New methods for survey and monitoring of cathodic protection systems for offshore platforms and pipelines

Ali Zeinabi[1], Saeid Kashefi[2]

[1]M.Sc. Student of Marine Engineering , Persian Gulf University (PGU), Bushehr, Iran; azeinabi@mehr.pgu.ac.ir
[2]Ph.D Student of Chemical Engineering, Sharif University of Technology (SUT),Tehran, Iran; saeid_kshf@yahoo.com

Abstract
Corrosion has long been one of the biggest problems in the maritime, oil and gas industries. Corrosion not only cause high repair costs, but also to stop production at the time of repair and safety issues are the enormous damage it creates. Construction and operation of offshore production facilities is tremendously expensive. The consequences of an offshore corrosion failure can be devastating. For these reasons, cathodic protection has become a universally applied technique for mitigating corrosion on subsea pipeline and production facilities. Newly developed survey methods, combined with innovative design software and low cost hardware, are helping take the pain out of asset life extension for many operators worldwide. The purpose of this paper is to present an overview of subsea cathodic protection and corrosion control survey techniques in use today for monitoring and maintenance of offshore pipelines and platforms.

Keywords: pipelines, offshore platforms, corrosion control, cathodic protection, survey and monitoring

Introduction

Cathodic protection methods for offshore platforms and pipelines have not changed very much in the last 40 years[1]. During the design of an offshore pipeline many corrosion mitigations methods are considered. These decisions are all considered during the design of an offshore pipeline. Figure 1 shows a flow diagram for a corrosion integrity management plan for design and operation of an offshore pipeline[2].

