"BENEFIT OF APPLYING POLARIZATION CRITERION" CASE HISTORIES

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Abstract

Many types of surveys are conducted over pipelines to determine the status of cathodic protection to a polarized potential (-850 mV_{CSE}) criterion and sub-criterion sections are then identified. One option to meet criterion is to increase the cathodic protection current to the sub-criterion section until the polarized potential criterion is met. There are times however when the capacity of the cathodic protection system is exceeded thus additions to the cathodic protection system are necessary. Before this expense is incurred, another option is to conduct a depolarized potential survey and calculate the amount of polarization that has occurred to compare it to the polarization criterion of 100 mV. The benefit of considering the last option before automatically increasing the cathodic protection capacity is demonstrated.

Introduction

A theory of cathodic protection (CP) was offered by Mears and Brown in 1938 "… *in cases where corrosion is entirely electrochemical in nature it is necessary to polarize the cathodes in the corrosion cell to the open circuit potential of the local anodes in order to obtain complete cathodic protection*" (See Figure 1). The application of additional current beyond that point only serves to polarize the original corrosion cathode and anode and is unnecessary. In practice this may be necessary for the distribution of the required current to remote locations.

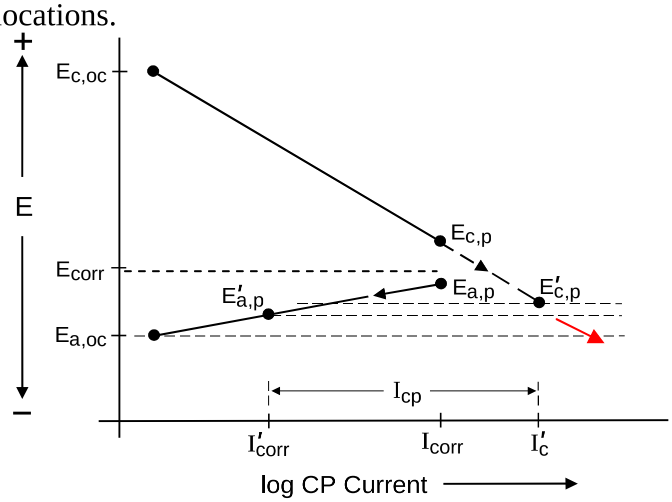


Figure 1: Evans Diagram for Corrosion Cell and Cathodic Protection
Source NACE CP-3 Manual

If it were possible to measure the potentials of all the corrosion anodes then the most electronegative anode potential would become the criterion for cathodic protection of that structure. This, of course, is impractical as the free corroding structure-to-electrolyte potential (Ecorr) actually measured is a mixed potential of the potentials of the corrosion anodes and cathodes. It therefore becomes necessary to have a surrogate criterion to indicate when cathodic protection has been established.

Proof that no corrosion is occurring on the structure at a given potential can be considered as a surrogate criterion such as in-line inspection however this requires time and the risk of corrosion occurring in the meantime. In the absence of this proof, there are criteria based on polarization offered in CGA-OCC-1-2005[1] supported by CSAZ662-2007[2], in NACE SP-0169[3] and ISO 15589-1[4].

One criterion for steel is a polarized structure-to-electrolyte potential that is equal to or more electronegative than -850 milliVolts (mV) when referenced to a copper-copper sulfate electrode (CSE). This potential is normally measured at the instant that all influencing current sources are interrupted. Another method is to take an "on" potential with all current sources operating and then at each reading location, subtracting a known or calculated IR drop due to the current in the soil. This method is often erroneously called a -850 mV_{CSE} "on" criterion however in fact it is the "on" potential minus IR drop that must be more equal to or more electronegative than -850 mV_{CSE}[5-7] or essentially it is another method to determine a polarized potential

Another criterion is polarization in the amount of 100 mV that can be measured in formation or decay. When measured in formation, the free corroding potential (Ecorr) is recorded and then current is applied. After time is allowed for polarization, the current is interrupted and an "instant off" potential is measured. The difference between the "instant off" potential and Ecorr is the amount of polarization that occurred. When measured in decay, an "instant off" potential is first measured and then the influencing current sources are left off to allow the system to depolarize. The difference between the "instant off" and the depolarized potential is the amount of polarization as measured in decay.

If Ecorr or the depolarized potential is less electronegative than -750 mV_{CSE} then the 100 mV polarization criterion will be met before the polarized potential criterion. Otherwise the polarized potential criterion will be achieved with less current.

