# SOLAR PV POWERED CATHODIC PROTECTION FOR A BURIED PIPELINE

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## ABSTRACT

Cathodic protection is employed intensively on the steel drains in oil and gas industry. It is a technique of prevention against the corrosion which transforms the structure into a cathode of a corrosion cell. This can be achieved either by using a more active sacrificial anode to create a driving current, or by using inert anodes and impressing a current onto the cathode surface using an external direct current (DC) source. ICCP needs a constant DC power supply that is usually provided through a grid connection or independent generators. The paper presents the possibility and the way of applying cathodic protection system by impressed current supplied with solar energy panels applied to a buried pipeline.

## INTRODUCTION

Corrosion protection is required to maintain the integrity of a buried pipeline system and coatings are the primary protection for a pipeline. As a buried pipeline is subject to corrosive attack if it is in contact with a wet environment, coating the pipeline to isolate it from this corrosive environment is an obvious approach to corrosion control. Since no coating system is defect free, cathodic protection is used to provide supplementary protection. Most countries have regulations that require pipelines to be coated and in general stipulate that a coating possess the following properties:

- electrically isolate the external surfaces of the pipeline from its environment;
- have sufficient adhesion to resist underfilm migration of electrolyte;
- be sufficiently ductile to resist cracking;
- resist damage due to soil stress and normal handling;
- Be compatible with cathodic protection;
- Resist deterioration due to the environment and service temperature.

Cathodic protection is fundamental to preserving a pipeline's integrity. Cathodic protection is a method of corrosion control that is achieved by supplying an external direct current that neutralizes the natural corrosion current arising on the pipeline at coating defects. Current required to protect a pipeline is dependent on the environment and the number and size of the coating defects. Clearly, for a particular environment, the greater the number and size of coating defects, the greater the amount of current required for protection. Coating plays an integral part in the functioning of a pipeline's cathodic protection system.

Grid-based and generator power tends to use high fossil fuel consuming sources, with 82% of global energy demand created by the burning of fossil fuels in 2011. For Pipelines structures in remote or difficult-to-access locations, power can be supplied by self-sufficient renewable systems such as thermo-electric generators, closed-cycle vapor turbines, wind or solar energy or diesel generators. Originally remote ICCP systems were heavily wind power based. Photovoltaic (PV) modules have since surpassed them in usage, with few examples of other renewable energy sources still present in industry. Both wind and solar systems require batteries or other energy storage mechanisms due to the intermittency of their supply.

Research into renewable energy systems for CP has been predominantly for metallic buried pipelines, occasionally extending to other metallic buried structures such as foundations. Buried pipelines are the most common application for ICCP, and therefore more research and development has been focused in this area. Furthermore, many buried metal pipelines exist remotely; where there is no access to grid power.

## CORROSION TYPES AND METHODS OF PROTECTION

### Corrosion Types

There are three main types of corrosion and they are briefly presented below.

1. Uniform corrosion: is considered an even attack across the surface of a material and is the most common type of corrosion.
2. Pitting: is one of the most destructive types of corrosion, as it can be hard to predict, detect and characterize.
3. Localized: attacks some areas of metal at different rates.

### Corrosion Prevention of Metal

Different methods of corrosion prevention of metal can be used. Main methods are following:

1. material selection,
2. coating,
3. modification of the environment (adding inhibitors),
4. Cathodic Protection - CP.

**Cathodic Protection CP**

Cathodic protection (CP) controls the corrosion of a metal surface and is used extensively in the oil and gas industry. Cathodic protection systems are most commonly used to protect steel, water, and fuel pipelines, wellhead casings and tanks, steel pier piles, and offshore oil platforms. Buried metal structures will experience a galvanic reaction with the ground due to the difference in the electrical potential of the structure and the ground. This reaction results in the loss of surface material from the structure to the ground and turns the structure into an anode and the ground a cathode (current always flows from an anode to a cathode). The loss of material (ions) eventually leads to corrosion of the metal structure, which can lead to a mechanical failure and can be extremely costly.
There are two basic techniques of cathodic protection. The first technique does not need a power supply to impress current from the sacrificed anode to the cathodically protected area, (Galvanic Anode).

