WEBINAR AND DEMO:
Enhanced IEC 61850 Sampled Values streaming with the RTDS Simulator's GTFPGA Unit

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AGENDA

- Hardware primer:
  GTNETx2 vs. GTFPGA Unit
- GTFPGA-SV-V3 capabilities
- RSCAD demonstration
- Q&A

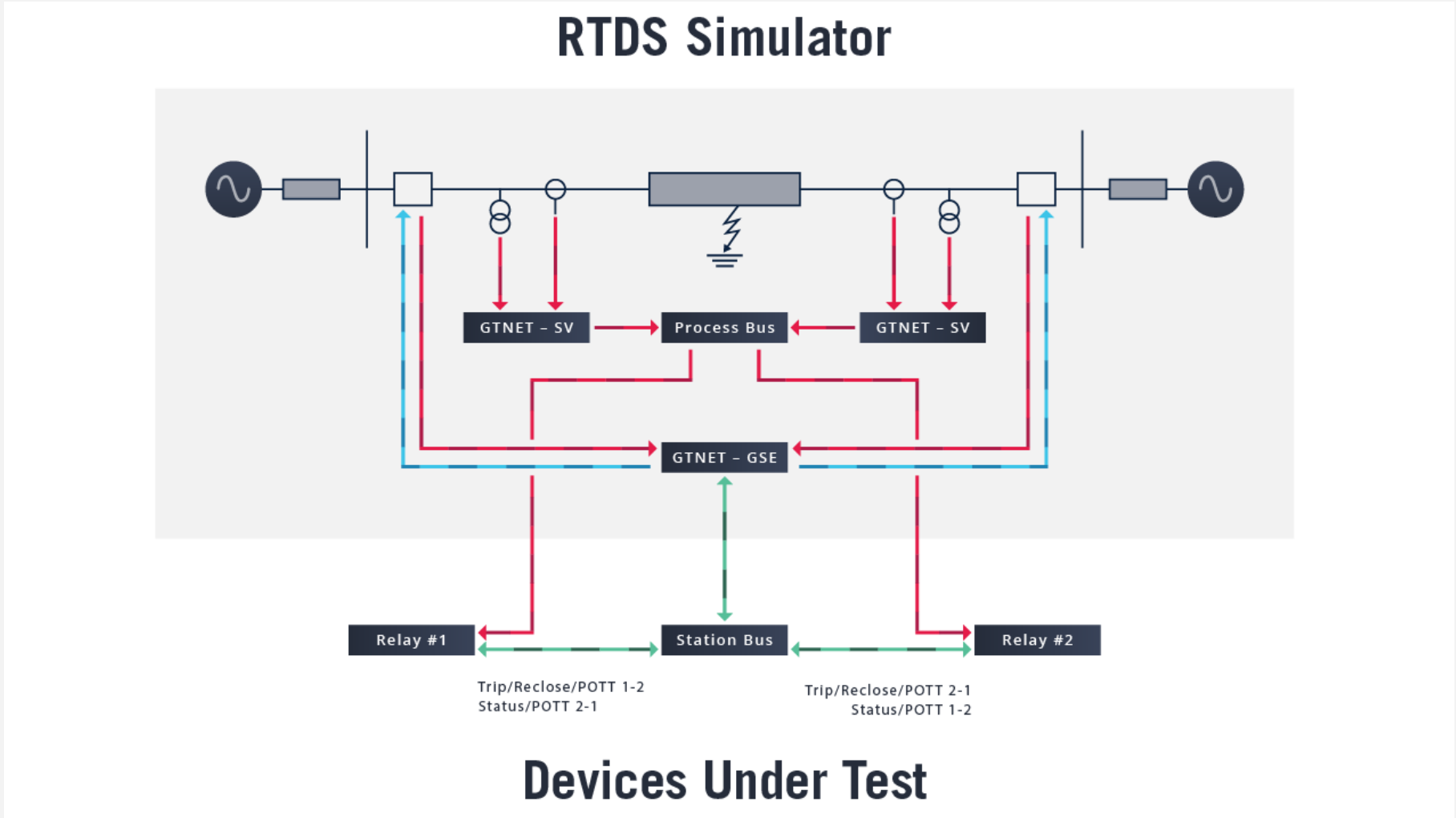
THE RTDS SIMULATOR AND IEC 61850

- The IEC 61850 standard defines communication protocols for substation IEDs and provide an overview of the communication/interaction architecture for substation automation systems

- RTDS Simulator development team actively participates in various industry events and working groups, including those focused on IEC 61850:
  - UCA IUG
  - IEC TC 57

- Industry direction and RTDS users drive development of new capabilities and features

HIL INTERFACE WITH IEC 61850



GTNETx2 Card for Network Communication

- Communication with external devices over Ethernet.
- Card has two “modules”, and can have two network protocols operating simultaneously.

Available firmwares:

IEC 61850
GOOSE Messaging
IEC 61850-9-2LE, IEC 61869-9

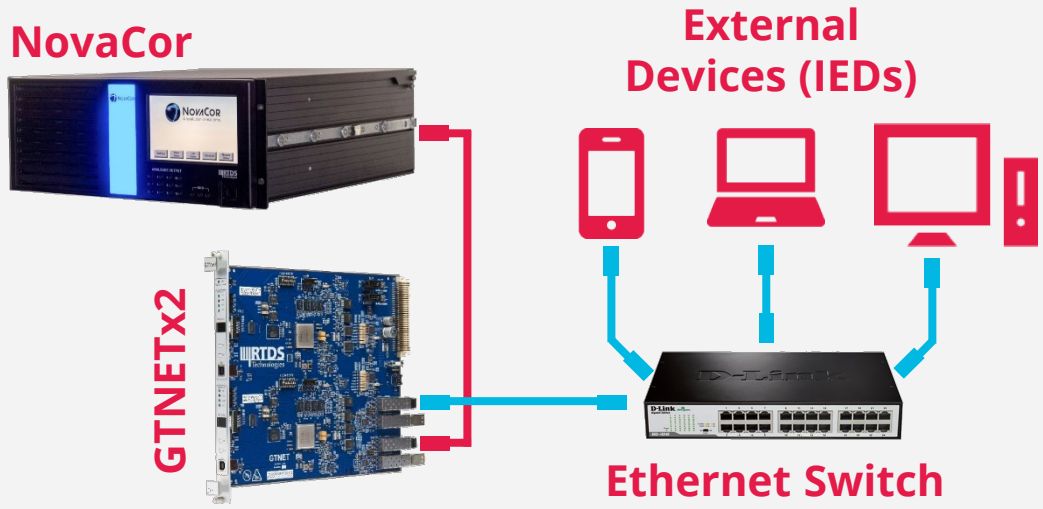
SCADA
DNP3 and IEC 60870-5-104

Large data playback

PMU
IEEE C37.118

MODBUS
TCP, RTU over TCP,
ASCII over TCP

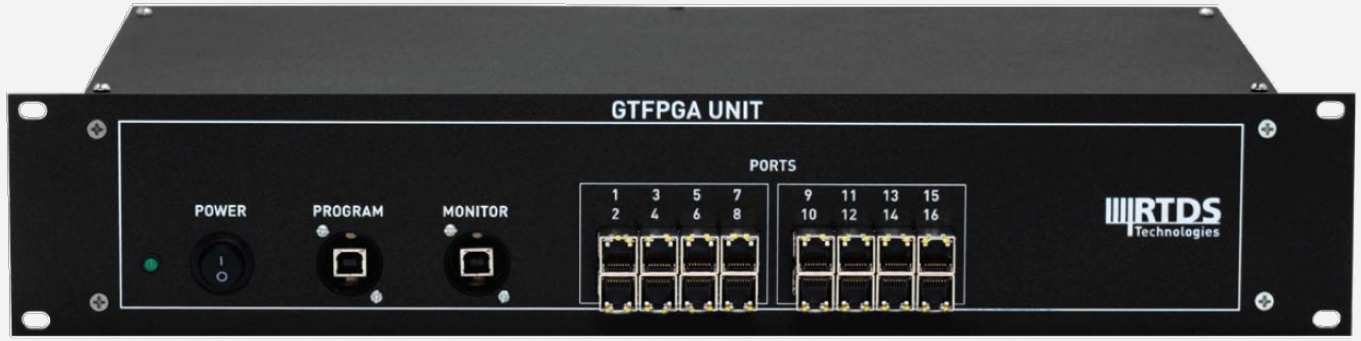
Generic TCP/UDP Sockets



GTFPGA UNIT

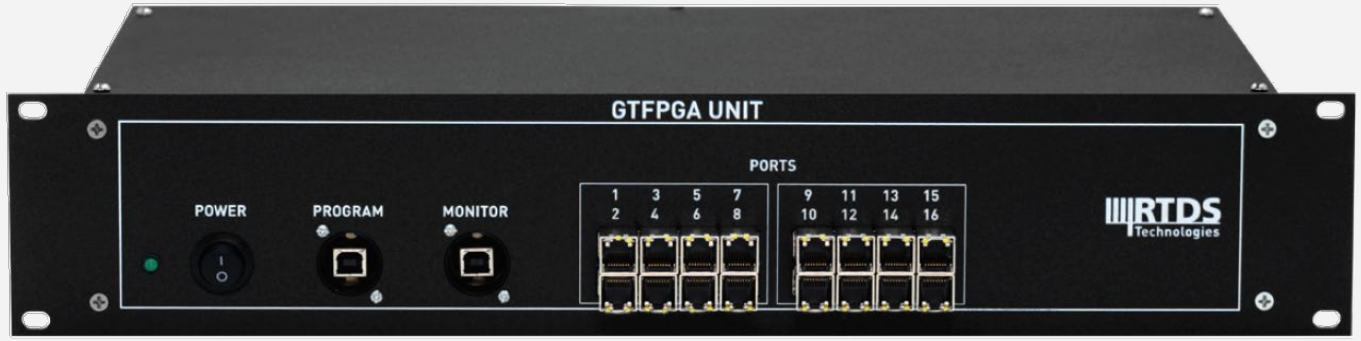
Optional FPGA-based auxiliary hardware

- Connects to central NovaCor or PB5-based hardware via fibre cable
- Function defined by firmware – multiple firmwares available
  - MMC Valve and Control
  - Small timestep frequency dependent tline (12 conductors)
  - Generic Power Electronics Solver (GPES)
  - **Sampled Values (-9-2LE + IEC 61869-9)**



GTFPGA UNIT

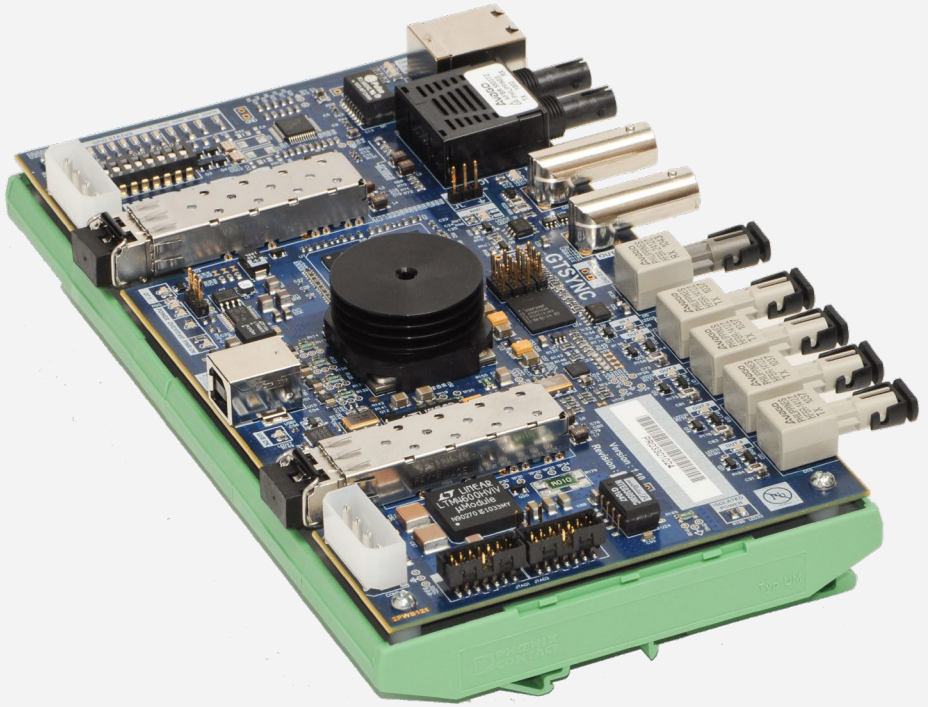
- 16 fibre/copper Ethernet ports
- Significantly more simultaneous published/subscribed SV streams than GTNET-SV
- Higher sampling rates than GTNET-SV (Substep operation possible)
- Now includes options for data/stream manipulation (not introduced for GTNET)
- Price is the same as GTNETx2 card



GTSYNC Card

for External Time Synchronization

- The GTSYNC card synchronizes the simulator to an external time reference (e.g. GNSS clock)
- Accepts external time reference inputs as,
  - 1 PPS (in/out via BNC or ST fiber)
  - IEEE 1588 PTP (in via RJ45 or ST fiber)
  - IRIG-B (in via BNC)
- If an external time reference is not available, an internal 1PPS source can provide a time reference
- Necessary for PMU testing
- **Advantageous for SV output**



Thank you!

