Medium Voltage Line Design – A Covered Conductor Alternative for Long Spans and River Crossings

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AERIAL CABLE SYSTEMS

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Abstract

Medium voltage line designers have numerous challenges and obstacles when designing a power line. These include, but are not limited to terrain, weather, routes, density (rural, suburban, urban, etc.) and pre-existing conditions, such as whether an existing pole line already exists and must be utilized. The design options normally include whether to use bare wire, underground cable, or one of two covered conductor options (tree wire or spacer cable).

Oftentimes line design is relatively straightforward, with span lengths pre-determined, and the decision whether to go overhead or underground already made. While long spans are quite common in transmission line design, they are less so in medium voltage. The long spans addressed in this paper have to do with challenges such as being inaccessible from a bucket truck.

Long spans may arise due to the fact that the line needs to cross a river or stream, or perhaps a rail line, or even traverse from one mountaintop to an adjacent mountaintop. The objective of this paper is to discuss some of those challenges, how they are addressed by the NESC, various construction option considerations, and the pros and cons of using a covered conductor construction.

NESC Guidelines

NESC doesn't address the challenge of long spans, per se, but addresses the challenging conditions presented by the long spans themselves. For instance, designers usually use deadends on either side of a long span. The practical reason for dead-ending long spans, however, is that they are tensioned more to reduce sag, and the height of the poles required to meet clearances. Also, under ice and wind conditions there are unbalanced loads with a long span adjacent to a short span and this overloads the pole and the pole hardware. The dead ends on either side of the long span can be guyed, which eliminates the imbalanced mechanical load on the pole.

NESC (1) comes into play on long spans when they involve highway, river (or bodies of water) and railroad crossings. These situations require Grade B construction, which has different overload factors than grade C construction. So applying these overload factors only to a single span requires that you deadend it on both ends.

NESC 242 (Table 242-1) requires Grade B construction for railroad crossings, navigable waterways, and "limited access" highways (footnote 10 on this table indicates that "there is no intent to require Grade B over ordinary streets and highways"). This then leads into the appropriate loading factors shown in Table 253-1, and NESC 261. The load factors are applied to the wires and cables and are used to design the structures, foundations, guying, and pole hardware.

Challenges

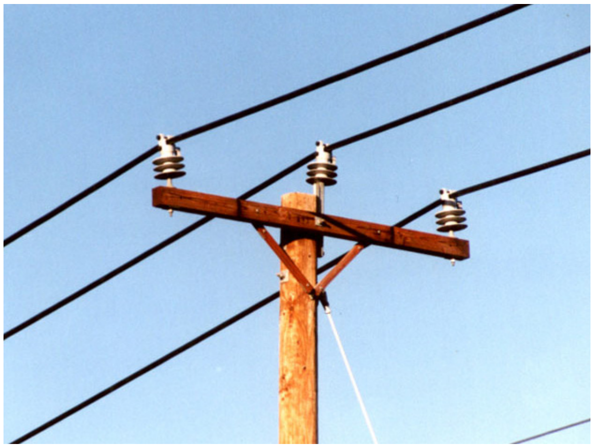
The challenges when confronting long span design can be numerous, depending on what is being crossed. Challenging crossings include, but are not limited to the following:

- **Crossing distance** – the longer the crossing, the greater the sag, and the more loading on the poles. This creates the need for more robust poles, and quite likely taller ones as well.
- **Elevation changes** – it is possible that one side is significantly higher than the other. This creates the need for accurate modeling, to ensure the pole and guying selections are adequate. It also creates additional challenges for installation, especially if the line angle is steep.
- **Crossings over navigable waterways** – such crossings have, in the past, been involved with accidents, and even deaths, estimated at 8-10 fatalities per annum in the US alone. This usually has occurred with sailboat masts touching bare wire lines and energizing the vessel. The risk is present because sailboats may have masts of 20 to 30 feet, while the minimum height for power lines is 18 feet. Sailboat strikes of powerlines have also occurred in Australia, the UK, and other nations.
- **Highway crossings** – these crossings pose unforeseen hazards for tall/overloaded transport vehicles, as well as maintenance vehicles which are not normally present (such as boomed vehicles, guardrail post pounders, and other construction vehicles).

