DCVG %IR for Coating Defects Assessment

Impact of Burial Depth and Soil Resistivity

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Abstract

As a cost-effective indirect coating defect assessment method, Direct Current Voltage Gradient (DCVG) survey is widely utilized in the pipeline industry to investigate the coating defect. It is a common practice that DCVG %IR is used for ranking the risk of coating defects. In this paper, we demonstrated the science case of a ranking defect with %IR as well as its limitation. Other than %IR, the variation of local soil resistivity, location of coating defect, burial depth and average soil resistivity is also having a great impact on DCVG %IR. Local soil resistivity decrease 0.2 of its original due to local rain, the same coating defect will show 5 times higher in %IR. If a coating defect located 5 m depth will show 88% %IR lower than the same coating defect in 1 m of standard burial depth. Pipeline engineer and corrosion engineer shall fully understand the implications for such practice to avoid misinterpreting of coating defect information due to skewed %IR.

Introduction

As a cost-effective indirect coating defect assessment method, Direct Current Voltage Gradient (DCVG) survey is widely utilized in the pipeline industry to investigate the coating defect. DCVG %IR at the defect indication ranking the seriousness of coating defects is a common practice, although DCVG standard stated that there is generally not directly related to defect size, as factors such as the shape and orientation of the defect, surface films on the exposed steel, local variations in soil resistivity and depth of the defect can greatly affect the calculation (AS 4827.1). The significance of burial depth and soil resistivity on DCVG %IR is often overlooked while %IR is used for pipeline coating defect ranking. However, pipeline engineer and corrosion engineer shall fully understand the implications for such practice to avoid misinterpreting of coating defect information due to skewed %IR.

DCVG Theory

DCVG is a method of measuring the change in the electrical voltage gradient in the soil and around the pipeline to locate coating defects. Its %IR is the IR drop between a point on the ground directly above the coating defect and remote earth, expressed as a percentage of the estimated signal amplitude between the coating defect and remote earth:

$$\%IR = \frac{S_{OL}}{S_{CD}} \times 100 \qquad (eq.\ 1)$$

S_{OL} is IR drop between a point on the ground directly above the coating defect and remote earth

S_{CD} is DCVG signal amplitude to remote earth at coating defect. This is illustrated in .

SoL: IR drop between a point on the ground directly above the coating defect and remote earth
ScD: DCVG signal amplitude to remote earth at coating defect

Figure 1 DCVG method for coating defect
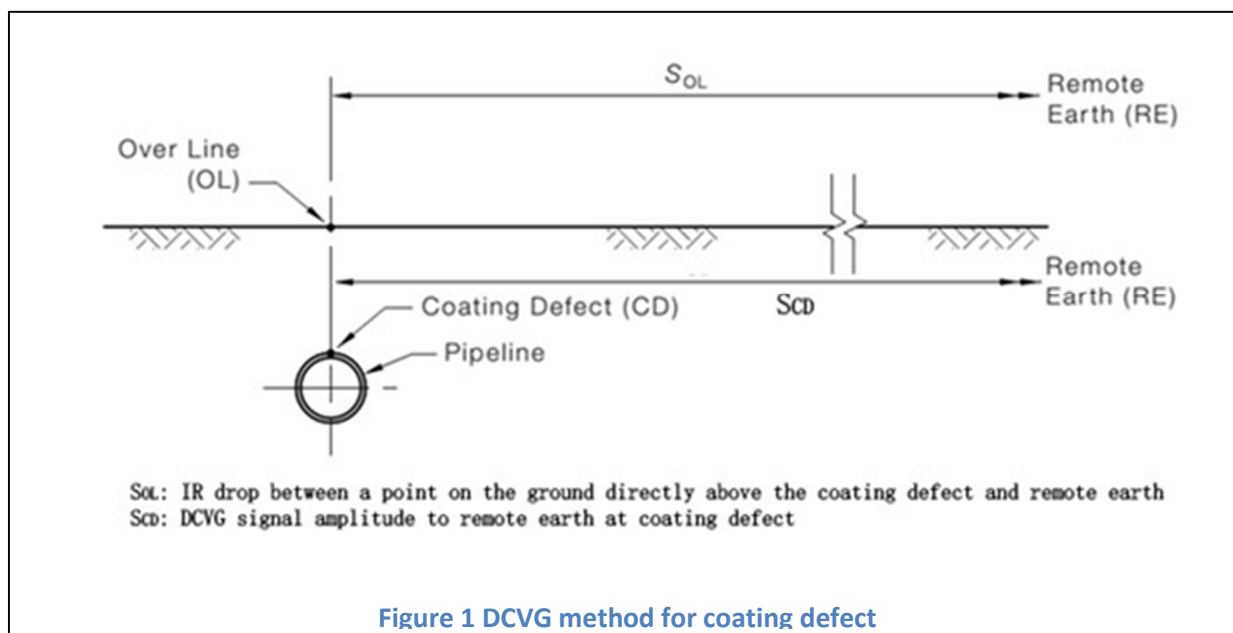
The measurement of %IR is illustrated in
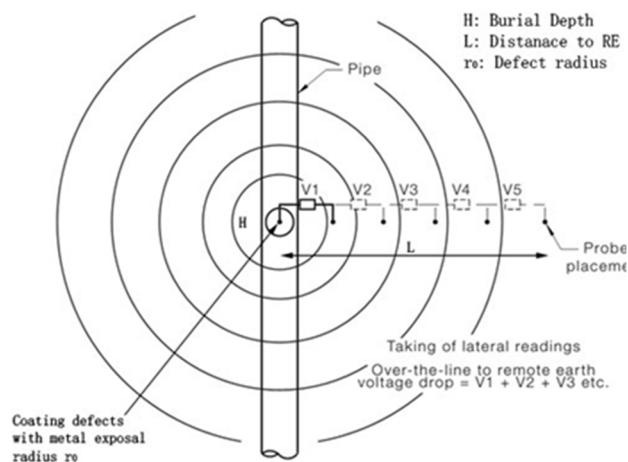

