Unlocking V2G: Opportunities and Challenges for EV Integration

Insights from Keysight's Grid-Edge Experts

Unlocking V2G: Opportunities and Challenges for EV Integration

Meet the team

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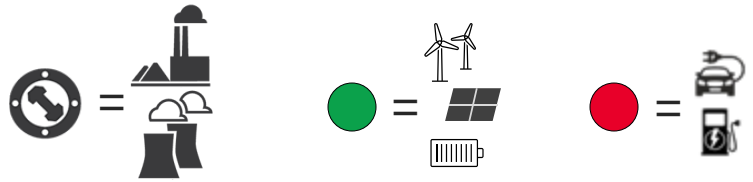
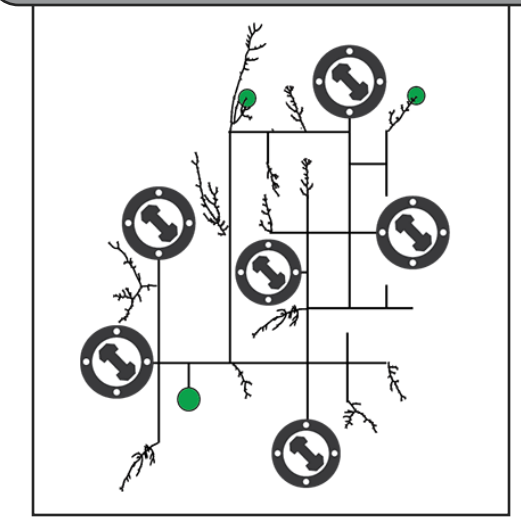
Agenda

1. Evolving grid architectures
2. Balancing the grid with DERs and EVs
3. Digitizing the smart grid
4. Testing grid integration
5. Anti-islanding and grid-code compliance
6. Questions and answers

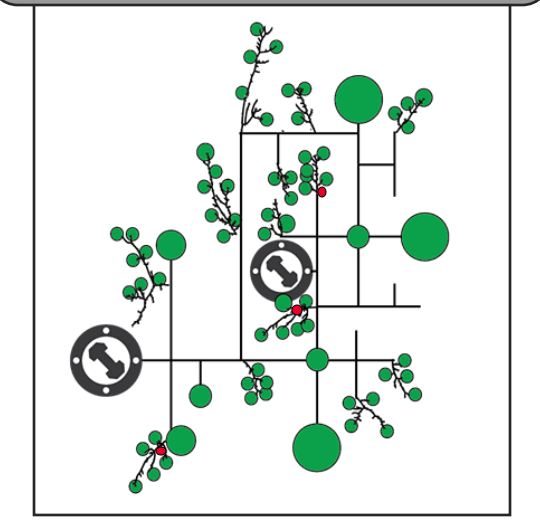
Growing Complexity of Grid Management



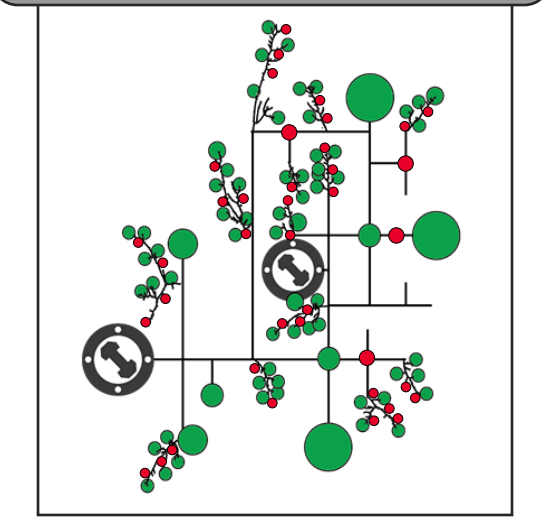
Vast majority of generation provided by **large central synchronous generators**. Unidirectional power flow.



High penetration of inverter-based DERs in the form of wind, solar, and stationary storage. Bidirectional power flow.

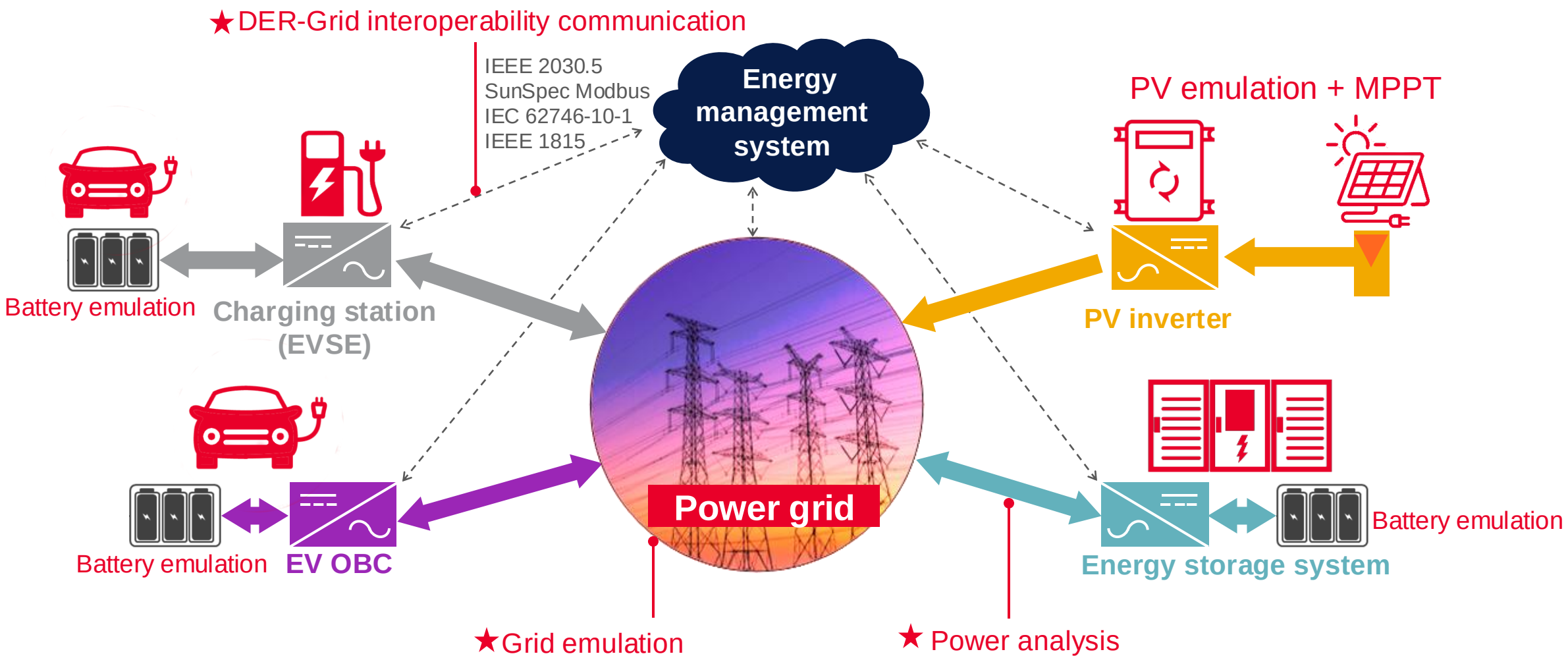


Mass adoption of EVs = higher DER penetration. Widespread private + commercial EV charging infrastructure.



