

A vertical image on the left side of the slide shows a close-up of a wind turbine's blades and nacelle against a bright sun in a blue sky with some clouds. The sun is positioned behind the turbine, creating a strong lens flare effect.

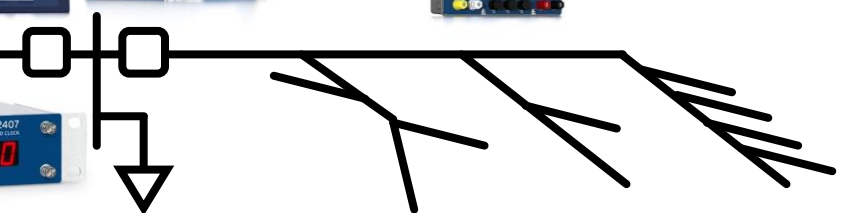
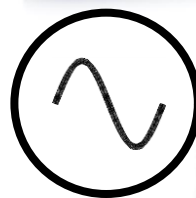
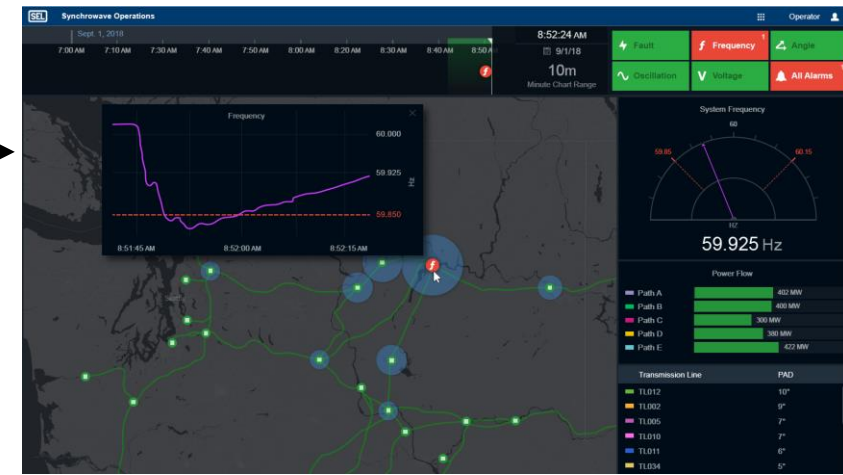
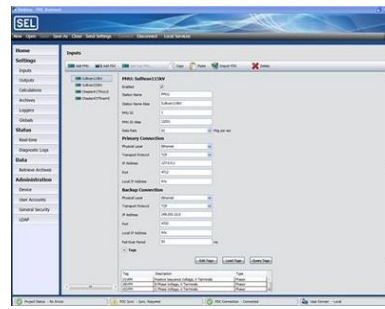
Schweitzer Engineering Laboratories

