Journal of Loss Prevention in the Process Industries 33 (2015) 124–128

Contents lists available at ScienceDirect

Journal of Loss Prevention in the Process Industries

journal homepage: www.elsevier.com/locate/jlp

Short communication

A new approach on troubleshooting of cathodic protection: A case study

M.H. Allahyarzadeh*, N. Zendehdel, GH. R. Saberi, P. Dehghan, F. Ahdeno, J. Kavid

Technical Protection and Corrosion Engineering Department, Iranian Offshore Oil Company (IOOC), Iran

ARTICLE INFO

Article history:
Received 6 October 2014
Received in revised form
30 October 2014
Accepted 29 November 2014
Available online 2 December 2014

Keywords:
Cathodic protection
Troubleshooting
Corrosion monitoring

ABSTRACT

The aim of this paper is to suggest an effective procedure to eliminate a major deficiency in impressed current cathodic protection (CP). Current work describes performed activities through jetty cathodic protection troubleshooting as a case study. Although CP troubleshooting is straightforward, sometimes it is very complicated and confusing. To eliminate the appeared imperfection, different procedures were carried out; the root cause of the trouble in the system was shown to be in reversed current. Here the current which passed throughout installed junction were measured to survey reversed current. Current work offers a new approach in CP troubleshooting.

1. Introduction

Corrosion management has an important role in corrosion engineering through different industries. According to "Corrosion Costs and Preventive Strategies in the United States," which was supported by FHWA (Federal Highway Administration) and NACE (National Association of Corrosion Engineers), the total cost of corrosion was estimated about $276 billion, which is about 3.1 percent of gross national product (GNP) (Roberge, 2008). One primary methods of corrosion control which applied extensively in offshore oil industries for submerged metal structures is cathodic protection. Cathodic protection has been applied in two methods: impressed current systems (ICS) and sacrificial anodes. In an impressed current system (ICS) a direct current is applied through water from a source outside the structure to the structure (Morgan, 1987; Uhlig and Revie, 2011). Applying the ICS for corrosion control is not sufficient and use of monitoring is necessary to ensure its performance (Wang et al., 2014). However, the basic fundamentals of ICS seem to be easy and straightforward, troubleshooting of these systems is sometimes very complicated and confusing. Present paper investigates the troubleshooting of ICS, which has been applied on a jetty as a case study.

2. Brief summary of the problem

ICS which has been applied on a jetty shown in Fig. 1, cathodically protected the submerged parts of that. This ICS was comprising a rectifier/transformer with the maximum voltage of 50 V and the maximum current of 150 A and also six lead–silver submersed anode in order to distribute the current more uniformly through entire of immersed structures. For more assurances regarding to establish the CP circuit, the electrical connections which denoted by *J* connect the bridges to Loading (L.D.), Berthing (*B*), and Mooring (*M*) structures electrically. Since the minimum cathodic potential for full protection is −800 mV with respect to (w.r.t) Ag/AgCl/Sea-water electrode based on NACE TM0497 (NACE, 2002), monitoring of cathodic potential of the jetty structure revealed that only the immersed Loading structures were near the fully protected conditions; and other underwater structures, including *B1*, *B2*, *M1* and *M2* were not protected and based on NACE TM0497 they were corroding. The problem was the lack of full protection criteria in *B1*, *B2*, *M1* and *M2*. Table 1 represents the potential of the jetty with respect to an Ag/AgCl/Sea-water reference electrode before troubleshooting. Fig. 2 schematically depicts distribution of rectified current among immersed 30inch lead–silver anodes. The history of the jetty and previous field data exhibited that, in the ordinary conditions, the jetty should be protected by applying a cathodic current about 100–105 A. Hence, first of all, the overall cathodic current was increased up to 103 A. However, this increase led to fully protection of underwater parts of Loading and *B1*, the other structures, especially the last one (*M2*)

* Corresponding author.
E-mail address: allahyarzadeh.mh@gmail.com (M.H. Allahyarzadeh).

