Turkish Journal of Electrical Engineering & Computer Sciences

http://journals.tubitak.gov.tr/elektrik/

Research Article

Turk J Elec Eng & Comp Sci
(2013) 21: 758 – 765
© TÜBİTAK
doi:10.3906/elk-1108-13

Investigation of the telluric effects arising along the cathodically protected natural gas pipeline between Karadeniz Ereğli and Düzce

Bilal DEMİREL,[1,*] **Hayri YALÇIN**[2]

[1]Department of Materials Science and Engineering, Faculty of Engineering, Erciyes University, Melikgazi, 38039 Kayseri, Turkey

[2]Department of Chemical Engineering, Faculty of Engineering, Gazi University, 06500 Ankara, Turkey

Received: 05.08.2011 • **Accepted:** 13.02.2012 • **Published Online:** 03.05.2013 • **Printed:** 27.05.2013

Abstract: Cathodic protection is one of the most widely used applications for protecting underground and submarine metallic structures from corrosion. This method is based on providing the electrons, which metallic structures lose as a result of electrolytic reaction, by the cathodic protection system. However, from time to time, it may be possible that there is some unwanted interference input into the metallic structure in such applications. This study is aimed at ascertaining the existence, arising frequency, and magnitude of an interference called the telluric effect that is going in and out of the natural gas pipeline between Düzce and Karadeniz Ereğli in Turkey, which is 60 km in length and has a 40.64 cm diameter, and is well coated with polyethylene. In this study, the pipe/ground potential values, electrical currents coming from the anode bed, and soil resistivity values were measured at different times and regions along the pipeline. In conclusion, it was found that these changes did not arise at a certain period or at any point between the Düzce PIG and Ereğli RMS station, although it did occur strongly around the Akal Take-Off.

Key words: Corrosion, telluric effect, cathodic protection, interference

1. Introduction

Inexplicable potential fluctuations were observed during control tests followed by the process of the cathodic protection system that was applied to the natural gas pipeline, which is 40.64 cm in diameter, 60 km long, and coated with polyethylene, installed between the Düzce PIG and Karadeniz Ereğli (K.Ereğli) RMS station. This pipeline's technical parameters and routes are given in Table 1 and Figure 1, respectively.

Table 1. Technical parameters of the Düzce–K.Ereğli natural gas pipeline.

Pipeline coating resistance (ohm m^2)	50,000
Length of pipeline (m)	65,500
Surface area (m^2)	83,626
Diameter (m)	0.4064
Thickness (m)	0.0071
Cathodic protection life (years)	20

Initially, these fluctuations were regarded as arising from interference, but later, it was revealed through a literature survey that this was due to an effect called the 'telluric effect' [1]. This phenomenon, encountered on

*Correspondence: bilaldemirel@erciyes.edu.tr

the long pipelines, was regarded as being due to meteorological events, such as the magnetic field that is caused by the earth's rapid rotation around its north and south poles like a magnetic stick, the tides that are caused by the pulling effect of the moon, and the sunlight altering the strength of the magnetic field [1]. Moreover, it is thought that this effect appears in the regions consisting of rocks that are characteristically polar.

Figure 1. Düzce–K.Ereğli natural gas pipeline route.

The telluric effect is seen in different regions around the world, such as in Canada [2,3] and the Kapuni gas pipeline in New Zealand [4,5]. This line is an uninterrupted, well-coated natural gas pipeline that is 72.42 km long. It lies in the southern hemisphere's 41st latitude, from the south towards the north, and intersects a high mountain range [4]. One end of this pipeline reaches the coast where tides occur. This pipeline, with all of these characteristics, is highly similar to the K.Ereğli–Düzce pipeline.

It is necessary to know the impact time and magnitude of this effect to determine how this telluric effect, encountered on the Düzce-K.Ereğli pipeline, causes corrosion. That is why a number of studies were conducted on this pipeline. First, a recorder was connected to the rectifier unit set in the K.Ereğli RMS in order to determine at what times and for how long this impact occurs. Through this recorder, the following were measured at certain times while the system was on and the same process was also repeated when the system was off:

- Pipeline/ground potential.
- Current that is drawn from the anode bed.
- Potential fluctuations between the anode bed and the pipeline.

