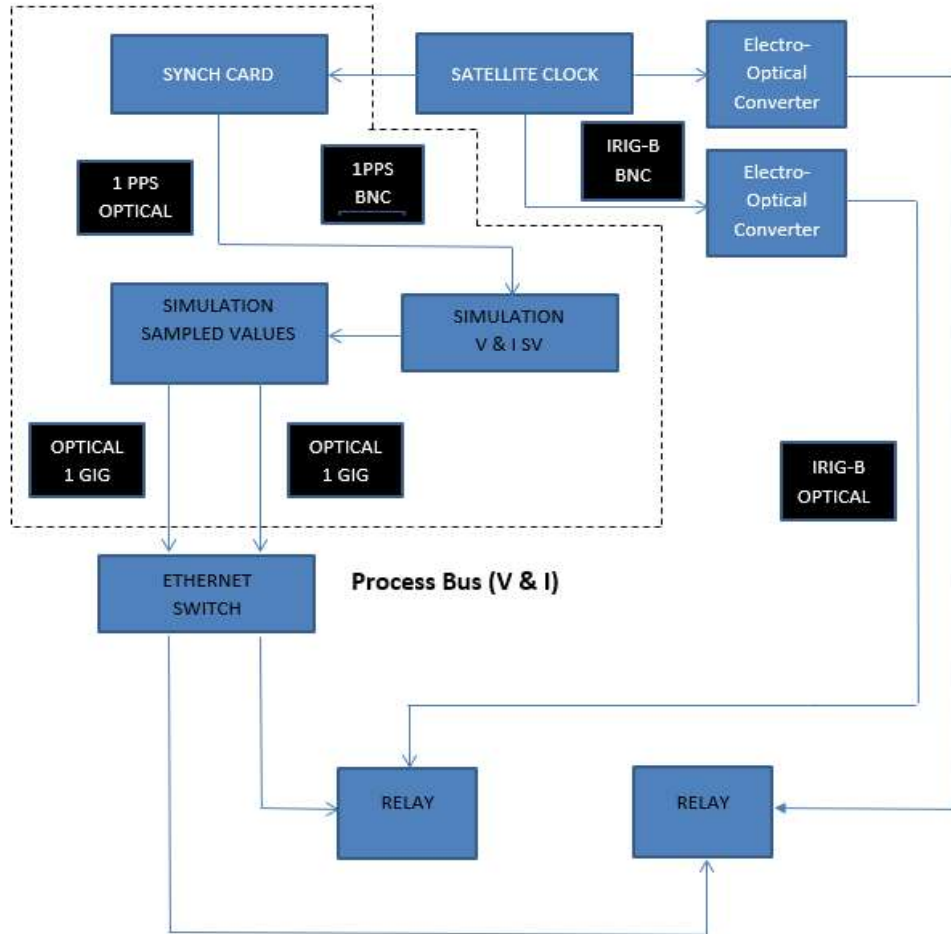
If **utility communication network**, however, can support SV and GOOSE messages reliably, **the same lab test setup** can be used to test **relays in the field** !

Test setup at BPA laboratory: GOOSE messages



- Relays publish messages with Trips, Permissive, Alarms and internal logic
- RTDS subscribes relays messages, and publishes breaker position, and reclose enable
- RTDS plots **one time-aligned** COMTRADE file with all the signals

Test setup at BPA laboratory: SV messages



- Copper analog connections replaced by SV streams
- Relays were tested with **five (5)** 3-phase currents used in the 87T scheme
- Relays support up to **eight (8)** SV streams

