Cathodic Protection Monitoring in Water and Wastewater Systems

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ABSTRACT

Web-based remote monitoring is widely used in the oil and gas pipeline industry to ensure corrosion protection systems are functioning reliably. The water and wastewater industries are not subject to the same regulatory mandates governing the oil and gas industry but are no less a part of the critical infrastructure. As these systems age and fail, the effects go beyond cost and inconvenience into potentially significant public health and safety issues. The water and wastewater industries deal with different challenges than the oil and gas pipeline industry. The budgets available for equipment and personnel for corrosion management are significantly lower. The materials requiring corrosion protection are much more varied, and there are typically less personnel within the organization trained to meet and overcome the challenges of implementing and maintaining effective corrosion prevention systems. This paper shows some case studies of municipal water and wastewater systems that successfully use web-based monitoring to evaluate the effectiveness of the corrosion protection systems, enabling the personnel resources available in the organization to focus on proactive, preventive maintenance and system improvement.

Other than some municipal water systems in the western US, corrosion prevention and the regular maintenance of the upkeep and repair of corrosion prevention systems is not widely seen in the water industry. Municipal utilities suffer from budget constraints, lack of experienced and well-trained personnel, and corrosion challenges that differ from those on typical oil or gas pipelines due to material differences, etc. Municipalities in areas of the US where water is considered more valuable than simply a convenient commodity have focused more on proactive pipeline integrity than have municipalities in the US as a whole. One result of this is a need to provide a few trained personnel within an organization with the data necessary to focus their efforts on preventing corrosion issues rather than reacting to pipeline failures. Remote monitoring provides a reliable and cost-effective means through which that critical data can be provided to the proper personnel.

Key Words: Cathodic protection, maintenance, water, primary water, wastewater

INTRODUCTION

In 2002 NACE International published a cost of corrosion study backed by the U. S. Federal Highway and Safety Administration estimating the annual cost of corrosion in the U. S. to be $276 billion. In the more detailed breakdown of these costs by industry/market segment the cost associated with the water and wastewater utilities segment in the "Utilities" category was estimated at $36 billion. The water and wastewater utilities segment represented the single largest cost segment in the study. The $36 billion estimate for this single segment of the Utilities category represented more cost than any of the other four categories: Transportation, Infrastructure, Government, and Manufacturing & Production.[1]

Many factors contribute to the corrosion issues facing the water and wastewater industries. First off, the average age of the estimated 1.6 million miles of water and wastewater pipes reached 45 years in 2020. Additionally, over 600 towns have cast iron pipes over a century old. As metropolitan areas expand, more gas distribution pipelines and electrical transmission lines are built, often sharing or near existing water and wastewater pipeline rights of way. These factors, along with concentrations of road salts, fertilizer runoff, and ground pollutants that alter soil chemistry all combine to increase the corrosion risk on the aging infrastructure.

Water and wastewater pipeline systems, unlike their oil and gas counterparts, are almost exclusively public utilities. As such, their budgets and revenue are tightly regulated making it more difficult to keep the infrastructure, systems, and processes up to date and in good working order. Also, unlike the oil and gas pipeline industry, there are not strict regulations and standards mandating adherence to corrosion protection, leak detection, and other common practices for maintaining a good pipeline integrity management program. The budget constraints imposed on most municipal utilities also prohibit these utilities from having trained and experienced corrosion prevention personnel necessary to develop and maintain the corrosion prevention programs that are commonplace in the oil and gas pipeline industry.

Maintaining effective cathodic protection corrosion control is reliant on timely and accurate data acquisition. More importantly, the data requires evaluation by personnel properly trained and qualified to act on the information. Due in part to the budget constraints, the use of cathodic protection remote monitoring is limited in the water and wastewater utilities except for areas with a history of water shortages, particularly west of the Rocky Mountains. Some utilities in the mountain regions and to the east have recently incorporated monitoring into their system integrity management programs but the use is far from widespread. Federal spending on capital improvements (repair and replacement) in water utilities peaked at $17 billion annually in the late 1970s and has steadily declined in subsequent decades to an annual rate of less than $4 billion by 2014. In the same period, the spending by state and local agencies for capital improvements in these utilities has grown from approximately $14 billion in the 1970s to more than $30 billion by 2014 (Figure 1).[2] As the water utilities infrastructure has continued to fall into disrepair, the money spent on keeping these systems operational has increased substantially, with the bulk of the bill footed by the state and local governments. This level of spending required for repair and replacement leaves little in the budget for corrosion prevention systems and trained personnel required to administer effective pipeline integrity programs. It is to this end that more efficient data acquisition methods can provide significant benefits to water utilities in their corrosion management systems.