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IEC 61850 Sampled Values Communication using RTDS Simulator and GTFPGA

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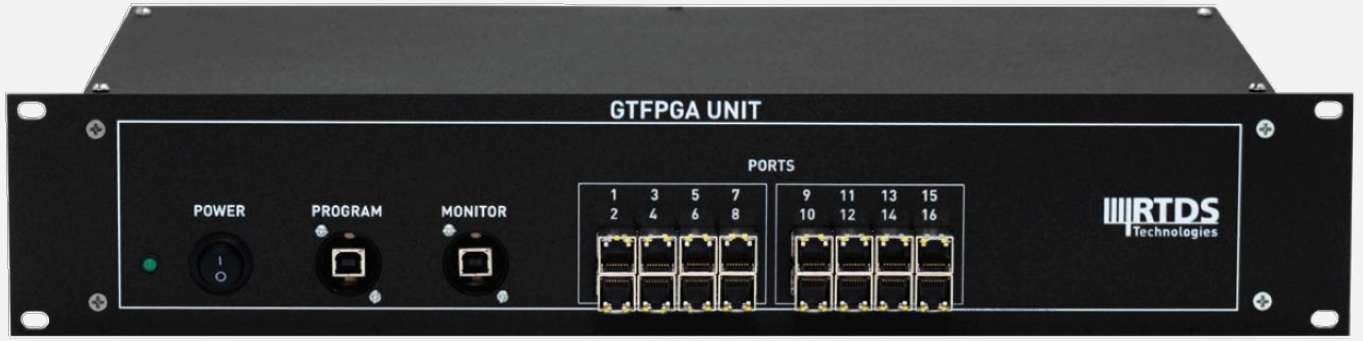
IEC 61850 SV

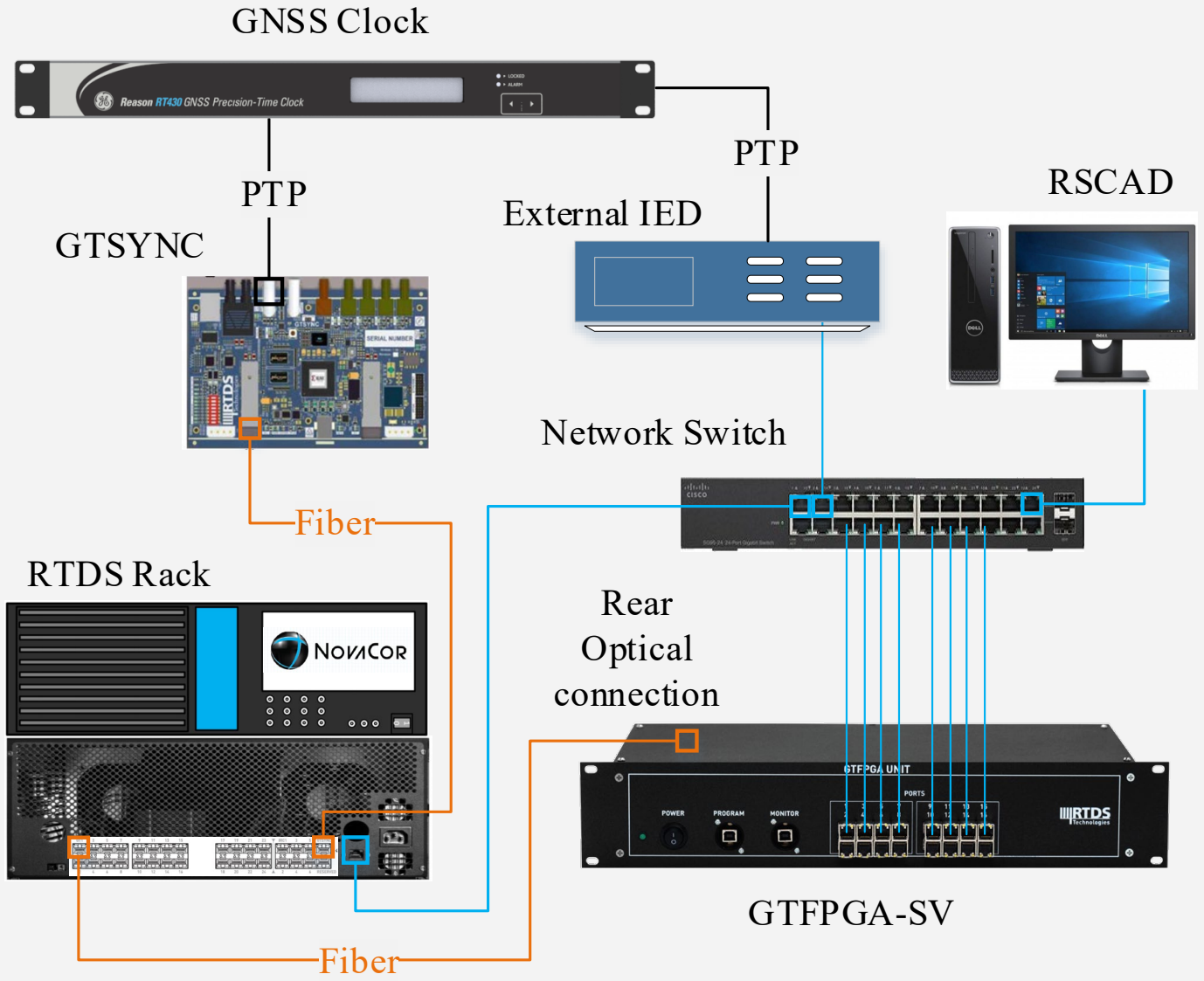
- Protection & control systems increasingly rely on critical measurements delivered through IEC 61850/IEC 61869 Sampled Value (SV)
- SV is one of the most commonly used protection & automation protocol to interface the simulator with external IEDs
- Non-genuine and non-ideal SV streams → misoperation, serious damage, cascading failures
- Need to identify the weakness and vulnerability of SV-based protection systems

