Monitoring and Measurement Techniques for IR Drop Test Spans

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ABSTRACT

The IR drop test span is a specialized cathodic protection test station that is very effective in determining magnitude and direction of DC current flowing on a buried structure. The test span can provide the CP technician with critical information pertaining to current distribution, interference current detection, excessive current loss, and current mapping on protected pipeline structures.

The data derived from an IR drop test span is most useful when compiled over a period of time. The technician can use that data to identify trends, changes, and to develop a concise overall profile of the current flow on the structure in the area of the test station. This type of profile is essential for detection of interference and inadequate protection in areas where multiple pipelines and other sources of interference share congested pipeline right of ways. It is also valuable to measure additional parameters at the site (AC interference, AC and DC density, instant-off voltage potentials) in order to create an accurate assessment of the cathodic protection on the structure at the test site. Typical methods of deriving measurements at IR drop test spans are periodic measurements using a hand-held volt meter, or the use of data-logging devices. Periodic measurements require a long period of time in order to acquire a significant amount of data and are labor intensive. Data-logging provides a significant amount of data in a shorter period of time, but are subject to limitations regarding the parameters that can be measured.

This paper is a case study on the adaptation of remote monitoring equipment to provide continuous data recording of multiple pipeline current and voltage parameters at IR drop test spans. Several sites in congested pipeline corridors were used to demonstrate the effectiveness of using remote monitor equipment with data-logging capabilities to record the data, transmit the data to the technician, and to provide notification of significant changes measured in any of the monitored parameters.

This method of data acquisition and analysis offers several advantages over typical methods. The technician is provided with time-stamped measurements of multiple parameters affecting the performance of the cathodic protection system. Data is continually recorded and stored in device memory, but can be transmitted on demand to the technician's computer. The technician can receive instant notification of any sudden significant (user defined) changes to any monitored parameter. The ability to use an interactive web interface for the display and use of the data makes graphing, comparing, and profiling data from multiple locations very simple to accomplish. These advances allow the technician to gather more data, faster, and in a more organized manner. This facilitates the use of this data in evaluating, designing, and measuring the ongoing performance of cathodic protection systems.

This case study provides information regarding how cutting edge technologies incorporated in current generation monitoring systems can be applied to specific tasks beyond the scope of basic rectifier and test point monitoring tasks. Through incorporation of advances in telemetry, electronics design, and data interface capabilities, remote monitor systems have evolved into multi-application tools for evaluation, benchmarking, and detailed CP system performance monitors.

Key words: IR drop, IR test span, remote monitoring, interference current detection, data-logging

INTRODUCTION

IR drop test spans are most commonly used to determine the direction and magnitude of DC current flow on a pipeline. An IR drop span is in essence a CP test station that measures the current flow across a section of pipeline. The resistance of the pipeline is calculated and the pipeline is used as a shunt to calculate current magnitude and current flow direction as a function of voltage drop over the calculated span. An IR drop test span uses a specific length of the pipeline, in this instance a 120 foot (36.6m) section of pipeline, with test leads connected at both ends of the designated span (Figure 1).

