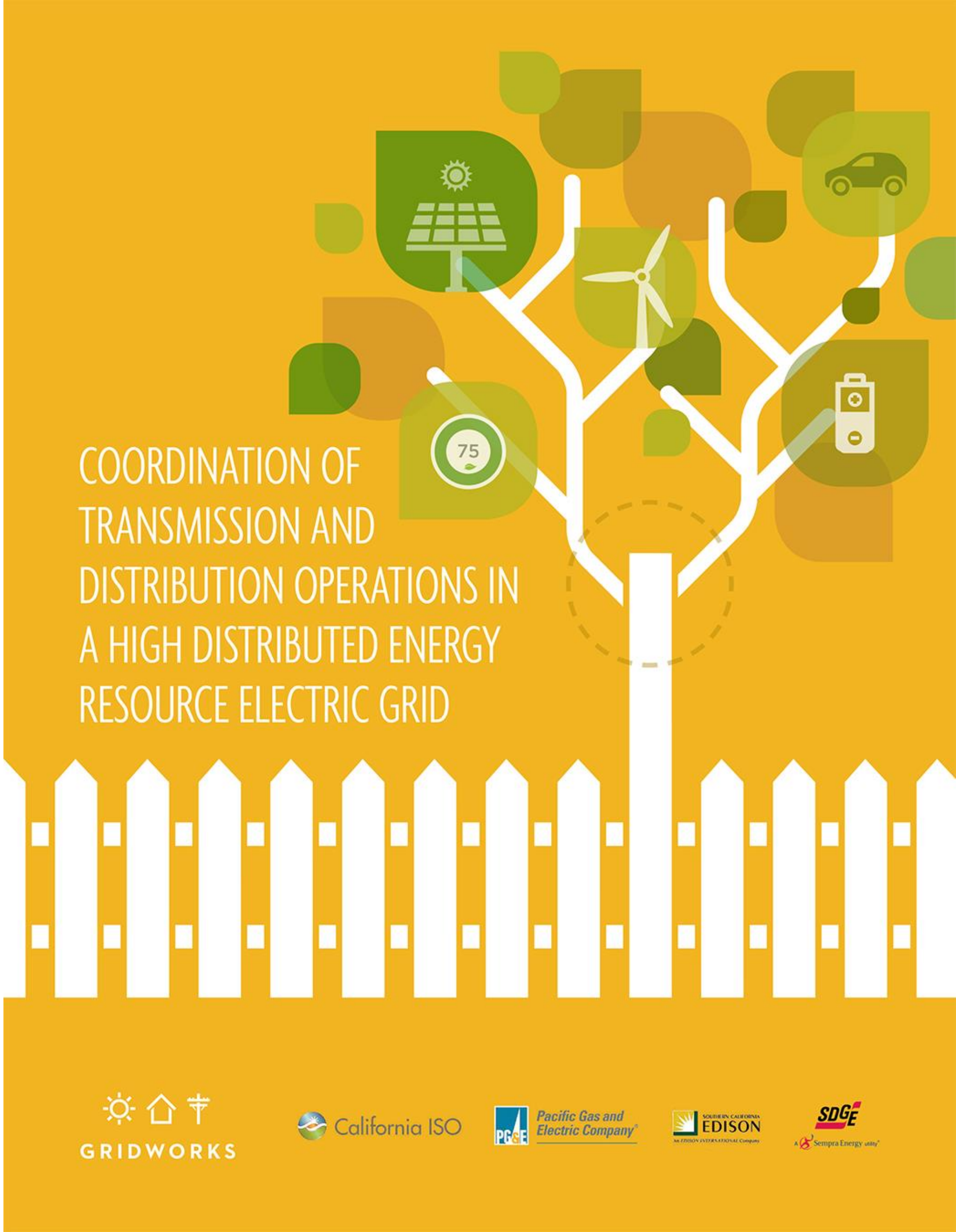
Coordination of Transmission and Distribution Operations in a High Distributed Energy Resource Electric Grid

May 8, 2018



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Gridworks would like to acknowledge the Energy Foundation whose support has made this effort possible.

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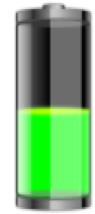
building a new energy future

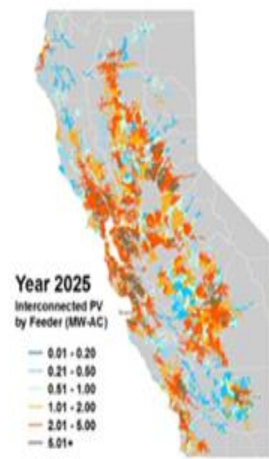
DER Growth in California

- California electric power mix is transforming
  - Less reliance on traditional, utility-scale fossil-fueled generation
  - More reliance on renewable distributed energy resources (DERs)
  - More than 300,000 plug in electric vehicles (EV) in CA

- Potential increased adoption of all DERs resulting in a more decentralized grid

