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COMPUTER MODELLING USED IN THE OPERATION AND MAINTENANCE OF OFFSHORE PLATFORM CP SYSTEMS

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SUMMARY

This paper presents results obtained using a computer program to evaluate the performance of a cathodic protection system of a North Sea platform. The CP software model package has been developed using potential and current density readings obtained from existing offshore structures.

The data presented in this paper was obtained from a platform jacket protected by a hybrid CP system. The jacket showed good protection with areas of overprotection. This study examined the possibilities of avoiding overprotection and retrofitting sacrificial anodes to the pile sleeve area. A computer model was used to establish optimum parameters for the retrofit and for subsequent operation of the impressed current system. The main areas of application of this approach is as follows:

- Design of CP for offshore platforms
- CP trouble shooting and retrofitting of anodes
- Training simulator
- Diagnosis, support of CP surveys, CP maintenance and operation.

INTRODUCTION

For the past several years computer modelling of offshore cathodic protection (CP) systems has been a subject for research and development. Techniques and programs now exist as practical tools for engineers.

This paper presents examples and results from use of such a program in performance evaluation of a CP system of an existing platform. The program used is named the SEACORR/CP Modelling System and has been described elsewhere. (1)

Computer models and simulation of CP performance can be used for a number of different purposes:

* Design of CP for new and/or existing structures. The resultant anode distribution is entered on magnetic tape for use with in-house CAD System for automatic preparation of drawings. Complete models for large structures in deep water have already been prepared.

* Diagnosis and Maintenance support. The system offers unique features in simulation of existing CP systems. The computer model allows the changing of main parameters of a CP system e.g. current output of the whole impressed system or outputs of individual banks of impressed current anodes to study the response of the system to additional impressed and/or sacrificial anodes and their distribution, possible interference effects of adding new structural elements like a riser, effects of changes in the environment etc.

* Training simulator - CP engineers may acquire a sound knowledge of CP by using the program as a training simulator, to study alternative CP designs, to study polarisation and ageing processes and resultant CP and current density distributions.

THE HYBRID CP SYSTEM OF THE CLAYMORE JACKET

The Claymore jacket is protected in the main by an impressed current system. The original system has been earlier extensively modified. Since the modifications 4 impressed anode/risers have been taken out of service for structural reasons and replaced with sacrifical anodes. For operational and other structural reasons several other risers had to be taken out of service.

An engineering study indicated that a limited sacrificial anode retrofit was required on several structural members, conductors and bottle legs and pile sleeves. Specially designed anode support frames would have been required for the pile sleeves and bottle legs.

A computer modelling study was therefore undertaken to assess the impact on cathodic protection levels, potential distribution and the requirements for retrofitting with additional sacrificial anodes. The main affected areas were bottle legs A1 and B5, pile sleeves and conductors at -67m (-220 ft) to seabed.(Figure 1)

It is generally accepted that steel is protected against corrosion in seawater when when polarised to more negative potentials than -800 mV versus Ag/AgCl reference electrode. Where conditions exist that corrosion fatigue may occur in welded regions, overprotection with the possibility of hydrogen evolution would not be acceptable. Potentials down to -1100 mV versus Ag/AgCl/seawater are considered safe, for lower strength carbon and C-Mn steels (i.e. steels with yield strength below 550 MNm^{-2}).

Several recent potential surveys showed good protection against corrosion, e.g. all measured potentials were more negative than -960 mV versus Ag/AgCl reference electrode. CP operating at these potentials explains the high-quality calcareous deposits that have been formed on the jacket (confirmed by visual subsea inspection surveys). These considerably reduced the overall current demand. Low current density requirements owing to calcareous deposits have been previously reported elsewhere. (2,3)

However, the surveys have also shown areas of overprotection necessitating in further reduction of the impressed current outputs. The computer modelling study was undertaken to establish likely CP potential distributions corresponding to the the various retrofit scenarios as a function of four current density levels assumed from the impressed system.

TUNING OF THE COMPUTER MODEL

The potential and current density demand on steel is dependent on environmental factors (seawater flowrate, temperature, salinity and oxygen content) and previous cathodic charging history or "aging" of the surface.

The relationship between current (density) requirements and structure potentials are shown in Figure 2. The data was obtained from a survey of five complex North Sea platforms in service for 3-7 years [2]. The formation of calcareous deposits reduces the current density demand, allowing operating at lower current outputs from impressed anodes as shown below for the Claymore jacket.

In January 1985 potentials between sleeves on leg A1 were measured. The boundary conditions (potential - current density relation) in the computer simulation were calibrated to meet these potential levels.

