

Validation Testing of IEC 61850 Process Bus Architecture in a Typical Digital Substation

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Texas A&M - 2021 Conference for Protection Relay Engineers

Questions to explore

What protection challenges exist for Process Bus systems?

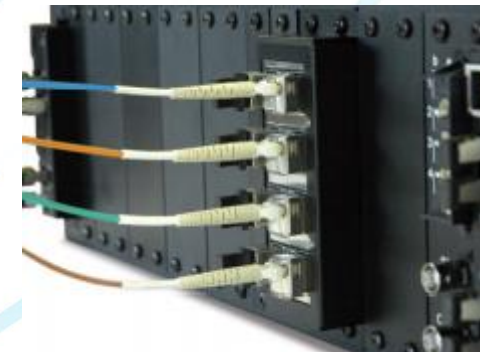
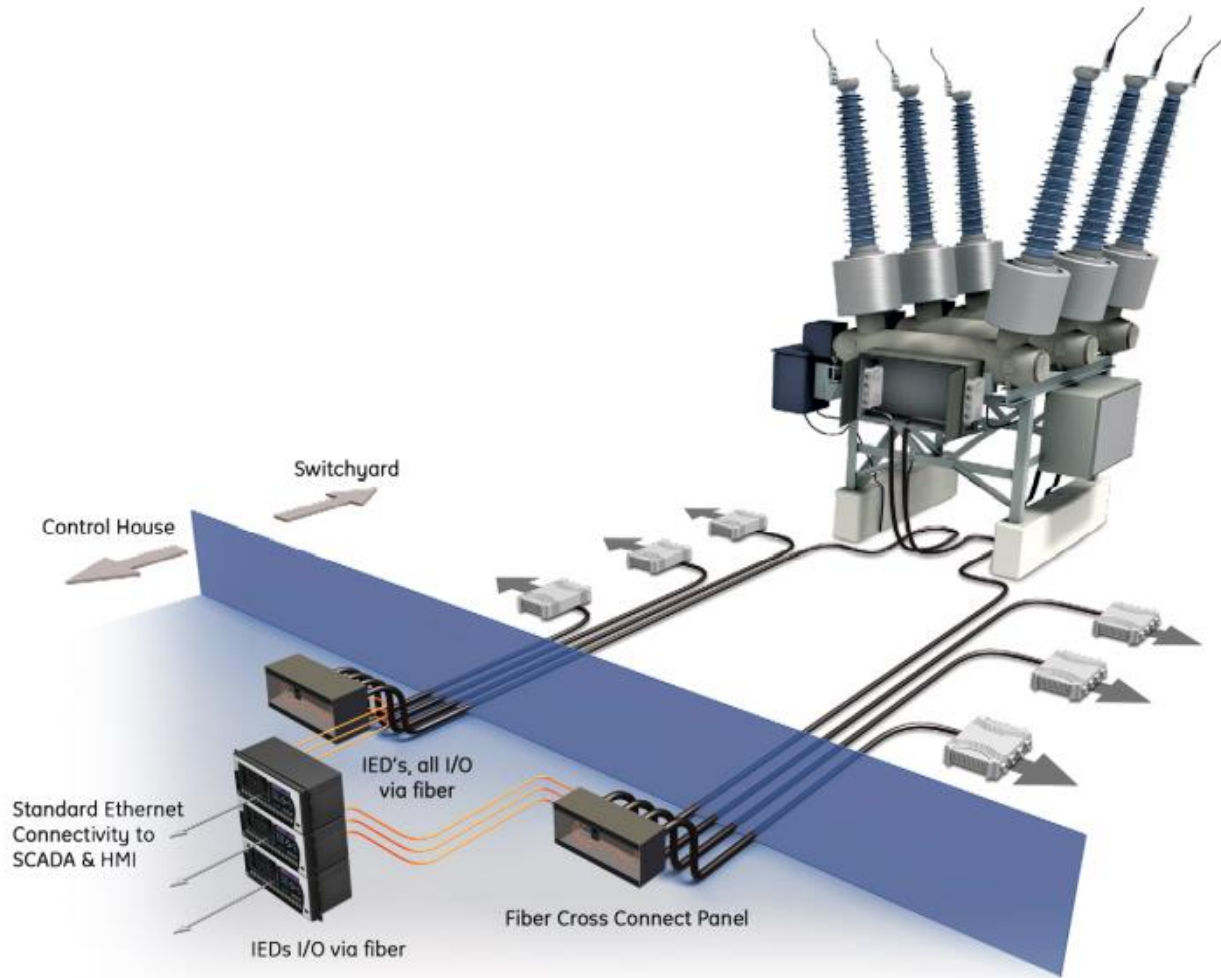
How do we identify issues in a real system?

What impact do these issues have on protection?

How do we design Process Bus protection to mitigate these impacts?

