2021 NERC-EPRI-NATF Planning and Modeling Virtual Seminar

November 4, 2021

Day 2 – Emerging Technologies

Policy Reminders

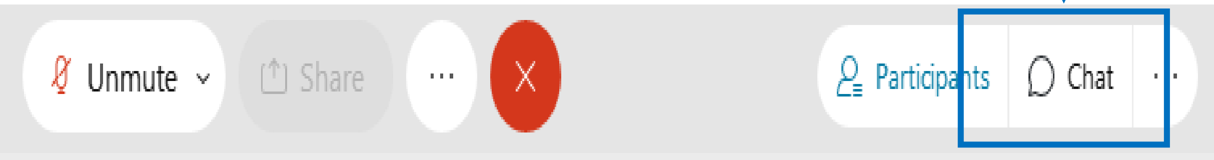
- Open forum
- Obey antitrust laws and guidelines
- Adhere to your organization’s standards of conduct
- Protect confidential information and intellectual property

Logistics for Meeting

- All lines were muted on entry
- Attendees may use chat to ask questions or make comments
- Questions will be taken as time permits for each presenter
- Presentations will be posted after the event
  - www.natf.net
  - www.epri.com

Using the chat feature:

Chat Feature



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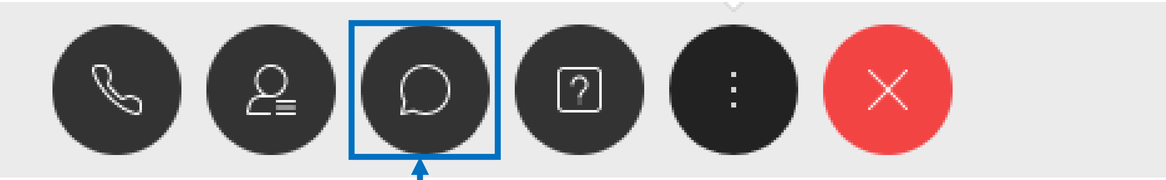
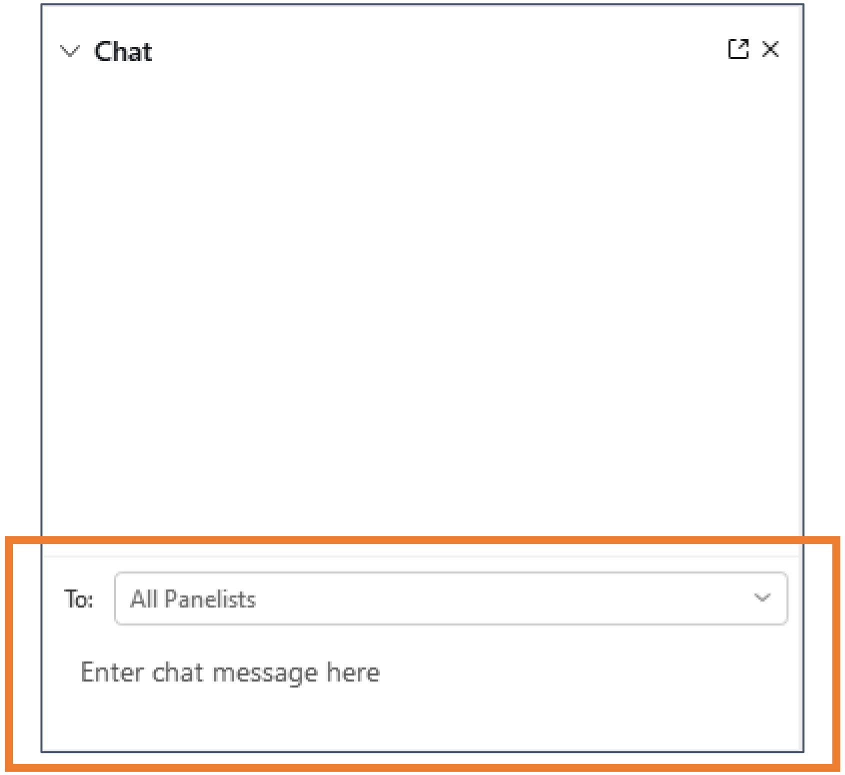


Chat Feature



Welcome and Introduction

Andy Balascak – *NATF*

NERC-EPRI-NATF Planning and Modeling Virtual Seminar

November 3, 2021

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Agenda

Day Two – Emerging Technologies

Session 2 – Resilience Planning		
Time (ET)	Topic	Presenters
1:00 p.m.	**Welcome**	NATF – Andy Balascak
1:05 p.m.	**Integrating Security into the Planning-Design Process**	EPRI – John Stewart
1:35 p.m.	**Extreme Climate Events & Transmission Resiliency**	EPRI – Anish Gaikwad & Dr. Delavane Diaz
2:05 p.m.	**Audience Interaction**	EPRI – Anish Gaikwad & Mobolaji Bello
2:25 p.m.	**Break**	
Session 3 – Technology Impacting the Utility Industry		
2:40 p.m.	**EMT Studies for Transmission Planning**	Eversource – Goodarz Ghanavati & Meiyan Li Electranix – Andrew Isaacs
3:20 p.m.	**Transportation Electrification & System Planning**	EPRI – Jared Green INL – Tim Pennington
4:00 p.m.	**Day Two Wrap-up and Closing Comments**	NATF – Andy Balascak

Security Integration

John Stewart
EPRI

NERC-EPRI-NATF Planning and Modeling Virtual Seminar

November 4, 2021

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Security Integration with System Planning

NATF Planning and Modeling

John Stewart
Principal Technical Leader, Cybersecurity

November 4, 2021

Session Agenda

- Background
- Collaborate on technology roadmaps
- Incorporate security objectives
- Provide context for security operations
- Security Vision 2030

The U.S. Saturn C 5 rocket, which on July 16, 1969, sent the Apollo spacecraft on its journey to the Moon, developed about 2.6 GW during its 150-second burn.

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EPRI Cyber Security Research Areas for Power Delivery

Incident and Threat Management TF:

- Integrated Security Operations Center
- Threat Management
- Security Orchestration, Automation, and Response
- Forensics for OT Systems

Transmission and Distribution Security TF:

- Control Center Security
  - System Architecture & Isolation
- Substation Security
  - Managing IEDs
- Field Systems Security
  - Cyber-physical protection

DER and Grid-Edge Security TF:

- Security Architecture for DER Integration
- Security Architecture for Energy Storage
- Cyber Security Requirements and Architecture for EV XFC
- Security for IoT and Connected Devices

Cross-Cutting Areas:

Cyber Security Metrics

Supply Chain Security

Cloud Security

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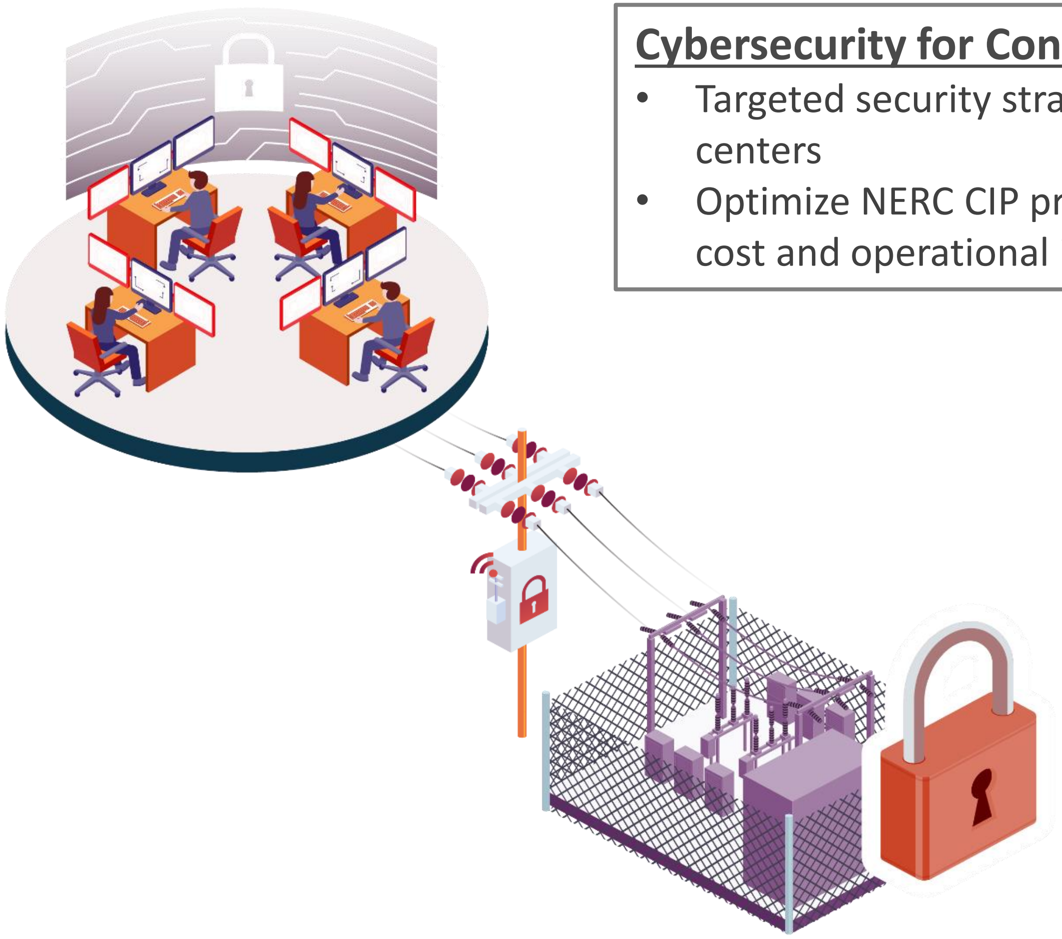
Cybersecurity - Transmission and Distribution Task Force

EPRI Lead: John Stewart



Cybersecurity for Control Centers

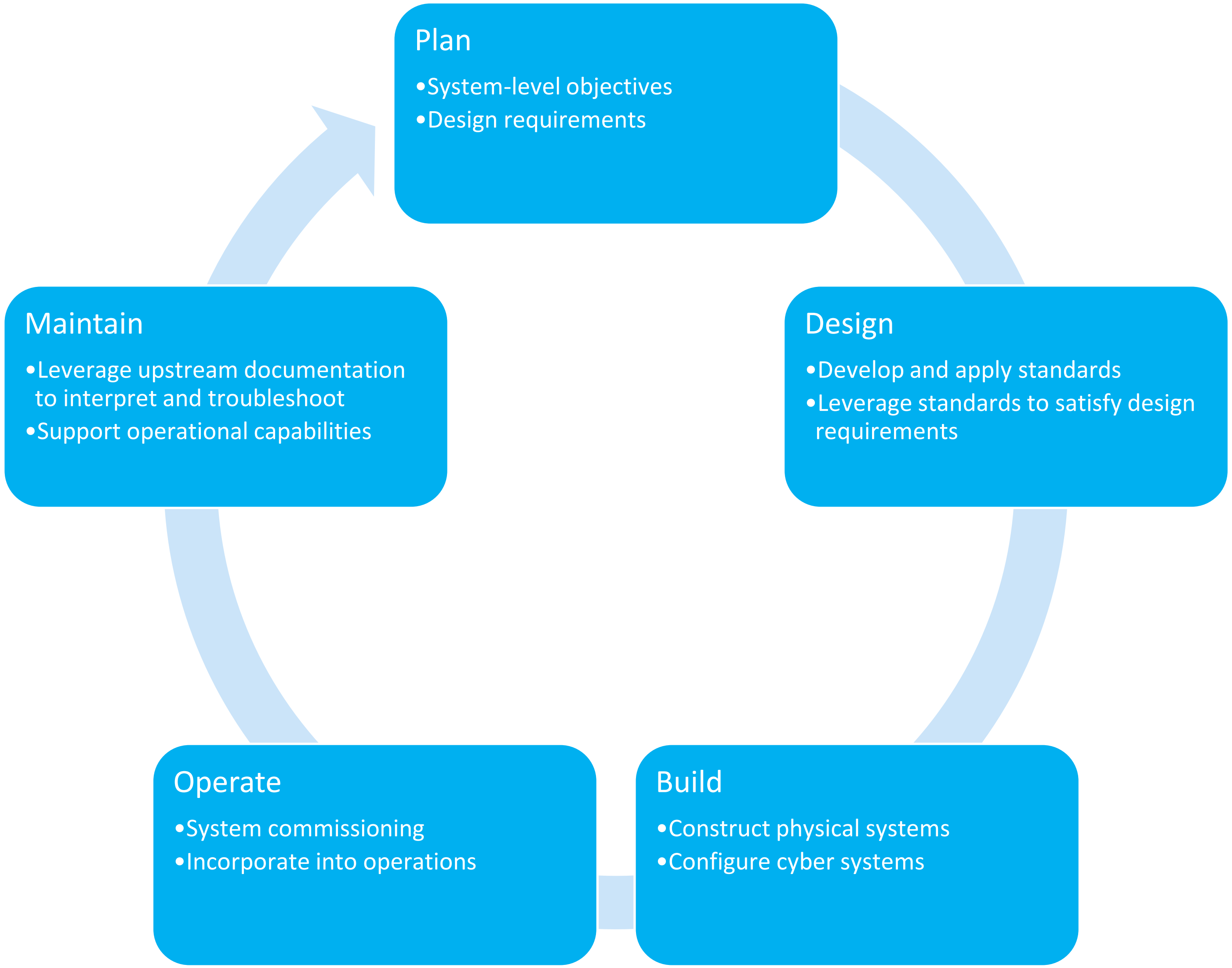
- Targeted security strategies for transmission and distribution control centers
- Optimize NERC CIP program to address compliance risk with minimal cost and operational impact

Cybersecurity for Substations and Field Systems

- Creative solutions to secure transmission and distribution substations
- Coordinated cyber and physical security controls for line-mounted controls

Support Security Integration

- Share and collaborate on technology roadmaps
- Incorporate security objectives
- Provide context for security operations



Technology Transition

- Around the same time two unrelated efforts produced new standards:
  - IETF IPv6
  - IEC 61850

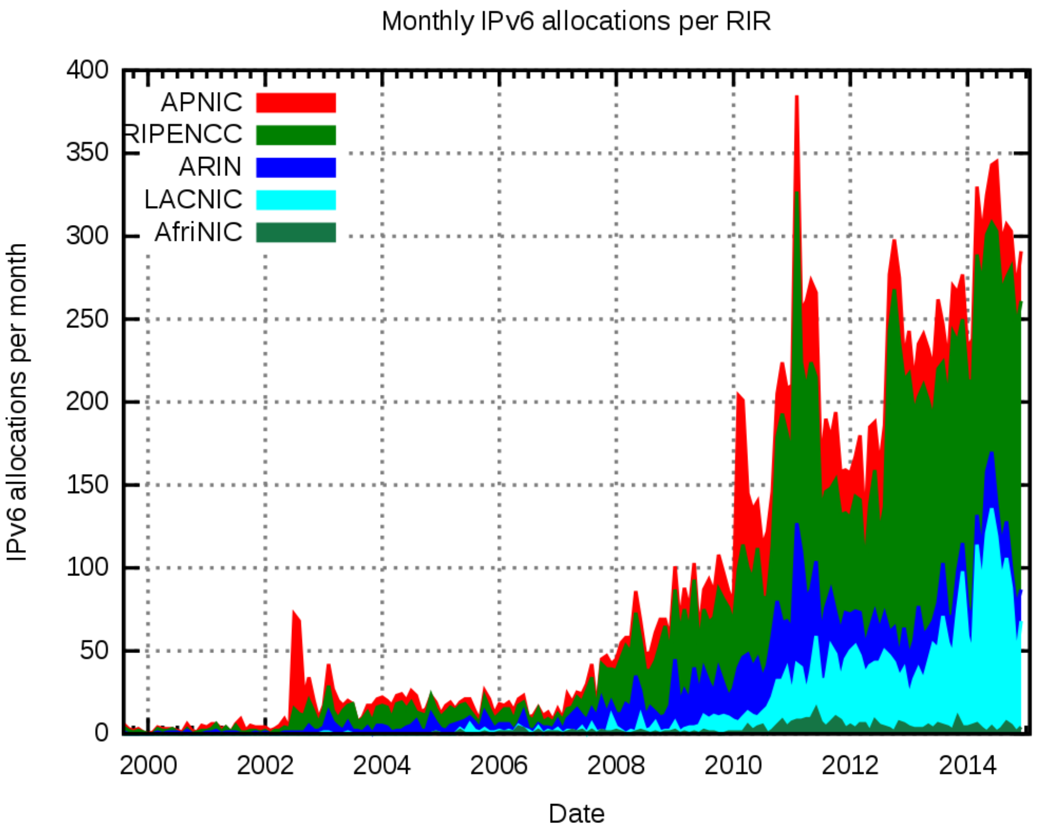
- In both cases, experts predicted that these new solutions would rapidly replace existing practices....

What actually happened?

Technology Transition

- Adoption of both solutions suffered due to similar circumstances

- Transition Costs
  - Hybrid operation
    - IPv4 and IPv6 in parallel
    - Conventional and 61850 in parallel
- Transition Benefits
  - Benefits are generally end loaded after full transition



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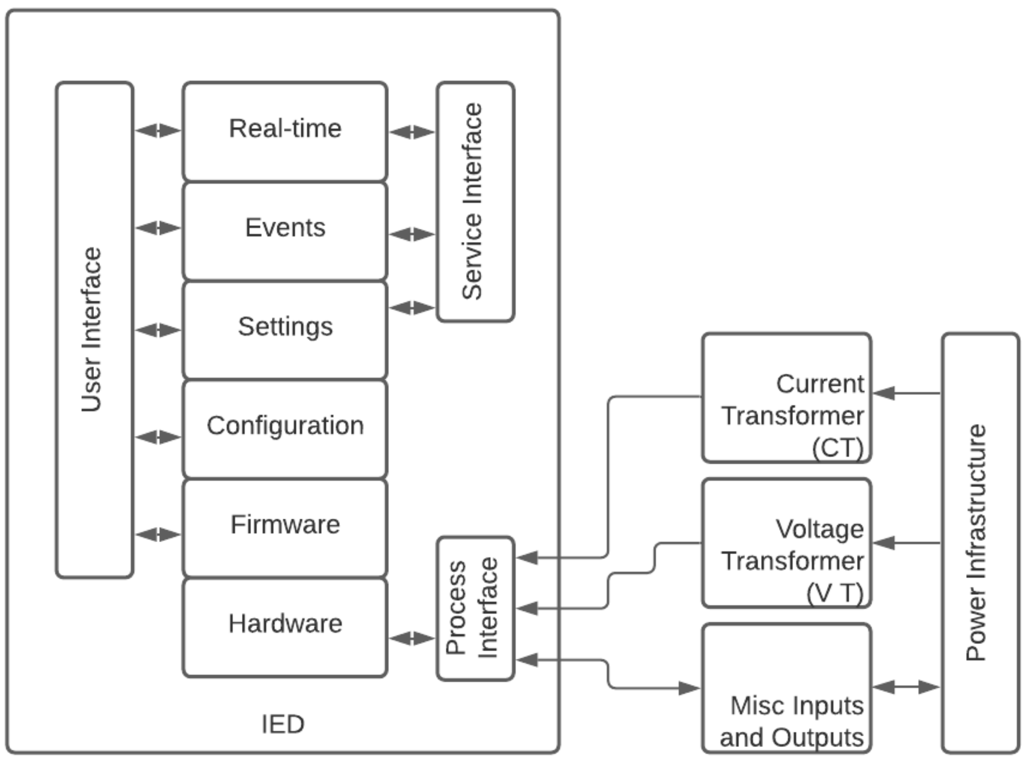
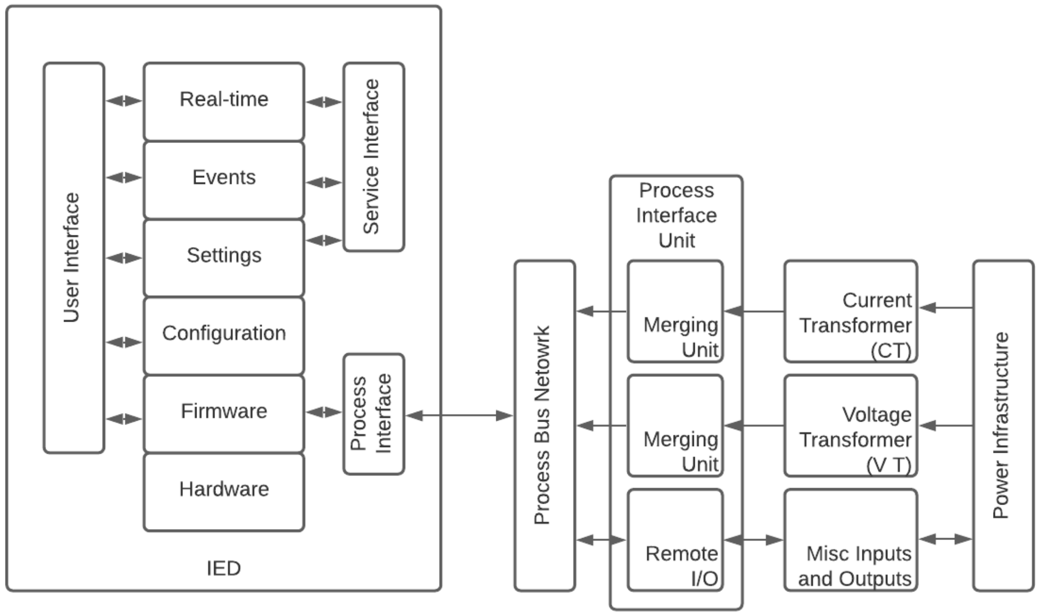
Technology Step Changes

Conventional Process Interface



Digital Process Interface



What are the security implications of this transition?