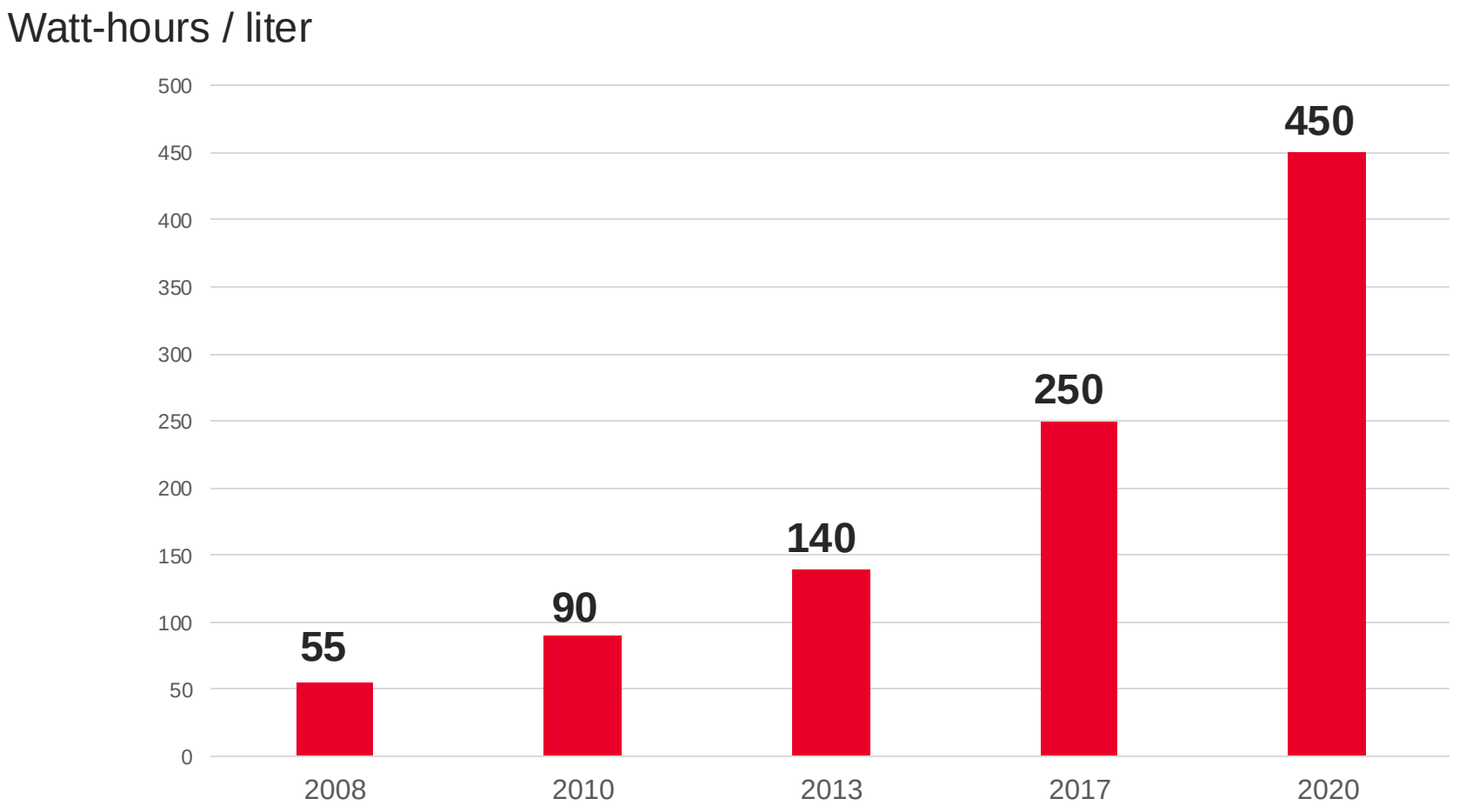
LOW **Management complexity and risk of security, variability, and congestion** **HIGH**

“Smart” Inverters = Enormous Growth in Test Needs



★ = common need for all DER inverter types

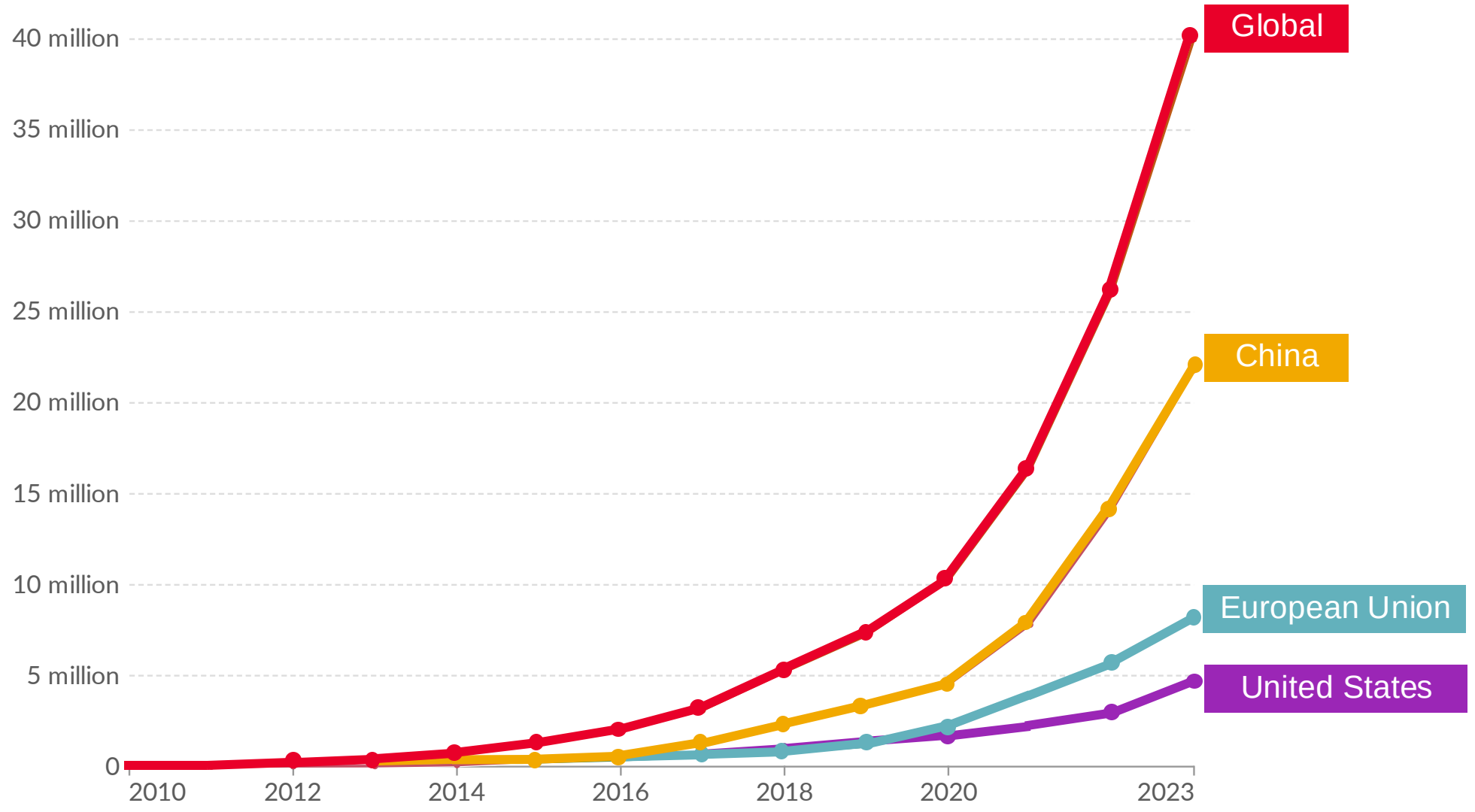
Energy Density of Lithium-ion Battery Packs



Energy density of Lithium-ion battery packs, 2008 — 2020

(Source: N. Muralidharan, et al., Advanced Energy Materials, 2020)

