Data Capture and Storage Capabilities of SEL Products

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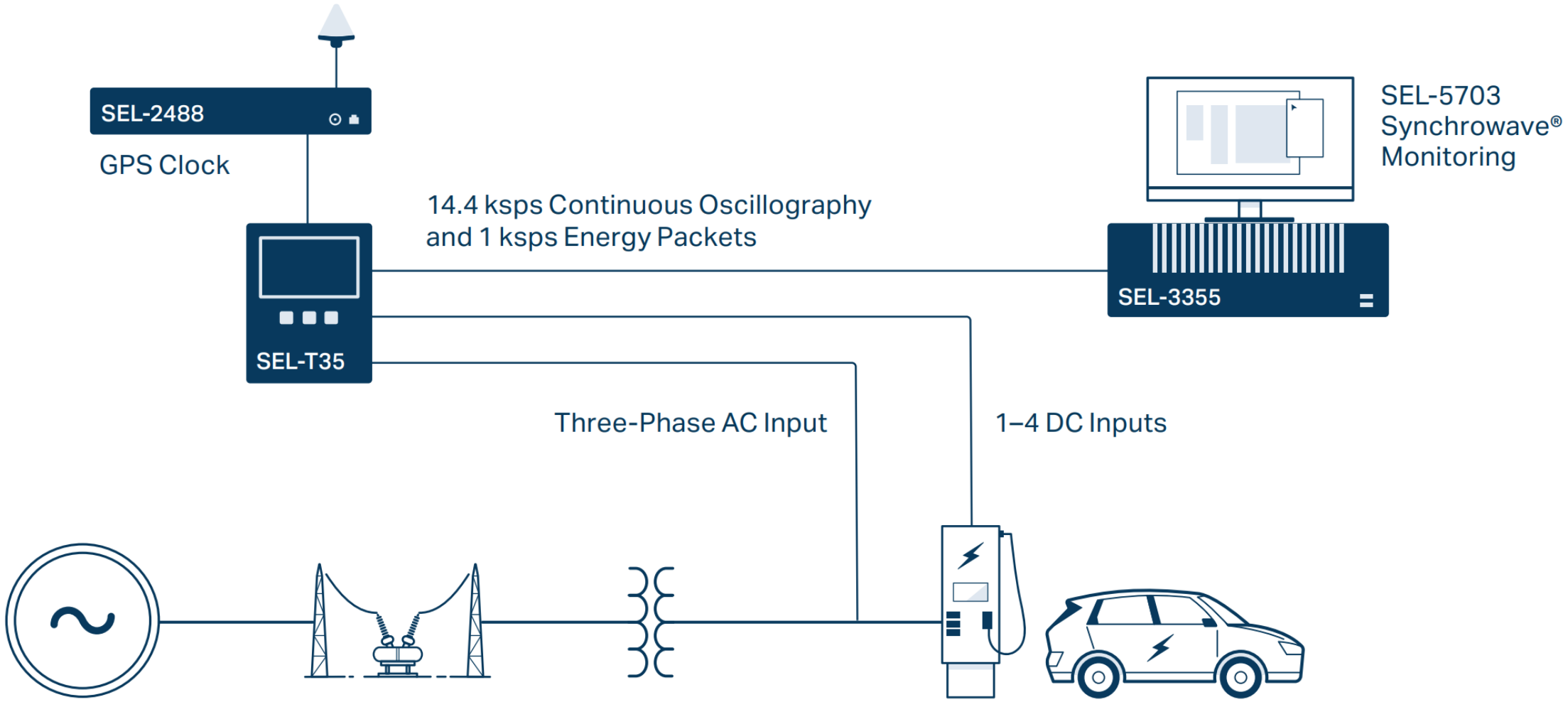
Agenda

- Types of disturbance monitoring
- Recording capabilities of SEL relays
- Time synchronization
- Capturing and storing disturbances using SEL automation products.

Types of Disturbance Monitoring

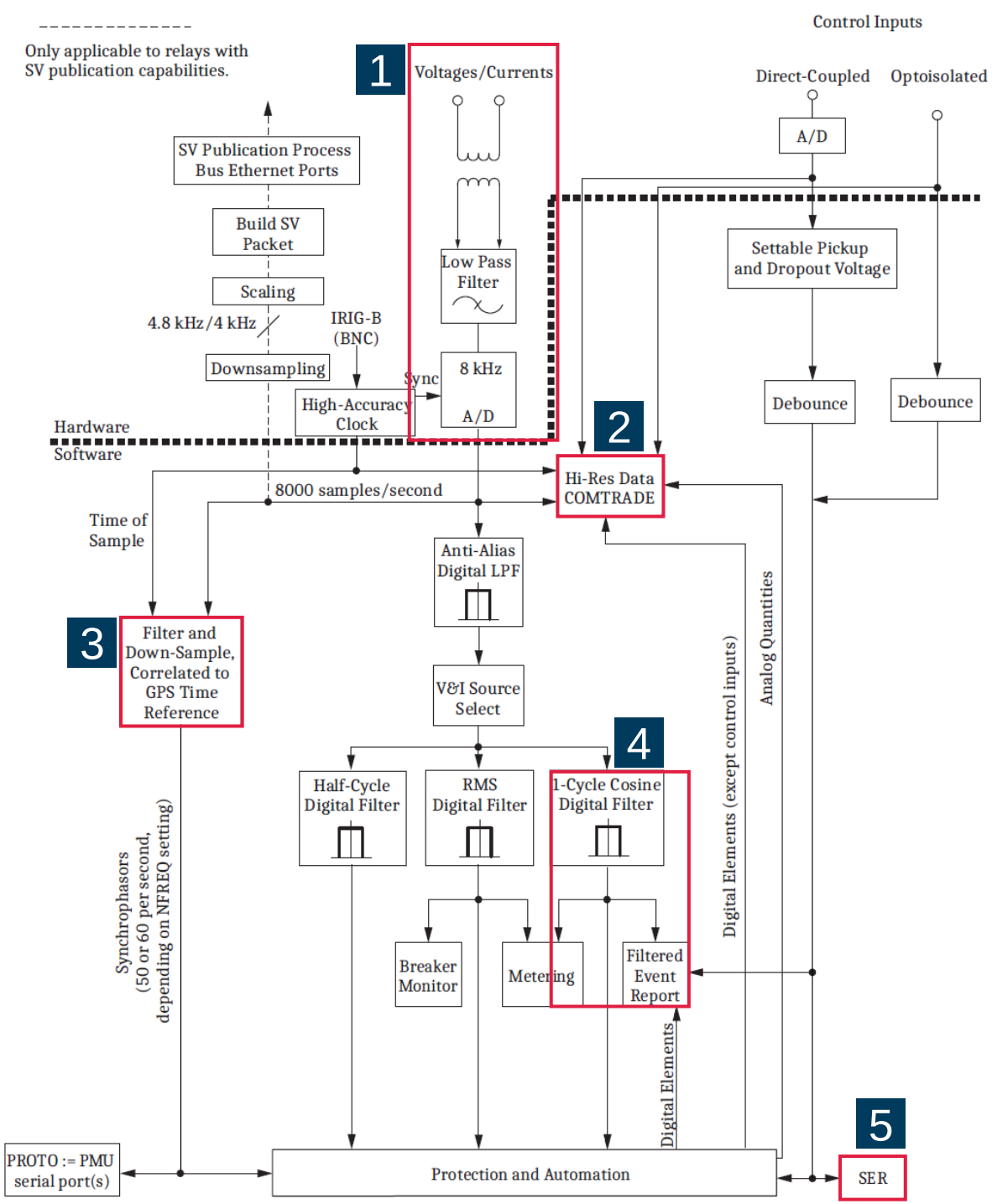
- Fault recording
  - Analog and binary signals, high-resolution, short duration
- Dynamic Disturbance Monitoring
  - Synchrophasors, up to 60 messages/second, continual capture
  - High-resolution streaming, continual capture
- Sequence of Events
  - Binary signals, captured during state changes only

High-resolution streaming



Signal path in relays

1. Digitization of voltage and current connections.
2. High resolution Event Report
3. Synchrophasor data
4. Filtered Event Report
5. Sequential Events Recorder



Event reports

- Event report formats
- Contents
- Length
- Event report storage
- Filtering and sample rate
- Triggering conditions

Event report formats in SEL relays

EVE

Human readable. Only provides subset of relay word bits.

Data available as filtered or unfiltered (raw).

CEV

Intended to be used with event analysis software.

