De-Mystifying AC Corrosion

An explanation of the phenomenon for non-corrosion and non-electrical specialists.

Written by Richard Lindley and Ken Lax and presented by Ken Lax of Asset Integrity Services Ltd

FIRSTLY WE ARE GOING TO LEARN ABOUT

- The relationship between direct current (DC) and corrosion rates
- Ac voltage characteristics
- How ac voltage gets on to a pipeline
- How a diode works
- How ac voltage is changed to a dc voltage
- Difference between resistance and impedance
- How electrical energy is stored

HEALTH WARNING!

This presentation will give you an understanding of the sources and indications of ac corrosion. It does not cover all of the mechanisms or all of the mitigation methods.

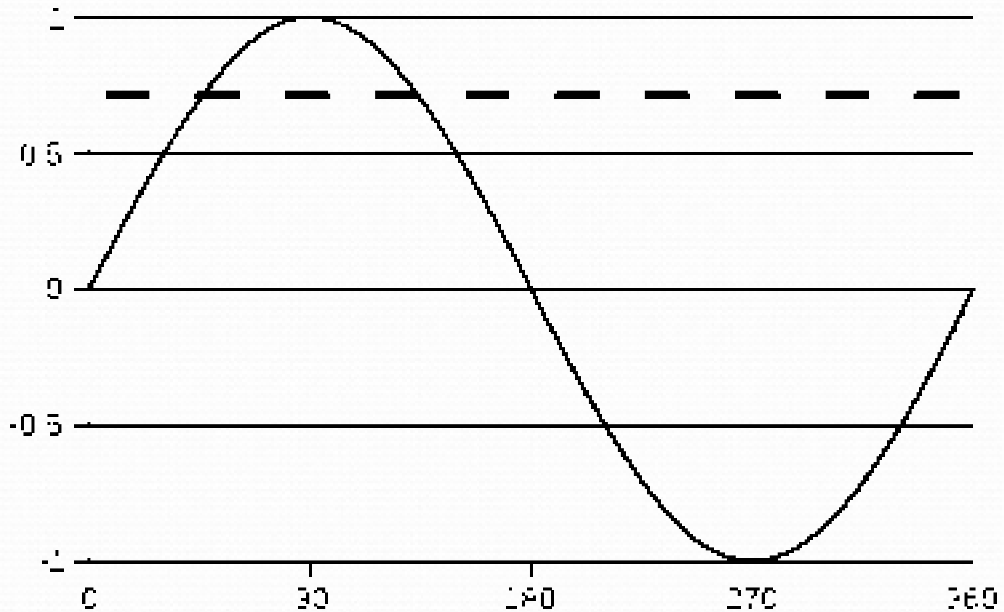
Corrosion

- In the context of electrical interference, corrosion happens when direct current (dc) leaves the structure via an electrolyte (e.g. Soil, water, concrete)
- The rate of corrosion is directly related to the magnitude of the current. More current = more corrosion.
- HORRIBLE FACT:
- ONE AMP DC FOR ONE YEAR WILL CONSUME NINE KGS OF CARBON STEEL

What is AC?

- AC is alternating current that alternates between positive and negative half cycles.
- In most countries the frequency at which this happens is 50 times per second (50 Hertz)
- In the USA it is 60 Hz
- Some railway systems operate at one third of this frequency (16.66 Hz)

Single cycle of a sine wave



How does the AC voltage get on to the pipeline?

IMPORTANT FACTS:

- Every electrical current has a magnetic field associated with it.
- The greater the current the stronger the magnetic field.
- If you place a conductor in a changing magnetic field then a voltage is induced in the metal conductor that is directly proportional to the strength of the magnetic field and the speed that the magnetic field changes.

How does ac voltage get onto the pipeline?

