Experiences Testing a Busbar Protection Using Process Bus with Simultaneous Injection in all Bays

Alex Takeda – ISA CTEEP
João Jorge – OMICRON electronics
Luiza Pio – GE

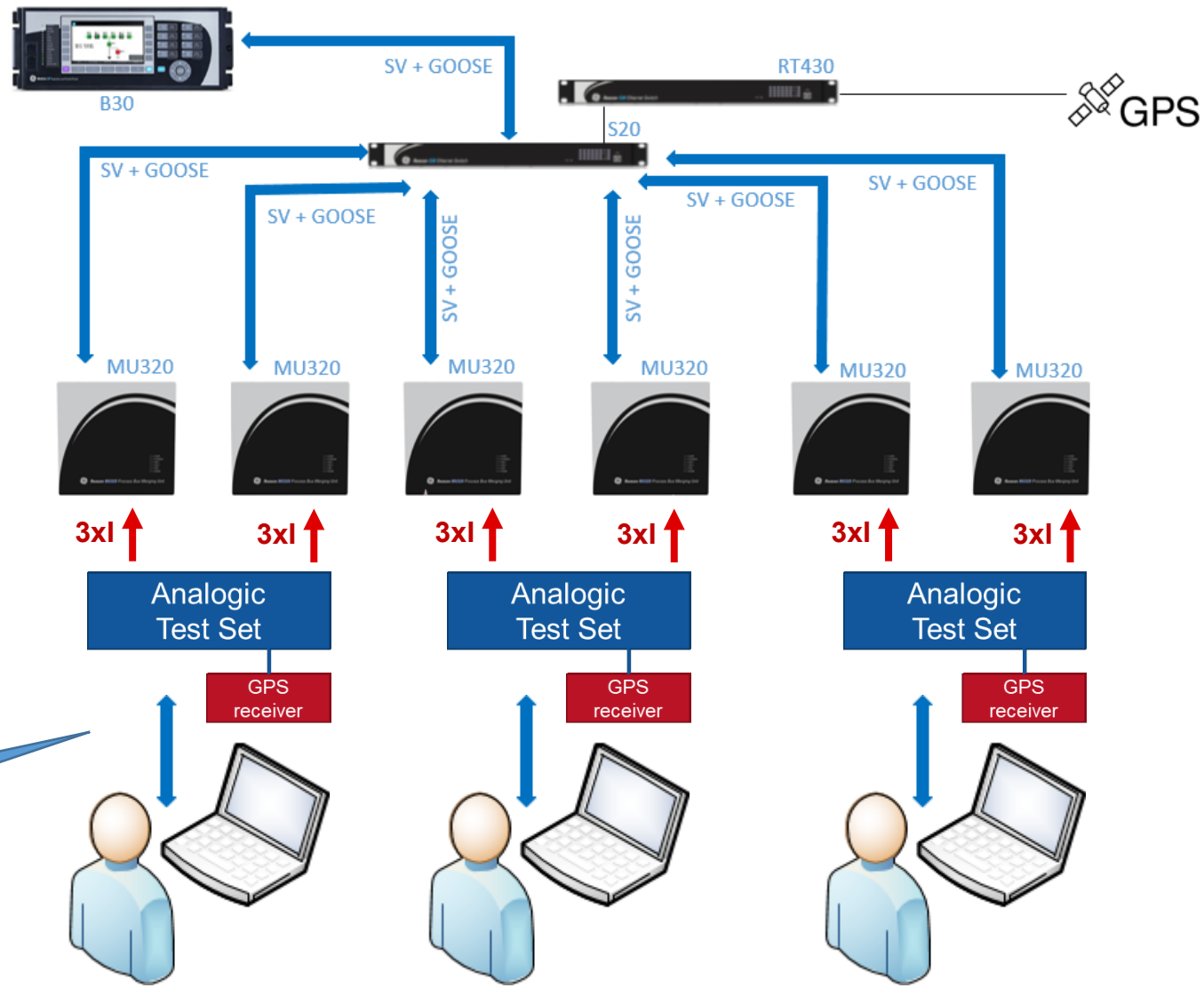
Presenter: Eugenio Carvalheira – OMICRON electronics

76th Annual Conference for Protective Relay Engineers

March 27-30, 2023

Challenges of a conventional integrated Busbar Protection Test

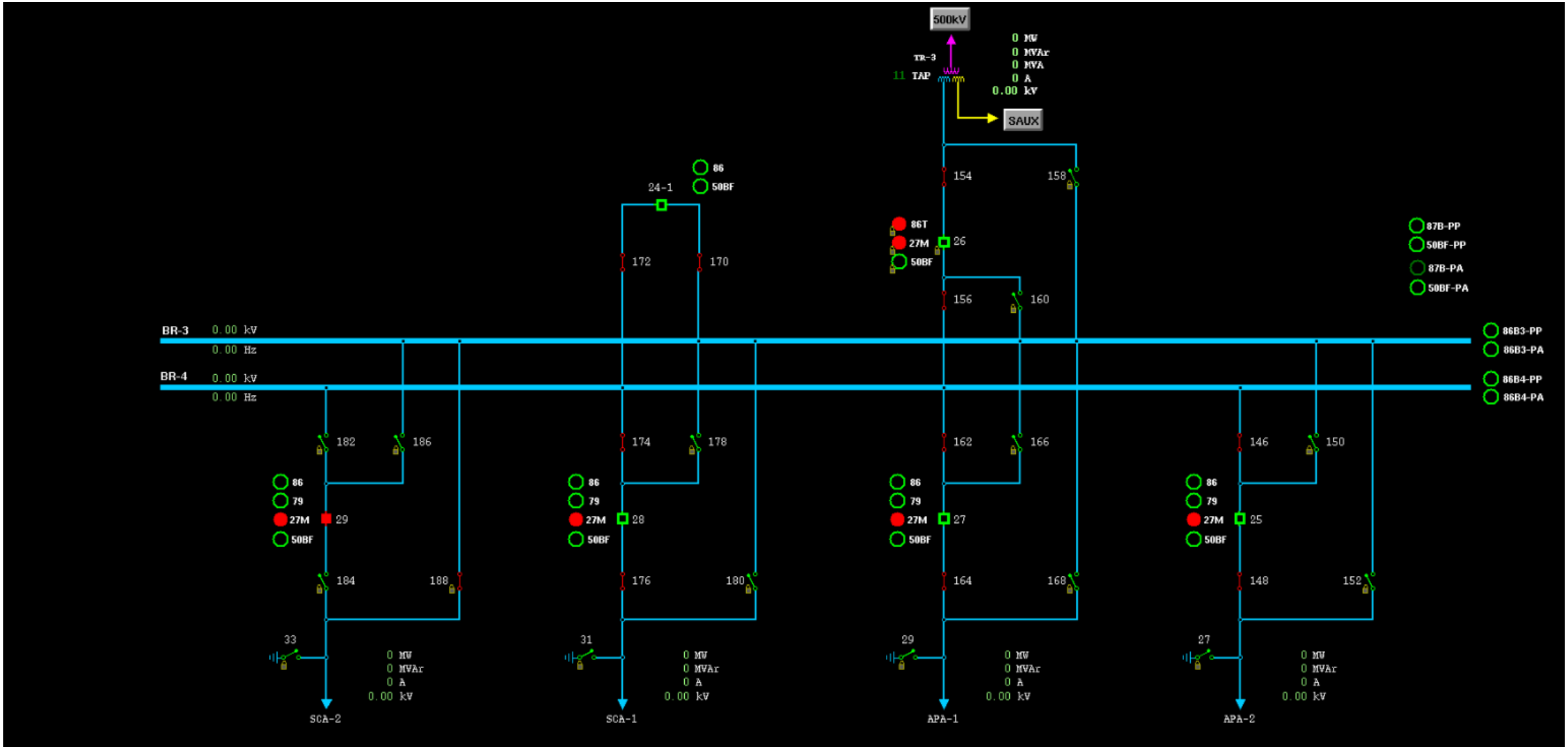
- Quantity of equipment
- Quantity of people
- Wiring assembly and simulation obstacles
- Time synchronization of test sets
- Simulation of circuit breaker failure
- Calculation of short circuit values
- Test 2 bays at a time with only 1 test set
- Test multiple bays at a time with many test sets and multiple GPS, separate test files and reports