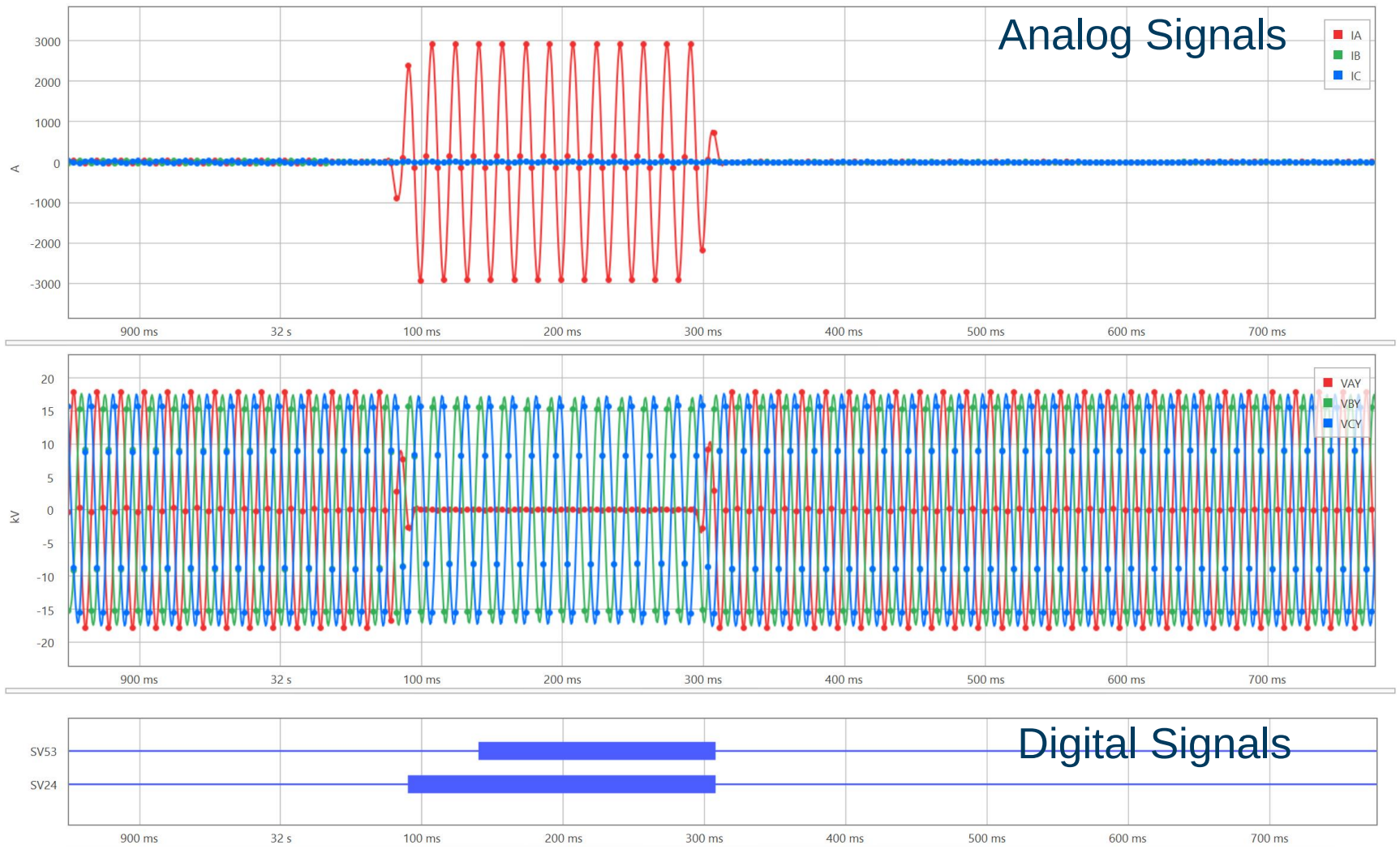
Data available as filtered or unfiltered (raw).

COMTRADE

IEEE C37.111 standardized format.

Unfiltered (raw) data only in most SEL relays.

Event report contents



Event Summary

1

CIRCUIT NAME - RELAY NAME
Time: 7/14/2021 10:24:32.095000 AM
File: C:\Users\tommcqu\OneDrive - Schweitzer Engineering Laboratories\Desktop\3_Resources\Event Data\CEV_S4_L60_12623.CEV
FID: SEL-651R-2-R411-V0-Z011003-D20210317
Event Type: AG T
Report Type: CEV, Filtered
Fault Location: 0.01
Frequency: 60.01 Hz Sample Rate: 4 Samples/Cycle
Targets: 10 101001010100 000000110000
Shot: 0
Fault Currents: IA:2078 IB:0 IC:1 IG:2074 3I2:2066

Relay Settings

CEV_S4_L60_12623.CEV - Relay Settings [1]

Grid View | Text View

Search | Next | Prev

```
Group 4

Group Settings

Identifier and Instrument Transformer Settings:
RID     :=RELAY NAME
TID     :=CIRCUIT NAME
CTR     := 1000.0    CTRN    := 1000.0    PTRY    := 266.67
PTRZ    := 266.67
VNOM    := 120.00

Enable Settings:
ESPB    := N         E50P    := 6         E50N    := N
E50G    := 6
E50Q    := 1         E51P    := 2         E51ABC  := 1
```

Event report contents – 3XX, 6XX, 7XX relays

- Analog Signals
  - All analog currents and voltages are included in both filtered and unfiltered reports.
- Digital Signals
  - All relay word bits available in the relay are included in both filtered and unfiltered reports.

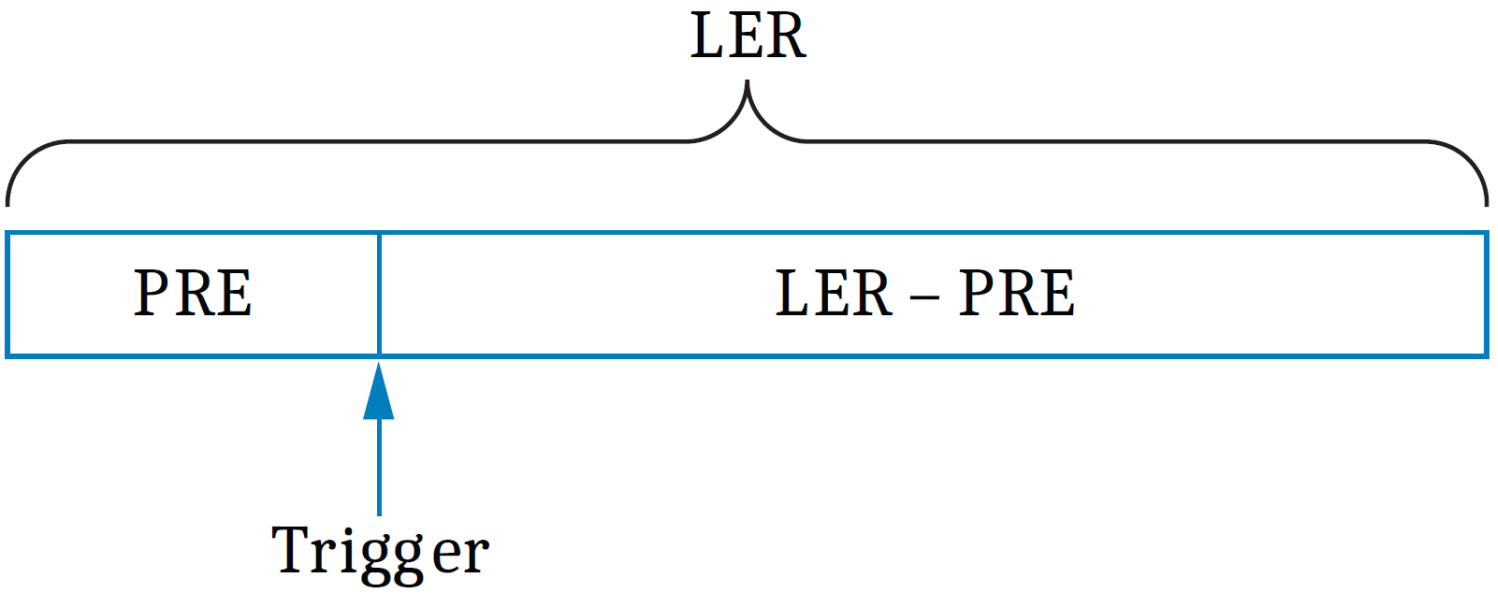
Event report contents – 4XX relays

- Analog signals
  - Filtered events report line currents and voltages + analogs specified by **ERAQ** setting.
  - Unfiltered events include individual current and voltage analog quantities only.
- Digital signals
  - Filtered events include base set (relay specific) + bits specified by **ERDG** setting.
  - Unfiltered events include base set + bits specified by **ERDG** setting or **all bits** if **ERDIG = A**.

