

Induced Currents in Pipelines

Virginia Mabel Silbergleit

CONICET, Instituto del Gas y del Petroleo, Facultad Ingenieria, Universidad de Buenos Aires, Buenos Aires, Argentina

Email: vms10ar@yahoo.com.ar

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Abstract

Changes in the geomagnetic field produce ground induced currents that can have impacts on artificial systems such as pipelines. According to these, geomagnetic perturbations observed during June 2005 are studied. The data measured on the Ottawa River Valley pipeline verify the appearance of induced currents greater than 700 mA and additional potential values larger than -850 V that can produce additional corrosive effects.

Keywords

Storm, Induced Currents, Pipelines

1. Introduction

Geomagnetic disturbances can impact the operational reliability of buried pipelines. Storm events provide compelling evidence of a general increase of corrosion in pipeline systems.

The cathodic protection (CP) is to prevent corrosion by maintaining buried pipelines at a constant potential with respect to the soil. Design requires characterization of the parameters impacting the corrosion process. A non corrosive coating is used to prevent damage, and additional protection is applied by means of CP in order to control galvanic current.

The voltage (PV) at test places must be in the safe range, which is within the -850 to -1150 mV which is affected by CP system. The PV readings are irregular and at times full outside the safe zone. They are influenced by the geomagnetic activity, the Earth conductivity and the pipeline structure [1]. Many authors studied the induced currents (PI), e.g. [2]-[4].

The corrosion could lead to a major ecological tragedy of oil poured out of a hole in a pipe line in the deserts of Alaska. They are, therefore, closely monitored and protected. To avoid the leakage of iron electrons into the ground, pipelines have a coating of low conduction material and are maintained artificially at a slightly negative potential in relation to the Earth (-0.85 V), to prevent migration of electrons. However, corrosion is increased by

the electric currents that spread through the ground during magnetic storms and substorms. High latitudes are particularly exposed to accelerated corrosion

The electric and magnetic fields observed at the Earth’s surface depend on magnetospheric-ionospheric currents and on currents induced in the Earth. Recent developments in the use of the Complex Image Method (CIM) permit fast and accurate computations of the electric field suitable for time-critical applications like GIC (geomagnetically induced currents) forecasting. The physical background and modeling of induced currents are discussed in his paper [5].

Telluric currents produced by geomagnetic disturbances during magnetic storms and substorms can cause variations in the difference in potential with the ground; they modify the electrochemical conditions of the pipe leaving which can be temporarily not protected [6]-[8].

Telluric current effects have had a significant effect on electrical systems for over 150 years [9] and on pipelines firstly observed in 1950. We examined the electromagnetic response of a buried pipeline in soil (placed in the Ottawa River Valley) during a perturbed periods.

2. The DSTL Approach

Geomagnetic field variations induce telluric currents in pipelines, which change the electrochemical conditions at the pipe/soil interface, probably contributing to corrosion of the pipeline steel. Pipe to soil potentials produced by the electric field induced in the pipe were considered by using a distributed source transmission line (DSTL) model. This was used and applied to geomagnetic induction in pipelines by different authors [3] [7]. In the DSTL approach each uniform section of the pipeline is represented by a circuit with specific series impedance and a parallel admittance (as it is shown in Figure 1).

$$\partial E'/\partial x = [\partial^2 (PV)/\partial^2 x - \alpha^2 (PV)] \tag{1}$$

$$-A'E' = [\partial^2 (PI)/\partial^2 x - \alpha^2 (PI)] \tag{2}$$

where $\alpha\sqrt{I'}\sqrt{A'}$ is the propagation constant along the pipeline, A' is the parallel admittance and I' is series impedance per unit length. The induced electric field is represented by voltage sources distributed along the transmission line (Figure 1).

Equations (1) and (2) are the basic equations for the voltage (PV) and current (PI) produced in any section of pipeline by induced electric field E' .

In the DSTL model, the pipeline is considered as a transmission line, with multiple segments of different lengths and orientations. The induced electric field is represented by voltage sources distributed along the transmission line. The electric properties of the pipeline are the series impedances per unit length and parallel admittance per unit length. Also, the conductance is through the pipeline coating. The potential difference between a pipeline and the adjacent Earth influences the electromechanical environment at the pipe surface, which modify possible corrosion occurrence. According to this, anodes and rectifier units are connected to the pipeline steel to drive it negative with respect to the surrounding soil. In this case, the pipe becomes the cathode of the circuit, leading to the name “cathodic protection” [10].

Recordings of the geomagnetic variations in the region of the pipeline can be obtained from permanent magnetic observatories or specially installed magnetometers. [11] studied characteristic of geomagnetic storms.

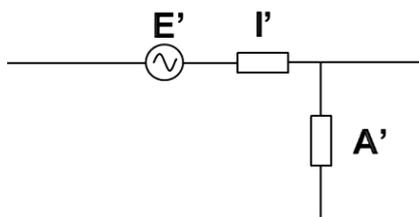


Figure 1. In the DSTL model, each uniform section of the pipe is represented by a circuit element with specific series impedance (I') and a parallel admittance (A'). The induced electric field is represented by voltage sources distributed along the transmission line.

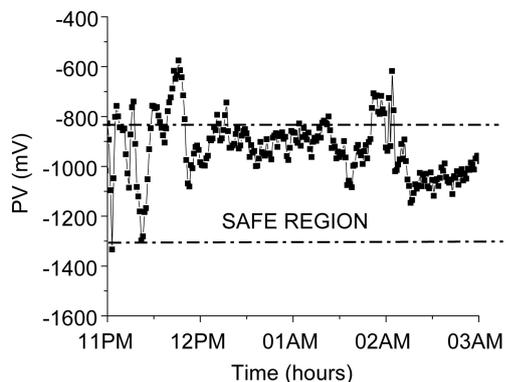


Figure 3. Pipe-to-soil potential difference (PV) on a pipeline in Canada, recorded at the same time of the magnetic storm period. During this period PV went outside the safe region indicating the possibility to increase the corrosion.

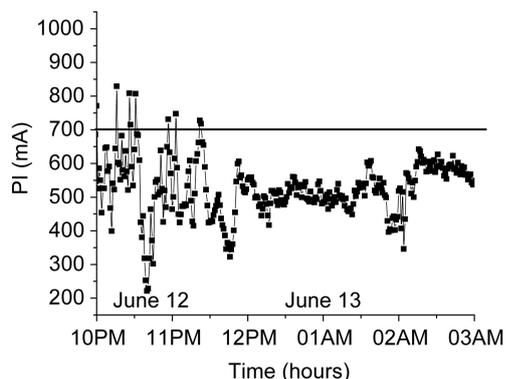


Figure 4. Induced currents (PI) for June 12-13, 2005. During some periods, the maximum PI values were up to 700 mA.

2) During some periods, the maximum PI values were up to 700 mA (**Figure 4**).

During some periods of this storm, PV values were outside of the safe region, and then the possibility of additional corrosion was increased.

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