Case Study: Successfully Designing, Installing, and Testing a Microgrid

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Chronological History of Microgrids

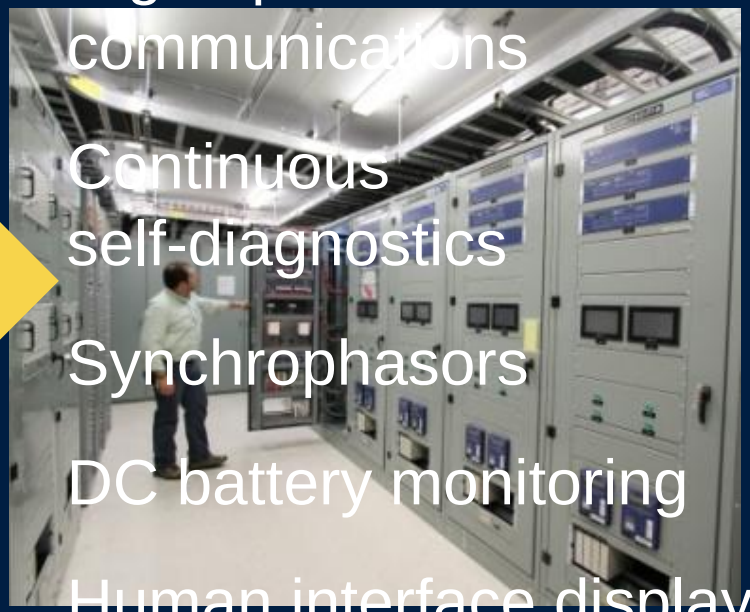
- Microgrid projects
- Lessons learned
- Technology advancements
- Remaining challenges

1984–2004 Microgrid Intelligence

Multifunction Microprocessor Relays Evolve Rapidly

- Multifunction protection
- Remote I/O
- Metering
- Power quality monitoring
- Programmable logic controller
- IEC 61850
- Sequence of Events records

- High-speed communications
- Continuous self-diagnostics
- Synchrophasors
- DC battery monitoring
- Human interface displays
- Trip and close controls
- Oscillography recorder



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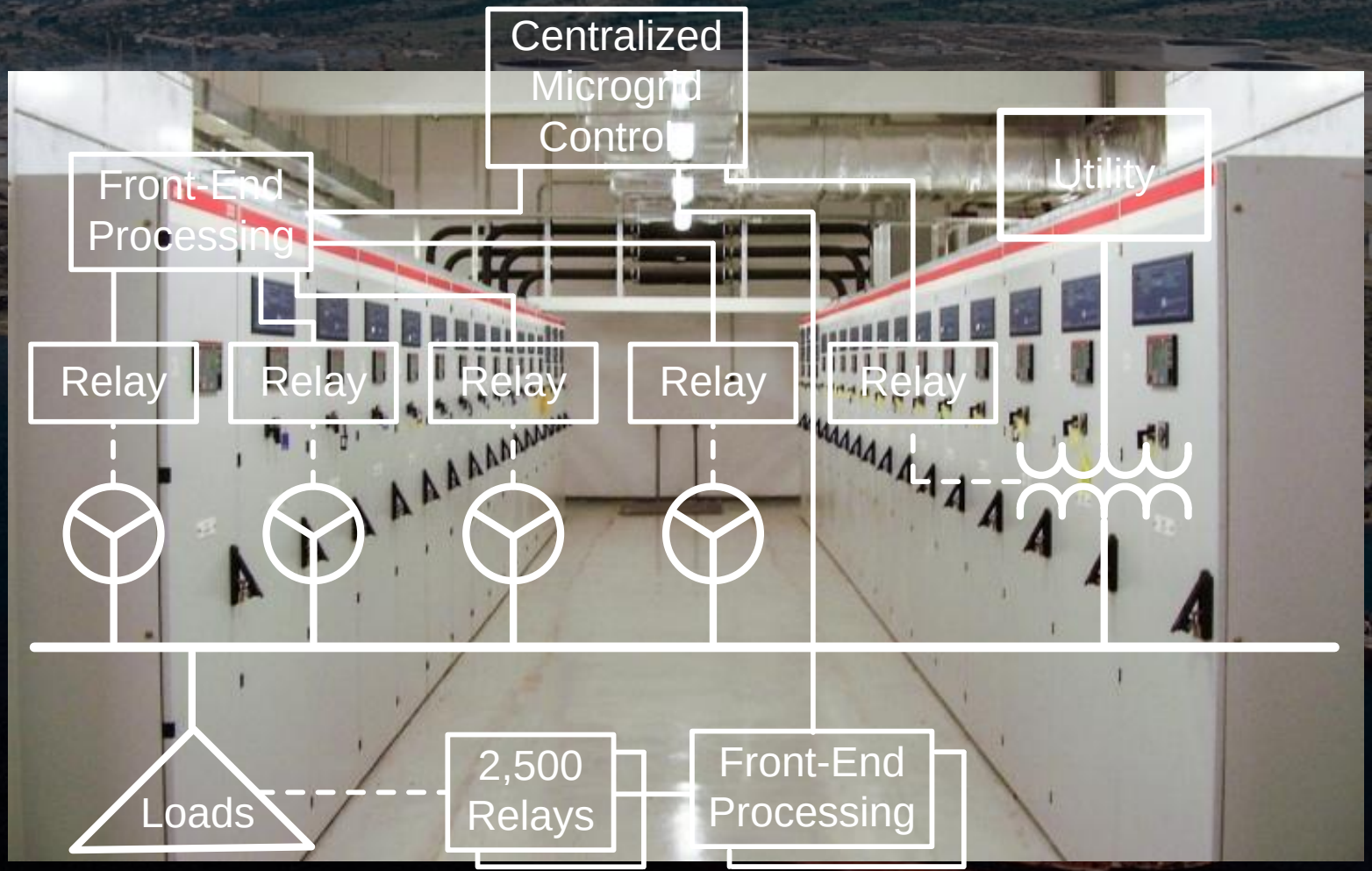
2002 – Motor Oil Hellas

Korinthos, Greece



2002 – Motor Oil Hellas

Speed Is Essential for Seamless Islanding!