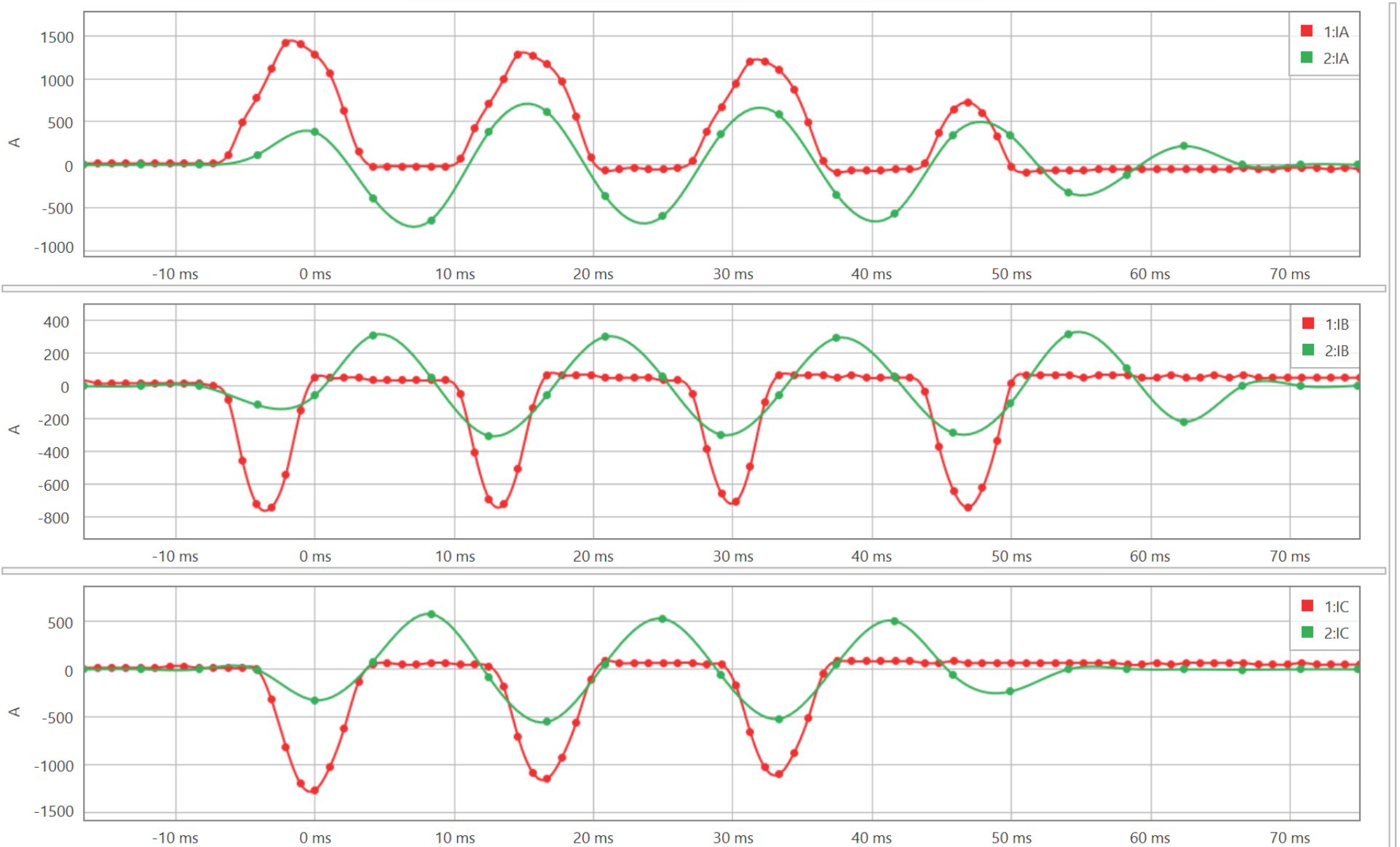
Note: This information does not apply to T4XXL relays.

Event report length

- Configurable in modern relays up to a maximum length.
- Maximum length varies by relay model and sometimes hardware version.



Sample rate and relay filtering



Events

Open

1

MAIN 751A - MAIN 751A
Time: 11/16/2010 1:07:44.023000 PM
File: C:\Event Files\CEV_R_1_Main.CEV
FID: SEL-751A-R402-V0-Z006003-D20100129
Event Type: CA
Report Type: CEV, Raw
Frequency: 60 Hz Sample Rate: 16 Samples/Cycle
Fault Currents: IA:529.4 IB:224.0 IC:415.7 IN:0.00 IG:7.24

2

FEEDER 751A - FEEDER 751A
Adjusted Time: 11/16/2010 1:07:44.035479201 PM
Original Time: 11/16/2010 2:08:41.262000 PM
File: C:\Event Files\CEV_L_1a_Feeder.CEV
FID: SEL-751A-R402-V0-Z006003-D20100129
Event Type: CA
Report Type: CEV, Filtered
Frequency: 60.1 Hz Sample Rate: 4 Samples/Cycle
Fault Currents: IA:529.5 IB:221.5 IC:413.0 IN:0.00 IG:9.01

How to choose the right event report

- Download unfiltered event data when analyzing the power system.
  - Choose the COMTRADE when available.
  - Otherwise, select raw CEV at highest available sample rate.
- Download filtered data when analyzing relay performance.
  - Select the resolution that corresponds to relay’s protection processing interval.

Sample rate by relay type

	3XX	4XX	6XX	7XX
Processing interval	4 spc	8 spc[a]	4 spc	4 spc
Maximum unfiltered sample rate	128 spc	8 kHz	128 spc	16[b]/32 spc

spc = samples per cycle

Notes:
Data for current generation of SEL devices.
a - Generally true but with a few exceptions.
b - 710-0, 751A, 787-0

Event report storage in relays

- Dependent on length of event report (LER)
- Varies by relay type
- Not upgradable
- Oldest overwritten first

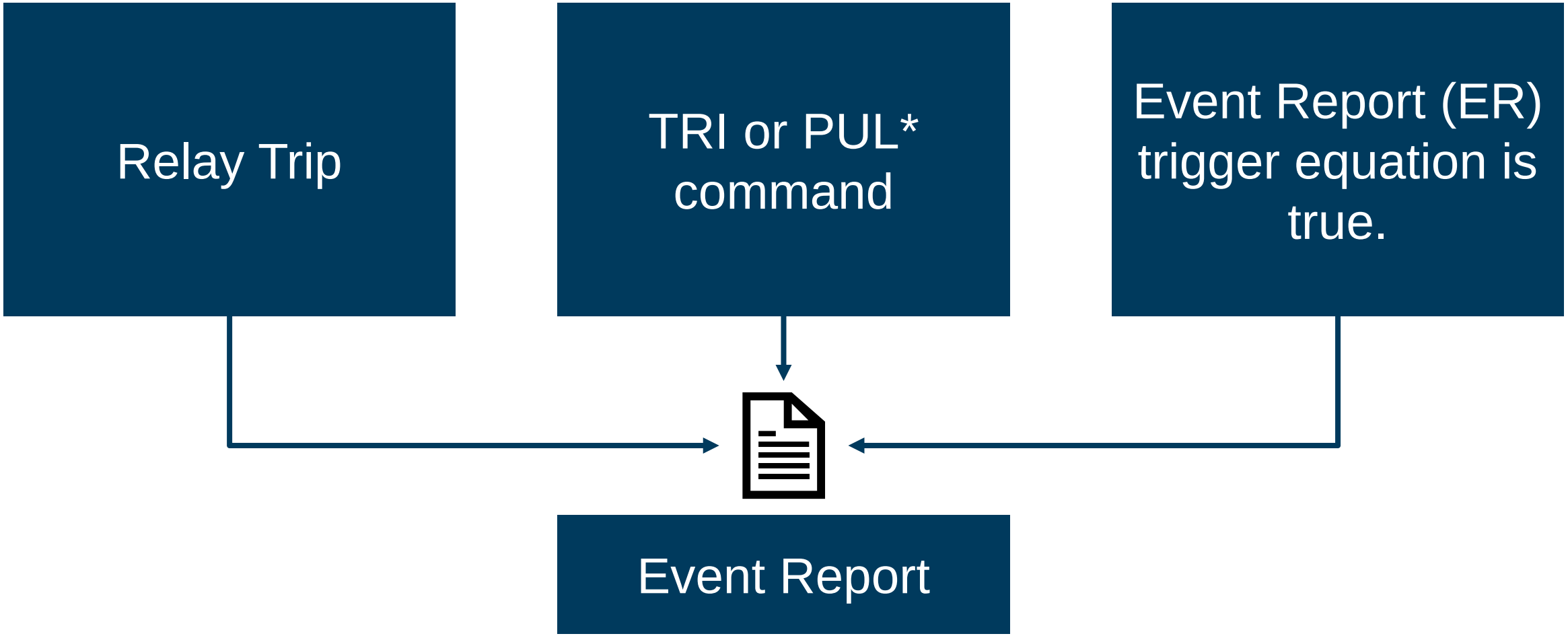
SEL-311C-2/3

LER Setting	Number of Event Reports Stored
15 cycles (factory default)	43
30 cycles	25
60 cycles	13
180 cycles	4

SEL-421-4/5

Event Report Length	Maximum Number of Stored Reports			
	8 kHz	4 kHz	2 kHz	1 kHz
0.25 seconds	161	193	212	248
0.50 seconds	98	123	139	173
1.0 seconds	54	70	82	107
3.0 seconds	19	25	30	41
6.0 seconds	N/A	12	15	21
12.0 seconds	N/A	N/A	7	10
24.0 seconds	N/A	N/A	N/A	4

Event report triggering



*Not supported in all relays.