Precisely time-stamped
Streaming
Time-series
Systems



April 14, 2021

Dr. Greg Zweigle, Jared Bestebreur



Most SEL Devices Include PMU Capability

Line Protection

- SEL-311C
- SEL-421
- SEL-411L

Distribution Protection

- SEL-351
- SEL-451

Reclosers

- SEL-651
- SEL-351RS

Generator Protection

- SEL-700G
- SEL-400G

Transformer Protection

- SEL-487E
- SEL-787

Capacitor Protection

- SEL-487V

Meters

- SEL-734
- SEL-735

Industrial/Utility Feeder

- SEL-751

Voltage Regulators

- SEL-2431

IEEE C37.118-2014 Compliant PMUs

SEL-735
Revenue Meter



SEL-400G
Generation Protection



SEL-2240 Axion
Automation Controller



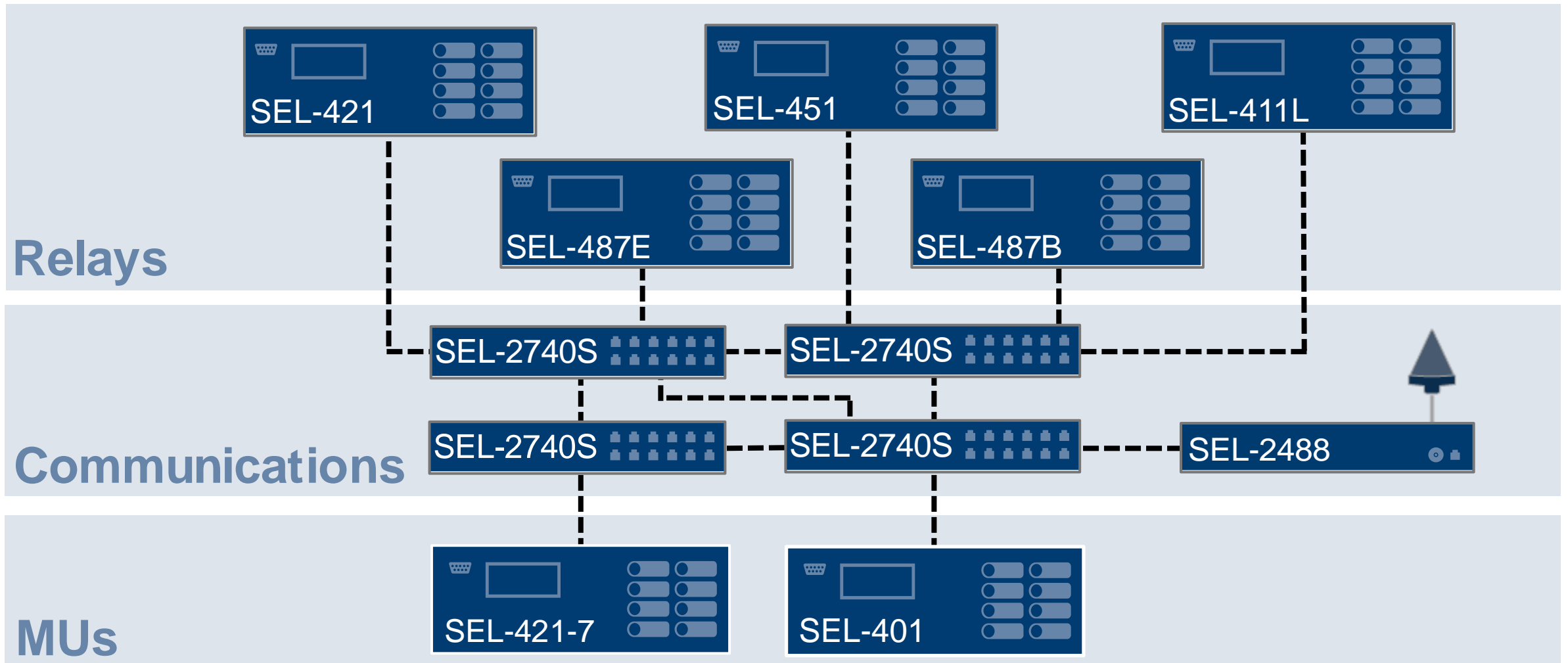
Digital Secondary Systems

IEC 61850-9-2 and SEL TiDL

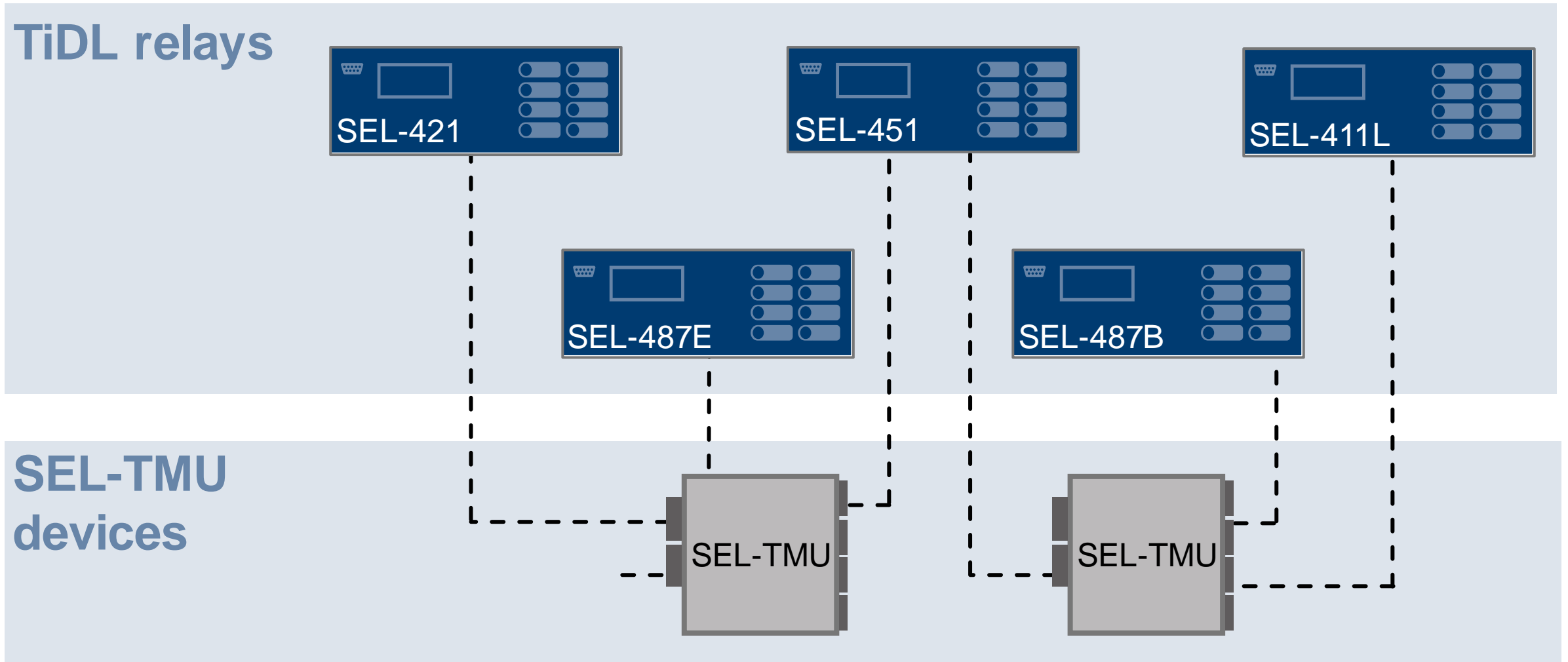
Streaming, time-stamped power system measurements

- Easier substation construction
- Move potential hazards out of the control house
- Solve unique remote data acquisition problems
- Speed up installation time

Interoperable, IEC 61850-9-2, Solutions



And.... TiDL = A Simple Point-to-Point Solution

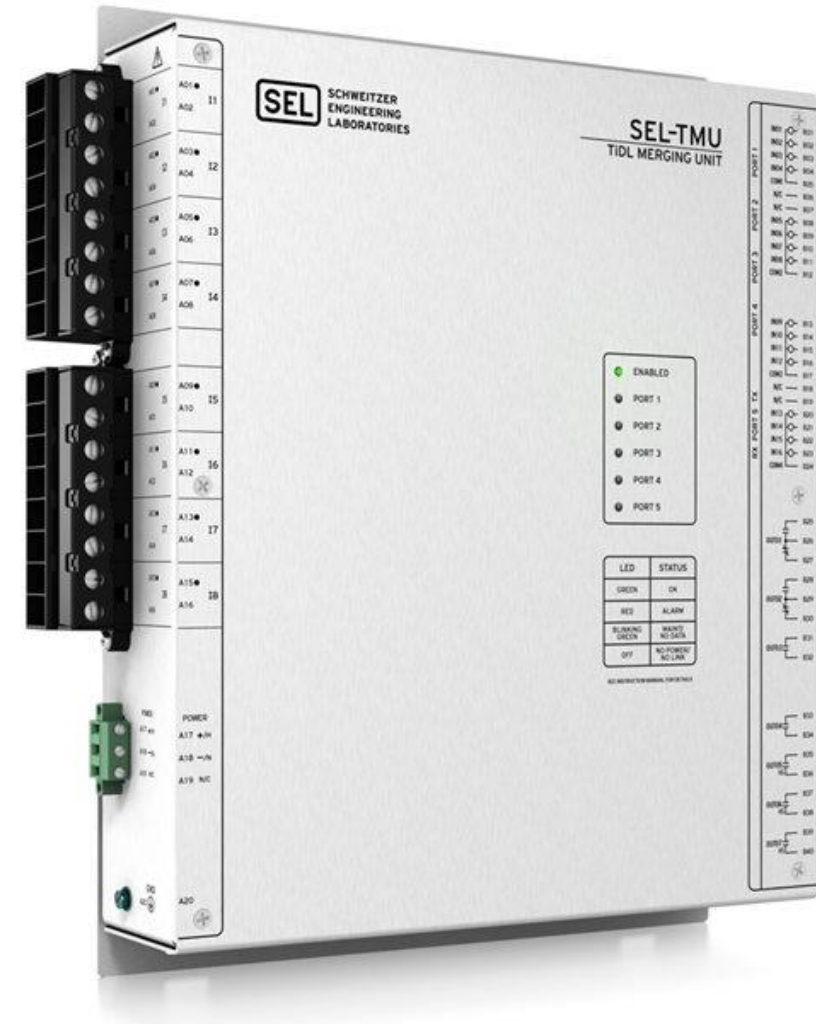


TiDL Simplicity

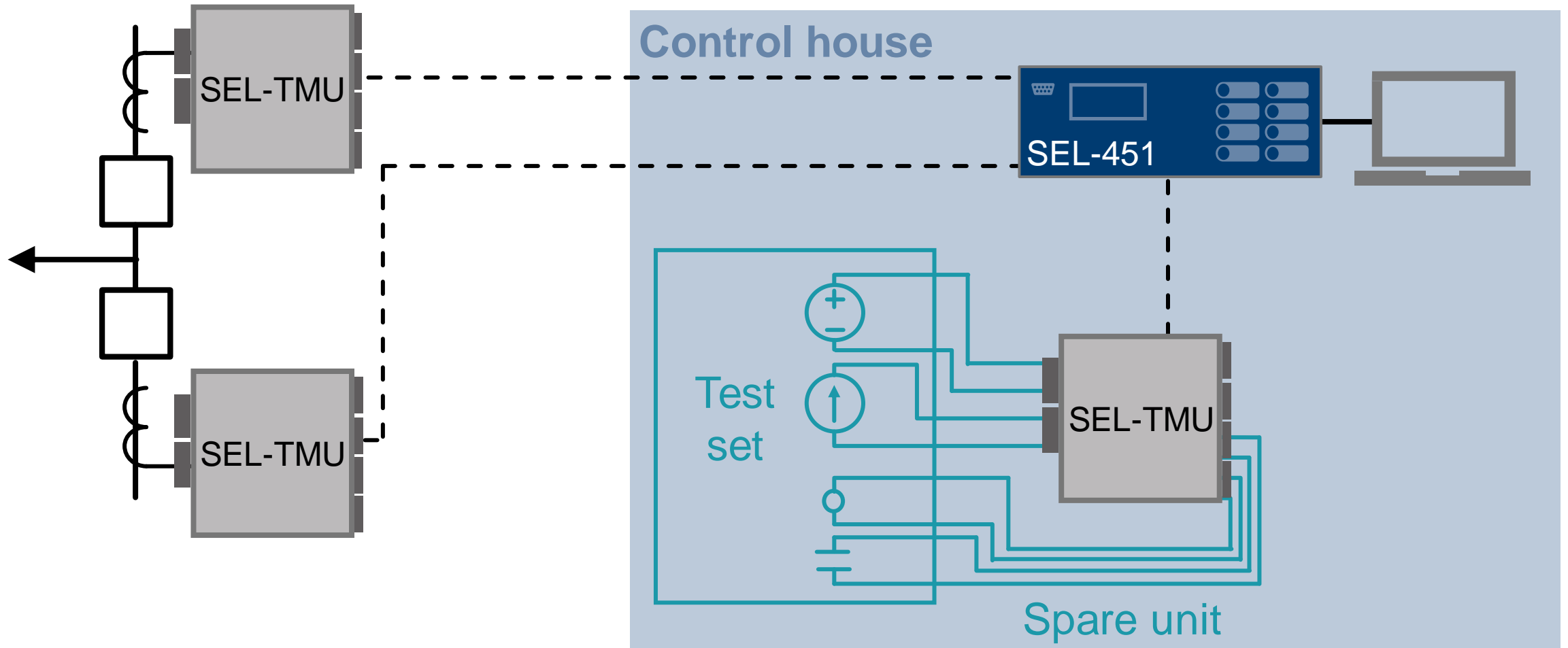
- Point-to-point means:
 - No network engineering
 - Point-to-point fiber instead of copper
 - Minimal latency
- Time-synchronized but no separate time source needed
- Better cybersecurity: connections are strictly between devices, which minimizes the attack surface