The pipe/ground potential values were continuously measured from different points along the pipeline within the periods in which the telluric effect occurs intensively in order to determine which section of the pipeline was affected the most.

1.1. Telluric effect

"Telluric", or earth current, is used to describe the electric currents moving underground or through the sea. For the occurrence of the telluric currents, there are a number of reasons, such as human activities, natural causes, and discrete currents. Discrete currents have a very complex interaction pattern due to being in low-frequency regions and moving over large areas of the earth [6].

There exist limited methods for exploring the structure beneath the earth's surface. Telluric and magnetotelluric methods are among them; these are used in geothermal exploration, mining exploration, petroleum exploration, ground water exploration and monitoring, etc. Use of telluric currents in the production of low voltage current through earth batteries is a useful technique that was used for telegraph systems in the United States as far back as in 1859 [6].

Telluric currents can be used in industrial prospecting activities. In such an application, in order to sense the voltage difference resulting from the oscillatory telluric currents between locations, electrodes are placed in the ground where telluric currents frequently occur. In the case of telluric currents passing through the earth's substrata, a low-frequency window can occur and the earth acts as a conductor [6].

As for the pipelines, differences in sun light intensity may cause the formation of an electrical field with low frequency. An induction current occurs along the pipelines within this electrical field. These currents are much more effective, especially on well-coated long pipelines. Interferences arising in this manner can cause corrosion on these pipelines [1,4].

It seems that there are short-term potential fluctuations on the cathodically protected pipelines. Sometimes the currents arising from the telluric effect are in one direction, and sometimes interferences may be in both directions.

To be protected from interferences arising from the telluric effect in pipelines, the installation of isolated flange over short distances is sufficient. Alternatively, grounding can be made by connecting the galvanic anodes to different parts of the pipeline [4].

Telluric effects sometimes occur due to magnetic fields caused by a variance of the sun's energy in the ionosphere [7]. The effects of such magnetic currents differ with different magnitudes and different geographic regions. The topographic structure and types of minerals may play a big role in the effect of the magnetic field [1].

Long pipelines, electric lines, metallic cables, and railways passing through these regions can cause potential changes because of the changing of the magnetic field. In the structures that are in contact with the ground (when ground structures are different from each other), transitions of the current and short-term electrical currents occur along the pipeline [1].

Telluric effect problems were encountered in the northern hemisphere, mostly at 40°N–50°N. For example, it is seen in the Orkney Islands and Shetland regions of Scotland [8].

Potential increments in a negative direction were observed in the pipeline because of the telluric effect. So far, however, such currents arising from the telluric effect have not been seen to cause corrosion on pipelines. However, it breaks the harmony of the anode–cathode current transaction in cathodic protection systems.

Sometimes, fluctuations in the potential values can be encountered in well-coated long pipelines due to the magnetic field effect. This is a result of the changes in the intensity of the earth's magnetic field [1]. The fact that the intensity of the magnetic field sometimes increases in the pipeline's direction causes a rise in the induction current in the pipelines. That the pipeline is well coated increases this effect. On the other hand, it is thought that this effect is related to the pooled effect of the earth's magnetism. In addition, that environment in a magnetic mineralogical structure causes occurrence of a magnetic field [9].

The time of the pipeline potential fluctuations and the intensity of the current passing through the pipeline can be experimentally measured by connecting a recorder to the pipeline and continuously recording the pipeline/ground potential values. Currents along the pipelines resulting from the telluric effect are short-term and may arise in different parts of the pipeline [10].

2. Experimental study

2.1. Soil-specific resistivity and humidity values measured along the pipeline

Ground resistivity values of the Düzce–K.Ereğli natural gas pipeline, measured by the method of Wenner's 4-point electrodes, and humidity values are given in Figure 2.

