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AC mitigation with Intelligent Switch Devices

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Abstract:

Electromagnetic induced ac-voltages on pipelines must be reduced to an acceptable level. Mitigation based on earthing the pipeline via electric capacitors is a safe approach that does not jeopardize the cathodic protection. It is recommendable that the capacitors are protected against electric surges by means of a simple semiconductor device. The semiconductor device can include an intelligent switch, which is tripped by a regularly pulsating on/off-potential. The capacitors are then automatically disconnected from the pipeline and cathodic protection measurements can be made. The pipeline operator saves man-hours when collecting cathodic protection data from the pipelines without manually having to disconnect the capacitors from the pipeline. Experience from a high-pressure natural gas pipeline in Copenhagen, Denmark is presented.

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1. INTRODUCTION

Greater Copenhagen Natural Gas Company (abbreviation: HNG) operates a large number of high-pressure pipelines, some of which are ac-influenced. This paper describes the ac-mitigation on section 3100/3200 South of Copenhagen, a 23.5 kilometres long pipeline. Section 3100 is routed in parallel with a two system 132 kV overhead line. The electric current in the high voltage line induces ac-voltages on the pipeline up to approximately 75 Volt. Earth fault currents in the high voltage systems may induce an ac-voltage up to 3 kV. The importance of keeping the ac-potential very low was realised shortly after the commissioning as an ac-corrosion risk was detected. On-potentials (dc) up to - 600 mV (vs. $Cu/CuSO_4$) were registered and it was evident that the dc-potential was linked to the ac-potential. Mitigation of ac-voltages is based on a number of earth electrodes, connected via intelligent switches. In figure 1 the proximity is shown and location of the earth electrodes is indicated as dots on the pipeline-route.

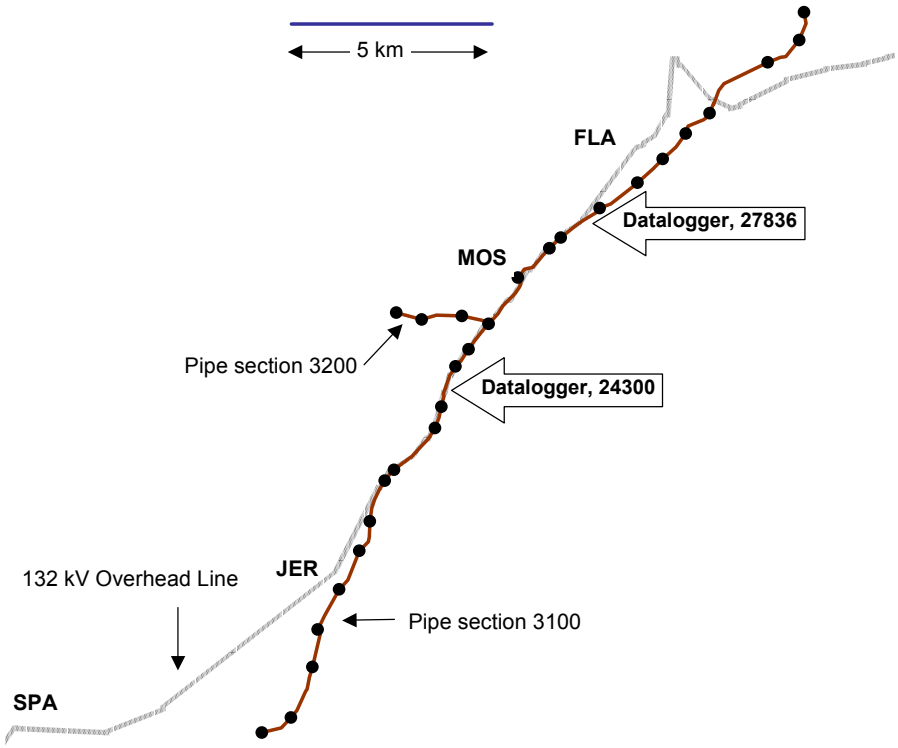

Figure 1. Map showing the HNG pipeline 3100/3200 and 132 kV high voltage lines in proximity. Dots indicate location of ac-mitigation earth electrodes along the pipeline.