- To maximize revenue opportunities, DER owners interested in providing multiple services to multiple entities (e.g. ISO, Distribution System Operator, and the end use customer)





California is Targeting:

Efforts in California to lower barriers to DER Participation

- California Public Utilities Commission (CPUC) Proceedings
    - Distribution Resource Planning and Non Wires Alternative Solutions
    - Multiple Use Applications for DERs

- California Independent System Operator (CAISO)
    - Worked with stakeholders to develop platform for DERs to participate in wholesale electricity market
    - March 2016, filed tariff revisions with FERC to enable resources connected to distribution systems within CAISO's balancing area authority to form aggregations of 0.5 MW or greater to participate in CAISO's energy and ancillary services markets.
    - FERC approved the CAISO's new DER aggregation platform in June 2016

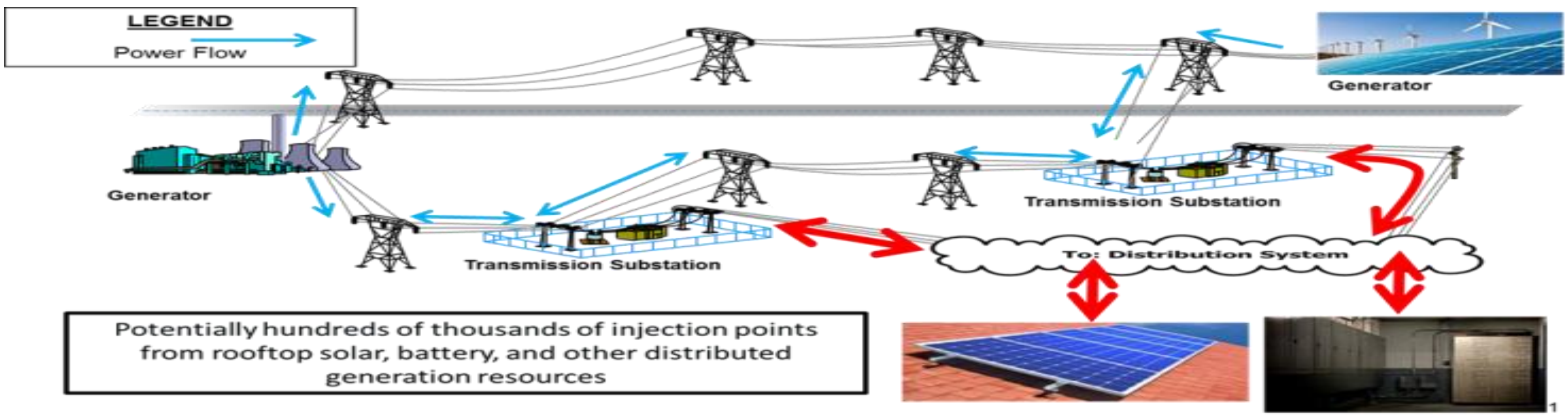
New Operational Challenges

1. ISO dispatches DERS without knowing the impact of those dispatches are feasible and supported by the distribution system

2. No adequate methods exists to forecast how DER participation affects net load and other characteristics at the T-D interface

3. DO does not have same level of visibility, control and situational awareness of DERs as the ISO does with transmission connected generators

4. Challenges will only increase with increasing DER penetration



DERs use both Transmission and Distribution Systems

- DERs use both Transmission and Distribution systems when they:
  - Participate in CAISO wholesale market
  - Operate autonomously or make sales and/or
  - Provide distribution services to the Distribution Operator (DO)
- Transmission and Distribution (T-D) are distinct with different structures, characteristics, functions & operating principles
- T-D "interfaces" are those substations where transmission and distribution interconnect
  - Historically, power flowed from transmission to distribution
  - DERs can inject power onto distribution system causing flow in the reverse direction (distribution to transmission)