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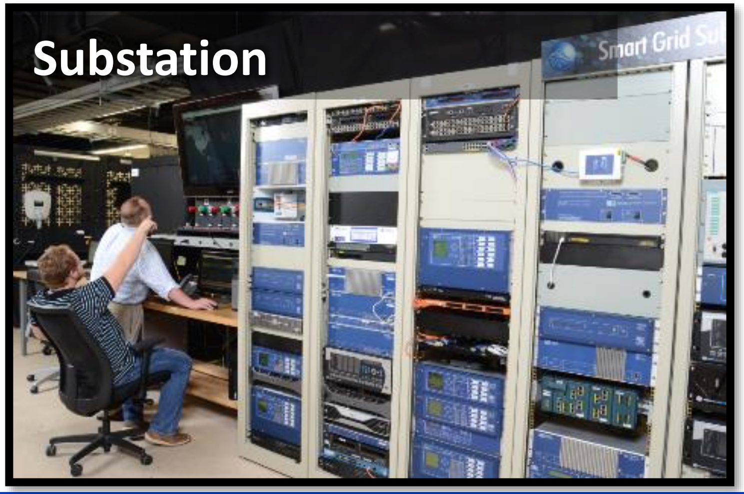
Digital Testbed

- **Current Environment**
  - 182 devices from over 35 manufacturers
  - Configured to support multiple SCADA protocols
  - DNP3, IEC 61850, Sunspec MODBUS, IEEE C37.118, IEC 104, IEC 101
- **Build next-generation digital testbed**
  - Explore security needs of emerging architectures
  - Sampled values enabled designs



Cyber Security Research Lab – A Resource for Members

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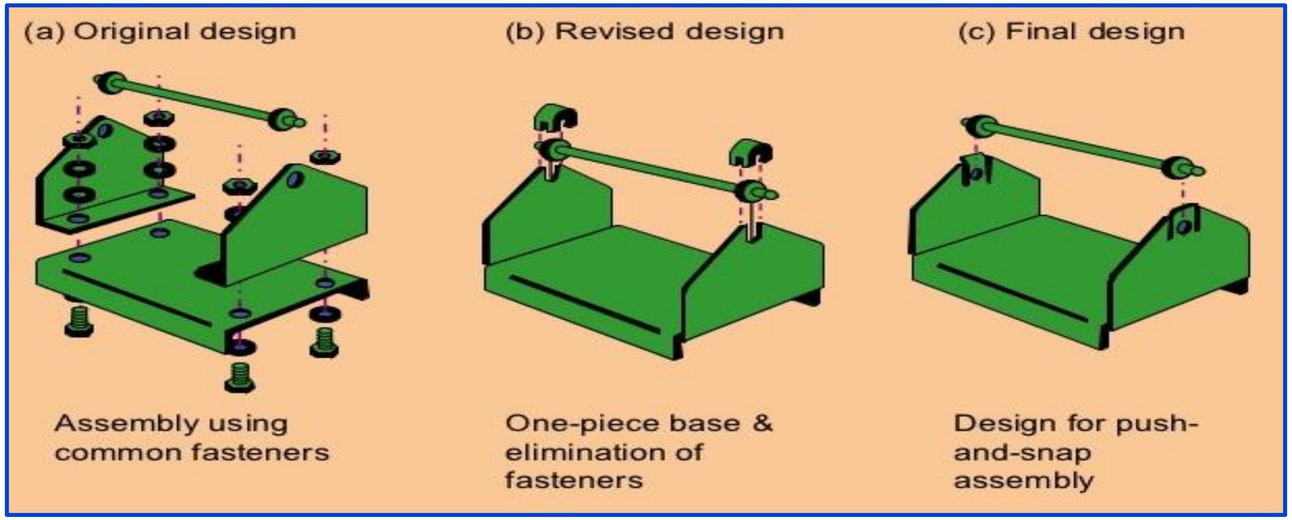
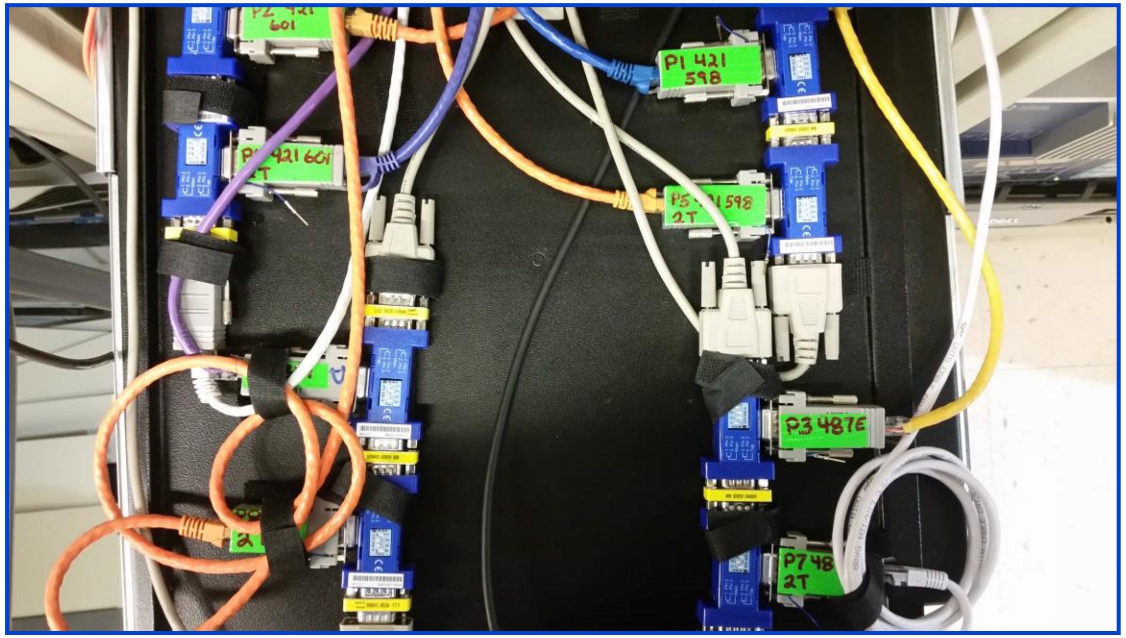
Incorporate Security Objectives

- Identify
  - Critical systems
  - Compromise vs failure
- Protect
  - Segmentation
  - Internal separation
- Detect
  - Monitoring
  - Anomalies and events
- Respond and Recover
  - Black sky conditions





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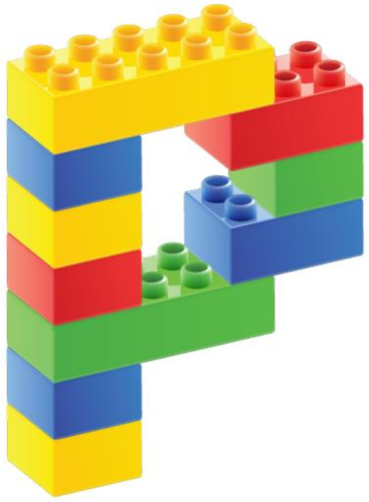
Security for T&D Systems

- T&D systems contain a wide range of assets with unique capabilities.
- Creative solutions are required to evaluate and secure these assets.

- Enterprise IT systems are more like Legos, and T&D systems are closer to Play-Doh.
  - Enterprise IT systems
    - Modular with well defined interfaces based on standard layers of technology.
    - Security can be snapped on the system
  - T&D systems
    - Proprietary designs delivered as an embedded hardware/software platform
    - Security must be molded in the system



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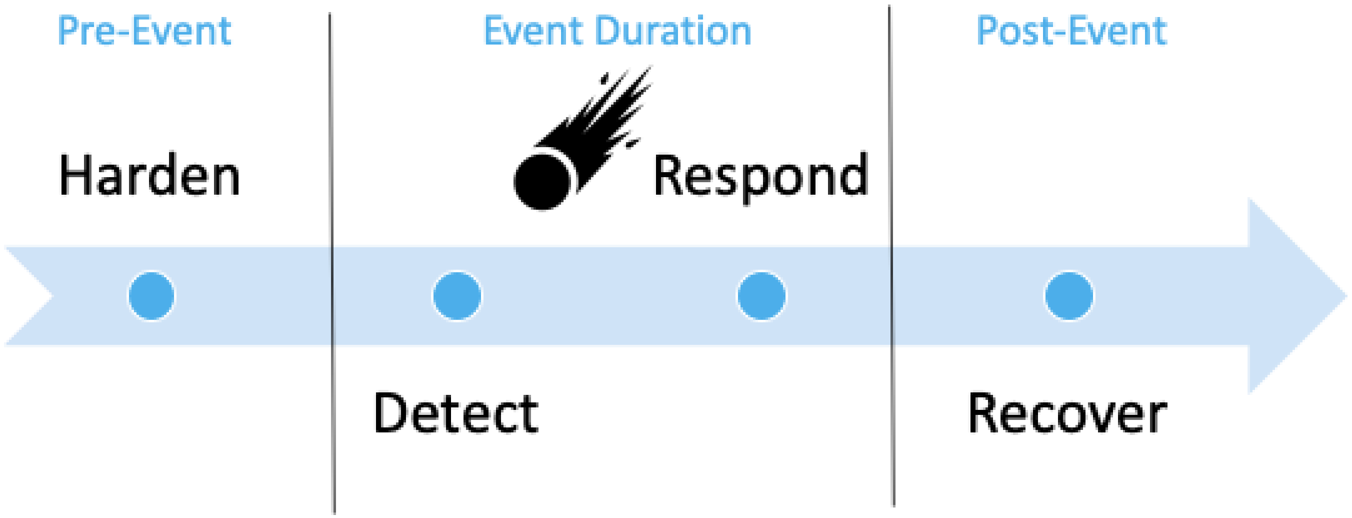
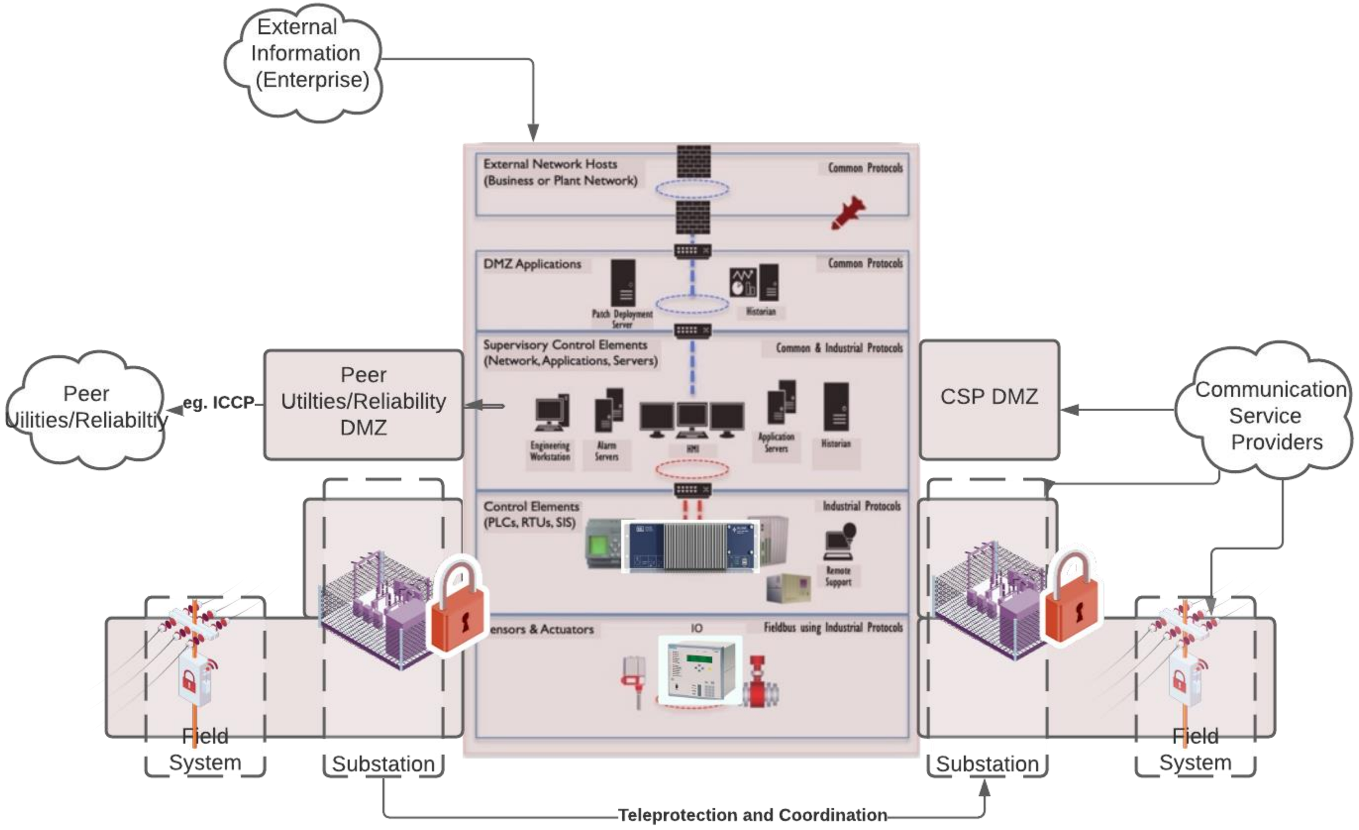
Resilience

- NIST 800-53 – Resilience
  - *The ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents.*



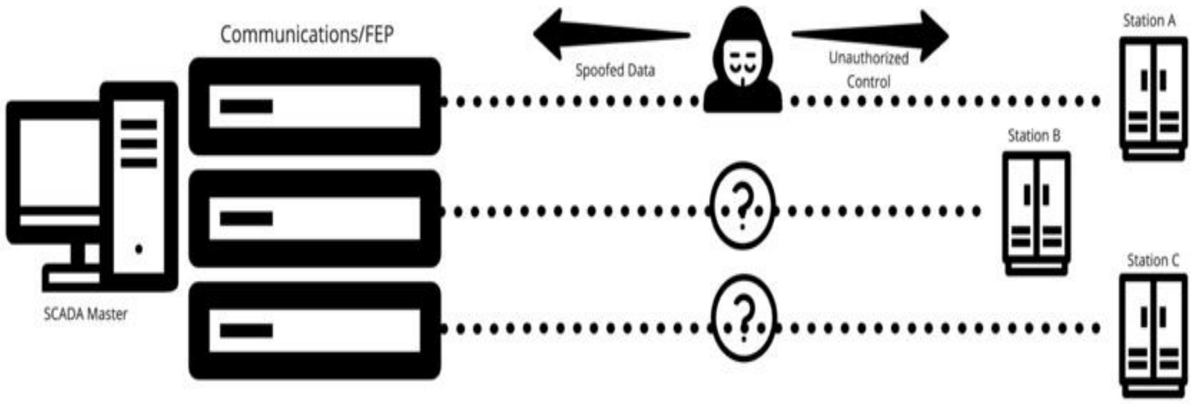
Beyond Resilience

- What’s the opposite of fragile?
  - Fragile systems are damaged by stress
  - Resilient systems can survive stress
  - What about systems that are enhanced by stress?
- Antifragility
  - *Antifragile: Things That Gain from Disorder*
    - Nassim Taleb
- Vision 2030
  - Cyber systems will continuously adapt to changing conditions and leverage events to enhance security



Context for Security Events

- An early utility cyber event
  - Overnight shift responds to unplanned operation of multiple breakers
  - Maintenance personnel verifies no operation occurred
  - (Unexplained SCADA system behavior)+(Recent Maroochy Shire event)

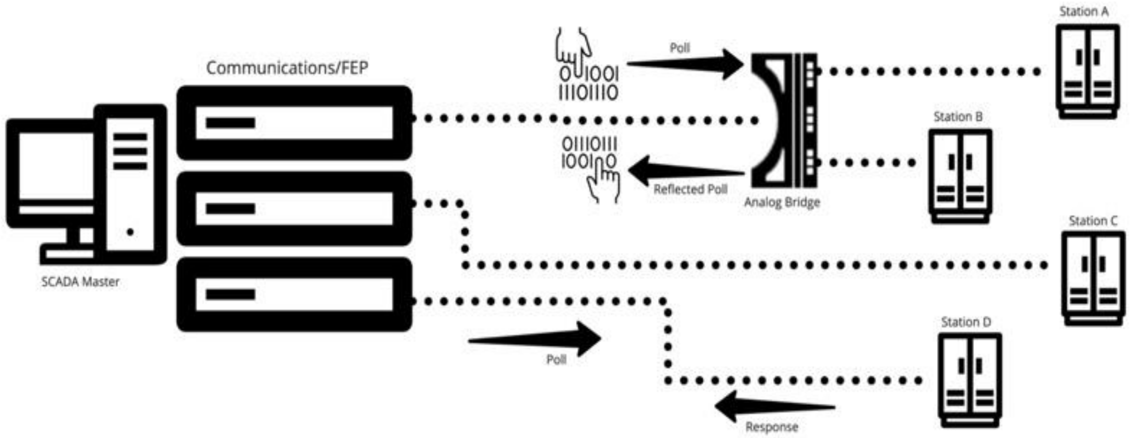


Has the SCADA circuit been compromised?

Context for Security Events

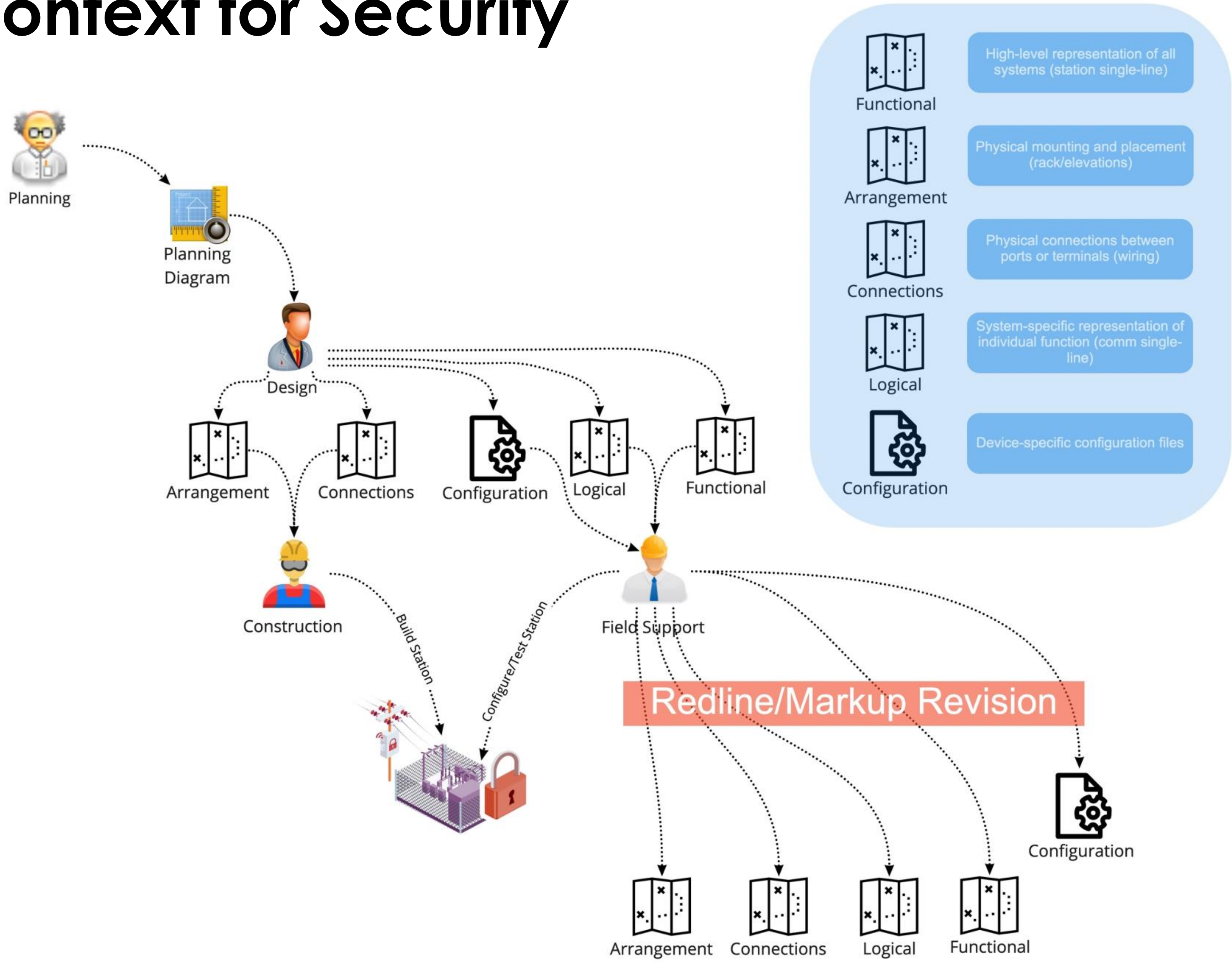
- Some additional details
  - SCADA circuit includes an analog bridge
  - TG legacy protocol in use

- What really happened
  - SCADA polls were reflected and interpreted as response
  - Master station error disregard CRC validation



Have we mitigated this risk?

Provide Context for Security



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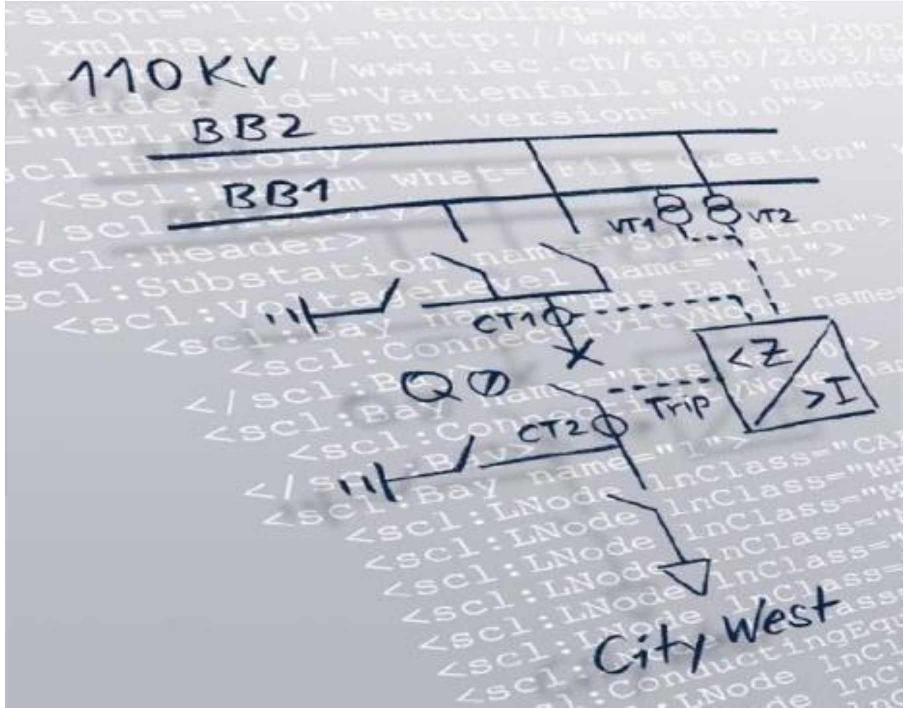
Provide Context for Security

- Substation Configuration Language (IEC 61850-6)
  - Standardized SCL files are created to exchange configurations between IED engineering tools and between system engineering tools from different manufacturers in a compatible way.

- Components of SCL
  - Substation functional specification
  - IED capability descriptions, and
  - Substation automation system description

- Contains valuable information about designed system behavior



Security Context – First Steps

P2808 - *Standard for Function Designations used in Electrical Power Systems for Cyber Services and Cybersecurity*

8

Why

How do we replicate IEEE Std. C37.2 for cyber?
How do we recreate this tried-and-true industry best practice and design process/flow for cyber?

IEEE Std.1686 IED Cybersecurity Capabilities

IEEE Std.C37.2 Cybersecurity Req. for Power System Automation, Protection, and Control Systems

Other IEEE: DNP3 SA, Virtualization, etc

NIST, IEC, NERC, Others

Cyber Function Numbers, Acronyms, and Designations →

Engineering Drawings, Procurement, Commissioning, Maintenance

Identify

Protect

Detect

Respond

Recover

Original Approach **Current Approach**

IEEE PES Power & Energy Society

IEEE

Nathan Wallace – S7 & S8 Working Group Chair

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Security Vision 2030

Near-term
0-15 years

Decarbonization

Accelerate economy-wide, low-carbon solutions
- Electric sector decarbonization
- Transmission and grid flexibility: storage, demand, EVs
- Efficient electrification

Long-term
~15-30 years

Net-zero clean energy system
- Ubiquitous clean electricity: renewables, advanced nuclear, CCUS
- Negative-emission technologies
- Low-carbon resources: hydrogen and related, low-carbon fuels, biofuels, and biogas

Transformation

Drive affordability of a clean and resilient energy system through digital transformation
- Power system modernization: pervasive sensors, monitoring, advanced analytics using AI
- Upgraded and expanded communications infrastructure and control systems

Resiliency

Near-term
0-15 years

Mitigate climate impacts and cyber/physical risks
- System and asset hardening
- Improved response
- Faster recovery

Long-term
~15-30 years

Future proof energy system design basis
- Resilient power system design
- Advanced asset design and strategic undergrounding
- Smart integration of energy carriers

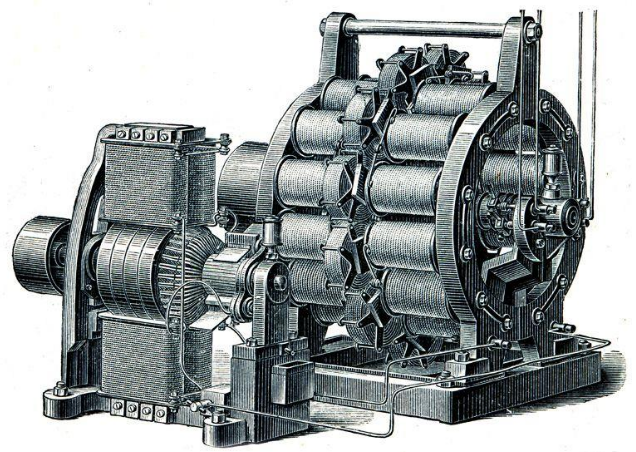
Making Energy More

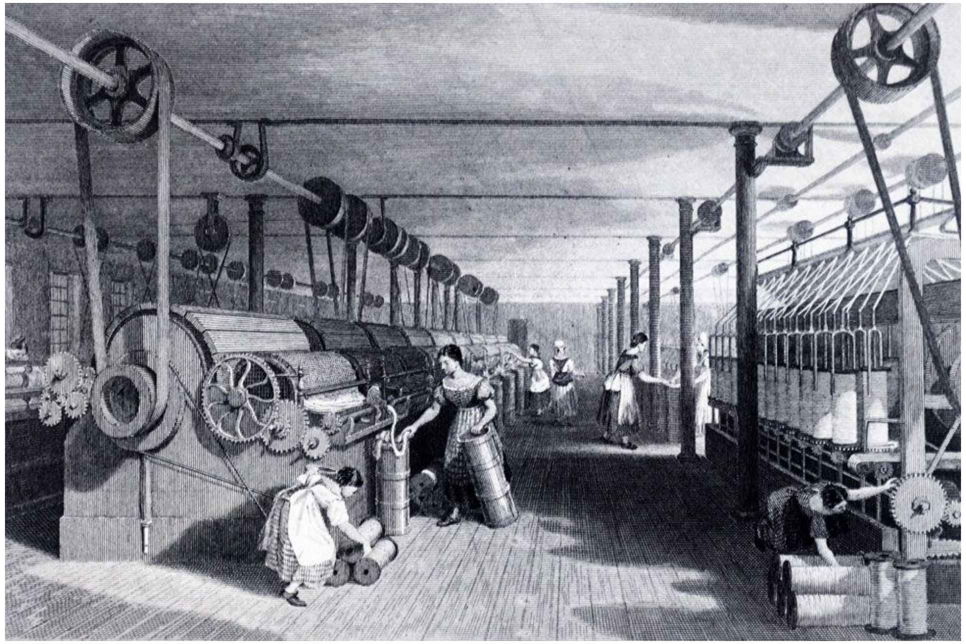
Clean | **Affordable** | **Reliable**

Leveraging Innovation

For the first 30 years of electrification, there were virtually no productivity gains.