2. HISTORY

This HNG pipeline was constructed in 1985. At that time only one high voltage system was running in parallel with the pipeline. The three phase conductors were located in a geometrical configuration that caused relatively high voltages on the HNG pipeline. Danish legislation requires that contact voltages on metallic pipelines be limited to 50 V if the duration of the contact voltage is more than 0.5 second. If the duration is less than 0.5 second, the limit is 300 V. It was hence necessary to reduce the possible contact voltages. A number of ac-mitigation earthings were constructed by use of band steel rolled out in the pipe trench. They were all connected directly (via measuring posts) to the pipeline in order to fulfil the 50 V limit as well as a strong demand for protection against ac-corrosion as it was recognised that the dc-potential followed variations in the ac-voltage.

The pipeline is cathodic protected from an impressed current installation. In 1999 environmental concerns for new neighbours to the cathodic protection rectifier station and anode bed forced HNG to take action to reduce the current send out via the anode bed. This was obtained by installing an electric capacitor in series with each earth electrode connected to the pipeline. The capacitors allow ac current, but not dc current, to pass. The approach reduced the output current from the cathodic protection station significantly and the solution was found effective in respect to ac-mitigation and control of cathodic protection. It was therefore decided to make the installation permanent and to protect the capacitors from excessive current. At the same time it was interesting to save operation and maintenance time/costs related to cathodic protection checks, as the capacitors would have to be disconnected before any dc measurements. An Intelligent Switch Device (ISD) was developed to handle these demands.

3. EXPERIENCE, BRIEF

There are 28 capacitors and ISD's installed on the pipeline. They have been in service for more than three years by now, and the experience gathered during this period is that the capacitors are effectively protected against lightning surges and excessive ac. The combination ISD and capacitor is hence providing a reliable connection between the ac-influenced pipeline and the ac-mitigating earth-electrodes.

4. FUNCTIONALITY/TECHNICAL DATA

When the ISD detects that the cathodic protection potential is shifting between "on" and "off", the ISD switches the capacitor/earthing off. It is therefore possible to check the cathodic protection (CP) and make true off potential and line current measurements on the pipeline without other effort than activating a timer/interrupter in the CP-station and take the measurements. Security against personal hazards is maintained in this mode as an ISD resumes the mitigation state if the ac-voltage exceeds 50 V. Terminating the "CP-on/off" state makes the ISD go back to normal ac-mitigation mode.

The ISD allows up to15 A (ac) to pass through the capacitor continuously. Larger currents (ac) and lightning surges are bypassed the capacitor, i.e. diverted to the earth-electrode without passing through the capacitor. The transition impedance in the ISD is 0.05 Ohm. The capacitors are bi-polar, capacitance 5 mF; equivalent to 0.64 Ohm at 50 Hz. Resistance to remote earth for the indi-

vidual earth electrodes is varying between 5 and 10 Ohm. The total impedance for the individual earth electrodes is therefore only marginally influenced by the capacitor and the ISD.

There are no batteries for power supply to be continuously exchanged; the combination capacitor/ISD is self-contained. The ISD is powered from the ac on the pipeline. When the ac-voltage over an ISD and capacitor exceeds 3.5 V, the ISD is activated and the capacitor is engaged. In "idle mode" the ISD takes power from the pipeline via a 1 µF capacitor. In "activated mode" the power is supplied via a transformer as the (ac) current diverted from the pipeline passes through the primary windings. In both cases, the ISD is powered without influencing the dc-potential on the pipeline.

5. TEST RESULTS

The functionality of the ac mitigation on section 3100/3200 is most convenient illustrated by means of test results.

5.1 Deactivating ISD's

Ac and dc potentials were recorded at chainage 24300 and 27836. Figure 2 is showing a time sequence where:

1. The ISD's are in engaged mode (off-potentials can not be determined)
2. A timer/interrupter is activated in the CP station after 15 minutes,
3. The ISD's are deactivated (ac voltage is increasing stepwise as the capacitors are disconnected)

