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Interference & corrosion due to HVAC power lines running parallel to cross country pipelines: Computer modelling vs. Field monitoring

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ABSTRACT

Pipelines paralleling or crossing high voltage power line in the same ROW, may be subject to electrical interference from electrostatic coupling, electromagnetic inductive and conductive effects. Predicting HVAC interference on pipelines is a very complex problem, with multiple interacting variables affecting the influence and consequences. In some cases, detailed modelling and field monitoring is used to estimate pipelines susceptibility to HVAC interference, identify locations of possible AC current discharge, and design appropriate mitigation systems to reduce the effects of AC interference

This paper addresses the technical background to high voltage interference with respect to collocated and crossing pipelines, and presents basic procedures , methods adopted in predicting and mitigating the HVAC interference i.e. collection of survey data, analysis of data, problems faced during survey and accordingly actions dealing with interference scenarios using computer modeling and field monitoring

Key words: Interference, Corrosion, Modelling, Power lines

INTRODUCTION

Due to limited land scenario, using the same ROU by different Power line and pipeline operators are common nowadays. This resulted in bringing the power line and pipeline in close vicinity which resulted a serious AC interference threat to operating personnel and equipment.

There are three modes by which AC voltage can be induced in pipelines coming in close vicinity of AC power lines that can cause damage to pipeline systems and present an electrical shock hazard to pipeline personnel,

TYPES OF AC INTERFERENCE

1. The first mode of interference is defined as “capacitive coupling”: It is of concern during construction when the pipe is elevated on skids and not in contact with the ground i.e when the structure is above grade .Here the energy from the power line is transferred through electrical capacitance, as shown in fig. , that exists between power line & pipeline and pipeline & ground. It does not result any corrosion of pipeline but can be a secondary safety hazard due to this capacitive induced voltage. This induced voltage can be eliminated by connecting the pipeline to the ground.

2. The second mode of AC interference on the pipelines, defined as “Conductive/ Resistive coupling”, This appears under powerline fault conditions i.e ground faults, line to line faults, lightening surges etc., The fault current flowing through the grounding/footings of the high transmission tower which produces a potential rise in the neighboring soil defined as “ground potential rise” (i.e. GPR). Part of this rise is transferred to the pipe and would be added to the AC induced voltage. Often to thousands of volts with respect to remote earth, and can result in a considerable stress voltage across coating or even on the pipeline itself. The higher the coating’s dielectric strength the lower the current transfer to the pipeline. In worst cases, large fault currents can cause coating damage or even pipeline failure due to melting or cracking the pipe wall.