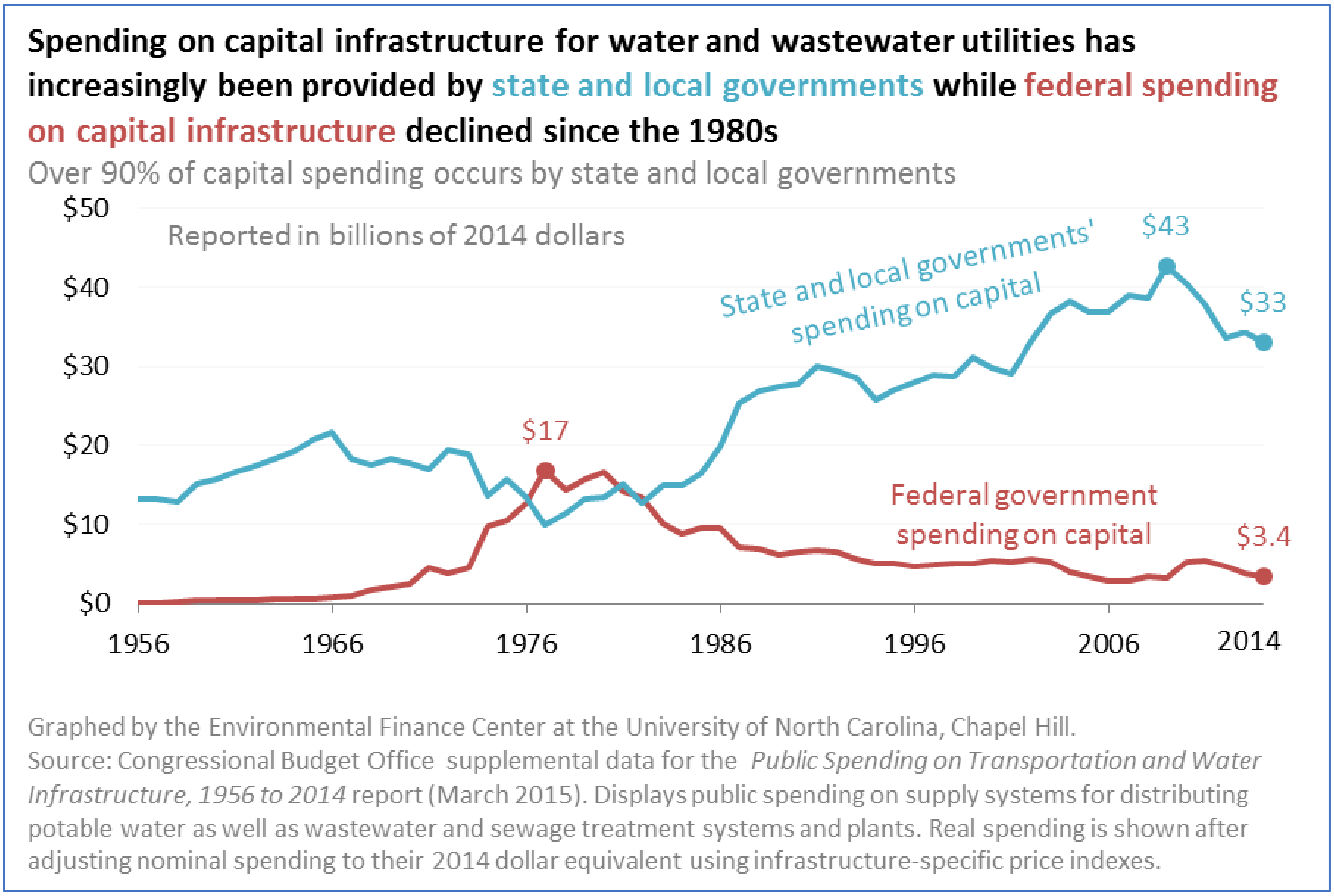


Figure 1: Graph showing State and Federal spending on municipal water infrastructure[2]

CORROSION PREVENTION AND DATA ACQUISITION

The water and wastewater industries share most of the external corrosion challenges faced by the oil and gas pipeline industries. As noted in the introduction, there is a significant difference regarding the personnel and resources available to water utilities in managing the corrosion issues. Often, evaluating corrosion risk and executing and maintaining corrosion prevention measures are the responsibility of operations personnel with many other tasks and insufficient training and experience in corrosion. As a result, the work required for maintaining an effective corrosion prevention program is often outsourced to third party contractors. The workarounds necessitated by the resource constraints facing the utilities can contribute in part to a lack of continuity over the long term regarding a comprehensive integrity program.

Municipal water and wastewater utilities have some unique pipeline materials and applications presenting a different set of challenges from both a cathodic protection and data acquisition/analysis than what is common in the oil and gas pipeline industry. Cast iron pipes, ductile iron pipes, and prestressed concrete pipes are all in widespread use in the water and wastewater infrastructure in the U.S. Each of these present challenges in the application and evaluation of cathodic protection corrosion control. Cast iron has not been used very frequently since the 1950s, when it began being replaced in new construction and rehabilitation projects by ductile iron. Still, it is estimated that over 600 counties and municipalities have cast iron pipes that are over 100 years old. Even with the aging infrastructure, corrosion, not age is the primary cause of water main breaks in iron pipes.[3] Typically, both cast iron and ductile iron systems consist of short pipe segments joined together using rubber seals at the joints, making the electrical continuity necessary for impressed current cathodic protection impossible without the installation of metallic bonds across the joints. Additionally, much of this infrastructure was installed without cathodic protection for external corrosion, or with galvanic protection using sacrificial anodes in high-risk areas. The parts of a municipal water or wastewater system where higher volume movement is necessary, larger diameter steel piping or pre-stressed concrete structures are often used, particularly in newer suburban, and semi-rural areas of municipal expansion, and the large diameter feeder mains from wells, reservoirs, and aquifers.

