Cathodic Protection Project (EPC) Cost Analysis with New Generation Designs

Mehdi Attarchi, Naser Mehrjooy, Alireza Sohrabi Farid,
Seyed Mohamad Sadegh Mirghafourian, Mohsen Nasri Karladani
Borna Electronics Co., Tehran, Iran
attarchi@borna-co.com/attarchi@gmail.com

Summary

Lump-Sum EPC is one of the most common contract types of cathodic protection projects, especially in Iran and other Persian Gulf countries. In this contract type, engineering and finding the optimum total cost in procurement and construction has key role. The latest cathodic protection design concept for piping in plant is based on distributed anode (localize protection) by utilizing wire and small tubular anode in comparison with traditional deep ground-beds.
The past two decades experiences in cathodic protection projects help us to extract the real cost analysis of different designs by utilizing critical path method (CPM) planning. The cost analysis along with CPM planning shows in a petrochemical plant with 12900 piping (13900 m^2) using “shallow ground-bed plus wire anode” design is 54% more costly than traditional “deep well” design. However “Distributed anode” cost is between “shallow GB plus wire” and “deep GB” but it has main technical advantage of shallow GB and wire anodes. Technical advantage and disadvantage of different cathodic protection design along with constructional issues of three design with cost effect will be discussed in this paper.

1 Introduction

Cathodic protection is one of the recognized industrial corrosion control method. Generally coating, separating environment from the structure, is the first line of corrosion preventing and cathodic protection (CP), reducing the corrosion tendency, is the second line. Because of constructional limitation in coating and the coating deterioration by time cathodic protection could not eliminate in corrosion protection methods, especially for the surfaces in contact with soil or corrosive liquid environments. Therefore cathodic protection is a part of plants in whole the world, especially in Middle East and Persian Gulf area which is one of the most important zones of oil and gas production and export with high corrosive environment.
CP contractors are willing to reduce the cost of the project alongside with the keeping the quality and healthiness of cathodic protection system as high as possible. Engineering concerns and CP technology is one side and constructional limitations and project schedule is other side of CP project costs. Normally, CP project schedule is a part of whole project schedule and CP contractor shall follow the main milestones of the project. So, normally there is not any option to change the project life time to reach an optimum cost for different CP technologies. Moreover in some cases, CP technology is clear and there is not any other option such as pipelines that normally protected by deep wells or typical shallow ground-beds while in plant piping different technology is available and possible. Therefor CP system for in plant piping could be based on different technologies while the project milestones is not changeable. So

reducing the project cost means selecting the best economical technologies which are the optimum of procurement and construction cost.
The General Contractors of plants are willing to define cathodic protection as a complete EPC or EPS job to achieve an integrated cathodic protection system [1, 2]. In a plant integrated CP has key role in reducing corrosion by stray current [3, 4].
EPC projects, including CP projects, could be analyzed by different methods. One of the recognized methods is Critical Path Method (CPM) or Critical Path Analysis [5, 6]. The valuable outputs of CPM are the time when each activity will take to complete, dependencies between activities and the critical activities or paths that have direct effect on the project schedule [5]. When there is a tide milestones and closed deadlines for the project, the manpower and instruments shall be considered as much as sufficient to complete job. In other hand for completing different amount of activity, assigned resource could defined as critical parameter in the project analysis. For example, in distribution anode system, secondary cable and total length of cable is more than deep well design so more manpower needed in period of cabling than the second assumption. So cable installation manpower could define critical for completing job in the predefined milestones and the project should give more attention and budget to that activity on specified period.
In this paper, CPM applied for extracting project cost for different technologies recommended for under construction plant.

2 CPS Technologies for In Plant Piping

Different CPS technologies are established on different CP components, especially anodes. In the past decades High Silicon Cast Iron (HSCI) anodes are installed in deep wells or shallow CP ground beds. Next generation anode could be MMO. MMO technology helps the CP engineer to have current source, anode, with different shape such as wire, ribbon, plate, low weight tubular with competitive price. Nowadays MMO anodes are wildly used and recommended, especially in Persian Gulf countries. Another cost effective parameter is procurement and installation of cable that could be significant in project cost. In this paper three common technologies, by utilizing different shape of current source and its concerns, are compared and the project total cost are extracted.

