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Effect of electromagnetic field of overhead transmission lines on the metallic gas pipe-lines

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ABSTRACT

This paper presents a study of the overhead transmission lines (OHTLs) electromagnetic fields effects on the metallic gas pipelines. The inductive and conductive voltages between the overhead transmission line and metallic gas pipelines, in normal operation and under phase to ground fault condition of the overhead transmission lines, are calculated. ATP software is used to simulate the OHTL under faulty condition. MATLAB program is used to calculate the induced voltages taking into account the effects of various parameters, such as: separation distance between the OHTL and the metallic gas pipelines, case of transmission line (phase to ground fault condition or normal operating condition), the screening factor and the soil resistivity on the magnitude of the induced voltage along the length of the metallic gas pipeline. The method used to calculate the induced voltage by inductive is based on the well known method "distributed source analysis". Case study, to measure the induced voltage on the metallic gas pipelines from OHTL under normal operating condition, is presented. The comparison between the measured and calculated results shows a good agreement between them.

1. Introduction

Corrosion of the metallic pipelines can be described by many ways, such as mechanical corrosion and chemical corrosion. Mechanical corrosion of the metallic pipeline occurred if the pipeline is cracked by over pressure, over temperature, or under temperature. Chemical corrosion of the metallic pipeline occurred if the pipeline is conducted by low activity chemical materials, where a galvanic cell is formed. High activity materials in this cell act as anode, while the low activity materials act as cathode. AC corrosion of the pipeline is a combination of these types of corrosions. This AC corrosion is occurred if there is an induced AC voltage on the pipeline by the interference effect between the pipeline and neighboring power transmission lines. This voltage increases the chemical activity of the pipeline, which acts as anode, hence the corrosion rate increases. There are many mechanisms that describe the pipeline induced voltage by the interference effect. These mechanisms depend on the type of coupling (capacitive, inductive and conductive) between the pipeline and the power transmission line. There are many hazards appear due to the induced voltage on the pipeline. These hazards can be subject of workers to high potential, damage of the pipeline coating and corrosion of the pipeline body.

An actual case study is presented in this paper and actual measurements are carried out. The actual case study is the Fayum metallic gas pipeline in which three transmission lines are parallel or crossing it, as shown in Fig. 1. Fig. 2 shows the Fayoum gas pipeline-power line geometry, which is taken as an actual case study in this paper. Also, this figure shows the variation of the soil resistivity along the length of the pipeline.

The leakage and stray currents on the metallic pipelines created by the induced voltages are calculated and measured. Also the rate of corrosion of the metallic gas pipelines that happened by induced voltage is calculated.

The pipelines are buried by depth of 1.5 m, according to the Egyptian Petrochemicals Holding Company specifications for the transmission pipeline of nature gas code and the international standards (IGEM) [1,2]. Hence, there is no effect of the capacitive coupling on these buried metallic pipelines because there is essentially no electric field transverse to the direction of the power line at that depth below the earth's surface [3,4]. Many researches dealt with this topic such as: Dawalibi et al. carried out computations for the analysis of electrical interference between power lines and gas pipelines [5]. Dan D. Micu et al. investigated the evaluation of induced AC voltages in underground metallic pipeline and deals

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Fig. 1. Fayum gas pipeline geometry, where the three transmission lines are parallel or crossing it.

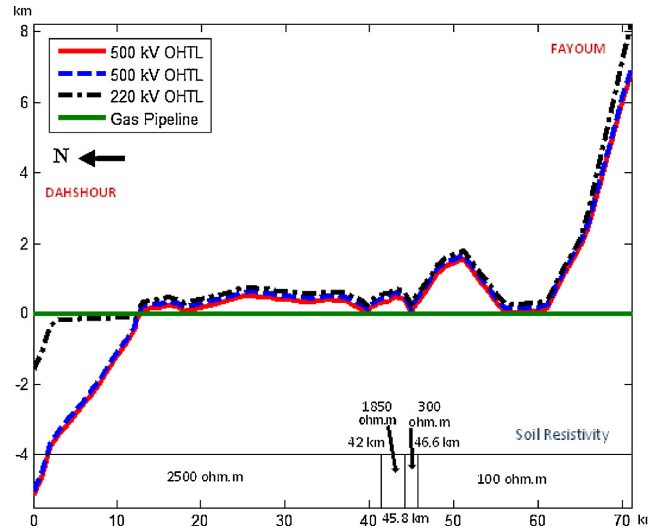

Fig. 2. Fayoum gas pipeline-power line geometry.

with parameters affecting such interference from double circuit power lines [6].

