2-01

Results of a new measurement philosophy within GASUNIE

K. Dijkstra, P.J. Stehouwer
GASUNIE - The Netherlands, p.j.stehouwer@gasunie.nl

Abstract

Gasunie, in the Netherlands, is a Company with about 12.000 km gas transportation pipelines with pressure varying between 40 and 60 bar. The pipelines are protected against corrosion using coatings and cathodic protection systems.

To comply with the CP-standards, Gasunie has done for 30 years annual CP-measurements on the 22.000 test posts. Because the measuring equipment, after 10 years of use, wasn't supplied anymore by the manufacturer, Gasunie had to look out for a new measuring device. This was the proper time to examine the total CP-cost, and the efficiency and quality of the measured data. This resulted in the design of a 4 channel measuring device (AC/DC) and a new measuring program based on 'selected test posts'.

A selected test post program was possible because al the rectifiers and DC-drains were prepared with remote monitoring devices which measure the performance of the CP-system. To select the necessary test posts, a decision matrix to place the test post in an annually, 3 year or 6 year measuring program has been made.

In this presentation the decision matrix criteria will be outlined and the performance of the system when compared to the historical approach and annual field data will be discussed. In addition to that, the use of advanced integrated modelling software in the control and optimization of the pipeline network will be demonstrated in detail. To that purpose a blueprint of the CP-system is modelled first and compared with field results. When required, the blueprint data are fitted with actual field data and the fitted model is used to find problems. Finally it will be demonstrated how the results of the 6 year measuring program are used to check the annual and 3 year measuring program and to choose the set points of the CP system at critical test posts.

Résumé

Gasunie, établie aux Pays-Bas, est une société comptant quelque 12 000 km de canalisations de transport de gaz, dont la pression varie entre 40 et 60 bars. Ces canalisations sont protégées contre la corrosion au moyen d'un revêtement et d'une protection cathodique. Étant donné que nous nous conformons aux normes relatives à la protection cathodique, nous procédons, depuis 30 ans, à des mesures annuelles de la protection cathodique sur les 22 000 bornes de test. Vu qu'après 10 années d'utilisation, notre équipement de mesure n'était plus disponible auprès du fournisseur, nous avons été amenés à chercher un nouveau dispositif. Nous en avons profité pour étudier en détail le coût total de notre protection cathodique, ainsi que l'efficacité et la qualité de nos données de mesure.
À la suite de cette étude, nous avons conçu un dispositif de mesure à 4 canaux (CA et CC) et élaboré une nouvelle approche de traitement des données de mesure.
L'étude « Vollehove » à donné les résultats suivants que nous vous présentons.

Historiquement, Gasunie a procédé à des mesures annuelles aux bornes de test. Ces mesures étaient réalisées conformément à un principe d'enregistrement des données. L'enregistreur mesurait le potentiel du CC toutes les 5 min., 60 min. ou 24 heures. Il collectait ensuite les valeurs minimales et maximales des données et fournissait le pourcentage de valeurs négatives selon quelques paramètres de référence critiques (-850 mV et –550 mV). Les mesures étaient effectuées de manière aléatoire. Toutes les données étaient enregistrées dans un système SAP et comparées aux points de réglage ; en cas de dépassement, le technicien chargé de la PC était tenu d'examiner le système de PC et de procéder à des investigations. Le système s'est avéré fonctionner correctement, mais l'état actuel des technologies et les réglementations supplémentaires ainsi que les exigences de l'Asset Management ont nécessité un contrôle plus poussé du système. Ces deux dernières années, tous les redresseurs et les drains de PC ont été préparés par commande à distance, ce qui permet de sectionner électriquement les tronçons de canalisation. Auparavant, la plupart des joints isolants étaient connectés électriquement.

Zusammenfassung

Die Gasunie, The Netherlands, ist Betreiberin eines Netzwerks von Gastransportleitungen mit einer Länge von rund 12 000 Kilometern und einem Druck zwischen 40 und 60 bar. Die Transportleitungen sind durch eine spezielle Beschichtung und einen Kathodenschutz vor Korrosion geschützt. In Erfüllung der CP-Standards haben wir in den vergangenen dreißig Jahren jährliche CP-Messungen an den 22 000 Teststationen durchgeführt. Da unser Lieferant der Messanlage, die wir seit zehn Jahren verwendet haben, diese nicht länger liefern konnte, mussten wir ein neues Messgerät suchen. Wir haben diese Situation genutzt, gleichzeitig auch unsere CP-Gesamtkosten, sowie die Effizienz und Qualität unserer Messdaten einer Überprüfung zu unterziehen. Als Ergebnis dieser Prüfung haben wir ein Vier-Kanal-Messgerät (WS und GS) konzipiert und einen neuen Ansatz der Verarbeitung unserer Messdaten entwickelt. Der folgende Testfall „Vollehove“ zeigt die Ergebnisse.

Bisher hat die Gasunie jährliche Messungen an den Teststationen gemäß dem Prinzip der Datenerfassung durchgeführt. Der Messwertsammler (Datenlogger) maß die GS-Potentialwerte alle 5 Minuten, 60 Minuten oder 24 Stunden. Der Datenlogger sammelte die Höchst- und Niedrigstwerte der Daten und lieferte die Prozentwerte anhand einiger kritischer Referenzparameter (-850 mV und -550 mV). Die Messungen erfolgten nach dem Zufallsprinzip. Alle Daten wurden in ein SAP-System übertragen und mit den Sollwerten verglichen. Wurden die Sollwerte überschritten, musste der CP-Techniker das CP-System einer näheren Prüfung unterziehen. Das System hat seine einwandfreie Funktionstüchtigkeit bewiesen, aber der Stand der Technik, zusätzliche Vorschriften und die Anforderungen an das Aktivamanagement erforderten eine stärkere Kontrolle des Systems. In den letzten beiden Jahren wurden alle Gleichrichter und GS-Drainagen per Fernsteuerung vorbereitet. Nach diesem Stand ist eine elektrische Sektionierung der Leitungsabschnitte akzeptabel. In der Vergangenheit waren die meisten Isolationsverbindungen elektrisch angeschlossen.

