Schweitzer Engineering Laboratories

Microgrid Systems: Best Practices

ECREEE Sustainable Energy Forum: Dakar, Senegal
13 November 2018

André du Plessis

SEL

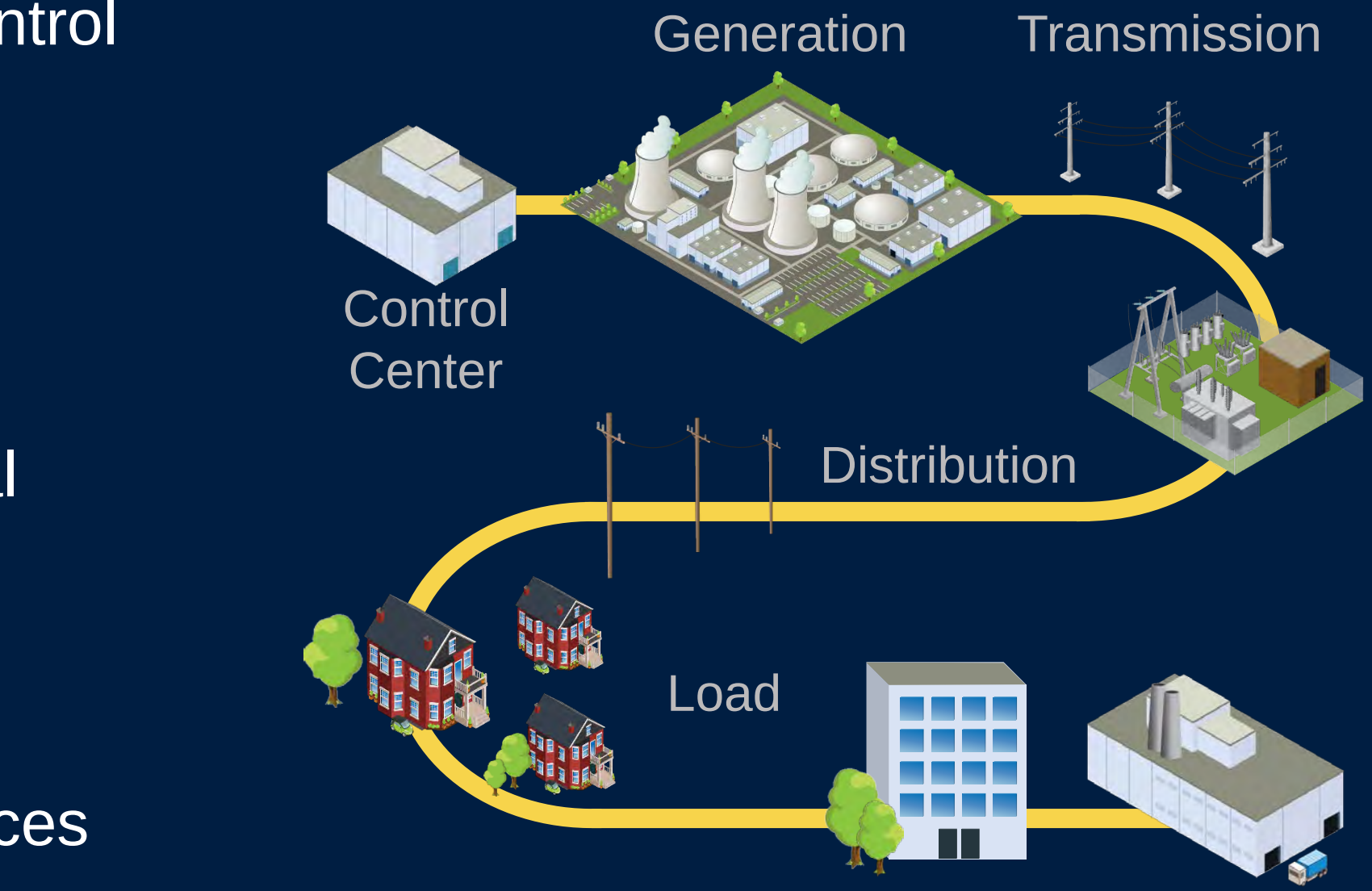
- Headquarters: WA
- US Manufacturing: ID, IL, WA
- Invent, Design, Build, and Support the Systems That Protect and Control Power Systems
- 5600 employees
- Product in 161 countries
- Africa offices: South Africa, Ghana