Merging Unit is Extremely Simple

- No microprocessor
- Easy to setup and configure
- Very reliable in harsh environmental conditions
- No settings
- Low cost



Minimize Outdoor Testing with TiDL





Main Street Substation

Feeder 1 - 451

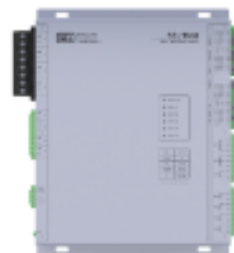
Feeder1 Bk1 TMU ...

Feeder1 Bk2 TMU

Device Overview

Part Number

I/O Interface



Feeder1 Bk1 TMU

SEL-TMU

Description: Give this device a description

ID:

Serial Number: Fill in the serial number

Firmware Version: Enter this device's firmware version

FID String: Enter this device's FID string

TiDL Associations

I/O	Port 1 Feeder 1 - 451.Port 6A	Port 2 Unmapped
Current Input		
Feeder1 Breaker1 PhaseA (I1)	IAW	
Feeder1 Breaker1 PhaseB (I2)	IBW	
Feeder1 Breaker1 PhaseC (I3)	ICW	
I4 (I4)		
Voltage Input		
Feeder1 Voltage PhaseA (V1)	VAY	
Feeder1 Voltage PhaseB (V2)	VBY	
Feeder1 Voltage PhaseC (V3)	VCY	
V4 (V4)		

Easy-to-use
System
Configuration
Software

Synchrowave Connects ALL Utility Data

Time-domain values

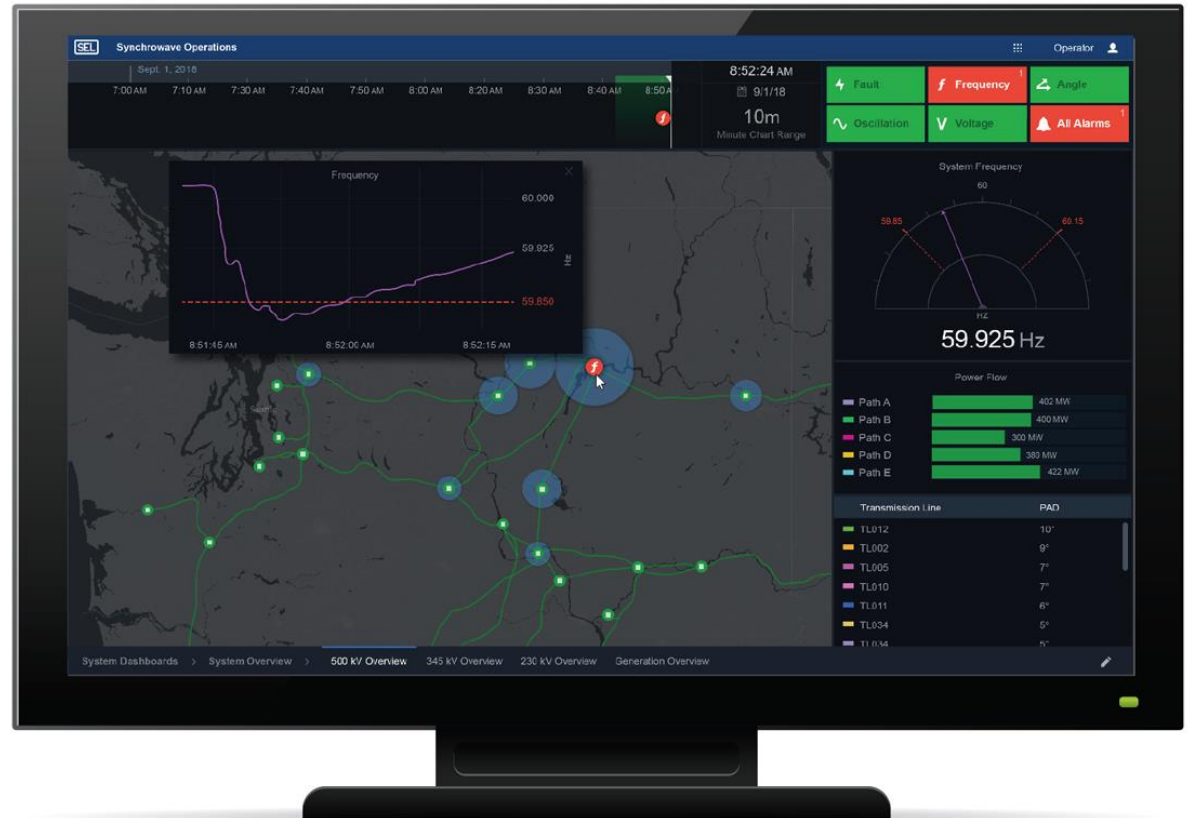
Weather / fire

Event reports

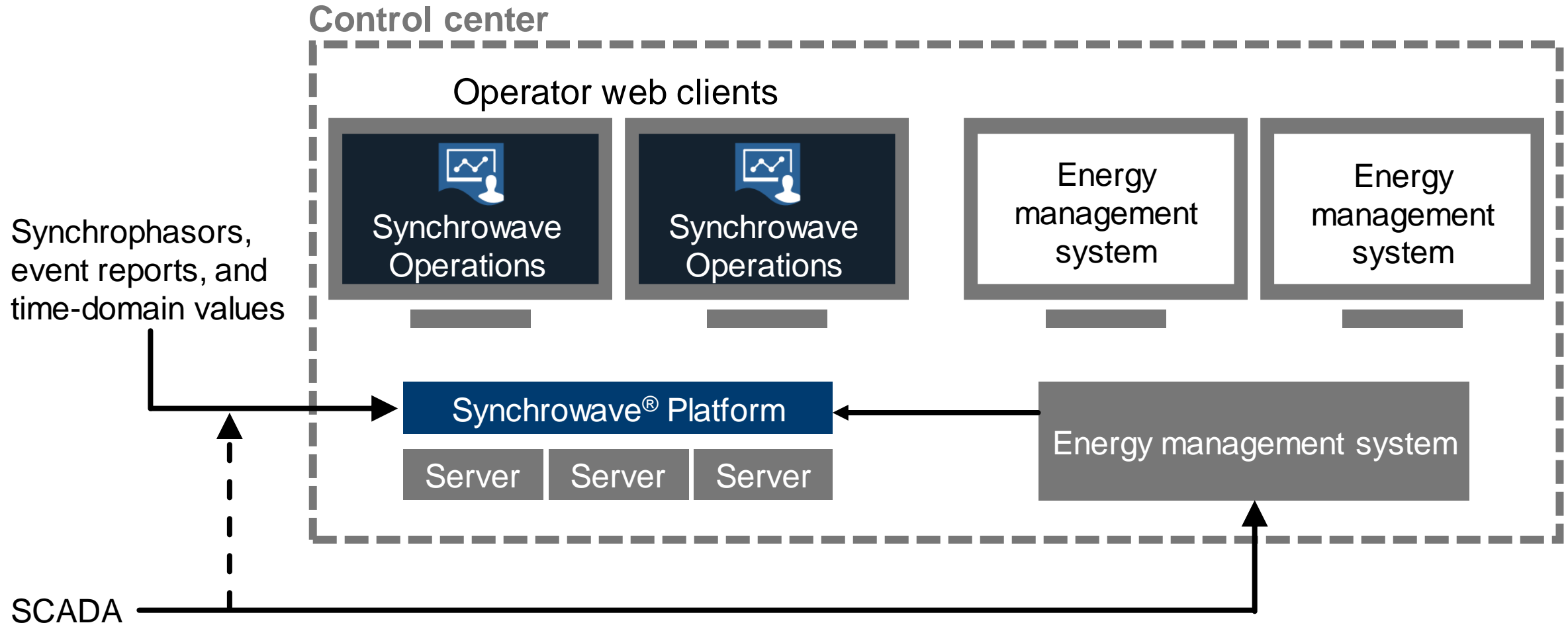
Fault indicators

EMS / SCADA (db)