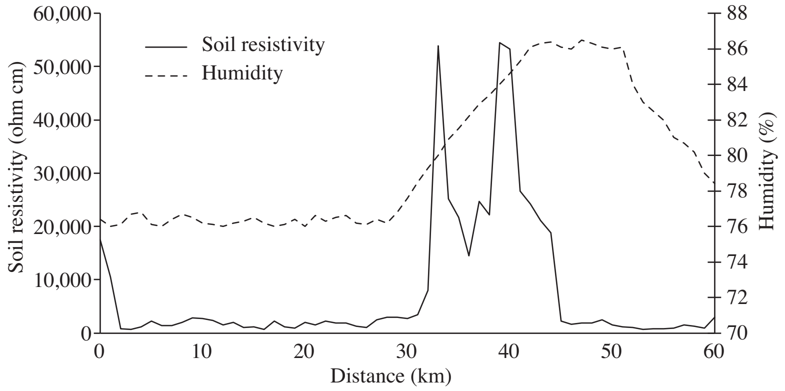

Figure 2. Soil-specific resistivity and humidity values along the pipeline.

2.2. Pipeline/ground potential values measured from certain points along the pipeline

While the pipeline was cathodically protected, the pipeline/ground potential measurements were carried out continuously at 5 test points when the rectifier system was both on and off. For the test point selections, the authors tried to choose points on the north and south of the mountain crossing. The test points are shown in Table 2. Similar tests, in which a $Cu/CuSO_4$ reference electrode was used, were carried out by Gummow and Eng [11].

Table 2. Selected stations on the natural gas pipeline between Düzce and K.Ereğli.

No.	Distance (km)	Station location
1	60 + 000	K.Ereğli RMS
2	52 + 380	Akal Take-Off
3	43 + 152	Kantar Deresi
4	28 + 736	Karabük Take-Off
5	0 + 000	Düzce PIG

2.3. Pipeline/ground potential measurement values at different locations when the rectifier system was on

The values taken from these stations are given in Figures 3–7. While taking these measurements, the rectifier unit value was set to –1200 mV. In addition, the potential values measured at the Akal Take-Off and Kantar Deresi stations were compared with each another while the rectifier unit was set to –1200 mV and when it was off, as seen in Figures 8 and 9.

2.4. Pipeline/ground potential measurement values when the rectifier system was switched off

While the rectifier was switched off, the pipeline/ground potential changes were recorded by a recorder connected to the connection point of the rectifier and the transformer unit that is located at the K.Ereğli RMS station. In this case, the pipeline potential values taken from the recorder are given in Figure 10.

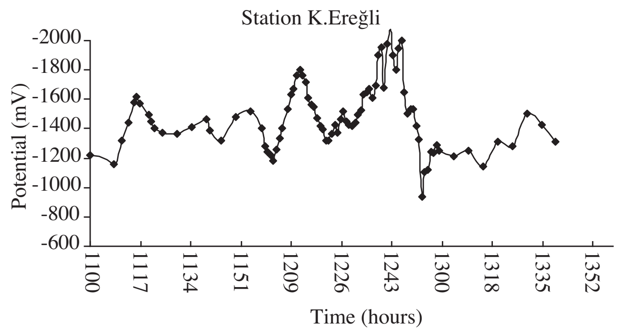

Figure 3. Pipeline/ground potential values at the K.Ereğli station when the rectifier was on.

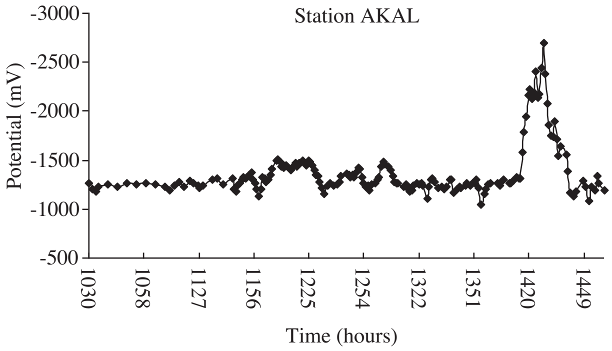

Figure 4. Pipeline/ground potential values at the Akal station when the rectifier was on.

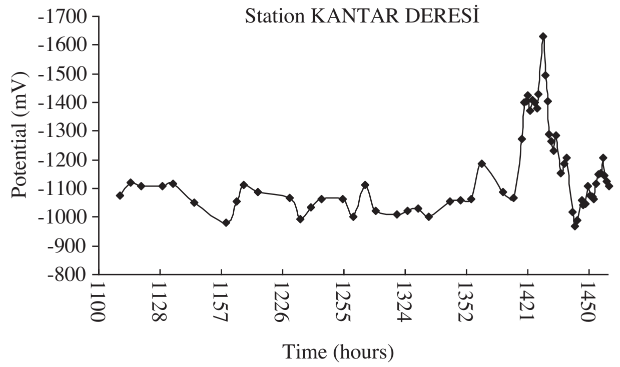

Figure 5. Pipeline/ground potential values at the Kantar Deresi station when the rectifier was on.

