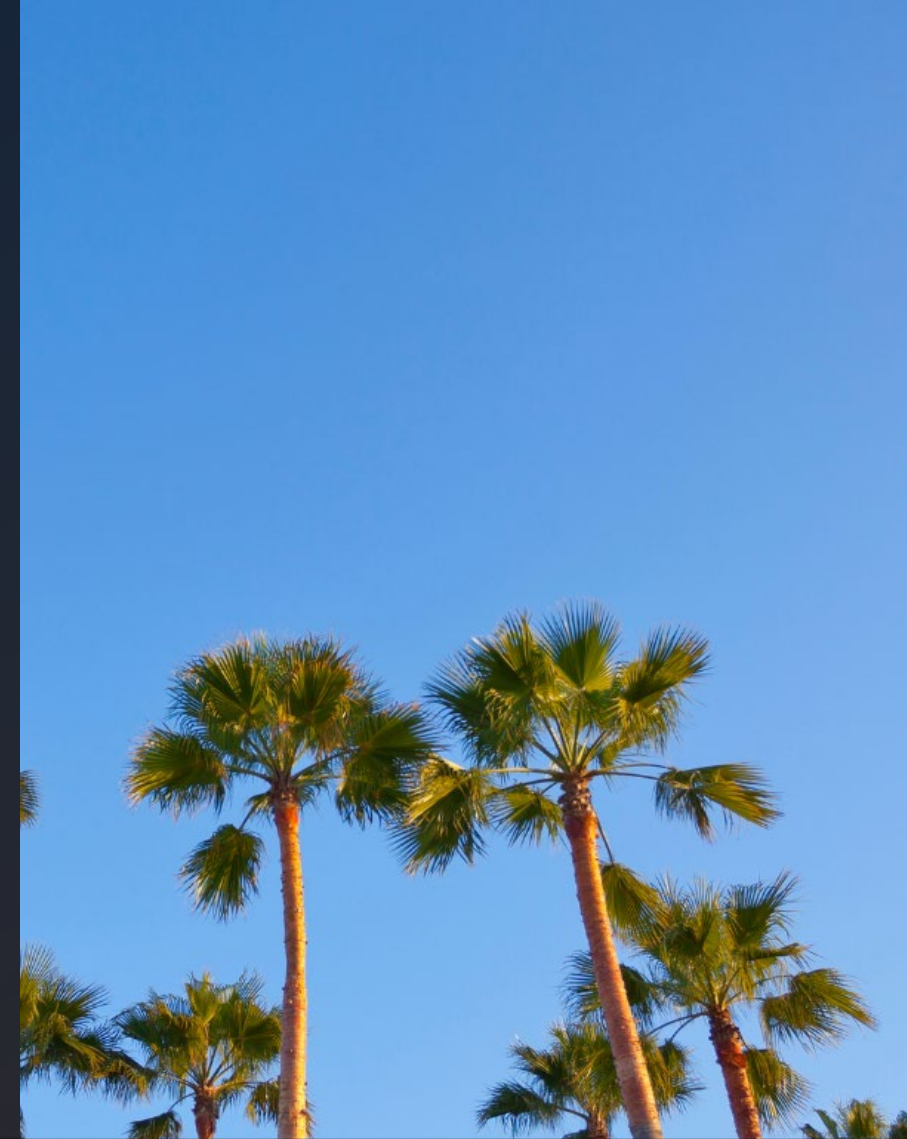


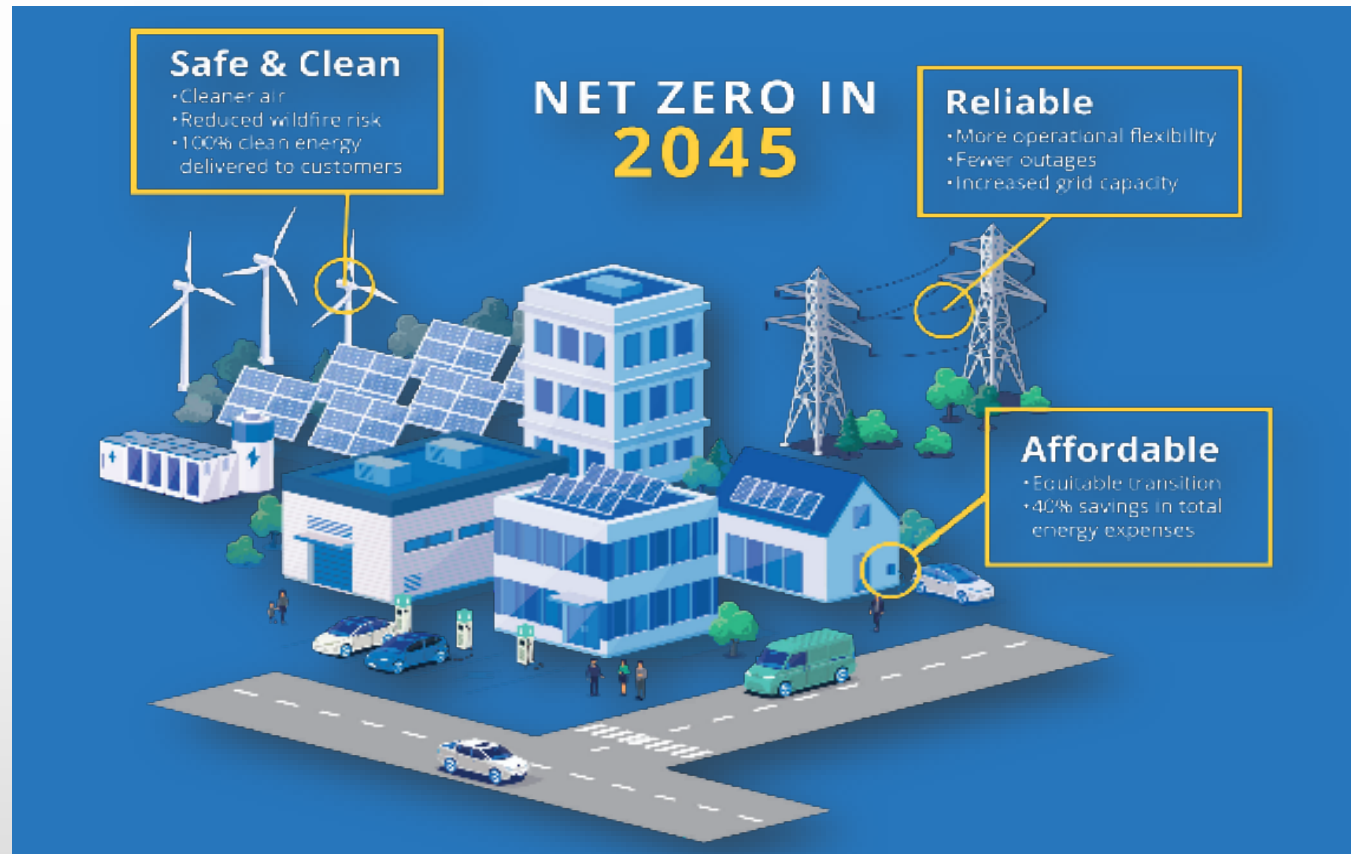
Transforming the Grid to Achieve California's Carbon Goals