Schematic of conventional test solution

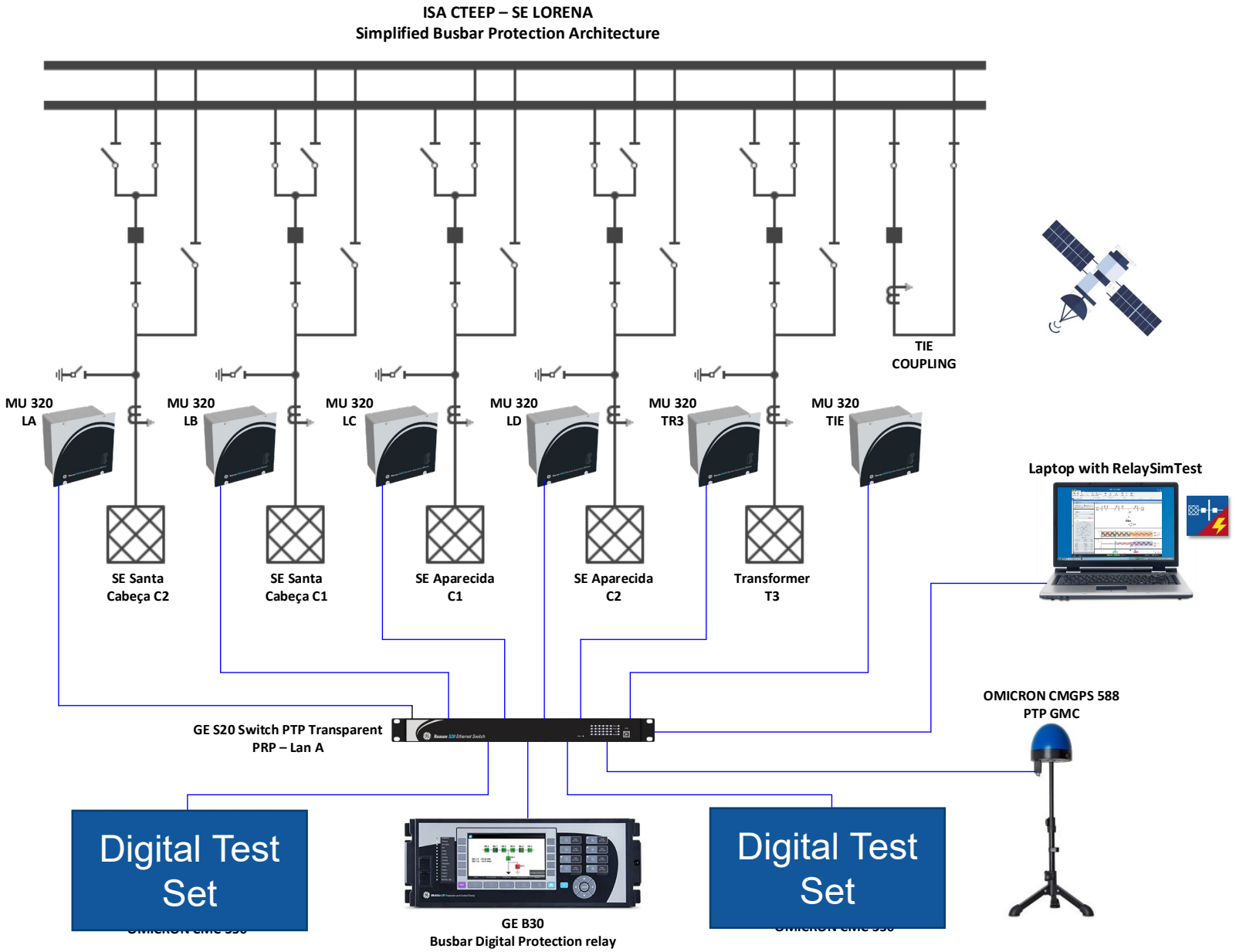
Single-line diagram of Lorena Sub (230kV)

(1st Fully Digital Substation of ISA CTEEP)



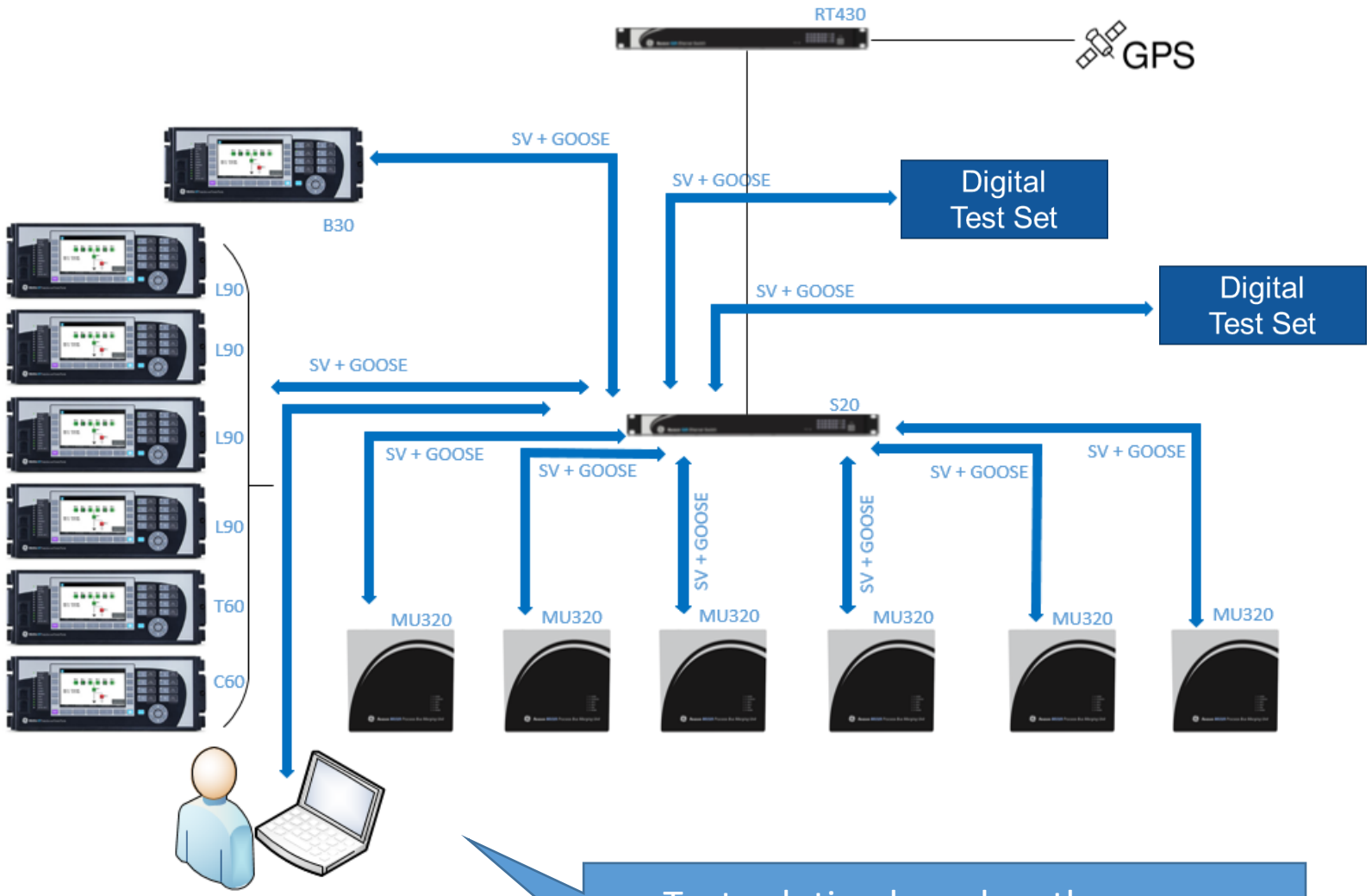
Full Digital test scheme proposed with system-based software

- Everything connected over the network
- Each test set publishes up to 4 streams of Sampled Values (1 SV = 1 Bay)
- Time Synch via PTPv2 Simulation and Injection of Real Transient Signals from system model
- Test scenarios defined by ISA CTEEP