IEC 61869

Digitization of process level signals in the field



Protection Challenges

An IED using Process Bus must deal with:

- Delay
- Missed samples
- Unacceptable quality samples

Process Bus Diagnostics

Real time diagnostics for:

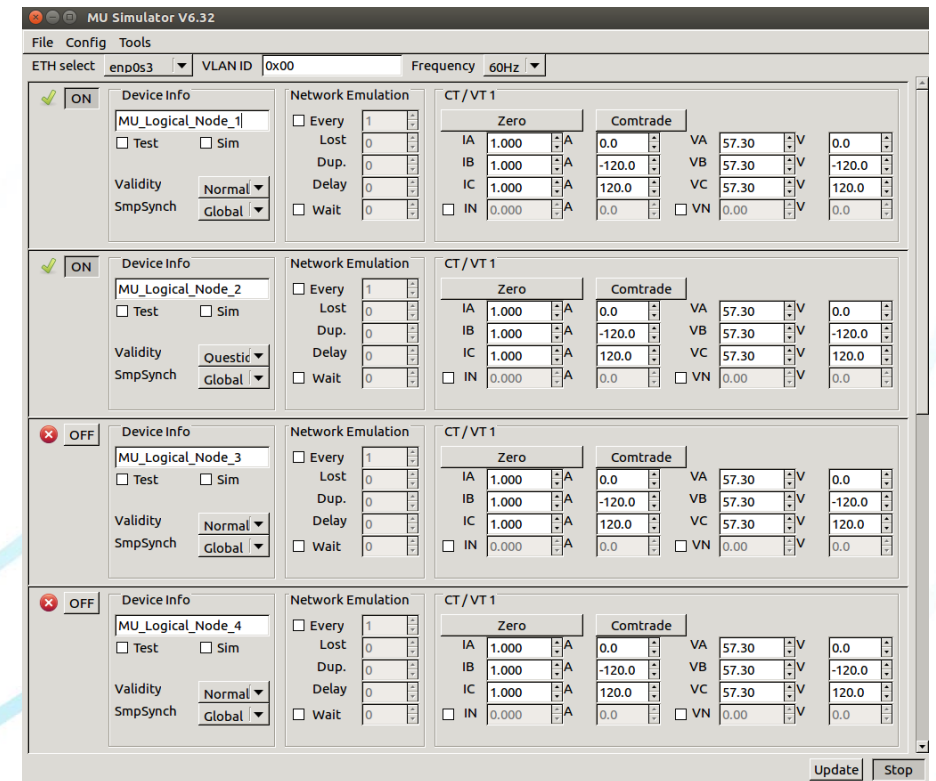
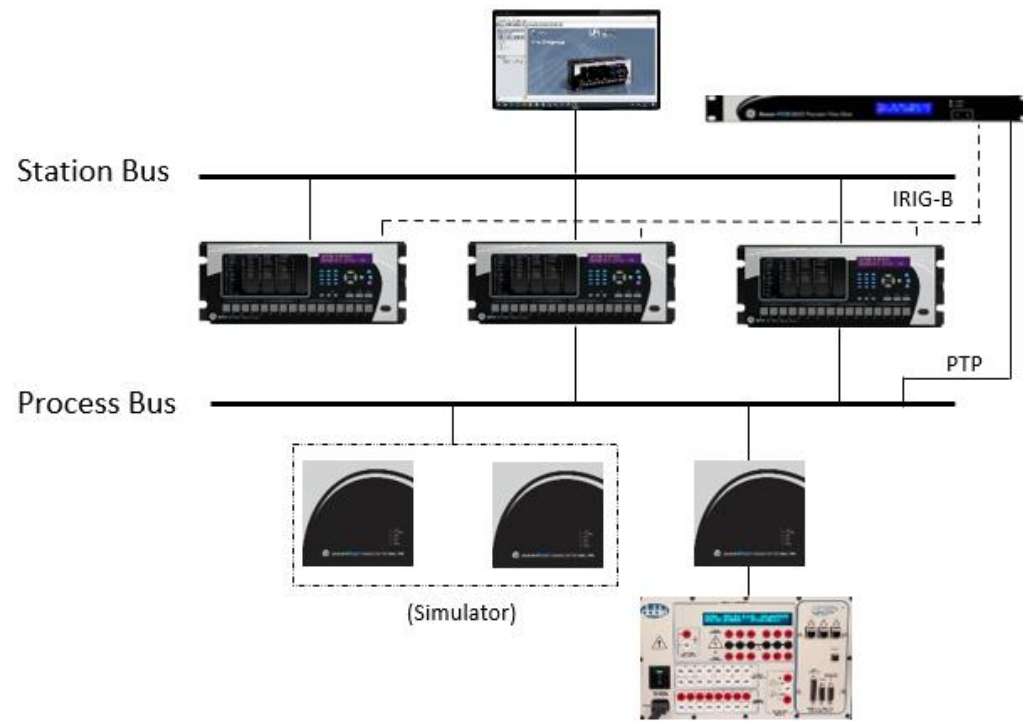
- Clock synchronization source
- Delay
- Simulation and quality flags

Persistent diagnostics for:

