



## IMPRESSED CURRENT CATHODIC PROTECTION FOR OIL WELL CASING AND ASSOCIATED FLOW LINES

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**ABSTRACT:** *Cathodic protection is an electrochemical technique for preventing corrosion of a metal exposed to an electrolyte. The process involves application of DC electrical current to the metal surface from an external source. By forcing the metal surface to accept current from the environment, the underground metal becomes a cathode of a corrosion cell and protection occurs. Cathodic protection is employed intensively on the steel drains in oil and gas industry. It is used extensively in preventing corrosion to underground and submerged steel structures; such as pipelines, production well casings, and tanks. Two types of cathodic protection systems are usually applied; the galvanic anodes system also called the sacrificial anodes system, in this system protection occurs due attaching sacrificial metals such as magnesium, zinc or aluminium which is electrochemically more electronegative than the structure to be protected, the other system is by impressed current system, powered by external source. The external source can use outside AC power through a transformer rectifier, thermo electrical generator or solar power unit with DC. current output towards the structure to be protected. The object of this study is to design a cathodic protection system by impressed current supplied with DC power source applied to oil production and water injection wells casing and their associated flow lines.*

**KEYWORDS:** Cathodic Protection, Corrosion, Electrochemical Technique, Electrolyte

### INTRODUCTION

The first practical use of cathodic protection is generally credited to Sir Humphrey Davy in the 1820s. Davy's advice was sought by the Royal Navy in investigating the corrosion of copper sheeting used for cladding the hulls of naval vessels. Davy found that he could preserve copper in sea water by the attachment of small quantities of iron or zinc; the copper became, as Davy put it, "cathodically protected" [1].

Corrosion is an electrochemical process in which a current leave a structure at the anode site, passes through an electrolyte, and re-enters the structure at the cathode site. Current would leave the structure at that anode site, pass through the soil, and re-enter the structure at a cathode site. Current flows because of a potential difference between the anode and cathode. The anode potential is more negative than the cathode potential, and this difference is the driving force for the corrosion current. The total system anode, cathode, electrolyte, and metallic connection between anode and cathode are termed a corrosion cell.

Cathodic protection techniques are used to reduce corrosion by minimizing the difference in potential between anode and cathode. This is achieved by applying a current to the structure to be protected (such as a flow line and/or well casings) from some outside source.



When enough current is applied, the whole structure will be at the same potential; thus, anode and cathode sites will not exist. The applied current (protection current) maybe produced by the external anode if this is a more active metal than the reinforcing steel (sacrificial anodes), or by an external power supply and discharged to the steel through a noble metal external anode (impressed current cathodic protection). Cathodic protection is commonly used on many types of structures, such as pipelines, underground storage tanks, well casings, and ship hulls.

Impressed current systems have a longer service life than the sacrificial systems and are more suitable for systems with high anode to cathode resistance, and structures with high resistivity concretes. Typically, with an impressed current system, a rectifier is used to produce the protection current. However, highly efficient photovoltaic (solar) power supplies and controllers have been developed for use in areas where AC current accessibility is limited or not available. These power supplies use available sunlight to produce the cathodic protection current and recharge the storage batteries. The batteries deliver the required current during the night, and daytime periods of low or no sunlight such that the C.P. current is always maintained. The effectiveness of a cathodic protection photovoltaic power supply for a concrete structure can be determined based on the level of polarization achieved on the reinforcing steel [2].