Synchrophasors



Synchrowave Compliments SCADA / EMS



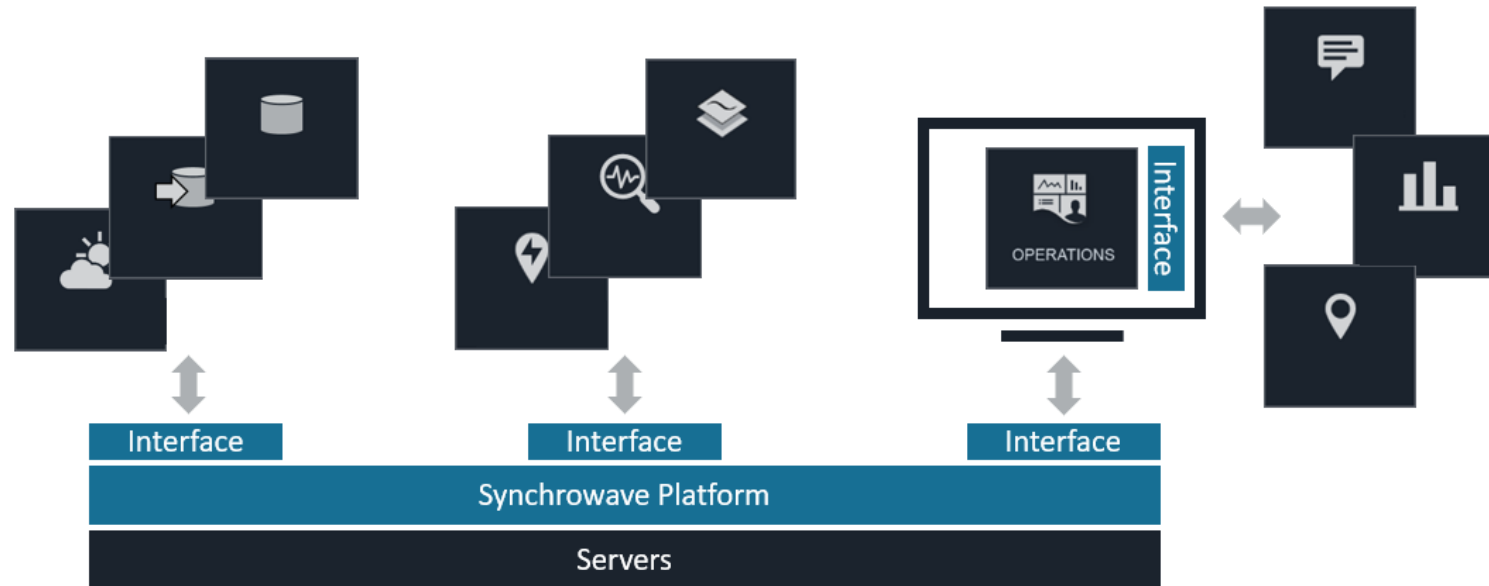
DOE FOA 1861

Big Data Analysis of Synchrophasor Data

Schweitzer Engineering Laboratories

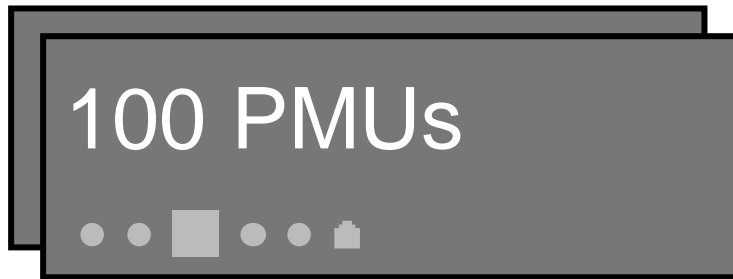
Oregon State University

Machine Learning Guided Operational Intelligence from Synchrophasors



1

We are overwhelmed with data



PMUs send
30 messages
per second

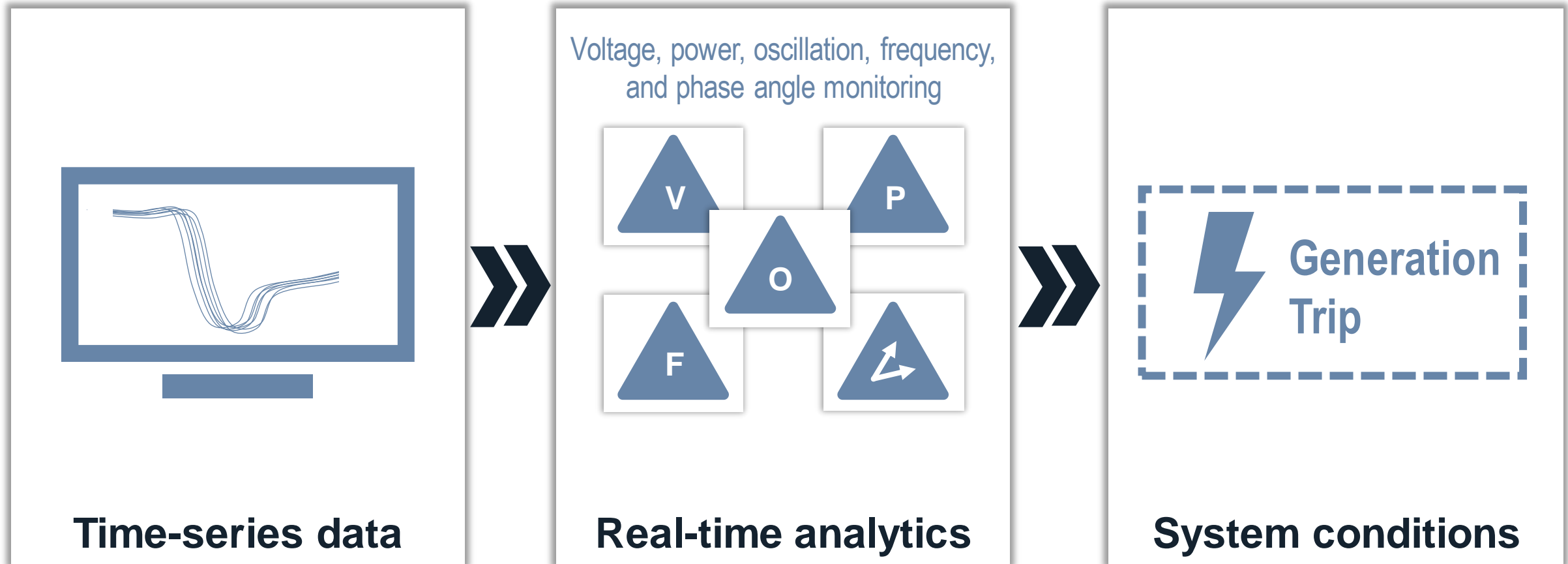


2 million data
points per hour

48 million data
points per day

17 billion data
points per year