Test setup at BPA laboratory: RTDS and relay racks



Test setup at BPA laboratory: switches, clock and com channel simulator

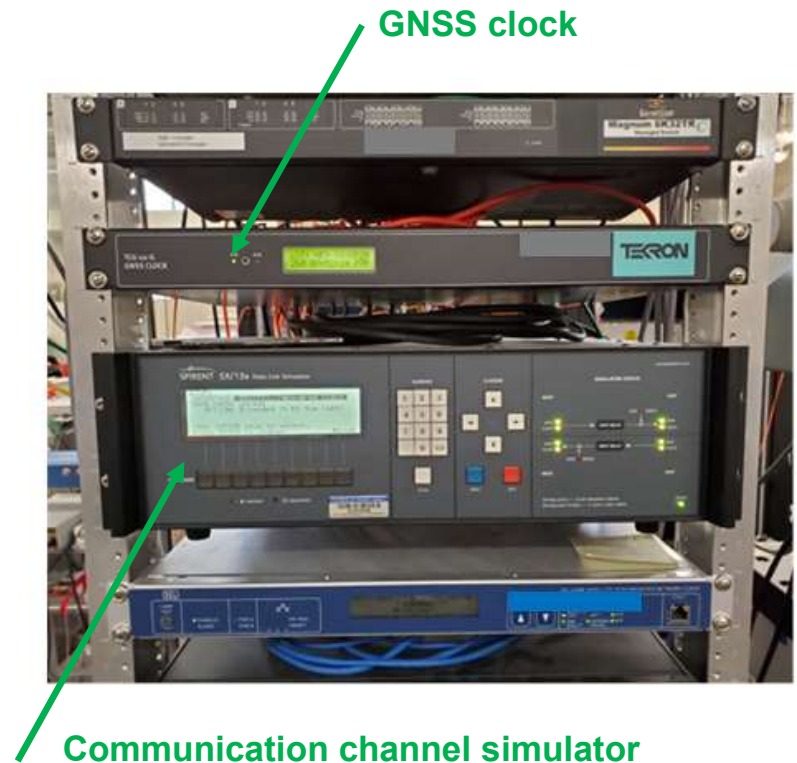


Line Terminal 1 relay

Line Terminal 2 relay

Process bus switch
(Sampled Values)

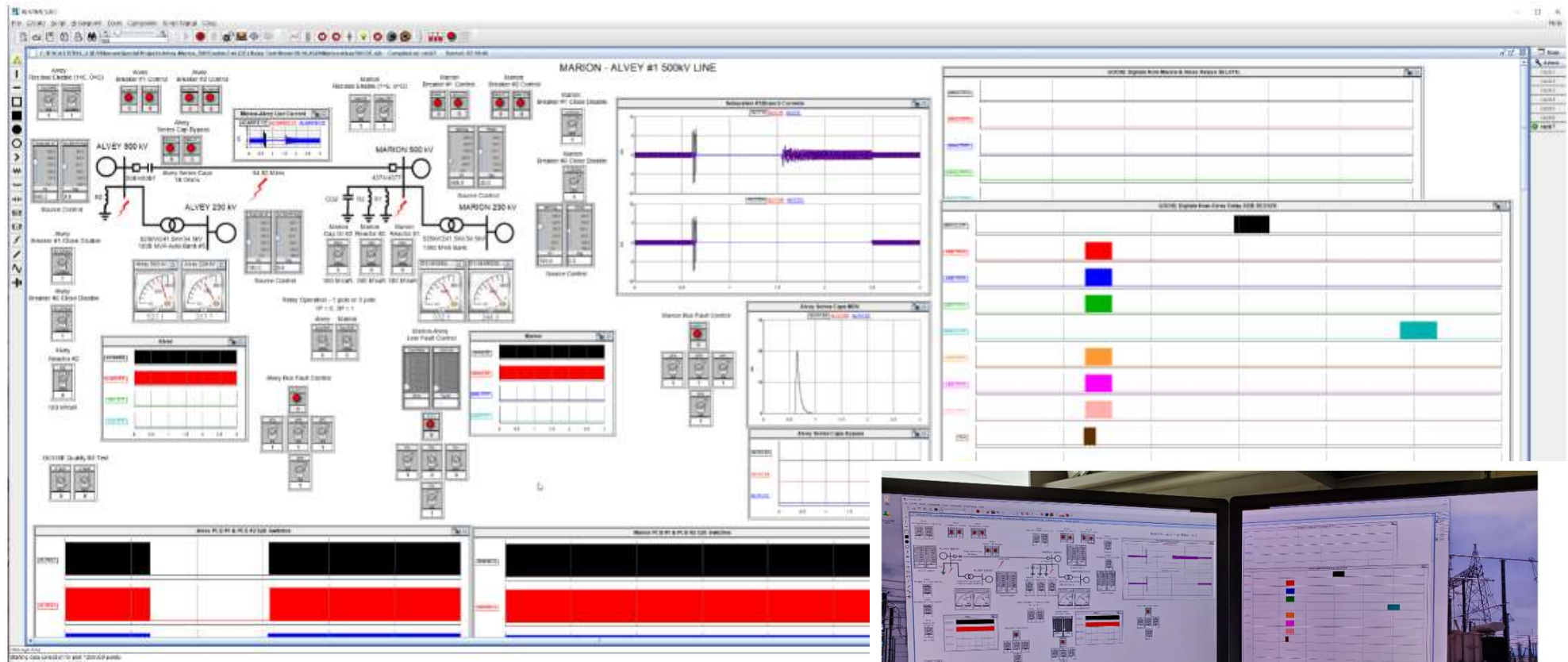
Station bus switch
(GOOSE messages)