- Delay
- Missed samples
- System events

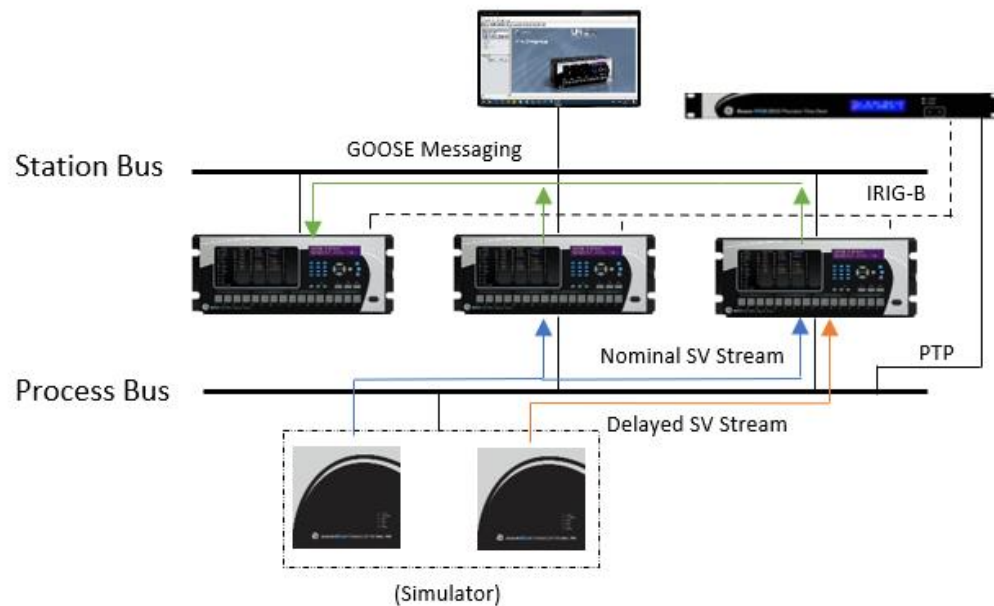
Testing Methodology

Used protection IEDs and switches along with real and simulated merging units to understand the impact of missing and delayed samples.



Impact of Delayed Samples

One IED subscribed to two SV streams, one of which had a fixed time delay applied. A second IED subscribed only to the delayed stream without delay as a reference. A third IED was used to measure the operate time delta of an IOC element in each IED.

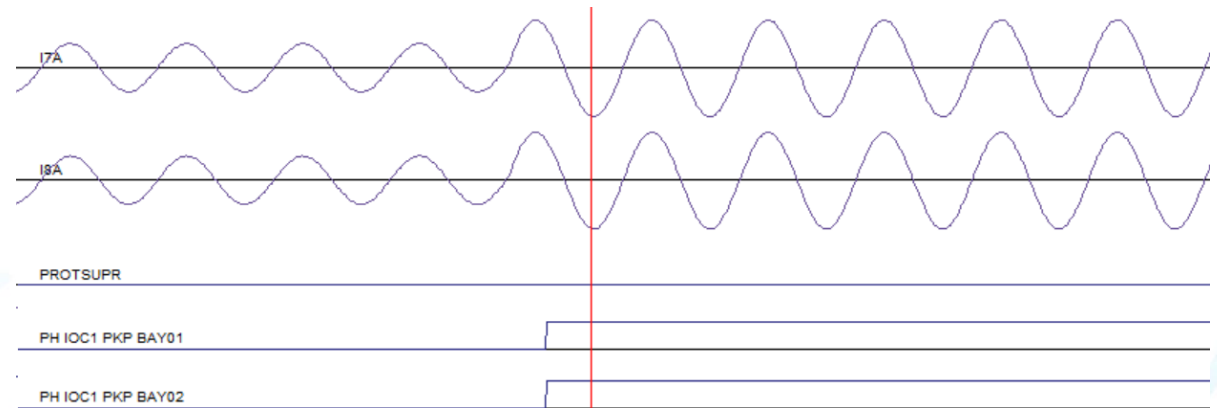
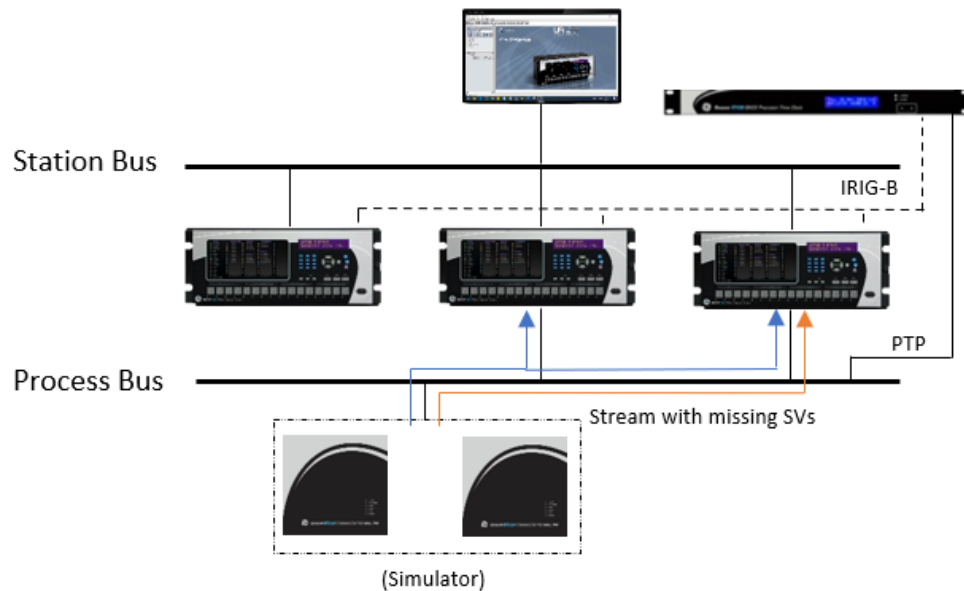


