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

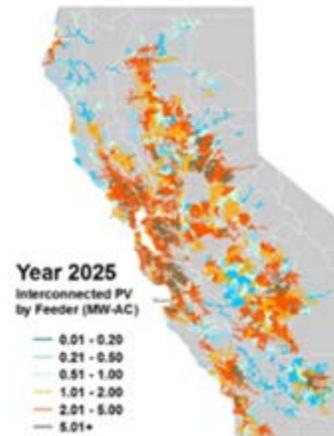
Mark Esguerra, PG&E

June 29, 2017



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 250,000 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:



50%
renewables by
2030



2X
energy efficiency
in existing
buildings by 2030



1.5M
electric vehicles
by 2025

Efforts in California to lower barriers to DER Participation

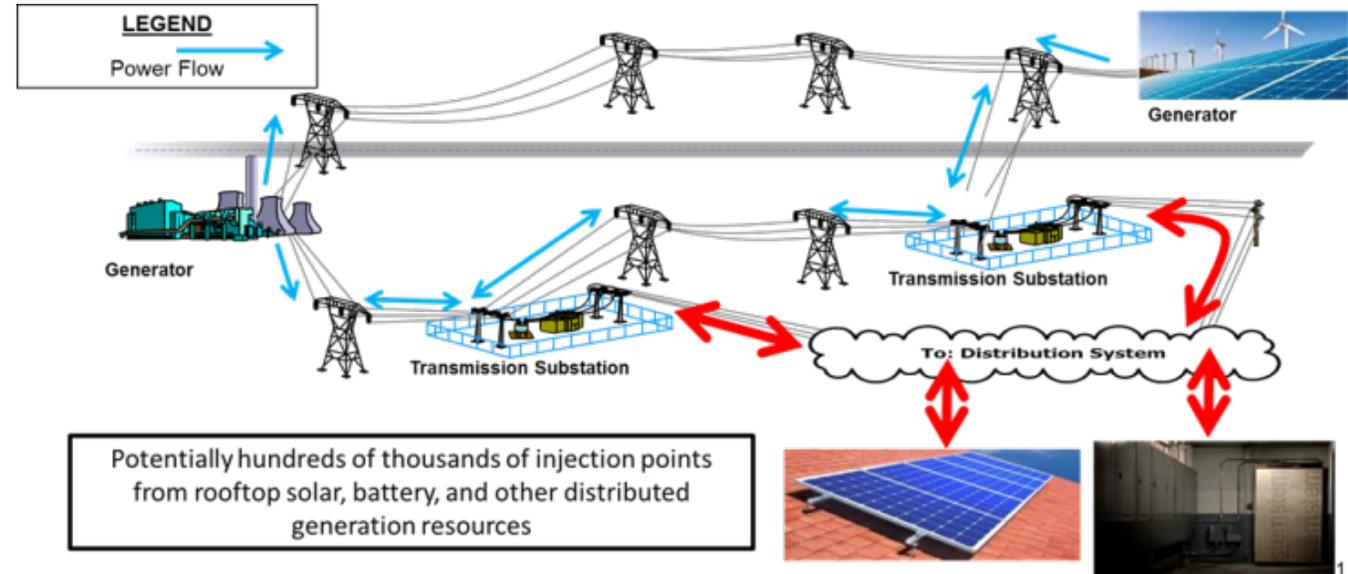


- California Public Utilities Commission (CPUC) Proceedings
 - Non Wires Alternative Solutions
 - Multiple Use Applications for DERs

- 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)