► Devin Rauss

Southern California Edison



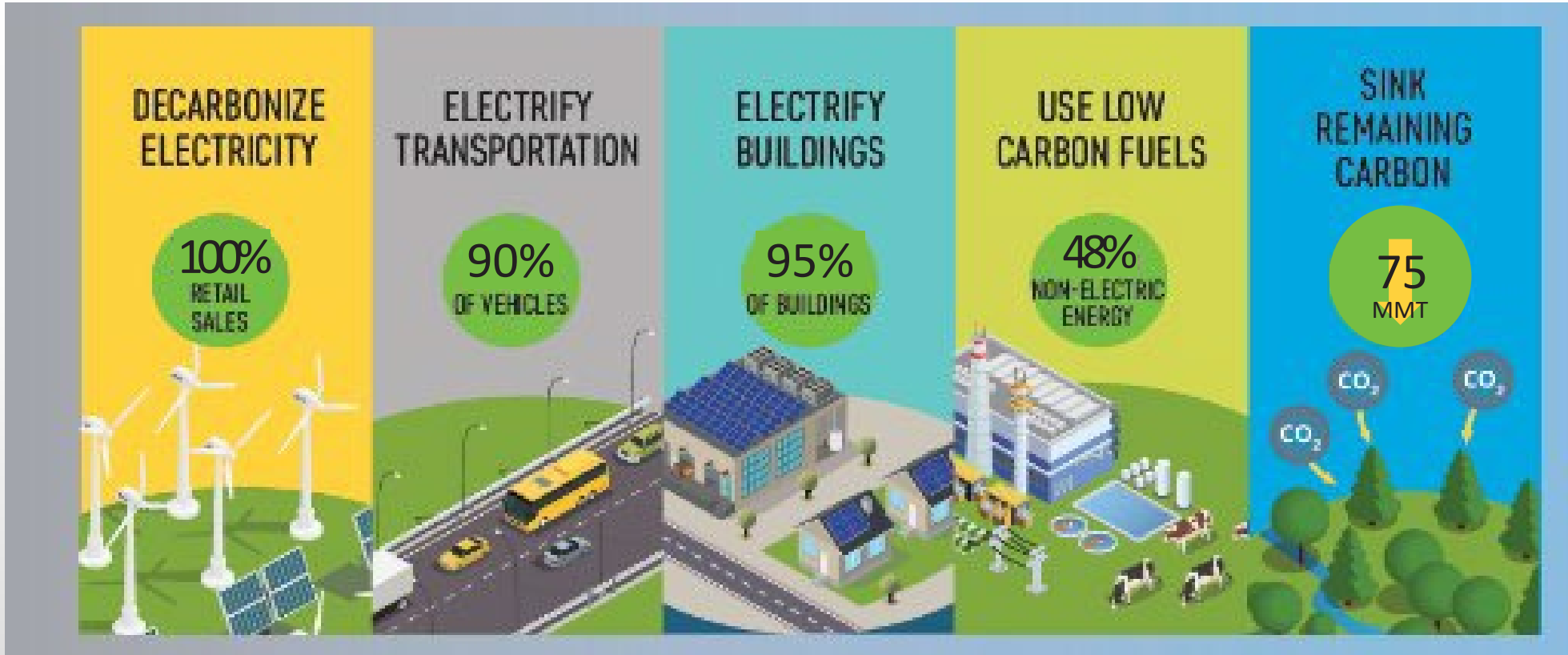
Edison's strategy focuses on a safe, reliable and affordable clean energy future



WHY IT'S IMPORTANT:

- **Clean Electricity:** Essential for nearly all economic sectors to achieve net zero
- **California's Goals:** Relies on the electric grid and clean power delivery by SCE and other utilities
- **Collaboration and Support Needed:** Local, state, and federal support and policies are crucial
- **Edison's Role:** A key player in California's clean energy future, ensuring safety, reliability and affordability

Edison's "Countdown to 2045" vision provides a roadmap for California ...



... and we'll need dramatic change to achieve carbon neutrality

KEY ELEMENTS GRID TRANSFORMATION



READINESS

Quickly increase capacity so the grid can supply electricity whenever and wherever it's needed.

RELIABILITY

Minimize outages as customers become more dependent on electricity.

RESILIENCY

Make our infrastructure resilient to climate change impacts and ensure safety for our communities.

AFFORDABILITY

Invest in expanding and strengthening the grid while keeping bills affordable for many struggling Californians.

These are monumental challenges, but they also present once-in-a-lifetime opportunities.

BIG LEAPS NEEDED TO OVERCOME CHALLENGES

2X electricity demand growth by 2045
~3X current demand in less than 10 years
in some locations



2-3X reduction in load
interconnection timelines



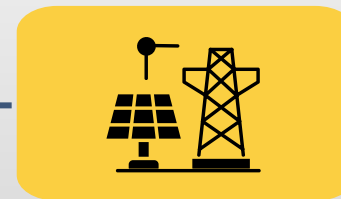
Extreme heat, rain and wildfires are
more frequent, intense and prolonged



