Microgrid Solutions for All Challenges and Sizes: POWERMAX®

SEL

Eduardo S. Palma, CISSP

1

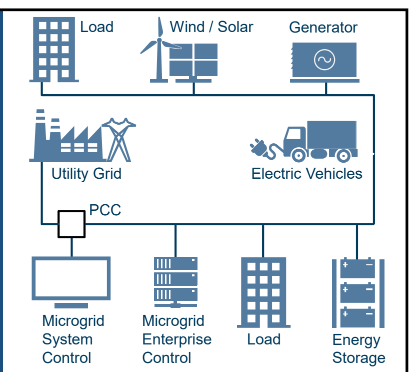
What is a microgrid?

"A Microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode."

Microgrid Exchange Group (MEG)

2

Microgrids Are Power Systems That Can Operate Islanded, or Off-Grid



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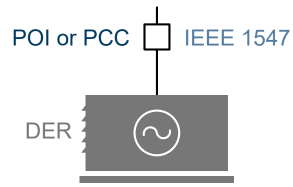
DER Catch-All Name For Traditional and Intermittent Sources



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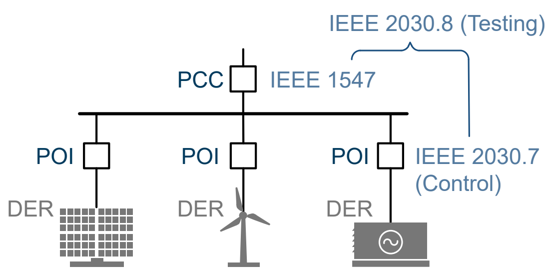
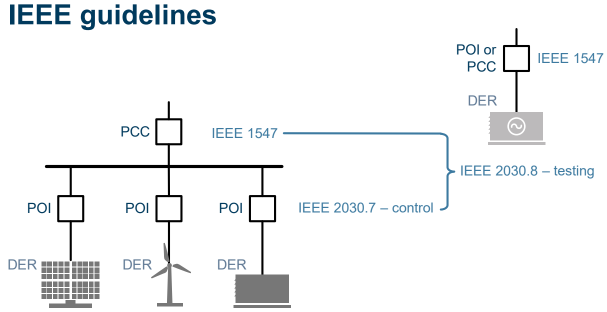
Microgrid Testing Standards Require Relays



5

IEEE guidelines



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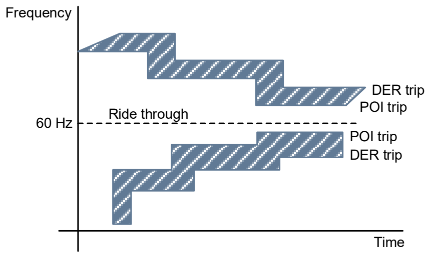
IEEE 1547 contract requirements leave very little room for seamless islanding



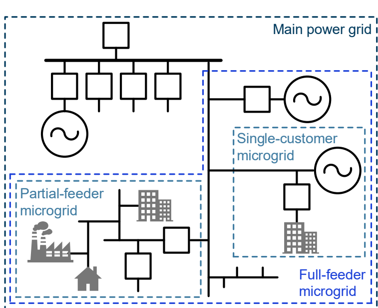
7

IEEE 2030.8-2018 requires three types of mandatory data collection, which are in relays

Requirement	SEL relay solution
SOE	SER
Event oscillography	Event records
Continuous data collection	SYNCHROWAVE® Central

8

Microgrids are everywhere



9

Goals and principles

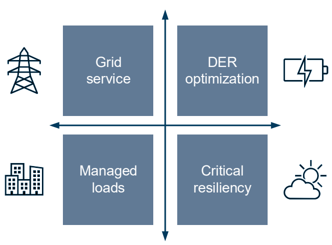
MICROGRID POWER SYSTEM

What are the objectives?

What challenges are there?