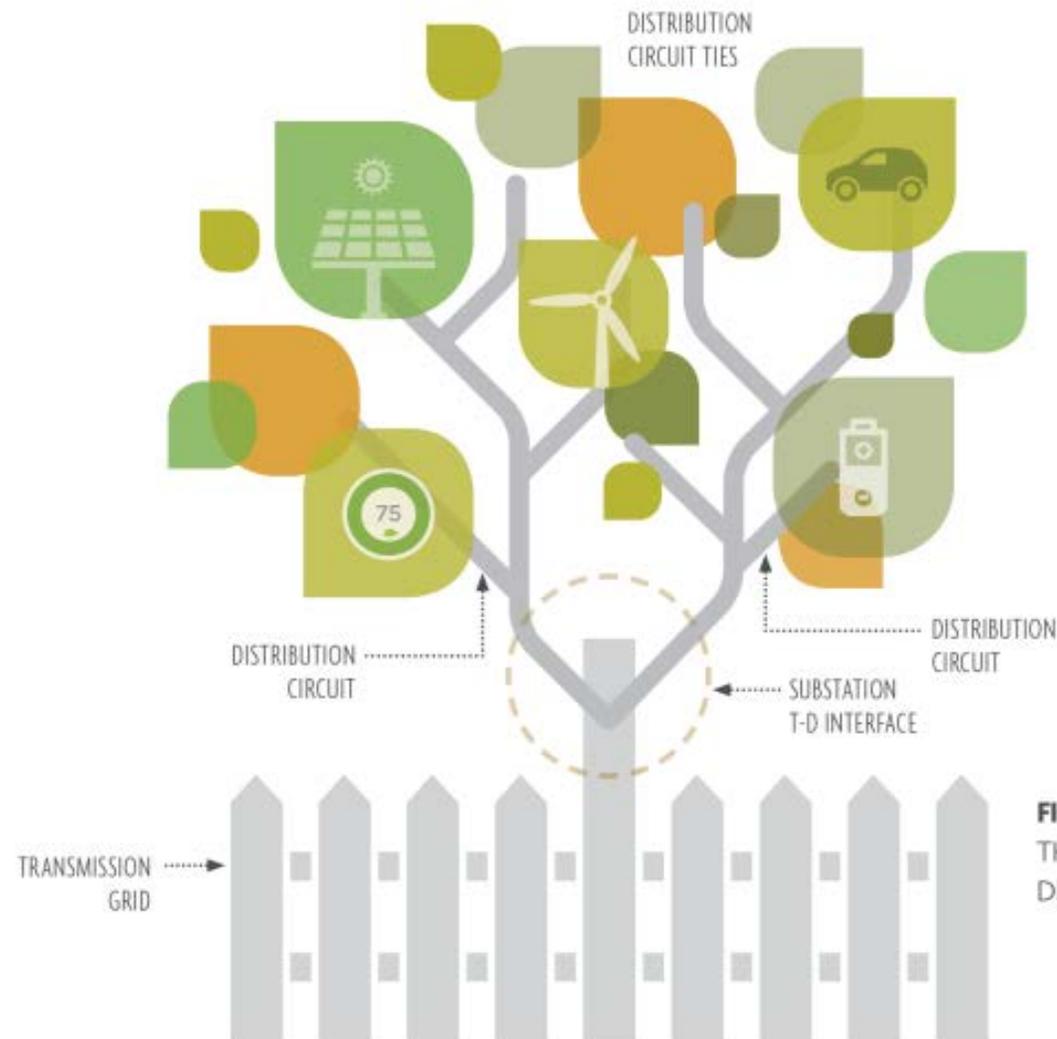