## LITERATURE HISTORICAL BACKGROUND

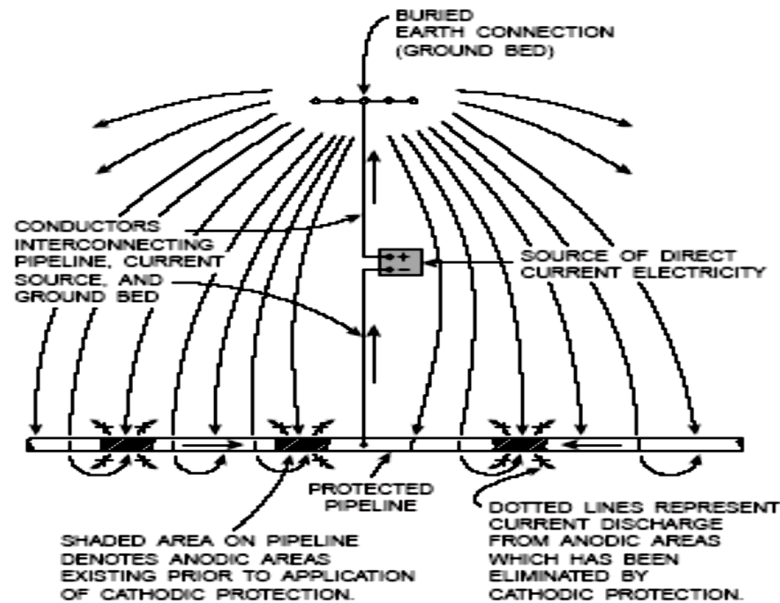
In 1824 Sir Humphry Davy reported that by coupling iron or zinc to copper, the copper could be protected against corrosion. The first application of cathodic protection by means of an impressed electric current in England and the United States was in 1910-1912. Nowadays, there are thousands of miles of buried pipelines and many structures which are protected in this manner [2].

Cathodic protection is a major factor in corrosion control of metals where the corrosion rate can be reduced, when an external electric current is applied. Under these conditions the metal can theoretically remain in a corrosive environment indefinitely without deterioration.

### Basic Theory of Cathodic Protection

Cathodic protection is defined as “the reduction or elimination of corrosion by making the metal a cathode, by means of an impressed direct current or attachment to a sacrificial anode (usually magnesium, aluminium or zinc)” [8].

Direct current is forced onto all surfaces of the structure. This direct current shifts the potential of the structure in the active (negative) direction, resulting in a reduction in the corrosion rate of the metal. When the amount of current flowing is adjusted properly, it will overpower the corrosion current discharging from the anodic areas on the structure, and there will be a net current flow onto the structure surface at these points. The entire surface then will be a cathode and corrosion rate will be reduced. This concept is illustrated in Figure (1).



**Figure (1) Cathodic Protection with Impressed Current System**

As shown by Figure (1), Current is forced to flow on to the pipe at areas that were previously discharging current; the driving voltage of CP system must be greater than the driving voltage of the corrosion cells that are being overcome.

So, if all anodic areas can be converted to cathodic areas, the entire structure will become a cathode and corrosion will be eliminated.

For the CP system to work, current must be discharged from an earth connection (ground bed). The sole purpose of this ground bed is to discharge current. In the process of discharging current, the anodes in the ground bed are consumed by corrosion. It is desirable to use materials for the ground bed that are consumed at a much lower rate than are usual pipeline materials. This will ensure a reasonably long life for the anodes [9].