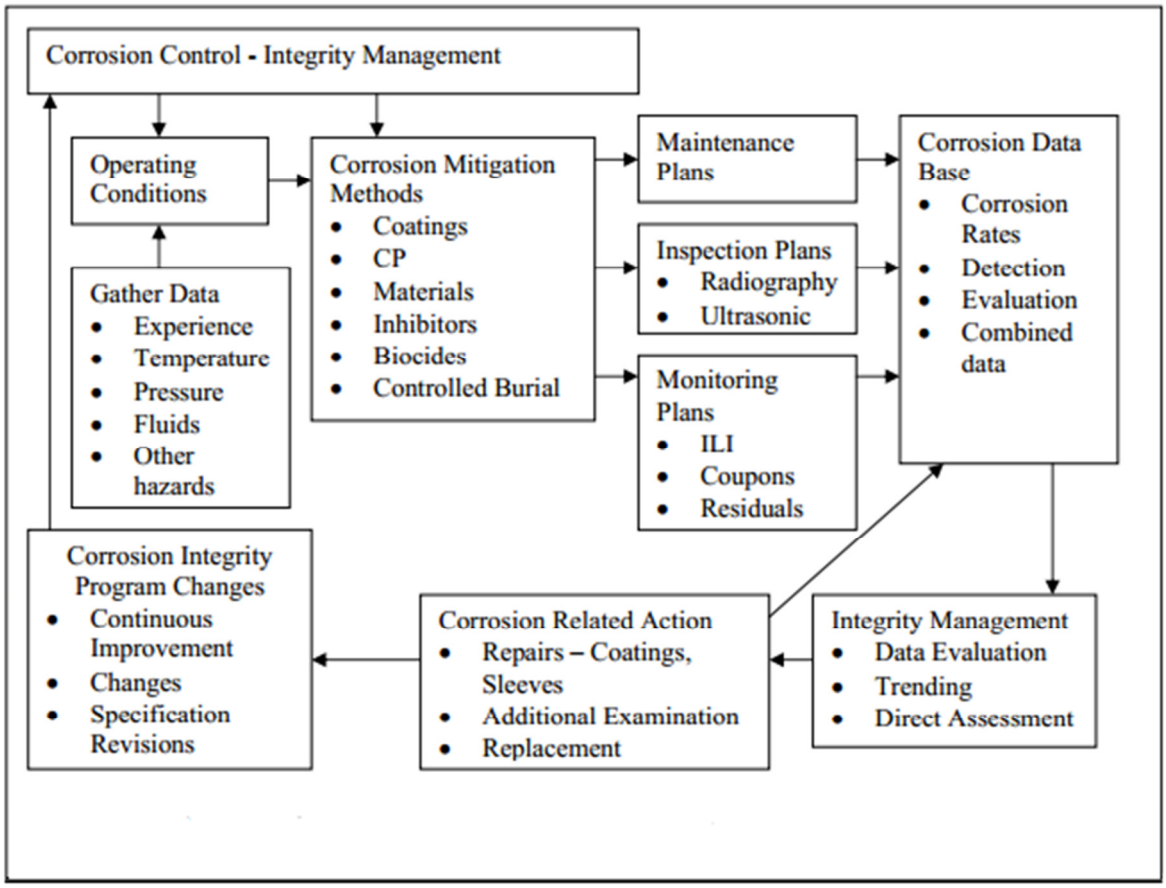

Figure 1. Development of a Corrosion Integrity Management Plan

The most widely accepted method of evaluating cathodic protection on pipelines and structures is through the use of potential measurements. Potential measurements on offshore pipelines have traditionally been recorded only at readily

accessible locations such as platform risers, wellheads, and test stations located near shore. Drivers can be used to take potential measurements on unburied pipelines, but this procedure is much too costly to use extensively.
Corrosion surveys and inspection of offshore platforms and pipelines are particularly important at this stage in development of our offshore petroleum resources. Many existing offshore platforms and pipelines are reaching the end of their cathodic protection system design lives.
Decisions must be made as to if and/or when additional cathodic protection must be retrofitted to prevent corrosion surveys and inspection plays a key role in this decision making process.
Probably the single most important development in the last several years with respect to offshore corrosion survey and inspection methods is the use of computers computerization of survey data acquisition, processing and management has provided the means for development of all the state of the art corrosion control techniques used today[3].

Monitoring and Inspection

As part of the corrosion designs for offshore pipelines corrosion monitoring and corrosion inspection plans are needed. These plans are intended to monitor the effectiveness of corrosion mitigation and to measure corrosion as the pipeline ages.
Monitoring consists for corrosion probes, coupons, and instrumentation. Normally resistance probes are used to measure the apparent corrosion rate. This data can be continuously monitored for day-to-day corrosion control.
Coupons are used to measure corrosion rates. Coupons are installed for a set time period. After exposure, the coupon is extracted, usually under full pressure, the coupon examined and weighed. This data is frequently used to determine the effectiveness of the inhibition and biocide used to control corrosion [2]. Cathodic protection monitoring is very important to an offshore platforms and pipelines. Cathodic protection monitoring should include a potential survey and current drain surveys. These surveys provide information about the condition of the cathodic protection system, as well as, information about the coating performance and the coating breakdown. Non-destructive examination methods such as radiography, ultrasonic survey, acoustic emission or other similar technique are frequently used to measure the remaining pipeline wall thickness. Where accessible the remaining wall thickness can be directly measured by ultrasonic surveys or radiographic surveys.
Unfortunately, at present in our country, most of the installed cathodic protection systems designed based on longevity has not worked, often in a shorter time than the above time, exposure with defect and the trouble.
There are several basic techniques for Monitoring and maintenance of cathodic protection systems for offshore platforms and pipelines,. The methods used depend on the employer's needs, some of the structural physical conditions and environmental conditions. this paper is to present an overview of subsea cathodic protection and corrosion control survey techniques in use today for monitoring and maintenance of offshore pipelines and platforms.

ROV Survey

The Cathodic Protection (CP PRO/R) system (figure 2) has been developed by UMG as a highly accurate and reliable method of gathering cathodic protection survey data[7]. ROV's are generally used for the detailed potential survey and visual inspections, followed by drivers for marine growth removal, cleaning, NDT and debris removal. A number of methods can be used to obtain information on the condition of a pipeline's cathodic protection system during an ROV based pipeline inspection. There are four different methods that are used for ROV based pipeline survey that are used and generally accepted in the industry.