Automatically detect events with Synchrowave Operations

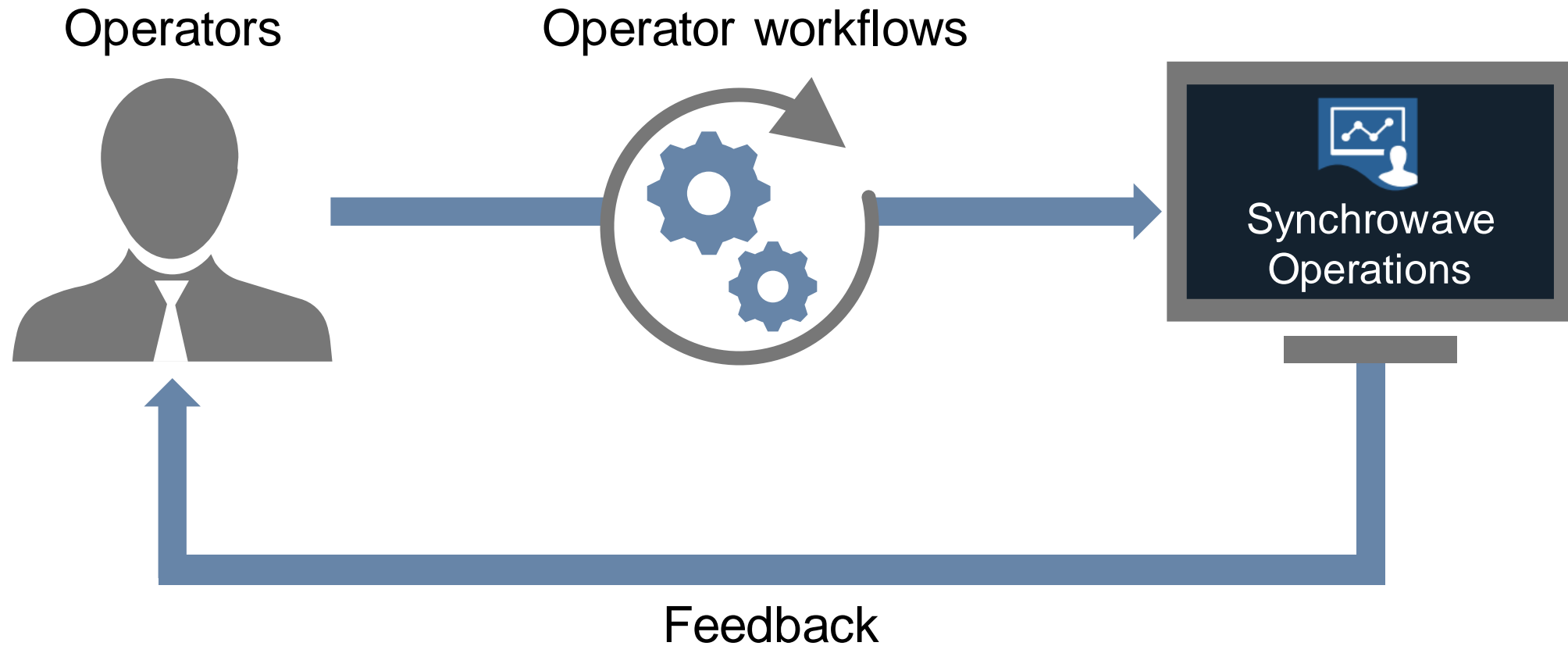


2

Our operators don't see the value of synchrophasors



Synchrowave starts with the operator



Synchrowave is for engineering too

Engineering supporting operations

Fast condition
assessments

Fault and
event location

Offline engineering analysis and design

Asset investigation

Root-cause events

Predictive and
anticipatory actions

Performance and
parameter validation

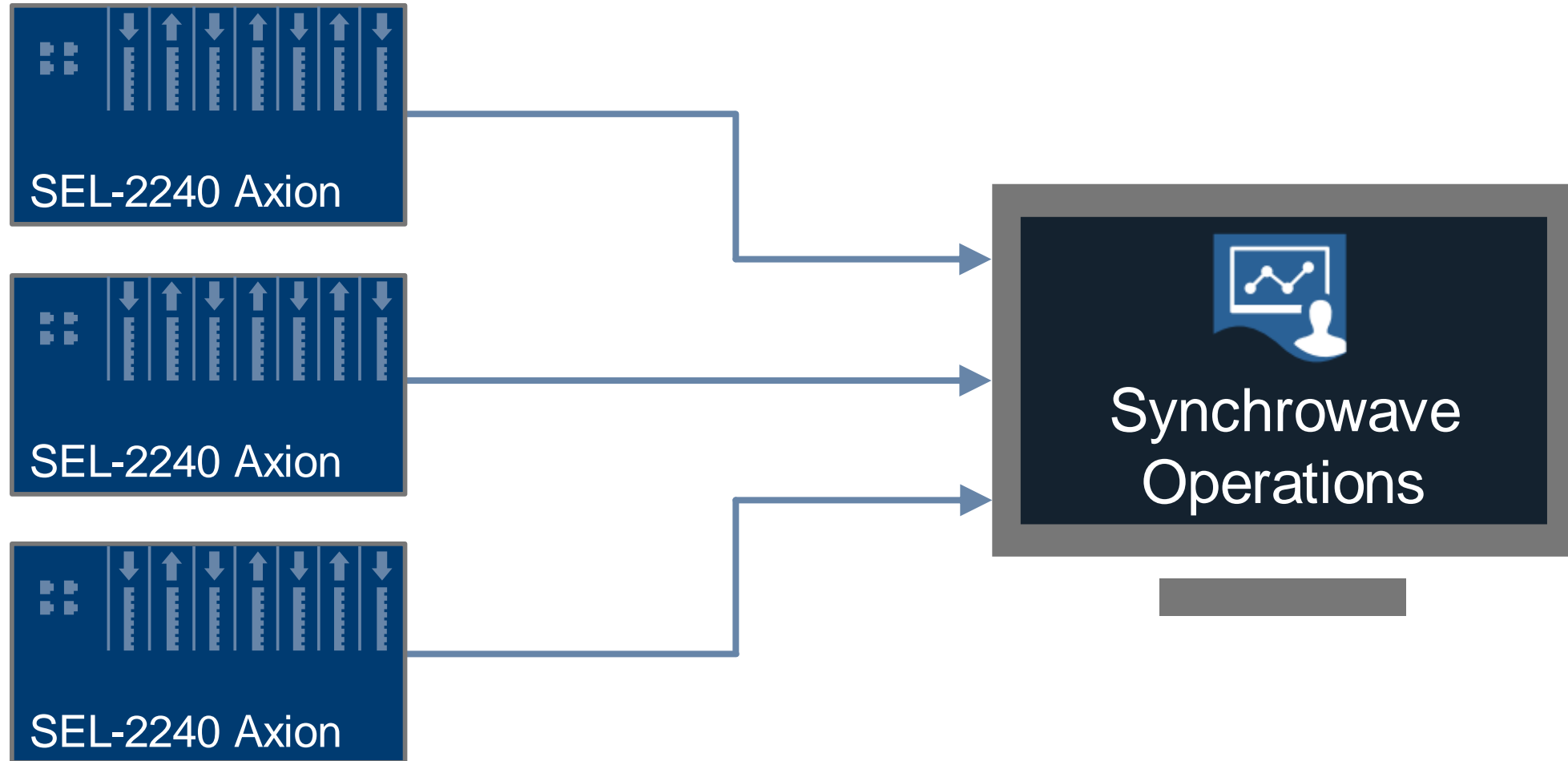
System protection
