

WHITE PAPER / CATHODIC PROTECTION PERFORMANCE

MANAGING SEASONAL EFFECTS ON CATHODIC PROTECTION OPERATION

Soil characteristics and pipeline corrosion are inextricably linked. It's well known that soil composition, temperature, moisture and concentration of ions can all influence where a buried pipeline corrodes and how fast the corrosion occurs.

But in many cases, soil temperature and moisture can vary significantly throughout the year causing large swings in soil resistivity and the corrosivity of the soil. Unfortunately, many cathodic protection (CP) systems do not adequately consider the seasonal variability of soil conditions when setting rectifier voltage output, potentially leaving pipeline assets more vulnerable to corrosion at certain times of the year.

CP remote monitoring units (RMUs) may not be properly configured to account for seasonal variability in soil conditions. This most commonly occurs with alarm limits, which are set to alert technicians when CP voltage, current or other parameters are measured outside of the limit boundaries. Such alarms are useful to alert technicians of potential problems, maintain pipeline integrity and protect the environment.

But alarm limits that don't incorporate seasonal variability in soil conditions may trigger alarms, even though the equipment is working normally. As a result, technicians may be overwhelmed with alarms, lack the information to prioritize their response to the alarms, and could even experience alarm fatigue, a potentially dangerous condition where they begin to ignore alarms and develop a mistrust remote monitoring equipment.

To cope, some technicians may widen the alarm limits of the problematic RMUs in an attempt to reduce the number of notifications. This may work in the short term but could also have the unintentional consequence of reducing the effectiveness of pipeline monitoring and protection.

Recent advances in data analytics and machine learning offer a solution. These technologies can leverage the historic, long-term data sets that RMUs collect to identify trends in seasonal operating data and help determine the optimal settings for CP voltage and RMU alarm thresholds.

The data sets and machine learning algorithms could also be used to set alarm limits for newly installed RMU devices on rectifiers that have never been monitored. In this case, technicians could reference operational data from RMUs in similar environments and combine it with local soil classification data to predict seasonal variations in soil conditions and then set the appropriate alarm limits.

STUDY SHOWS CONSISTENT SEASONAL CYCLES

A recent study illustrates the advantages of these methodologies in setting seasonally adjusted alarm limits for RMUs. The study consolidated more than ten years of data that was collected from about 7,000 RMUs installed on impressed current cathodic protection (ICCP) rectifiers. In most cases, the rectifiers provided near-constant voltage output that was set manually by configuring taps. The RMUs recorded the DC voltage and the DC current and transmitted the data by satellite or cellular networks to a secure storage database.

Examining the historical data from a single RMU (Figure 1), shows that the voltage levels (top chart) remain consistent at about 8.5 volts throughout the collection period. The few data outliers could be caused by scheduled instant-off potential readings or power outages. The lower chart shows the DC current, which must travel through the soil to complete the circuit. The oscillation in the measurements reveals that the current changes in a cyclic pattern from year to year, which can be attributed to seasonal changes in soil resistivity.

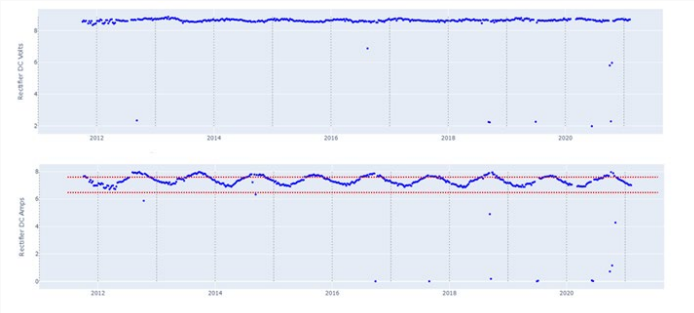


Figure 1. Measurements from a single RMU unit collected since 2011. Red lines indicate upper and lower limits that trigger an alarm during exceedances.

The red bars indicate the upper and lower alarm limits for the current measurements. If a measurement is taken outside of these limits, the RMU would trigger an alarm and notify a technician. This is an effective way to manage CP performance; however, it's quite likely that these limits do not take seasonal variations of soil conditions into account. It is possible that if the limit values were set in the summer, the winter behaviour of soil resistivity would likely be different, causing an exceedance and alarm even though the system was working normally.

Calculating system resistance (voltage divided by current) and plotting the resulting data set shows that resistance also changes cyclically with clear maximum and minimum periods. The calendar date with the highest soil resistance can be calculated by fitting the data to a cosine curve (Figure 2) with a fixed period of one year, and a fixed offset from the beginning of the year.

To understand this phenomenon more wholistically, historical system resistance for thousands of RMUs located throughout North America were fit to a cosine curve, and the calendar date with maximum resistance was calculated. This data is expressed as a histogram (Figure 3) of phase offset fit parameters. The chart shows that the highest soil resistance in this case is in the February to April range, with the peak in mid-March.

With this information, technicians can set more accurate alarm limits that are based on actual seasonal variations in soil conditions and reduce or eliminate false alarms.