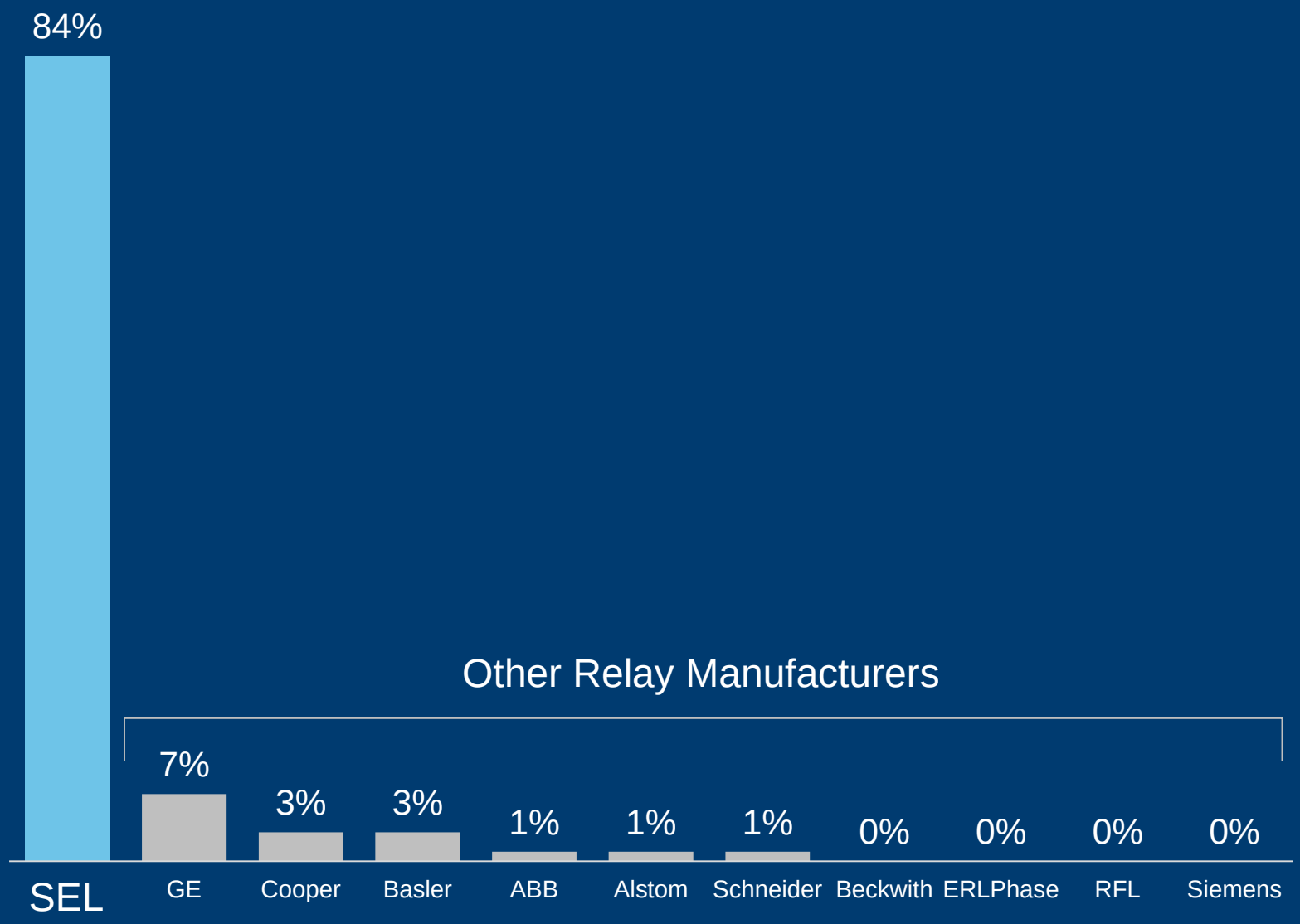


We Provide End-to-End Solutions

- Protection and control
- Automation
- Computing
- Software
- Precise time
- Security for critical infrastructure
- Metering
- Communications
- Engineering services
- Training