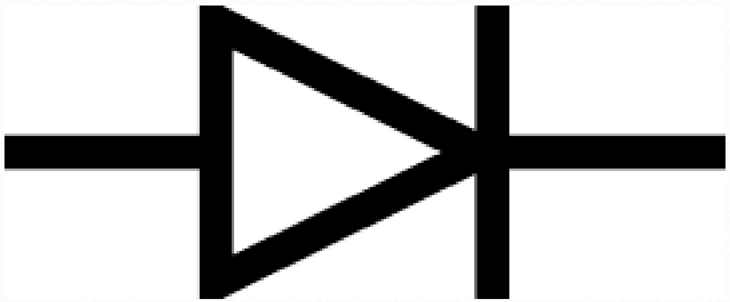
- Three basic modes
  - Resistive
  - Capacitive
  - Inductive
- Resistiver – proximity to pylons
- Capacitive – mainly during construction
- Inductive – most significant

How does the AC voltage get onto the pipeline?

- If you have a voltage (induced from the overhead cables)and a resistance (pipeline) then you will have a current.

How a diode works

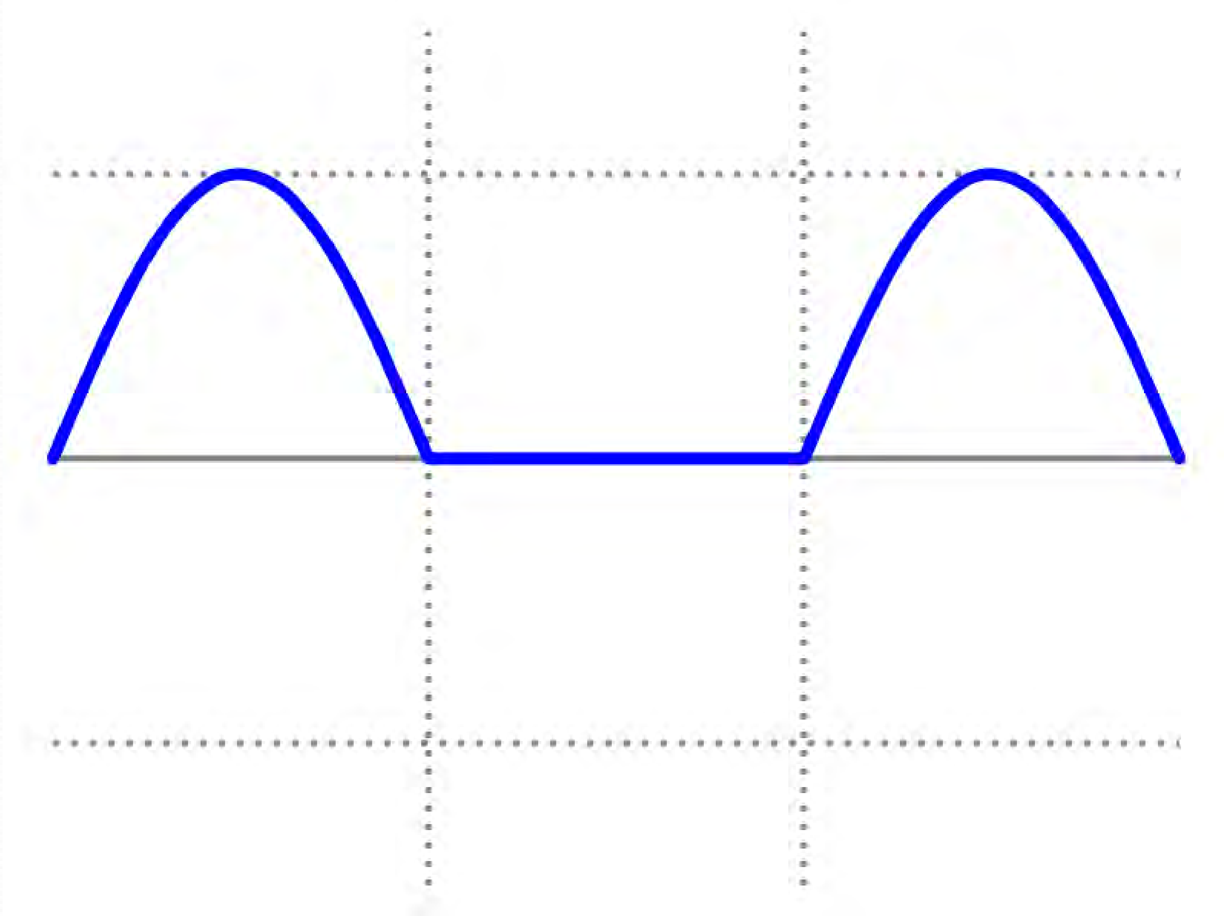
- A diode is like a one way valve. It allows current to pass in one direction only, so when a sine wave is positive it conducts and when it is negative it does not conduct.
- So a single diode will produce a pulse of dc every half wave



How does the AC turn into DC?