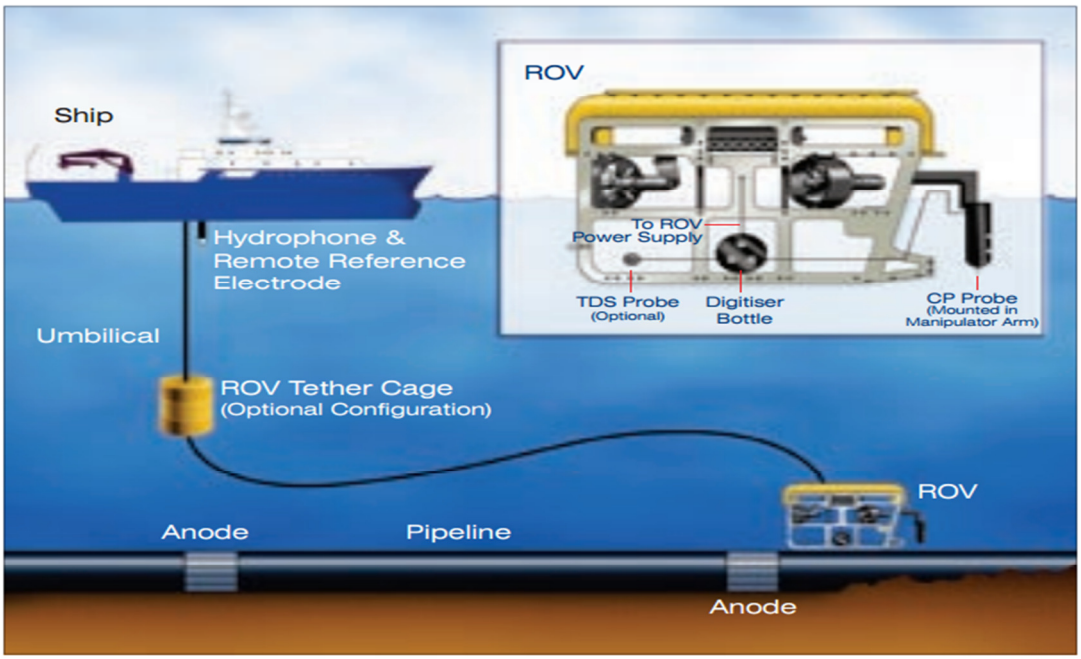

Figure 2. Operational Arrangement ROV Surveys

Depending on the level and detail of information required detail any one or more of the four methods described below may be applicable[6].

- Proximity half cell
- Single point contact systems (spot CP)
- Single point contact with continues CP (Cell to Cell Method)
- Single point contact with continues CP & Field Gradient

A major advantage is that it does not require continuous contact with the pipeline, relying instead on the 'remote' electrode technique between direct contacts.

Some of its features are[7]:

- Highly detailed results, accurate to within ±2mV.
- Locates and measures the magnitude of the current flow
- Calculation of anode current output and life predictions
- Compiled with video/ bathymetric survey data providing full picture of pipeline status.

Cathodic Protection (CP) Snake Survey

The CP Snake is dragged directly on the sea floor and has special systems on-board to indicate when pipe is crossed. The survey pattern is made with lateral passes, at as close to 90 degrees as possible - no trailing wire is needed. If conducted correctly, the CP Snake passes laterally over the pipeline.

Some of its features are[8]:

- Proximity of Reference Electrode to Pipeline : Electrodes are on bottom and directly over pipeline when data is logged.
- Survey Progress : Designed lateral passes across line at intervals
- Costs equivalent to trailing wire type surveys.
- Electrode is a close as physically possible to the pipeline under survey.
- Additional internal instrumentation confirms pipeline has been crossed.
- No copper wire discarded into the ocean, no stoppages due to wire breaks.
- If pipe location isn't verified, data are not reported.

Towed Fish/Trailing Wire Platform and Pipeline Survey

Cathodic Protection Survey System (CPS/TF-TW) measures pipeline potential using a towed fish incorporating a silver/silver chloride reference cell, maintained close to the pipeline, and a trailing-wire connected to the pipeline riser at the platform. Figure 3 shows the normal operation arrangement of the equipment during a survey. The key-measuring device is the silver/silver chloride reference cell, which is mounted on the carrier system (towed fish). During the survey the fish is towed directly behind the vessel, as near to the pipeline and seabed as practical, whilst the wire, attached to the riser to complete the circuit, is paid out[4].

