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PERFORMANCE OF IMPRESSED CURRENT SYSTEM OF CATHODIC PROTECTION IN SEAWATER: A CASE STUDY

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ABSTRACT: *In this paper, the impressed current system (platinum cadmium) was investigated in terms of capability to polarize structures submerged in seawater at Qua Iboe field Nigeria. Data for potentials were generated by the drop cell method with Ag/AgCl reference electrode and digital multi-meter and analyzed. These structure potentials were measured at various elevations of platform tagged top, middle and bottom from the deck at five different measuring locations labeled south, east, west and center of platform. It was observed that measured structure potentials increased from top to the bottom of seawater because of higher corrosion rate at the surface due to environmental factors coupled with the effects of IR (Voltage) drop with sea depth. The potential values obtained in most cases fell within –0.956V and –1.99V. The recommended range of potential values is – 850mV to – 950mV. Hence, the facilities are overprotected, though this is uneconomical, and leads to hydrogen embrittlement.*

KEYWORDS: Cathodic Potential, Impressed Current, Drop Cell, Seawater

INTRODUCTION

Impressed current cathodic protection (ICCP) systems consist of anodes connected to a direct current (DC) power source, often a transformer – rectifier connected to an alternating current (AC) power. In the absence of an AC supply, alternative power sources may be used, such as solar panels, wind power or gas-powered thermoelectric generators. The ICCP system has been commonly used because it provides remarkable protection against corrosion in all types of ships and offshore platforms, pipelines, ports, and steel piles, etc (Tashin and Yight, 2014).

Ameh and Ikpesene (2017) reported the cathodic protection design methodologies for impressed current using 0.5m diameter and 10000m length of x65 steel pipeline in onshore and 1.2m diameter and 12000 length of x42 steel pipeline in offshore. The impressed current design calculation showed 259150mA of current demand and voltage of 1127585mV required to adequately protect the x65 pipeline with external surface area of 86405m^2.

The current and voltage requirements were achievable by installing six transformer rectifiers with minimum direct output of 500 amperes and direct voltage output of 200 volts. The design for fuel pipeline network at Indonesian Naval base using impressed current cathodic protection was reported by Susilo et al (2017). The result showed that theoretical voltage of 33.759 (DC) and protection current of 6.6036A (DC) and 6.554A (DC) from pipeline specimen was required to cause a corrosion rate of 0.25 mpy.

After a cathodic protection system has been installed it should be checked periodically to ensure that the equipment is functioning properly and that the protected structure is being maintained at the required potential. (Milliams and Van Gelder, 1996).

It becomes essential therefore to have an effective monitoring system for the cathodic protection. The drop cell method has been developed as such a system and it has the function of monitoring the potential of the structure under protection; this is the prime criterion adopted in cathodic protection particularly to judge the efficacy of the system. (Britton and Tofield, 1988). The "drop cell" method for potential measurement uses a portable reference electrode usually silver/silver chloride (Ag/ Agcl) on a long wire. (Walker and Maddux, 1989).

The electrode is dipped from the platform at the desired number of elevations, and the potential is recorded on standard digital voltmeter topside, (from the deck). The structure connection is made to any welded component on the platform and lead wire connected to the negative terminal of the digital voltmeter while the reference electrode is connected to the positive terminal. (Walker and Maddux, 1989). The system therefore consists of permanent equipment, the meter that measures the potentials and the reference electrode that sense the potentials at various points on the structure. The silver chloride electrode has a great accuracy in constant seawater, it is highly stable but has to be made carefully, has to be protected from contamination, it is a comparatively sensitive electrode, it polarizes and has a high resistance. (Shier and Burstein, 1994).

As conditions which affect protection are subject to change with time records must be kept of structure potential values obtained from such potential measurement surveys for analysis after every survey, and where necessary corrective actions must be taken and fast too in order to restore normalcy. The required protection potential is fixed at –850mV or –950mV in the case of the presence of sulphate reducing bacteria. (Pearson, 1974).

EXPERIMENTAL PROCEDURES

The investigation was carried out offshore at a platform equipped with an impressed current system of cathodic protection. Weekly potential surveys were conducted on this platform for a period of six weeks. For the purpose of this investigation the following materials/equipment were used: copper cable (polytethylane – sheated copper conductor cable) of cross sectional area 3365mm^2 and resistance 532 micro-ohm per meter run; a silver-silver chloride (Ag/AgCl) reference electrode, a hand held battery – powered digital multimeter capable of measuring a maximum of 1000 volts (both ac and dc).

