TEST METHODS AND MONITORING OF INTERFERENCE AND CATHODIC PROTECTION OF PIPELINES IN JOINT FACILITY CORRIDORS

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ABSTRACT

This paper investigates a pipeline operator's options and techniques for testing, monitoring, and the maintenance of AC mitigation and cathodic protection systems after these systems have been designed, installed, and commissioned for a pipeline in a joint facility corridor with high voltage AC electric transmission lines. It can be very confusing and intimidating to a pipeline operator to monitor and test these systems for company and regulatory compliance and safety of company personnel and the general public. In addition, there are a number of safety precautions that should be adhered to whenever tests are being conducted in joint facility rights-of-way near high voltage AC electric transmission lines.

Keywords: joint facility corridors, electrical isolation, DC decoupling devices, zinc grounding cells, Polarization cells,

INTRODUCTION

AC mitigation and cathodic protection systems installed for pipelines in joint facility corridors of high voltage electric transmission circuits can be comprised of different equipment and materials either connected together as one system or isolated from each other for the purposes of reducing the induced and conducted AC voltages and currents on the pipeline and providing cathodic protection to the pipeline.

AC INTERFERENCE EFFECTS

To reduce AC interference effects to pipelines in close proximity to high voltage AC electric transmission circuits, the primary method is by reducing the pipeline resistance to earth. This is accomplished with AC mitigation systems installed at areas of peak AC voltages along the pipeline. In addition, in order to maintain safety under fault conditions, gradient control mats will be installed at aboveground appurtenances where contact with the pipeline could be made. The lowering of the pipeline's resistance to earth, however, can affect the operation of a cathodic protection system on the pipeline. These cathodic protection systems depend on a dielectric coating with high resistance to reduce current requirements and to maximize current distribution [1].

AC MITIGATION SYSTEMS

There are a number of different systems used for mitigation of AC on aboveground and buried structures. These include zinc ribbon anode material, packaged magnesium anodes, carbon steel, galvanized steel and bare copper wire. Some of these methods, including the zinc ribbon and the packaged magnesium anodes, can be used for both cathodic protection and mitigation of AC on the pipeline.

Use of the other methods of AC mitigation requires the isolation of the pipeline from the grounding system to reduce cathodic protection requirements and maximize current distribution. Isolation devices such as zinc grounding cells, polarization cells, and solid-state isolator-surge protectors are used to isolate the pipeline from the grounding system and to protect isolated fittings from lightning and AC interference damage. These devices are considered a part of these mitigation systems and require monitoring and maintenance.

CATHODIC PROTECTION & AC MITIGATION TESTING

When conducting tests of cathodic protection and AC mitigation systems in joint facility corridor rights-of-way, a number of safety and equipment issues are of concern. If these measurements are not conducted correctly, the interaction of these two systems can produce field measurement data that is not consistent with data recorded in areas without the influence of high voltage AC electric transmission lines. This data may indicate that areas of the pipeline system do not comply with minimum National and local regulatory requirements.

These measurements must be taken properly, the appropriate criteria applied, and each measurement appropriately evaluated. These activities are performed to maintain public safety, reduce operating costs from corrosion, and meet regulatory requirements. Proper training, well-documented measurement procedures, and an automated record keeping system can address these challenges [2].

Once criteria have been selected for use on underground structures, documented testing procedures are required so that evaluation results reflect the protected level of the structure and can be compared to previous and future data with confidence [3].

Testing and maintenance are also required at meter & regulator stations, valve sites, and compressor stations if these facilities are located on, or close to, high voltage AC electric transmission corridors. Testing of the cathodic protection and AC mitigation systems in meter and regulator stations and other facilities can be difficult due to the fact that most of these facilities have gradient control mats installed for aboveground pipe runs and other appurtenances. These gradient control mats are installed to reduce step and touch potentials to personnel.

National and local laws dictate the types of measurements that must be made on pipeline facilities. All cathodic protection systems need to be tested at least on an annual basis. The most common test employed to evaluate the effectiveness of an existing cathodic protection system is the pipe-to-soil potential measurement. In fact, the majority of the existing criteria for determining whether a pipeline is cathodically protected are all based on this particular measurement. All procedures associated with monitoring and testing of the cathodic protection system should include the recording of AC voltages and the integrity testing of gradient control mats. Whenever DC current measurements are made for cathodic protection monitoring, AC currents should also be recorded. AC IR drop measurements can be in error due to the impedance of the pipeline. Accurate AC IR drop measurements can be obtained with a large clamp-on ammeter if it is practical to use. Two different methods are used to record the AC current measurements:

1. An external shunt with a large current capacity.
2. Pipeline current measurements based upon voltage drop measurements at pipeline test stations.