- Front-end processing facilitates scaled architecture and *subcycle* communications
- Crosspoint switch enables *subcycle* load shedding
- *Subcycle* load shedding allows seamless islanding

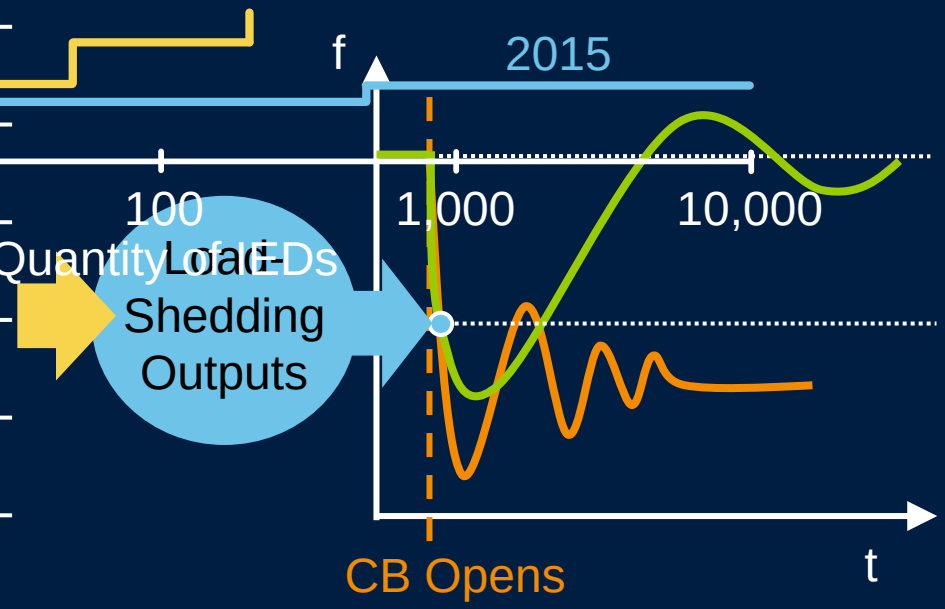
2002 – Motor Oil Hellas

Lessons Learned

Trigger Inputs

Crosspoint Switch

Contingency	Loads Selected to Shed					
	1	2	3	4	5	6
Closed Loop Load-Shedding Time (ms)	120	40		2002	0	
G1 Trip		X	X			
G2 Trip	X					X
G3 Trip	X			X		
G4 Trip			X		X	X
Bus Tie Trip		X		X	X	



2006 – Saudi Aramco
Shaybah, Saudi Arabia

Plant 1
(230 kV GIS)

Plant 2
(230 kV GIS)

Plant 2
(115 kV GIS)

Plant 3
(69 kV AIS)

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2006 – Saudi Aramco

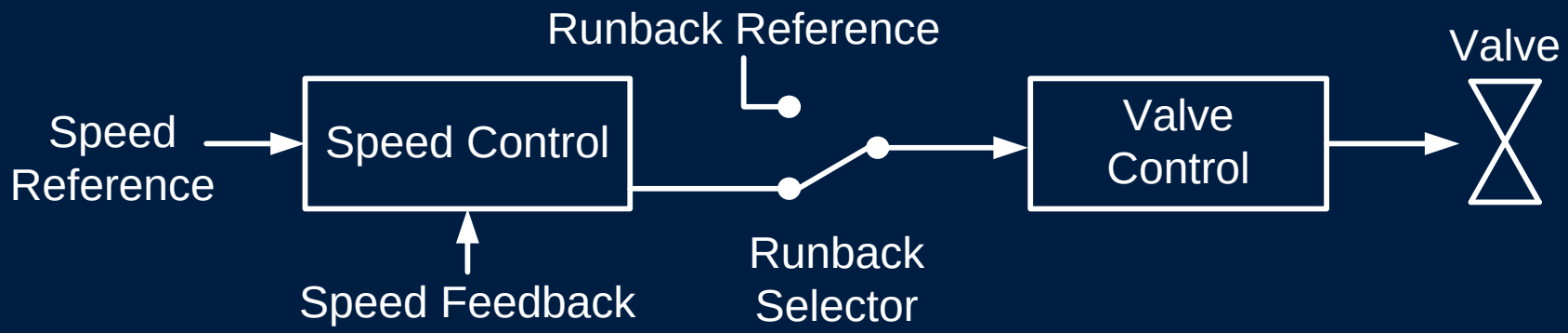
Factory Acceptance Tests Improved With Hardware-in-the-Loop Testing