SEL Is Consistently Ranked North America's #1 Favorite Relay Supplier

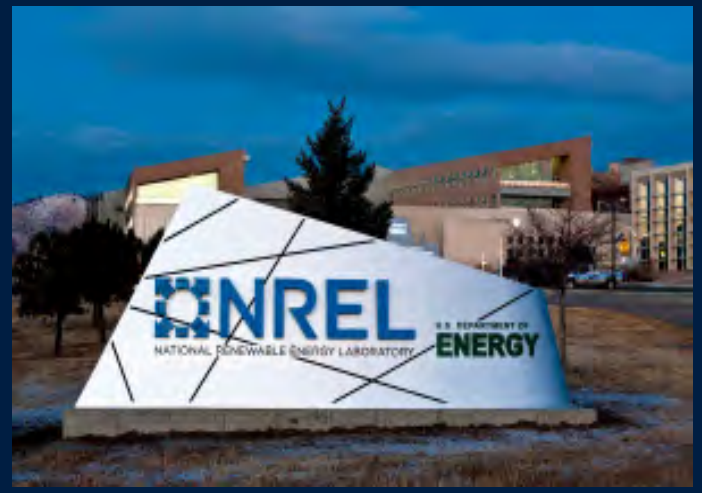


Newton-Evans Research Company Survey: "The Worldwide Study of the Protective Relay Marketplace in Electric Utilities: 2016–2018; Volume 1: North American Market"

SEL Leads in Micro Grid Control Technology

- Winner of two international microgrid technology competitions: MIT & ENREL
- Top performer of a world-wide microgrid performance evaluation among 15 suppliers: NAVIGANT

Massachusetts Institute of Technology



NAVIGANT RESEARCH

SEL PowerMax References (power management)

- Motor Oil Hellas, Greece
- GDF Suez, UK
- Braskem BA, Brazil
- REVAP, Brazil
- Chevron MSP, Africa
- Chevron JSM / Bigfoot, USA
- Motiva Refinery, USA
- Braskem RS, Brazil
- Marathon Oil, Africa
- Shaybah Refinery, Saudi Arabia
- Manifa Refinery, Saudi Arabia
- Ma’aden Phosphate, Saudi Arabia
- BALCO, India
- WAPL, Australia
- Chevron Wheatstone, Australia
- Chevron Gorgon, Australia
- International Paper, USA
- Chevron Kern River, USA

SEL Microgrid References

- TDX Power, Saint Paul Island, Alaska
- University of San Diego, California
- AEP Presidio, Texas
- Borrego Springs, California
- University of Bridgeport, Connecticut
- Port Hueneme Naval Base, California
- City of Woodbridge, Connecticut

