WORLD PIPELINES

Pipeline integrity

J.P. Nicholson, Cathodic Technology Ltd, Canada, assesses a variety of techniques for pipeline surveillance and protection.

Cathodic protection is an electrical method of reducing the corrosion rate of buried or submerged metallic structures, such as a pipeline. Since cathodic protection requires the flow of electrical current through the soil and onto the pipeline, chemical changes occur at the pipeline soil interface. Current flowing onto a metallic pipeline results in the formation of a calcareous deposit, which consists principally of calcium hydroxide and magnesium hydroxides. The result is an increase in the pH at the soil pipeline interface, and the formation of hydrogen on the surface of the pipeline; a situation commonly referred to as polarisation.

In order to reduce the current required for the protection of underground or underwater pipelines, they are usually coated with an inert material such as polyethylene (PE), coal tar or fusion bonded epoxy (FBE). The cathodic protection current then flows principally to holidays or voids in the coating. For a pipeline to be considered cathodically protected, a potential of at least -850 mV in neutral soils needs to be measured between the pipeline and a saturated copper reference electrode. Moreover, the -850 mV has to be measured without any IR drop, due to the possibility of cathodic protection current flow through the soil influencing the measurement. This is often referred to as an IR free reading, or instant OFF potential.

Close interval survey (CIPS)

The most tried and tested method of measuring the effectiveness of cathodic protection on pipeline systems is a close interval potential survey (CIPS). These can be undertaken on coated or bare pipelines, either on land or underwater. The spacing between readings can vary from less than a metre to several metres. The CIPS surveyor walks over the pipeline, taking readings at regular intervals, with a connection to the pipeline through a trailing wire. Figure 1 shows a surveyor performing a CIPS survey.

Recent advances in computer technology and awareness, along with the use of global positioning system (GPS) timing, has significantly improved the accuracy and effectiveness of CIPS surveys. Figure 2 shows the graphic results of a close interval survey.

Unlike traditional test station surveys, where the cathodic protection system is only monitored at test stations which may be as much as 2 km apart, CIPS surveys provide considerably more information about the level of cathodic protection and the integrity of the pipeline coating along the full length of the pipeline.

Figure 1. CIPS surveyor equipped with GPS data logger, trailing wire dispenser and half-cell poles.

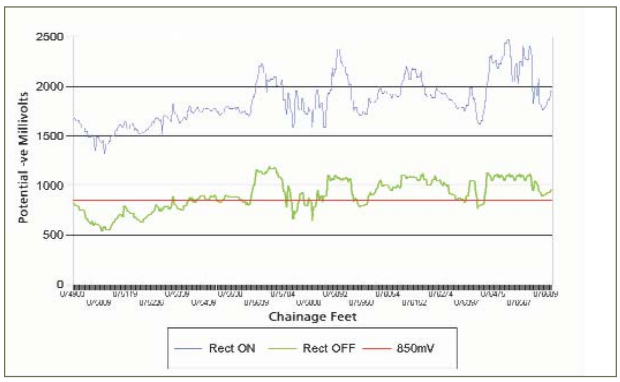

Figure 2. Graphic results of CIPS survey showing rectifier ON and instant OFF potentials correlated with distance.

Figure 3 shows the pipe-to-soil potential of a pipeline cathodic protection system that has been monitored for many years by performing an annual test station survey. Over the years, corrosion personnel have noted unprotected potentials during the annual test station survey, and have installed sacrificial anodes at the test stations in order to improve the level of cathodic protection. Lacking proper survey equipment, they were unaware of the absence of cathodic protection between the test stations. With modern CIPS survey equipment, the level of cathodic protection over the entire length of a pipeline can easily be measured and recorded to reveal any defects in the cathodic protection system.

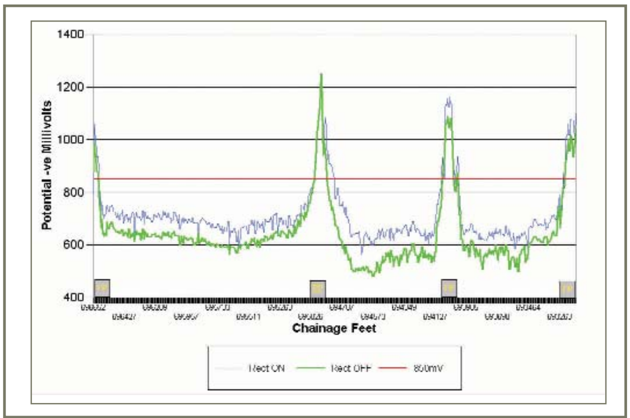

Figure 3. Close interval potentials showing the influence of sacrificial anodes installed at test stations.