CASE STUDY 1

This project was implemented on the transmission pipeline system of a water utility district providing water to approximately 1.4 million customers through over a dozen county and municipal water utilities in northern California. In addition to the transmission pipelines from 2 reservoirs in the Sierra Nevada mountains, this district is responsible for 5 terminal reservoirs, 4,100 miles (6,600 km) of water mains, 6 water treatment plants, 29 miles (47 km) of sewer lines and a regional wastewater treatment facility. This water district had experienced a spotty record of corrosion prevention on the main transmission pipelines. Due in part to extended periods of intentional disconnection during construction, insufficient resources, and the difficult to access locations of assets along these pipelines, adequate cathodic protection has not been consistent on these lines. Below is a graph showing the cumulative number of leaks directly attributed to external pipeline corrosion occurring on the oldest of the reservoir-to-bay area pipeline as logged over time. This graph shows a marked increase in the number of leaks occurring in relatively short periods of time during which adequate cathodic protection was not applied (Figure 1). Additionally, it clearly shows during the periods in which cathodic protection was applied the number of leaks incurred dropped dramatically, particularly in more recent decades when better supervision and monitoring of the cathodic protection systems were available.

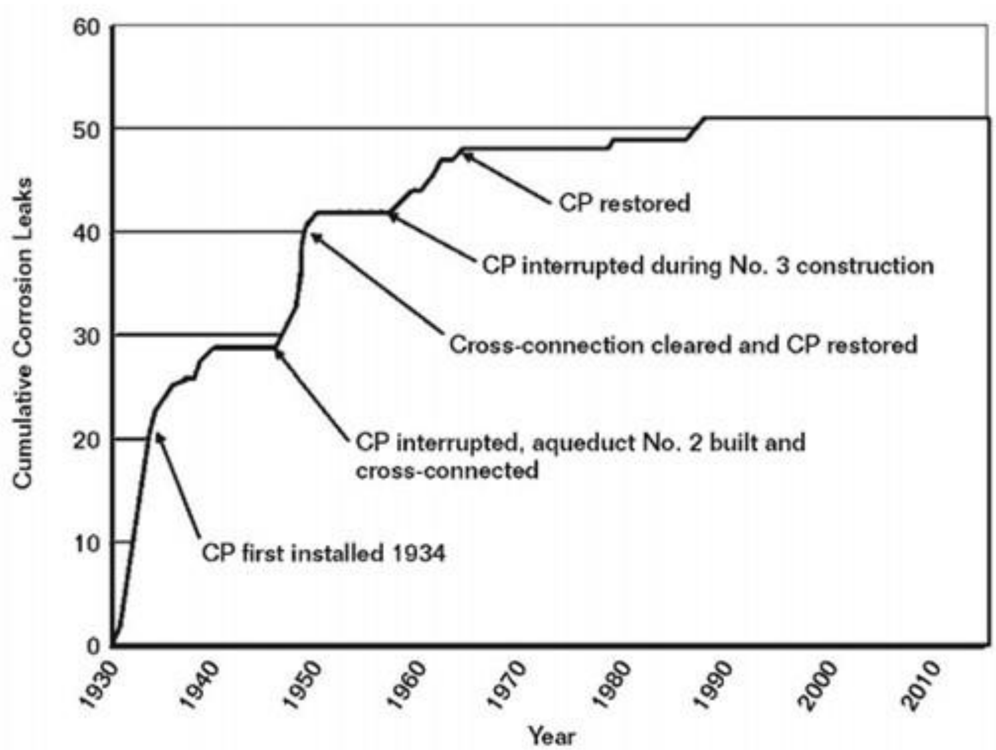


Figure 1: Graph showing cumulative leaks over time[3]

This water district has substantially increased the level of awareness regarding the performance of the cathodic protection systems on the pipelines feeding the system from the reservoirs and are now embarking on a program to implement continuous measurement and oversight on the area water mains under their jurisdiction. This effort focuses primarily on implementing remote monitoring of rectifiers and test stations, enabling the available trained personnel responsible for these systems to have the system performance data necessary to evaluate the system effectiveness and concentrate limited resources on areas requiring attention on a proactive basis.

CASE STUDY 2

This application of monitoring technology was preceded by a catastrophic rupture in a main supply line from a storage reservoir. The rupture drained a significant portion of the reservoir, flooded an upscale residential area damaging or destroying several homes and vehicles, and was attributed to corrosion related failure of the steel reinforcement bands in the pre-stressed concrete constructed main. Unfortunately, this type of failure is all too common in the industry. In this municipality's situation, there was cathodic protection on the pipeline in question, but there were not trained personnel at the time monitoring the presence and effectiveness of the cathodic protection. Lapses in the cathodic protection went undetected for an undetermined length of time resulting in corrosion to the reinforcing steel bands and the subsequent catastrophe. Following this occurrence, a pipeline integrity team was put in place staffed with trained and qualified personnel. Some of the remedial steps undertaken were: 1) an evaluation of the integrity of the pipelines in the system, 2) a review of the pipeline and cathodic protection data for the system, and 3) a program was developed to improve the acquisition and efficacy of data pertaining to the functionality of cathodic protection measures system wide. Eventually, this intensified focus on cathodic protection and corrosion control led to incorporating remote monitoring for cathodic protection data acquisition on the large diameter main transmission lines, and eventually on the water mains throughout the distribution system. One challenge the data acquisition effort addressed was the different critical levels of cathodic protection required for the different types of materials used in the transmission and distribution systems. The large diameter, pre-stressed concrete mains were particularly susceptible to cathodic overprotection damaging the coating and enabling undesired water ingress to reach the steel bands. Because of this, pipe to soil voltage potential measurements were required at each rectifier location in addition to the more standard rectifier voltage and current output measurements common throughout the pipeline industry. Care was taken at these sites to ensure the voltage potential did not go more negative than -1200mVDC, while also ensuring the voltage potential remained sufficient to indicate cathodic polarization. This was enabled through including instant off measurements as well at the rectifier locations. On the smaller diameter steel mains throughout the distribution system, the measurements required were more standard, but a mixture of newer and older pipeline materials with a varied degree of coating integrity presented challenges as well. On these parts of the system ongoing monitoring aided the technicians in managing the varied rectifier outputs and current requirements necessary to ensure adequate protection throughout the system. The additional benefit of an accurate, continuous data history log simplified the process of maintaining cathodic protection record keeping.