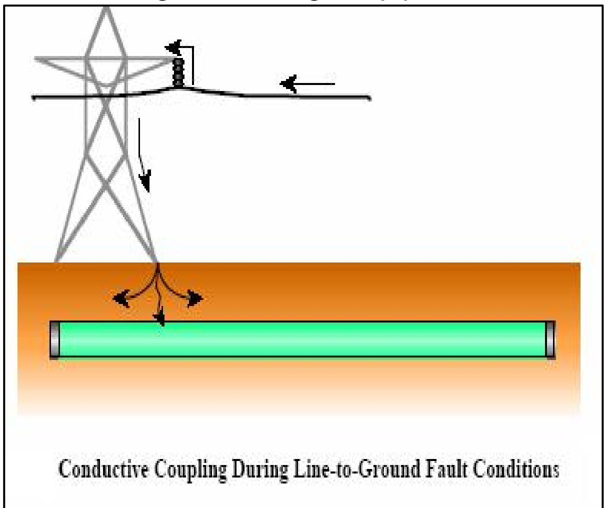

Figure-1: Conducting Coupling during Line to fault conditions

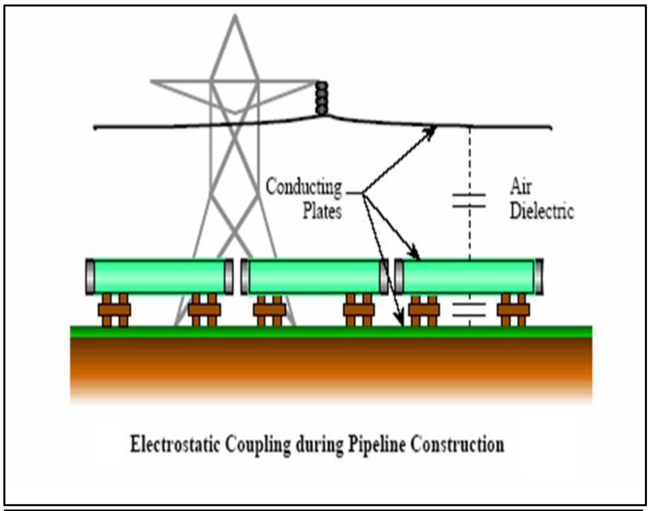

Figure-2: Electrostatic Coupling during Pipeline Construction

[illegible] maintaining safe separation distance between the power structure and the pipeline. As suggested by **E M Sunde**, who provided the following equation for the distance, r (mtr) over which an arc could occur, based on soil resistivity, ρ (Ω-m) and fault current magnitude, If (kA)

$r = 0.08 \sqrt{(If.\ \rho)}$ where, $\rho \leq 100\ \Omega$-m

$r = 0.047 \sqrt{(If.\ \rho)}$ where, $\rho \geq 1000\ \Omega$-m

a) Installation of screening electrodes near the pipeline.
b) Installation of gradient control loops above the pipeline.
c) Most importantly, avoid activities involving pipe/ appurtenance contact during storms/ lightening.

3. The third mode of interference is Inductive coupling occurs when the structure is either above or below ground. In this case, the structure acts as the single turn secondary of an air-core transformer in which the overhead power line is the primary. This inductive coupling occurs
   Both under steady-state (normal operation) and fault conditions and the magnitude of the induced AC voltage depends on depends on many factors. The most important are
   - Phase current,
   - The length of parallelism
   - The distance between pipeline and powerline
   - The pipeline-powerline configuration.
   - Coating resistance of the structure
   - Grounding present on the structure
   - Soil resistivity

The induced voltages reach maximum values at locations in which there are abrupt changes in the parameters. The abrupt change in parameters are usually those locations in which power lines and structures deviate away from or cross one another or at power line phase transposition locations. The induced voltages reach maximum values at discontinuities and gradually attenuate along the pipeline.

SAFE TOUCH VOLTAGE: As per NACE SP0177-2014, Steady state touch voltage of 15V or more with respect to local earth at above grade or exposed sections and appurtenances is considered to constitute a shock hazard.

MISCONCEPTION: The induced voltage of less than 15 V doesn't mean that the pipeline is safe in respect of AC corrosion but is safe for "Touch"

The following formula is used for evaluating AC corrosion;

$$i_{ac} = \frac{8V_{ac}}{\rho \pi d}$$

Where,

i_{ac} = AC current density, A/m2

Vac = Induced AC volts

ρ = Soil resistivity, ohm-mtr

d = holiday diameter, mtr

Applicability of the formulae is when the holiday size is greater than the thickness of the coating, which, for practical purposes, applies to the vast majority of situations.

European standard CEN/ TS 15280 offers the following guidelines:

- iAC < 30 A/m2 : No or Low likelihood
- iAC > 30 A/m2 and < 100 A/m2 : Medium likelihood

GENERAL FIELD MEASUREMENTS FOR AC INTERFERENCE MITIGATION:

The most common field measurements for initial study of AC interference are as follows

1. Soil resistivity measurements along the common ROU ,
2. Separation distance between pipeline and power lines,
3. Visual inspection of pipeline and power line facilities,
4. Measurement of steady state voltages on the pipeline and
5. Cathodic protection logging.
6. AC and DC coupons or corrosion rate probes at pipeline test stations, at locations of electromagnetic discontinuities, and at locations where the calculated AC current density is greater than 30 A/m2 , so that actual AC current densities or AC corrosion rates can be measured during future surveys

MITIGATION OF INDUCED VOLTAGES ON PIPELINES:

Using the above field parameters following are the mitigation methods used for the Induced AC voltages.