Full Digital test scheme proposed with system-based software

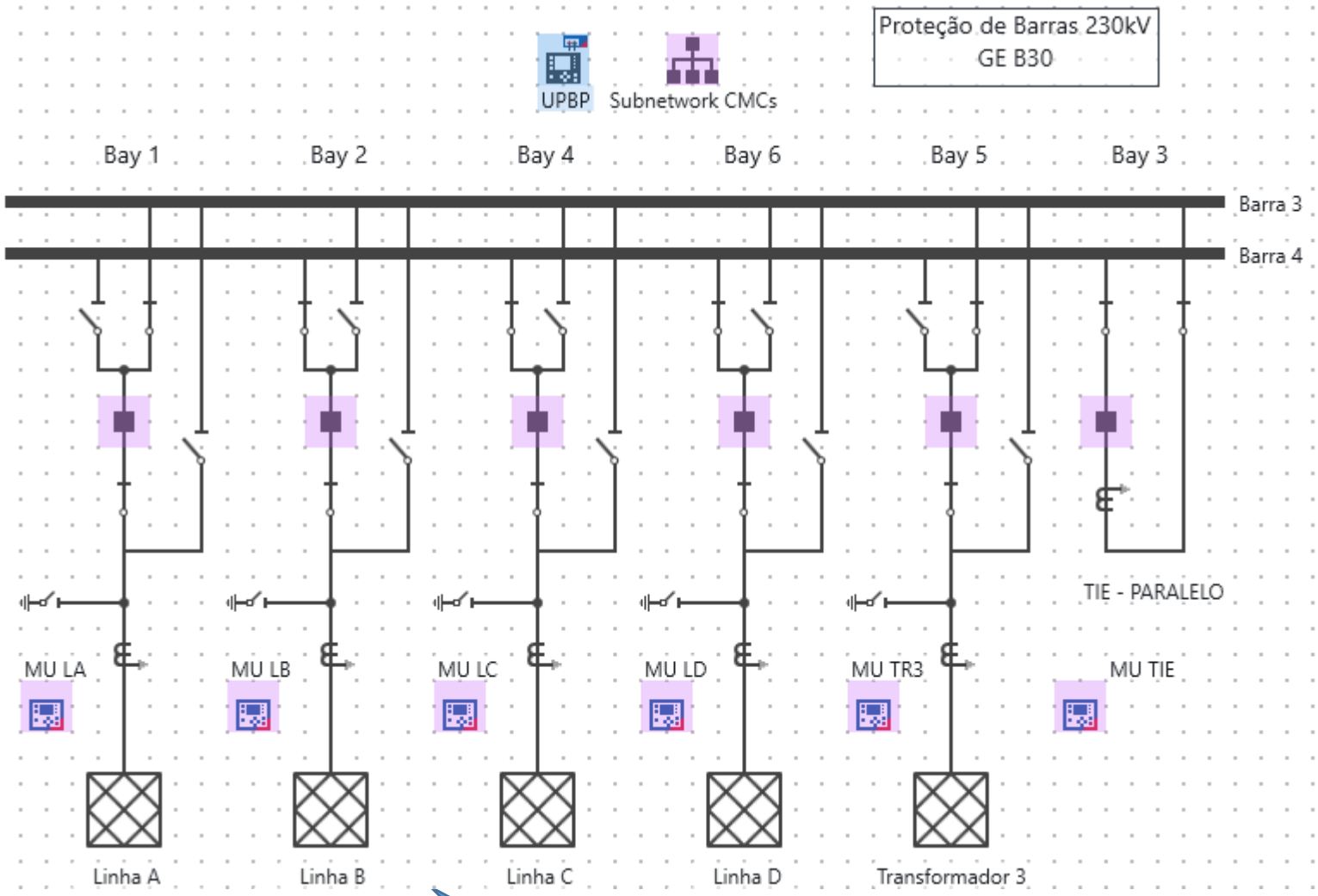
- Everything connected over the network
- Each test set publishes up to 4 streams of Sampled Values (1 SV = 1 Bay)
- Time Synch via PTPv2 Simulation and Injection of Real Transient Signals from system model
- Test scenarios defined by ISA CTEEP



Test solution based on the power system model used for 87B tests at Lorena Substation

Full Digital test scheme proposed with system-based software

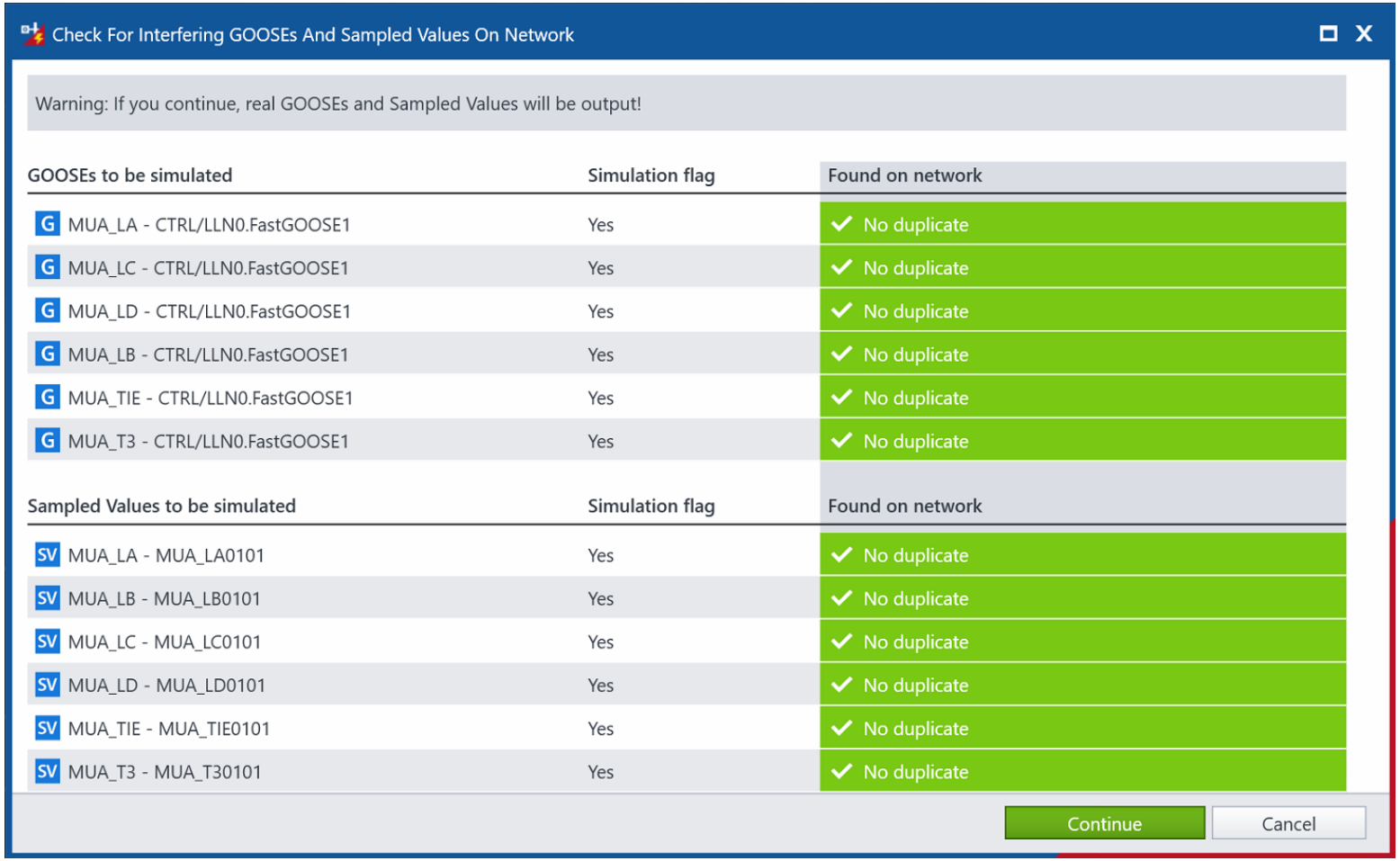
- Simulation of circuit breakers and disconnectors contacts via software through GOOSE
- Simulation of faults inside and outside the protected busbar
- System modeling with the equivalent Thevenin source of each bay for injection of realistic short circuit currents
- CT saturation by inserting CT's nameplate data into the system model