Setting up an ER trigger

- Identify the criteria you wish to trigger for.
- Setup a relay element to operate at desired threshold.
- Add the output of the relay element to the ER equation.
- If a relay element is not available, determine feasibility of custom logic to address requirement.

Protective elements for ER triggering

Relay Element	3XX	4XX	6XX	7XX
Undervoltage (27)	Yes	Yes	Yes	Yes
Overvoltage (59)	Yes	Yes	Yes	Yes
Overcurrent (50)	Yes	Yes	Yes	Yes
Over/Under Frequency (81)	Yes	Yes	Yes	Yes
Rate of change of frequency (ROCOF)	No	SELogic	Yes[a]	Yes[ab]

Notes:

a – Settings range: 0.10 – 15.00 Hz/s

b – Available in SEL-700G, SEL-751/A

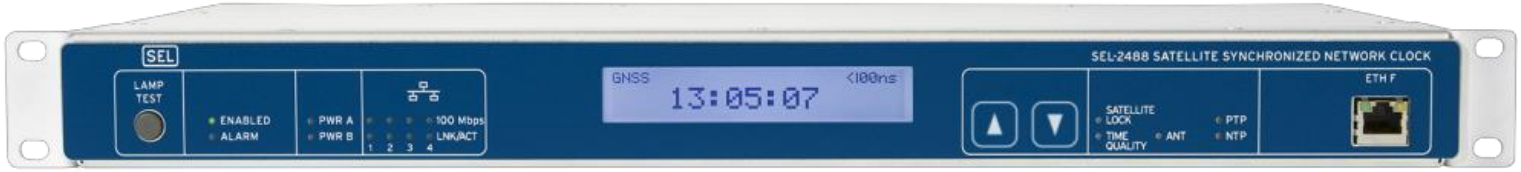
Sequential Events Recorder (SER)

- Tracks state changes of binary data (relay word bits).
- Which binary data are tracked determined by settings.
- Capacity is dependent on relay type.
- First in first out (FIFO) non-volatile memory buffer.

```
=>SER 8 <Enter>

SEL-751                                    Date: 02/28/2007   Time: 16:34:28
FEEDER RELAY                                Time Source: Internal

Serial No = 2007XXXXXXXXXX
FID = SEL-751-R100-V0-Z001001-D20070410                CID = 5052

#      DATE         TIME                ELEMENT              STATE
8    02/28/2007  13:54:09.602   51P1P                      Asserted
7    02/28/2007  13:54:09.602   51AP                       Asserted
6    02/28/2007  13:54:10.003   51P1T                      Asserted
5    02/28/2007  13:54:10.003   TRIP                       Asserted
4    02/28/2007  13:54:10.219   51P1P                      Deasserted
3    02/28/2007  13:54:10.219   51AP                       Deasserted
2    02/28/2007  13:54:10.236   51P1T                      Deasserted
1    02/28/2007  13:54:10.511   TRIP                       Deasserted
=>
```

Time Synchronization

- +/- 2 microseconds



- With or without Local time offset

Time Input

Available Sources	Time Quality
GPS (Selected)	**< 100 nsec**
Holdover	< 100 nsec
Local Time Offset:	-08:00
Daylight Saving Time Status:	Inactive
Daylight Saving Time Begins At:	2024-03-10T02:00:00-08:00

Time Output

Output	Format	Time Reference
TO1	IRIG-B004	UTC
TO2	IRIG-B004	UTC
TO3	IRIG-B004	UTC
TO4	IRIG-B004	UTC
TO5	IRIG-B004	UTC

Time protocol comparison

Time distribution methods	IRIG-B	NTP	PTP
Communication model	Master-slave Client-server	Ethernet	Ethernet
Synchronization accuracy	~100 ns to 1µs	~1 to 100 ms	~100 ns to 1µs
Compensation for latency	Yes, using cable length as user input	Yes	Yes
Update interval	Once per second, 100 pulses per second	User configurable, typically, minutes	User configurable, typically once per second
Ease of Implementation	Extra cable	Network-wide design	Network-wide design
Scalability	Hundreds of end devices	Thousands of end devices	Thousands of end devices
Aligned with IEC 61850	No	No	Yes

