2-02

Methods and experiences on DC-rail electrical interference

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Abstract
Gasunie, The Netherlands, is a gas transmission operator with about 12.000 km of pipeline. Most of these pipelines are situated in congested right-of-ways (ROW's), including 1500 V DC traction systems. According to the Dutch Standards NEN EN 50162 and NEN EN 50122 it is not unlikely that both systems interfere on each other. Looking at the Gasunie field measurements one can conclude that about 50% of the pipeline is under interference of stray current. The Gasunie pipeline network includes 120 DC-drain unit's that are operational.

To get a better understanding of DC-traction interference, Gasunie started a joint working group with the Dutch Railway (ProRail). This technical committee aims at a better understanding of theoretical and practical principals of DC-traction stray current. It tries to approve field procedures and to get information on what has to be done to solve CP-related problems.

In this presentation it will be demonstrated how the field measurement technique that has been designed will be used. It will be discussed how the measured data needs to be interpreted to determine the rail resistance to earth and the risk area's for the pipelines.

Zusammenfassung
Gasunie ist ein Gasversorger mit ungefähr 12.000 km Rohrleitung. Der grösste Teil davon liegt in engen Energietrassen zusammen mit 1500 V DC Bahnstromversorgung. Entsprechend den Holländischen Standards NEN EN 50162 und NEN EN 50122 ist es nicht unwahrscheinlich, dass sich beide Systeme gegenseitig beeinflussen. Aus Sicht von Gasunie sind ungefähr 50% der Rohrleitungen durch Streustrom beeinflusst. Die Rohrleitungen werden duch 120 Streustromdrainagen geschützt.
Um ein besseres Verständnis für die Streustrombeeinflussung zu erhalten hat Gasunie eine Arbeitsgruppe mit der Holländischen Eisenbahn (ProRail) gestartet. Dieses technische Komitee soll ein besseres Verständnis der theoretischen und praktischen Auswirkungen von Streuströmen erarbeiten. Es versucht Feld Feldmessmethoden zu etablieren und Lösungen für Streustromprobleme zu erarbeiten.
In der vorliegenden Arbeit wird der Einsatz der Feldmessmethode aufgezeigt. Die Interpretation der Messdaten zur Bestimmung des Ableitungsbelags der Schienen und der Beeinflussungsbereiche der Rohrleitung wird diskutiert.

Introduction

Gasunie, The Netherlands, is a gas transmission operator with about 12.000 km of pipeline. Most of these pipelines are situated in congested right-of-ways (ROW's), including 1500 V DC traction systems. According to the Dutch Standards NEN EN 50162 and NEN EN 50122 it is not unlikely that both systems interfere on each other. Looking at the Gasunie field measurements one can conclude that about 50% of the pipeline is under interference of stray current. The Gasunie pipeline network includes 120 DC-drain unit's that are operational.

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In this presentation it will be demonstrated how the field measurement technique that has been designed will be used. It will be discussed how the measured data needs to be interpreted to determine the rail resistance to earth and the risk area's for the pipelines.

At the CeoCor conference in 2009 in Vienna a first presentation was given on this subject. In this presentation measurement results will be discussed. First an introduction of the parties involved will be given, followed by a short explanation of the measurement technique.

DC-traction task-force

In 2007 Gasunie started a joint working group with the Dutch railway and several other companies that worked on the phenomena of DC-traction interference on pipeline networks. This task-force for which Gasunie provided the convenor was unique since it combined expertise in modelling, measuring equipment, CP and DC-energy systems. The project team consisted out of Gasunie, ProRail, Rendo, Elsyca, NLR, Hommema KB and Movares.

It was soon realised that in the past a lot of time already had been spent trying to solve DC-traction interference issues and that a clear and step-by-step multi-year plan was requested. The subsequent steps that formed the backbone of the plan are listed below:

In 2007

1. Study the theoretic principles of DC-traction interference and put them in a model
2. Fit the model to the Dutch railway parameters
3. Perform field measurement on a railway with standard techniques

In 2008

4. Design the ideal measuring system

5. Create a practical measuring device with the available data log-computers (9 programmable channels)
6. Start testing the advanced measuring method, first results

In 2009

7. Collect more data to define risk area's
8. Find methods to decrease risk area's

Field measurements – new approach

In cooperation with ProRail the NLR modified an existing system that was used during the implantation of the first 25 kV AC rail system in the Netherlands. The system exists out of a ruggedized computer with a 10 channel configuration and a software packet that is able to analyze and report the measured data.

The type of reference electrode that is used to measure the potential of the rail and soil with respect to remote earth is not important. The only requirement is to have a good contact with the soil which allows to use an iron pin with a foot stamp. The measuring cables used are numbered and put on special reels. After putting all the "ingredients" together Gasunie finally did some laboratory testing (Figure 1) before starting the real field work that gave very good results.

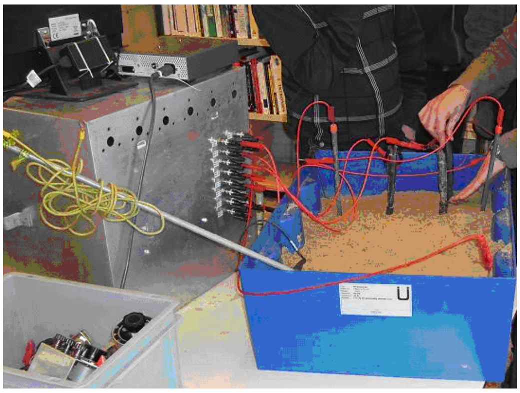


Figure 1: Laboratory tests to validate the new measuring approach

One of the questions that came up was how to be sure that al the input signals are correct. Since some cables are up to 120 m away from the command post it is impossible to see if a cable is accidently disconnected. This open question and some other practical considerations resulted in a new approach to measure soil and track potentials and resulted in the design of a new measuring device. The principle is based on the scheme of Figure 2.

