

DC Decoupler Modelling to Predict the Effects of Capacitance on CP Potential Surveys

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ABSTRACT

New DC decoupling technology provides operators with a solution to capacitance-related data accuracy challenges seen with traditional devices when recording structure to electrolyte potentials. When CP current sources are interrupted for systems that utilize DC decouplers, the capacitors discharge. If structure to electrolyte potentials are taken prior to full discharge, data inaccuracies can result. Data accuracy challenges have historically been difficult to predict definitively, which can present challenges in selecting the appropriate device prior to mitigation installation. Computer modelling in the mitigation design phase can proactively predict the magnitude of capacitance and rate of capacitive discharge. Further, different interruption cycles and their effect on capacitive discharge can be analyzed to determine the magnitude of the issue, so the optimal DC decoupler can be chosen, minimizing project inefficiencies and costs.

Key words: AC Interference, Decoupler, Capacitance, Isolation, Mitigation, Cathodic Protection, Energy Transmission, Testing, Corrosion Control, Simulation and Modelling, Test Methods

INTRODUCTION

Background – CP and Grounding Systems

Extensive and increased collocation of high voltage AC (HVAC) electrical transmission lines, coupled with advances in coating technology, has resulted in the emergence of the possibility of transfer of electrical energy from the HVAC line to paralleling utilities through electrical induction. That transfer of energy can result in safety risks for personnel, as well as corrosion risks for below grade assets.^{1,2} In order to mitigate those risks, operators ground the induced AC using grounding electrodes, typically consisting of bare copper cabling or zinc ribbon.

Cathodic Protection is commonly used in the utility industry to prevent external corrosion of below grade metallic assets as a result of interaction with the environment. Cathodic protection works by using a DC current to polarize a structure's cathodic sites to the open circuit potential of its

most anodic site.³ The current required to achieve cathodic protection is dependent on multiple factors, including the surface area of bare metallic structure in contact with the electrolyte.

When operators use grounding electrodes to reduce induced AC voltages, those grounding electrodes function as bare metallic structure in contact with the earth, which increases cathodic protection current requirements. In order to prevent that increase in cathodic protection current requirement, the DC decoupler was invented. The DC decoupler is AC-continuous but DC blocking, so installation of the device between the asset and the grounding electrode allows for grounding of AC voltages without resultant DC CP current requirement increases. The downside to DC decouplers is their effect on monitoring CP efficacy during interrupted surveys involving rapid changes in DC potentials. DC decouplers utilize a capacitor in their design, and when CP systems are ON, that capacitor accumulates charge. When CP systems are interrupted to test functionality, that capacitor discharges, affecting CP potential reads until current discharge from the capacitor has ended. If not accounted for, that capacitance can affect the accuracy of cathodic protection surveys, as this appears as an additional current source that has not been interrupted.

CAPACITANCE THEORY

Capacitor Theory

When a voltage is applied to a capacitor, the capacitor's internal plates start to accumulate a charge imbalance. One plate accumulates a positive charge, and the other accumulates a negative charge. When that voltage is removed, if the capacitance is applied to a circuit, the charge imbalance starts to dissipate through current flow. Initial discharge current is high, but as time increases, the amount of current discharged decreases to approach zero. The same happens when the voltage is reapplied. Initial charging current for the capacitor is high, before gradually decreasing to zero as the capacitor reaches full charge. Factors affecting time to charge and discharge a capacitor include the following ⁴:

- Circuit Resistance: Increased circuit resistance increases charge and discharge timelines
- Capacitance Value: Increased capacitance value (ability of the capacitor to store charge) increases charge and discharge timelines

Applying the above theory to cathodic protection systems, as identified earlier, some systems that are subject to AC interference utilize decouplers, which operate using a capacitor. When CP sources are ON, the capacitors initially charge until they cannot accumulate any additional charge imbalance. Once charged, capacitors do not affect CP circuits in a meaningful way during steady state CP operation.