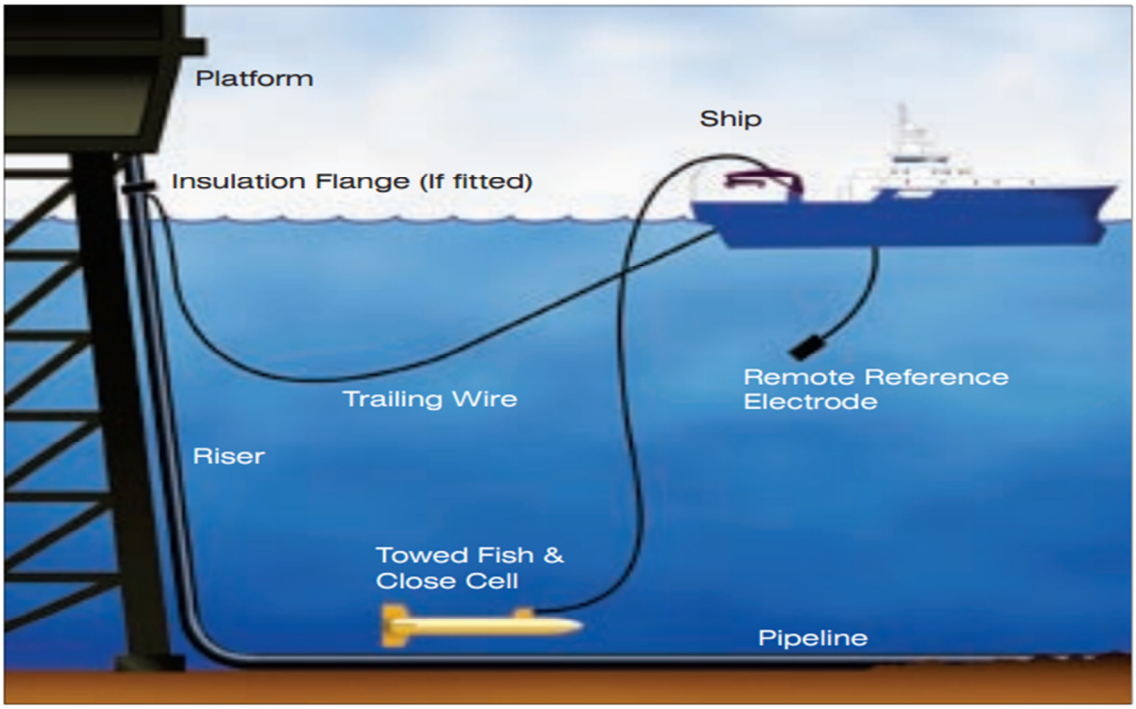

Figure 3. Operational Arrangement Towed Fish/Trailing Wire Pipeline Surveys

This survey is probably the most widely used method for monitoring cathodic protection levels along offshore pipelines.A silver/silver chloride reference electrode is towed above the pipeline from a vessel while maintaining the test connection. The pipe-to-electrolyte (P/E) potential is measured and recorded on board with a computerized data acquisition system. The potential is displayed on video terminal and plotted on a graphics printer (figure3).
The trailing wire system is a fast and convenient method of undertaking cathodic protection surveys on buried pipelines, where ROV methods are not practical or cost effective. It is ideally suited to infield pipelines up to 40km in length. Beyond this distance, operational difficulties and increased inherent inaccuracies can make the method ineffective. The system has the following advantages: [4,5]

- Indicates the effectiveness of cathodic protection.
- Allows rapid rate of survey.
- Relatively low cost,when compared to submersible or diver assisted surveys
- Simplicity of theory and operation
- The only technique which can be used economically on buried pipelines

The primary disadvantage is lack of sensitivity to minor anomalies such as individual anode bracelets, small coating defects, and poorly insulated field joints.