System model used for 87B tests in Lorena Substation

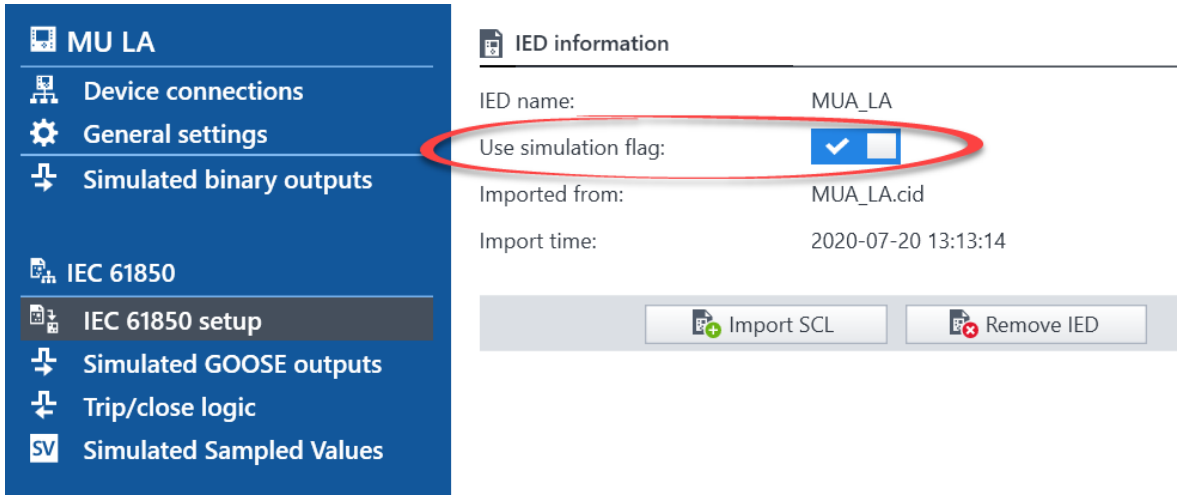
Validate simulated streams

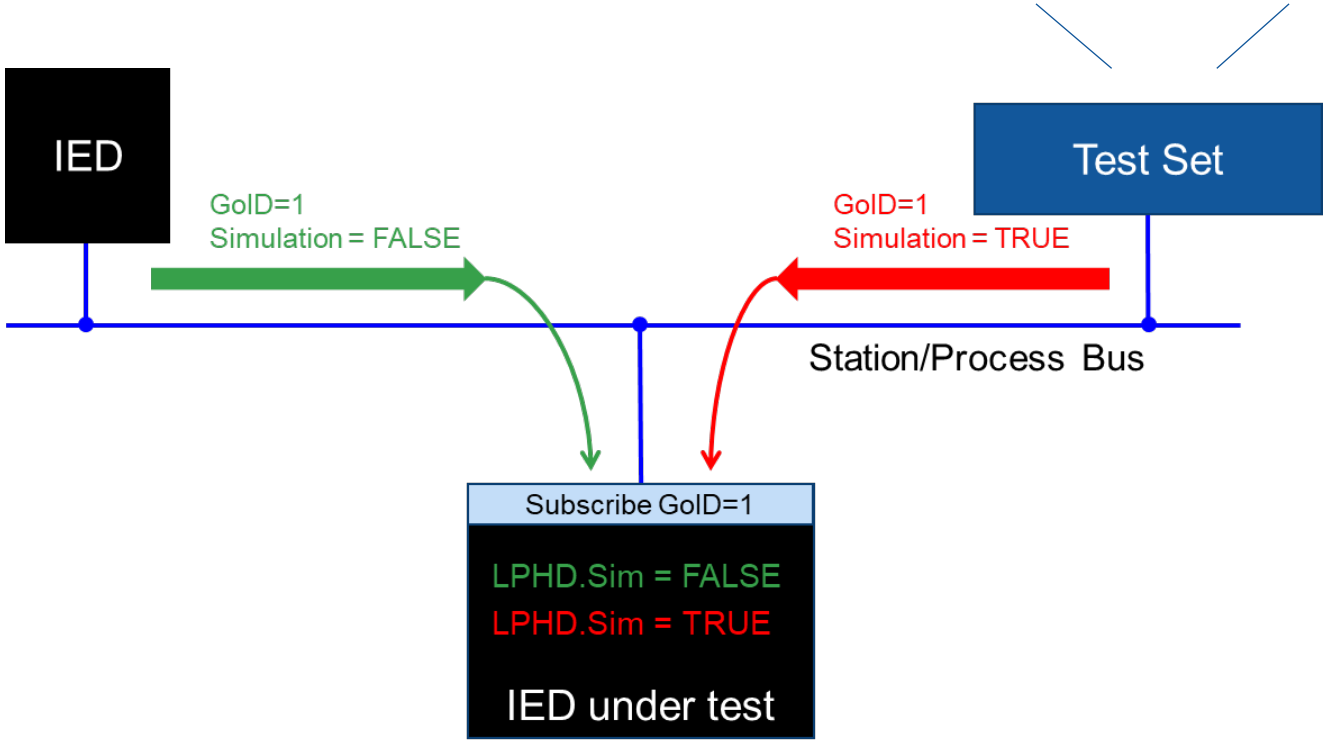
- Sniffer the network prior to start the test
- Check that there are no conflicts between the simulated SV and GOOSE and those present in the network
- Avoid duplicate signals on the network



Simulation Mode

- From IEC 61850 Ed 2
- Method for virtual/digital isolation of digital data during test

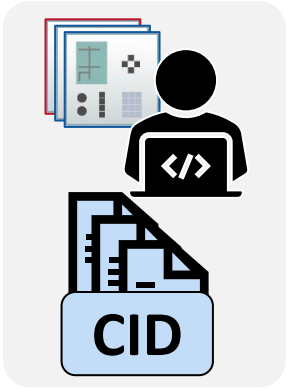


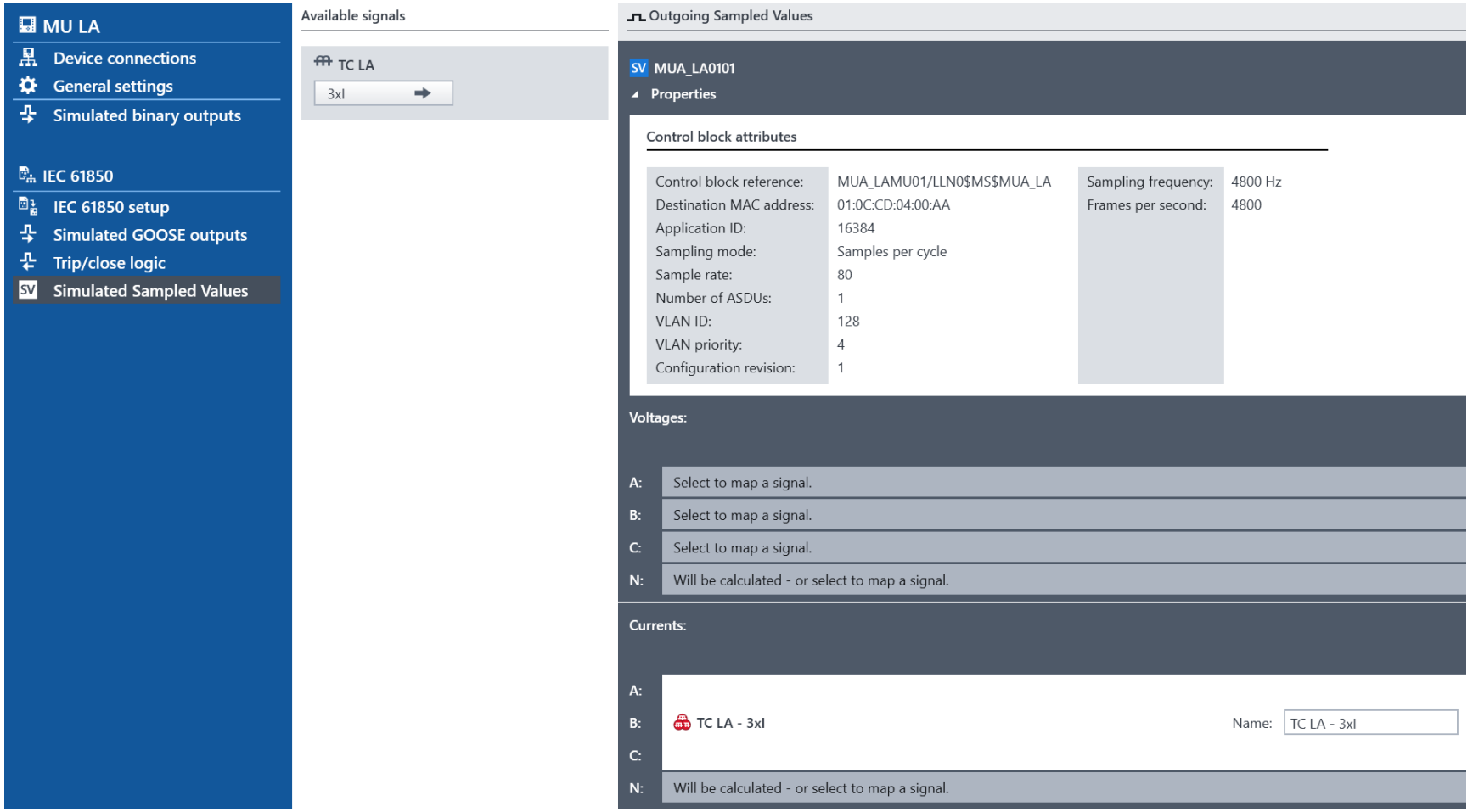


System Configuration Files

- Data such as SvID, appID, priority, vlan, etc taken automatically from imported SCL files (*.cid) of Merging Units

