UniversalPegasus INTERNATIONAL

Alternating Current Interference Mitigation on Pipelines

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INTRODUCTION

The installation of pipelines within electrical power distribution rights of way is becoming increasingly common as available land and routing options are limited due to a variety of causes. While the utilization of these rights of way is not new, our knowledge related to the alternating current interference and corrosion effects induced on co-located pipelines and structures in general continues to evolve. Unfortunately, while the corrosion process itself is straight forward, predicting the effects of Alternating Current (AC) interference is a complex matter with a significant number of variables requiring sophisticated mathematics to analyze the system. Most interactions between co-located pipelines and overhead electrical power distribution infrastructure require specialized software or complicated analytical techniques to render actionable results. Electrical energy can be transferred to a pipeline from overhead power lines in several different ways, conductive coupling (usually fault conditions), capacitive or electrostatic coupling, and inductive or electromagnetic coupling, just to name a few. The high voltages and high currents encountered on these systems, combined with long distances of parallel electrical lines and pipelines create an arrangement that could result in significant interference requiring an engineered solution. Fortunately, the methods for dealing with the transferred energy are not overly complex; but, an understanding of the transfer mechanism is useful in engineering effective mitigation measures.

ELECTRICAL ENERGY TRANSFER

There are several ways in which electrical energy is transferred onto a pipeline; but interference problems are most often encountered with three-phase power transmission lines. Discussed here are the common AC coupling modes directly associated with overhead transmission and distribution power lines co-located with pipelines. It should be noted that telluric or earth currents that are geomagnetically induced are not specifically discussed technically in this document, but should be recognized as having a potential impact to the interference mitigation systems due to their similarity to AC power lines. Mitigation of telluric currents bears a striking resemblance to mitigation of interference for AC distribution as they are both induced currents. At a minimum considerations to compensate for telluric current effects during close interval survey should be included.