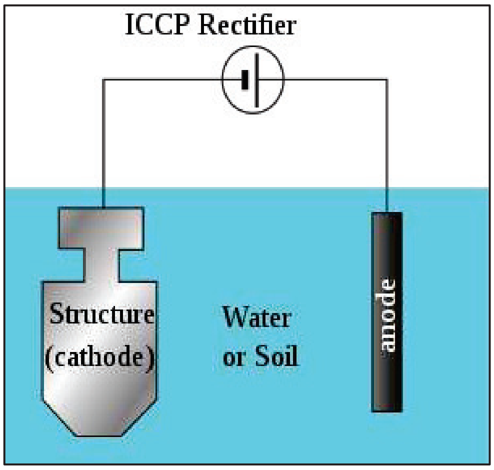


Fig.1 Simple ICCP system

For larger structures, or where electrolyte resistivity is high, galvanic anodes cannot economically deliver enough current to provide protection. In these cases, impressed current cathodic protection (ICCP) systems are used. These consist of anodes connected to a DC power source, often a transformer-rectifier connected to AC power. In the absence of an AC supply, alternative power sources may be used, such as solar panels, wind power or gas powered thermoelectric generators.
Figure 1 presents a simple ICCP system. A source of DC electric current is used to help drive the protective electrochemical reaction.

**Principles of Cathodic Protection**

Corrosion in aqueous solutions proceeds by an electrochemical process, and anodic and cathodic electrochemical reactions must occur simultaneously. No nett overall charge builds up on the metal as a result of corrosion since the rate of the anodic and cathodic reactions are equal.
Anodic reactions involve oxidation of metal to its ions, e.g. for steel the following reaction occurs.

$$Fe \rightarrow Fe^{2+} + 2e \quad (1)$$

The cathodic process involves reduction and several reactions are possible. In acidic water. Where hydrogen ions (H+) are plentiful, the following reaction occurs.

$$2H^{+} + 2e \rightarrow 2e \quad (2)$$

In alkaline solutions, where hydrogen ions are rare, the reduction of water will occur to yield alkali and hydrogen.

$$2H_2O + 2e \rightarrow H_2 + 2OH^{-} \quad (3)$$

Anodic reaction produce electrons pass from metal (anode) to cathode that electrons consumed by cathodic reaction. In the water is reduction of oxygen producing alkali at the surface of the metal.

$$O_2 + 2H_2O + 4e \rightarrow 4O4^{-} \quad (4)$$

<u>The anodic reaction:</u>
That metal withdraw electrons from its surface, that increase reaction (1) (Anodic reactions) increase corrosion and decrease reaction (2) (The cathodic process) and increase dissolution metal.

<u>The cathodic reaction:</u>
When supply metal with electrons from external power supply, that decrease reaction (1) (Anodic reactions), decrease corrosion decrease dissolution of metal, increase reaction (2) (cathodic protection). To prevent corrosion, we have to continue to supply electrons to the steel from an external source to satisfy the requirements of the cathodic reaction. Reducing the rate of the anodic process will increase the rate of the cathodic process.

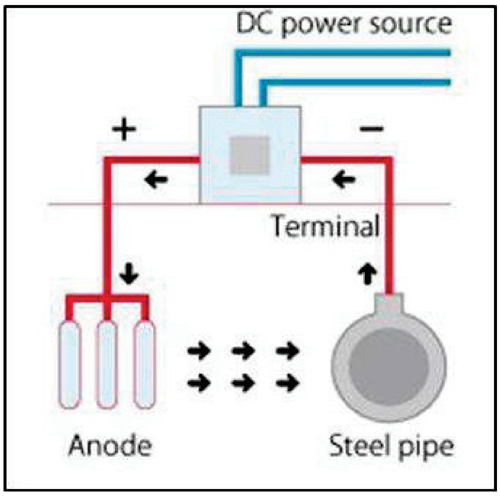


Fig.2 Schematic of the impressed current protection method

**SOLAR POWERED CATHODIC PROTECTION SYSTEM (SPCP)**

The basic design of a PV system for attachment to ICCP consists of the following items:

- PV solar modules with support structures: to generate DC power from solar radiation;
- Solar charge controller: to prevent batteries overcharging;
- Battery bank: to store PV energy;
- An electronic control unit energized by the storage batteries, and acting as a voltage regulator for the load; this part of the system can consist of maximum power point tracking (MPPT);
- system cabling and mounting hardware.

