Instant OFF Measurements on coupon: Practical advantages of a continuous remote monitoring
Ivano Magnifico
Automa S.r.l., Ancona, Italy
ivano.magnifico@byautoma.com

ABSTRACT

Stray currents increase and in some cases coatings improvement lead to more difficulties in evaluating Eon measurements than in the past. Switching remote monitoring to Eoff measurements let Cathodic Protection technicians lead better evaluations on CP efficiency by eliminating field voltage drop effects, thus letting them concentrate efforts only where really needed. Moreover, rectifiers remote control based on Eoff measurements, allows resources optimization and injecting in the field no more current than that really needed.
This work is focused on showing real advantages on leading cathodic protection efficiency evaluation on continuous Eoff remote monitoring and rectifier remote control Eoff based, presenting real cases where such kind of monitoring lead to huge advantages with respect to Eon remote monitoring.

Keywords: remote, monitoring, instant-off, coupon

INTRODUCTION

The introduction of new coatings, with high insulation resistance, mainly increases the average distance between the measured point and possible holidays with respect to older coatings; moreover, this distance changes considering different installations on the same pipe, introducing also difficulties to compare ON potentials measured at different points.
Furthermore, increasing non-stationary stray currents, mainly due to new AC-powered high speed railways, generate the necessity of a deeper analysis of the Eon potential measurement. It is known that ON potential measurements are affected with voltage drops generated from IR components in the field between reference electrode and pipe, and these components, particularly non-stationary ones, can lead to some difficulties in determining the real pipe potential based on the Eon potential.

CONTINUOUS REMOTE MONITORING ON COUPONS.

One of the possibility to obtain IR free potential measurements, is by using coupons, allowing to reduce the distance between electrode and steel surface where the measure is carried out and so lowering the stray current effects in the measurement: the coupon is disconnected to reduce the IR drops (from stray current interferences and CP currents entering the pipeline).

From a data-logger point of view, a measurement technique has to be developed that allows for continuous monitoring of the IRfree potential. Moreover, battery consumption optimization and an internal interrupter for the connection between pipe and coupon are a must.

What information do the standards give with respect to IRfree measurements?

- According to European Standard EN13509, an external potential test probe is the only technique that can be used in any interference conditions
- ISO 15589-1 explains when the measurement must be carried out after interruption of the connection between coupon and pipe

A measurement technique must therefore be developed to achieve a continuous monitoring of the OFF potential, obtaining a measurement every second by managing the internal interrupter of the data-logger.

The theory behind this technique is the following (Fig.1):

- the measurement of OFF potential, with the aim to approach as much as possible the IRfree value, must be taken immediately after the coupon is disconnected from the pipe, and needs to be carried out at an as short as possible measurement interval (according to the characteristics of the signal to measure),
- this could be achieved by opening the interrupter every second (in a correctly designed electronic circuit, including a solid state switch, to avoid bouncing or delays) for a few milliseconds, needed to carry out the measurement, and then close it again immediately, to bring back the coupon in polarization for the remaining part of the second.

![Figure 1: coupon connection and disconnection during On-Off measurement](image-url)
The fundamental timing parameters to carry out the measurement are (Fig.2):
- time to wait (ms) after the opening of the interrupter, to avoid transients
- duration of the measurement (ms)
- time over which the switch is kept open

**Time to wait**
Many tests have been carried out in different sites, in different countries and in different external conditions, and has been verified how the IR drops disappeared in the first 0.5 ms. Measurements after 1ms were thus free of transients.

**Time period for the measurement**
It is obvious that to catch a measurement that approaches the IRfree potential as much as possible, the measurement interval needs to be as short as possible: taking into account the fast coupon depolarization (up to 50mV in the first 100ms), a long measurement interval would allow the coupon to depolarize even more.

Two main cases are identified:
- no oscillations in the coupon measurement (fig.3, left)
- oscillations in the coupon measurement (in high current density conditions, for example near the CP rectifiers, or with strong AC interference from High Voltage Lines) (fig.3, right)
This brings us to consider two possible measurement intervals:

- 1ms in absence of oscillations
- 20ms (in case of 50Hz) in presence of oscillations (this will give a little bit more positive values with respect to 1ms, but can guarantee a more stable value by accepting the trade-off).

Summarizing, the available parameters to be configured in the data-loggers are:

- time to wait (ms) from the interrupter opening before starting the measurement (suggested time 1ms)
- time over which the measure is carried out (suggested time: 1ms without oscillations, 20ms with oscillations)
- time over which the interrupter is kept open (this time should be much smaller than the measurement interval of 1s, to avoid depolarization of the coupon).

These parameters can be configured on the devices by software or remotely from the server or locally.

Below are shown examples of the results that can be obtained.

Intensive measurements of Eoff and Eon for 86400 seconds (Fig.4):

Figure 4: 24hrs Eon and Eoff measurement second by second (86400 samples per day)
FIELD TESTS

This measurement technique is actually implemented by many European transmission and distribution gas companies in the remote monitoring and remote control of their CP systems.

In the following chapters will be shown different real cases where such kind of measurement brought great advantages in CP maintenance.