GTFPGA-SV Hardware

- 16 fiber/copper Ethernet ports
- 100 Mbit/s or 1Gbit/s
- Publish (output) and subscribe (input) up to 16 independent SV streams simultaneously
- GTFPGA unit connects to the simulator by an optical fibre



Typical Connection



Sampling Rates

Table 902 – Standard sample rates

Digital output sample rates Hz	Number of ASDUs per frame	Digital output publishing rate frames/s	Remarks
4 000	1	4 000	For use on 50 Hz systems backward compatible with 9-2LE guideline.
4 800	1	4 800	For use on 60 Hz systems backward compatible with 9-2LE guideline, or 50 Hz systems backward compatible with 96 samples per nominal system frequency cycle.
4 800	2	2 400	Preferred rate for general measuring and protective applications, regardless of the power system frequency.
5 760	1	5 760	For applications on 60 Hz systems backward compatible with 96 samples per nominal system frequency cycle.
12 800	8	1 600	Deprecated, only for use on 50 Hz systems.
14 400	6	2 400	Preferred rate for quality metering applications, regardless of the power system frequency including instrument transformers for time critical low bandwidth d.c. control applications.
15 360	8	1 920	Deprecated, only for use on 60 Hz systems.
96 000	1	96 000	Preferred rate for instrument transformers for high bandwidth d.c. control applications.

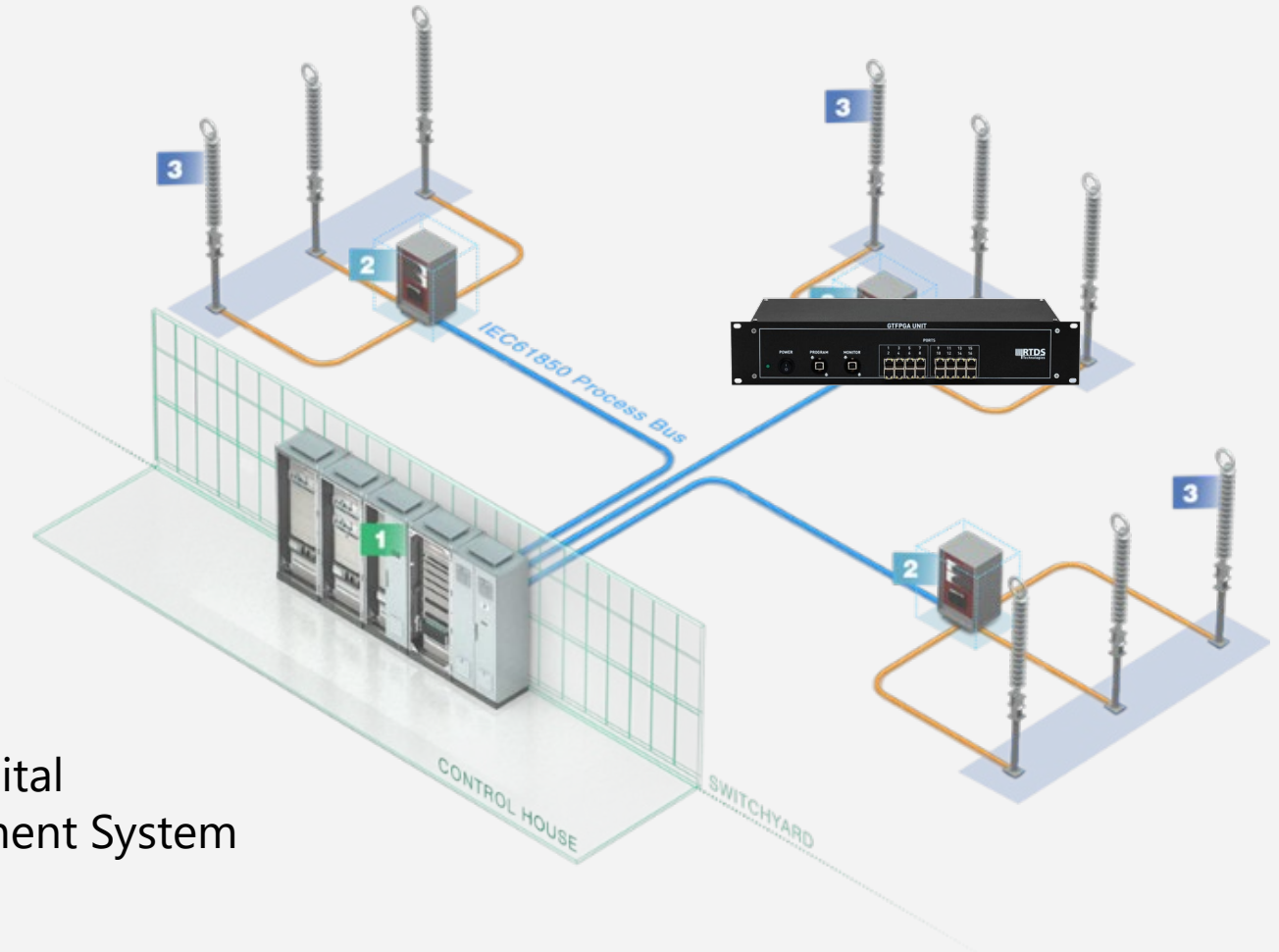
Capabilities

Sampling Rates and Number of Channels

Mode	Max. Number of SV Streams	Sampling Rate	Max. Number of Channels per Stream
Mainstep	16 Outputs and 16 Inputs	80 s/c, 96 s/c, 4800 Hz	24
		256 s/c, 14400 Hz	9
Substep	2 (Output only)	96 kHz	24
	1 (Output only)	250 kHz	48