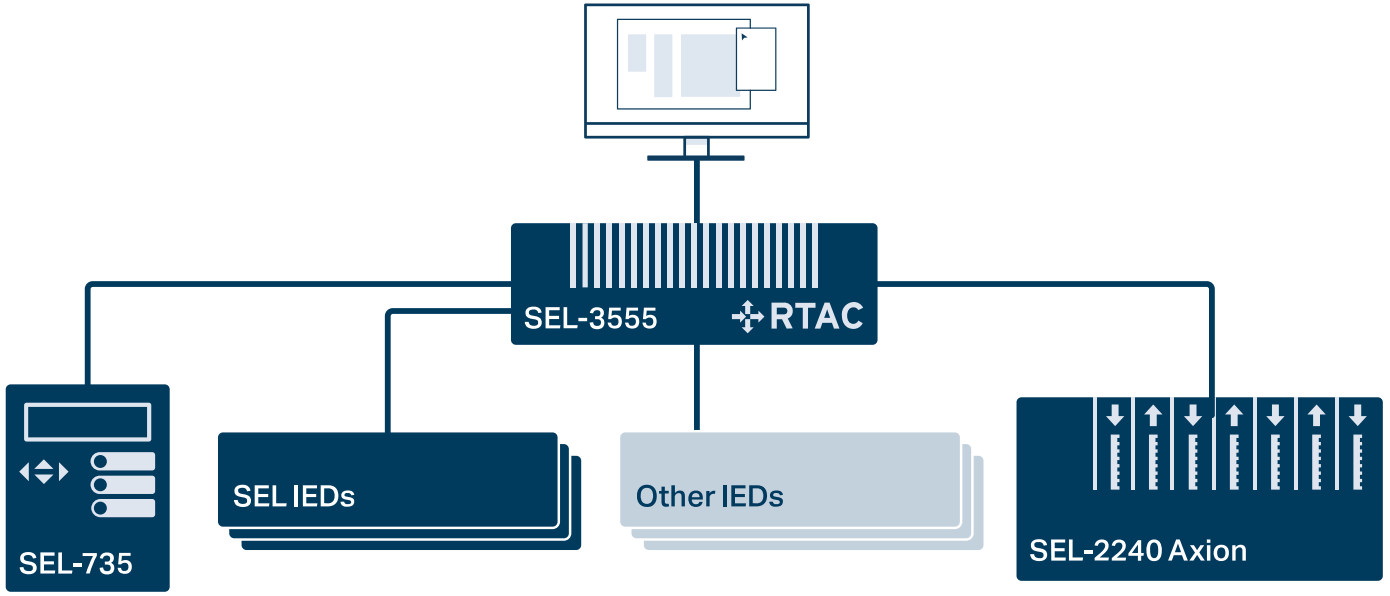
SEL-2731 Ethernet Switch

- PTP Transparent
- Configurable ports
- Redundant power supplies

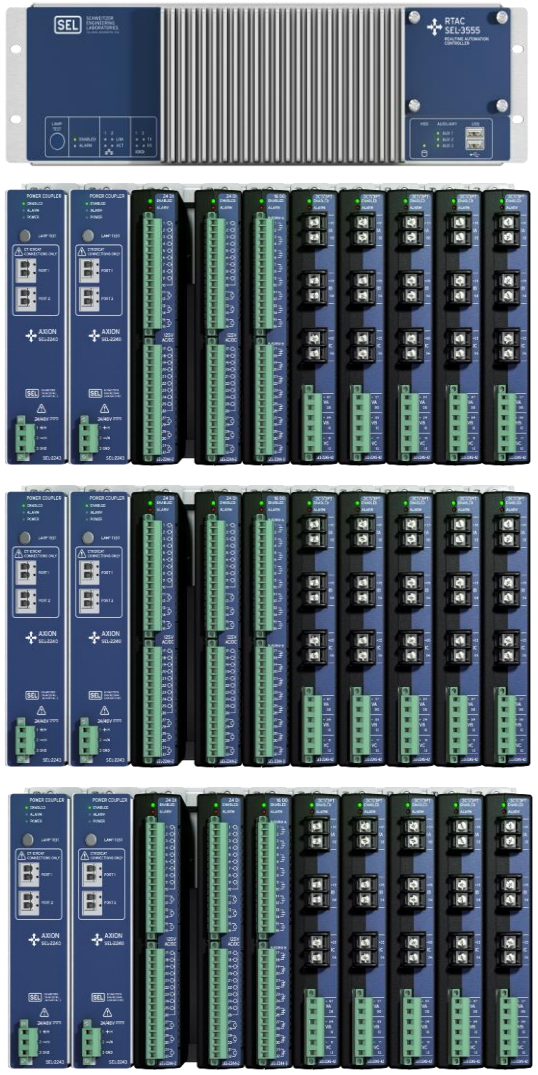
Comprehensive disturbance monitoring

SUBSTATION-WIDE VISIBILITY

- IED oscillography and SOE collection
- Distributed CT/PTs with multiple sensing options available
- Synchrophasor data generation, concentration, and recording – supports up to 100 phasor measurement units



Axion as a Disturbance Monitor



Fault Recording Requirements

Recording Settings - Fault Recording			
Recording Rate	24	24,8,4,2,1	Fault recording rate in kHz.
Recording Length Min.	1	REAL, 0.1 increments from 0.5 to 24	The minimum length of the fault oscillography capture, in seconds
Recording Length Max.	2	REAL, 0.1 increments from <Min> to 24	The maximum length of the fault oscillography capture, in seconds
Pre-Trigger Length	0.33	REAL, 0.01 increments from 0.05 to <Min-0.05>	The pre-trigger length of the fault oscillography capture, in seconds

- 16 samples per Cycle (<1khz)
- Pre-trigger of 2 cycles (.033 sec)
- Length of 60 cycles (1 sec)

Voltage Triggers

- Undervoltage .85 PU
- Over-Voltage 1.15
- > 2 Cycles (33ms)

Settings

Voltage Triggers

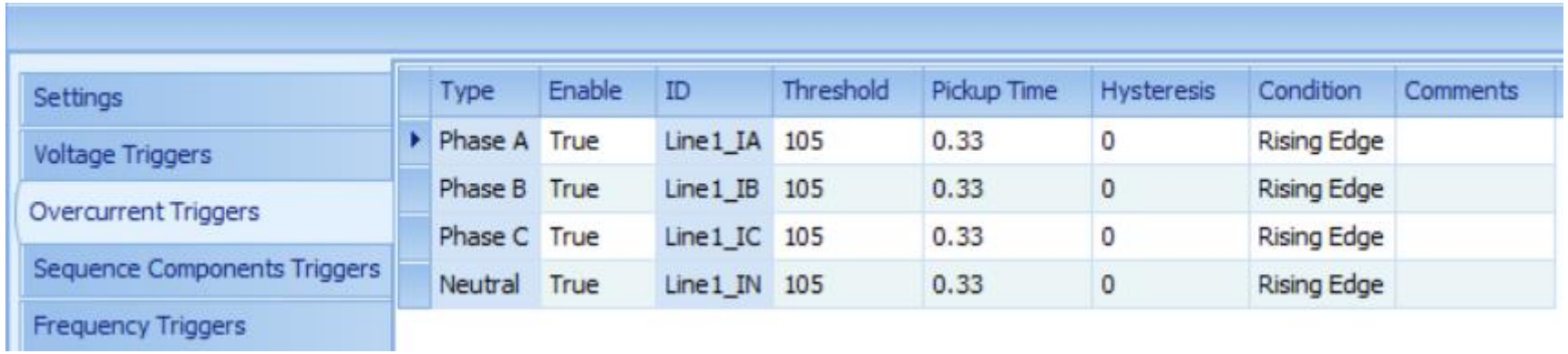
Overcurrent Triggers

Sequence Components Triggers

Frequency Triggers

Type	Enable	ID	Pickup Time	Enable Overvoltage	Overvoltage Threshold	Enable Undervoltage	Undervoltage Threshold
Phase A	True	Line1_VA	0.33	True	115	True	85
Phase B	True	Line1_VB	0.33	True	115	True	85
Phase C	True	Line1_VC	0.33	True	115	True	85
Neutral	True	Line1_VN	0.33	True	115	False	90

Overcurrent Triggers



Type	Enable	ID	Threshold	Pickup Time	Hysteresis	Condition	Comments
Phase A	True	Line1_IA	105	0.33	0	Rising Edge	
Phase B	True	Line1_IB	105	0.33	0	Rising Edge	
Phase C	True	Line1_IC	105	0.33	0	Rising Edge	
Neutral	True	Line1_IN	105	0.33	0	Rising Edge	

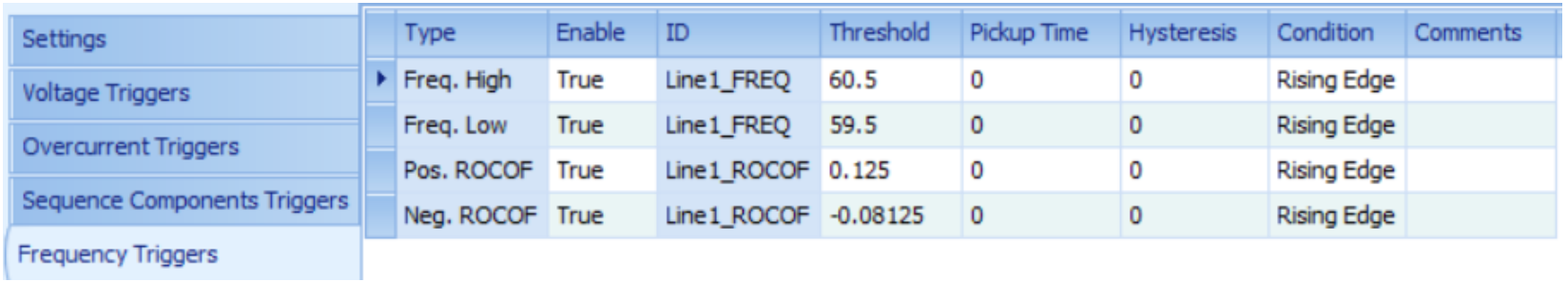
- 1.05 overcurrent PU – Neutral
- 1.05 overcurrent PU – Phase

Frequency Triggers

- Frequency above 60.5 Hz

- Frequency below 59.5 Hz

- ROCOF
  - -0.08125 Hz/s
  - 0.125 Hz/s



Type	Enable	ID	Threshold	Pickup Time	Hysteresis	Condition	Comments
Freq. High	True	Line1_FREQ	60.5	0	0	Rising Edge	
Freq. Low	True	Line1_FREQ	59.5	0	0	Rising Edge	
Pos. ROCOF	True	Line1_ROCOF	0.125	0	0	Rising Edge	
Neg. ROCOF	True	Line1_ROCOF	-0.08125	0	0	Rising Edge	

Continuous Recording

Recording Settings - Continuous Recording

Include High-Resolution Channels	True	False, True	Include high-resolution 3 kHz analog channels in the Continuous Recording records.
Data Retention Duration	30	1-365 (days)	The data retention period for Continuous Recording records.