10

Microgrid objectives



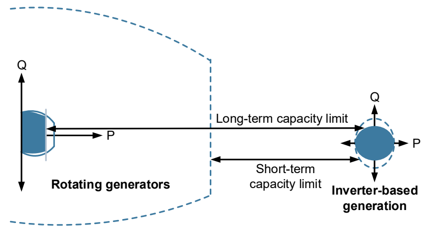
11

So many challenges

- System design
- Protection and automation
- Integration and operation
- Black start
- Resiliency

12

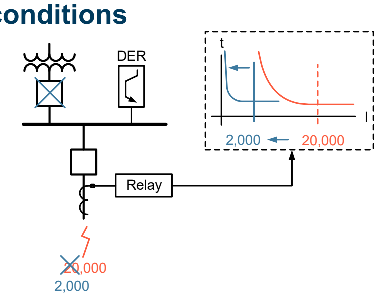
Inverter-based DERs have limited transient overload capacity



13

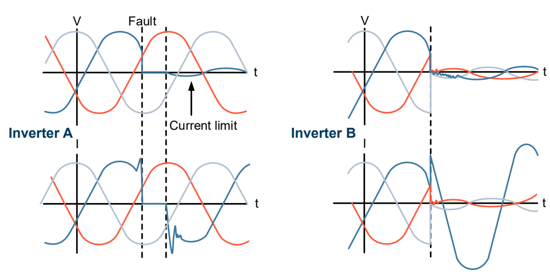
Protection must adapt to changing fault conditions

- Fault levels
- Grounding
- Directions
- Impedances



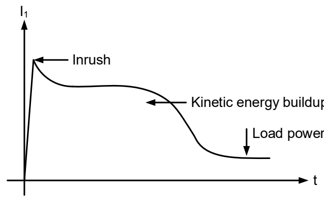
14

With inverters, fault behavior is subject to human preference



15

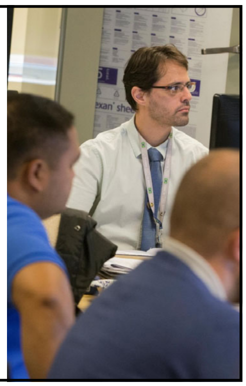
Black-start profile includes magnetic inrush, cold-load pickup, and steady-state power



16

Operation modes for DER assets

- Grid-forming vs. grid-following sources
- Droop-based operation
- Transients during in-between transition



17

Operation modes for DER assets

PV

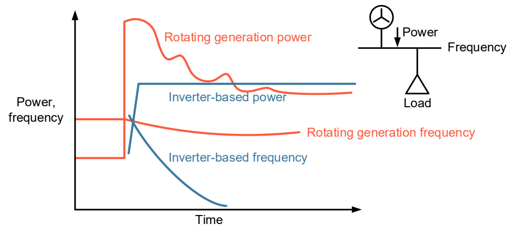
- P/PF mode
- Volt-VAR mode
- Frequency watt mode
- Voltage watt mode

Wind

Type 1, Type 2, Type 3, or Type 4

18

Dispatch and load balancing must happen **faster** with inverter-based DER



19

What is POWERMAX?

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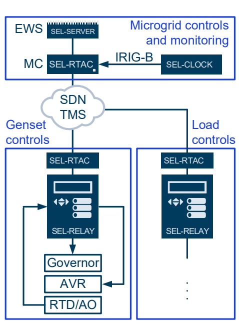
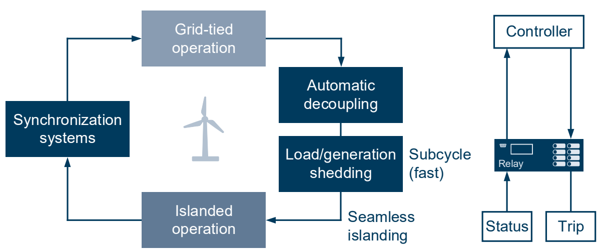
INCLUDES RELAYS, CONTROLLERS, COMMUNICATIONS, CYBERSECURITY, AND REMOTE MONITORING

