Results of a new measurement philosophy on complex structures within GASUNIE

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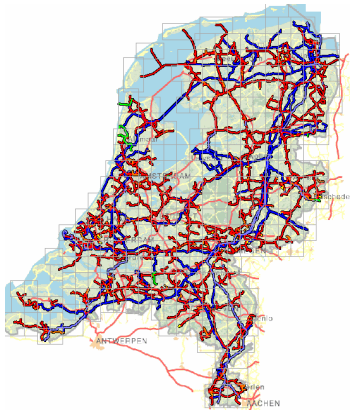
Introduction

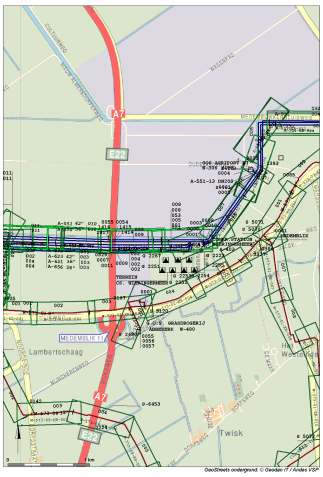


Gasunie, The Netherlands, is a company with about 12.000 km gas transportation pipelines with pressure varying between 40 and 60 bar. To keep the system functionally according to the set points, pressure and gas quality, Compressor-, Mix-, LNG-, N2-, Export-, UGS and Reduce stations are used. According to national regulations, personal safety and ATEX, the pipelines must be electrically isolated from the stations by using isolation joints/flanges.

As a consequence two fundamental CP systems are placed.

1. EN 12954* system
    a. Pipelines are not connected to the stations (structures),
    b. All steel is coated,
    c. No connections to earthing systems,
    d. Distributed current of the CP-system is a ‘integrity parameter’; coating related and/or fault situations (short-circuit with e.g. casing, piles, cables).
2. EN 14505* system
    a. Pipelines and structures are connected,
    b. All steel is coated,
    c. Connection with earthing systems,
    d. Distributed current of the CP-system has no relationship with pipeline-coating-fault situations.

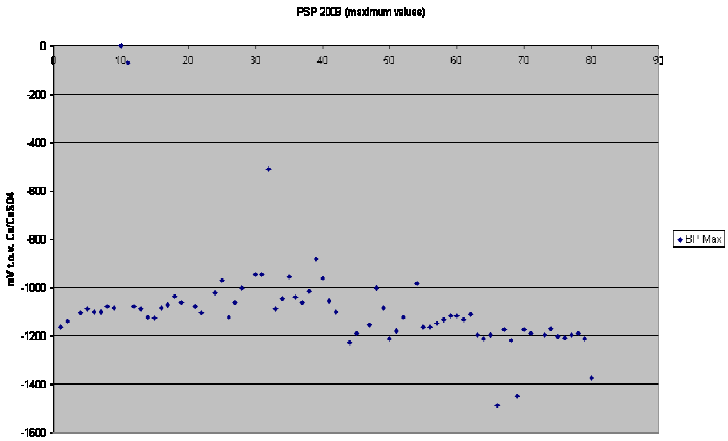
** To achieve effective cathodic protection a combination of ‘impressed current ’and/or ‘distributed groundbed’ can be used.*



In 2009 and 2010 it has been demonstrated at CeoCor how Gasunie does their CP-measurements and interpretation of the measured values. In this presentation it will be demonstrated how our measuring philosophy has been re-arranged for complex structures using new equipment to comply with CP-standards.

Gasunie has done for 30 years annual CP-measurements on the 1.500 test posts positioned on the ‘stations’. 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 also 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 four channel measuring device (AC/DC), the implementation of a single channel (market conform) 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 randomly with all data 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 (coating of complex structures) and validation together with additional regulations and requirements from asset- and operational management asked for a better 'control' of the system. Also the need to produce
This approach was also primarily developed for a pipeline system that is under influence of DC-stray current.

In addition to that Gasunie decided to use advanced modelling software to optimize and validate the chosen criteria.