- Configurable rolling local storage
- Selectable recording
- 3 kHz recording = 700MB per stream per day

ContinuousRecording

Settings
CRG EtherCAT Modules
PMUs
Digital Channels
Analog Channels
Custom Channels
Calculations
POU Pin Settings
Channels
Tags
Controller

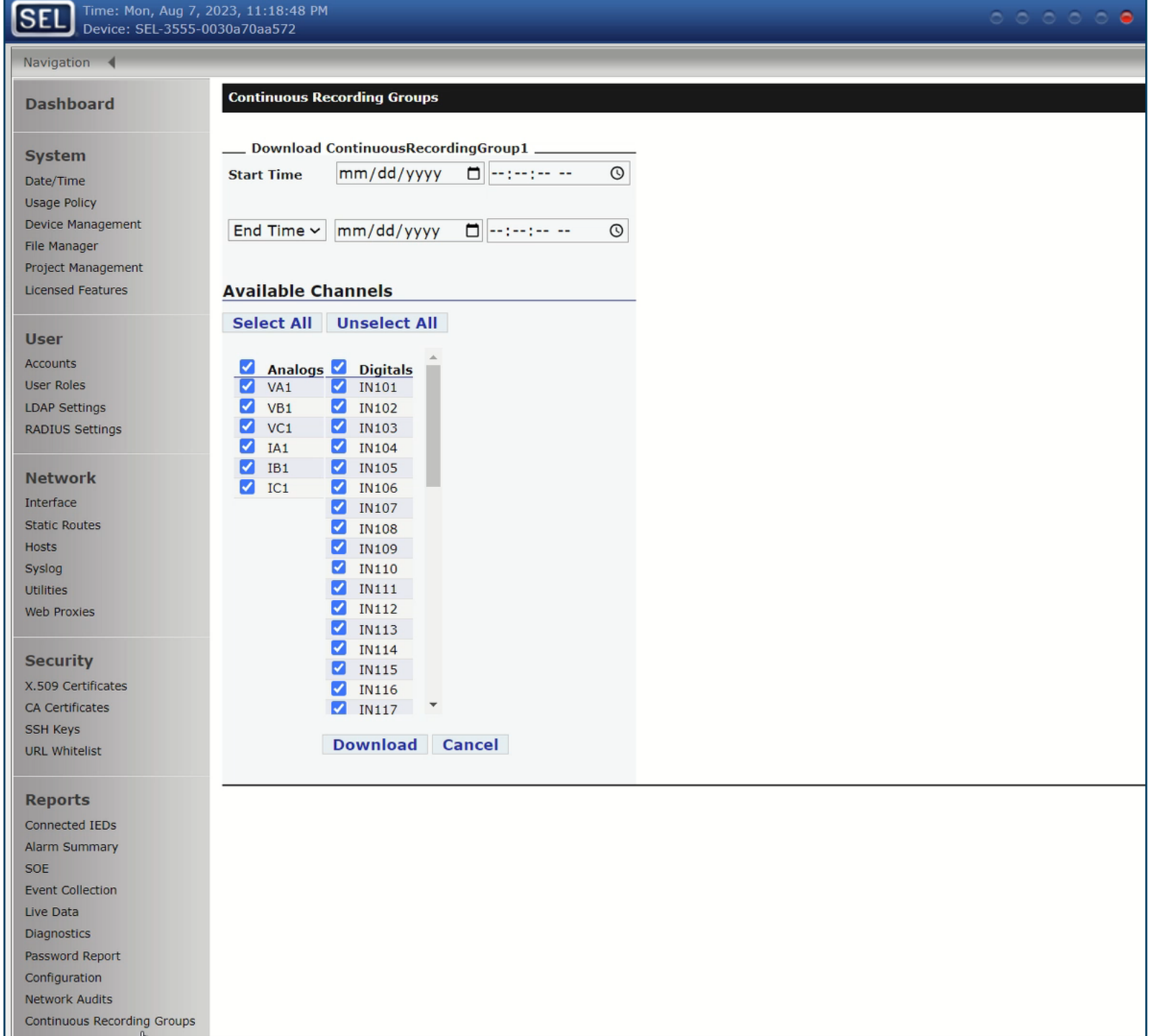
Drag a column header here to group by that column

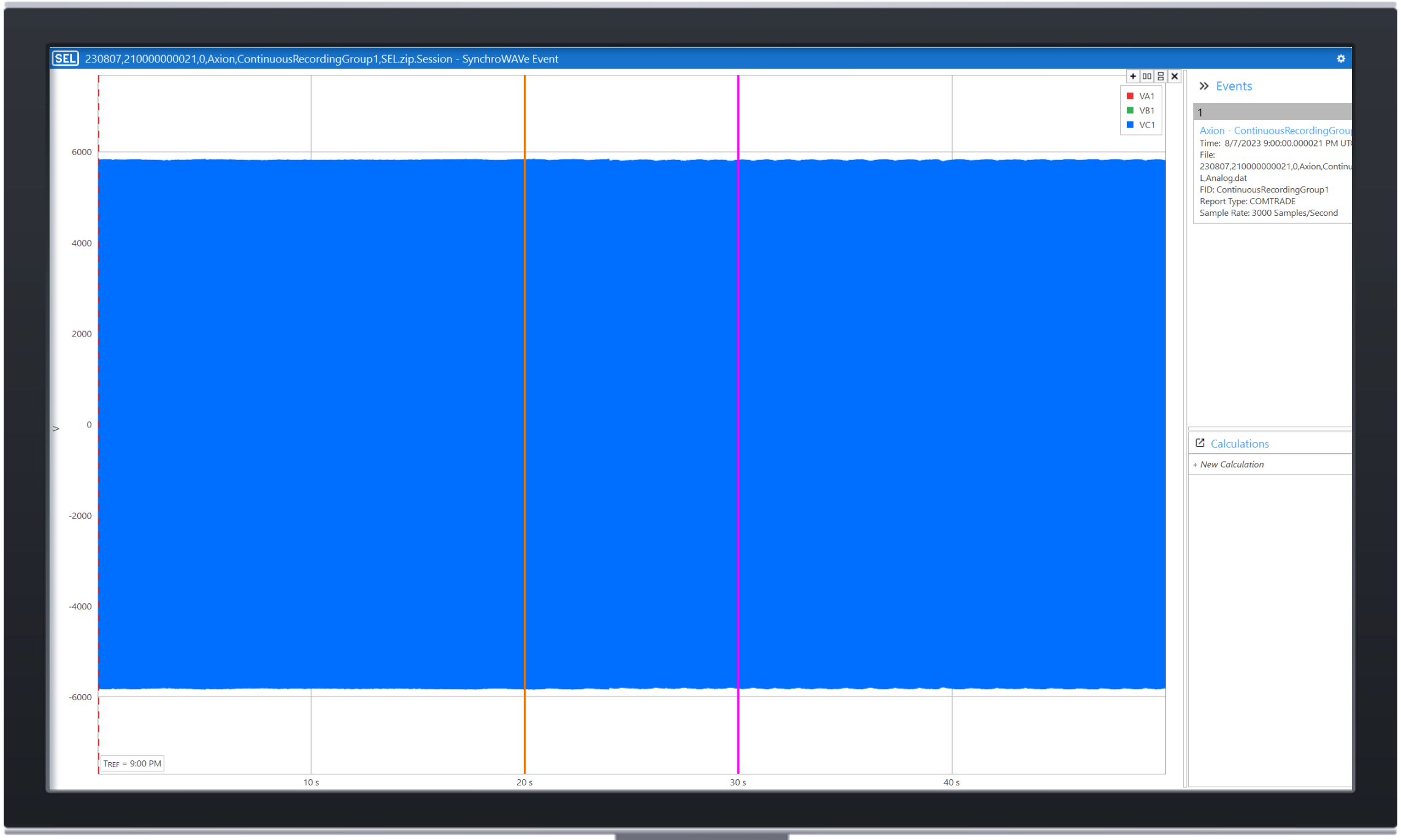
Enable	Device	Channel	Channel Name	Source Type
True	Bus1_PMU	FREQ	Bus1_FREQ_PM	PMU
True	Bus1_PMU	DF_DT	Bus1_ROCOF_PM	PMU
False	Bus1_PMU	TREA	TriggerReason1	PMU
False	Bus1_PMU	TQUAL	TimeQuality1	PMU
False	Bus1_PMU	ULKTIME	UnlockedTime1	PMU
True	Bus1_PMU	V2	Bus1_V2_PM	PMU
True	Bus1_PMU	V1	Bus1_V1_PM	PMU
True	Bus1_PMU	V0	Bus1_V0_PM	PMU
True	Bus1_PMU	VC	Bus1_VC_PM	PMU
True	Bus1_PMU	VB	Bus1_VB_PM	PMU
True	Bus1_PMU	VA	Bus1_VA_PM	PMU
True	Bus2_PMU	FREQ	Bus2_FREQ_PM	PMU
True	Bus2_PMU	DF_DT	Bus2_ROCOF_PM	PMU
False	Bus2_PMU	TREA	TriggerReason2	PMU
False	Bus2_PMU	TQUAL	TimeQuality2	PMU
False	Bus2_PMU	ULKTIME	UnlockedTime2	PMU
True	Bus2_PMU	V2	Bus2_V2_PM	PMU
True	Bus2_PMU	V1	Bus2_V1_PM	PMU
True	Bus2_PMU	V0	Bus2_V0_PM	PMU
True	Bus2_PMU	VC	Bus2_VC_PM	PMU