SEL POWERMAX® solution is **fully integrated**



21

POWERMAX operation



22

KEY POWERMAX SOLUTION DIFFERENCES

Segment	Technology	MW range	Key differences
Mobile MG	TMS	0.01 – 1	Disaster reliefs, army bases, and remote islanded facilities – mainly for diesel generators using distributed communications architecture
Garrison MG	TMS and Garrison	0.10 – 10	Solution for small- to mid-sized microgrids using DG, solar PV, or BESS for simple bus topology using distributed communications architecture

24

Key POWERMAX solution differences

Segment	Technology	MW range	Key differences
Commercial MG	POWERMAX RTAC	1 – 1,000	Solution for mid- to-large sized microgrids using any kind of DER (NG, DG, steam, solar PV, BESS, wind, or fuel cell) using centralized communications architecture
Industrial MG	POWERMAX RTAC	10 – 5,000	Solution for mid- to large-sized industrial facilities using any kind of DER (NG, DG, steam, solar PV, BESS, wind, or fuel cell) using centralized communications architecture
Utilities MG	POWERMAX RTAC	Transmission level	Solution for wide-area protection to maintain grid stability using distributed and centralized architecture – RAS (Remedial Action Schemes)

25

POWERMAX Mobile Technology



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26

POWERMAX Mobile Technology

Interoperable, Simple Solution for Microgrids <1 MW

American Red Cross

FEMA

Mining and Drilling Industrials

Private Disaster Relief

Forward Operating Base

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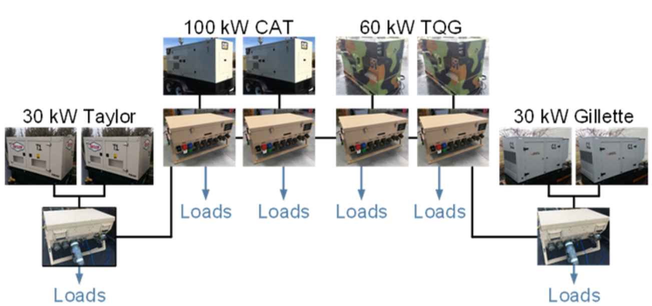
POWERMAX Mobile Technology



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POWERMAX Mobile Technology

SEL POWERMAX®
for Mobile Microgrids

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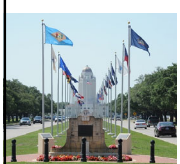
29

POWERMAX Garrison Technology



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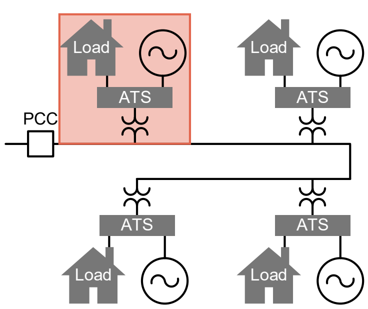
30

POWERMAX Garrison Technology

Creating <10 MW Microgrids out of Existing Equipment



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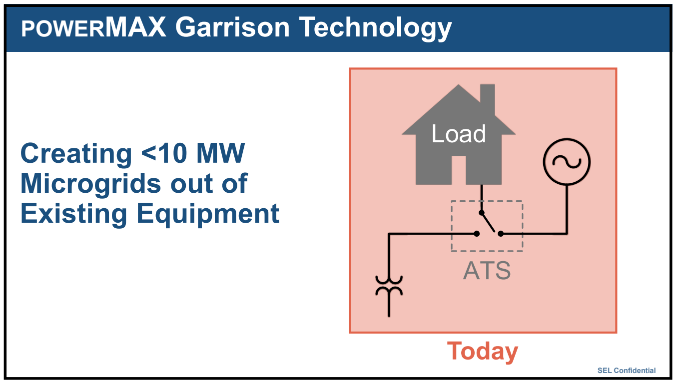
31