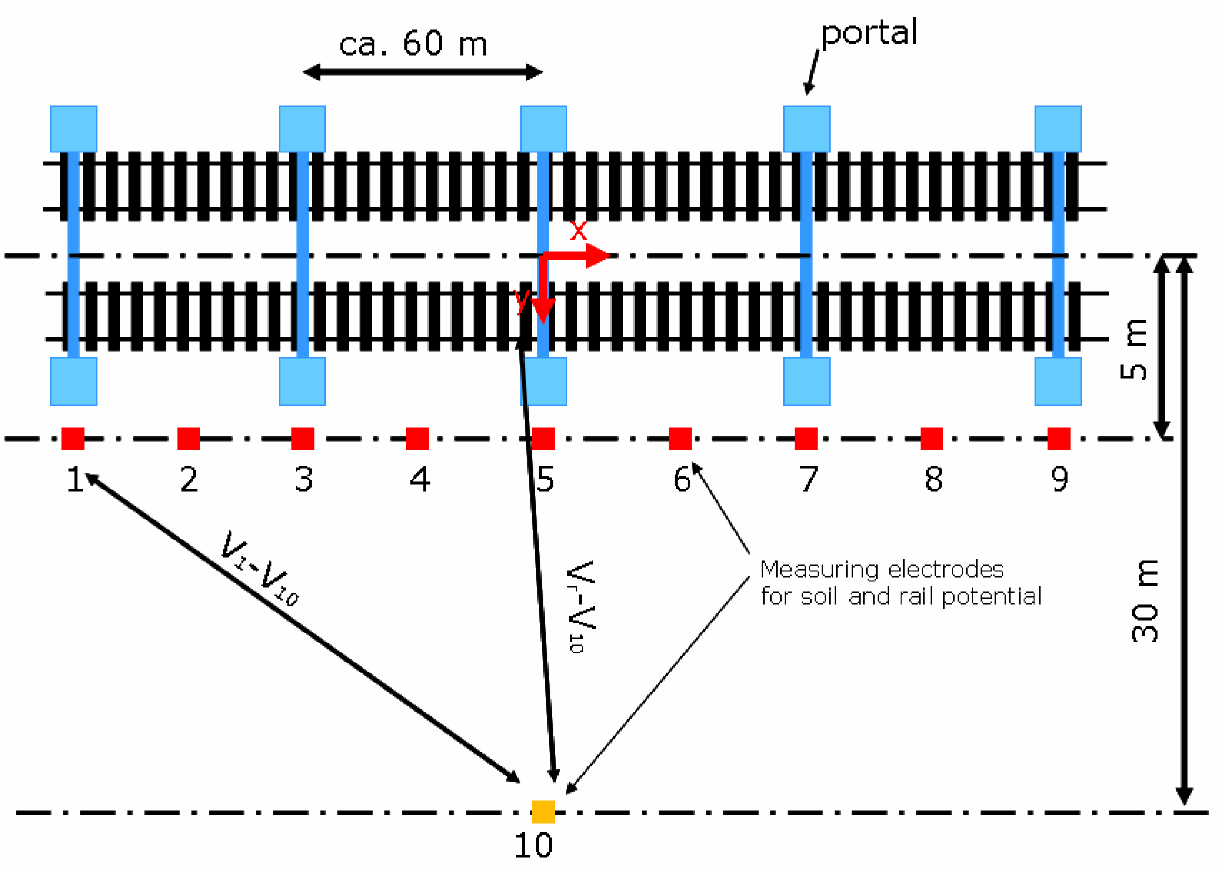


Figure 2: Measuring potentials without the need to go to remote earth

This approach allows to measure soil and pipe potentials without the need to go to remote earth:

- A "local remote earth" at about 30 meters away from the track is used to measure the potentials. By using validated analytical equations a formula has been derived that allows to use a local earth instead of real remote earth.
- The soil potential is measured in 9 equally spaced reference points along a line that runs 5 m parallel to the track. The distance between the reference points is about 30 m and the potentials are measured with respect to the local remote earth. The soil- and rail potential shifts may be measured in "high ohmic" mode using the metal pins, because soil potential shifts do not have any influence.

- After completing the experimental set-up and wiring the measurement is started. When a train shifts the track potential with a value of at least 2.0 V the average value in a span of 1 second before and after the trigger moment is send to the computer. Both the 2.0 V threshold as the 1 s span are arbitrarily chosen but can be adjusted when needed.

Figure 3 presents the computer set-up as developed, showing the following parameters:

- Real-time voltage of channels 1 – 10
- Min/max voltage of channels 1 -10
- Number of triggers (times the voltage passed the potential shift criteria)
- Frequency spectrum (FFT)
- Visualizes the alpha’s 1 – 9, along the railway
- Opportunity to show the representative of the measurement of each channel
- GPS positioning
- Add comments to every session
- Set points, filenames and software version

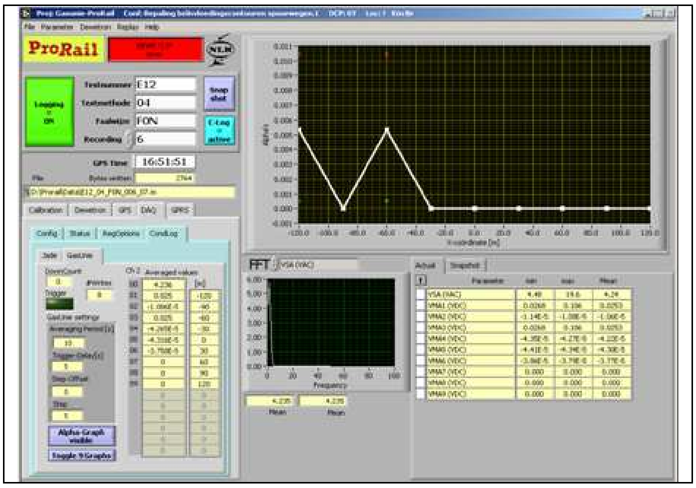


Figure 3: Computer set-up with real time result visualization

Because it is assumed that the measured soil and rail potential vary with respect to each other in a linear way it is possible to visualise the nine ratio’s between the soil and rail potential (□ = soil potential/rail potential, see figure 4), being the slope of the nine regression lines. By using these □’s the potential shifts between electrodes are not an issue. By visualising each channel in a separate window it is possible to find discrepancies in the measurement.

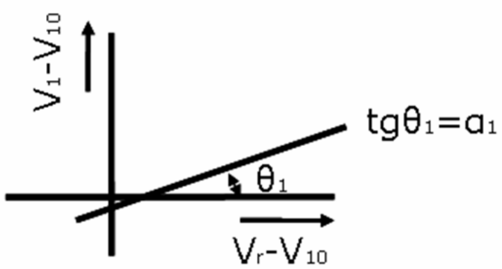


Figure 4: Definition of alpha value

To analyse the alpha’s

After obtaining the alpha’s they have to be analysed.
In the case that all alpha’s have more a less the same value the rail behaves as a line source. The constant alpha values are a direct input to calculate the soil potential disturbance along the track as a function of distance to the rail (safety contour) according the maximum and/or minimum rail potential. In this way (safety) contours can be obtained (in accordance with NEN EN 50162:
-200 mV < allowed soil potential shift < 500 mV) and used to find out if the pipeline is in a risk area.

If the soil resistance is measured the rail resistance can directly be calculated from the constant alpha value.

However when the □’s differ substantial the rail no longer can be approached as a line source which could indicate that there do exist additional disturbances. Suppose that there do exist n additional sources (e.g. shorted portals) at locations x_i along the track. The equation below provides a formula that links the □’s in the nine measuring points with the soil resistivity and ratio soil/rail resistance and soil/additional disturbance resistances:

Formula 1:

$$\underset{k=1\ t/m\ 9}{\alpha_k} = \left(\frac{\rho}{Rr}\right)\frac{1}{\pi}\ln\frac{a30}{a5} + \frac{1}{2\pi}\sum_{i=1}^{n}\left(\frac{\rho}{Rp}\right)_i \times \left(\frac{1}{\sqrt{(x_k-x_i)^2 + a5^2}} - \frac{1}{\sqrt{x_i^2 + a30^2}}\right)$$

For the moment the parameters in the above equation are manually fit in order to get the best possible agreement between measured and calculated values. Work is going on to develop a software tool that finds the optimal values in real time.

If one knows the ratio between the soil/rail resistances (ρ/Rr) and the ratio’s of the soil/additional disturbances (ρ/Rp) together with the absolute value of the soil resistance (ρ), the absolute rail and additional disturbances resistances can be calculated.

Variying alpha values indicate additional disturbances along the track. Looking at the alpha graph already gives an idea about the size and location of the additional disturbances.

High alpha values at the boarders of the inspected area indicate that the additional disturbance(s) are outside the inspected aria.
When the parameter values in formula 1 are obtained, new alpha values can be calculated that show the soil potential variation near the pipeline compared to the rail potential variation.

Formula 2:

$$a_k = \left(\frac{\rho}{Rr}\right)\frac{1}{\pi}\ln\frac{4000}{a} + \frac{1}{2\pi}\sum_{i=1}\left(\frac{\rho}{Rp}\right)_i \times \left(\frac{1}{\sqrt{(x_k - x_i)^2 + a^2}}\right)$$

a = distance to rail

Vsoil = α x Vrail

Knowing the rail potential variation the soil potential variation can be calculated/predicted.

When large alphas are found inspection should be done to analyse what the cause of the additional disturbances is and to see what has to be done to increase the rail to soil resistance. If the soil potential disturbance is not in accordance with NEN EN 50162, additional matters have to be addressed.

Discussion of field measurements

In the following section results obtained at 4 different locations along the Gasunie pipeline network will be discussed in more detail.