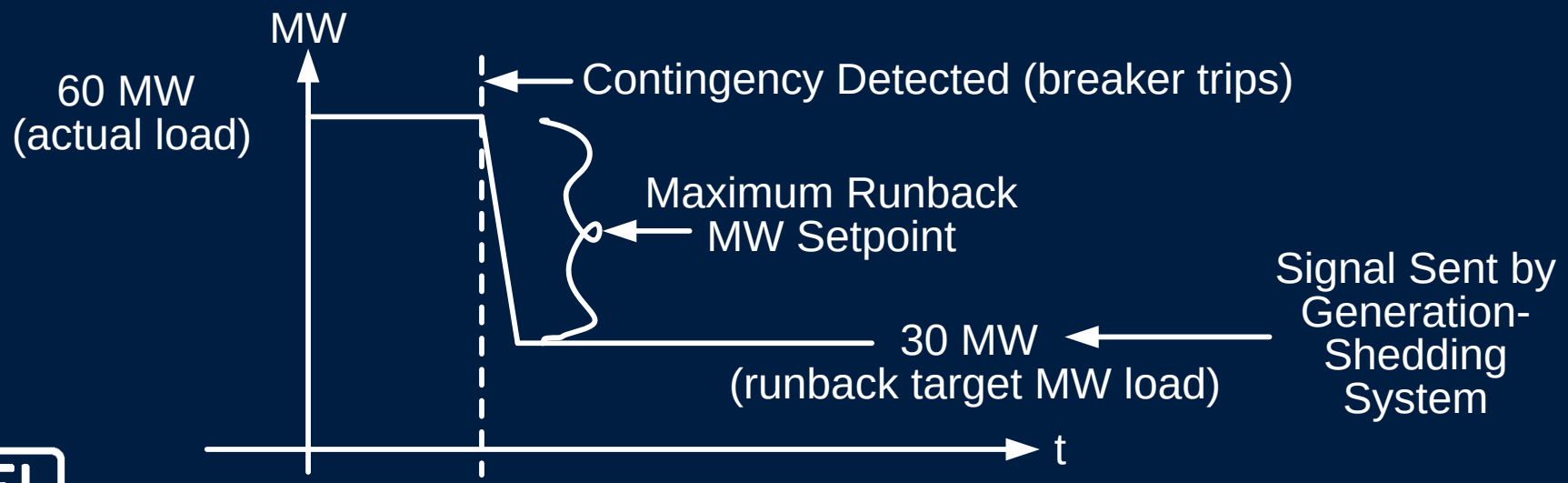
Status

Dynamic Simulation

Generation Runback

Making Turbine Respond at Speed of Inverter





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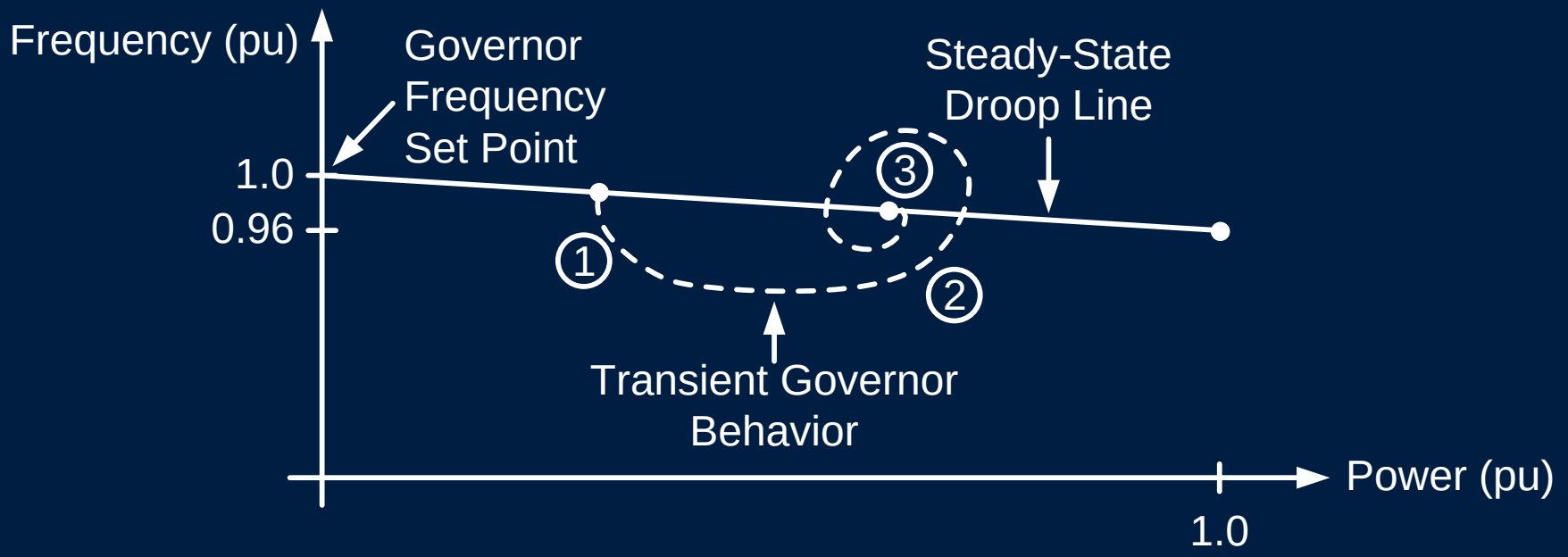
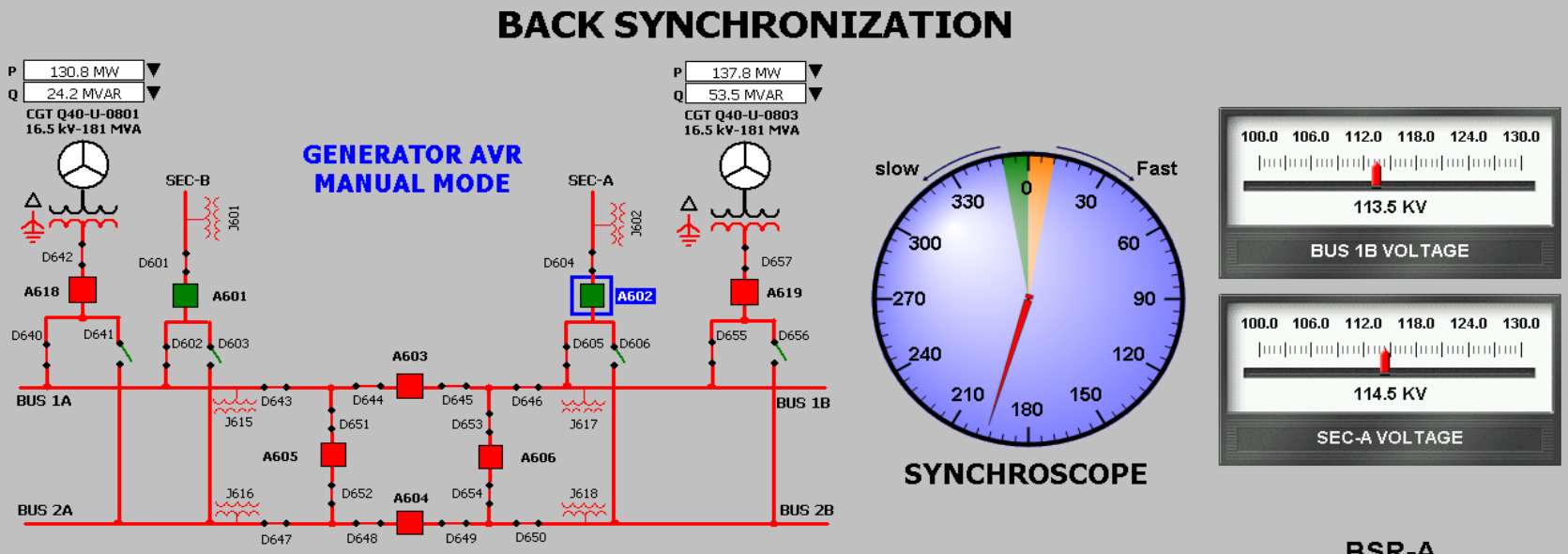
Dynamic Behavior Requires Modeling Mechanical *and* Electrical Systems



System Synchronization

Safely Reconnecting Islanded Grids



BUS 1B FREQUENCY	60 HZ
SEC-A FREQUENCY	60 HZ
SLIP FREQUENCY	0
ANGLE DIFFERENCE	197
BUS 1B VOLTAGE	113.5 KV
SEC-A VOLTAGE	114.5 KV

BSR-A

ENABLED		CLOSE FAILED	SELECT CB601
TRIP	Target Reset	VOLT. OK TO INITIATE	SELECT CB602
SYNCH SUCCESSFUL		VOLT. DIFF. OK	SELECT CB603
FREQ. OK TO INITIATE		dV/dT OK	SELECT CB604
SLIP OK		SELECTED CB OPEN	SELECT CB605
dF/dT OK		BREAKER STATUS ALARM	SELECT CB606
ANGLE OK		CLOSE LOCKOUT	ABORT SYNCH PROCESS
MASTER		SYNCH COMM. ALARM	INITIATE SYNCH PROCESS
REQUEST UNAVAILABLE		VOLT. HI	CLOSE SELECTED CB
		VOLT. LO	AUTO LOCAL
GEN. FREQ. HI		RAISE VOLT.	AUTO REMOTE
GEN. FREQ. LO		LOWER VOLT.	LOCAL MANUAL
RAISE GEN. FREQUENCY			
LOWER GEN. FREQUENCY			