Introduction

Gasunie, The Netherlands, is a company with about 12.000 km gas transportation pipelines with pressure varying between 40 and 60 bar. The pipelines are protected against corrosion using coatings and cathodic protection systems.

To comply with the CP-standards, Gasunie has done for 30 years annual CP-measurements on the 22.000 test posts. Because the measuring equipment, after 10 years of use, wasn't supplied anymore by the manufacturer, Gasunie had to look out for a new measuring device. This was the proper time to examine the total CP-cost, and the efficiency and quality of the measured data. This resulted in the design of a 4 channel measuring device (AC/DC) and a new approach to handle the data obtained.

Historically Gasunie performed annual measurements at the test posts. The measurements where done according to a data-log principle. The logger measures 5 min, 60 min or 24 hours DC-potentials, collects only the minimum and maximum values and gives the %-values according to some critical references (-850 mV and -550 mV). These measurements have been done at every testpost. The measurement were done according to a time restricted program, monthly or 6-month cyclus. This means that one pipe section could be measured on different days under different conditions. All the data is dumped in a SAP system and compared with reference values. If these values are passed, the CP-technician has to look at the system and do further investigation.

The approach described above proved to work but the state-of-the-art in CP-design and validation together with additional regulations and requirements from asset management asked for a better control of the system. As a result, the last two years al Gasunie rectifiers and DC-drains have been equipped with remote monitoring. Having this it is acceptable to electrically sub-divide the pipe network in sections that are electrically not continuous while in the past most of the isolation joints were connected.

In addition to that Gasunie decided to integrate advanced modelling software in the control and optimization of their pipeline network. The software is used both in the design and evaluation stage. In this presentation it will be demonstrated in detail how the software can be used to pin-point problem area's by creating an up-to-date computer model of the pipeline section under investigation and validate this model using measured potentials and currents at test-stations.

Selected test post program

The first decision that was made was to use a selected test post principle to monitor our CP system. Doing this, one has to define what a CP system is. Gasunie's definition of a CP system is "everything that is nodded to make sure that a normal coating defect (max surface area ≈ 100 cm^2) is properly protected, and that external (potential gradient) threats are monitored and under control".

This requires to define criteria's/statements that will be used and that are based on standards. Here the following statements have been defined:

- Al rectifiers (500) and DC-drain units (120) must be remote monitored.

- Al AC-drain units (200),consist of a 3-2 diode configuration, must be supplied with capacitors to avoid DC leakage.
- CP-on potentials must be between -1200 mV and -1600 mV (Cu/CuSO4) measured to remote earth.
- Because it was not sure if our CP-system could be divided into acceptable sections to be able to measure decent CP-off potentials, it was decided to use coupons to measure the IR-free potential. These coupons (at least 2) are placed at a representative location.
- At critical points with AC and/or DC interference annual measurements Nod to be done including data logging (1 – 24 hours) if necessary.
- Al test post must keep there functionality even in stand-by situation.
- Annual measurements are used to make sure that the CP-system is functionally properly and steady according to former measurements (requirement standards).
- 3 year measurements are used to inspect and monitor critical areas and to measure the coupons.
- Ever 6 years all drawings and test post are looked at and the results of the past 6 years are studied.
- 6 year measurements are used to measure all ‘complex’ test post, coupons, AC – and DC influence areas, current requirement and remote earth potentials!
- Results of the 6 year measurement are used to fine tune the 6 year measuring program and to make an integrity report of the measured pipeline section.
- Results of the 6 year measurements are used in the CP modelling tool CatPro (see further).

Gasunie has about 250 CP sections (trajects) which are divided in 150 (RTL 40 bar) and 100 (HTL 60 bar). Each statement is worked out in memorandum’s, in which the problems are summarized and the decision/statement/measurement/work instruction are declared. This is al placed in a CP integrity management document and adopted by the asset management.

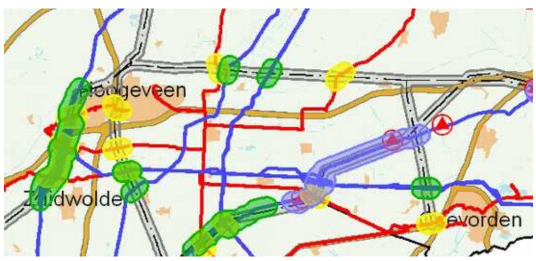
Selected test post in practice

According to the statements a test post decision matrix has been made. Each test post is reflected to the decision matrix and is classified. In the next steps the decision matrix will be looked at in further detail.

Before one can start the classification on has to know how the CP system is designed/made in order to be able to make proper decisions. The following phenomena/facts should be taken into account.
- Understanding the potential gradients caused by a ground bed.
- Knowing where the isolation joints are installed.
- Knowing if an isolation joint is connected or not and knowing CP- cable configuration.
- Understanding of the pipeline attenuation.
- Knowing the contract borders of your pipeline system (responsibility)
- Understanding soil condition in relationship to DC-interference source and contours
- AC-interference source and contours.

Information on the 1 year decision matrix is provided below.