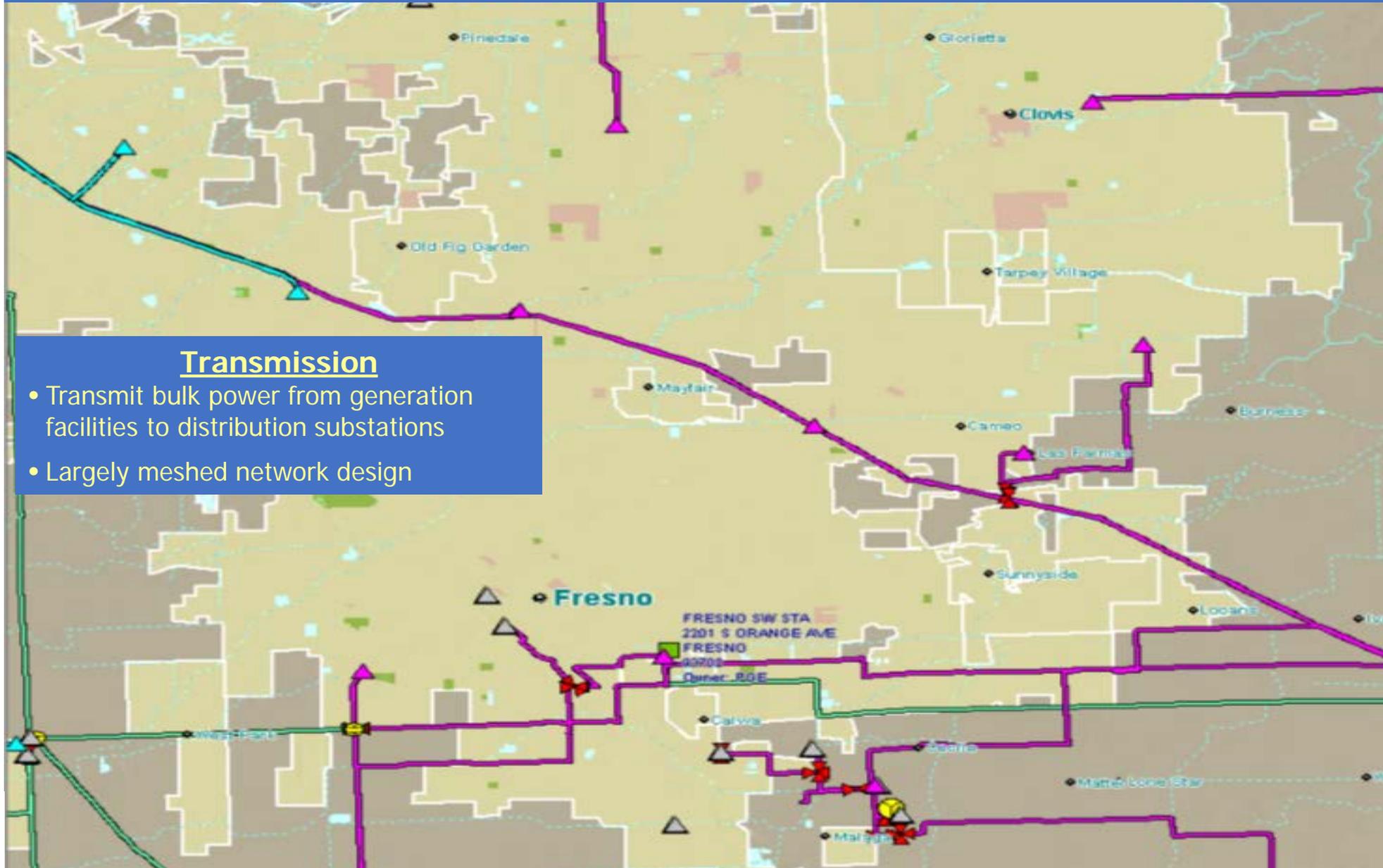