Graphical Interfaces

Teach Operators to Dispatch Grid Differently

Contingency	#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
NGL BC B721	1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
NGL BC B723	2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
NGL BC B722	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
NGL BC B720	4	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
GOSP-4 BC B712	5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
GOSP-4 BC B714	6	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
GOSP-4 BC B713	7	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
GOSP-4 BC B711	8	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
GOSP-4 BC B612	9	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
GOSP-2 BC B505	10	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
NGL/G4 Tie A	11	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
NGL/G4 Tie B	12	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
GOSP-4 Intertie A	13	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
GOSP-4 Intertie B	14	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
GOSP-4 GOSP-2 Tie	15	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
NGL/GOSP-3 Tie A	16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
NGL/GOSP-3 Tie B	17	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
GOSP-3 BC B701	18	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
GOSP-3 BC B702	19	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
GOSP-3 BC B703	20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

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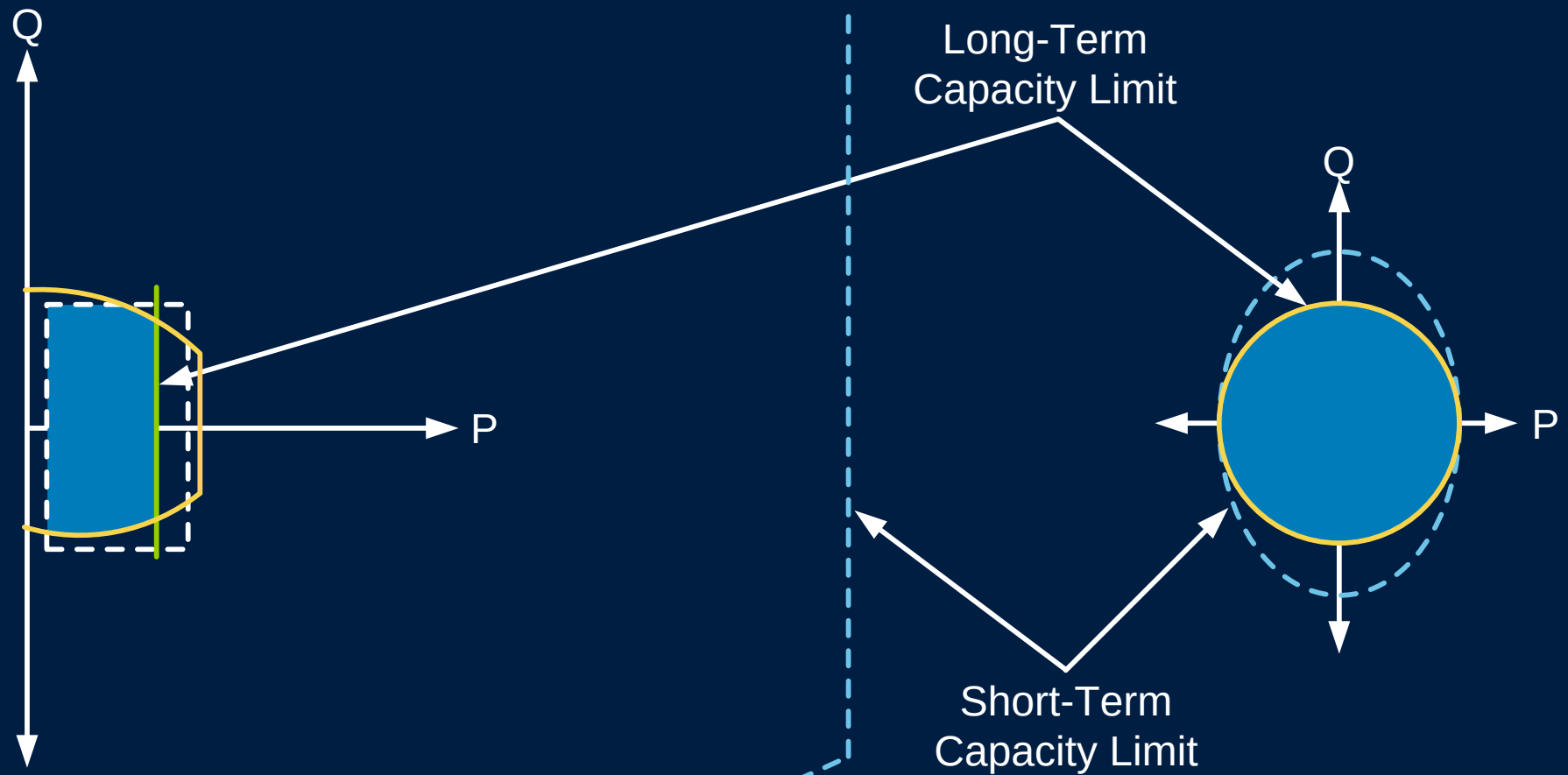
2008 – Presidio, Texas

4 MW NaS Battery Microgrid Controls

2008 – Presidio, Texas

Inverters Are Not as Robust as Rotating Machinery



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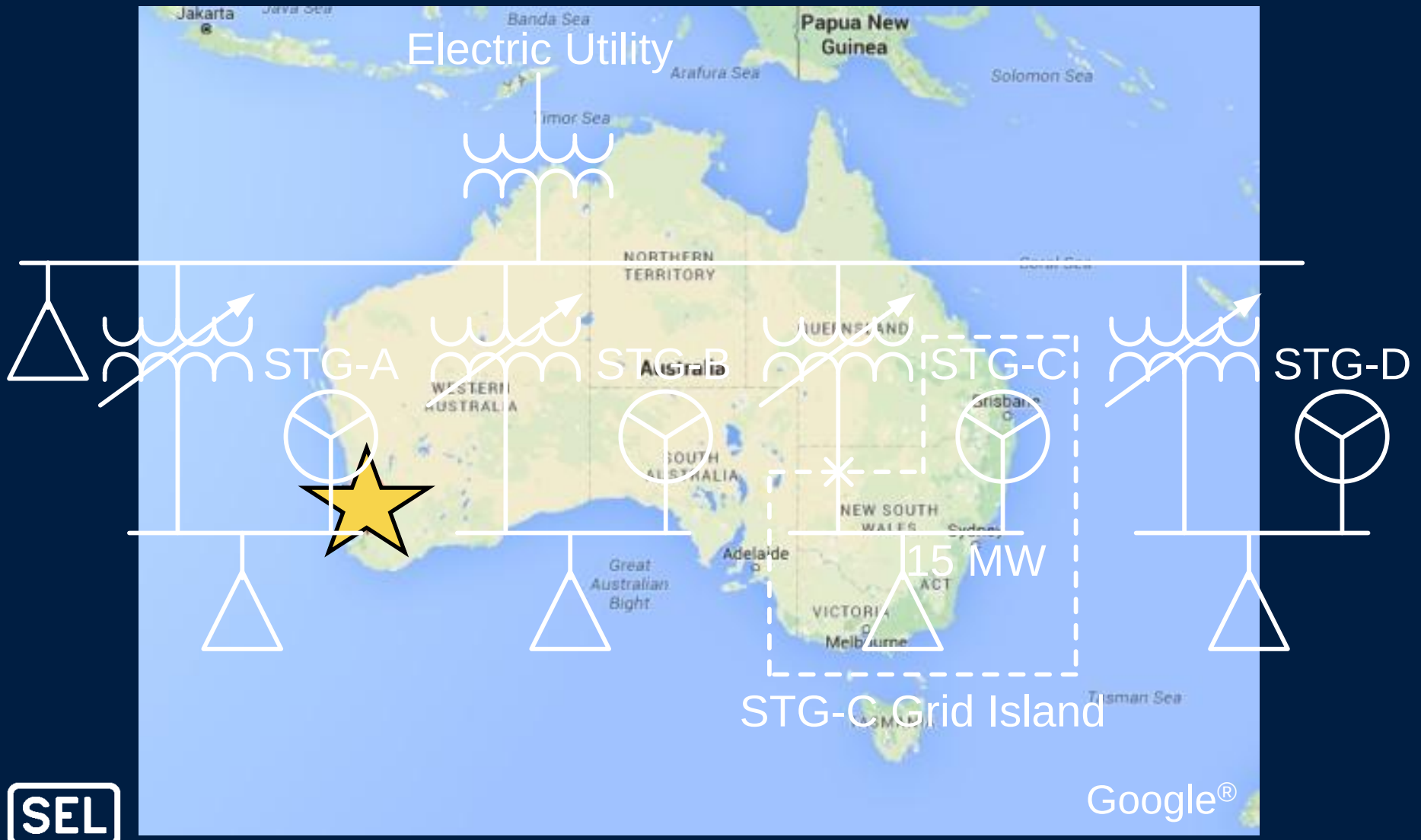
2010 – BHP Worsley Alumina

