STRAY CURRENT DETECTION ON HAZARDOUS LIQUID BURIED PIPELINES AS A PART OF PIPELINE INTEGRITY MANAGEMENT

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ABSTRACT

This paper shows the examples of stray current measurements in the region of dynamic DC interferences. Stray current phenomenon presents a serious threat to pipeline integrity and is a major concern for pipeline operators since the beginning of the last century. In the intervening century it has only become a bigger problem due to the development of industrial facilities fully followed by growth of underground and aboveground electrical installations. Evaluation of stray current corrosion likelihood is particularly challenging in urban areas due to the multiplicity of possible stray current sources and the complexity of buried infrastructure. A characteristic location in Zagreb municipal area was chosen, where buried high pressure gasline is followed by aboveground DC electric tram rail system. State-of–the-art technique for the detection of hot spots on the pipeline under the influence of stray current, the Stray Current Mapper (SCM) device has been used. The device gives information in real-time about the direction and strength of the current which runs through pipeline. Although measurements with SCM device are relatively easily conducted, the design of measurement in complex situations and interpretation of data requires a qualified person in order to be successfully applied for planning and implementing mitigation measures. Simultaneous measurements of pipeline potentials, potential gradients, coupon currents and pipeline currents at multiple points along the pipeline route enable spatial and temporal resolution of stray current action. Stray current corrosion

likelihood based on observed results presents a valuable input data of the pipeline integrity management system.

INTRODUCTION

In Zagreb, dynamic stray currents from DC current operated transit systems influence utility steel pipeline systems, including the subject gas distribution pipeline. The operating potential of the DC transit systems is 600 volts and the streetcar system load current can reach thousands of amperes in peak periods. The current returns to the substation via the rails that are due to design and deterioration improperly insulated from the ground and current leaks to the ground and nearby utilities. The traction system generates stray currents, the magnitude and direction of which depends on the location of the load and the horsepower being expended in relation to the source. Stray current activity results in a corresponding change in the pipe-to-electrolyte potentials. These continually changing potentials make it difficult to measure true potentials and hence, make it difficult to establish proper cathodic protection system.

Stray currents can travel for miles over a network of pipelines, and whenever they leave the pipelines active corrosion may result if mitigation measures are not taken. When testing for rail-induced currents, however, it is impossible to interrupt the current to identify its source, but the pattern of the current is consistent along the pipe. In the present study, simultaneous measurements of: pipe-to-soil potential, lateral potential gradient, probe current and pipe current have been done. As shown in Figure 1, at the investigated point (denoted by A in the map), the tramway passes in parallel to the pipeline, the distance between the two structures, being approximately 10 m.

Figure 1.

EXPERIMENTAL

The measurement setup is shown if Figure 2. Data logger was used to record the pipe-to-soil the potential lateral potential gradient and the probe current. The sampling frequency was 3.33 Hz. Positive sign of the voltage gradient denotes the current flowing towards the pipeline, and the positive sign of the probe current denotes the current entering the probe. The distance between the reference electrodes was approximately 7 m. $Cu/CuSO_4$ reference electrodes were used.

Pipe current was measured by the Stray Current Mapper (SCM) device. Since the flow current along the pipeline results in an electro-magnetic (EM) field, measuring the EM field surrounding the pipeline under test by SCM yielded the pipe current. Additionally since most types of ground cover (dirt, sand, water, asphalt and concrete) do not alter EM fields, the measurements by SCM was taken from the ground level immediately above the pipeline. The SCM sampling frequency was equal to 20 Hz. Positive current shift denotes passage of pipe current in the direction from north to south (Figure 1).

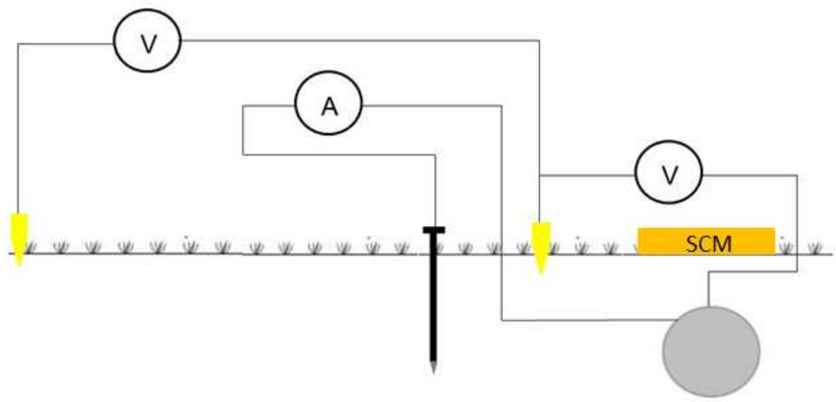

Figure 2.

