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A computerized cathodic protection survey system for offshore platforms*

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The increasing use of remotely operated vehicles in the inspection of deep water offshore platforms, has led to the development of a new computerized cathodic protection survey system. This new system has been specifically designed to gather continuous potential and current density data without any significant increase in offshore inspection time. The system has been employed on a number of structures in the Gulf of Mexico throughout the 1985 offshore season. The survey technique demonstrates how computer technology has facilitated rapid collection of comprehensive cathodic protection system performance data in 300 ft (92 m) water depths.

Introduction

A NUMBER OF REMOTELY OPERATED VEHICLES (ROV) interfacable systems are available for pipeline surveys, but they have not been specifically designed to address the fixed offshore platform.[1] ROV platform surveys have typically been limited to measurement of structure/seawater potentials. This has been accomplished by the attachment of a simple silver/silver chloride reference electrode to the ROV. Data collection has mainly been manual at a number of point locations on the structure, with on-line potential values being displayed on the ROV's video monitor. This system has certain limitations:

1. Manual data collection tends to slow the survey progress.
2. Data are subject to human error.
3. The system is limited to logging of potential data only.
4. Data processing and reporting are cumbersome.
5. There are severe restrictions on the number of structural areas that may be economically investigated and maintained in a data base.

This new approach enables the operator to monitor the overall performance of a cathodic protection system with increased accuracy, as well as providing vital supplementary data: current density, anode current estimates, seawater resistivity, and seawater temperature, with a typical reduction in survey time and at minimal cost increase.

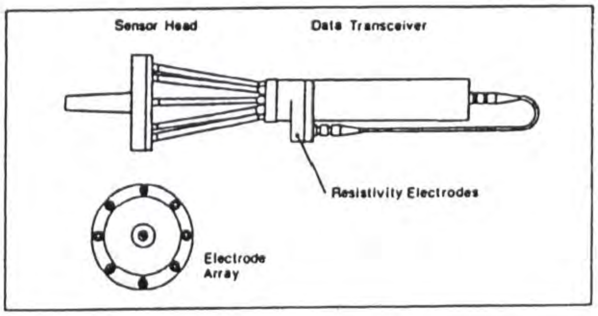

FIGURE 1 — ROV mounted equipment.

Subsea hardware

General

There are two basic components that constitute the subsea half of the system: the sensor head and the subsea data transceiver. For convenience, the two may be either bolted together or mounted discretely. This allows interfacing to a wide range of ROVs where weight distribution is critical.

Sensor head

The sensor head is comprised of a total of nine closely balanced, saturated, silver/silver chloride reference electrodes. Eight of these are arranged radially at 45 degree intervals, on a 20-cm circle. These are responsible for sensing the electric field gradient in the seawater. The remaining electrode is located on a "snout" that protrudes vertically from the center of the circular electrode array. This electrode is dedicated to sensing the structure/seawater potential.

Because these electrodes are called upon to provide accurate signals over a wide range of depth and temperature, it is essential that they be pressure compensated and contained in their own electrolyte of known constant chloride concentration.

The sensor head also houses the two stainless steel electrodes used to measure seawater resistivity. All the electrical connections within the head are secured within a pressure compensated oil chamber. Connection into the subsea data transceiver is achieved via a standard underwater connector.

The housing is constructed from a combination of thermoplastic materials. The general arrangement of the head unit is shown in Figure 1.

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Subsea data transceiver

The data transceiver comprises a pressure resistant housing inside of which is located: (1) A power supply circuit board; (2) a microprocessor control card; (3) a 16-channel analog/digital converter; (4) an electronic switching card with autoranging voltage measurement; (5) resistivity driver and measurement circuits; and (6) a temperature sensor and its measurement circuit.

Electrical power for the data transceiver is derived directly from the ROV. There are two standard underwater connectors on the outside of the housing; one connector links the data transceiver to the sensor head previously described. The second connector provides power to the unit and the communication link to the surface via the ROV's umbilical. Three conductors in the umbilical are used to establish the signal transfer path. Subsea to surface communications, as well as surface to subsea instructions, are accomplished via a shielded twisted pair. The third conductor is used to provide a structure reference ground to the subsea measurement circuits. Where spare umbilical conductors are limited, it is usually possible to utilize a twisted pair which is designed to link a sonar system. This facility normally is not required on a platform inspection.