- Datasets 9-2-LE

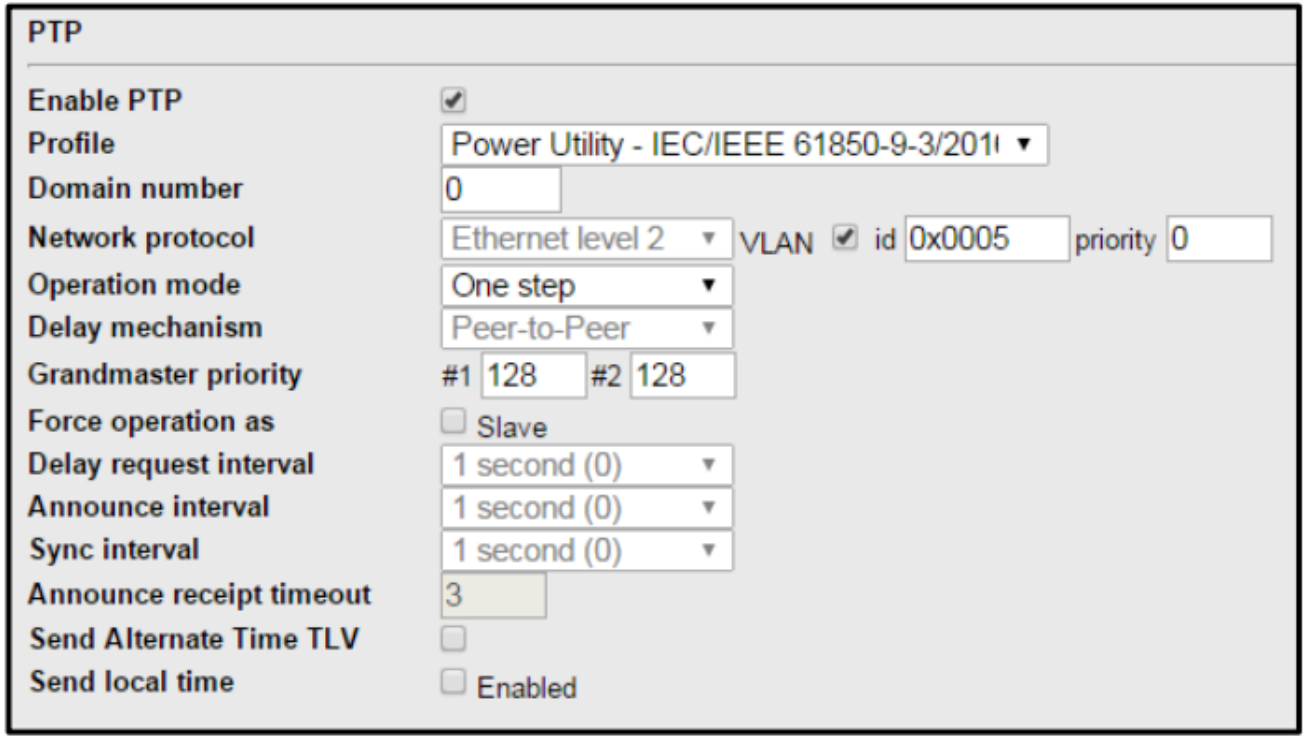




Time Synchronization

- All test sets and IEDs synchronized by the same source GMC PTP
- PTP profile selected: IEC/IEEE 61850-9-3: 2016 (Utility Profile)

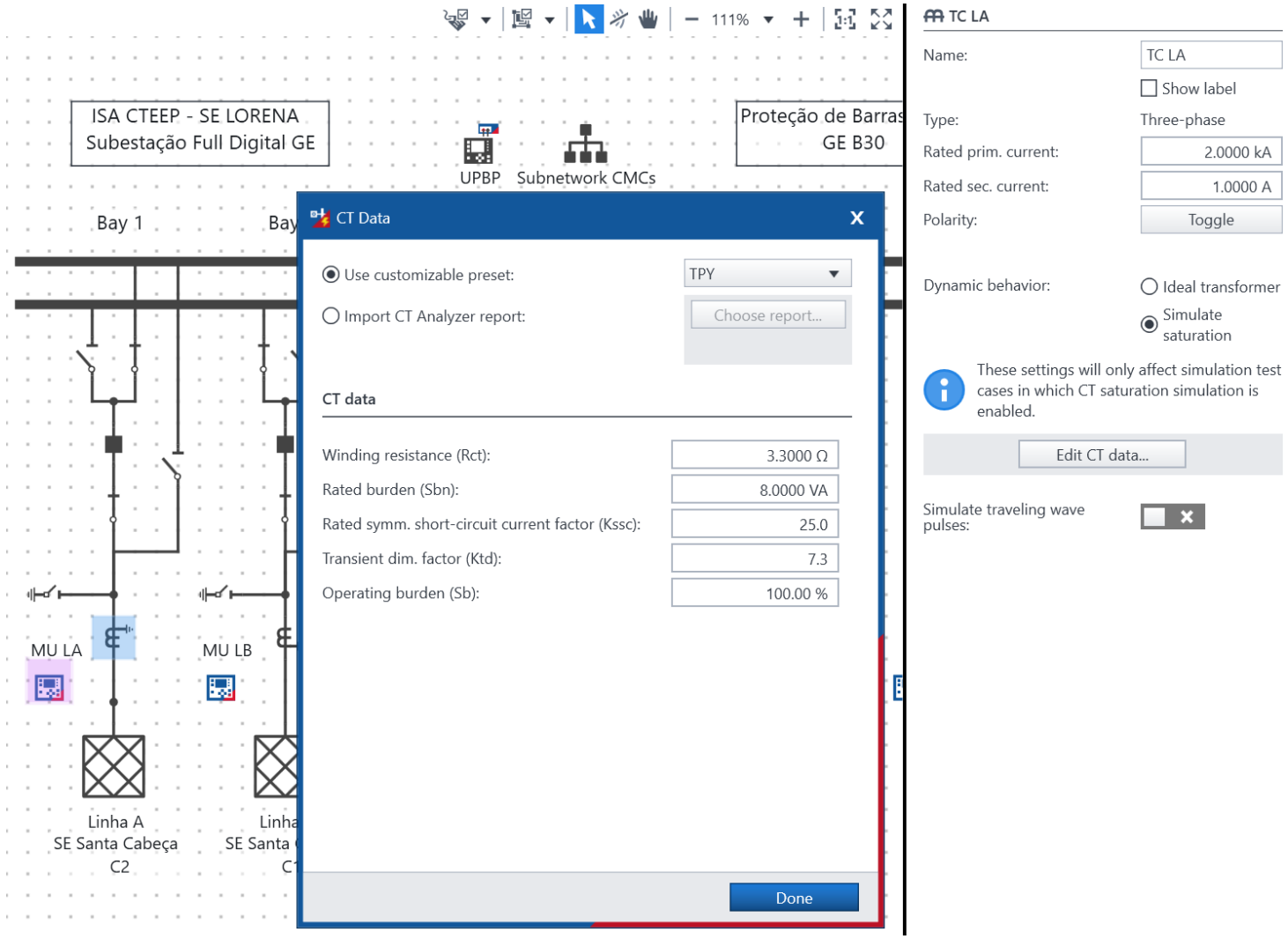
Example of settings from GPS RT430



CT realistic simulation

- Nameplate data representing the nonlinear saturation behavior of the CTs in each bay during the simulation of the transients published through Sampled Values