RESULTS

Figure 3. shows recordings in a 20 minute period during the time of the day when the trams pass most frequently. The mean value, the standard deviation, the minimum and the maximum of the measured parameters for the whole recorded period are given in Table 1. Seven tram passes were recorded as seen from the pipe current data shown in figure 3 a). Due to the rather erratic change of the pipe-to-soil potential, the potential gradient and the probe current the influence of tram passes is not easily discernible from those data.

Figure 3 b) shows a period between 575 and 650 s where both positive and negative shifts from the baseline pipe current (arbitrarily set to approximately 0) are observed. Consequently, both cathodic and anodic shifts in pipe-to-soil potential are observed as well as the corresponding pattern of the potential gradient and the probe current, that due to the chosen polarities, mirror the pipe-to-soil potential.

Table 1.

TIME PERIOD/s	NUMBER OF POINTS	PARAMETER	MEAN	STD DEVIATION	MINIMUM	MAXIMUM
0-1190	3968	**POTENTIAL/V**	-1.3041	0.1293	-0.9058	-1.6504
		POTENTIAL GRADIENT/V	0.15798	0.12072	-0.23193	0.46753
		PROBE CURRENT/mA	0.8059	0.2872	-0.030518	1.6479

From analysis of all occurrences of tram passages, the following conclusions were drawn:

– the passage of tram is not easily discernible from the recorded potentials and pipe currents without comparison to the SCM data
– the pipe current shifts are not detected when the tram passes the measuring point but rather when it passes the end-points of the parallel conduction of the pipeline and the rails, exactly where the points of current pick-up and/or discharge would be expected
– in general, positive and negative shifts from the baseline pipe current (southward and northwards direction of pipe current) cause anodic and cathodic shifts of pipe-to-soil potential, respectively, and the corresponding shifts of potential gradient and probe current
– the shift of the of the recorded potentials and the probe current is not proportional to the pipe current alteration
– the change in the sign of the potential gradient is not followed by the change in the direction of the probe current.

a) b)