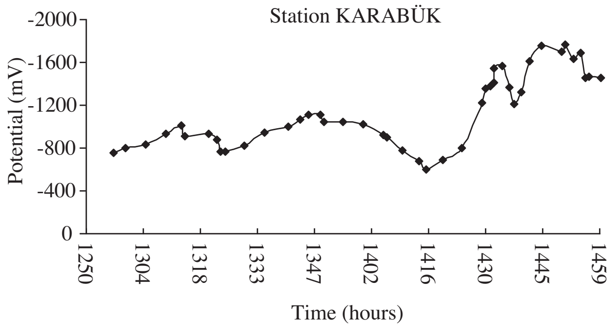

Figure 6. Pipeline/ground potential values at the Karabük station when the rectifier was on.

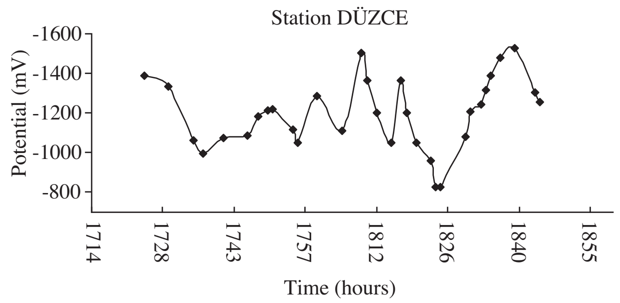

Figure 7. Pipeline/ground potential values at the Düzce station when the rectifier was on.

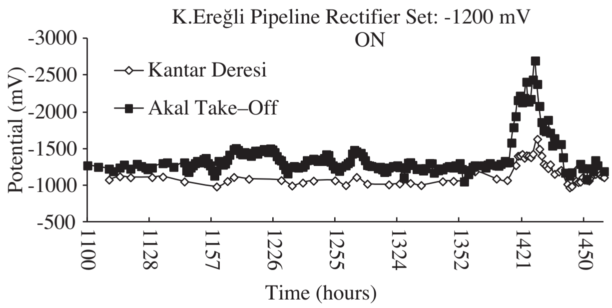

Figure 8. Comparison of the pipeline/ground potential values between the Kantar Deresi and Akal Take-Off stations when the rectifier setting was –1200 mV.

2.5. The difference in the pipeline/ground potential when the rectifier system was switched on

All of the measurements done while the rectifier was switched off were repeated when the rectifier was switched on. The values taken from the recorder are given in Figure 11.

3. Results

The following outcomes were achieved from this study conducted on the cathodically protected natural gas pipeline between Düzce and K.Ereğli. For the first 2 days, when the rectifier system was switched on, the pipeline/ground potential values were measured by both a recorder located near the rectifier system and manually from certain points along the pipeline for certain time periods. The same process was repeated for the following 2 days when the rectifier was switched off. The obtained results are given in Figures 10 and 11.

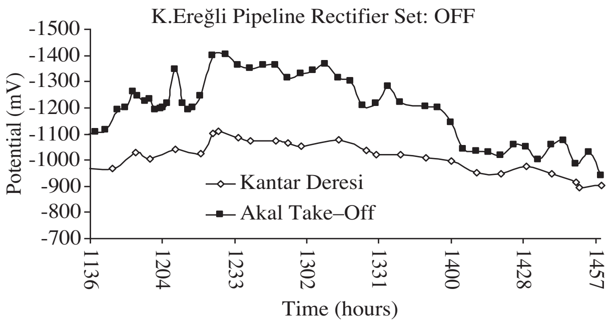

Figure 9. Comparison of the pipeline/ground potential values between the Kantar Deresi and Akal Take-Off stations when the rectifier setting was off.