Current interruption

In order to measure a pipeline's level of cathodic protection effectively, it is necessary to eliminate the IR drop component of the reading from the polarised potential of the pipeline. This is accomplished by momentarily interrupting the output of the cathodic protection rectifiers.

Current interrupters (timers) are installed in rectifiers that influence the area to be surveyed. On a large pipeline system, this may involve 10 - 20 rectifiers over several hundred kilometres, in order to ensure that all cathodic protection current flow is halted during the instant OFF pipe-to-soil potential measurement.

Only a few years ago, crystal oscillators controlled the timing of current interrupters. The frequency of the crystals drifted with time and temperature and it was necessary to re-set the current interrupters frequently in order to keep them synchronised. This became an onerous task on long cross-country pipelines, with someone having to drive several hundred kilometres on a weekly basis to re-synchronise the current interrupters.

Figure 4. A modern GPS synchronised portable current interrupter.

Global positioning system

The global positioning system consists of 24 satellites in orbit around the world. These satellites receive the precise time from an atomic clock in Boulder Colorado, USA. The satellites broadcast information about their position, as well as the precise time and a timing pulse once per second. The time and the pulse (PPS) broadcast each second are utilised by the survey equipment, current interrupters and SmartLogger™ for precise timing of the rectifier interruption and reading.

By utilising the GPS timing pulse, modern GPS synchronised current interrupters (Figure 4) have significantly advanced the accuracy of CIPS surveys by offering a timing synchronisation accuracy of greater than 1 x 10^{-3} seconds. As the timing is controlled by the GPS satellite system they are always synchronised, provided that they are receiving the GPS satellite signals. GPS synchronised current interrupters are able to meet the needs of the corrosion engineer regardless of the size of the rectifier to be interrupted. GPS synchronised interrupters are typically available from 10 - 200 A, and custom units capable of interrupting the AC supply on three phase rectifiers can be built. The use of GPS synchronised current interrupters has eliminated the need to re-synchronise the current interrupters. As long as they have power and can receive the satellite signal, they will always be synchronised with other GPS interrupters on the system.

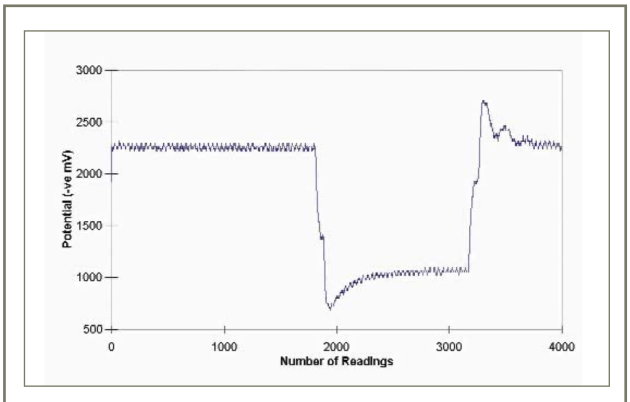

Figure 5. Waveform showing the effect of interruption of the cathodic protection rectifiers on the pipe-to-soil potential. Inductive spikes can be seen following turn OFF and turn ON of the rectifier.

Figure 5 shows a waveform recorded during a CIPS survey on a coated pipeline. The waveform shows the interruption of the rectifiers operating on a 2 sec cycle with an OFF time of 600 ms. The waveform was recorded by a Hexcorder™ CIPS survey instrument, which recorded 4000 pipe-to-soil potential readings over a 2 sec interval. The waveform clearly shows that all interrupted rectifiers were synchronised. The waveform also shows that there is inductance in the interrupted circuit, with a voltage spike that lasts for approximately 100 ms after the turn OFF and turn ON of the rectifier current.

By recording waveforms at regular intervals, the surveyor can observe that the equipment is functioning correctly, and that the gathered data will be accurate.

For decades, corrosion engineers have been measuring the effectiveness of cathodic protection systems by measuring the pipe-to-soil potential of the pipeline. Until the development of GPS synchronised current interrupters and survey equipment, the pipe-to-soil potentials were often in error, as the IR drop component of the reading was not always accounted for. With GPS synchronised interrupters and survey equipment (such as the Hexcorder™ with its built-in GPS synchronisation), accurate polarised potentials can be measured and recorded; thus indicating the level of cathodic protection with the IR drop component taken into consideration (Figure 2).