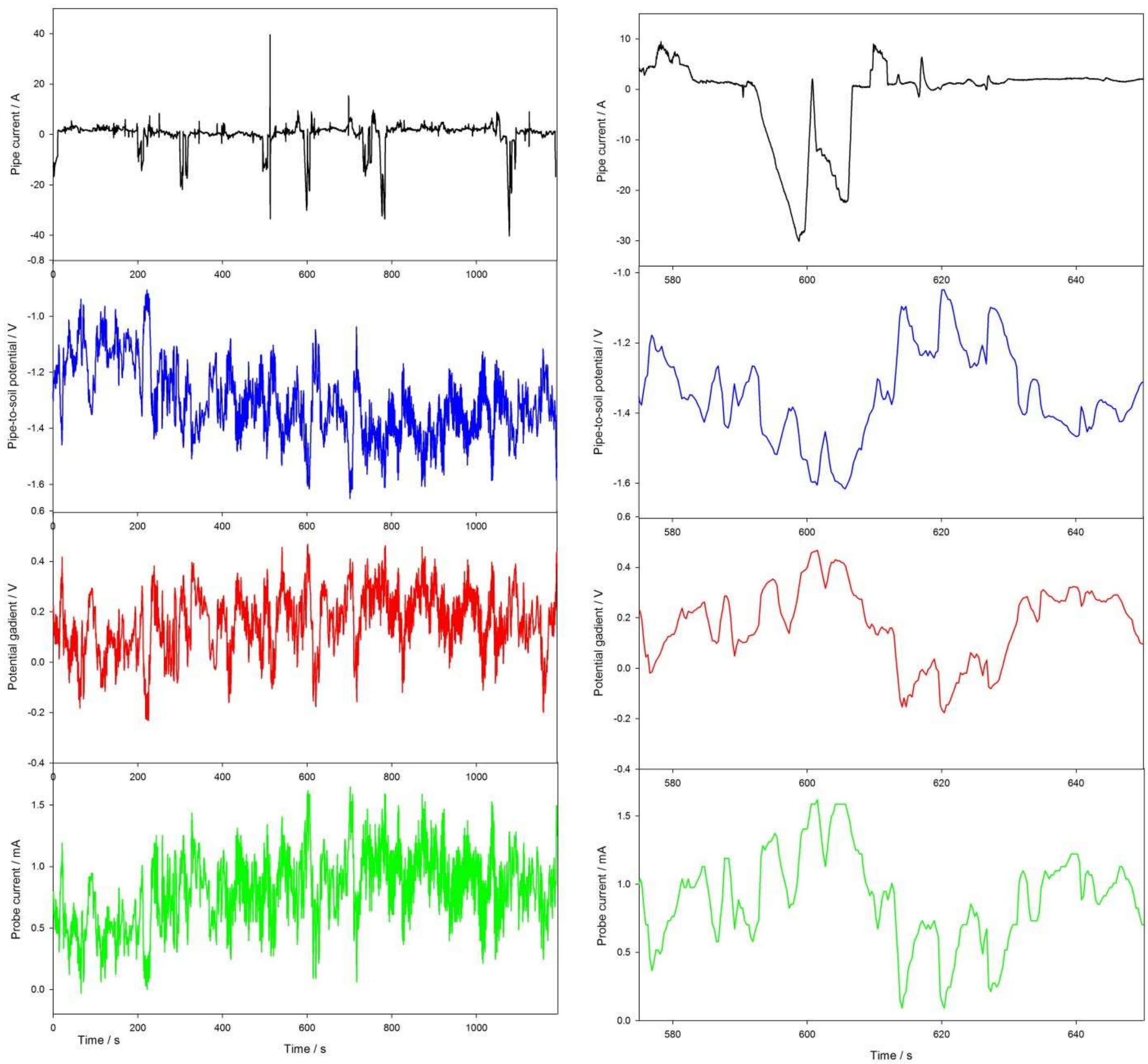

Figure 3.

It is visible form the SCM recordings showing overlapped periods of tram passes that the duration of the stray current interference is approximately 40 seconds. The magnitude and direction of the pipe current depends on the regime of movement of the tram.

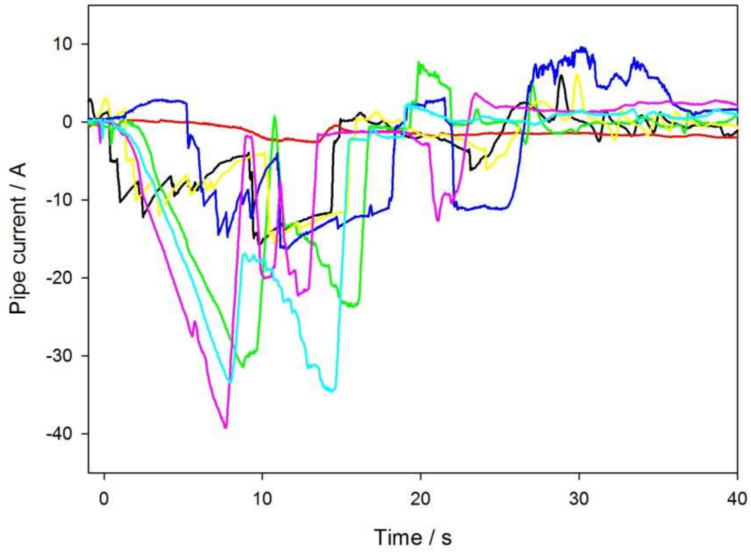

Figure 4.

Frequency plots for the pipe-to-soil potential and the probe current (expressed as time vs. measured quantity) are shown on Figure 5. The data were fitted to the modified Gaussian 5 parameter function and have passed the normality test showing that the distribution is close to normal. The corrosion likelihood may be deduced from the probe current frequency plot by calculating accumulated duration at various levels of cathodic protection and comparing the result to the current criteria in case of interference due to d.c. traction systems given in EN 50162.