The measurement of a polarized potential survey can be completed in one survey while polarization must be completed in two separate measurements at the same locations therefore a polarized potential survey is by far the most popular. For this reason the benefit of using the polarization criterion is often overlooked and additional cathodic protection equipment is installed when a polarization criterion is already achieved.

"Where a system consists of mixed metals, the 100 mV of polarization must be applied to the metal with the most electronegative Ecorr, (the most active metal) receiving cathodic protection and not to the mixed metal potential. When it is impractical to measure the most active metal potential, this criterion can not be used."

This benefit is demonstrated on two vary different piping configuration.

CASE HISTORY 1 – CLOSE INTERVAL SURVEY (CIS) OF HIGH PRESSURE GAS TRANSMISSION LINE

BACKGROUND

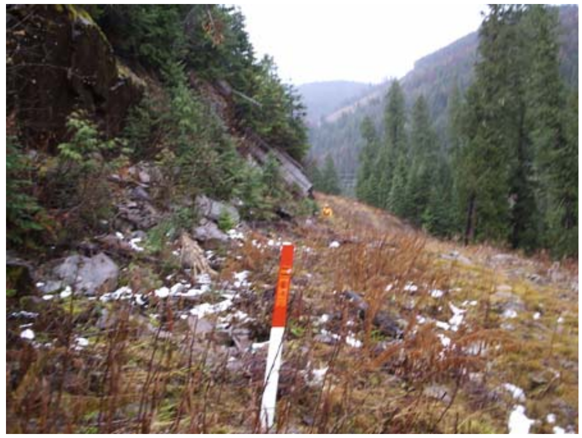
The pipeline was constructed in 1958 with an asphalt tar coating in very rocky and mountainous conditions. Although it was sand padded to protect the coating, the sand has been washed away with water running down the trenches on steep slopes therefore severe coating damage has occurred.

Although cathodic protection was achieved initially, the current required for cathodic protection has increased significantly over they years as the coating deteriorated requiring the addition of new rectifier and anode bed sites. Suitable anode bed sites are at a premium along this pipeline route due to the terrain and lack of available power.

Due to the extreme attenuations in potentials at coating "holidays" a test station survey does not provide adequate information on the status of cathodic protection. A close interval structure-to-electrolyte potential survey (CIS) must therefore be conducted for this purpose. The annual test station potentials can then related to the results of the CIS.

PIPELINE SURVEY PROCEDURE

Due to the rocky soil conditions a "walking-cell" method was impractical as this method requires that one reference be in contact with the soil at all times. A single reference electrode was used and the soil contact was made between rocks in a till type soil. The surface conditions are illustrated by the photo in Figure 2.



Figures 2: Typical Pipeline Terrain Conditions

At the next pipeline contact (test station), the potential to the trailing wire was compared to the potential at the new location to note the amount of voltage drop in the pipeline due to the return cathodic protection current. Where required a correction was made for this error.

All rectifiers were interrupted for the first pass where the "on" and "instant off" structure-to-electrolyte potentials were captured by a datalogger. When this pass was completed, any pipeline segments that did not meet the -850 mV_{CSE} polarized potential criterion were identified.

The rectifiers were then turned off and the rate of depolarization was tracked. The change in potentials became insignificant after 2 to 3 days and a depolarized structure-to-electrolyte potential survey was conducted.

The "on", "instant off" and "depolarized potentials" were then plotted using a computer program as shown by the top three profiles in Figure 3. The program also calculated the amount of polarization and then plotted it to a separate scale as shown at the bottom profile in Figure 3.