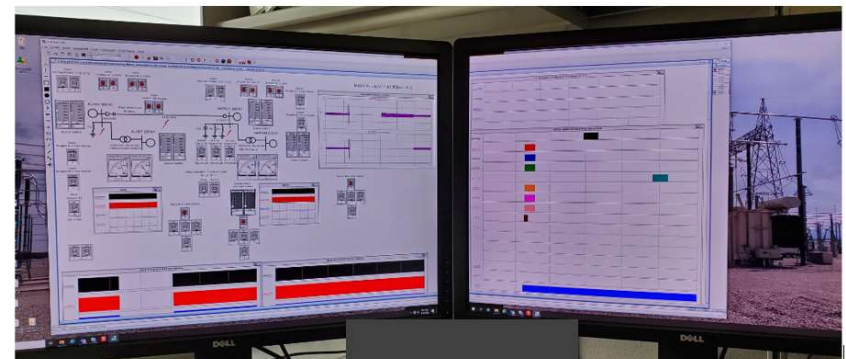
GNSS clock

Communication channel simulator

Test setup at BPA laboratory: oscilloscope-like RTDS plot



Time aligned signals from all terminals are shown

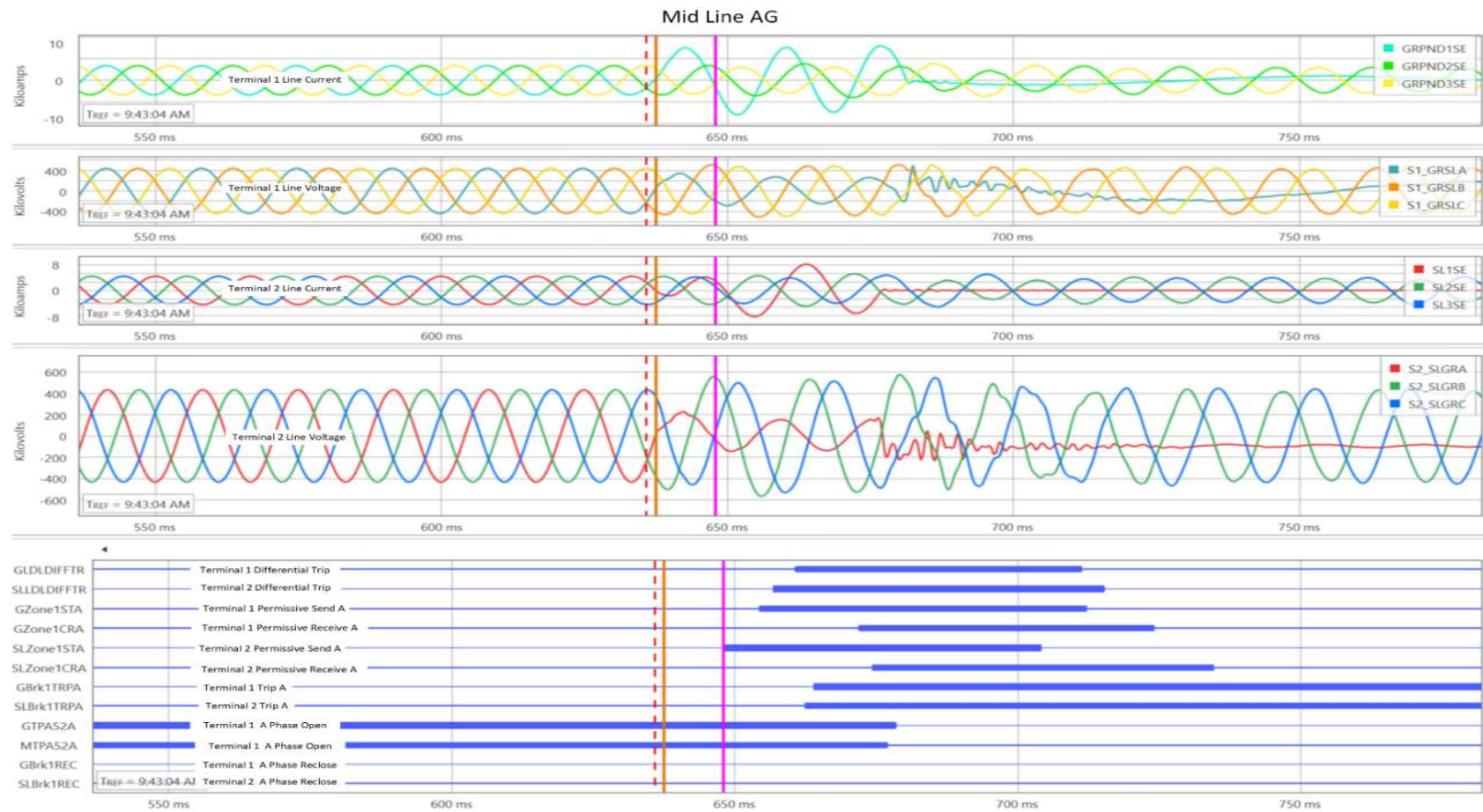