Construction Options

1. **Raising the bare wire line elevation over the crossing** – this is a viable, although unsightly, solution to the problem. This gets the bare wire line higher up and out of harm's way. It also likely invokes NESC rules for increased loading if the pole is 60 feet tall or higher. This, in turn, increases pole costs, guying, and quite possibly installation costs as well.
2. **Undergrounding** – putting a line underground is always an attractive option. If one goes under a highway, however, directional boring may elevate costs significantly. If one goes under a navigable waterway, the costs are elevated even further, and time delays may be introduced if a governmental agency review and approval is required.
3. **Covered Conductor options** – there are two options here: **Tree Wire** and **Spacer Cable**. A short description of each follows.

3a. Tree Wire – this consists of three heavily covered phase conductors strung in an open wire configuration, and mounted on polymeric insulators on standard crossarms. The phase conductors are tensioned similar to their bare wire counterparts, as shown in the photo below.



3b. Spacer Cable – this consists of three heavily covered phase conductors (with the same insulation covering design as used for tree wire), supported by a high strength messenger wire, with the phase conductors attached to and hung by the messenger at 30 foot intervals using polyethylene spacers.

Case Studies

Carrol White REMC, Indiana

This involves a 1,600 ft. span crossing Lake Shafer. The lake is a significant recreational area, with growing electrical load, and required reconductoring the #2 AWG to a 336 kcmil to meet increased demand. The existing line consisted of three poles, one for each phase conductor, separated by 20 feet. The large separation was needed in order to avoid conductor clashing midspan. The existing poles were inadequate for the new cables and also required replacement, and the expense of six new, high mechanical strength structures, for a bare wire replacement, was a cost issue.

The second, and seemingly most attractive option, was to use a submarine cable under the lake. This was going to cost, in 2004 dollars, in excess of one million, which was difficult to justify. The third option was simply to build a line around the perimeter of the lake with conventional bare wire. The cost of this option, however, due to the long route around the lake, was not much below the cost of the submarine cable option, and came in over $800,000.

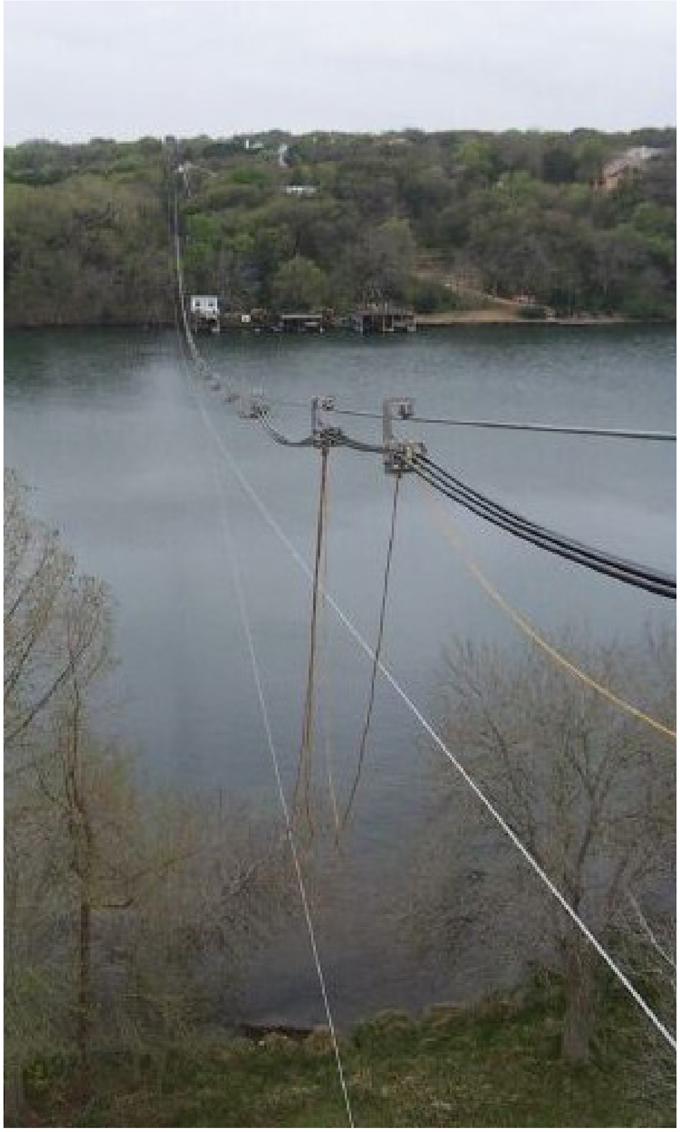
The last option was to maintain the existing aerial route, but rebuild with spacer cable. Modular 12-sided steel guyed poles of 90 ft. height were used, and installed farther up the incline to be at a reasonable elevation above the water level. Installation required the use of a bosun's chair. The cost of the spacer cable was approximately $250,000, or 25% of the submarine cable option, and 31% the cost of the bare wire option.

