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PowerSouth's World Record Breaking 115kV HDD Installed Underground Transmission Line Feeding Orange Beach, Alabama
Part 1 of 3 - Site Selection and Horizontal Directional Drill Design

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PowerSouth Underground Transmission Line - Orange Beach, Alabama

Introduction

PowerSouth commissioned NELSON to provide a screening study to determine if Horizontal Directional Drilling (HDD) could be successfully applied to install High Voltage (HV) transmission lines under the Intracoastal Canal and Wolf Bay between Sapling Point and Orange Beach, Alabama. This screening study was required not only to determine that the project was technically feasible and practical but also that regulatory agencies could agree with the design and installation concepts and provide permits required for such an ambitious undertaking.

A similar technology was successfully applied in 2004 to install transmission lines under the Mississippi River just south of New Orleans. However, the PowerSouth installation required a 6,131 foot directional drill significantly exceeding the 3,495 foot Mississippi River crossing that strained installation technology and construction limits of the time (see "Mississippi River 230kV Transmission Line Under River Crossing" July/August 2004 Consultant Article). The PowerSouth project success relied on breaking several world records associated with these types of installations. Technical solutions for electrical cable ratings, length, HDD duct installation and thermal grout application exceeding all previous installation attempts had to be found or the project would fail.

This Consultant article discusses some of the challenges associated with site selection and HDD design

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considerations. Future Consultant articles discuss the HDD installation, termination structures, 115kV cable and associated challenges.

HDD Design

One of the first requirements of any Horizontal Directional Drill design is to identify drill entry and exit locations along with the route plan and profile. However, even after feasible entry/exit locations were identified along with the route plan and profile, significant challenges still existed that required addressing before the project could be successful. Extremely long cable lengths and exceptionally high 115kV cable ampacity requirements (300MVA - 1,500 amp) greatly exceeded all previous designs and proved to be just some of the very significant challenges that required addressing. Several world class cable manufacturers were contacted throughout the screening study to help develop a solution. Unfortunately, all the cable manufacturers contacted took the position that even if cables of these lengths and ratings could be manufactured and transported to the construction site, the installation forces would greatly exceed the cable's pulling capacity preventing a successful installation. The cable challenges along with many other technical challenges required significant "out of the box" brainstorming to create a successful design and installation for PowerSouth.

Fortunately, PowerSouth, the Orange Beach City Council and appropriate government regulatory agencies appreciated the technical challenges as well as the step out technologies required, and they proved to be outstanding team members greatly contributing to the success of this project. Their support and acknowledgement of the technical challenges are deeply appreciated.

HDD Entry/Exit Site Selection

Directional drill entry and exit site selection is one of the first tasks required for any successful HDD installation. During this selection the design engineer strives to select entry and exit sites with the shortest route possible while minimizing bends and maximizing bend radius where changes in direction are unavoidable.

The Sapling Point entry/exit site selection was relatively easy since much of this area was undeveloped. This site also provided an area north of the entry/exit location allowing for backstring fabrication as well as "pullback" installation upon completion of the directional drill. The biggest issue with Sapling Point site selection was picking a location outside wetland designated areas, which unfortunately greatly increased the total length of the directional drill, further increasing our design and construction challenges.

Unlike the Sapling Point site selection, the Florida Avenue Substation entry/exit site selection proved significantly more challenging. Overhead transmission lines on Orange Beach were not an option, so only entry/exit sites immediately adjacent to the Florida Avenue Substation

Sapling Point

Florida Avenue Substation

Florida Avenue Substation Drill Sites

could be considered. Also, with property to the east and west of the substation unavailable, the only remaining entry/exit possibilities were limited to areas immediately to the north or south of the substation.

The area north of the Florida Avenue substation appeared to provide the preferred entry/exit drill location. This property was larger and closer to the Sapling Point site, and it did not require drilling or cable installation under an energized substation or work next to an energized overhead 115kV line. Unfortunately, detailed design confirmed this site was not an option. Drill clearance under road as well as the directional drill bending radius required to maintain a route between the Orange Beach Library and the Orange Beach Senior Activity Center were both unacceptable.