Collie, Australia



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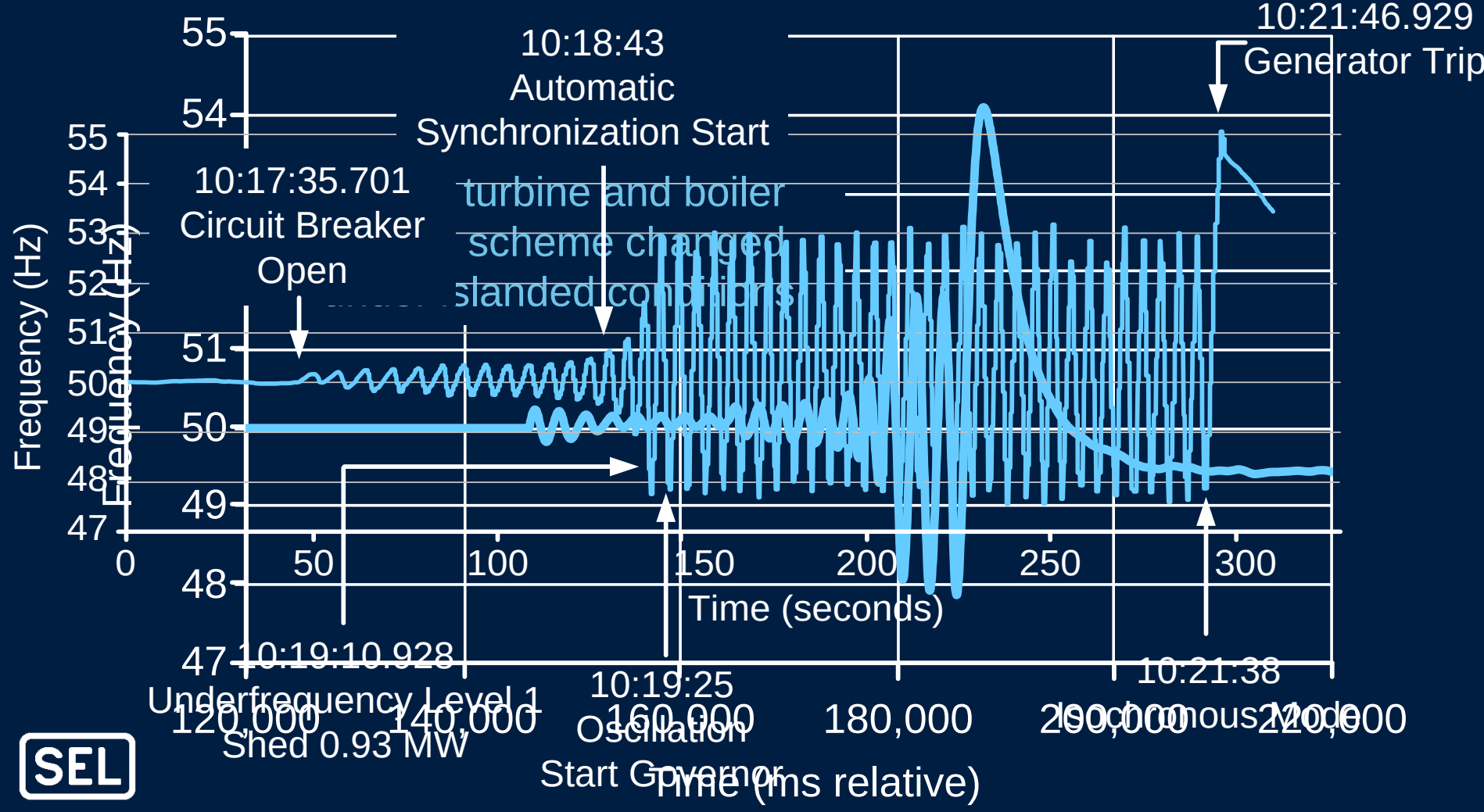
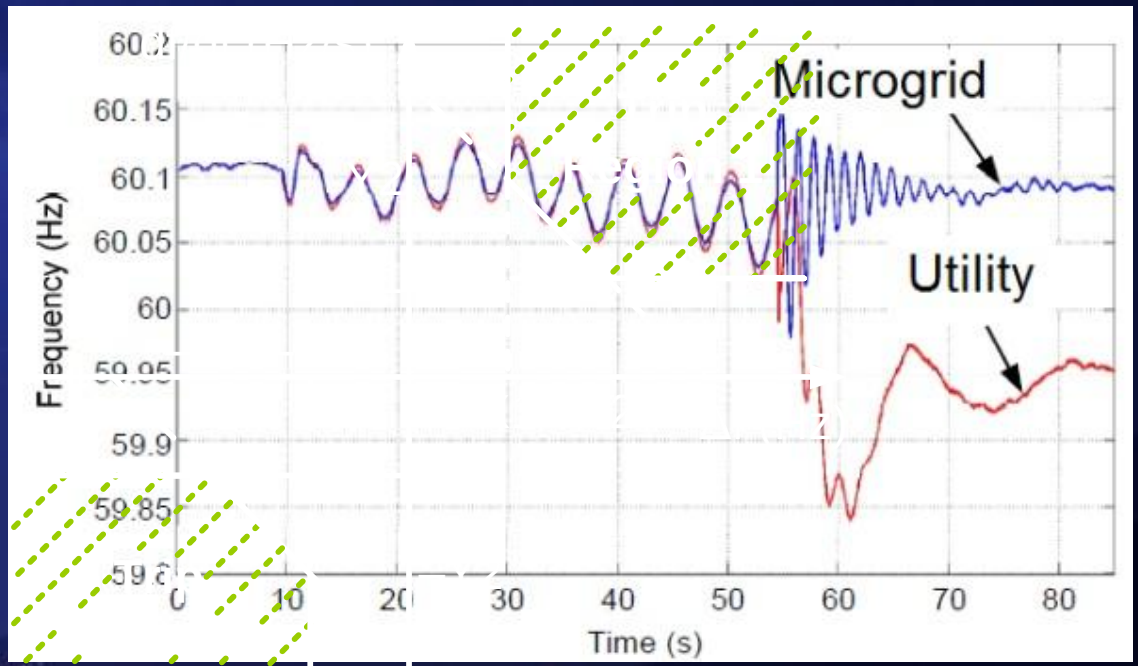
2010 – BHP Worsley Alumina