- Not because electricity wasn't the right solution
- They stopped at the drive shaft
- System drive vs unit drive
- Productivity soars





Are we deploying new solutions and stopping at the drive shaft?

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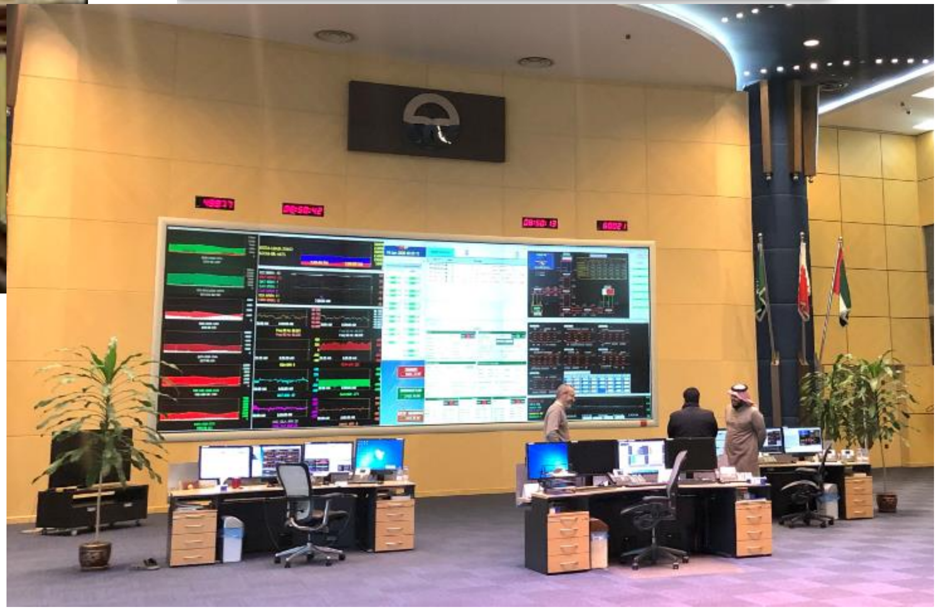
Discussion



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Together…Shaping the Future of Electricity

Extreme Climate Events & Transmission Resiliency

Anish Gaikwad & Dr. Delavane Diaz
EPRI

NERC-EPRI-NATF Planning and Modeling Virtual Seminar

November 4, 2021

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Climate Resilience Assessments of Transmission Systems

LADWP Case Study

Anish Gaikwad, EPRI
Delavane Diaz, EPRI

Eknath Vittal, EPRI
Laura Fischer, EPRI

NATF-NERC-EPRI Modeling & Planning Meeting
November 4, 2021

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Assessing Climate Impacts on Transmission Systems

Long-Term Scenario Level Impacts

- Primary response to mitigate future climate change is to transition the power system to include more low-carbon resources
- Electrification of load
- Expansion decisions
- Climate or weather impacts on generation or transmission system components

Acute Event Impacts

- Climate change is expected to drive an increase in the severity and frequency of extreme contingency events
- Manifests as weather driven consequences to transmission system infrastructure
- Events that result in the loss or unavailability of significant portions of the transmission system infrastructure


Objective: Assess the resilience of the 2030 LADWP transmission system in response to extreme contingency events driven by climate change and natural disasters

Review of the "*Resilience Assessment of the LADWP Transmission System*"

Synthesis Climate Assessment

Overview of Climate Threats and Vulnerabilities Prioritized by LADWP and included in the Synthesis Climate Assessment

Climate threat	Historical trends[1]	Projection (*confidence*)[1]	Potential asset vulnerabilities*
Temperature	Warming (100+ years)	Warming (*very high*)	Increasing CDDs, changing seasonal demand shapes (*chronic*); higher peak demand for cooling/heating during extreme heat/cold, outage risk (*acute*); T&D efficiency, sagging lines; reduced thermal generator efficiency; cooling efficiency
Precipitation	No significant trend	Unknown (*low*)	Equipment damage from heavy downpours, local flooding, risk of mudslides, facility access, changes to hydropower resources
Wildfire	Increasing (30+ years)	Increasing acres burned (*med-high*)	Power outages, infrastructure damage
Drought	No significant trend	Increasing frequency (*med-high*)	Reduced hydropower resource availability
Sea level rise (SLR)	Rising (100+ years)	Rising (*very high*)	Coastal flood risks include physical damage, inundation, corrosion, erosion, facility access

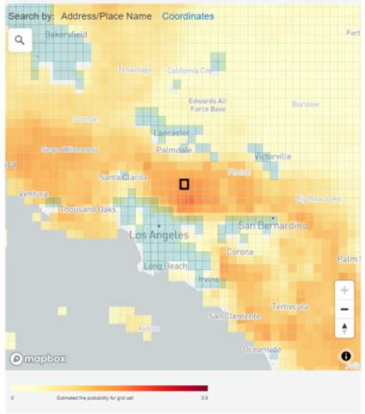
1 Adapted from CCCA4 Statewide Summary Report, Table 3. Trend refers to influence of anthropogenic climate change on climate threat above baseline climatology.
** Climate impacts can be direct (infrastructure damage, service interruptions) or indirect (resulting impacts to customers and surrounding community).*

Moving beyond exposure assessment to explicitly integrate climate impacts into quantitative assessment of transmission resilience

1 Review & Interpret Climate Projections for Location and Variables of Interest

CMIP6, NCA, state data and other existing detailed local climate datasets

Ex: Characterize change in wildfire probability in Los Angeles County

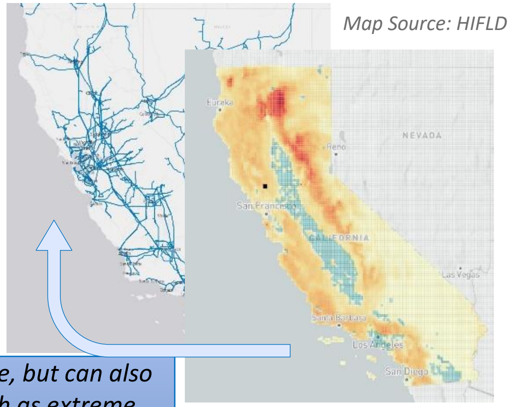


Map Source: Cal-Adapt

2 Map Climate Impacts Geographically to Identify Highly Impacted Electrical Equipment

Assess locationally-specific climate vulnerabilities

Capture and evaluate projected changes across utility service territory



Map Source: HIFLD

Map Source: Cal-Adapt

Example shown for wildfire, but can also consider other threats such as extreme heat and sea level rise / storm surge inundation

3 Translate Climate Impacts into Electrical Consequence and Define RSIF Events

Generate extreme contingency events for RSIF analysis

Define electrical consequence based on anticipated climate impacts

```
CONTINGENCY '2 STATION
WILDFIRE OUTAGE'
DISCONNECT BUS FROM BUS 12345
DISCONNECT BUS FROM BUS 23456
END
CONTINGENCY '3 STATION
WILDFIRE OUTAGE'
DISCONNECT BUS FROM BUS 34567
DISCONNECT BUS FROM BUS 45678
DISCONNECT BUS FROM BUS 57890
END
END
```

Climate Data Informs HILF Event Definition for Transmission Resilience Analysis

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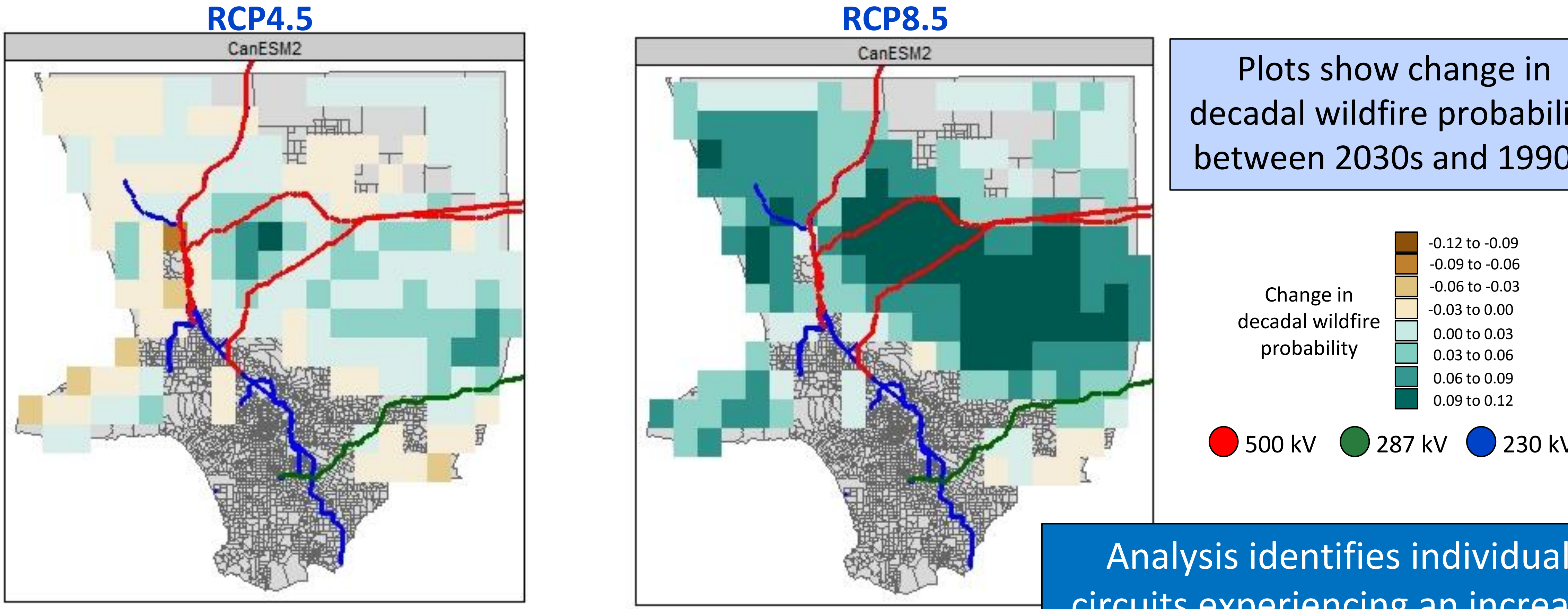
Within LA County, the greatest near-term risk from wildfire is to transmission assets in inland areas along the 500 kV line.



Plots show change in decadal wildfire probability between 2030s and 1990s.

Analysis identifies individual circuits experiencing an increase in wildfire risk – this finding is robust across climate models

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Transmission Resilience Assessment: LADWP Case Study

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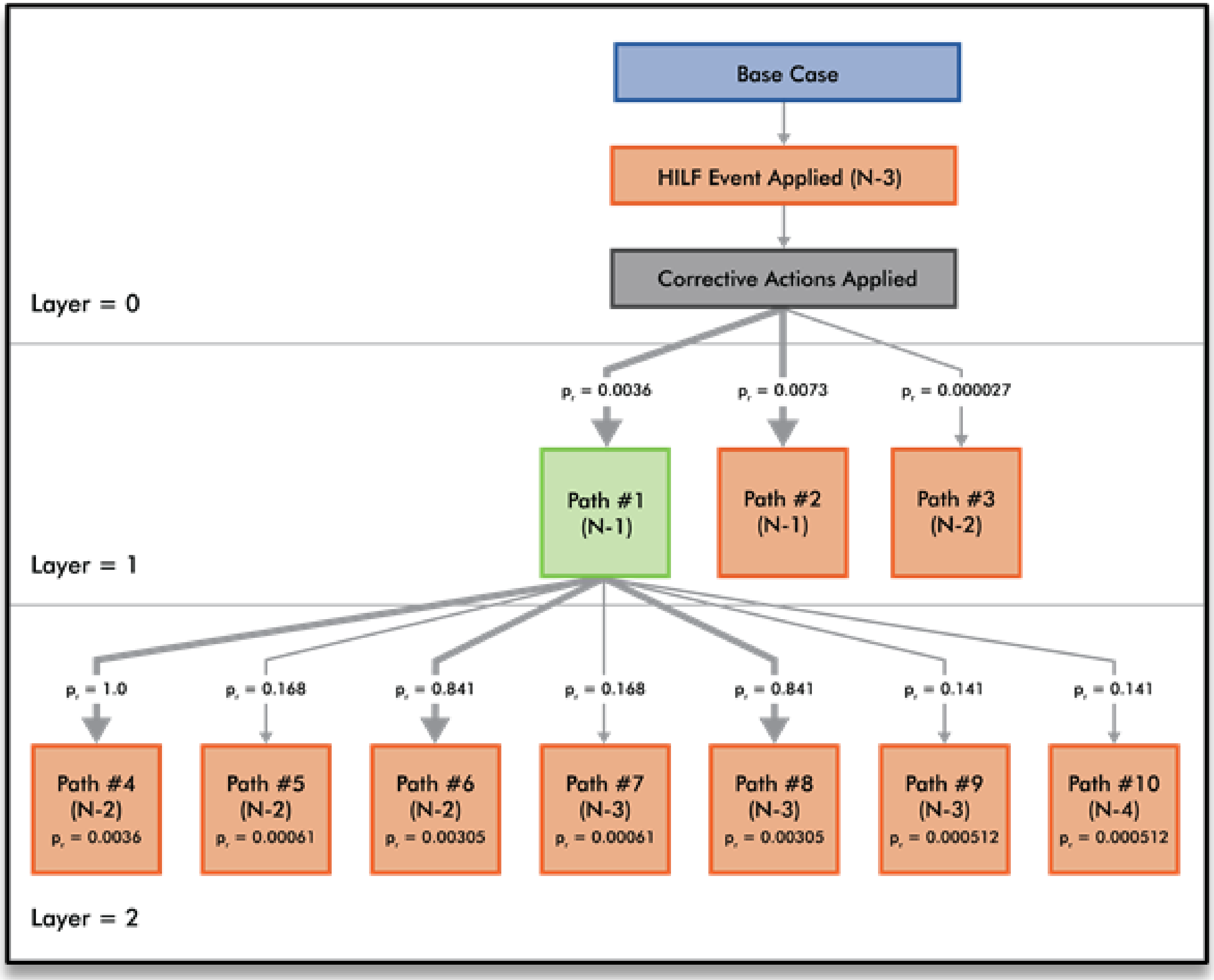
Resilient System Investment Framework (RSIF)

» PSSE-Python based framework for steady state analysis of extreme events
» Can generate potential cascading paths
  - Each path is assigned a probability based on level of violation (thermal for lines & transformers, voltage for generators)
» *layer = n* indicates the depth of the cascade (n = 1, 2, 3, etc.)
  - Each *layer* can have multiple states, depends on the number of violations present in the end state of the previous layer
» Risk is calculated for each end state across the *layer*
» End state occurs when there are no more violations (thermal or voltage)
» Risk calculated when an end state exists
  - Accounts for load loss, generation loss and divergence of the system



Scenarios that have significant divergence across the cascading paths imply less resilience

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Power Flow Scenarios and Events

Studied Scenarios

Scenario 1	Scenario 2	Scenario 3
• Full retirement of the once-through cooling (OTC) generation units in the LA Basin • ***Total Gen: 7325 MW and 1732 MVAr***	• **627 MW** of additional firm generation in-Basin compared to Scenario 1 • ***Total Gen: 7952 MW and 1741 MVAr***	• **871 MW** of additional firm generation in-Basin compared to Scenario 1 • ***Total Gen: 8196 MW and 1760 MVAr***

- » Weighed multiple possible future configuration of the LADWP system and compared the resilience of the network in response to a set of defined events
- » Network topology identical in all cases
  - One network sensitivity assess (new cable not completed by 2030)
- » Evaluated the impact of 12 contingency events
  - Combination of severe planning contingencies, natural disasters, and wildfire events
  - ***Used climate projections to identify contingency events based on the wildfire threat***
- » Probabilistic resilience assessment completed using the Resilient System Investment Framework (RSIF)

Resilience is measured as the level load loss risk present in the system

Set II: Saddle Ridge Fire

- » First wildfire event studied (*N-82*)
- » Scenario 3 produces the most resilient response to the Saddle Ridge Fire contingency
  - Additionally, there is no cascading in the system following the initiating event
- » Cable sensitivity again critical to supporting resilience, especially with increased in-Basin generation

Scenario 3 has the lowest levels of load loss risk for all studied scenarios and mitigates further cascades

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Set II: Sayre Fire

- » Most significant event studied (*N-100*)
- » Scenario 1 cannot survive the initiating event
- » Scenario 2 and Scenario 3 suffer from large levels of load loss
- » Network sensitivity results in an increase in load loss risk for Scenarios 2 and 3

Overall, Scenario 3 has the lowest levels of load loss risk for all studied scenarios.

Network upgrades also play a critical role in improving resilience

Future Work and Next Steps

» Expand transmission asset exposure assessment to include climate-related threats beyond wildfires (e.g., SLR).

» Explore methods to model wildfire spread under different climate futures

» Characterize more complex interactions between climate threats and the transmission system

» Use those interactions to define scenario level impacts for transmission analysis (e.g. derating transmission lines or other assets)

» Explore methods to assess dynamic impacts of extreme events and incorporate complex corrective actions and protection interaction

» Identify optimal transmission investments based on risk mitigation and cost-benefit

Acknowledgements

EPRI would like to thank Los Angeles Department of Water and Power (LADWP) for their support for the case study

- Environmental Affairs: Nancy Sutley, Mark Sedlacek, Julie Van Wagner
- Resource Planning, Development and Programs: Jason Rondou, Jay Lim, Robert Hodel, Luis Martinez
- Transmission Planning: Faranak Sarbaz, Jonathan Flores
- Energy Control and Grid Reliability: Glenn Barry, James Wells, Vin Vongvaravipatr

Together...Shaping the Future of Electricity

Audience Interaction

Anish Gaikwad & Mobolaji Bello

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Break

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EMT Studies for Transmission Planning

Goodarz Ghanavati & Meiyan Li
Eversource

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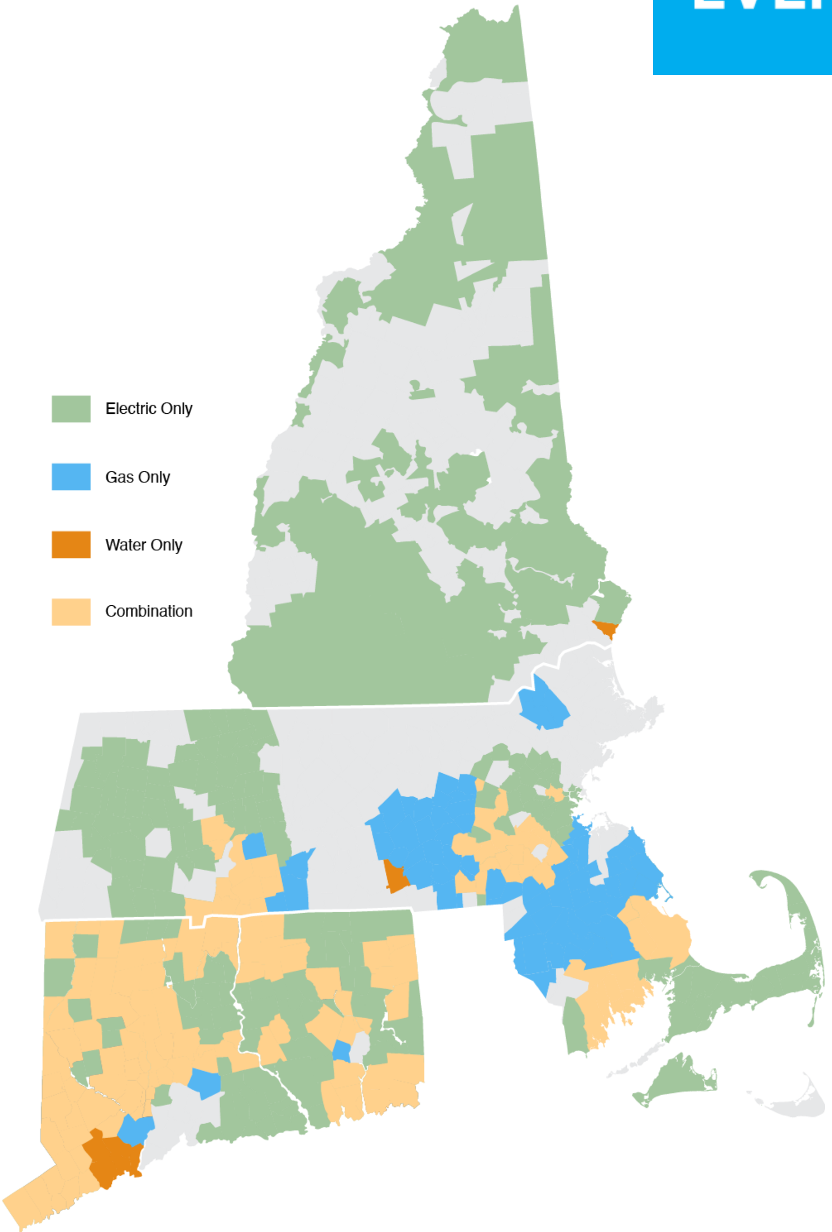
Eversource Southeast Massachusetts DER Cluster Interconnection EMT Study

November 4th, 2021

Eversource at a Glance

EVERSOURCE ENERGY

- **Largest Energy Company** in New England
- **9,100 employees** in three states
- Approximately **4.3 million** customers
  - Electric
  - Gas
  - Water



Overview

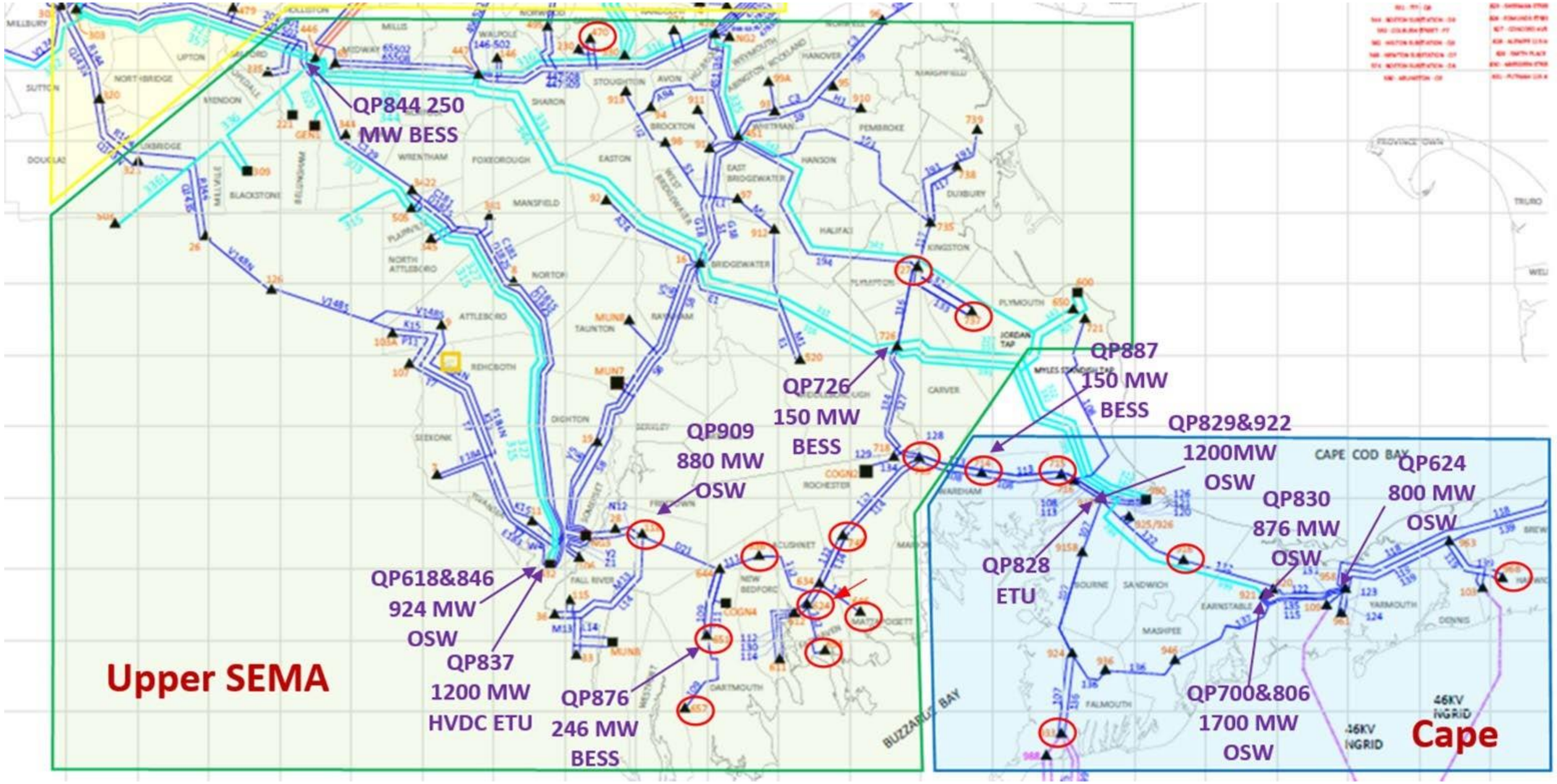
- Study Objective
- Project Description
- Analyses Performed and Study Results
- Computational Considerations

Study Objective

- Ensure the proposed ~240 MW distributed energy resources (DERs) do not in aggregate cause a significant adverse impact on the reliability and operating characteristics of the Eversource transmission system, the transmission facilities of another Transmission Owner, or the system of a Market Participant, and if they do, to recommend system improvements that would eliminate the adverse impacts.
- For this purpose, an electromagnetic (EMT) study was performed to:
  - Verify acceptable control stability and interactions between inverter-based technologies connected to Distribution and Transmission
  - Verify acceptable DER ride-through capabilities
  - Corroborate transient stability results and capture issues not identified due to the limitations of transient stability analysis

Geographic Location of the Study Area

- The study area covers a significant part of the transmission system in Southeast Massachusetts (SEMA).
- SEMA and Cape Cod has become an offshore wind hub with a couple of large-scale projects approved and several projects under study.



