

Obtaining the polarized potential under AC interference

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ABSTRACT

Obtaining the polarized potential (off potential / instant-off potential / IR compensated potential) of a pipeline is considered extremely difficult, if not impossible, when the pipeline is interfered by an alternating voltage, and particularly if the pipeline is fitted with capacitive AC mitigation devices. Yet, a number of procedures exists to obtain information on the polarized potential, due to its importance in cathodic protection operation. Two distinct approaches are measurements on the structure/pipeline itself, and measurements on coupons. While it can be agreed that the structure measurement is challenging, some believe that the coupon method is error-free, as the AC interference is not present on a disconnected coupon. This paper will illustrate that this is not entirely true. Some of the present challenges and some of the approaches to get meaningful measurements are presented.

Key words: Cathodic Protection, Polarized Potential, Instant-Off.

INTRODUCTION

The -850 mV (CSE) criterion refers to the polarized pipeline potential that is free of any IR-drop. Different methods to obtain the polarized potential exist. Some of these are listed below:

Pipeline instant-off

Interruption of the CP current will cause the current, I , and thus the IR-drop to become zero and the remaining polarization immediately after the interruption is representative of the polarized potential of the pipeline. This is illustrated in Figure 1.

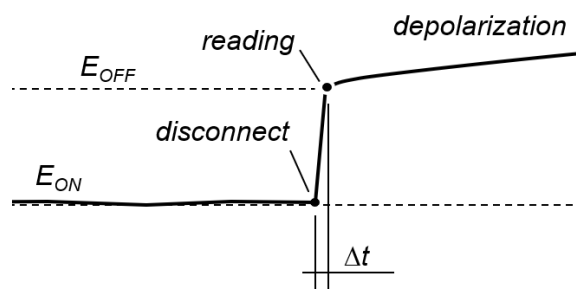


Figure 1: Instant-off disconnect curve of a simple DC system. The interruption of the CP current will cause an immediate shift of the potential from its on-potential to the “off”-potential, representative of the polarized potential. From there, the polarized steel will slowly depolarize over time. In praxis, a small time is necessary before a measurement is taken. This can be as short as a few milliseconds.

This potential is a mixed potential of coating defects on the pipeline in proximity of the measurement location. The defects closest to the reference electrode and the larger defects will influence the measurement the most. Any capacitance built into a system will cause an altered depolarization behaviour and complicates this approach. Some operators try to reduce the effect of capacitance by disconnecting decouplers during an instant-off survey. This approach is however questionable due to the altered polarization behaviour of the pipe under an AC interference level which is higher than normal operating conditions. I.e., the result of such a survey is possibly affected by the AC. Also, the risk of AC corrosion and safety to personnel during the survey shall be considered.

Though the DC current is interrupted, the same cannot be said about the AC, since this is induced onto the pipeline by external sources and is still present. Figure 2a shows how this makes a reliable reading of the instant off potential impossible. The curves in Figure 2 are based on the authors experience. Therefore, the device used to record instant-off disconnect curves shall be able to apply a form of low pass filter, in order for the result to be readable. This in turn flattens the potential curve and removes the sharp distinction between IR-drop and depolarization (Figure 2 b).