Modern close interval survey equipment, such as that shown in Figure 6, can measure distance in either metric or imperial units, allowing accurate pipeline chainages to be tagged to each recorded pipe-to-soil potential reading. Accurate chainages allow the pipeline operator to locate or verify areas of inadequate protection. By accurately measuring the rectifier ON and instant OFF potential, the level of cathodic polarisation on the pipeline system can be readily identified, and corrective action taken if deemed necessary.

Further information can also be tagged to each reading, such as the latitude and longitude of each reading location and its elevation above sea level.

The universal co-ordinated time (UCT) of each reading is of great importance for telluric and stray current correction, and will be discussed below.

During close interval surveys, external factors often affect the results. Telluric and dynamic stray currents can seriously affect the measured and recorded pipe-to-soil potentials. This can lead to erroneous data, or to data that is difficult to analyse and interpret.

A log of the pipe-to-soil potential is obtained during the survey by using a SmartLogger™ (Figure 7), which has a GPS engine, and synchronises with the GPS interrupters to record each rectifier interruption cycle. When there is telluric or stray current activity, the potentials recorded by the SmartLogger™ will vary from the mean value (Figure 8). A simple mathematical formula in a spreadsheet programme can calculate the deviation from the mean value at each point in time. As each rectifier ON and OFF potential is stamped with the UCT, the time-stamped data recorded by the survey instrument can be compared with the SmartLogger™ data, and correction made for the potential deviation from the mean value. Although this method is not perfect, as the SmartLogger™ is placed at discreet points along the pipeline, and there may be a difference in the magnitude of the deviation from the location to the location of the survey instrument, it still works reasonably well.

Figure 6. Modern GPS synchronised CIPS survey instrument with GPS synchronisation.

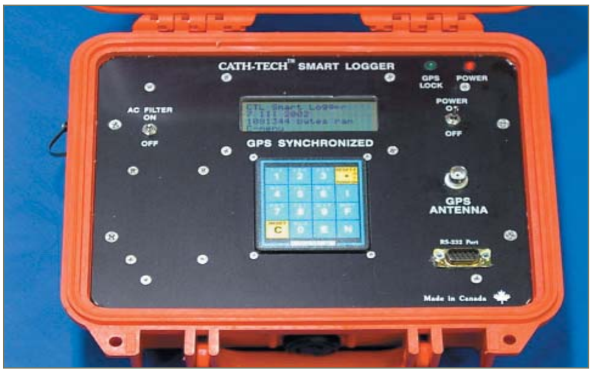

Figure 7. SmartLogger with GPS synchronisation logs the rectifier ON and instant OFF pipe-to-soil potential at each rectifier interruption.

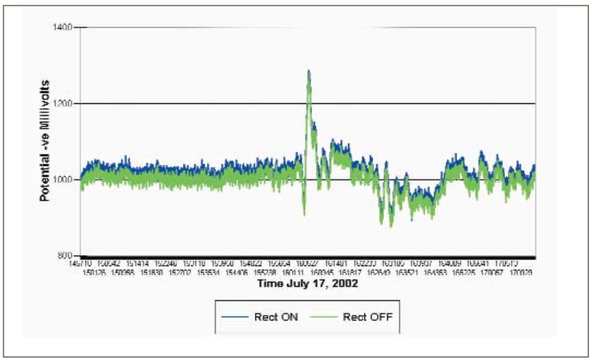

Figure 8. SmartLogger data showing the effect of telluric activity on the pipe-to-soil potential of a pipeline.

DCVG survey

Direct current voltage gradient survey (DCVG) is an electrical method of measuring the voltage gradient of potential between two reference electrodes placed on the surface of the soil close to a pipeline. Wherever a pipeline coating is damaged (holiday), there will be increased current flow. This current flow will result in a voltage gradient in the soil if the voltage gradient is equal to the current flow multiplied by the resistance of the soil path (Ohms Law, E = IR). The larger the holiday, the greater the current flow, and consequently the larger the voltage gradient.

This technique can be useful in locating large coating defects. However, the surveyor must have considerable knowledge of the pipeline, the soil resistivity, the moisture content of the soil, the cathodic protection system, and the location and output of the rectifiers. For a given holiday size, the voltage gradient will be much smaller in low resistivity soil than in high resistivity soil, as determined by Ohms Law. The surveyor must constantly be aware of the limitations of the DCVG survey.

