WHITE PAPER

Increasing Electric Distribution Reliability by Modernizing Underground Cable Systems

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Electrical distribution grids are under increasing stress today as new demands emerge. From the need to accommodate distributed renewable energy sources and new smart technologies to the greater frequency of extreme weather events, grid modernization programs utilize undergrounding assets to improve resilience and reliability.

Placing electrical cables and related infrastructure underground within a power distribution system can greatly improve resilience and reliability. Many times, the underground portions are so reliable that utilities focus primarily on maintenance and replacements of overhead assets that are more prone to seasonal weather conditions. As a result, many utility operations groups are experiencing a diminishing pool of knowledge pertaining to underground systems. Utilities that need to replace underground assets might not have experienced veterans in-house to do so. For some utilities that installed underground cable systems several decades ago, the underground systems are past their original design lives and are starting to have more failures than desired. Given the nature of the underground system, these failures often have widespread impacts resulting in significantly degraded system reliability and prolonged outages. As utilities see an increase in system failures, they're creating plans to launch cable replacement programs to revive the health of their underground distribution systems.

The road map for utilities to launch these programs starts with a careful assessment of existing assets to develop approaches that are appropriate for their own unique system configurations and load patterns.

Considerations for Establishing a Cable Replacement Program

Many utilities are facing the prospect of upgrading much of their underground assets as they move aggressively to improve grid resilience and reliability. Most of the underground cable duct bank and manhole system and related power delivery equipment is in densely populated urban areas. Oftentimes, underground assets in these urban centers are lower voltage, ranging between 4- and 12-kV, and in some instances, include a secondary network composed of a lower-voltage network interconnected with network transformers and network protectors. Many of these underground circuits have been in service for several decades.

These dense urban centers, which generally involve multiple utilities, can be some of the most complex distribution networks systemwide. Having a solid plan that addresses the idiosyncrasies of engineering, design and the complexities that will arise during construction is key to success.

An effective cable replacement program further depends on access to experienced underground distribution resources. If internal utility resources are lacking in capacity or experience, utilities can rely on an owner's engineer to help assess current conditions, review processes and set the program up for success. Further consideration should be based on whether or not the understand system received proper and consistent maintenance; if records have not been maintained, additional time and funding may be required to acquire necessary tools and develop processes.

Finally, cable replacement programs can be expansive and last for multiple years. Establishing achievable, measurable key performance indicators that align with expectations of utility executive leadership, customers and regulating bodies will be critical to demonstrate success and secure year-over-year funding to complete the program.

Process Specifics of a Programmatic Cable Replacement Program

For many utilities across the United States, legacy distribution systems have reached a breaking point, warranting significant capital investment to upgrade existing underground cable as well as augment the system with new conduit and equipment.

The first step in getting a major capital program underway is to undertake a comprehensive desktop review of the system, including types of cable, vintages of cable and other equipment, as well as installation dates, if available. At this stage of program development, recommended construction standards for joints and splices should be reviewed and necessary improvements made.

A review of paper-based inventory and construction records is likely required to determine when the cable and other assets were installed and any subsequent maintenance that has been performed. Manhole inspection data, for example, will give the design and planning team important insight into the state of splices, racking facilities, manhole walls, duct faces and other connection points for the underground network.

Another useful approach is to gather available field books showing sketches and notations compiled by crews working on-site at various locations to perform maintenance and routine inspections. These records can serve as an important source of truth to begin building a digital geographic information system (GIS) or similar system that will help track construction progress and plan future maintenance. Ultimately, a GIS can help reduce future operation and maintenance costs by consolidating information into an extensible and consumable platform for future design and planning needs.

A spreadsheet or database tracking system has proved to be an effective tool for helping the team zero in on cable types and sizes, voltages, distances of cable sections between duct faces, and notations of cable splices made within the manholes. Utilizing these trackers, utility crews can easily enter the data needed for specifics like the slack length of cables running from the duct face where it enters the manhole to the splice joint.