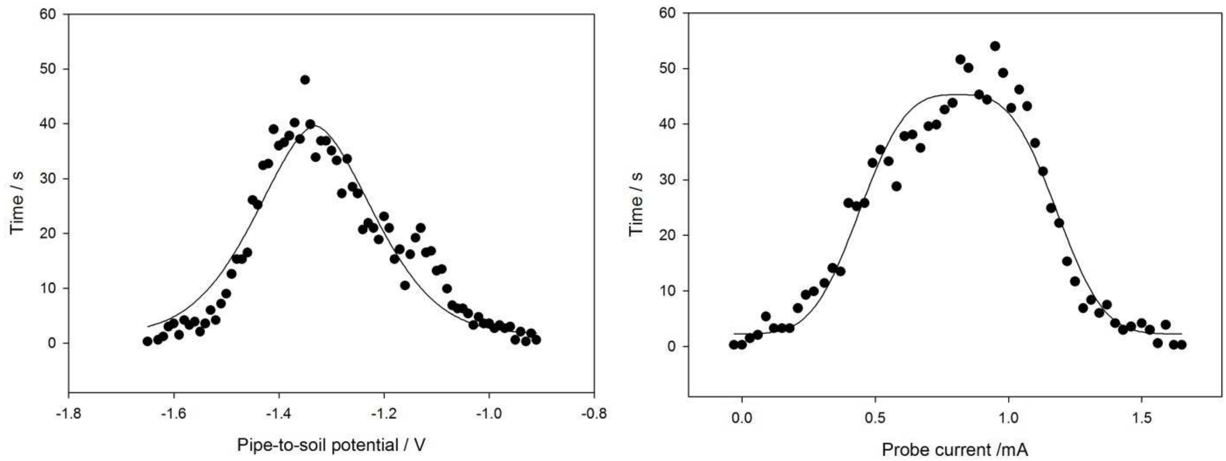

Figure 5.

From the probe current vs. pipe-to-soil potential plot (Figure 6 a) it is seen that the zero probe current is obtained at the potential of -0.926 V. This corresponds to the potential gradient of -0.151 V (Figure 6 a) and the current flowing from the pipe towards the rails. This result implies that the current flowing through the soil or the current being exchanged with the nearby structure coating defects does not equal the current exchanged with the probe.

a) b)

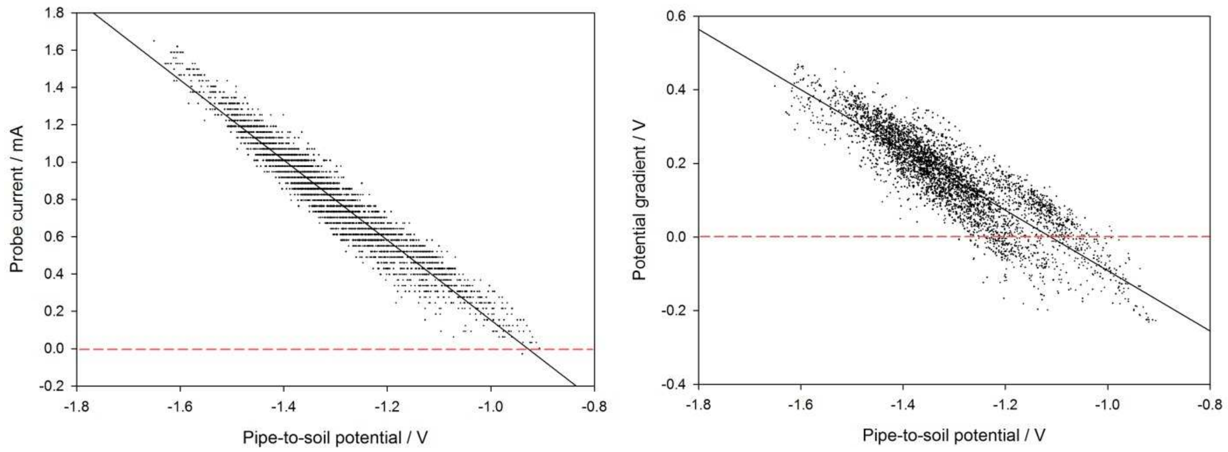

Figure 6.

The on-potential measurements contain the ohmic drop contributions. In correspondence of cathodic areas, the measured potential is more negative than the true potential at the metal-electrolyte interface and vice-versa for anodic areas. On the other hand, zero potential gradient is obtained at the pipe-to-soil potential of –1.115 V (Figure 6 a). This potential may be interpreted as the off-potential in case of the structure under the assumption of ohmic system.

CONCLUSION

Simultaneous measurements of pipe current, pipe to-soil-potential, lateral potential gradient and probe current have yielded valuable information about the dynamic d.c. stray current influence on the investigated pipeline. By visually observing the tram movement and the pipe current pattern recorded by SCM, the probable points of current pickup along the pipeline may be found. Due to the erratic variation in time of the other measured parameters, stray current interference is not easily discernible without comparison to the SCM data. Also, characteristic pattern, duration, magnitude and direction of the pipe stray current has been detected by SCM. Stray current corrosion likelihood based on this type of measurement results may present a valuable input data of the pipeline integrity management system, especially having in mind increasingly complex matrices of potential stray-current corrosion sources that have made mitigation of corrosion problems both more difficult and more important.

LITERATURE

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