In the figure you can see the following contours:
- Black line/grey area (HVAC- powerline)

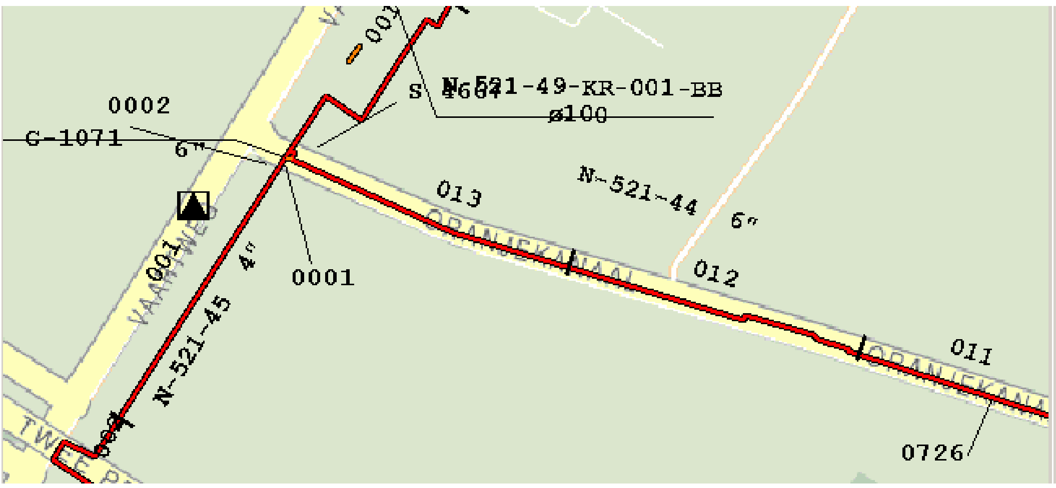


- Blue line = HTL
- Red line = RTL
- Yellow/Green area = RTL/HTL within 250 m. HVAC.
- Red circle with triangle = AC-drain unit

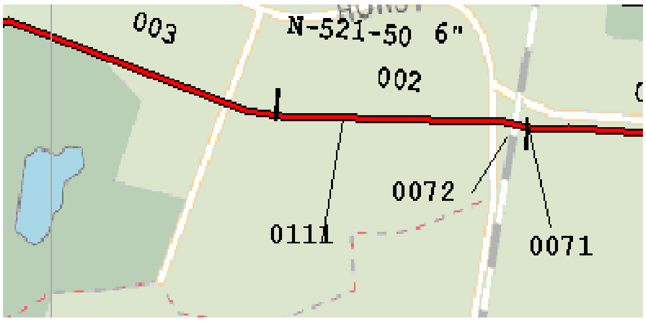
<table>
<tr><th>Inspection regime</th><th colspan="4">Reason</th><th>Reason SAP</th></tr>
<tr><td rowspan="15">Annually</td><td rowspan="8">Separation / end point</td><td rowspan="5">GOS</td><td rowspan="2">Connected HD-LD</td><td>Connected contract border</td><td>End + 60 mA alarm</td></tr>
<tr><td>Contract border open</td><td>End + separation TP</td></tr>
<tr><td rowspan="3">HD-LD open</td><td>HD end point</td><td>End TP</td></tr>
<tr><td colspan="2">+</td></tr>
<tr><td>LD end point</td><td>End + CP third party</td></tr>
<tr><td rowspan="2">M&R / CS / EX</td><td colspan="2">B</td><td>End TP</td></tr>
<tr><td colspan="2">BC/[BD]</td><td>Separation TP</td></tr>
<tr><td>Traject separation</td><td colspan="2">BD</td><td>Separation TP</td></tr>
<tr><td rowspan="3">Influence</td><td colspan="3">Rule: DC-influence (d < contour [500 m])</td><td>DC-influence</td></tr>
<tr><td colspan="3">Rule: DC-influence (d < contour [250 m])</td><td>DC- influence</td></tr>
<tr><td colspan="3">Rule: AC-influence (d < contour 500 m above ground/ or contour 50 m underground)</td><td>AC- influence</td></tr>
<tr><td colspan="4">1e test post after Rectifier (max 1km)</td><td>-1600 mV controle</td></tr>
<tr><td>Monitor test post (CatPro setpoint)</td><td colspan="3">not electr. Continu. / Electr. weak / shortcircuit</td><td>Catpro setpoint</td></tr>
<tr><td colspan="4">Monitor testpost CP technician + reason</td><td>Monitor</td></tr>
<tr><td colspan="4">stand-by</td><td>Stand-by</td></tr>
</table>

Some examples are presented below.

Example 1.
Test post N-521-44-**E0726** = 1e test post after rectifier, G-1701 (-1600 mV setpoint)
Test post N-521-45-**E0001** = Connected Isolation joint, used as monitor ‘current balance Rect.’

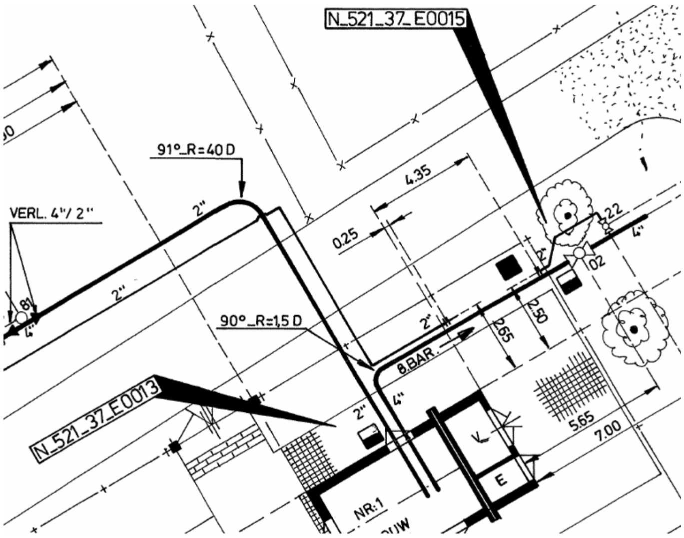


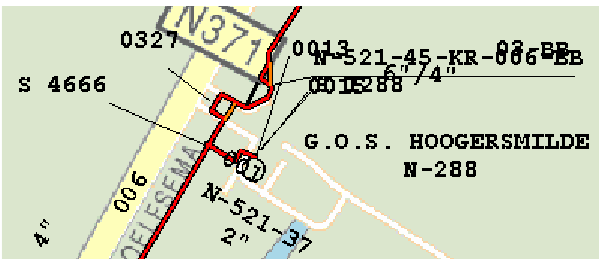
Example 2.
Test post N-521-50-E0111 = Stand-by
Test post N-521-50-E0072 = DC-interference (- - - - = railway) and easy accessibly
Test post N-521-50-E0071 = Stand-by annually, but measured in the 3 and 6 year program.