1. Tynaarlo

Figure 5 presents the layout for the first case considered. Measuring electrodes were placed at the right side of the railway track. Numbering down side to up side. A DC-drain unit is present at the crossing.

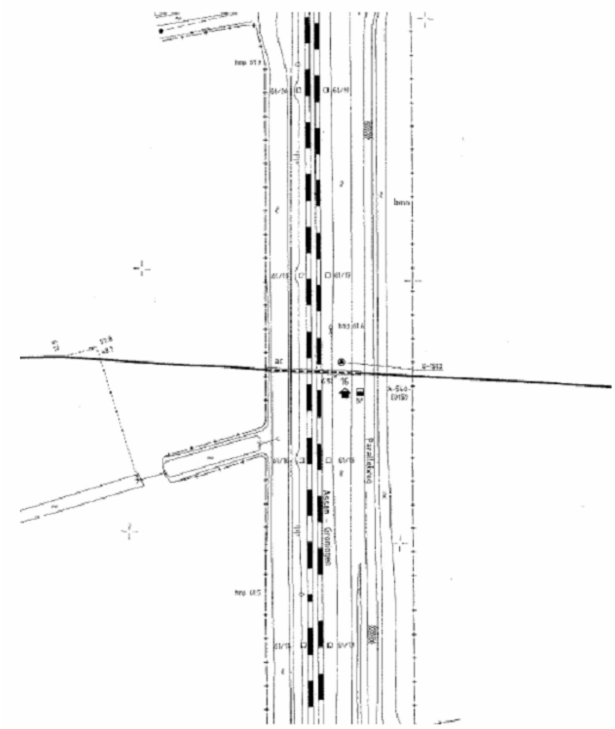


Figure 5: Case 1 – Tynaarlo (layout)

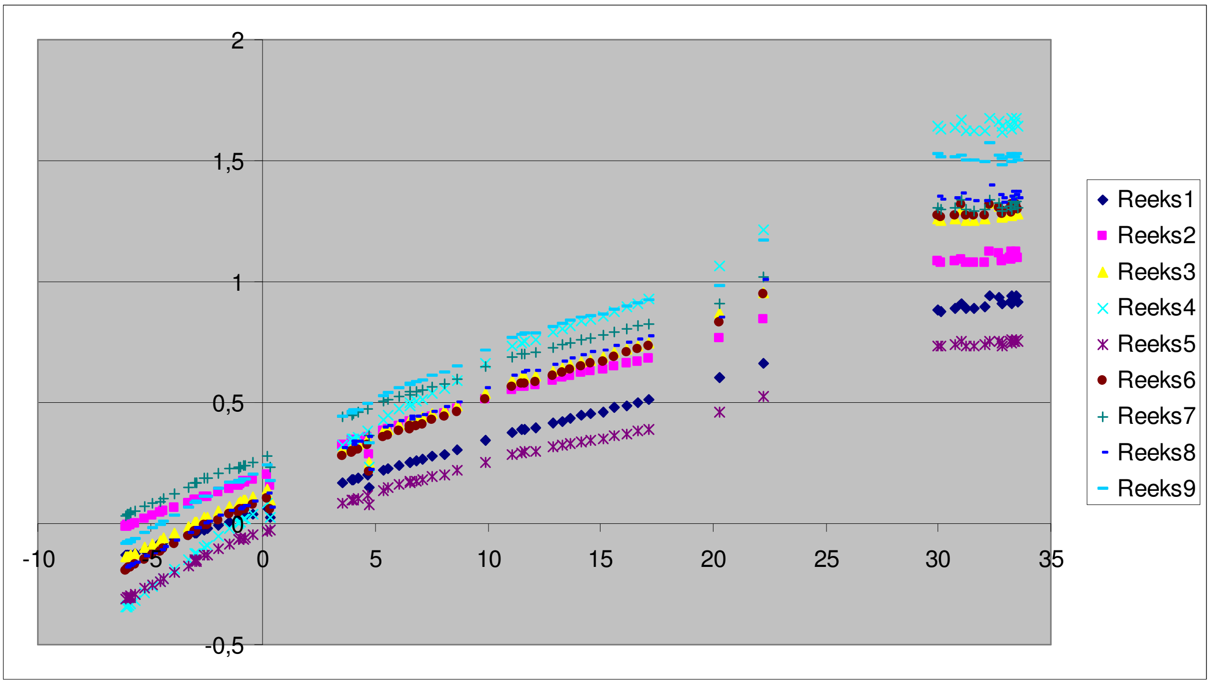


Figure 6: Case 1 – Tynaarlo (measured alpha's)

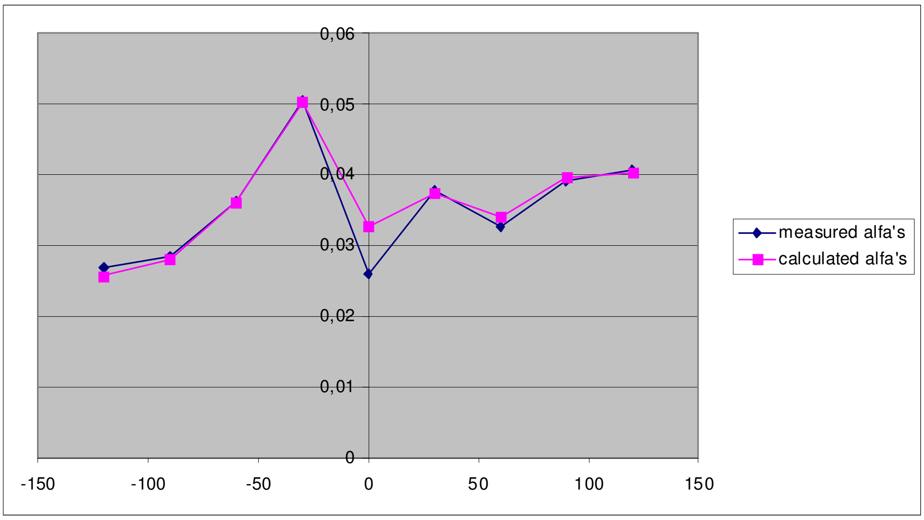
Figure 6 presents on the y-axis the soil potential disturbances of the nine measuring electrodes with on the x-axis the rail potential. The rail potential of the right railway track varies between -7 and 34 V. The crossing of the pipeline is at measuring point 5. The two railway tracks are not well connected at this point (potential differences between the left and right railway tracks of 8 V have been measured). In theory it would be better to measure the soil potential disturbances against the average potential of both railway tracks. However to do this one has to pass the railway tracks which has not been done because of safety reasons. In addition, it has been observed that trains running at different railway tracks give slight different angles (alphas) in the graphics which explains why sometimes the graphics aren't straight lines. Despite the above mentioned imperfections, a good impression of the different alphas is obtained.

One can observe from figure 6 that electrode 5 (Reeks5) has a larger angle on the negative side than on the positive side of the graph. This phenomenon has been observed several times. The explanation of the variation of the angle on the negative and positive side of the graph is as follows. The measuring electrode 5 is placed above the crossing pipeline. If the rail becomes negative the DC-drain unit starts working and pulls the pipeline in a more negative direction. The local soil can become more negative due to local coating defects.

Therefore, the alpha values are extracted from the positive part of the curve (for which the drain has no effect).