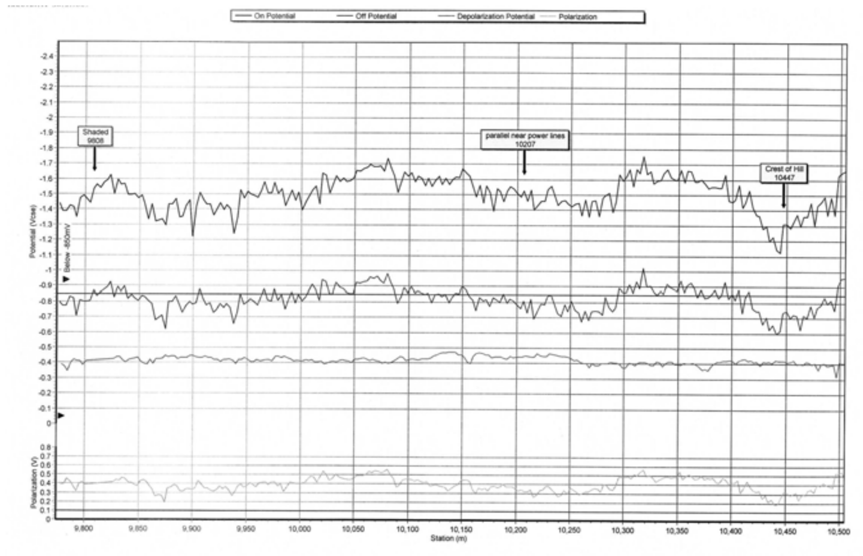


Figure 3 Typical CIS Plot

RESULTS OF PIPELINE POLARIZED POTENTIAL SURVEY

The pipeline originally was considered as meeting the polarized potential criterion but over time the potentials have become less electronegative. The results of the polarized potential (“instant off”) survey are given as an example.

An approximate 23 kilometer segment of pipe is located in a remote mountainous terrain with few power lines therefore suitable anode bed locations are scarce.

There were multiple sections totally 15.1 km in this segment that did not meet the polarized potential of -850 mV_{CSE} (Figure 4). The cause in each case is due to deteriorated pipeline coating.

Since the pipeline coating is extremely poor, the attenuation of potentials along the pipeline is high thus several current drain points are required to distribute the current along this relatively short section of pipeline. To upgrade the cathodic protection system for all segments to meet the polarized potential criterion under these terrain conditions a minimum of four (4) additional anode beds would be required. It has already been established that suitable locations for anode beds do not exist in this segment therefore extreme and costly measures will be necessary to achieve the polarized potential criterion. The other options are to test for another criterion or to recoat.

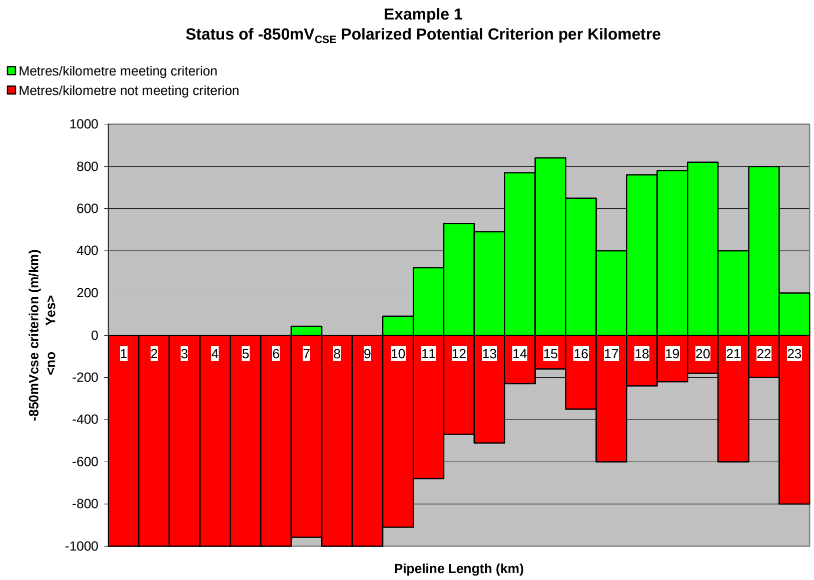


Figure 4 Case History 1, Status of -850 mV_{CSE} Polarized Potential Criterion per Kilometre

RESULTS OF PIPELINE DEPOLARIZED POTENTIAL (POLARIZATION) SURVEY

Using the results of the first pass CIS and comparing the "instant off" potentials with the second pass "depolarized" potential the amount of polarization was calculated by the difference of the two potentials. The calculated polarization data revealed that only 0.395 kilometres failed to meet the 100mV of polarization criterion.