Example 3.
Test posts N-521-37-E0013 & N-521-37-E0015 depend on the situation at the GOS (station) which reduces the pressure from 40 bar to 8 bar.
The following situations are possible:

1. If the 2" pipeline is connected with to the 4" one only Nods to measure the potentials and the current (I<60 mA) in TP E0013.
2. If the 2"pipeline is not connected to the 4" one Nods to measure both TP, because test post TP E0015 will give us information about the CP level provided by the third party (GOS), and TP E0013 is an 'end' TP of our CP-system.





The session is completed when al test posts are arranged in the selected test post program.

For the 3 and 6 year measurements every test post Nods to be classified. Information on the 3 and 6 year decision matrix that is used is given below. Since the implementation of this system is ongoing for the moment all chosen criteria are looked at very carefully. Especially the AC and DC influence area are sometimes hard to define because not all parameters are known. It is expected to learn more while implementing the measuring programs.

The second thing that is not clear is the magnitude of the potential gradients caused by our CP–system and the number of areas in which the CP-system interferes on other pipelines (Gasunie and/or third party). Because the remote earth potential measurements are only done in the 6 year program, the program can only be fine tuned after finalizing a 6 year program.

Another interesting measurement that is done in the 6 year survey is to collect the shorted currents from structures nearby the pipeline like casings and piles. This should help to interpretive the values when the potentials from the pipeline and e.g. a casing are getting closer to each other.

Inspection regime	**Reason**			**Reason SAP**
3 year	Annual inspection program			
	Coupons			Coupon
	Bx-meetpalen (manco / deviation)	BE/H	I > if shorted Monitor	BX-shorted
		BD	Current balans	
		BC	Third party interference	BX-influence
		BE	potential gradient monitoriing	BX-potential gradient
		BS	Insulated cassing	BX-solitair CP system

Inspection regime	Reason				Reason SAP
6 year	Annual inspection program				
	3 year inspection program				
	Influence (Rules copied from 1 y)	24 hour logging DC-influence			24-hour log. DC-influence
		24 hour logging AC- influence			24-hour log. AC-influence
	Bx Shorted measurement	All Bx TP	Norms / Standards	* DC drain out. * Always remote earth potentials	
	Catpro verification	Synchronic measurements			Catpro Verification

Results historical approach versus selected test post

		Historically				Selected post program		
Total	**TC nr**	**TC name**	**Separ.**	**AC**	**DC**	**1 y**	**3 y**	**6 y**
24	T22372	Hoogersmilde	2	0	2	**9 (37%)**	**10 (42%)**	**12 (50%)**

The most important reason to introduce a selected test post measuring program is to get annual data to monitor the CP-system and check if it is functionally properly and steady state. It also allows monitoring critical area's, every 3 years to look at the current distribution and monitor 'know' problems. In the 6 year program detailed measurements are done and analyses. Finally, in the annual and 3 year program the data is checked to the adjusted set points.

Conclusion selected test post decision matrix

- Only possible if there is knowledge about the electrical scheme and properties of the CP system.
- The influence areas from AC and DC sources should be known.
- Monitoring a CP-system is not the same as 'making sure the whole pipeline has achieved CP according to the standards'.
- When using a selected test post program it has to be clear for the CP engiNor that de pipeline CP, including the sections between the (measured) test posts, is functioning properly (*no difference with the historical approach*).
- A selected test post program is only possible if the critical 'parts' like rectifiers and DC-drainage units are remotely monitored.
- It is mandatory that the standby test post keep there functionally. Within Gasunie these test posts are maintained by the GIS people and there maintenance department/program.
- Using a selected test post program stringent borders and alarms must be defined, because the chance to detect problems depends on the amount of measured locations.

In the list below one can see the program that is made for each test post in the section Hoogersmilde. In can be observed that a different measuring time in the AC - DC influence area, 5 min., 1 hr. or up to 24 hr can be is issued.
The coupons are not yet placed.