Selected test post program for stations

The first decision made was to use a selected test post principle to monitor our CP system. Our definition of a CP system is "every thing needed to make sure that a normal coating defect (area is max. ≈ 100 cm^2) is properly protected, and that external threats are monitored and under control". Consequently criteria's/statements had to be defined based on the standards that will be used. In our situation the following statements have been defined:

- The extent of the structure should be clearly defined (electrical isolation)
- All rectifiers (160) units must be remote monitored.
- The following criteria where defined;
    - CP-on potential must be between -1200 mV and -1600 mV (CSE - Cu/CuSO4) measured to remote earth.
    - In the vicinity (within 0,5 m) of (large) cathodes (groundings, concrete structures, piles, ect.) the CP-on potential must be more negative than -1000 mV and at pipe depth more negative than -1200 mV (CSE)

- IR-free potential shall be measured using of coupons.
- Coupons (2 at the time) are placed at a representative location and in the most critical areas.
- The complex structure must be electrically continuous.
- All test post must keep there functionality even in ‘stand-by’ situation.
- The annual measurements are used to make sure that the CP-system is functionally properly and at steady-state.
- The 3 year measurements are used to inspect and monitor critical areas and to measure the coupons.
- Every 3 years all the drawings are reviewed and a CIPS survey at location where the situation has been changed needs to be done.
- Every 6 years a CIPS survey is defined for the whole location.
- The results of the 3 and 6 year CIPS-survey are used to identify the critical areas.
- Critical areas have to be investigated to define and solve the cause.
- Every 6 years the measuring program and the ‘long term’ integrity report of the CP-system are made. In some cases the integrity report will be reviewed after the 3 year measurement/CIPS survey especially when changes have taken place that affected the CP-system.
- In the annual and 3 year program the data is checked to the adjusted set points (SAP).
- Test posts are placed at critical areas and are distributed over the location as a cathode connection to the structure. (Each test post has a CIPS-cable range of about 50 meters, this is necessary to keep overview when doing measurements)

Each statement will be (are) worked out in memorandum’s, in which the problems are summarized and the decision/statement/measurement/work instructions are declared. All this information will be placed in a CP integrity management document and adopted by the asset management and operations staff.

Selected test post positions

When using a selected test post program it is necessary to decide which test posts are needed to control the CP-system and its effectiveness. The following statement can be made:

- The above is only possible if there is knowledge about the electrical- scheme and properties of the CP system.
- The influence area from cathode sources should be known.
- Monitoring a CP-system is not the same definition as saying that ‘the whole pipeline’ has achieved CP according to the standards, but checking the ‘steady-state situation’.
- Using a selected test post program stringent borders and alarms must be defined, because the chance to detect problems is dependant upon the amount of measured locations.
- A selected test post program is only possible if the critical ‘parts’ like rectifiers are remote monitored.
- The standby test posts should keep there functionally. This is a stipulation. In the Gasunie case these test posts are maintained by the GIS people and there maintenance department/program.

Using advanced modelling software to optimize and validate the chosen criteria

When designing the new approach it was soon realized that a lot of parameters are affecting the CP-system, especially the different foundation techniques (cathodes) used which influences the 'soil' potential to remote earth. Therefore the fundamental choice to use modelling software was made.

The numerical simulations are performed using the CPMaster software package [1-2]. The software is based on the Finite Element Method (FEM) and is fully integrated in the 3D CAD package SolidWorks®. This offers the possibility to calculate potential and current density distributions on 3D structures with complex geometrical features in full detail.

The software solves the potential and current density distribution in the domains that surrounds the structure to be cathodically protected taking into account:

- CAD of the structure to be protected, including anodes and reference electrodes
- ohmic drop in the domain or domains
- anodic polarization
- cathodic polarization
- ICCP and SACP systems
- resistive effect of all cabling

The software calculates the IR-free potential values, current density and corrosion rates over the complete structure. Full details on the mathematics behind the model are presented in reference [1-2]. More information on the software is provided in reference [3].