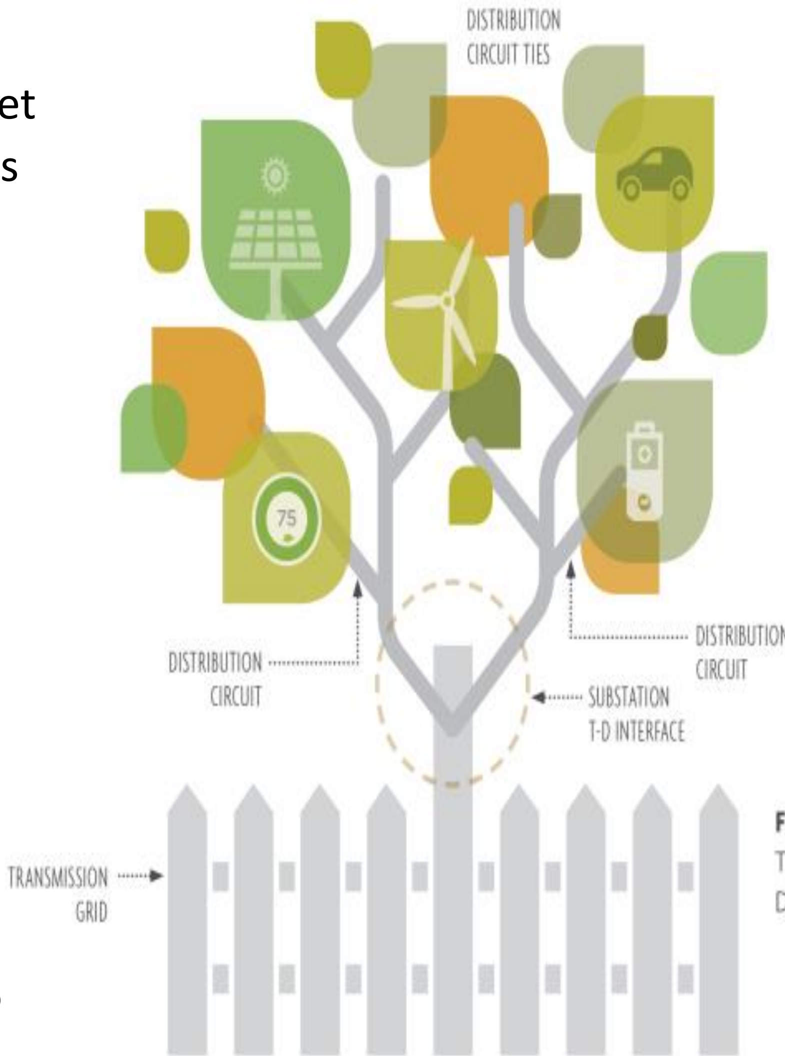
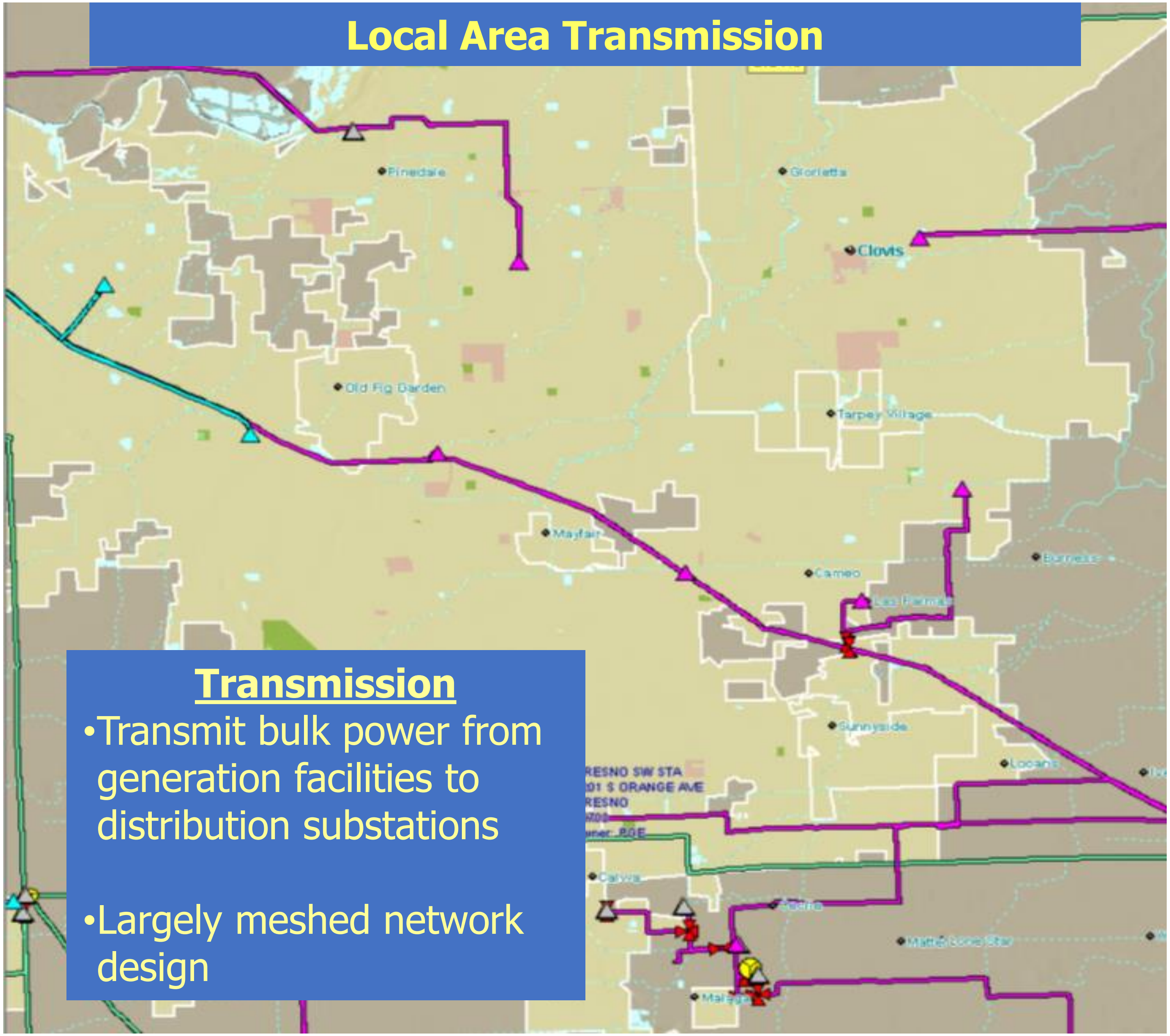