Manco			**General data**				**1 YESAR**			**3 YESAR**		**6 YESAR**	
area - nr	**Type**	**traject**	**Name**	**Separ.**	**AC**	**DC**	**1 y**	**reason**	**comment**	**3 y**	**reason**	**6 y**	**reason**
N-521-37-E0013	BA	T22371	Hoogersmilde	No	No	No	0	SB		0		0	
N-521-37-E0014	BV	T22371	Hoogersmilde	No	No	No	1	EndTP+60mA+TP	Low pressure indication	1		1	
N-521-37-E0015	B	T22371	Hoogersmilde	No	No	No	0	SB	Low pressure indication	0		0	
N-521-44-E0040-1	**D**	**T22371**	**Hoogersmilde**	**Yes**	**No**	**Yes**	**1**	**SecTP+DC250**	**1hr DC**	**1**		**1**	**SecTP+24hr DC**
N-521-44-E0280-1	B	T22371	Hoogersmilde	No	No	No	0	SB		0		0	
N-521-44-E0517-1	B	T22371	Hoogersmilde	No	No	No	0	SB		0		0	
N-521-44-E0726-1	B	T22371	Hoogersmilde	No	No	No	1	1600		1	1600+BX	1	1600+BX+KS
N-521-45-E0001-1	BH	T22371	Hoogersmilde	No	No	No	0			1		1	
N-521-45-E0002-1	D	T22371	Hoogersmilde	No	No	No	1	MMP	Current control	1		1	
N-521-45-E0327-1	B	T22371	Hoogersmilde	No	No	No	0	SB		0		0	
N-521-45-E0626	BA	T22371	Hoogersmilde	No	No	No	0	SB		0		1	
N-521-45-E0627	BV	T22371	Hoogersmilde	No	No	No	1	MMP	Current control LP-TP	1		1	
N-521-45-E0628	BD	T22371	Hoogersmilde	No	No	No	1	EndTP+SecTP		1		1	
N-521-45-G1071-	GL	T22371	Hoogersmilde	No	No	No	0	B-beurt		0		0	
N-521-49-E1238	BA	T22371	Hoogersmilde	No	No	No	0	SB		0		1	
N-521-49-E1239	BV	T22371	Hoogersmilde	No	No	No	1	EndTP+60mA+AFN	Low pressure indication	1		1	
N-521-49-E1240	B	T22371	Hoogersmilde	No	No	No	0	SB		0		0	
N-521-50-E0111-1	**D**	**T22371**	**Hoogersmilde**	**Yes**	**No**	**Yes**	**1**	**SecTP+DC250**	**1hr DC**	**1**		**1**	**SecTP+24U DC**
N-521-50-E0310-1	B	T22371	Hoogersmilde	No	No	No	0	SB		0		0	
N-521-50-E0316-1	B	T22371	Hoogersmilde	No	No	No	0	SB		0		0	
N-521-50-E0574-1	B	T22371	Hoogersmilde	No	No	No	0	SB		0		0	
N-521-50-E0787-1	B	T22371	Hoogersmilde	No	No	No	0	SB		0		0	
N-521-50-E1093-1	B	T22371	Hoogersmilde	No	No	No	0	SB		0		0	
N-521-50-E1388-1	D	T22371	Hoogersmilde	No	No	No	1	MMP	Stroomcontrole	1		1	

The backbone of the measuring program

Every six years a CP section is measured. These measurements are, like already mentioned, much more comprehensive than the annual and 3 year measurements. One of the big differences is that the potential against remote earth is measured. This way, data are collected that can be used to analyse the CP-system, setting points and the suspected electrical parameters. If the outcome does not match it means that something is wrong and needs to be investigated. Experience learns that lot of things can go wrong including GIS data, coating and pipeline properties, misunderstanding of CP cables connections, measuring faults, parameters modelling tool, input data files, etcetera.

The software simulation tool

The cathodic protection analysis tool used within Gasunie is based on CatPro, designed by Elsyca (Belgium).

CatPro is a numerical simulation software package for the design and optimization of the cathodic protection of complex pipeline networks, with the possibility to take into account DC and AC interference. The basic idea of CatPro is to link the potential and current density distribution in the soil with the current and axial voltage drop along the pipeline. In addition, the local soil resistivity in the area around the pipe is taken into account in the calculation of the equivalent coating resistance.

As a result, CatPro is able to calculate the pipeline potential with respect to remote earth as well as the "On", "Off" and "IR-free" potential. In the Gasunie approach we work primarily with the potential to remote earth and the current distribution.

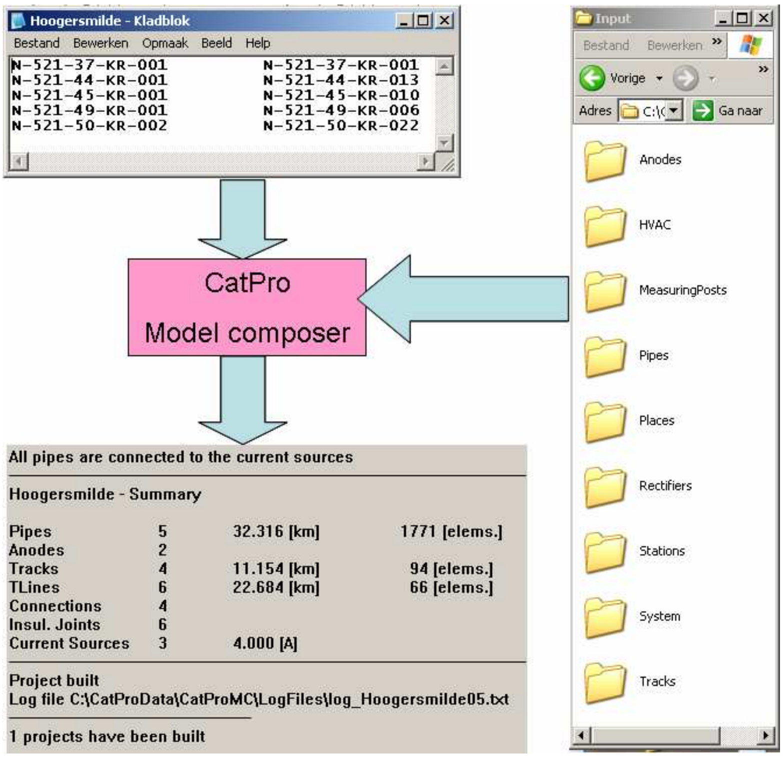
Full details on the CatPro model can be found in references [1-2].

Test case – trajectory "Hoogesmilde"

<u>CatPro Model composer</u>
In this paragraph, the results from the 40 bar (regional transportation pipeline) trajectory Hoogesmilde, number T22371, in the region Hoogezand will be presented.

Before starting, the geographical information from the test posts, pipelines, isolation joints, rectifiers and AC- and DC drains, place(city) names, HVAC, DC traction were updated in the Gasunie GIS system. With this information a detailed design of the pipeline system has been build. The CP-system consists out of a single rectifier and is electrically isolated from other systems by using isolation joints at the extremities/borders.

Using the CatPro Model Composer (MC) that has been developed in collaboration with Gasunie and Elsyca, it takes only a minute to create a CatPro simulation model. Depending on the input data, the model is in 95% of the cases ready to use.



The section is 32 km in length and has two ground beds. One is near the rectifier and one in a remote area. The remote ground bed is used to model current from/to third party pipelines that are connected and to simulate ‘current’ defects. One can also see that the HVAC and DC traction geo-information is inserted in the model and that de MC has made 4 connections between pipelines and added 6 isolation joint.

