Distribution System Monitoring:
Intelligence to manage variability and uncertainty

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to Advance 12 GW of Distributed Generation
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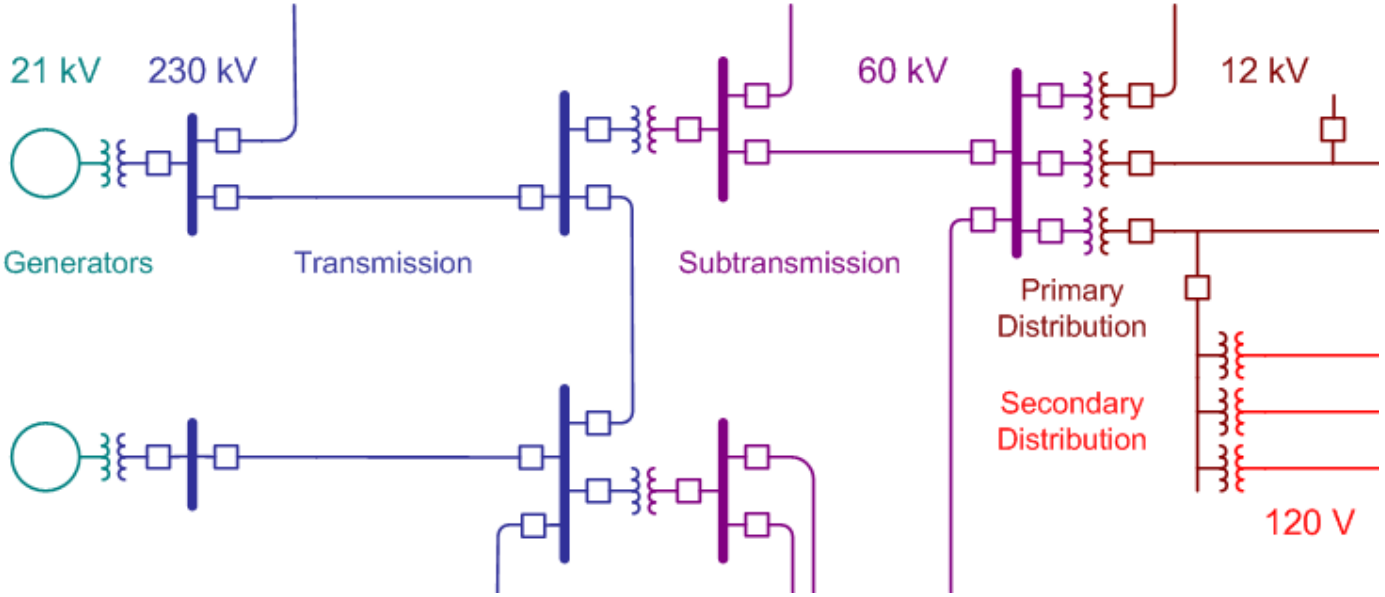
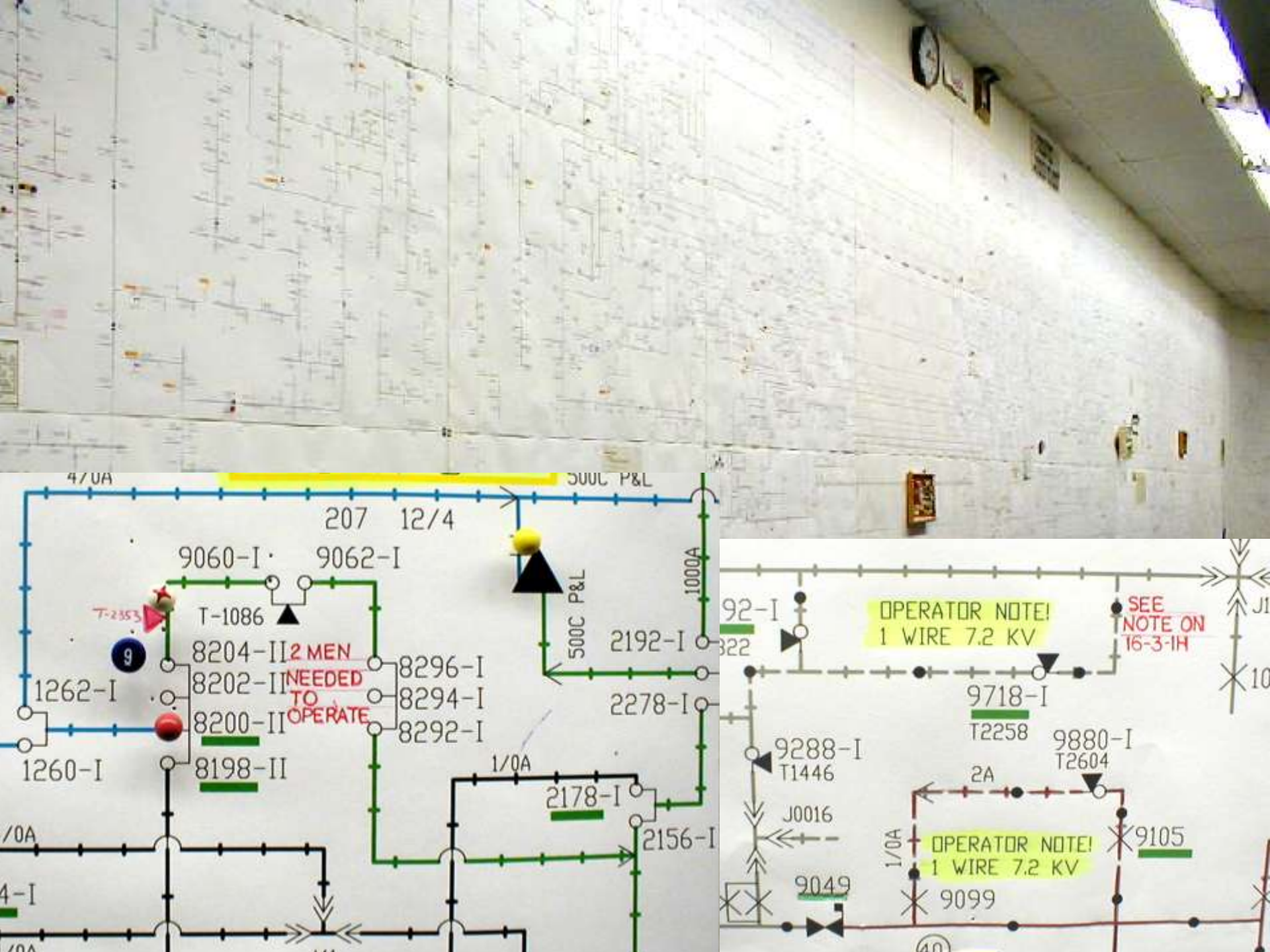
How distribution systems are different than transmission systems:
Architecture, Diversity, Variation, Vulnerability, Opacity