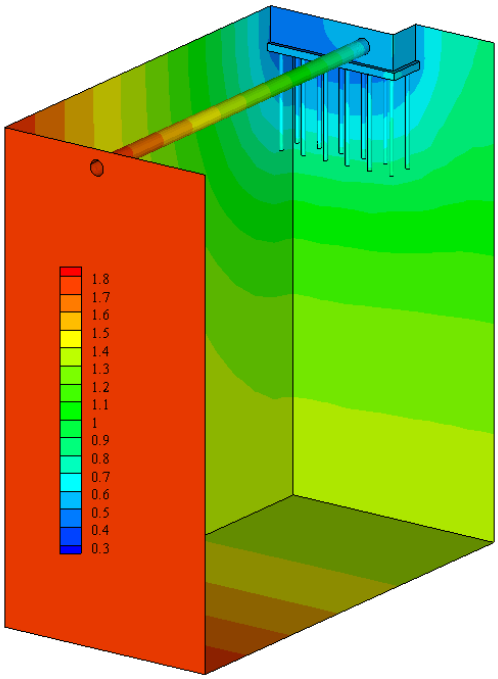
In order to get more insight on the basis principles a few configurations were defined and advanced modelling software used to get more inside information. The selected configurations where defined to look at two things: the influenced area and the possibility to reduce the influenced area. With this information the theoretical approach was defined and the critical areas could be visualized. The insight of the critical areas based on simulation results gives valuable information when it is 'impossible' to inspect the pipeline with traditional equipment. These areas are called 'blind spots' and need an other inspection methodology (guided waves, pigging, etc.).

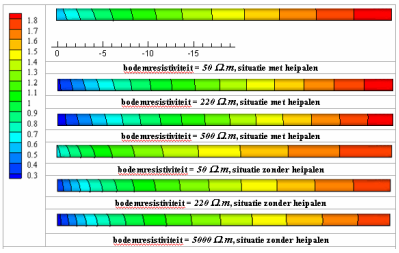
A few examples of the configurations that have been used in the modelling studies.

Example 1. Pipe that enters a steel reinforced concrete structure at a right angle.

This configuration gave use the possibility to;

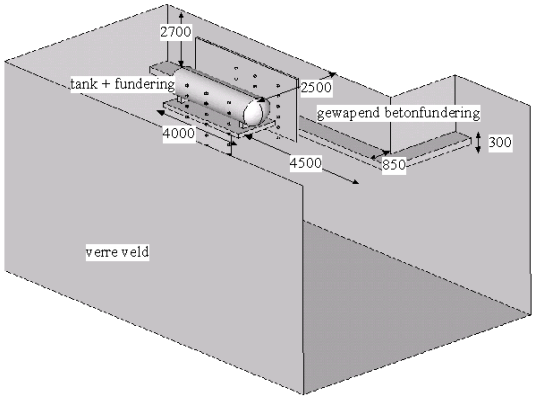
- Change the soil resistivity,
- Connect and disconnect the pipe c.q. concrete structure c.q. piles with each other,
- Define the borders of effective CP e.g. -850 mV and -1200 mV (Cu/CuSO4),
- Define the 'blind spot' areas for different situations,
- Visualise the different results and summarize the worst case situations (X-Y-Z).