SEL Microgrid Economic Dispatch Capabilities

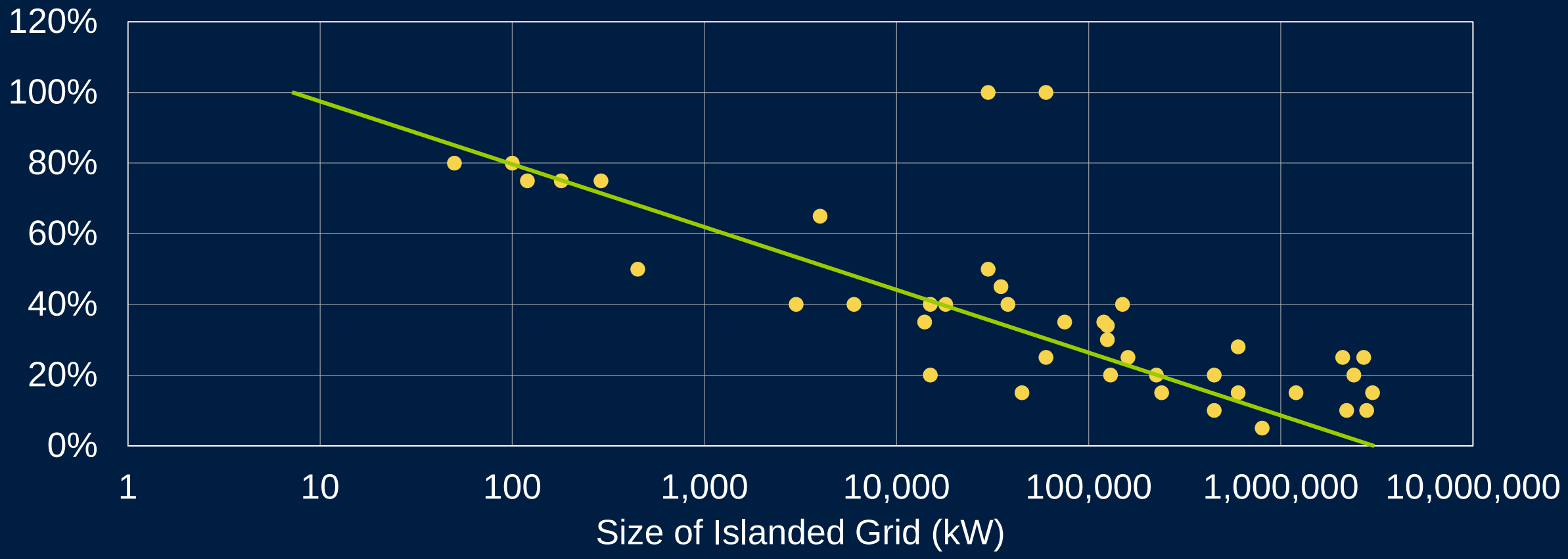
SEL microgrid library provides cost factor management that optimizes (calculates):

- Energy price
- Fuel price
- Generator transition cost
- Generator efficiency curves
- Generator operation region constraints
- Battery state of charge strategy
- Load and Generation Forecasting
- Dispatch Scheduling

SEL Relays are Microgrid controllers

- Multifunction protection
- Remote I/O
- Metering
- Power quality monitoring
- Programmable logic controller
- IEC 61850
- Sequence of Events recorder
- Embedded & Whitelisted
- Military-spec environmental ratings
- High-speed communication
- Continuous self-diagnostics
- Synchrophasors
- DC battery monitoring
- Human interface displays
- Trip and close controls
- Oscillography recorder
- No operating system
- 100s of thousands in operation

