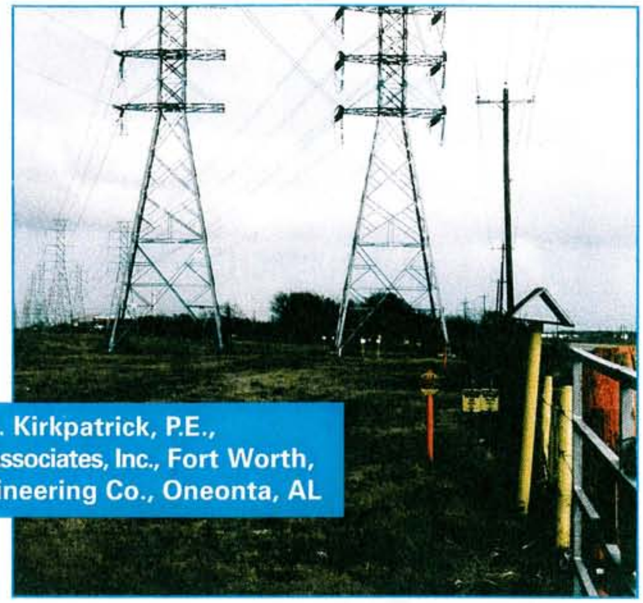
Induced AC Voltages On Pipelines May Present A Serious Hazard



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The problem of induced AC voltages on pipelines has always been with us. Early pipeline construction consisted of bare steel or cast iron pipe, which was very well grounded. Bell and spigot, mechanical, or dresser-style joint couplings often were used, creating electrically discontinuous pipelines which are less susceptible to AC induction. Although induced AC affects any pipeline parallel to a high-voltage alternating current (HVAC) power line, the effects were not noticeable on bare pipelines. With the advent of welded steel pipelines, modern cathodic protection (CP) methods and materials, and the vastly improved quality of protective coatings, induced AC effects on pipelines have become a significant consideration on many pipeline rights-of-way.

In the last two to three decades, we have been seeing much more joint occupancy of the same right-of-way by one or more pipelines and power lines. As the cost of right-of-way and the difficulty in acquisition, particularly in urban areas, have risen, the concept of joint occupancy rights-of-way has become more attractive to many utility companies. Federal and state regulations usually insist on joint-use right-of-way when a utility proposes crossing regulated or publicly owned lands, wherever there is an existing easement. Such joint use allows the induced AC phenomena to occur and may create electrical hazards and interference to pipeline facilities. Underground pipelines are especially susceptible if they are well-coated and electrically isolated for CP.

Induced AC Mechanisms

There are three coupling modes of primary concern by which voltages are induced in pipelines.

Electrostatic coupling, commonly known as "capacitive" coupling, is caused by the electrostatic field surrounding the energized conductor. This electrostatic field is proportionally produced by the voltage in the overhead conductor. The closer the pipeline is to the energized overhead conductor, the stronger the electrostatic voltage induced in the pipeline.

Electrostatic coupling is of primary concern when a pipeline is under construction near an overhead HVAC system. The length of the exposed conductor is also a factor in the electrostatic charge induced in the structure. A relatively short conductor isolated from ground, such as a single joint of line pipe supported by a nonmetallic sling or on a rubber-tired vehicle on the right-of-way, will become charged like a capacitor. (A rubber-tired vehicle on the right-of-way should have drag chains to ground the vehicle.)

Once the pipeline is backfilled, electrostatic coupling is no longer of any real concern because the pipeline coating will allow sufficient leakage to earth through pinholes or holidays, which will effectively ground out the electrostatic effects.

Electromagnetic Coupling

Electromagnetic coupling is also known as "transformer action." When current flows in an energized conductor, it produces an electromagnetic field at right angles to the conductor. In AC power systems, electric current flowing in the conductor changes direction 120 times per second for 60-Hz and 100 times per second for 50-Hz systems. Thus, the electromagnetic field surrounding the energized conductor is constantly expanding and contracting.