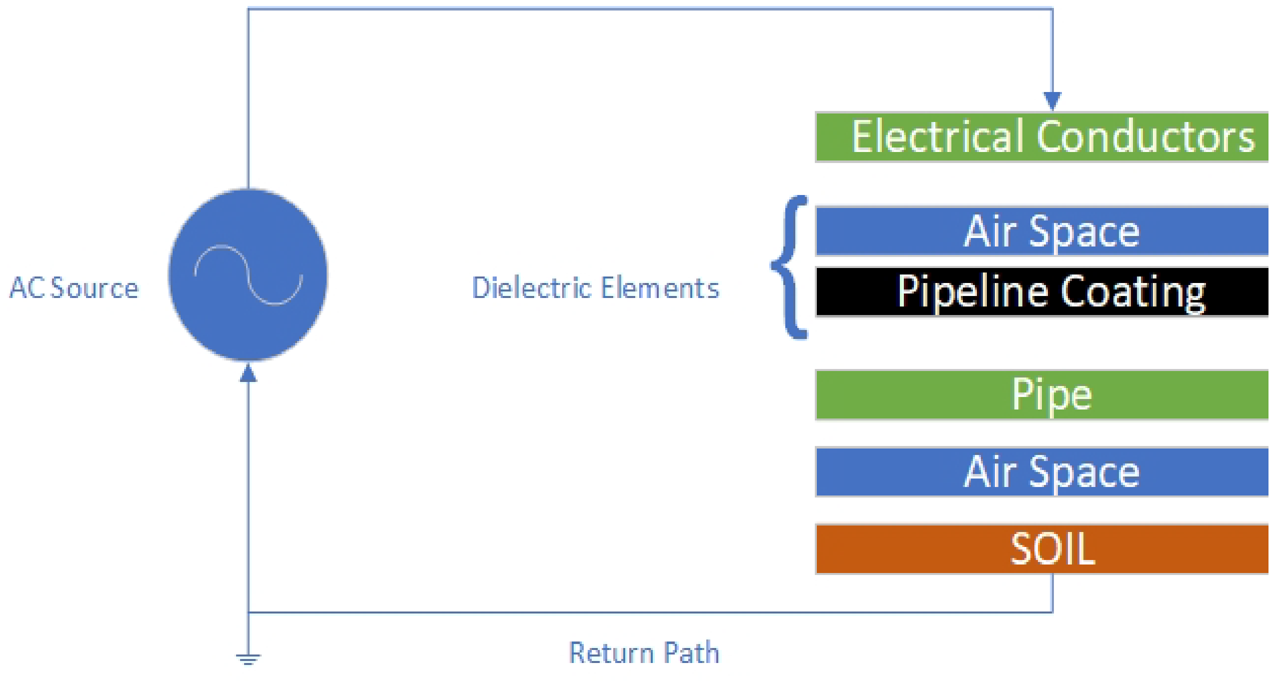
Conductive Coupling

Significant amounts of energy can be transferred to the pipeline during a short circuit or fault condition on an overhead transmission system resulting in a line-to-ground short circuit. While electrical faults are abnormal, given the life span of pipelines, the likelihood that a pipeline will be exposed to a line-to-ground fault is very high and the risks should be mitigated to prevent damage to the infrastructure. Electrical faults on the power lines can occur as a result of lightning, high winds, structure or insulator failure, or even accidental contact between the power line and another structure or piece of construction equipment.

During fault conditions the energy being transmitted by the power line will return to its source using all available paths including static lines, shield wires, the earth, and even pipelines. The path of the fault current is predicated upon the relative impedances of all parallel paths available to the fault. Separation distance between the faulted system and the pipeline as well as the impedance between the pipeline and the surrounding soils are critical factors in determining the expected current flowing through the pipeline. Pipeline coatings contribute significantly to the impedance between the earth and the pipeline. The higher the coating quality (fewer holidays) and the higher the coating's rated breakdown voltage, the lower the amount of current carried by the steel. Unfortunately, the magnitude of a fault current can be many times greater than the steady state current normally present in the power lines and can result in high pipeline voltages. Fortunately, these fault currents are only present for very short periods of time as the power line protective system can react in milliseconds to remove the fault, but even that short period of time can result in coating damage, melting, or cracking of the pipeline to say nothing of the safety hazards presented to pipeline personnel and even the general public where accessible.

Capacitive or Electrostatic Coupling

During capacitive coupling, energy is transferred through the natural capacitance that exists between two conductors separated by a dielectric material (electrical insulator). This type of energy transfer is often encountered during the construction process, where the power line and the pipe are separated only by air and the pipeline coating. The electromagnetic field of the AC transmission line can induce a charge on the aboveground pipe that is isolated from ground. This arrangement forms a simple capacitor. A key value in the evaluation of this system is capacitance which is a measure of the ability to store an electric charge. Capacitance is proportional to the area of the conductors but inversely proportional to the separation between the conductors.