Electromagnetic Transient Analysis Modeling

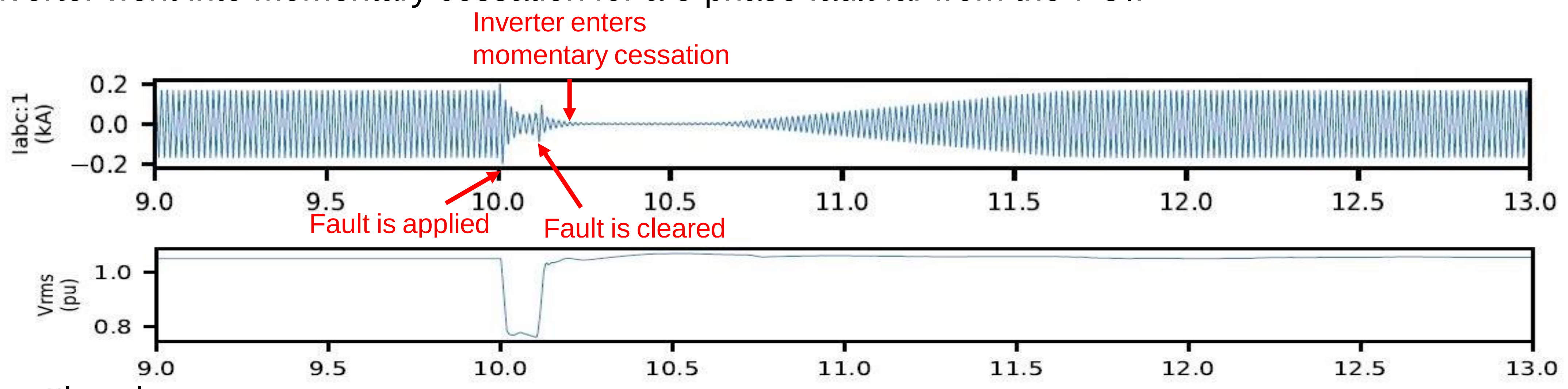
- Around 240 MW inverter based distributed energy resources (DERs) were studied.
- Around 400 MW existing inverter-based DERs were modeled in the study area.
- The most representative types of inverters were selected (up to 4) at each distribution substation to represent the DERs.
- Modeling includes 64 inverter based DERs, two offshore wind projects, two transmission connected battery energy storage projects, and FACTS devices in the study area.
- All models are vendor specific models.
- Each inverter-based resource/power electronics device was modeled in a separate PSCAD case. The cases are solved in parallel and communication among cases is through designated port numbers.
- Used the ETRAN+ PSCAD library to distribute the computation among several processors.

Analysis Performed

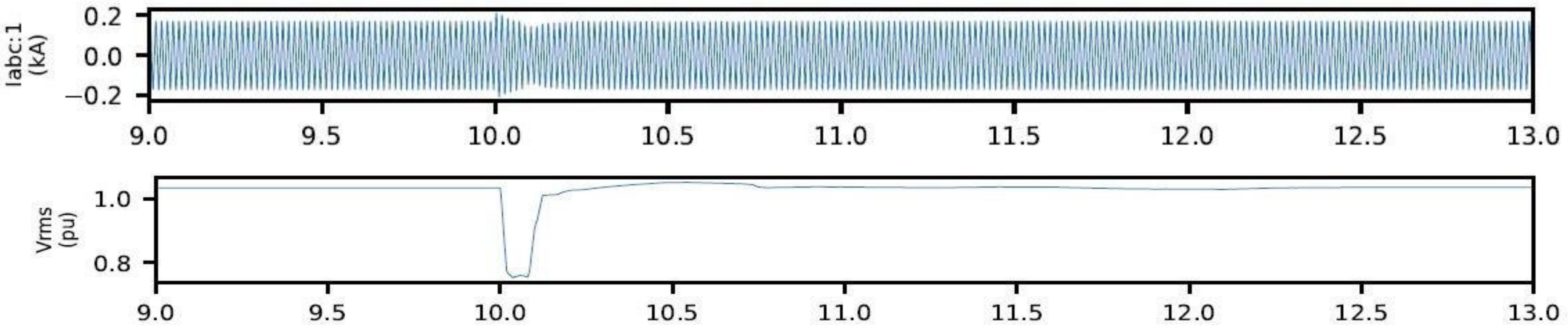
- Inverter Model Validation
- N-1 and N-1-1 Fault Testing
  - Balanced and unbalanced faults tested
  - Contingencies selected based on the result of prior interconnection studies and considerations of potential weak grid conditions
  - Transmission circuit, shunt device, double circuit tower, stuck breaker contingencies tested
  - Recloser operation was modeled
- PSSE and PSCAD Benchmarking

Inverter PSCAD Model Validation

PV inverter went into momentary cessation for a 3-phase fault far from the POI:

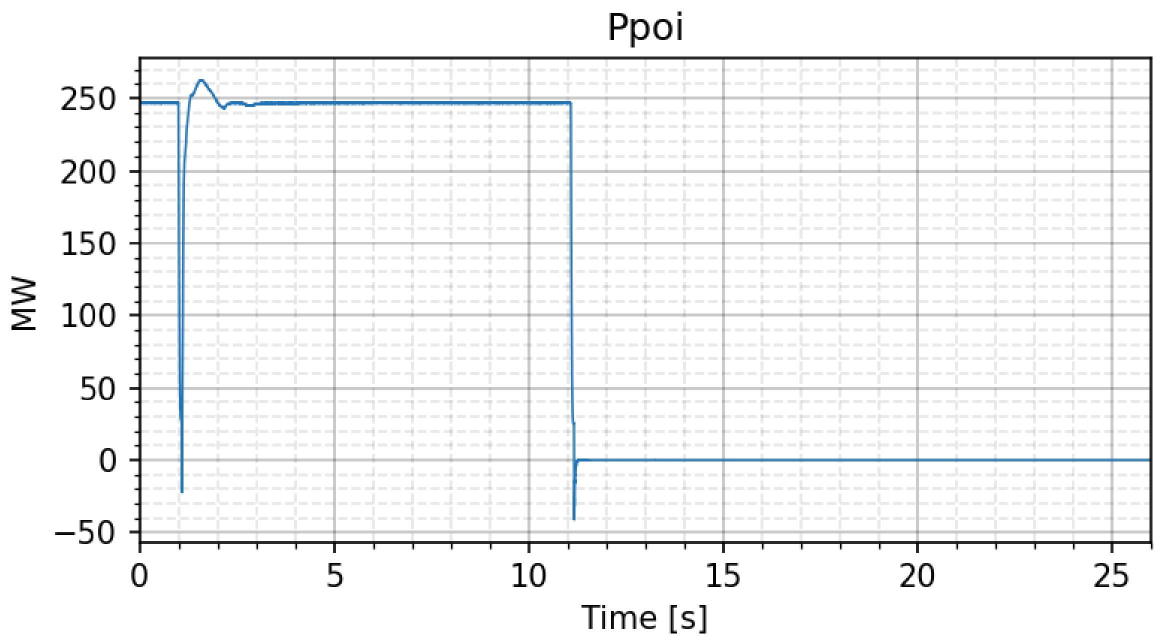


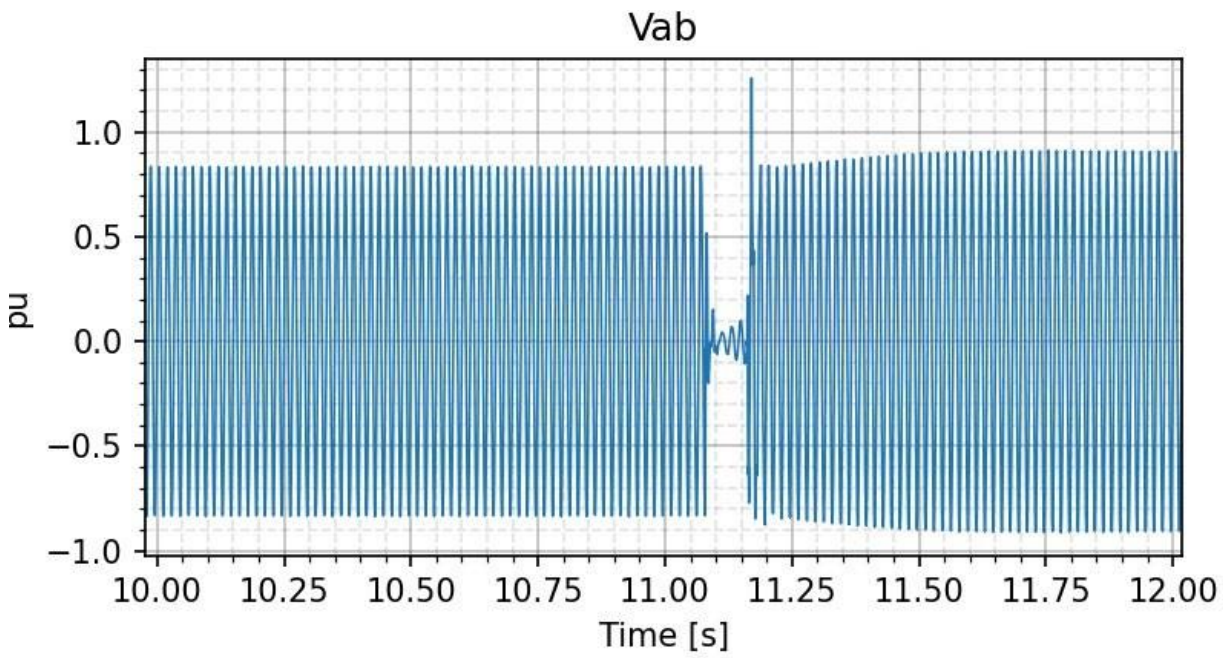
After setting change:



Electromagnetic Transient Analysis Results

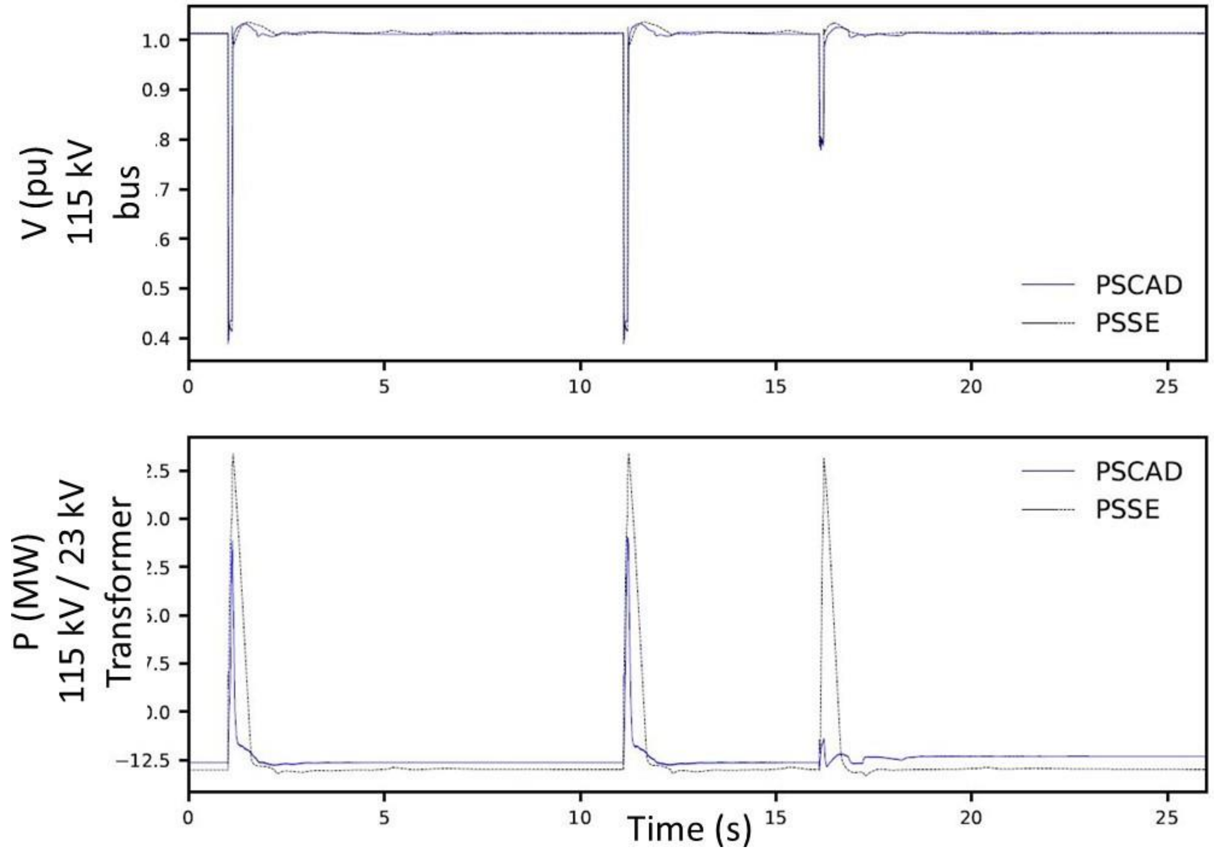
- A 250 MW BESS tripped at reclosing for an N-1-1 contingency in both pre and post project cases due to transient overvoltage caused by the BESS plant capacitor banks
- A 4.9 MW DER project at a station nearby tripped due to overvoltage as well





PSSE PSCAD Benchmarking

- Comparing the results for a three-phase fault with nonsimultaneous recloser operation



Electromagnetic Transient Analysis Results

- The proposed DER additions did not cause an adverse stability impact. System response was acceptable for contingencies tested per applicable criteria.
- PSCAD and PSSE simulation comparisons show dynamic responses of the models benchmarked well.
- EMT studies are necessary to integrate future inverter-based resources (IBRs) into the system and address any stability and control interaction issues due to large increase of IBRs in certain areas and retirement of synchronous generators.
- Improvement of EMT study efficiency under consideration.
  - Automation of simulation and post-processing

Computational Considerations

EVERSOURCE ENERGY

- Simulations were tested on two server machines with 112 cores, 512 GB memory.
- Each 35-second simulation of in cases with about 70 power electronics PSCAD models took about 4 hours to run.
- Study scope was carefully established to ensure adequate modeling detail and study accuracy and consider computational resources, e.g., the number of cases and contingencies to be tested, the size of the study area, and relevant projects to be modeled.
- A significant part of the study involves tasks other than running the simulation including model validation, case building, fault automation, post processing the results
- Better computational tools will facilitate performing and scaling up resource-intensive EMT studies

QUESTIONS?

EMT Studies for Transmission Planning

Andrew Isaacs
Electranix Corporation

NERC-EPRI-NATF Planning and Modeling Virtual Seminar

November 4, 2021

Open Distribution

Leveraging Advanced Hardware and Computing Techniques for EMT studies

EPRI-NERC-NATF Planning and Modeling Virtual Seminar

November 4, 2021

Presented by Andrew L. Isaacs

Who is Electranix

Established in 2000, We offer power system consulting services for ISOs, TOs, GOs, and larger consultants, mainly in studies and simulation. We develop E-Tran, E-Tran Plus software, and primarily use PSCAD/EMTDC, PSS/E, PSLF and E-Tran. We are located in Winnipeg, Manitoba, Canada

Leadership Team

- Dennis Woodford – *President, Engineer, Founder*
- Garth Irwin – *VP, Engineer, Founder*
- Andrew Isaacs – *VP, Engineer*

Modelling and Studies Team

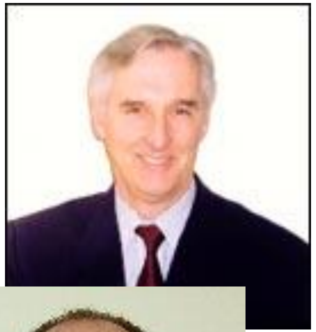
- Anuradha Dissanayaka M.Sc. –Study Engineer
- Francisco Gomez Ph.D. –Study Engineer
- Chaminda Amarasinghe Ph.D. – Modeling Specialist Engineer
- Xiuyu Chen Ph.D. – Study Engineer
- Amit Jindal Ph.D. – Study Engineer
- Jeremy Sneath M.Sc. – Study Engineer
- Lukas Unruh – Study Engineer
- Kumara Mudunkotuwa Ph.D. – Study Engineer
- Kasun Samarawickrama M.Sc. – Study Engineer
- Alex Poersch – Study Specialist
- Hang Li – Research Engineer
- Vianey Mateo – Study Specialist
- Anuradha Kariyawasam – Study Engineer
- Gabriel Molin – Engineering Intern
- Ting Lin – Engineering Intern/MITACS Scholar

Software Team

- Joel Dyck M.Sc. – Computer Scientist
- Nathan Kroeker – Computer Scientist
- Suren Dadallage M.Sc. – Electrical Engineer
- Pokyee Tsu – Computer Science Intern

Admin Team

- Janet Woodford
- Crystal Isaacs M.Sc.
- Gagandeep Saini MBA



What's going on in EMT studies?

- We know we need them, they're not going away, and they're getting more common. So here's what we are doing these days in:
  - Software
  - IBR Plant Models
  - Hardware
  - Studies
  - Building Industry Capability!
  - Gaps

- Note: Other people are doing good work, and other tools are available… this is just our own experience.

Software Advances

- PSCAD version 5 was released this year. Lots of good improvements, but version 4.6.3 is still widely used.
- E-Tran Version 5.2 is currently used in all studies, Version 6.0 is planned for release this month.
  - E-Tran is used for translation from PSS/E to PSCAD, study model building, parallelization, and hybrid/co-simulation.
  - E-Tran development focus is currently study building and automation.
  - Improvements to:
    - API for building E-Tran runs into automated processes
    - Updated generic solar and load models
    - 64 bit support
    - Improved parallelization support (automatic parallelization)
    - Substitution library template generator
    - Improved logging, help and tooltips
    - UFLS model support
    - Updated generic models and standard library support
- Software is key!! Custom scripting and automation is advancing to handle the masses of data input and plotting requirements. These may find their way into future E-Tran releases.
  - Eg. Electranix now has 4 in house computer scientists, and a number of python specialists in the engineering group

IBR Plant Modelling:

- Model requirements: We continue to maintain ours here: http://www.electranix.com/wp-content/uploads/2021/02/Requirements-Rev.-10-Feb-3-2021.pdf
- Other industry guidance is coming quickly:
  - Regional standards have become quite advanced.
  - 2017, 2019 NERC IBR interconnection guidance
  - IEEE 2800 draft standard, IEEE 2800.2 forthcoming
- With a few exceptions, we are seeing good quality models coming out. Parameterization and control tuning are the main trouble points now.
- Utilities and ISOs are adopting recommendations from NERC and others to request EMT models for all IBR projects.

IEEE/Cigre WG to develop a DLL standard for controller models – "Real Code"

- "Real code" is desirable for maximum accuracy. These models wrap the actual inverter source code into a .dll which can be called from any software tool.
- >100 OEMs, tool developers, and end users participating. Most major simulation tool suppliers are contributing.
- V1.0 of the DLL interface has been reviewed by the team, and has been used by approximately 10 OEMs of converter controllers.
- V1.1 has been reviewed by a small team, and is nearly ready for release to the entire WG. V1.1 includes:
  - Ability to use other input, output or parameter types (ie use of C structures vs Double vectors)
  - Removal of program specific information (leftover from the earlier IEC starting point)
  - Removal of features that are not used in real firmware controllers (ie iterations, derivative based central solvers etc.)
- Electranix has a new DLL import tool based on the standard for both PSCAD and PSS/E which includes features to support snapshots and multiple instances even if the code doesn't group state variables.
- Documentation, user-guide, examples are in development.

Hardware Advances

- We are currently captive to chip supply issues… our simulation computers in house are either:
  - Largest models: AMD Ryzen Threadripper 3990x based: 64 core, 128 thread
  - Standard models: AMD Ryzen Threadripper 3970x based: 32 core, 64 thread
- Some utility customers are using Intel Xeon based solutions to satisfy IT departments who don't want AMD solutions:
  - Much more expensive
  - Slower per-core performance
- Coming:
  - Threadripper 5000 series (Zen 3) arriving this month, but won't be much different (still 64 cores)
  - Threadripper Zen-4 based chips will have 128 cores, 256 threads. Rumored for Q2 2022, rumored 40% speed increase over Zen 3 in addition to core count.
  - Some utilities (ISONE) experimenting with cloud based computing. Currently not suitable for our application, but we are watching it.

Electranix Computer Build Reference 2021:

Type 1 – Basic Workstation: Intel Core i9-10900 or similar (10 cores, 20 threads, but very high speed per core) (approx. 3000 CAD for full machine)

- We use these as basic workstations which will be running PSCAD, but not massively parallelized cases. Good for design, troubleshooting, case creation, etc.
- 32 GB RAM (4 channel DDR), liquid cooled, 2 TB NVM.e SSD drive, 750 Watt PSU, onboard Intel video (no external video card required if you get a workstation motherboard with multiple screen outputs available).

Type 2 – Study Workstation: AMD Ryzen 3970X (32 cores, 64 threads, approx. 6000 CAD for full machine)

- We use these as workstations for engineers routinely running large parallelized cases.
- 64 GB RAM (4 channel DDR), large liquid cooler for CPU, 2 TB NVM.e SSD drive, min. 750 Watt PSU, discrete video card will be required (just enough to support your monitors, usually around 100 dollars).

Type 3 – Advanced Study Workstation: AMD Ryzen 3990X (64 cores, 128 threads, approx. 10000 CAD for full machine)

- We use these for very large parallelized cases. Individual core speeds are excellent as well as large parallelization capability.
- 128 GB RAM (4 channel DDR), large liquid cooler for CPU, 2 TB NVM.e SSD drive, min. 850 Watt PSU, discrete video card will be required (just enough to support your monitors, usually around 100 dollars).

Electranix Computer Build Reference 2021:

General Computer Assembly tips:

- Get a large case to make your assembly easier, and make sure that the CPU cooler fits inside the case before purchasing it.
- Although the power supplies may be more wattage than you need to supply the CPU, the larger power supplies tend to have more available outputs which you often need for the high performance motherboards.
- Use only high quality power supplies.
- The biggest failure point so far has been CPU coolers. Expect that it may fail in 2 years if the computer is used heavily.
- If the person assembling the computer has no experience, get some help from the computer store to mount the CPU to the motherboard and research cooling paste application before mounting the cooler. Some computer stores offer assembly services which may be good if the engineer is uncomfortable.
- You can override the stock CPU clock settings to allow higher speed when all the cores are utilized together. Just keep an eye on temperatures and clock speeds, and back it off if you're having instability issues.

Studies

- Study covering large areas are more frequent than ever:
  - 20-200 IBR models, 500-1000 busses.
  - DER cluster studies (ISONE)
  - High penetration regional studies (Texas, Australian states, ATC, ISONE, others)
  - Island systems (HECO, Australia)
- More than just PSCAD and E-Tran models now, they sometimes require additional customized layers of scripting and automation software to setup and run.
  - This makes challenges for model portability, on top of IP constraints.
- Some utilities are starting to take these on with minimal support from consultants
  - ERCOT, HECO, Eversource
- Many utilities are gearing up for increased in house capability, working with smaller systems and updating their model intake capability

EMT is great… but also really hard!!