Surface equipment

Five basic components are required topside, this equipment being conveniently located in the ROV control van; they are a frontend data interface unit, a scientific computer of standard manufacture, a compatible keyboard, a dual disk drive, and an ink jet printer. In addition, a compatible plotter is normally provided although this is only required to post process data.

The data interface unit provides the interface between the subsea transceiver and the topside computer. It links the incoming data stream via a standard RS232 serial interface to the computer. The same unit receives instructions from the computer and transmits them to the subsea data transceiver.

With the operating software loaded into its memory, the computer controls the entire system. The incoming data streams can be displayed on the screen, both numerically and, in the case of the potential data, graphically. All these data are regularly downloaded to a standard 5¼ in. (13 mm) floppy disk data storage unit. The keyboard is used to issue instructions to the computer throughout the progress of the survey. Measurement and display of resistivity and temperature data are available on demand. Another critical function performed by the computer is to accept and log the following information relevant to each section of the survey: (1) Dive number; (2) date; (3) platform name; (4) member diameter and designation; (5) run start and end positions; (6) distance—sensor/structure; (7) sensor and member orientations; and (8) anode length, width, height, and standoff.

These data need only to be updated and are convenient to enter from a displayed menu. Depth information is recorded against time at selectable depth increments.

The main incoming data stream, potentials, and four field gradients are each measured at a rate of 5/s. The exact time of each measurement is logged. This is true of all measurements. The entire survey is real-time based; synchronization of the computers chronometer with that of the ROV system allows accurate matching of the visual and numeric survey data.

The on-line printer allows instant potential profiles to be generated on demand at the end of each survey section, a feature greatly appreciated by the company corrosion engineer because it allows an immediate decision to be made as to whether a "closer look" is appropriate. Since the same computer is used both to control the survey and to post process data, it is possible to generate potential vs current density vs depth profiles on site; the only additional equipment required being a plotter.

The computer hardware equipment has demonstrated excellent offshore performance and is readily available worldwide. Being designed for scientific applications, it has the required speed to handle data and is readily interfaced to most offshore computer systems. A schematic arrangement of the entire system is shown in Figure 2.

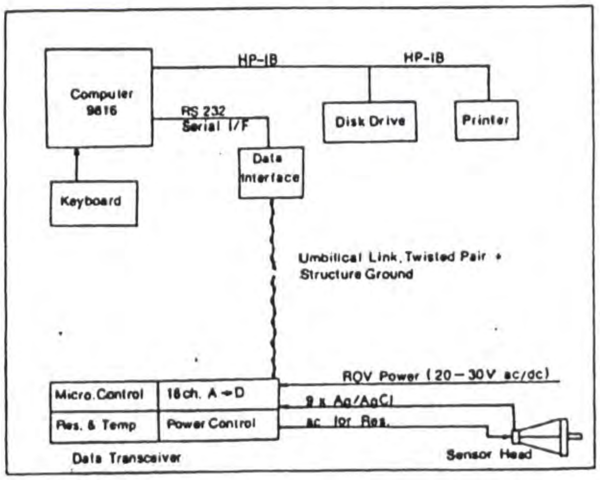

FIGURE 2 — Schematic system layout.

Survey capabilities

As previously mentioned, the overall capabilities of the survey method in its present configuration are continuous structure/seawater potential, continuous electric field gradient in four orientation, on demand seawater resistivity and on demand seawater temperature measurement. The latter two are required primarily for derivation of surface current density and correction of reference potentials, rather than being gathered as critical points of interest.

Potential measurements

Because great care has been taken to ensure the stability of the reference cells as well as to eliminate the major sources of signal contamination, the accuracy of the system is better than 1 mV. Electrolyte and structural IR losses can be considered to be negligible given the close cell to structure proximity and the conducting mass of a typical offshore platform.

Current density measurement

Various techniques have been described for the derivation of surface current density from field gradient measurements taken in the adjacent electrolyte.[1-3]

The method selected for this system most closely resembles that described for a pipeline survey system.[2] The method basically involves precise measurement of the voltage drop between two closely matched reference cells on a known spacing. If the distance from the first electrode and the cathode surface, the radius of the cathode under observation and the resistivity of the surround-electrolyte are known, then basic equations can be employed to derive the surface current density. A prerequisite to the validity of this approach is that the field sensing electrodes are perpendicular to the cathode under observation, hence, the arrangement of four pairs of electrodes described earlier. The operating software samples all four channels, selects the channel indicating the maximum field strength, compares the two adjacent pairs and curve fits to give a very close approximation of the true maximum field gradient without the necessity for time consuming alignment of the electrode pair. This feature is of particular significance when comparing platform geometries to those of a pipeline.