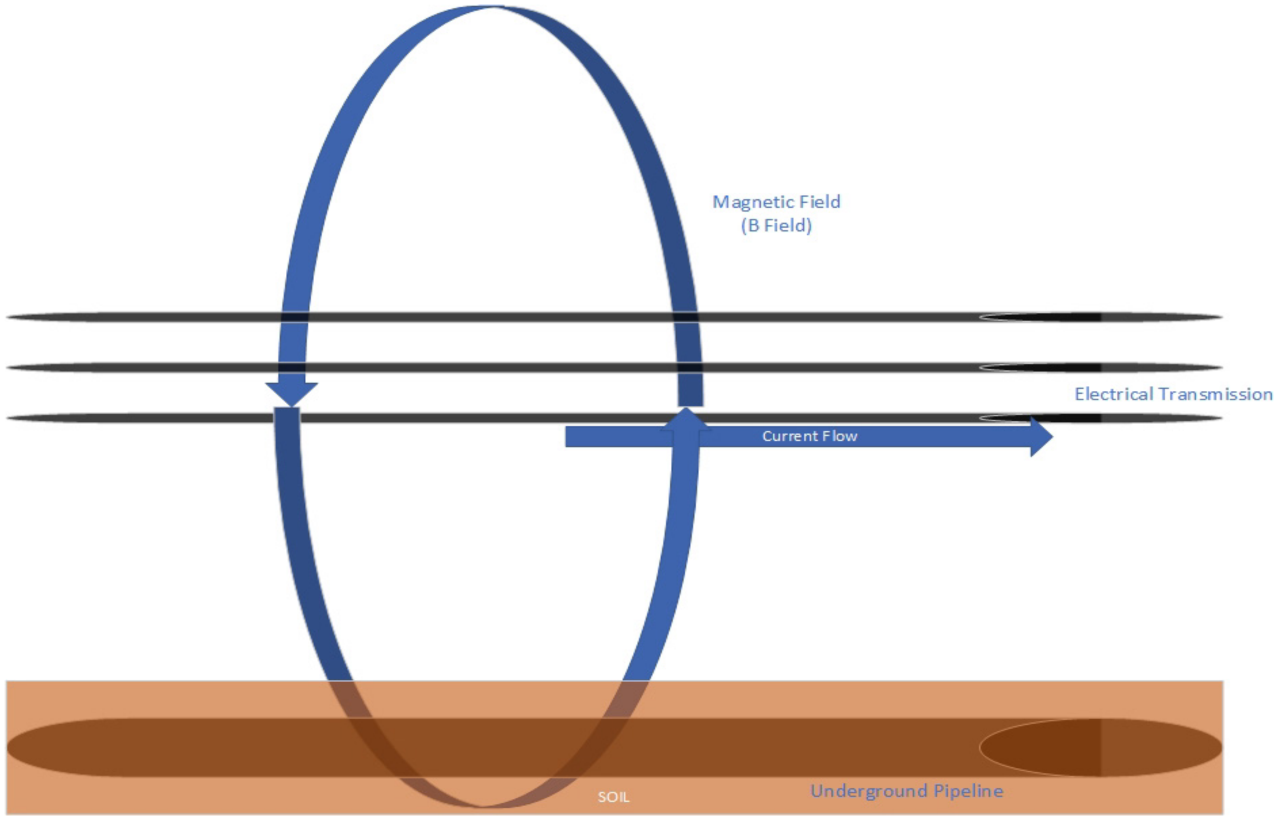


It should be noted that the interaction between the dielectric elements is much more complex than is represented in the above diagram. As an example, any additional elements present will change the relative permeability (dielectric constant) between the conductors, but it also may act as a return path back to the voltage source, creating multiple series capacitances that must be considered.

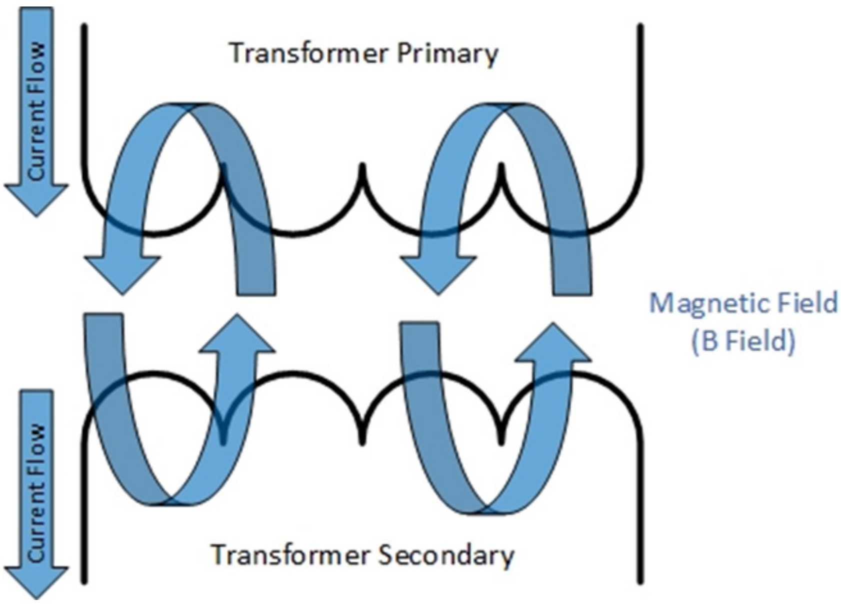
Typical values of capacitance between power lines and pipe is very small, on the order of picofarads (10^{-12}), resulting in a capacitive reactance that is very large and can result in very large voltages electrostatically generated on well insulated pipe. Despite the high potentials, there is a relatively small driving current limiting the electrical shock hazard.

Inductive or Electromagnetic Coupling

The flow of an electric current though a conductor creates an electromagnetic field around that conductor, commonly visualized utilizing the "Right Hand Rule". The strength of the magnetic field is directly proportional to the current and inversely proportional to the separation distance. Further complicating the effects of the electromagnetic field on the system are shielding effects from other objects in the Right of Way (ROW) which must also be considered. Electromagnetic induction occurs when there is a relative "motion" between an electrical conductor and the magnetic field essentially "cutting" the magnetic lines of force. In the case of an AC system, the magnetic field "moves" through the stationary conductor, inducing a current and voltage in the structure or pipeline.



