STRAY CURRENT DETECTION AND CORRECTION

Author: Elizabeth Nicholson, B. Eng

Cathodic Technology Ltd, Bolton, Ontario, Canada

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1. Abstract

Stray currents can impact the ability to protect a pipeline or other buried metallic structure from corrosion. They can be generated from a variety of manmade and natural sources. Common sources of stray currents are cathodic protection on other lines, DC transit systems and telluric activity. Detecting these stray currents is done by deploying stationary data loggers to monitor the pipe to soil potential over an extended time period. Dynamic stray currents can affect the pipe to soil readings used in CIPS surveys to analyze the effectiveness of the cathodic protection system. By using GPS synchronization between the current interrupter, CIPS survey instrument and stationary logger, the time stamped data from the logger can be used to correct the CIPS data for the influence of the stray currents. Once the source and magnitude of the stray currents are found, mitigation measures can be put in place if necessary to protect the pipeline.

2. Introduction

Stray currents are caused by sources of current flowing through unintended paths. These can have significant effects on buried pipelines and other metallic structures. Water combined with dissolved minerals, such as in soil, becomes conductive and allows the conduction of current. This is important to the pipeline operator as these stray currents can initiate and/or accelerate the corrosion of a pipeline. It is important to the pipeline operator to determine whether stray currents are affecting the pipeline and then define the probable source of the stray current. The stray currents will affect the effectiveness of any cathodic protection system on the pipeline. Test station readings and close interval survey data can be distorted by stray currents. Once the extent of the stray currents has been identified, mitigation strategies may be necessary to protect the pipeline.

Stray current is particularly destructive at the location the current leaves the pipeline. This creates a localized anodic area on the pipeline which can overcome the cathodic protection applied. Often these areas are in close proximity to the generator of the stray currents or at a holiday in the coating or at a crossing of lines. There are two types of stray currents, static and dynamic. Static stray currents maintain a steady current flow and are often from other cathodic protection systems on pipelines or other structures. Dynamic stray currents fluctuate over time and can come from natural or manmade sources.

3. Sources of Stray Current

Static stray currents are common where one pipeline is in close proximity to another. The cathodic protection current from one line can travel through the soil and be picked up by another pipeline. Where the line is picking up current, it can provide extra cathodic protection. The area of concern is where the current leaves the line, as this can cause an electrochemical corrosion cell. In a simple world, this point would be the crossing of the two lines, where they are closest together. However, the real world can be a bit more complicated. In congested areas, the stray current can move on and off of multiple pipelines before returning to the source line. In other cases, the current can flow through a layer of low resistance soil to return to the source. Another factor influencing where the current discharges is the coating of the pipeline. On a well coated line, there are few holidays to allow for current flow. The point of discharge can be at the point where the holiday is, rather than where the lines are in close proximity. Depending on the complexity of the area, a variety of tests may be required to determine the extent of the stray current influence.

Dynamic stray currents are caused by both manmade and natural sources. The most common manmade source is DC transit systems. As urban areas build up, public transit is expanded and often comes in close proximity to buried pipelines. Water mains in the same urban areas can be highly affected. DC transit usually transmits the power through overhead lines or a third rail and completes the circuit by returning through the rails. These rails are never perfectly isolated from the ground and some of the current leaks into the ground and onto any pipelines or other metallic structures in the ground. These currents are driven by the subways and streetcars running on the tracks. As the car moves along, it causes a moving localized current source. Mining operations may have a similar setup.

Other sources of manmade stray currents are welding operations as they sometimes ground their welding equipment to the ground. Overhead AC and DC transmission lines can also induce current onto the pipeline. More study is being done on the influence AC transmission lines have on buried metallic pipelines. All buried metallic items such as conduit and cable can pick up and discharge current to another structure.

Natural stray currents are caused by tellurics, the fluctuations in the earth's magnetic field. The sun is the main source of tellurics on the earth as sunspot activity and flares can cause large fluctuations. The most common telluric phenomenon the public is familiar with is the aurora borealis, or northern lights. Telluric activity is most often seen in pipelines that are away from the equator and are aligned in a north-south direction, not east-west. Telluric activity does not seem to increase or decrease the corrosion on a pipeline; however, it can cause major errors in reading pipe to soil potentials. Figure 1 shows the telluric effect on a pipeline as logged by a Cath-Tech Smart Logger.