Number of EV's On The Road

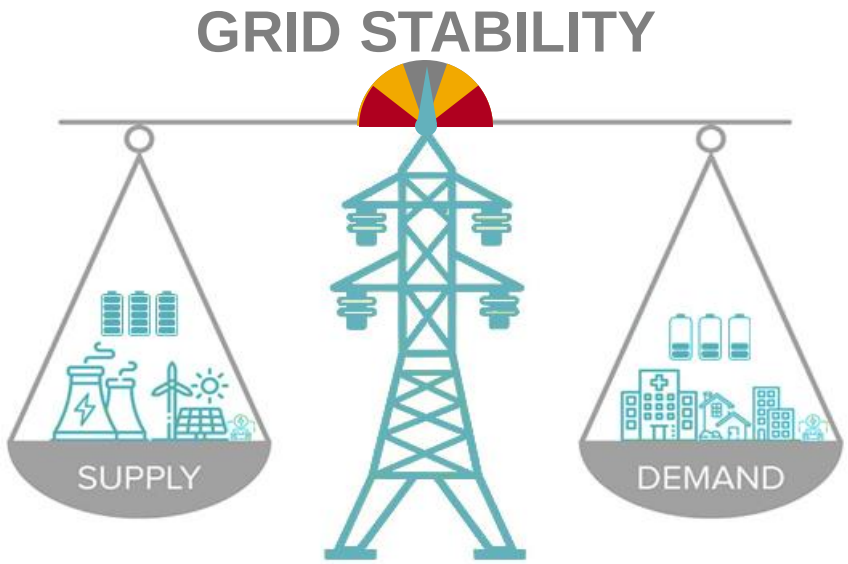


Data source: IEA Global EV Outlook 2024 | OurWorldinData.org | CC BY

Challenge: Balancing the Grid in a DER + EV World

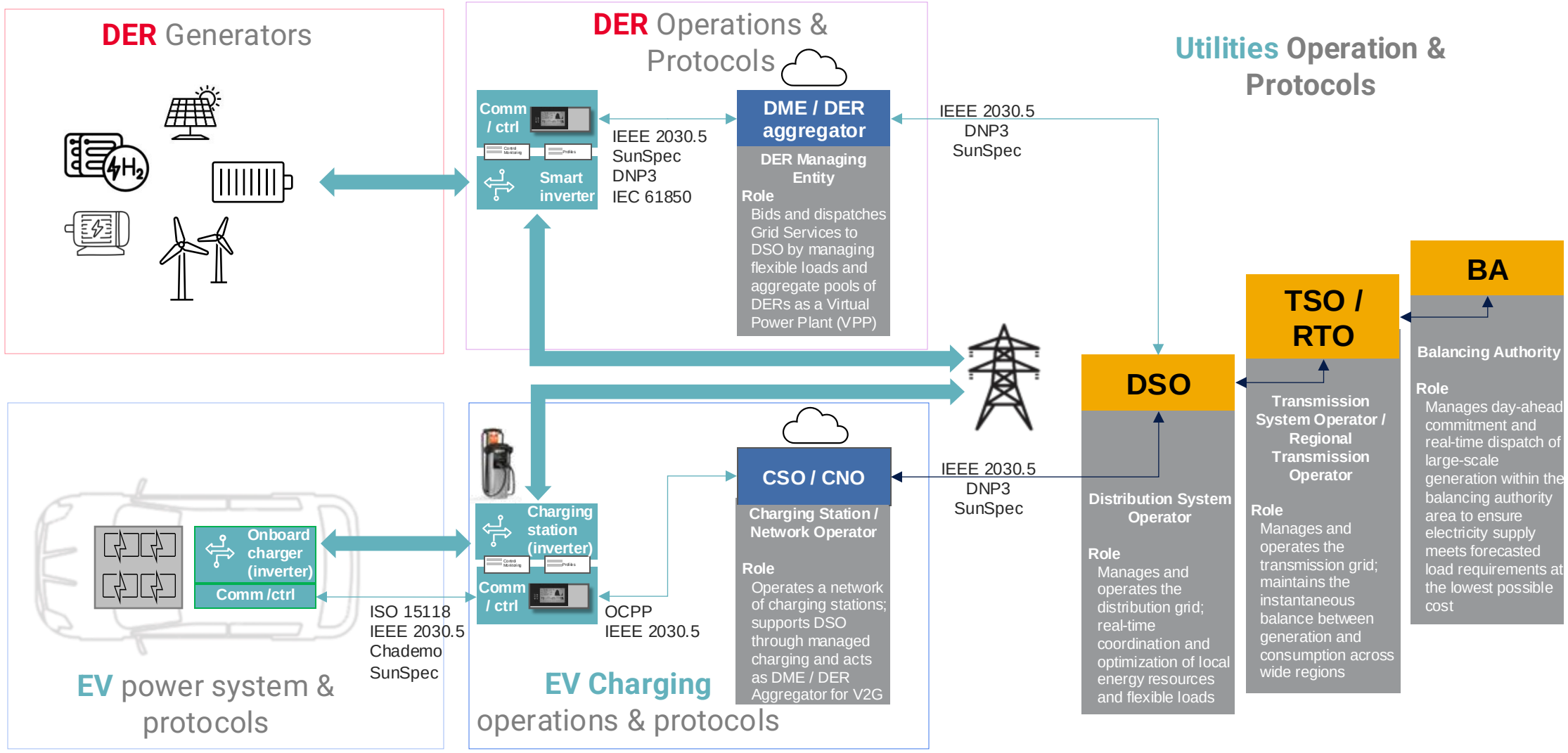
Managing the Modern Grid

CAUSE	EFFECT
Higher proportions of **renewables**	More **variability** in grid power sources
Decentralized architecture	**More** energy **assets** = more **difficult to manage**
Mass adoption of EVs, fast chargers	Large **unpredictable** electricity **demand**
Transition to **inverter-based resources**	Greater **concern** for grid **power quality issues**



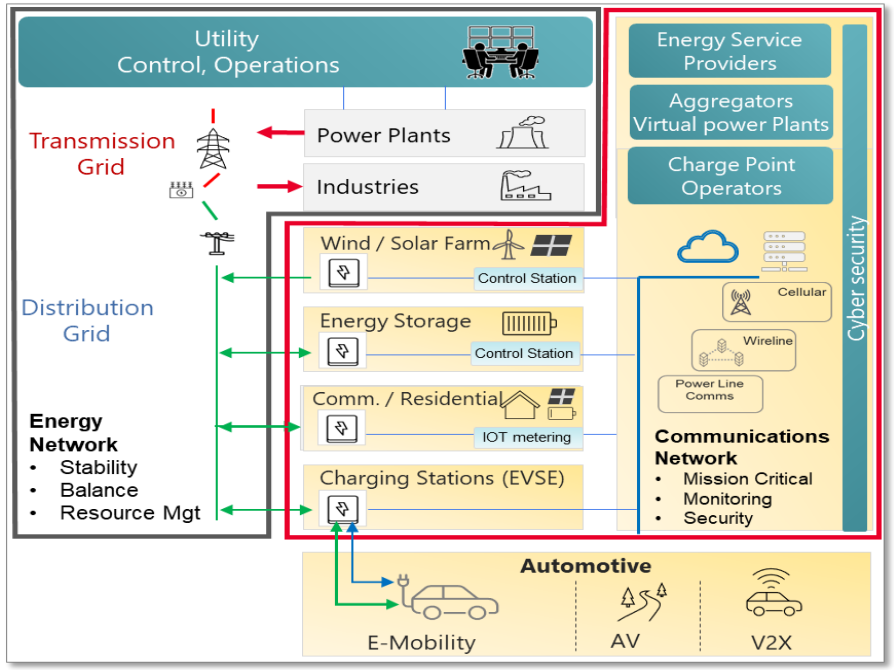
Transitioning to new grid architectures risks stability, reliability of the power grid
New solutions are needed to minimize risks of grid modernization

DER Management and Grid Operation



Electric Grid Digitalization

Software Companies
Distributed Energy
Resource Management (DERM)



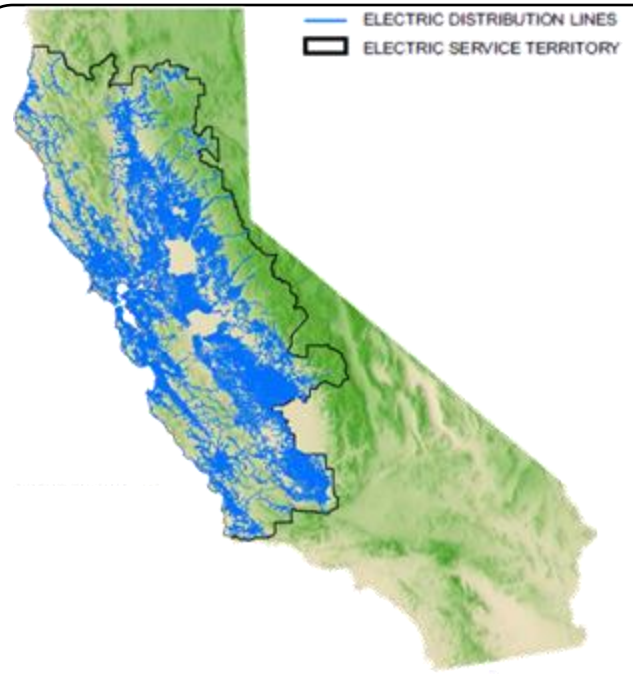
Oil Companies
Migration towards
Energy Aggregation
And delivery Business

Network Equipment Manufacturers (NEMS) & Wireless Companies
Investment in V2X & Energy

Grid Equipment manufacturers expanding into EVSE

Automotive Manufacturers
Investment in Electric
Ecosystem, Charging,
Storage

V2G-Capable EVs/EVSEs as an Asset to Grid Operators and EV Owners



Pacific Gas and Electric (PG&E), California

- 3rd largest utility in US (metric: electricity sold)
- Population served: *16 million people*
- Peak electricity demand: *21 GW*
- Registered EVs: *~ 670,000 as of Feb-2024*
- *New EV's being added as DER's: ~ 13,000 per month*
- **Cumulative mobile energy storage: *~45 GWh***