FIGURE 1. STRUCTURE OF THE TRANSMISSION AND DISTRIBUTION SYSTEMS

Local Area Transmission



Transmission

- Transmit bulk power from generation facilities to distribution substations
- Largely meshed network design

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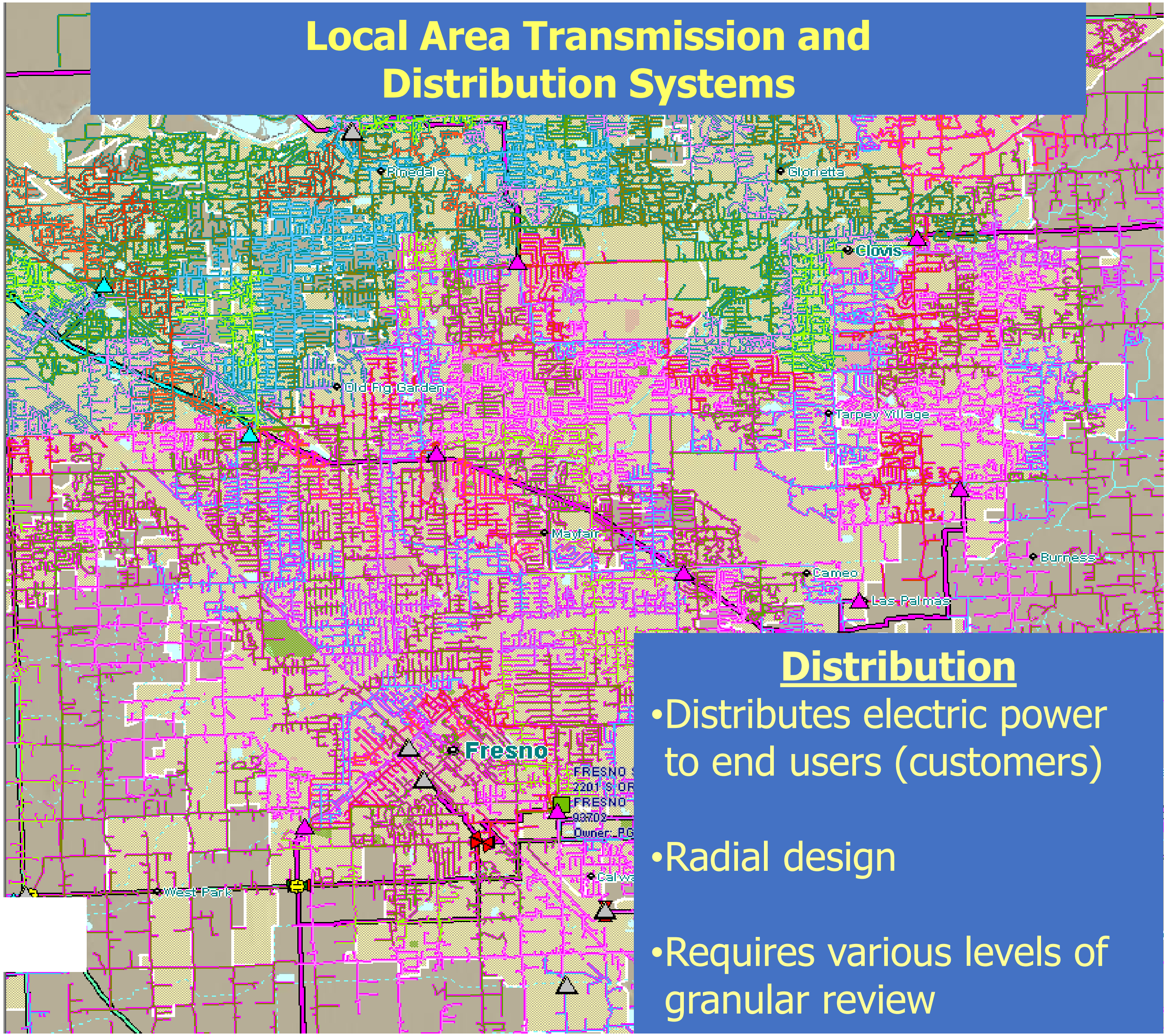
Local Area Transmission and Distribution Systems