Hybrid ROV/Trailing Wire Survey

This is dual survey method which combines the best features of the ROV and Trailing Wire techniques. It has been developed in response to the requirements of major operators who need highly accurate measurements of the status of corrosion protection systems on covered pipelines in the area immediately surrounding platforms (see figure 4).
Some of its features are[7]:

- Ideal for surveying 'rock dumped' pipelines and other specialized in-field requirements.
- Field joints, anodes, flanges and areas of bare metal can be clearly identified.
- Contact readings can be made which is impossible with the conventional trailing wire technique

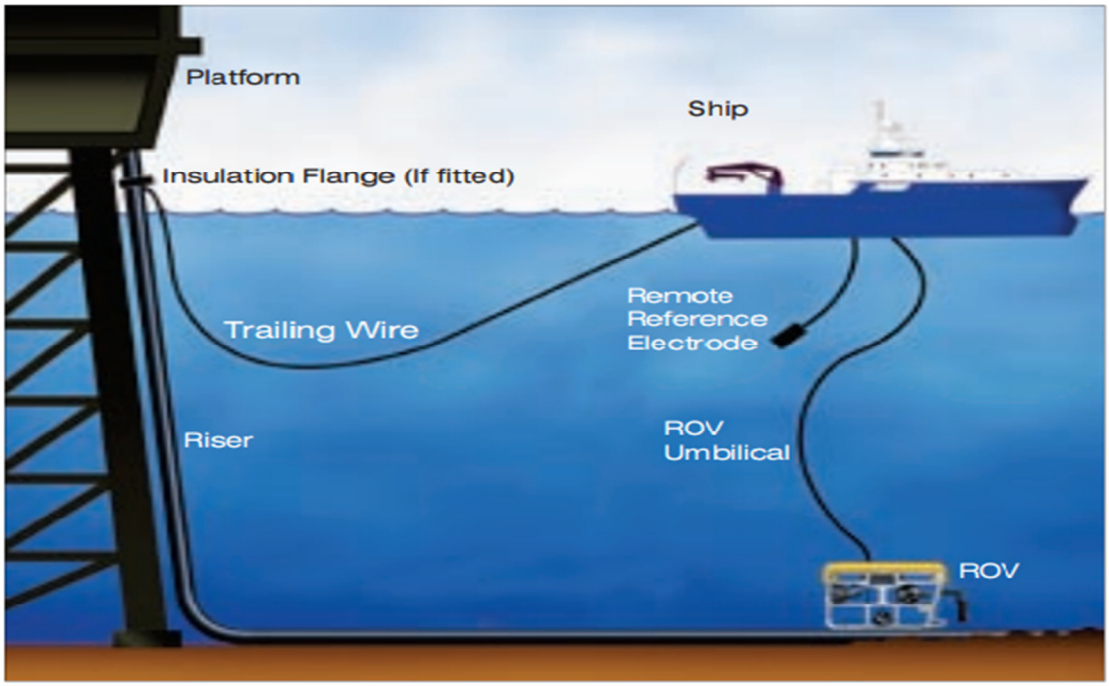

Figure 4. Operational Arrangement Hybrid ROV/Trailing Wire Surveys

Trailing Wire Landfall/Outfall Survey

This survey technique has been developed from the trailing wire method to enable in-shore surveys to be carried out more efficiently. It is designed for surveying cathodic protection systems on offshore pipelines leading to landfall and sewerage outfalls. The CP PRO/L system is a quick and convenient method for surveying the levels of cathodic protection for buried pipelines where ROV surveys are not possible (figure 5).
Some of its features are[7]:

- Ideally suited to pipelines up to 10km in length.
- Longer pipelines up to 40km can be surveyed by trailing wire or 'cell to cell' methods.
- Provides detailed illustration of potential trends along pipeline.