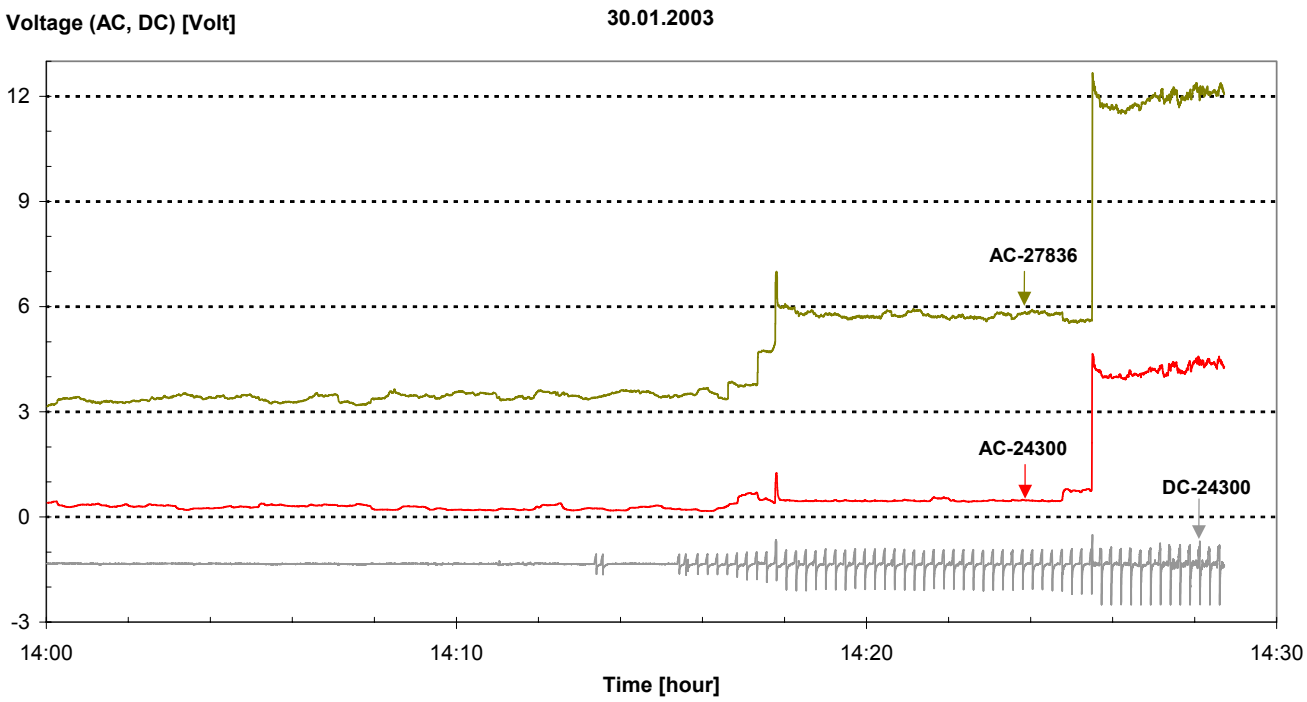

Figure 2. Potentials, dc and ac before during and after deactivation of ISD's

Re point 1. The ac-voltages are approximately 0.5 V and 3.5 V up to timestamp 14:17 where the first ISD's are deactivated. An off-potential cannot be determined while the ac-mitigation capacitors are connected to the pipeline, see figure 3. The potential rises with a time constant, $\tau = R \cdot C$ governed by the large capacitance C of the capacitors.

Re point 2. The dc-potential is pulsating periodically from timestamp 14:15 where a timer/interrupter was activated in the CP-station with an on/off time =12/3 seconds. It should be noticed that the first ISD's were deactivated after seven on/off-periods and one or more followed four periods later. At 14:25 and three periods later the remaining ISD's were deactivated. A dc-traction railway parallel to the pipeline influences the dc-potential as trains accelerate; the traction current makes the pipeline potential fluctuate. One or more dc-fluctuations during an on/off period invalidate the period. It takes three consecutive on/off periods for the ISD to determine that it is a repeated signal addressed to the ISD.

Re point 3. The ac-potential is rising stepwise as the ISD's are deactivating, i.e. disconnecting the ac-mitigation capacitors from the pipeline from timestamp 14:17 to approximately 14:26. For comparison the current in the high voltage lines is shown in figure 4. Please notice that the relevant time period is indicated with a shaded background.