2.1 System Define

The scope of the project is the CPS for in plant piping with 12900 meter length and 13900 m^2 surface. By imposing temperature effect and miscellaneous structure with 20 and 1.25 $mA.m^{-2}$ protection current for uncoated and coated steel pipeline respectively and 30% final coating breakdown after 25 years, total needed current capacity is 313 ampere. Piping size diversity is from 2 to 68 inches and the piping is distributed in whole plant.

2.2 Option 1: Deep Well Ground bed

Deep well ground bed is known as remote earth current source in CP systems, especially in North America. By definition deep ground bed has more than 15 m depth [7]. In this design total length of well is 51 meter which has 25 meter inactive length. The MTO of this design is:

Table 1: MTO for Option 1, Deep Well Design

Item	Description	Qty.	Unit
1	TR- 50V/50A	9	No.
2	MMO anode 25X1000 with 55 m Cable 1X16 mm^2 HMWPE/PVDF	9	No.
3	MMO anode 25X1000 with 52 m Cable 1X16 mm^2 HMWPE/PVDF	9	No.
4	MMO anode 25X1000 with 49 m Cable 1X16 mm^2 HMWPE/PVDF	9	No.
5	MMO anode 25X1000 with 46 m Cable 1X16 mm^2 HMWPE/PVDF	9	No.
6	MMO anode 25X1000 with 43 m Cable 1X16 mm^2 HMWPE/PVDF	9	No.
7	MMO anode 25X1000 with 40 m Cable 1X16 mm^2 HMWPE/PVDF	9	No.
8	MMO anode 25X1000 with 37 m Cable 1X16 mm^2 HMWPE/PVDF	9	No.
9	MMO anode 25X1000 with 34 m Cable 1X16 mm^2 HMWPE/PVDF	9	No.
10	Cable 1X50 mm^2 XLPE/PVC	900	m
11	Cable 1X25 mm^2 XLPE/PVC	1350	m
12	Cable 1X16 mm^2 XLPE/PVC	2000	m
13	Cable 4X16 mm^2 XLPE/PVC	90	m
14	AC Box	9	No.
15	Positive and Negative Box	18	No.
16	Test Bond Box	50	No.
17	Permanent Ref. Electrode with 10m Cable 1X16 mm^2	50	No.
18	12" Metallic Casing	234	m
19	12" Non-Metallic Casing (PE)	225	m
20	Cad Weld Powder	227	m
21	Cad Weld Unit and Accessories	5	Set

The advantage of this method is producing even current distribution by making remote earth, installation in congested area and using low resistive layer of ground. The problem of this method is the high current leakage possibility and cathodic current shielding in complex plant. This method is traditionally used in pipelines and there is a vast number of successful CP project of pipeline, not as much as in plant piping, that confirmed this method.

2.3 Option 2: Distributed Shallow Anode

The new successful experience of cathodic protection system for in plant piping shows that the benefits of distribution of current source, anode, in whole piping routes and close to the protection surfaces. The proposed MTO is:

Table 2: MTO for Option 2, Distributed Anode

Item	Description	Qty.	Unit
1	TR 50V/(15+15+15A) with 3 module	9	No.
2	MMO 25X500 Canister Anode with 50 m Cable 1X16 mm^2 HMWPE/PVDF	162	No.
3	Cable 1X50 mm^2 XLPE/PVC	450	m
4	Cable 1X25 mm^2 XLPE/PVC	3240	m
5	Cable 1X16 mm^2 XLPE/PVC	2000	m
6	Cable 4X16 mm^2 XLPE/PVC	90	m
7	AC Box	9	No.
8	Positive and Negative Box	54	No.

Item	Description	Qty.	Unit
9	Test Bond Box	50	No.
10	Permanent Ref. Electrode with 10m Cable 1X16 mm^2	50	No.
11	Cad Weld Powder	281	No.
12	Cad Weld Unit and Accessories	6	Set

The advantage of this method is distributing current all around the plant and installed near the protection surface. In comparison with wire anode, all the shallow ground bed could be tested easily and reinstalled if necessary, which is not reasonable and possible for wire anode. The disadvantage of this method is that the construction is not in congested area and the anodes shall be installed all around the plant and in many cases troubleshooting of the system could be complicated because of the current supplies from different sources. Moreover, the anodes are installed near the ground level and the soil resistivity is almost higher than the deep wells.