Unfortunately, this method is not totally without limitations. The method can only be legitimately applied where well defined cylindrical geometry exists. It cannot, therefore, give accurate data in complex geometry areas such as nodes, inside conductor bundles, or on members heavily laden with structural appurtenances. It is on the other hand valid for the outside surface of most legs and freespan members and can give valuable comparative data on conductor bundles.

Anode currents

The methodology described permits one to measure both gradient magnitude and direction. It can be applied to the measurement of the field gradients around an anode. If the anode dimensions are input, a valuable estimation of the anode current can be derived. The authors concede that this is more valuable as a comparative rather than an absolute quantitative value. It can be particularly relevant on structures in extremely deep water where general trends vs depth are desired.

Resistivity and temperature

Resistivity is measured by inducing an AC voltage between two electrodes of known geometry and resistance and noting the resulting current flow. Since the voltage is constant and the electrode spacing is also a known constant, basic formulas in the operating software produce the result. Temperature is measured directly from a temperature sensor on the inside of the aluminum housing of the data transceiver.

Survey procedure

Operating experience has shown that interfacing of the survey equipment, both subsea and topside, can be readily achieved in one day. There are certain precautions that must be observed. The sensor head should be mounted on an adjustable backet so the array can be moved quickly to conform to the orientation of the members to be surveyed during the course of any particular dive. Additionally, the sensor should be mounted so it is not susceptible to impact damage. This is typically achieved by the fitting of a protective guard around the head.

As with any survey technique, care should be taken to minimize spurious electric fields caused by the ROV itself. These fields emanate from two major sources, bimetallic couples and electrical system leakage. The former can normally be eliminated readily by spray painting or taping exposed metal surfaces in the general vicinity of the sensing head. The latter can present a greater problem, but it can be solved by a process of elimination. It is also necessary to ensure that the twisted pair selected for the communication link is free of noise.

Topside interfacing comprises the synchronization of the chronometer systems, interfacing of the potential channel into the ROV video writer system, and interfacing of depth information from the ROV system into the computer. These exercises can normally be performed with "off the shelf" interfaces.

As with any offshore inspection, a preliminary planning session will minimize offshore indecision and will provide the client with an opportunity to tell the survey crew exactly what it hopes to achieve from the investigation. This meeting should be used to define the scope and, where possible, the general order of events during the inspection. Structure drawings, safety procedures, communication paths, and equipment checks are other points that should be addressed.

Before heading offshore, a full wet operational check of the system should be performed at dockside. As with all offshore systems, 100% equipment redundancy is provided.

The precise time required on any given structure is obviously a function of the size of the structure and the scope of the inspection. Recent experience has shown that a 330 ft (100 m) 8-pile jacket in the Gulf of Mexico can be covered in 2½ days with approximately 75% of the members flown.

Typically, the corrosion survey will not comprise the entire inspection, and it can be completed in conjunction with the visual fly-by survey normally specified and then demobilized to allow other aspects of the inspection to proceed.

The actual logging of the data is achieved with minimal interruption of the fly-by. Logging is started or suspended with a single key stroke. On line calibration is simply achieved by periodically flying the ROV to a remote ground location so residual fields from the ROV can be noted and compensated.

Data processing and reporting

After gathering the data, it must be checked for errors before processing. Because of the many individual members on a platform, it is necessary to store the data for each one in a separate file. This file will contain all the relevant data for that member including all of the manually entered data. Once the validity of these data have been confirmed, the file is processed to produce a result disk. This disk contains the potential and current density vs depth and position data, a tabulation of anode potential and currents, and resistivity and temperature vs depth. It is this disk that generates the final composite profiles. The disk stores the data in a format so final presentation can assume an almost infinite variety of options.

Once a baseline survey has been performed, the data can be entered into any one of many data base management systems. The comprehensive nature of the data will allow more accurate planning of maintenance from both an economic and a technical standpoint. Subsequent survey results need only be reported to highlight areas of change.

Summary

The rapidly improving micro-computer systems coupled with an ever growing availability of reliable, versatile ROVs will no doubt lead to the evolution of more computerized inspection systems over the next 5 y. These revolutionary systems will pave the way eventually for confident re-evaluation of the presently used cathodic protection design criteria for deep water installations and will provide a reliable offshore survey for new approaches to subsea corrosion control that will inevitably emerge within the next decade.

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