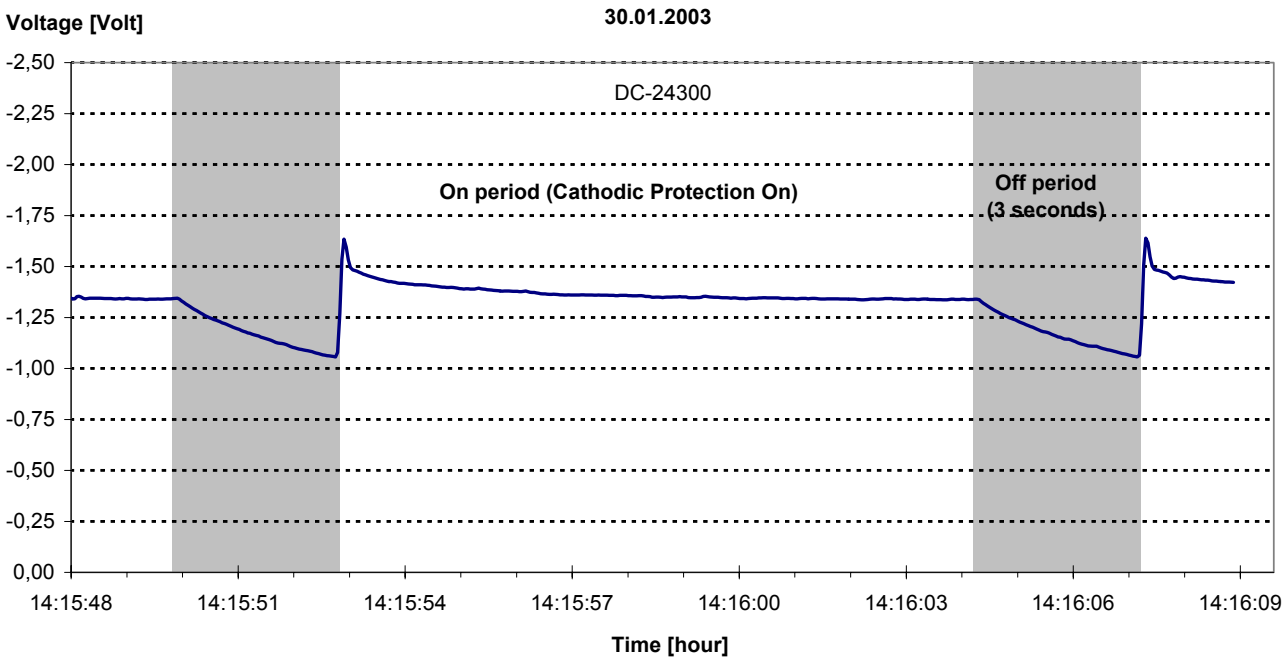

Figure 3. On/off -potential recorded with ac-mitigation capacitors connected to the pipeline. In the off-period, the potential rises with a timeconstant, τ governed by the capacitors.