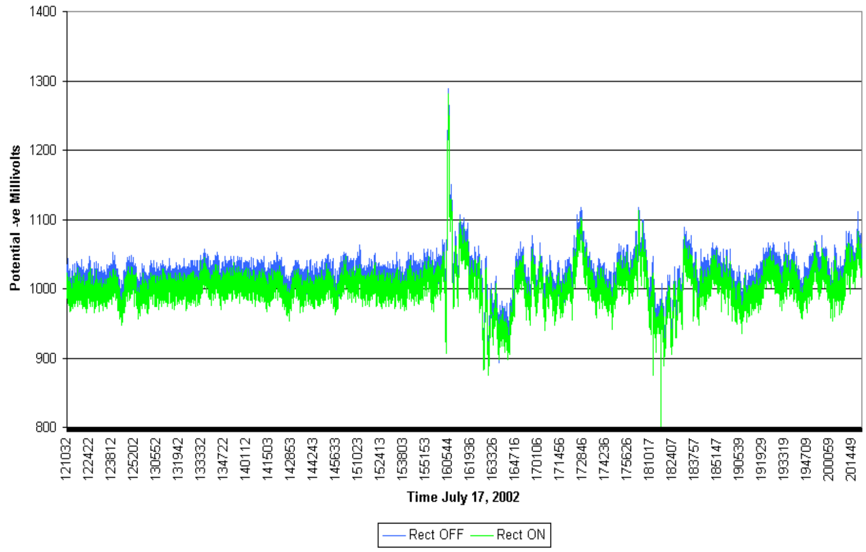

Fig. 1 - Telluric Interference

All sources of stray current can have an effect on the pipeline. At the point where the current enters or leaves the pipeline, it can cause accelerated corrosion in the local area. Stray currents also affect different metals in different ways; lead can be damaged at both the pickup and discharge areas, while iron and steel are usually only affected at the discharge area. Besides the potential for accelerated corrosion, the stray currents can also significantly affect any pipe to soil readings. These can create an error in the readings, making the pipeline appear to have better or worse cathodic protection than it actually has. This should be taken into account in every analysis of any pipe to soil potential data.

4. Detecting Dynamic Stray Currents

The best way to detect dynamic stray currents is to place a stationary data logger to record the pipe to soil potentials over time. In the past paper tape chart recorders were used. Now most recorders are electronic, allowing the data to be stored and analyzed on the computer. Placing stationary loggers at multiple points for hours or days allows for the detection of stray currents. To simply monitor the pipeline for dynamic stray currents, a small logger such as the one shown in Figure 2 can be used to take readings at a specified interval. This can be reviewed to detect the scope of the stray current and the area affected.

Fig. 2 - Small Stationary Logger, Cath-Tech MiniLogger

5. Correcting CIPS for Stray Currents

Close Interval Potential Surveys (CIPS) are widely used to monitor the level of cathodic protection on a pipeline. The goal of the survey is to measure the instant off potential, which minimizes any effect from the other resistances in the circuit. The difference between the on potential and the instant off is called the IR drop. CIPS is accomplished with two types of survey gear, current interrupters and a specialized mobile data logger as shown in Figures 3 and 4. All the equipment is synchronized using the global positioning system (GPS) time signal to trigger the current interruption. This allows for fast survey cycles; a typical example being 200ms off, 800ms on for a total 1 second cycle. This allows the surveyor to take one reading per second and progress down the pipeline at a walking pace. The surveyor takes the pipe to soil potential readings by walking the line with half cells and a trailing wire connecting him to the nearest test station.

Fig. 3 - GPS Synchronized CIPS Survey Equipment, Cath-Tech Hexcorder

Fig. 4 - GPS Synchronized Current Interrupter, Cath-Tech CI-50

Fig. 5 - Stationary Data Logger, Cath-Tech SmartLogger

When performing a CIPS survey, an accurately synchronized data logger is required as shown in Figure 5. Dynamic stray currents affect both the on and off readings, so the logger must be capable of logging both values at the correct time, exactly coordinated with the CIPS survey instrument. Both the logger and the CIPS instrument must record the universal time coordinate (UTC) time stamp. This allows for correlation of both data sets later. The logger should be placed within the area expected to be surveyed. Common practice is to place the logger at a test station in the middle of the particular section to be surveyed each day. Stray currents change with distance, so it is best to keep the logger near the surveyor if the both sets of data are to be used together for analysis of the CIPS data.

Through using the GPS synchronized data from CIPS and the logger, the CIPS data can be corrected by removing the dynamic stray current effects. This gives a more accurate pipe to soil reading as it removes the influence by external interference. The correction can be accomplished in a spreadsheet or database program. A correction factor is calculated from the stationary logger data that is then applied to the CIPS data. The on and the off values are calculated separately. The correction factor is calculated by finding the average of all the entries for the day, then finding the difference between each reading and the average. For each CIPS reading, the time stamp is used to find the correction factor from the logger data and then added or subtracted as necessary. There will be a different correction factor for the on and the off readings. It is very important to have a stationary logger with the same GPS synchronization and set up to ensure that the readings are taken the same way at the same time. This will not eliminate all the interference from the data, as the logger is stationary while the CIPS instrument is in motion, but it will improve the validity of the data obtained.