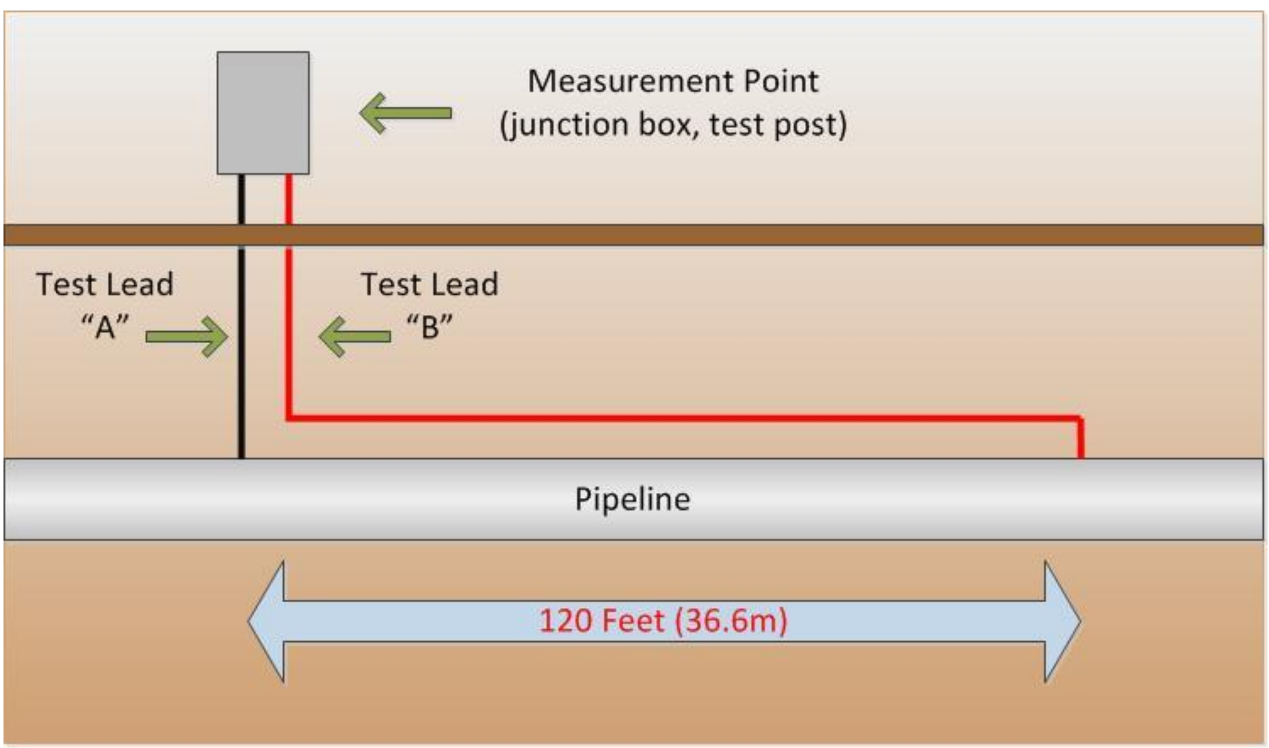

Figure 1: Diagram of a basic IR Drop test span.

The resistance of the section of pipeline is calculated based on the characteristics of the pipe (material, diameter, wall thickness). The resistance is tested measuring voltage drop across the span with a range of test current applied. These comparative measurements are used to calculate the shunt factor applied to the voltage measurements for conversion to amperage. The operator can then determine the DC current flowing across the span by measuring the voltage drop from point "A" to point "B" with a high impedance multi-meter. The magnitude of the DC current is calculated using the resistance of the pipe and the direction of current flow is determined by the polarity of the DC voltage. On a protected pipeline this data aids in the verification of current distribution, detection of stray current, area of influence of rectifiers on the pipeline, and can help gauge the rate of degradation of anode beds. On unprotected pipelines IR drop spans can identify anodic sections and stray current interference.

IR drop test spans are normally read with a meter on a periodic basis to detect changes that may have occurred, such as significant changes in magnitude or reverse of the current direction (polarity reversal), or used with a data logging device during periods of interference testing. Periodic measurements and occasional interference testing will not capture all of the significant data generated at the test site[1]. Stray current, interference from other protected structures, changes or faults on the CP system, and changes on system on or near the right of way can all affect the performance of the CP system at or near a test site. CP technicians typically do not have the time or resources to make data gathering at an IR Drop test span a priority, except when focusing on a particular known problem. Using a data logging device to gather data on a more continual basis is an option, but then the time consuming task of reviewing large amounts of data for significant events becomes the constraint.

Remote monitoring technology for monitoring the CP system is prevalent on oil and gas transmission pipelines and is increasingly used on distribution systems and on protected water pipelines. The primary application for these monitors is rectifier monitoring, and selected test station and critical bond monitoring. Test point and bond monitoring is particularly focused in high consequence areas, locations where induced AC is a problem, and remote sites where periodic data retrieval is difficult. This case study highlights the advantages of using a proven, reliable, data gathering/management technology to enhance the value of the IR Drop test span.

CASE STUDY

The design for the monitored IR drop test spans included the addition of the remote monitoring equipment, a permanent reference cell used for pipeline potential measurements, and a coupon for use taking "off-potential" readings at the test sites (Figure 2).