http://dx.doi.org/10.1016/j.jlp.2014.11.022

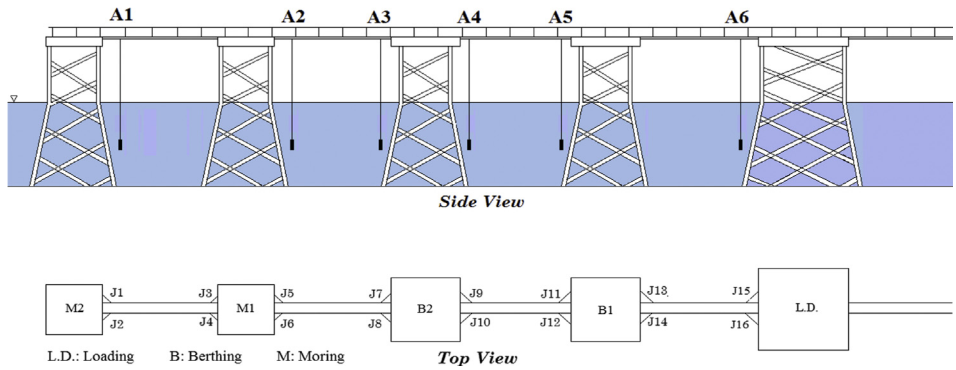

Fig. 1. Schematic of side and top view of jetty including Loading, *B1* (Berthing), *B*, *M1* (Mooring), *M2*, and electrical joints from *J1* to *J16*.

Table 1
Jetty cathodic potentials (−mV) w.r.t. Ag/AgCl/Sea-water reference electrode.

	V_{dc}	I_{dc}^{net}	*M2*	*M1*	*B2*	*B1*	L.D.
Before troubleshooting	7.5	80	704	717	722	734	762
After first step	8.8	103	750	791	793	800	849
After second step	8.4	115	736	781	812	831	861
After third step	9.5	135	749	797	827	839	891

were not protected, and they were corroding based the existed criteria. This problem was dominant, even so, the applied cathodic current increased up to 135 A.

3. Results

ICS troubleshooting was carried out in four independent phases. In each phase, the problem was corresponded to an assumption or a specific part of cathodic protection systems (CPS). In order to remove the failure, separately in each phase, several main solutions in different steps were conducted; however, performed activities were much more than it was expected. The main phases are: Transformer/rectifier, Anode replacement/addition, External consumers/interference risk, and Reversal current.

1st phase: transformer/rectifier

The starting point for all troubleshooting in ICS is the rectifier. Detailed surveying of the transformer/rectifier has shown that it was working properly and all the current and voltage measurements regarding to the rectifier were in their normal state. After investigating transformer/rectifier and ensuring its normal condition, next phases were carried out.

2nd phase: anode replacement/addition

Based on the current distribution among immersed anodes shown in Fig. 2, the *A3* anode consumed the least current amount. In this stage, the first assumption was about the *A3* anode; and it was expected that the least current consumed here might be the reason of the failure. Therefore, a new one replaced this anode. Replacing this anode increased the current consumption of *A3* anode from 2.5 A to 22 A. This increase in current consumption and enhancing to better current distribution over the immersed structure, however, did not eliminate the problem completely, but it led to increase in the cathodic potential of L.D. and *B1* structures. After this step, lack of full protection in *B1*, *B2*, *M1* and *M2* structures was also evident hence another new anode named (*A1′*) was added next to the first. The new one has been subjoined to increase the current consumption and distribution through *M2* and *M1* structure. In order to increase the cathodic current over the structures, the D.C. voltages of transformer/rectifier were also increased to 8.8 V from its initial value 7.5 V; therefore, this led to increase of the rectifier output current up to 103 A (Based on the history of structure potential measurements and previous data, the jetty should be fully protected by this amount of current). Further cathodic potential measurements were performed after complete polarization. Fig. 3 and Table 1 represent the new current distribution and jetty cathodic potentials, respectively, after first step.

As represented in Table 1, the potentials of *M2*, *M1*, and *B2* structures were still less than the required amount for full protection (−800 mV w.r.t. an Ag/AgCl/Sea water reference electrode).

New condition, after first step, led to decrease of the quantity of current consumption in *A4* anode as shown in Fig. 3. Therefore, in the second step, anode *A4* was removed and a new lead–silver anode was also employed. The current distribution was measured in new condition after devoting appropriate time for full polarization. The new condition, after second step, leads to increasing up

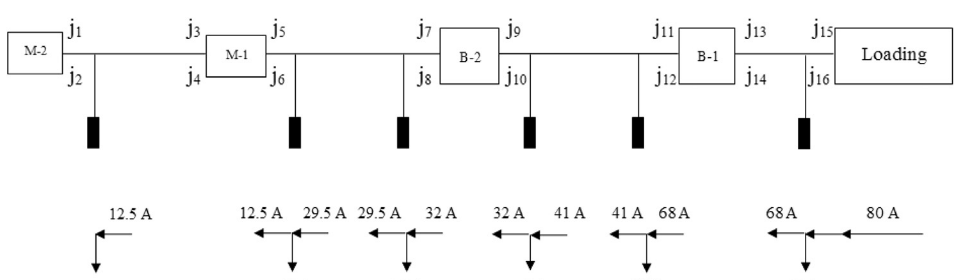

Fig. 2. Schematic distribution of rectified current among immersed lead–silver anodes before troubleshooting.