Figure 7 shows part of the Excel spreadsheet that has been developed to fit the measured data using formula 1 listed before.

local soil resistance ohm.m			117	deep soil resistance ohm.m			117	(moet over het algeme		
distance between railway centre and measuring electrodes m			6							
distance between railway centre and common reference electrode m			30	positie ver.veld evenw.aan spoor			0	(kan nu ook varieren tı		
number of railway tracks			2							
electrode positions m	-120	-90	-60	-30	0	30	60	90	120	
alfa measured	0,026948	0,02849	0,03636	0,050534	0,025989	0,037853	0,032703	0,039097	0,040753	



	rho/Rr	rho/Rp1	rho/Rp2	rho/Rp3	rho/Rp4	A/U=1/0			
	0,06	1,8	0,7	1,6	0	1			
position m		-39	40	106	115				
electrode positions m	-120	-90	-60	-30	0	30	60	90	120
alfa calculated	0,0257	0,0281	0,0362	0,0503	0,0328	0,0374	0,0341	0,0397	0,0403

Figure 7: Case 1 – Tynaarlo (fitting of measured data)

The manual fitting procedure as adopted is as follows. First, the measured alphas are plotted in order to have an idea of the behaviour of the different values. By varying the rail resistance and the position and resistance of additional disturbances one tries to reconstruct as good as possible the measured alpha values. This procedure is based on a trial and error approach and requires good engineering skills.

For the case as described above it turns out that adding three additional disturbances at locations -39, 40 and 106 m gives a good agreement between measured and calculated data as can be seen from figure 7. However, the measured and calculated alpha value at the position of the pipeline crossing do not fit as well as for the eight other values. This can be due to the fact that the pipeline coating could be damaged at the position of the crossing, which could result in a better local electrical connection of the ground near the railway tracks at crossing position to far earth. Therefore the influence of the railway tracks on the surrounding is smaller. This phenomenon has been observed at several locations.

By using the assumption of a “negative” additional disturbance at the crossing while maintaining the track to soil resistance a better fit is obtained. (Probably this is the better approach for the future.)

Based on the obtained values for (ρ/Rr) and (ρ/Rp)/location the soil potential disturbance at pipeline depth influenced by both railway tracks can be calculated as presented in figure 8.

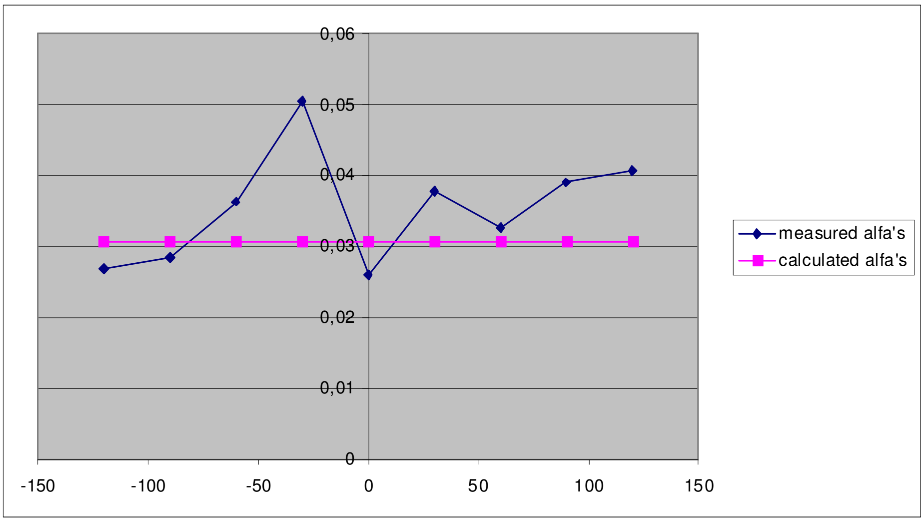
distance between pipeline and railway m	3	ongestoord verre veld op m				4000			
position m	-120	-90	-60	-30	0	30	60	90	120
alfa at pipeline depth	0,1429	0,1453	0,1537	0,1712	0,1500	0,1557	0,1514	0,1576	0,1585
permissible minimum railpotential V	-1	-1	-1	-1	-1	-1	-1	-1	-1
permissible maximum railpotential V	4	3	3	3	3	3	3	3	3
railresistance ohm.km	3,75	3,69	3,49	3,13	3,57	3,44	3,54	3,40	3,38

Figure 8: Case 1 – Tynaarlo (calculated soil disturbance values)

At zero position the pipeline crosses the railway tracks at a depth of 3 m. The alpha value at this place is 0.15. This means that the soil potential disturbance compared to remote earth at the depth of 3 m below the railway tracks is 15 % of the rail potential. According to the norm, the soil can not become more negative than -200 mV and not more positive than +500 mV. This means that the rail potential may only vary between -1.0 and 3.0 V. In practise however, the variation of the track voltage at that location is much larger and therefore the DC-drain unit is necessary at this place.

Finally, let us see what happens if we assume the problems with the additional disturbances are solved. Is the DC-drain unit still necessary in that case? To answer the question, the additional disturbances are switched off such that only the influence of both railway tracks remains. As can be seen from Figure 9, the alpha value at pipeline depth will reduce to 0.14 or 14 %. The difference with the situation before with additional disturbances (15 %) is small and as a result the DC-drain unit is still necessary. Only additional isolation of the rail can solve this local problem.

local soil resistance ohm.m			117	deep soil resistance ohm.m			117	(moet over het algeme		
distance between railway centre and measuring electrodes m			6							
distance between railway centre and common reference electrode m			30	positie ver.veld evenw.aan spoor			0	(kan nu ook varieren tu		
number of railway tracks			2							
electrode positions m	-120	-90	-60	-30	0	30	60	90	120	
alfa measured	0,026948	0,02849	0,03636	0,050534	0,025989	0,037853	0,032703	0,039097	0,040753	



	rho/Rr	rho/Rp1	rho/Rp2	rho/Rp3	rho/Rp4	A/U=1/0			
	0,06	1,8	0,7	1,6	0	0			
position m		-39	40	106	115				
electrode positions m	-120	-90	-60	-30	0	30	60	90	120
alfa calculated	0,0308	0,0308	0,0308	0,0308	0,0308	0,0308	0,0308	0,0308	0,0308

distance between pipeline and railway m	3	ongestoord verre veld op m				4000			
position m	-120	-90	-60	-30	0	30	60	90	120
alfa at pipeline depth	0,1375	0,1375	0,1375	0,1375	0,1375	0,1375	0,1375	0,1375	0,1375
permissible minimum railpotential V	-1	-1	-1	-1	-1	-1	-1	-1	-1
permissible maximum railpotential V	4	4	4	4	4	4	4	4	4
railresistance ohm.km	3,90	3,90	3,90	3,90	3,90	3,90	3,90	3,90	3,90

Figure 9: Case 1 – Tynaarlo (fitting of measured data – assuming no additional point sources)

2 Assen

Figure 10 presents the layout for the second case considered. The pipeline crosses the railway tracks in the middle of two large traffic viaducts (not presented on the map). The measurement electrodes were placed along the upper side of the railway tracks.