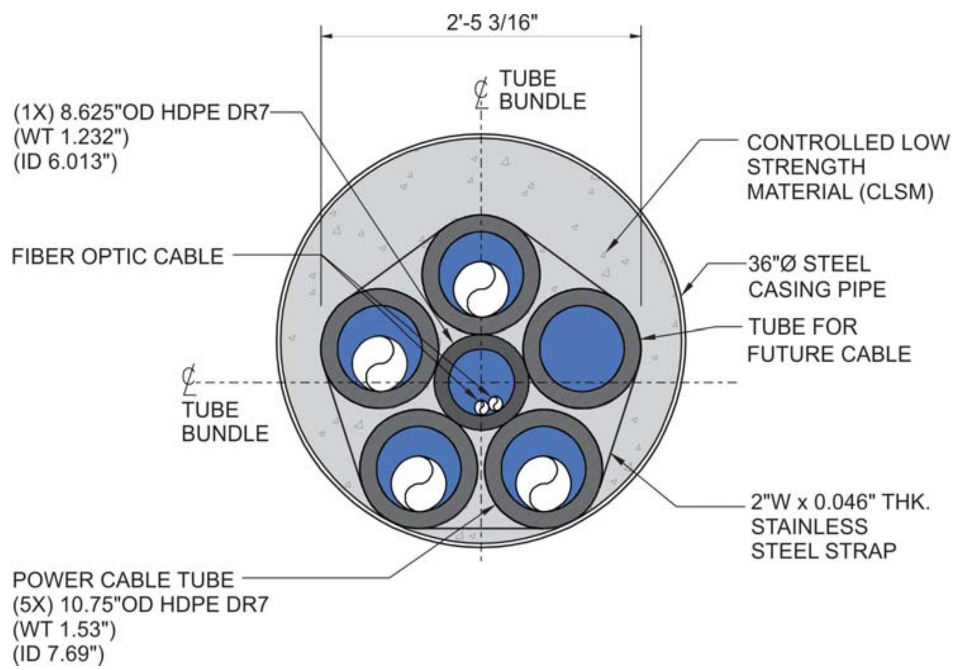
With remote entry/exit sites as well as sites east, north and west of the substation eliminated, the only remaining entry/exit site possibility would be located within the area south of the substation. Unfortunately, this option would require directional drilling as well as cable installation under an energized 115kV substation with an available property footprint significantly smaller than typically required for directional drilling equipment setup and operation. However, since this area proved to be the only site available, the significant technical challenges it presented had to be addressed. These challenges and their solutions will be discussed in parts 2 and 3 of this article.

Sapling Point Worksite Access

The undeveloped Sapling Point area made entry/exit site selection relatively easy; however, the same undeveloped area

Sapling Point Access/Egress Construction Road

that aided site selection created heavy equipment access/egress challenges. Approximately 2-miles of heavy construction road was needed not only for directional drill heavy equipment access/egress but also through project completion for termination structure construction, cable installation, termination and commissioning. Also upon project completion the temporary construction road had to be removed with the area then restored to preconstruction conditions.