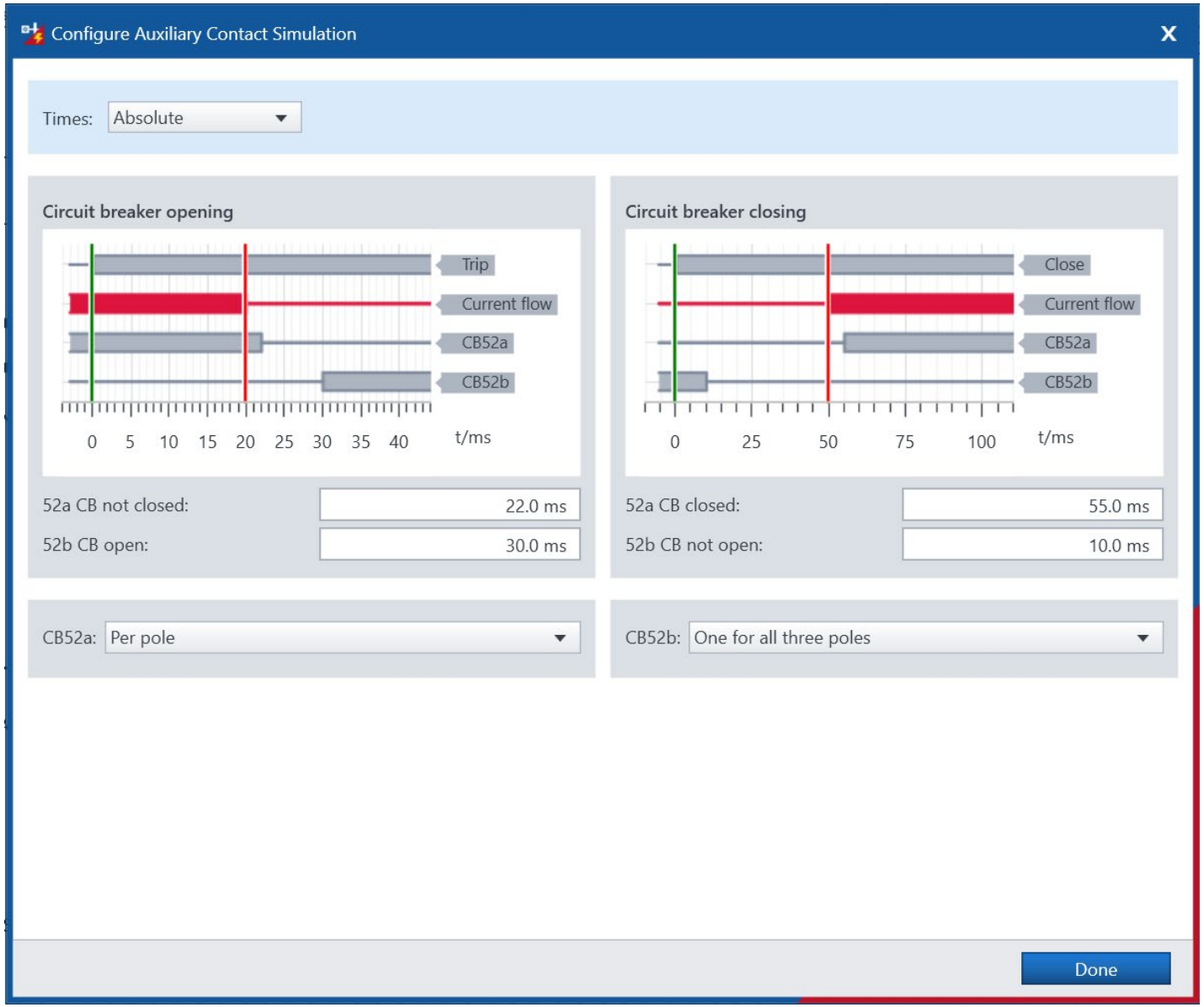
- Data taken from Lorena Substation CT's nameplate (TPY)



52a and 52b simulation

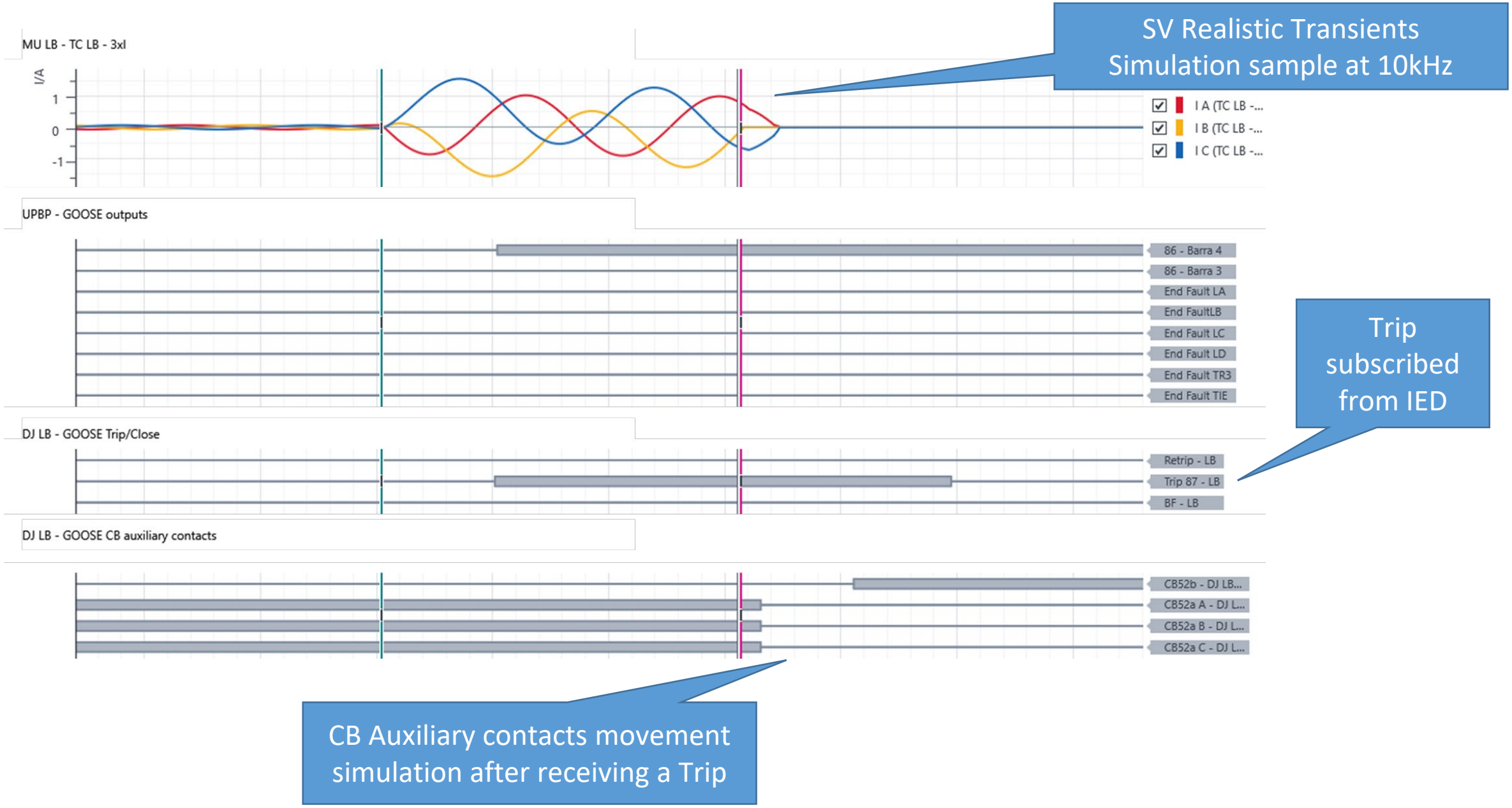
- Simulation of circuit breakers and disconnectors contacts via software (considering the timing values for movement of the contacts) through GOOSE