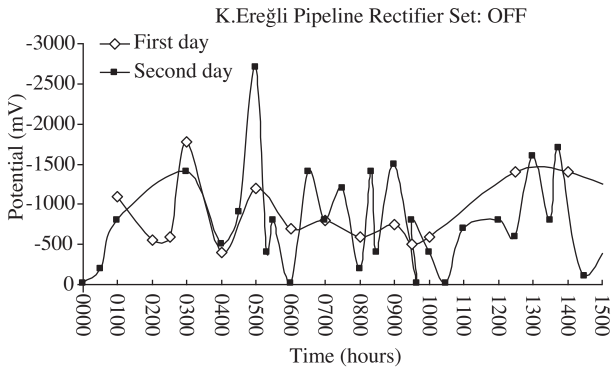

Figure 10. Comparison of the pipeline/ground potential values to days at the K.Ereğli station when the rectifier setting was off.

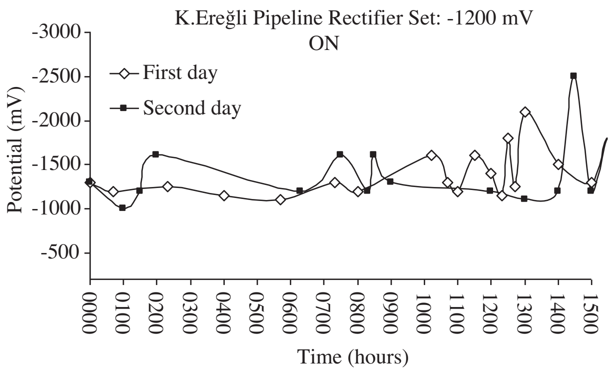

Figure 11. Comparison of the pipeline/ground potential values to days at the K.Ereğli station when the rectifier setting was set to –1200 mV.

As seen in Figures 10 and 11, the telluric effect did not occur within a certain period. Short-term potential changes occur along the pipeline at different times of the day and these impacts cause the increment of the pipe/ground potential, both positively and negatively. Both the magnitude and the direction of the potential increase do not periodically occur during the day.

The potential changes were minimum around Kantar Deresi (–1700 mV), whereas the maximum potential changes were observed around the Akal Take-Off (–2700 mV) (Figure 4). The reason for this phenomenon is thought to be that soil resistivity values of Kantar Deresi are significantly higher than those of the Akal Take-Off; however, the distance between both locations is nearly 10 km. The telluric effect incident was also seen all along the pipeline from K.Ereğli to Düzce, as seen in Figures 3–7.

During the study, when the rectifier system was on, it was observed that the pipeline/ground potential values fluctuated between –600 mV and –2700 mV. In general, except for these extreme points, the pipeline/ground potential values have been measured to be between –1200 mV and –1600 mV. This is due to the fact that the rectifier automatically adjusts the pipeline/ground potential value to –1200 mV. When the pipeline/ground potential value increased to over –1200 mV, the rectifier system automatically stopped feeding the current. Therefore, the potential values were not affected by the potential increments.

When the rectifier system was switched on or off, the same trends in the pipeline/ground potential values were observed in the locations close to each other, as shown in Figures 8 and 9. When the pipeline/ground potential was –1200 mV, the current was from the pipeline to the anode bed. However, when the potential values dropped down to –1200 mV, the current flowed in the opposite direction. When the rectifier unit was switched off, the pipeline/ground potential values became inconstant and were found to vary continuously between positive values and –2700 mV (Figure 10).

This study proved that the natural gas pipeline between Düzce and K.Ereğli included interference currents caused by the magnetic field effect from time to time. The pipeline/ground potential values showed that the aforementioned magnetic field strength changes over short periods, as presented in Figures 10 and 11. The fact that the pipeline is 60 km long in a single piece, well-coated, and of high quality makes the induction current generation by magnetic field easy.

If the average potential values and average humidity values along the pipeline stations are considered, the graph in Figure 12 is obtained, where it can be seen that the potential values follow the humidity curve. Both of these curves have local maxima near the station at Kantar Deresi and the AKAL Take-Off. In addition, these peaks may be due to the increasing soil resistivity between 40 and 50 km, as shown in Figure 2.