0 days 0 h : 0 m : 0.006251 s

Event Number	Date/Time	Cause	Data
7	Mar 09 2021 20:50:06.607138	Delayed Stream IED2 Off (RI3)	
6	Mar 09 2021 20:50:06.607138	Nominal Stream IED2 Off (RI2)	
5	Mar 09 2021 20:50:06.600898	Nominal Stream IED1 Off (RI1)	
4	Mar 09 2021 20:50:05.880055	Delayed Stream IED2 On (RI3)	
3	Mar 09 2021 20:50:05.880055	Nominal Stream IED2 On (RI2)	
2	Mar 09 2021 20:50:05.873804	Nominal Stream IED1 On (RI1)	
1	Mar 09 2021 20:49:57.080057	EVENTS CLEARED	

Impact of Missing and Invalid Samples

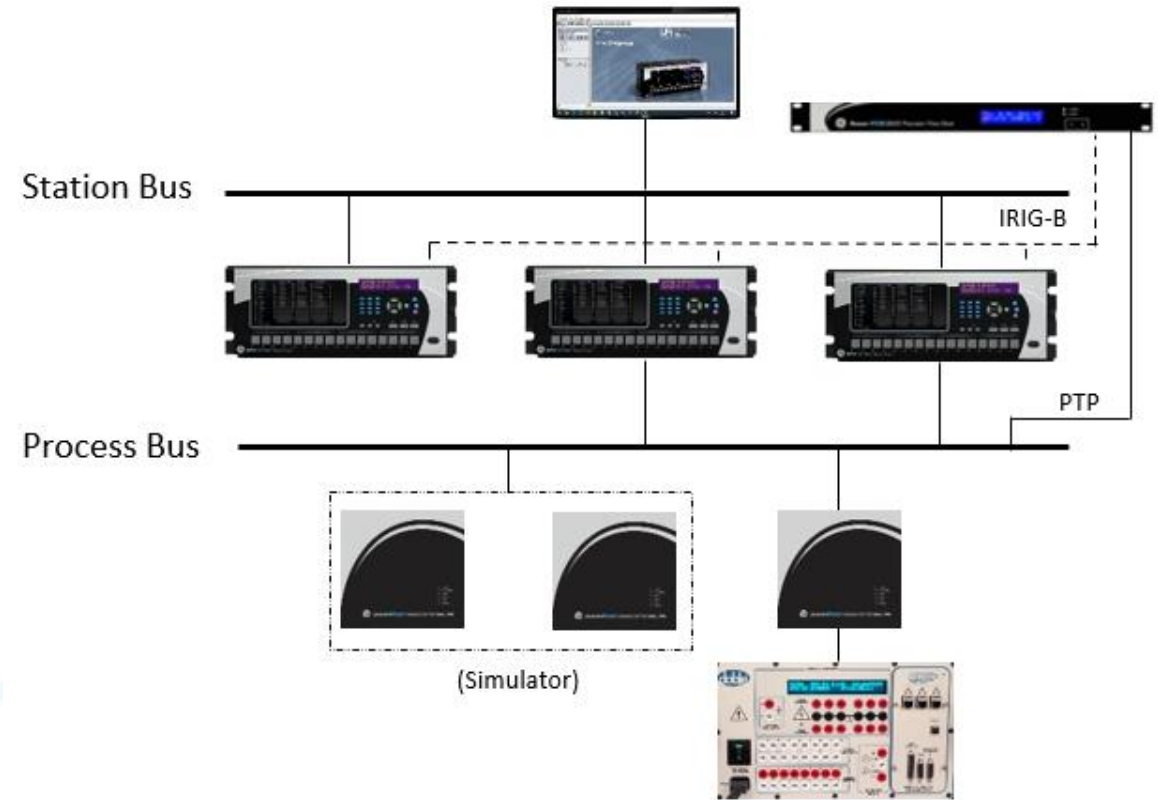
One IED subscribed to two SV streams, one with consecutively missing samples.