EQUIPMENT AND SYSTEMS

The field equipment and web-based data acquisition systems used for these monitoring applications are available from an assortment of vendors specializing in pipeline remote monitoring. The field equipment generally communicates via the public cellular telephone networks and small packet satellite networks. The systems are designed to "report by exception" meaning the field units take measurements at relatively frequent intervals (daily, or several times per day), but report to the web interface periodically (weekly or monthly). The field units will override the report to the web schedule whenever an "out of range" or alarm measurement is detected. This data communication architecture is ideal for balancing the criticality of the data with the communication costs associated with data acquisition from multiple field sites.

The field devices in these monitoring systems communicate to a web-based data interface. The web platform houses and displays the data using any web-enabled device. The data interface portals can display the site data in tabular form and in graphical form enabling trending of data over user programmable periods of time. Sites can be grouped and the data for multiple sites in a geographic area can be viewed as a group enabling the user to compare values across multiple sites. Report generation tools enable automating data aggregation for export to external databases or automating periodic status and historical data reports. Additional features available on most system platforms include perpetual data storage and data history, remote configuration for field units, and control interaction for rectifier interruption and on-demand polling for measurement values. The web interface also generates alarm notifications to users in the event of any out-of-range measurements detected by the unit. Most field units have GPS capability for populating the sites on map tools on the web interface. The site markers on the map can denote site status (normal, alarm, lost communication, etc.) and may also be enabled as “hot links” to drill directly into the site page for additional investigation of alarm events.

The following section includes screen capture graphics of typical web portal views and features. A typical “Company View” landing page is where the user can view all of the field sites represented as marker points on the map as well as the geographic “Groups” into which the corresponding field sites are aggregated (Figure 2). This view provides instant site status information via the colors of the site markers, green indicating normal and red denoting an alarm condition. In the group listing below the map the user is able to tell at a glance which group or groups have units in alarm, and how many units in the group are in alarm. Also, on this view the user can see what technicians are assigned to each group and receiving the alarm notification alerts from sites in the respective groups.

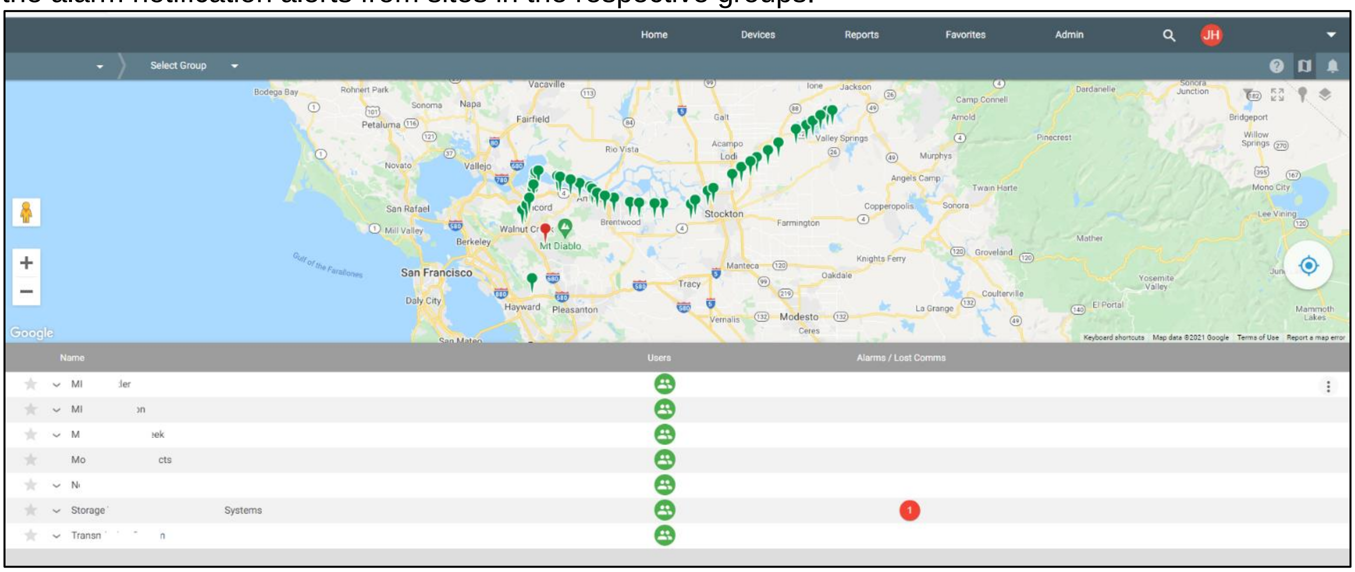


Figure 2: “Company view” landing page

From the Company Landing Page the user can click into a Group Page (Figure 3) to view sites, site measurements, alarm status, and other activity associated with the site such as rectifier interruption. In this view the interactive map section displays only the sites in the group being viewed. Latest site measurement data is displayed in a standard “column/row” tabular form. This view also provides information regarding the site status such as current interruption for survey or interference testing, alarm status, and communication status. This view also incorporates some tool buttons for initiating interruption and polling of units in the group.