The model shows a typical 100 mV drop between the inside and the outside of the leg (positions 3, 4 and 1,6 resp., Figures 3,4), which can also be seen in the measurements on leg A1. On the sleeves an approx 50 mV potential drop is observed. The continuity checks on top end of the pile sleeves of leg A1 measured on October 1985 confirm the more than 120 mV potential drop on sleeves around the leg.

Some small local potential variations have also been observed, which are not included in the computer model. This is due to the simplification of the surrounding geometry. However, the adjustment shows that the model is capable of predicting potentials with an accuracy better than 50 mV.

THREE IMPRESSED CURRENT SCENARIOS

The calibrated model is used to simulate different retrofits of sacrificial anodes. The required number of anodes was calculated for the following operation conditions:

Four different average current density (c.d.) levels were chosen:

- high output of impressed anodes, corresponding to:
  * 46 mA/m2
  * 59 mA/m2

- low output of impressed current anodes, corresponding to:
  * 30 mA/m2

- very low output (15 mA/m2)
  * over short time
  * over longer time

Very low output conditions were chosen to simulate the effects of a situation, where e.g. a number of impressed current anodes were to become inoperable.

Operation at High Output Current Densities

The model shows that there is no need for additional anodes operating at 46 mA/m2 overall operating current density as additional anodes affect the potential only marginally. At an average impressed current density of 30 mA/m2 on steel the output of the sacrificial anodes is very low. This effect is even more pronounced at an impressed current density of 59 mA/m2.

At potentials more negative than -1050 mV vs. Ag/AgCl the sacrificial anodes become cathodic i.e. the current changes direction, and their surface becomes passive. The need to study performance of sacrificial anodes in hybrid systems is quite evident.

To avoid overprotection of members and braces close to impressed current anodes their output density has to be reduced.

The calculation of a bottle leg with 59 mA/m2 average current density on steel shows potentials as negative as -1218 mV w.r.t. Ag/AgCl. This potential is on the hydrogen evolution part on the polarisation curves at potentials more negative than -1050 mV w.r.t. Ag/AgCl. Therefore the current demand is higher in the vicinity of impressed current anodes. Operation at negative potentials with an average overall jacket current density of 59 mA/m2 will therefore result in lower current densities at remote areas i.e. lower current at pile sleeves around bottle legs. Reducing the the current carefully will therefore reduce current density close to impressed current anodes, and cause more uniform distribution. In addition overprotection can be avoided.

Operation at Low Output Current Densities

Due to the high quality calcareous deposits on the steel an impressed CP operation corresponding to 30 mA/m2 on steel is possible.

The model predicts further reduction in overprotection, i.e. the most negative potential of -953 mV on the leg. However, the least negative potential on the rest of the structure is now to change to approximately -850 mV.This leaves a margin of 50 mV above the protection limit of -800 mV. Three additional anodes at the outside corner of the leg increase this reserve to 78 mV and 11 anodes 95 mV.

The platform CP system has in fact operated at about 25 mA/m2 for several months. There was a general increase in potential levels but still below those predicted by the model, i.e. the model was rather conservative. It is felt that the likely reasons are better than anticipated calcareous deposit and the fact that the model was done on a small part of the jacket and did not take into account historical data (potentials and current outputs) over the life of the platform.

Operation at Very Low Output Current Densities

The operation at an average current density of 15 mA/mA2 was considered as follows:

- a short time under this condition (months)
- long time effect (years)

Such low impressed anode output levels can be considered due to the present high quality of the calcareous deposit. A short period of operation at 15 mA/m2 will not remove or significantly reduce this deposit. The calculated potential profile shows marginal protection. In addition, destruction of the deposit through e.g storms can not be well-balanced and built up again although this is unlikely to occur at the depths presently considered.

Using typical North Sea polarisation data from reference (2) may result in underprotection even if an overall average current density from the impressed system of 15 mA/m2 is assumed. The model shows that eleven sacrificial anodes may not ensure protection under certain conditions. Two additional sacrificial anodes may not assure protection at 30 mA/m2.

The performance of the CP system and potential distribution would probably deteriorate under such conditions eventually. However, in view of the recent operating experience at 25 mA/m2 it may be that modelling a larger part of the jacket or whole jacket or alternatively further tuning of the model would be in place.

EXAMPLE FOR MANUAL USE OF CALCULATIONS.

