ISSN 2229-5518

An Experimental Investigation of Impressed Current Cathodic Protection system (ICCP) In Basra Soil

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Abstract— This work involved experimental investigation for impressed current cathodic protection. The work involve site reading for the soil resistivity and potential difference between pipe and soil in four sites (AL-Zubair1, AL-dawajin, Sport city and Hamdan) along oil exporting pipeline in Basra /Iraq. Simulated cathodic system has been installed in Laboratory in order to calculate current density required for full cathodic protection of steel pipe (X60). Depending on data survey and experimental work results; optimum cathodic system has been designed. The result of optimum design reduce the current required for Cathodic Protection system from 247 Ampere to 206 Ampere, Also the number of anodes reduced from 139 to 116 anodes.

Index Terms— Cathodic protection, ICCP, Underground corrosion, corrosion, pipeline, CP, impressed current cathodic protection

1 Introduction

In External pipeline corrosion control work, the prime objective is to maintenance-free system, at the lowest annual cost. The primary method of control or mitigating external corrosion on buried pipelines involves a combination of (a) coatings and (b) cathodic protection (CP) [1]. Many studies have conducted experimentally and analytically the relation between soil properties and underground corrosion and methods used to reduce the risk of underground corrosion, mainly "Cathodic protection" methods. Ikechukwu et.al, (2014), investigated the effect of soil properties such as pH and resistivity towards metal loss of carbon steel. Results shown that, both parameters had an influence on buried steel corrosion but the soil resistivity had a greatly influence compared to soil pH [2]. Kim and Wook Kim (2001) explained the effect of temperature on the cathodic protection criteria of steel pipeline. Full protection could not be achieved at (-0.85V) vs CSE at high temperatures, while extra negative potential difference was required to obtain full cathodic protection [3]. Al- Jawary, (2005), studied the effect distance between the anode and cathode on cathodic protection current density. It was found the current density increased with increasing of distance between cathode and anode [4]. Saleh, (2005), studied the influence of some parameter on the cathodic protection current density (ICP). These parameters are conductivity, temperature. The results found that the current density increased proportionally with increasing these parameters. [5].

2 Materials & Methods

2.1 Materials

The material used in laboratory work was carbon steel pipe (X60) with dimensions of 10cm length, 5.2cm inside diameter, 6 cm outside diameter, and 4mm wall thickness, and rod of scrap iron with 1cm diameter and 10 cm length as auxiliary anode.

2.2 Field measurements

Field readings were taken for the soil resistivity and potential difference between pipe and soil, in four sites AL-Basra along the whole exporting pipeline from AL_Zubair to Faw. The four cathodic protection stations are: Zubair 1, AL-Dawajin, Sport city and Hamadan.

i) Soil resistivity:

Wenner Four-Electrode Method was used to measure the soil resistivity, the Wenner four-electrode method requires four metal electrodes be placed with equal separation in a straight line at the surface of the soil.

ii) Potential difference:

The potential difference between pipe and surrounding soil measured by using a copper standard electrode ($Cu / CuSo_4$), in which a wire end is linked with the pipe, while the other end linked with the standard electrode.

2.3 3 Installation of ICCP rig

Simulated cathodic protection system was installed both of the cathode (carbon steel pipe segment) and the anode (Scrap steel) were suspended in the solution, all in the glass bath. The working and auxiliary electrodes were 40 cm apart and immersed in the solution at a depth of 5 cm from the top and the bottom respectively. Copper/copper sulfate standard electrode (CSE) used to measure the potential difference required. It has to be indicated that all the immersed parts of stands made from stainless steel in order to eliminate any possible corrosion that may lead to stray current effect and cause an error in the measurements. The distance between reference electrode and cathode (pipe) was about 5 cm in order to avoid IR drop. Two multiameter was linked to measure the current required and potential difference between pipe and standard electrode. The test solution was changed after each run and the water bath was emptied from the used solution and washed by DM water, Moreover all the accessories immersed in the solution were washed by DM water to ensure that there is no corrosion product traces from the test solution of the last run were left and to ensure the solution was empty from electrical charge, the specimen (cathode) was also rewashed and re-cleaned after each run.

2.4 ICCP calculations

2.4.1 Total current demand

The total current required to provide the protection of a pipeline surface can be calculate from the following equation, assuming the distribution of the current is uniform along the metal surface [6]:

$$I = (A)\ (i)\ (1.0 - CE) \quad (1)$$

Where:

I is total current required in (A), A is surface area of the pipeline to be protected in (m^2), i is maximum current density requirement in (A/m^2), CE is coating efficiency

2.4.2 Number of anodes

To estimate number of anodes required to impressed current cathodic system there are three values of anodes number should be calculated and the design anodes number based on the large value of them. These values calculated from the following equations [7].

i) Calculate number of anodes needed to satisfy manufacture's current density limitations.