Another way to consider the inductive coupling described above where voltages and currents are induced electromagnetically onto a pipeline is to recognize that this is the same “transformer action” in which the primary winding of a transformer induces current flow through secondary windings.



This "transformer action" is further intensified as the amount of parallelism between a pipeline and the electrical conductors increases and can result in significant induced voltages and currents on the pipeline. These induced effects can be a danger to personnel but also have the potential to damage the pipeline coating and lead to AC corrosion effects on the structure or pipe.

HAZARDS AND DELETERIOUS EFFECTS

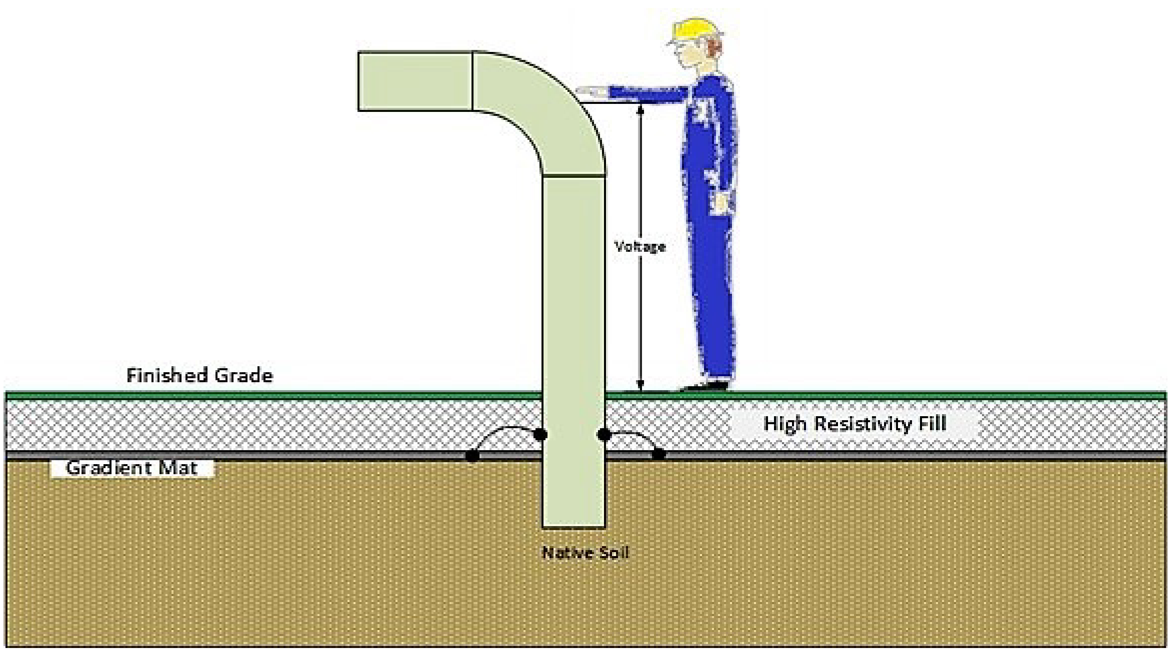
The precise effects of electric shock can vary from person to person and depends upon mass, body composition, physiology, fill material, soil conditions, as well as other factors. Electric shocks can not only be painful, but at currents lower than is commonly believed can result in shocks, loss of muscular control, interference with normal heart function, seizure, and death.

Equipment

Induced voltages, regardless of source, present several hazards to infrastructure. Fault currents, despite their transient nature (often lasting less than 100 milliseconds) can impart very high voltages onto the pipeline. These high voltages can breakdown coatings, crack or even melt the pipe wall. Coating damage requires increases current requirements from the cathodic protection system and exposes the steel to further opportunity for corrosion if not properly addressed. A further complication of damage to coatings aside from the additional risk of both AC and Direct Current (DC),or galvanic, corrosion is the increased likelihood of further damage from future faults as damage to pipeline coatings provides an easier path for future fault currents.