Some distribution feeder attributes:

- underground vs. overhead
- voltage level
- topology (e.g. radial, loop, network), sectionalizing options
- circuit length, load density
- load characteristics (time profile, load factor, predictability)
- anticipated load growth, EV, DG
- sensitivity of loads to power quality
- phase imbalance
- extent of SCADA capabilities in place
- type of voltage regulation equipment in place
- type of protective equipment and protection scheme used
- exposure to environmental insults, susceptibility to tripping

Illustration:
Michael Sowa


470A
500C P&L
207 12/4
9060-I
9062-I
T-2353
T-1086
9
8204-II
8202-II
8200-II
8198-II
2 MEN NEEDED TO OPERATE
8296-I
8294-I
8292-I
1262-I
1260-I
500C P&L
1000A
2192-I
2278-I
1/0A
2178-I
2156-I
OPERATOR NOTE!
1 WIRE 7.2 KV
SEE NOTE ON 16-3-1H
9718-I
T2258
9880-I
T2604
2A
9288-I
T1446
J0016
9105
9049
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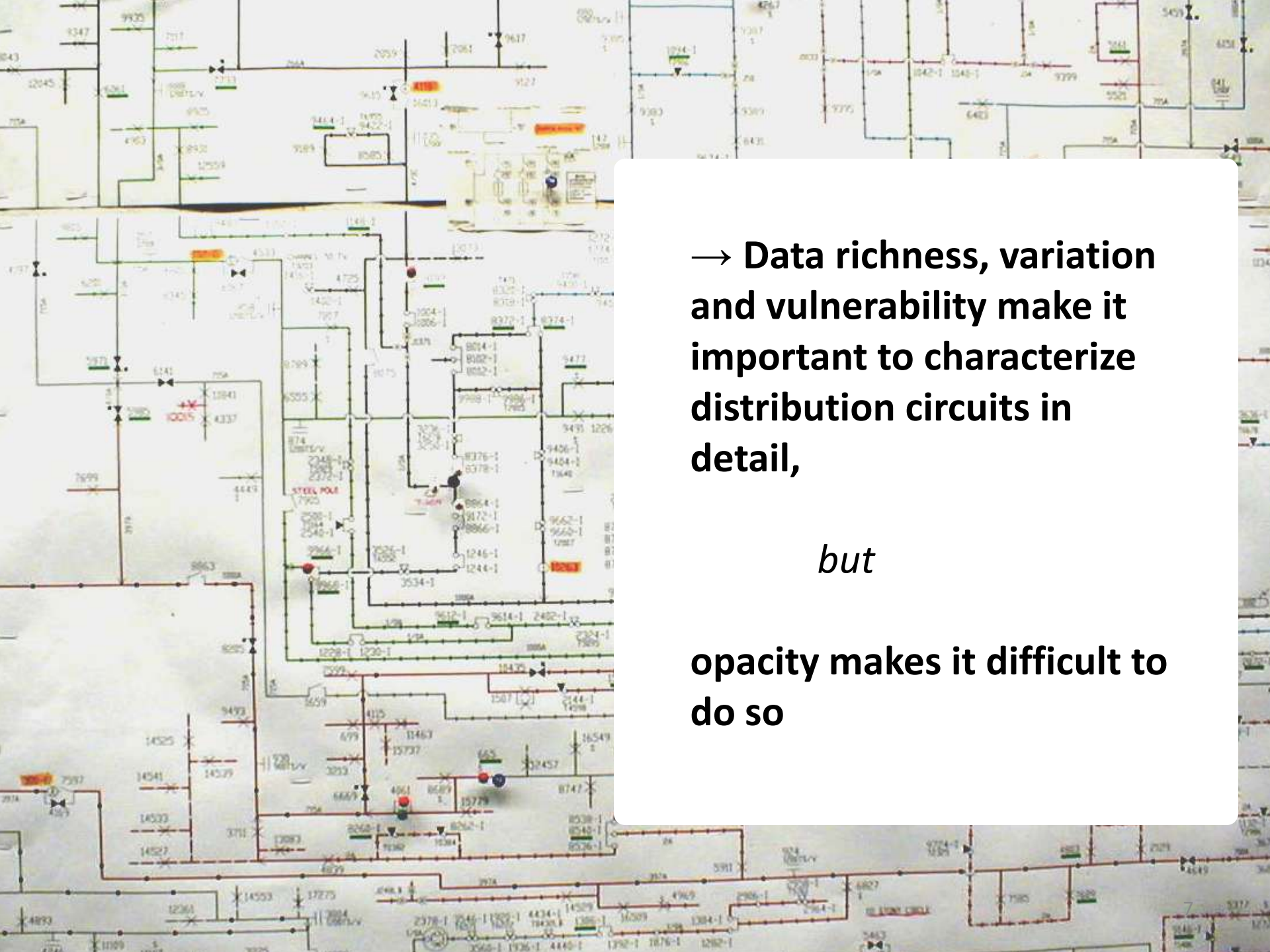


→ **Data richness, variation and vulnerability make it important to characterize distribution circuits in detail,**

but

opacity makes it difficult to do so

What can we see, and what would we like to see?

- **Direct measurement on distribution circuits**
  voltage, power flow, harmonics
- **Behavior of DG and loads**
  inverters, forecasting, adoption rates
- **Inference from observations**
  predictive & aggregate models

Direct measurement on distribution circuits

SCADA gives power and voltage data at substation (where available)