BPA Testing and Results

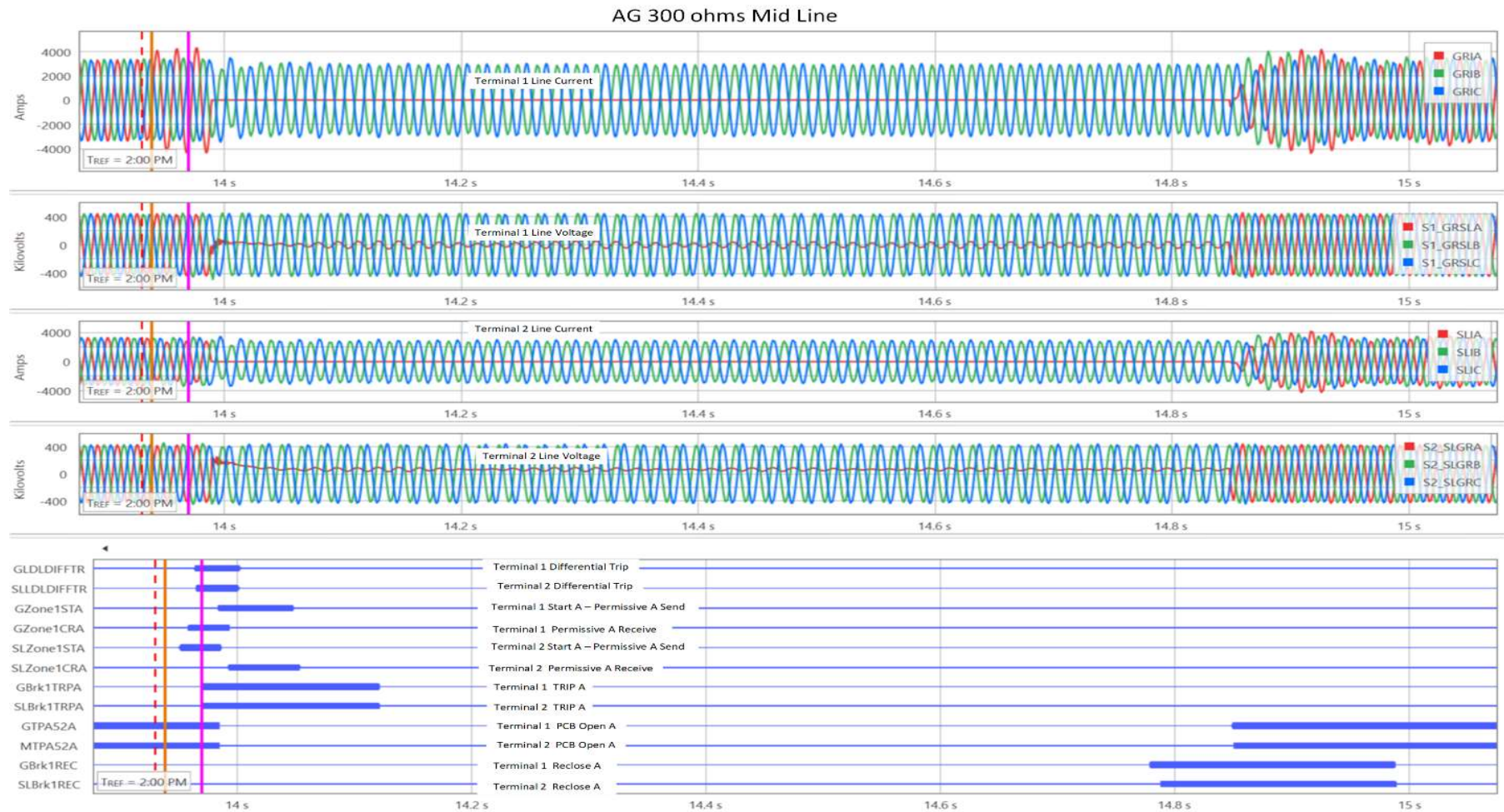
BPA successfully performed numerous relay RTDS tests using the described setup. The paper includes 6 examples to illustrate the benefits of the testing method used.