2.4 Option 3: MMO Wire Anode and Distributed Anode

As mentioned above, MMO technology give an opportunity to CP engineers to supply even current distribution close to the protection piping as much as possible, by producing MMO wire anodes. In this method MMO 3 mm wire anode could supply even protection current to piping size from 2 to 10 inches. For bigger size, one MMO wire anode neither supply the needed protection current for each meter nor produce even current distribution if installed 30 cm of pipe. In complete plan, other pipe size will be protected by distribution shallow anode. The proposed MTO is:

Table 3: MTO for Option 3, MMO Wire Anode and Distributed Anode

Item	Description	Qty.	Unit
1	TR 50V/(30+30A) with 2 module	3	No.
2	TR 50V/(25+25A) with 2 module	6	No.
3	MMO 3mm Wire with 1X10 mm^2 Cable HMWPE/PVDF	10500	m
4	MMO 25X500 Canister Anode with 5 m Cable 1X16 mm^2 HMWPE/PVDF	72	No.
5	2-Way Splicing Kit	280	No.
6	3-Way Spicing Kit	72	No.
7	Cable 1X25 mm^2 HMWPE/PVDF	840	m
8	Cable 1X50 mm^2 XLPE/PVC	900	m
9	Cable 1X25 mm^2 XLPE/PVC	2160	m
10	Cable 1X16 mm^2 XLPE/PVC	2000	m
11	Cable 4X16 mm^2 XLPE/PVC	90	m
12	AC Box	9	No.
13	Positive and Negative Box	36	No.
14	Test Bond Box	50	No.
15	Permanent Ref. Electrode with 10m Cable 1X16 mm^2	50	No.
16	Cad Weld Powder	254	No.
17	Cad Weld Unit and Accessories	6	Set

The advantage of using wire anode is supplying even protection current for the structure and the current leakage is the minimum so achieving highest protection criteria is easier than the other methods. Moreover, in process piping that normally has small

size and installed closed to each other in congested area, wire anode installation grantee the current directly reaches to all protection surfaces, even below the paving area. Current leakage for system includes close earthing system is significant for both deep well and shallow ground bed [8] while for wire anode is reasonably low. There are three negative point about using MMO wire anode; for big size or hot pipes that need high protection current one line MMO wire may not be sufficient and the installation should be at same time of pipe installation and before backfilling. It meant time scheduling is really important for EPC project including MMO wire anode installation. Moreover there is not any option for repairing and reinstallation. Generally this technology is competitive with deep well design in piping, not pipelines.

3 Construction Analysis of Different CPS Technologies

As mentioned above, each of the three design has its own advantage and disadvantage, especially in construction step. Based on project milestones total project time is 140 day. The major points of scheduling are:

- Total construction period is 140 days
- Main cable shall be installed in the last layer of main LV cable trenches
- Cable connection to pipes shall be done after pipe installation and before holiday test of coating and backfilling
- Permanent half-cell shall be installed near the pipes and before backfilling
- After ground levelling all TR units could be installed
- Deep well could be installed after levelling the just 9 predefined location
- Shallow anode could installed after ground levelling the majority of the site
- Wire anode shall be installed alongside the piping, after all coating tests and before complete backfilling

Based on the above assumptions and consequences the manpower histogram of the three option in CPM would be:

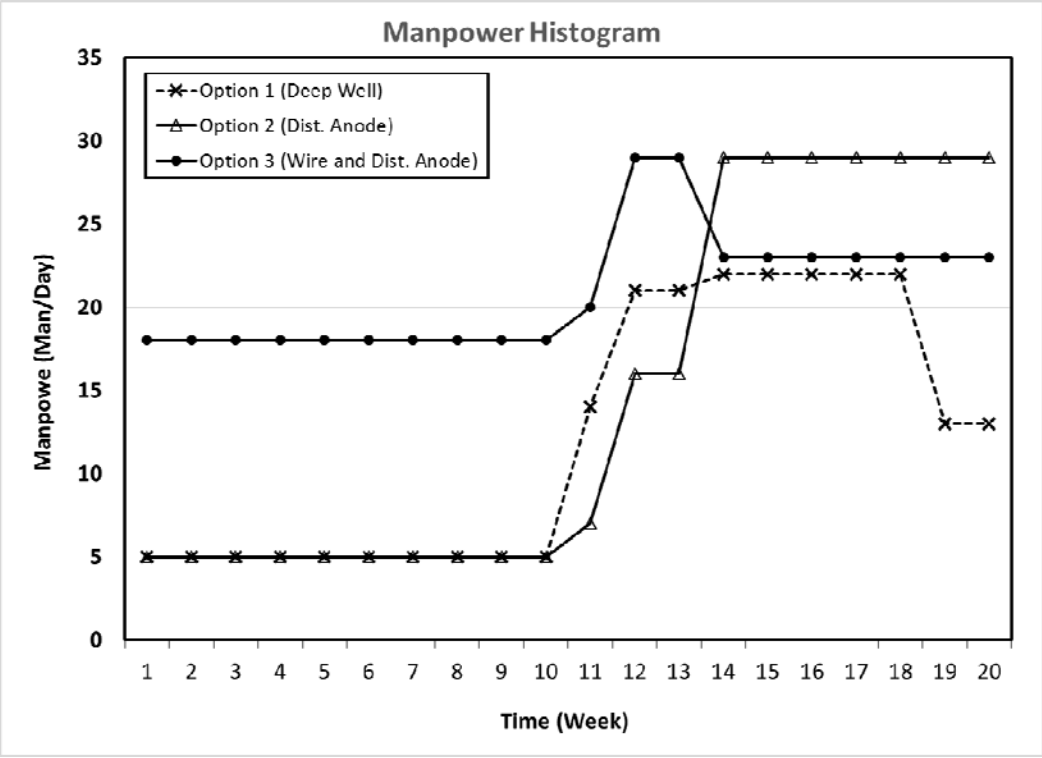

Figure 1: Manpower Histogram for 3 Design Option (Critical Path Analysis)

4 Discussion and Conclusion

The summery of cost analysis of procurement and construction of the three options is presented in Table 4.

Table 4: EPC cost of three design options

Item	Design Option	Total EPC Cost (Euro)	Changes
1	Deep Well	246,000	-
2	Distributed Anodes	293,000	19%
3	Wire Anode and Distributed Anode	378,000	54%

The changes column in Table 4 is related to the changes of total cost in comparison with deep well design, option 1. One point that should be considered in cost analysis is the same monitoring and potential reading system for all three options that make around 15 to 20 % of total cost constant. Generally, as presented in Table 4, Deep well is the lowest price for the mentioned project in Persian Gulf region, same as Lewis report about North America [9]. As presented in figure 1, the manpower of option 1 shows the lowest of the three options.

Increasing the safety factor of healthiness of the CPS cost at least 19%. If the owner wants to have the most conservative design, wire anode and distributed anode, it means the project cost will increase around 50%. In the other hand if the all three option is available for a project, wire anode could not be a competitive option.

Technically, both option 2 and 3, distributed anode with and without wire anode, are conservative designs but option 2 has three advantages; (a) Project Total Cost: the option 3 is 30% costly than option 2. (b) Construction: option 3 including wire anode needs to follow piping installation schedule precisely to install the wire close to the piping in the same backfill and (c) Maintenance and Troubleshooting: If the shallow ground beds fails it is possible to reinstall while it is not reasonable and possible for wire anode. The main and significant advantages of wire anode are their application in congested area for process piping which are installed close to each other and normally in paving area. Wire anode grantee to reaches current to the protection surface in the best way.

5 References

[1] API RP-1632, Cathodic Protection of Underground Petroleum Storage Tanks and Piping Systems, 2002.

[2] NACE SP-0113, Pipeline Integrity Method Selection, 2013.

[3] EN 50162, Protection against Corrosion by Stray Current from Direct Current Systems, 2005.

[4] NACE SP-0177, Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems, 2014.

[5] J. M. Antill and R. W. Woodhead, Critical Path Methods in Construction Practice, 4th Ed., John Willy and Sons, 1990.

[6] T. Uher and A. S. Zantis, Programming and Scheduling Techniques, 2nd Ed., Spon Press, 2011.

[7] NACE SP-0572, Design Installation Operation and Maintenance of Impressed Current Deep Anode Beds, 2007.

[8] G. Cui, Z. Li, X. Bai and J. Liu, The Influence of a Grounding System on Cathodic Protection, Materials Performance, December 2014.
[9] T. H. Lewis, Deep Anode Systems, Design, Installation and Operation, NACE Publication, 2000.