- The process of converting ac to dc is known as rectification
- This is usually achieved by the use of diodes
- Diode can form naturally e.g. Corrosion product on telephone lines or at a macroscopic level on bare steel
- HORRIBLE FACT
- DIODES CAN FORM ON BARE STEEL AND SOMETHING CALLED FARADAIC RECTIFICATION CHANGES THE AC TO DC

Half wave rectification



Difference between resistance and impedance

- Resistance is used when talking of dc circuits
- With ac circuits capacitance and inductance are significant
- Capacitance is the charge that appears between two plates and is expressed in Farads
- An inductor has an inductance of one henry if an emf of one volt is induced in the inductor when the current through the inductor is changing at the rate of one ampere per second.

Difference between resistance and impedance

- The affect of ac on a capacitor and an inductor is that they react against and impede the current flow (and also change the relationship between the phase of the voltage and the current)
- Impedance is a combination of resistance, capacitive reactance and inductive reactance and is expressed in ohms (just like resistance)
- Inductive reactance is directly related to the frequency
- Capacitive reactance is inversely related to frequency

How electrical energy is stored

- Capacitors store energy as an electric charge. The energy is proportional to the square of the voltage.
- Inductors store energy as a magnetic field. The energy is proportional to the square of the current.

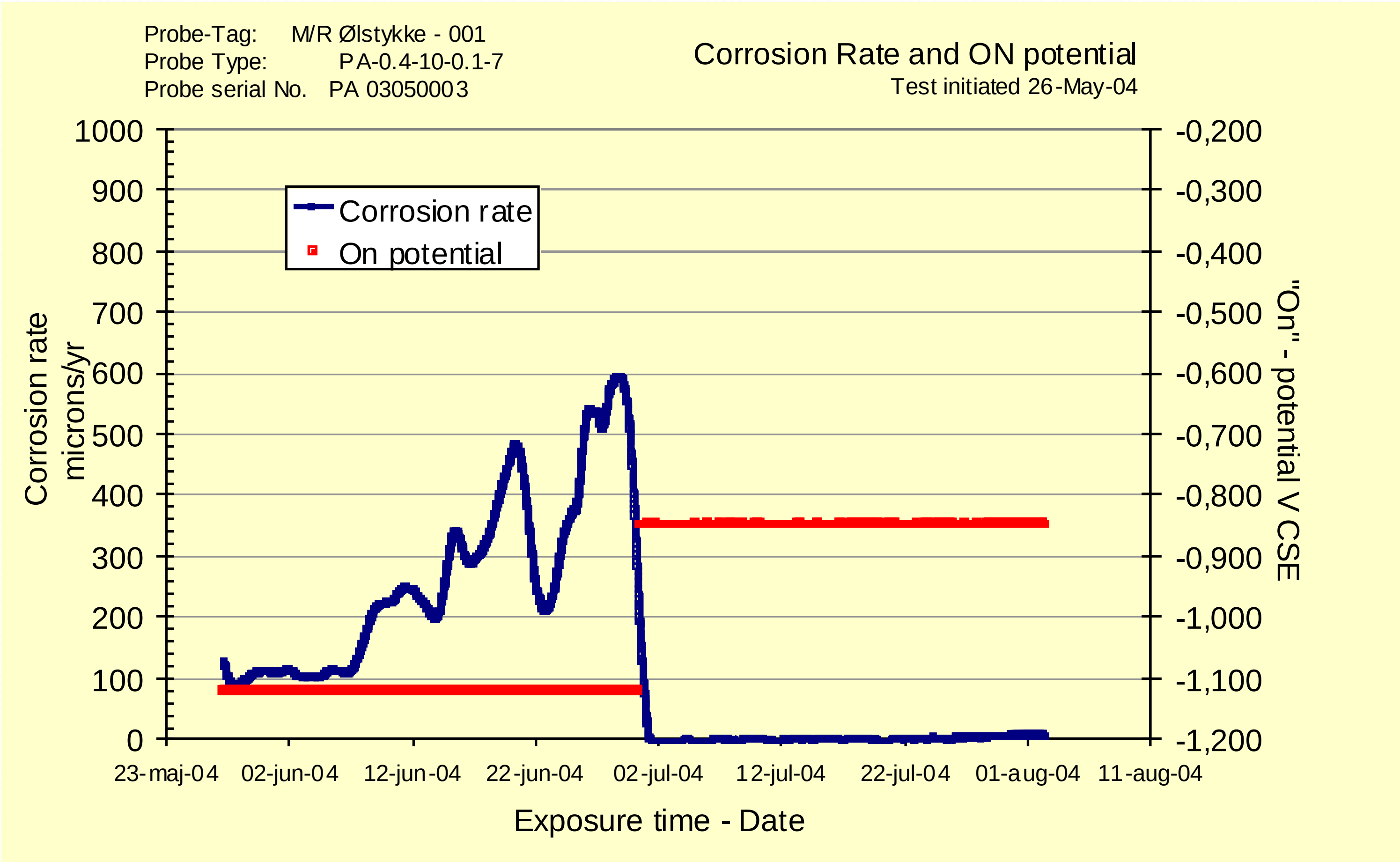
What do we know so far?