Data Source + Image Credit: PG&E, DistribuTECH 2024

Proliferation of Advanced Grid Codes for DERs / Digitalization

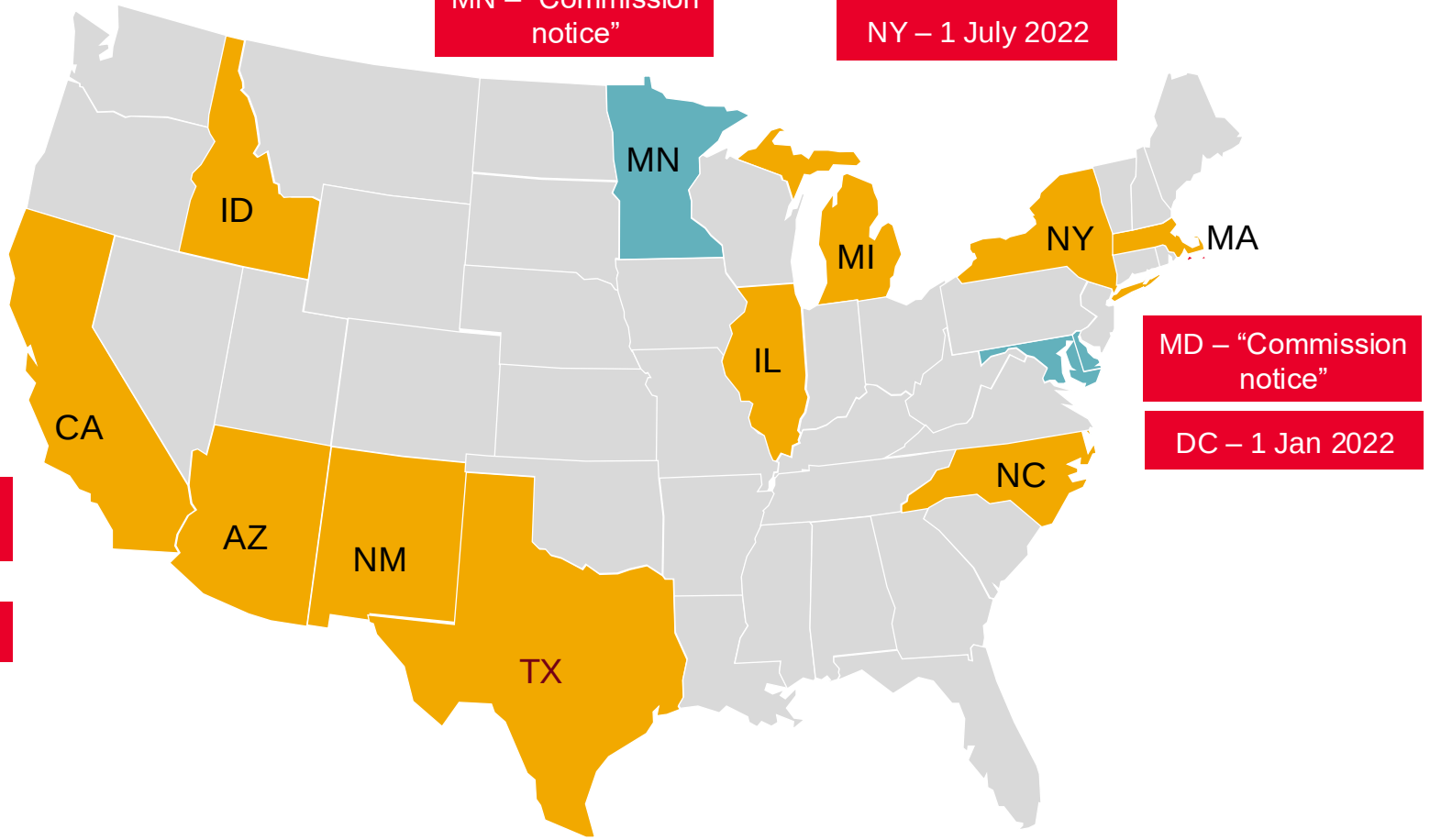
April 2021 – States adopting IEEE Standard 1547-2018

Inquiry or open docket

Completed order, not yet enforced

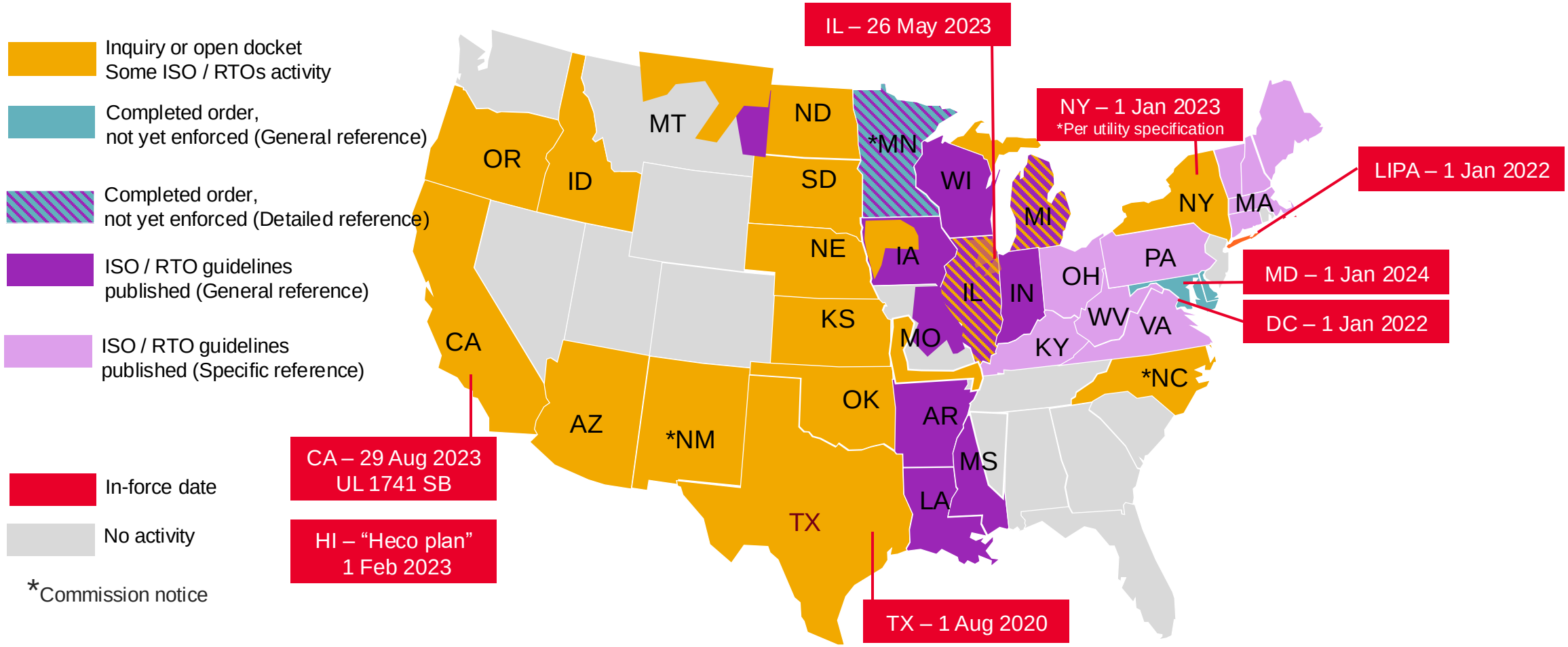
No activity

In-force date



Proliferation of Advanced Grid Codes for DERs / Digitalization

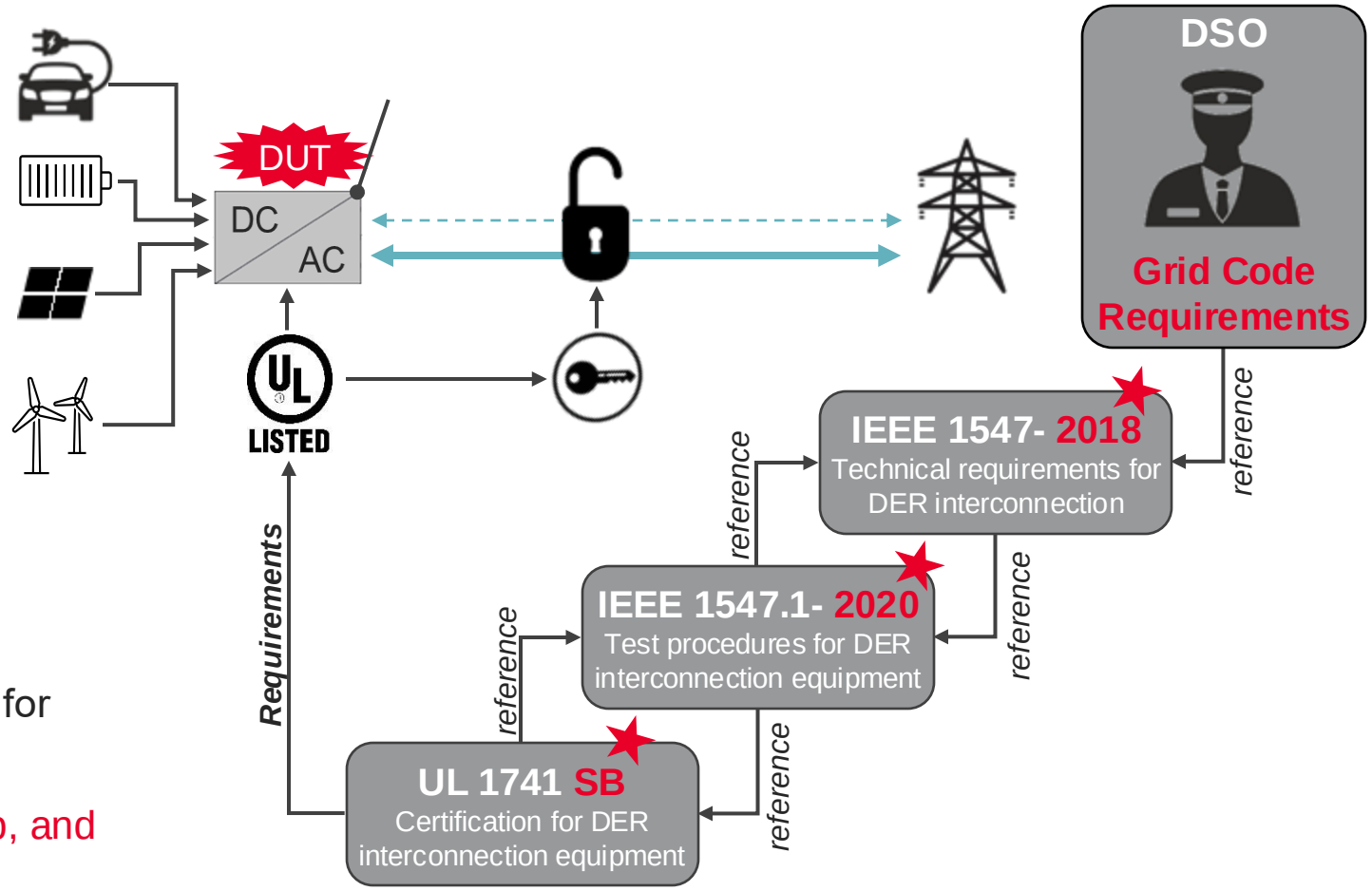
Jan 2024 – States, ISO / RTOs, and utilities adopting IEEE Standard 1547-2018