Solutions to System Failures

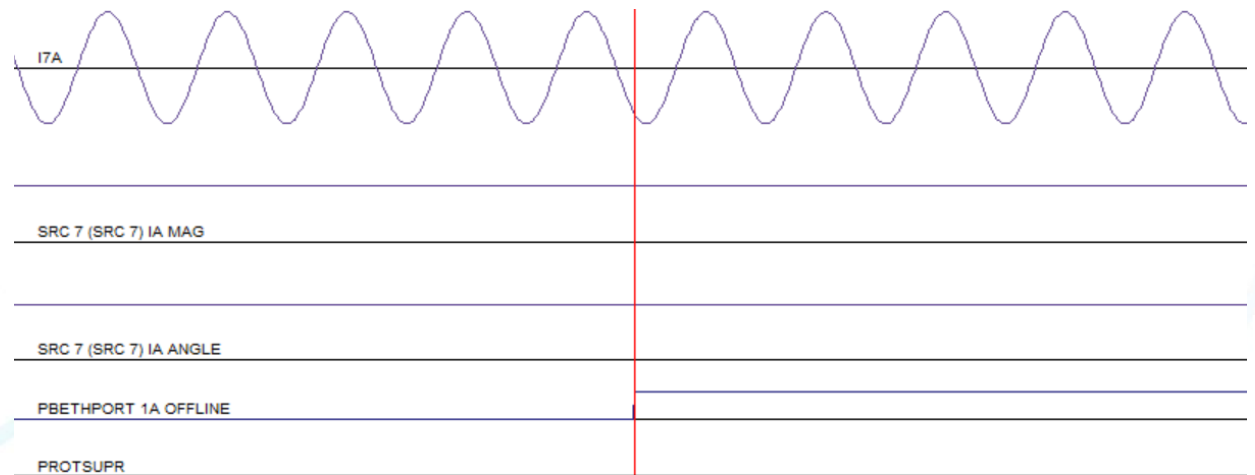
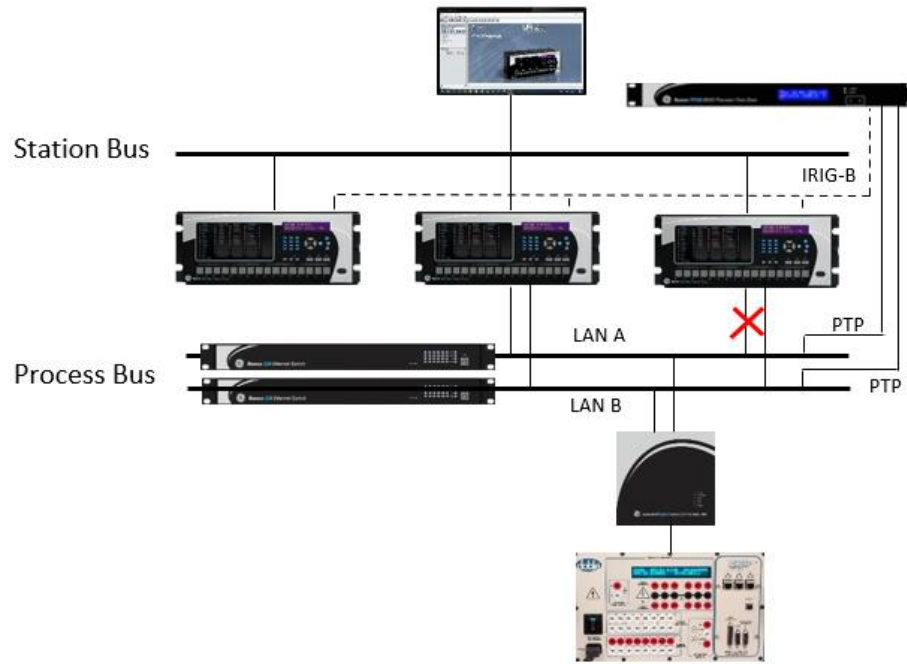
Scenarios considered:

- Loss of network
- Loss of stream or MU
- Loss of synchronization source



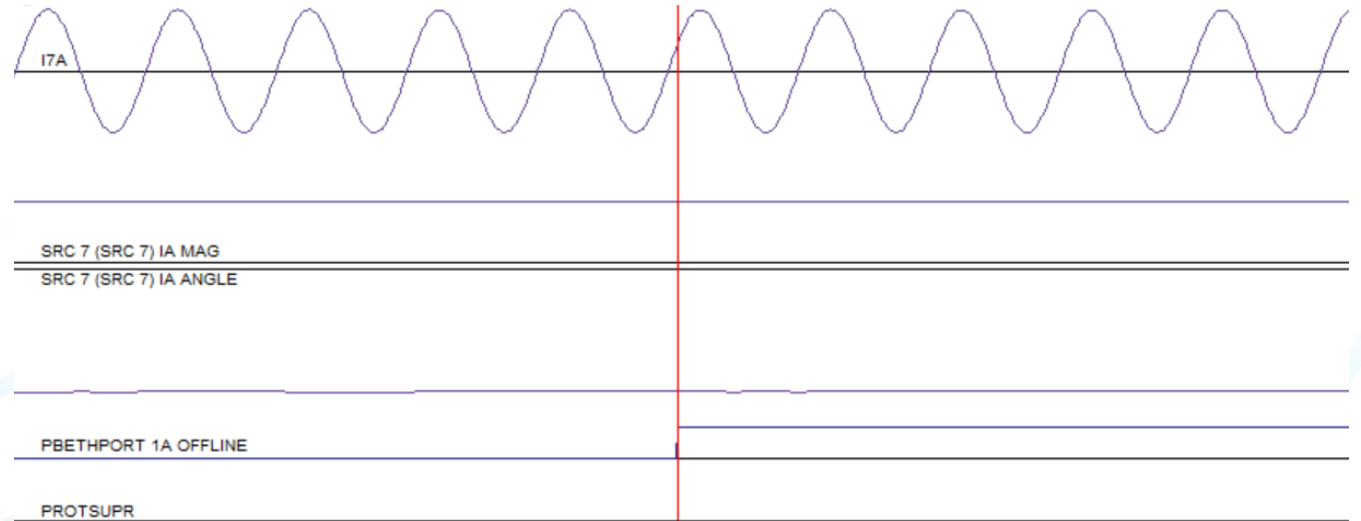
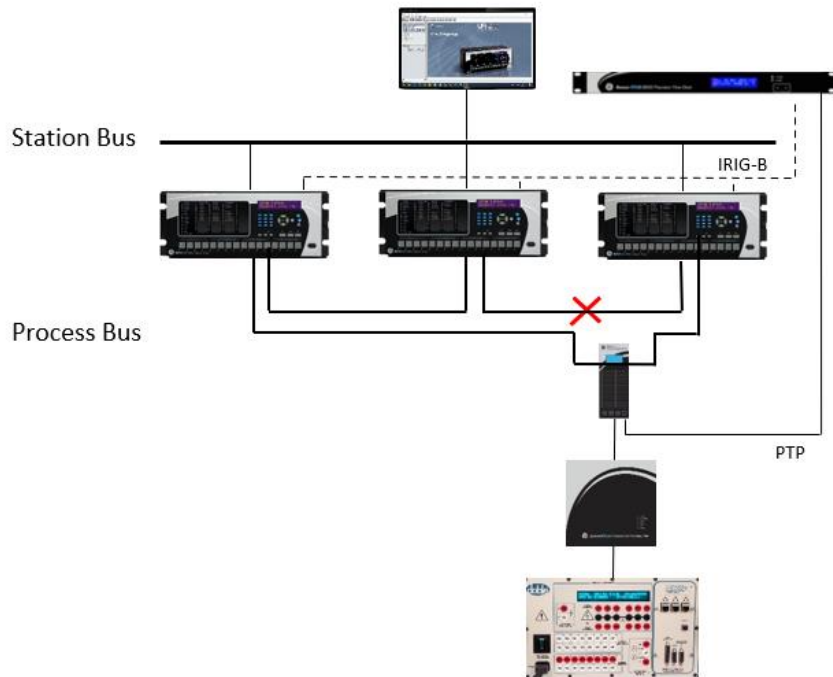
Loss of network – Solution PRP

