Reenergizing Cathodic Protection of an Aging Offshore Platform

Challenges Are Overcome to Bring System Back to Full Protection

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The boat crew prepares to install the first anode sled. Photo courtesy of John Bollinger, Farwest Corrosion Control Co.

The impressed current cathodic protection (ICCP) system protecting an aging offshore oil drilling platform located off the coast of Southern California was experiencing anode failure, and some submerged areas of the steel platform structures were not being fully protected against corrosion. To address the problem, an anode sled was custom designed and installed near the platform on the sea floor, which successfully upgraded the ICCP system to provide full protection of the underwater support structures and portions of the pipelines that transfer product from the platform to the shore.

According to John Bollinger, corrosion engineer with Farwest Corrosion Control Co. (Gardena, California) and project engineer for this assignment, the ~30-year-old fixed platform is located in water that is ~300-ft (91-m) deep. It sits on a steel jacket structure—a three-dimensional underwater frame with supporting vertical legs and criss-crossed horizontal bars made of tubular steel—that is piled directly into the seabed. Vertical pipelines or risers, located together in clusters, run down from the various decks of the platform into the water. Bollinger explains that offshore platforms such as this, with numerous underwater structures in close proximity to one another, usually demand a larger amount of current for CP.

The platform was originally fitted with an elaborate ICCP system with four rectifiers custom designed for this platform. Each are large, air-cooled, 24-V/1,000-A units that powered 12 individual platinum screen anodes (~5-ft [1.5-m] long and ~1-ft [0.3-m] wide) attached to the legs and various cross members throughout the platform. Historically, a total operational applied current of 900 to 1,100 A was sufficient to provide full protection for the underwater structures.

In 1994, all of the anodes in the anode group assigned to one of the rectifiers on the platform had failed. Two years later, the anode groups assigned to all four rectifiers were experiencing anode failures. In

1996, two supplemental anode sleds were installed, providing a total additional 480 A of current, and all structure-to-water potentials at that time indicated full protection. By 2003, however, just a few of the original anodes were still functioning, and the total current output capability of the ICCP system was only 625 A. As a result, some areas of the platform were not fully protected by the ICCP.

In 2009 Farwest Corrosion Control was asked to design and install a supplemental anode system that would utilize one of the existing rectifiers and add a minimum of 600 A to the ICCP system. While the project was achievable, the engineers faced many challenges that are inherent with retrofitting older CP systems in aging offshore structures. One challenge was selecting and configuring anodes to meet the project requirements. Replacing the original anodes was not pursued for several reasons, Bollinger comments, including high cost, susceptibility to damage, and performance unreliability.

Two other popular options were considered: tensioned anodes that are tethered to the platform and sled configurations that sit on the sea floor. Tethered anodes in water deeper than 100 ft (30 m) sway in the water currents and can strike the platform, which may result in anode and/or cable damage and failure, he remarks. Although anode sleds sit away from the structure on the sea floor, he says, current from the anode sleds tends to distribute throughout the platform's structures because seawater is virtually an infinite conductor. However, there must be a means to connect the cables from anodes on the seabed to a rectifier on a platform. This platform had an existing spare J-tube (an 8-in [203-mm] conduit in the shape of the letter "J" that runs vertically down the middle of the platform and bends horizontally at the sea floor), and cables from anodes located on the sea floor could be routed up through the tube to the rectifier on the platform. The presence of the J-tube was the deciding factor in choosing the sled anode configuration.

Anode sled designs vary in approach but all have some common requirements, says Bollinger. A sled needs to contain adequate anode material to provide the required current discharge over its assigned design life, and the anodes need to be contained in a support structure that will keep them in position and properly supported while enduring seabed conditions unique to the specific project site. For this project, the plan was to connect two identical anode sleds to one of the existing 24-V/1,000-A rectifiers and have the capability to generate as much as 400 A from each sled (a total of 800 A). Each anode's operational design life is 20 years at a continuous 400-A discharge.

Over the years platinum-clad anodes have proven to be very reliable and are capable of discharging large amounts of current from a relatively

To fit the 50-ft platinum-clad anode rod into a compact sled, it had to be carefully formed into a modified "U" shape. Photo courtesy of John Bollinger, Farwest Corrosion Control.

Shown is the completed anode sled. Photo courtesy of John Bollinger, Farwest Corrosion Control.

The pulling head is removed from the anode cable ends at the top of the J-tube aboard the platform. Photo courtesy of John Bollinger, Farwest Corrosion Control.