1. Line protection tests
 - Example 1: Mid-line phase to ground fault
 - Example 2: Mid-line phase to ground fault with 300-ohm fault impedance
 - Example 3: 3-Phase Bus Fault
2. Transformer protection tests
 - Example 4: Internal fault
 - Example 5: External Fault
3. Commissioning test, Example 6.

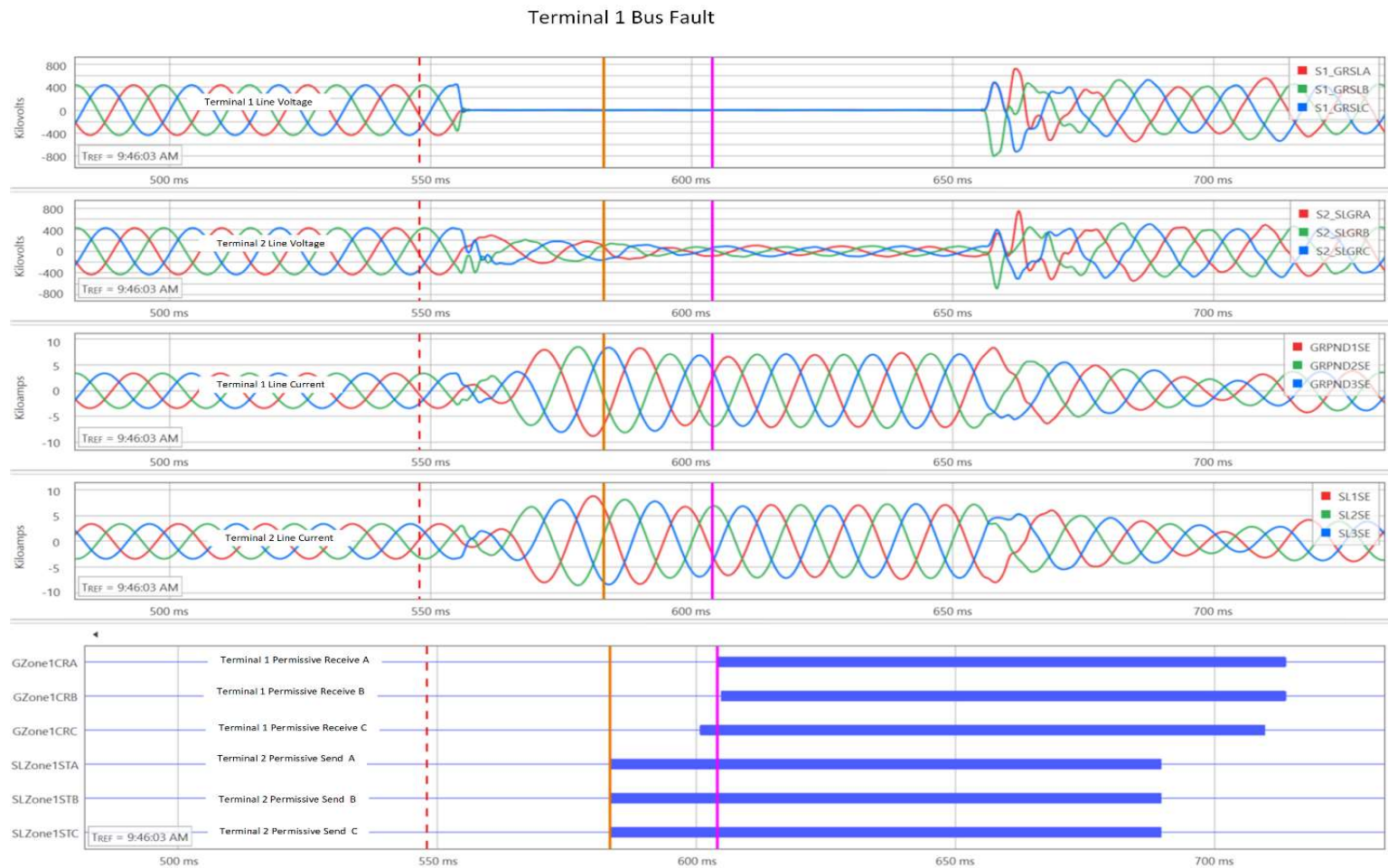
BPA Testing and Results: Line protection test (Example 1)