- A utility or entity that wishes to begin doing EMT studies must do the following:
  - Develop knowledge of what is required (What don't you know?)
  - Regulatory framework is required to get models and perform studies
  - Software acquisition (what tools/modules do you need?)
  - Hardware acquisition
  - Model acquisition (you need to get the models)
  - Model quality control (you need to check the models against your criteria)
  - Develop knowledge of specific tools and techniques (Training)
  - Perform EMT studies within your existing regulatory framework and schedules.
- Each of these has its own challenges, and the only one that's "easy" is the actual software purchase.

Training: *Plan* to do this yourself *eventually*

- EMT is challenging, and it requires years to develop a utility's capability to the point that they are self-sufficient. But it is possible!!
  - Start with a pre-made standard, and prepare to adjust it to meet your own needs.
  - Begin immediately taking in models for new IBRs
  - If needed immediately, hire consultants to get you through "crunch time"
  - Hire or dedicate your own specific staff to learn this skillset. This isn't a casual enterprise, and any casual approach will fail.
  - Get basic training in software tools, and expert training in study applications.
  - Training isn't a "one-and-done". You should plan on continued training, or ongoing support for a while. This will only work if you have dedicated staff working on EMT.

Key Gaps

- IBR OEMs have largely kept up with model requirements (Thanks!)
- Gaps in model testing, parameterization, and matching requirements against controller capabilities
- Gaps in modeling and simulation standards
- Gaps in planning group knowledge and human resource capabilities
- Gaps in timeline possibilities vs expectations
- Gaps in E-Tran capabilities… we have work to do to help planners automate their studies and quickly build models.
- **Gaps in protective relay EMT models!!! Help us help you!!! "Relay OEMS need to get out of the EMT dark ages" - Garth Irwin**

Thank you! Questions?

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Transportation Electrification & System Planning

Jared Green
EPRI

NERC-EPRI-NATF Planning and Modeling Virtual Seminar

November 4, 2021

Open Distribution

Estimating the Size of Future Electric Fleets

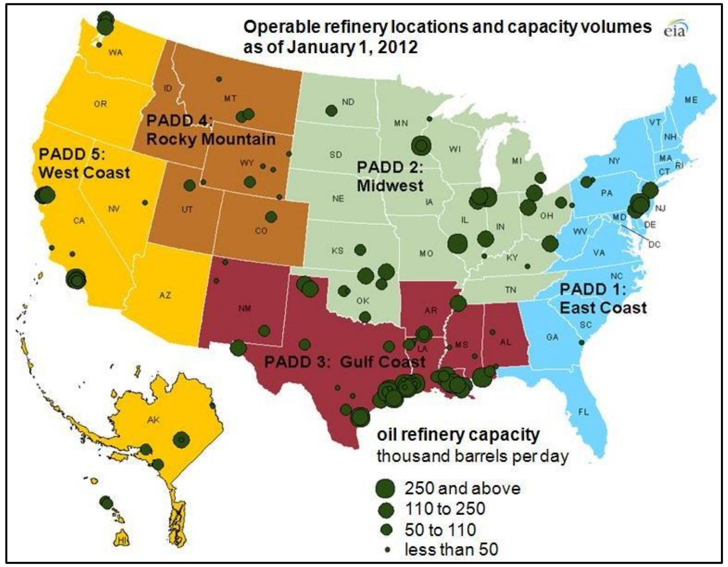
Using Imagery to Help Forecast Future Loads

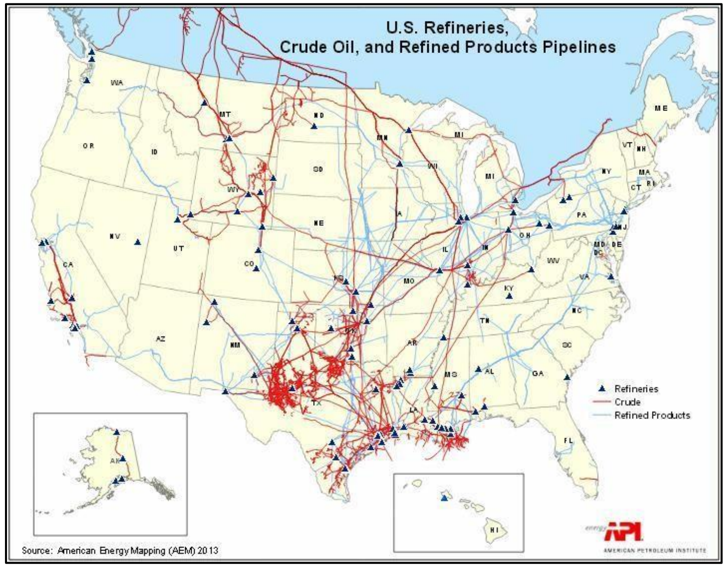
Jared Green
Sr. Technical Leader – Distribution Operations and Planning

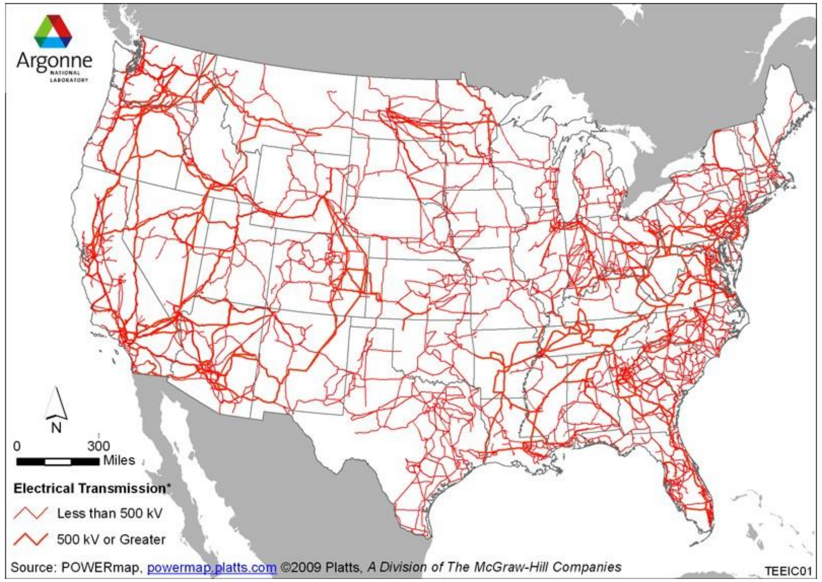
EPRI-NERC-NATF 2021 Planning and Modeling Virtual Seminar

November 3-4, 2021

Transition from Centralized to Distributed Energy Supply Locations for Transportation





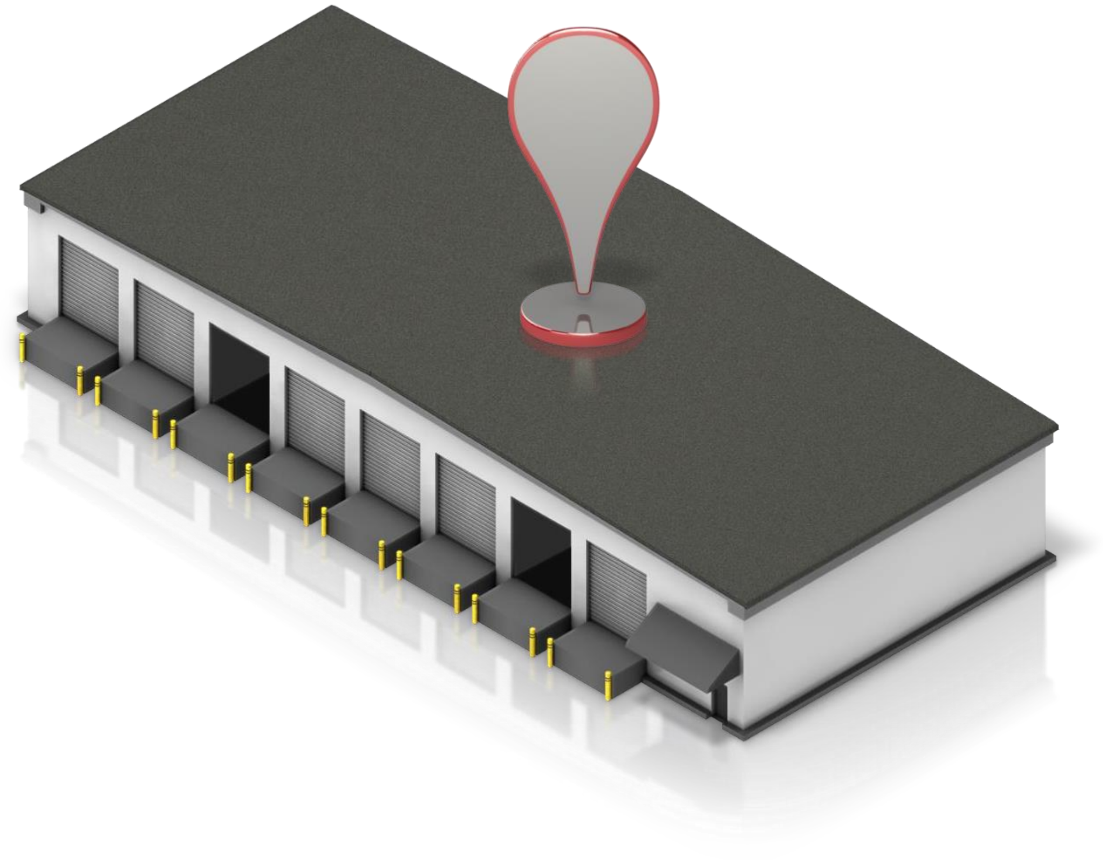


Electric Fleet

Open Distribution

Fleet Assessment Using Remote Imagery + Analytics

- EV Fleet Conversion Data Required
  - Location of facility
  - Number of vehicles
  - Type/size of vehicles
  - Daily route distance
- Other Detectable Characteristics
  - Bays (type and number)
  - Square footage: warehouse / parking lot / lot
  - Roof usable area, pitch, and orientation
  - Examples: Google Earth and Bing Maps
- Other supporting datasets



Open Distribution

Challenges

- Most optical imagery taken midday.
- Seasonal and daily variations of fleet ops.
- Different ops characteristics per location.
- Road striping and concrete pads may appear to be fleet vehicles.
- Some fleet vehicles are inside the facility.

Open Distribution

Comparison of Imagery

Panchromatic Sharpened Image
(30 cm – highest resolution available for satellites)

Bing Image (higher resolution than satellite)

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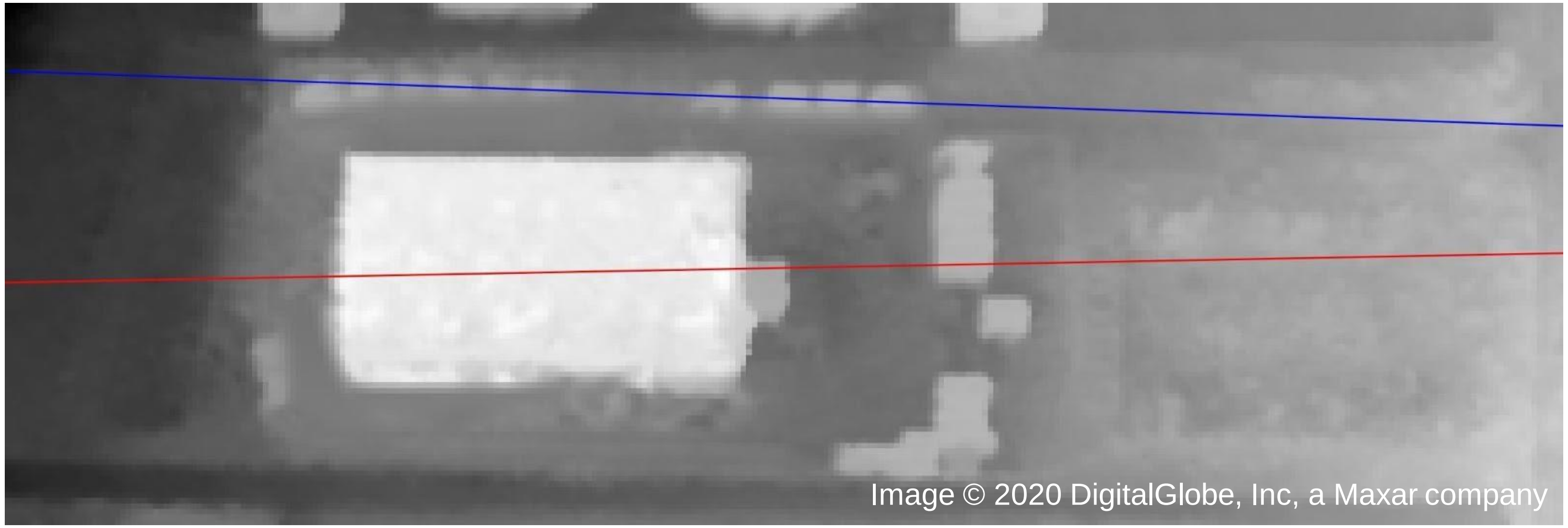
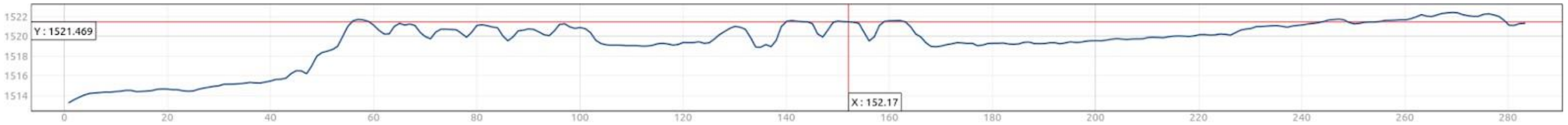
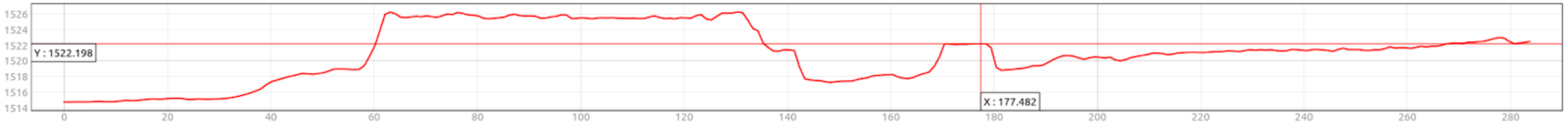
ELECTRIC POWER RESEARCH INSTITUTE

How can stereo satellite imagery be used?

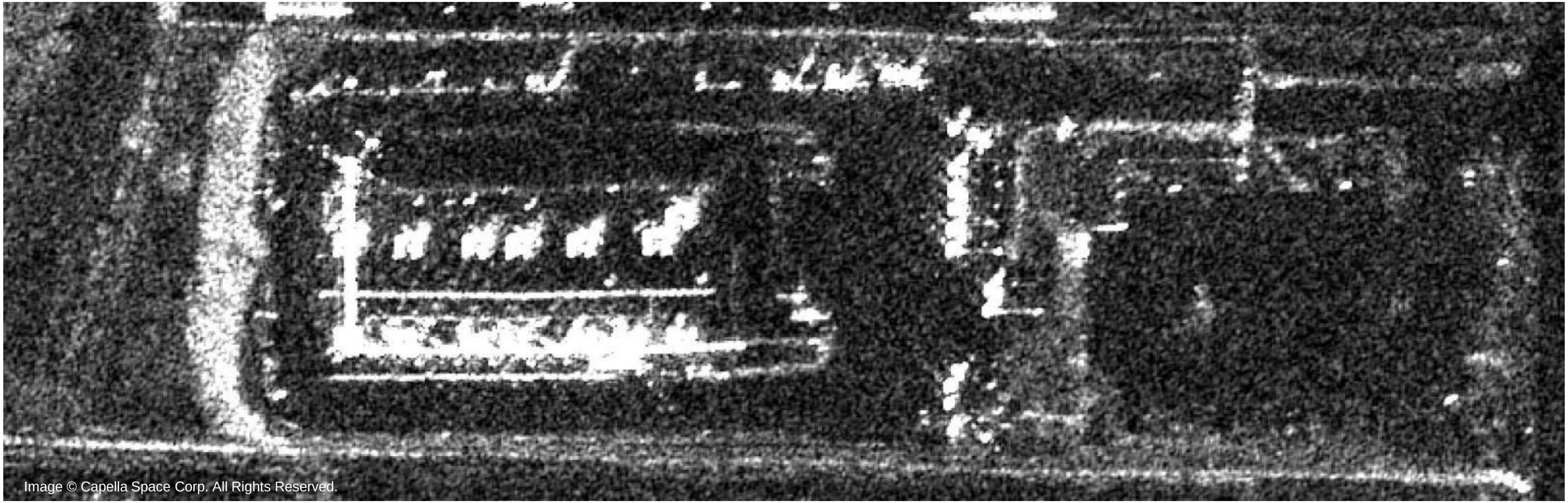






Stereo Imaging – Adds element of height

How About SAR(Synthetic-aperture radar) Imagery?



Identification is ALL about the Pixels

Analytical Method Used: Contour detection

Vehicle	Size (m)		Google (135m)		Bing (lvl=19)		WorldView3		WorldView2	
Pix/m			15.5		4.2		3.3		2	
	W	L	W	L	W	L	W	L	W	L
USPS (LLV)	1.88	2.77	29.1	42.8	7.9	11.6	6.3	9.2	3.8	5.5
Delivery (Van)	2.04	4.95	31.5	76.5	8.6	20.8	6.8	16.5	4.1	9.9
Step (Van)	2.44	6.1	37.7	94.3	10.2	25.6	8.1	20.3	4.9	12.2
Highway Trailer	2.59	6.7	40.1	103.6	10.9	28.1	8.6	22.3	5.2	13.4

None of the research approaches evaluated use less than 100 pixels.

Results

Without Element of Height

With Height Included in Analysis

Intelligence Embedded in Fleet Orders of EVs

Vendor and Model	Range	Cargo	Payload	Battery	Charging	Major Orders
	km	m^3	kg	kWh	kW	
Arrival	180 240 290 340	14	1975 1875 1736 1615	67 89 111 133	120	UPS 10,000
Chanje V8100	240	19	2730	100		FedEx 1,000
Ford eTransit	200	13.8	1730	67	115	
GM/BrightDrop EV600	100 400	17	1000	50 200	120	FedEx
Mercedes eSprinter	115 150	11	1040 900	44 55		Amazon 1,200
Oshkosh NGDV						USPS 50,000 to 165,000
Rivian	240	14.2, 19.8, 25.5				Amazon 100,000
Workhorse	160	18.4, 28.3		70		UPS 950

Example – Demonstration Site Forecast

- 50 fleet vehicles
- 10 bays (Another good indicator)
- Fleet vehicles/infrastructure assumptions: GM/BrightDrop EV600 with 120 kW DC fast charger
- Must consider other factors for full evaluation (other loads, operational characteristics, etc.)
- Example shows largest impacts to grid per scenario.

Number of DC Fast Chargers	Avg. Duration for Charging (hours)	Load using 120 kW DC Fast Charger (kW)	Total Energy (kWh)	5 vehicles 10% Error in Vehicle Identification (ΔkWh)	10 vehicles 20% Error in Vehicle Identification (ΔkWh)	Likely transformer sizing
50	1	6000	6000	600	1200	5000 kVA
25	2	3000	6000	600	1200	5000 kVA
10	5	1200	6000	600	1200	1500 KVA
5	10	600	6000	600	1200	750 KVA

Is forecasting the future size of a fleet like a game of horseshoes?

A Potential Path Forward

Build a Model with Readily Available Data

- Available datasets:
  - Imagery
    - Square footage of building/parking lot
    - Count number of cars in the parking lot and fleet vehicles within facility
    - Count number of bays
  - Fleet Datasets
    - Total number and maybe type of vehicles in fleet
  - Misc. datasets
    - Census data for population growth
    - DOT for miles of roadway in counties
    - Size of distribution transformer (rule of thumb barometer)
    - Others
  - Obtain ground truthing for fine-tuning of the model

$$Number\ of\ fleet\ vehicles = \#.\#\# * employee\ cars + \#.\#\# * sqft\ of\ building + \#.\#\# * miles\ in\ county$$

Together…Shaping the Future of Electricity

Open Distribution

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Transportation Electrification & System Planning

Tim Pennington

Idaho National Laboratory

NERC-EPRI-NATF Planning and Modeling Virtual Seminar

November 4, 2021

Open Distribution

Transportation Electrification High Fidelity Grid Impact Modeling

EPRI – NERC – NATF

Planning & Modeling Seminar

4 November 2021

Timothy Pennington
Sr. Research Engineer

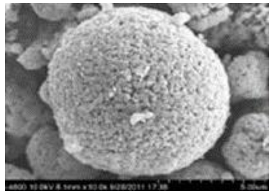
Caldera™

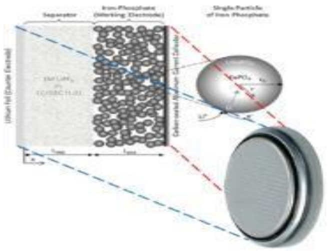
An Idaho National Laboratory Tool for Modeling Electric Vehicle, Grid, and Stationary Energy Storage Interactions

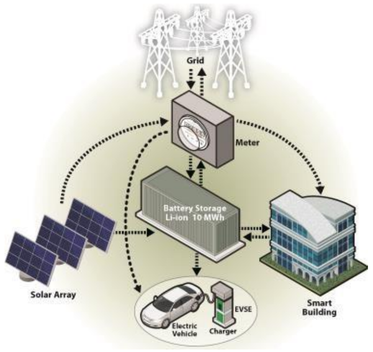
Idaho National Laboratory

INL/CON-21-65069 Approved for public release.

Energy Storage and Advanced Transportation Department







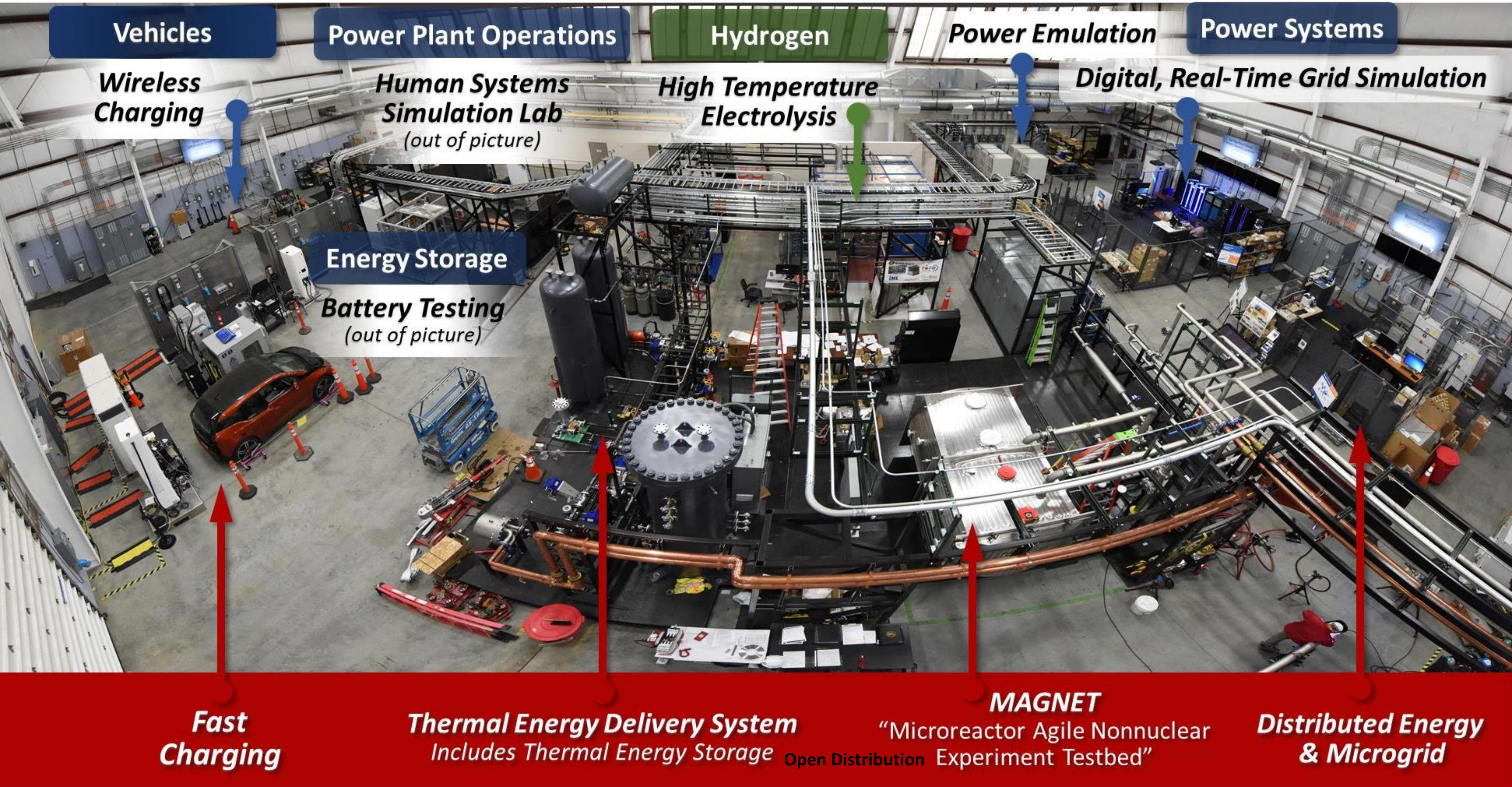
Molecular Material Studies → ***Advanced Battery Characterization*** → ***Future Electrified Mobility***

Battery Test Center (BTC)

Non-destructive Battery Evaluation Lab (NOBEL)

Electric Vehicle Infrastructure Laboratory (EVIL)

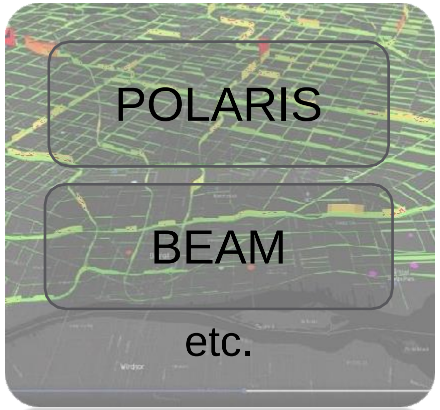
INL's Integrated Energy Systems Laboratory



Why Caldera?