The Process Bus was configured as a parallel redundant network and one LAN was removed. Breaking the connection on a single LAN had no impact on the metering and protection of the IED.



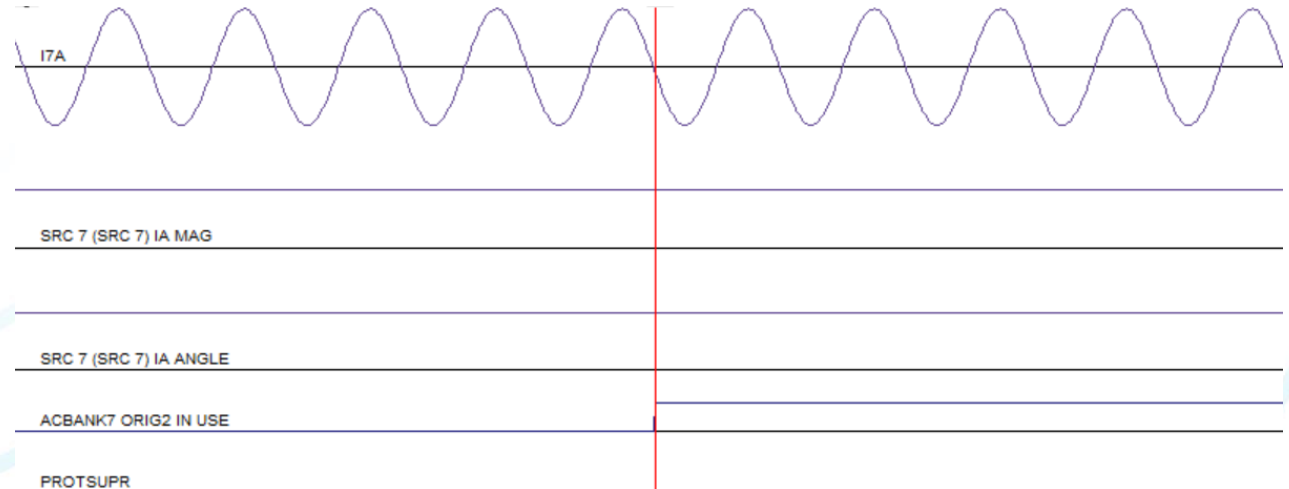
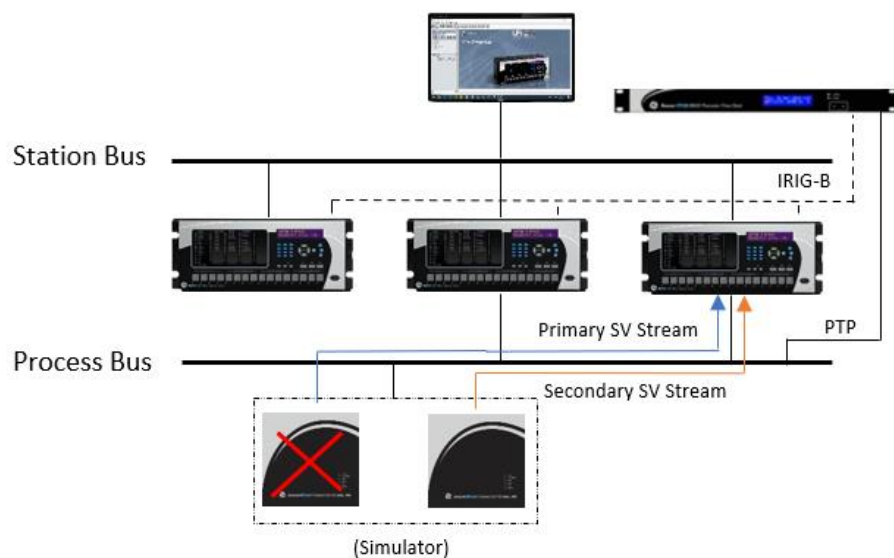
Loss of network – Solution HSR

The Process Bus was configured as a HSR network and one link was removed. Breaking the connection had no impact on the metering and protection of the IED.