250 kHz Sampling Rate

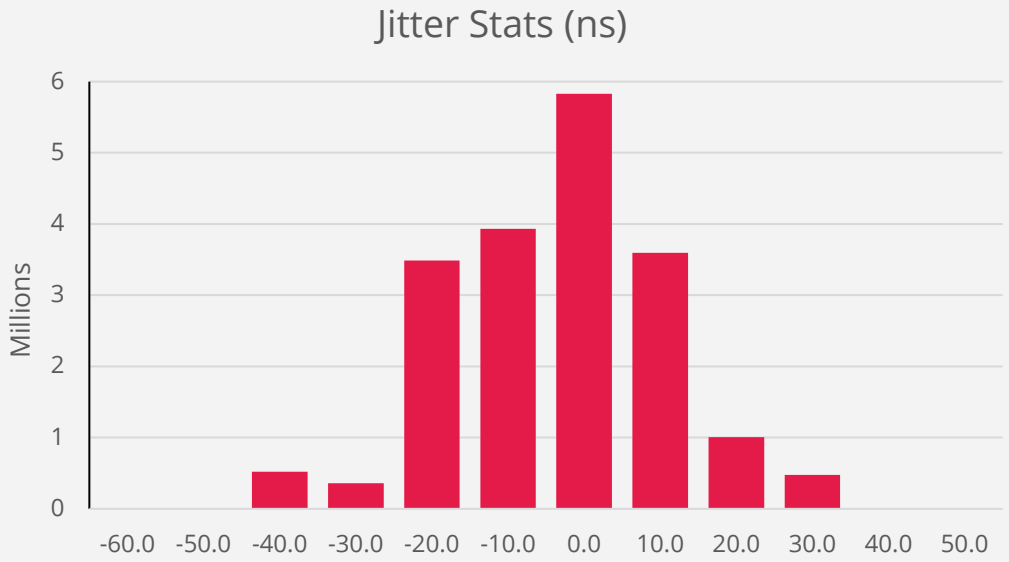
High bandwidth HVDC protection and control applications



HVDC Digital
Measurement System

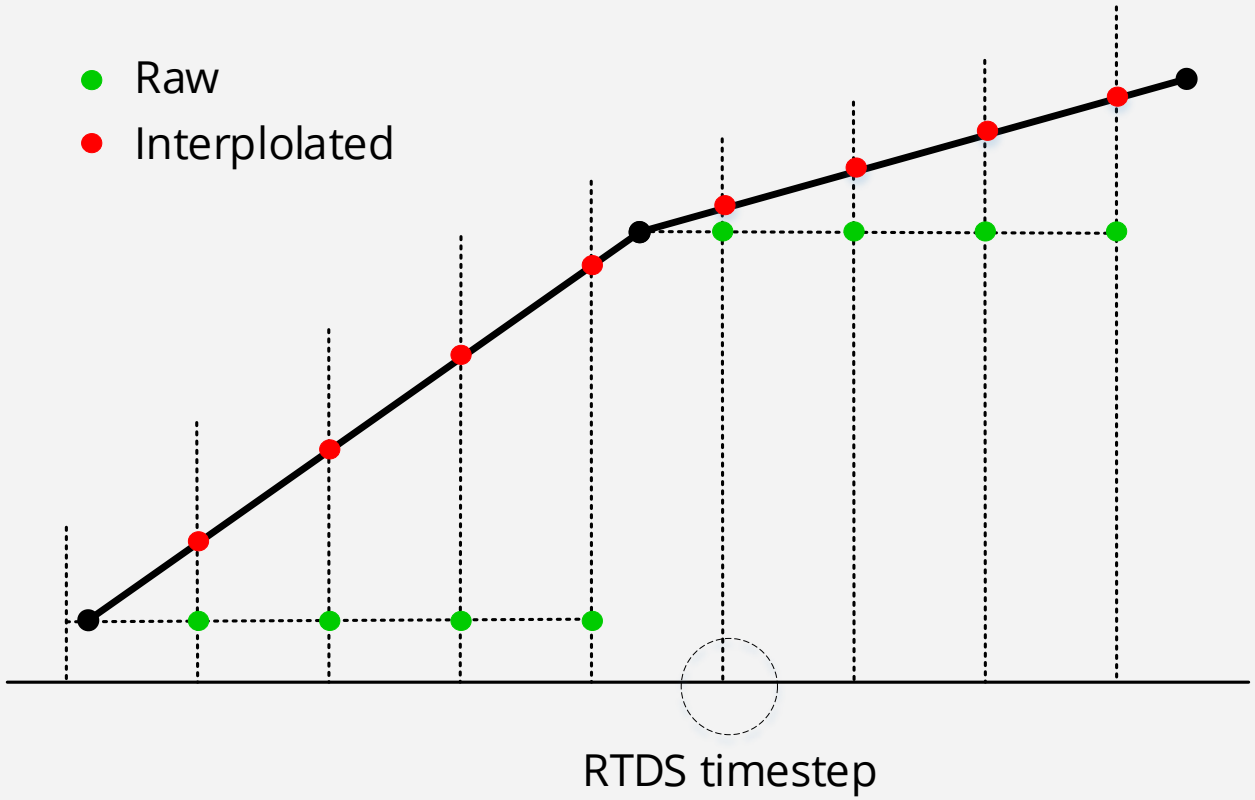
Subscriber

- SCL file parsing
- Filtering
  - APPID
  - Simulation Flag
- Monitoring
  - Packet interval (jitter stats)
  - Detailed subscription status (SV stream lost, CRC error, etc.)