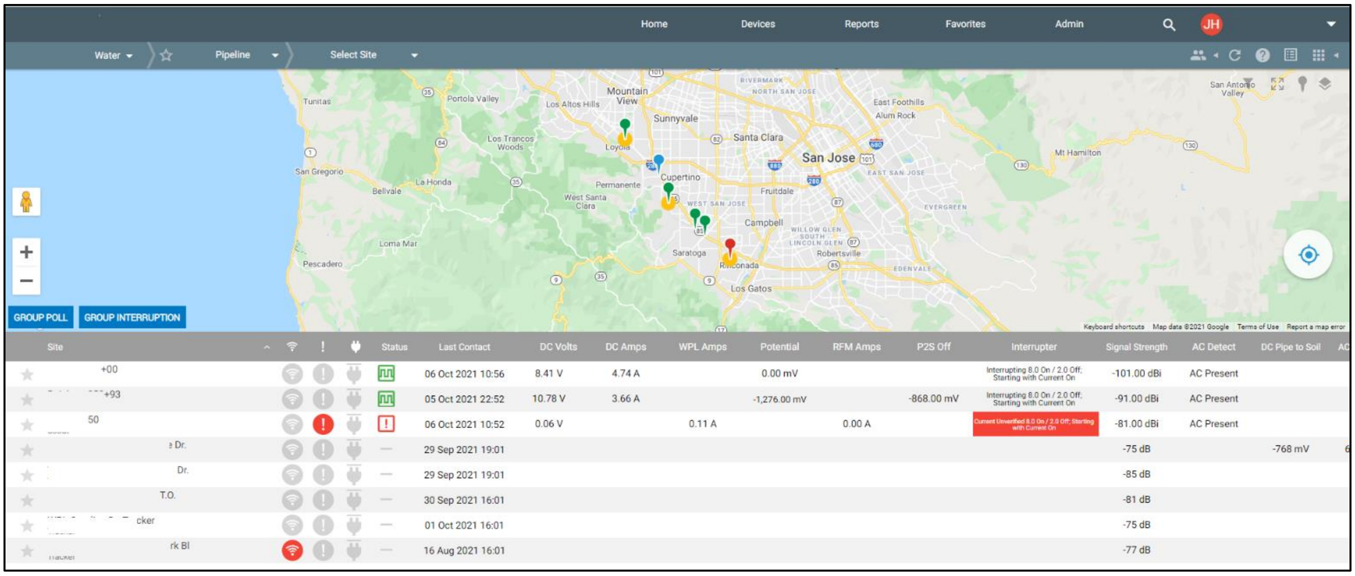


Figure 3: "Group view" page

Clicking on a site name in the leftmost column opens the page for the specific site (Figure 4). In this view the user is able to poll the unit for values, configure alarm set points, and initiate rectifier interruption if enabled for the site.