Relays Are Controllers for Small Microgrids

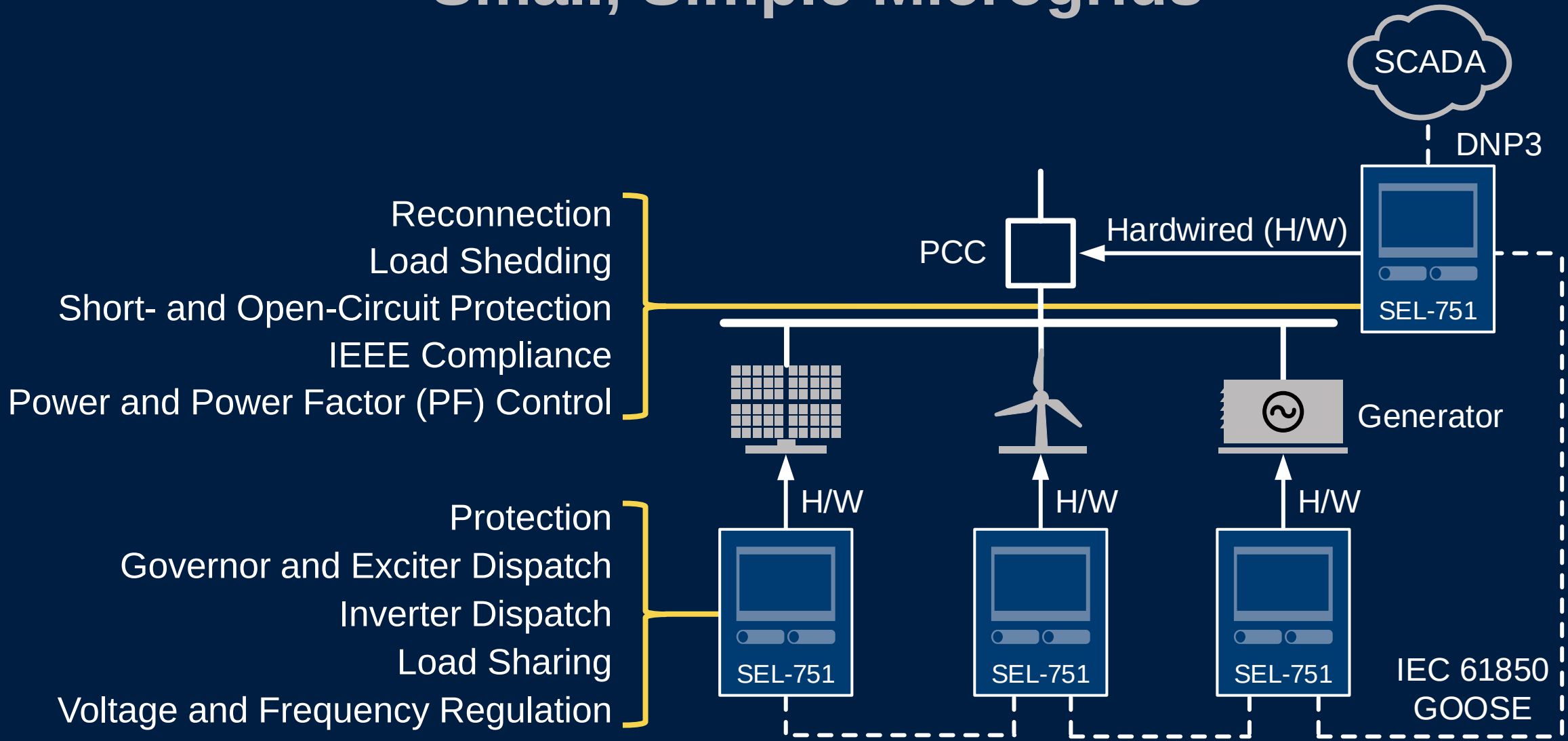


Relay-Based Microgrid Controls

POWERMAX® Power Management and Control System

All-Relay Solution Architecture

Small, Simple Microgrids



SEL POWERMAX Central Controllers for Large Microgrids: Angola & Equatorial Guinea

SCADA System

Generation Control System (GCS)