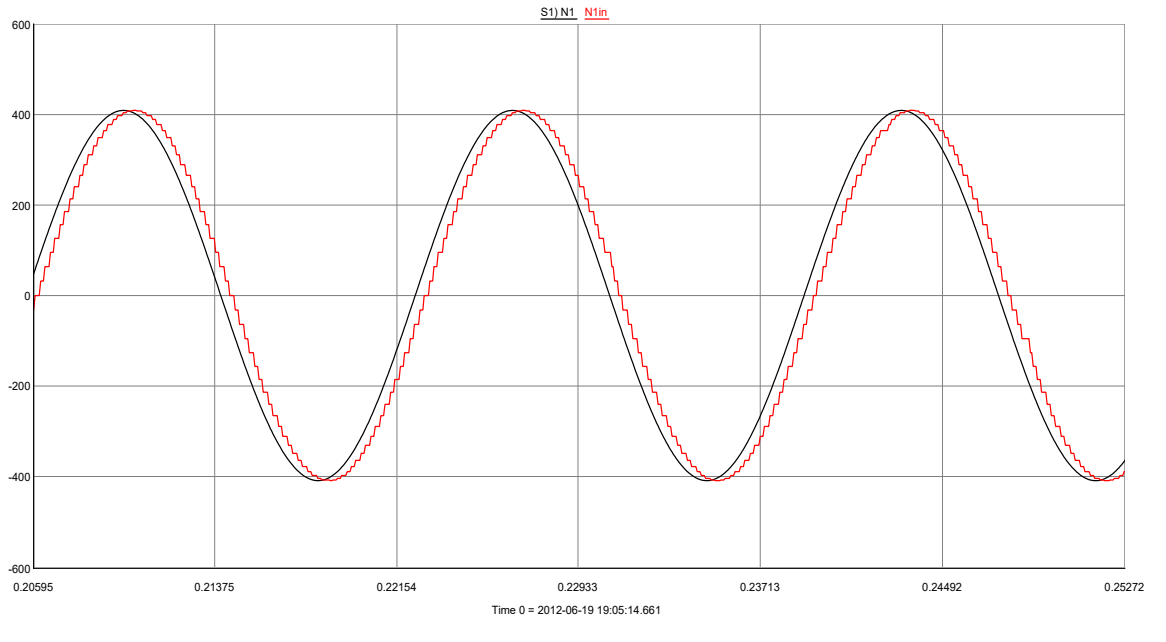
Subscriber

Raw vs Interpolated

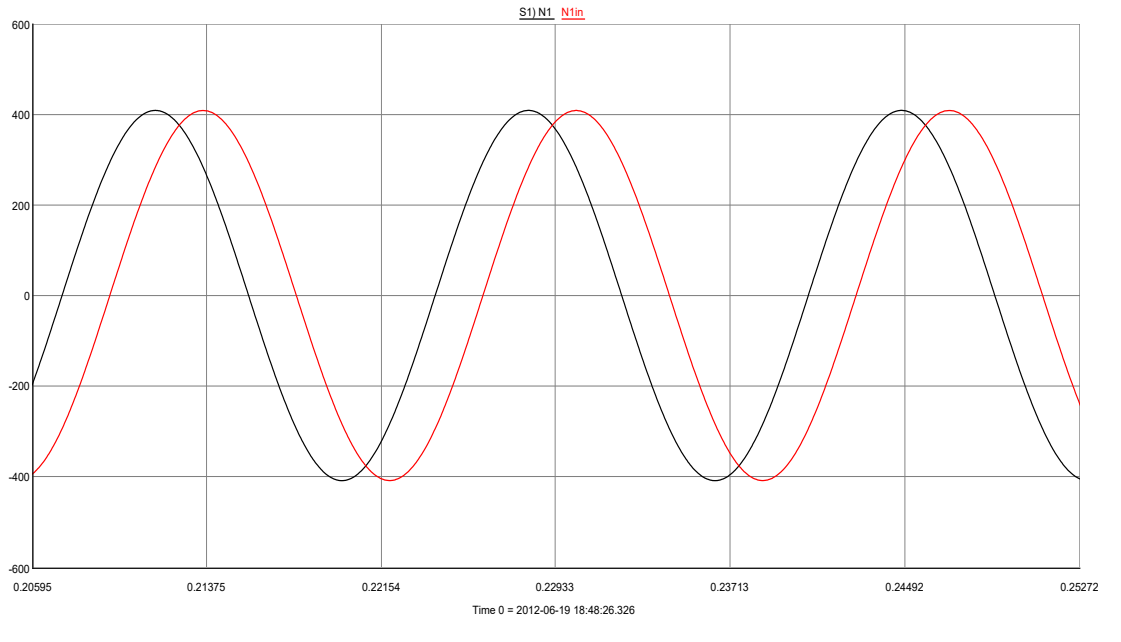


Subscriber

Raw

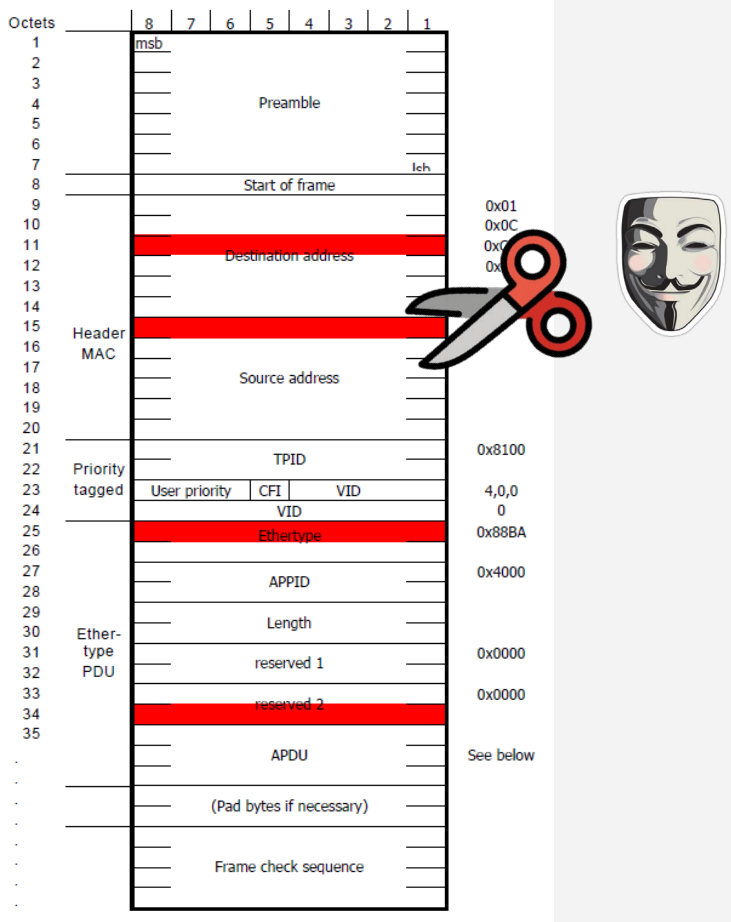


Interpolated

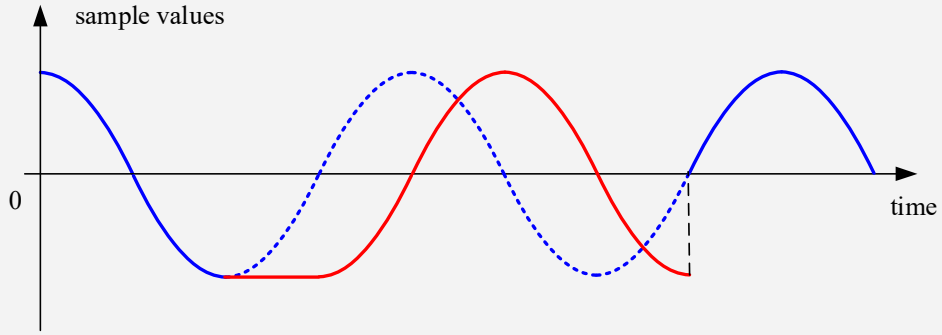


SV Publisher Manipulation

Data Manipulation

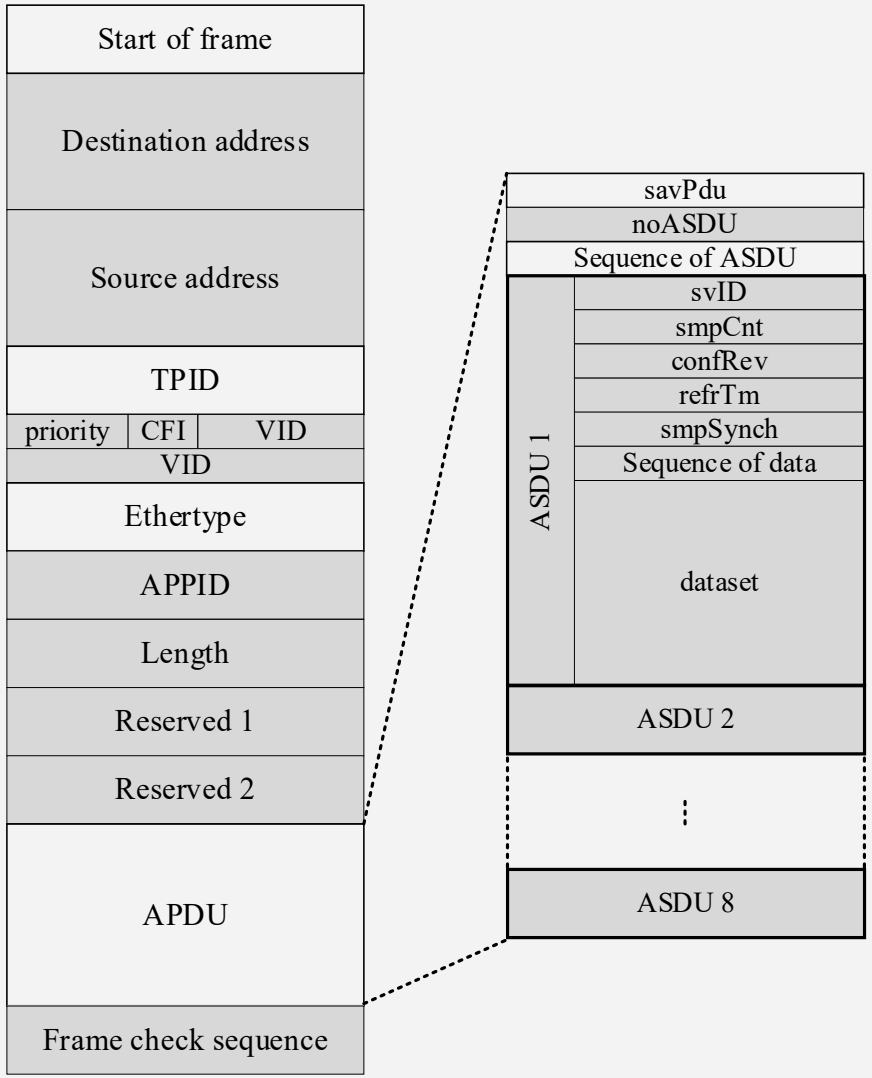


Stream Manipulation



Data Manipulation

1) VLAN Priority
2) VLAN ID
3) Application ID
4) Length of SV packet