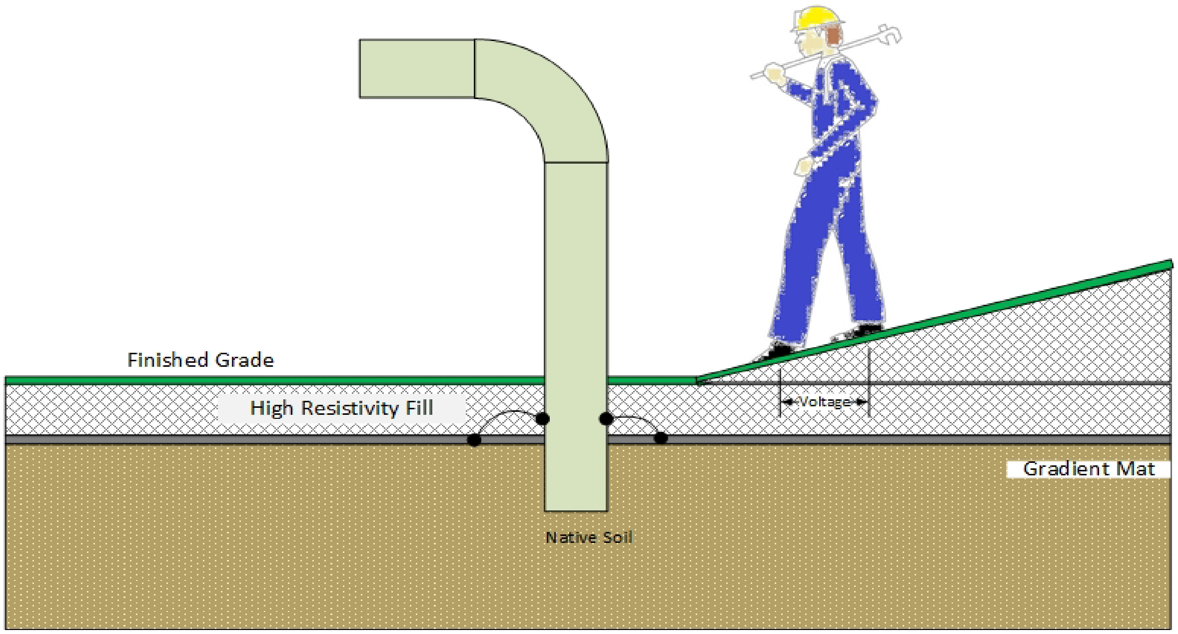
Touch Voltage

Touch voltage, as defined by IEEE 80, is "the potential difference between the ground potential rise (GPR) and the surface potential at the point where a person is standing while at the same time having a hand in contact with a grounded structure." There is an assumption among many that any grounded object can be safely touched; however, there is no simple relationship between grounding system, energized structures, surrounding infrastructure, and personnel. As discussed previously, pipelines can develop thousands of volts when high degrees of parallelism between co-located transmission lines and pipelines. When a disruption to the system occurs, which allows a point discharge (i.e. person touching the pipe) a current path is created through the person which can result in injury or death at currents as low as 100mA.



Step Voltage

Risk to personnel as a result of energized structures can occur not only by touching, which is intuitive, but simply by standing or walking in the vicinity of an energized structure that is in contact with the earth. Electrical engineers have been addressing this issue in substations for a long time, and it is from this body of work that many of our terms and mitigation methodologies are derived. Step voltage, as defined by IEEE 80, is "the difference in surface potential experienced by a person bridging a distance of 1 m with the feet without contacting a grounded object." Specifically, when fault current is passed from a structure to the ground a voltage gradient is produced. This voltage gradient can be visualized as an expanding set of circles when seen from above or hemispheres in a section view. Each of the circles or hemispheres represent a different voltage. The further removed from the structure, the lower the voltage. As an individual bridges the gap between one gradient "band" and another, an additional path for current is established and will flow from high potential to lower potential. A person, especially when equipped with the proper Personal Protective Equipment (PPE), presents a current path of significant resistance. A current in the range of 9 to 25 mA may cause a painful shock and involuntary muscle contractions. Currents as low as 100 mA can be lethal depending on the frequency of the impulse. For this reason, it is highly recommended to provide a high resistivity fill (i.e. crushed granite) to the area around a structure which can further reduce current flow through an individual. Risk evaluation of the possible hazards for step and touch potentials should take place for pipelines co-located with High Voltage Alternating Current (HVAC) power lines.