Contingency Load Shedding

Synchronization Systems

Underfrequency Load Shedding

Remedial Action Schemes

Engineering Databases

Communications

SEL-735

Meters

SEL-2411

I/O Modules

SEL-751

Relays

Substation Protection and Control

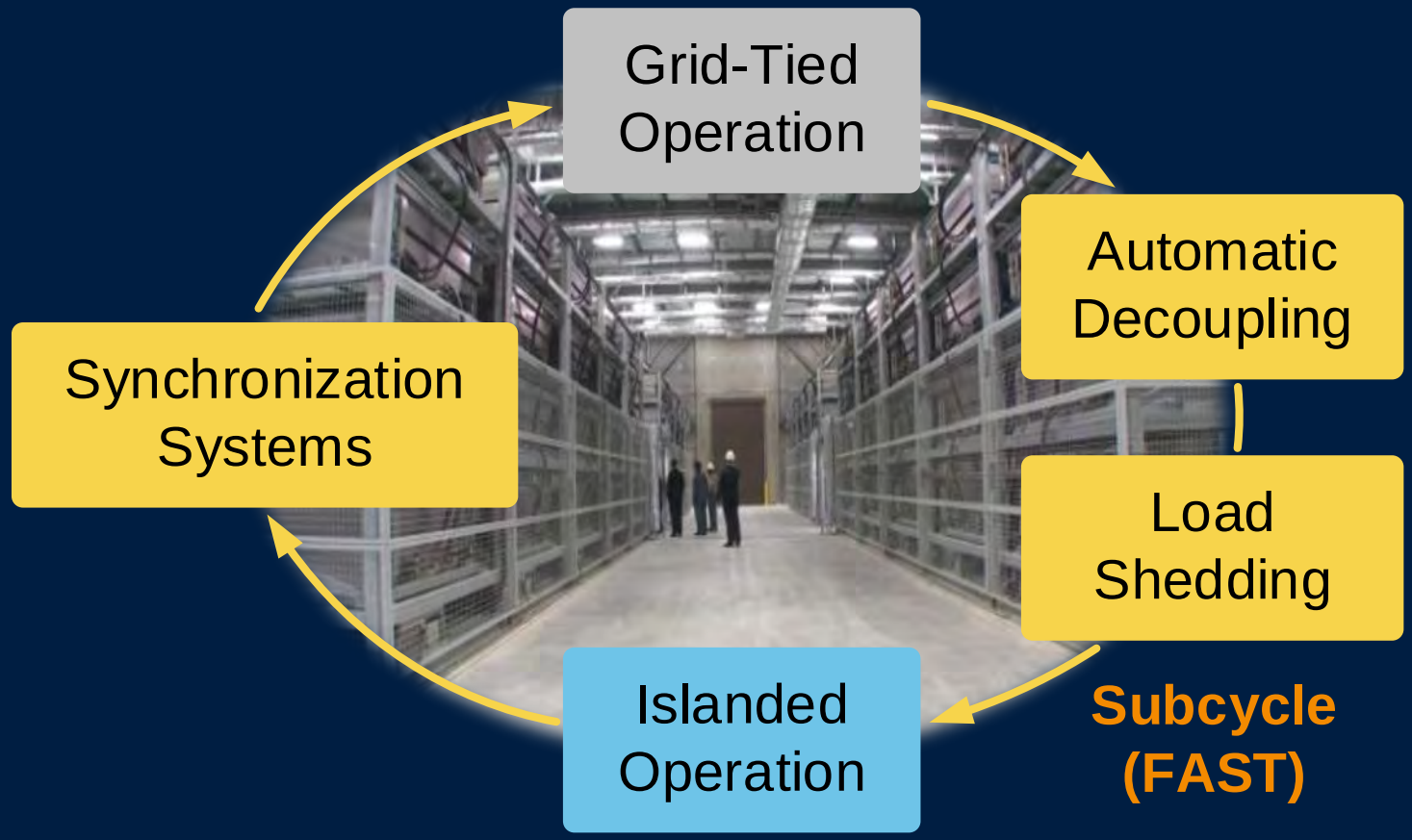
SEL Microgrid Control Solutions Scale Up

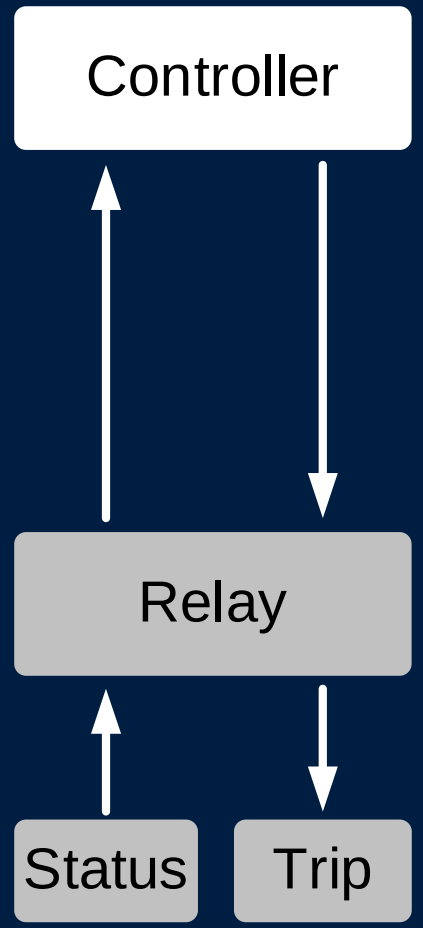
Feature	100% Relay Solution	POWERMAX
SEL relays	✓	✓
SEL controllers	–	SEL-3555
SEL POWERMAX libraries	–	Complete
Generators	<10 MW	>10 MW or mixed suppliers
Security	Comprehensive	Comprehensive
Hardware-in-the-loop (HIL) testing	Universal Power Flow (UPF)	RTDS® (Real Time Digital Simulator)
Grid topology	One bus	Unlimited complexity

