



# CEC / CITRIS Workshop

## **Selection of Diagnostic Techniques for Underground Distribution Systems at PG&E**

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# PG&E Background



- 70,000 square miles
- 23,000 MW Peak electric load
- 4.1M gas customers
- 5.2M electric customers
- 45,800 miles of gas pipeline
- 139,000 miles of electric lines
  - 27,000 cir miles MV cables
- 71 generation facilities
- 20,000 employees

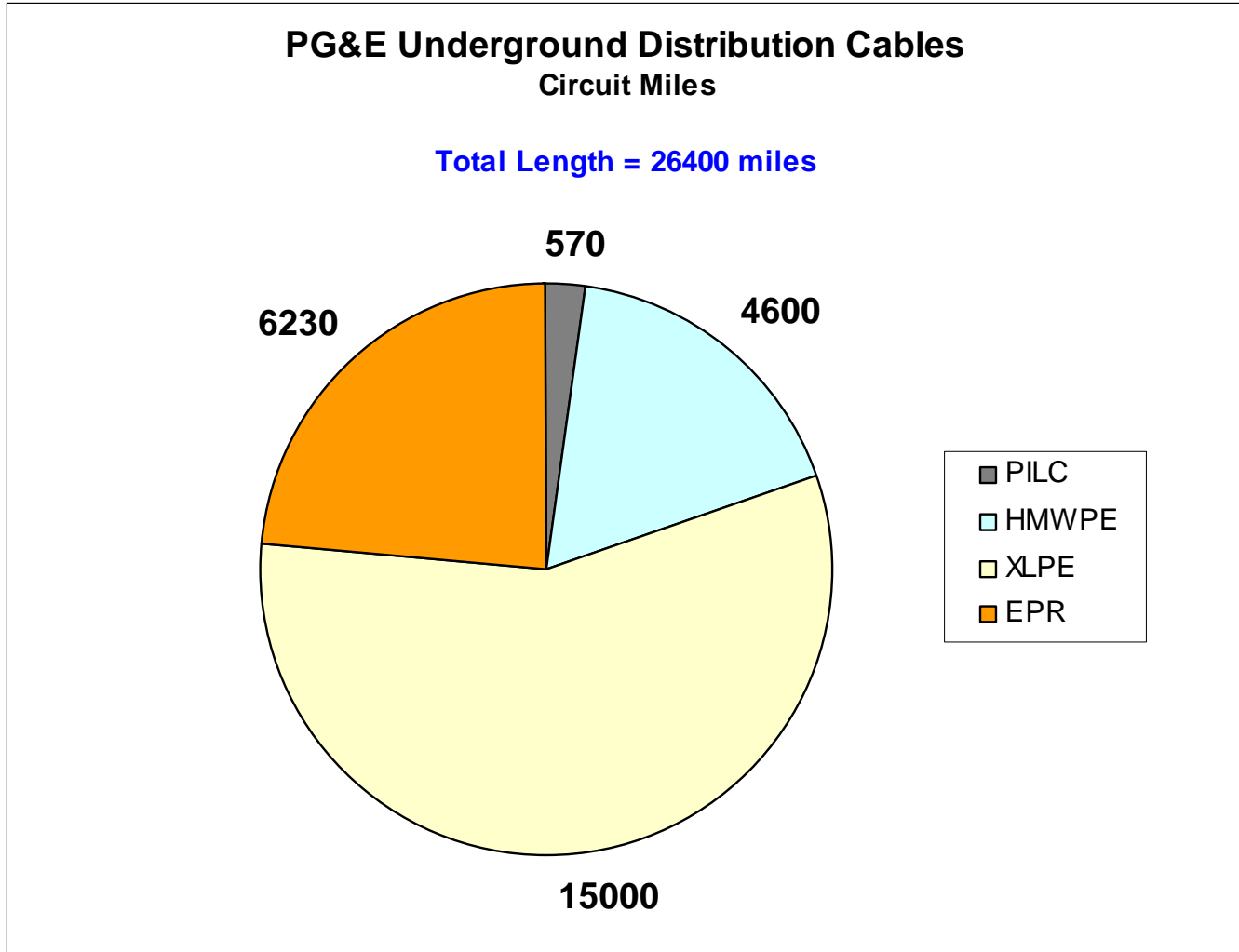
## Drivers for Diagnostic Techniques

- Increasing focus on system reliability
- Increasing failure rates of cables and accessories ( splices and terminations )
- Lack of granular asset records for older systems
- Only about 20% of tested cable require replacement
- Prioritization of cable system replacement
- Long term planning of cable system replacement budgets

# Selection Parameters for Cable System Diagnostics

- System Design
- Cable System Failure Rates
- Available Diagnostic Techniques
- Operational Considerations
- Economics
- Diagnostic Pilot Program

# System Design



# System Design

- Early cable designs had heavy insulation wall thickness – 295 mils for 12kV and 21kV
- Early installations mostly Cable-in-Conduit (CIC) for small conductor sizes and conduit for main lines
- Very limited direct buried installations
- Early installations with either terminations (live front) or dead break elbows
- Many subsurface components ( transformers, switches )

# Cable System Failure Rates

- Low cable system failure rates when compared to national benchmarks
- Failure rates split:
  - 57% cables (water treeing, defects, neutral condition)
  - 43% splices, elbows and terminations (workmanship, manufacturing defects)
- Marginal products
  - Cables prior mid 1980's; HMWPE
  - Types of elbows
  - Pin and socket splices
- Concentrations of higher failures rates within certain areas
- Improved failure reporting

# Available Diagnostic Techniques

- Selection based on
  - Literature review
  - CDFI Handbook
  - available EPRI work
  - Experience
- Commercially available
- Sufficient accuracy and efficiency
- On-line vs. Off-line techniques
- Suitable for different failure modes
- Service providers or equipment purchase

# Available Diagnostic Techniques

- Detection of key failure modes
  - Water treeing (wt) in cables / wt conversion in electrical trees
    - Off-line VLF Tan  $\delta$
    - Off-line VLF withstand test
    - Off-line IRC: Determine suitability for US cable systems
    - Off-line DS: Determine accuracy extruded dielectric cable
    - On-line PD: Low level aging signals
    - Off-line PD: Dormant or slow growing electrical trees
  - Partial discharges and tracking in accessories
    - On-line PD
    - Off-line PD
    - Off-line VLF withstand test
    - Off-line VLF Tan  $\delta$

# Operational Considerations

- Customer impact
- Switching for off-line technologies
  - Elbows / terminations: require customer outages
- Clearances and notifications
  - Lack of flexibility in scheduling
- Failures on test
  - Back feeds
  - Repair vs replacements
- Interpretation of test results with purchased equipment

## Economics

- Cost of diagnostics
- Cost for crews
  - On-line testing / Off-line testing
- Main line vs. local loop / radial
- Efficiency
  - Time per test / waiting time
- Accuracy
  - False positives / false negatives
- Justification in case of low failure rates
- Develop diagnostic strategy and business case

# Diagnostic Pilot Program

- Integrity of Concentric Neutral
- Review performance of past diagnostics
- Select potential providers
  - On-line PD
  - Off-line PD 60Hz
  - Off-line VLF tan d, VLF proof test, VLF PD,
- Possible new techniques
  - IRC ( Iso-Thermal Relaxation Current )
  - Dielectric Spectroscopy (DS)
  - VLF proof test
- Select feeders with prior history of problems
- Select either on-line or on-line and one subsequent off-line test
- Perform 2 weeks of testing for each provider
- Analyze results (in-house and Neetrac/CDFI) and observe system performance for at least two years