Improving reliability and resilience of electric power distribution by cost-effective undergrounding and high-performance maintenance technologies

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Acknowledgment – The Undergrounding Team

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US SAIDI is steadily going up – the problem we are trying to solve

SAIDI = \frac{\text{sum of all customer interruption durations}}{\text{total no. of customers served}}

(System Average Interruption Duration Index)

- US Power outages from severe weather have doubled in 20 years
- 32,562 power line-ignited wildfires (1992-2020)

https://insideclimatenews.org/news/11072022/is-burying-power-lines-fire-prevention-magic-or-magical-thinking/
Majority of power outage happens at distribution (MVAC, 4-35 kV)

- 94% (SAIDI, interruption duration) and 92% (SAIFI, interruption frequency) are from distribution[1]

- Cost of reliability ranging from $150 to $400 billion/year[3]

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Undergrounding can reduce storm SAIDI/SAIFI up to 64-67%\(^1\)

\(^1\) Distribution Grid Resilience Technologies (EPRI report, 2015)
\(^2\) Full study by Council of European Energy Regulators (CEER) - Benchmarking Report 6.1 on the Continuity of Electricity and Gas Supply (2018) 
https://www.ceer.eu/documents/104400/104400/1552dd34c
Undergrounding power lines is a proven way to improve reliability.

**SAIDI** = \[
\text{sum of all customer interruption durations} \div \text{total no. of customers served}
\]  
(System Average Interruption Duration Index)

Barriers to undergrounding power distribution infrastructure

- Too high upfront cost
  - Up to 10x higher cost than overhead
  - Shorter lifespan (20-30 years) than overhead (>50 years)
  - Too much work to get PUC approval, rate hike
  - This view is changing with life cycle cost comparison and reliability consideration
    - Transformative technologies to reduce upfront cost and increase life cycle?

- Shifted risk with underground assets
  - Safety concerns for operation and maintenance
  - Not visible and difficult to maintain and locate fault
  - Difficulty in quickly restoring the power
  - New kind of risks that operators are not familiar
    - Transformative technologies to improve operational safety and reliability?
# Program development - RFI questions category

## Q1. Technology prioritization
- What are the major barriers to wide adoption of undergrounding?
- Cost reduction – what moves the needle the most?
- Which of the technology categories should ARPA-E prioritize and why?

## Q2. Reduce the cost of UG construction
(construction technologies for borehole, conduits, vaults)

## Q3. Improve sensing and awareness of UG infrastructure
(detecting buried utilities)

## Q4. Reduce errors in UG installation
(cable splice and such)

## Q5. Incorporate health diagnostics, prognostics, and fault location

## Q6. Identify/develop repair technologies
(fast, minimal surface disruption)

## Q7. T2M
avg. 4-5 crossbores per mile
112,917 strikes in 2010 alone (mostly HDD)
up to $100M cost per a crossbore event
Component failure modes and root causes (MV cable)

https://netaworldjournal.org/partial-discharge-tests-for-medium-voltage-power-cable-systems/
External inputs (green box = contributed to RFI)

Industry

Gov./non-profit

Utilities/Co-ops

Universities/Nat’. Labs

26 written responses many ‘team’ responses (as of April 6th)
Which of the following technology categories has the most potential impact on lowering the cost and improving reliability of UG power distribution?

Q2. Reduce the cost of UG construction
Q3. Improve sensing and awareness of UG infrastructure
Q4. Reduce errors in UG installation
Q5. Incorporate health diagnostics, prognostics, and fault location
Q6. Identify/develop repair technologies

special thanks to Dr. Drew McGuire & Dr. Joshua Perkel at EPRI
Proposed program strategy (pre-workshop)

Which of the following technology categories will meet ARPA-E criteria: “High-risk white space” and “If it works, will it matter?”

Full Program Technology Categories

Q2. Reduce the cost of UG construction
- Q3. Improve sensing and awareness of UG infrastructure
Q4. Reduce errors in UG installation
Q5. Incorporate health diagnostics, prognostics, and fault location
Q6. Identify/develop repair technologies
Technology categories for breakout discussions

Category 1.1: Cost-effective, safe, and fast underground construction

Category 1.2: Underground survey and mapping

Category 2: Safer, efficient, reliable cable splicing

Category 3: Fault prediction and location

Group A: Dr. Jack Lewnard (Program Director)

Group B: Dr. Bob Ledoux (Program Director)

Group C: Dr. Emily Yedinak (Fellow)

Group D: Dr. Dick O’Neil (Senior Fellow)

Group E: Rakesh Radhakrishnan (T2M Advisor)
Technology categories for breakout discussions

**Group A**
- Dr. Spencer Aertker (tech SETA)

**Group B**
- Dr. Sade Ruffin (tech SETA)

**Group C**
- Dr. Toni Marechaux (tech SETA)

**Group D**
- Dr. Kathleen Lentijo (tech SETA)

**Group E**
- Dr. Kalena Stovall (tech SETA)

Cost-effective, safe, and fast underground construction  
Category 1.1

Underground survey and mapping  
Category 1.2

Safer, efficient, reliable cable splicing  
Category 2

Fault prediction and location  
Category 3
DAY 1: Breakout Session #1 (Program scope/boundaries)

- Invited speaker presentations -> networking fast pitch -> B/O #1
- Five B/O groups with a mix of different stakeholders with same questions
- Questions for program scope
  - Identify technical white space and ‘ARPA hard’ R&D challenges
  - Prioritize key technology R&D areas
- Discuss program level goals, structure, and metrics
- ARPA-E staffs will facilitate the discussion to get your ”opinion”
- Report back on Day 2 (6 minutes/group)
DAY 2: Breakout Session 2 (Technical directions/metrics)

- DAY 1 recap -> B/O #1 report back -> B/O #2
- **Complete the polls by EOD today**

- Five B/O groups of similar interest (+ utility companies in each group)
- Promote transformative, out-of-the-box ideas
- Specific boundary conditions will also be discussed
- We’ll not prescribe the solutions/approaches
- Discuss ‘how to test’ different ideas objectively
Undergrounding is a problem of diverse scenarios

A fixed cost target may not work

FEASIBILITY STUDY FOR UNDERGROUNDING ELECTRIC DISTRIBUTION LINES IN MASSACHUSETTS

December, 2014
Why would potential program outcomes matter even more?

- Decarbonization by electrification, adoption of more renewable power generation, and de-centralization of energy systems will drive the need for more localized distribution grid infrastructure.

- Where do we put these new infrastructure? overhead or underground?

- ...and other infrastructure? (water, gas, broadband, CO₂ pipeline, H₂ pipeline)

- However, it is extremely costly and slow to underground power lines today even for just 5-10% of conversion or expansion (except for greenfield)

- Need both cost-effective and speedy methods.
Both planned (Public Safety Power Shutoffs) and unplanned outages disproportionately affect Low-income Communities

Fair and Equitable Solutions?
Workshop guidelines and rules

- Workshop goal is **NOT** reaching a consensus nor making a decision
- ARPA-E wants to gather inputs and opinions **from all of you**
- Ask many questions after speaker presentations
- Be actively engaged during B/O sessions (your opinion matters!)

- Break the ice and get to know each other!
- Introduce (fast pitch and more) and network
- Look for potential partners
- Request follow up meetings
  - one-on-one meetings are possible right after the workshop (except for 3-4 pm)

*The laws of physics still apply, but erase the 'box' around your thinking and have fun!*