1) Safe separation distance between pipeline and high voltage line:
   During the construction and planning phase, Increasing the distance between the pipeline and the Power line reduces the level of induced voltage on the pipeline.
2) Transposition of Power lines :
   To reduce the induced voltage is to transpose the phase wires, which mean physically changing the position of the phase wire on the high voltage pole, three times at least, within an interfered area.
3) Earthing of pipeline with earth electrodes:
   Grounding of the pipeline as a mitigation measure so as to ground the induced ac voltage can be done by two ways:
   - Direct grounding
   - Indirect grounding.

   Direct grounding system is done by directly connecting pipeline and grounding electrode via cables or ribbons lying parallel to pipelines. However indirect grounding system operates with a De-coupler unit like Kirk cell, semiconductors, dischargers, capacitors unit etc.) This provides electric separation between the pipeline and the grounding.
4) Compensation of induced ac voltage:
   The transmission line would induce voltages in the cancellation wire which were out-of-phase compared to the ones induced on the pipelines. The cancellation wire had a common point with one end of the pipeline and ideally voltages should cancel each other. It could be positioned between pipeline and power transmission line or on the other side of power transmission line looking from pipeline.
5) Insulating joints:
   They are also used to divide the pipeline into sections to confine cathodic protection systems failure to single sections. Insulating joints can mitigate the AC interference effects on a

pipeline by reducing the electrical length of the pipeline exposed to power lines. This way the maximum value of induced AC voltage on the pipeline is reduced as the maximum induced voltage is proportional to the length of parallel sections.

If this method is used, the following should be considered:

• Installation of the isolating joint within the interfered section of the pipeline reduces the maximum value of induced ac voltage, which is proportional to the length of parallel interfered section

• The ac voltages on both sides of the isolating joint have a phase shift of 180°. The ac voltage measured over the isolating joint is the double of the peak voltage.

6) Repair of coating damages:

   Risk of ac corrosion is higher on small defects than on large ones. In order to prevent ac corrosion no additional defects arise on the pipeline during the normal course of operation of pipeline.

7) Exchange of soil in the vicinity of pipeline:

   This is practically impossible as the changing the whole area of soil is a expensive matter > But the main purpose of this is to change the soil resistivity as reflected in the ac corrosion equation above.