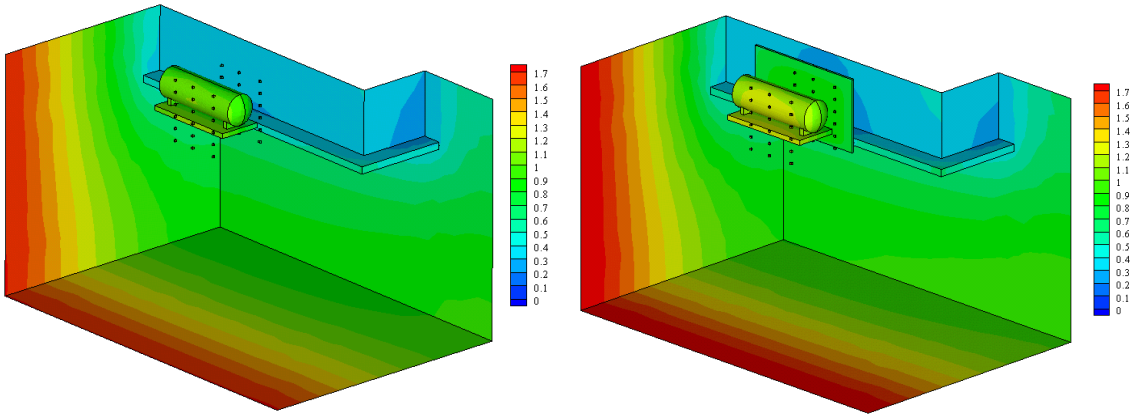




Example 2. Underground storage tank located in the ‘cathode-area’ of nearby steel reinforced concrete structure.
This configuration gave use the possibility to;

- Change the soil resistivity,
- Connect and disconnect the UG c.q. concrete structure with each other,
- Define the borders of effective CP e.g. -850 mV and -1200 mV (Cu/CuSO4),
- Define the ‘blind spot’ areas for different situations,
- Implementation a PVC screen (electrical isolation shield) and checking different sizes (lxh) to ‘coat/shield’ the structure and reduce the soil disturbance to acceptable levels,
- Visualise the different results and summarize the worst case situations.



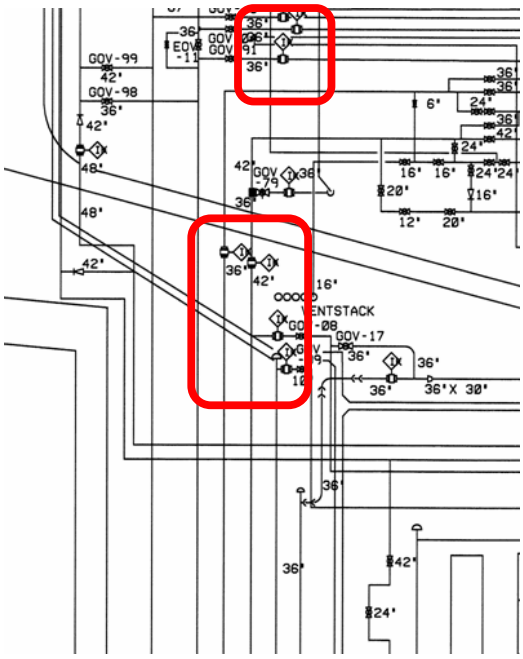


The results of the modeling where summarized and have been used at meetings to inform and convince the responsible department. This resulted in more fundamental attention when (re) designing buildings and foundations.

The backbone of the measuring program

Every six years the whole location is subject to a CIPS-measurement. These measurements are, like already mentioned, much more comprehensive than the annual (also the historical) and 3 year measurements. One of the big differences is that the ‘soil’- and pipe potential against remote earth are measured. The second big difference is that ‘polarisation coupons’ are used that are placed in an optimal location and in critical areas. In this way data are collected that can be used to analyse the CP-system and the suspected electrical parameters. If the outcome does not match it means that something is wrong and needs to be investigated.

Pilot project – Station 'A-403'



Define the extend of the 'structure'
According to the point of departure the extent of the structure should be clearly defined (electrical isolation). To do this a general project has been started to;

- Investigate where the extent of the structure at the moment is situated,
- If the existing electrical isolation is according to the company, local and national regulations,
- If the electrical isolation is not functional, what should be done to repair it,
- Make an inventory of the ideal situation.

The best place to install an electrical isolation is before moving on the stations borders. This way one does not have to take care of all kinds op appendages, that are connected to the pipe line, "on the wrong side' of de electrical isolation (isolation joint/flange).
The results of the inventory where that the electrical isolation wasn't 100% functional. After changing some devices the situation was acceptable to go on with the pilot project.

Check the CP-system layout
Before starting the CIPS measurements it is necessary to check the configuration of the CP-system. This check is primarily based on electrical continuity and makes sure that all pipes, buildings and earthing systems are connected. A secondary reason for this inspection is to make sure that the 'connections' between the various constructions are based on solid connections (bonds or mechanical connections) and not on accidentally connections (pipe lays on a earths structure).

