MicroMax Instruments

Technical Brief: AC Zero Crossing and MicroMax GPS300

In a typical cathodic protection (CP) application, factors exist in the environment that can cause stress to the electrical equipment in use. Consequently, the design of this equipment must be robust enough to withstand these factors. Even with the use of protective measures in an electrical design, however, electrical components have a finite lifetime, and environmental stress can minimize this lifetime.

The stressful effects of the environment in a CP application are sometimes observed during current interruption surveys, in which a current interrupter is generating a control signal to toggle the relay on a rectifier's DC output or AC secondary. When controlling a relay, the current interrupter itself can employ techniques to minimize the stress on both the relay and the rectifier. One technique in particular is AC zero crossing interruption, and the American Innovations MicroMax® GPS300 Current Interrupter is the first interrupter in AI's product line to include selectable AC zero crossing interruption.

This Technical Brief will explain how the MicroMax GPS300 AC zero crossing interruption feature can reduce stress on your CP assets, and ultimately prolong their lifespan.

AC Zero Crossing and MicroMax GPS300

Pipelines and Anode Ground Beds as Inductors

Three fundamental components in a cathodic protection application are the rectifier and interconnects, the anode ground bed, and the pipeline. The primary function of the first two components is to serve as the source and conductors of electrical current with the intent of protecting the pipeline from corrosion. An ideal rectifier, interconnects, anode ground bed, and pipeline present no resistance to the flow of electrical current, nor do they present other electrical conditions such as inductance. These components, however, are not ideal conductors and can be modeled as a combination of a resistor and an inductor, as shown in Figure 1:

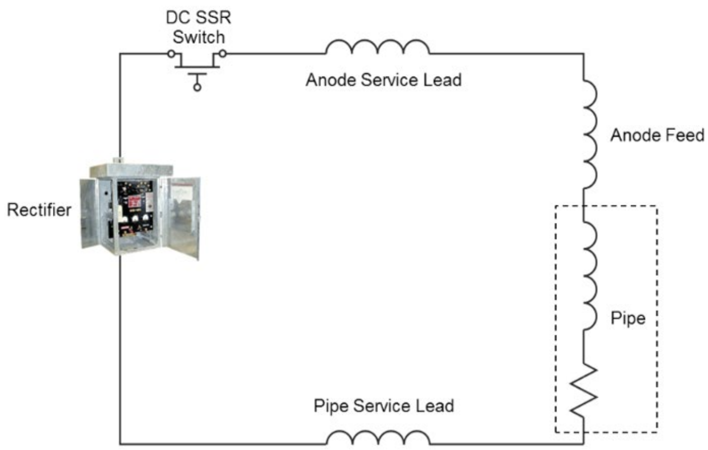

Figure 1

It is the behavior of the pipeline and anode ground bed as inductors that can have the most influence over other components in a CP circuit, in particular the relay (shown in Figure 1 as a DC SSR switch) and the rectifier.
An inductor is an electrical circuit element that stores energy in a magnetic field, and inductance is a measure of the ability of an inductor to store magnetic energy. Inductance is present in all electrical conductors, not just the discrete circuit element of an inductor. Miles of pipeline present inductance, and a fair amount of this inductance is due to the length of the pipeline. The amount of energy stored in an inductor is a function of the inductance and the current flowing through the inductor, calculated with the following formula:

$$U_L = \frac{1}{2} L i^2$$

Where UL is energy (in Joules), L is inductance (in Henries), and i is current (in Amps). As inductance and/or current increases, the energy stored within the inductor increases, and this energy could be harmful to other components in an electrical system under certain conditions.

AC Zero Crossing and MicroMax GPS300

Switching circuit elements and power supplies are particularly prone to the effects of inductance, and therefore these components must be selected or designed carefully. The CP circuit model from Figure 1 can be simplified to the electromagnetic circuit presented in Figure 2:

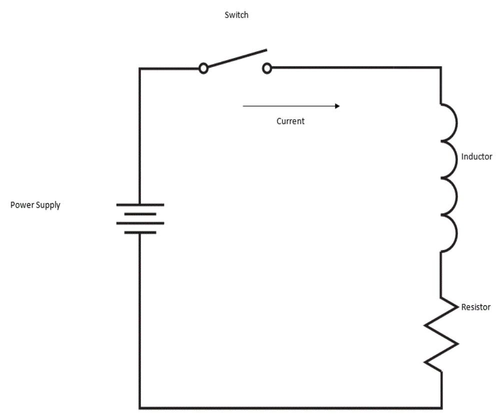

Figure 2

When the switch is closed in the circuit in Figure 2, current flows from the power supply through the inductor and resistor. The voltage drop across the inductor is given by the following formula:

$$V_L = L\frac{di}{dt}$$

Where VL is in volts, L is inductance (in Henries), and di/dt is the rate of change of current (in amps per second). As inductance and/or the rate of change of current increases, the voltage drop across the inductor increases.