Caldera is the "Missing Link" to high-fidelity modeling of EV impacts on the Transportation System and the Grid

Transportation Models



POLARIS

BEAM

etc.

HELICS

Co-simulation

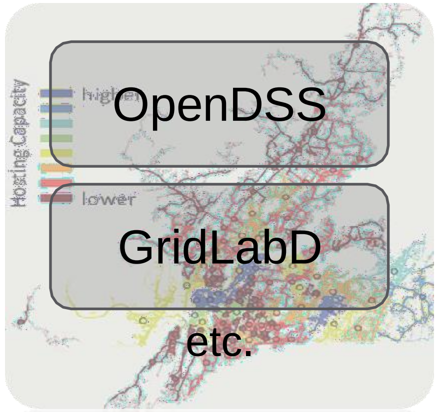
Caldera

EV Modeling Platform

HELICS

Co-simulation

Grid Models



OpenDSS

GridLabD

etc.

Simulating mobility

Existing tools lack understanding of: grid topology, power availability, charging cost information, detailed charge profiles

Linking Transportation and Grid Tools

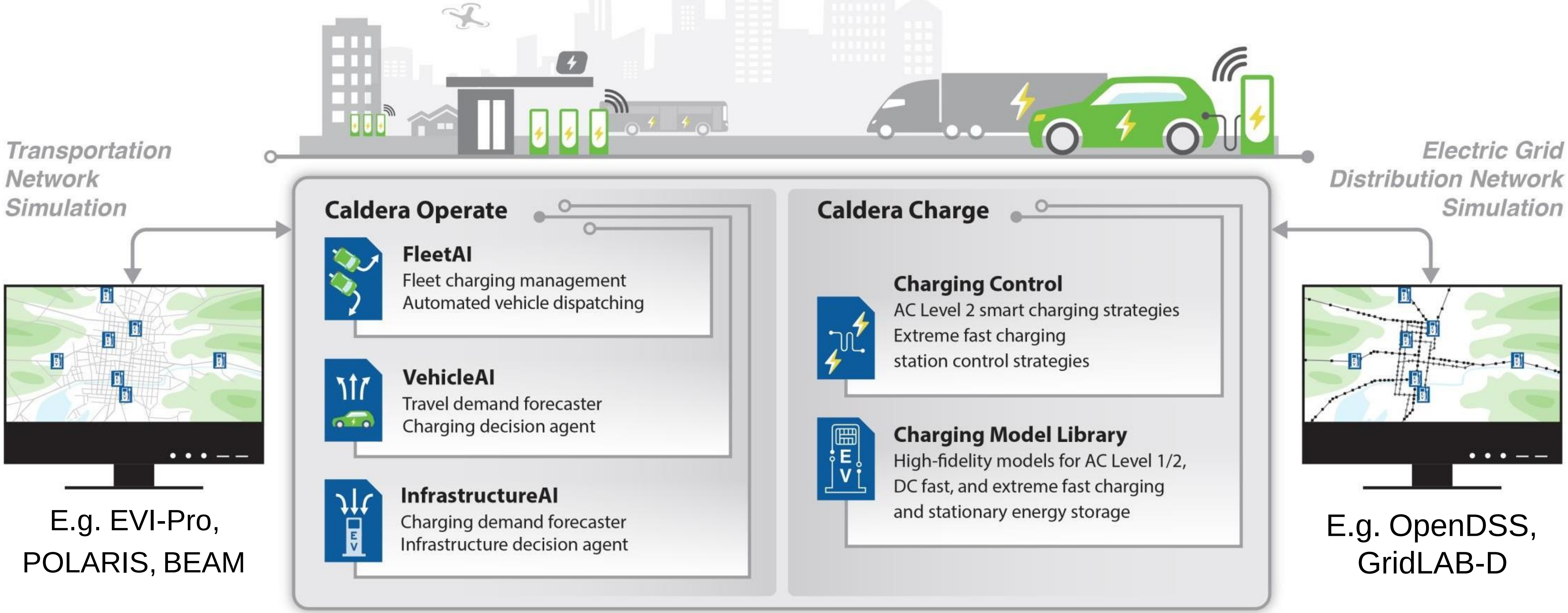
Demonstrates EV charging effects and illustrates system optimization by co-simulating both grid and driving conditions

Simulating distribution and traditional loads

Existing tools lack understanding of: when and where EVs will charge, detailed load profiles, effects of control strategies

Caldera

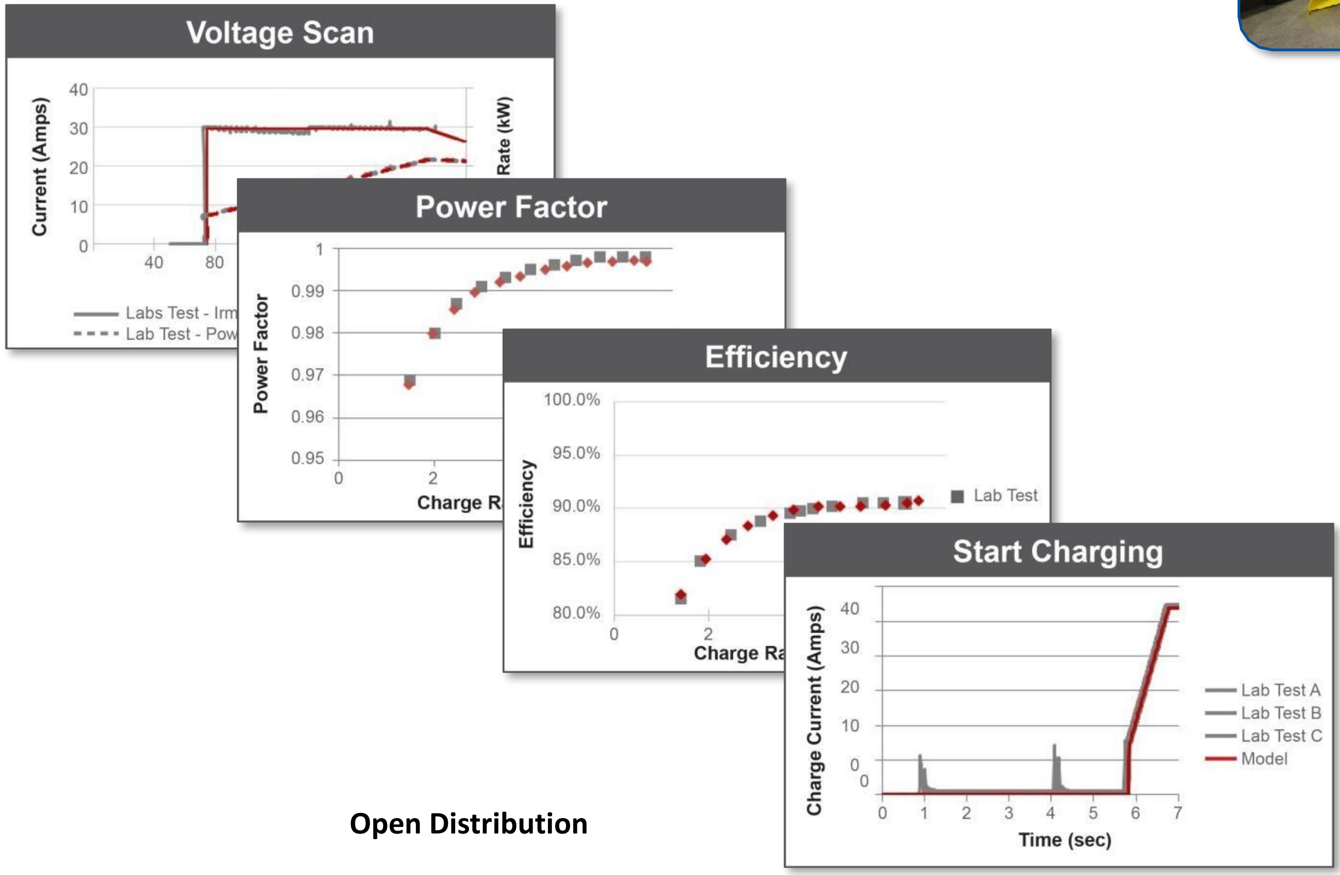
Electric Vehicle & Infrastructure Decision Management Simulation Platform



Caldera is an agent-based modeling platform for predicting detailed system impacts and demonstrating intelligent management strategies

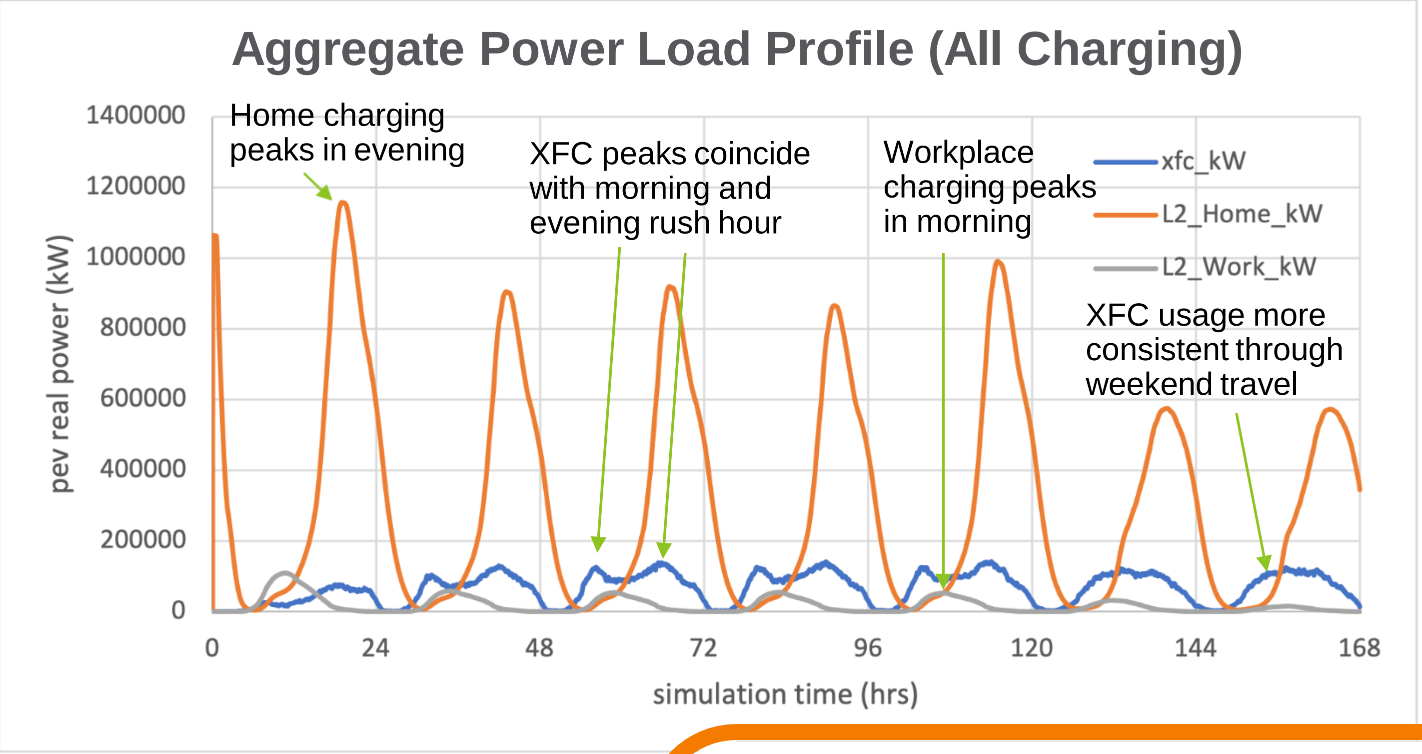
High Fidelity EV / EVSE Charging Model library

- In Caldera EVs and EVSEs are modeled **individually** using high-fidelity models. Aggregate or composite models are **not** used.
- These high-fidelity models are based on results from testing real EVs, EVSE, and batteries in the laboratory.



- The testing is done in INL's BTC and EVIL labs.
- Each of these graphs compares lab test results to outputs from one of INL's high fidelity EV charging models.

Sample Results: Predicting Charging Demand from 1.1M Personal-Use EVs (2040 Vehicle Fleet – 40%)



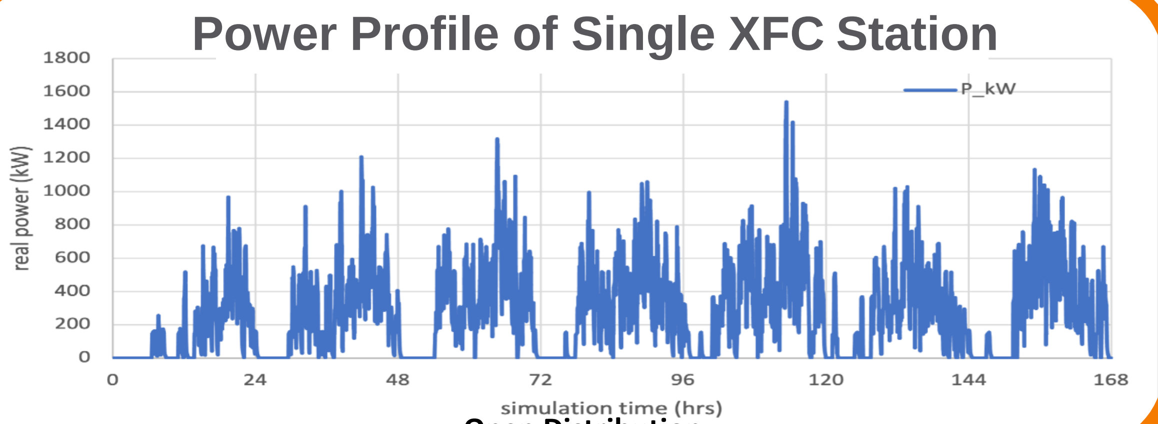
- Results from week-long Caldera simulation of personal-use vehicles shows capability to predict charging demand that is easily extended to fleets
- Results also produced (not shown) for individual vehicle travel itineraries, including routing to and dwelling at charging stations for least cost/time/distance

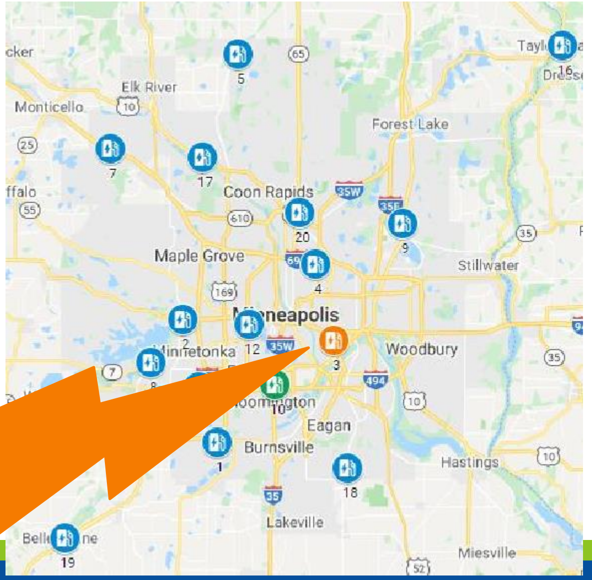
Total Power breakdown:

- 78% L2 Home
- 17% XFC Public
- 5% L2 Work

Charging Access Assumptions:

- 70% have Home Charging
- 25% have Work Charging
- 22% have only XFC Public





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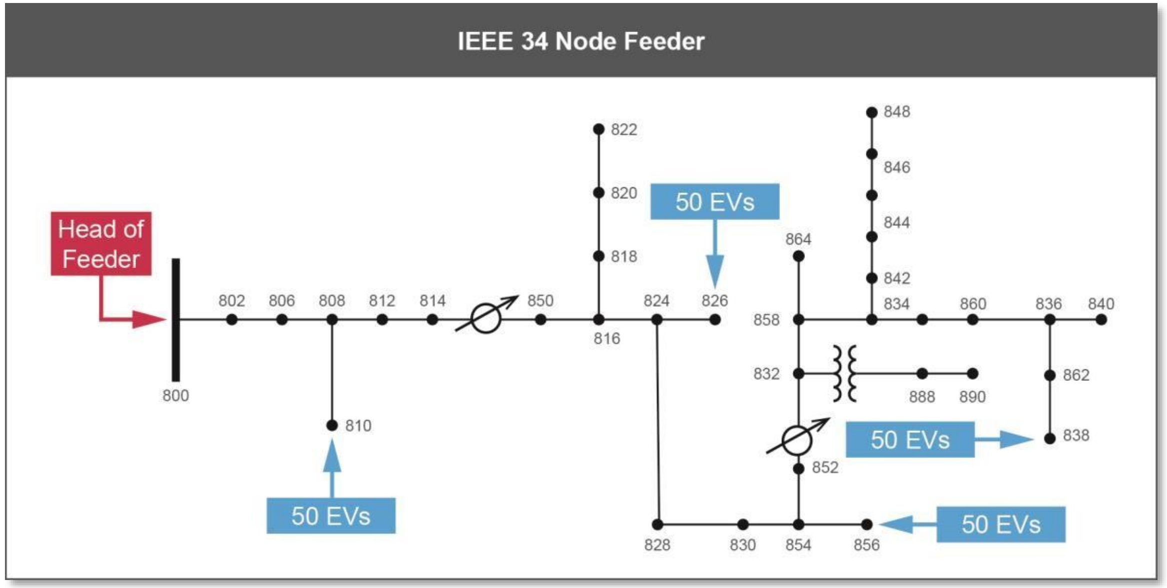
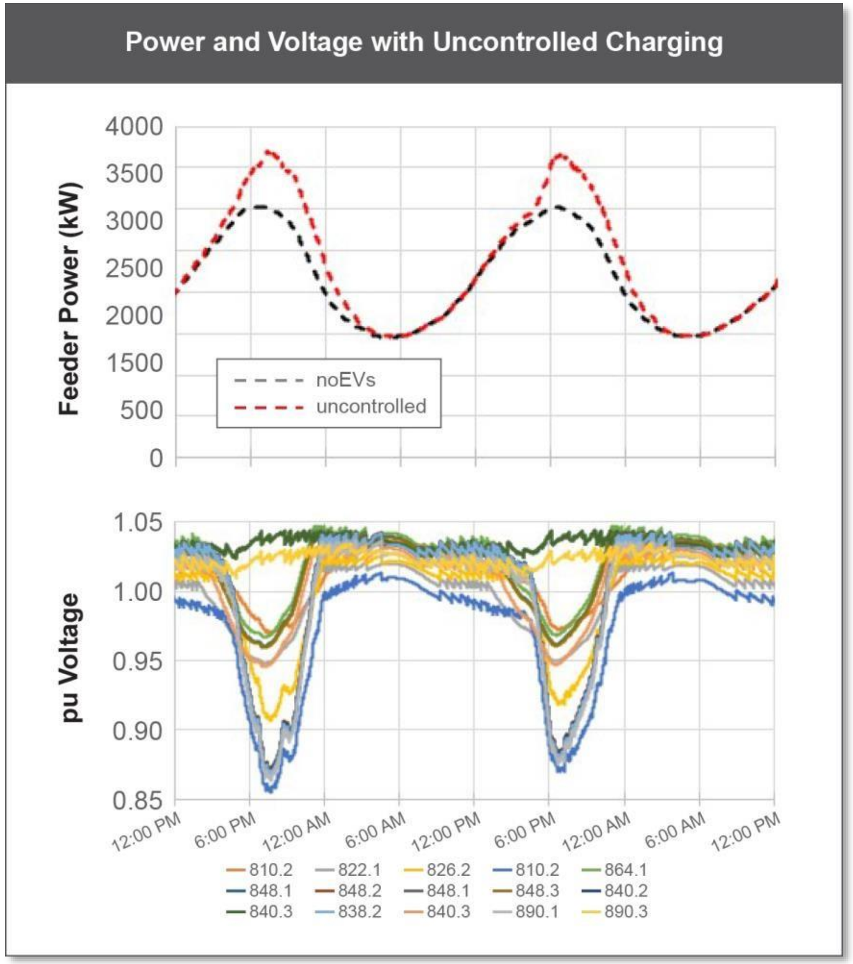
Grid Impact Demonstration Platform

- Transportation simulation determines when and where vehicles are connected to the grid
- Charging model library accurately simulates loads which are applied to the grid model and can be viewed as an aggregate impact
- **Uncontrolled charging** is demonstrated and resulting impacts on the grid such as peak feeder power and node voltage are assessed for improvement