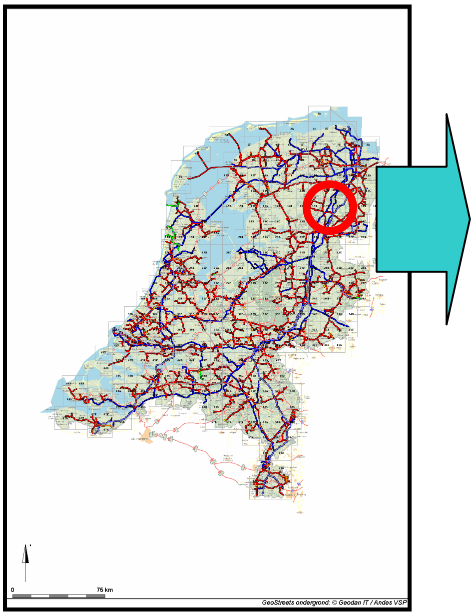
The model composer automatically creates all output files that are needed to run the CatPro modelling software and analyse the investigated section (Hoogesmilde).

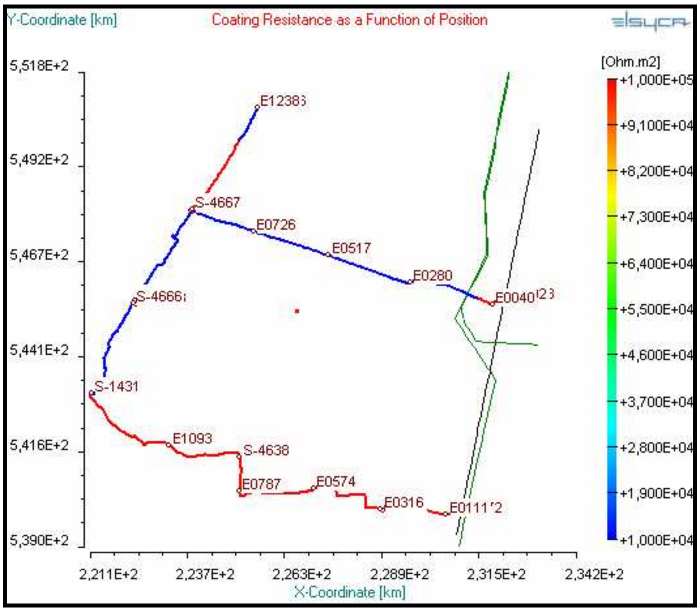
<u>CatPro calculator/modelling</u>
Before Gasunie started using the modelling facilities for daily practice, it worked out how to use modelling in such a way that it would help and <u>not</u> create a lot more, very difficult to answer, questions. Also the input parameters have been limited to avoided nonsense values used in de model to fit the field data. This resulted in the following approach:

1. Make a blue print of the present situation using defined parameters (criteria/field experience) and answer the questions:
    a. “Should the CP-system be able to work in the long run if we built it this way?”
    b. “Does the blueprint comply with the criteria?”
2. Fit the measured field data (6 yr) in the blue print and compare the values.

3. Fit the blue print model to an actual (logical) model. At this step one is able to make a overview of sections that meet the criteria and sections that do not meet the criteria and need more explanation and/or examination.
4. If the actual model still deviates from the field data, additional measurements should be made and used to find the cause of the deviation.

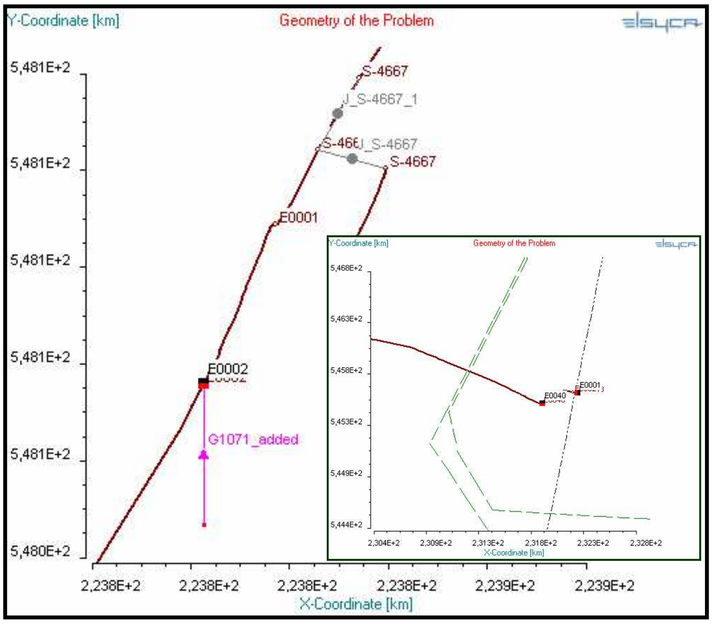
The figure on the left presents Hoogesmilde as a red circle on the map from the Netherlands, while the figure on the right shows the geometrical layout as made in CatPro with the coating resistance, valve scheme and test posts.