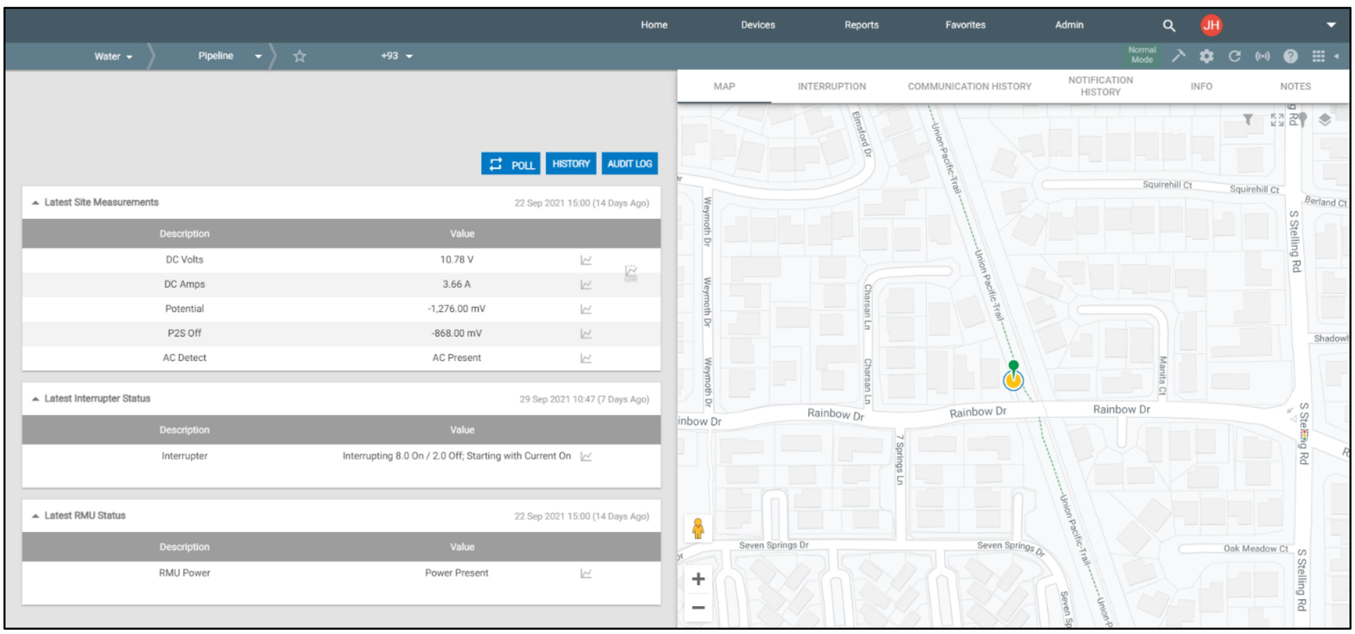
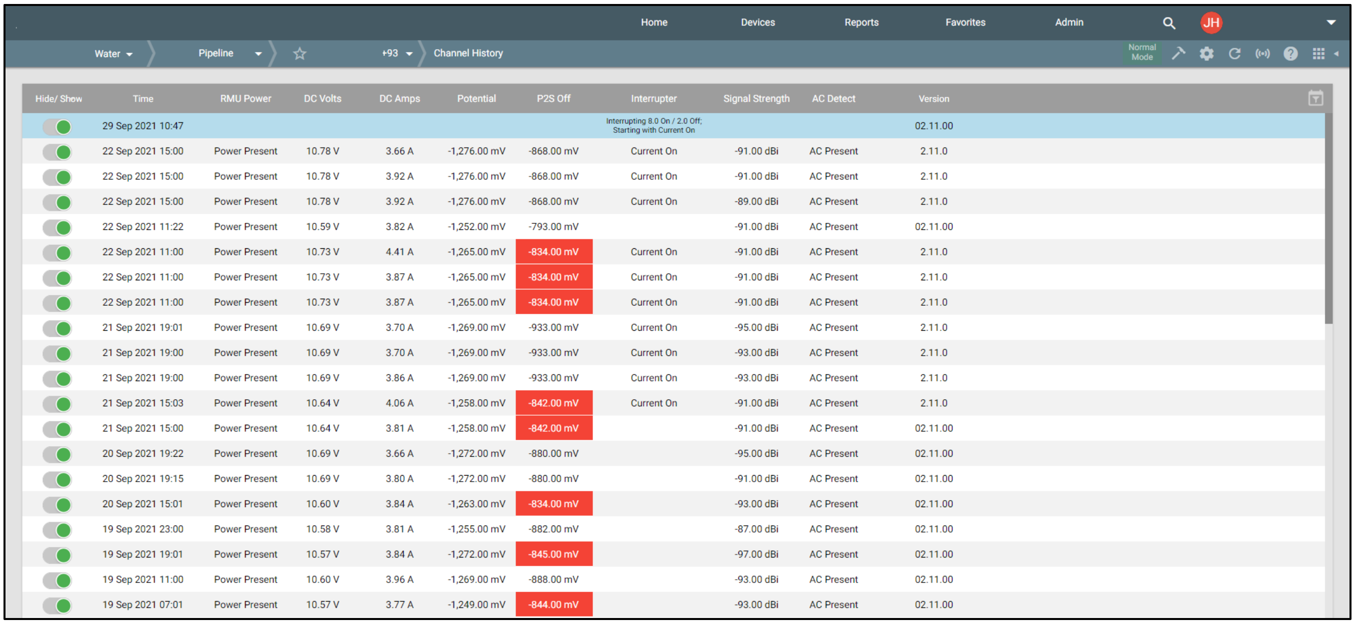


Figure 4: "Site view" page

Clicking the "Site History" button on the site page opens a tabular view of the site history descending in time from the most current readings (Figure 5). On this view the any measurements tagged as alarm values are highlighted enabling the user to view patterns of alarm occurrances. Most monitoring systems store the data for a minimum of three years in order to provide ample historical references for detecting and evaluating trends. This can be particularly useful in evaluating anode bed depletion in impressed current protection systems as well as evaluating anode depletion in sacrificial anode protection systems.