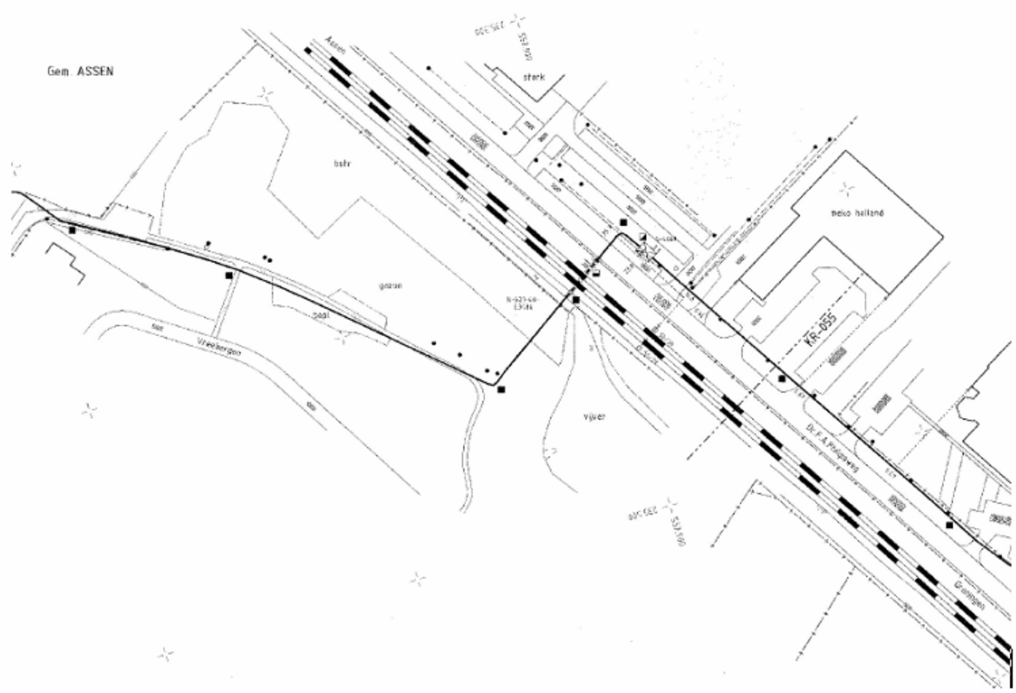


Figure 10: Case 2 – Assen (layout)

Figure 11 presents the measured alpha's. Also at this location trains were running over different tracks and again reasonable potential differences were measured between the two railway tracks.

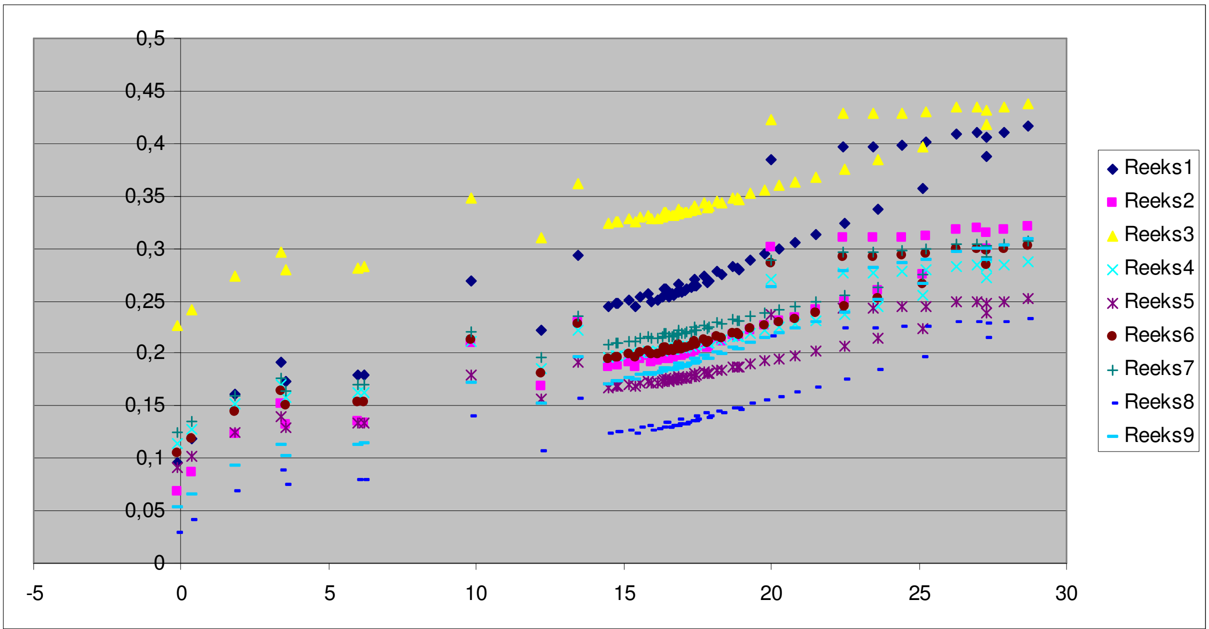
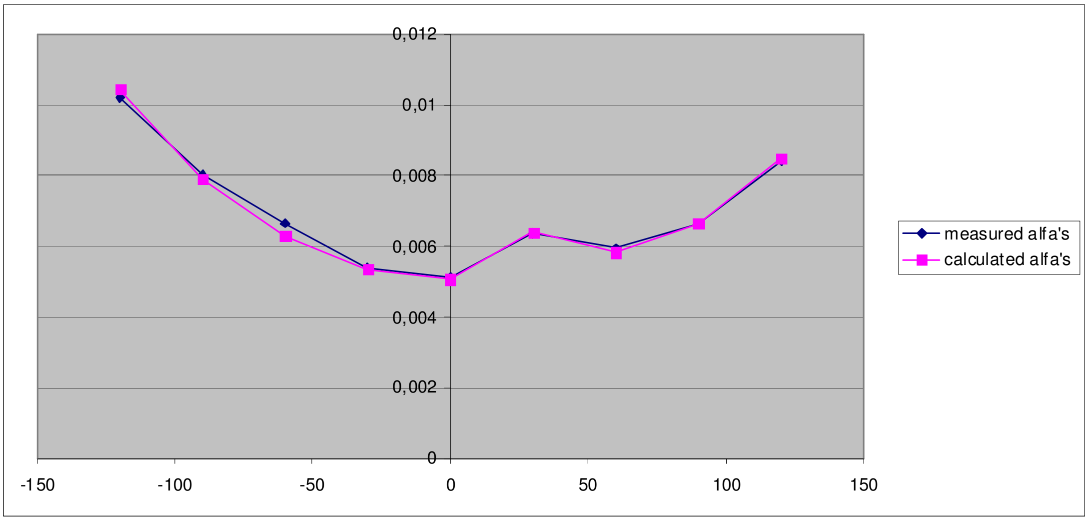


Figure 11: Case 2 – Assen (measured alpha's)

Reasonable alpha values were extracted from these graphs as observed from figure 12.

local soil resistance ohm.m			11	deep soil resistance ohm.m			11	(moet over het algeme		
distance between railway centre and measuring electrodes m			6							
distance between railway centre and common reference electrode m			30	positie ver.veld evenw.aan spoor			0	(kan nu ook varieren tı		
number of railway tracks			2							
electrode positions m	-120	-90	-60	-30	0	30	60	90	120	
alfa measured	0,010198	0,008012	0,006654	0,005397	0,005146	0,006366	0,005955	0,006626	0,008421	



	rho/Rr	rho/Rp1	rho/Rp2	rho/Rp3	rho/Rp4	A/U=1/0			
	0,0095	25	0,09	21	0	1			
	position m	-300	36	300	115				
electrode positions m	-120	-90	-60	-30	0	30	60	90	120
alfa calculated	0,0104	0,0079	0,0063	0,0054	0,0051	0,0064	0,0058	0,0067	0,0085

distance between pipeline and railway m	3		ongestoord verre veld op m			4000			
position m	-120	-90	-60	-30	0	30	60	90	120
alfa at pipeline depth	0,0519	0,0494	0,0478	0,0469	0,0466	0,0484	0,0474	0,0482	0,0500
permissible minimum railpotential V	-4	-4	-4	-4	-4	-4	-4	-4	-4
permissible maximum railpotential V	10	10	10	11	11	10	11	10	10
railresistance ohm.km	0,97	1,02	1,05	1,08	1,08	1,04	1,06	1,05	1,01