### **Cathodic Protection Types**

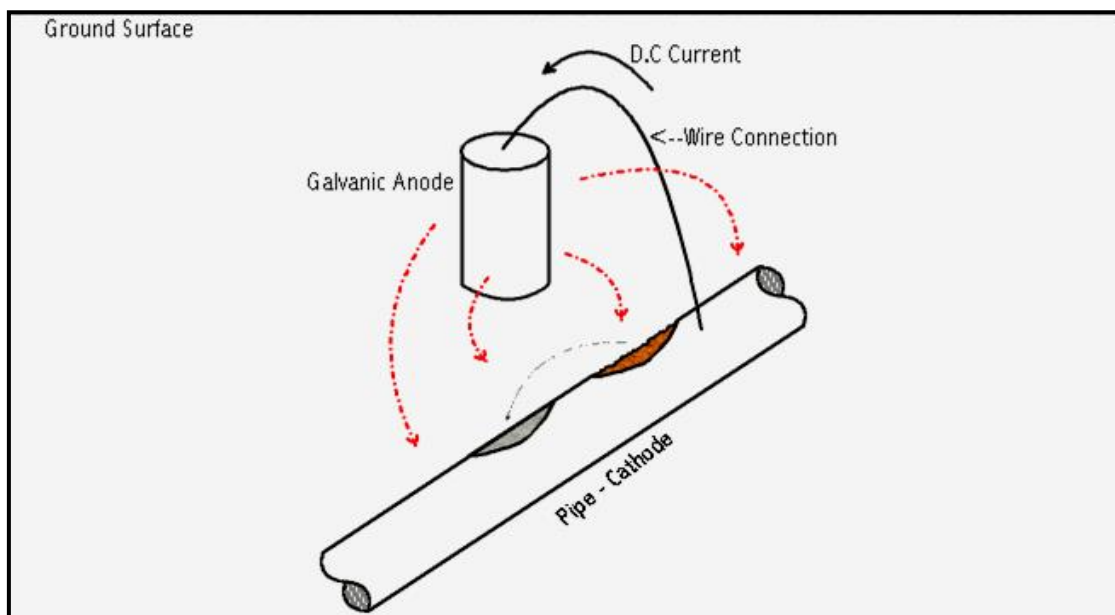
#### **Cathodic Protection with Galvanic Anodes**

In such a cell, one metal is active (negative) with respect to the other and corrodes. In CP with galvanic anodes, this effect is taken advantage of by purposely establishing a dissimilar metal cell strong enough to counteract corrosion cells normally existing on pipelines. This is accomplished by connecting a very active metal to the pipeline.

This metal will corrode and, in so doing, will discharge current to the pipeline as shown in Figure (2). In the case of CP with galvanic anodes, CP does not eliminate corrosion; rather, it displaces corrosion from the structure being protected to the galvanic structures (sacrificial anodes). Under normal circumstances, the current available from galvanic anodes is limited. For this reason, CP by galvanic anodes normally is used where the current required for protection is small.

Similarly, the driving voltage existing between pipe steel and galvanic anode metals is limited. Therefore, the contact resistance between the anodes and the earth must be low for the anodes to discharge a useful amount of current. This means that, for normal installations, galvanic anodes are used in low resistivity soils. A normal installation, as considered here, is one in which the current from a galvanic anode installation is expected to protect a substantial length of pipeline.

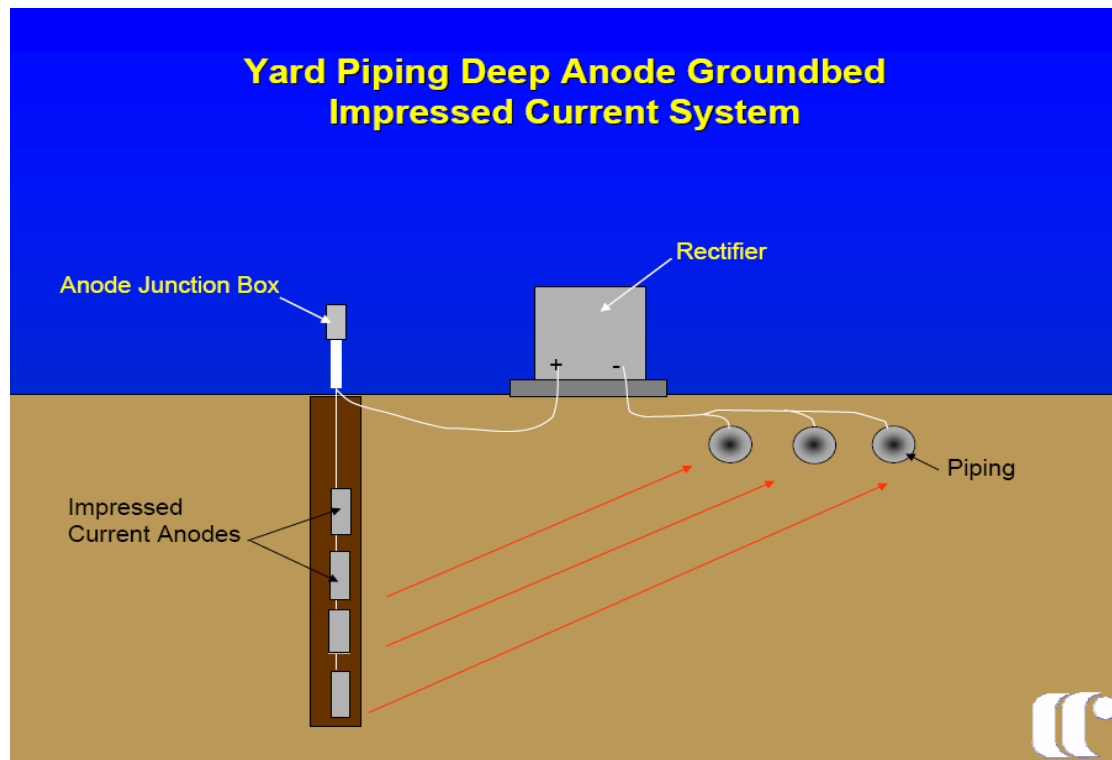
There are also instances where galvanic anodes are placed at specific points on a pipeline (often termed hot spots) and maybe expected to protect only a few feet of pipe, especially where the line is bare [10].