- The varying magnetic field from the overhead lines will induce a voltage in the pipe
- Current will leave the pipe at a coating defect
- The ac current is rectified at the defect by Faradaic rectification and dc current leaves the pipe
- Dc current will consume metal

Cathodic Protection

- Cathodic protection provides corrosion protection where coatings have failed by ensuring that no current leaves the pipe
- The chemical characteristics change at the coating defect (changes the pH) and it becomes more alkaline
  - pH at a corrosion pit can be between 10 and 12
- The more cathodic protection current the greater the alkalinity
- Alkalinity has an impact on the ac corrosion risk

Cathodic protection & ac corrosion



What can we do about it?

- Make sure there are no coating defects.
  - Impossible for anything other than a very small length of pipe.
- Stop the ac getting on the pipe.
  - Not usually possible to move the pipe, the ac cables, or to switch the power off.
- Increase the cathodic protection
  - Too much cathodic protection will exacerbate the problem

How do we know if we are at risk?

Some rules of thumb for when there may be a risk:

- Ac powerline voltage greater than 110kV
  - Between 275 and 400kV of most concern
- Pipeline within 150m of the overhead line
- If pipeline is longer than 2Kms the risk increases
- Ac current density greater than 30A per square metre increasing risk
- Pipe to soil potential more negative than -0.950

Measurements

- Details of measurement techniques is beyond the scope of this presentation
- Typical measurements are:
  - Pipe to soil potential (ac)
  - Pipe to soil potential (dc)
  - Coupon current density
  - ER corrosion probes

Commonly adopted Measurement Criteria

- < 10v ac on the pipline
- < 4v ac if soil resistivity less than 25 ohm.m
- Ac to dc current density ratio < 5 = low risk
- Ac to dc current density ratio 5 – 10 = medium risk
- Ac to dc current density ratio > 10 = high risk

Conclusions

- Well coated pipelines near to high voltage cables (> 110kV) are at greatest risk
- Typically high risk areas are where the pipeline or the ac cable changes direction
- Simple measurement of the ac voltage is not an indication of the risk
- Increasing the cathodic protection current may increase the ac corrosion
- Coupons and ER probes are essential to determine the key characteristics

Further reading

- CEOCOR handbook
- CIGRE Booklet
- CEN Technical note
- CEN Standard (in preparation)