New Grid Code Requirements for Enabling Grid Modernization

NEW GRID CODE REQUIREMENTS

- Shall be capable of **actively regulating voltage**
- Shall be capable of **frequency response**
- Shall ride through **abnormal voltage / frequency**
- May provide inertial response
- Shall provide local **interface for communicating with DER managing entity (DME)**

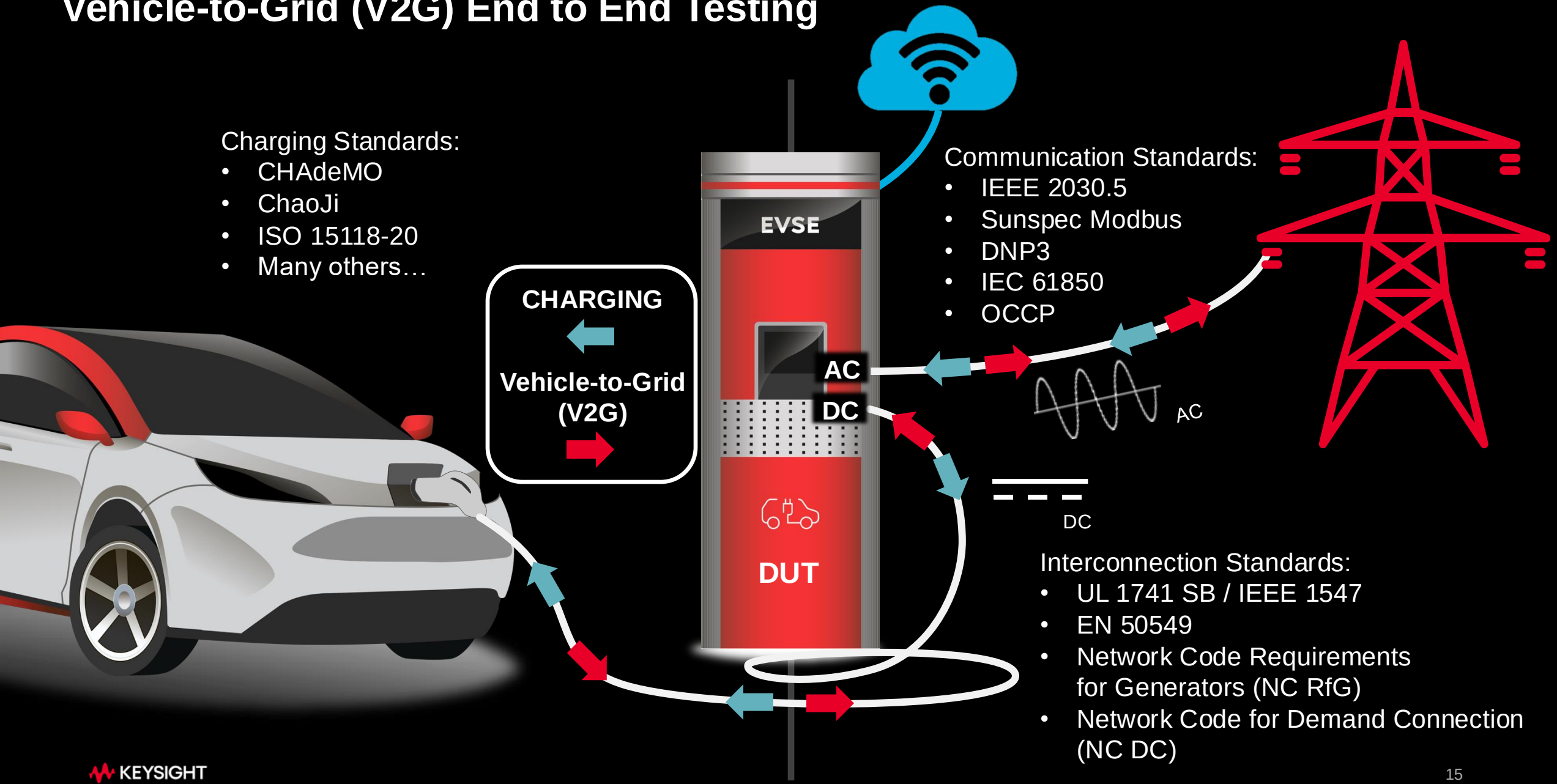


Grid operators set very strict rules (“grid codes”) for connecting DERs to the grid

DER device manufacturers must design, develop, and certify their products to meet the standards referenced in grid codes

Vehicle-to-Grid (V2G) End to End Testing

Charging Standards:
- CHAdeMO
- ChaoJi
- ISO 15118-20
- Many others…

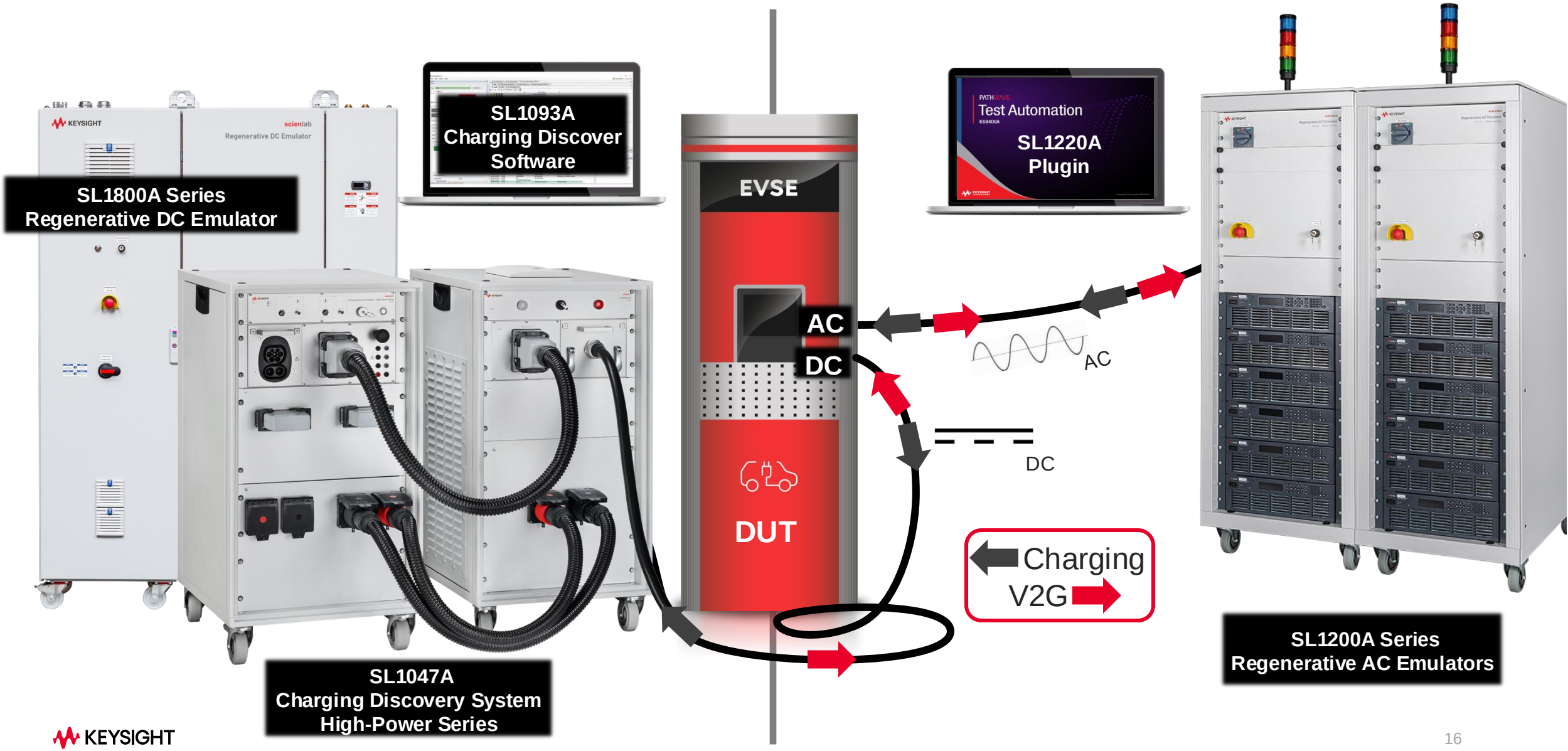


Communication Standards:
- IEEE 2030.5
- Sunspec Modbus
- DNP3
- IEC 61850
- OCCP