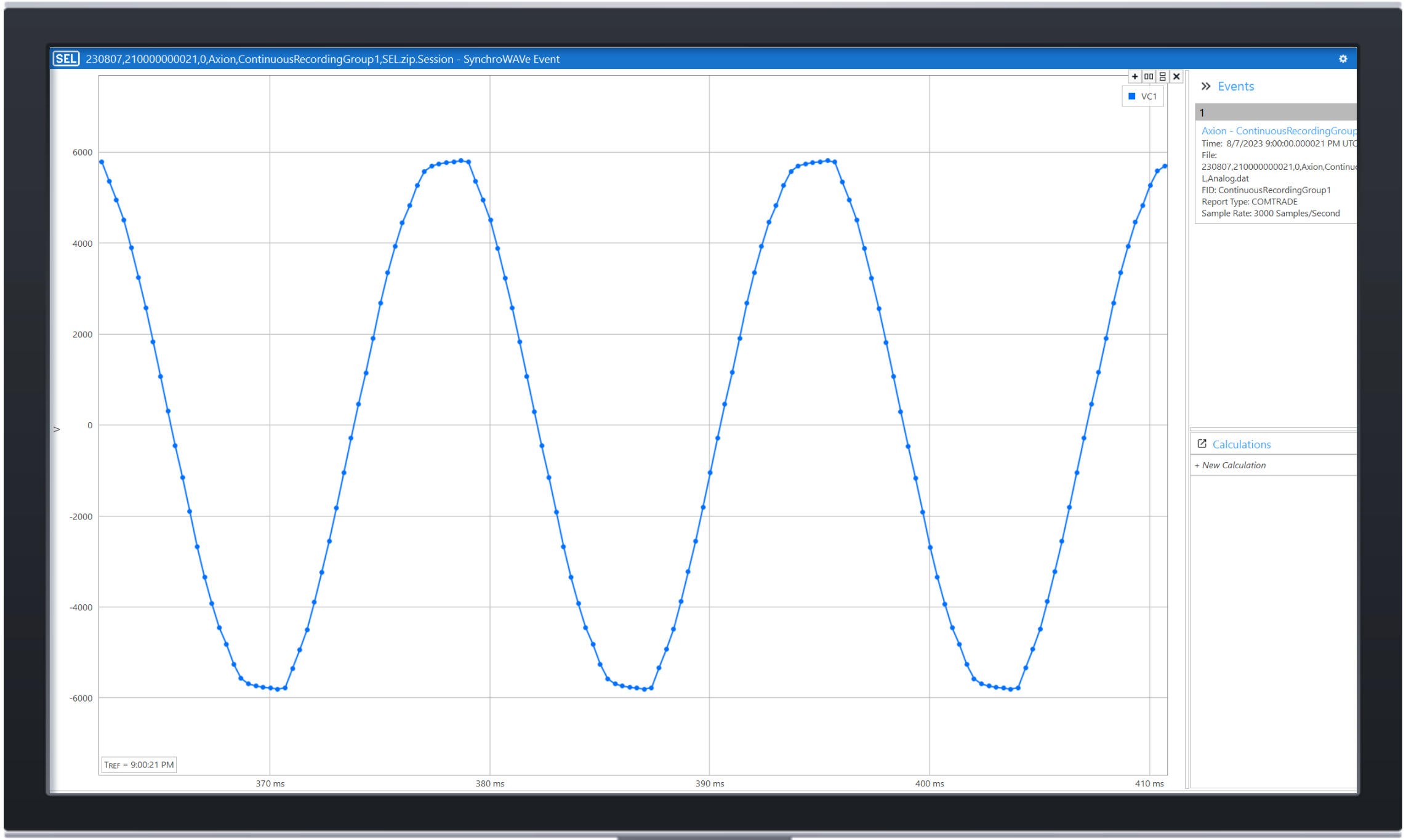
Continuous recorder file retrieval

- Custom COMTRADE record retrieval
  - RTAC webpage report
  - RTAC web API
- Inputs
  - Start time
  - End time or duration
  - Channels to add to the record

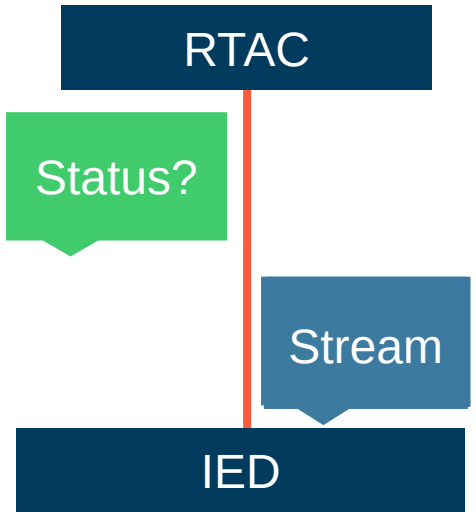
Continuous recording event download

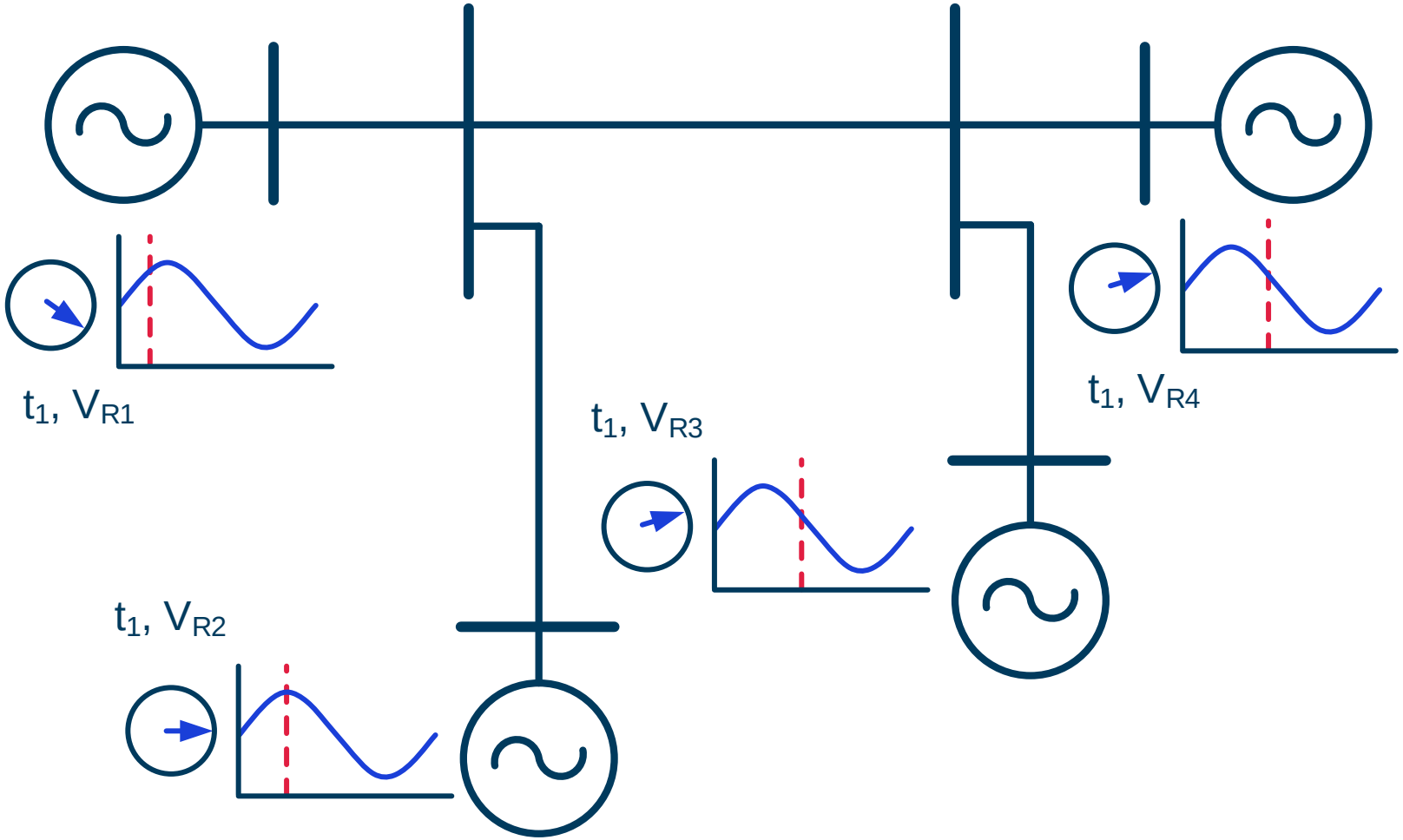



SEL 230807,210000000021,0,Axion,ContinuousRecordingGroup1,SEL.zip.Session - SynchroWAVe Event
VA1
VB1
VC1
6000
4000
2000
0
-2000
-4000
-6000
V
TREF = 9:00 PM
10 s
20 s
30 s
40 s
Events
1
Axion - ContinuousRecordingGrou
Time: 8/7/2023 9:00:00.000021 PM UT
File:
230807,210000000021,0,Axion,Continu
L,Analog.dat
FID: ContinuousRecordingGroup1
Report Type: COMTRADE
Sample Rate: 3000 Samples/Second
Calculations
+ New Calculation