**Figure (2) Cathodic Protection with Galvanic Anodes**

### **Impressed Current Cathodic Protection (ICCP)**

As in galvanic anode systems, impressed current systems supply current for cathodic protection of a metal surface. However, in the case of an impressed current system, the protective current is supplied by a DC power source instead of by the natural potential difference of the anode to the structure as shown in Figure (3).



**Figure (3) Impressed Current Cathodic Protection (ICCP)**

The potential difference between the anode and cathode is forced from a non-reactive anode bed by the action of additional energy from a DC power source to force the electron flow that would be normally produced in the corrosion reaction. The effect of these electrons at the structure being protected is the same as that derived from the sacrificial anode system. However, the anode material serves only as a source of electrons and anodic (oxidation) electrochemical reactions.

In practice, materials such as graphite, high silicon cast iron (HSCI), graphite, platinum or mixed metal oxide, are used for impressed current cathodic protection system anodes because they are slowly consumed (they have a very low kilogram (pound) per amp year weight loss).

To provide a uniform electrolyte, a lower resistance to earth, and venting of gases and acids, a special backfill is used. This earth contact backfill is normally coke breeze. Anodes in impressed current systems must be periodically inspected and replaced if consumed or otherwise damaged.

As is the case for any electrical equipment, Dc power source used for impressed current cathodic protection systems require preventive maintenance and recurring operational checkouts to ensure proper operation. Impressed current system anode leads must have a special insulation to preclude the copper lead wire from becoming part of the anode system. Since the power source is forcing everything connected to the positive terminal to act as an anode (and corrode) any defect or nick in the insulation of the anode lead wire would result in copper metal loss ending in failure of the anode system.



Impressed current systems are fundamentally the same as galvanic anode systems in their operation, except that in impressed current systems a rectifier or other direct current power source is used to increase the potential of the electrons from the anodes to provide the desired protective current. Thus, in addition to an anode and a connection to the structure being protected, an impressed current cathodic protection system uses a rectifier or other DC power source [9].

## **DESIGN CONCEPT**

### **Objective**

This study lays down the basic design criteria for the cathodic corrosion protection of the oil production well casings and their flow lines.

### **Design Philosophy**

The purpose of this study is to design a cathodic corrosion protection system for the oil production well casing and their flow lines. Design of the Impressed Current Cathodic Protection has long period of life time (e.g. 30 years). Technical data must be obtained from site through field survey measurements (e.g. soil resistivity and current drain test).