POWERMAX Garrison Technology
Creating <10 MW Microgrids out of Existing Equipment
Load
ATS
Today
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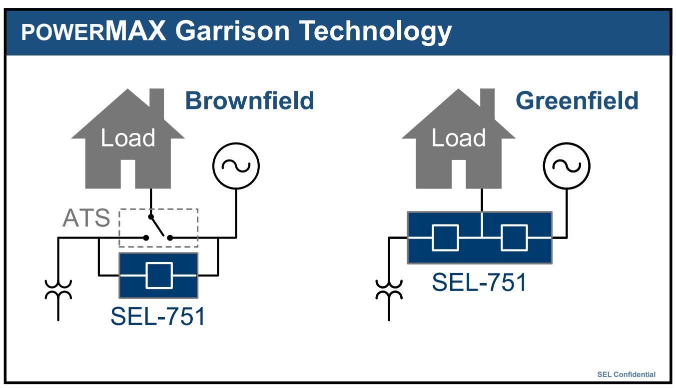
32


POWERMAX Garrison Technology
Brownfield
Load
ATS
SEL-751
Greenfield
Load
SEL-751
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33


POWERMAX Commercial Technology
NREL
ENERGY
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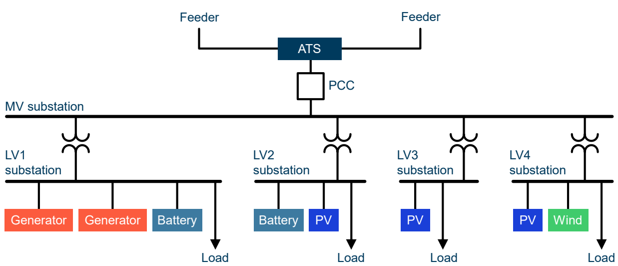
35

Smart energy campus



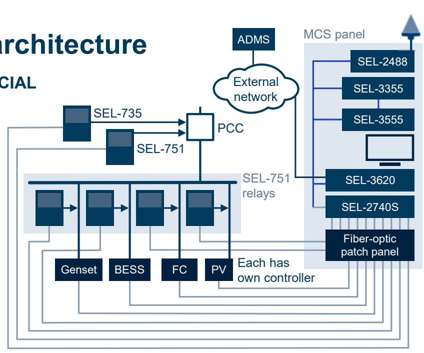
36

Centralized architecture

POWERMAX COMMERCIAL

Distributed controls
- Protection
- Metering

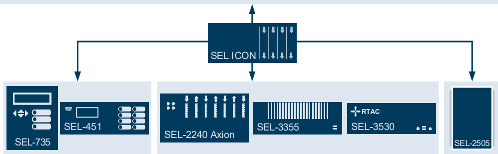
Centralized controls
- HMI/historian
- PCC control
- DER dispatch
- Load shed/control
- Auto sync
- Closed-loop P, Q, V, and F



37

POWERMAX commercial microgrid

Visualization	Protection	Load management	**DER management**	PCC management	Cybersecurity
HMI/SCADA, and event and SOE reports	Coordination, logics, and relay settings	Priorities, load shed, and load restore	V and F control, power share, mode switch, and generation shed	IEEE 1547 power factor, sync (25 A), and IDDS	Networking and NERC CIP



38

POWERMAX Commercial Technology

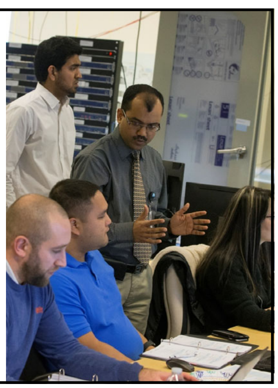
Award-Winning Controls for Complex Grids >10 MW

Navigant Research Leaderboard Grid

39

Microgrid control principles

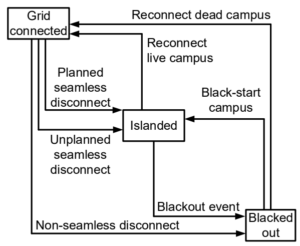
- Competing objectives
- Diverse asset capabilities
- Dispatch strategies