wide-area analysis

3

We are researching streaming time-domain point-on-wave data



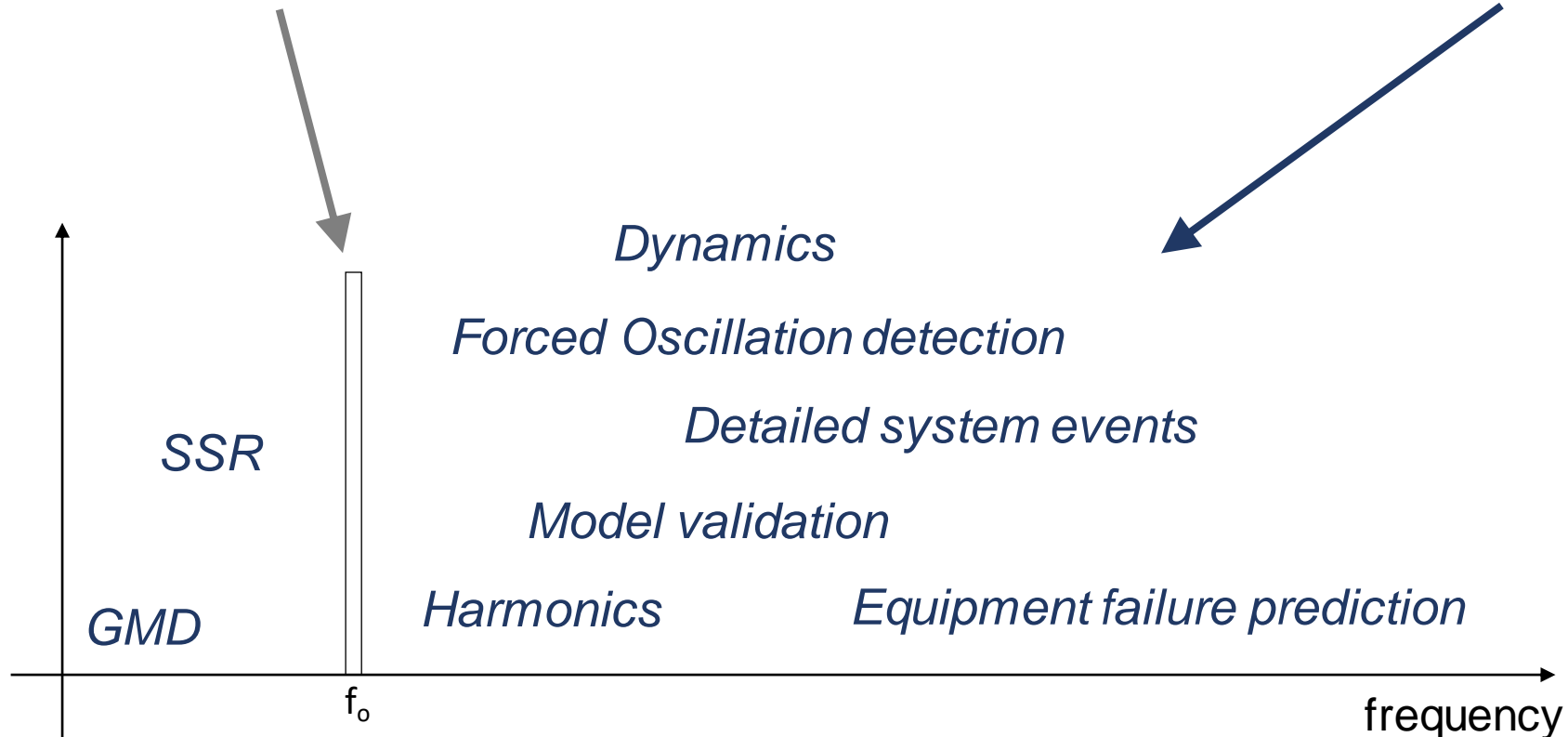
3,000 samples-per-second streaming with SEL Axion[®]



Time-Domain Gives New Insight

Both SCADA and synchrophasors rely on the same quasi-steady-state, lossy, phasor approximation.

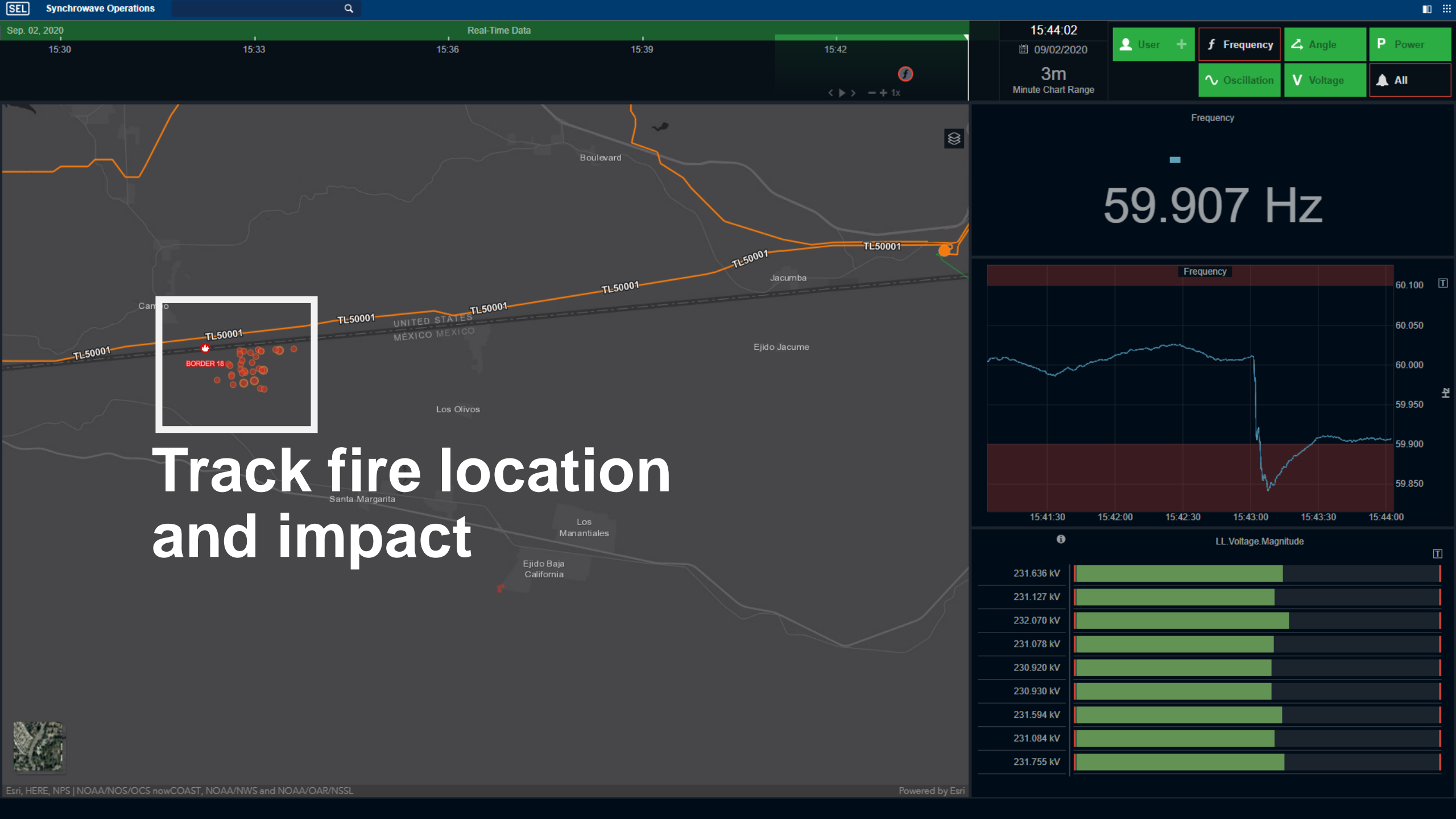
Wide-area time-domain makes all information available. This enables new benefits and innovations.

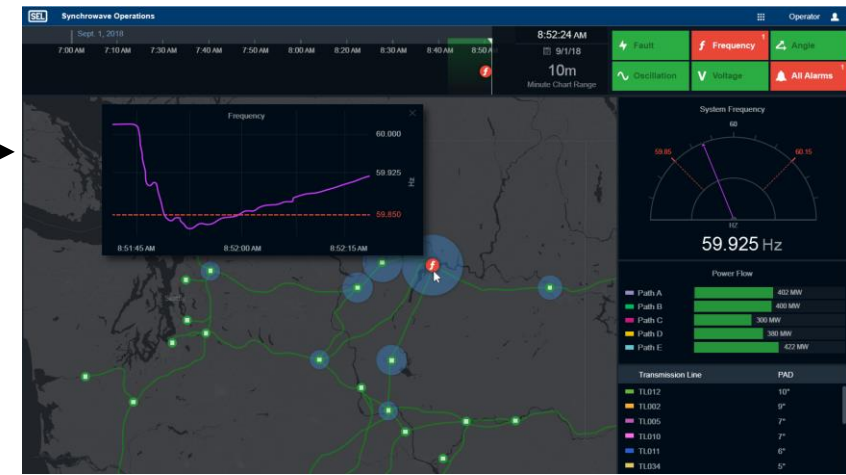
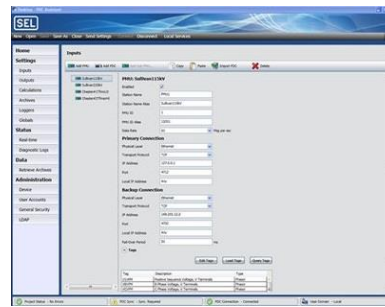


