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HVDC & HVAC Powerline Interference on cross country Pipeline: A Case Study

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ABSTRACT

This paper discusses case studies of high voltage direct current (HVDC) & high voltage alternating current (HVAC) crossing Pipelines right of way (RoW) showcasing the effects of alternating current (AC) interference with respect to AC corrosion and Safety Hazards while running parallel and crossing at different angles to the same pipeline at multiple locations in a short span of length and restricting the AC current & safe voltage within maximum tolerable limits through deployment of mitigation measures as per industry code of practice, globally.

The paper discusses effects of both powerline fault conditions as well as induced steady state on underground pipelines, AC interference modelling for enhancing effectiveness of Cathodic protection and analysis of AC interference mitigation measures. A comprehensive technical analysis involving collection of baseline information on both the pipeline and powerline and determining powerline fault current effects adjacent to each tower, on the pipe wall, the pipe coating, and the resulting safety hazard for pipeline personnel.

Key words: HVDC/HVAC Powerline crossings, steady state & fault condition, AC Interference

INTRODUCTION

When a pipeline is parallel to a high voltage power line for a significant distance, voltages can be transferred to the pipeline under both normal power line operating conditions and short-circuit conditions on the power line. These voltages can result in electrical shock hazard for maintenance personnel; they can also be detrimental to the integrity of cathodic protection equipment, the pipeline coating, and the pipeline steel, particularly during short-circuit conditions.

The challenge is to identify the extent of AC interference on underground pipelines and mitigate these effects for the protection of pipelines.

PROBLEM STATEMENT

There are three modes of AC interference that can cause damage to pipeline systems and present an electrical shock hazard to pipeline personnel, namely; inductive coupling, resistive (conductive) coupling and capacitive (electrostatic) coupling.

INDUCTIVE COUPLING:

Inductive coupling occurs both under steady-state (normal operation) and fault conditions and the magnitude of the induced AC voltage depends on the phase current, phase wire configuration, layout and distance between pipeline and transmission line. The induced voltages reach the maximum values at discontinuities and reduces subsequently along the pipeline.

RESISTIVE COUPLING:

Resistive coupling appears under fault conditions only. The fault current flowing through the grounding of a high voltage structure (i.e. pole/tower) produces a potential rise in the surrounding soil, also referred to as “ground potential rise”.

CAPACITIVE COUPLING:

Capacitive coupling occurs only during construction when the pipe is elevated on skids and not in contact with the ground.

ADVERSE EFFECTS OF AC INTERFERENCE ON PIPELINES

1. Step & touch potential threats - Under steady-state conditions, the AC interference may result in safety problems for people coming in contact with the above ground metallic appurtenance of the buried pipeline.
2. External corrosion - Accelerated external corrosion on the underground section of the pipe (i.e. AC corrosion) at existing pipe coating holidays, thereby resulting in metal loss.
3. Under fault conditions, the AC interference may result in damage to the pipe itself over a period of time (i.e. an electrical arc between the structure ground and the pipe), resulting in safety concerns for pipeline personnel and damage to the pipeline coating, isolation joints and cathodic protection (CP) equipment.

The identification, monitoring and mitigation of electrical interference between electrical transmission lines and underground pipelines is a mutual concern that requires the cooperation of both stakeholders to optimize the effectiveness of any corrective measures. Mitigation measures ideally require design of an AC electrical grounding systems for safety in accordance with industrial standards & practice.

In addition to the above issues, following are the other circumstantial challenges that lie in addressing & mitigating AC interference on pipelines:

1. Suppression of pipe to soil potential (PSP): PSP is the potential of pipe with respect to soil measured at a particular location through a reference cell (Copper-Copper sulphate electrode). DC PSP of pipeline gets suppressed in the vicinity of Transmission line and its extent varies with

varying load/ unbalance load of the transmission line. As a result, PSP measurement & its correlation with loading of transmission line is a challenge. This is primarily an erroneous, often misleading PSP reading as the reference ground potential changes due to increase in ground potential at location of measurement.

2. Induced AC current on Pipeline: AC Current induced on pipelines at High tension transmission line (HT) crossing locations is very difficult to be monitored on a continuous basis, which is another major challenge and potential hazard to personnel working on the pipeline at these crossings especially during planned maintenance activities.
3. Mitigation measures – Finding out cost-effective mitigation measures and identifying the extent of the pipeline requiring AC interference mitigation needs to be addressed thoroughly.