Structure potentials were measured at various elevations tagged top, middle, and bottom from deck at five different measuring points separated from each other by a distance of 50m – 100m and tagged North, South, East and Centre of platform. These potentials were obtained on the measuring digital multimeter as the reference electrode (Ag/AgCl) reference electrode) connected to the positive terminal of the multimeter was lowered to the different elevations, top, middle, bottom and contact made from the negative terminal of meter to protected structure by tack welding of the lead wire to the structure as shown in Figure 1.

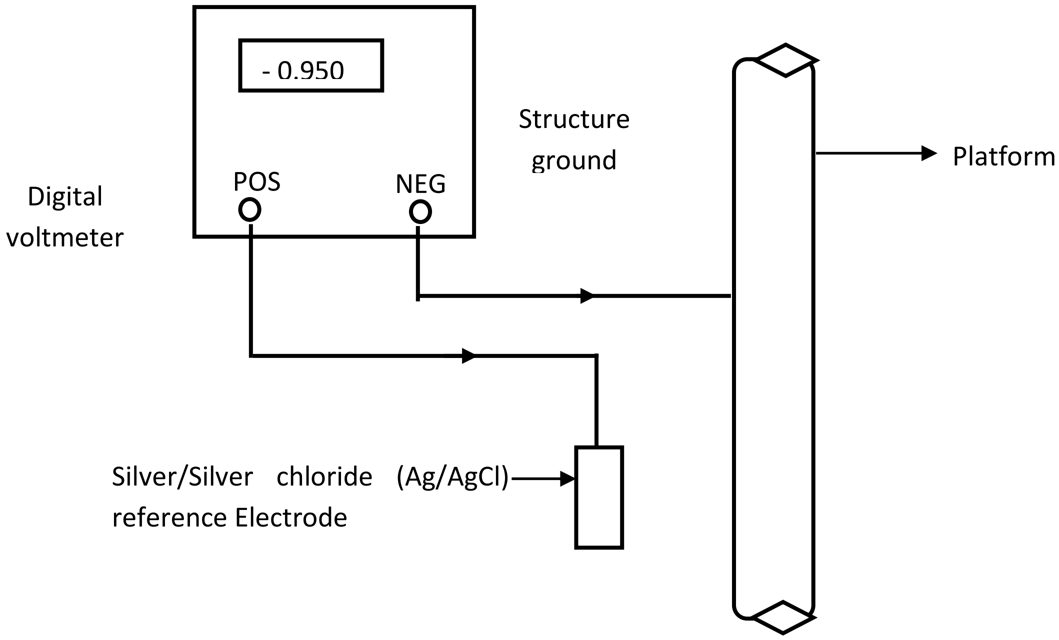

Fig. 1: Potential Measurement (Drop Cell Type)

RESULTS AND DISCUSSION

The result of the weekly potential surveys for the platform covering the period of six weeks under study from the five different measuring points of the platform tagged North, South, East, West and Centre are contained in Tables 1-5. Potential data included in the Tables were taken along the outside of jacket legs. Table 1 shows potential data for the platform during week one. The centre of platform gives higher negative potentials right through from top to bottom than the other locations.

Furthermore, all the recorded potentials at the locations are in excess of the potential range of 0.850V – 0.950V recommended in practice. It is to be noted that these potential values include IR (voltage) drops. IR drop is a drop in potential between the tip of the reference electrode and the structure (platform) owing to the ohmic resistance of the electrolyte (seawater) which is proportional to the current flow and is added to the measured potential. The increase in measured potential values due to IR drop normally amount to -10mV to -100mV in practice. (NACE, 1983).

Table 1: Potential Values (Volts) for the Platform Week 1

Location	North (of Platform)	South (of Platform)	East (of Platform)	West (of Platform)	Centre (of Platform)
Top	-1.037	-1.057	-1.048	-1.046	-1.077
Middle	-1.038	-1.059	-1.052	-1.048	-1.078
Bottom	-1.041	-1.060	-1.062	-1.049	-1.079

Table 2 shows potential data for the platform during week 2. It could be observed that as in the case of Table 1, the potentials recorded are quite in excess of the potential range some amount of IR (voltage) drop being part of the potentials obtained.