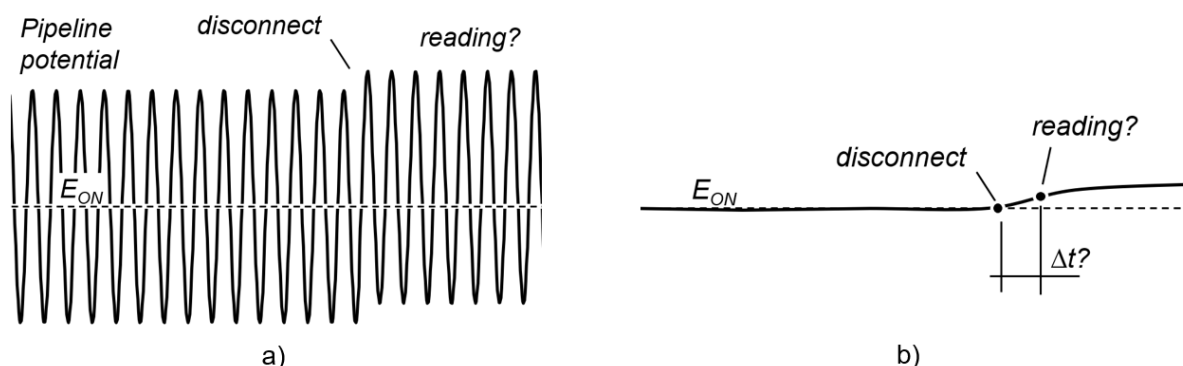


Figure 2: a) Interrupting CP on a pipeline with AC interference. The DC shift is often indistinguishable due to the overlayed AC. b) A low pass filter can be applied to remove the AC, but the DC curve is flattened, the sharp distinction between IR-drop and depolarization is lost and the Δt must be longer.

Coupon instant-off

Where coupons are installed as artificial coating defects connected to the pipeline, the coupon can be disconnected rather than interrupting the CP current to the entire pipeline. This method yields only the polarized potential of the coupon itself. It is an advantage of this approach that it can be performed

where capacitance is built into the remaining system, and that the AC being induced on the pipeline is not being induced onto the coupon after the interruption. Also, the current interruption is performed locally, rather than at the rectifier/anodes, which makes the approach simpler from a practical perspective. However, if the pipeline CP is left on, there can be significant IR in the soil between the reference and coupon, which shall be considered. Some operators prefer to disconnect both the coupon and the pipeline CP for this reason.

However, it is a common misunderstanding that a probe is unaffected by AC as soon as it is disconnected from the pipeline. The coupon potential will oscillate with the AC frequency, and the potential depolarization will happen from the instantaneous potential of the coupon. Therefore, the coupon instant-off potential will be highly influenced by the time of disconnecting, especially for small Δt values. Figure 3 shows this by two examples. a) where the disconnect occurs at the zero-passing of the AC signal and b) where the disconnect occurs on the positive half-cycle of the sinus curve.

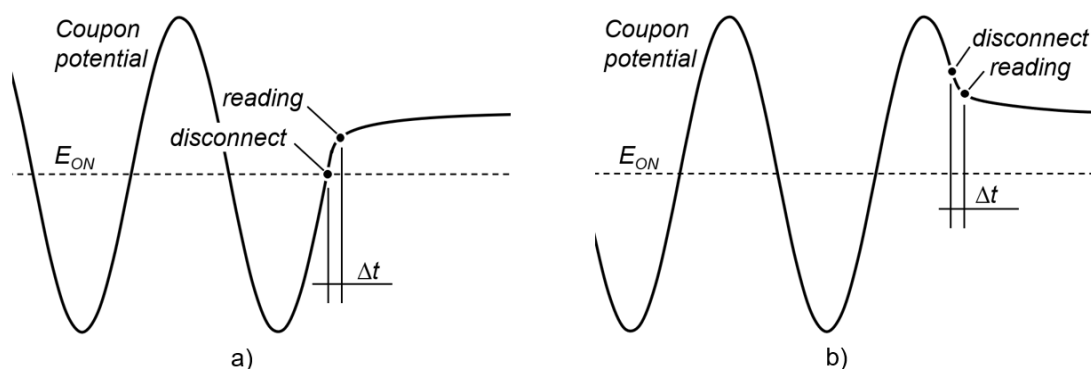


Figure 3: Coupon disconnect curves. a) The disconnect occurs at the zero-passing of the AC signal. b) The disconnect occurs on the positive half-cycle of the sinus curve.

Unless this is taken into account, one should be careful to rely on a single measurement of a coupon instant-off potential under AC interference.

It is standard practice to perform the coupon instant-off measurement 100-200 ms after the disconnection to remove the described effect. From a theoretical perspective this will introduce an error, but from a practical perspective, this is likely acceptable in most cases. The size of the error will however be dependent on the amount of polarization on the coupon, i.e. how far from equilibrium conditions it is under CP operation.

Ramlog measurements on coupons

A technique that embraces the effect described in Figure 3 is the Ramlog measurements as used by Pourbaix et.al.¹ The use of this and relevant analysis is described elsewhere.² To the authors' knowledge this is mainly useful for laboratory studies, but still this technique deserves mentioning in this paper.

