Abstract

Historically offshore pipeline cathodic protection monitoring has relied on the use of portable survey techniques. This has typically relied on ROV assisted or surface deployed survey methods. These methods have been shown to have technical as well as economic shortcomings, this is particularly true of buried offshore pipelines where accuracy is always questionable. As more focus is being placed on offshore pipeline integrity, it was time for a new method to emerge. The technology discussed involves the retro-placement of permanent clamp-on monitors onto the pipeline which can measure pipeline to seawater potential as well as current density. The sensors can be interrogated locally using light powered subsea voltage readouts. Application of the technology can be either during pipeline construction, during installation of life extension CP systems, or during routine subsea pipeline interventions. The new method eliminates the need for long cables or expensive acoustic or modulated data transfer and provides all the information required to fully verify CP system performance, thus eliminating the need for expensive close-interval surveys. Some deployment case histories will be presented along with feasibility of application on deepwater pipelines and comparative economics.

1. Introduction – Limitations of Existing Survey Methods

There have been many survey methods developed in an attempt to accurately assess CP on existing offshore pipelines. Many of these have produced questionable results. A survey that produces questionable results has zero value. The writers company has been at the forefront of technology improvement in this area for over twenty years [3]. After having surveyed thousands of miles of offshore pipeline with divers, ROV’s and using towed survey arrays we have learned the following important lessons:

1. The accuracy of any offshore pipeline survey is only as good as the number of contact potentials measurements which are used to correct the potential profiles.
2. Towed surveys (without frequent re-calibration) produce data that is of little or no value, and can be misleading. It is for this reason that the writers company has discontinued its version of this method.
3. The accuracy of survey on buried pipelines, even with a ROV is questionable. This has to do with difficulties in obtaining the required number of calibration contacts, and the in-ability of the current technology to measure the very small field gradients that are present at or above the mudline.
4. The cost of offshore vessels and ROV support is a volatile variable, this can result in excessive cost to run a survey that yields questionable results.

It is for the aforementioned reasons that CIS surveys on offshore pipelines are virtually non-existent on the OCS of the Gulf of Mexico where virtually all the pipelines are buried in water depths less than 200 feet. Operators are reluctant to spend the money when they cannot take the results to the bank.

While we have all this skepticism about offshore pipeline survey, the industry is coming under increasing regulatory scrutiny, and asset integrity is becoming a higher priority with pipeline operators. There is however light at the end of the tunnel. Two new technologies could provide the answer to meaningful, cost effective monitoring of offshore pipeline CP.

BS Corrosion Technology, CEO/President - DEEPWATER CORROSION SERVICES, INC.
2. In-Line Tools

A new technology which is adapted from old well casing survey technology may well provide the answer for pipelines that are able to accept a smart pig. The tool which has been developed is in its early days but has shown real promise, and appears to be favorably priced versus using boats and ROV’s. The system (CPCM) Cathodic Protection Current Mapping [3] is presently undergoing offshore evaluation having produced good data on some onshore pipeline projects. Basically the system is a spaced caliper which continuously samples current flow in the pipeline imparted mainly by the cathodic protection system. This provides a level of information which can be interpreted to positively verify CP levels on the outside of the pipeline. It is truly a Close Interval Survey. There are of course limitations which will mean that every offshore pipeline is not a candidate for this method. Fig 1. shows the tool.

Even with this tool it is required to calibrate the current and current density reports against the resultant pipeline CP potential. The potential measurement made from outside the pipe and once available must either be sent inside the pipe to the in-line tool or recorded externally.

Figure 1: CPCM Inline Tool

3. Test Stations

3.1. Onshore Test Stations
For many years onshore pipeline monitoring relied on periodic measurement of the pipe to soil potential at scheduled test points spaced along the pipeline. This method evoked some concern following some pipeline failures when test point data indicated that all should be well. Several problems emerged that led to the development of presently used close interval survey technology for onshore pipelines. Some key problems identified were:
1. IR Errors – Since most onshore pipelines have impressed current systems operating across a wide variation of electrolyte resistivity, measured potentials included error which led the pipeline owner to think he was protected when often the actual CP levels were inadequate.

2. Induced AC problems from power transmission systems. These effects were not always detected on regular test station surveys.

3. Short range changes in soil conditions between test points caused “hot spots” where protection levels were inadequate. These changes resulted from imported backfill or pipelines routed through areas of contaminated soil.

4. Stray current interference with DC traction systems or other impressed current CP sources.

NONE of the aforementioned problems apply to offshore pipelines for the following reasons:

1. IR errors are minimal in the electrolyte based on the fact that resistivity values are at least an order of magnitude lower and are very homogenous as compared to most soil onshore values. Also it is much easier to place the reference electrode on the surface being evaluated.

2. Induced AC problems do not exist as there are no overhead power lines paralleling pipeline routes offshore. It has not shown to be a problem with subsea power lines.

3. The short range resistivity variables generally do not exist offshore.

4. Stray current is not an issue since there are no sources and galvanic anode systems cannot develop sufficient voltage to cause a stray current problem.

It would appear therefore that test points could serve a very useful function on offshore pipelines, and that going to a few spaced locations on a long pipeline could provide a meaningful and repeatable CP survey method. In addition, the calculation of potential attenuation along a pipeline offshore has been shown to be very reliable [4] even making somewhat of an appearance in the latest ISO Document [1]. It is therefore relatively easy to predict a “worst case scenario” of low potential between two fixed points at a known separation provided that there were no side taps or other major geometric upsets, between the two monitored points.