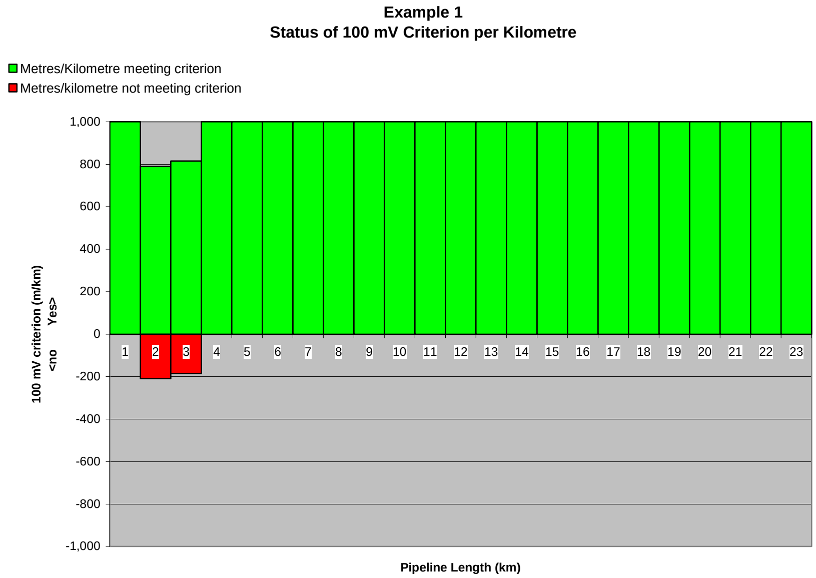


Figure 5 Case History 1, Status of 100mV Polarization Criterion per Kilometre

CASE HISTORY 2 – END POINT SURVEY ON DISTRIBUTION SYSTEM

BACKGROUND

In order to ensure that all piping in a gas distribution system is completely cathodically protected an end-point or end-check survey is conducted by measuring a structure-to-electrolyte potential at the ends of each main and lateral. The survey is used to identify areas not meeting criterion by either lack of CP current or inadvertent isolation. With the practice of using polyethylene (PE) pipe when replacing steel piping, sections of isolated steel piping is becoming more of a concern.

The results used are from an end-point survey of a distribution system in BC. The oldest piping in the distribution system is approximately 50 years old. The gas distribution system is isolated into seven (7) cathodic sections and protected by four (4) impressed current anode beds.

RESULTS OF POLARIZED POTENTIAL SURVEY

All influencing rectifiers were interrupted and “on” and “instant off” structure-to-electrolyte potentials were taken at 217 locations. Only 96 of the 217 structure-to-electrolyte potentials taken met the -850 mV_{CSE} polarized potential criterion. The distribution system was isolated from other utilities during the survey.

Current outputs of three of the four rectifiers were increased and all sub-criterion points were re-checked. After the rectifier increases an additional 15 points met the -850 mV_{CSE} criterion bringing the total number of points meeting the polarized potential to 109.

RESULTS OF DEPOLARIZED POTENTIAL (POLARIZATION) SURVEY

In order to determine if the 100 mV of polarization criterion could be met, all influencing rectifiers were de-energized and the piping was allowed to de-polarize. Once the gas distribution system was de-polarized structure-to-electrolyte potentials were taken at all -850 mV_{CSE} sub-criterion points. These readings were used along with the "instant off" structure-to-electrolyte potentials to calculate the amount of polarization at each point. The results indicated that all the points met the 100 mV of Polarization criterion.