The potential values at the K.Ereğli station when the rectifier was set to –1200 mV were taken on 3 different days, between 0000 and 1500 hours. These values are shown in Figure 13, where it can be seen that the magnitudes of the oscillation are not greater than 500 mV and the average values of the 1st, 2nd, and 3rd day are –1372, –1371, and –1392, respectively. These results show that the average values of the potential values do not change considerably on different days.

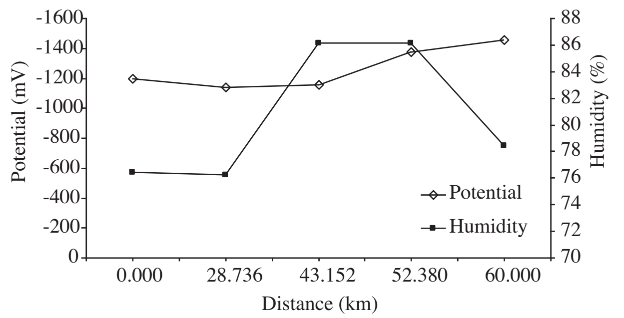

Figure 12. Average potential and humidity values at the stations along the pipeline.

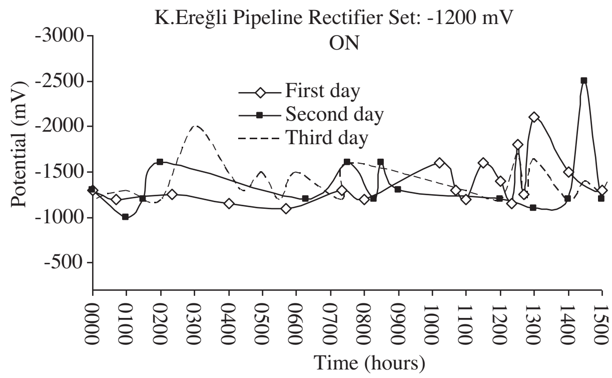

Figure 13. Pipeline/ground potential values at the K.Ereğli station over a 3-day period when the rectifier was set to 1200 mV.

4. Future work

In order to determine the magnitude of the current occurring along the pipeline, the current's measurements should be taken from certain points. Based on these measurements, the current's direction can be determined, and thus the required cathodic protection can be done effectively.

Acknowledgment

We would like to express our gratitude to the BOTAŞ Petroleum Pipeline Corporation, Turkey, for its valuable contribution to our experimental study. The measurements carried out on the Turkish natural gas pipeline were done with the help of Özcan Nerse from BOTAŞ Petroleum. Hence, our special thanks go to him for both his great technical support and his interest in this study.

References

[1] D.H. Boteler, R.J. Pijola, H. Nevanlinna, "The effect of geomagnetic disturbances on electrical systems at the Earth's surface", Advances in Space Research, Vol. 22, pp. 1–21, 1998.

[2] N.J. Allison, W.E. Huddleston, "Extraneous currents noted on large transmission pipe line system", NACE International - The Corrosion Society, Vol. 8, p. 1, 1952.

[3] W.H. Campbell, "Induction of auroral zone electric currents within the Alaska pipeline", Pure and Applied Geophysics, Vol. 116, pp. 1143–1173, 1978.

[4] J. Morgan, Cathodic Protection, Houston, NACE International, 1987.

[5] T.G. Proctor, "Experience with telluric current interference in the cathodic protection of a buried pipeline in New Zealand", Materials Performance, Vol. 13, pp. 6–24, 1974.

[6] Wikipedia, "Telluric current," at http://en.wikipedia.org/wiki/Telluric_current, accessed on 18 December 2011.

[7] R. Pirjola, A. Viljanen, A. Pulkkinen, J. Amm, "Space weather risk in power systems and pipelines", Physics and Chemistry of the Earth Part C, Vol. 25, pp. 333–347, 2000.

[8] A. Ashworth, C. Googan, Cathodic Protection Theory and Practice, West Sussex, Ellis Horwood Ltd., 1993.

[9] L.L. Shreir, Corrosion Control, London, Newness-Butterworths, 1972.

[10] A.W. Peabody, Control of Pipeline Corrosion, Houston, NACE International, 1967.

[11] R.A. Gummow, P. Eng, "GIC effects on pipeline corrosion and corrosion control systems", Journal of Atmospheric and Solar-Terrestrial Physics, Vol. 64, pp. 1755–1764, 2002.