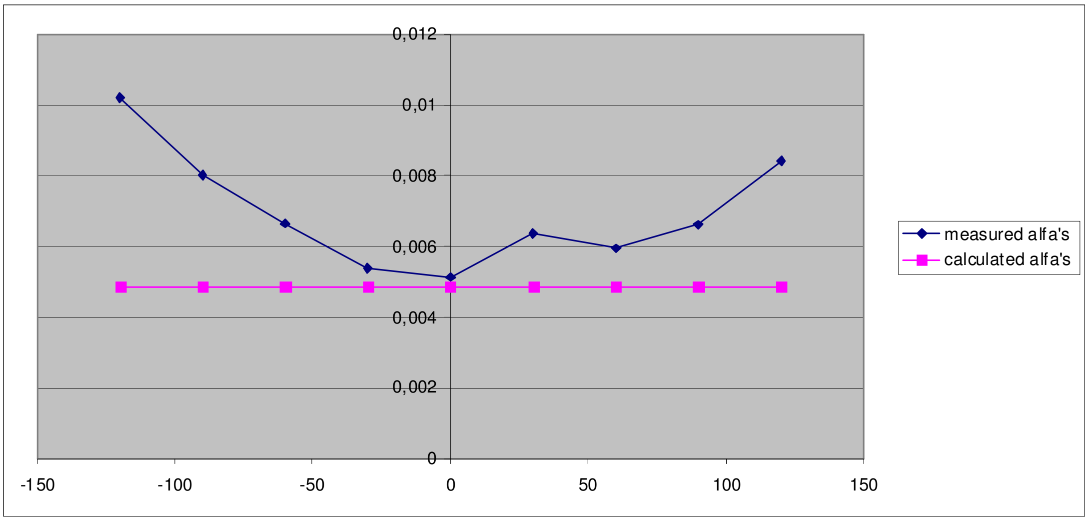
Figure 12: Case 2 – Assen (fitting of measured data)

To get a good agreement between measured and calculated alpha values, very large disturbances at the places of both traffic viaducts have been assumed. Most likely, the concrete reinforced steel of both viaducts is connected to the railway tracks.

The alpha value at pipeline depth is about 5 %. In this situation the railway potential may vary between -4 and 11 V. Negative railway potentials have not been observed and railway potentials more positive than 11 V means more overprotection.

Figure 13 presents the situation that would appear if all additional disturbances are solved. The alpha value at the pipeline depth reduces to 2.2 % and the practical railway potentials varies within the permissible range.

local soil resistance ohm.m			11	deep soil resistance ohm.m			11	(moet over het algeme		
distance between railway centre and measuring electrodes m			6							
distance between railway centre and common reference electrode m			30	positie ver.veld evenw.aan spoor			0	(kan nu ook varieren t		
number of railway tracks			2							
electrode positions m	-120	-90	-60	-30	0	30	60	90	120	
alfa measured	0,010198	0,008012	0,006654	0,005397	0,005146	0,006366	0,005955	0,006626	0,008421	



	rho/Rr	rho/Rp1	rho/Rp2	rho/Rp3	rho/Rp4	A/U=1/0			
	0,0095	25	0,09	21	0	0			
	position m	-300	36	300	115				
electrode positions m	-120	-90	-60	-30	0	30	60	90	120
alfa calculated	0,0049	0,0049	0,0049	0,0049	0,0049	0,0049	0,0049	0,0049	0,0049

distance between pipeline and railway m	3		ongestoord verre veld op m			4000			
position m	-120	-90	-60	-30	0	30	60	90	120
alfa at pipeline depth	0,0218	0,0218	0,0218	0,0218	0,0218	0,0218	0,0218	0,0218	0,0218
permissible minimum railpotential V	-9	-9	-9	-9	-9	-9	-9	-9	-9
permissible maximum railpotential V	23	23	23	23	23	23	23	23	23
railresistance ohm.km	2,32	2,32	2,32	2,32	2,32	2,32	2,32	2,32	2,32

Figure 13: Case 2 – Assen (fitting of measured data – assuming no additional point sources)

3 Wijster

Figure 14 presents the layout for the third case considered. Three pipelines are crossing the railway tracks. Measuring electrodes are placed at the upper side of the railway tracks, numbering from left to right. A DC-drain unit is present at the upper side of the railway tracks.

Figure 15 displays the alpha’ for which no special remarks are made: the nine values can be subtracted from this graph.

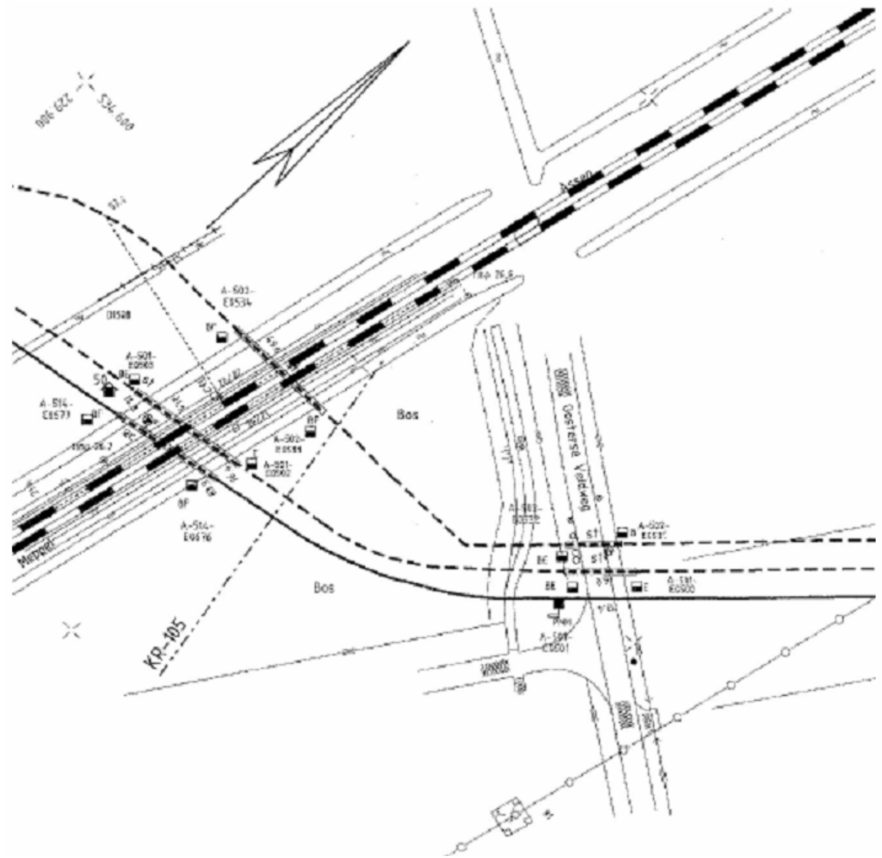


Figure 14: Case 3 – Wijster (layout)