Whenever electromagnetic lines of force cut through another conductor, a voltage is induced in that conductor. This is the principle upon which power transformers, alternators, and generators function. A well-insulated pipeline parallel to an overhead HVAC line then becomes the secondary of an air core transformer. With sufficient parallel length, very significant voltages and currents can be induced into the pipeline. These voltages can be hazardous to anyone who comes in contact with the exposed pipeline or appurtenances. The parallel power lines may induce sufficient power into the pipeline to damage the pipeline or related facilities.

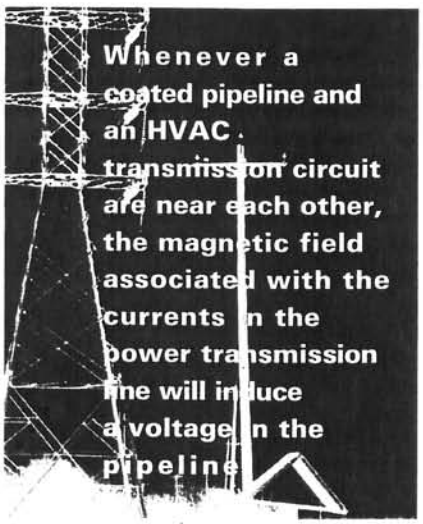
Pipeline Hazards

A products pipeline failed because of lightning and fault current actually penetrating the pipeline wall. This was a clear case of arc burn penetration of the pipe wall. There are other case histories where actual pipe wall penetration has occurred with or without a fire being started. People have been killed by contacting an energized pipeline under construction. We must be aware of these electromagnetic and electrostatic effects on influenced pipelines and know how to avoid injury and damage. An excellent source of information on this subject is NACE Standard RPO177-95. Additional information is contained in IEEE Standard 80.

Resistive Coupling

Resistive coupling is another mode of electrical coupling between a pipeline and a parallel overhead power system. This is a concern during "fault conditions" on a power system. If lightning strikes one of the energized conductors on the overhead power line, the resulting voltage rise on the wire will exceed the breakdown insulation level (BIL) of the insulator at the nearest tower. When the BIL is exceeded, a flashover will occur from the energized conductor to the tower and then fault current will flow through the tower to the tower ground. Current will flow from the energized conductor to the tower structure via the ionized gases (plasma) generated by the lightning. Fault current will flow through the tower and the tower ground into the earth for a fraction of a second, until the circuit protection device has a chance to operate.

As a result of these fault currents, current will radiate from the tower foundation and grounds in all directions from the faulted tower. A very severe potential gradient will occur across the earth, radial to the faulted tower. If there is a nearby pipeline in the earth, the gradient field will be distorted and accentuated. This effect is greatest with bare pipelines and pipelines that are near the tower foundation. Consequently, a significant portion of the fault current may flow in the pipeline as a result of resistive coupling.



Physical separation between the pipeline and the power line tower is an important factor in determining the extent of the damage that will occur on the pipeline as the result of a fault.

Predicting AC Voltages on a Pipeline

Induced AC voltage on a pipeline can be measured by methods similar to those used to conduct a DC pipe-to-soil cathodic protection potential survey. A multimeter is placed on the appropriate AC voltage range and a steel pin is used in place of the copper/copper-sulfate reference electrode. A detailed AC pipe-to-soil potential survey should be conducted over any area where induced AC voltages are suspected. It is important to note the time of each reading because many power companies maintain a record of currents in the circuit. The voltage induced in the pipeline is directly proportional to the line currents in the overhead conductors. This can provide valuable information to assist in calculating the peak voltages that can be anticipated at each location under maximum line loading conditions.

Whenever a coated pipeline and an HVAC transmission circuit are near each other, the magnetic field associated with the currents in the power transmission line will induce a voltage in the pipeline. The actual magnitude of the induced AC voltage depends on many factors, including the overall configuration of all the structures involved, soil resistivity, pipecoating effectiveness or resistance to remote earth, pipeline propagation constant, magnitude of the line currents in the power circuit(s), and any current imbalance between the phases.