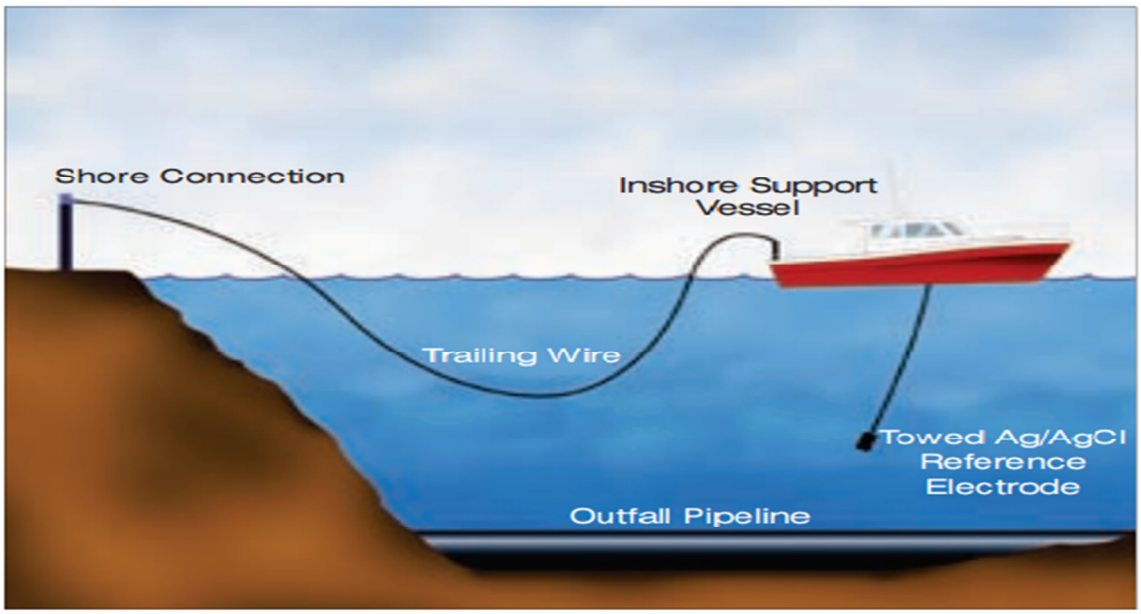

Figure 5. Operational Arrangement Trailing Wire Landfall/Outfall Surveys

Electric Field Gradient Survey

Electric field gradient (E.F.G) measurements are usually made in conjunction with potential measurements obtamed using an R.O.V.E.P.G. measurements are made by measuring the potential of two electrodes placed at a known distance apart in a plane perpendicular the pipeline. This is typically accomplished by mounting two or more electrodes on a submersible, aligned so that they are normal to the pipeline, as the ROV proceeds along the pipeline.

The electrodes may be spaced from a few inches apart to over two feet apart depending on the equipment.one operator uses a rotating "T sensor" with two electrodes to measured EFG The sensor is rotated to eliminate errors caused by electrode potential drift over the course of a survey. The operator claims precision of up to 1 micro-volt/cm using this technique.

Some of its features are[3,5]:

- EFG measurements are used to defect changes in current density and direction at all points along a pipeline.
- EFG provides data useful for estimation of current densities associated with anodes (current output) and coating holidays.
- EFG measurements are extremely useful for determining location and relative severity of coating holidays, and for locating dysfunctional anodes.

Drop Line Platform Survey

The most commonly used method for monitoring cathodic protection levels on offshore platform jackets is to lower a weighted Ag/AgCl reference electrode from the platform deck and record structure-to-electrolyte potential values at uniform intervals from the water surface to the sea floor.

This procedure is generally repeated at several representative locations on the platform jacket. Electrical connection to the structure is made above the water line. The electrical connection should be made to a welded structural member and should not be in the vicinity of welding activity.

Some of its features are[3,5]:

- The chief advantage : Simplicity and low cost
- The primary disadvantage: lack of ability to control reference electrode position relative to the structure.

Guy Line Platform Survey

The guy line platform survey employs a tensioned guy wire which runs from the sea floor to the water surface inside the platform jacket. A reference electrode is attached to the guy wire and lowered to the bottom while potential measurements are taken at selected intervals.

Some of its features are[3,5]:

- The chief advantage: Potential measurements are recorded at the same location during each cathodic protection survey.
- The primary disadvantage: the reference electrode cannot be placed at specific locations, such as nodes or anodes.

Platform EFG/Current Density survey

Several major operators, particularly in the North Sea, regularly employ EFG/Current Density measurements as a component of comprehensive ROV assisted jacket inspections. The EFG measurements are used to calculate cathode current densities and anode outputs.

This data is useful in diagnosing current distribution problem, estimating cathodic protection system life, and designing new and retrofit cathodic protection systems.

Some of its features are[3,5]:

- Method measurements are particularly useful for design of cathodic protection for deep water structures.
- EFG measurements are generally recorded at representative anodes, nodes, conductors and pile guides. The data is later used to calculate current densities and anode outputs.