This data can determine the possibility of AC corrosion occurring on the pipeline.

If a galvanic anode system is being used for AC grounding, a special circuit is required to measure galvanic DC current. This is required to reduce the AC current magnitude into the shunt resistor path so that DC current can be measured with a clamp-on ammeter or a voltmeter connected across the known shunt resistor [4]. This circuit is outlined in Figure 1.

Both AC & DC measurements of pipe-to-soil potentials should be recorded at each test station or other aboveground appurtenance of the pipe. If a gradient control mat is buried at these test stations and connected directly to the pipe, the reference electrode must be placed above the pipe but sufficiently remote from the gradient control mat so that the influence of the mat is reduced on the AC & DC potential measurement [5]. A distance of 10 ft. (3 m) from the end of the mat, which is usually 3 ft. (1 m) beyond the test station or aboveground appurtenance, is usually sufficient but this may require experimentation at these test stations to determine a remote location. This is outlined in Figure 2.

If a close interval survey is to be conducted on a section of pipeline in a joint facility corridor, the presence of AC voltage on the pipeline during a close interval survey should be monitored by recording AC measurements at specified intervals to determine if it is safe to continue.

TEST EQUIPMENT

Cathodic protection system test personnel require well maintained equipment that is adequate for the job. All testing and training should be geared toward minimizing error in the measurements taken in the field. Voltmeters or multimeters used for cathodic protection measurements such as voltage, current, and resistance must have an adequately rated AC filter to protect the meter from these induced AC levels.

If a close interval survey is to be conducted on a section of pipeline in a joint facility corridor, the voltmeters used should have a high AC voltage rejection rate. This high AC voltage rejection rate is required to reduce the possibility of picking up induced AC voltage on the survey wire while testing along these rights-of-way. This survey wire should be reconnected to the pipe wherever possible to minimize the length of wire along the right-of-way and reduce the induced voltage levels.

ELECTRICAL ISOLATION

Electrical isolation of piping networks is often essential for the effective operation of the cathodic protection system [6]. Prior to testing any pipeline system in a joint facility corridor, it is important to know what type(s) of electrical isolation is being used for insulated fittings and grounding systems.

Surge protection devices such as DC decoupling devices, zinc grounding cells, and polarization cells, are used to connect across insulated flanges and fittings. These devices can provide an alternative path to steady-state induced AC and fault current. Additional information on these devices is outlined below. Spark gaps and lightning arresters have also been used in the past in this application. They have been somewhat effective against lightning and small fault currents, but they are also subject to high maintenance and not suitable for draining continuous steady state induced AC currents.

DC Decoupling Devices

Within the past 15 years, solid-state DC Decoupling devices have been available and proved to be successful in providing a low resistance AC path for draining AC interference currents from the pipeline while maintaining a high impedance to DC, thus maintaining the DC cathodic protection voltage levels on the pipeline. The failure mode of DC decoupling devices is a short circuit condition which is a safe condition for AC hazards but a disadvantage to the cathodic protection system.

Zinc Grounding Cells
Zinc grounding cells are also frequently used as an electrical isolation device by providing a low resistance path for both AC & DC. One drawback of these cells is that AC can depolarize the zinc grounding cell allowing more cathodic protection current to pass through the cell. The typical failure mode for zinc grounding cells will be an open circuit thereby creating a possible safety hazard.

Polarization Cells
Polarization cells are similar to zinc grounding cells in that as AC depolarizes the internal plates it can lower the back voltage, which may compromise the operation of the cathodic protection system. If the solution in the polarization cell becomes diluted or the solution level is low in the cell, this can cause failure of the cell. The typical failure mode for the polarization cells will be an open circuit thereby creating a safety hazard.

OTHER ISSUES

There are other issues concerning the testing and maintenance of AC mitigation and cathodic protection systems in joint facility corridors near high voltage AC electric transmission circuits. These include casings and electric power line facilities including towers, electric system grounds, and guy anchors.