Duct Design Cross Section

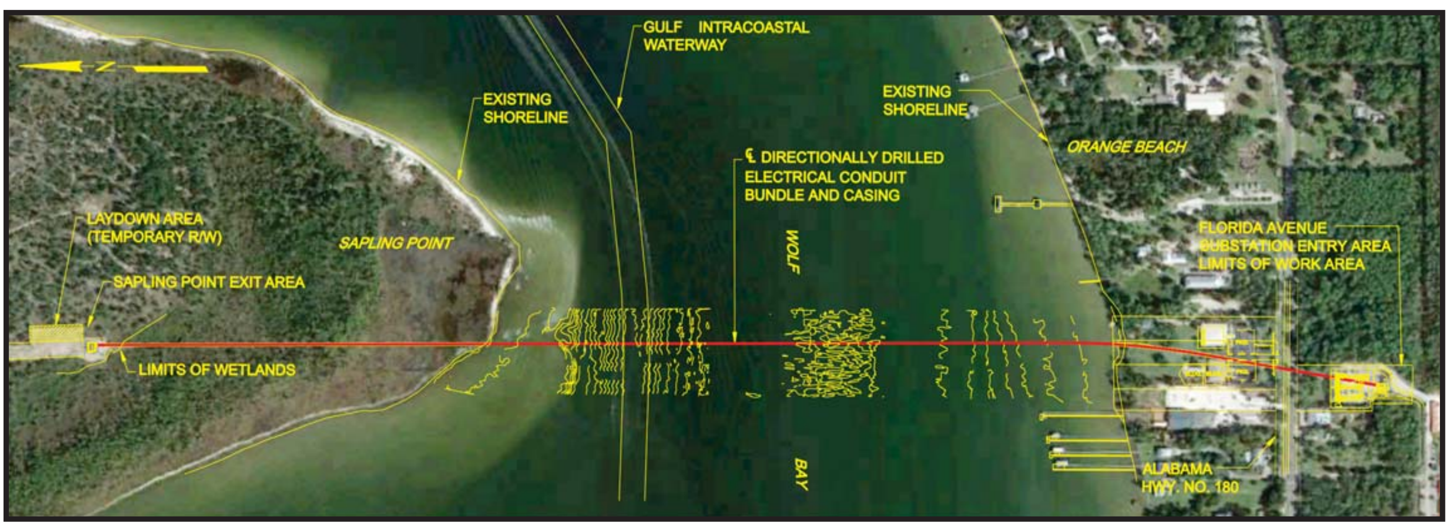
Duct Selection and Design

With an acceptable route for the HDD found, the next hurdle was developing a duct design capable of not only making the 6,131-foot crossing but also allowing installation of a 115kV cable design that would provide the 300MVA power capability required.

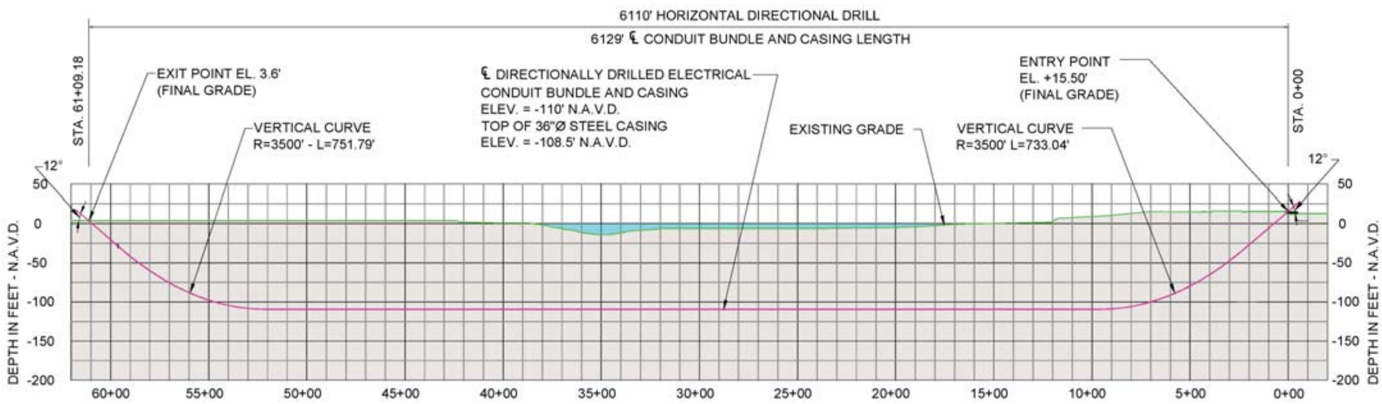
HDPE and PVC pipes were both considered for the electrical ducts that would be used to install the 115kV cable upon completion of the drill. These ducts needed to be non-ferrous in order to house the single conductor power cables while minimizing electrical losses. Both HDPE and PVC are ethylene-based polymer (i.e. plastic) materials and met the non-ferrous criteria required. However, PVC and HDPE pipes behave very differently. PVC's physical high tensile strength and elastic modulus properties make it higher in strength for the same cross sectional area as HDPE but also very stiff and less flexible. HDPE's physical properties on the other hand make it more impact resistant than PVC, and a low elastic modulus make it very tough but flexible, although with a lower tensile strength than PVC of the same cross sectional area.