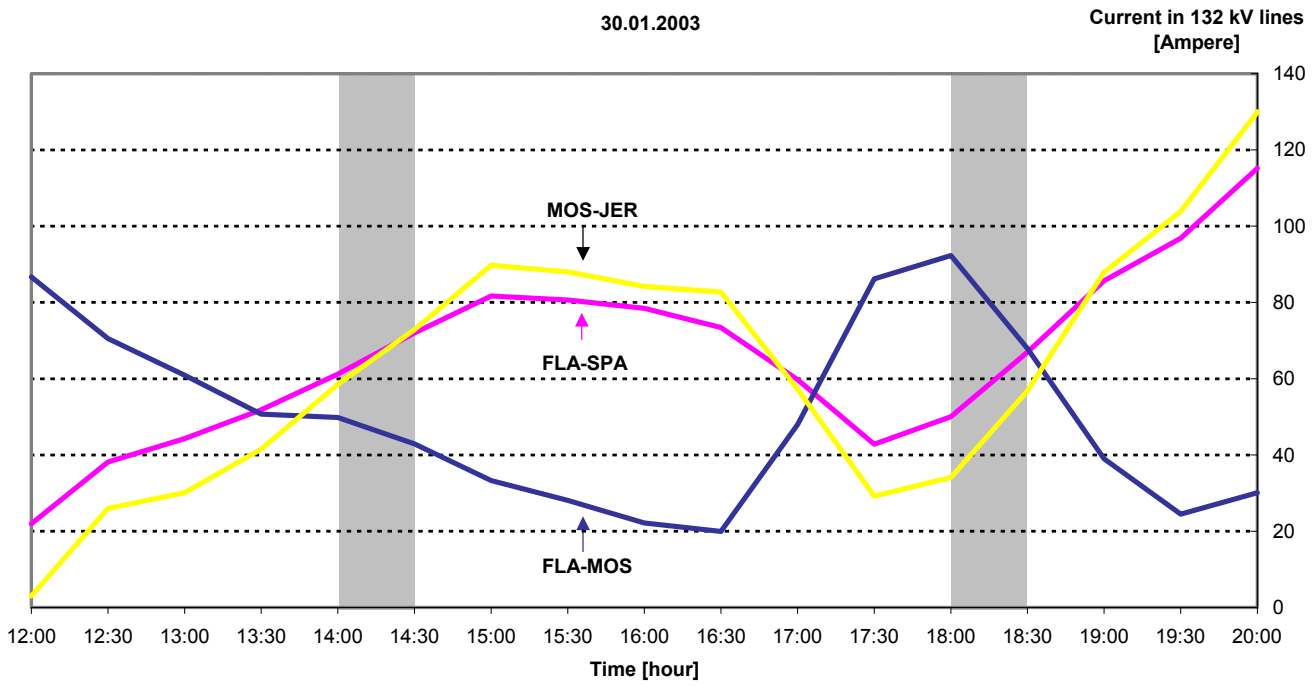

Figure 4. Current recorded in the high voltage lines. Measuring periods on the pipeline are indicated with a shade.

5.2 Cathodic protection measurements

The pipeline measurements were made with data loggers. The data loggers were set-up to record over two periods. The first period between 14:00 and 14:30 was set for illustrating the deactivation of the ISD's. The timer/interrupter in the CP-station was activated at 14:15 and was not deactivated until all measurements had been made. A second measuring period was set for 18:00 to 18:30 after the most intensive rush hour traffic on the dc-traction railway. The data recorded during this second period is shown in figure 5.

A detailed picture of two on/off sequences is shown in figure 6. The slope in the start of the off period is now controlled by the coating related capacitance of the pipeline and the depolarisation of the cathodic protected structure. This is a normal recording as HNG makes them for operation and maintenance purpose on the pipeline. HNG will of course make more measurements for adjustment and verification of the cathodic protection. The measurements discussed here are only meant do describe the functionality of the ISD.

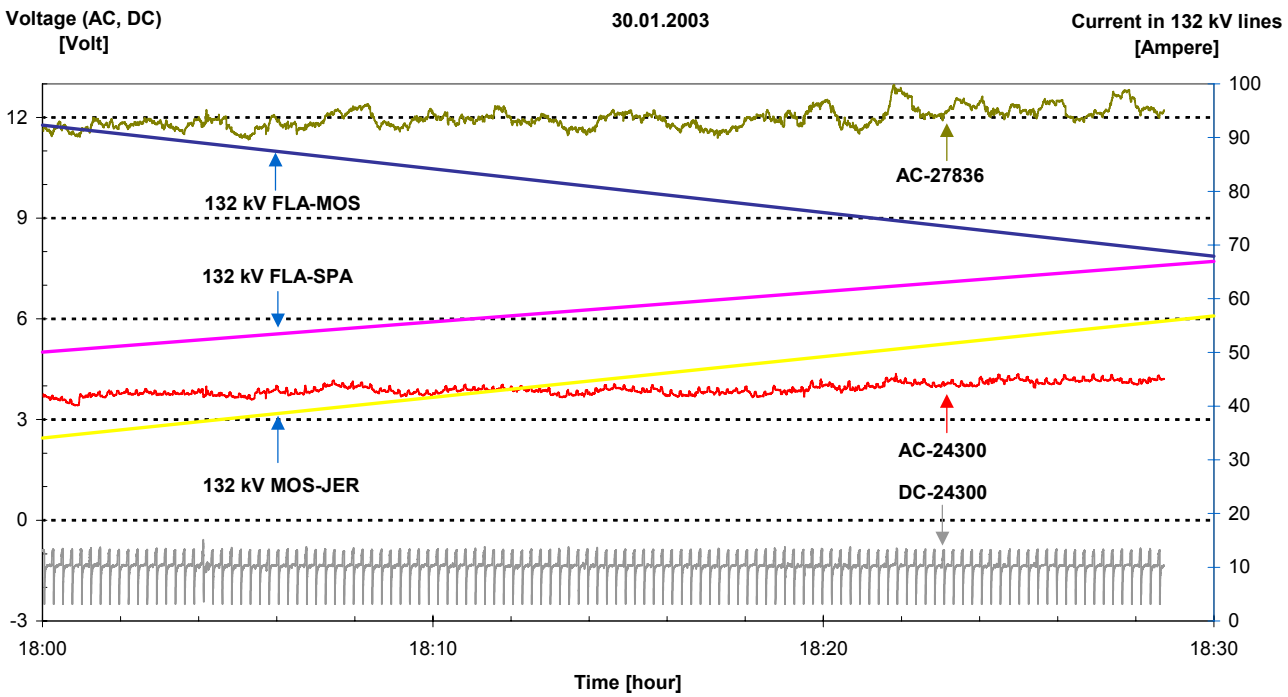

Figure 5. Potentials dc and ac at chainage 24300 and 27836. Current in high voltage lines.