The Ramlog recorder is placed in series between a coupon and pipeline, and is also connected to the reference electrode. It has a measurement cycle of 73 ms, during which it records the on-potential as an average of potential measurements performed during one AC cycle (20 ms for 50 Hz). In the end of the measurement cycle, the coupon is disconnected for 2 ms, and the instant-off potential is recorded during the second of these milliseconds. The continuous recording with this uneven measurement cycle with respect to the AC frequency will produce a range of instant-off potential

measurements that are supposed to represent the IR-free AC voltage on the pipeline. Since this will be a potential range it is difficult to relate this to a well defined protection criteria.

Figure 4 shows an example of the obtained potential profile recorded with a Ramlog recorder, i.e. an on-potential and a potential span representing the IR free AC potential.²

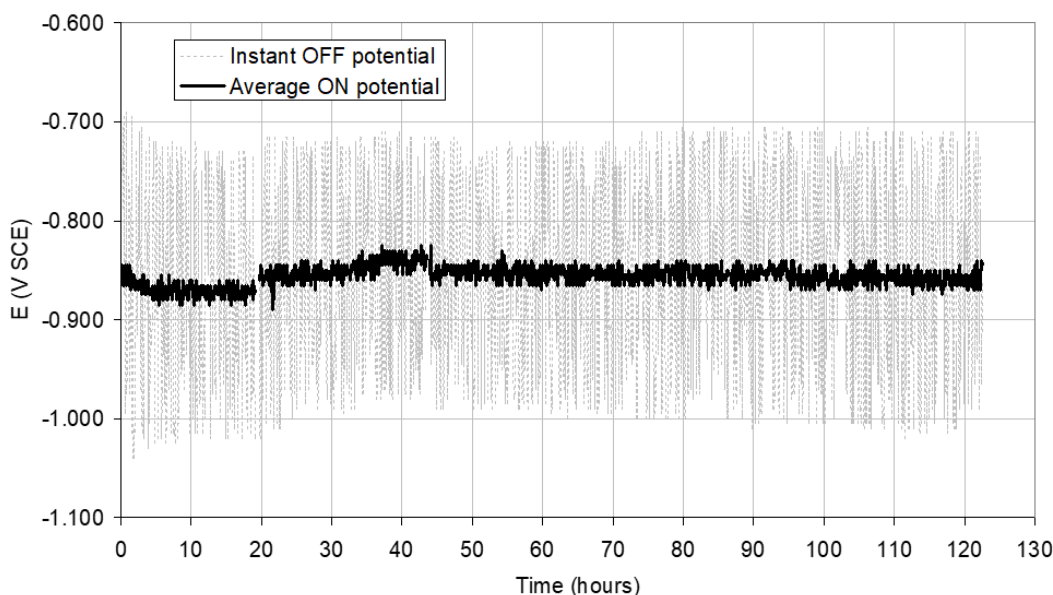


Figure 4: Ramlog measurements of a DC + 50 Hz AC signal (-0.85 mV and 2 V_{AC}). [1]

Coupon IR compensated potential

If AC and DC current and voltages are measured on the same coupon, it is possible to compensate the IR-drop using equation (1). This approach requires presence of AC and is only representative of the coupon polarized potential. It can be performed without interruption of the CP current and is thus free of effects from capacitance in the system.

$$E_{IR-free} = E_{on} - I_{dc} * R = E_{on} - I_{dc} * (U_{ac} / I_{ac}) \quad (1)$$

Note that this is an approximation for high frequencies.³ In reality, there is an interface impedance in series with the resistance yielding equation (2)

$$R + Z_{interface} = U_{ac} / I_{ac} \quad (2)$$

For a simple Randles circuit representation of the electrochemical double layer, this impedance can be written as (3)

$$Z_{interface} = R_{ct} / (1 + j * 2 * \pi * f * R_{ct} * C_{dl}) \quad (3)$$

Where,

j = the imaginary unit

f = frequency

R_{ct} = charge transfer resistance

C_{dl} = double layer capacitance (of the electrochemical double layer)

But this entire expression can be seen to reduce to ≈ 0 for high frequencies. This is true for frequencies of 50/60 Hz, and equation (1) is valid as it is written for practical applications.