Islanded Steam Turbines and Electronic Loads May Not Mix!



2010 – BHP Worsley Alumina

Intentional Disconnecting at PCC Increases Reliability

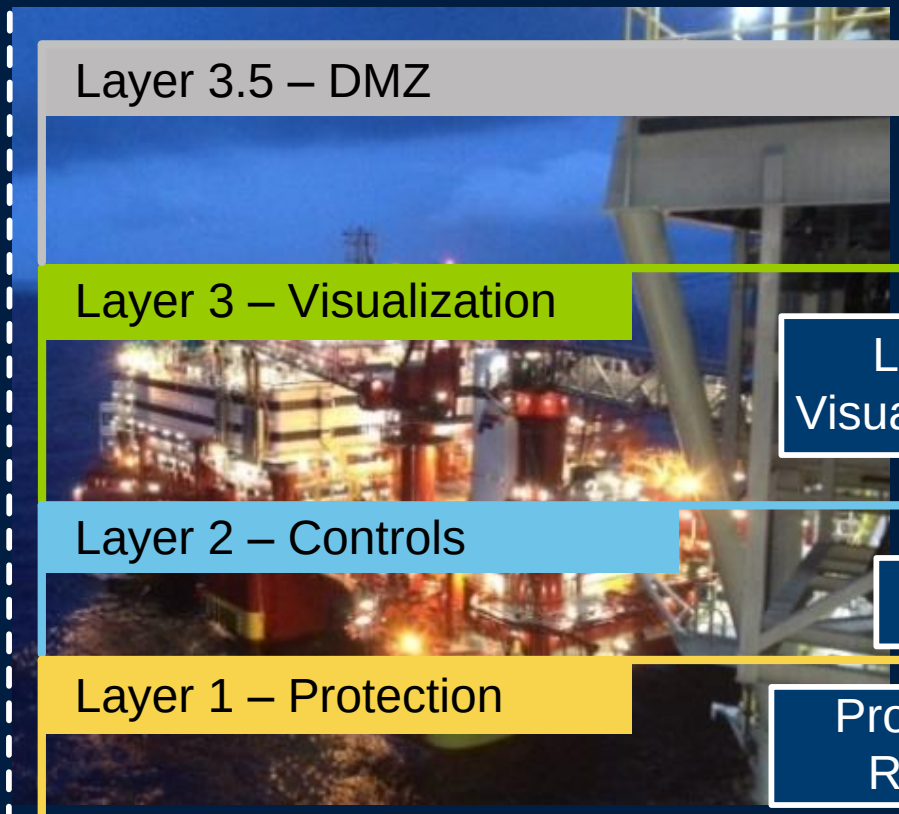


2012 – Chevron Jack and St. Malo Offshore Platforms

In-Depth Cyber Security Required to Be Scaled Down for Remote Facility

Layer 3.5 – Business Networks

Physical Security Perimeter



Layer 3.5 – DMZ

Firewalls

Thin Clients

Layer 3 – Visualization

Firewalls

Local Visualization

Engineering Applications

Layer 2 – Controls

Firewalls

Microgrid Controller

Layer 1 – Protection

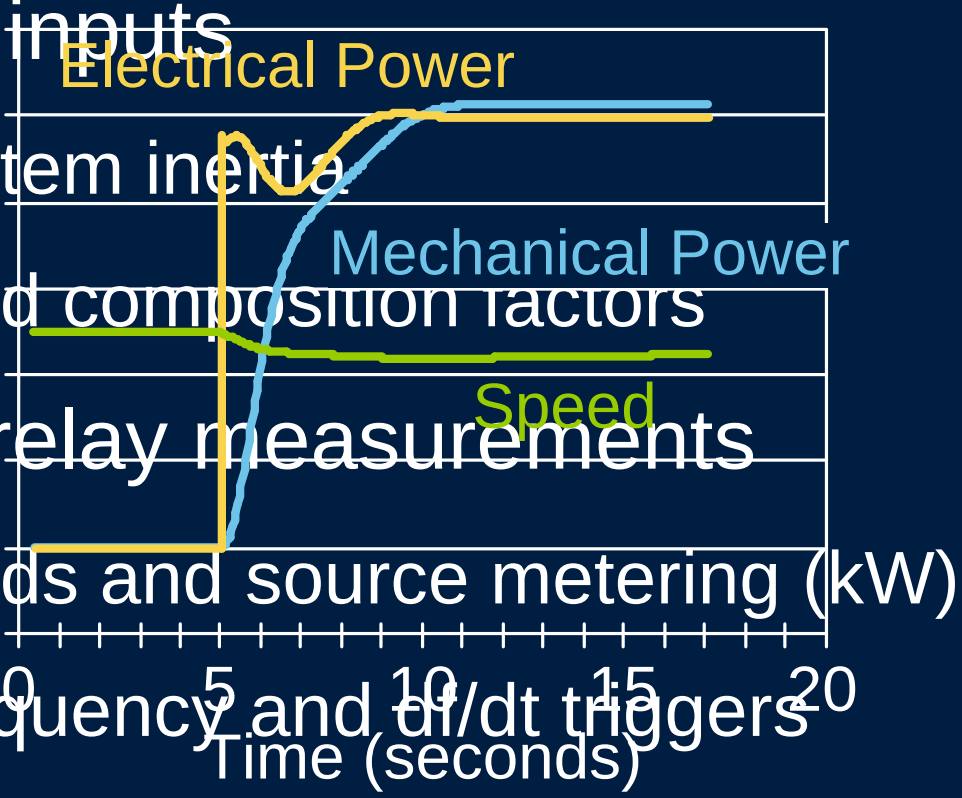
Protective Relays

IO modules

Inertia Compensation and Load Tracking (ICLT)