Corrosion coupons at a test location such as this can provide the operator with data inferring the corrosiveness of the environment, and IR drop free measurements inferring the current protection level on the pipe from a polarized potential[2]. The monitoring equipment used had the capability to measure the current on the pipeline at the test span, and DC and AC pipe to soil voltage potential at the monitor site. The monitor equipment also had the capability to measure an "off potential" using the protected coupon, and AC and DC current density at the test site, though these measurements were not used in this test.

The site selected for this case study was on an 1800 foot (548.6m) section of 34 inch (86.4cm) diameter crude oil pipeline in a suburban area. Average wall thickness on the pipe was 0.281 inches (7.14mm). In this particular location, the pipeline runs generally north to south, but in one section the pipeline turns west at a right angle for 400 feet (121.9m), then turns at a right angle to the south again. Several other protected pipelines operate in the area and stray current interference has been an issue in the vicinity. There are also several points in the area where the pipeline intersects or shares the right of way with high-voltage transmission power lines. There are two IR drop test spans installed on the pipeline, approximately 500 feet (152.4m) apart from one another. There is a rectifier/anode bed installed approximately 150 feet (45.7m) from the Parkway East test site (Figure 3).

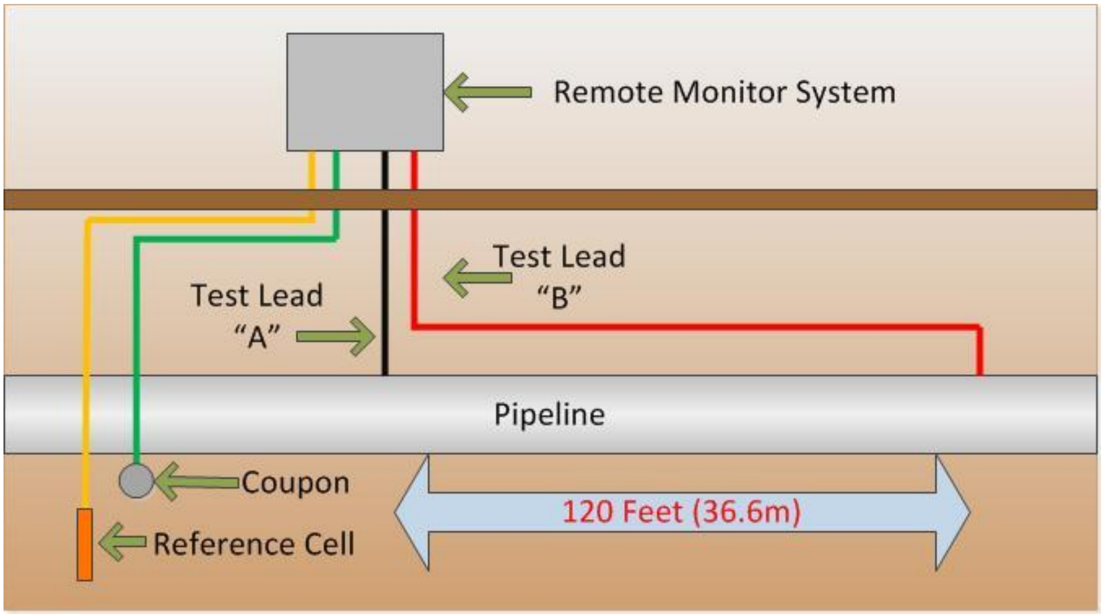

Figure 2: Diagram of a remotely monitored multi-application IR Drop test span.