Casings
Carrier pipe, inside a casing in a joint facility corridor or subject to steady-state induced voltage or AC fault currents, should be connected to the casing through a surge protector type device to reduce the possibility of failure of the carrier pipe within the casing due to AC corrosion [7]. This connection is outlined in Figure 3.

Electric Power Line Facilities
Consideration for DC interference on electric power line towers, grounds, and guy anchors is often overlooked when designing an impressed current system for the pipeline in a joint facility corridor [8]. An interference survey should be conducted with the electric transmission system operator, at regular intervals, such as every two (2) years, to determine the extent of the interference and possible damage to the electric systems' buried facilities from DC interference.

RECOMMENDED PRACTICES

NACE Standard RP0177-95 "Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems" [9] outlines recommended practices in the areas of AC interference mitigation and cathodic protection in joint facility corridors. Some of the main recommendations concerning testing and monitoring of these systems are outlined or quoted below.

Personnel Protection
1. The possibility of hazards to personnel during construction and system operation due to contact with metallic structures exposed to AC electrical and/or lightning effects must be recognized and provisions made to alleviate such hazards. Personnel shall be informed of these hazards and of the safety procedures to follow for testing in areas near high voltage transmission lines.

2. Not more than one device intended to limit AC potentials on the pipeline shall be disconnected at any one time. In all cases, tests to detect AC potentials, on the pipeline, should be conducted first and the pipeline treated as a live electrical conductor until proven

otherwise. All cathodic protection test records should include AC potential readings taken at these locations also.

3. Safe work procedures must include methods of connecting and disconnecting test instruments. Test leads must be connected to the instrument first and then the structure. Test leads must be removed from the structure and then from the instrument.

4. Tools, instruments, or other implements shall not be handed, at any time, between a person standing over a ground mat or grounding grid and a person who is not over the mat or grid.

5. 15 Volts AC (RMS) open circuit or a source current capacity of 5 mA or more is considered to constitute a shock hazard. Mitigation systems should be designed to reduce and maintain AC voltage potentials below 15 V AC to prevent shock hazards to personnel and the general public.

Equipment Protection
1. The AC Current in the pipeline to be protected may flow to ground through the cathodic protection equipment. Current flowing in the cathodic protection circuits under normal AC power system operating conditions may cause sufficient heating to damage or destroy the equipment. Heating may be significantly reduced by the use of properly designed series inductive reactances and/or shunt capacitive reactances in the cathodic protection circuits.

System Testing
1. If galvanic anodes are used for cathodic protection in an area of AC influence and if test stations are available, the following tests should be conducted during each pipeline corrosion survey using suitable instrumentation: a) Measure and record both the AC & DC currents from the anodes, b) Measure and record the AC & DC pipe-to-soil potentials.

2. Grounding facilities for the purpose of mitigating AC effects should be carefully tested at regular intervals to ascertain the integrity of the grounding system.

CONCLUSION

Although AC mitigation and cathodic protection systems installed for pipelines in joint facility corridors can be confusing, with a basic understanding of the systems and personnel safety requirements, these systems can be tested and maintained to provide a safe and compliant cathodic protection system and reduce the induced levels of AC voltage on the pipeline to safe levels. Safe work procedures and safety training should be reviewed prior to any testing of the pipeline system on a joint facility corridor.

REFERENCES

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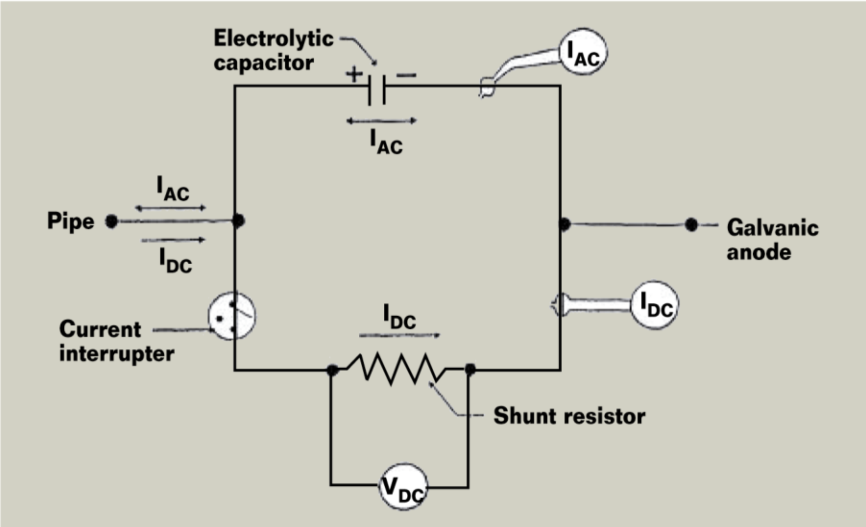
AUTHOR'S BIOGRAPHY