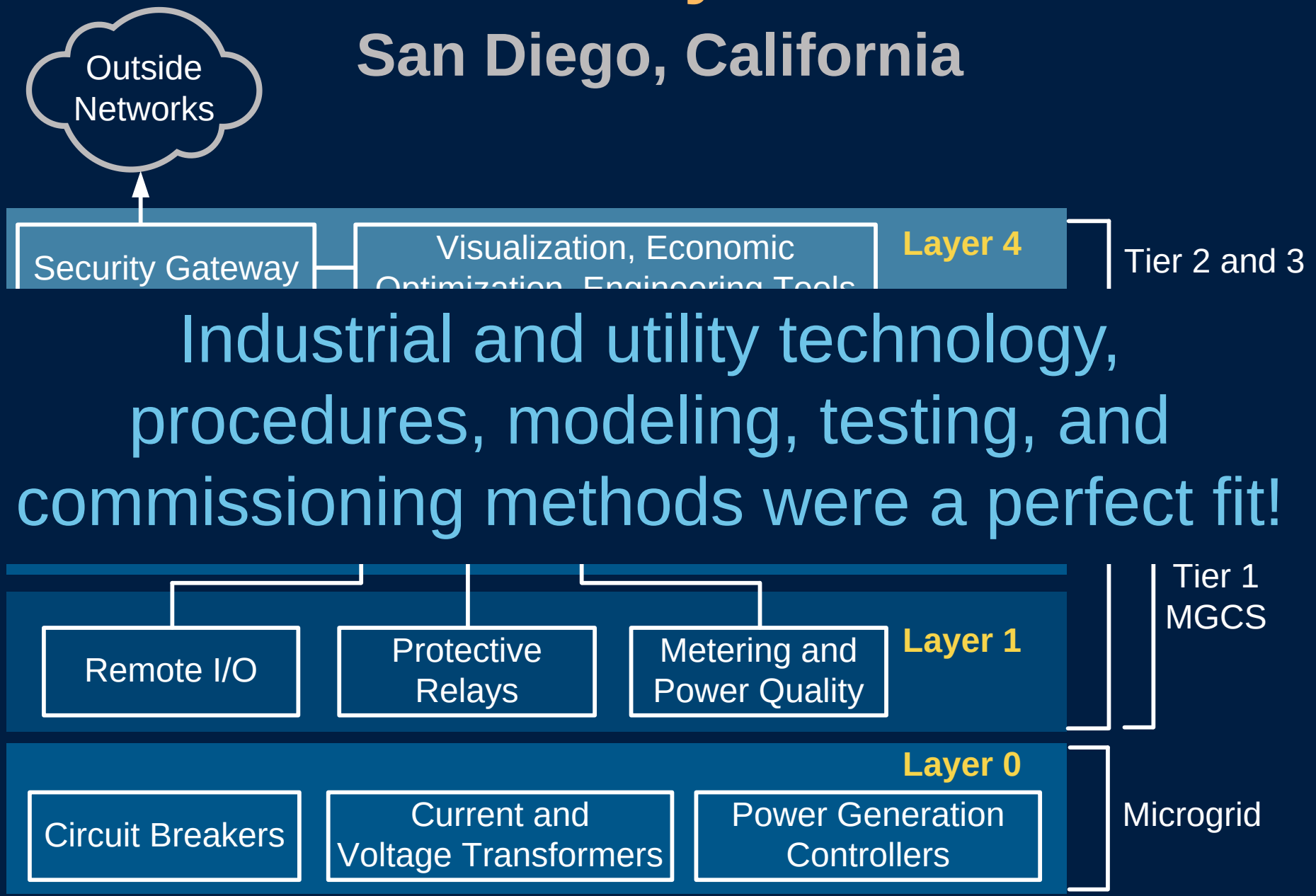
Balances Power Mismatch for Underfrequency Events!

- User inputs
  - System inertia
  - Load composition factors
- Live relay measurements
  - Loads and source metering (kW)
  - Frequency and df/dt triggers