Based on the computer calculations for leg A1, approximate potential levels for changed conditions can be estimated manually using the diagram in Figure 4. The horizontal axis shows the average current density on steel which can be achieved by operating all impressed current anodes at the same output. A loss of 2 or 3 anodes out of 12 in the bottom section is tolerable. The vertical axis shows the most positive potential on the leg with 11 sacrificial anodes. For comparison the most positive potentials without sacrificial anodes are also indicated in Figure 6. Additional failures of impressed current anodes or changes in settings of individual transformer rectifiers requires further investigation.

CONCLUSION

The computer analysis proved to be useful in optimising the platform CP system. The original scope of retrofitting with sacrificial anodes had not been necessary and significant cost saving was made.

The quality of the calcareous deposit on this structure is very good, resulting in lower than average current densities for platforms in this region. Operation of the CP system at an average current density of 30 mA/m2 with predicted most positive potentials of around -850 mV could still be too conservative and lower current density may be required. Current density levels as low as 15 mA/m2 would not have serious detrimental effect if run for shorter periods of time.

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CLAYMORE PLATFORM

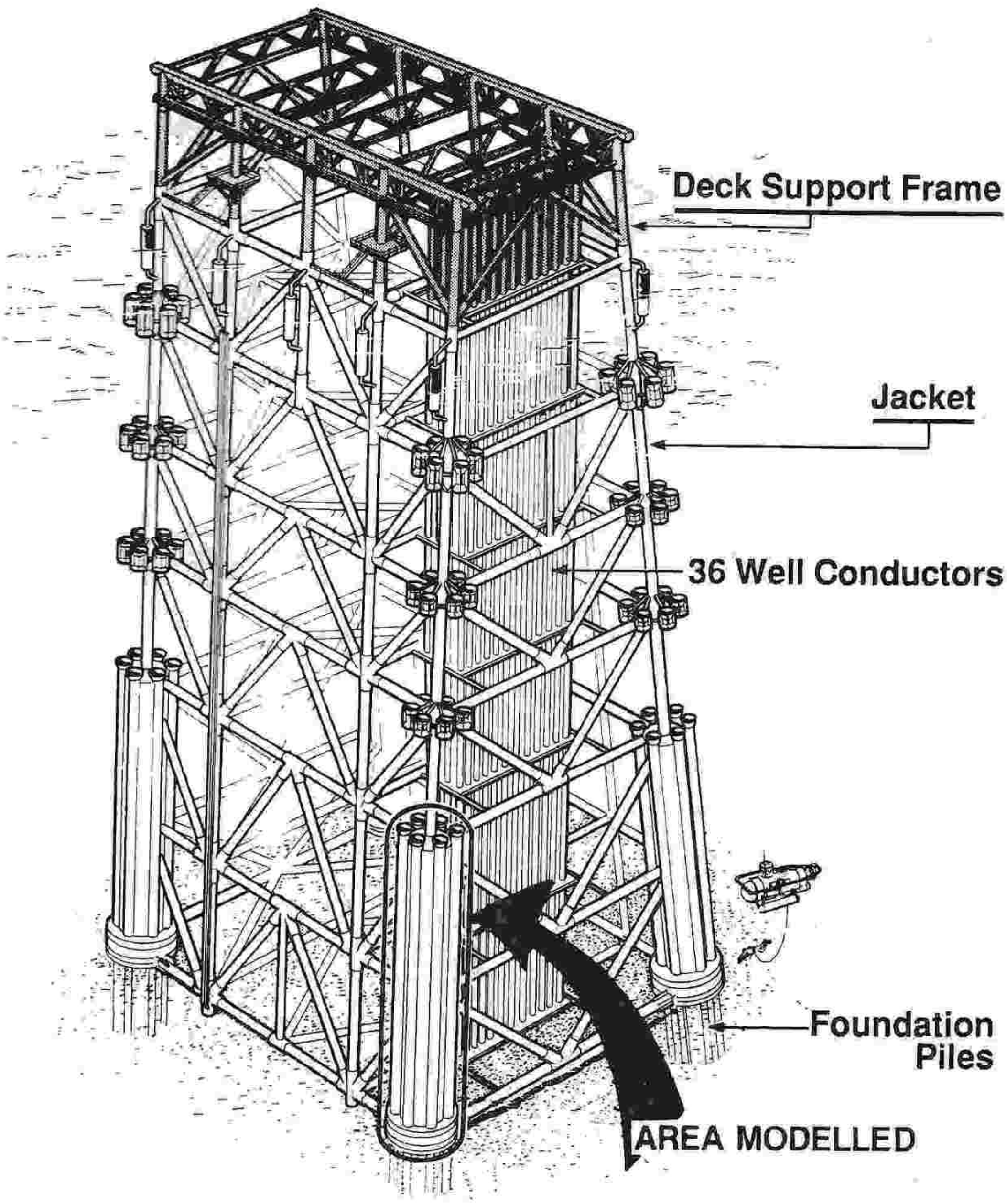

Fig 1: The CLAYMORE Steel Jacket with pile sleeve area chosen for the Computer Modelling