4

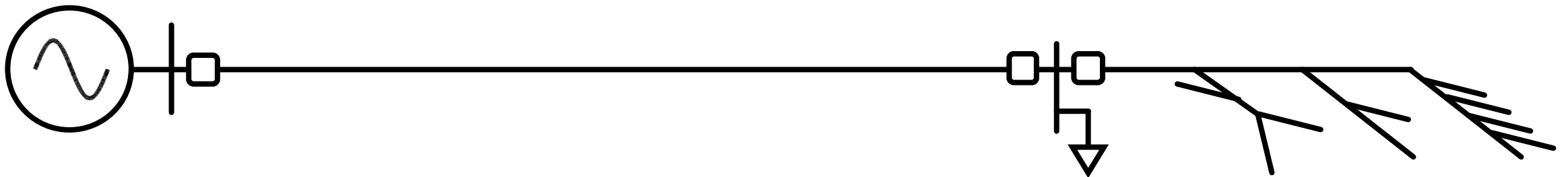
We need to improve fire visibility







Streaming Time-Series Data System



Streaming Time-Series Data @ Transmission



Clocks and Timing System

Generator Protection + PMU
Line Protection + PMU



Streaming Time-Series Data @ Distribution

Hardware and software Phasor Data Concentrators

Distribution Protection + PMU

Voltage Regulators + PMU

Reclosers + PMU



Streaming Time-Series Data Everywhere!

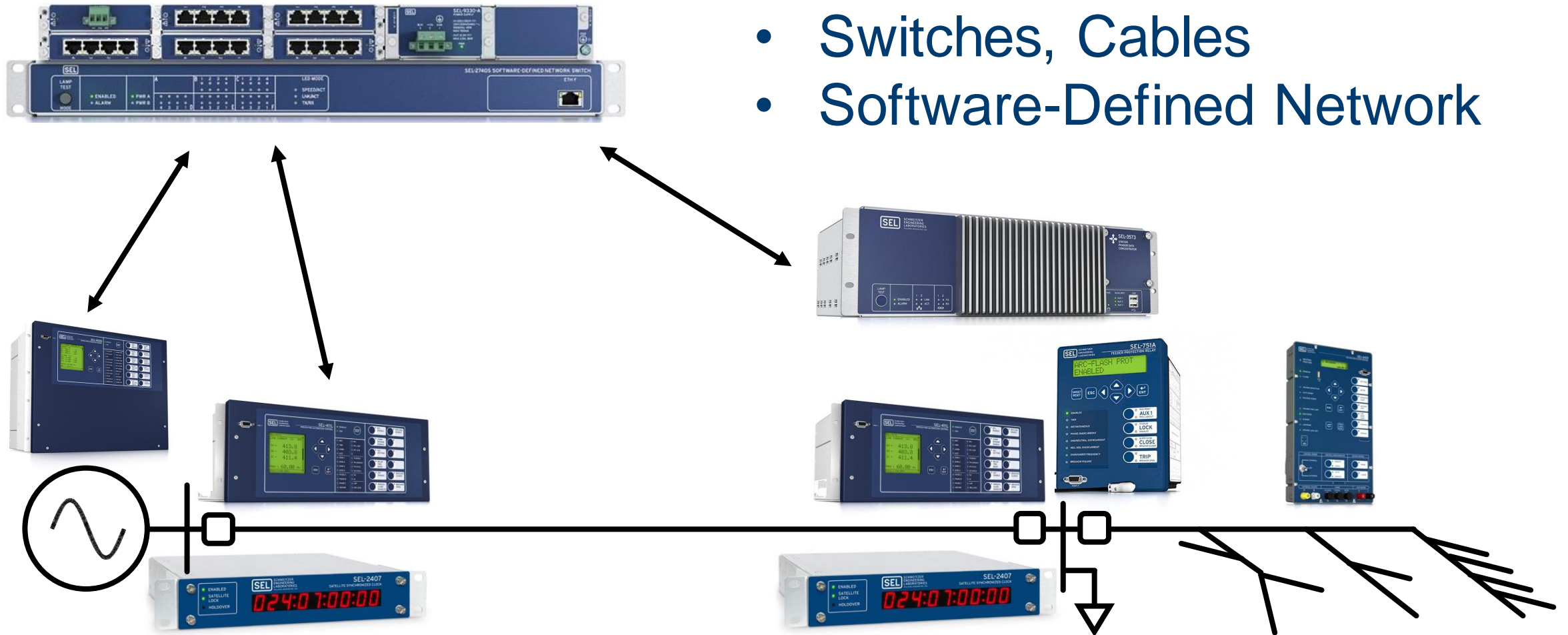
Generation, Transmission, Distribution, and Industrial
Everything ships with Synchrophasors



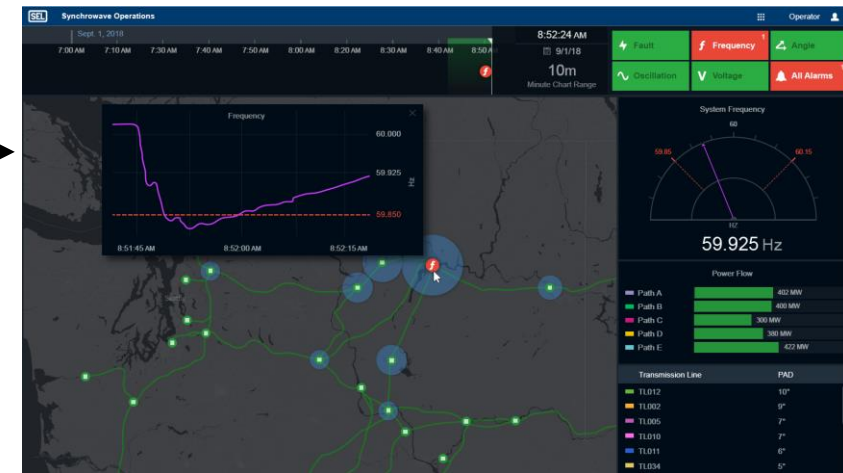
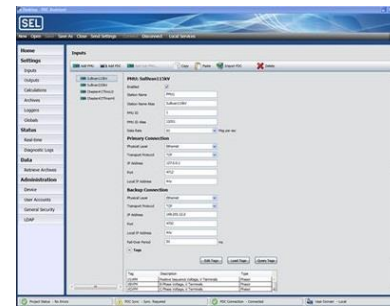
Streaming Time-Series Data @ Comms

Communication Equipment

- Switches, Cables
- Software-Defined Network



System PDC



Operations and Analytics Software

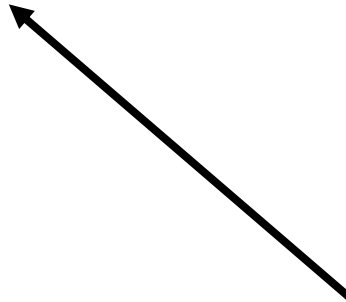


Fast Time-Domain Values (FTDV) Streaming



- 1Gbps port
- 1Mpps
 - 6 currents
 - 3 voltages

UDP multicast/broadcast
25,000 packets per second
Precisely time-stamped



PowerMAX Control Systems & Time-Series

Power Management System (PMS)

Heavy Industries

Blackout Prevention

Process Survivability

Remedial Action Scheme (RAS)