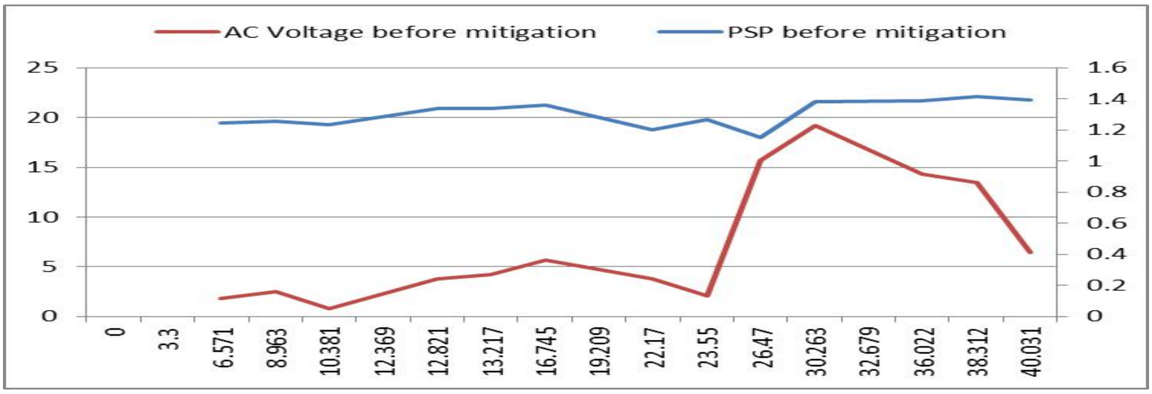

Figure-3: PSP & AC Voltages Before Mitigation without software modelling

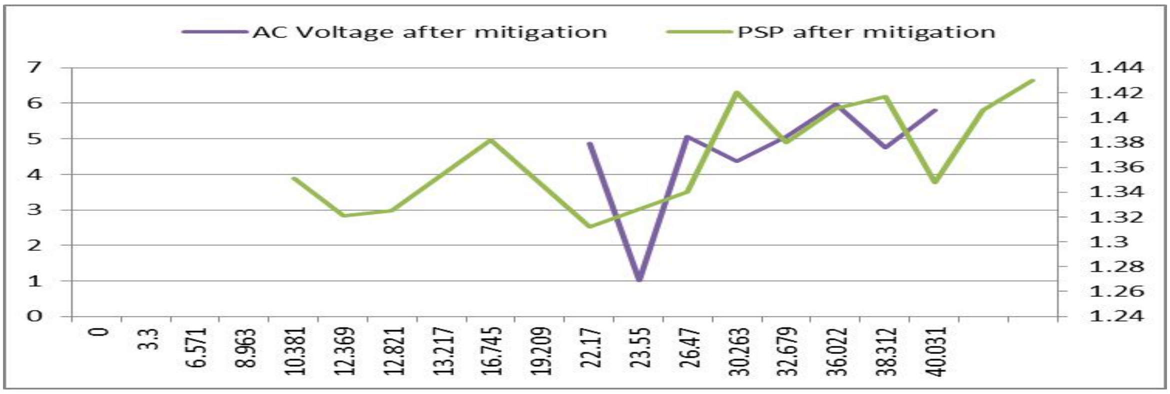

Figure-4: PSP & AC Voltages After Mitigation without software modelling

All this methods used above used are taken into consideration after taking the field reading and the maximum goal achieved is to bring the induced voltage to a safe level of 15v and below at installation but the major problem of AC interference still exist. The above fig 1 & 2 represents the same wherein the same method described above was used for field reading and mitigation action All these field data are not sufficient to give the real picture. The below points are not clarified from the above field readings.

- The induced voltage during the steady state
- Effect of variance of load on induced voltage
- The induced voltage during Fault condition
- The drainage/ Earthing point for drainage of Stray current
- Effect on Coating stress voltage

And beside of all the above factors AC mitigation is required if AC Induced voltage in pipeline is greater than 15 Vac, or if the calculated current density at a 1 cm2 holiday and the soil resistivity survey data for pipe depth is greater than 50 A/m2 for the AC Induced voltage based on the average current loading.

All these point can be achieved using field monitoring technique. But have to be inferred through the AC interference modelling software. A brief of all the data required for the interpretation is given below

DATA COLLECTION:

First step in the modelling of the AC interference problems is the collection of data which are required for modelling and correctness and avability of data leads to true mitigation programmes. The required data can be divided into items related to the pipelines and to the power system.

Data Request for AC Interference Study:

- **Pipeline Data**

1. System overview: A detailed map is required (geographical) indicating the following:
The pipelines under study,

- All parallel or roughly parallel high voltage circuits which come within 1 km of the pipelines,
- All other pipelines feeding or being fed by the pipeline under study,
- All exposed structures, such as valve sites, pig launchers & receivers, M&R stations compressor stations, and other such facilities on the pipelines listed above,
- All insulating flanges on the pipelines listed above,
- All anode beds on the pipelines listed above,
- Other pipelines which are parallel to the pipelines under study for significant distances (i.e., on the order of ½ km or more), or which cross them, or which come within 10 m of them,
- All electric substations and generating plants within 300 m of the pipelines under study or fed by the pipelines under study.
- Electric substations of both ends of each high voltage circuit shown on the map.