A 3-dimensional model of the wellbore and backstring was developed incorporating various combinations of water and drilling fluids that would help make the backstring as neutrally buoyant as possible to minimize installation pullback forces. Unfortunately the coefficient of friction between the pipe and soil during pullback is not an exact science. Actual soil/pipe friction can vary significantly between different sites even under similar soils conditions and pipe materials. The problem is that these frictional forces aren't known until backstring pullback, when it's too late to make any changes in the design. Even relocating a drill as little as 10' can have significant impacts on not only drill bore completion but also backstring pullback forces.

The model predicted that it may be possible to install an HDPE or PVC



HDD Plan



HDD Profile

bundle without a steel casing but that pullback forces may be very close to the maximum allowable for each material. Since actual pipe/soil friction wouldn't be known until backstring installation and too late to modify the design, a 36" diameter steel casing was included in the backstring design. This steel casing would be flooded with water during much of the installation making the steel pipe essentially neutrally buoyant in the higher density drilling fluids used to maintain borehole integrity. Also the higher strength of the steel casing significantly increased the allowable installation pulling forces over HDPE or PVC materials should frictional forces between the soil and pipe be greater than anticipated.

Once the decision was made to include a 36" steel casing in the backstring design, HDPE became the obvious duct material choice for the following reasons:

- Friction between steel and HDPE is well documented
- HDPE density is close to that of water allowing the HDPE bundle to be essentially neutrally buoyant during pullback within the water flooded steel casing.
- HDPE/Cable coefficient of friction is well documented from previous projects
- HDPE strength and flexibility improved constructability by significantly reducing risk of pipe fracture during installation

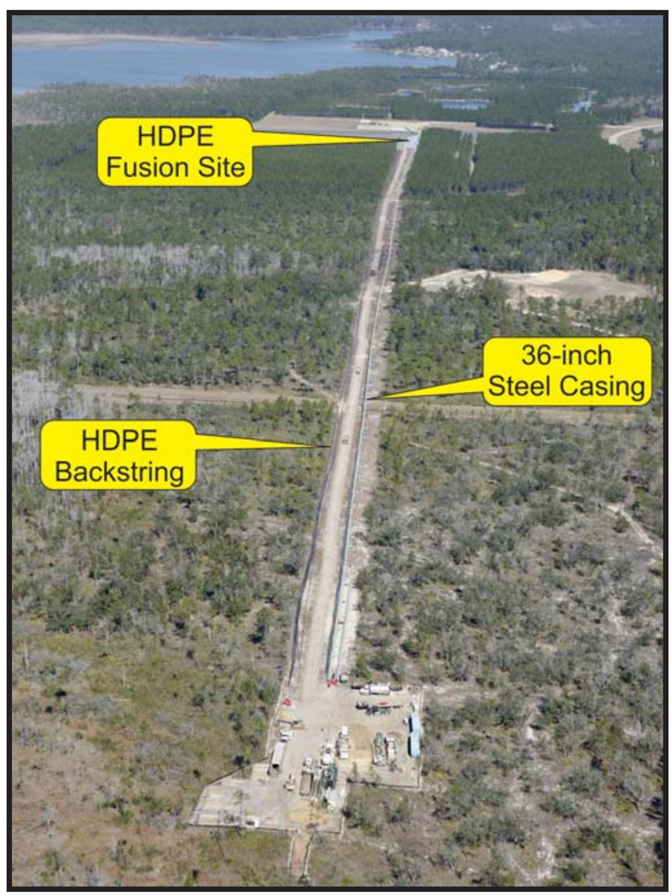
The decision to include a steel casing in backstring design paid huge dividends during pullback when the casing got stuck in the hole and had to be pulled back before reworking the borehole and re-installing. Without the steel casing a large portion of the backstring would have been lost along with much if not all the bore, forcing the HDD contractor to essentially start over in many areas of construction. Fortunately the steel casing could be removed after it was stuck in the hole saving not only the backstring but also the completed drill.

Backstring Fabrication

The "Backstring" is an assembly of multiple pieces of pipe (as seen in the duct design cross section) to create a continuous length as required for installation by pulling the completed assembly in the drilled hole without stopping if at all possible. The concern with stopping during installation is that the backstring could seize within the hole during pullback and we would lose both the drilled hole and the backstring.