5) Reserved 1
6) Reserved 2
7) Number of ASDU
8) Configuration revision
9) Sample count
10) Destination MAC address
11) Source MAC address
12) Stream identification

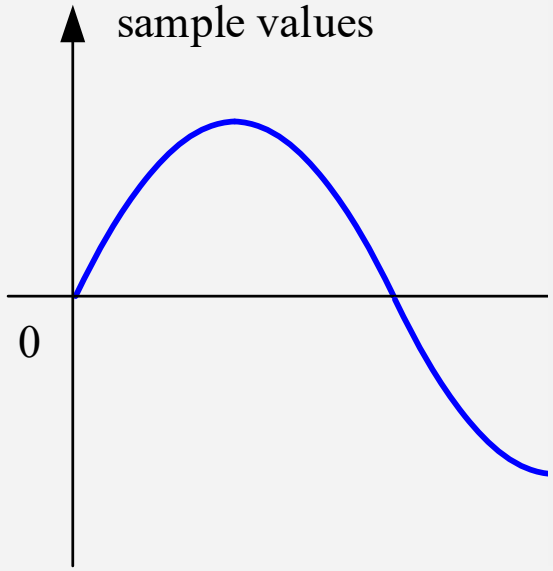


Stream Manipulation

1) Stop/resume
2) Duplicate
3) Swap
4) Delay
5) Jitter

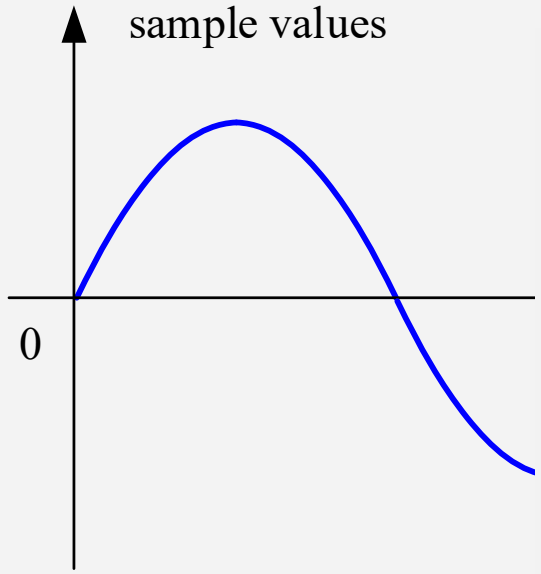
1) Stop/Resume

stop/resume publishing during runtime to simulate the loss of packets on the network