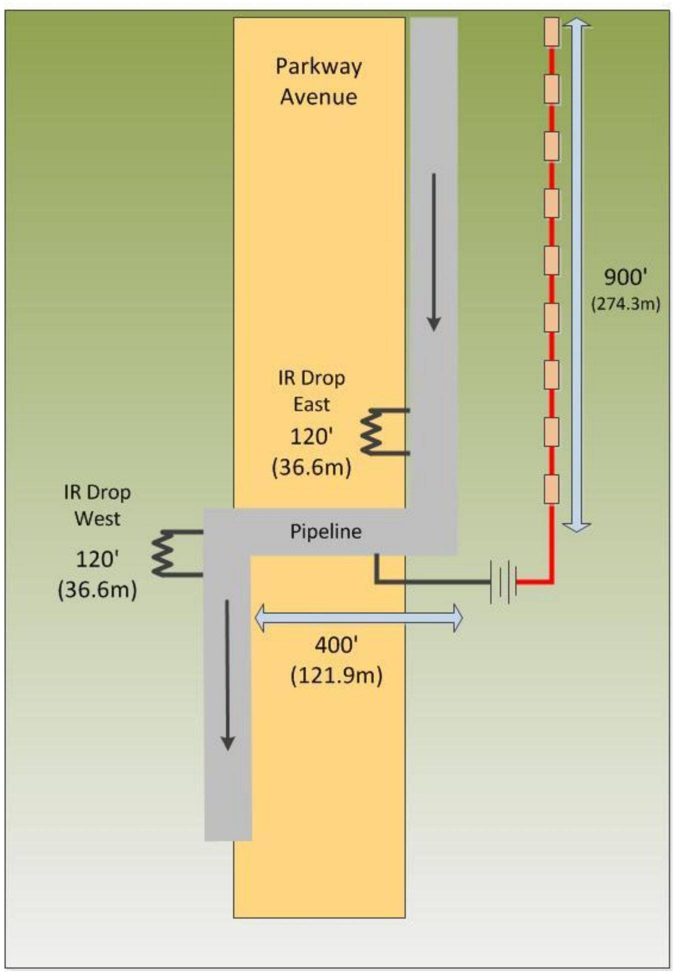

Figure 3: Diagram of the Parkway East and Parkway West IR Drop test span sites.

Remote monitoring equipment was installed at each of the test span locations. For this study, the equipment was set up to monitor pipe-to-soil potentials and the test span current values only. The voltage potential was displayed in millivolts, and the test span current was calculated from the voltage drop across the span and displayed in milliamps. A shunt factor of 2.97 mA /1.0mV calculated by averaging the voltage drop over a range of known values was applied as a conversion factor[3]. The monitoring equipment was programmed to take the potential and current measurements once per hour, and to report the measured value once every three days. All of the readings were stored in the monitor unit memory. The monitor system included a capability to retrieve any or all measured values from the memory using the monitor unit's remote telemetry. In order to simulate failure or interference events that can occur on a pipeline, the current was turned off at the rectifier at the test area on several occasions for short durations of time. The readings reported to the monitor web interface were displayed graphically allowing the operator to easily identify significant events (Figure 4 and Figure 5).

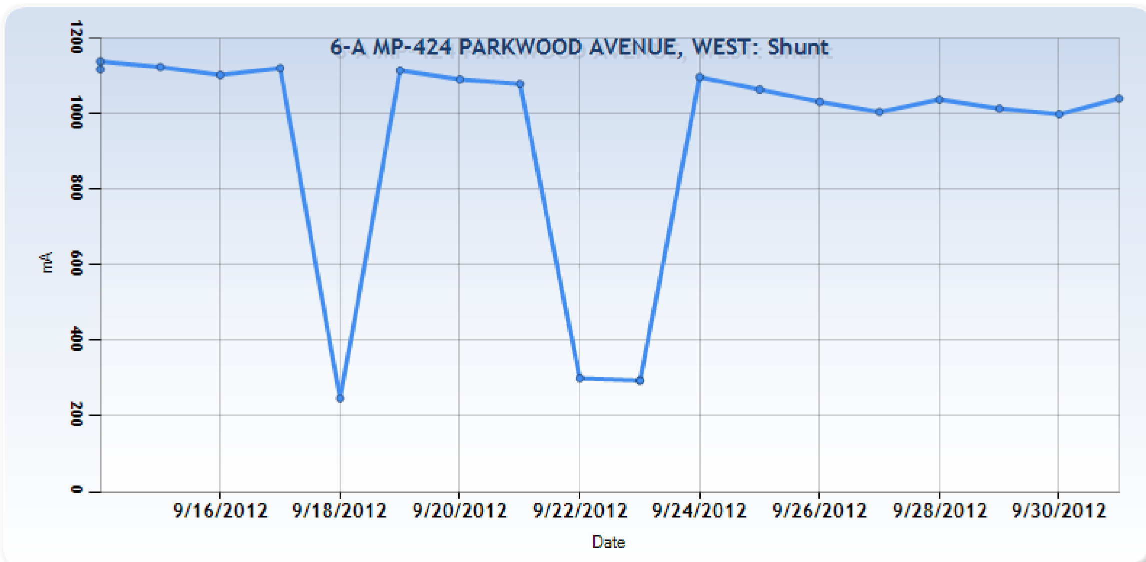

Figure 4: Graph of test span current reported at the Parkway West test site 9/12/2012 – 10/1/2012