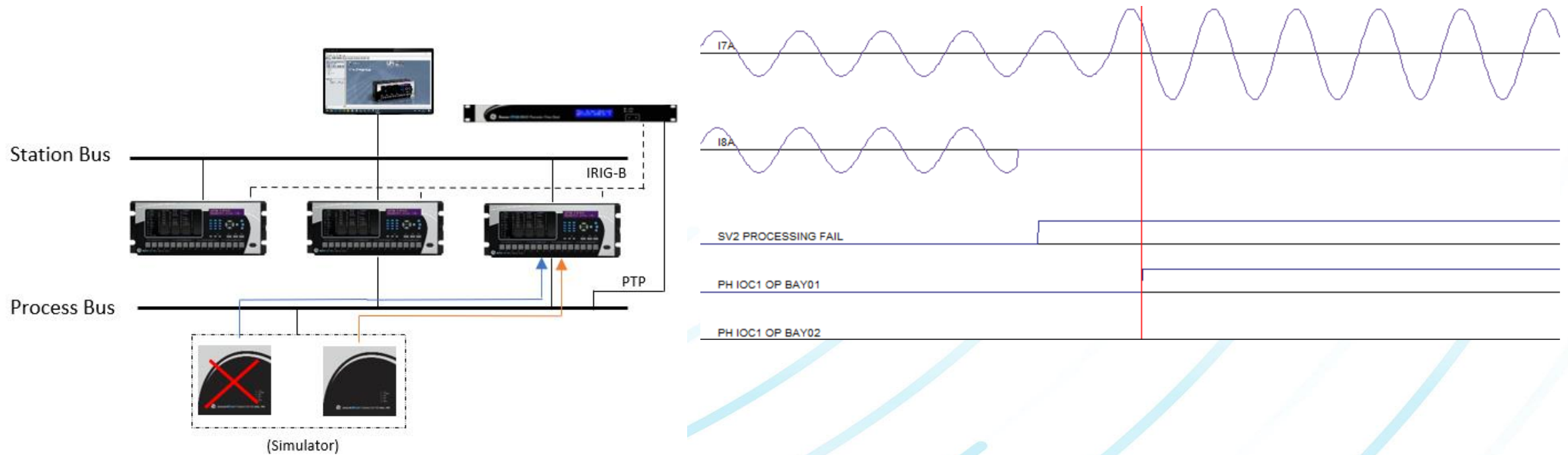
Loss of stream – Solution crosschecking

The IED application was configured with crosschecking, subscribing to two simulated SV streams. Disabling the preferred stream had no impact on the metering and protection of the IED as the IED switched to the secondary stream.



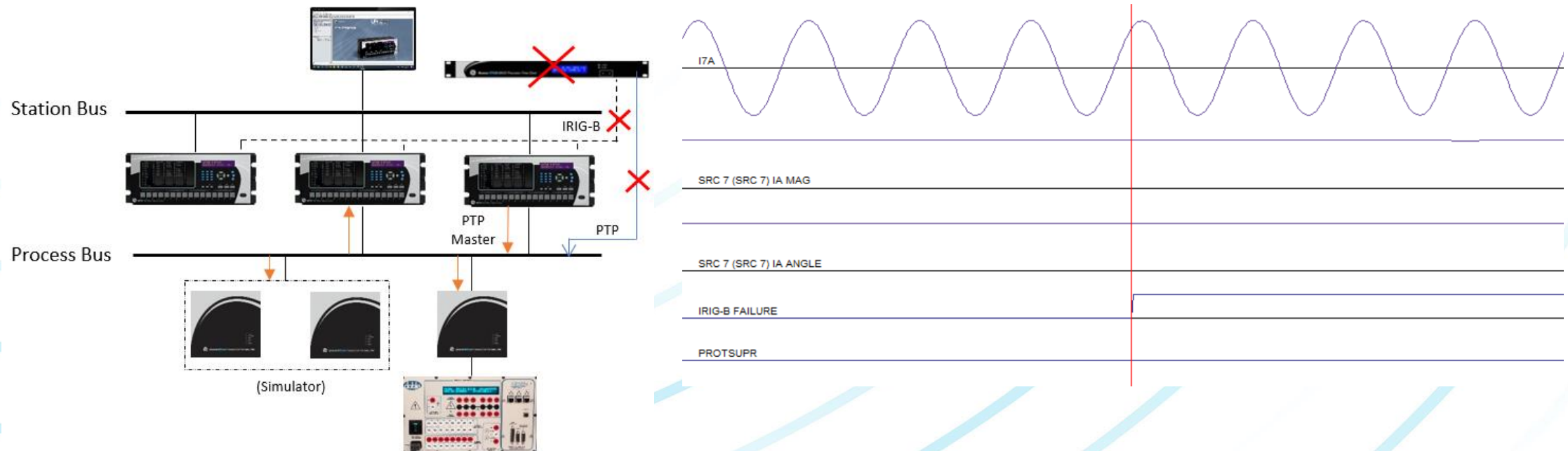
Loss of stream – Solution partial block

The protection functions of an IED were configured to use signals from different simulated SV streams. Using partial blocking, only impacted protection is blocked when a stream becomes unusable.