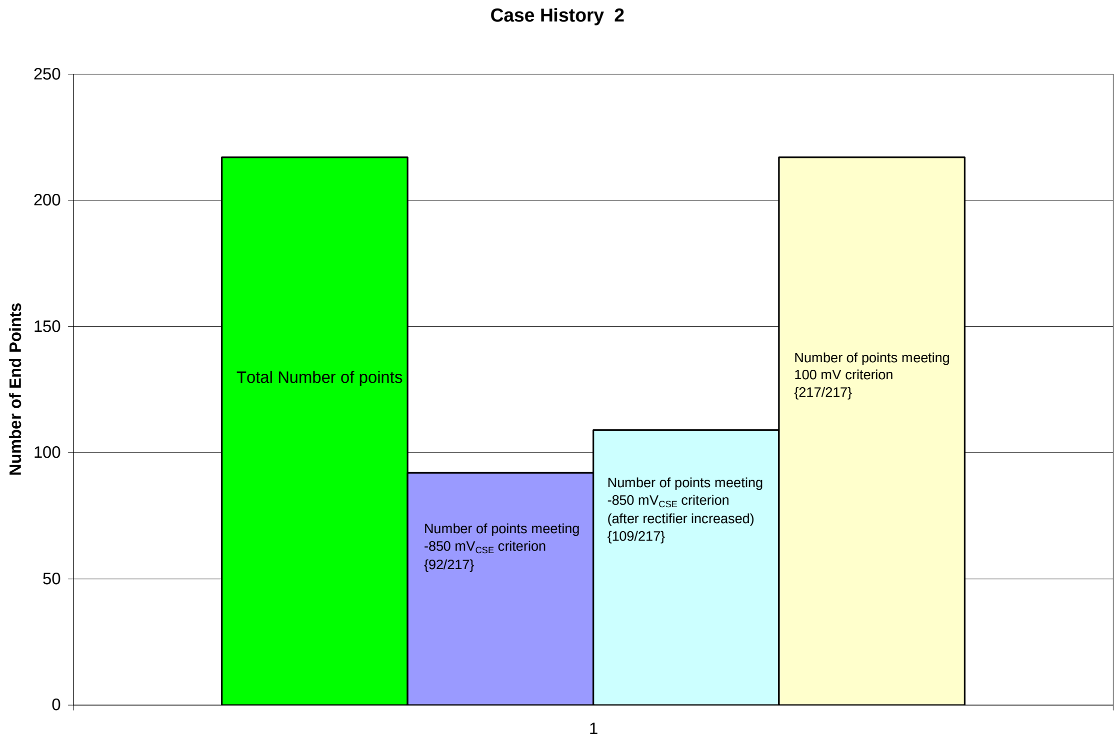


Figure 6 Case History 2, Status of Polarized Potential versus Polarization Criteria Based on Number of End Point Readings

COSTS

The capital costs to meet the 100mV of polarization criterion in Case History 1 are estimated at a quarter of the cost of meeting the -850 mV_{CSE} criterion. These costs include the additional survey cost of a second pass CIS to measure depolarized potentials.

No additional capital cost was required to increase the capacity of the cathodic protection equipment in Case History 2 however there was a cost to conduct a depolarized potential survey.

The added cost to complete a depolarized potential survey is compared to the cost of the additional cathodic protection capacity that would be necessary to meet the -850 mV_{CSE} polarized potential criterion in Figure 7.

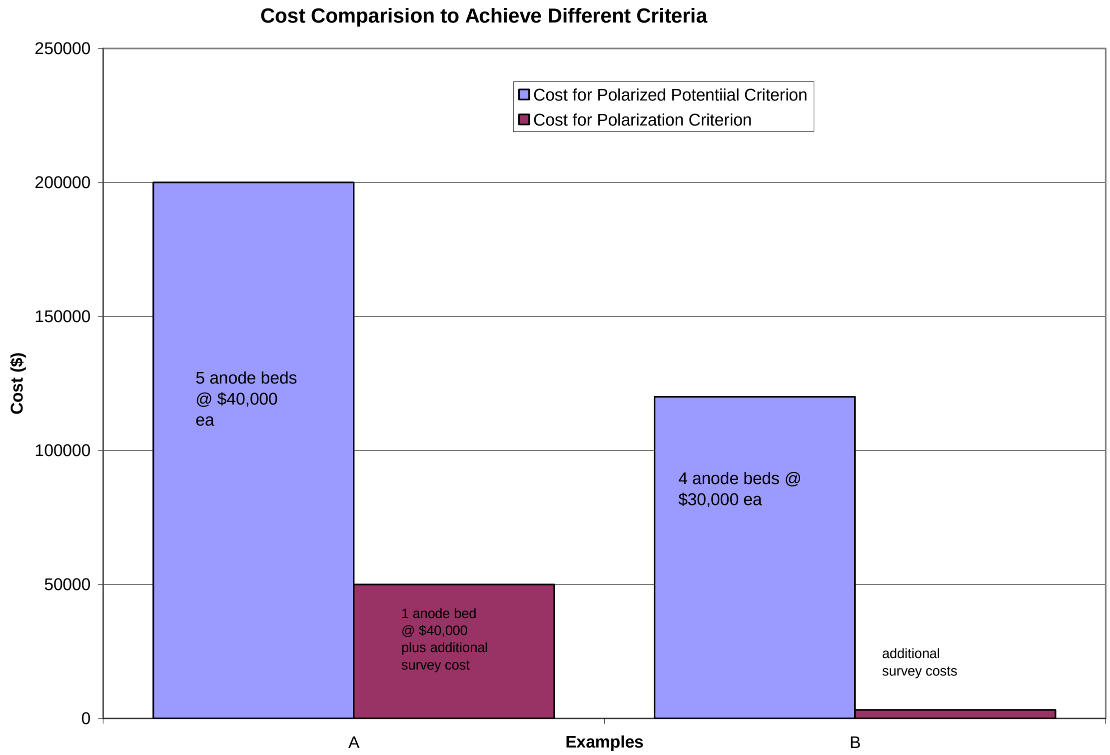


Figure 7: Cost Comparison to Achieve Different Criteria

Although the Case History 1 (Example A) comparison is extreme due to the adverse terrain and lack of power, significant benefits are also possible under other conditions as in Case History 2 (Example B).

CONCLUSIONS

Once a cathodic protection criterion has been achieved, additional cathodic protection current is wasteful.

The use of the polarization criterion of 100 mV is cost effective when the polarized potential of -850 mV_{CSE} for steel can not easily be met.

REFERENCES

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