Schweitzer Engineering Laboratories

Precisely time-stamped Streaming Time-series Systems

April 14, 2021
Dr. Greg Zweigle, Jared Bestebreuer
Most SEL Devices Include PMU Capability

<table>
<thead>
<tr>
<th>Line Protection</th>
<th>Distribution Protection</th>
<th>Reclosers</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEL-311C</td>
<td>SEL-351</td>
<td>SEL-651</td>
</tr>
<tr>
<td>SEL-421</td>
<td>SEL-451</td>
<td>SEL-351RS</td>
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<tr>
<td>SEL-411L</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Generator Protection</th>
<th>Transformer Protection</th>
<th>Capacitor Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEL-700G</td>
<td>SEL-487E</td>
<td>SEL-487V</td>
</tr>
<tr>
<td>SEL-400G</td>
<td>SEL-787</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Meters</th>
<th>Industrial/Utility Feeder</th>
<th>Voltage Regulators</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEL-734</td>
<td>SEL-751</td>
<td>SEL-2431</td>
</tr>
<tr>
<td>SEL-735</td>
<td></td>
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</tr>
</tbody>
</table>
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

Relays
- SEL-421
- SEL-451
- SEL-411L
- SEL-487E
- SEL-487B
- SEL-2740S
- SEL-2740S
- SEL-2740S
- SEL-2488
- SEL-421-7
- SEL-401
And.... TiDL = A Simple Point-to-Point Solution

TiDL relays

SEL-421
SEL-451
SEL-411L
SEL-487E
SEL-487B

SEL-TMU devices

SEL-TMU
SEL-TMU
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
Easy-to-use System Configuration Software

**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**

<table>
<thead>
<tr>
<th>I/O</th>
<th>Port 1</th>
<th>Port 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Input</td>
<td>Feeder1 - 451.Port 6A</td>
<td>Unmapped</td>
</tr>
<tr>
<td>Feeder1 Breaker1 PhaseA</td>
<td>IAW</td>
<td></td>
</tr>
<tr>
<td>Feeder1 Breaker1 PhaseB</td>
<td>IBW</td>
<td></td>
</tr>
<tr>
<td>Feeder1 Breaker1 PhaseC</td>
<td>ICW</td>
<td></td>
</tr>
<tr>
<td>I4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage Input</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeder1 Voltage PhaseA</td>
<td>VAY</td>
<td></td>
</tr>
<tr>
<td>Feeder1 Voltage PhaseB</td>
<td>VBY</td>
<td></td>
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<td>Feeder1 Voltage PhaseC</td>
<td>VCY</td>
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<td>V4</td>
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</table>
Synchrowave Connects **ALL** Utility Data

- Time-domain values
- Weather / fire
- Event reports
- Fault indicators
- EMS / SCADA (db)
- Synchrophasors
Synchrowave Compliments SCADA / EMS

Control center

Operator web clients

Synchrowave Operations
Synchrowave Operations

Energy management system
Energy management system

Synchrowave® Platform
Server Server Server

Synchrophasors, event reports, and time-domain values

SCADA
DOE FOA 1861
Big Data Analysis of Synchrophasor Data

Schweitzer Engineering Laboratories
Oregon State University
Machine Learning Guided Operational Intelligence from Synchrophasors
We are overwhelmed with data

PMUs send 30 messages per second

100 PMUs

2 million data points per hour
48 million data points per day
17 billion data points per year
Automatically detect events with Synchrowave Operations

Time-series data → Real-time analytics → System conditions

Voltage, power, oscillation, frequency, and phase angle monitoring

Generation Trip
Our operators don’t see the value of synchrophasors
Synchrowave starts with the operator

Operators → Operator workflows → Synchrowave Operations → Feedback
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
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.

- Forced Oscillation detection
- Detailed system events
- Model validation
- Harmonics
- Equipment failure prediction

Dynamics

SSR

GMD

f_o frequency
We need to improve fire visibility
Track fire location and impact
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
- 1Mps
- 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

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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

Diagram showing the connections between different models of SEL relays and communications units.
TiDL = A Simple Point-to-Point Solution