SEL

- Headquarters: WA
- US Manufacturing: ID, IL, WA
- Invent, Design, Build, and Support the Systems That Protect and Control Power Systems
- 5600 employees
- Product in 161 countries
- Africa offices: South Africa, Ghana
We Provide End-to-End Solutions

- Protection and control
- Automation
- Computing
- Software
- Precise time
- Security for critical infrastructure
- Metering
- Communications
- Engineering services
- Training
A Household Name in the US
Top U.S. Utilities Trust SEL

99% of top investor-owned utilities use SEL

198 of 200 municipal utilities are SEL customers

97 of 100 rural electric co-ops use SEL
Sustained Employee Growth

# of Employees vs Year

Year: 1984 to 2017
Content

• Challenges
• Solutions
• Case Studies
Problem
When the power went out, linemen had to physically search power lines for the problem

$6,000
Solution

SEL introduced the world’s first all-digital protective relay with fault-locating technology
Performance and Reliability Matter

• SEL 10 Year Warranty
• Mean Time Between Failure (MTBF)
• Life Cycle Costing
• Type Testing
Problems and Solutions

We learn from our mistakes to find solutions that work
2003 Northeast Blackout
Lessons Learned

- Time synchronization for digital fault recorders (DFRs)
- Phasor measurement units (PMUs) for better system-level view
- Events time-tagged within 4 ms accuracy
Correlation of Time-Stamped Data
Real-time as opposed to estimated time
SCADA Misses Information

PMU Real Power
SCADA Real Power
What Is a Synchrophasor?

A synchrophasor is a measurement of electrical variables (such as voltage and current) at a specific moment in time, expressed in terms of both magnitude and angle, relative to a reference phasor. This reference phasor is often provided by a GPS clock or a synchronized IRIG-B pulse, which helps in synchronizing the measurements across different locations.
Event Reports for Detailed Analysis
Event Database for Analysis
Benefits

• Faster analysis of system events
• Better understanding of power system during disturbances
• Situational awareness for operations
Cost Effective Solutions

Wide area monitoring and control pays itself when it operates:

- Cost of a Blackout
- Social Implications
- Political Implications
- Better Power System
Which Power Systems?

- Weak power system
- Radial power systems with concentrated generation
- Intentionally or unintentionally created Islands
- Isolated power systems (MicroGrids)
  - Small populated areas with generation-load unbalance
  - Isolated Industries
    - Refineries
    - Floating Oil Platforms
Why Faster Trip Times Matter

• Better stability
• More energy transmitted
• Less loss of life and property
• Less damage from faults
• Less cascading
• Less stress from overloading
• Less stress on transformers
• Less stress on generators
• Less voltage sag
• We can because we have the technology
The Need for Speed

Moving Energy at the Speed of Light

Safer • Less Damage • Improved Dynamics

15 MW more per millisecond saved

R. B. Eastvedt, BPA, 1976 WPRC
Sub 40 ms Scalable Architectures

Small
<20 ms

Controller
Scan Time: 2 ms

Detection

20 Relays
Scan time: 2 ms

Medium
<30 ms

Controller
Scan time: 2 ms

Substation FEP
Scan time: 2 ms

200 Relays
Scan time: 2 ms

Large
<40 ms

Controller
Scan time: 2 ms

Central FEP
Scan time: 2 ms

1000 Relays
Scan time: 2 ms

Substation FEP
Scan time: 2 ms

Controller
Scan time: 2 ms

Controller
Scan time: 2 ms
Fast SEL Products are the Fastest Systems in the World

![Graph showing load-shed timing with SEL products as the fastest systems](image)

- **Load-Shed Timing (ms)**
  - SEL
  - Other
- **Quantity of IEDs**
  - 10
  - 20
  - 30
  - 40
  - 50
  - 100
  - 250
  - 500
  - 1,000
  - 5,000
Wide Area Monitoring & Control: Microgrids

• A form of Wide Area Monitoring and Control - grid-tied microgrids

• Navigant 2018 Global Research Leaderboard for Microgrid Controls:
  ♦ 15 vendors reviewed
  ♦ SEL #1

• About performance (not only standards)
Wide Area Protection and Control Projects

**Guatemala:** Synchrophasor control Modal analysis (MA) – Electromechanical Instability

**Republic of Georgia:** Emergency Control System – Country Wide Mitigation

**Uruguay:** Over-Load and Stability Control – Country Wide Mitigation

**Peru:** Power Angle Control – Stability

**Spain-France:** HVDC Data for HVDC Link – Control

**Idaho-USA:** Generation Shedding – Stability
Central America and Its Link to Mexico

Map showing the countries of Central America and their link to Mexico, including Mexico, Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, Panama, and Mexico.
July 28, 2012 – MA Trip: Frequencies
Control Center
SCADA / Synchrophasors
Georgia Power System
Georgia Centralized Architecture
Emergency Control System or
RAS/SPS

Crosspoint Switch
Preloaded and Ready to Go

<table>
<thead>
<tr>
<th>Contingency</th>
<th>Loads selected to Shed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Load 1</td>
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<tr>
<td>Loss of G1</td>
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</tr>
<tr>
<td>Loss of G2</td>
<td>X</td>
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<tr>
<td>Loss of G3</td>
<td>X</td>
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<tr>
<td>Loss of G4</td>
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<tr>
<td>Bus Tie</td>
<td>X</td>
</tr>
</tbody>
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Load-Shedding Outputs

CB Opens

Trigger Inputs
Georgia Special Protection System Operations for 2014

Source: GSE
Georgia Reliability Increases

• ECS operates country-wide between 30-40ms

• Georgia’s GDP during this time was about $1.95 million per hour. Assuming an average duration of 1 hour per blackout this solution has saved Georgia $39 million. The solution cost about $2 million.*

• Quality/robustness of equipment allows installation in the yard, not control room (Certified: -40 to +90 C, Margin testing included: -45 to +95 C). Philosophy of Quality. Not standards.

* GSE statistics
USAID GSE Substation Project

- 12 Substations renovated
- Project finished 1 year ahead of schedule – USAID request
- Why mention of protection and wide area monitoring together?
  - In combination, protection rehabilitation and wide area monitoring we observed a significant increase in reliability
GSE 12 Substation Rehabilitation Project
Relay Maloperation due to Complex Circuits

Source: GSE
Georgia Reliability Increases

- Protection devices serve dual purpose: protection as well as wide area monitoring & control
  - Synchrophasors imbedded in conventional protection equipment such as relays, meters, etc.
  - Complex circuits reduced
Basic Monitoring and Control

Controller

Communications

Monitoring and Detection Equipment

Mitigating Equipment
CONCLUSIONS

WIDE AREA MONITORING PROTECTION AND CONTROL NEEDED

- Human control too slow and risky – we get speed and automation
- Need power system visibility
- Angular Instability
- Electromechanical Oscillations
- Instantaneous load shedding of non-critical load
- Islanding
- Accurate fault location
- Reliability and revenue
Making Electric Power Safer, More Reliable, and More Economical for Over 30 Years

Questions?