10X reduction in outages as
electrification increases

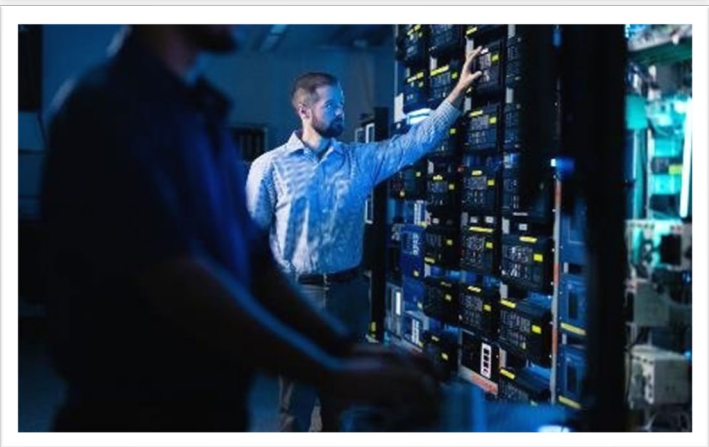
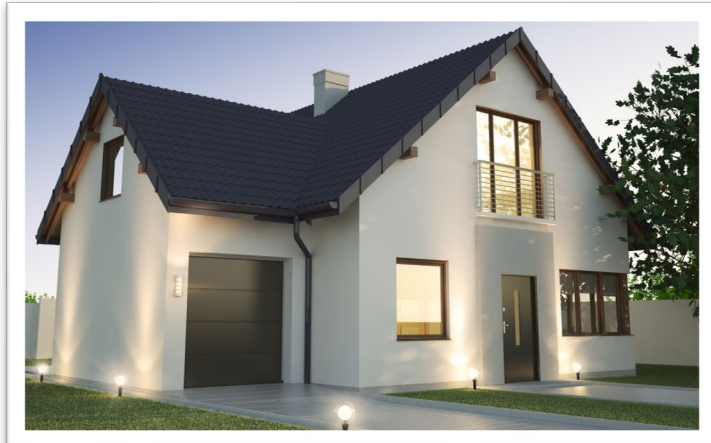


10X reduction in vegetation
and inspection costs



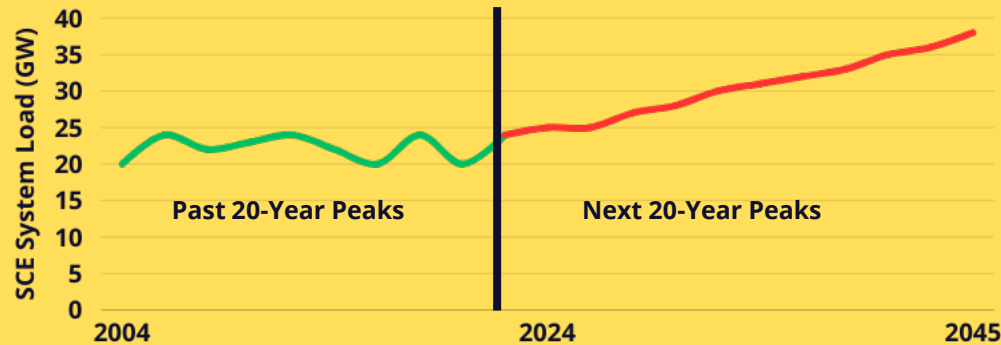
150-200X increase in smart grid and
customer devices to be coordinated

INSATIABLE DEMAND FOR ELECTRONICS



EXPONENTIAL ELECTRIFICATION GROWTH REQUIRES MASSIVE GRID EXPANSION

SCE Historical and Anticipated Peak Loads



Substation Needs

85

New

350

Rebuilt or Expanded

10X

Distribution Growth vs Historical

1,400 new distribution circuits totaling 16.5k circuit miles

4X

Transmission Growth vs Historical

2,100 miles of new subtransmission lines

2,500 miles of new transmission lines

80%

Load Growth Expected By 2045

THE SCALE OF ENERGY DEMAND AHEAD

Demand Drivers, Scenario Ranges, and the Timing Problem



Digital Infrastructure

Large digital and data-driven loads moving faster than the grid was designed to absorb, driven by AI workloads and cloud expansion

20+

TWh Potential Demand



Transportation Electrification

Including heavy-duty freight and fleet charging — projects often don't apply for service until late in development, compressing grid timelines

~75%

EV Adoption by 2045



Building & Industrial Electrification

Statewide push to electrify heating, cooling, cooking, and industrial processes across residential and commercial sectors

80%

Potential Demand Increase



Speed & Shape of Demand

It's not just how much demand — it's the speed and shape. Major transmission and greenfield projects take 10-12 years to plan, permit, and build; timing is the core challenge

10-12

Years for Major Projects

Sources: SCE Reaching Net Zero, Oct 2024; CEC IEPR Data Center Forecast, 2024; Infraday Panel, Apr 2026

HOW MUCH AND HOW FAST

Our ambition isn't the problem — it's timing. Under high-electrification scenarios, demand could rise ~80% by 2045, requiring both new capacity and flexibility while major projects take years to deliver.

80%+

Scenario-based demand increase
by 2045

10-12

Years for major transmission
and greenfield projects

\$41.8B

CPUC-authorized revenue
for 2025-2028

Grid Readiness Timeline

Near-Term 2025 – 2028

Bridging solutions, earlier customer engagement, flexible service connections, targeted substation and circuit upgrades

Mid-Term 2029 – 2035

Major transmission buildout, compact higher-capacity substations, grid-enhancing technologies, storage integration at scale

Long-Term 2036 – 2045

Full grid transformation for net-zero, clean firm generation, flexible demand orchestration

Sources: SCE Reaching Net Zero Analysis, Oct 2024; CPUC 2025 General Rate Case Decision; SCE IEPR Demand Forecast Filing, 2024

PHYSICAL GRID SOLUTIONS

Targeted investments in capacity, resilience, and clean energy integration, with illustrative examples below



Capacity Expansion

- Upgrading substations and transmission lines to handle growing demand
- Reconductoring existing lines with higher-capacity conductors
- Deploying compact substation designs for faster buildout in space-constrained areas



Bridging & Resilience

- Flexible connection options (where feasible) so customers can energize sooner while long-term upgrades continue
- On-site battery storage as interim power while permanent infrastructure is built
- Wildfire hardening through covered conductors, undergrounding, and advanced vegetation management



Clean Energy Integration

- Pairing renewable generation with large-scale battery storage to manage peak demand
- Supporting emerging clean energy sources to reduce reliance on fossil-fuel generation over time
- Strengthening distribution networks to support distributed energy and EV charging growth

Sources: SCE 2025 GRC Capital Testimony; Grid Safety and Resiliency Plan, 2025; CPUC Proceedings, 2025–2026

TRANSFORMING THE GRID



ULTRA HIGH-CAPACITY SUBTRANSMISSION AND TRANSMISSION SYSTEM

HIGH CAPACITY, FLEXIBLE DISTRIBUTION SYSTEM WITH INCREASED AUTOMATION

Community Energy Storage

Community Energy Storage
Compact Substation

Superconducting Cable

Compact Substation

INTEGRATED PLANNING AND DESIGN AT LONG BEACH

AUTONOMOUS AND ADAPTIVE GRID

A software enabled grid using a coordinated network of sensors, smart devices, distributed compute, and AI to manage growing grid complexity incorporating AMI, GETs, automation, storage, and digital substations.