Figures 6 through 8 show the stationary data, CIPS data and corrected data. Figure 6 is the results of a stationary SmartLogger placed during a survey of a gas line. The spikes are likely from a nearby DC subway system. The CIPS data is shown in Figure 7. There are significant fluctuations shown in the data. A time based correction factored is calculated from the stationary logger data and applied to the CIPS data with the final results shown in Figure 8. As can be seen in the graphs, the data shown in Figure 8 has significantly less fluctuation than Figure 7.

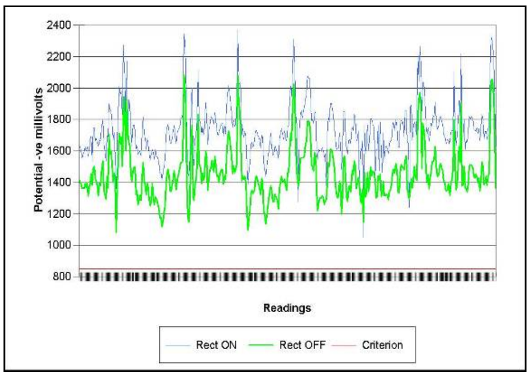

Fig. 6 - Stationary Logger

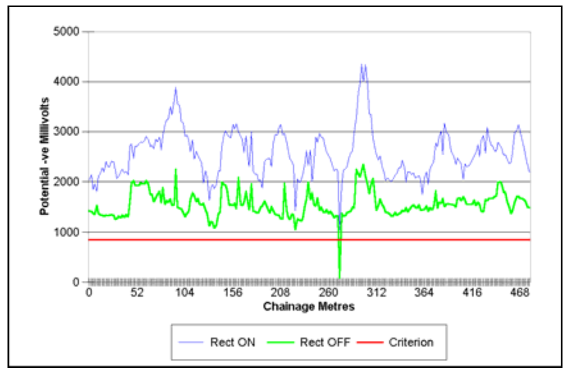

Fig. 7 - CIPS Data

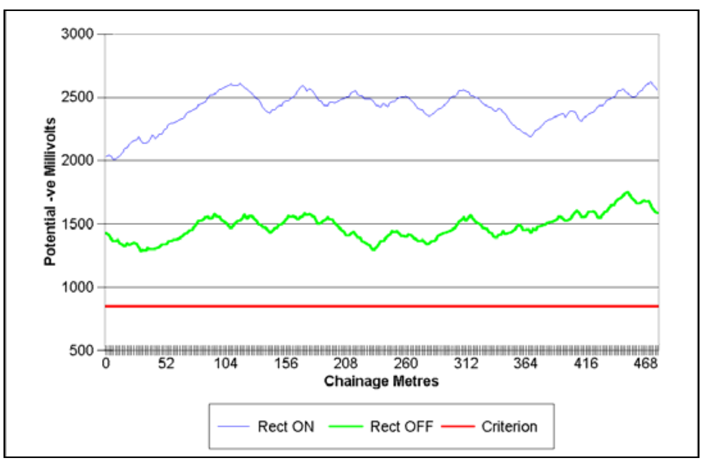

Fig. 8 - Final Corrected CIPS Data

This correction method works for sources of dynamic stray current, both manmade and natural. By looking at the stationary logger data, the source of the stray current can sometimes be identified. For example, if there are regular spikes in the voltage at 15 minute intervals, local mass transit schedules should be checked. When the readings seem to be random, sunspot activities should be investigated. Further investigation for the source of the stray currents can be done with the cooperation of other potential parties. Loggers can be set out to monitor for longer periods to see if there are any changes to the level of activity during overnight periods or on weekends.

6. Detecting Static Stray Currents

Stray currents from other static sources such as another cathodic protection system can be detected using GPS synchronized equipment. The potential current source is interrupted, then the suspected area of interference is surveyed with CIPS. If there is no interference, there should not be any difference between the on and off readings. Where there is a current pickup point, the pipe will show an on reading higher than the off. Where there is a current discharge point, the on readings will go below the off readings. Figure 9 shows current discharge from 0 to 800 feet. Note that the on potential is more positive than the off, indicating that current is leaving the pipeline in this section.