$$N = \frac{I}{(A)(I')}$$

Where: N is number of anodes, I is total current required in (A), A is surface area per anode in (m^2), I' is maximum current density output in (A/m^2).

ii) Calculate number of anodes needed to meet system design life requirement.

$$N = \frac{(L)(I)}{(416)(W)}$$

Where: L is system design life in (year), W = weight of one anode.

iii) Number of anodes needed to meet maximum anode ground-bed resistance requirements.

$$R_a = \frac{\rho .K}{N .L} = \frac{\rho .P}{S}$$

Where: ρ is soil resistivity in (Ω.cm), Ra is maximum anode ground-bed resistance (Ω)., K is the anode shape factor, P is paralleling factor, S is center-to-center spacing between anode backfill columns in (m), L is length of the anode backfill column in (m).

By rearranging of above equations, the following equation obtained to calculate number of anodes needed to meet maximum anode ground-bed resistance requirements.

$$N = \frac{\rho .K}{L .Ra}$$

The value of (K) depends on the ratio between length and diameter of anode (L/d). (P) Value depends on numbers of anodes (N) installed in parallel. Table (1) and (2) used to obtain (K) & (P) respectively

Table 1 Shape functions (K) for impressed current cathodic protection anodes.

L/d	K	L/d	K
5	0.0140	20	0.0213
6	0.0150	25	0.0224
7	0.0158	30	0.0234
8	0.0165	35	0.0242
9	0.0171	40	0.0249
10	0.0177	45	0.0255
12	0.0186	50	0.0261
14	0.0194	55	0.0266
16	0.0201	60	0.070
18	0.0207		

Table 2 Anode paralleling factor (P) for various numbers of anodes (N) installed in parallel

N	P	N	P
2	0.00261	14	0.00168
3	0.00289	16	0.00155
4	0.00283	18	0.00145
5	0.00268	20	0.00135
6	0.00252	22	0.00128
7	0.00237	24	0.00121
8	0.00224	26	0.00114
9	0.00212	28	0.00109
10	0.00201	30	0.00104
12	0.00182		

3 Results & Discussion

3.1 Soil resistivity survey

The soil resistivity survey has been done by using four-winner method. The survey shows very high values of resistivity at AL- Zubair site and is gradually diminished as going head toward the south down to Faw. This is due to the sandy soil of Zubair , this type of soil does not retain moisture, while it was find that the soil of FAW is muddy and heavy moisture. The reading of soil resistivity at site shown that the soil resistivity gradually decrease with depth, however after 3 meter depth, the difference in soil resistance is slight compared with that on the surface.

Table 3 Resistivity values measured at each site.

ISSN 2229-5518

3.2 Pipe - soil potential difference

Site	Soil resistivity (ohm.m)	Coinductivity mS/cm)(
AL-Zubair 1 site	134.500	0.074
Al-dawajin site	9.760	1.020
Sport city site	8.275	1.200
Hamdaan site	8.218	1.220

Potential difference between pipe and surrounding soil is measured by using Cu/$CuSO_4$ standard electrode at each site.

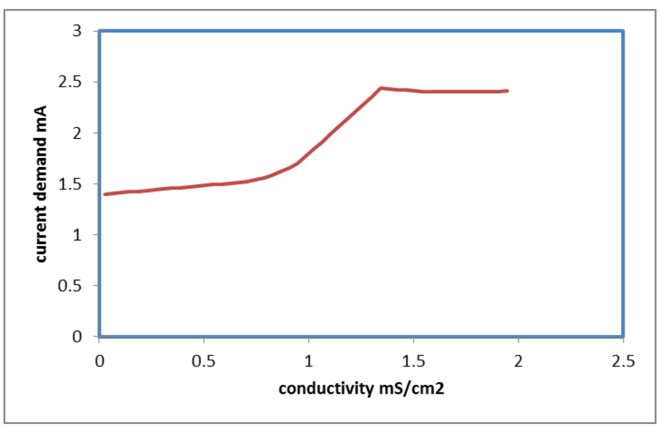
Table 4 potential difference results at each site.

3.3 Effect of conductivity on the CP current

Site	Potential difference
AL-Zubair 1 site	- 0.95
Al-dawajin site	-1.05
Sport city site	-1.10
Hamdaan site	-1.39

The increasing in conductivity leads to increasing ions and electrons movement causing current flow, in order to show the influence of solution conductivity on (ICCP) current, different weights of NaCl was added to solution to increase the conductivity. It was clear that, whenever the electrical conductivity of the solution increased (resistivity decreased) with increasing salt concentration, the impressed current required for protection also increased. That is because NaCl is an ionic compound, thus when it is dissolved in water conducts electricity and cause further current flow which leads to more CP current required to achieve desired potential shift between cathode (pipe) and solution.