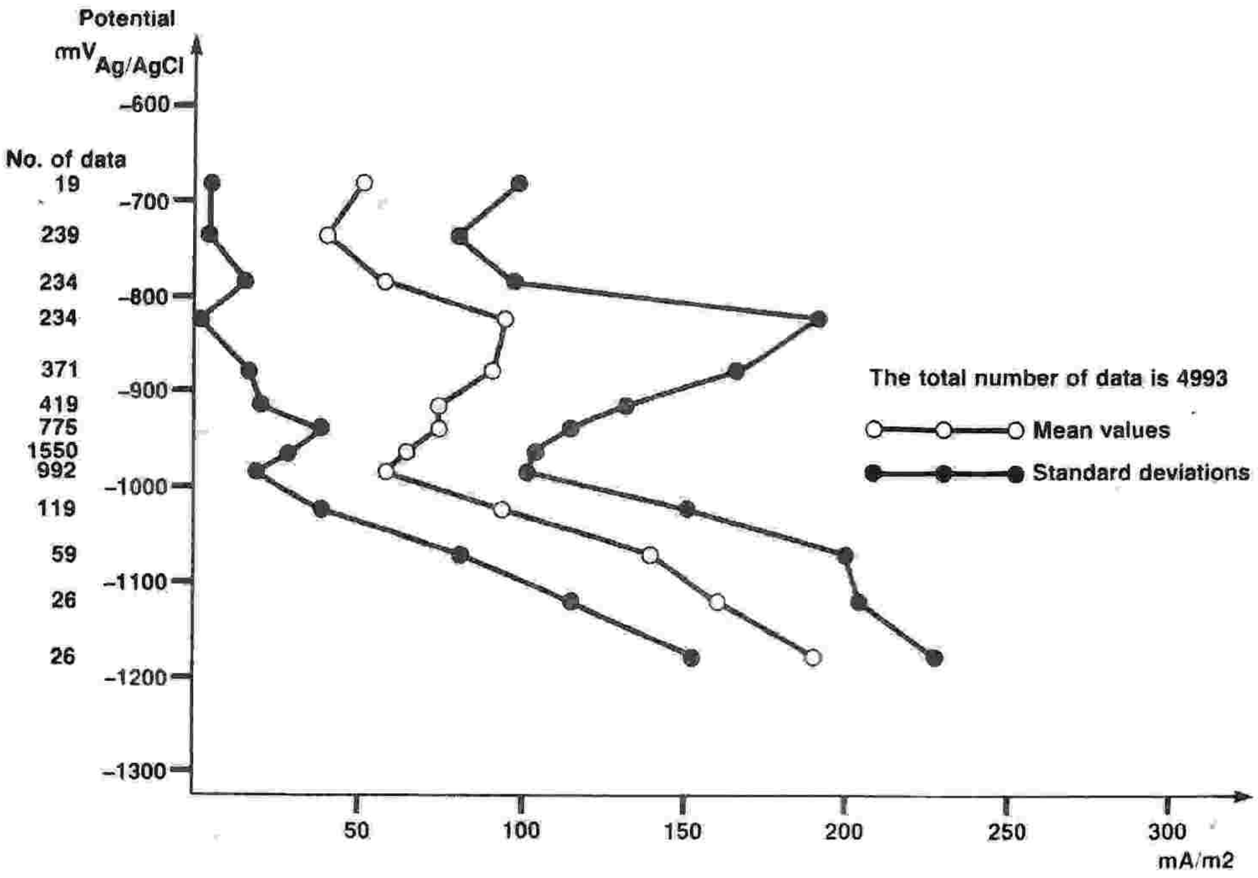

Fig 2: Polarization curve for steel based on data from 5 platforms in the North Sea Area.