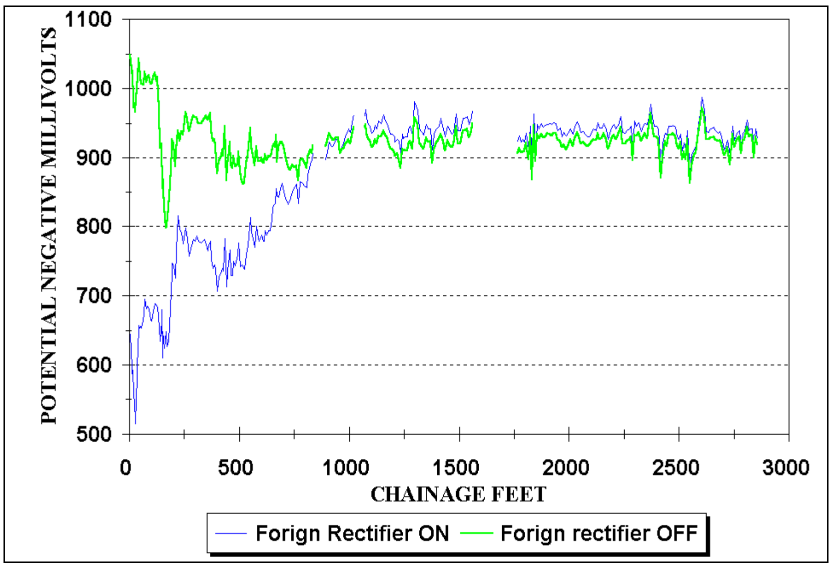

Fig. 9 - Graph of CP Interference

In areas with multiple pipelines and potential cathodic protection sources, these tests need to be coordinated with the cooperation of all parties. Only one potential source of stray currents should be interrupted at a time to allow for identification of each specific source of the stray currents. Depending on the area affected and the amount of current involved, mitigation measures may be necessary.

7. Mitigation

Depending on the amount of stray current involved, mitigation measures may be necessary. There are a variety of options depending on the source and type of stray current. All measures try to create a preferred path for the current to discharge from the structure without causing harm. Where areas of stray current interference are identified, it is important to have test stations available to monitor the stray current and the effect of any mitigation strategies. It is best to place these test stations as close as possible to either the point of closest proximity to the source or to the point of crossing. Care should be taken so that the test point is in an accessible and safe location. For example, if the crossing is in the middle of a farmer's field, best practice is to run the wires for the test point from the point of crossing to the field boundary and install the test point there.

As usual, the first layer of defence against corrosion is to ensure that there is a good coating on the pipeline. A good coating prevents the pickup or discharge of stray currents from the pipeline. In some cases, electrical shielding can be installed in between the pipeline and the stray current source. For DC mass transit, the shielding between the rails and the ground can be improved. This can be of benefit to the transit system as well, as better shielding can reduce power consumption.

The two common mitigation strategies for interference between cathodic protection systems are sacrificial anodes and bonds. Sacrificial anodes are attached to the interfered with line at the point of discharge and laid parallel to the line. This allows the current to flow from the line to the anode and then discharge, creating a situation where the anode sacrifices itself. This can be the preferred method for many pipeline operators as the only direct connection is to their line. When these anodes are installed, it is important to have a test station where the anode leads are connected to the pipe lead for future monitoring. The second method involves installing a resistive bond between the two pipelines. The resistance of the bond must be adjusted to return the potentials of the interfered with line to usual levels. Any time the cathodic protection level of either pipeline could be disturbed, the bond must be recalibrated.

Fig. 10 - Diode Installed Between Pipeline and DC Transit System

Dynamic stray currents require a slightly different approach due to the fluctuation of the current. In the case of a DC mass transit system, the same point on the pipeline can be a point of both pickup and discharge depending on the location and movement of the transit vehicle. Because of this fluctuation, any connection between the pipeline and the transit system must restrict the current flow to one direction. This can be accomplished by installing diodes or relays in the bond between the two. A diode to mitigate stray current between DC transit and local pipelines is shown in Figure 10. Another option is to use electrolysis rectifiers that respond to the dynamic current in the area to provide the cathodic protection.

8. Conclusions

Stray currents can have a wide range of effects on a pipeline, the most harmful being the creation of localized electrochemical corrosion cells that attack any buried metallic structure. It is important to detect the area and magnitude of the stray currents and identify the source. Stationary loggers are used to detect any fluctuations in pipe to soil potential over time. Stray currents can come from both manmade and natural sources and can produce static or dynamic stray currents. By using GPS synchronized survey equipment, dynamic stray current influence can be corrected for when performing CIPS surveys. Static stray currents from foreign cathodic protection sources can be detected by interrupting the cathodic protection source and performing CIPS on the affected area. Depending on the magnitude and influence of the stray currents, mitigation measures may need to be implemented to prevent further damage to the pipeline. It is important for the corrosion engineer to be aware of the potential source and impact on the pipeline in order to make informed decisions.

9. References

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