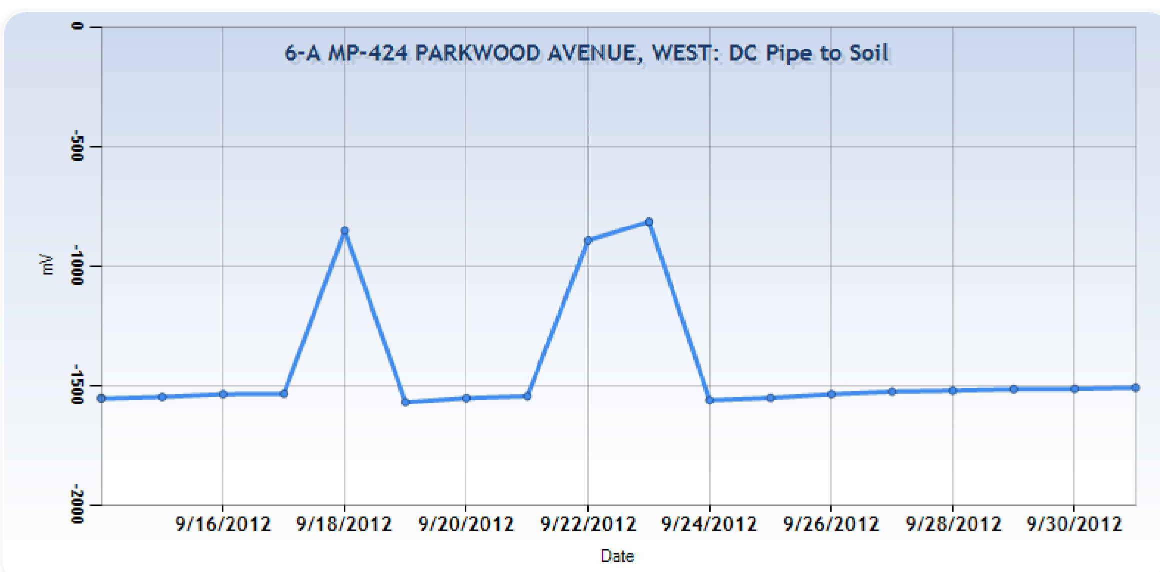

Figure 5: Graph of DC voltage potential reported at the Parkway West test site 9/12/2012 – 10/1/2012

The time periods when the rectifier was shut off are clearly visible on the graph as the reports where the test span current changed from approximately 1150mA to approximately 270mA. During the same periods the pipe-to-soil voltage potential reading at the site changed from approximately -1550mV to approximately -870mV. The hour by hour logged measurements from the monitor unit memory was downloaded to the web interface and the readings were displayed graphically (Figure 6).