2. Pipeline induced voltage

2.1. Inductive coupling between pipelines and OHTLs

Pipeline induced voltage, by the inductive coupling mechanism, depends on the load currents of the overhead transmission lines, the separation distance between the overhead transmission lines and the pipeline, and the soil resistivity [7].

The method used to calculate the induced voltage by inductive in the buried pipelines due to the power frequency (50 or 60 Hz) power line is based on the well known method "distributed source analysis", which is fully explained in [8,9]. In this technique the pipeline and its surrounding earth form a lossy electrical transmission line, which characterized by the propagation constant; γ, and the characteristic impedance; Z_0. In this technique the inductive voltage is calculated with the help of the longitudinal driving electric field; E_z, which is along the path of the pipeline, and is calculated as a contribution of each phase current. Hence, E_z can be positive or negative, and it can be expressed as follows [8,9]:

$$E_z = I_{ph\_a} Z'_{ph\&pipe\_a} + I_{ph\_b} Z'_{ph\&pipe\_b} + I_{ph\_c} Z'_{ph\&pipe\_c} + \sum IZ \qquad (1)$$

where: I_{ph} is the current of each phase a, b and c; $Z'_{ph\&pipe}$ is the mutual impedance between each phase a, b and c of the power line and the underground pipeline including the effect of ground wires and $\sum IZ$ presents the effect of the ground wires. This mutual impedance can be calculated as follows [8,9]:

$$Z'_{ph\&pipe} = Z_{ph\&pipe} \times K_{sf} \qquad (2)$$

$$Z_{ph,pipe} = 0.04935 + j0.14468 \log_{10}\left(\frac{D_e}{D_{ph,p}}\right) = \left|Z_{ph,pipe}\right| \angle\theta \qquad (3)$$

where $D_{ph,p} = \sqrt{(x_{ph} - x_p)^2 + (y_{ph} - y_p)^2}$, (x_{ph}, y_{ph}) are the coordinates of the phase conductor, (x_p, y_p) are the coordinates of the buried pipeline, $D_e = 658\sqrt{\rho/f}$ [10], ρ is the soil resistivity, θ depends on the ratio of $(D_e/D_{ph,p})$, hence it may be positive or negative and K_{sf} is the screening factor which can be calculated from the following relation [11]:

$$K_{sf} = 1 - \frac{M_{12}}{L_2} \qquad (4)$$

where M_{12} is the mutual inductance between the earth wires and each phase of the power line and L_2 is the earth wire inductance.

In case of non-homogenous and multilayered soil, other formula for the mutual impedance like that in [12,13] can be used.

Finally, the inductive induced voltage at any distance x along the length of the pipeline is calculated as follow [8,9]:

$$V(x) = \frac{E_z(x)}{\gamma}\left(\frac{-Z_1}{Z_1 + Z_0} e^{-\gamma x} + \frac{Z_2}{Z_1 + Z_0} e^{-\gamma(x - L_p)}\right) \qquad (5)$$

where Z_1 and Z_2 are obtained by the Thevenin equivalent circuit, L_p is the pipeline sub-section length, where the pipeline is subdivided into many sub-sections, each of them is assumed to be less than 10 km. In this case study, the actual measured value of the soil resistivity for each pipeline sub-section length is used in the calculations; hence the non-homogenous soil effect is ignored in this study.

2.2. Conductive coupling between pipelines and OHTLs

In conductive coupling phenomenon, the flowing of the currents through the ground raises its potential. Ground potential decays as the distance from the current discharging point increases. This means that, the ground potential is increased in the domain. Also, as the discharged current increases, the ground potential increases. So, if the buried pipelines are located in this domain, they will be subject to this potential. The ground potential will be very high in case of grounding fault conditions of the overhead transmission