Preparing for the CIPS-measurements
Unfortunately the Gasunie drawing system is not based on a geometrical lay-out which raised the question on how to measure and visualize the CIPS results. After comparing the manual method (data converted manually on the drawing) and the GPS method (data combined with GPS location plotted to Google/Top10) it was clear that the GPS method was much more efficient.

The used GPS module did have a rather big offset (3 m.) and bad connection near buildings, but the measuring result where fast (GPS location) and accurate enough to define the critical locations.
To do the measurements the Allegro [4] MX handheld data logger from American Innovations was used.

A CIPS-measurement can be done in various ways. Eventually our system is suitable to measure with the following configuration;

- Pipe-soil potentials (Cu/CuSO4) or
- soil –remote earth potentials (Cu/CuSO4)
- combination of both

The choice made, soil – remote earth potentials, was based on the fact of the awareness of DC-interference that reaches the station because of not properly functioning electrical isolation. In this way, when the pipe potential get more negative because the DC-drainage are draining current, the soil gradient will only get 'bigger' (worst case). If the pipe-soil configuration is used, the situation will get 'better' because the DC-current drained makes the PSP more negative. In this case the disturbed area would not be detected.

The CIPS measurements are done above al pipelines. In the areas where the potential-delta bigger is than 200 mV the distance between the measurement is reduced from

The rectifiers at the station are adjusted to a remote earth potential of -1600 mV CSE, which is the set point potential.
Additionally the following measurement where carried out during the CIPS-measurements.

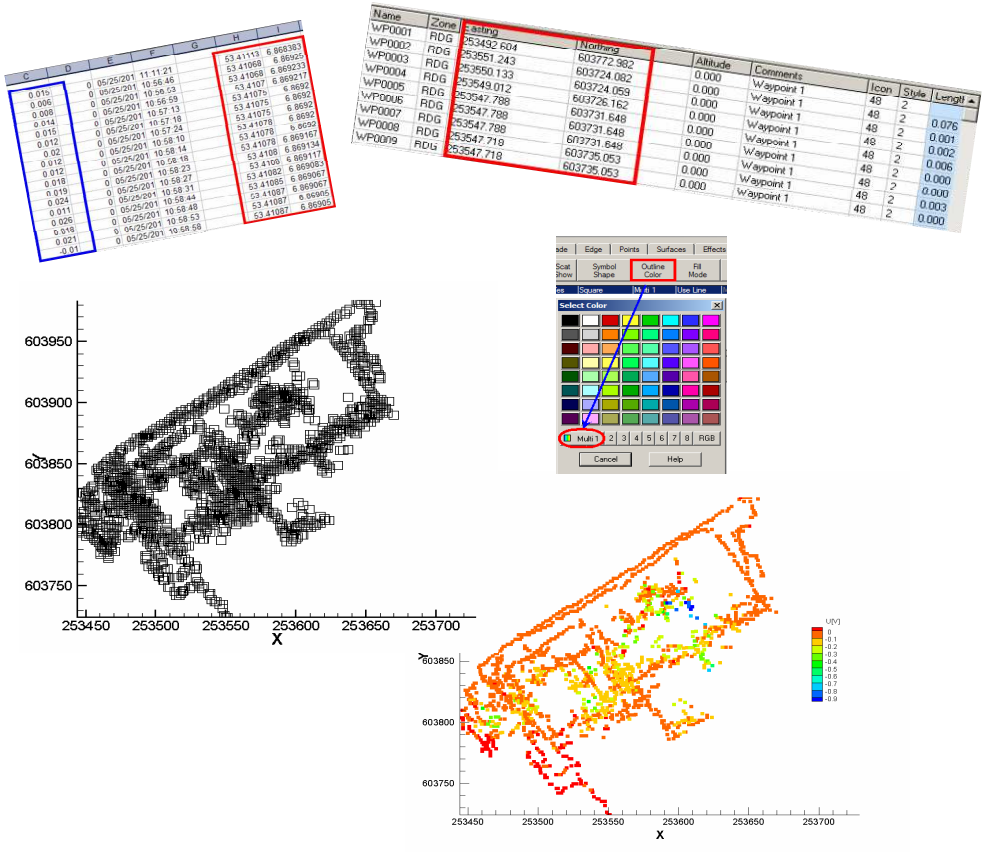
- Recorded pipe – remote earth potentials
- Pipe – soil potentials at al test post
- Current and Voltage demands from al rectifiers
- Delta-V measurements between test post
- Installation of one coupon location (2 coupons) at an ideal spot