The photo below shows the line under construction. The messenger was pulled in first. One phase of the existing ACSR bare wire line was used to pull in the messenger across the river. The messenger was then tensioned, and then the three phase conductors were pulled in simultaneously using the "Roll-By Method." The phase conductors were then "sagged" while still in the Roll-By stringing blocks, then placed within the preformed dead end grips on each end of the line. The photo below left shows the stage where the lineman is preparing to ride across the river in a bosun's chair, remove the Roll-by stringing blocks one at a time, pass them to the person in the boat below, and then replace them with spacers. He passes the Roll-by blocks to the person in the boat below, who passes up a spacer for installation. The photo below right shows the finished installation.

City of Austin River Crossing

The need was to build a 1,200 ft. span to cross a river, with relatively heavy 795 kcmil, 15 kV cable. As in the project above, the messenger was pulled in first. One phase of the existing 4/0 AWG ACSR line was used to pull in the messenger across the river. The messenger was then tensioned, and then the three phase conductors were pulled in simultaneously using the "Roll-By Method."

The method used to install the spacers was similar to the method discussed above, but instead of traversing the river to install spacers using a bosun's chair, the crew used an Aerial Messenger bucket, pictured below.



Swan River Crossing, Perth, Australia

The existing distribution line crossing the river had boat traffic regularly passing underneath it. At one point a sailboat struck the bare wire and a fatality resulted. The responsible safety authorities required the local utility to revise their crossing design to ensure this event would not occur in the future. A special crossing was designed which included not only spacer cable, but two cables on either side of the spacer cable line, termed “striker” cables.

The concept of the striker cables was that if a sailboat mast managed to hit the configuration, the phase conductors would be protected. If the mast did manage to hit with such force that the conductor insulation was compromised and current flowed, then the striker cable would act as a ground and prevent the discharge from flowing to the boat (2). This project involved rebuilding 57 crossings, with some using underground cable where viable/economical.

The benefits accrued to the utility were not limited to safety, however, and were enumerated as follows:

- Vastly improved safety from electrocution for passing sailboats and derricks
- Eliminated conductor clashing should a flock of small birds take off simultaneously
- Reduced tree trimming requirements on the land sides of the crossing
- Provided a visual safety warning for large and/or migratory birds who otherwise collide with the lines

The line crews also used a unique installation technique. We saw earlier that crews have used a bosun’s chair, riding on the messenger to install spacers, or an Aerial Messenger Bucket. Here, the entire line was assembled on one side of the crossing. Then, with the messenger attached to the puller-tensioner, the fully assembled line was then pulled over the water. At the end of the pull, some spacers were not perfectly vertical, but they straightened themselves out over night.

First Quantum Minerals Ltd., Minera Panama

The previous cases showed long spans which were water crossings. There are cases, however, where a long span is needed over inaccessible land. Examples include going from mountaintop to mountaintop, crossing a roadway, a chasm, or a gorge.

Minera Panama is the 2nd largest copper mine in the world and, in addition to using spacer cable throughout the mine, also use it for their road crossings, which are in excess of 1,600 feet. The bare wire option was not considered, as mine safety protocols prohibit bare wire lines, especially where vehicles are passing. The underground option was rejected, as underground cables and directional boring facilities face possible damage when in close proximity to rock blasting.