BPA Testing and Results: Line protection test (Example 2)



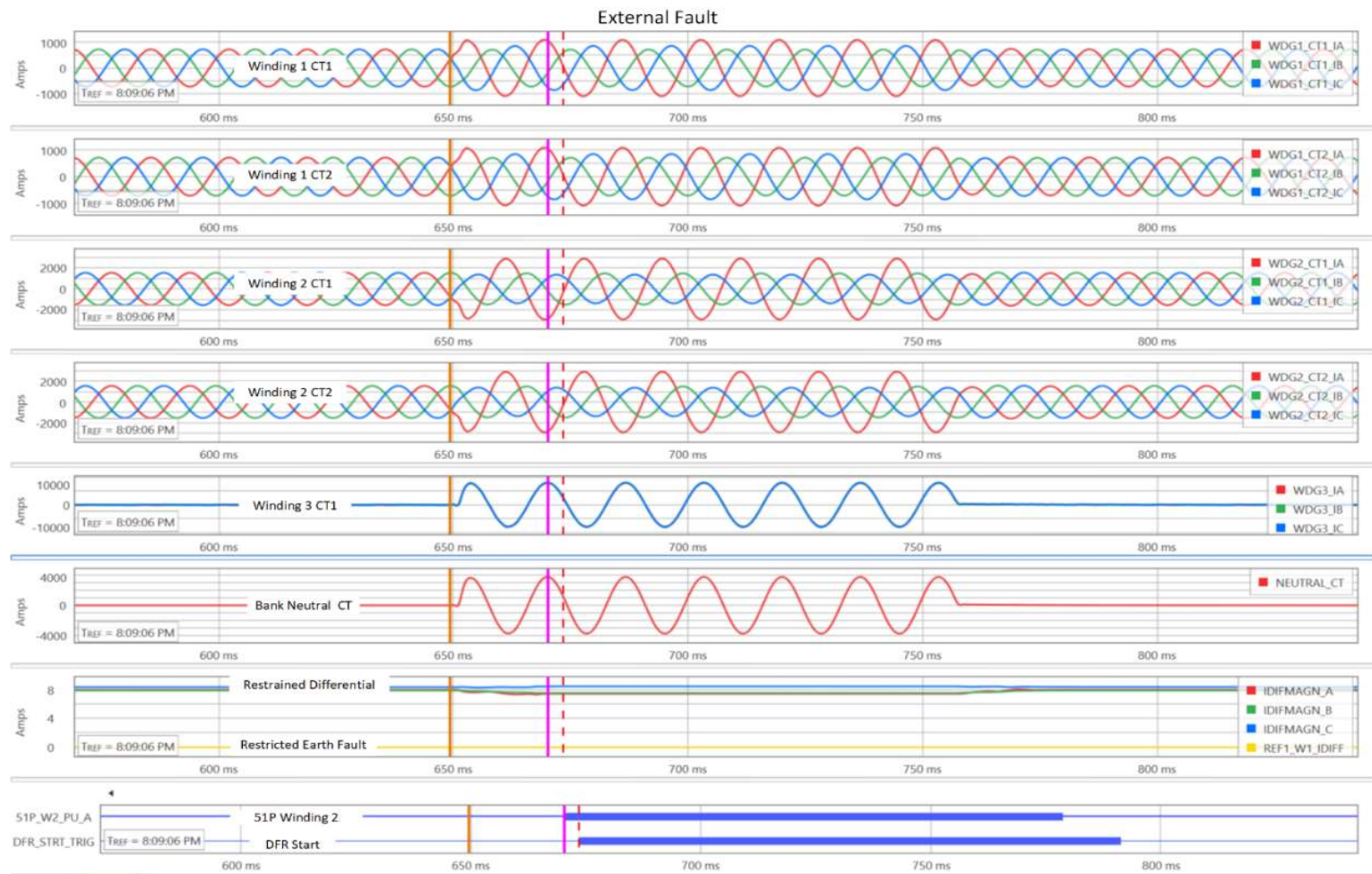
BPA Testing and Results: Line protection test (Example 3)



