Modification Works of Impressed Current Cathodic Protection System for Steel Sheet Piles Bulkhead Wharf

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Abstract. The steel sheet piles have been protected effectively by the cathodic protection system against seawater corrosion for 40 years. There is no phenomenon of corrosion perforation and corrosion damage. However, many instruments and parts of the cathodic protection system do not work properly now, whilst many new cathodic protection materials are produced and more effective. In order to prevent the steel sheet piles from seawater corrosion, the ICCP system should be modified perfectly.

Keywords: Impressed current cathodic protection (ICCP); Steel sheet piles wharf; Corrosion control

1. Introduction

The steel sheet piles bulkhead wharf was built in 1977. There are two 100 000-dwt berths in the wharf. In order to prevent corrosion of the steel sheet piles in seawater, impressed current cathodic protection (ICCP) system was applied to the steel sheet piles in 1979. The service life of the cathodic protection system is designed for 20 years. Although the periodical maintenance is carried out, the ICCP system has already operated for a long period in close to 30 years [1].

The cathodic protection effect and corrosion status of the steel sheet piles were investigated in 2008. The results showed that ICCP restrains effectively the seawater corrosion of the steel sheet piles. However, with the production of new materials and the deterioration of partial instruments and parts, the ICCP system should be modified perfectly so as to prevent the steel sheet piles from seawater corrosion [2].

2. System Component and Modified Schematic Design

Impressed current cathodic protection systems consist of DC power, auxiliary anode and shield board, cable and cable ducts, junction well, reference electrode, check and test control device [3,4]. Overall layout diagram is shown in figure 1. According to the modified scheme, the whole parts of the cathodic protection system are almost replaced by new materials except the cables.
2.1. DC Power

All the original DC powers were replaced in the modification works of cathodic protection system. The output voltage range of the new DC power specification is 0~24V, and the output current can be adjusted continuously from 0A to 20A. The new DC power can run in steadily for continuous 24h, including the following characteristics, namely digital independent show of output voltage and current, free switch of voltage and current, excellent loading ability, short circuit protection function, low noise and high precision.

The cathodic protection system is controlled by constant DC voltage. Each DC power supplies current for two auxiliary anodes. There are thirty DC powers, wherein 22 ones are operated normally and 8 ones are reserved. Each ten DC powers are placed in a case having a length of 56cm, a width of 40cm and a height of 170cm. As shown in figures 2 and 3, the DC powers are fixed in the corresponding cases (1-3 from left to right) with the order of 1~10 from top to bottom (see figure 2).

![Figure 2. DC power and the front of case.](image1)

![Figure 3. DC power and the back of case.](image2)

2.2. Auxiliary Anode

Auxiliary anodes are of bar-shape. The auxiliary anode was a kind of mixed metal oxide (MMO) anode in terms of good electro-conductivity, small size and light weight, high work current density, and high electric efficiency at low polarization potential in sea water [4,5]. Fifty MMO anodes with the diameter of 32mm and the length of 500mm were utilized in present work. Actually, 44 ones are normally used and others are reserved. The cable of the anode is anti-seawater cable.

Two anodes, designated as NO.1 and NO.2, were fixed on riprap bank under seawater in the north end of the wharf and they are about five meters far from the steel sheet piles. Other anodes (NO.3 to NO.44) were placed along the riprap bank from the north end to the south end. The distance is set as 9.6m between the anodes. Each anode was fixed on the centre of a shielding slab which was placed the front edge of the steel sheet piles.

Each DC power can supply current for two auxiliary anodes. The detailed distribution of auxiliary
anodes and their corresponding DC powers are shown in table 1.

2.3. Connected Box

There are 22 connected boxes, designated as J1 to J22. The connected box is made of steel pile, having a diameter of 30cm and the height of 35cm.

**Table 1.** Auxiliary anodes and their corresponding DC powers.

| The No. of DC power | The No. of auxiliary anode | The No. of DC power | The No. of auxiliary anode | The No. of DC power | The No. of auxiliary anode |
|---------------------|---------------------------|---------------------|---------------------------|---------------------|---------------------------|
| 1-1                 | No.1, No.2                | 2-1                 | No.15, No.16              | 3-1                 | No.29, No.30              |
| 1-2                 | No.3, No.4                | 2-2                 | No.17, No.18              | 3-2                 | No.31, No.32              |
| 1-3                 | No.5, No.6                | 2-3                 | No.19, No.20              | 3-3                 | No.33, No.34              |
| 1-4                 | No.7, No.8                | 2-4                 | No.21, No.22              | 3-4                 | No.35, No.36              |
| 1-5                 | No.9, No.10               | 2-5                 | No.23, No.24              | 3-5                 | No.37, No.38              |
| 1-6                 | No.11, No.12              | 2-6                 | No.25, No.26              | 3-6                 | No.39, No.40              |
| 1-7                 | No.13, No.14              | 2-7                 | No.27, No.28              | 3-7                 | No.41, No.42              |
| 1-8                 | backup                    | 2-8                 | backup                    | 3-8                 | No.43, No.44              |
| 1-9                 | backup                    | 2-9                 | backup                    | 3-9                 | backup                    |
| 1-10                | backup                    | 2-10                | backup                    | 3-10                | backup                    |