2. System layout: A detailed plan is required of the system which will allow any length , And separation distances of all pipelines and power lines to be determined**.**

3. Pipeline dimensions:

- Soil cover of the pipeline
- Diameter of the pipeline
- Pipeline wall thickness
- Pipeline coating thickness

- Separation distance of the pipeline under study from the center & edge of the transmission line structure

4. Soil Resistivity Data:
Soil measurements to be taken at the following location
- At exposed structures
- At locations where the pipeline and power line diverge from each other, at power line crossings, at phase transposition locations etc
- In situations where the pipeline is extremely close to the power lines, substations or other types of grounded structures

5. Electrical Data:
- Pipeline coating resistance (from factory data).
- Anode bed dimensions, resistance, their interconnection configuration with the pipeline, and material type

Power Company Data

1. Power Transmission Line Data
- Conductor Positions and Phasing
- Power line cross sections indicating phases, earth wires, conductor spacing and heights above ground
- The locations of all phase transpositions as well as the configuration of all conductors whose positions change due to the transpositions
- Maps indicating transmission line routing through the same ROU
- Power line grounding indicating the description and dimensions of tower footings
- Remote substation locations including distances from the shared corridor
- Nearby substations or power plant grounding system with distances from the
- pipeline, and a detailed description and layout of the grounding system

2. Conductor Characteristics
Conductor type of all phase wires and static wires of all circuits in the common right-of-way.

3. Power Line Voltage/Current Data and other information:
- Voltage
- Magnitude and phase angle of load current
- Maximum load and emergency loading levels
- Maximum expected current unbalance level
- Future expected load growth
- Expected expansion possibilities of the power system in the future

4. Fault Current Data:
- Fault type & their fault levels
- Protection response time of protective device
- Fault Current Contributions
- Soil Resistivity values used in fault level calculations

5. Power Plants, Substation and Power line Grounding
- Map showing all circuits connected to the plant or substation.
- Layout of grounding grids.

- Design value or measured value of grounding system impedances.

Upon receipt of all the data the Software modelling tool calculate the following data:

- The Steady State Pipeline Induce Voltage.
- Steady State Pipeline Induce Shunt Current.
- Steady State Pipeline Induce Sectional Current.
- Fault Condition Pipeline Induce Voltage.
- Fault Condition Pipeline Induce Longitudinal Current.
- Total Interference Coating Stress Voltage.
- Computed Multi-layer Soil Resistivity.
- Location of Drainage point of stray current.
- The touch voltage and GPR during fault conditions.

INTERFERENCE MITIGATION DESIGNS THROUGH SOFTWARE MODELING.

At pipeline installation s, touch and step voltages need to be reduced to the levels as pert the Standards usually by means of a Grounding/Earthling. Mitigation is also provided for the pipeline coating stress voltages levels that are safe for the existing coating. The most common methods of mitigation are grounding, insulating joints and gradient control wire at the predefined place as calculated through modeling. This mitigation system has to be included in the computer model of the common corridor for the interference study and the field readings are taken and modelled repeatedly until mitigation objectives are met.

Below is the table showing the parameters which can be obtained through from field monitoring technique and from Software modelling.

Sl. No	Result obtained	Field Monitoring	Software modelling
1	Multilayer soil Resistivity data	No	Yes
2	The complex series impedance and shunt admittance matrices corresponding to respective paralell corrridor section	No	Yes
3	Induced voltage in steady state condition	Yes	Yes
4	Induced voltage in steady under fault condition	No	Yes
5	Pipeline grounding and its effectiveness	Partially Yes	yes
6	Location of discharge points for grounding effectiveness.	No	YES
7	Steady State Pipeline Induce Shunt Current	No	YES
8	Steady State Pipeline Induce Sectional Current	No	YES
9	Fault Condition Pipeline Induce Voltage	No	YES
10	Fault Condition Pipeline Induce Longitudinal Current	No	YES
11	Total Interference Coating Stress Voltage	No	YES
12	AC corrosion current density	Yes	Yes
13	Safe distance from power lines	Yes	Yes
14	Mitigation for safe touch voltages at pipeline installations	Yes	Yes

Table1: Comparison between Field Monitoring and Software Modelling Technique

CONCLUSIONS

Therefore we have seen that the field monitoring as well as the AC interference modelling software used in conjunction gives the true picture and helps in mitigating design for the AC induced interference system. The data collection on of the important parameters fort his modelling which is a time consuming and tiresome job. The trueness of this data will gives us the real picture and helps us in proper designing of mitigation system which is not possible using the field monitoring techniques.

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