During the early stages of the program, the engineering team will review all cable data with an overlay of outage data to identify where trouble spots might be located on the system. These insights help create a prioritized list of circuits to begin directing capital investments efficiently. Once the list is established, individual project scopes are developed, based on decisions such as whether entire sections need to be replaced or if splicing in some new sections with older cable is acceptable.

With the priority list and project scopes in hand, work orders can be issued and design can begin to structure the necessary construction packages. The design phase should not only specify cable sizes but also specify if construction crews need to pull all-new cable through conduit without a shutdown or if it will be pulled and spliced into the system during a shutdown. The design phase must also detail all new system conduit, manholes or equipment needed to facilitate the cable system upgrade.

The design and construction plan can be rolled up into a scope and budget estimate that informs capital portfolio plans. The utility can set budgets and determine which projects can be executed within the fiscal year, based on construction estimates developed in design. The construction phase can then focus on completing a project within the year or outline a hybrid approach based on projects that can be fully completed and those that can start based on available pre-work, outage coordination and remaining budget. The budget typically includes both the underground and overhead work where the cable terminates at poles and transitions to the overhead grid. Additional equipment like switchgear at substations may also be budgeted during this phase if required by the engineer for system upgrades. Once a budget is confirmed and approved, the cable replacement program proceeds and assets are put into service.

Critical Components of a Cable Replacement Program

There are several critical aspects to consider when planning a cable replacement program.

Physical Inspections

On most cable replacement programs, physical inspections are required for manholes and existing conduit. Once inspection documents are developed and issued, manhole inspection crews can be assigned and dispatched. The goal is to minimize the time that an inspector is physically down inside a manhole as safety is the top priority during these inspections.

Before this operation commences, all water is pumped out and a pH test is performed to detect the presence of any hazardous substances. Air monitoring devices are dropped in the manhole, and a thermal inspection is performed to detect any heat signatures that might indicate failing or hazardous splices. Once cleared, an inspector enters the manhole and begins taking photos or scans. Sketches may also be created to depict locations of joints, present cables, key manhole dimensions and cable training. The data captured is used to further inform engineering drawings, construction plans and design packages to develop a constructable solution.

Design and Construction Standards Updates

Standard updates and revisions are common for most new programs. A comprehensive review of existing standards and current cable technology is recommended ahead of starting inspections or design. When parts of a system are being replaced, new sets of standards will likely be needed to accommodate new technology, current codes or safety practices for today's requirements. Starting with standards that are customized for efficient programmatic replacements of cable systems allows for the lowest costs for design and installation, which ultimately provide a reliable and prudent final product.

Outage Planning

In most cable replacement programs, it is reasonable to expect that much of the system will need to be completely removed and replaced. In this event, it will be necessary to create a detailed outage plan so that service is maintained while construction is performed. An intensive scenario analysis and cost-benefit analysis of different options will be needed to plan the sequence of work packages for both replacement and restoration of circuits.

When detailing a strategic outage plan, the engineering and planning team will need to consider critical facilities and loading conditions that will commonly change with seasonal loading trends, especially in extreme weather environments. This will require both electrical system studies and coordination with customers. The plan will also need to consider routine maintenance and concurrent construction taking place for other programs. Outage planning often becomes a critical component of completing projects on schedule and within budget.

Defining Measures of Success

Though each utility has unique configurations and system designs that must be taken into consideration, measures of success are generally defined through key performance indicators related to budget, quantity of assets energized and improvements in outage performance metrics.

For one utility, a goal for the underground cable replacement and rehabilitation program could be to replace a specified number of units of cable each year. A unit, for example, would typically be defined as 1,000 feet of cable, and the goal for the year could be to replace 50 units, or 50,000 feet. Costs of replacement programs can be quantified based on how much material, equipment and labor will be required for that level of activity.

These quantifiable goals are critical in filing rate cases with regulatory authorities. In most cases, the utility will file a request for rate relief based on projected costs of a replacement program. With that request on record, the public utility commission can approve or reject the requested rate relief based on whether the utility has historically met its goals and, above all, provided improved service for its customers.

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