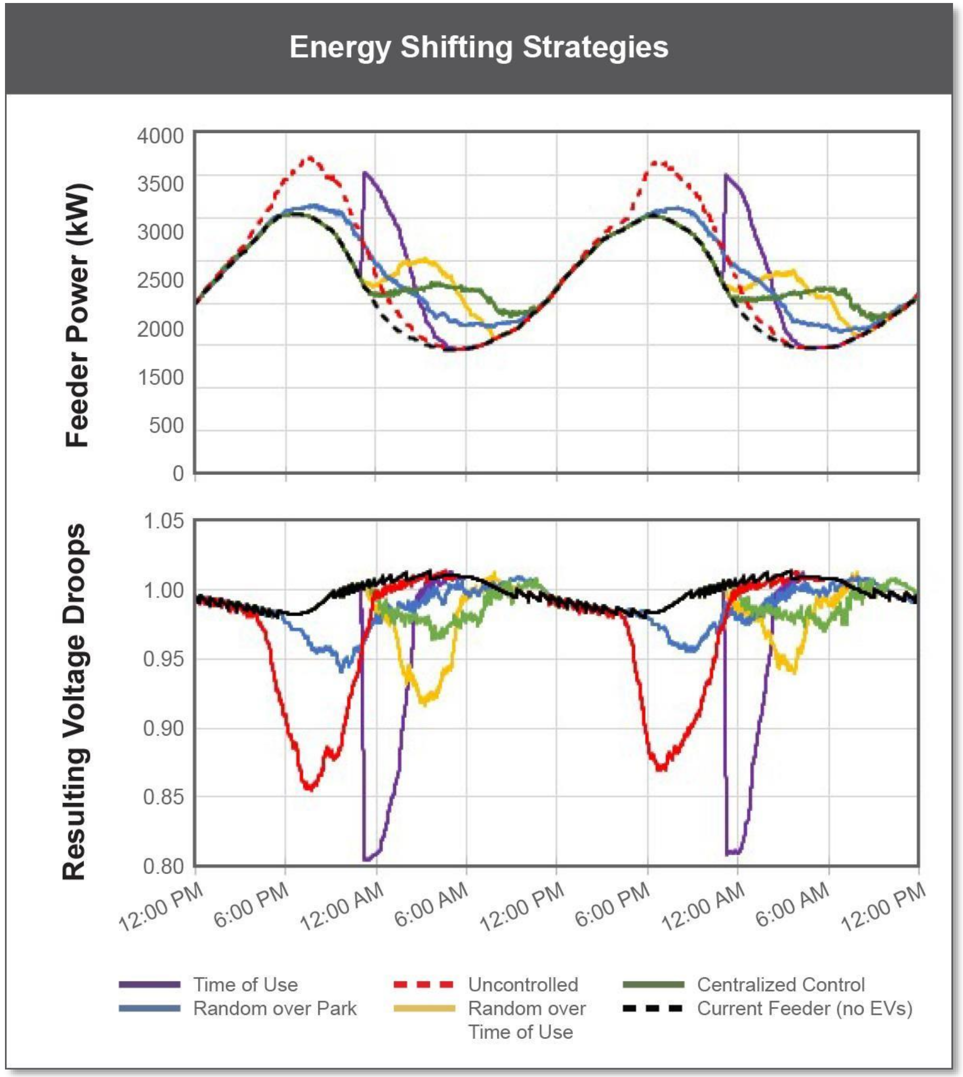




Open Distribution

Results from Caldera in RECHARGE DOE Project

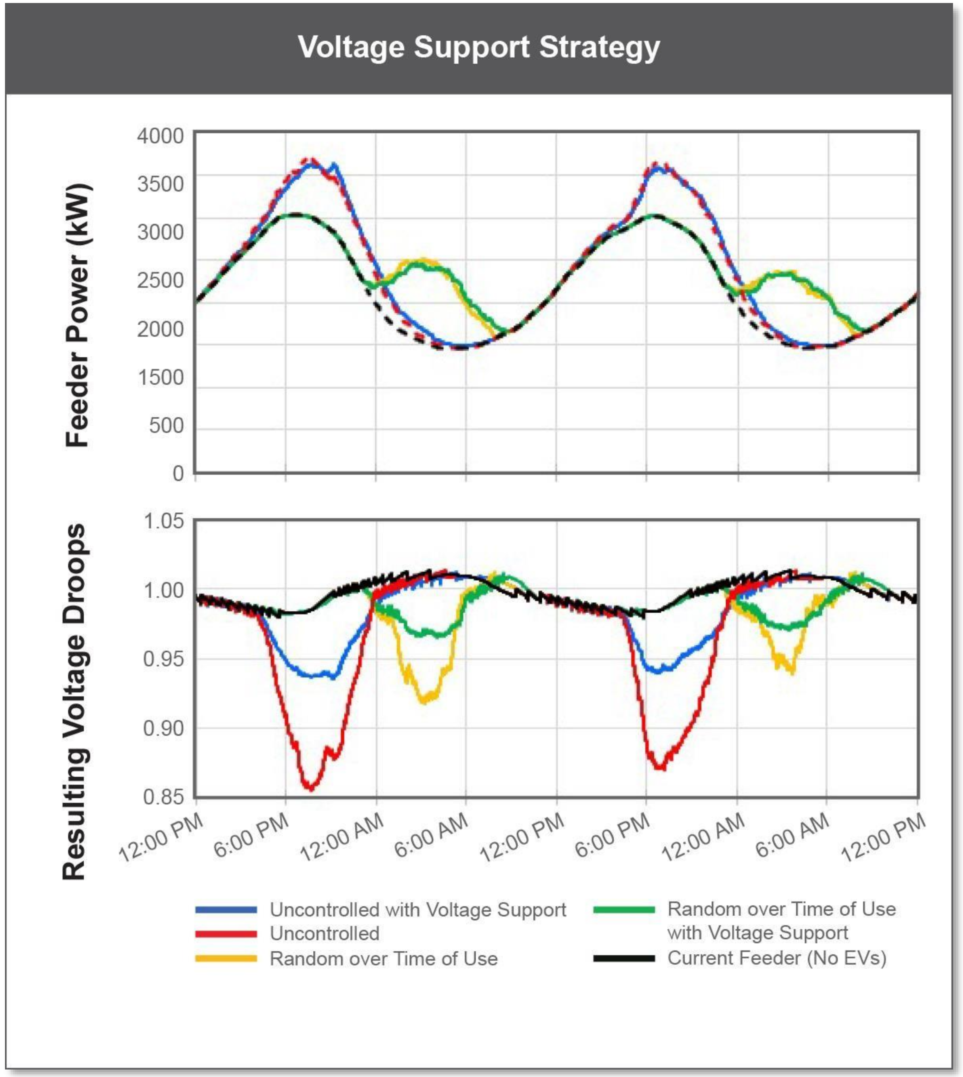
Control Strategy Demonstration Platform



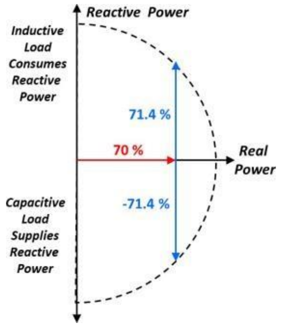
- Control Strategies are developed, tested, and compared in Caldera
- Energy shifting control strategies shown here include:
  - Centralized aggregator
  - Distributed random start
  - Time-of-Use rates (TofU)
  - Random starts during TofU
- Benefits increase with increasing EV Adoption, filling in trough can consume otherwise curtailed renewables
- Voltage may continue to be a problem

Results from Caldera in RECHARGE DOE Project

Voltage support using Reactive Power



- Just as Smart Inverters are currently proliferating in the solar industry and allow solar generation to provide better support to the grid, we envision improved power electronics in EV battery charging hardware could provide reactive power and substantially lessen EV impacts on the grid; and Caldera can prove that.



- EVs (with smart invertors) charging at less than 100% power, or connected and not charging are able to provide reactive power to the grid.

- The results show that with the energy shifting decentralized strategy of random starts over the Time of Use rate period, the peak power is not increased, but the voltage would fall to unacceptable levels; until the Reactive Power strategy is added and it then stays above 0.95 puVA

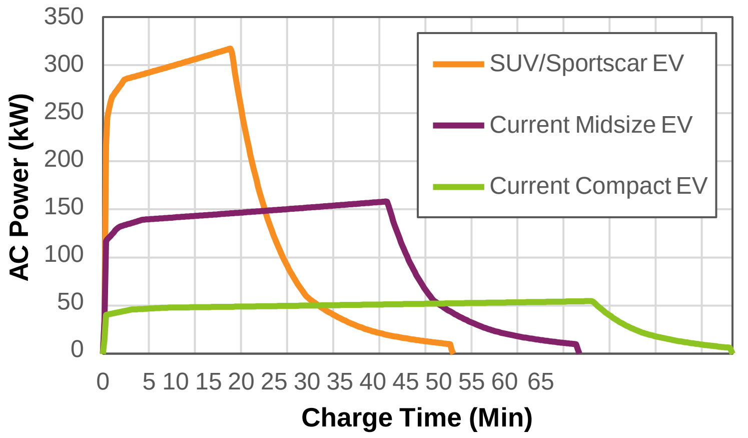
Results from Caldera in RECHARGE DOE Project

Challenges of an XFC Station

Caldera Simulation of XFC Station:

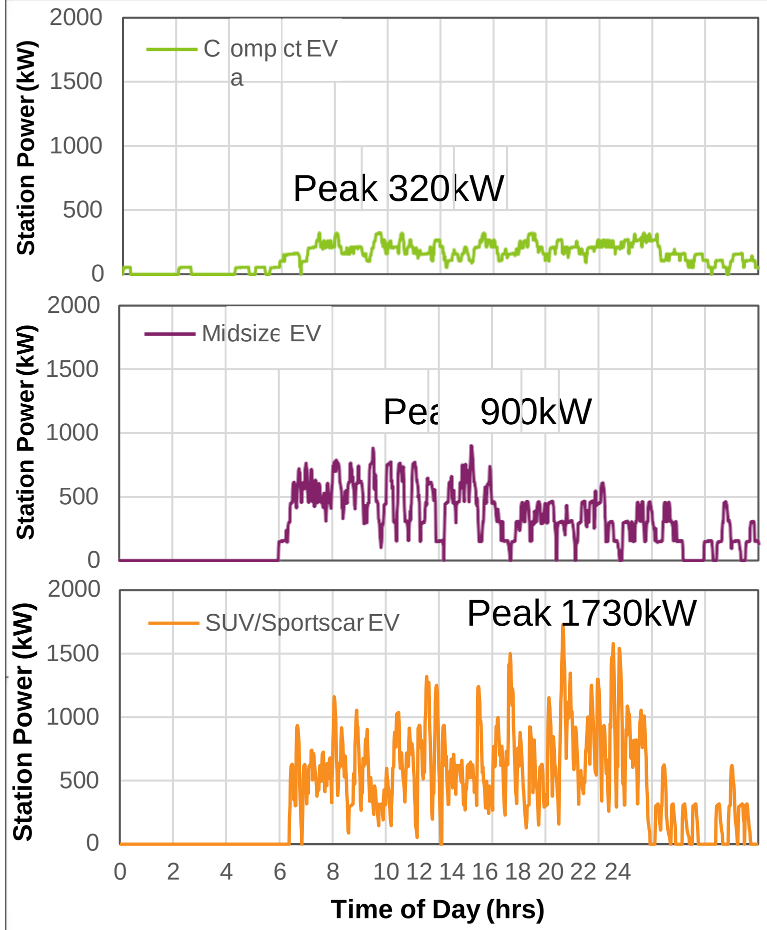
- 6 x 350 kW chargers collocated
- Vehicles are detailed agents representing classes in SCM projects
- Vehicle use based on actual EVgo station data, bounded by busy gas station data (46% utilization)
- Note abrupt ramping and high peaks for high charge power vehicles
- Demand charges impact the station operator. Electrify America has said "up to 80% of a station electricity bill can be demand charges."

XFC Charge Profiles for Hypothetical Vehicles



	SUV/ Sportscar EV	Current Midsize EV	Current Compact EV
Max Charge Rate (kW)	300	150	50
Vehicle Range (Miles)	250	275	150
Vehicle Resembles	Porsche Taycan	Tesla Model 3	Nissan Leaf

XFC Site Power

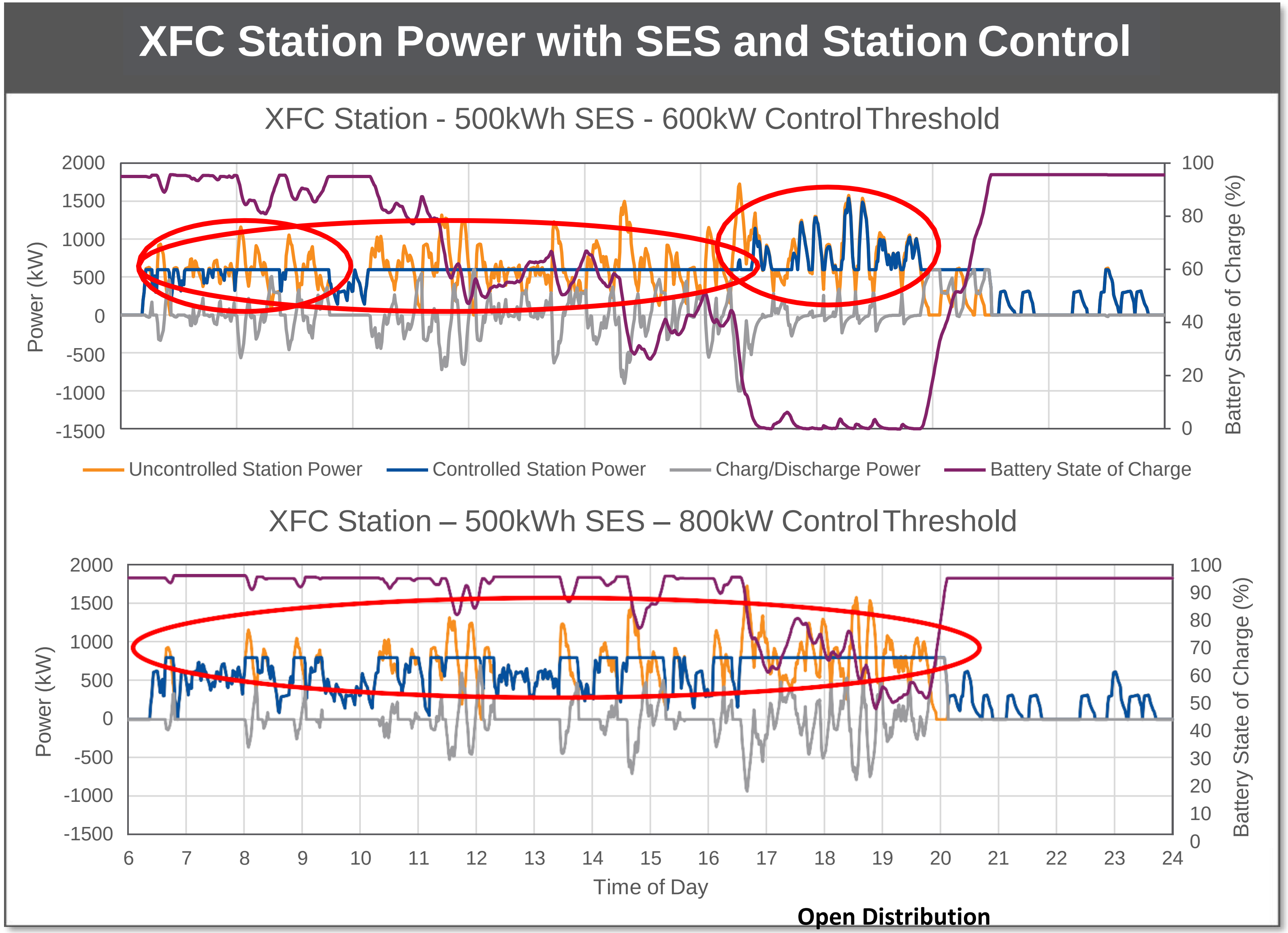


- **Demand charge might be >$25k per month**
- **While energy charge is <$2k**

Stationary Energy Storage – Charging Station Site Management

- Local station controls and the presence of stationary energy storage (SES) can smooth and reduce peaks
- With lower peak loads more XFC stations can be placed on weak grid, increasing convenience for EV owners
- Stationary energy storage can mitigate demand charges, increase profits for charge station operators
- Caldera incorporates an accurate Stationary Energy Storage Electro-Chemical Model and site management system in the Infrastructure AI
- This is a tool for utilities and CNPs to study the benefits and aging effects of specific battery energy storage systems on their network

Simulating XFC with SES and station control



Caldera Simulation of XFC Station:

- 500kWh battery costs ~$500k
- Reduces 1730kW peak to 725kW on this day
- If demand charge were $15/kW SES saves $15,000/month
- SES payback period=33months
- 50kW vehicle population with 50kWh SES reduced 320kW peak to 230kW
- 150kW vehicle population with 250kWh SES reduced 900kW peak to 500kW

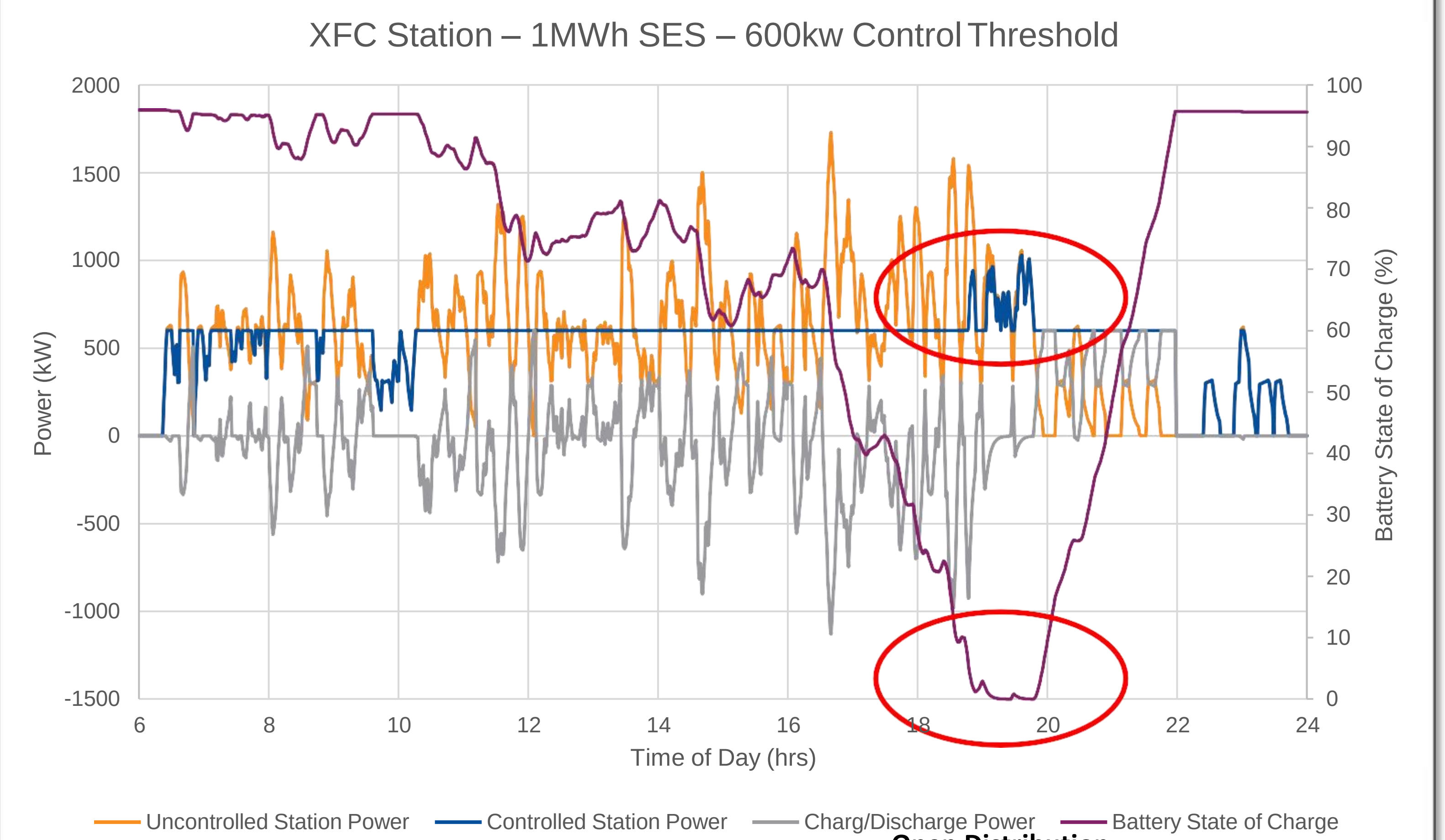
- All seem to be financially viable with ~3year pay back
- **BUT THAT IS NOT ENOUGH**

Open Distribution

Results from Caldera in DirectXFC DOE Project

How do you predict and set the threshold? What happens when it is broken?

XFC Station Power with SES and Station Control



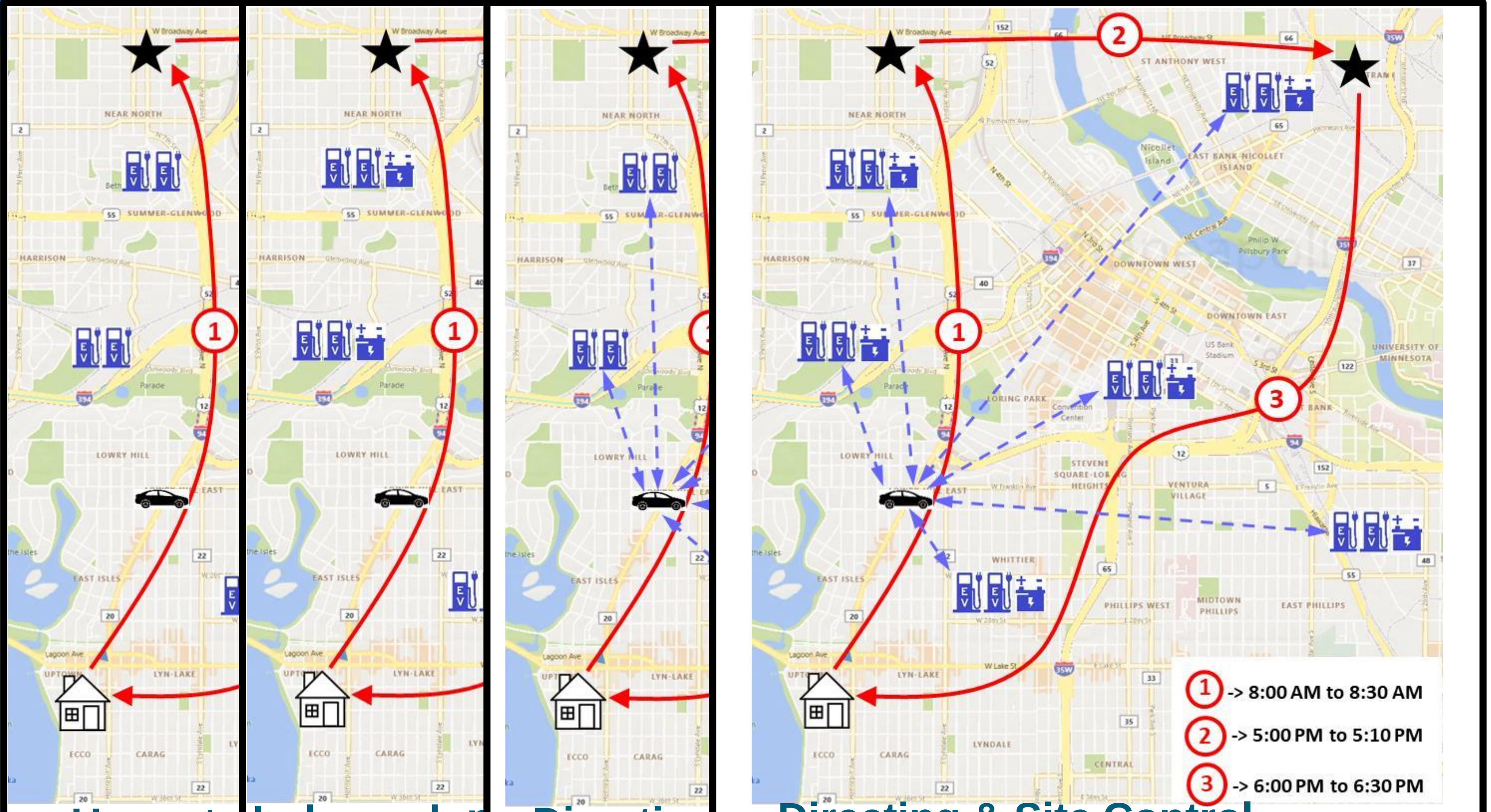
Open Distribution

A few extra charges costs a lot:

- Machine Learning prediction = very accurate
- But just a few unexpected customers or increases in frequency - deplete the SES and incur substantial costs.
- Example:
- 1MWh SES ($1M)
- Threshold set to 600kW
- 4 or 5 EVs bring peak >1000kW
- Costs > $6000

- **SCM MUST DO MORE**

Communications and Reservations as SCM



Uncontr
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- Occasional
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Independen
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- Smooth and
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- Grid service

Directing
- Stationary
- Communic
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- Incentivize
- Higher usa
- Less wait,

Directing & Site Control
- Stationary energy storage
- Communication for price/availability
- Reservations

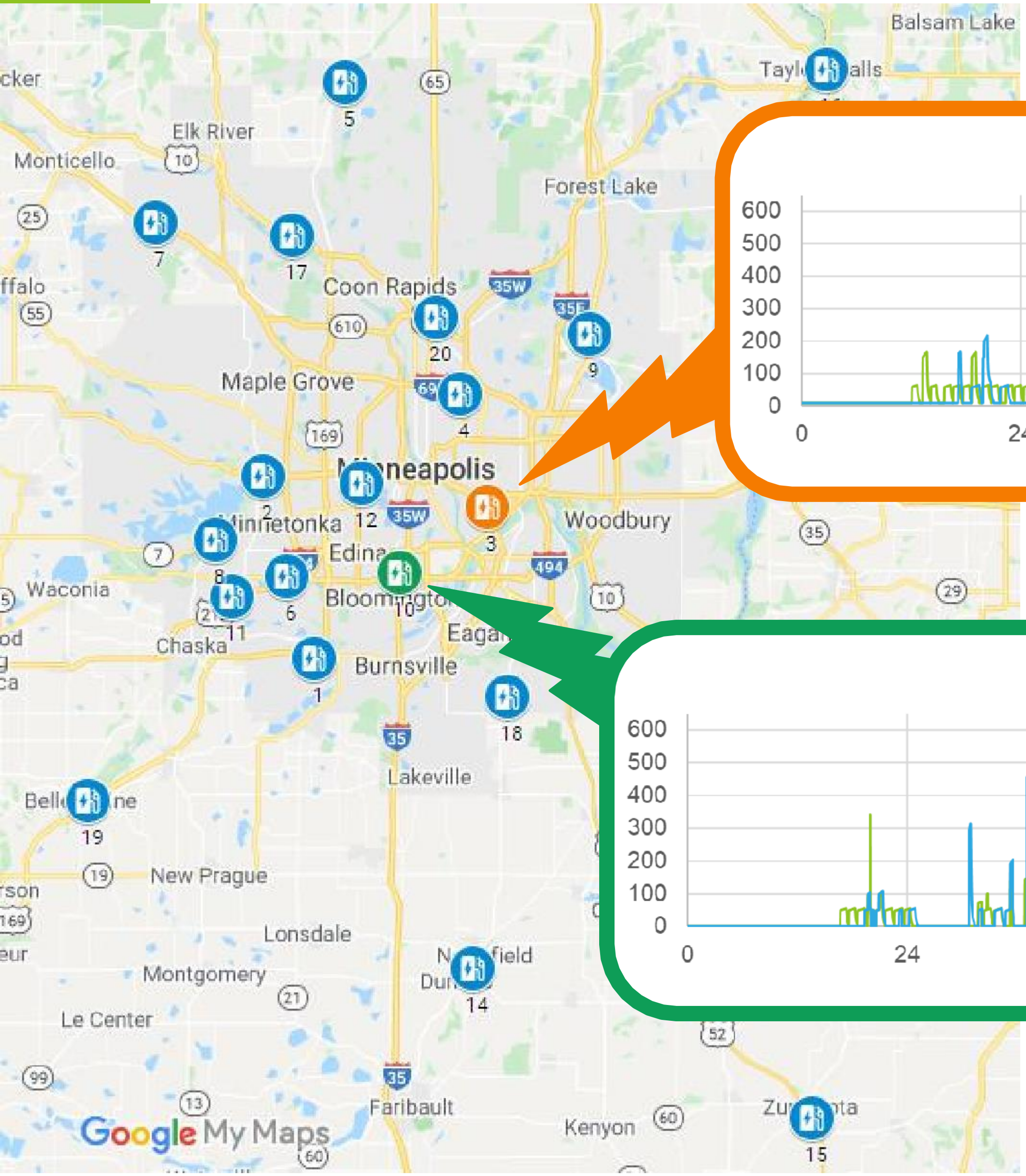
- Reduce cost: EVs, XFC operator, grid upgrades
- Smooth, reduce, and shift load profile
- Less wait, no station 'hunting', find low cost

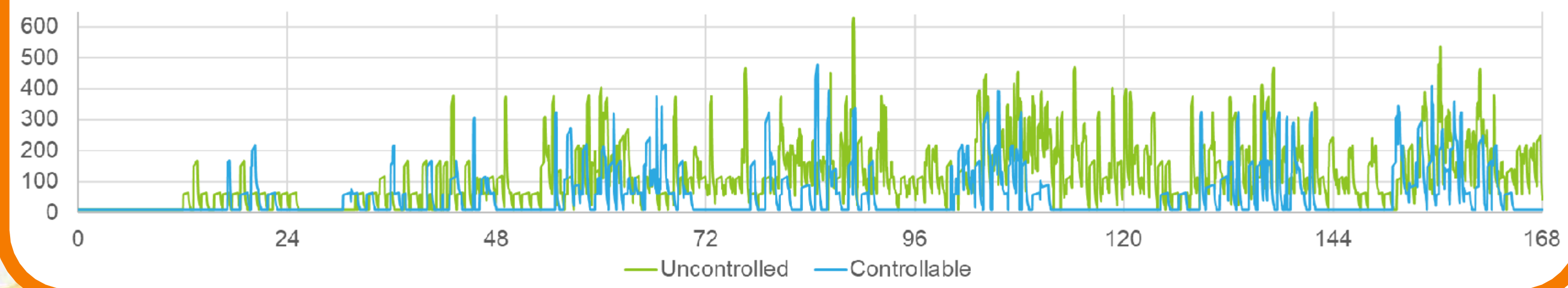
- What are the Options?
  - Close the station?
  - Charge the last EVs $1000s?
  - Close some charge points?
  - Limit the charge power?