Figure 9 shows the voltage correlated with distance for gradients along a pipeline with severe coating damage. Each voltage gradient was tagged with the UCT, the GPS co-ordinates and the elevation of the reading. The GPS co-ordi-

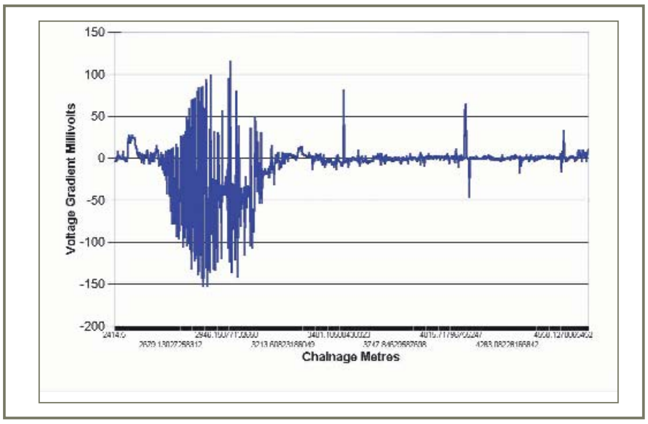

Figure 9. Direct current voltage gradients (DCVG) correlated with distance.

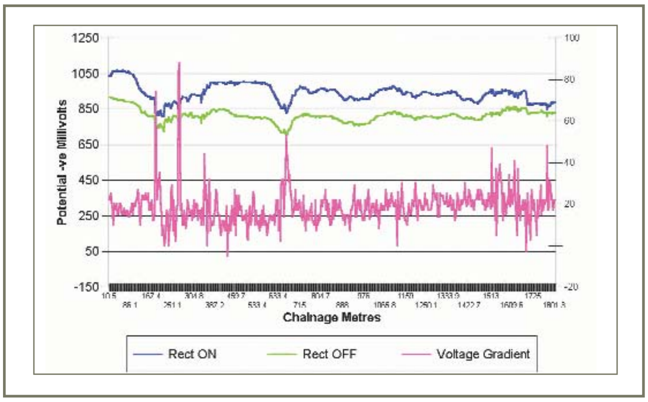

Figure 10. CIPS combined with DCVG showing correlation of voltage gradients with pipe-to-soil potential data.

nates were used to establish the chainage of each reading.

A DCVG survey measuring only the voltage gradient in the soil (traditional method) gives no indication as to the level of cathodic protection on a pipeline. Finding and repairing coating defects does not ensure cathodic protection or corrosion prevention, and may actually accelerate corrosion. If the pipeline is not receiving sufficient cathodic protection current to achieve a polarised potential that meets the criterion for protection (-850 mV), then even with the IR drop taken into consideration (i.e. eliminated), corrosion may occur and may be accelerated if the area ratio of anodic areas (holidays) to cathodic areas (coated pipe) is small. A DCVG survey should never be considered as either equal to or a replacement for a close interval potential survey. A DCVG survey should be used as a supplement to a close interval potential survey to locate areas of severe coating damage.

Cathodic Technology Ltd has discovered that digging up a pipeline often results in coating damage. No matter how carefully the work is performed, coating damage is inevitable. Thus, a coated pipeline should only be excavated for coating repair if the level of cathodic protection cannot be increased to result in a polarised potential that meets the criterion for protection.

An improved method of DCVG survey

One way of improving the DCVG survey is to record the voltage gradient of the pipeline simultaneously with the ON and OFF potential of the pipeline. By recording the distance (chainage), the rectifier ON and rectifier OFF potentials, and the GPS co-ordinates and UCT, an accurate picture can be constructed of the level of cathodic protection, the location of holidays in the coating and their effect on the level of cathodic protection.

Figure 10 shows the graphical results of a combined DCVG and CIPS survey with each reading correlated with distance. Each recorded value was tagged with the chainage, GPS co-ordinates and UCT. It is easy to see the effect coating holidays has on the rectifier ON and OFF potentials and on the cathodic polarisation of the pipeline. The pipeline operator makes decisions as to whether to increase the level of cathodic protection, or to recondition the coating in order to maintain effective cathodic protection.

Internal inspection

Internal inspection of a pipeline is a costly and onerous procedure, which reveals metallurgical problems such as laminations, buckles, dents and internal corrosion, none of which can be measured or recorded by CIPS or DCVG techniques. Internal inspection also reveals areas of external corrosion where the cathodic protection was deficient and corrosion has resulted in thinning of the pipe wall.

Numerous older pipelines are not equipped for internal inspection, and require the addition of pig launchers and retrievers, a costly supplement to a pipeline system. Properly applied and maintained, cathodic protection backed up by regular CIPS surveys will ensure that corrosion of the external surfaces of the pipeline will not occur. In most pipeline systems, the interval between internal inspections can be increased if regular CIPS and DCVG surveys are undertaken, resulting in a significant reduction in cost for the pipeline operator.

References

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