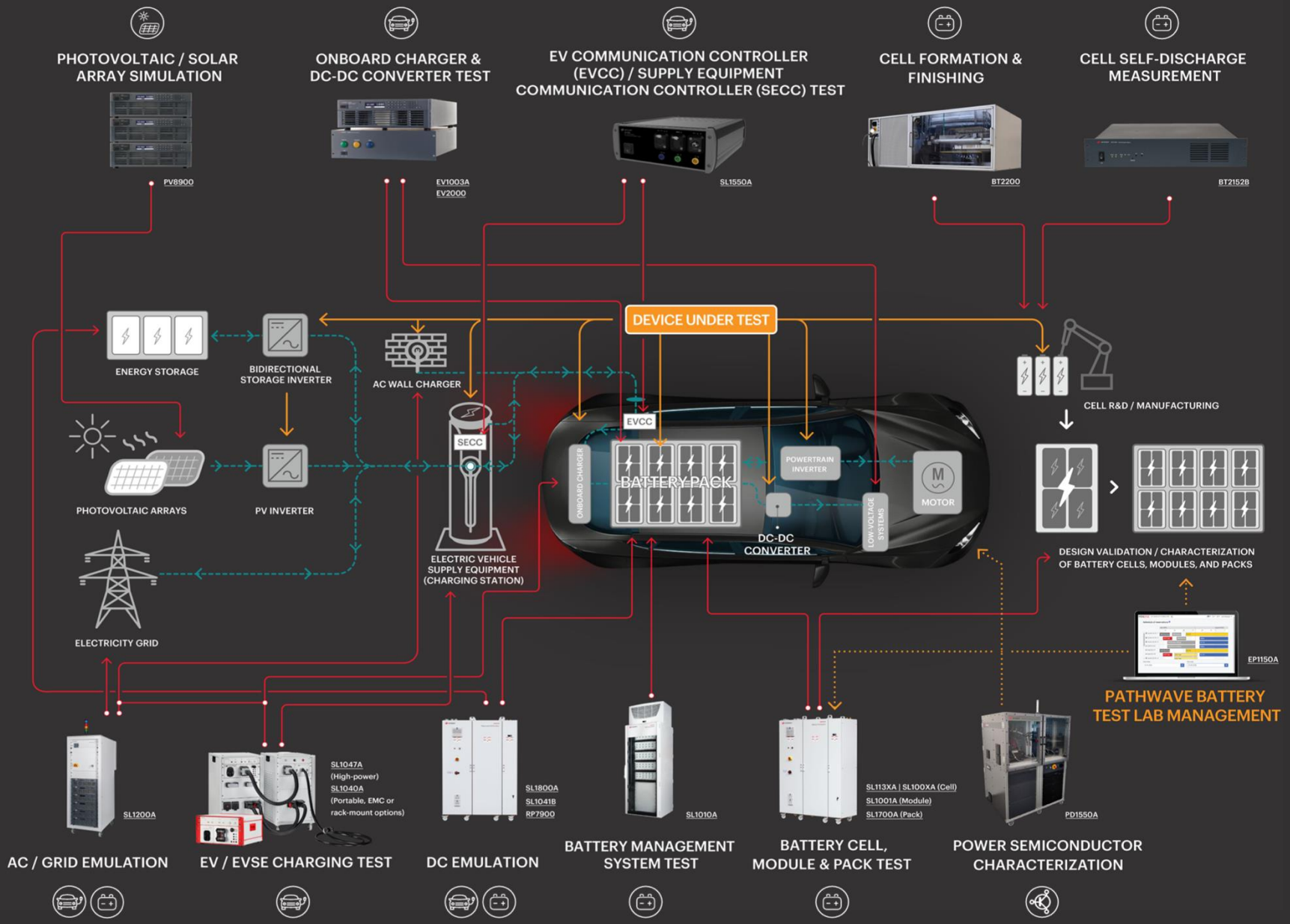
Interconnection Standards:
- UL 1741 SB / IEEE 1547
- EN 50549
- Network Code Requirements for Generators (NC RfG)
- Network Code for Demand Connection (NC DC)