Distribution

- Distributes electric power to end users (customers)
- Radial design
- Requires various levels of granular review

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Frequency of Distribution Outages and Use of Switching Configurations

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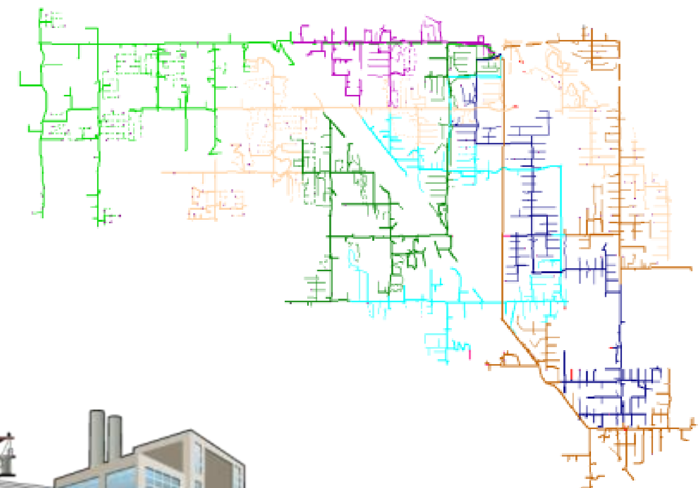
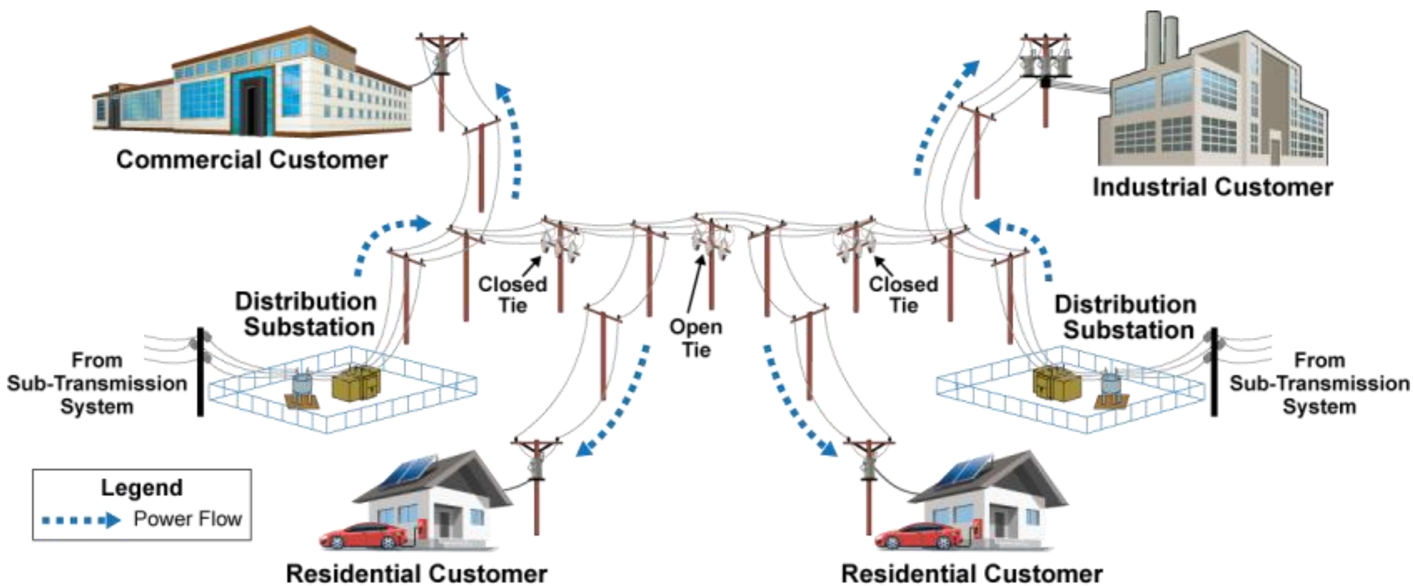
- Radial distribution design is reconfigurable
- Many possible configurations adding to operational complexity
- Outages and abnormal circuit configurations can create capacity constraints, which can affect DER’s ability to participate in wholesale markets



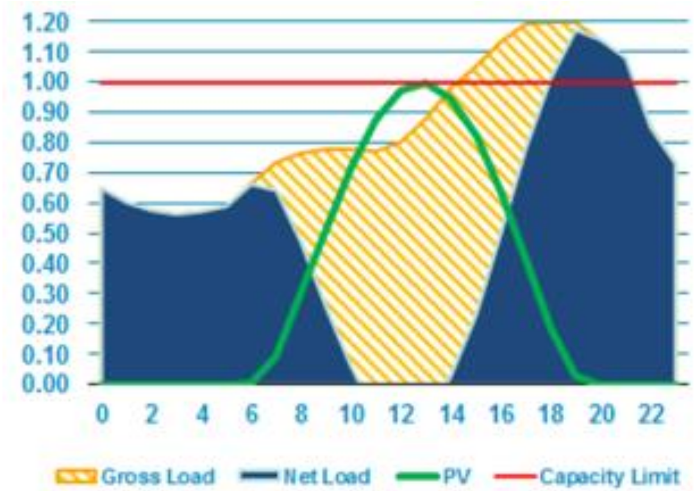


Forecasting Short-Term Effects of DERs on Gross and Net Load

- ISO and DO need accurate short-term forecasts to operate reliably and to run real-time wholesale markets