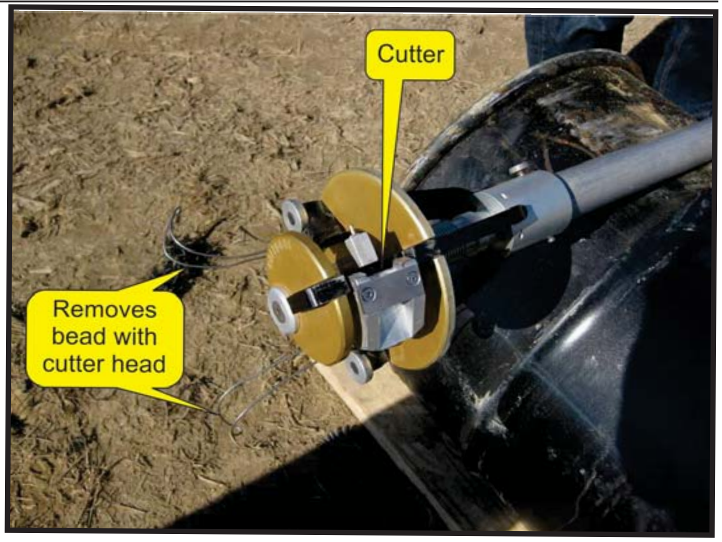
Backstring duct fabrication progressed concurrently with drilling operations and was scheduled for completion to coincide with directional drill completion. This schedule allowed pullback operations of the duct bank to start as soon as the borehole was complete. The backstring was designed for installation in two parts, first the 36-inch, 5/8th inch thick steel casing would be installed followed by installation of the HDPE bundle within the steel casing.

The 10-inch and 8-inch HDPE



Backstring Fabrication Site

HDPE Pipe Fusion Process



Bead Removal Tool

Note: Cutter seen in retracted positon is released by counter rotation once cutter head reaches joint location

pipes required by the duct design came in 50 foot pipe lengths that had to be fused together to create the 6,200 foot backstring required for the crossing. A fusion machine clamped both ends of the pipes where rotating knife blades shaved each pipe end creating smooth and true matching surfaces. Once complete, the rotating knife blades were removed and a heated plate inserted between the pipe faces to bring the HDPE material to a semi-molten temperature. When the proper temperature was achieved the heating plate was removed, and the fusion machine brought the two pipes together holding a specified pressure until the fusion sufficiently cooled creating the fusion bond.

During this fusion process HDPE material is squeezed from the joint creating both internal and external beads as excess HDPE material is squeezed from the joint. The outside bead didn't create a problem but the inside bead had to be removed to provide a smooth duct for installation of the 115kV cable. These internal HDPE beads were removed with a manually operated cutter placed on the end of a 52 foot extension handle. Each bead was carefully inspected upon removal to verify that no sharp edges remained in the duct or that the removal process caused a reduction in pipe thickness.

Any concerns noted during this inspection required cutting the connection from the fused pipe and re-fusing the connection following a rigid QA/QC process to ensure a smooth duct system for cable-installation.

The HDPE pipe was pulled on rollers after the fusion of each joint until the required 6,200-foot length of HDPE had been completed. Each completed 6,200' pipe length was then removed from the rollers and placed on the ground making room for the next length of pipe to be fused and allowing each end of the completed pipe to be sealed and hydro-tested ensuring fusion joint integrity. Upon successful hydro-testing a foam pig was pushed through each pipe using air to remove water and prepare the conduit for pullback. After all conduit lengths had been completed, tested and dried, they were again placed on rollers in preparation for the pullback. Immediately prior to pullback the five 10-inch and one 8-inch HDPE pipes were strapped together using 2-inch wide, 0.046-inch thick stainless steel bands spaced on eight foot intervals to maintain the designed duct cross section and evenly distribute bundle pulling stresses across each pipe.

Part 2 - Horizontal Directional Drill and Termination Structures will appear in the 2nd Quarter Edition of The Consultant.