Advanced Conductors

Control/ Switching Center

Data Center

Mobile Battery Energy Storage System

Substation Level Energy Storage

COMPACT MODULAR DISTRIBUTION SUBSTATION

ENERGY STORAGE ACROSS THE SYSTEM AT GRID EDGE, COMMUNITY, DISTRIBUTION AND SUBSTATION LEVELS

Compact Substation

Distribution Level Energy Storage

Electrified Warehouse

INTELLIGENT SERVICE POINT AND GRID EDGE KIT INCLUDING AMI 2.0

Advanced Conductors

DIGITAL GRID SOLUTIONS

Grid digitalization means adding intelligence — using digital tools, sensors, and analytics/AI with governance to plan more accurately, reduce manual work, and detect and fix problems faster



AI-Powered Grid Intelligence

- Using analytics and AI to support grid planning, asset inspection, and incident response
- Digital twin simulations to model power flow across the network
- Edge computing for real-time optimization closer to where decisions are needed



Advanced Planning & Modeling

- Decision support to accelerate response and anomaly detection, progressing toward more automation
- Integrated long-term planning that accounts for capacity and asset needs together
- High-fidelity modeling tools to simulate grid behavior at scale



Real-Time Grid Management

- Centralized control systems for monitoring and responding to grid conditions in real time
- Managing distributed energy resources like solar, EVs, and battery storage
- Self-healing applications (where feasible) that reroute power to shorten outages

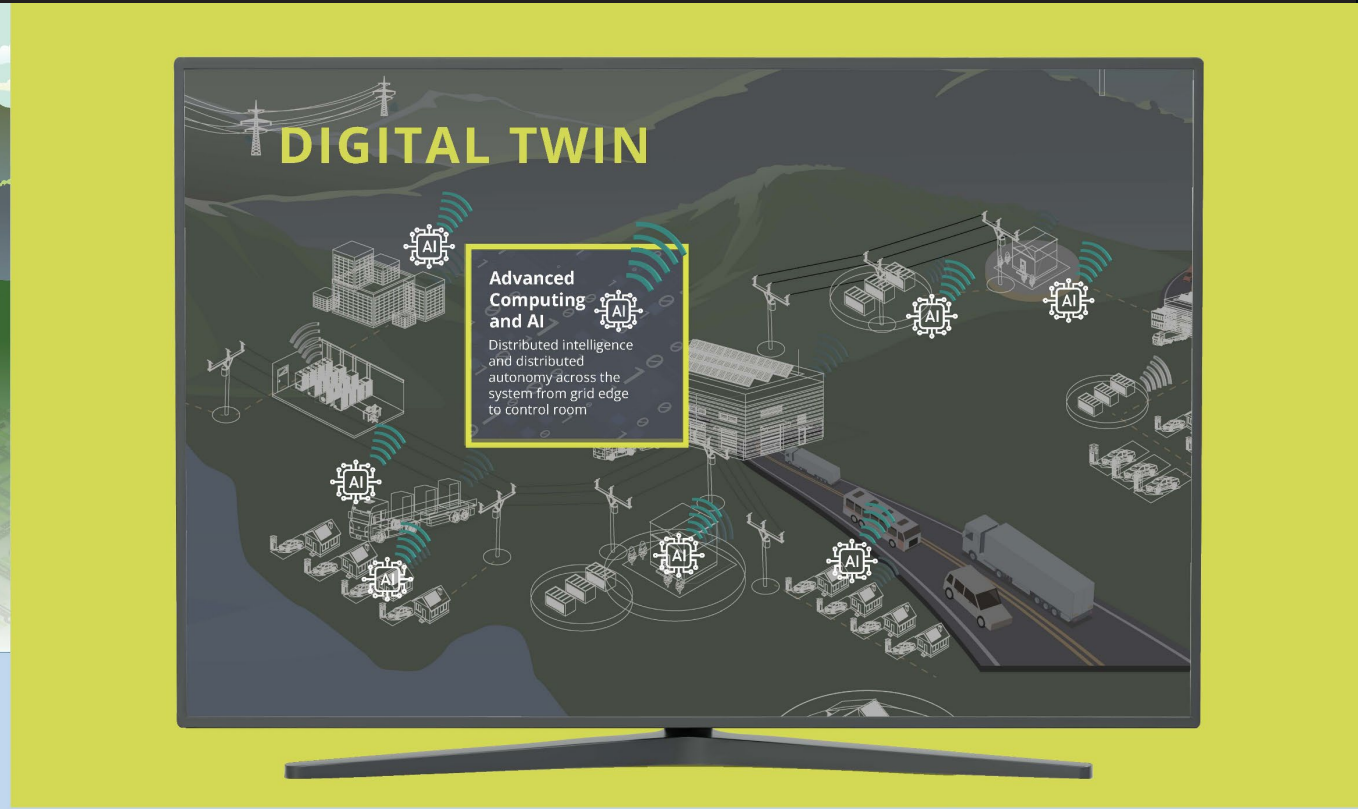
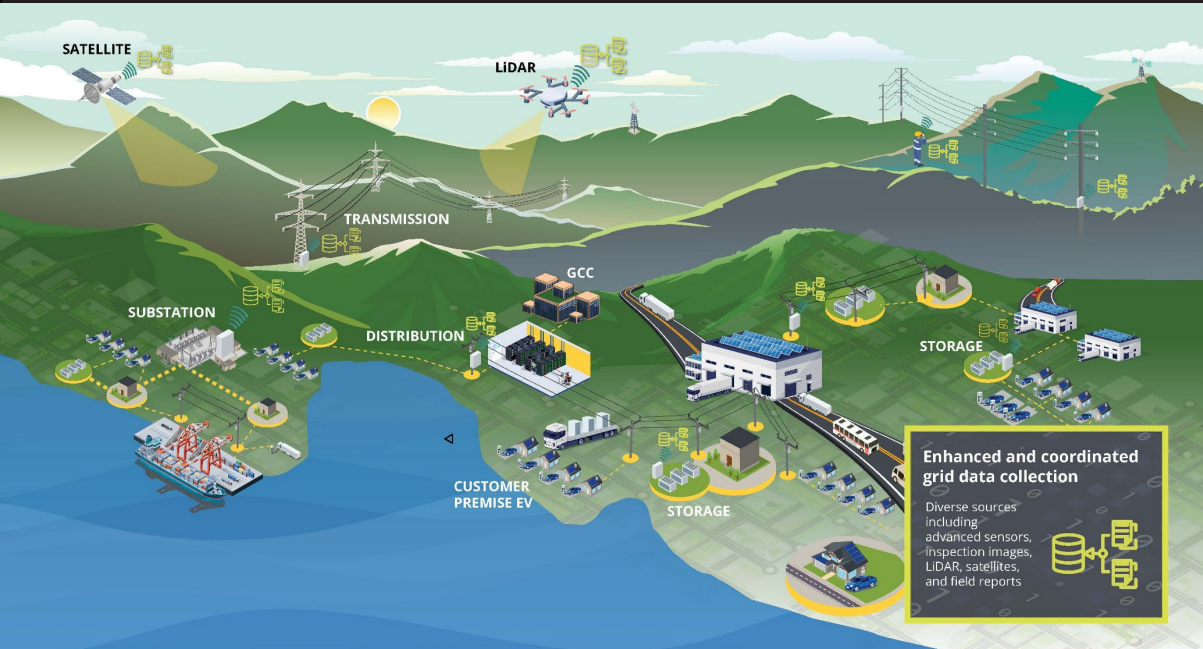


