Stormy Weather: Going Underground as Part of a Resiliency Program

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KEY TAKEAWAYS

- PDi², a resource for power industry infrastructure decisions, facilitates smart resiliency decision-making.
- Undergrounding fits in a larger resiliency ecosystem.
- To analyze a targeted undergrounding program, consider the actual costs and the ability to withstand severe weather.
- Eight specific steps to create an effective resiliency program.
- Properly setting objectives and measuring progress are critical to a successful outcome.
OVERVIEW
Targeted undergrounding of power industry infrastructure is one component of a resiliency program to limit the frequency and duration of outages. Undergrounding has proven to make the infrastructure better able to withstand severe weather events, but costs more to install than overhead infrastructure. Targeted undergrounding can maximize the impact while containing the costs.

The nonprofit resource Power Delivery Intelligence Initiative (PDi²) has published eight clear steps to an effective resiliency program:
1. Defining objectives
2. Creating a program
3. Developing the plan
4. Obtaining approval
5. Implementing
6. Reporting progress
7. Evaluating success
8. Lessons learned and other issues

Xcel Energy offers a case study in implementing targeted undergrounding and lessons learned.

CONTEXT
In this live webinar, David Lindsay explained the role of PDi², Mark Bridgers detailed PDi² research, and Lonnie Martinez shared the experience of Xcel Energy.

KEY TAKEAWAYS
PDi², a resource for power industry infrastructure decisions, facilitates smart resiliency decision-making.

Power Delivery Intelligence Initiative (PDi²) is a non-profit resource whose mission is to help stakeholders make informed decisions around the best use of overhead or underground infrastructure for both new construction and rebuilds. Considerations include rate recovery, resiliency, and reliability of the system.

To help enable planning of resiliency programs with the possible hardening technique of targeted undergrounding, PDi² is publishing the Utility Infrastructure Resiliency Playbook (the “Playbook”). The Playbook takes the reader step-by-step to create a resiliency program. Eight case studies address the topic of each chapter of the Playbook, culminating with a comprehensive case study that is an amalgamation of multiple utilities across four states. Most importantly, each of these case studies includes contact information for individuals who can serve as a resource.

Undergrounding fits in a larger resiliency ecosystem.

Key terminology in this ecosystem includes:
- **Reliability**, the benchmark of utility service, is based on long-term and operational steps that reduce the probability of power interruptions.
- As the frequency and severity of weather-related events increases, **resiliency**, limiting outage frequency and hastening restoration, is at a premium. Key events in recent decades have propelled the issue to the fore: 1992’s Hurricane Andrew in Florida, four hurricanes in 2004 that left no county in Florida untouched, and in 2012 the twin impacts of Superstorm Sandy and the derecho that devastated the Northeast and Mid-Atlantic.
• **Hardening** consists of physical changes that improve the durability and stability of specific parts of the electric distribution or transmission system infrastructure.

• **Undergrounding**, locating electric infrastructure underground, is a hardening technique to avoid exposure to extreme weather.

• **Targeted undergrounding** involves specific portions of the infrastructure. In one case study, the utility determined that 60-65% of the outages experienced after two large storms stemmed from approximately 20% of the mileage. This led the utility to pursue targeted undergrounding as a component of its resiliency program. This utility decided to implement the program over a 10-year timeline, 300 miles per year, 4000 miles in total.

To analyze a targeted undergrounding program, consider the actual costs and the ability to withstand severe weather. Undergrounding has traditionally been calculated as six to 10 times more expensive than overhead line installation. Targeted undergrounding, however, drives down these costs significantly, to as low as three to six times the cost of overhead. The earlier iterations were calculated by focusing on undergrounding the most critical lines, which tended to be in highly urban or highly trafficked areas with higher installation costs. The case studies in the Playbook illustrate the real costs, depending on the location, type of soil, construction methodology, etc.

Undergrounding has proven to withstand major weather events. In the face of repeated storm damage, the legislature in Virginia encouraged its utility to undertake a strategic undergrounding program. Undergrounding is possible at all voltage levels even in earthquake prone areas, as demonstrated by the hundreds of miles of underground distribution and transmission in California. The cables are technically designed to be underground, to operate in wet conditions. Survey data after Superstorm Sandy and other events shows that equipment above grade experienced failures; the underground components were not damaged by flooding. (See Additional Resources)

The conclusions we were able to draw is that underground transmission assets are less likely to be impacted by major weather events. The failures that do happen are associated with the equipment that is above ground.