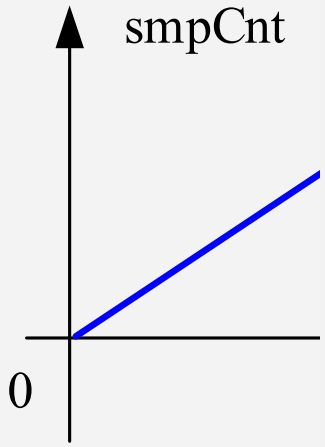
2) Duplicate

duplicate packets to simulate a problematic network topology



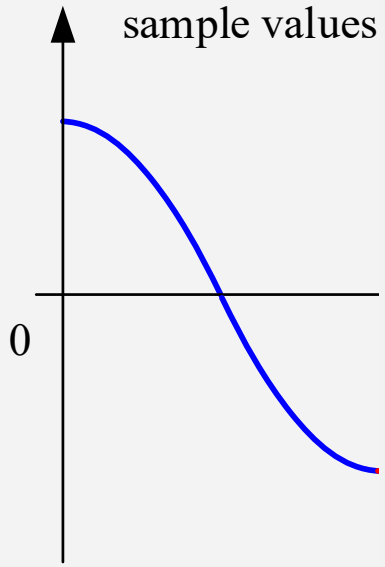
3) Swap

swap the order of two packets to simulate non-sequential arriving of packets, due to problematic network routing



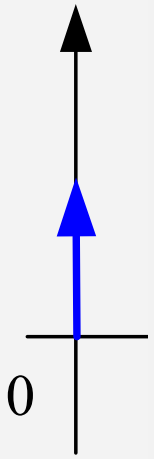
4) Delay

delay publishing to simulate unwanted latency on the network



5) Jitter

- add positive/negative jitter to simulate the variance of latency
- Resolution: 10 ns

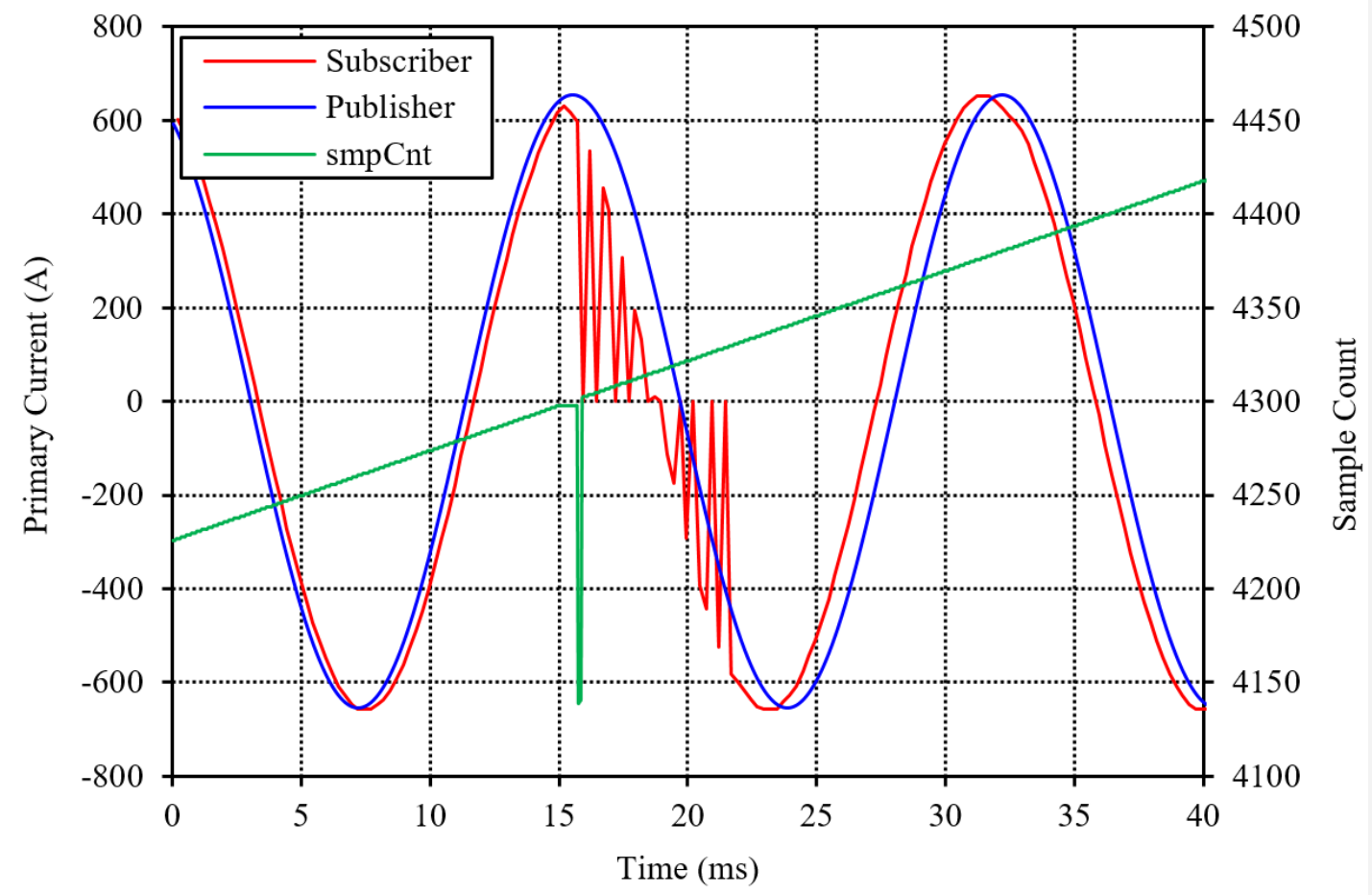


Data Manipulation

Field name	IED response
Destination MAC	Subscription stop
Source MAC	Does not affect
VLAN priority	Does not affect
VLANID	Subscription stop
APPID	Subscription stop
Length	Subscription stop
Reserved 1	Does not affect
Reserved 2	Does not affect
noASDU	Subscription stop
svID	Does not affect
smpCnt	Affected for operation
confRev	Subscription stop
smpSynch	Does not affect

Data Manipulation: smpCnt

- Manipulate 3 smpCnt
- Half-cycle abnormal measurements
- Corrupt IED buffer
- During resampling, generate incorrect values



Stream Manipulation: latency & jitter

- Latency
  - Delayed 2.5 ms
  - IED operated normally
  - IED’s data buffer reduce the impact of delay
- Jitter
  - Gaussian distribution jitter
  - Standard deviation 2.5 ms
  - IED operated normally
  - IED’s data buffer reduce the impact of jitter

Summary

- GTFPGA unit combined with RTDS simulator allows for efficient/accurate testing of many SV-compliant devices
- Up to 16 SV streams can be published/subscribed simultaneously and independently
- Suitable for ultra high bandwidth applications such as HVDC protection and control applications
- SV manipulation allow users to identify and address vulnerabilities in SV-based protection before the deployment on the grid

RSCAD Demonstration

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