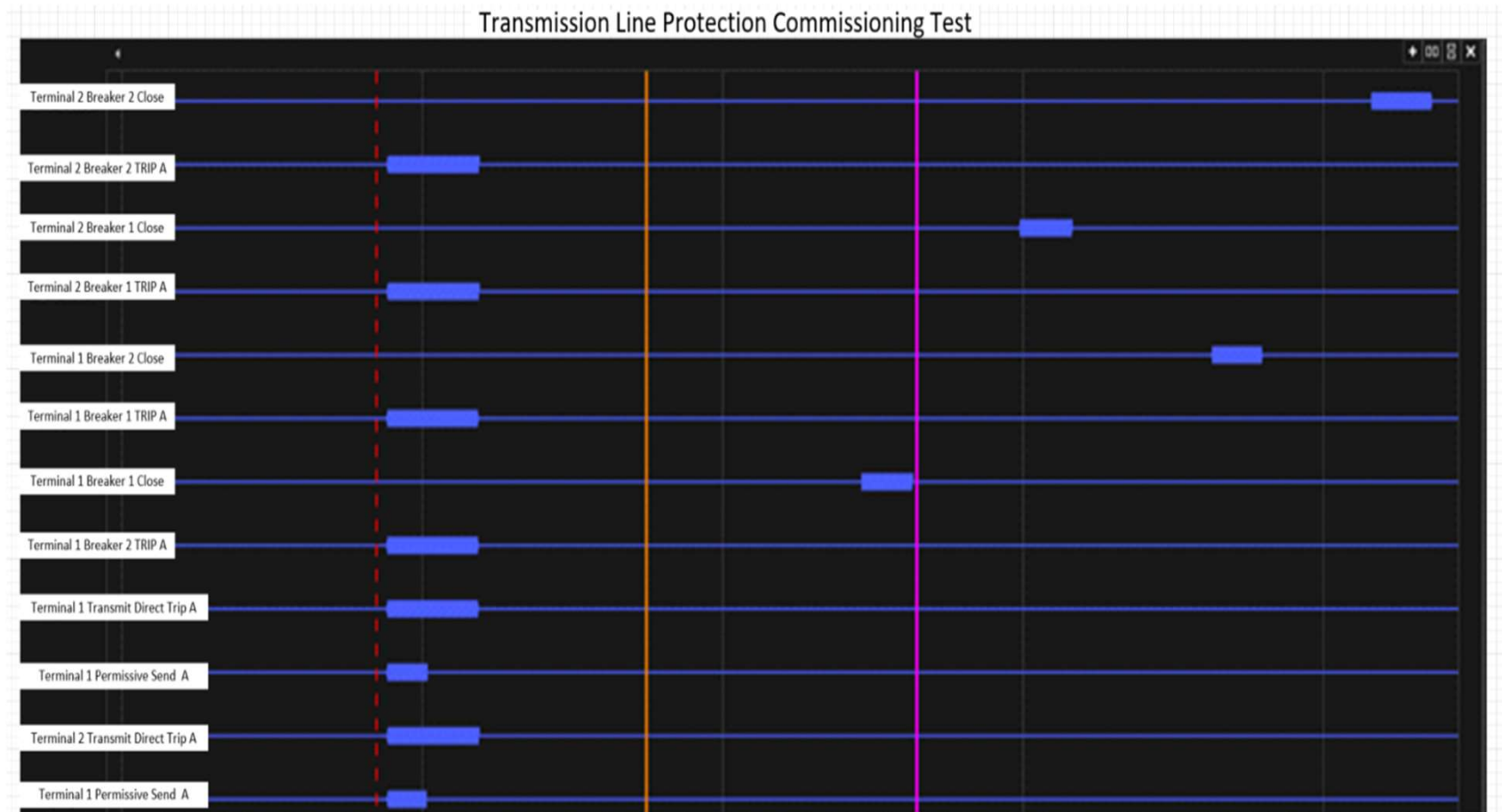
BPA Testing and Results: Transformer protection test (Example 4)