The magnitude of steady-state AC potentials induced on an underground pipeline by parallel high-voltage transmission lines can be estimated accurately using the appropriate mathematical formulas. The formulas characterize the circuit in terms of "steady-state" line currents, phase relationships, pipeline-to-conductor distances, pipeline propagation constants, characteristic impedances, soil resistivity, and other factors. The technique can predict, with reasonable accuracy, the areas where the maximum AC potentials will occur and approximate the actual induced voltage at that point. These calculations require the use of advanced mathematics which can best be done on a computerized workstation by an experienced professional.

Mitigation Techniques

Mitigation techniques that can control induced voltages on an influenced pipeline include the following.

- ❖ Supplemental grounding of the pipeline with sacrificial anodes or other grounding means.
- ❖ Bonding the pipeline to individual power line pole grounds or towers through the use of polarization cells.
- ❖ Installation of parallel mitigation wires bonded to the pipeline at regular intervals.
- ❖ Bonding the pipeline to purposefully designed "made" grounds.
- ❖ Changing phase relationships between multiple power line circuit conductors.
- ❖ Use of Faraday cages with sacrificial anodes.
- ❖ Relocation of the pipeline or power line to provide greater separation from the influencing power system.
- ❖ Installation of a nonmetallic pipeline such as high-density polyethylene pipe, if design pressures permit.
- ❖ Installation of gradient control electrodes or mats at all aboveground appurtenances.
- ❖ Security fencing around aboveground appurtenances do not mitigate induced voltages but they do limit access to the structure.

Whenever there is a pipeline closely parallel to a power line for any significant distance (for example, closer than 500 ft or more than 2,000 ft), further investigation is warranted. If 5 volts AC or more is measured at any point on the parallel section, this voltage should be related to line loading to estimate the pipeline-induced AC voltage at peak line-loading conditions. The induced voltage should be mitigated if the calculated values approach or exceed 15 volts AC. Fault conditions and step-and-touch voltages also must be considered.

Personnel Safety

On any construction or maintenance project, safety is an attitude. This attitude is developed by proper training. A valuable source for such information is Section 4 of NACE Standard RPO177. NACE also offers an audiovisual presentation that deals with the effects of electric shock in such situations. RPO177 should be included in the construction specifications whenever a pipeline is built or exposed for maintenance on an energized HVAC right-of-way. One of the inspectors should be designated in charge of electrical safety. This individual must be familiar with and properly equipped to test for safe levels of induced voltage in the pipeline. A safety meeting should be held prior to construction with all construction employees to discuss electrical safety requirements.

The right-of-way must be vacated if thunderstorms come within 10 miles of the pipeline right-of-way or the power line(s) that are influencing the pipeline. Never work on an influenced pipeline during a thunderstorm because of the potential for a direct lightning strike. Power system fault currents will flow in the earth if lightning causes flashover of a power line insulator. A person on the right-of-way is in danger, even if they are not touching the pipeline.

Corrosion and maintenance personnel should be very cautious about stringing test lead wire on the right-of-way where the lead wire parallels the influencing HVAC line. Extremely hazardous voltages can be induced on a significant length of test lead wire laid on top of the ground.

The practice of using insulating rubber gloves should also be discouraged unless the work is being performed by a trained power company employee. "Rubber Goods" must be specially cared for and tested to ensure their reliability.

The only safe alternative in the pipeline environment is to test the level of induced AC on the pipeline before contacting anything that may be a conductor. If voltages are safe, normal measurement or repair and maintenance techniques may be employed. If unacceptably high voltages are encountered, one must work on a ground mat. A ground mat can be as simple as a piece of 6-foot road mesh laid on top of the ground and bonded to the pipeline or appurtenance with an automotive jumper cable. Since the individual, the ground mat, and the pipeline appurtenance are all at equal potential, it matters little as to how high the actual measured voltage is on the pipeline. **P&GJ**