- Most DERs do not participate in ISO markets as supply resources, but "self-dispatch" as load modifiers, altering overall load shape

- ISO and DO have less certainty about whether sufficient resources are available and committed to serve load and maintain system stability
  - Leads to over commitment of supply resources



Lack of Visibility, Situational Awareness and Control

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- DO and the ISO do not have visibility and situational awareness about location, status and output of DERs
- DER Operator does not have visibility into distribution system to ensure exported energy is feasible and deliverable
- DO need better visibility into own distribution systems
    - Predict DER behavior
    - Real time DER response
    - Forecast DERs' impacts on grid

DER Effects on Distribution System Phase Balancing and Voltage Regulation

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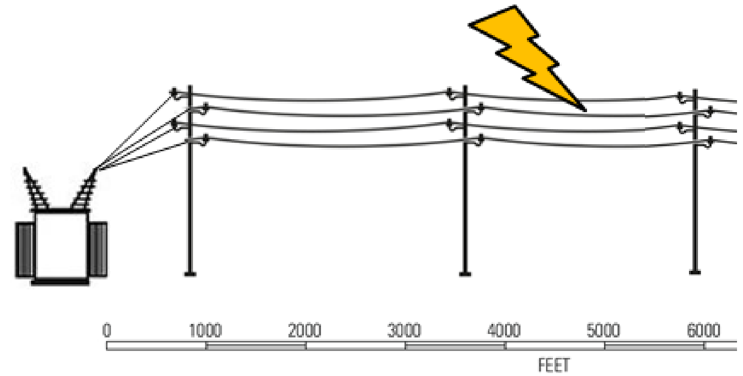
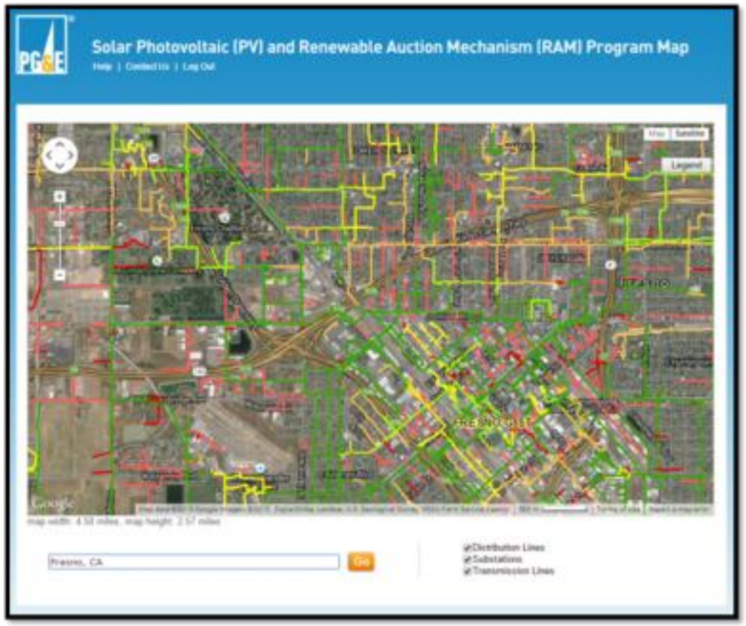
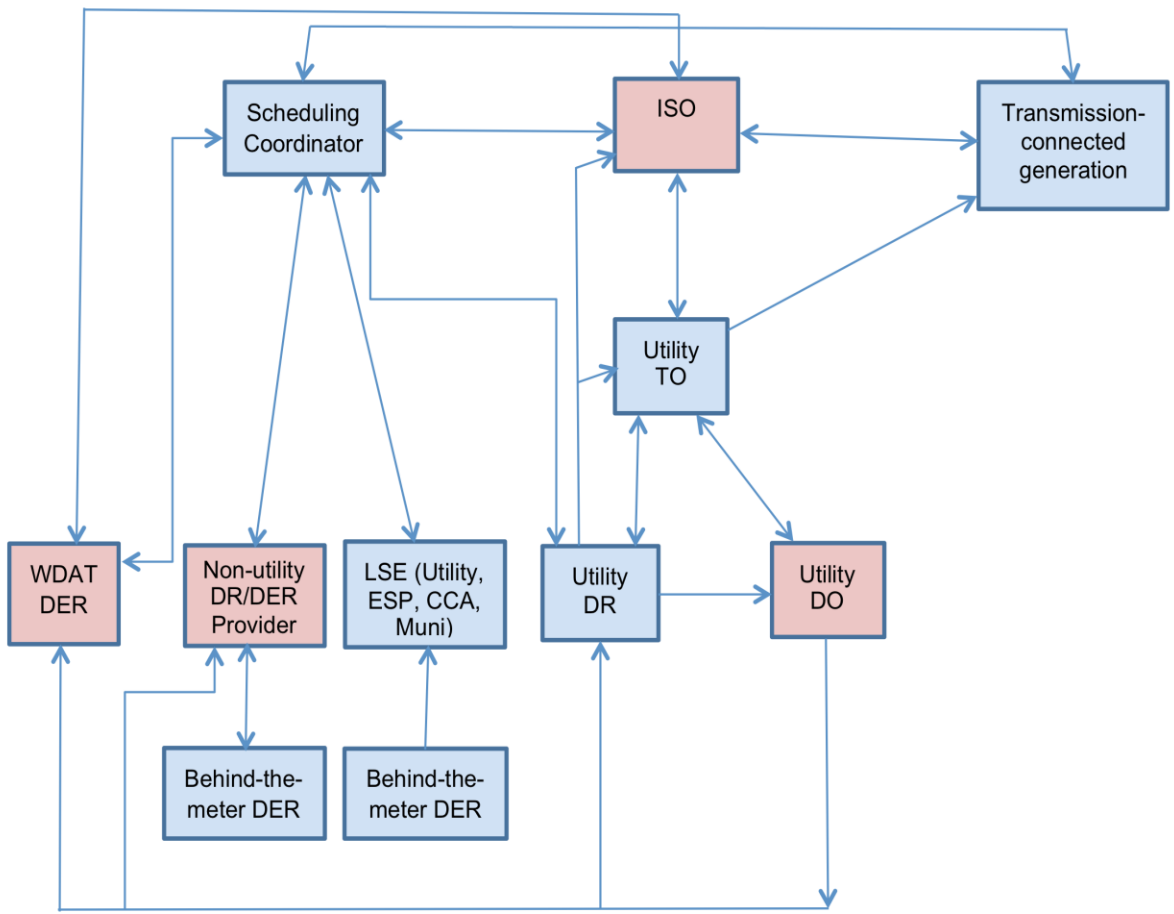
- Balancing Loads between three phases of distribution system becomes challenging with higher DER penetration
- Must consider effects of DERs' output, location and characteristics on distribution system to mitigate phase imbalance and voltage regulation problems
- More sophisticated interconnection and planning processes, and construction methods will be required to maximize efficient use of distribution system