The cables from the newly installed anode sleds will be routed from the J-box to one of the platform's rectifiers. Photo courtesy of John Bollinger, Farwest Corrosion Control.

small anode, Bollinger observes. Platinum is consumed very slowly and has demonstrated good performance over time, and a smaller platinum anode has the design life equivalent of a larger anode fabricated from a different material. Since it is cost prohibitive to fabricate an anode out of solid platinum, Bollinger adds, a platinum layer is clad over a substrate that will carry current and not deteriorate. Niobium can carry up to 100 V before it will start to break down, but it is not a good conductor. To solve this problem, Anomet Products had developed a hybrid platinum-clad anode, referred to as a Pt-Nb-Cu anode, that contains a copper core (80% of the anode) for better conductivity, an outer shell of niobium (20% of the anode), and a platinum layer clad over the niobium. "This was the anode of choice for our sled project," Bollinger says. "It provides everything we want—a good conductor that will accommodate a large amount of current and last a long time."

The anode used in each sled is a single 50-ft (15-m) long by 0.625-in (16-mm) diameter rod with a 2.258-oz (64-g) platinum layer that is 165-μin (4-μm) thick, and a current capacity of 8,000 A/h. To fit the 50-ft rod into a compact sled, the anode rod had to be carefully formed into a modified "U" shape, which behaved as four short anodes.

Bollinger notes, "In order to achieve the performance goal, it was imperative to keep the resistance very low. I had a certain maximum resistance that was allowable in the circuit that included the anode interface to the water and in the cabling that goes between the rectifier and the sled. Since I was adapting to the available resources, there were limitations on how much resistance the whole circuit could tolerate." To achieve the low resistance requirement plus provide redundancy for system reliability, two 4/0 American wire gauge (AWG), double layer, steel-armored copper cables, capable of being pulled through the existing J-tube, were connected in parallel to each end of the anode on both sleds with encapsulated thermite splice welds. Although a straight anode would have yielded the lowest resistance to seawater, Bollinger adds, a 50-ft long anode would be have been difficult and expensive to support properly. The "U" shape kept the overall sled size as small as practical.

The sled/anode support frames are a hybrid of non-metallic structural components. The non-metallic components eliminate any stray current corrosion of metallic elements from the high current gradients in the vicinity of the sled. The only exceptions on the sleds are the steel lifting eyes and the mounting brackets for the bending strain relief. These are all coated with fusion-bonded epoxy (FBE). To facilitate ease of installation without sacrificing reliability and stability on the sea floor, sled assemblies should be as small and compact as possible, Bollinger says.

The sled frames measure 15-ft (4.5-m) long by ~8-ft (2.4-m) wide by 2-ft (0.6-m) high and weigh ~2,850 lb (1,292 kg) each. They are constructed of high-strength, lightweight cast concrete reinforced with non-metallic fiberglass-reinforced plastic (FRP) rebar. The structural beams, channel, brackets, and bolts are also constructed of FRP. Because the anode rods need to be suspended above the seabed in free-flowing seawater to maximize the performance of the anode material, they are mounted below the cross braces on the sled frame assemblies.

Another challenge was installation of the anode sleds. Specialized equipment was designed and installed on the work boat to accommodate the installation. Each sled has two 550-ft (167-m) lengths of ~1-in (25-mm) diameter armored cable permanently attached to each end of the anode. The other ends of all four cables were attached to a pulling head that would pull the cables across the sea floor and up the J-tube to a deck on the platform. First the pulling head with the cable ends was lowered overboard and positioned on the seabed so it could be winched up the J-tube onto the platform. Custom overboard cable guides were designed and fabricated to allow the stiff armored cables to be lowered overboard without exceeding the bend radius allowed by the cable manufacturer. Next, an onboard winch system suspended the first sled over the stern of the boat and lowered it into the water. Both sleds were launched in a predetermined location so they would land on the seabed about 250 ft (76 m) from the base of the platform.

The sleds were located at a minimum of 100 ft apart to minimize any interaction between them from the voltage/current gradients, which required the boat to be repositioned after the first sled was launched. If the sleds were sitting next to each other, Bollinger explains, their interaction would increase the apparent circuit resistance, which would reduce the ability to generate the full rated 400 A per sled.

Finally, the cables were pulled through the J-tube while a remotely operated vehicle (ROV) was used to watch the progress so operators would know if the cables became kinked or fouled with debris on the sea floor. "Weeks of planning and coordination were needed to orchestrate the installation phase," says Bollinger. "Once the installation started, it took about six hours to complete. The sleds were installed with no physical problems and best of all, no one was injured," he comments.

After the sled cables were secured and connected, the rectifier was energized and initially set to discharge a total of ~500 A (250 A per sled). After a period of system polarization and stabilization, the rectifier was readjusted and the performance level of the CP system was tested. After approximately one month of operation, the upgraded CP system was providing full protection for the submerged surfaces of the platform. MP