SEL
230807,210000000021,0,Axion,ContinuousRecordingGroup1,SEL.zip.Session - SynchroWAVe Event
VC1
6000
4000
2000
0
-2000
-4000
-6000
V
TREF = 9:00:21 PM
370 ms
380 ms
390 ms
400 ms
410 ms
Events
1
Axion - ContinuousRecordingGroup
Time: 8/7/2023 9:00:00.000021 PM UTC
File:
230807,210000000021,0,Axion,Continu
L,Analog.dat
FID: ContinuousRecordingGroup1
Report Type: COMTRADE
Sample Rate: 3000 Samples/Second
Calculations
+ New Calculation

Synchrophasors provide snapshot of power system





C37.118 Streaming Requirements

BACKWARDS COMPATIBILITY

- RTAC
  - C37.118-2011
- Relays
  - C37.118-2005

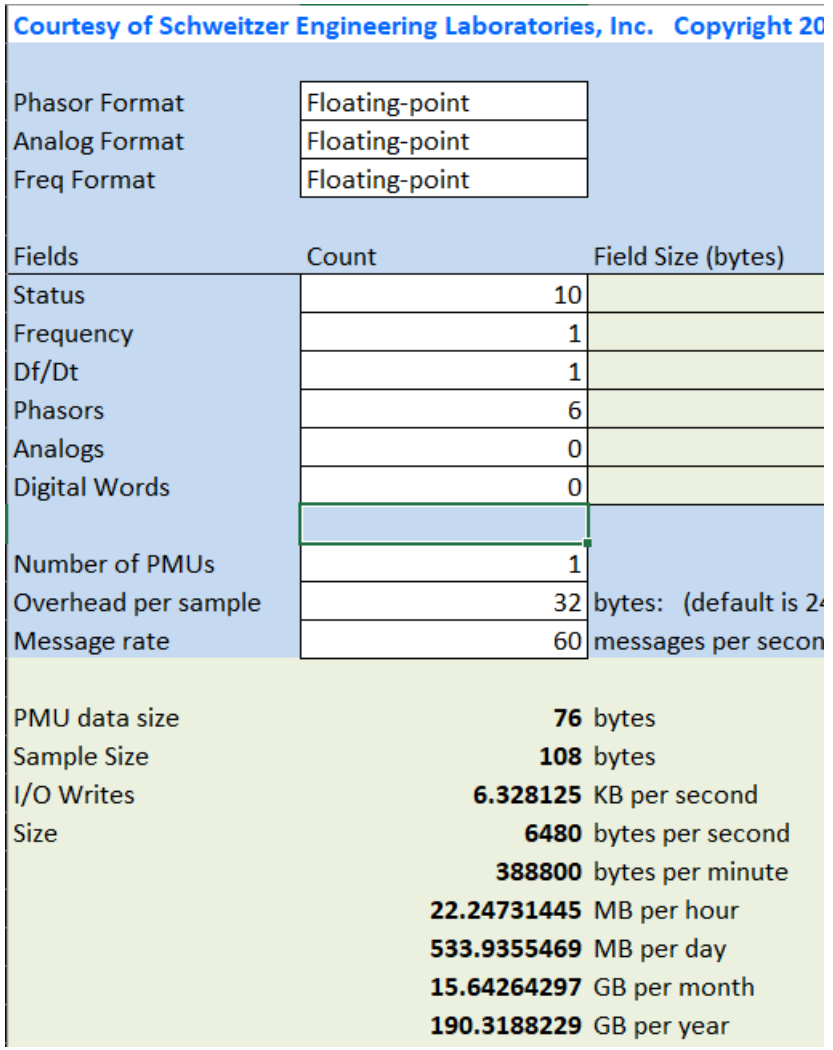
PMU SERVER

General		
PDC Id	100	1-65534
Data Rate	60	1,2,3,4,5,6,10,12,15,20,30,60,120,240 (hertz)
Waiting Period	200	4-1000 (milliseconds)

- Selectable data rate
- Supports up to 100 streams

Local Storage for PMU Data

- RTAC Selectable SSD drive
  - 32GB – 2TB
- 16 GB per month per device



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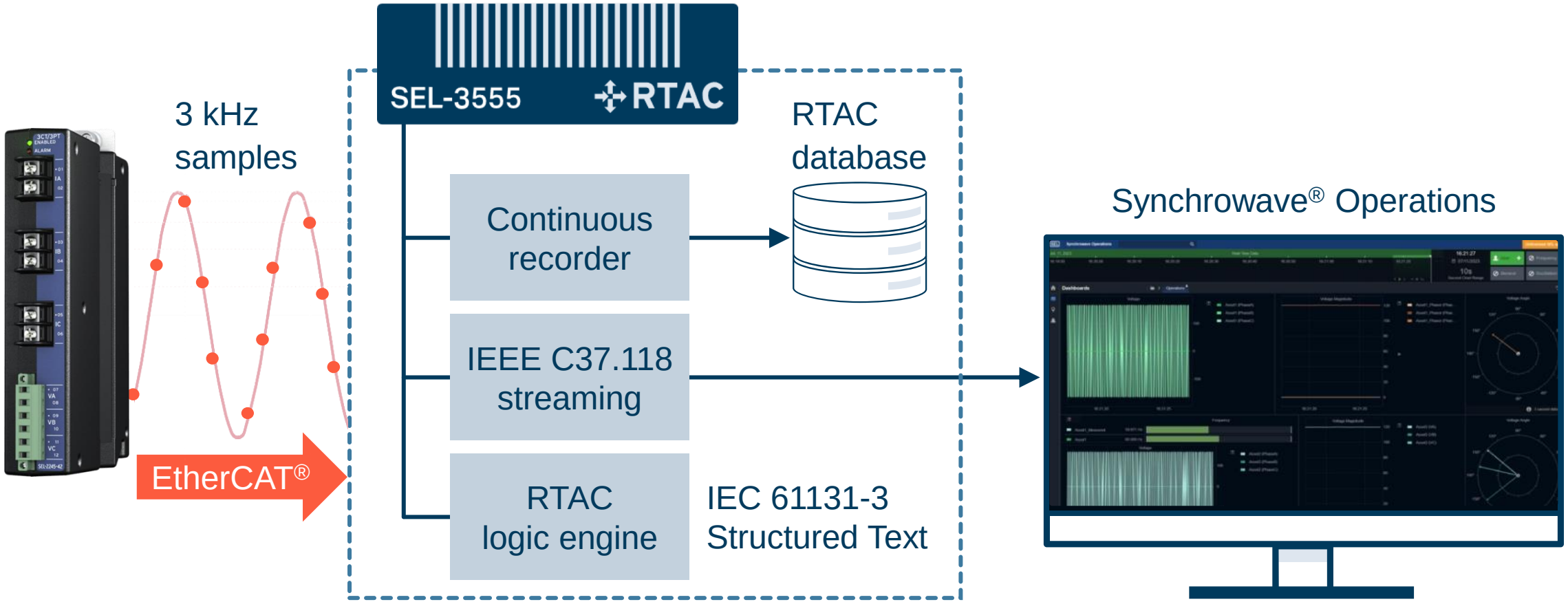
Phasor Format	Floating-point	
Analog Format	Floating-point	
Freq Format	Floating-point	
Fields	**Count**	**Field Size (bytes)**
Status	10	
Frequency	1	
Df/Dt	1	
Phasors	6	
Analogs	0	
Digital Words	0	
Number of PMUs	1	
Overhead per sample	32	bytes: (default is 2
Message rate	60	messages per secon

PMU data size	**76**	bytes
Sample Size	**108**	bytes
I/O Writes	**6.328125**	KB per second
Size	**6480**	bytes per second
	388800	bytes per minute
	22.24731445	MB per hour
	533.9355469	MB per day
	15.64264297	GB per month
	190.3188229	GB per year

Axion provides 3 kHz data for every application



Thank you

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