Hide/ Show	Time	RMU Power	DC Volts	DC Amps	Potential	P2S Off	Interrupter	Signal Strength	AC Detect	Version
	29 Sep 2021 10:47						Interrupting 8.0 On / 2.0 Off; Starting with Current On			02.11.00
	22 Sep 2021 15:00	Power Present	10.78 V	3.66 A	-1,276.00 mV	-868.00 mV	Current On	-91.00 dBi	AC Present	2.11.0
	22 Sep 2021 15:00	Power Present	10.78 V	3.92 A	-1,276.00 mV	-868.00 mV	Current On	-91.00 dBi	AC Present	2.11.0
	22 Sep 2021 15:00	Power Present	10.78 V	3.92 A	-1,276.00 mV	-868.00 mV	Current On	-89.00 dBi	AC Present	2.11.0
	22 Sep 2021 11:22	Power Present	10.59 V	3.82 A	-1,252.00 mV	-793.00 mV		-91.00 dBi	AC Present	02.11.00
	22 Sep 2021 11:00	Power Present	10.73 V	4.41 A	-1,265.00 mV	-834.00 mV	Current On	-91.00 dBi	AC Present	2.11.0
	22 Sep 2021 11:00	Power Present	10.73 V	3.87 A	-1,265.00 mV	-834.00 mV	Current On	-91.00 dBi	AC Present	2.11.0
	22 Sep 2021 11:00	Power Present	10.73 V	3.87 A	-1,265.00 mV	-834.00 mV	Current On	-91.00 dBi	AC Present	2.11.0
	21 Sep 2021 19:01	Power Present	10.69 V	3.70 A	-1,269.00 mV	-933.00 mV	Current On	-95.00 dBi	AC Present	2.11.0
	21 Sep 2021 19:00	Power Present	10.69 V	3.70 A	-1,269.00 mV	-933.00 mV	Current On	-93.00 dBi	AC Present	2.11.0
	21 Sep 2021 19:00	Power Present	10.69 V	3.86 A	-1,269.00 mV	-933.00 mV	Current On	-93.00 dBi	AC Present	2.11.0
	21 Sep 2021 15:03	Power Present	10.64 V	4.06 A	-1,258.00 mV	-842.00 mV	Current On	-91.00 dBi	AC Present	2.11.0
	21 Sep 2021 15:00	Power Present	10.64 V	3.81 A	-1,258.00 mV	-842.00 mV		-91.00 dBi	AC Present	02.11.00
	20 Sep 2021 19:22	Power Present	10.69 V	3.66 A	-1,272.00 mV	-880.00 mV		-95.00 dBi	AC Present	02.11.00
	20 Sep 2021 19:15	Power Present	10.69 V	3.80 A	-1,272.00 mV	-880.00 mV		-91.00 dBi	AC Present	02.11.00
	20 Sep 2021 15:01	Power Present	10.60 V	3.84 A	-1,263.00 mV	-834.00 mV		-93.00 dBi	AC Present	02.11.00
	19 Sep 2021 23:00	Power Present	10.58 V	3.81 A	-1,255.00 mV	-882.00 mV		-87.00 dBi	AC Present	02.11.00
	19 Sep 2021 19:01	Power Present	10.57 V	3.84 A	-1,272.00 mV	-845.00 mV		-97.00 dBi	AC Present	02.11.00
	19 Sep 2021 11:00	Power Present	10.60 V	3.96 A	-1,269.00 mV	-888.00 mV		-93.00 dBi	AC Present	02.11.00
	19 Sep 2021 07:01	Power Present	10.57 V	3.77 A	-1,249.00 mV	-844.00 mV		-93.00 dBi	AC Present	02.11.00

Figure 5: "Site history view" page

For an alternate view of the historical data, specific site parameters may be displayed graphically enabling the user to easily see the interaction of different measurements (Figure 6). In the view shown here the rectifier current ouptut is displayed (blue line) along with the pipe to soil "On" potential (yellow line) and "Off" potential (red line).

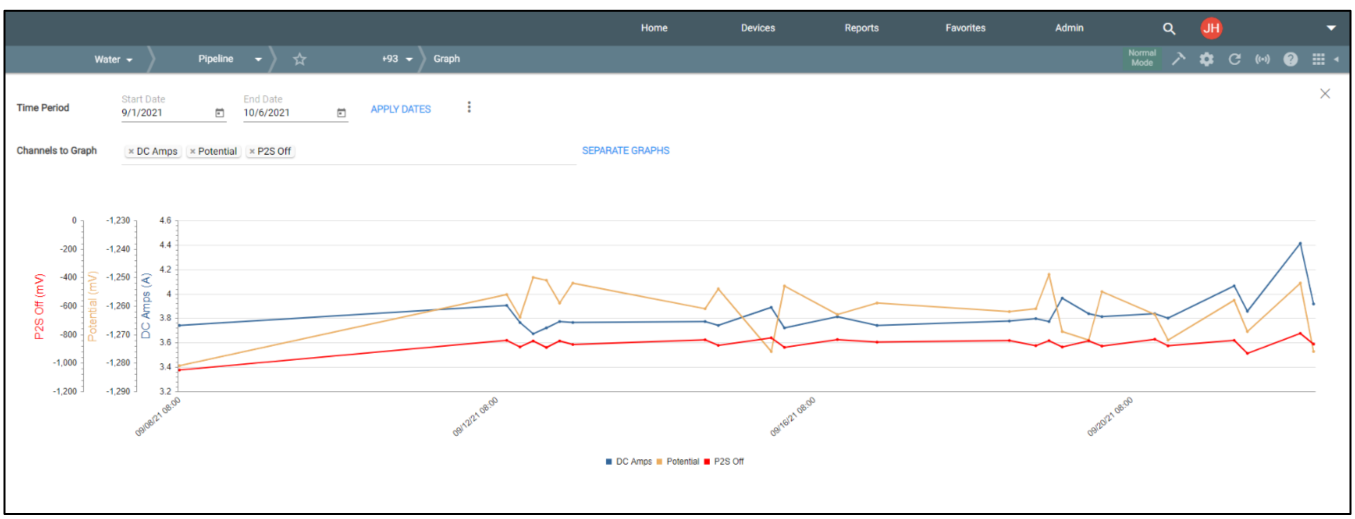


Figure 6: "Graph view" of site history

While in the graph view the user is able to place the curser over any data point on a line and see the measurement value as well as the high and low alarm set points for that parameter (Figure 7)

