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A Non-Contact Remote Monitoring System for Measurement of AC Transmission Line Power Flows

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ABSTRACT

Information sharing between power line operators and pipeline corrosion engineers is a critical component to accurately assess and design mitigation for any possible interference effects on pipelines. However, this information is often challenging to obtain and does not show the complete picture of the dynamic nature of power flows on transmission lines.

An innovative new monitoring technology is now being utilized by pipeline owners and operators to monitor real-time power flows on transmission lines and determine the phase arrangement when intersecting pipelines are located in shared right-of-ways. The monitoring systems utilize non-contact, ground-based, electromagnetic field sensors coupled with geometric data to analyze and quantify the AC power flows without needing the involvement of the electric utility companies. Data collected is remotely communicated to cloud servers where advanced computations are performed and the data is made available for remote viewing or system integration via an API.

The information collected from the monitoring systems can be utilized in the analysis of AC interference studies for mitigation system design, for real-time continuous monitoring to detect changes in power flows as electric utilities modify their systems and additional sources of generation come online or others are retired, for integration into pipeline integrity management software solutions for further analysis, or for active control of mitigation systems.

Key words: AC Interference, AC Corrosion Risk, Induced Voltages, Pipeline Integrity Monitoring

INTRODUCTION

With increasing scenarios of high voltage alternating current (AC) power lines being co-located with pipelines in a shared right-of-way, the importance of obtaining high quality information on the AC power flow of the nearby power lines is critical to appropriately design mitigation for, and monitor for the effects of AC corrosion. The AC voltage induced onto the pipeline creates a potential difference between the pipeline and the surrounding soil. This potential difference creates elevated risk for accelerated AC corrosion of the pipeline wall, especially in locations where insulating coatings have failed (holidays) [1]. It is often a challenging process to obtain this AC power flow data from the power line companies, and if obtained, often does not communicate the dynamic load flow patterns of power lines as they typically vary minute to minute and seasonally. Multiple factors contribute to the threat severity of AC corrosion including the separation distance from the pipeline to the AC source, the soil resistivity, co-location length, crossing angle, phasing arrangement, and the power line current. Without insight into the actual power line current, assumptions must be made creating uncertainty in the confidence of an AC mitigation system design [2,3].

A technology has been developed that can collect data on the AC power flows and conductor phase arrangement independent of the involvement of the power line companies. The patented technology called LineVision PACT™, utilizes magnetic and electric field sensors to collect measurements of the Electromagnetic Field (EMF) that the power lines generate when AC power is flowing on them. The collected measurements are remotely communicated to servers where the data is processed through proprietary algorithms and the AC current flowing on the power line is able to be determined.

EMF MEASUREMENT

When AC current flows along an electric transmission lines in North America, a 60 Hz AC magnetic field (B-field) is produced. In other parts of the world, such as Europe, a 50 Hz electric system is used but the same physics apply and the equivalent measurements can be made. The voltage on the power line is usually constant as the electrical equipment is designed to a specific voltage level. The voltage of the power line produces an electric field (E-field). However, the current on the power line can vary greatly based upon the demand for power or nearby levels of generation. Transmission circuits typically are in sets of 3 conductors with each representing a phase, annotated as A, B, and C. Each phase is offset by 120 degrees so that the power is delivered to the load as smoothly and continuously as possible.

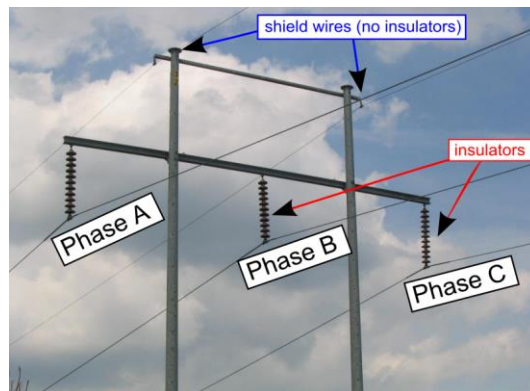
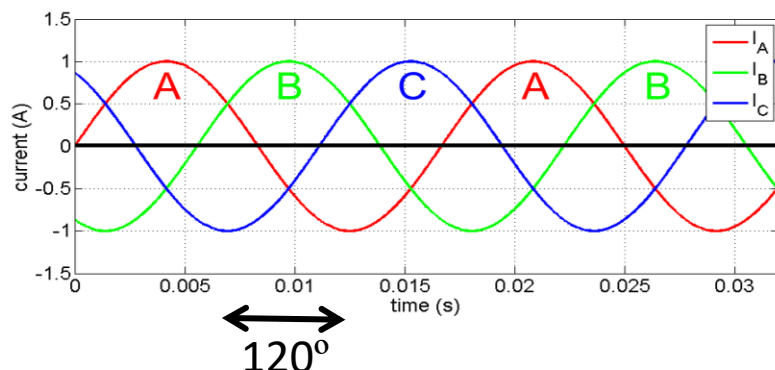


Figure 1: 3 Phase Timing Diagram and 3 Transmission Line Conductors

The remote monitoring system is ground-level based, with no equipment contacting the pipeline or power line and typically installed in the shared right-of-way where pipeline owner easements exist. EMF values are measured by an array of sensors, then securely and wirelessly transmitted to servers where analytical computations take place.

The vector magnetic field phasors are measured along multiple axes in the cross-sectional plane of a typical shared right-of-way. This measurement is made using magnetometers oriented in multiple directions or by additional methods. The sensors produce a signal that is passed through a filter before being sampled by an Analog-to-Digital Converter. The magnetic field phasor measurements and the electric field phasor measurement are performed simultaneously, allowing the computation of relative phase angle between the three pairs of 60 Hz sinusoidal signals.

The 60 Hz AC electric field (E-field) created by voltage on energized overhead conductors is measured by using electrodes or additional methods to form a capacitive electrometer. The voltage across the electrometer is filtered and amplified through a signal conditioning path and sampled using an Analog-to-Digital Converter.

The fundamental equation utilized to determine the current flowing on a transmission line is the Biot-Savart law (Equation 1), which describes the magnetic field generated by an AC current.

$$\mathbf{B}(\mathbf{r}) = \frac{\mu_0}{4\pi} \int_C \frac{I d\mathbf{l} \times \mathbf{r}'}{|\mathbf{r}'|^3}$$

$\mathbf{B}(\mathbf{r})$ = Vector magnetic field at position $\mathbf{r}$

μ_0 = Permittivity of free space

I = Electric current

$\mathbf{r}'$ = Radial distance from conductor

$d\mathbf{l}$ = Conductor element

Equation 1: Biot-Savart Law

This sensing method allows for the determination of relevant line characteristics, as the amplitude of the magnetic field can be related to the amount of current on the line provided that the distance from the remote monitoring system to the power line is known.

