Design Aspects of Cathodic Protection

Keywords: Cathodic Protection Design, Choice of Protection, Engineering Aspects.

Advantages and uses of cathodic protection:

- Compared to alternative protection methods, cathodic protection is applied by simply maintaining a DC power circuit and its effectiveness can be continuously monitored.
- Generally applied to coated structures to protect areas where coatings are damaged-enable longer life span for existing structures.
- Can avoid other design considerations for corrosion resistance (such as corrosion allowance) if cathodic protection is pre-specified.
- Can be applied to all metallic structures / including concrete).

Application for protection of exterior surfaces of
Ship hulls
Pipelines
Storage tank bases
Seashore structures
Off shore platforms
and internal surfaces of
- Large diameter pipelines.
- Storage tanks (water and oil)
- Water circulation systems

**Basic requirements:**

For galvanic protection (sacrificial anode)

- Sacrificial anodes
- Direct connection to the structure.
- Minimum resistance between anodes – connection.

For impressed current protection

- Inert anodes (backfill – ground-bed)
- DC power supply.
- Well insulated, minimum resistance and secure conducting connections

**Background information for choice of cathodic protection type and design considerations:**

- Structure’s physical dimensions (surface area).
- Size, shape, material – type and locations.
- Electrical isolation and elimination of short circuits.
- Corrosion history in the area with respect to environment.
- Resistivity survey information.
- Information on pH, potential between structure and environment, current requirements per unit area.

For ensuring reliable and cost-effective protection, the following aspects need be ascertained.

- Electrical continuity – minimize iR drop.
- Coatings to minimize current requirements.
- Structure isolation – introduction of isolation joints (insulating flanges).
- Availability of test stations with facilities for monitoring and data acquisition.
Current requirements for complete protection can be assessed through.

- Actual tests on existing structure using a temporarily – organized cathodic protection setup.
- Based on prior experience and theoretical calculations based on coating efficiency.

Suggested formula

Total protective current = (Area in ft$^2$) (required current density) x (1.0 – coating efficiency)

<table>
<thead>
<tr>
<th>Soil at natural pH</th>
<th>0.4 – 1.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly acidic soil</td>
<td>3 – 15</td>
</tr>
<tr>
<td>Fresh water (static)</td>
<td>1 – 6</td>
</tr>
<tr>
<td>Flowing water with oxygen</td>
<td>5 – 15</td>
</tr>
<tr>
<td>Seawater</td>
<td>5 - 10</td>
</tr>
</tbody>
</table>

Total current requirements can be estimated by multiplying current density requirements with surface area

Choice between the two methods of cathodic protection depends on

- Conditions at site
- Current density requirements
- Soil resistivity

If the soil resistivity is lower and current requirements are less than about 1mA/ft$^2$, galvanic anodes can be used. For larger resistivity and current requirements, impressed current protection may be opted for.
Design aspects for galvanic anode cathodic protection

- Soil resistivity assessment – Site of lowest resistivity to be chosen for location of anode.
- Choice of anode material – Data from commercially available anodes to be carefully assessed.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Potential (Cu / CuSO₄)</th>
<th>Density, g/cm³</th>
<th>EEC (amp – h / Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>- 1.15 V</td>
<td>2.7</td>
<td>2700</td>
</tr>
<tr>
<td>Magnesium</td>
<td>- 1.55 V</td>
<td>1.7</td>
<td>1230</td>
</tr>
<tr>
<td>Zinc</td>
<td>- 1.10 V</td>
<td>7.1</td>
<td>780</td>
</tr>
</tbody>
</table>

Aluminium and magnesium – alloy anodes can also be chosen:

- Open circuit potentials for various anodes to be known to facilitate selection. Similarly, for protection of steel, its potential in soil or water need be known. Net driving potential between the metal to be protected and the sacrificial anode in the environment to be the criterion. This will involve the polarized potential of the steel (protected) when contacted with the anode such as magnesium.
- Estimate number of anodes required for desired protection and to compensate resistance limitations (anode to electrolyte and lead – wire resistance as well as structure to electrolyte resistance).

Based on the knowledge of ground-bed resistance and life expectancy of anodes, requirement of number of anodes is calculated.

Design aspects for impressed current cathodic protection

- Soil resistivity
- Estimation of required current density. Actual current requirements can be assessed using a provisional test setup, where battery-power supply can be used. Effectiveness of insulating joints (as in a pipeline) can be tested.
• Selection of appropriate ground-bed anode (high silicon, chromium bearing cast iron commonly used). Backfill materials such as coal-coke breeze, calcined petroleum coke or graphite can be chosen for ground-bed anodes for protection of subsoil steel structures such as pipelines.
• Number of anodes to meet current density and design requirement.
• Selection of anode sites and calculation of total circuit resistance.
• Selection of suitable DC power system.

Table 18.3 Comparison between the two cathodic protection systems.

<table>
<thead>
<tr>
<th>Galvanic</th>
<th>Impressed current</th>
</tr>
</thead>
<tbody>
<tr>
<td>No external power</td>
<td>External power supply required</td>
</tr>
<tr>
<td>Driving potential fixed</td>
<td>Adjustable applied potential current</td>
</tr>
<tr>
<td>Used in low resistivity environment</td>
<td>Can be used even in high resistivity environment</td>
</tr>
<tr>
<td>Lower maintenance</td>
<td>High maintenance</td>
</tr>
<tr>
<td>Cannot originate stray currents</td>
<td>Can cause stray current problems</td>
</tr>
<tr>
<td>Used for small and well-coated structures</td>
<td>Suitable for larger structures (coated or uncoated)</td>
</tr>
</tbody>
</table>

REFERENCES

2. J. P. Guyer, Introduction to cathodic protection, 2009, CED enginerring.com (from web)
3. J. B. Bushman, Impressed current cathodic protection system design, Bushman and Associates. Ohio (from web)