### **Standards and design CODES**

The Cathodic Protection system is designed in accordance with the respective valid codes and the internationally recognized and proven technical regulations, such as the following:

#### **DIN Standards**

DIN 30676 Design and Application of Cathodic Corrosion Protection for External Protection  
DIN 30675 External Cathodic Corrosion Protection of Buried Pipelines Parts 1 & 2.

### **Design Conditions**

All works and materials suitable for satisfactory operation under climatic conditions at site:

<b>Location</b>	:	Oil Field - Libya	
<b>Ambient temperature</b>	:	max. 50 °C,	min. - 5°C
<b>Relative humidity</b>	:	max. 96 %	
<b>Wind velocity</b>	:	max. 140 km/h,	average 15 km/h

### **Objects to be Protected**

The cathodic protection system is protected the following objects: -

- Oil production well casings,
- The flow lines connected at the oil production well up to the manifold.



## **Cathodic Protection Requirements [13]**

In accordance with the applicable standards, the oil production well casing and the connected flow lines below ground protected actively against corrosion by a Cathodic Protection system. The Cathodic Protection requirements for the oil production well casings and their flow lines are as follows:

- Electrically isolated from any connected pipeline and earthing (grounding system),
- Electrically isolated from reinforced concrete foundations at valves, vent stacks and scraper traps etc. by means of plastic material of sufficient strength and thickness.
- Instrumentation requiring electrical earthing isolated from the protected pipeline by insulating joints.
- Earth leakage circuit breakers are used for motor operated valves in order to avoid direct connection to the earthing system.

## **FINDINGS**

1. The installed cathodic protection stations should be capable of providing the required protection current for all structures which are integrated into the subject system.
2. The protection Criteria  $-850\text{ mV}$  "OFF" w.r.t ( $\text{Cu}/\text{CuSO}_4$ ) must be achieved during commissioning period.
3. All wells, at which the "ON" potentials of well casing are more positive than  $-1000\text{mV}$ , are not receiving the required protection current.
4. CP system reduces the economic losses and environmental side effect caused by corrosion in oil structures.
5. The availability to use (ICCP) system in remote area far away from transmission lines (desert area) by use of PV solar cells as current source.

## **DISCUSSION AND CONCLUSION**

1. In order to increase the protective current to those well casings which are not receiving enough protective current to achieve adequate protection level either the cathode cable could be disconnected from the flow line and extended up to the well casing or an insulating flange with a sufficient spool piece could be installed in the flow line between the drain point and manifold or tie-in to other pipes.
2. Due to the required bonding of the insulating flanges (for the mitigation of internal corrosion on the insulating flanges) because of the water cut, all different systems are still electrically interconnected. Under these conditions, synchronized current interrupters must be installed in all TR units in order to switch them simultaneously and to measure the instant "OFF" potentials. There are current interrupters available which can be





synchronized by GPS time signals and which can be remote controlled by GSM services, meaning that remote control and monitoring of all units is possible in areas where there is reception of GSM signals. In order to define the real protection status, the possibility of measuring the instant “OFF” potentials should be provided.

3. The performance of the deep anode ground bed is measured in its ability to provide the necessary current for the desired life of installation. Quality control and inspection of the ground bed materials is important to ensure top performance. The areas of prime interest are anode, cable to anode connection, the cable insulation and coke breeze. Due to the poor backfill around anodes from hand backfilling operation, backfilling by pumping coke breeze slurry has proven to be much more effective; this can be achieved by pumping of coke breeze from bottom of the hole to displace the drilling mud and to get a superior backfill. Adequate coke breeze must be pumped to allow for any washouts of the hole, fraction in the formation or expended diameter.
4. Installation of permanent reference electrodes at the drain points of solar power units and transformer rectifiers units in order to operate the units in potential controlled mode to automatically control the current output depending on changed soil conditions during rainy seasons. This is recommended because it always reported by the maintenance coordinator that during rainy days it was recognized that the potentials of flow lines became positive and the maintenance group should be adjusted the current output during rainy season on daily basis.
5. Immediate repair of defective components.
6. Regular inspection in order to repair of visible painting damages of CP equipment.

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