AC MITIGATION

AC mitigation of the various sources of AC imposed on a pipeline are surprisingly similar in practice, allowing for singular installations to perform multiple mitigation functions when properly engineered.

Capacitive coupling typically encountered during the construction process is fairly easy to address to ensure the safety of workers. AC corrosion is not usually a concern with this type of energy transfer. Providing an adequate grounding path for the pipe allows for any charge to simultaneously be returned to ground and prevents buildup of a significant voltage.

The resistive coupling seen during fault conditions such as a Single Line to Ground (SLG) fault or a lightning strike to a near-by structure is usually mitigated by a combination of measures. The first and often easiest to implement is to increase the distance between the structure and the pipeline during the design phase. Increasing the distance between a transmission tower foundation for instance, forces any fault current to travel though more soil complicating the fault currents ability to establish a sustained arc and damage the pipeline. Energy in this case is dissipated through the earth and presents a significantly lower risk to the underground structure.

Another method to reduce resistive coupling and damage to the pipeline is though the utilization of shielding conductors. These conductors, often bare zinc ribbon, provide a lower impedance path for dissipation of the current than is seen through the pipeline due to coating, physical separation, etc. The shielding conductors are usually installed at pipeline depth with reasonable separation between the pipeline and the ribbon. The separation between the pipeline and the ribbon is critical to function properly as the ribbon dissipates energy into the surrounding soil and if not surrounded by adequate native soils, the pipeline can become the lower impedance path likely resulting in significant damage.

The objective for mitigation methods related to inductive coupling is to allow the alternating current to be removed from the pipeline while maintaining the Cathodic Protection (DC) on the protected structure. A DC Decoupler (DCD) maintains the operating characteristics of the CP system while effectively allowing AC to pass to ground. Classically, electrolytic cells known as polarization cells have been used to achieve this result. While polarization cells are still effective, they require periodic maintenance to ensure proper functioning of the device. Current designs make use of solid-state devices which provide essentially maintenance free operation. Polarization cells, or their active electronic replacements, are bonded to the pipeline and a grounding electrode, typically in the form of a drain well or a wire installed beside the structure, so that the AC can be dissipated away from the pipe. Some cases allow for the utilization of the shield wire used for protection from resistive coupling to be a dual-purpose current sink for both induced current as well as fault current.

Regardless of the AC source, it is imperative due to the complexity of the interaction of electrical transmission and distribution systems that the utility or utilities are contacted to characterize the overhead distribution system. This includes identifying utility requirements for sharing the right of way, document ground conditions and resistivity, as well identifying existing cathodic protection or alternating current interference mitigation systems already in the corridor. This data should be used to calculate and then simulate the expected induced currents on the underground structure to identify the need for mitigation. With UPI's extensive experience in pipeline and facility installations in conditions from subsea to desert and arctic installations, we stand ready to assist you with not only the design but also the long-term protection of all your installations.

UPI CAPABILITIES

UPI offers a full complement of services for pipelines and related facilities including: conceptual design, FEED, project development, including Total Installed Costs for funding, and EPC/EPCM. Services include project management, engineering and design services, procurement services, sub contractors management, survey, laser scanning, construction management, inspection, Mobile Inspection Platform (MIP), systems integration, automation, process controls, as-built documentation, commissioning, and decommissioning.

UPI has a rich heritage of project experience for pipelines and related facilities. UPI has provided professional services (engineering, surveying, and construction management) for thousands of miles of pipeline and installed millions of horsepower of pumps and compressors.

A representative list of UPI's projects for CP and ACIM services includes:

- 275 mile long steel pipeline coated with FBE transporting HVL through east Texas. Soil conditions range from wet sandy condition to rock while sharing a significant portion of the route with electrical utility Right of Way. The pipeline includes multiple main line valve (MLV) stations requiring additional considerations for CP and ACIM to ensure safety of workers and the public.

- 40 mile long 16-inch diameter steel pipeline with 3LPE pipeline coating transporting refined products. The pipeline shares a high voltage utility right of way for approximately 20 miles with varying soil conditions. This project was further complicated due to the high number of horizontal directional drills which limited the ability to tie into drain points or shielding wires.

- 36 miles of interconnecting steel pipelines with FBE coating transporting feedstock. The pipeline is located in South East Texas with multiple shared rights of way and facility interconnects.

CLOSING

UPI looks forward to talking with you about how we can help you with your project.