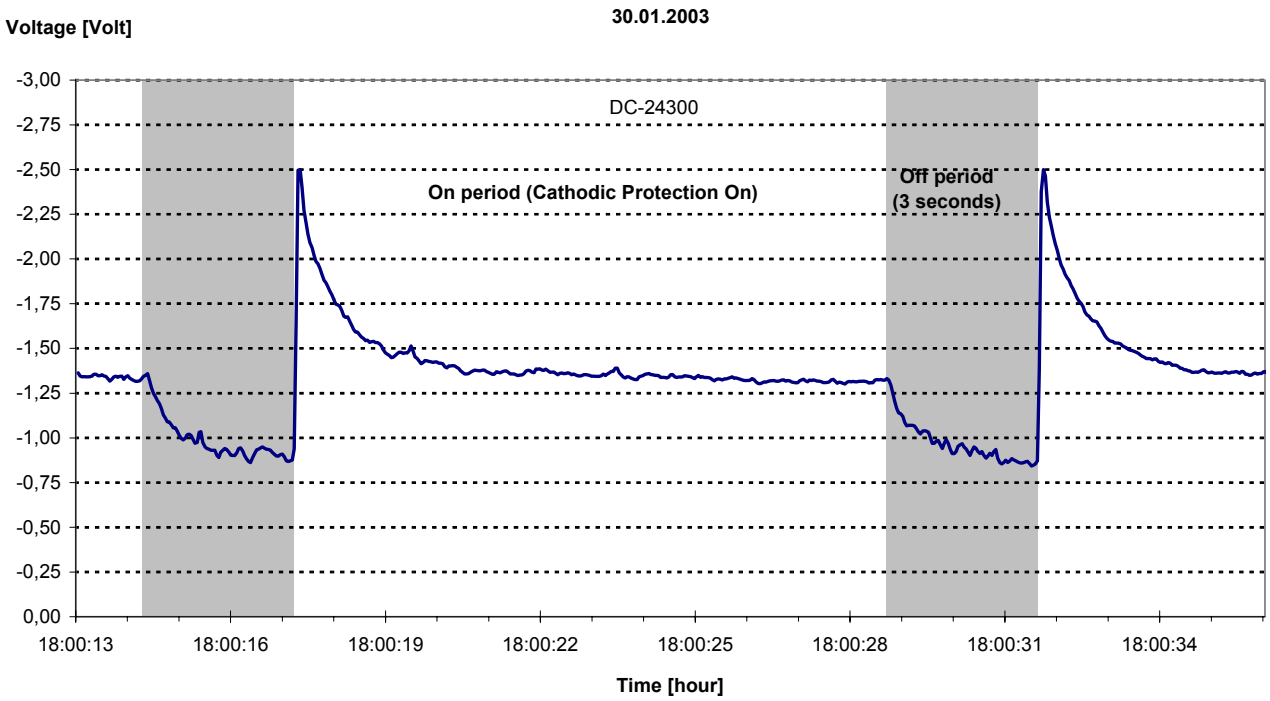

Figure 6. On/off sequences at chainage 24300.

6. CONCLUSION

Ac-mitigation is an important part of the corrosion protection as well as the personal safety aspect on HNG pipeline section 3100/3200. The mitigation is based on a relatively large number of earth electrodes distributed along the pipeline.
The electromagnetic induced ac-potential on the pipeline is reduced to a level where the dc-potential on the pipeline shows no sign of fluctuation with relation to the ac-potential. It is therefore unlikely that significant ac-corrosion is taking place on this pipeline.
In 1986 after the commissioning it was clearly observed how the dc-potential followed the ac-potential. A risk of ac-corrosion was therefore recognised and all earth electrodes were connected galvanic to the pipeline. This was the case until 1999 where HNG due to concerns for new neighbours to the CP-station and anodebed, decided to reduce the output current from the CP-station. The (dc) current was reduced to a few mA by inserting electric capacitors in series with the individual earth electrodes. As this was found effective with respect to ac- as well as dc-potentials, it was decided to make the installation permanent. The ISD was therefore developed to protect the capacitors, maintain the personal security and reduce maintenance work.

The ISD has fulfilled the requested demands. General CP-measurements are made during low peak ac-load periods. An ISD saves two visits to the location where the ISD is installed, as the ISD's automatically disconnects the capacitors and earth electrodes for a limited period of time without jeopardizing the ac-corrosion protection and without unnecessary work effort.