2.4. Cables and Cable Channel

Although the original cables have been used more than thirty years, the aging does not occur due to a fact that they were placed in cable channel. Therefore, the original cables are continued to use. There are 70 cables, include anode cables, cathodic cables, testing cables and reference electrode cables. All the cables were checked and passed through plastic tunnel pipe. In final, they were placed in cable channel again.

The detailed quantity of cables and the No. of connected boxes are shown in table 2. The serial numbers of the cables were marked on the connected poles in connected boxes and control room.

**Table 2.** The quantity of cables and its location.

| No. | Name          | Quantity | The No. of connected box | Remark                                                                 |
|-----|---------------|----------|--------------------------|------------------------------------------------------------------------|
| 1   | Anode Cable   | 44       | 1#~22#                   | There are two anode cables in a connected box, packaged with red adhesive tape is the even number anode, green is odd number. |
| 2   | Cathodic Cable| 16       | 3#~7#, 9#~11#, 13#~17#, 19#~20#, 22# | There is a cathodic cable in the No. of connected box.                  |
| 3   | Testing Cable | 5        | 2# , 8# , 12# , 18# , 21# | There is a testing cable in the No. of connected box.                   |
2.5. **Cathodic Index Cable**

A groove with a width of 6cm and a depth of 8cm was cut on the parapet nearby each connected box. A hot-dip galvanizing rebar (φ10mm) and a plastic pipe (φ1 inch) were mounted in the groove together, wherein the plastic pipe was clamped every 50cm. The surface of the groove was buried with mortar. The hot-dip galvanizing rebar is considered as the cathodic link line and its two ends were welded with steel sheet piles and connected box, respectively. The anode cables and reference electrode cables were passed through the plastic pipe and connected with cables derived from the control room in the connected box.

2.6. **Reference Electrode**

Five fixed Ag/AgCl seawater reference electrodes were installed along the wharf on seaside, and the locations are listed in Table 2.

2.7. **Automatic Inspection System**

The automatic inspection system was composed of industry computer and five fixed reference electrodes. The protection potential of steel sheet piles can be automatically collected, tested and stored. The real-time alarm will be sent out in the case that the protection potential value is insufficient. On the other hand, the test real-time data and the history data were also automatically stored.

2.8. **Commissioning of the ICCP System**

The commissioning of the ICCP system was conducted in January, 2019. The results showed that the steel sheet piles were gradually cathodic polarized. For one anode, the output voltages and currents of the DC power were controlled at 7.0~7.7V and 3.9~5.1A, respectively.

The protection potentials of the steel sheet piles were also measured using a portable Ag/AgCl seawater reference electrode. Output voltages of the DC power were adjusted many times until the protection potential satisfies the design requirement.

2.9. **Operation of the ICCP System**

In the normal operation stage of the ICCP system, the output voltage and output current of each DC power are shown in Table 3. The output voltages and currents are controlled in the range of 5.7~10.7V and 7.7~13.0A, respectively. The protection potentials of the steel sheet piles were measured by automatic inspection system. The measured value is displayed in the range of -0.83~0.86V (vs. Ag/AgCl seawater reference electrode), which satisfies the requirement of design criterion [5, 6].

| The No. of auxiliary anode | Output voltage/V | Output current/A |
|---------------------------|------------------|-----------------|
| 1#, 2#                    | 9.9              | 9.7             |
| 3#,.4#                   | 9.9              | 9.7             |
| 5#,.6#                   | 9.8              | 9.7             |
| 7#,.8#                   | 9.6              | 9.7             |
| 9#,.10#                 | 10.7             | 13.0            |
| 11#,.12#               | 10.4             | 12.5            |

**Table 3.** The output voltage and output current of each DC power.
3. Conclusions
After more than one-year operation, the modified ICCP system is steady. At present, the modified ICCP system can effectively prevent the steel sheet piles bulkhead wharf from seawater corrosion. The life of the ICCP system is expected to prolong to more than twenty years.

Acknowledgements
This work is supported by the National Key R&D Program of China (Grant No. 2018YFC0406702) and the National Natural Science Foundation of China (Grant No.51809183).

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