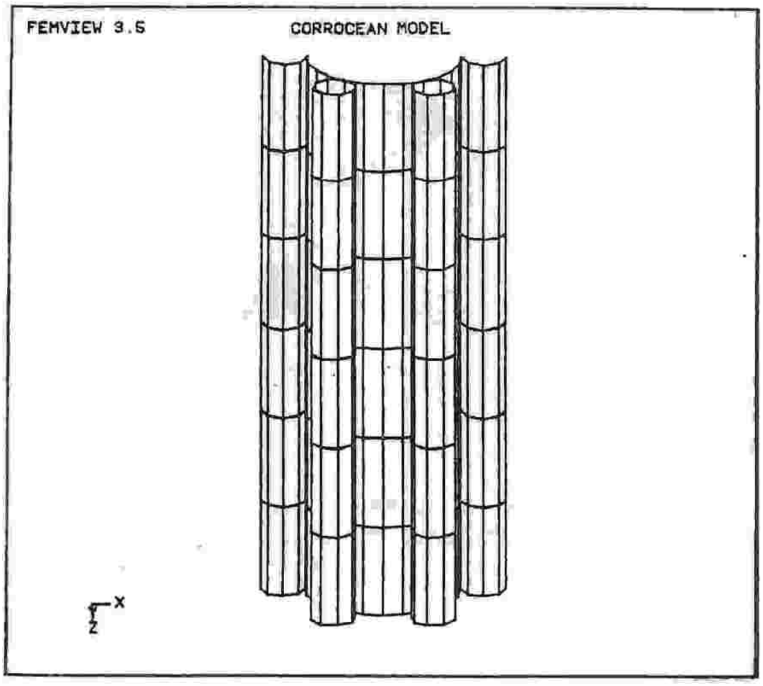

Figure 3 : Computer model of the pile sleeve area.

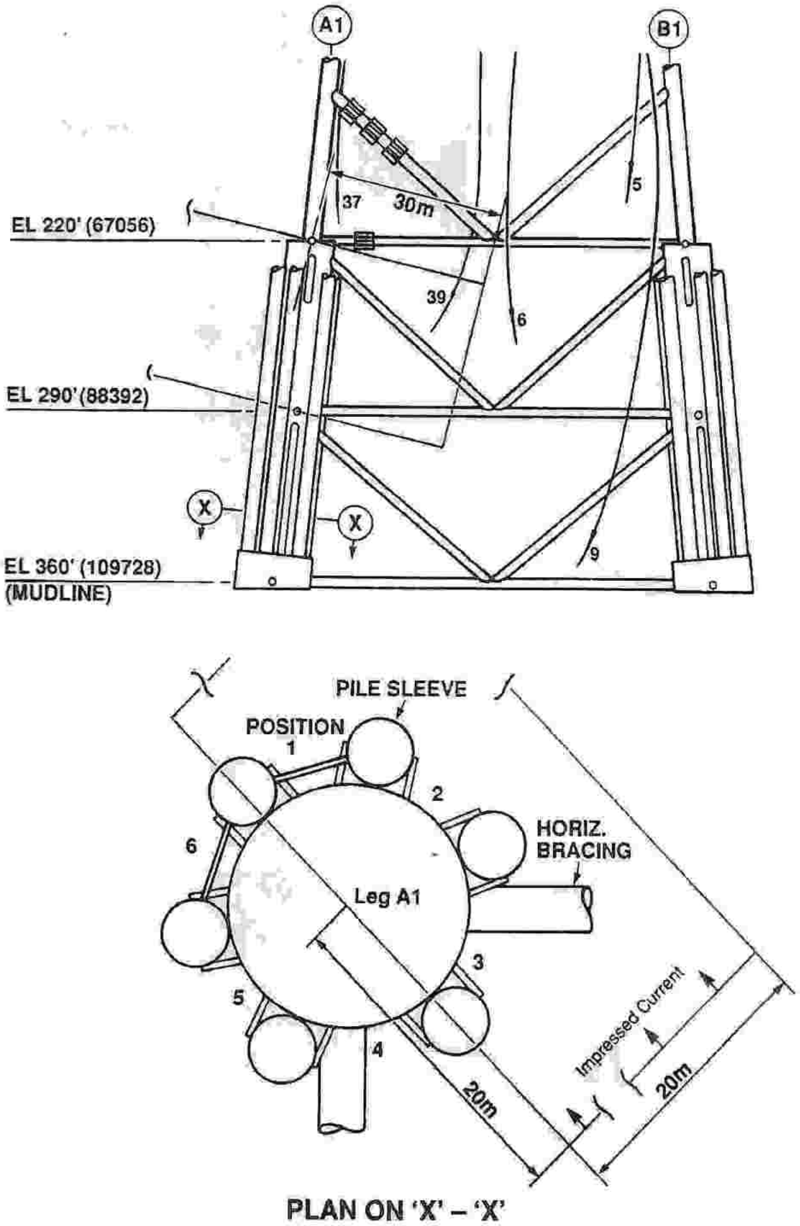

Figure 4:

The two-dimensional computer model covers position 1, 2 and 3. The three-dimensional model covers position 4, 5 and 6. Current i_A impressed from a distance of 20m for two-dimensional (30m for three-dimensional) model.