David Lindsay

Eight specific steps to create an effective resiliency program.

Each step, designed to walk through the process of establishing a resiliency program including targeted undergrounding, is a separate chapter in the Playbook.
Utility Infrastructure Resiliency Playbook

**Executive Summary**

**Stormy Weather: Going Underground as Part of a Resiliency Program**

<table>
<thead>
<tr>
<th>Steps in the Playbook</th>
<th>Explanation</th>
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<tr>
<td>1 Defining Program Objectives</td>
<td>Define the resiliency program and undergrounding strategy objectives. A clear set of objectives defines the size and nature of the program.</td>
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<td>2 Creating a Resiliency Program</td>
<td>The program can include targeted undergrounding as one of the techniques in pursuit of the objectives.</td>
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<td>3 Developing the Program Plan</td>
<td>Begin to detail how it would potentially be implemented and how the program should be positioned successfully with regulators, customers and other stakeholders.</td>
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<td>4 Obtaining Approval</td>
<td>Introduce pathways chosen to pursue legislative support (perhaps in combination with regulatory approval), as an alternative to an exclusively regulatory approval route.</td>
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| 5 Implementation Strategies | Effectively communicate, construct, and measure the implementation.  
   *Communications*: Including with regulators, stakeholders, community.  
   *Construction*: Range from using internal utility crews to using contractors. Considerations to ensure work is efficient.  
   *Key Performance Indicators*: Critical to understanding program directionally. In absence of significant storms, measure progress of implementation. |
| 6 Reporting Program Progress | Ensure routine reporting on a week-to-week, month-to-month, and year-to-year basis, using milestones. |
| 7 Evaluating Overall Program Success | Monitor resiliency of the program after a storm. Demonstrate improvement in resiliency. |
| 8 Collection of Lessons Learned/Other Implementation Issues | Ensure that implementation issues that arise are evaluated and addressed. |
The steps are designed to help somebody walk through the process that they might go through in order to identify the use of a resiliency program, and then more specifically the use of targeted undergrounding as one of the techniques to achieve that resiliency.

Mark Bridgers

**Properly setting objectives and measuring progress are critical to a successful outcome.**

Recognizing that undergrounding is an expensive and often slower process of installation, utilities must clearly identify the problem or problems to be solved. Three possibilities in the area of customer satisfaction are:

- **Aesthetics:** New neighborhoods typically place the facilities underground, which is more pleasing to customers.
- **Outage frequency reduction:** Reduce the impact of severe weather events with fewer outages.
- **Outage duration reduction:** Mitigate the effect of any outages with more rapid restoration of service.

Having clarity around the problem to be addressed will dictate the proper type of resiliency program and whether, what type, and what level of undergrounding may be an appropriate component.

Measuring success against these objectives is similarly critical to ensuring proper, targeted investment. The most common indicators utilities use to measure reliability, SAIDI and SAIFI, are often overwhelmed by the overall system statistics that make it difficult to isolate the improvements achieved from resiliency programs centered on highly targeted undergrounding strategies. This imbalance has led utilities to consider nontraditional ways to assess performance. One looks at total line restoration time, measured in hours or days. Another common option is geographic-specific measures of SAIDI or SAIFI that examine the performance improvement in the specific location where undergrounding was implemented, rather than the totality of the system. For example, the utility described above that is implementing a 10-year plan of targeted undergrounding has achieved significant performance improvements in geographic-related SAIDI and SAIFI metrics, and forecasts a reduction of 40-50% in outage duration in the event of a significant storm.

**ADDITIONAL RESOURCES**

Studies commissioned by PDi² are found at [https://www.pdi2.org/resources/](https://www.pdi2.org/resources/)

These studies include:

1. **Going Up or Down: Factors to Consider Before Going Overhead or Underground**
2. **Underground Transmission Circuit Performance During Flooding due to Major Weather Events (Survey)**
3. **Utility Infrastructure Resiliency Playbook (the “Playbook”)**
**XCEL ENERGY CASE STUDY - Cherokee Substation**

**CONTEXT:** Xcel operates in 13 states, with over 50 miles of underground transmission lines. The Cherokee substation illustrates how Xcel approached targeted undergrounding and what it has learned so far.