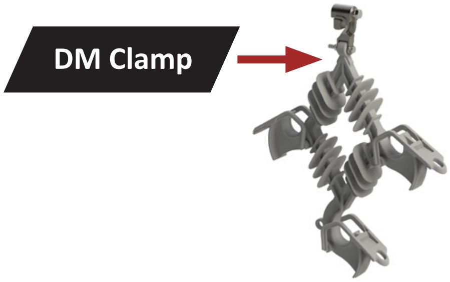
Chilibullo, Ecuador (Empresas Electricas de Quito)

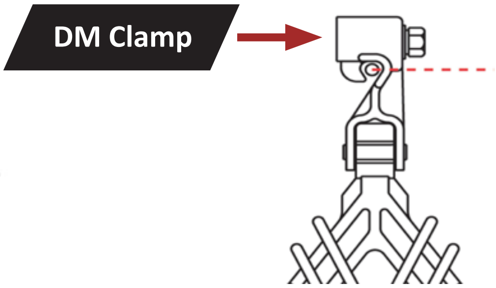
The Ecuadorean utility wanted to supply a remote village with electricity, but had limited access to the village via land route. The proposed line was 25 kV, and the route was 2.3 miles in length, but contained a 1,610 ft. crossing over a ravine with a 688 ft. elevation change.

Bare wire was not considered an option due to environmental concerns. Underground cable was rejected due to numerous reasons (longer route, need to blast, difficulty to bury, cost, etc.). The shortest and most cost effective option was to use spacer cable.

Since there is a line elevation angle in excess of twenty degrees, there was some concern that the spacers, normally connected to the messenger by a ratchet, might be influenced to move, either from wind, vibrations, or gravity. To mitigate the risk of spacer slippage (“walking”) in such cases, a special “DM” spacer was used which attaches the spacer to the messenger with a clamp to prevent any type of movement. This is shown in the illustration below.

The line was installed using the standard “Roll-By Method,” and spacers were installed using a bosun’s chair.





Highway Crossings

The preceding cases all dealt with river, canyon, or industrial site crossings. The use of spacer cable for highway crossings, however, is widespread at many utilities. Some of the benefits of spacer cable for highway crossings are as follows:

- **Road widening projects** – once a road is widened, there may be little room for bare wire replacement, and the use of spacer cable allows the bundle to be suspended over the roadway.
- **Safety** – if the line drops for some reason (car/pole impact) and an individual comes into contact, there is a negligible probability of a personal injury incident.
- **Cost** – spacer cable costs are significantly lower than underground cable, and a fraction of the cost if directional boring is required.

The photo below shows a 600 ft. highway crossing in San Antonio, Texas, which is a 25 kV, 795 kcmil double-circuit over Interstate 35.

The photo below is a highway crossing in Eastern Tennessee.

Still other highway crossings achieved with spacer cable were warranted due to the unavailability of locations close to the roadway for pole placement. When highway-adjacent pole placement is not possible, the poles have to be located farther back from the road, which lengthens the span and creates the need for taller poles, with the attendant concern for both conductor clashing and vegetation contact. The photo below shows such a case in Copan, Honduras.

Installation

One of the difficult aspects of "inaccessible" crossings, whether over water, swamp, canyon, highway, bridge, or even railroad, is the fact that there may not be bucket truck access. This creates the need to find a work method for removing the stringing blocks and installing the spacers once the phases have been pulled in, sagged, and deadended. Methods discussed above include the use of a bosun's chair, aerial messenger bucket, or harness. While helicopters are seldom used in distribution line work, one utility contractor used a helicopter to install spacers on a 12 kV line that crosses the Kanawha River in West Virginia, and a video of that can be found on YouTube. Fundamental to the installation of spacers on a Hendrix line is safety, and the need to follow each utility's Safety & Work Methods.

References

1. "National Electrical Safety Code" ANSI C2-2017.
2. A. Izydorek, P. Brazendale, "Distribution in 21st Century – New Solutions for River Crossings," Western Power Corporation, 2005.