Attenuation Modeling

Recently updated pipeline design codes (ISO, DNV, NACE) stress the importance of attenuation modeling as a design aid. Attenuation models predict the potential distribution along a pipeline at various distances from known cathodic protection (CP) current sources attached to the pipeline. And knowing potential distribution can be useful not just during pipeline design, but also during the life-cycle maintenance of the pipeline. Thus, it is fully acceptable to predict the worst-case potential at the mid-point between two known current source drain points[1]. This fact can be put to good use when a pipeline is retrofitted with intermittent anode sleds. Once we have measured the potential at the drain point (point of connection of the anode sled to the pipeline) and the mid-point pipeline potential between sleds and the current output (EFG) associated with each sled, we have a good baseline from which to develop a life-cycle maintenance/survey program. Interval surveys need only consist of drain point measurements; potential attenuation modeling can do the rest.

Conclusions

Cathodic protection is used to protect holidays in the coating. In order to avoid failures caused by corrosion on offshore platforms and pipelines, design and installation of cathodic protection systems on these structures is essential. Then the design and installation of cathodic protection systems to ensure them optimum and proper performance, must be used appropriate control and monitoring methods[9]. All of the survey methods have been used extensively and are constantly being modified and improved. The choice of the method, or a combination of methods, is dependent on a wide range of factors including water depth, water currents, location, depth of burial, size or length, cathodic protection system age, and cost. The requirements of each individual pipeline or platform will help dicate the method to be used. In general, the following guidelines are offered:

1. For completely buried pipelines, the Towed Fish/Trailing Wire Survey is the most reliable for obtaining the P/E potential profile.
2. For measurement of overall P/E potential and location of major problem areas the Towed Fish/Trailing Wire method is far and away the most economical, particularly for long pipelines.
3. To obtain detailed information concerning relative output of anodes, size and location flows, and integrity of field joint warps, electric field gradient (EFG) measurements are most effective.
4. ROV survey provide more detail for evaluating the effectiveness of cathodic protection systems. This method is the most economical and effective for deep water platforms.
5. For measurement of P/E potential pipelines up to 10km in length, the Trailing Wire Landfall/Outfall Survey is the best method to use.
6. Hybrid ROV/ Trailing Wire survey is the Ideal for surveying ‘rock dumped’ pipelines and other specialized in-field requirements.
7. For design of cathodic protection for deep water structures, the platform EFG/Current Density method measurements is the useful.
8. Computerized information management systems are a valuable tool for the inspection manager. The most advanced systems utilize CAD technology for graphic display of jacket components and inspection results.

References

[1] Britton, J. N.,‘‘ Improvements in offshore pipeline cathodic protection and anode life extension,’’ Technical paper, Deep water Corrosion Services, 2006.

[2] Klechka, E. W.,‘‘ Corrosion Protection for Offshore Pipelines’’, NIST Special Publication 1035, Coatings for Corrosion Protection, Biloxi, Mississippi, April 14-16, 2004.

[3] Weldon, C. P., Weldon, F. C., ‘‘Methods for Monitoring Effectiveness of Cathodic Protection on Offshore Pipelines,’’ paper presented at the middle east corrosion conference,Bahrain,May,1983.

[4] Pownall, I., ‘‘Trailing Wire Cathodic Protection (CP) Curvey Methodology ,’’ Unique Maritime Group FZC, the International Marine Contractors Association, UAE,Sharjah, 2003.

[5] Weldon, C. P., Wolfson, S. L., ‘‘The Sumersible Assisted Offshore CPLtmm Survey Method", paper presented at South Regional N.A.C.E.,Octobr,1982.

[6]Guidelines for Subsea Pipeline Cathodic Protection Survey, Technical Report,ISIS,2010.

[7] http:// www.corrintec.co.uk

[8] Britton, J. N.,‘‘The Deficiency in Data From Trailing-Wire/Tow-Fish Cathodic protection Surveys’’ Technical paper, Deep water Corrosion Services, 2000.

[9] Shahrabi, T., Badarkhani, O.,‘‘Corrosion protection systems for marine and port structures, methods of them controlling ’’ ICOPMAS, Tehran, Iran,1998.