Automation & Orchestration

- Automating routine network changes to reduce manual effort
- Streamlining equipment deployment and upgrades through automated provisioning
- Modernizing enterprise systems for finance, supply chain, and asset management

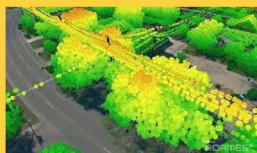
Sources: SCE Grid Modernization Plan, 2025 GRC; Technology Partnership Filings, 2024–2025; EPRI Reports, 2024

THE DIGITAL GRID



GRID DIGITALIZATION

Strategic Asset Management (SAM):



Augmented intelligence to assist engineers in selecting assets, what infrastructure should be constructed and how they should be maintained.

Workforce Intelligence and Smart Execution (WISE)



Faster modeling, virtual job walks, AI-assisted design, workflow vis visualization, chatbots for safety, training and field inquiries.

Autonomous and Adaptive Grid (A2G)



Automated grid operations including switching, dispatch and orchestration of customer and SCE smart devices based on prediction and detection of issues

Demand Flexibility



Manage customer resources to shape load profiles to reduce necessary grid buildout and help increase electrification

ADVANCED DISTRIBUTION SYSTEM INTEGRATION

Multi-Voltage Compact Substation

Dry Air Insulated Switchgear with full digital substation capabilities

34.5kV Circuit

5-8 large customers per circuit (e.g., fleet charging & warehouses)

12/16kV Circuit

Serves mainly residential customers and some commercial/industrial

Community Energy Storage

Deployed in new residential communities

Distribution Energy Storage

Located with customer load blocks on mainline circuits (or substations)

Underground Design

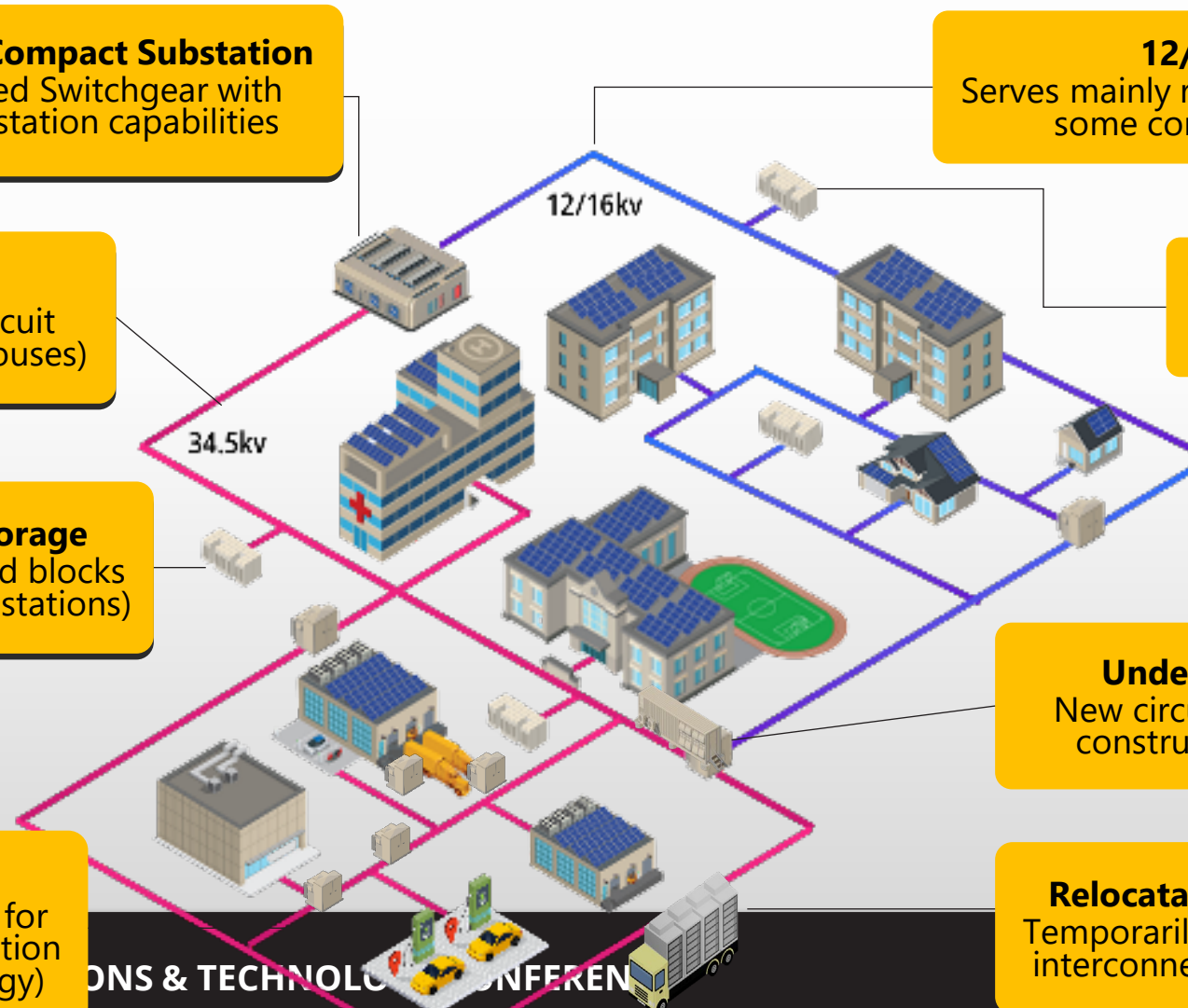
New circuits will primarily be constructed underground