FIGURE 1. STRUCTURE OF THE TRANSMISSION AND DISTRIBUTION SYSTEMS

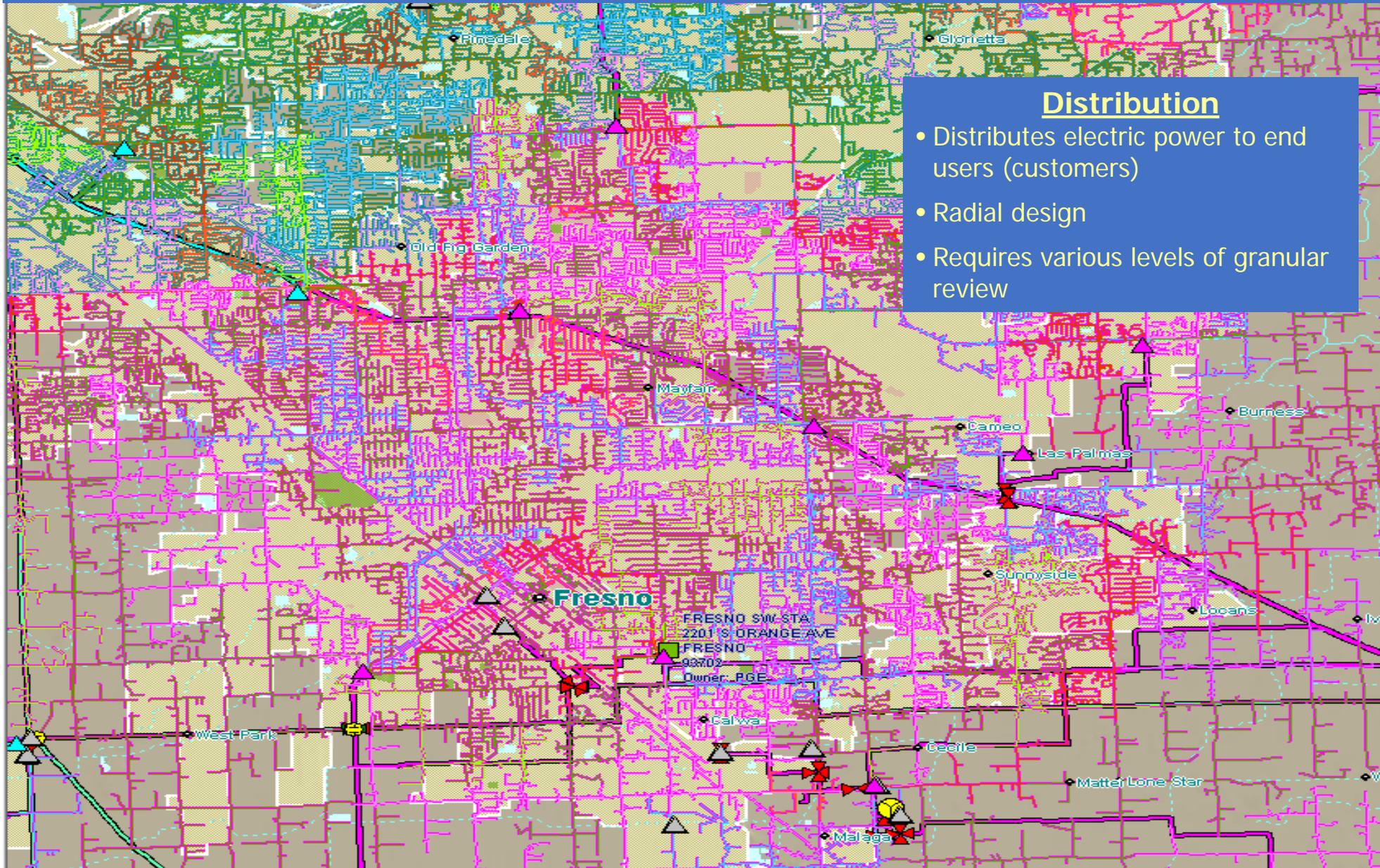
Local Area Transmission



Transmission

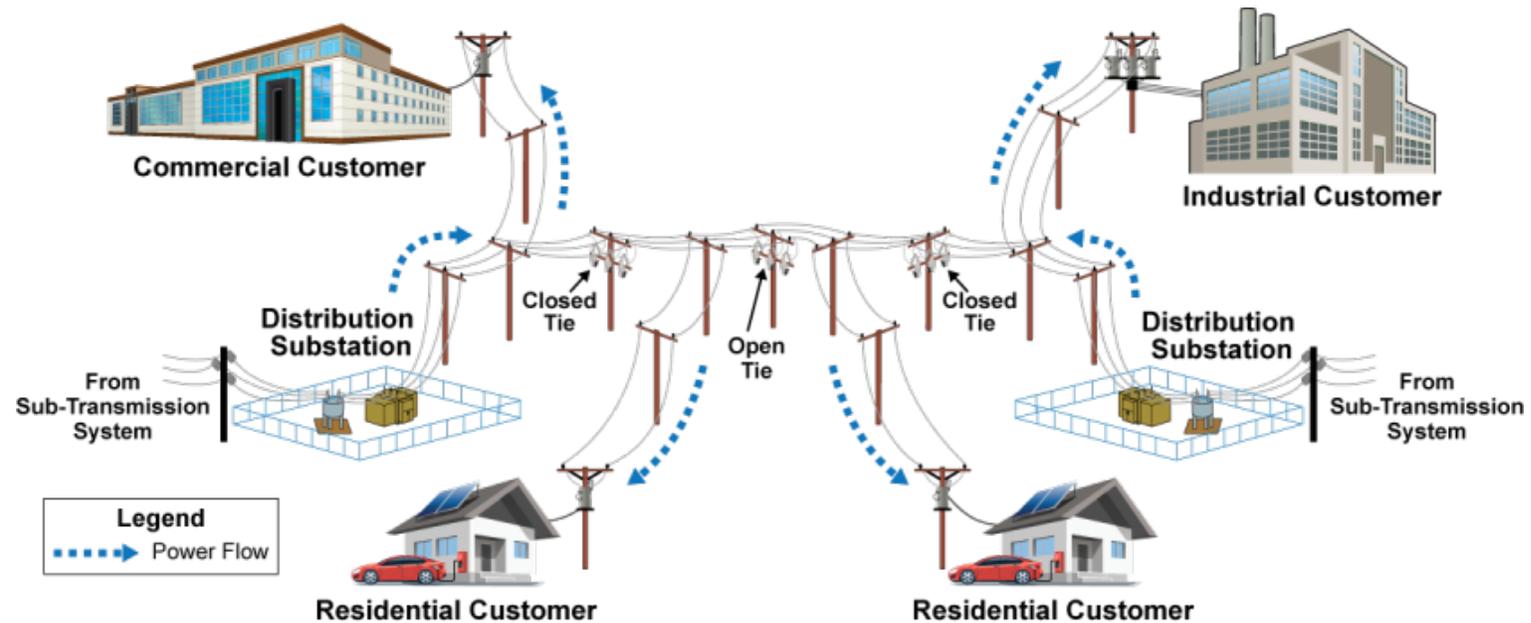
- Transmit bulk power from generation facilities to distribution substations
- Largely meshed network design