Table 2: Potential Values (Volts) for the Platform Week 2

Location	North (of Platform)	South (of Platform)	East (of Platform)	West (of Platform)	Centre (of Platform)
Top	-1.102	-1.127	-1.109	-1.105	-1.132
Middle	-1.104	-1.129	-1.111	-1.107	-1.134
Bottom	-1.106	-1.139	-1.112	-1.110	-1.158

In Table 3 the potential values for the platform during week 3 are presented. It could be observed in this case too, that all the potential values are quite in excess of the potential range stipulated in practice with the bottom depths of the platform especially for the centre of platform giving very high negative potentials. The reference electrode, it was observed, moved appreciable distances away from the surface of the structure due to serious waves leading to high IR drops particularly with the bottom end of center of platform. The value of IR drops is proportional to the distance between the reference electrode tip and the surface of the protected structure.

Table 3: Potential Values for the Platform Week 3

Location	North (of Platform)	South (of Platform)	East (of Platform)	West (of Platform)	Centre (of Platform)
Top	-1.123	-1.117	-1.111	-1.108	-1.105
Middle	-1.151	-1.127	-1.104	-1.126	-1.180
Bottom	-1.182	-1.147	-1.100	-1.143	-1.214

Table 4 shows the potential data for week 4. The potential values are quite high with the lowest negative potential being -1.106V and the highest -1.189V i.e. -156mV to -239mV outside the specified -950mv of the recommended potential range. This shows that the potentials are on the average about -198mv outside the recommended potential range. These high potentials could be attributed mainly to adjustment of the rectifier by the operators since in week 4 the weather was relatively calm.

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Table 4: Potential Values (Volts) for the Platform Week 4

Location	North (of Platform)	South (of Platform)	East (of Platform)	West (of Platform)	Centre (of Platform)
Top	-1.106	-1.145	-1.114	-1.128	-1.129
Middle	-1.173	-1.147	-1.129	-1.132	-1.138
Bottom	-1.189	-1.127	-1.127	-1.147	-1.149

In Table 5 potential data during week 5 are prevented. It could be observed from the Table that in this case potentials measured from North, East and West of platform falling within -0.981V to 0.987V are not too high for an impressed current system. It was observed that the anode joints to chutes on these areas of the platform unlike those on South and center of the platform had a problem of current leakage leading to low potentials.

Table 5: Potential Values (Volts) for the Platform Week 5

Location	North (of Platform)	South (of Platform)	East (of Platform)	West (of Platform)	Centre (of Platform)
Top	-0.986	-1.011	-0.981	-0.984	-1.978
Middle	-0.987	-1.013	-0.983	-0.983	-1.999
Bottom	-0.980	-1.016	-0.986	-0.982	-1.997

It could be observed generally that the potential values recorded seen to increase from top to bottom at each point. This could be attributed to higher dissolved oxygen and greater wave action at the surface (3.5 meters below water line) than the middle and bottom regions which lead to increased depolarization of the structure and increased corrosion rate in this region.

Also, the higher temperature of seawater in this region results in higher rates of corrosion. In general variations in potentials are obtained when the reference electrode is placed too close to the anode, when a higher reading is recorded and when it is positioned further away from the anode recording a lower potential. To avoid such variation, efforts are made to take readings always on same spots on the platform. Unfortunately, this is not always possible to achieve because the position of the electrode is subject to water movement. This difficulty can be overcome by providing conduit attached close to jacket legs during platform construction, thus the electrodes are installed permanently in the conduits. The only disadvantage is that localized low potential areas may be missing with this type of survey. Potentials within the range of -850mV to 950mV (Ag/AgCl) are positive evidence that a cathodic protection system is providing adequate protection.

CONCLUSION

Cathodic potential monitoring of a platform equipped with the impressed current system of Qua Iboe field Nigeria was investigated as a case study in terms of capability to polarize structures submerged in seawater. The following conclusions could be drawn from the investigation. The system consistently gave higher potential values than -950mv the limit stipulated in practice leading to over protection and waste of power. However, due to the prevailing hostile marine environment at Qua Iboe field during the period of this investigation, significant IR (voltage) drops were included in the potential values obtained. The increase in potential values owing to IR drop which normally amount to -10mV to -100mV can be minimized by making efforts to place the reference electrode as close to the structure as practicable.

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