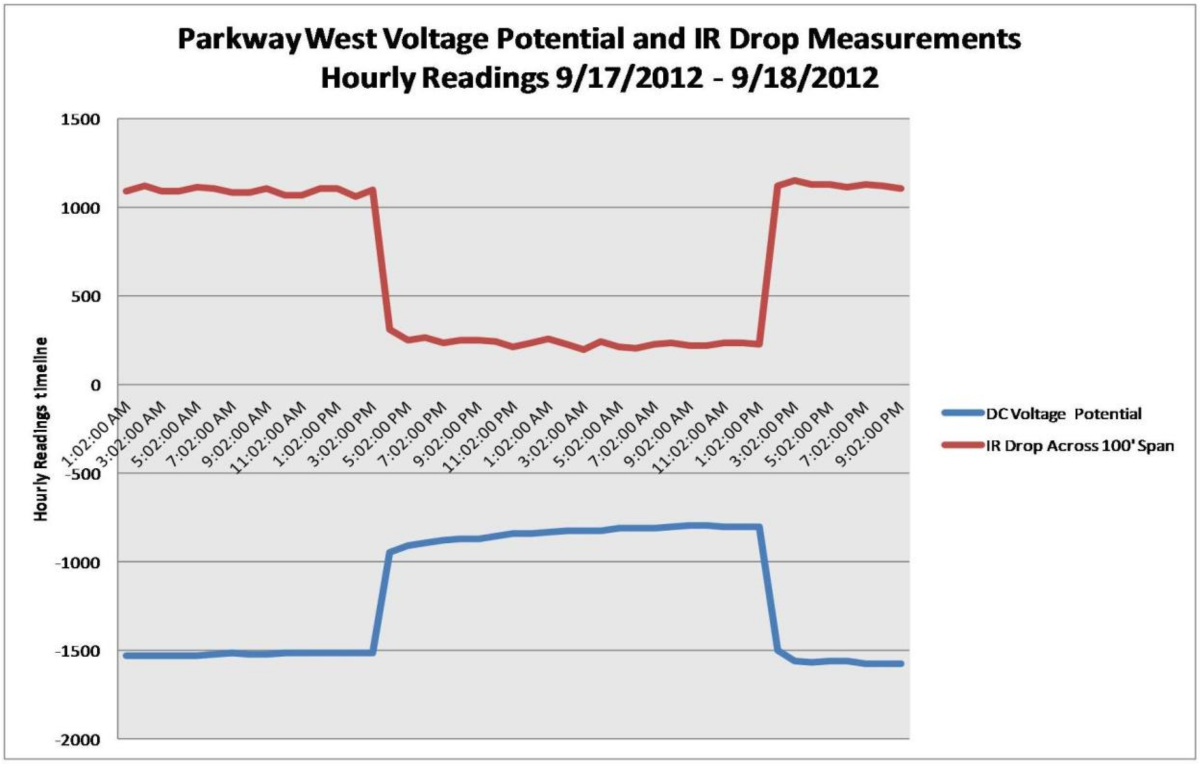

Figure 6 – Graph of test span amperage (mA) and DC pipe to soil voltage potential (mV) hourly measurements for Parkway West test site 9/17/2012 through 9/18/2012

The hour by hour readings provided the detail filling in the gaps between the scheduled reports. When the current was initially turned off, the current on the test span dropped immediately to 311mA, and within 5 hours dropped to 234mA and remained at roughly that level for the duration of the test. The pipe-to-soil voltage potential initially changed to -950mV and continued to gradually change as the pipeline depolarized. The -100mV shift point (-846mV) was measured 7 hours after the current was turned off, and the pipeline depolarized to -806mV during the entire 22 hour period the current was off. The detail data from the Parkway East location was downloaded for the same time period and also displayed some interesting results (figure 7). Most notably, the pipeline showed a much slower rate of depolarization. There was one measured potential value that may have reflected measurement error or interference that is clearly displayed as an anomaly during the depolarizing period. Also interesting to note is the test span current at the Parkway East location was measured as a negative value as opposed to the positive current value reported at the Parkway West site. The polarity of the voltage measurement is indicative of the direction of current flow across the test span[4]. Both of the test locations where oriented directionally the same on the pipeline, but the current on the pipeline was flowing back to the rectifier. As the rectifier was located between the two test sites, the current flow back to the rectifier passed south to north across the Parkway West span and north to south across the Parkway East span. Finally, it is significant to note the magnitude of current at the Parkway East site was significantly greater than that measured at the Parkway West site. The rectifier and anode bed are both located significantly closer to the Parkway East test span.