40

High-level objectives

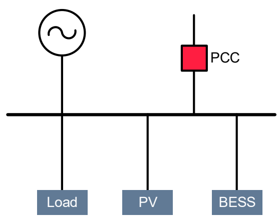
- Manage interconnections
- Maintain island stability
- Control transitions
- Dispatch diverse asset types



41

Grid connected objectives

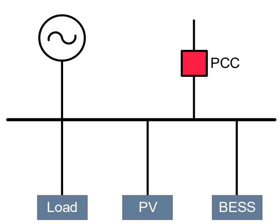
- Serve load
- Maximize renewables
- Import and export limits
- Limit high and low voltage
- Dispatch fixed power



42

Grid connected objectives

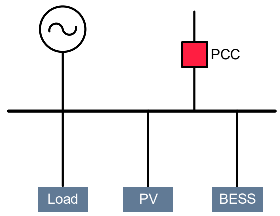
- Shave peak and shift load
- Support frequency and voltage
- Manage battery charge
- Participate in grid services



43

Planned disconnect – proactive

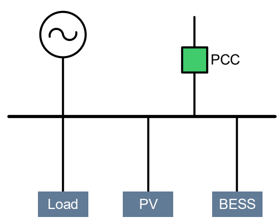
- Start generators
- Limit renewables
- Identify regulation
- Reduce load
- Reduce PCC power flow
- Open PCC breaker
- Switch DER modes



44

Unplanned disconnect – reactive

- PCC breaker opens
- Shed load fast
- Account for reserve margin
- Start generators
- Limit renewables
- Switch DER modes
- Restore load



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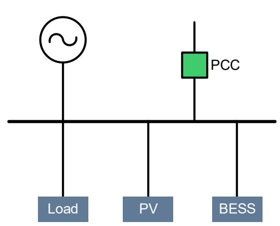
Islanded objectives

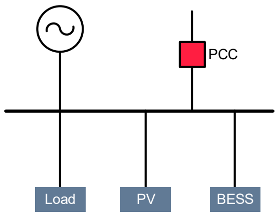
- Frequency control
- Voltage control
- Isochronous priorities
- Renewable contribution limit
- Reserve management
- Critical load



46

Reconnect

- Match voltage
- Match frequency
- Reduce angle
- Close PCC breaker
- Remove renewable limits
- Stop backup generators
- Restore load



47

Asset capabilities

RENEWABLES

- Real power fluctuations
- Limit real power
- Control reactive power

BATTERIES

- Limited stored energy
- Control real and reactive power
- Modes of operation

48

Asset capabilities

LOADS

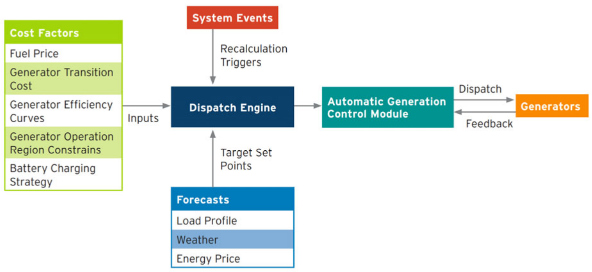
- Subcycle shedding
- Restoration
- Controllable

GENERATORS

- Long-lasting fuel source
- Capability curves
- Modes of operation

49

Dispatch Engine



The dispatch engine accounts for various factors and user inputs in order to optimize a microgrid's generation.