Utilities

Blackout Prevention

Wide-Area Schemes

Efficiency

Security

Microgrid

Commercial

Resiliency

Economics

Renewables

Speed of Operation

Adaptive Protection

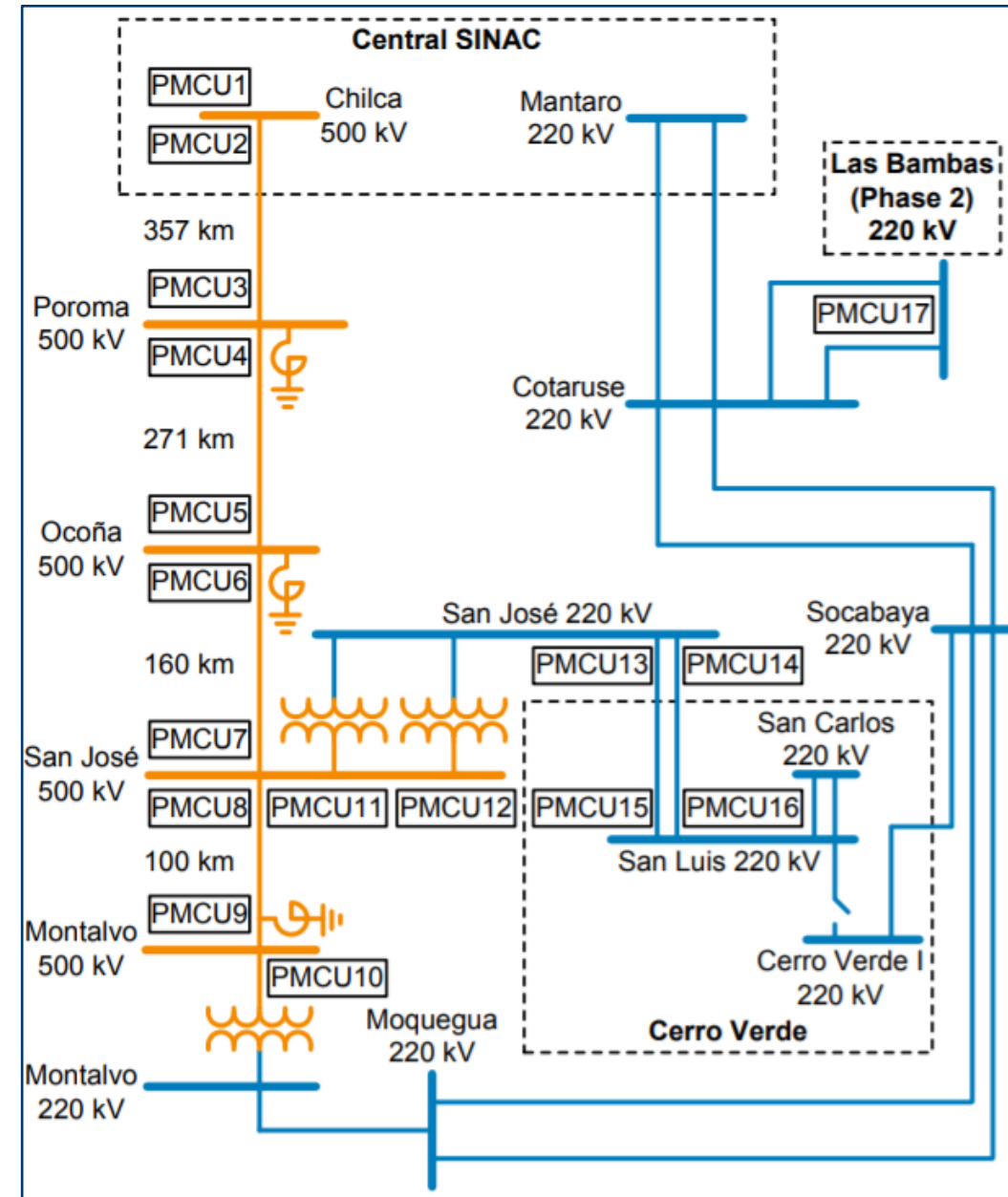
Remedial Action Scheme Based on Synchrophasor Measurements and System Angle Difference for Peru's 500 kV Grid

Yofre Jacome
COES SINAC

Luis Figueroa
Sociedad Minera Cerro Verde

Eduardo Palma, Fernando Calero, Pedro Loza, Alejandro Carbajal, and Ashish Upreti
Schweitzer Engineering Laboratories, Inc.

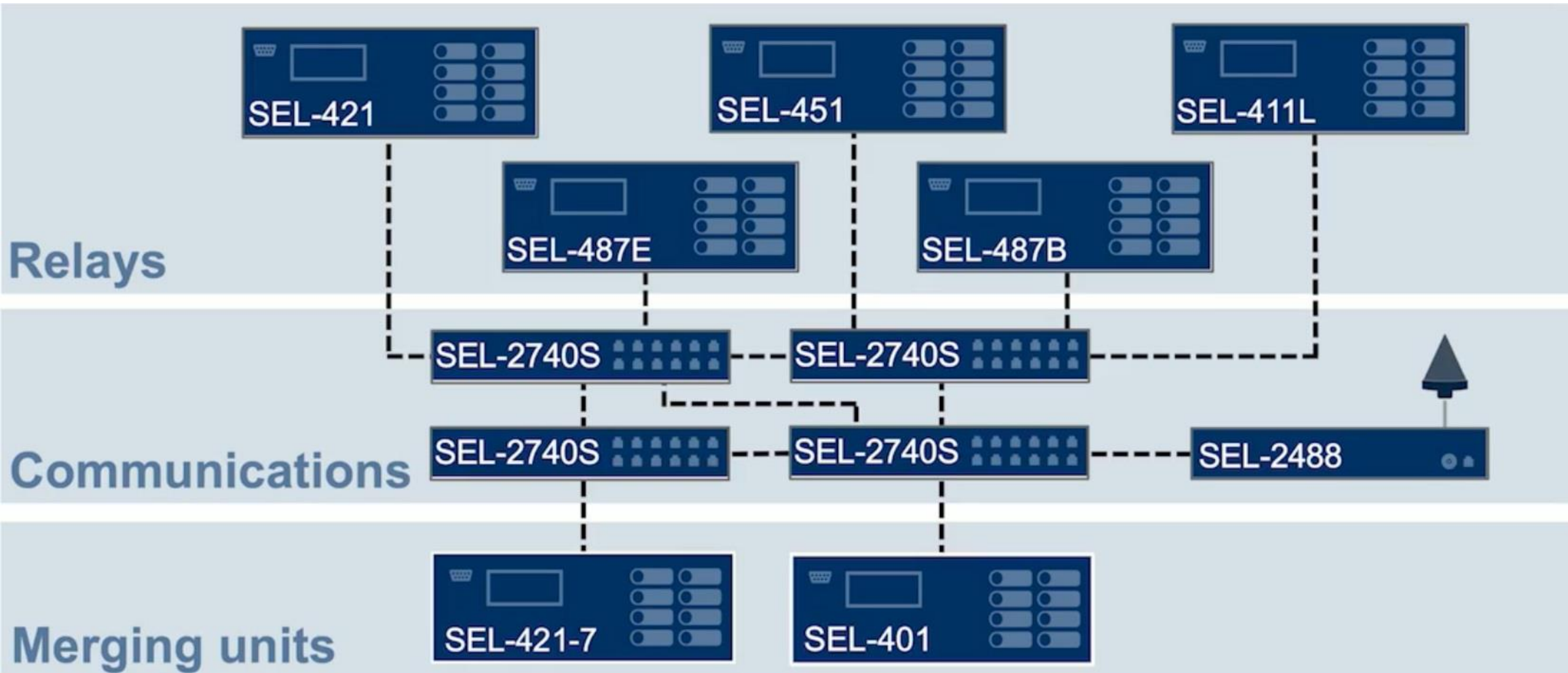
8th Annual Protection, Automation and Control World Conference, June 2017,
71st Annual Georgia Tech Protective Relaying Conference, May 2017,
and XIII Simposio Iberoamericano Sobre Proteccion de Sistemas
Electricos de Potencia, February 2017



University of California, San Diego

- Contingency-based load shedding (CLS)
- Underfrequency-based load shedding (UFLS)
- **Synchrophasor-assisted monitoring, recording, and island detection system**
- Comprehensive HIL testing
- Campus-wide monitoring, panels, and event collection
- Isochronous/droop mode control
- High-speed utility breaker closing
- Autosynchronization

Interoperable, IEC 61850-9-2, Solutions



TiDL = A Simple Point-to-Point Solution

TiDL relays



SEL-TMU
devices