52a and 52b simulation

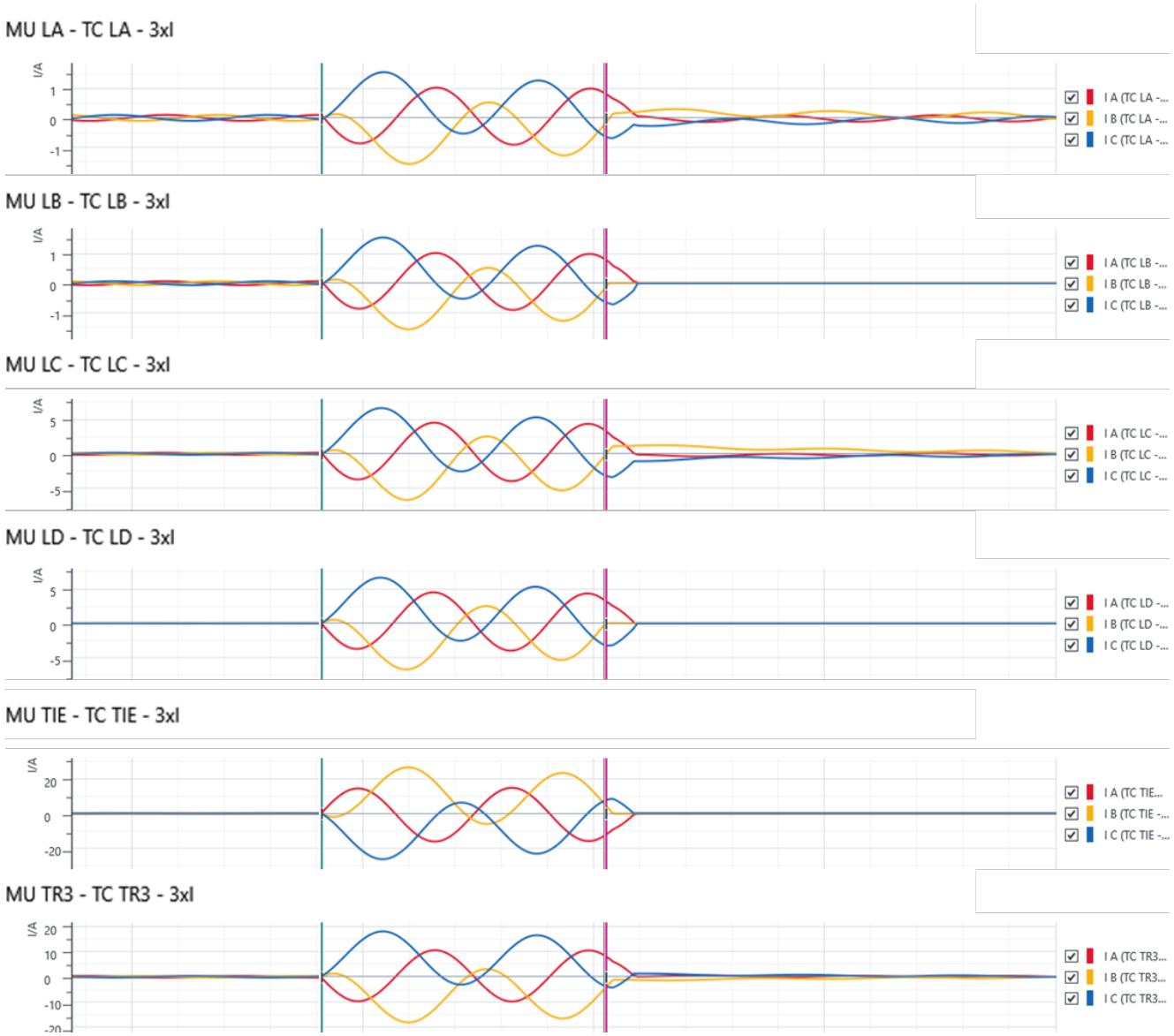


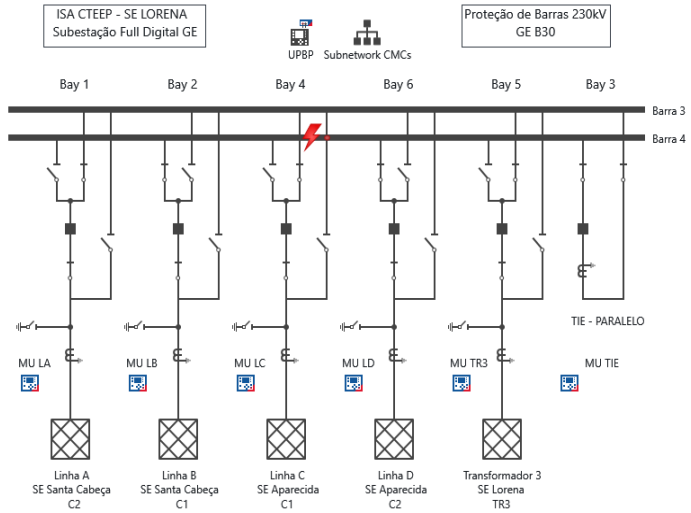
- Timers of the Simulation Setup from the reception of a Trip or Closing command

Example of published and subscribed data



Simultaneous Current published in all Bays

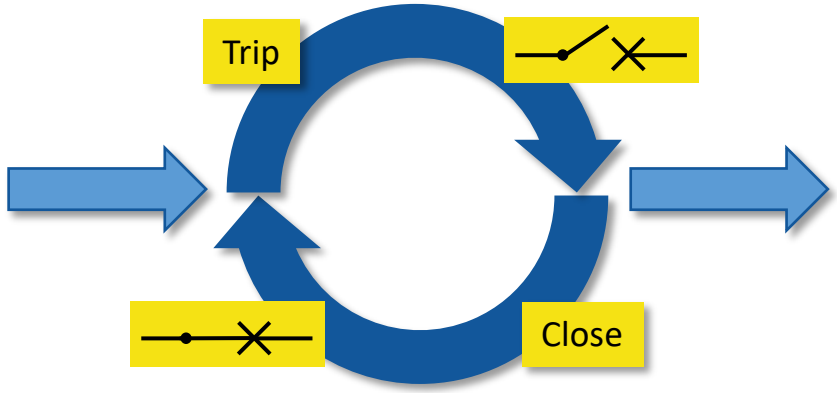


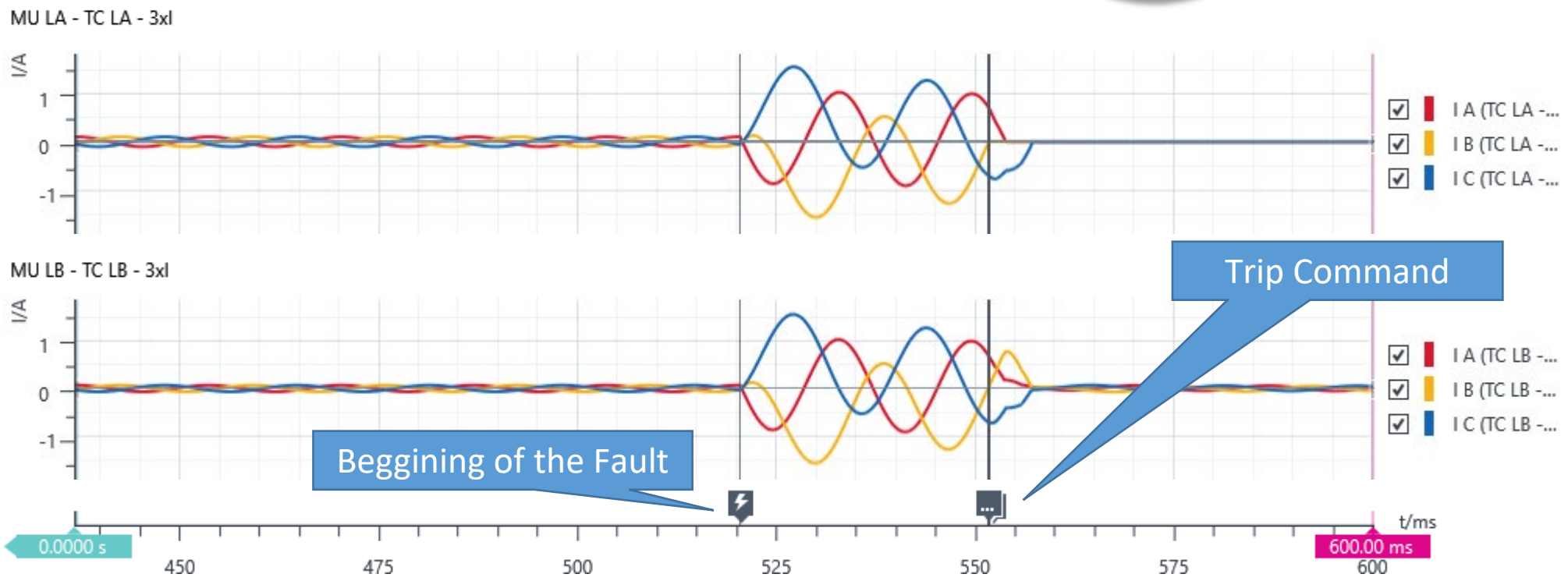


- 3-Phase Fault on Busbar 4
- After clearing the fault, the bays that weren't connected to the Busbar 4 continued to feed normal currents (bays LA, LC and TR3) and the current of the other bays were interrupted after the simulated CB opening time