50

POWERMAX Industrial Technology

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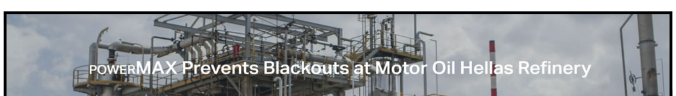
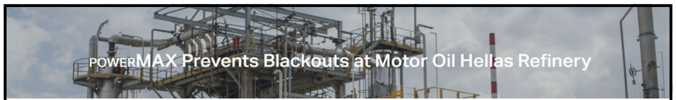


POWERMAX Prevents Blackouts at Motor Oil Hellas Refinery

- Oil refineries have critical processes that depend on reliable power sources. Power outages or interruptions potentially have devastating economic and environmental consequences.
- PowerMAX provides protection and wide-area control.
- Designed to prevent, detect, and mitigate blackouts and maximize system uptime.
- Automatic control of major power system assets for optimal economic operations.
- System operating time is less than 40 milliseconds.

75



POWERMAX Prevents Blackouts at Motor Oil Hellas Refinery

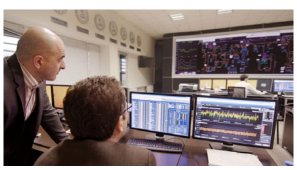
"With the new complete package of integrated protection and monitoring, we have made significant progress toward improving the reliability of our electrical distribution system.

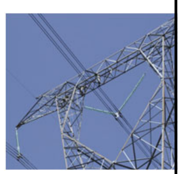
The system is much better now . . . We also now truly know that our protection system is always working. [Several times], the new PowerMAX system has helped us avoid losses of major transformers and motors."

Vassilis Viziryiannakis, Section Head - Motor Oil Hellas

76

POWERMAX Utility Technology





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77

POWERMAX Utility Technology

Fast Controls for Bulk Electric Grids >1 GW

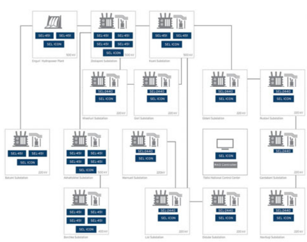
Before POWERMAX

8–14 partial blackouts and
2–5 total blackouts annually

After POWERMAX

0 blackouts in the last 3 years!

78



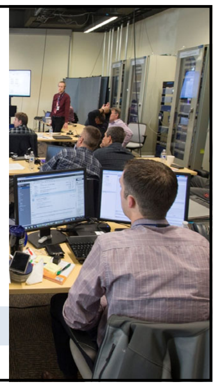
"When you lose a generator or transmission line, you can't be waiting 10 seconds or even 300 milliseconds to start shedding load because then it's over," said Mr. Ashish Upreti. "Everything's blacked out."

79

Testing and system validation

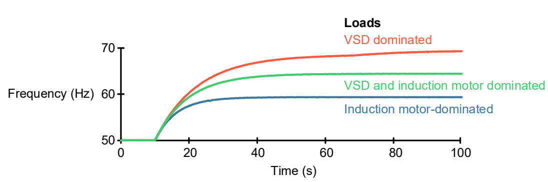
- Control hardware-in-the-loop testing
  - Ensure reliable performance
  - Streamline commissioning
  - Avoid headache down the road
- UPF-deployable HIL testing and simulation
- IEEE 2030.8 – testing

What details need to be considered?



80

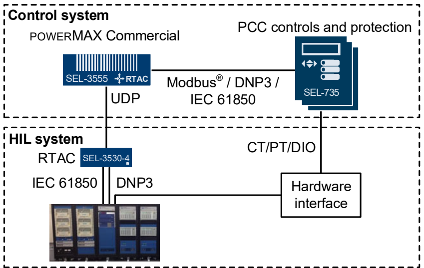
Load composition affects frequency stability – noninertial effects



Academics call this sensitivity analysis

81

Control hardware-in-the-loop testing



82

Final thoughts

- Real challenges – power system experience
- Microgrid objectives – many objectives, and some are competing
- DER capabilities – all assets are not created equal
- Control strategies – innovative approaches
- Modularity and scalable solutions – both hardware and software
- Expert support – multidisciplinary team

83

Questions

DER count, type, and size?

Tolerance for interruption?

Load size?

Existing protection technology?

When can your team meet for a Q&A?

84

Thank you

85