BPA Testing and Results: Transformer protection test (Example 5)

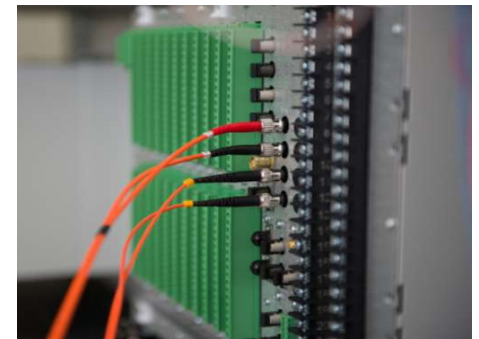
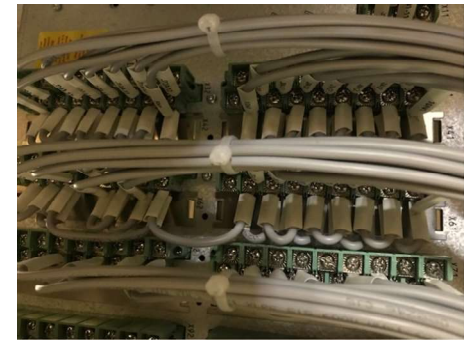


BPA Testing and Results: Commisioning test (Example 6)



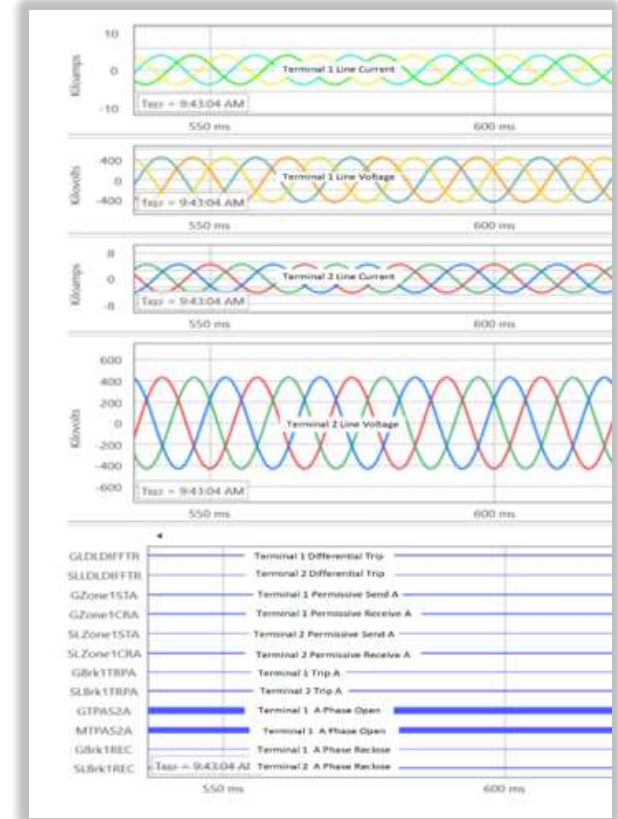
Conclusions: Benefits of testing with IEC 61850 messages

- Much quicker set up that allows for much quicker switching from one test to another. It is not uncommon for more than one test project to be waiting in line for testing. It was found that this test method has fewer components and test failure modes.
- RTDS HMI plots can be saved as COMTRADE screen captures that can be played in the field test sets.
- The real time display from both terminals allows for much quicker determinations of correct and incorrect operations. Testing personnel is more focused on the problem that is being analyzed when there is no need to sort through information that is not pertinent to the task.



Conclusion: Benefits of testing with IEC 61850 messages

- SVs replace numerous amplifiers. Relays can be tested with all current and voltage inputs and run more realistic models. There is also no need to maintain calibrations for D/A converters and current and voltage amplifiers.
- Data on the RTDS HMI plot can have relatively high sample rates for a better resolution of the event data. COMTRADE plots can be down sampled as needed.
- Once an SCD file is tested it can be saved for future use. There is no need to wire and re-wire test set to perform quick testing in emergencies.
- The RTDS HMI plot can be set up to view most of protection and logic functions in a relay. Specific elements of interest can be included.



Comments, Other Opinions or Questions ?



Thank you !