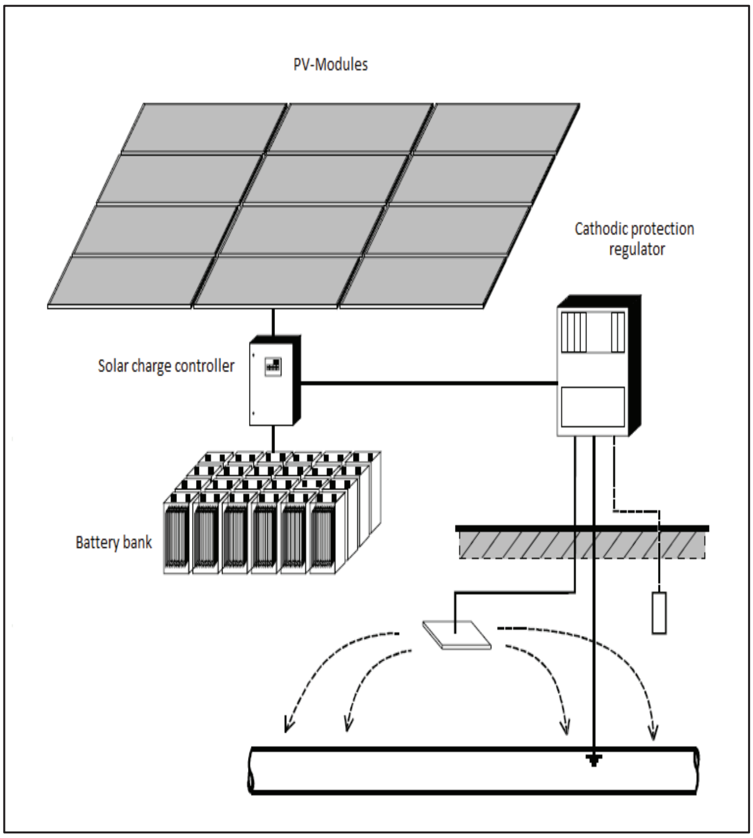


Fig.3 Schematic illustration of the basic elements of PV CP System

**GENERAL DESIGNING STEPS**

The well know cathodic protection system is implemented for a pipeline, mainly described by some characteristics, summarized in list:

- Material;
- Longitudinal isolation Resistance, Ωm;
- Resistance, Ωm;
- Characteristic resistance, Ωm;
- Length, m;
- Attenuation coefficient;
- Linear isolation resistance, Ωm;
- Surface to protect, $m^2$;
- External diameter, m.

The essential of cathodic protection is based on two parameters, the evolution of the potential and the current of protection.

The steps elaborated to the design are:

1. Estimate the cathodic protection voltage and current according to equations and estimate electric power requirement per day.
2. Estimate the optimal angle of the photovoltaic plane sensor to reach the maximum of electrical energy output
3. Design the anodic backfill.

**SUMMARY AND CONCLUSIONS**

Corrosion is the major issue in Pipeline structures deterioration, affecting both serviceability and safety. Cathodic protection (CP) has proven to be a reliable long-term solution. This paper presented an overview of the main CP systems for pipeline structures using up-to-date information from research and industry. It may be concluded that PV supply systems for supplying electrical energy to remote and isolated CP units are justified based on economic and technical reasons.

Cathodic protection should turn ever more towards renewable sources of energy. A greater understanding of the level and frequency of protection needed could facilitate the design of more efficient systems and advancement in novel and renewable sources of energy. The conclusion of this review is that further research needs to be conducted into the potential for intermittent sources providing adequate protection, renewable energy based CP and the appropriateness of other novel power sources for ICCP.

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