Advanced Automation

Switch for each C&I customer for enhanced reliability and protection (expansion of grid mod strategy)

Relocatable Energy Storage

Temporarily placement for faster interconnection & emergencies



IONS & TECHNOLOGY CONFERENCE

GRID DIGITALIZATION IS PARAMOUNT

AUTONOMOUS AND ADAPTIVE GRID

Fast, flexible, efficient and decentralized grid operations

INTELLIGENT GRID PLANNING & EXECUTION

Automated processes and better decision-making for engineering, inspections and vegetation management

DIGITAL TWIN PLATFORM

Data visualization and curation, with integrated physical and electrical models in business processes

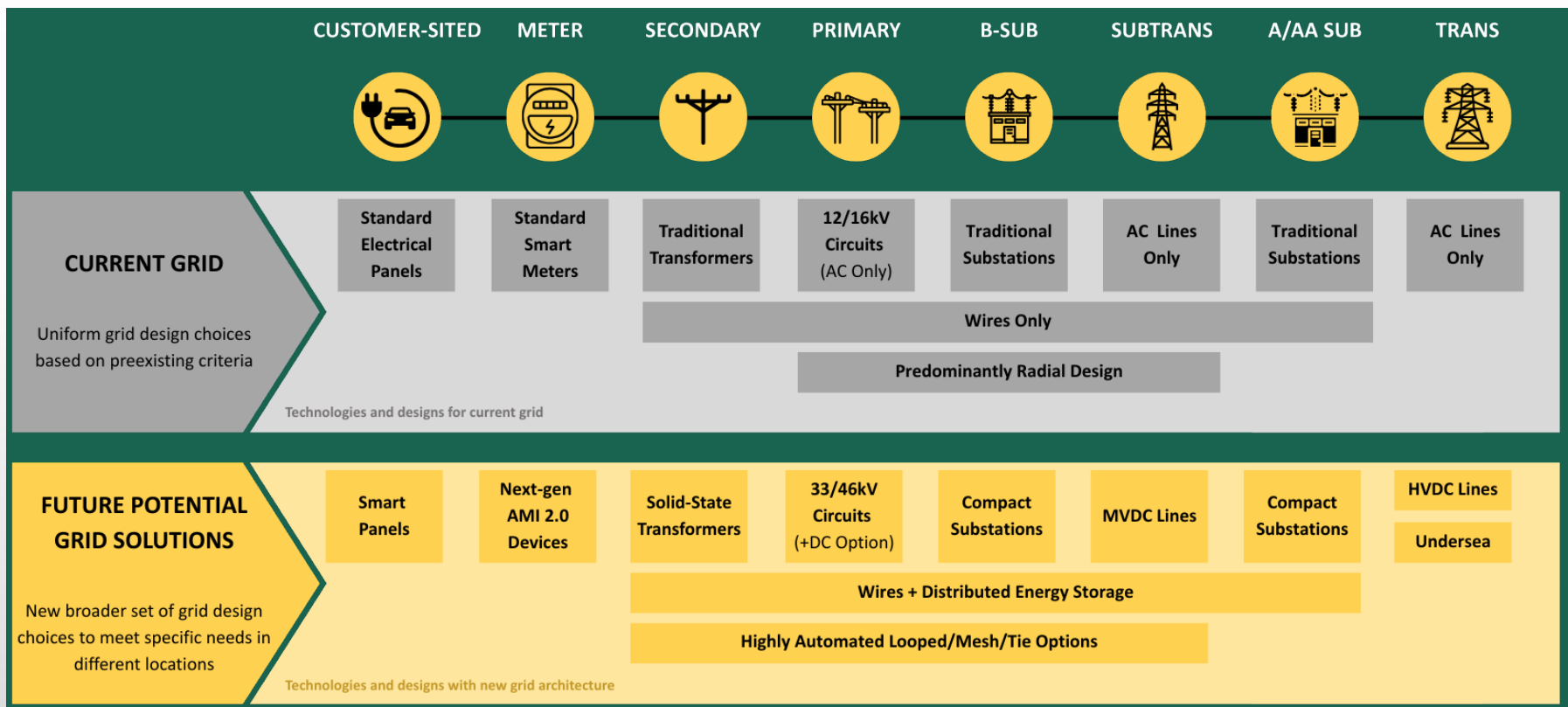
Enhanced computation and AI is the future

Utilities must innovate quickly and learn from other industries

Tech market is abundant, vast and diverse, but also fragmented



DEPTH OF POTENTIAL GRID ARCHITECTURES CONSIDERED ACROSS ALL GRID LEVELS



RTDS Use Case: Capital Deployment

- SCE upgraded a Static Var Compensator (SVC) at a substation. As part of the upgrade, SCE procured a lab replica controller of the SVC controller
- Leveraged an RSCAD model of SCE's existing 500 kV and 230 kV bulk power transmission network.
- The SVC HIL evaluation provided valuable insights into controller performance and supported fine-tuning of various parameters.
- The lab replica system and HIL models supported the completion of FAT for commissioning to proceed

