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Technical Brief

Guide for Transmission Line Foundations with Least Impact to Environment

Transmission Overhead Line Design & Extreme Event Mitigation (TODEM) Interest Group
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Report Background

This report is a best practices guideline for the evaluation and selection of appropriate transmission line foundations with the least environmental impact. The methodology focuses on the review of published case studies supplemented with selected utility and consultant surveys, along with the contractor's personal files on transmission line foundations susceptible to various sensitive and difficult environmental conditions. Difficult environments can be classified as wetlands/waterways, mountainous/rough terrain, permafrost/frozen ground, woodlands, conservation/wilderness areas, and desert/rangeland. Utilities often use traditional foundations in sensitive conditions, controlling impacts with construction mitigation measures, such as improved access or modular matted paths. Environmental impacts can be mitigated by a combination of good planning, design, and construction practices (i.e. avoiding sensitive environments, minimizing activity in these conditions, etc.), or through using foundation installation practices that limit construction time. Gaining access for geotechnical investigations in these conditions can be costly, but doing so offers great potential to reduce overall foundation construction cost, due to reduced uncertainty. This report details the advantages and disadvantages of both traditional foundation systems (driven piles, drilled shafts, direct embedment poles, steel grillages, spread footings, and anchored structures), and alternate foundation systems (helical anchors/piles, vibratory caissons, micropiles, rock socketed anchors, and auger cast piles). Local practices, economy, available equipment, and site access generally control the selection of foundation alternatives for projects in sensitive environments. A rational step-by-step model is presented where information is organized and numerical values are assigned to criteria for each foundation option.

Summary

This report seeks to identify transmission line foundation technologies used in sensitive environmental conditions, and to make recommendations for best practices regarding both design and selection practices that minimize impacts. The scope incorporates decision making processes that aid in the selection of foundation alternatives which best meet the economic, engineering, and environmental needs of the project. The report is divided into six major tasks:

1. Review of case histories;
2. Assess foundation environmental impacts;
3. Summarize mitigation strategies;
4. Evaluate alternative access methods;
5. Evaluate foundation alternatives; and
6. Describe the foundation selection process.

The literature review includes case histories and an industry survey to characterize foundations installed in difficult environments. Twenty-six documented case studies representing various sensitive environments were reviewed for this report. Nineteen unpublished cases were received through solicited survey.

Traditional foundations plus environmental mitigation via access controls are used in just under 40% of case studies. Case studies employing alternate foundation designs (e.g. micro-piles, vibratory caissons, and helical piles) tend to use minimally invasive access methods (helicopters, barges, boats, marsh buggies, light/small equipment, etc.). Nearly 85% of survey respondents indicated a preference for construction mitigation measures over the use of alternative foundation types (improved access or modular matted paths). Alternative access methods, such as hauling in equipment by hand, improving the ground with stabilizers, and helicopter use, were less common.

Wet environments can result in foundation construction access restrictions due to the presence of near surface water or open water. Since these environments are home to many plant and animal species, construction will likely be seasonally limited and include pre- and post-construction mitigation. Foundation construction may include constraints/mitigations for drilling debris, machinery fuel, and sediment turbidity. Access will likely need to be improved to compensate for weak surfaces. Otherwise, equipment will need to be delivered to sites by boat, air, or crane.

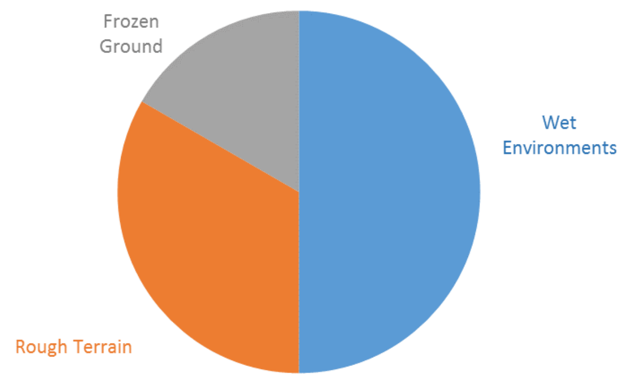

Figure 1 –Environment Distribution from Case Studies

Rough terrain includes highly variable topography in mountainous regions, posing access considerations due to inclines, remoteness, and climatic extremes. Mountain forests tend to be conservation areas, often having access restrictions related to the seasonal flora, fauna, and fire risk. Subsurface conditions are often dense/hard, requiring special foundation installation tooling/equipment. Few foundation options exist if roads cannot be built. Small diameter (micropile) foundation drilling equipment is often mobilized to sites by helicopter. Otherwise, foundations may need to be constructed by hand with small-size portable equipment transported via 4-wheeled vehicles, ATVs, or carried by construction workers.