Transmission-Distribution Coordination Today

- Diagram shows how demand response (DR) is coordinated today
- Utility DR and non-utility DR providers create DR resources for ISO market
- ISO issues DR dispatch instructions to the appropriate scheduling coordinators to dispatch market DR resources
- ISO communicates with Utility TO to dispatch utility-controlled DR
- Today the ISO and Utility DO do not exchange information or coordinate activities for real-time operation
- Relationships between red boxes are crucial for high DER T-D coordination



The High Distributed Energy Resource (DER) Future

Focusing on the DER/DER Provider, the Utility DO and the ISO

What new coordination activities will be needed to enable each entity to fulfill its roles and objectives?

- Consider two time frames
  - Near-term => 2017-18, relatively low DER penetration, some new DER aggregations participating in the wholesale market
  - Mid-term => 3-5 years and possibly beyond, higher volumes and diversity of DER

- Consider three scenarios, from simpler to more complex
  1. A single DER participating in the ISO market (and perhaps also to an end-use customer, if located behind the customer meter)
  2. A single DER provides services to the Utility DO (and perhaps also to an end-use customer, if located behind the customer meter)
  3. The DER provides services to the Utility DO and participates in ISO market

DER providers seek to provide services and earn revenues at multiple levels of the system

"DER" = all energy resources connected at distribution level, on customer side or utility side of the customer meter

- Plus communications & controls to aggregate & optimize DER

- Behind the end-use customer meter (BTM)
  - Time of day load shifting, demand charge management, storage of excess solar generation
  - Service resilience – smart buildings, microgrids, critical loads
- Distribution system services
  - Deferral of new infrastructure
  - Operational services – voltage, power quality
- Transmission system and wholesale market
  - ISO spot markets for energy, reserves, regulation
  - Resource adequacy capacity
  - Non-wires alternatives to transmission upgrades
- Bilateral energy contracts with customers, DOs & LSEs

Each entity's objectives and responsibilities drive needed tools, information flows and procedures