Capacitors begin to affect CP circuits during testing. During many testing scenarios, cathodic protection systems are interrupted (CP current abruptly goes to zero) on a repeating, square wave cycle to remove an error due to voltage drop from IR during a CP measurement and assess structure polarization. Structure to Electrolyte potentials during that interruption time typically appear similar to Figure 1 below. All measurements are with respect to a copper sulfate electrode (CSE):

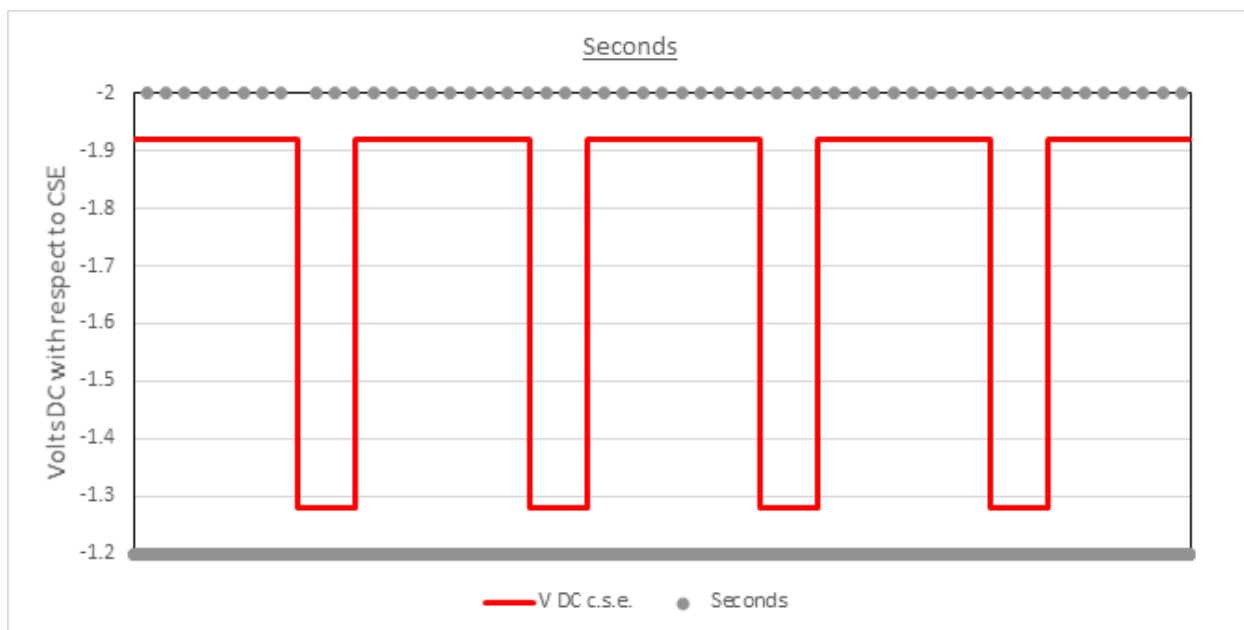


Figure 1: Typical 9 seconds ON 3 second OFF Cycle Without Capacitance

If decouplers are present on a system, when CP current sources are cycled ON and OFF, the capacitors charge and discharge, respectively. Figure 2 shows the effect of capacitor charge and discharge structure to electrolyte (S/E) potential readings:

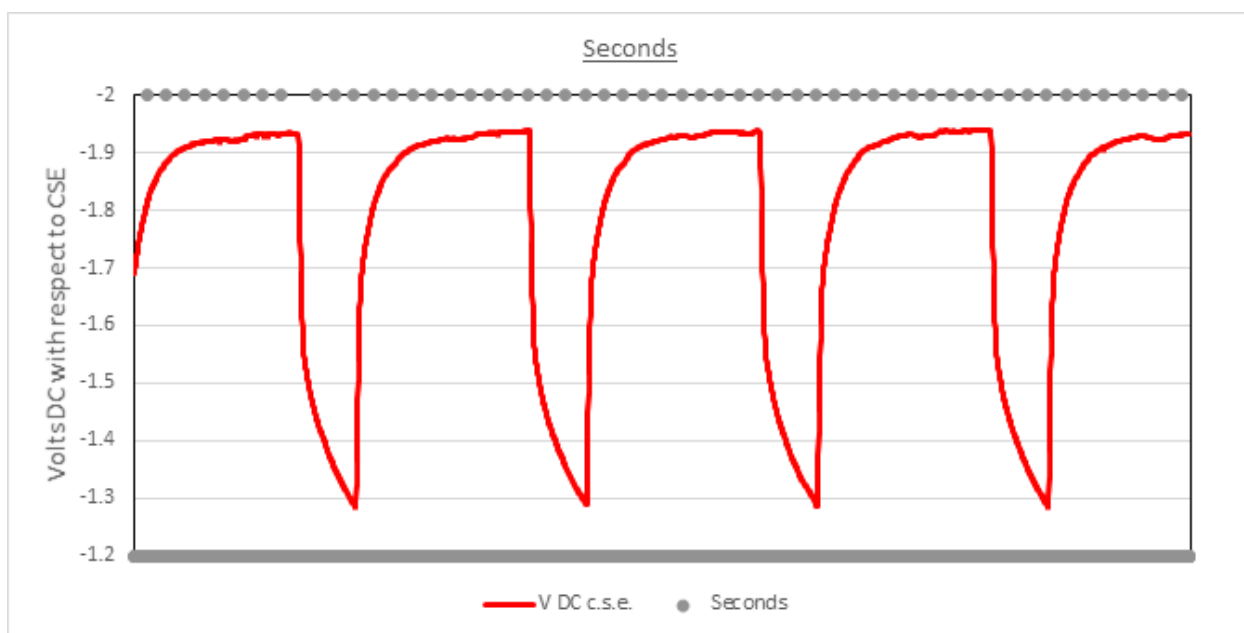


Figure 2: Common 9 seconds ON 3 second OFF Cycle With Capacitance

As can be seen in Figure 2, if a structure to electrolyte potential is taken prior to full capacitor charge and discharge, artificially electropositive ON potentials and artificially negative OFF potentials would be observed, which could impede CP system effectiveness evaluation.

Survey Techniques to Counter Capacitance and Related Survey Impacts

In order to counter data accuracy-related issues, current source interruption cycles may be extended. For example, a commonly used CP current source interruption cycle for CP testing is 3 seconds ON, 1 second OFF. If full capacitor charge and discharge is not achieved within that timeline, it is common to switch to a longer cycle, such as 9 seconds ON, 3 seconds OFF. In more extreme cases with very high circuit resistances, even longer cycles such as 45 second ON, 15 second OFF may be necessary to achieve accurate data, though longer cycles may impact polarization. Those longer cycles directly impact survey efficiency, in particular, close interval survey (CIS). During CIS, S/E potentials are taken at close intervals, typically every 5 feet (1.5 meters). In order to avoid repeat readings, for a 3/1 cycle, a technician cannot move faster than 5 feet (1.5 meters) per 4 seconds (75ft/min) (23m/min). For a 9/3 cycle, a technician cannot move faster than 5 feet (1.5 meters) per 12 seconds (25ft/min) (7.6m/min). For a 45/15 cycle, a technician cannot move faster than 5 feet per 60 seconds (5ft/min). Using the above figures, a one-mile (1600 meter) survey segment would take at least 1.2 hours for the 3/1 cycle, 3.5 hours for the 9/3 cycle, and 17.6 hours for the 45/15 cycle. Increased survey timelines result in increased labor costs to collect data, which illustrates the economic impact of increased capacitor discharge times on CP surveys.

CAPACITANCE PREDICTION AND SOLUTIONS

Capacitance Technology Solutions

In response to the economic impact that capacitance can have on CP surveys, decoupler technology has evolved. Decouplers are now commercially available that mask the effects of capacitance, thus allowing for shortened survey cycles and reduced economic impact. Those devices have been evaluated against the system with no decoupler installed, and have been shown to achieve accurate potential measurements.⁴ This decoupler feature to aid CP surveys has been added to standard decoupler functions of providing over-voltage protection and mitigation of steady-state AC induction. However, due to product development costs and more advanced circuitry, devices with the new technology are significantly more expensive than traditional devices, which makes it advantageous for an operator to know whether they need a device that masks capacitance, or if a standard unit would work instead, as well as impacts to survey timelines.

Capacitance Prediction Status Quo

There are ways that capacitance can be predicted prior to decoupler procurement. In general, capacitance can be expected if:

- Coating quality is excellent (high resistance)
- Asset diameter is small
- Multiple decouplers are specified/required
- Soil conditions are dry regularly/high soil resistivity

Presence of the above conditions points toward, but does not necessarily guarantee, that capacitance could be an issue. However, variation of the above variables does not necessarily directly correlate to capacitance in a quantitative way. For example, a 50% reduction in soil resistivity does not cause a 50% reduction in observed capacitive effects. Therefore, the above can be used as guidelines for when to suspect that capacitance will be an issue, but they do not