PROPOSED SOLUTIONS

METHODS TO IDENTIFY AC INTERFERENCE POINTS DURING STEADY STATE, FAULT CONDITION & VARYING LOAD CONDITIONS –

1. Identification of varying loading state in Transmission Line - Transmission line phase current loading varies seasonally depending upon consumer requirements both domestically as well as industrially. Also, seasonal moisture conditions vary from a typically wet or dry season, which can affect the resistance of AC mitigation systems. Because of these variable conditions, measurement of AC induced voltages and AC mitigation currents can be done more frequently (such as on quarterly basis) than is normally required for PSP measurements. It is also important to understand that the electrical power utility can increase the phase current magnitudes at any time, depending upon requirements for emergency purposes or for new demand loads, causing an increase in AC interference. Use of remote metering units or data loggers for measurement on continuous basis can be beneficial although the same may not be as fruitful in locations prone to poor network connectivity/remote locations and prone to vandalism by locals.
2. Magnetic Flux measurement – Induced AC current on underground pipelines is directly proportional to the magnetic flux induced by the AC current flowing in the corresponding overhead transmission line. The optimum & accurate way to measure this varying load condition of transmission line is through measurement of magnetic flux at ground level, particularly at the crossing locations.

Magnetic fields can be measured using non-contact methods in open space at a point and compute currents that gave rise to them. Measurement is possible by standing at the very bottom, between power transmission line towers and with pointing of magnetic probes in open air for estimating the currents in overhead line. As opposed to a current transformer (CT), the field sensors, (here, hall-effect based sensor is used ¹⁵ which are light and very small in size. It is highly portable, flexible and mobile in nature.

The Magnetic field measurement can correlate the loading conditions with the rate of AC interference/PSP suppression of underground pipelines ¹⁶. This measurement can be used to understand the extent of AC interference and accordingly an informed decision can be taken for further investigation at the location. However, at places where there are multiple transmission line circuits in the vicinity of the crossing, it is very difficult to arrive at a conclusion.

3. Installing corrosion rate coupons - Corrosion coupons can be installed to facilitate measurement of both AC and DC current density. The coupon can also help with the measurement of a reference polarized potential on the pipeline for comparison with industrial criteria. It is effective in areas

where problems in measurement of an accurate instant-off potential is difficult. Also, AC current through DC decouplers or directly connected grounding facilities can also be measured using an AC clamp-on ammeter over the cable connected to a corrosion coupon.

4. Ratio of (I_{ac}/I_{dc}) - AC corrosion rate is directly correlated with the cathodic protection current density (I_{dc}) and the AC current density (I_{ac}) at a coating holiday. As per industrial practice, a current density of greater than 30 A/m² and up to 100 A/m² is questionable and there is probability of AC corrosion depending upon soil resistivity, ground potential rise (GPR) & current density. Any value of current density above 100 A/m² has high probability of causing AC corrosion. On the other hand, from personnel safety point of view, threshold value of 15V AC is the acceptable value as per NACE RP-0177³.

Routine monitoring of AC and DC PSP potentials can determine if the AC voltage is less than 15V³ and an acceptable AC corrosion current density, a maximum of 30 A/m² or an I_{ac}/I_{dc} ratio of less than 5. A maximum current density of 30 A/m² is selected as it typically indicates that corrosion can occur at current densities greater than this threshold². Various case studies and research papers have indicated occurrence of AC corrosion in lower ranges of current density in the bracket of 30 - 100 A/m² AC current density range. Monitoring of I_{ac}/I_{dc} can be done only through corrosion coupon installed at test stations.

MITIGATION TECHNIQUES

The design of AC corrosion mitigation technique broadly covers the following:

- a) Safe pipe-to-transmission line separation distance for minimizing the risk of arcing to the pipe during a transmission line fault.
- b) Installation of gradient control mats at pipeline isolation valves to protect personnel doing pipeline maintenance work during a transmission line fault.
- c) Electrically grounding the pipe to earth to prevent any hazardous voltages under fault and steady-state conditions and to minimize AC corrosion risk.

MITIGATING HARMFUL EFFECTS FROM A POWERLINE FAULT

1. Shielding by casing pipe- An approach of “shielding” can be explored in the form of installation of a sealed dielectric casing (such as high density poly ethylene (HDPE) pipe) around the pipeline near the tower and filling it with gel, so that the risk of water entering the casing is minimized. The section of the pipe with casing can be provided with cathodic protection as is the case in cased crossings.

2. Screening electrodes - Screening electrodes can be used to intercept a fault current and thereby shield the pipeline and coating. It can be a non-galvanic material, such as copper cable, connected to the pipe either directly or through a DC decoupler. It can also be in the form of packaged zinc anodes or a zinc ribbon surrounded by sulphate rich backfill.

3. Gradient Control mat – Gradient control mats are used for personnel protection from being exposed to a lethal shock hazard, when in contact with the above ground metallic surface/appurtenances of pipeline. A gradient control mat is not a grounding mat but its a metallic grid that is kept near the surface of the ground and connected to the pipeline such that the touch and step voltage is minimized during a fault.