Make a 'Blue print' of present situation

After de CIPS-measuring program has been carried out the result are checked and prepared for visualization reporting. During the preparation of the data some time was needed to find out the most convenient way to handle the data but eventually a very easy way to convert the data has been obtained. This procedure has been defined and proved to work: it only takes about 1 hour to get the final results!

The data converting procedure is as follows;

1. Fitting data to GPS coordinate where the GPS did not have contact with the satellites (checking the remarks).
2. Change GPS coordinate to "Dutch Grid"
3. Export data to Tecplot
4. Set voltage default (+200 mV till -400 mV to remote earth)
5. Make colour contour
6. Import to Google Earth or Top10.nl



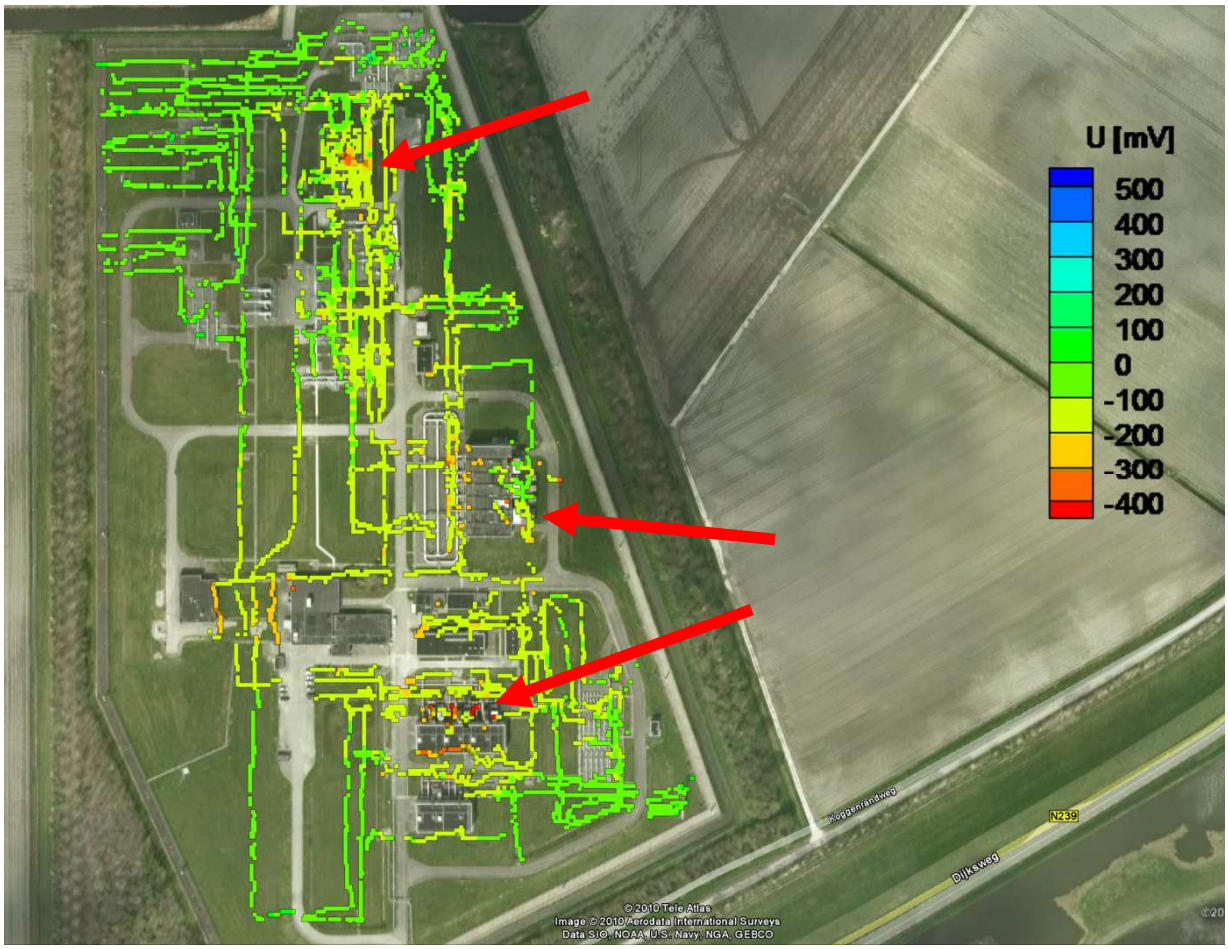
The following defaults settings (Legend) have been chosen;