Industrial and Community Microgrids Have Different Requirements

Requirement	Community Microgrid	Industrial POWERMAX
Power reliability	✗	✓
Energy efficiency	✓	✗
Intermittent energy sources	✓	✗
Inverter-based generation	✓	✗
Payback period	Years	Days

FAST Load Shedding Prevents Blackouts





St Paul Island Microgrid

- Main Elements:
  - 2X diesel gensets with automated controls (320kW)
  - 3X Wind Turbines (225kW)
  - 160kW Flywheel with 25 kwh storage
  - Combination of critical and non-critical loads
  - Automatic load shedding and balancing

St Paul Island Microgrid Objectives

- Project Objectives:
  - 80% of all electrical and thermal heating requirements for the community of St. Paul by 2020
  - Supports the community's energy security goal
  - Demonstrate the merits of Microgrids
  - Demonstrate integration of renewables as primary power sources
  - Use lessons learned in communities throughout Alaska and beyond
  - Develop and test a Microgrid Controller, with universal application

St Paul Island Microgrid Objectives

- Research Objectives (Department of Energy):
  - Develop and test a Microgrid Controller, with universal application
  - Reducing outage time of critical loads by >98%
  - Reducing emissions by >20% with renewables
  - Improving system energy efficiencies by >20% with renewables
  - Enhance energy resiliency and increase robustness

Add Dedicated Controller for Economic Dispatch

Cost Factors

Weather

Energy price

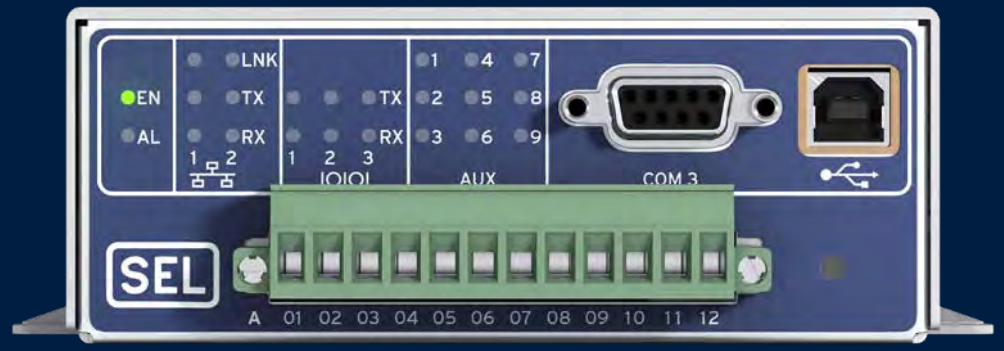
Fuel price

Generator transition cost

Generator efficiency curves

Generator operation region constraints

Battery charging strategy



Generator Storage Wind Solar

Microgrid Key Performance Parameters
(Price Factor Calculations)

- KPP 1: Resiliency and Reliability (energy delivered to different loads)
- KPP 2: Onsite Fuel Usage
- KPP 3: Interconnection Contract (measuring the import and export of power at PCC connections)
- KPP 4: Ancillary Services (measuring the microgrid’s ability to generate additional revenue by providing services on request)

Microgrid Key Performance Parameters
(Price Factor Calculations) continued ... 1

- KPP 5: Power Quality (measuring violations of the clearing times defined in IEEE1547a-2014 standard)
- KPP 6: Microgrid Survivability (ability to optimize battery dispatch while maintaining a resiliency reserve of the battery’s state of charge in case of an unplanned event)

Microgrid Key Performance Parameters
(Price Factor Calculations) continued ...2

- KPP 7: Operation and Maintenance (the cost of operating and maintaining a microgrid)
- KPP 8: Economical Operation
  - The sum of all KPP's. By analyzing these results, operators can develop strategies for achieving the highest possible KPP8 value
  - Purpose: maximizing economic viability and profitability of the microgrid

Lessons Learned

- Physics are the same, big or small
- HIL testing simplifies commissioning
- Fast control systems prevent outages
- Reliable load balancing maintains stability
- Advanced controllers are superior to PID methods
- Seamless islanding requires protective relays at PCC
- Security-in-depth is mandatory
- Engineering is required

Questions?