**SITUATION:** Cherokee Substation was fairly old, with limited bay positions and a lot of existing overhead lines. There was a need to connect three new generator positions. This presented Xcel with a challenge to get direct connections to the substation yard. In addition, the plant is approximately 60 feet lower than the substation, requiring crossing a steep slope.

Xcel decided to install a new underground cable system from one generator to the substation, a total length of about 600 feet (the red line shown below).

The first problem to solve was determining the cable route, examining old, out-of-date plant drawings, and working with the plant site team to find the best option to avoid potential issues.

In order to optimize the reliability of the generator connection, Xcel decided to install two cables per phase, ensuring redundancy. The second cable can handle 75% of the normal load if there is a problem.

To deal with the slope, the team used a horizontal directional drill (HDD). Considering different routes, they took many borings to evaluate the soil, bedrock, and thermal values. They hit bedrock at both the top and bottom, and anticipated no concerns in using the HDD to lay pipe.

**RESULT:** No overhead crossings for the generators, with two cables per phase for reliability. The substation team also wanted a ground continuity conductor between the substation and the plant, so copper cables were installed to tie that.

**LESSONS LEARNED:** Xcel confronted unexpected slope issues during the installation. The soil had appeared at the top and bottom to be better than the sand encountered throughout the hill. This required installing flow fill, repairing the hill, and using an engineered geo fabric to maintain stability. This surprise could have been avoided with specialized equipment for borings in the slope area.

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**Cherokee UG System - Challenges**

- Generator positions

**Cherokee - Solutions**

- Proposed routes
EXECUTIVE SUMMARY

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BIOGRAPHIES

David Lindsay
Marketing Manager – Energy Business, Borealis North America

David Lindsay has worked in wire and cable for over 20 years in design, development, product and project management and construction roles with various manufacturers, R&D companies and electrical contractors, and now at Borealis where he is responsible for marketing and product line strategy for the North American energy business.

David is a Senior Member of IEEE and actively engaged in the IEEE Insulated Conductor Committee where he is past chair of two discussion groups. David served for six years as U.S. representative to Cigré Study Committee B1 (Insulated Cables). He has authored numerous technical papers on cable system design, operations and testing as well as authored chapters in the 2006 revision of the EPRI Underground Transmission Systems Reference Book and 2010 revision of the EPRI Underground Distribution System Reference Book.

David serves on the board of the non-profit Power Delivery Intelligence Initiative. He is also a member of the Advisory Board to the National Electric Energy Testing Research and Applications Center (NEETRAC) at the Georgia Institute of Technology. He earned a Bachelors of Materials Engineering from the Georgia Institute of Technology and a Masters of Business Administration from the University of West Georgia.

Mark Bridgers
Principal, Continuum Capital

Mark Bridgers is a consultant to the design and construction industry and leads a Utility Vertical Market team. He works primarily with gas/electric utilities, power generators, pipeline companies, and energy companies to support the planning, design, and construction of capital assets. In addition, he frequently works with the service providers to these firms including overhead or pipeline contractors, industrial and mechanical contractors, engineering firms, and value added material and equipment suppliers. As a recognized expert in capital construction and operational challenges, Mark was recently honored with membership in both the Society of Gas Operators (SOGO) and the Gild of Ancient Suppliers.

Mark holds a master’s degree in business administration from the University of Virginia’s Darden School and a bachelor’s degree in financial management from Clemson University. He has earned the titles of Chartered Property & Casualty Underwriter (CPCU) and Associate in Reinsurance (ARe).

Lonnie Martinez
Principal Engineer, Xcel Energy

Lonnie Martinez is a Principal Engineer with Xcel Energy. He specializes in underground transmission line engineering. He has experience in pipe-type and solid dielectric underground transmission cable systems. He is a senior member of the Insulated Conductor Committee of the Power Engineering Society of IEEE.