Keysight's end-to-end EV portfolio accelerates your path to V2G

Speed Through Regulatory Challenges of Connecting EVs and EVSEs to The Grid



Advancing the E-Mobility Ecosystem



KEYSIGHT

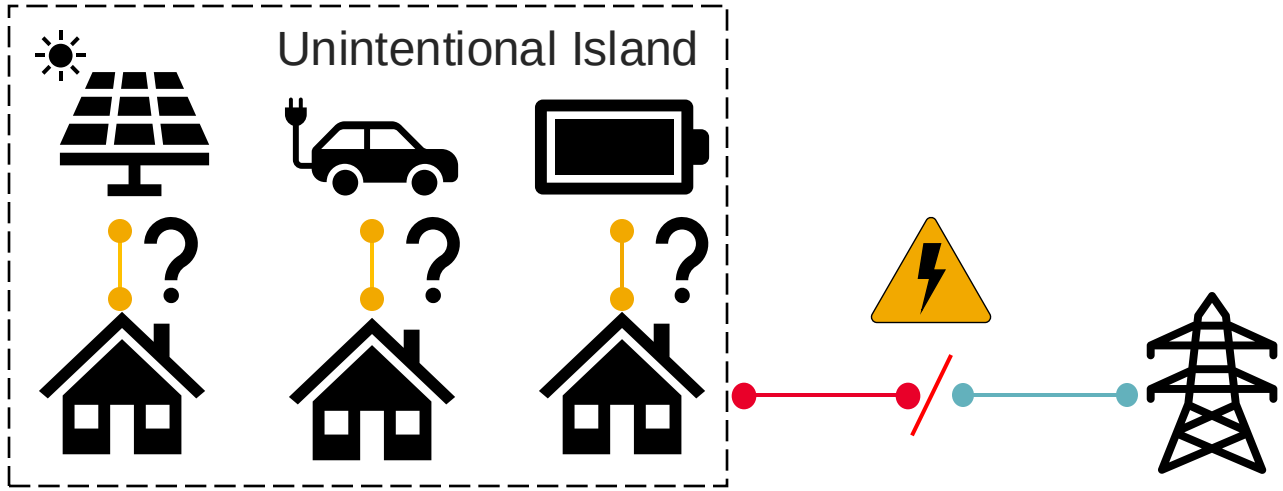
Achieving Anti-Islanding Protection

An innovative approach for IEEE 1547.1-2020 /

UL 1741 SB anti-islanding compliance testing

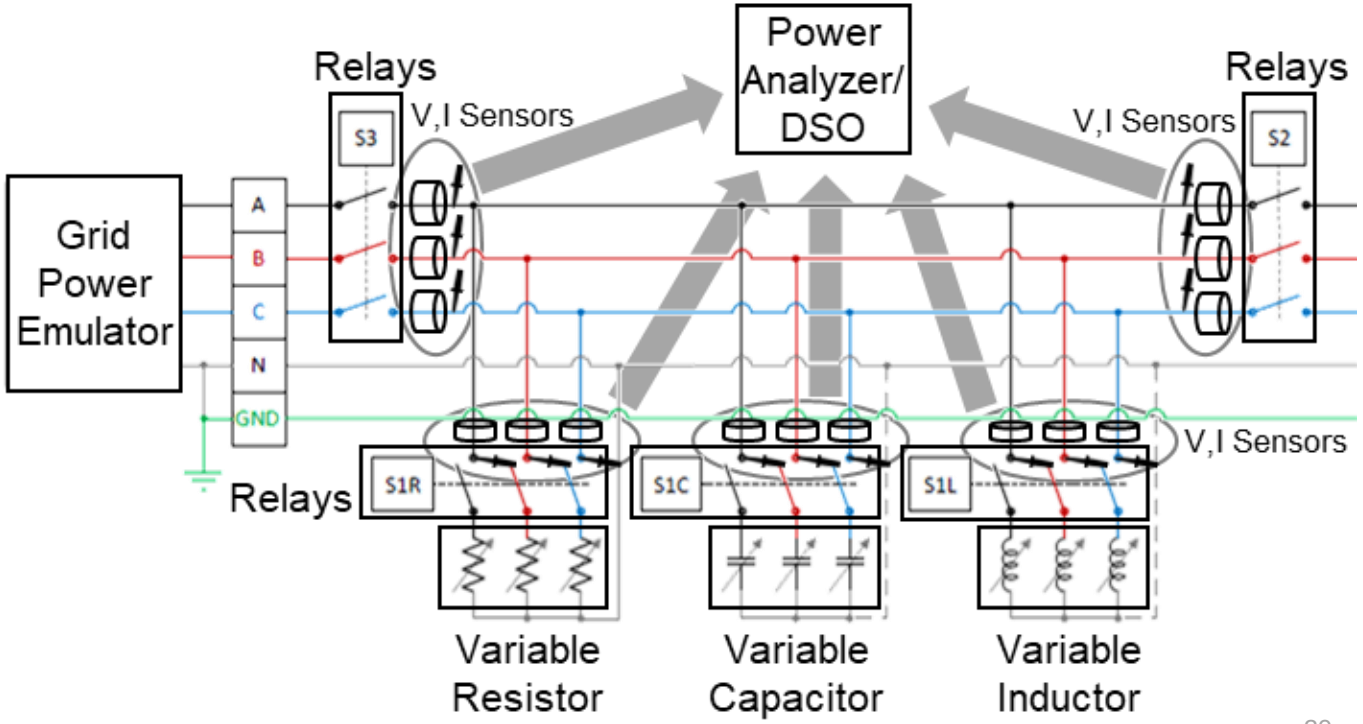
Anti-islanding and Grid Code Compliance

- Island = A portion of an electric grid which has been disconnected from the rest of the grid but is still energized with both sources and loads
- Unintentional Island = island that has been disconnected by accident, most commonly by damage to electrical infrastructure
- Risks
  - Lines are still energized and present a hazard to line workers
  - Island cannot be added back to the main grid



Traditional Test Setup – IEEE 1547.1-2020 Section 5.10

- Large set of equipment
  - Grid emulator
  - RLC load or separate R, L, and C loads
  - Power analyzer with sensors and transducers
  - Multiple relays
- Many moving pieces
  - Adjustment of RLC elements
  - Acquisition of Data
  - Relay control
  - Programming of DUT



Source: IEEE 1547.1-2020 Fig. 7

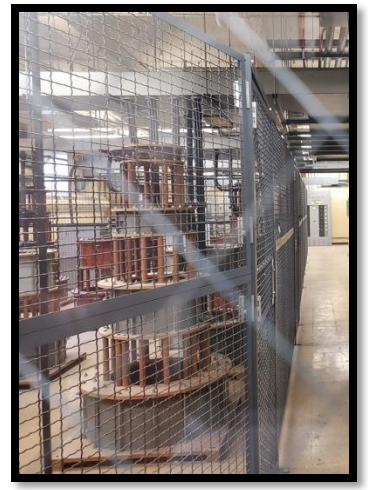
Anti-Islanding Testing at UL Solutions – **Before Keysight Solution**

Accelerating Grid Code Compliance Testing

- **3** engineers / technicians
- **4** rooms of lab space
- **1** 3ph capacitive load
- **6** 1ph inductive loads
- **3** 1ph resistive loads
- **1** grid emulator
- **1** DC power source
- **4** data acquisition units
- **numerous** sensors + relays
- **significant** wiring / infrastructure
- **100%** manual test process

IEEE 1547.1-2020 / UL 1741 SB anti-islanding testing typically takes ***2+ weeks***

Manual Capacitor Tuning



Manual Inductor Tuning

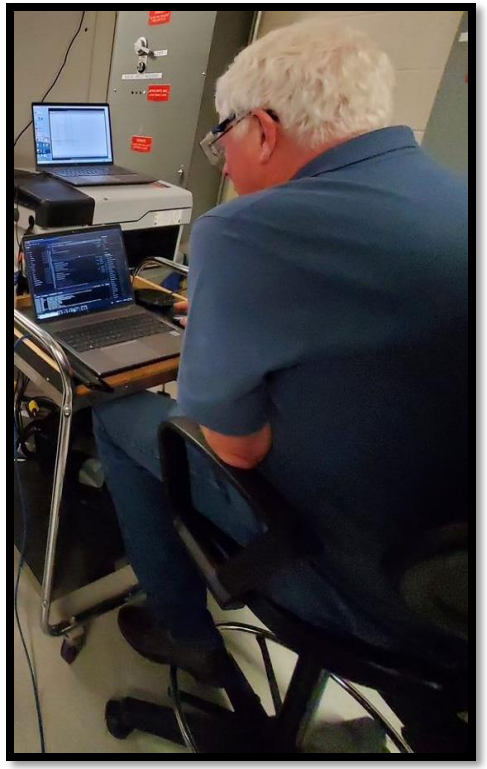
Anti-Islanding Testing at UL Solutions – **After Keysight Solution**

Accelerating Grid Code Compliance Testing

- **1** engineer / technician
- **1** DC source
- **1** SL1200A series grid emulator
- **1** SL1221A test automation SW

IEEE 1547.1-2020 / UL 1741 SB anti-islanding testing in as little as **4hrs**

FASTER, CHEAPER, EASIER



95%+ less equipment

95%+ time savings

85%+ electricity savings

85%+ less heat removal

95%+ space savings

66% less personnel

Based on side-by-side testing at UL Solutions in Northbrook, IL

WHAT IS IT:

- Automated, optimized implementation of power hardware-in-the-loop (PHIL); simplifies and accelerates IEEE 1547.1-2020 anti-islanding testing for UL 1741 SB certification.
- Re-uses SL1200A grid emulator as power amplifier for simulated anti-islanding subsystem; no other HW needed.
- UL-validated test solution; being deployed at UL facilities for official IEEE 1547.1-2020 testing / UL 1741 SB certification.

A New Solution for Anti-Islanding Testing per 1547.1-2020 / UL 1741 SB

Grid Code Compliance

FASTER – Reduces anti-islanding test time from days/weeks to hours.

CHEAPER – Eliminates expensive infrastructure and reduces lab real estate.

EASIER – Simple test setup, one-click automation, automatic pass/fail verdict and test reports.

PROVEN – Tested with leading US NRTL; goal of putting into practice for US grid codes.

NEW!

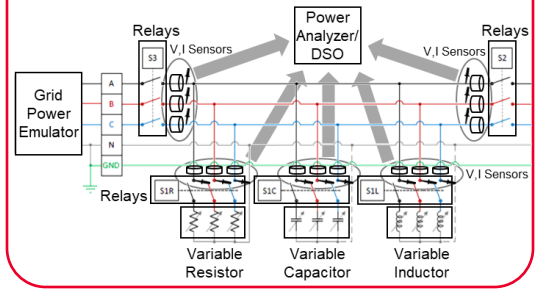
***SL1221A** Anti-Islanding Test Automation Software*

Anti-islanding standard test case automation with patent-pending virtual RLC auto-tuning