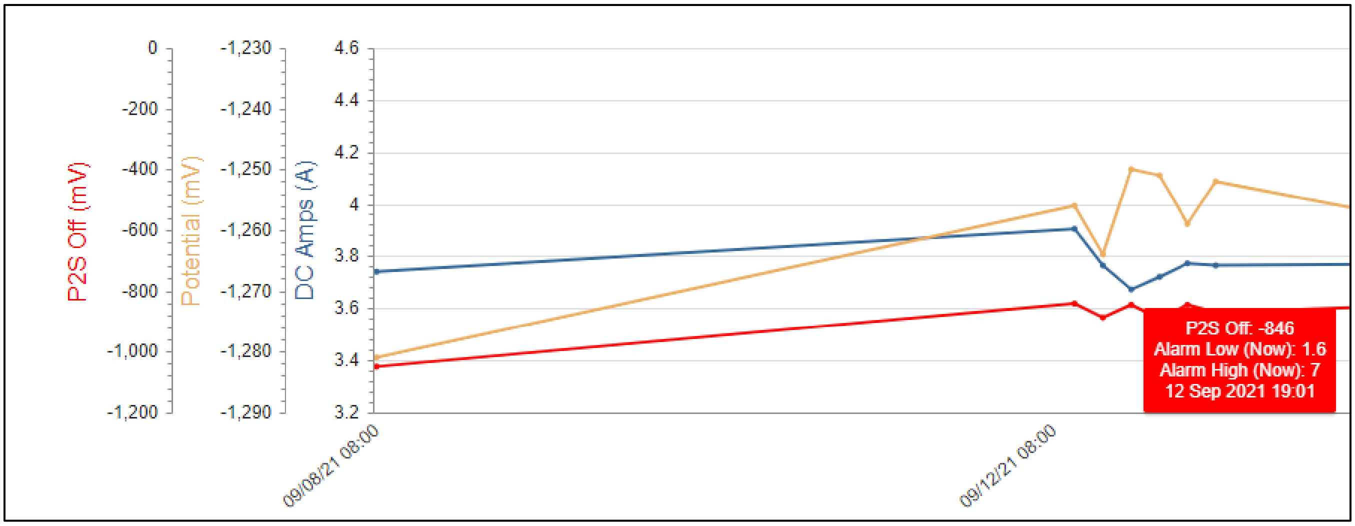


Figure 7: "Graph view"

As noted, the screens displayed are typical of the data interface provided by remote monitoring systems. There are some variations among different vendors of these types of monitoring systems but in general the features and functions described in this paper are representative of the industry. Similarly, the field hardware available from the various vendors exhibit more similarities than differences in the features and functions that are available.

SUMMARY

The primary purpose of this paper is to provide information regarding features, functions, and capabilities of remote monitoring systems that are currently in widespread use in the oil and gas pipeline industries to the municipal water utilities industry. Though the challenges faced by water utilities in corrosion abatement and cathodic protection are more similar than not to those faced by their oil and gas counterparts, the use of these types of data acquisition tools are still relatively rare in water utilities. Part of this of course pertains to the mandates imposed by federal and state regulatory agencies on the oil and gas industry. Due to the hazardous nature of the hydrocarbons flowing through these pipelines there are strict regulations regarding data acquisition and reporting in order to ensure adequate pipeline integrity management is undertaken in order to protect our health, safety, and the environment. However, the purpose of the mandates is to ensure pipeline integrity and reduce or eliminate pipeline leaks. These goals are shared by water utilities as well. The reasons why water utilities have not embraced monitoring technology vary. The absence of mandated pipeline integrity reporting requirements is likely a significant factor even though the cost of corrosion, as exposed in the NACE study, is extremely high in the water industry. It is telling that the areas in the United States where monitoring of cathodic protection systems is most prevalent in the water industry are areas where water is increasingly scarce and treated as a valuable commodity. Most projections for the future indicate water scarcity is likely to become a greater issue worldwide including areas of the United States currently unaffected by drought and water shortages. Another reason why some water utilities have not employed monitoring for cathodic protection systems is the perception that the systems are too costly to use on the restricted budgets afforded to price regulated utilities. A couple of decades ago as this technology was just emerging many oil and gas pipeline companies balked at the cost of monitoring systems, noting that they had technicians available for data acquisition for regulatory reporting. As the use of monitoring expanded, this perception was challenged. Not only is remote monitoring more cost effective than sending personnel to field sites every two months, it also provides additional, cost saving benefits in terms of early detection of problems and enabling limited resources to be focused on issues requiring attention rather than searching for problem areas. Another reason water utilities are not avid users of remote monitoring for cathodic protection is a lack of awareness of the cost and capabilities of the monitoring systems. It is for this reason in part that this paper was written. If awareness of the features and benefits of monitoring technology is expanded throughout the water industry that will ultimately result in use of monitoring technology in a greater portion of the industry.

REFERENCES

1. "Corrosion Costs and Preventive Strategies in the United States", Report FHWA-RD-01-156, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161
2. "Public Spending on Transportation and Water Infrastructure, 1956 to 2014" Report (March 2015) Congressional Budget Office supplemental data
3. Graph courtesy of East Bay Municipal Utilities District 375 11th Street Oakland, CA 94607-4240
4. J. Lary, Materials Performance Magazine, April 2001