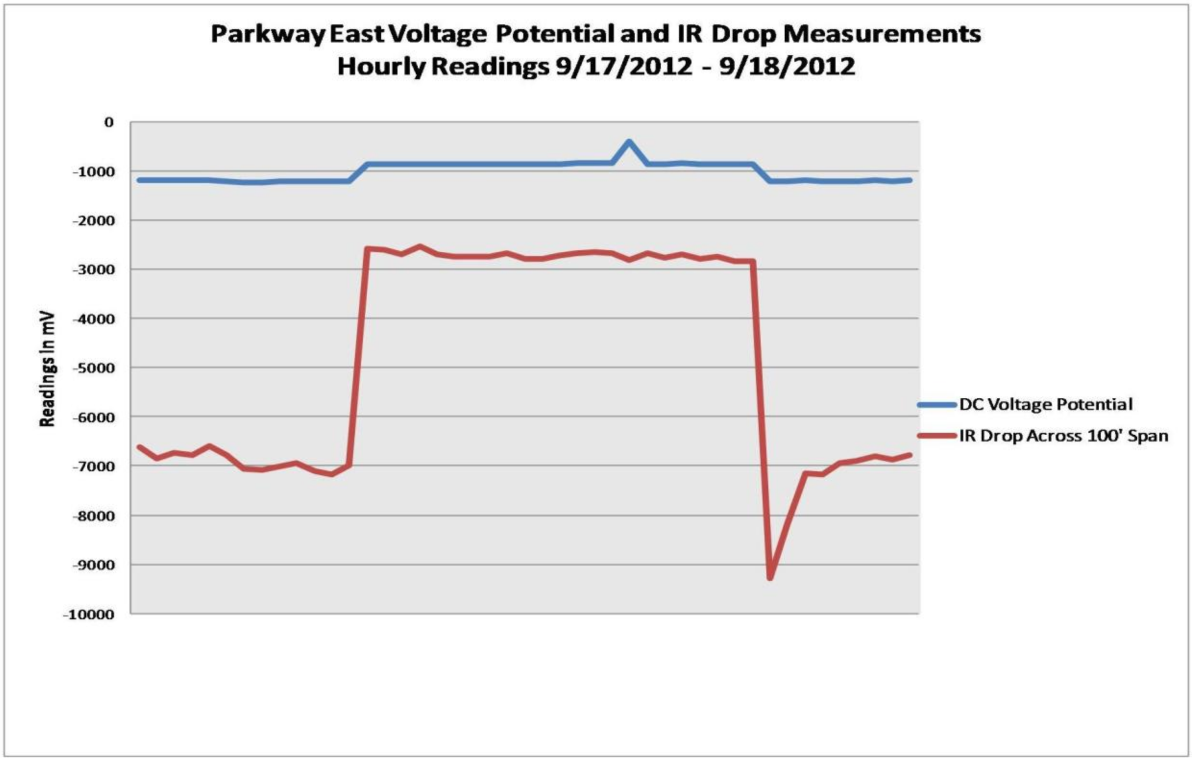

Figure 7 – Graph of test span amperage (mA) and DC pipe to soil voltage potential (mV) hourly measurements for Parkway East test site 9/17/2012 through 9/18/2012

RESULTS

The measurements used in this case study were derived by simulating a significant event affecting the performance of a cathodic protection system. In this test, the current was shut off for periods of time at a rectifier directly influencing the voltage and current values at the test location. The simulation does clearly demonstrate that the information available at a test span location (potential, current magnitude, and current direction) can be very useful if measured on a continual basis and easily accessed by the operator. Interference current and current reversal such as experienced a sites influenced by electric rail and other pipelines in close proximity can be detected using periodic measurements. Alarm thresholds can also be used on any measurement acquired via remote monitor. The occurrence of an alarm condition can identify a “significant event” and the detailed measurements acquired over the duration of the event can be retrieved from the device memory and analyzed in detail. Additionally, other significant values at the test site can be measured and stored concurrently with the test span measurements, including AC voltage potential, AC density, DC instant off potential, and native potential. The ability to view the entirety of these measurements and the changes occurring in all of them over the duration of a significant event provides the operator with much more data for analytical breakdown of the event and the potential effects on the protection of the pipeline at the site.

CONCLUSIONS

Remote monitoring technology provides a means by which data can be acquired from the test site on a continual basis. Significant changes can be identified as “alarm events”, and notification of the occurrence forwarded to the responsible technician. Data retrieved by remote monitoring systems is easily accessible, and the data management systems are much more user friendly than a data dump from a logging device. Typical test station data, including structure-to-soil measurements, current density measurements, instant off potential readings, and induced AC voltage levels, can be measured by the monitoring equipment at the test span site as well. The combined data provides the operator with a much more complete view of the influence of stray current, the effectiveness of the cathodic protection system at the site, and changes that can occur and the monitored location. The inclusion of the monitoring technology makes an IR Drop test span a more effective tool for current mapping and stray current detection, as well as providing ongoing evaluation of the effectiveness of cathodic protection systems on pipelines located in congested right of way areas.

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