Transients after CB reaction

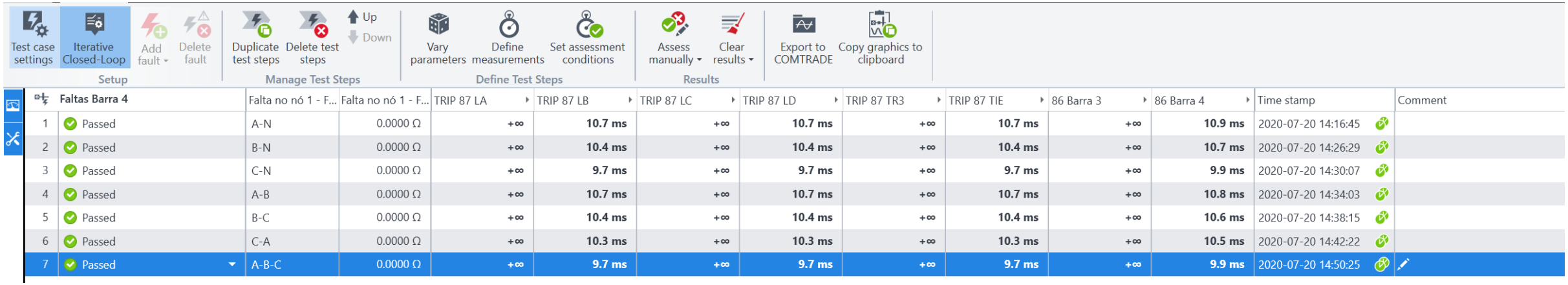
- Simulation of the opening CB currents in each bay through iterations





Test Assessment

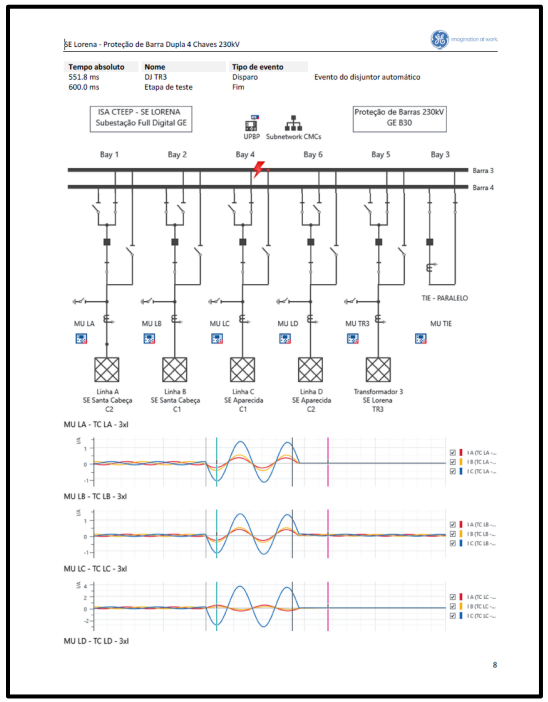
- Results based on predetermined criteria for operating times or non-operation of each bay



	Faltas Barra 4	Falta no nó 1 - F...	Falta no nó 1 - F...	TRIP 87 LA	TRIP 87 LB	TRIP 87 LC	TRIP 87 LD	TRIP 87 TR3	TRIP 87 TIE	86 Barra 3	86 Barra 4	Time stamp	Comment
1	Passed	A-N	0.0000 Ω	+∞	**10.7 ms**	+∞	**10.7 ms**	+∞	**10.7 ms**	+∞	**10.9 ms**	2020-07-20 14:16:45	
2	Passed	B-N	0.0000 Ω	+∞	**10.4 ms**	+∞	**10.4 ms**	+∞	**10.4 ms**	+∞	**10.7 ms**	2020-07-20 14:26:29	
3	Passed	C-N	0.0000 Ω	+∞	**9.7 ms**	+∞	**9.7 ms**	+∞	**9.7 ms**	+∞	**9.9 ms**	2020-07-20 14:30:07	
4	Passed	A-B	0.0000 Ω	+∞	**10.7 ms**	+∞	**10.7 ms**	+∞	**10.7 ms**	+∞	**10.8 ms**	2020-07-20 14:34:03	
5	Passed	B-C	0.0000 Ω	+∞	**10.4 ms**	+∞	**10.4 ms**	+∞	**10.4 ms**	+∞	**10.6 ms**	2020-07-20 14:38:15	
6	Passed	C-A	0.0000 Ω	+∞	**10.3 ms**	+∞	**10.3 ms**	+∞	**10.3 ms**	+∞	**10.5 ms**	2020-07-20 14:42:22	
7	Passed	A-B-C	0.0000 Ω	+∞	**9.7 ms**	+∞	**9.7 ms**	+∞	**9.7 ms**	+∞	**9.9 ms**	2020-07-20 14:50:25	

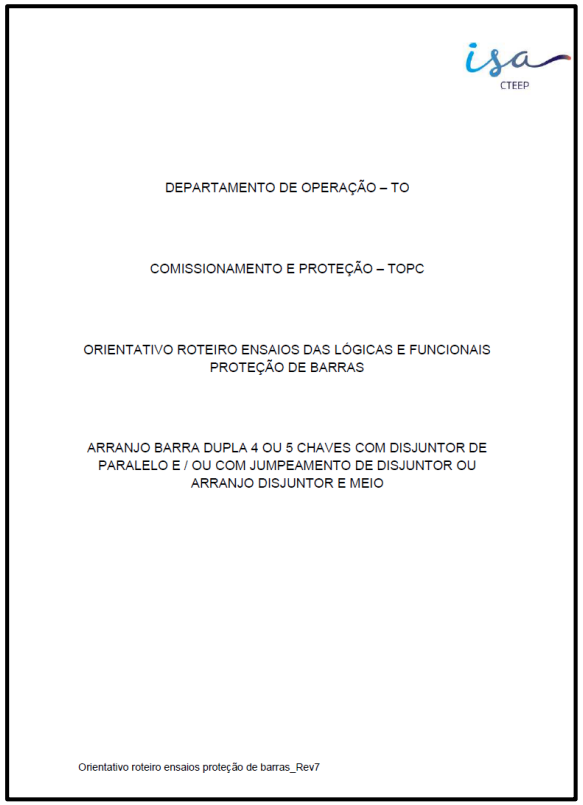
Performed tests

- Stability and polarity tests
- Faults in both busbars with different bay connection topologies (according to ISA CTEEP script)
- Transfer Topology
- “Busbar Totalization” test
- END Fault
- Breaker Failure



Test report

ISA CTEEP 87B test script

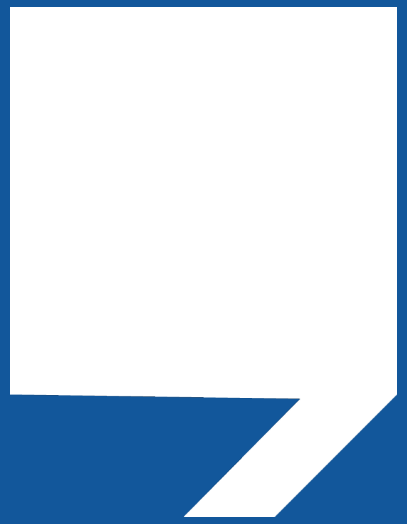


Cost Benefit Analysis

	Conventional Single Phase	System Based	Conventional 3 Phase
Time for initial preparation (hours)	12	8	8
Time for test preparation (hours)	0.5	0.25	0.5
Quantity of tests	120	40	40
Total time (hours)	72	18	28
Number of engineers	1	1	3
Engineer man-hour cost	4X	X	4,66X
Quantity of Test Sets	1	2	3
Test set rental (R$/hour)	100	100	100
GPS rental (R$/hour)	0	0	87.5
Total	3,33Y	Y	4,11Y

Conclusions

- Busbar protection testing by simultaneous injection in all bays and using realistic transient signals calculated from power system simulation software
- Enormous time and cost savings with the use of this test method
- Great gain in quality when applying this method compared to the traditional way
- Test technology applied in full digital substations must evolve and be applied using all the test features provided by the standard
- IEDs compatible with IEC61850 Ed 2.1, as well as PTP DAN GPS and transparent PTP switches allow the application of modern testing tools, which were widely used in Lorena Substation



Questions?

OMICRON