Electrical Risks in Transmission Line – Pipeline Shared Rights-of-way

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Pipeline Induced Disturbances
Metallic pipelines used for fluid transportation (gas, oil, water, etc.) are typically underground, but they may also have above-ground sections. Underground sections are protected by an external anti-corrosive coating. Above-ground sections are usually uncoated (just painted against corrosion) and isolated from the underground sections by means of insulating joints. Both behave like long conductors insulated from the ground.

The pipeline-induced disturbances are basically induced voltages on the pipeline metal. They are caused by the power line operating voltage and circulating currents. Some of these voltages are induced when the power line is under normal steady-state operating conditions. Other induced voltages may occur only during short-circuits on the transmission line.

Overhead power lines as well as underground power lines can induce harmful disturbances on nearby metallic pipelines.

Coupling Mechanisms
Generically, a physical process of transferring disturbances to a nearby installation requires the existence of a source of disturbances, a coupling mechanism and a receptor. In the present analysis, the source of disturbances is the power line, the receptor is the metallic pipeline and the coupling mechanism is the capacitive, inductive and conductive coupling between power line and pipeline.

The capacitive coupling disturbance is produced by the electric field of the power line and needs to be evaluated only for above-ground sections of pipeline that are electrically isolated from the ground. As shown in Figure 1, the capacitive coupling functions as a capacitive voltage divider. Otherwise, there is no capacitance between the power line and underground sections of pipeline. Any pipeline-to-ground connection makes this disturbance negligible. Usually, the evaluation of this disturbance is performed only for steady-state operation condition of the power line, assuming the line operates at its maximum operational voltage.

Figure 1 – Capacitive Coupling
Figure 2 shows that the inductive coupling disturbance is produced by the magnetic field of the power line and needs to be evaluated for underground sections of pipeline. It needs to be evaluated for above-ground sections of pipeline, only if these sections are grounded. This disturbance depends directly on the transmission line current unbalance. The evaluation of this disturbance is usually performed for steady-state, as well as short-circuit operational condition of the power line. This disturbance shall be evaluated taking into account the maximum anticipated levels of steady-state and short-circuit currents.

The conductive coupling disturbance is produced by the ground potential rise due to the electrical currents injected into the ground from the transmission line. It needs to be evaluated for underground sections of pipeline. It needs to be evaluated for above-ground sections of pipeline, only if these sections are grounded. The evaluation of this disturbance is performed only for short-circuit condition of the power line. This disturbance shall be evaluated taking into account the maximum anticipated level of short-circuit current.

It is important to mention that under short-circuit condition the disturbances due to inductive and conductive coupling occur simultaneously as shown in Figure 3.
Potential Risks

The most basic concern regarding the proximity between a power line and a pipeline is to make sure that the electrical clearances between the mentioned installations are large enough to avoid electrical discharges from the former to the latter, as shown in Figure 4. Besides that, the following risks may exist:

- Electric shocks to people who may contact the pipeline: This can happen at above-ground sections of pipeline and above-ground metallic accessories connected to underground sections of pipeline, as shown in Figure 5. The tolerability of people to electric shocks depends on the shock duration;

- Damage to the pipeline insulating coating: This can happen at underground sections of pipeline, as a consequence of the application of an excessive voltage stress across the pipeline coating. The coating becomes internally exposed to the pipeline metal electric potential $V_p$ (produced by inductive plus conductive couplings) while becoming externally exposed to the local ground electric potential $V_s$ (produced by conductive coupling), as shown in Figure 6;
• Damage to the pipeline insulating joints: This can happen to insulating joints used to separate above-ground from underground sections of pipeline, or insulating joints used to separate pipeline sections connected to different cathodic protection systems. These insulating joints can be damaged if exposed to voltage stresses above their maximum voltage withstand capability, as shown in Figure 7;

• Damage to the pipeline cathodic protection system: This can happen if the pipeline electric potential (at the point of connection to the cathodic protection system) is above the maximum reverse tolerable voltage of the cathodic protection system rectifier. See Figure 8.
**Safety Criteria**

People who may contact the pipeline can be exposed to electric shocks (touch voltages) caused by long-duration pipeline induced voltages (produced during the steady-state operation of the power line) or short-duration pipeline induced voltages (produced during short-circuit occurrences on the power line).

Typically, long duration shocks should be limited to 5 mA (estimated shock current that would produce loss of muscular control for 0.5% of children) while short duration shocks should be limited to 164 mA (estimated minimum shock current that would produce a ventricular fibrillation probability equal to or less than 0.5% for a 50 kg weight person, according to Dalziel's Equation for a shock duration time equal to 0.5 seconds).

Damage to the pipeline insulating (anti-corrosive) coating could lead to pipeline corrosion problems. This risk can be avoided if short-duration voltages applied across the pipeline external coating are limited to 5 kVrms. Such a level has been considered appropriate for the regularly used thicknesses of plastic (polyethylene) and bituminous (coal-tar) coatings. Plastic coatings have high thermal stability whereas bituminous coatings have low thermal stability.

Damage to the pipeline insulating joints can be avoided if the voltage stresses across them are limited to a level below the maximum withstand voltage of the mentioned joints. The maximum withstand voltage depends on the type of insulating joint. Some of them are able to withstand 5 kV when submitted to short-duration voltage stresses. If higher voltage stresses are anticipated, surge arresters should be installed across the insulating joints. In this case the nominal voltage and the energy dissipation capability of the surge arrester need to be appropriately specified.

Damage to the pipeline cathodic protection system (CPS) can be avoided by limiting the pipeline induced electric potential at the point of connection to the CPS to a voltage level that is smaller than the maximum reverse tolerable voltage of the CPS rectifier, which varies with the type of rectifier. If higher voltage stresses are anticipated, surge arresters should be installed. This analysis is usually done for the worst condition that typically occurs during short-duration disturbances.

Although these are typical limits, each country or state has its own regulation which must be respected.
Siemens PTI's Capabilities in the Analysis of Real Cases
Siemens PTI's consultants have extensive international experience in providing solutions for real cases, as well as accurate modeling capabilities. These are essential skills for assessing the pipeline induced voltage levels and proposing recommendations to make these installations electromagnetically compatible.

Figure 9 - Electromagnetic Compatibility between Power Lines and Pipelines