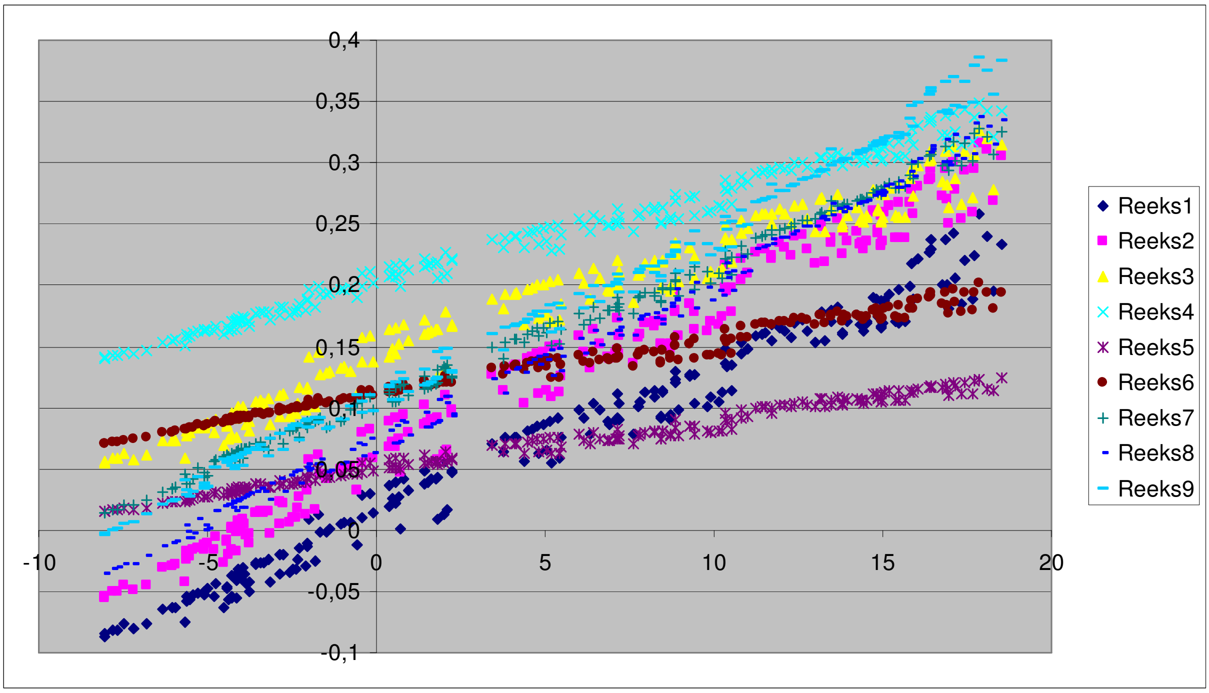
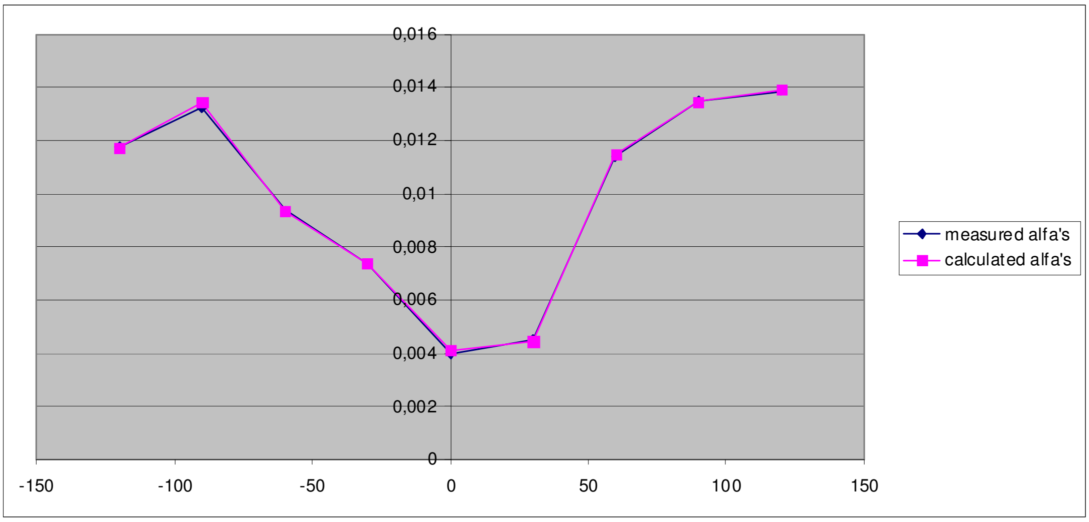


Figure 15: Case 3 – Wijster (measured alpha's)

	-120	-90	-60	-30	0	30	60	90	120
local soil resistance ohm.m			90 deep soil resistance ohm.m				90	(moet over het algeme	
distance between railway centre and measuring electrodes m			6						
distance between railway centre and common reference electrode m			30 positie ver.veld evenw.aan spoor				0	(kan nu ook varieren tu	
number of railway tracks			2						
electrode positions m	-120	-90	-60	-30	0	30	60	90	120
alfa measured	0,011783	0,013241	0,009363	0,007381	0,003976	0,004535	0,01142	0,013502	0,013862



rho/Rr	rho/Rp1	rho/Rp2	rho/Rp3	rho/Rp4	A/U=1/0
0,007	1,23	0,55	0,27	1,37	1
position m	-104,5	-46	60	105,9	

electrode positions m	-120	-90	-60	-30	0	30	60	90	120
alfa calculated	0,0117	0,0134	0,0094	0,0074	0,0041	0,0044	0,0115	0,0135	0,0139

distance between pipeline and railway m	3		ongestoord verre veld op m			4000			
position m	-120	-105	-75	-30	0	30	60	90	120
alfa at pipeline depth	0,0308	0,0832	0,0272	0,0261	0,0226	0,0229	0,0371	0,0326	0,0333
permissible minimum railpotential V	-6	-2	-7	-8	-9	-9	-5	-6	-6
permissible maximum railpotential V	16	6	18	19	22	22	13	15	15
railresistance ohm.km	13,38	4,96	15,18	15,79	18,26	17,98	11,11	12,65	12,39

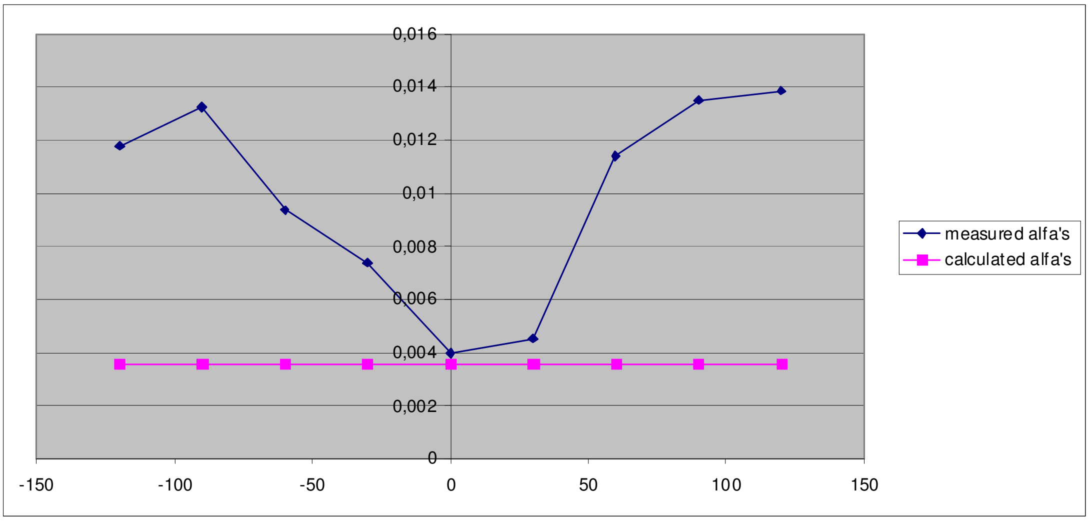
Figure 16: Case 3 – Wijster (calculated soil disturbance values)

Figure 16 shows the fitting procedure. The pipelines are crossing the railway tracks at -105 and -75 m position. Probably additional disturbances are located close to the pipeline. The practical railway potentials are outside the permissible calculated range. The DC-drain is necessary in this situation.

Figure 17 shows what would happen if all additional disturbances would be removed. The practical railway potentials are inside the calculated permissible railway potential range. That means the DC-drain unit could be switched off.