- maximum soil potential – remote earth of +500 mV (anode location)
- minimum soil potential – remote earth of -400 mV (cathode area)

If everything seems OK then the results are checked against the potential criteria of -1600 mV > -1200 mV CSE, remote earth. This is the situation that gives information if the CP-system should work properly.

If the minimum ‘soil potential – remote earth’ criterion is reached the conclusion is that the CP-system may not be capable to apply sufficient CP to the pipeline c.q. structure. In this case the conclusion is “critical area” which needs to be investigated.

The following figure is the final result of the CIPS-measurement and the ‘blue print’ of the current situation. In this figure one can see a few areas that are “critical” (red arrows) according to the Gasunie criterion.



Investigation of critical areas

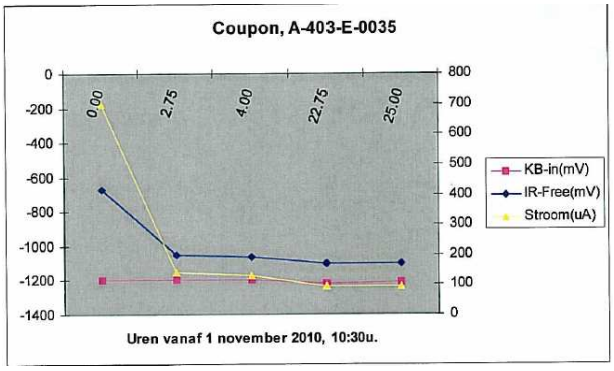
According to the report we have a few places with soil potential to remote earth that have a more negative shift than -400 mV. These areas need to be inspected. The inspection of the critical areas exits in the following approach.

1. Soil – remote earth potential measurements to find the ‘hot spot’ (worst area) above the pipeline/structure.
2. Pipe to soil potential (Cu/CuSO4) measured at ground level, -30 cm, -60 cm, -90 cm and -120 cm.
3. Define the cause of the potential shift. (grounding, structure, coatingdefect, etcetera).
4. Compare the measured data (critical area) to the ideal coupon location measurements.

5. Report the measurements, advise priority and the financially consequents to the responsible manager. This way it can be implemented in the maintenance work and upcoming projects/budgets.

In this report we will discus three location. 1= top arrow, 2 = middle arrow and 3=bottom arrow.

In preparation of the investigation we directly installed one ‘polarisation’ coupon in a ‘remote area’ (no potential shift in de soil). The coupon has acclimated before it was connected to the CP-system of the station. When connected we where able to stipulate the ‘spread resistant’ of the coupon. We also had done several measurements to accomplice the polarisation behaviour.



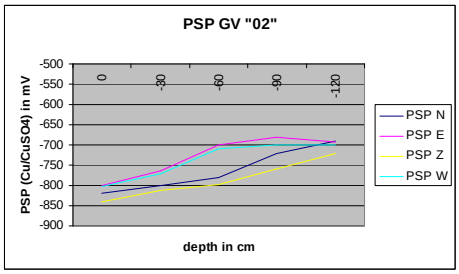
Results of investigation.