The Effect of Inductance on CP Electrical Components

At the moment the switch in Figure 2 is opened, the current through the inductor approaches zero amps at a fast rate. However, the voltage across the inductor will rise sharply because of the instantaneous rate of change of current. The sharp increase in voltage across the inductor results in a similar sharp increase in voltage across the switch terminals. Comparing to the CP circuit in Figure 1, the DC SSR switch/relay will see a significant rise in voltage across its terminals during an interruption cycle at the moment the relay is opened. This increased voltage, and corresponding increase of power dissipation in the relay, can reduce the lifetime of the relay or in extreme cases damage it.

AC Zero Crossing and MicroMax GPS300

At the moment the switch in Figure 2 is closed, the current delivered from the power supply approaches the maximum current delivered to the resistive/inductive load at a fast rate. This instantaneous demand of current, or inrush current, creates stress on the components of the power supply.

Comparing to the CP circuit in Figure 1, the rectifier will see an inrush current condition at its output during the interruption cycle at the moment the relay is closed. This increased current, and corresponding increase of power dissipation in the diode stack of the rectifier, can reduce the lifetime of the rectifier diodes or in extreme cases damage them.
DC SSR relays from American Innovations and most rectifiers used in cathodic protection are designed to be robust enough to withstand the inductive stress of a CP circuit. However, even with robust design it is good practice for users to operate those relays and rectifiers in a manner that minimizes the stress the components experience. One way to minimize stress on the components used in a CP application is to control them with a current interrupter that has AC zero crossing interruption capability.

Since both the AC power line as well as the DC output of the rectifier are waveforms that change with time (i.e. they have a strong AC component), performing zero crossing interruption can be beneficial whether the switching is done on the AC side or on the DC side of the rectifier.

AC Zero Crossing Interruption

The MicroMax GPS300 current interrupter from American Innovations is the first interrupter in AI's product line to include selectable AC zero crossing interruption. While being powered from an AC power source with this feature enabled, the GPS300 monitors the AC input sine wave to determine the points in time in which it crosses zero volts. The GPS300 will adjust its output switching cycle such that the relay is switched synchronously with the zero crossing points of the AC input, as shown in Figure 3:

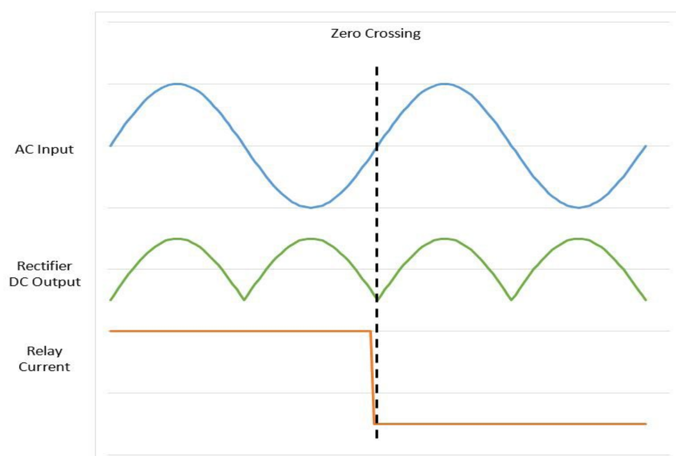

Figure 3

AC Zero Crossing and MicroMax GPS300

With AC zero crossing enabled, the rise and fall times from the switching output waveform from the GPS300 can have up to 8ms more jitter (one half of a 60Hz AC sine wave period) compared to the feature being disabled. However, this jitter is extremely small relative to the normal switching speed of a relay, or to the interruption cycle itself, and it can be considered as negligible.

By opening the relay at the zero crossing points of the AC input, the magnitude of the voltage spike observed across the relay terminals can be significantly reduced, thereby minimizing stress on the relay and prolonging its life. Similarly, by closing the relay at the zero crossing points of the AC input, the magnitude of the inrush current experienced by the rectifier can be significantly reduced, thereby minimizing the stress on the rectifier diode stack and prolonging the rectifier's life.

Click here for more information about the MicroMax GPS300 current interrupter.