More research is planned since at present it is not clear what causes these additional disturbances. Extra measurements with electrodes closer to each other should give a better indication for the disturbance location. When the problem is identified an investigation into the possibility to disconnect (or isolate) the disturbance (metal object in the ground) will be started.

local soil resistance ohm.m			90	deep soil resistance ohm.m			90	(moet over het algeme		
distance between railway centre and measuring electrodes m			6							
distance between railway centre and common reference electrode m			30	positie ver.veld evenw.aan spoor			0	(kan nu ook varieren t		
number of railway tracks			2							
electrode positions m	-120	-90	-60	-30	0	30	60	90	120	
alfa measured	0,011783	0,013241	0,009363	0,007381	0,003976	0,004535	0,01142	0,013502	0,013862	



rho/Rr	rho/Rp1	rho/Rp2	rho/Rp3	rho/Rp4	A/U=1/0
0,007	1,23	0,55	0,27	1,37	0
position m	-104,5	-46	60	105,9	

electrode positions m	-120	-90	-60	-30	0	30	60	90	120
alfa calculated	0,0036	0,0036	0,0036	0,0036	0,0036	0,0036	0,0036	0,0036	0,0036

distance between pipeline and railway m	3		ongestoord verre veld op m			4000			
position m	-120	-105	-75	-30	0	30	60	90	120
alfa at pipeline depth	0,0160	0,0160	0,0160	0,0160	0,0160	0,0160	0,0160	0,0160	0,0160
permissible minimum railpotential V	-12	-12	-12	-12	-12	-12	-12	-12	-12
permissible maximum railpotential V	31	31	31	31	31	31	31	31	31
railresistance ohm.km	25,71	25,71	25,71	25,71	25,71	25,71	25,71	25,71	25,71

Figure 17: Case 3 – Wijster (fitting of measured data – assuming no additional point sources)

4 Meppel

Figure 18 presents the layout for the last case considered in which a pipeline crosses two railway tracks and the pipeline is protected by a DC-drain unit.

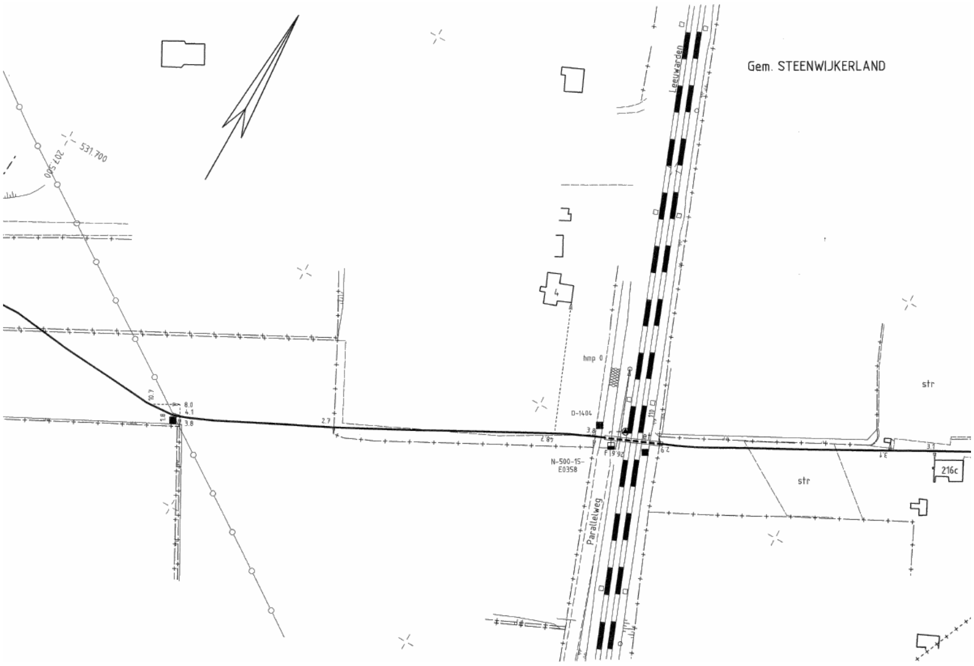


Figure 18: Case 4 – Meppel (layout)

Figure 19 displays the alpha'. On the positive side of the graph all alpha values are nearly zero (horizontal lines). That means that no influence of the railway tracks to the surroundings is observed.
On the negative side of the graph, nine almost identical negative alpha values can be observed. Probably this is caused by influence of the pipeline on the local remote earth electrode. If the DC-drain unit subtract current from the pipeline the pipeline becomes more negative. If the pipeline has coating defects at the position of the local remote earth electrode, soil and electrode will become more negative resulting in the nine negative alpha values.

A coating survey is planned which must show the applicability of this assumption. If the assumption about the cause of this phenomenon is correct the DC-drain unit can be switched off.

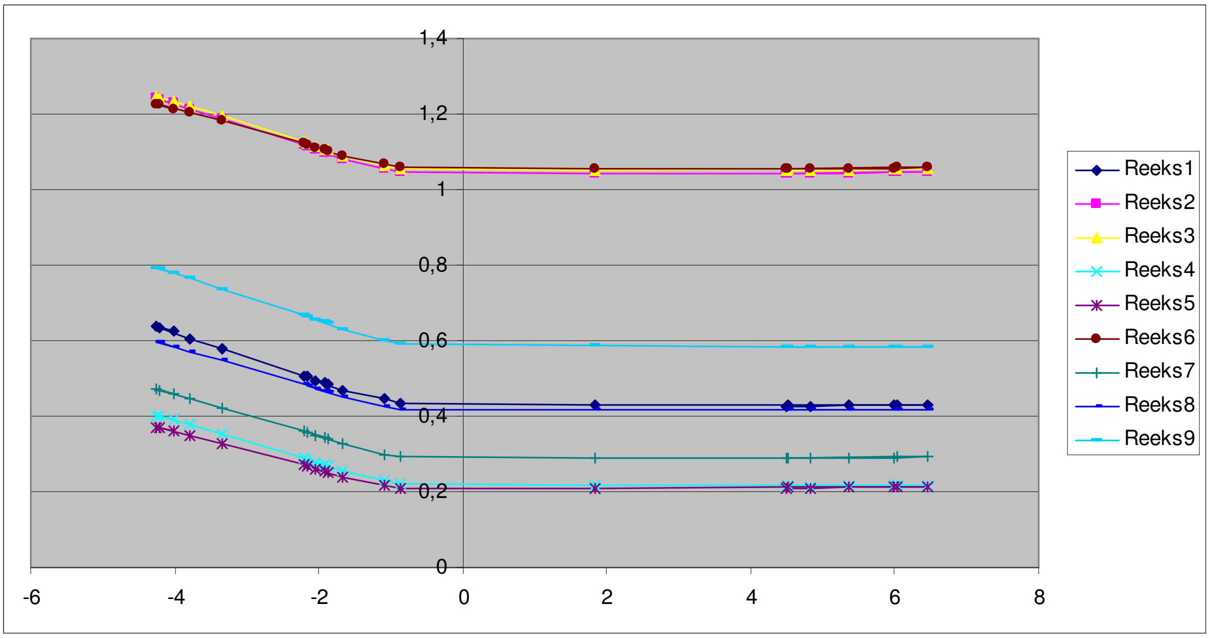


Figure 19: Case 4 – Onna (measured alpha's)

Conclusions

Measurements at about 20 locations showed that the new measuring technique as adopted by Gasunie is practical and allows analyzing and judging different situations. This technique allows to measure the alpha values that give the ratio of the soil potential with respect to the track voltage. Using the analytical formula and the trial and error procedure as presented here allows to determine the minimum and maximum track voltage that is allowed according to the standards applied within Gasunie.

Therefore, the key point to decide whether or not a situation is save and a given DC-drain unit remains necessary, is the availability of minimum and maximum tracks potentials at a certain risk area. For this reason ProRail has to find a method to predict or measure rail potentials in suspected areas.

Next steps

§ Do more measurements and get a better feeling with the alpha values.
§ Develop software to automatically identify the parameters based on measurements such that the trial and error method can be abandoned . This implementation will make the technique more effective (a more practical tool).
§ Find out ways to decrease the risk area, e.g. by isolating the rails or looking at the possibility to rearrange (clean) the "stone ballast".
§ Get rid of as many as possibly DC-drain units.
§ Make a set of design parameters for the distance between railways and steel pipelines.

- If the procedures work out well the system can be made more sophisticated so that up to 10 km/day can be inspected in suspected areas.