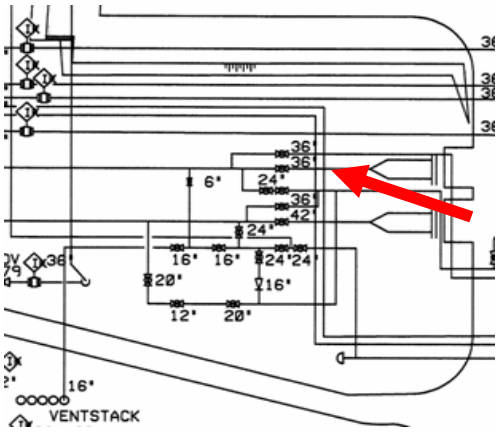
The first situation that we discus is the ‘top’ arrow. In this situation there are 6 valves in the diameter varied from 24”, 36” and 42”. The valve between the 1st en 3rd valve is the cause of the ‘hot spot’.

		N		
		-820		
W	-802	**GV "2"**	-800	E
		-840		
		Z		

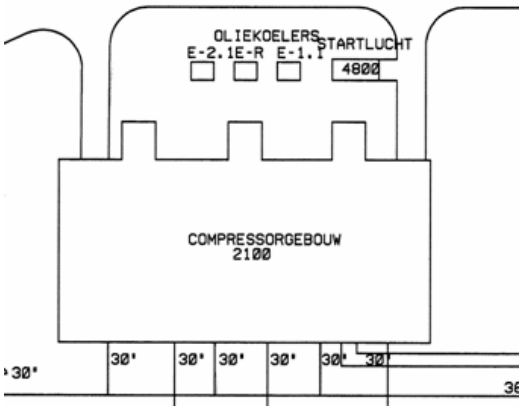
Around the valves measurements where done on different depth. These measurements showed us that the potential shift more positive going deeper. If we compare the results with the polarisation coupon the conclusion can be made that this is a critical spot and needs to be repaired.

The advice is given to remove the soil and inspect the reason of the high current demand. When that is done it will be possible to find a solution to solve the problem.





The second situation that we discus is the ‘middle’ arrow. In this situation there are niches where pipelines enter the building. Is this situation we also found PSP potentials up to -540 mV. If we compare the results with the polarisation coupon the conclusion can be made that this is a critical spot and needs to be repaired.
The advice is given to remove the soil and coat the complete concrete surface with electrical isolating coating. When the pipelines are free of soil the coating and the steel surface should be inspected on damages.



The last situation that we discus is the ‘bottom’ arrow. In this situation a pipeline was situated under the foundation according to the drawing. The measurements showed us that where was no CP protection (-410 mV).
When looking at the possibility to inspect the pipeline we found out that the pipeline wasn’t laid near to the reinforced foundation but it followed the pipeline bridge over the top op the building! Problem solved! ☺

Conclusion

This paper presented the principles and results of a new measurement philosophy for complex structures like compressor- export- M&R- RS stations and the visualisation of the results within Gasunie. In the development of this philosophy the use of advanced simulation software helped us to look fundamental at the chosen criteria.

The first step was to make defined statements which are based on the company standards, national and international standards. Knowing these statements it was able to define the selected test post program and the measuring philosophy. The measuring philosophy is based on a 6 year program.
The biggest different to the historical approach is that the whole station is measured according to the CIPS-methods every 6 years to get a Blue print of the present situation which is visualized. The selected test program results in annual measurements to prove 'steady-state' and every three year coupon measurements.

An attendant advantage is that "One figure says more that one page of text". With the knowledge that Gasunie gets from this approach it is capable to zoom in on a given (problem) area and conduct (if necessary) further investigations to find the problem.

References

[1] M. Purcar et al., "Numerical 3D Simulation of a CP system for a Buried Pipe Segment Surrounded by a Load Relieving U-shaped Vault", Corrosion 59 (2003), pp. 1019–1028.
[2] L. Bortels, A. Dorochenko, B. Van den Bossche, J. Deconinck, "3D BEM and FEM simulations applied to stray current interference problems. A unique coupling mechanism that takes the best of both methods", CORROSION—Vol. 63, No. 6.
[3] CPMasterV3.0 tutorial www.elsyca.com
[4] http://www.cath-tech.co.uk/allegro-field.html