3.2. Offshore Test Stations (Times New Roman, 10, Bold, Left Aligned)

This is now possible due to the development of subsea solar powered systems, which leverage the light sources from underwater vehicles such as ROVs (Remotely Operated Vehicles) or AUVs (Autonomous Underwater Vehicles) to power up simple potential measurement displays [1].

Currently four iterations of the system are contemplated, two of which are already in service on offshore pipelines.

Type 4 is presently under construction.

Type 1: For bottom laid pipelines in deep water. (Fig. 2). Integration of a power module, a readout module and reference electrode onto a retrofittable clamp.

![Figure 2: Clamped Potential Measurement Station on deepwater flowline – Power module and readout units separate. Reference electrode on clamp.](image)
Type 2: For buried pipelines buoyed display. (Fig. 3)

Figure 3: Buoyed Test Station for Buried Pipelines – Instruments include reference electrodes and current density monitor clamped to the pipeline.

Type 3: For buried pipelines seabed pod display. (Fig. 4)

Figure 4: Over fishable seabed sled – for buried pipelines.

Type 4: For pipelines with above seabed valve or manifold covers. Panel can be integrated at a convenient location. (Fig. 5)

Figure 5: Preassembled panels designed to interface to existing hardware.

They all have the following common features.

a. An electro-mechanical contact to the pipeline that can be post-installed by diver or ROV. (Fig. 6)
b. Permanently mounted reference electrode(s) or current density sensors. (Electrodes are normally Zn. sw with an Ag/AgCl sw. calibrator electrode. (Fig. 7)

c. Short cable connection between instruments/reference ground and the voltage display.

d. Photovoltaic powered voltage display. (Fig. 8)

e. Visual station identification.

f. Back-Up stab point for conventional contact probe measurements. (Fig. 9)
4. Data Retrieval

One major advantage of the subsea readout is that it facilitates surveys of convenience, leveraging other subsea visits that are in support of production or other mandated inspection activity. The readouts and the actual sensors can be some distance apart, thus allowing the readouts to be placed at or near the location where the subsea visits will be focused.

The entire system is being readied for the inevitable AUV entry and subsequent domination of the offshore pipeline survey market. The currently available vehicles have everything that is required to perform these inspections (lights, video cameras, inertial positioning, sonar, shape recognition, surface GPS). Of course the high end AUV systems can operate from a fixed structure and do not require a support vessel, coupled with reduced operating crew and lower day rates, major cost savings are realized. In the meantime the system can still be interrogated with a low cost ROV or Divers [Fig. 10]

![Image of test stations for ROV or AUV intervention.]

5. Advantages / Pitfalls

The advantages of this approach are simple to define, and on the face of it make the system look too good to be true.

1. Reduced cost.
2. Improved data accuracy & repeatability.
3. Improved asset integrity.
4. Reduced and simplified data management / reporting.
5. Simplified logistics.

This is of course new technology that will no doubt encounter pitfalls in design and operation that will have to be solved. The individual aspects of the technology are however proven over many years in non-synergistic applications.

Offshore permanent reference electrodes are well proven [3].

The pipe clamp system has been used on hundreds of offshore CP retrofit systems where the connection reliability is critical. [4]

The area where we are learning, is the deployment of the solar panels subsea and the maintenance of light transparent materials and systems. Marine fouling only poses challenges in shallower (< 300 f.s.w / 100 M.s.w) depths. The acrylic lens and glass technology is well proven in deepwater with bubble levels (circular bulls-eye spirit levels) used on seabed skids and tree frames.

5. Applications

5.1. Deepwater Offshore Risers

The first pipeline application was on subsea isolation joints in SCR (Steel Catenary Riser) systems on offshore floating production systems. Initially these were retrofitted to provide CP potentials on either side of the joint (a regulated inspection) (Fig 11). On future systems they are being included as day-one attachments (Fig. 5).
Figure 11: Typical inspection record – It can be this simple – ROV video overlay confirms Date / Time / Depth / Position / Location

This application demonstrates perfectly the advantages of the system. The operator of the pipelines has equipment on a foreign structure. The owner has to perform ROV inspections of the SCR hangoff porches as part of his hull inspection requirement, the CP survey is leveraged, no people or equipment to coordinate.

5.2. Buried Offshore Loading Line

This line was tied into an existing subsea pipeline and run out to an offshore loading location. Both ends of the new section were buried and stabilized. The required CP measurements can now be obtained with a low cost ROV. Several over-fishable seabed structures were installed on the system to house the test stations. Monitoring instruments were attached to critical points on the subsea piping and cabled back to these structures.

(Figs 4,10)

Figure 4: Over fishable seabed sled – for buried pipelines.
6. What Next?

The viability of these systems depends on installing the permanent monitors, this can be leveraged against one or more activities which involve the required access with suitable equipment on the pipeline.

New construction is relatively simple and pre-installation of the systems is often possible, post installation retrofit may be a more cost effective option depending on the circumstances.

Scheduled inspections will allow instruments to be quickly and easily fitted to points of known interest.

Perhaps the best opportunity exists when the pipeline has a cathodic protection life extension system. A retrofitted CP system should be inspected periodically, the monitoring can be retrofitted at the anode retrofit sites to verify full protection of the pipeline and provide a few scheduled inspection points on the pipeline.

7. Summary and Conclusions

The slow, but hopefully not too late, realization of the strategic and economic importance of the world’s offshore pipeline infrastructure is leading to heightened regulatory awareness and elevated spending on asset integrity programs. External corrosion control verification must be at the very heart of this effort [9].

Recent history has shown costs of survey and inspection to be high in comparison to their value. The systems discussed in this paper will raise the inspection quality while significantly lowering its cost; this will encourage more diligence in monitoring the pervasive enemy, corrosion, leading directly to improved asset integrity assurance.

8. References