2014 – University of California

San Diego, California

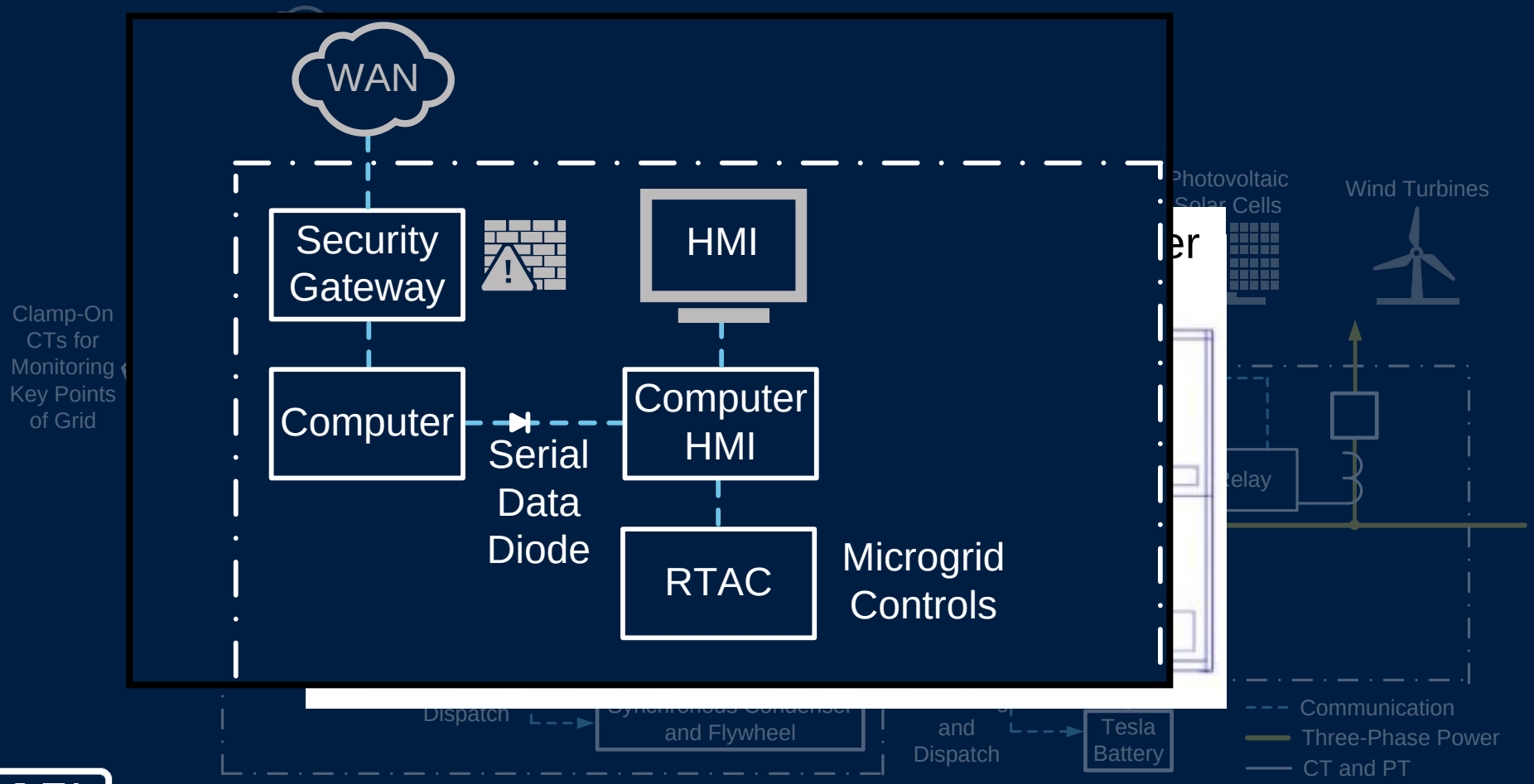


2015 – Borrego Microgrid 2.0

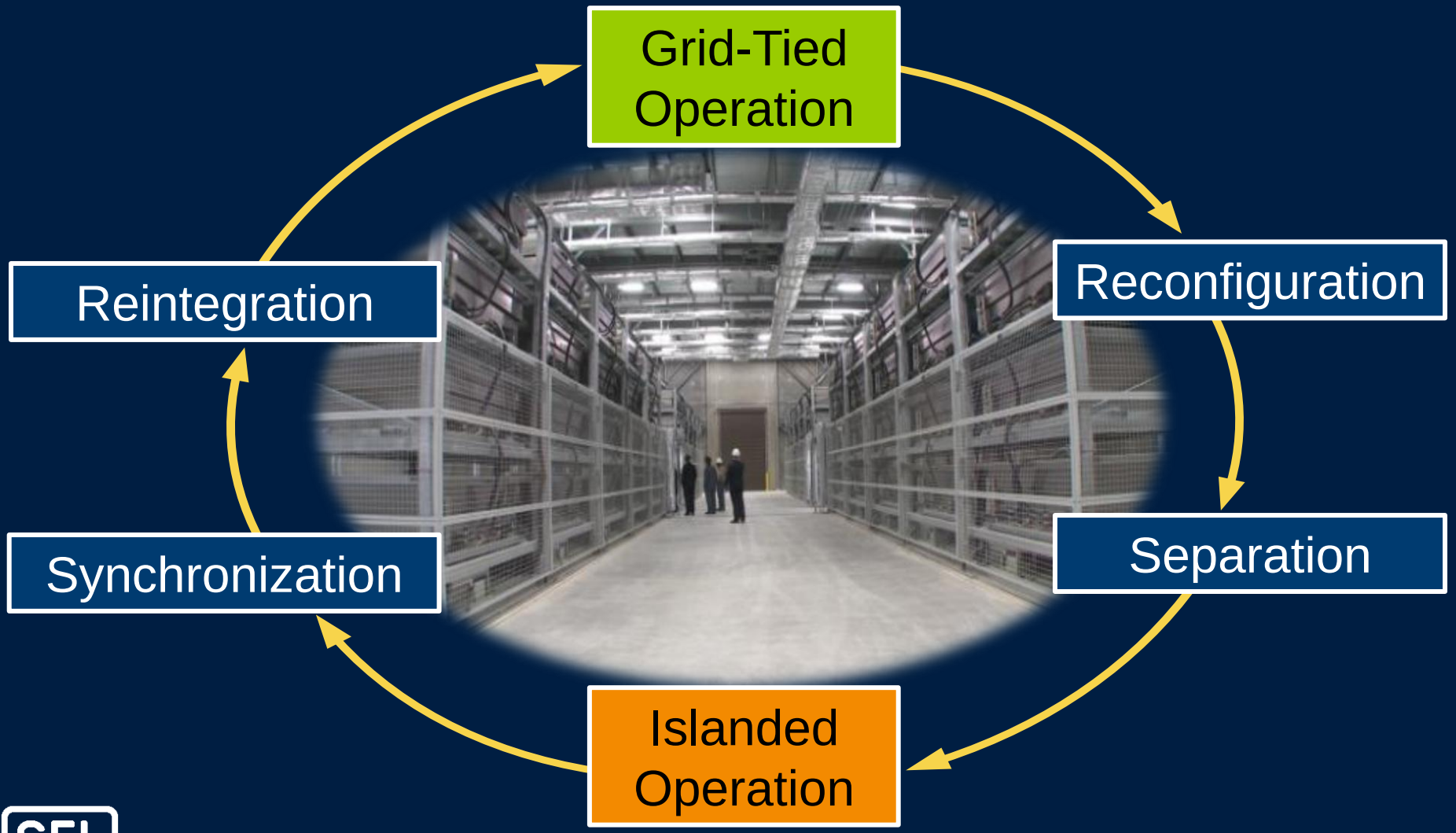
PCC Is Protection Challenge

2016 – Navy Seabees

Microgrid Controls, Protection, and Security Can Be Small and Portable



Modern Microgrids Automatically Separate, Survive, and Synchronize



Questions?

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References

[1] E. R. Hamilton, J. Undrill, P. S. Hamer, and S. Manson, “Considerations for Generation in an Islanded Operation,” proceedings of the 56th Annual Petroleum and Chemical Industry Conference, Anaheim, CA, September 2009.

[2] A. Al-Mulla, K. Garg, S. Manson, and A. El-Hamaky, “Case Study: A Dual-Primary Redundant Automatic Decoupling System for a Critical Petrochemical Process,” proceedings of the 6th Annual Petroleum & Chemical Industry Committee Europe Conference, Barcelona, Spain, May 2009.

[3] S. Manson, A. Upreti, and M. J. Thompson, “Case Study: Smart Automatic Synchronization in Islanded Power Systems,” proceedings of the Power and Energy Automation Conference, Spokane, WA, March 2013.

[4] S. Manson, A. Khatib, M. Checksfield, and P. Duffield, “Case Study: Simultaneous Optimization of Electrical Grid Stability and Steam Production,” proceedings of the 61st Annual Petroleum and Chemical Industry Technical Conference, San Francisco, CA, September 2014.

[5] S. Manson, G. Zweigle, and V. Yedidi, “Case Study: An Adaptive Underfrequency Load-Shedding System,” proceedings of the 60th Annual Petroleum and Chemical Industry Technical Conference, Chicago, IL, September 2013.

[6] S. Manson, B. Kennedy, M. Checksfield, “Solving Turbine Governor Instability at Low Load Conditions,” proceedings of the 62nd Annual Petroleum and Chemical Industry Technical Conference, Houston, TX, October 2015.

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