CASE 1 – BRINGING THE EOFF POTENTIAL IN THE DESIRED RANGE

A transmission company started an important project in 2015 to bring the Eoff potential as close as possible to the desired range - (Eoff below -0.95Vcse (“must have”) and above -1.2Vcse (on a best effort basis) - in three steps. This action was only possible with a permanent monitoring of the OFF values on the network.

- The settings of the cathodic protection devices (impressed current) were adapted using the telemetry system to quickly react in case the OFF values in the area were other than expected.
- Remote monitoring of the OFF potential was of course a “must have” in the project as this is the criterion to evaluate if the CP current is correct. Having all the measurements remotely transmitted was of great advantage. For instance, if the current of the CP device was reduced, the impact on all measured points equipped with telemetry could be followed, showing the effect of the protection current. This careful approach was needed to make sure that all measurement points were staying protected.

The first step consisted in performing little modifications (the impact on the OFF potential remained low, with an average increase of 10 mV) obtaining a global reduction of about 17% of the current provided by the CP rectifiers on the whole network (Fig.3)

The second step consisted in bringing all the Eoff potentials below -0,95Vcse, increasing the global reduction of the current provided by the CP rectifiers on the whole network to about a 30%

The third step consisted in bringing all the Eoff potentials above (where possible) -1,2Vcse, increasing finally the global reduction of the current provided by the CP rectifiers on the whole network to about a 40%, with a very important cost reduction for electrical energy and less consumption of anodes.
CASE 2: URBAN AREA, INFLUENCE OF THE SUBWAY

The pipeline is situated in an area subject to many influences, but the average OFF measurement was always in the protection range, indicating a sufficient level of cathodic protection.

Intensive OFF measurements brought more detailed information:
- The maximum value of the OFF measurement went above -0.85 Vcse a couple of times in the day
- The measurement of current on the coupon showed some peaks where the current flowed in the opposite direction (leaving the coupon).

The examination of the interference period brought capital information:
- The site was subject to combined stray currents from the subway and the railway. A matching between the periods with higher influences and the different service hours of the subway / railway pointed to the possible cause of the detected behavior and corrective actions were initiated.
- Current flows through valves were checked and it appeared that the distribution of the stray currents flowing from the railway changed in the area due to civil works (bonds between railway and pipe were temporary disconnected).

Corrective actions (re-establishment of the broken connections) had a significant impact on the peaks in potential. Difference between average and OFF value changed from +/- 0.5 V to +/- 0.3 V. (Fig.6)

![Figure 6: Off potential measurement on coupon before (left) and after (right) corrective actions](image)

CASE 3 – RAILWAY INFLUENCES

Proximity of the railway is an identified source of interference. This particular situation was already known and monitored before installation of Off-measurement telemetry. Using remote OFF measurements helped to make a more precise diagnostic of the areas where current might be entering or leaving the pipeline.

Below are shown the ON and OFF values on three different measuring points along a specific railway (Fig.7):

![Graphs showing ON and OFF values](image)
The Eon measurement gives different information on the protection level of the pipeline. Furthermore, continuous remote monitoring allows to retrieve information on the evolution of the influences overtime. In the example shown, there are interferences appearing only at certain times: in this case this corresponds to the train passage. The use of a regenerative braking system on the railway locomotives has recently increased in Europe. This requires a new approach and extra evaluations to understand the impact of this technology on the pipelines. Cross checking the timetable of trains with regards to the evolution of the Eoff measurement provides useful information.

**CASE 5: MEASURES INCLUDING IR DROP SHOWING BAD VALUES BUT ZONE REVEALED PROTECTED BASED ON THE EOFF MEASUREMENT**

In this case, the difference between a measurement including IR drop and the Eoff measurement is highlighted. Both measurements are showing variations at the same periods but the peaks values are leading to different assumptions. The measurement including IR drop would lead to the conclusion that the pipe is not protected, while the Eoff measurement is showing that the potential remains in the zone of protection. (Fig.8)
It is also possible to analyze the real effects of polarization current on both On and Off values, and to find some cases that possibly could open a discussion about particular conditions to be examined more deeply.

This graph shows:
- An external interference coming, with Eon moving to more positive values.
- Polarization current (negative, flowing towards the pipe) decreases and few seconds where:
  - Current moves to anodic.
  - Eon value moves to more positive values than -0.85V.
  - Eoff value always remains below -0.85V.

These measurements allow a remote control of the rectifiers no longer based on ON potential values but according to the analysis performed on OFF potential values.

CONCLUSIONS
Continuous monitoring of Eoff values helps technicians involved in cathodic protection analysis to better evaluate the protection of the pipeline based on IRfree potential measurements. In this way, resources and efforts can be focused on the real needs. Possible corrosion threats can be easier identified and investigated.

Moreover, the remote control of the rectifiers and the possibility of setting an Eoff reference value instead of Eon, could lead to the following advantages:
- The rectifiers do not have to follow the ON potential variations due to voltage drops in the field.
- The current injected in the field is reduced, since using Eoff as a reference prevents from too high current output and more than needed protection.

Bibliography