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- ISO's primary DER concern is at the T-D interface or p-node
  - Predictability/confidence re DER responses to ISO dispatch instructions
  - Short-term forecasts of net interchange at each T-D interface
  - Long-term DER growth scenarios for transmission planning
- DO's concern starts with reliable distribution system operation
  - Visibility/predictability to current behavior of DER
  - Ability to modify behavior of DER via instructions or controls as needed to maintain reliable operation
  - Long-term DER growth scenarios for distribution planning
- DER provider/aggregator is concerned with business viability
  - Ability to participate, in a non-discriminatory manner, in all markets for which it has the required performance capabilities
  - Ability to optimize its choice of market opportunities and manage its risks of being curtailed for reasons beyond its control

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FIGURE 3. NUMBERED DOTS INDICATE POSSIBLE COORDINATION ENHANCEMENTS FOR 2017 (NTE) AND FOR THE MEDIUM-LONG TERM (M/LTE) TO SUPPORT RELIABLE OPERATION WITH HIGH DER

INFORMATION TYPE	ISO	UTILITY TO	UTILITY DO	DERP
1 | DER/DERA bids into ISO market	✓		NTE (2)	✓
2 | Installed capacity of each DER and DERA			✓	✓
3 | Total installed DER capacity per T-D substation			✓	
4 | Transmission topology and conditions	✓	✓		✓
5 | Distribution topology and conditions			✓	NTE (1)
6 | DA forecasts of DER impacts	M/LTE (9)	M/LTE (10)	M/LTE (7)	
7 | RT forecasts of DER impacts	M/LTE (9)	M/LTE (10)	M/LTE (8)	
8 | DA schedules (results of ISO market)	✓	M/LTE (11)	NTE (3)	✓
9 | RT dispatches (results of ISO market)	✓	M/LTE (11)	NTE (3)	✓
10 | Transmission feasibility of schedules	Ensured by ISO market optimization			Ensured by ISO market optimization
11 | Distribution feasibility of schedules	NTE (6)		NTE (4)	NTE (5)
12 | DER/DERA revenue meter data	(for participating DER/DERA)			✓
13 | Generation Telemetry (for real-time observation)	(>= 10 MW or providing AS)		(>= 1 MW)	✓
14 | T and D System Telemetry (for real-time observation)	T system (consistent across the system)	T system (consistent across the system)	D system (inconsistent)	

Near-term recommendations

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These recommendations may be implemented as pilots or manual procedures for the near term, and then considered for automation as DER volumes increase.

1. DO should communicate advisory info on current system conditions to DER providers, so that DER providers can modify their ISO market bids accordingly and if necessary submit outage or derate notifications to the ISO
2. The ISO should provide day-ahead DER schedules to the DO, for the DO to pilot a feasibility assessment to identify schedules that may create distribution system reliability problems.
3. The DER provider should communicate constraints on its resources' performance to the ISO, in the form of updated market bids or outage notifications if needed
4. The DOs should pursue a pro forma DER Provider (DERP) "integration agreement" with the DER provider with regard to DER aggregations.

Thank you!

For more information, contact info@gridworks.org

Background Slides

Topics for continuing working group effort:

1. Prepare an initial white paper that summarizes the 2016 effort, including description of existing coordination procedures, anticipated operational challenges with high DER, and communication and coordination improvements identified to date
2. Educate the WG on grid modernization from IOU perspective and consider implications of operational coordination needs on grid modernization
3. Develop example use-cases reflecting likely DER integration scenarios to ground discussion in practical implications. Consider how future pilot proposals may stem from identified use cases.
4. Specify potential real-time coordination procedures to manage potential conflicts between DO needs and ISO dispatches. Begin with scenario approach and then broaden as needed
5. Identify principles for a DO approach to DER curtailment resulting from distribution level constraints
6. Consider any unique perspectives or challenges for municipal utilities w/in ISO footprint
7. Describe the process and timeline for integration of a new DERA into the wholesale market, including utility process for 30-day review of DERA under ISO DERP tariff as well as ISO integration process
8. Develop methods for short-term DER forecasting and impacts at T-D Interface (IOUs)
9. Develop method for DO feasibility assessment of ISO's day-ahead DER schedules and real-time dispatches
10. Explore how various DSO models would impact design of the T-D interface coordination framework

ACRONYMS

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CCA	Community Choice Aggregator
CPUC	California Public Utilities Commission
DA	Day Ahead
DR	Demand Response
DER	Distributed Energy Resource
DERA	Distributed Energy Resource Aggregation
DERP	Distributed Energy Resource Provider
DO	Utility Distribution Owner/Operator
DSO	Distribution System Operator
ESP	Energy Service Provider
FERC	Federal Energy Regulatory Commission
LSE	Load Serving Entity
ISO	Independent System Operator
M/LTE	Medium- /Long-Term Enhancement
MUA	Multi-Use Applications
NERC	North American Electric Reliability Corporation
NTE	Near-Term Enhancement
PV	Photovoltaic
RT	Real Time
RTO	Regional Transmission Organization
SCADA	Supervisory Control and Data Acquistion
T-D	Transmission-Distribution
TO	Utility Transmission Owner
WDAT	Wholesale Distribution Access Tariff