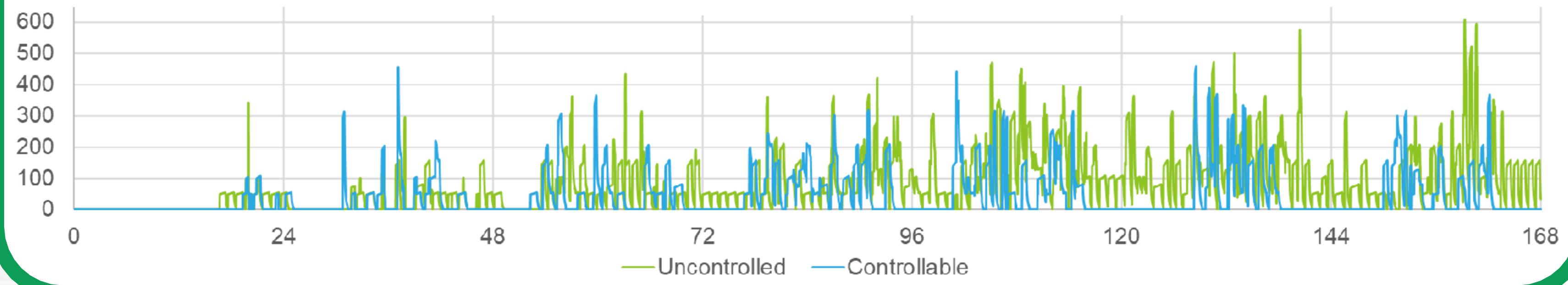
  - Require reservations
  - Price disincentives
  - Manage the end SOC

- Customer Relations
  - Some charge points or some station operators might be first come first serve
  - Peak capacity reservation only
  - Well integrated communications would only recommend available stations and present variable pricing in logical, consumable fashion

Individual Station Functionality (preliminary results)



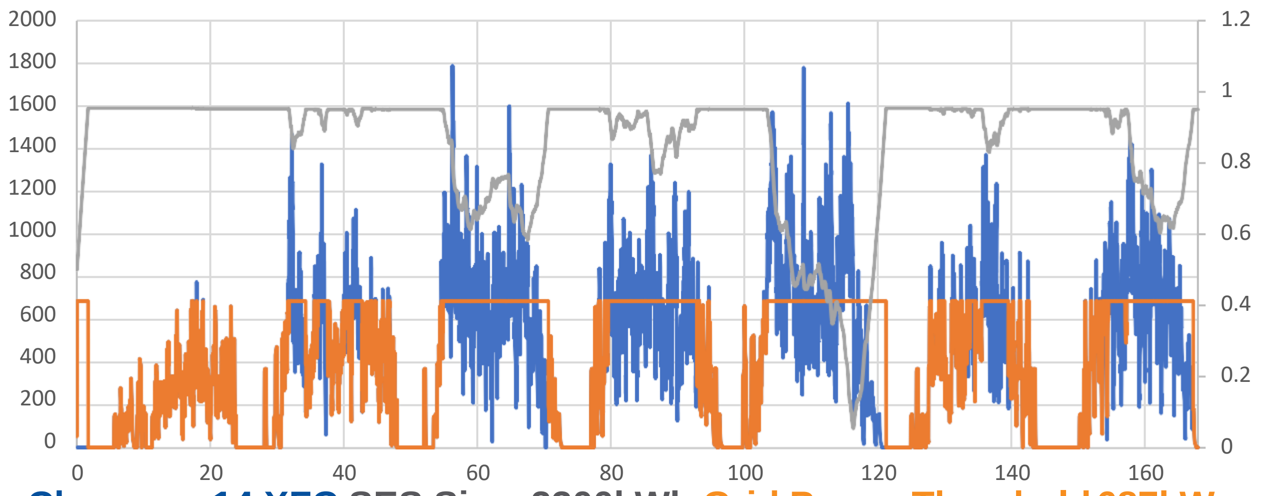




Simulated Station Management with SES

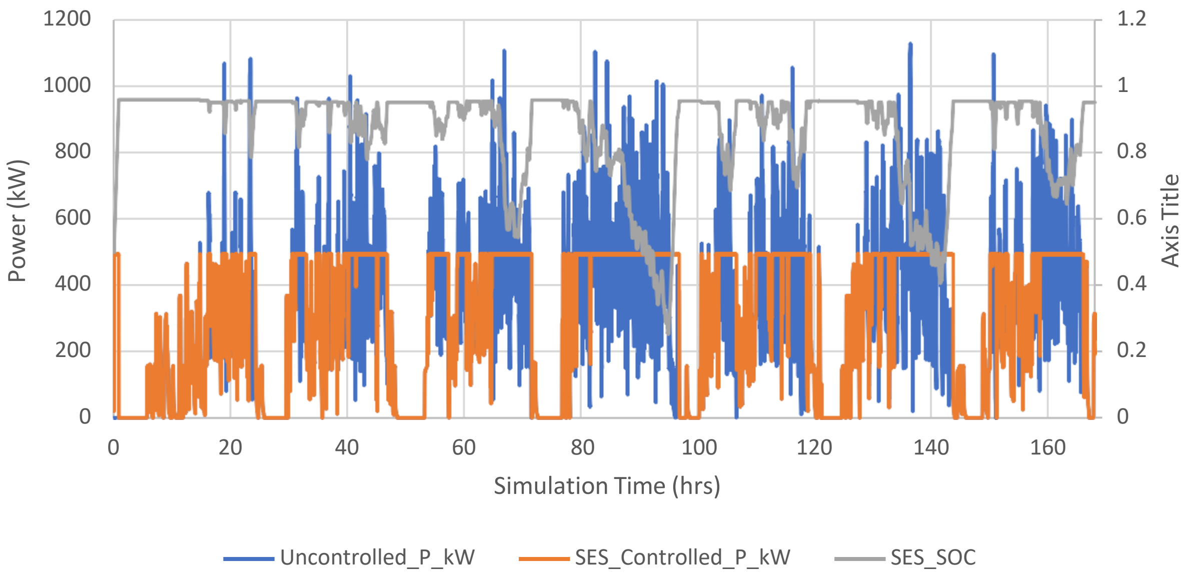
- System wide impacts of Station Management with SES
  - Evaluated each station's mean power and 15min peak power (demand charge)
  - Targeted a 75% reduction of the peak above mean to identify Grid Power Threshold (kW) and then found minimum SES size (kWH) capable of that.
  - Applied to all 350 XFC stations across the 2040 Simulation

Large XFC Station with High Usage



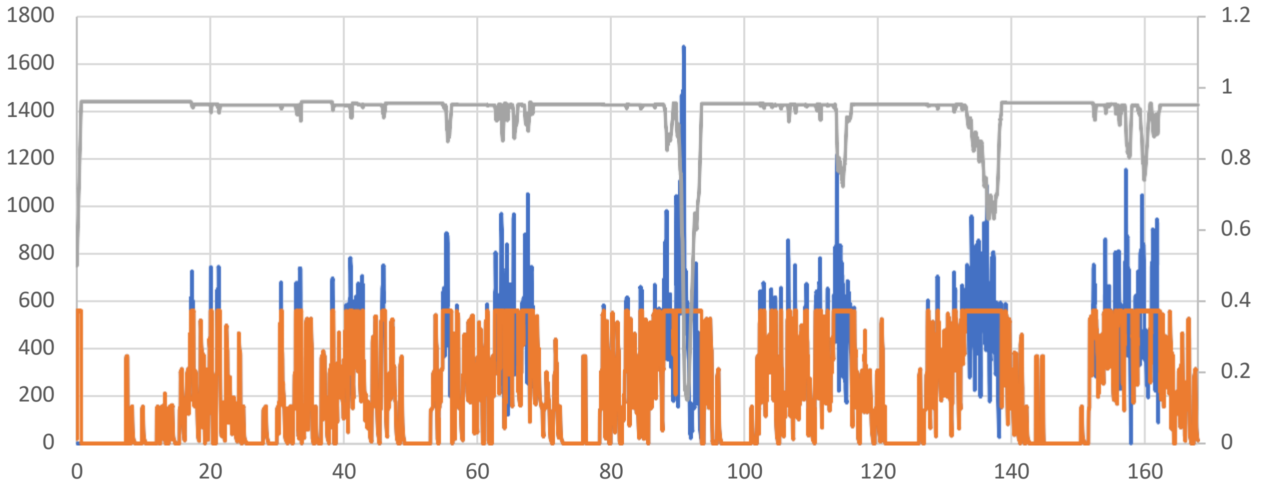
Chargers: 14 XFC SES Size: 2300kWh Grid Power Threshold 687kW

Small XFC Station with High Usage – Consistent Peaks



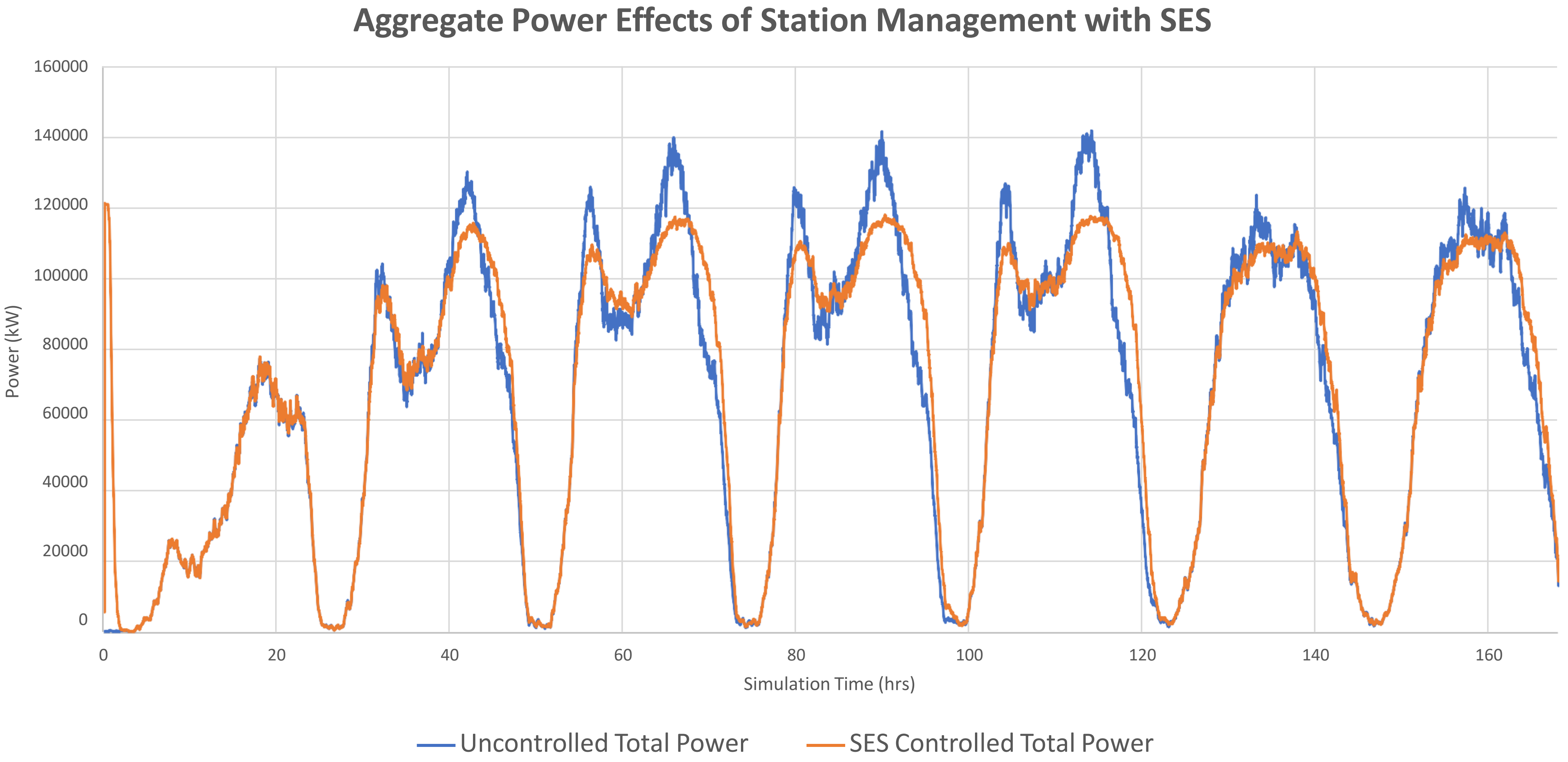
Chargers: 4 XFC SES Size: 800kWh Grid Power Threshold 493kW

Large XFC Station with Lower Usage Inconsistent Peaks



Chargers: 8 XFC SES Size: 700kWh Grid Power Threshold 559kW

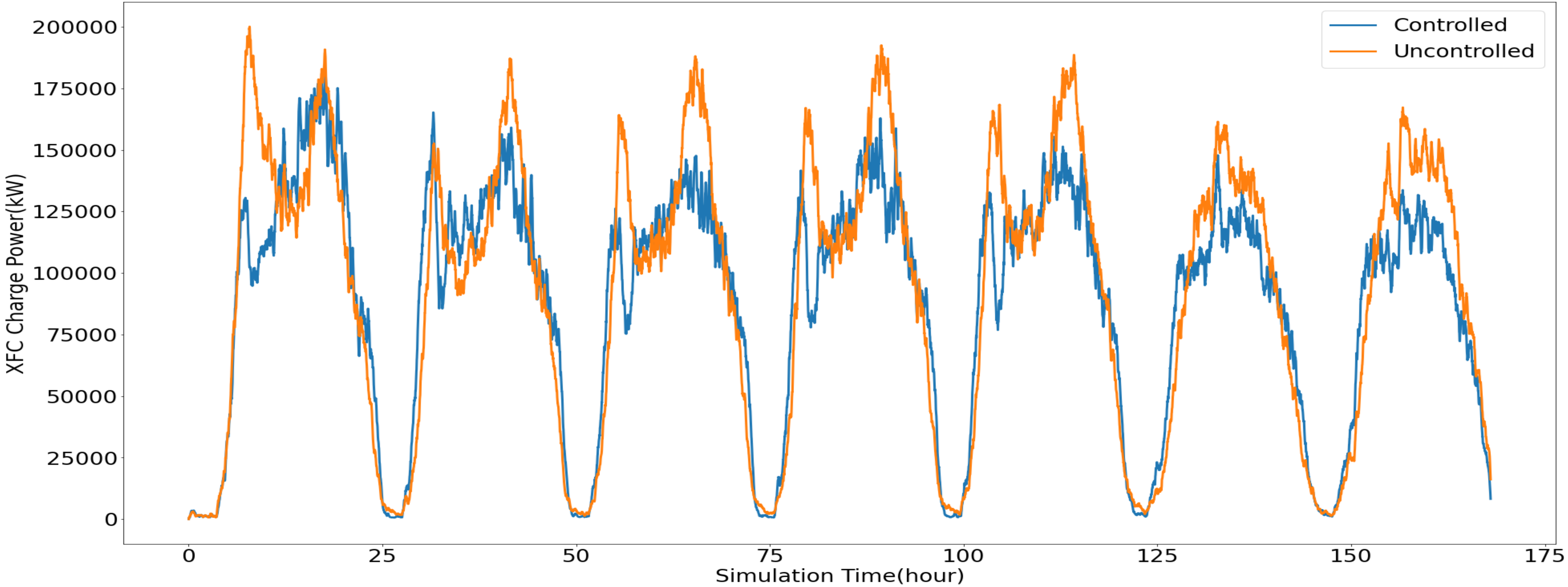
Simulated Station Management with SES



- **Peak Reduction 18%** (142MW to 117MW) during Friday afternoon rush hour

Tim, these are the numbers for energy and power in aggregated load profile: Total Energy(controlled): 14869571.64kWh; Total Energy(uncontrolled): 15657709.33kWh Maximum Power(Wed-Sun)(controlled): 162902.

Price (Dis)Incentive Control Aggregated Effect – Preliminary Result



- All stations use base price up to desired "threshold grid power", additional chargers are offered with price multiplier.
- Vehicles chose alternate station or charge time through cost optimization algorithm.
- Not an economics project.
- **Peak Reduction 16%** (193MW to 163MW)

Assessing Specific Distribution Networks

We have simulated transportation and distribution networks in several metro areas working with major utilities.

DTE

Georgia Power

PG&E Pacific Gas and Electric Company

Xcel Energy

We look forward to working with different regions and utilities to assess and improve their unique future with electrified transportation. In addition, we are working on non-proprietary generalized solutions for public distribution.

Other Applications for Caldera

- Distributed Energy Resource (DER) modeling on the grid
  - Caldera is well suited to study stationary energy storage, and PEVs with L2 and XFC
  - An augment to OpenDSS's capabilities for other DERs
  - **V2X**
- EV fleets conducting SCM have added opportunities which need modeling
  - Enforced directing is acceptable
    - Precise forecast schedules
  - Company Owned, On Premises EVSE – Distro Center
  - Can integrate EV loads with facility loads

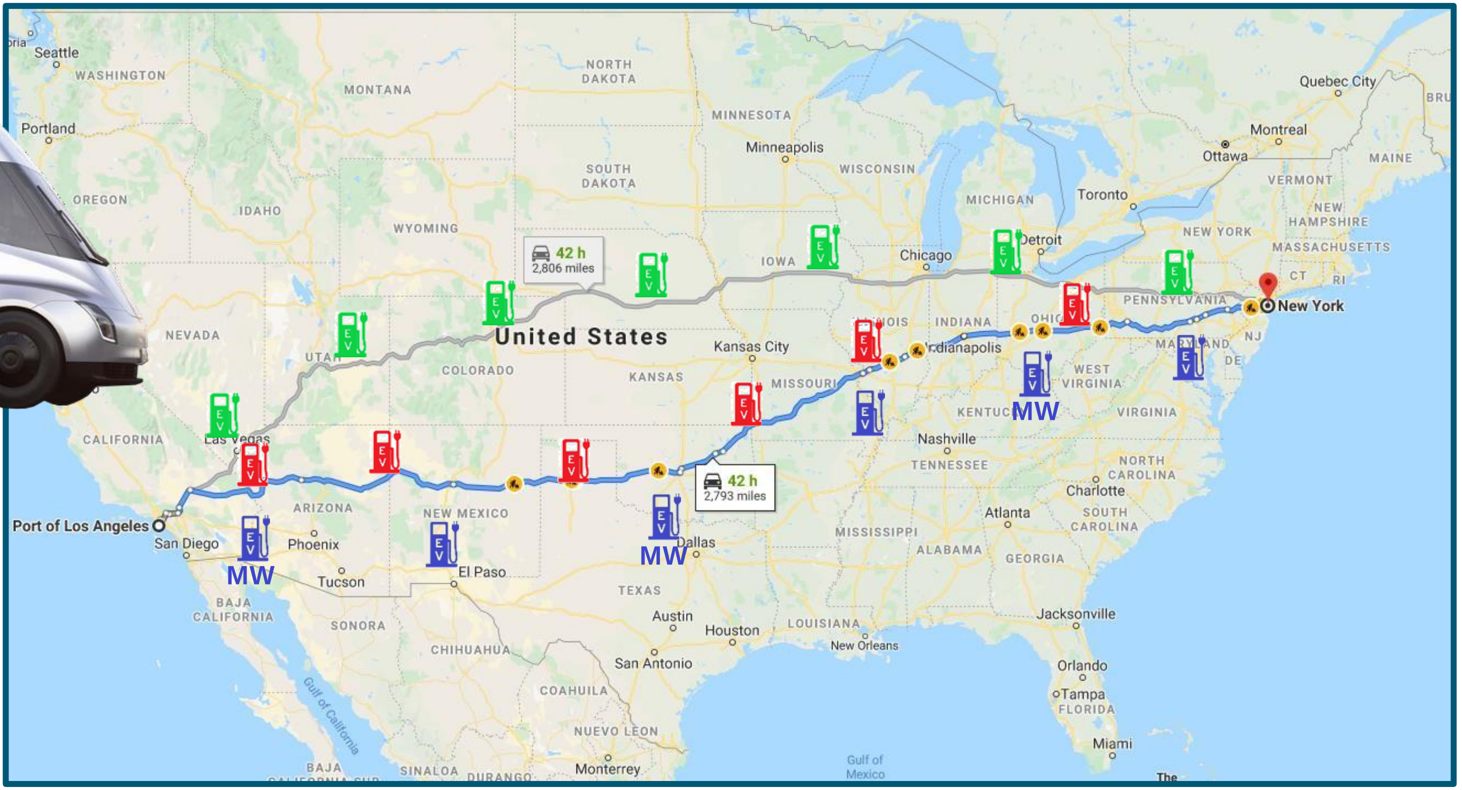
•Each application may have unique management but a combination of storage, control, and communication needed

- Long haul
- Hub and spoke
- Last mile
- Municipal
- Utility
- Taxis
- Transit…

Open Distribution

Smart Charge Management for Long Haul Trucks

- Guide truckers toward optimal charging decisions that minimize cost, grid impact, and maximize miles driven
- Advance communication and scheduling of 1+MW charging and onsite energy storage is necessary
  - Onsite generation may happen, and predictable/managed schedules will help



- Use of lower-power, cheaper infrastructure when possible
  - Coordinate lower power chargers with “Hours Of Service” stops

What are you working on?
How can you use Caldera?
Where can we collaborate?

Questions?

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Wrap Up

Thank you!

Meeting Materials will be posted at:

www.natf.net

www.epri.com