36-inch Steel Casing Backstring

William E. Rushing Jr., P.E., FACI Installed As President of ACI International and Inducted Into the LSU Civil and Environmental Engineering Department Hall of Distinction

William E. Rushing Jr., FACI, is a Vice President with Waldemar S. Nelson & Co., Inc. His responsibilities and assignments have included project management and lead structural engineer for design of numerous industrial and marine facilities, including container marshalling yards, chemical plants, oil storage terminals, oil and gas production facilities, bulk storage facilities, and hard rock mine ore processing facilities in Indonesia.

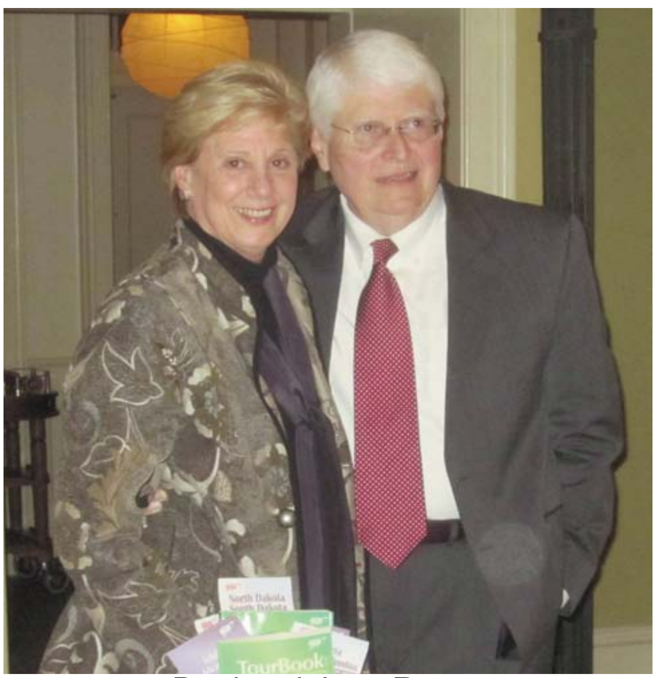
Rushing was just installed as president of ACI International at their Convention, and he was inducted into the LSU Civil and Environmental Engineering Department Hall of Distinction, both in March, 2014.

Rushing has chaired numerous ACI national and Louisiana chapter committees, including the ACI Strategic Plan Drafting Task Group, the Task Group on Managing Translations of ACI Products and Services, the ETC Product Development Committee, the ACI Financial Advisory Committee, and many technical committees. He received the Henry L. Kennedy Award in 2011 "in recognition of his outstanding service to the Institute and his leadership of many educational and administrative committees." He received the Chapter Activities Award in 2003. He received the ACI Louisiana Chapter Activity Award in 2004 and the Chapter Distinguished Member Award in 2010.

Rushing received his BS in civil engineering from Louisiana State University in 1981. He is a licensed professional engineer in Louisiana, Mississippi, Alabama, Arkansas, and Arizona. Rushing is also a member of the American Society of Civil Engineers (ASCE) and the Structural Engineers Institute, serving on those committees in New Orleans.

William E. Rushing Jr., P.E., FACI

Brad Rogers Retires



Brad and June Rogers

Brad Rogers, Assistant Vice President in our Civil and Environmental Department, retired after a total of 29 years with NELSON. We congratulate him on his achievements and appreciate his many years of service to the firm and the profession.

Brad has worked on challenging offshore, industrial, marine, navigation and flood protection projects. His depth of technical expertise is recognized as an important asset by our project managers and clients such as Southern Natural Gas, Freeport, Shell Oil and ExxonMobil. Brad was also an excellent mentor to our new engineers starting out in their careers and a source of guidance for all of our structural engineers; a common refrain is: "Ask Brad." He is registered in eight states. Along with numerous accolades from clients over the years, Brad was inducted as a Life Member of the American Society of Civil Engineers in 2013.

We wish him a happy and enjoyable retirement, but we are also happy that he has agreed to periodically consult with us when we have a particularly difficult technical issue and need to "Ask Brad"!

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Engineering News Record magazine recently published its 2014 lists of rankings for various categories of design firms and activities. Nelson is proud to have placed well on several of these lists:

Top 500 Design Firms: No. 172
Top 225 International Design Firms: No. 160
Top Design Firms in Petroleum: No. 32
Top Design Firms in Mining: No. 10
Offshore and Underwater Facilties: No. 8