Mr. Robert Allen is Vice President of ARK Engineering & Technical Services, Inc. He is a member of NACE International and a NACE certified Cathodic Protection Specialist. Mr. Allen has more than 18 years experience in corrosion control and AC electrical interference analysis in the pipeline industry. He is the author of a number of papers and articles on the subjects of electrical interference effects, cathodic protection and electrical grounding. Mr. Allen has provided expert witness testimony and conducted technical seminars on these subjects. Mr. Allen holds a BS in Electrical Engineering from Northeastern University and a MBA from Bryant College.

Figure 1 – Using Shunt Capacitor & Resistor to Facilitate Measurement of AC & DC current (Redrawn from Ref. 1, p. 51)

Figure 2 – Pipe-to-Soil Potential Measurements in the Vicinity of Gradient Control mat (Redrawn from Ref. 5, figure 8-1)

Figure 3 – Electrolytic Capacitor with Surge Voltage Protection (Redrawn from Ref. 1, p. 47)



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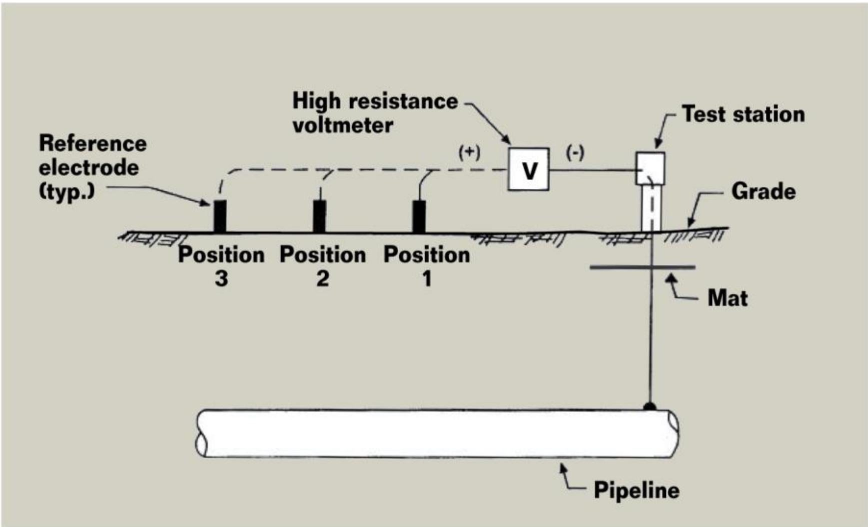
(Redrawn from Reference No. 1, page 51)



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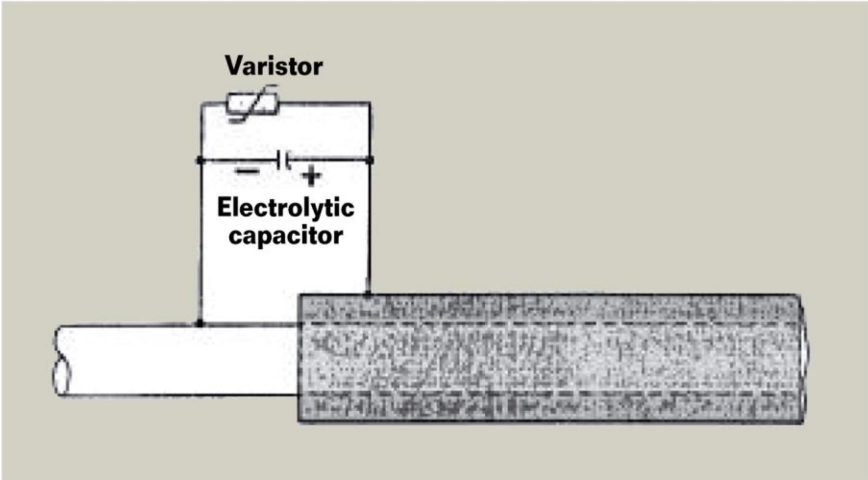

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