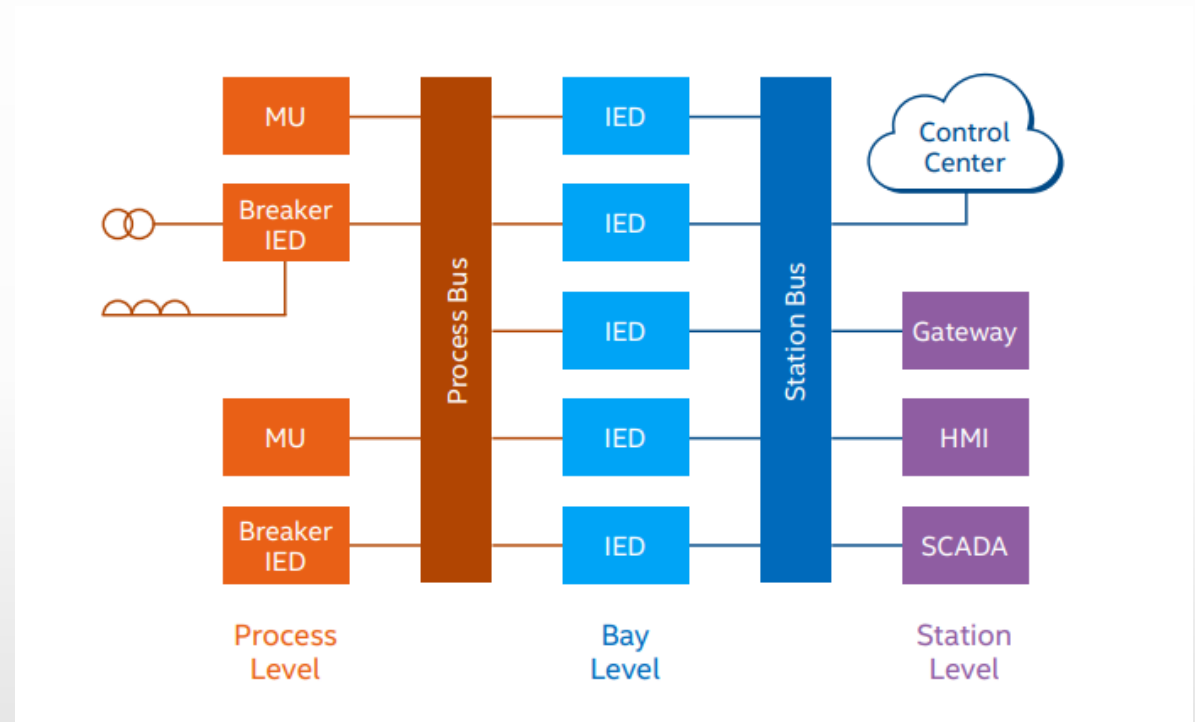


SCE was able avoid significant costs and delays, while ultimately deploying key equipment

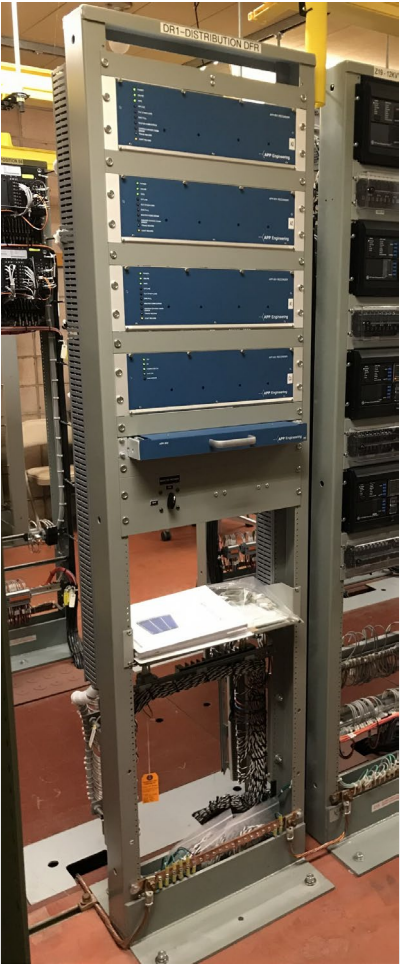
RTDS Use Case: Technology Advancement & Standardization

- Used Real-Time Digital Simulator (RTDS) for hardware-in-the-loop validation of protection schemes
- Simulated realistic grid faults and operating conditions using a full system model
- Conducted scalable system-level testing using analog and digital signal injection (SV/GOOSE)
- Performed network stress testing by injecting high volumes of SV traffic to evaluate bandwidth limits, latency, and resilience
- Identified impact of network congestion and validated need for traffic engineering (VLANs, prioritization)

SCE was able to validate performance of new technology and is working on standards required for deployment on SCE system



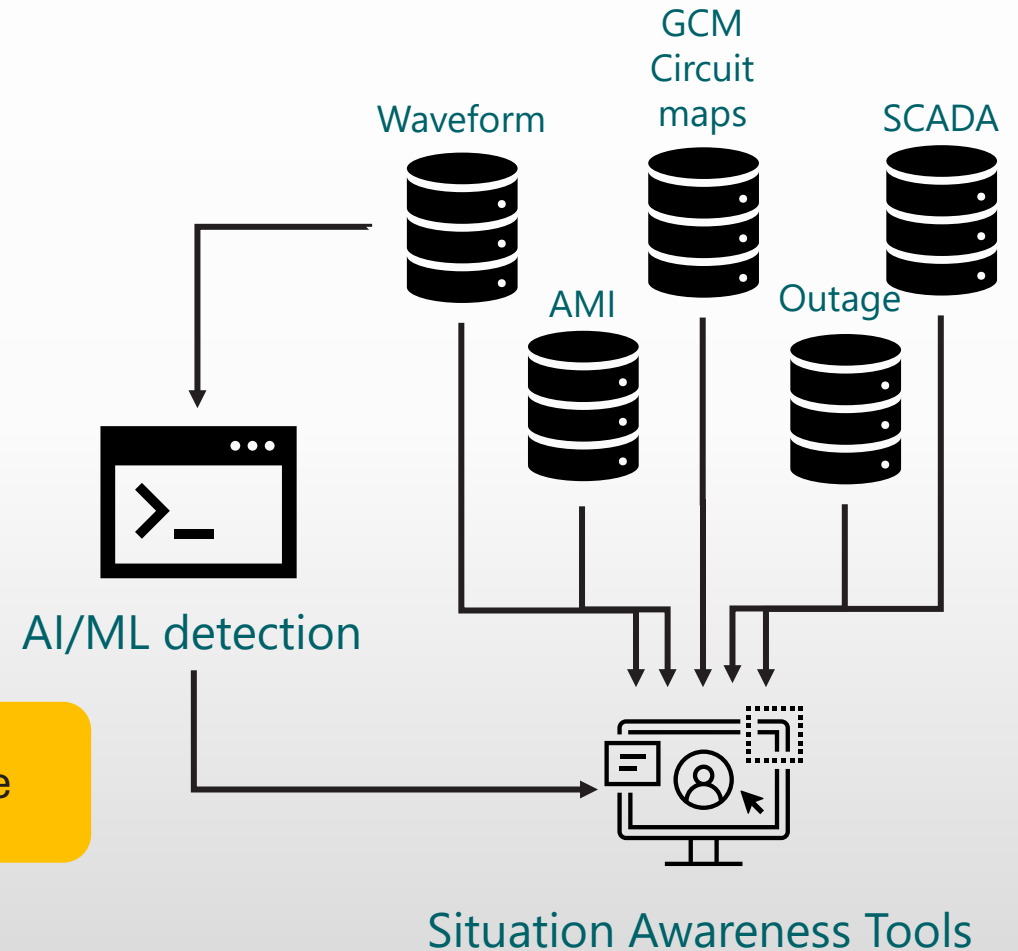
RTDS Use Case: Simulated Data to Accelerate AI