Grid Communication Protocol – Configure DER Settings

Power System Control and Measurement Data

Anti-islanding test circuit model

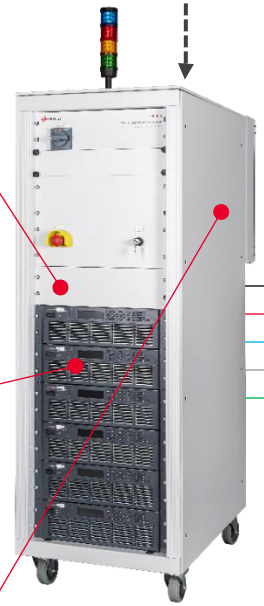


FPGA-based real-time simulation

4Q bidir. regen. power stages

High-accuracy V,I sensors

P-HiL

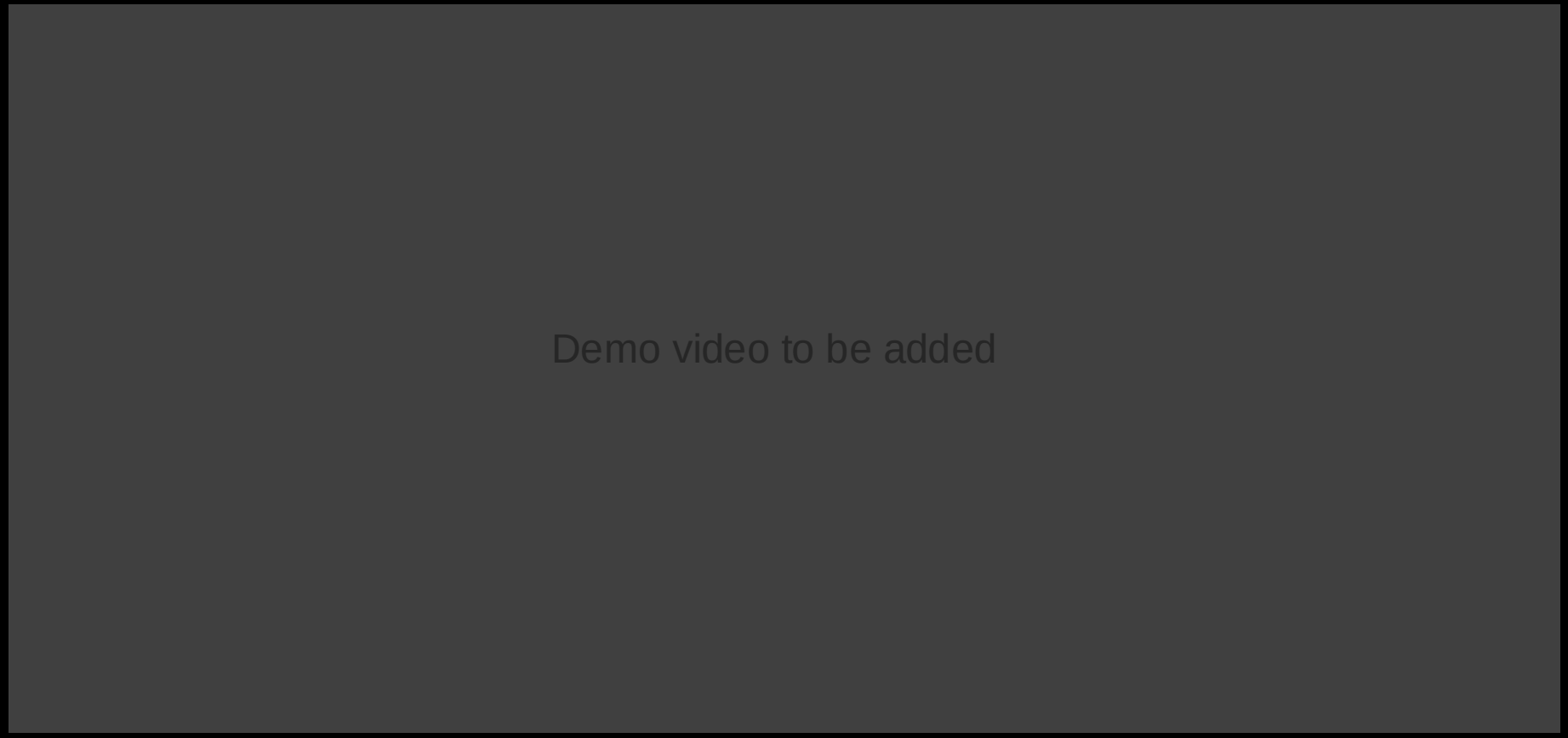


SL1200A Series Grid Emulator

Anti-Islanding Subsystem Emulator

SL1040A + RP7900A Series Battery Emulator = EV Emulator

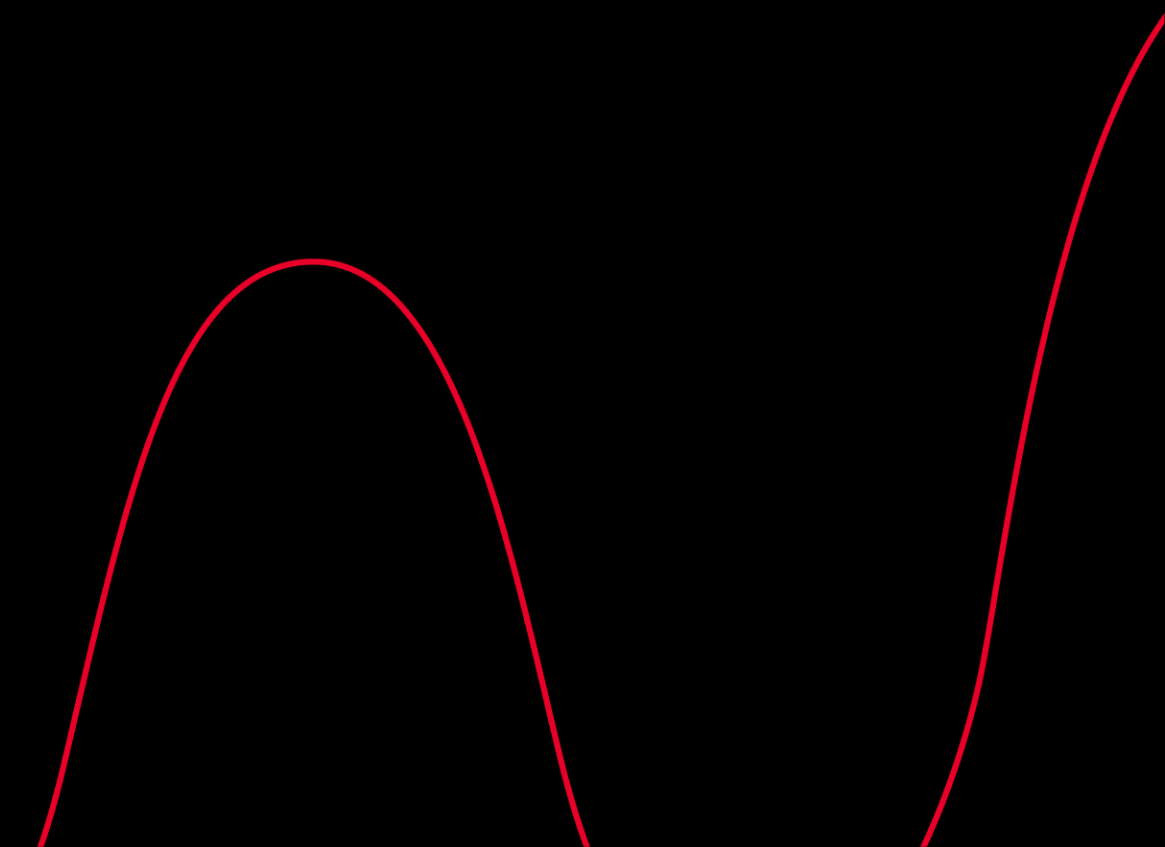
Solution Demo



Questions and Answers

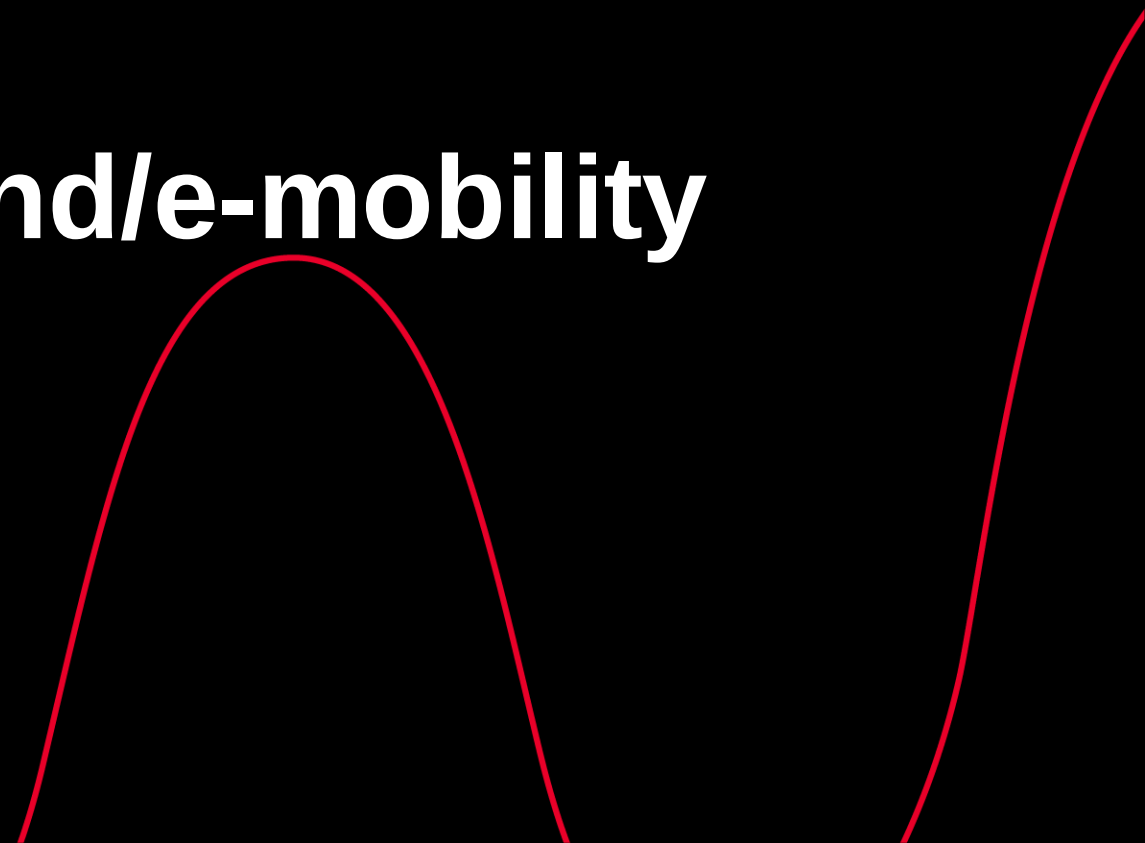
Submit your questions using the Q&A tab

If we do not address your question during the webinar, we will try to follow up via email.



Thank you!

www.keysight.com/find/e-mobility



KEYSIGHT