Local Area Transmission and Distribution Systems



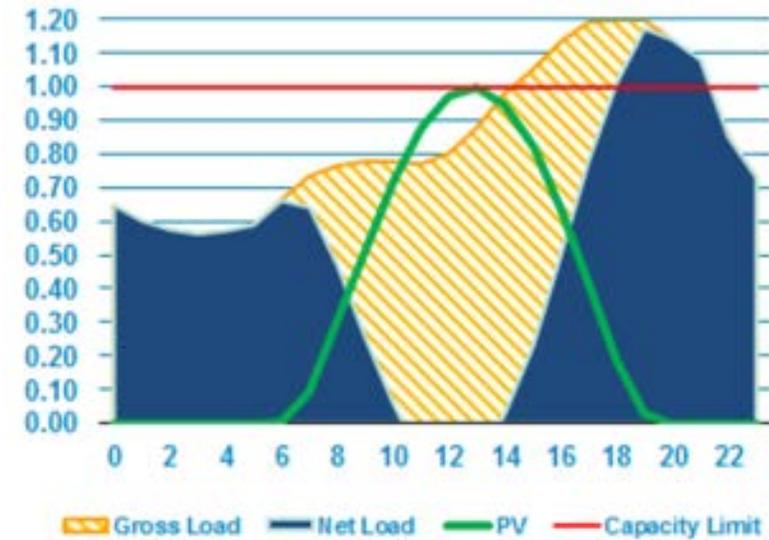
Frequency of Distribution Outages and Use of Switching Configurations

- 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



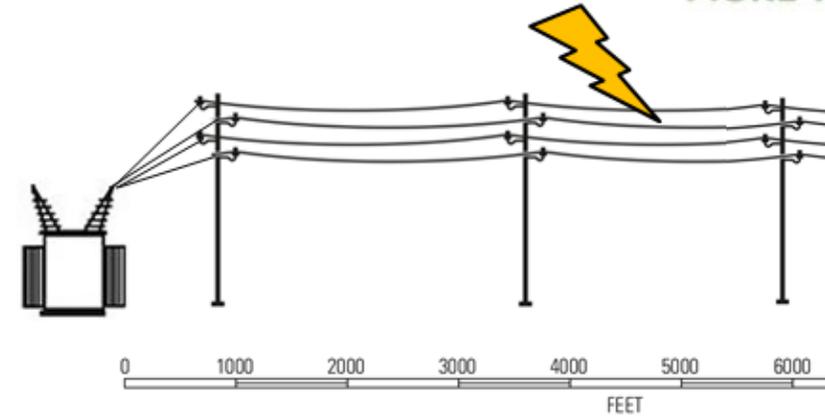
Lack of Visibility, Situational Awareness and Control