If one takes a closes look at the model one can see that the following connections/objects are made automatically which makes the software very user friendly J and saves lots of time (e.g):

- There was no ground bed data, so the MC added a ground bed according to user defined specifications (-40m deep, R=3 Ohm)
- Separate pipeline sections (GIS) are joined through S-schemes (valves)
- Isolation joints and rectifiers are connected to the pipelines.
- AC and DC trajectory's are shown (small figure right)

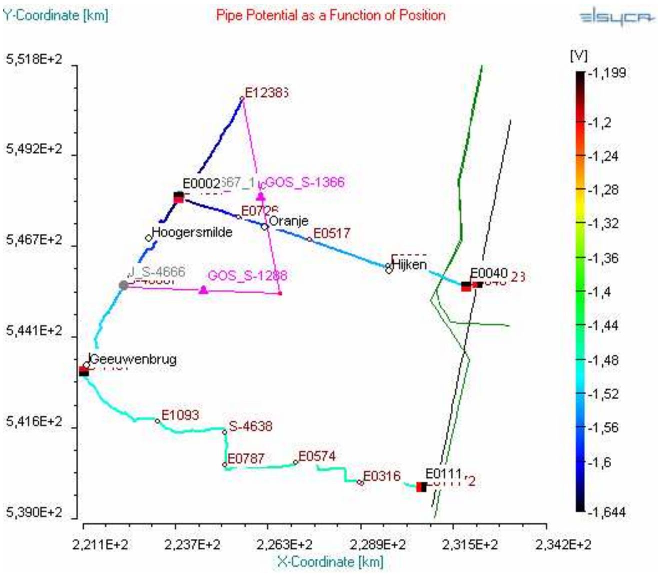


1. Blue print of present situation

Once the geometrical lay-out is finished, the rectifiers in the trajectory are adjusted to a remote earth potential of -1600 mV CSE, which is the set point potential. After the modelling program has delivered the result, the trajectory is checked to see if the result are acceptable. In this stage the model is checked to make sure that al pipelines are connected, isolation joint are electrically closed/open and the rectifier s are adjusted correctly.

Based on this set-up it is investigated if the complete system works according to the standards (Gasunie and European). The Gasunie standard specifies that the complete system must have a pipe to soil potential between -1600 [mV] and -1200 [mV] to remote earth (versus CSE) at al test posts.

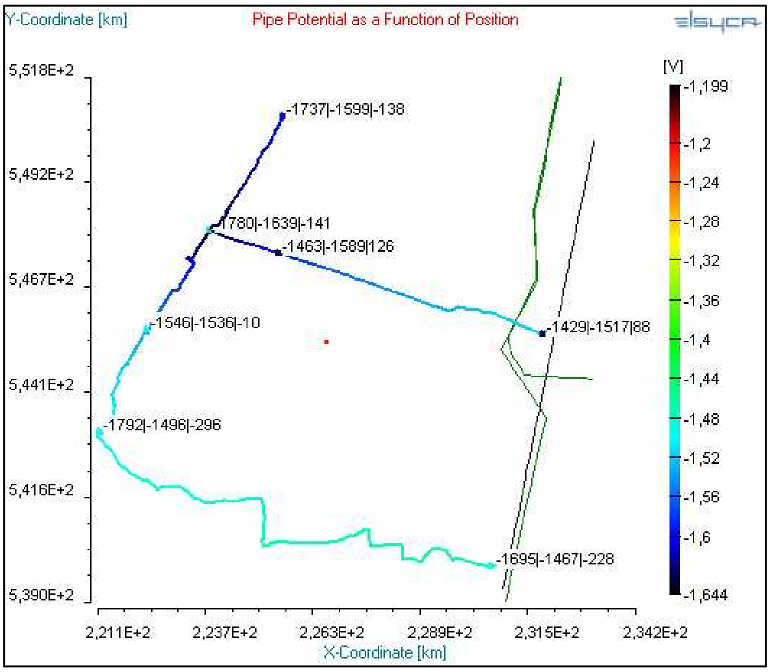
This is the situation that gives us the information that tells us that the CP-system should work properly in the long run if it was made according to our electrical scheme.

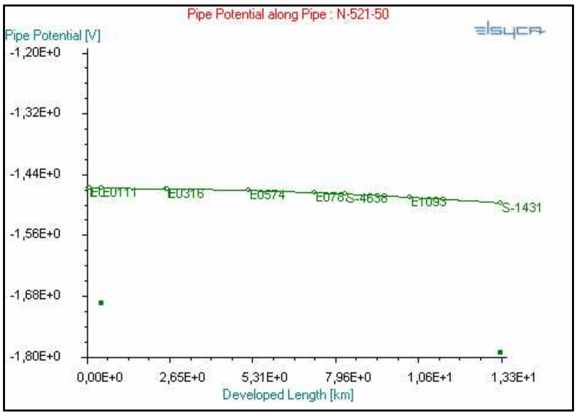


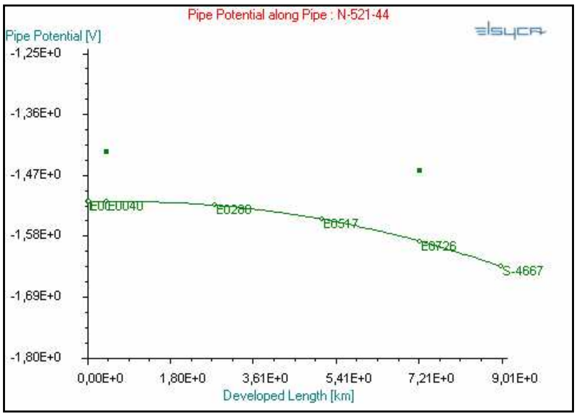
In this phase one can decide that the present chosen configuration is incorrect and needs to be changed. If the potential criterion is reached the conclusion is that the CP-system should be capable to apply sufficient CP to the pipeline. In this case the conclusion is “no problem”.

2. Fit field data (6yr.) in blue print

In a second step the measured field data are used to further optimize the numerical model in the third step. In the trajectory studied here, field data from the 1 year measurement program have been collected. The figure presents a colour plot of the calculated pipeline potential w.r.t. remote earth. In the same graph the measured (left), calculated (middle) and difference between both (right) potentials (all values in [mV]) are printed with allows to have a complete overview of the situation in a single plot (ex. -1737I-1599I-138).