Digital fault recorder at an SCE substation

- Digital Fault Recorder (DFR) deployed at ~40 distribution substations
- Triggered waveform event recordings by preset settings
- In-house analytics utilize fault modeling, signal processing algorithms, and AI/ML to analyze waveform events, AMI events, grid models, and SCADA data in centralized system.
- Detect signs of equipment failure and estimate their locations for fast, proactive, and safe field

SCE was able to develop machine learning algorithms quicker and more confidently



RTDS Use Case: POC Testing Before First Deployment

- RTDS and Hardware-in-the-Loop (HIL) testing enable real-time validation of microgrid control systems, protection devices, and DER integration using field-representative hardware
- Lab simulations replicate grid-connected, islanded, and transition scenarios to evaluate system stability, control sequencing, and operational performance
- Testing supports stress, performance, and resilience evaluation across a wide range of operating conditions
- Enables early identification of control, protection, and integration issues, allowing refinement prior to deployment
- Supports development of standardized control and protection approaches, improving consistency across deployments
- Lab validation improves deployment readiness, reduces field risk, and increases overall system reliability

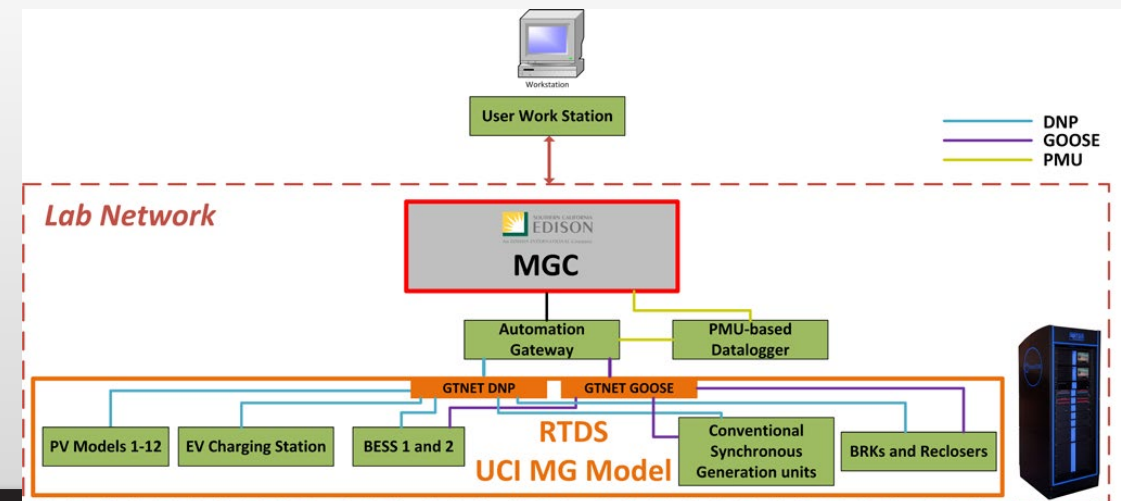
SCE was able to validate system performance and is currently field deploying this system



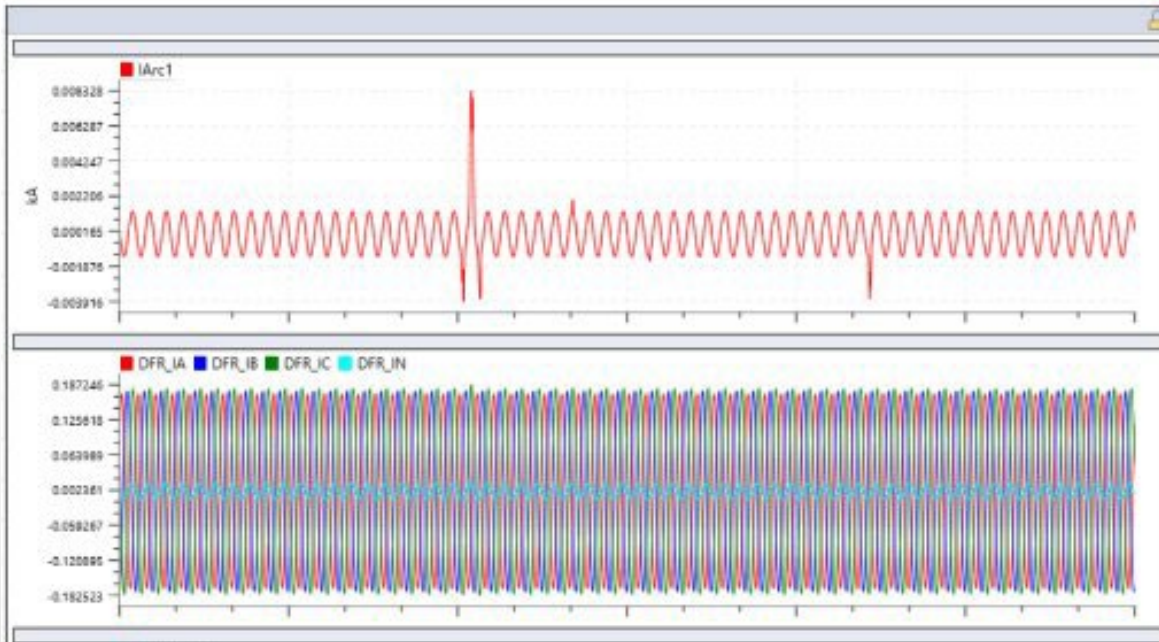
Pomona Lab QAS CHIL Testbed



Fenwick Lab CHIL Testbed



RTDS Use Case: Informing Regulatory Ask



Subtle current spikes are nearly impossible to detect without data analytics

- Next generation Advanced Meter Infrastructure (AMI 2.0) are early stage, with limited deployment
- Vendors claim significant increases in fault detection, which can be key benefit for deployment
- Test environment was established to simulate faults and determine effectiveness of AMI 2.0 meters to identify them

SCE was able to validate vendor claims, quantify benefits and include as part of AMI 2.0 application

Closing Remarks

- Grid transformation is achievable, but won't come easy
- De-risking investments and deployments is key tool for affordability and performance concerns
- Collaborating across RTDS users and use cases can advance the industry further and faster