Seasonal frozen ground, regions of permafrost, and permanently frozen tundra encompass the extremely high latitudes/altitudes of the world. Frozen ground is often seasonal; affecting schedules, access, and construction. In areas of discontinuous permafrost, access may be limited to frozen periods, as the locations often become wetlands or bogs during the warmer seasons. The major foundation impact to frozen ground is land disturbance needed for access. In extreme cases, snow and water are used to build ice roads to support machinery. Transmission line tower types located in frozen ground regions typically include down guys, driven piles, and helical piles as a means to reduce the foundation footprint.

Foundation construction environmental impact mitigation assesses practices that result in the most desirable combination of available options. These options include avoidance, activity minimization, and protection at sensitive sites. Access practices commonly used as mitigation include ungraded paths, matted drives, spur road construction, and frozen ground work. More costly mitigation strategies include temporary geotextile drives, the creation of ice roads, and manual construction. Alternative access to structure sites by air or water may require the use of helicopeters, marsh buggies, or barges.

Foundation types can positively influence construction schedules and reduce environmental impacts by providing alternative methods for construction in undesirable situations, or negatively affect these same elements due to the nature of the equipment, placement, or materials. Some foundation types require more time for material design and fabrication, while other options can be readily constructed. Foundation construction schedules must account for the time needed to design, fabricate, and build foundation elements to mitigate environmental exposure.

Figure 2 –Helical Pile Tower Foundation

Engineers have a wide array of tools and techniques for founding transmission line structures. The most common foundations (traditional) along with less frequently used (alternate) foundation systems are presented in terms of the advantages and disadvantages inherent to each system. These systems are then considered in relation to design and construction processes in sensitive environments. Traditional foundation systems discussed include driven piles, drilled shafts, direct embedment poles, steel grillages, spread footings, and anchors. Alternate foundation systems presented include helical anchors/piles, vibratory caissons, micropiles, rock sockets with anchors, and auger cast piles.

Descriptions of foundation systems (plus design methodologies and models) are given in general form to provide an understanding of design and construction. Foundation design equations are reported without safety or resistance factors in order to illustrate model relationships. The engineer's final design must include these factors to ensure proper performance. This report should not be considered a design manual, as the details of design are intentionally omitted, with the reader guided to more comprehensive texts. This guide presents foundation options/models for various transmission structure types and their use in sensitive environments, to aid in the selection of the most advantageous option(s) for a particularly difficult environment.

For any given site, environment, and condition, multiple foundation options are available to either support transmission line structures or to span a sensitive environment. The project owner and its engineers, therefore, have the challenge of selecting one or more feasible and economical option for further consideration. Organizing this information is critical to performing a logical assessment that arrives at an economical foundation alternative for a project producing the least environmental impact. A rational model is presented as flow charts and decision matrices, via a step-by-step process in which criteria are ranked. Predicted outcomes allow the designer to select one or more option with the highest likelihood of successfully meeting project goals.

Conclusions

Environmental impacts can be mitigated by a combination of good planning, design, and construction practices, including avoidance, activity minimization, and protection at sensitive sites. Plans developed as part of early studies evaluate site mitigation, monitoring, and compliance, and are often incorporated into construction activities. Foundations (or at least structure locations), should be assessed as part of this process to provide greater flexibility in later foundation design and construction. Best practices include avoiding sensitive environments, minimizing activity under these conditions, or using foundation installation practices that limit construction time.

Improved access practices offer the best opportunity in all sensitive environments to minimize impacts. Most projects include a carefully thought-out construction access plan to minimize environmental impacts. These plans should be prepared in conjunction with final selected structure and foundation design alternatives.

This guideline presents a great deal of information, options, and alternatives that must be assessed to select the optimal foundation in sensitive environments. Organizing relevant information is critical to the performance of a logical assessment that arrives at the best foundation alternative for a project. This organization is done via:

- Flowcharts to guide the process;
- Tabularized criteria to categorize and quantify options and impacts; and
- Matrixes to assemble information and provide a quantitative comparison of options.

There is an element of subjectivity in the evaluation of foundation options using the tools presented in the guide document. Flowcharts provide defined values for ranking each factor and criterion, but must be used along with foundation description summary data and detailed discussions for each foundation option. When used together, these tools provide an excellent basis for making good decisions regarding the selection of the foundation system that least impacts a particular environment.

Recommendations

Foundation evaluation methods presented in the guide document can be used by utilities to assess the favorable alternatives for a specific project. The case histories suggest this effort is best done early in the project, starting with the planning and land acqusition phase of the project.

Although feasible, highest ranked foundation options may not necessarily be the least costly. Preliminary design and cost estimation should be performed for the most feasible options to determine the best course of action. This may be done via traditional means where staff engineers and estimators develop detailed designs, costs, and schedules. Alternately, preliminary design work can be value engineered as a joint effort of the design team and foundation construction experts.

Upon review of the state of the practice, the authors see future opportunity in the following areas:

1. Performing trial cases for the evaluation of alternatives to better develop value engineering methods;
2. Research and development in the area of Vibratory Caissons; and
3. Formal development of guide specifications for electric system foundations.

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