- 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



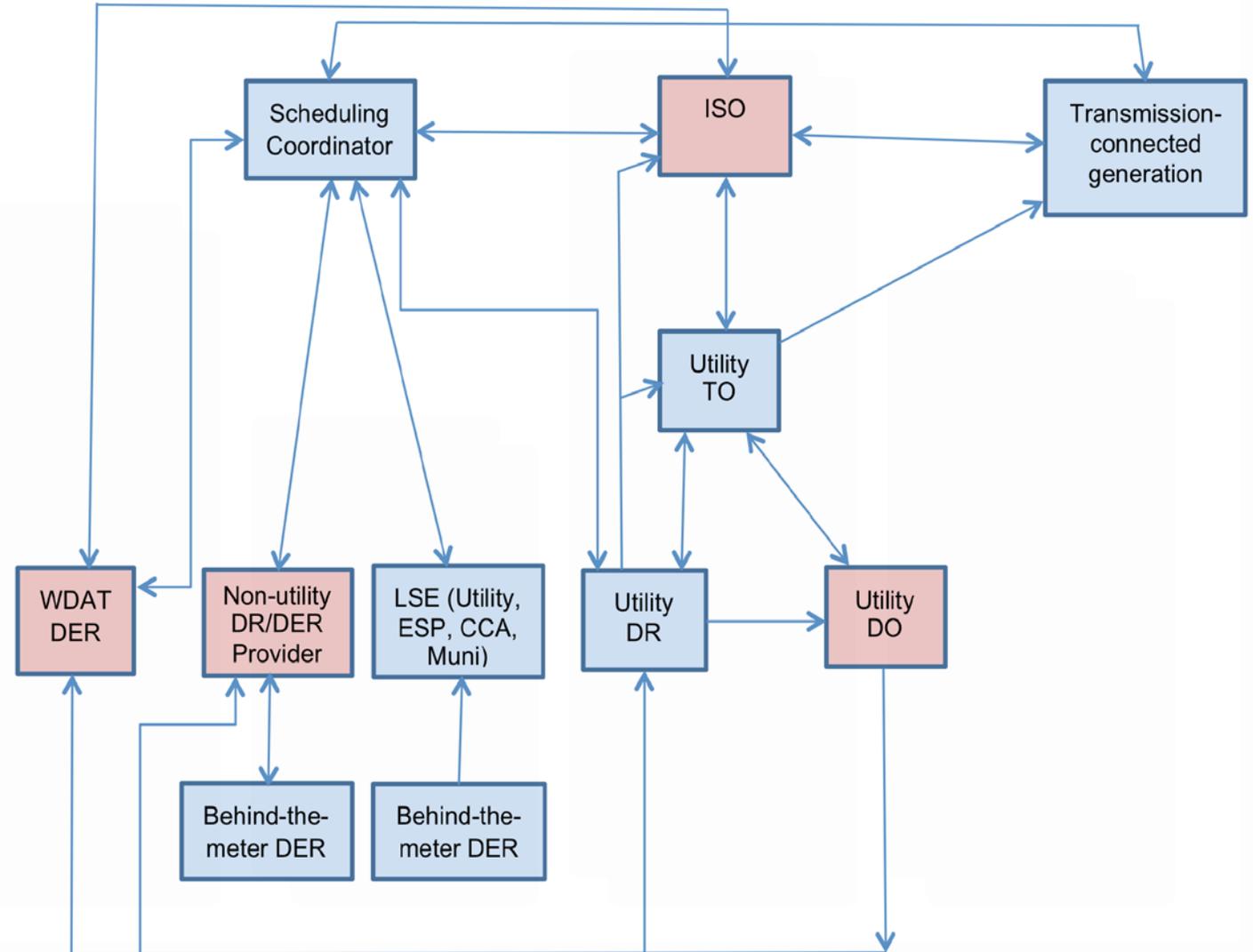
DER Effects on Distribution System Phase Balancing and Voltage Regulation

- 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

- 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

Near-term recommendations

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.