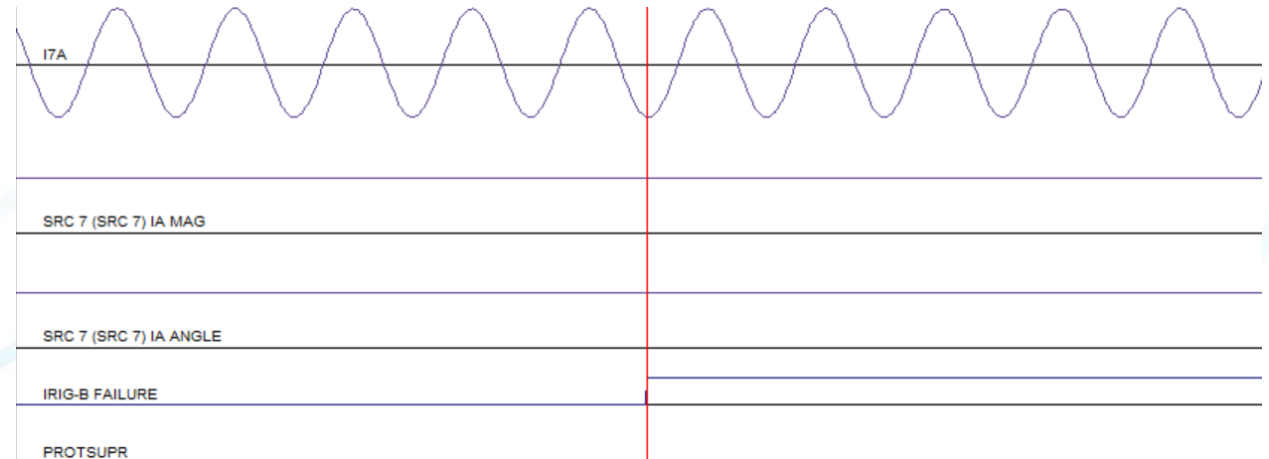
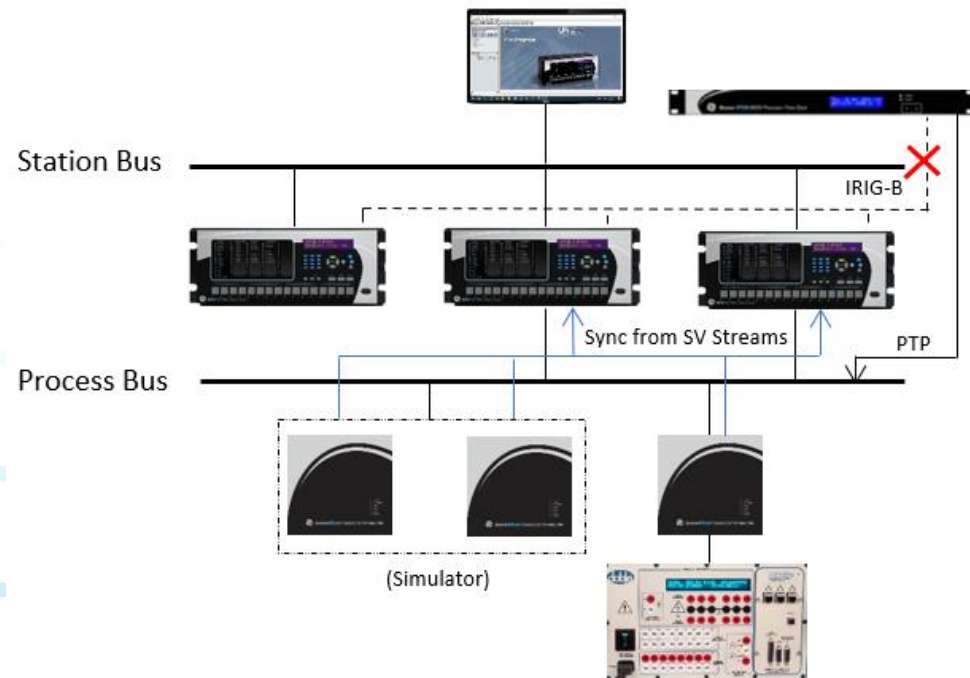
Loss of synchronization – Solution IED Becomes Grandmaster within a Protection Zone

The station clock was shutdown and the IED became the grandmaster clock to synchronize all other devices. Shutting down the station clock had no impact on the metering and protection of the IED.



Loss of synchronization – Solution Asynchronous Mode

The IED synchronization source was removed but the MUs remained synchronized to an external clock. The IEDs operated in asynchronous mode and there was no impact on the metering and protection of the IED.



Conclusions

- Delayed samples may delay protection. At some level of lost samples, protection will be impacted. The likelihood of these situations arising can be minimized with several design solutions.
- Redundancy at network and application level offer seamless continuity of protection in event of compromised equipment
- Advanced synchronization algorithms ensure protection is not impacted in the event the station clock is lost

Thank You

Questions?