Fig (1) shown relationship between CP current and



conductivity

3.4 Current density calculations

The values of current density required for full cathodic protection were obtained from simulated cathodic system , Current density was measured for each solution two times, one when the standard potential difference , equal to -850 mV (Vs. Cu/CuSo4) and the other time a potential difference according to site reading for each station. in order to calculate the current density required the value of each reading divided by cathode (pipe) surface area.

Table 5 the current density required for each site

3.5 Cathodic protection calculations

The following calculations used to design optimum cathodic protection system to protect the oil exporting pipeline under study. The optimum design, then compared with exist cathodic system used to protect this pipeline. In this work four stations are placed out of the seven stations along 32km of the pipeline with an external diameter of 42 inches.

No.	Site	conductivity mS/cm^2	Current density (i) (mA/m^2)	
			Standard conditions	Field conditions
1	Al-zubair	0.074	53.2	62.6
2	Al-dawajin	1.020	67.9	70.1
3	Sport city	1.200	74.2	80.5
4	Hamdaan	1.220	76.3	90.4

3.5.1 Total current demand

The coating efficiency assumed to be 97% i.e. 3% of total pipe-line area is bare, and the total pipeline area should be protected by each station equal to 26630 m^2.
Table 6 shows the results of the total Currents obtained by the software according to standard condition and according to excited CP systems conditions. The effect of variation in soil conductivity value on the total current required for the cathodic protection techniques is very obvious ,decreasing in the soil resistivity leads to increasing in current required and vice versa. The soil resistivity plays two main roles in this case, the first is that with increasing the humidity of the soil, the possibility of corrosion becomes more and this means more impressed current has to be given to stop this phenomenon. It is more convenient to present the results schematically as shown in Figure 2.

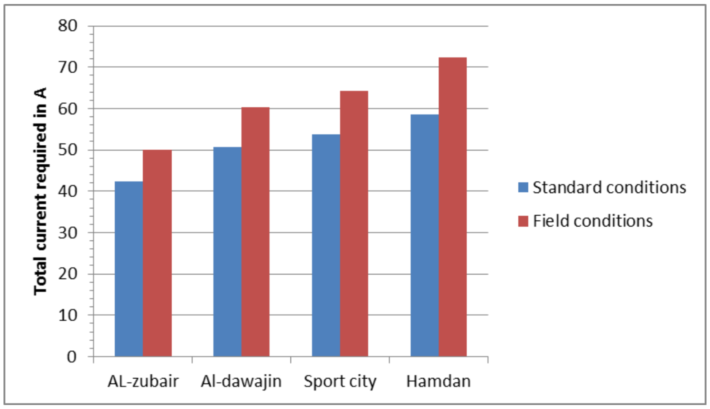


Fig 2: Comparison between current values (standard and field conditions)

3.5.2 Number of Anodes

South Oil Company (SOC) is installing 25 anodes for each station. The standard operational life of these anodes is 20 years, but according to readings, anodes consumed in a period not exceeding four years under field conditions, this short age of anodes result from supplying large amount of current from external source larger than their capacity. In order to calculate the real number of anodes required for cathodic protection, The results shown that the total number of anodes required matching potential requirement in field for all 4 stations equal to 139 Anodes while the optimum conditions required only (116) Anodes as shown in Fig 3 This explains the short age of anodes in field.

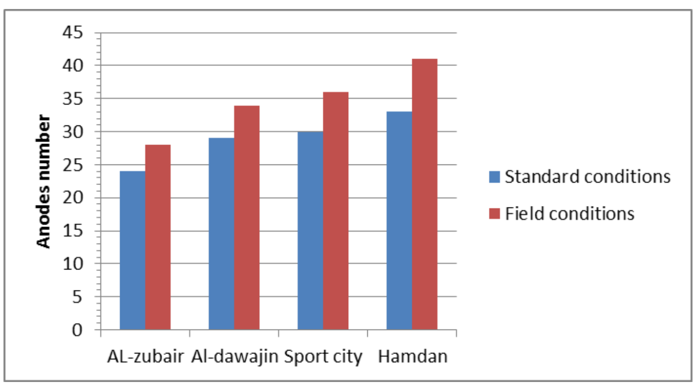


Fig 3 Anodes number comparison (standard vs. field conditions).

5 Conclusions:

The following conclusions can be drawn from the present work:

1 –The current density required for full cathodic protection increased proportionally with conductivity increased (inversely with resistivity).

2 – The potential difference at field exceeded normal range at all stations, especially in Hamdan site, the potential difference in Hamdan site reach -1.39 V, this huge value of potential difference can cause harm effect on coating and also can cause hydrogen embrittlement for steel.

3 – The number of anodes installed at each station does not commensurate with the amount of current supplied to reach the field potential difference between pipeline and surrounding soil, the required number of anodes is 139 Anode, while the actual number of supplied anodes is only 100 Anode.

4 – Pipeline should not buried deeper than 3 meters because the change in soil resistivity after 3 m very little and not consider.

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6.1 Figures and Tables

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