The following remarks/conclusion where made:

- The current output of the rectifiers in the model (900 mA) is much lower than the true current (4000 mA)!
- The coating of N-521-50 (-1792; -1695) is in all likelihood better than the used default value. The potential distribution doesn’t give a reason to suspect CP from a third party. No further investigation. In the 6 yr. measuring program the current will also be measured at S-1431.
- The potentials of N-521-44 (-1463; - 1429) are much more positive than suspected, even though they are within the criteria! There are two major choices that can be made to fit the potential curve. The first one is to make the coating more conductive. The second one is to introduce one or more ‘current’ defects and fit them such that the potential curve fits. In both situations the curve could be fitted but it did not ‘look’ very realistic. Further investigation is required.
- The DC-influence nearby the railway is acceptable.
- The potential deviation measured at S-4666 is most likely caused by the location of the test post, in the middle of an underground valve scheme (poor coating). In the 6 yr. program the potential gradient to remote earth will have to convince this conclusion.

3. Adjusting the blue print to the actual situation

The critical “unknown” in the CP simulation is the coating quality (resistance) along the trajectory. The idea is to find the coating resistance that best fits the measured potentials and currents in the field. The starting point for the simulations is the as-built coating specifications used within Gasunie which have been implemented in the MC.

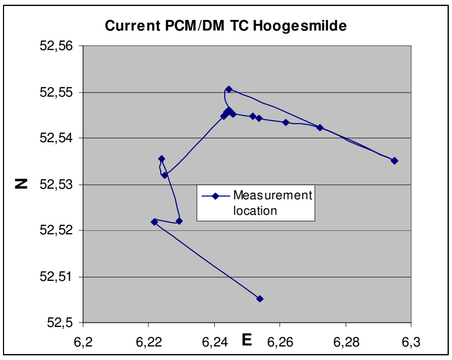
It is very important to make sure that realistic coating values are maintained. According to the Gasunie standards new bitumen coating has a design current requirement of 0.01 to 0.1 [mA/m^2]. Degraded bitumen has a current requirement of 0.1 to 0.5 [mA/m^2]. (For PE/PP coatings the ranges are respectively 0.001 to 0.01 [mA/m^2] and 0.01 to 0.2 [mA/m^2]). The degraded design criterion is reached after 10 years. If a pipeline has a current requirement of 0.1 [mA/m^2], with a potential shift of 500 [mV], this results in a coating resistance of 5 [$k\Omega m^2$]. (For PE/PP a degraded coating resistance of 50 [$k\Omega m^2$] is obtained.)

When the measured data in a certain section of the pipeline network do not fit the simulations at all there is a good reason to believe that something else is happening. This could be a “large fault” like a shorted casing, contact to foreign steel objects or faulty isolation joints. CatPro makes it very easy to plug in “pseudo defects” with an adjustable current to fit the model.

4. <u>Additional measurements for investigations</u>

It seems that the current requirement of pipeline N-521-44 is too high. Although the potentials seem to be acceptable, if there is a ‘current consumer’ (shorted casing, contact with earthing/cable/pipeline) one knows that at that location the CP system probably will not be sufficient. To find out if this is correct it is necessary to collect more field data. At the moment, if there is a pipeline section where a problem is suspected, more field data are collected doing the following measurements:

- Measure the current at all Isolation joints in the test post, at the boundaries (GOS) and connection to other systems.
- Measure far field potentials (6 yr.) at all test posts.
    - Practically this means that about 2 – 8 measuring devices that measure simultaneously are connected. Then an amount of current at different locations along the pipeline is inserted and the attenuation graphs of the measurements are interpreted. At the moment it is observed that it is better not to insert a huge amount of current into the pipeline. (due to polarisation effects)
- Using a PCM (Pipeline current mapper) or a DM (defect mapper)
    - This method is based on inserting a known signal, with special frequencies, that simulates the CP current. It can also give information about the pipeline location, the depth and current direction. The DM is equipped with a GPS and software to plot the results in Google maps. In the trajectory Hoogesmilde the DM has been used to measure the current distribution. These results looked quit good and fitted nice in the model. Before getting too excited, these results need to be confirmed using a second method.



- Measure the potential drop in the pipeline using test posts and valves as connection points.
- Measure the current through the pipeline using a (SWAIN)clamp on meter.
- Follow the pipeline with a suitable pipeline locater looking for unusual signal drop/change.

It depends on the situation which method from the above is started with. Starting point is that two methods should give the same information before any expensive steps are made (such as excavating the pipeline).

Al these measurements, except measuring the current at joints, collect an indirect current distribution. When using this type of indirect method the operator should have enough experience to determine if shown values/results are realistic.

Conclusion

This paper presented the results of a new measurement philosophy within Gasunie. In this philosophy the use of a selected test post measuring program and advanced simulation software is of fundamental importance. To demonstrate the principles the cathodic protection of the Hoogesmilde trajectory (network of 5 pipelines with a total length of about 33 km) has been studied in more detail.

In a first step it has been outlined how a decision matrix has been made for annual, 3 year and 6 year measuring programs. This learned that it is possible to reduce the amount of measured test post if there is an understanding of the total CP–system.

In a second step the blue print design of the Hoogesmilde trajectory has been used to show how we are using the CatPro simulation tool. From this it turned out that the obtained potentials did not agree with the Gasunie standards at some sections along the network. After tuning the model with field measurements, Gasunie found out that the coating conditions in the field where better and worse than the assumed values. This led to the conclusion that on one pipeline section an investigation should be done. Finding this anomaly without the use of the simulation tool would have been pretty difficult because the obtained potentials were not too far from the minimum Gasunie standard. By using the model composer and the model it is very easy to change the parameters and immediately see how this affects the pipeline potential across the complete network.

It is obvious that the approach presented here, gives qualitative better information to analyse the functionality of the CP-system even though less test post are measured. With the knowledge that Gasunie gets from the model simulations it is capable to zoom in on a given (problem) area and conduct (if necessary) further investigations to find the problem.

References

[1] L. Bortels, J. Deconinck, “Numerical Simulation of the Cathodic Protection of Pipeline Networks under Various Stray Current Interferences”, Chapter in book “Modelling of Cathodic Protection Systems”, WIT Press.

[2] CatPro V2.0, www.elsyca.com