ENHANCING PREDICTIONS WITH SOIL CLASSIFICATION DATA

Soil classification data from the United States Department of Agriculture (USDA) Soil Database was also incorporated into the study to evaluate its value in predicting seasonal variations in soil conditions and RMU alarm limits. Soil temperature and soil moisture

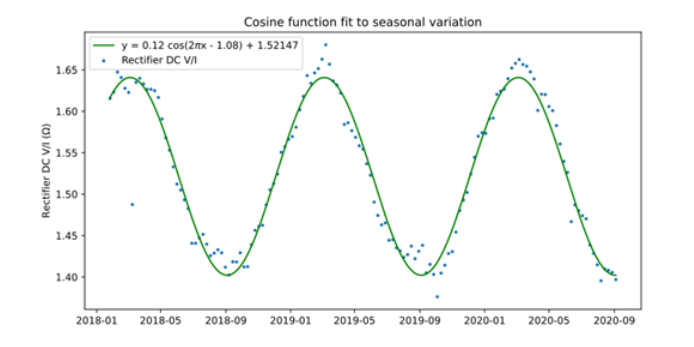


Figure 2. A cosine function fit of the seasonal variation in the DC system resistance.

classifications were queried for each of the 7,000 sites and if available, plotted against the cosine fit parameters.

For different soil moisture and temperature classifications, there is a subtle difference in the cosine fit parameters. The differences are significant enough to use the soil classifications as an input to a machine learning algorithm. The implication is as follows: if you know the soil conditions of the asset being monitored, an informed prediction can be made of the seasonal variation in future readings.

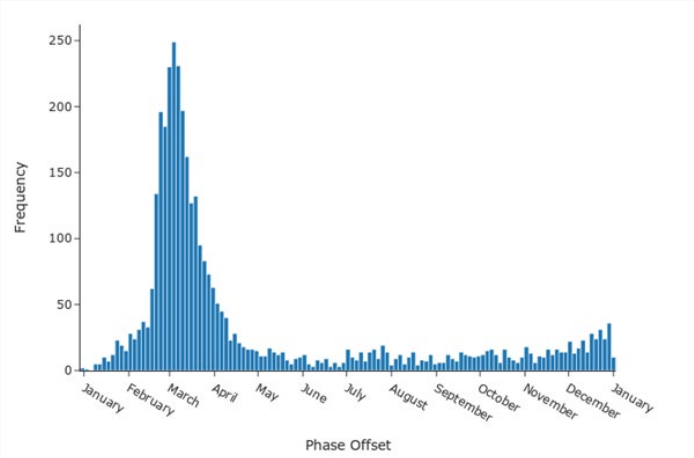


Figure 3. A histogram of phase offset fit parameters. The phase offset represents the time of year with maximum resistance in the rectifier system and clearly shows a peak in mid-March.

Moisture, according to previous studies, has been said to have the biggest impact on modifying resistivity. [1] [2]. But in the case of buried pipelines and anode ground beds, seasonal variation of temperature may play a larger role in influencing system resistance than moisture. One explanation is that soil moisture is fairly consistent beyond one to two metres in depth, whereas temperature variation can be experienced at greater depths. [3] However, it may take several days or even weeks for cold temperatures at the surface to reach buried pipelines. This lag may account for the observed maximum system resistance that occurs in mid-March at the depth of the pipeline soil anode system, more than one month after the average coldest air temperatures

A decision-tree algorithm has been developed to select the soil moisture or temperature classification according to the fit parameters of the RMU data. The initial model is about 60 percent accurate at selecting the correct classification and could be improved with a larger dataset of RMU readings or additional soil data such as local resistivity measurements.

TWO-STAGE APPROACH FOR SETTING ALERT THRESHOLDS

A large data set of RMU measurement data, soil classifiers and data analytics provide a powerful tool for optimizing alarm thresholds to account for seasonal soil variations. The process can be applied to existing RMU devices—to predict future conditions—or to new RMU installations to set initial threshold limits that are in line with anticipated seasonal variations and soil classifiers.

Technicians could achieve these optimizations using a two-step process. Once a rectifier is equipped with an RMU for the first time, the location latitude and longitude can be used to obtain soil classifiers. The data can be added to a model that references similar operational conditions and seasonal variations to generate a predictive cosine curve and suggest reasonable alarm limit values.

After the RMU has collected a sufficient number of readings (depending on the frequency of measurement and transmission), resistance data will automatically be fit to cosine curve. If a good fit can be achieved, then highly accurate alert parameters can be set based on the actual seasonal variations the rectifier experiences. The settings could also incorporate a standard deviation to establish a range that is large enough to avoid nuisance alarms and ensure the rectifier is operating properly to fully protect the pipeline (Figure 4.)

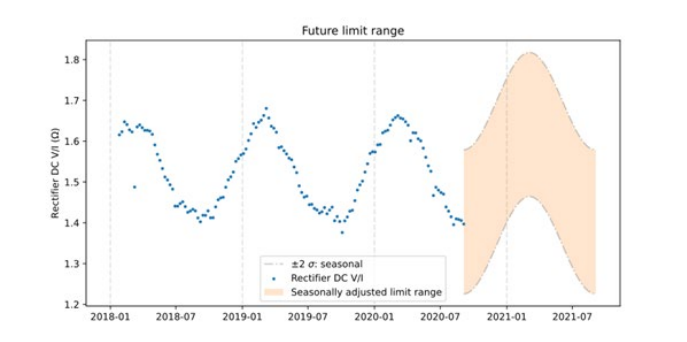


Figure 4. Soil classifiers and a sufficiently large data set of operational data can be used to predict future operating conditions and optimal alarm limits to avoid unwanted alerts.

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