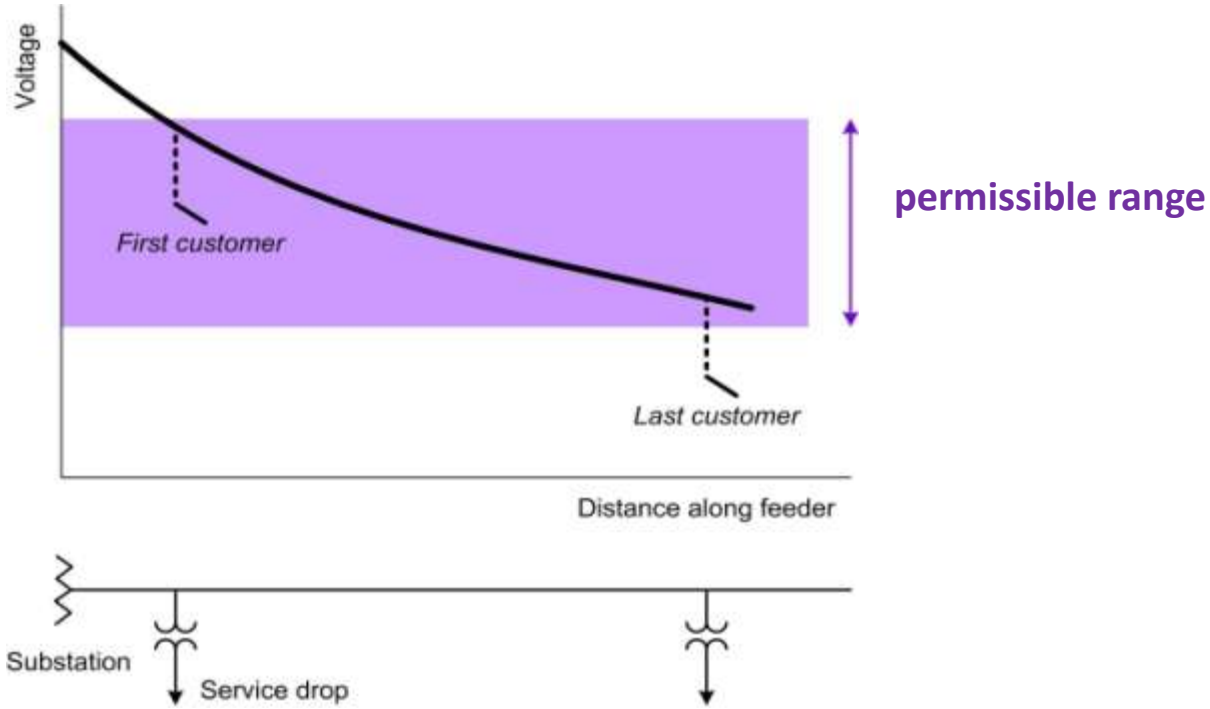
Capacitor banks give voltage reading along circuit (where available)

AMI customer meters can be enabled to give voltage reading (where available)

→ ***need additional sensing and monitoring to evaluate and anticipate DG impacts***

Additional sensing and monitoring

How closely spaced? What sampling rate?



PIER Transmission Research Program
Policy and Technical Advisory Committees have agreed:

- **Distribution systems harbor some of the greatest challenges for renewable resource integration today.**
- **Increased monitoring and characterization of distribution systems is a fundamental need in order to facilitate higher levels of DG integration.**
- **Existing work by utilities on distribution systems with high-penetration DG should be shared and knowledge gaps identified.**
- **Collaborative, coordinated efforts to monitor distribution circuits should provide compatible and complementary data.**

Distribution Monitoring Research: Overview

1. Characterization of sample feeders
2. Local DG impact assessment
3. Information sharing
4. Coordinated data analysis
5. Feeder modeling for future DG and EV impact predictions
6. Implementation of broader feeder monitoring where indicated
7. Distributed resource behavior specifications

Distribution Monitoring Research: Next Steps

1. **Characterization of sample feeders**

   a. Individual studies: Utilities are already conducting

   b. Coordinated, statewide effort:
   Utilities perform, PIER helps coordinate

2. **Local DG impact assessment**

   a. Individual studies: Utilities are already conducting

   b. Collective interpretation and gap analysis: PIER funded

3. **Information sharing**

   Utilities participate, PIER helps coordinate

4. **Coordinated data analysis**

   PIER funds research

continued...

Distribution Monitoring Research: Next Steps

5. **Feeder modeling for future DG and EV impact predictions**

   PIER funds research, utilities participate and advise

6. **Implementation of more comprehensive feeder monitoring where indicated**

   TBD

7. **Distributed resource behavior specifications**

   TBD

Distribution Monitoring Research: Next Steps

1. **Characterization of sample feeders**

   a. Individual studies: Utilities are already conducting

   b. Coordinated, statewide effort

   Working group has been formed to determine scope, resolution and protocol for collecting compatible and complementary data

2. Local DG impact assessment
3. Information sharing
4. Coordinated data analysis
5. Feeder modeling for future DG and EV impact predictions
6. Implementation of broader feeder monitoring where indicated
7. Distributed resource behavior specifications

Desired Benefits of Distribution Monitoring Research

- **Safe and reliable distribution system operation with increasing presence of distributed generation and EVs**
- **Visibility for transmission operators beyond the substation**
- **Informing DG specifications and interconnection standards**
- **Informing needs for strategic upgrades**

All of the above depend on good data.