Figure 2. There are two parts S_{OL}, which is an IR drop between a point on the ground directly above the coating defect and remote earth, and S_{CD}, which is DCVG signal amplitude to remote earth at coating defect.

S_{OL} can be calculated by the equation:

$$S_{OL} = \sum (V_i^{ON} - V_i^{OFF}) = \frac{\rho I}{2\pi} \left(\frac{1}{H} - \frac{1}{\sqrt{H^2 + l^2}} \right)$$
(eq. 2)

in which
     H is the burial depth,
     l is electrode spacing to remote earth
     ρ is the average soil resistivity
     I is current

$S_{CD} = U_{ON} - U_{OFF} = IR$ (eq.3)

in which R is soil resistance

For a coating defect with a radius of r_0, the soil resistance(R) for the defect is

$R = \frac{\rho_0}{4r_0}$ (eq.4)

Therefore,

$S_{CD} = \frac{\rho_0 I}{4r_0}$ (eq.5)

In which

r_0 is the radius of coating defect

ρ_0 is soil resistivity in the vicinity of the coating defect

The IR ratio of S_{OL} and S_{CD} eliminates the current I, and directly relates to the size of a coating defect r_0:

$\%IR = \frac{S_{OL}}{S_{CD}} \times 100 = \frac{2\rho}{\pi\rho_0}(\frac{1}{H} - \frac{1}{\sqrt{H^2+l^2}}) \cdot r_0 \times 100$ (eq.6)

In normal conditions, since soil resistivity, local soil resistivity and burial depth are all considered as constant, then the %IR is directly related to the size of the coating defect r_0.

$\%IR = \frac{S_{OL}}{S_{CD}} \times 100 = C \cdot r_0$ (eq. 7)
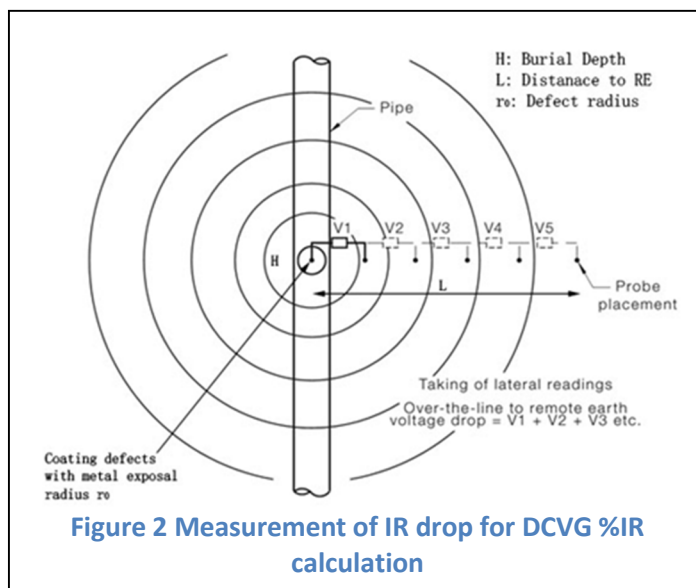
In which C is a constant and equals to:

$C = \frac{2\rho}{\pi\rho_0}(\frac{1}{H} - \frac{1}{\sqrt{H^2+l^2}}) \times 100$ (eq.8)

This is the science behind by using %IR for sizing the coating defect. However, when we closely looked at %IR, burial depth (H), and average soil resistivity (ρ), and local soil resistivity (ρ) in the vicinity of the coating defects are also

Figure 3 Coating checking defect, coating damaged however no metal exposure therefore zero %IR

functions of DCVG %IR measure, i.e. to the actual size of coating defect.

H: Burial Depth
L: Distance to RE
r₀: Defect radius

V1 V2 V3 V4 V5

Pipe

Probe placement

Taking of lateral readings
Over-the-line to remote earth
voltage drop = V1 + V2 + V3 etc.

Coating defects
with metal exposal
radius r₀

Figure 2 Measurement of IR drop for DCVG %IR calculation

Coating defects v.s. exposed metal surface

It is evident that only the exposed metal surface will result in such a voltage gradient. In reality, large coating defect may show little metal exposed. A typical example is checking, in which the surface of the paint film to become brittle
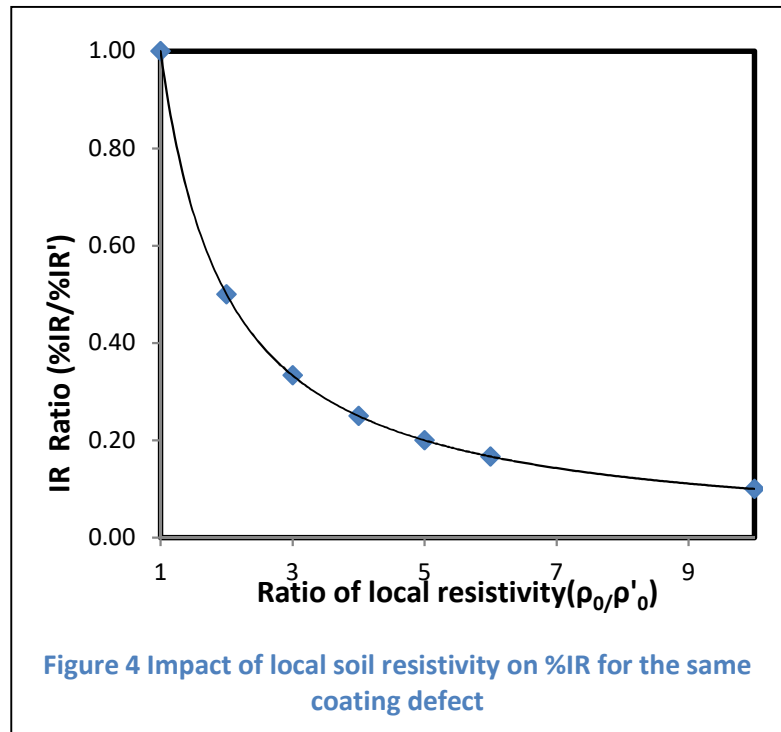
and crack (Figure 3). However, fine cracks do not penetrate the metal surface. In this case, the DCVG will show no %IR unless the metal surface is exposed.

Local soil resistivity in the vicinity of coating defect

Local soil resistivity in the vicinity of coating defect is inverse to the IR indication even exposed metal surfaces are the same. The %IR is much lower with high local resistivity near the defect:

$$\%IR == \frac{2\rho}{\pi\rho_0}\left(\frac{1}{H} - \frac{1}{\sqrt{H^2+l^2}}\right) \cdot r_0 \times 100 = C \cdot \frac{r_0}{\rho_0}$$
(eq.9)

For example, if the local resistivity in defect A is 5 times of that in defect B, the %IR$_A$ is only 20% of %IR$_B$. This explains the difficulty in identifying the coating defects in dry soil or sandy soil conditions. One common practice is to spray

water and moisturized the local soil, which lowers down the local soil resistivity for the better %IR signal. This relationship is illustrated in Figure 4.

Burial Depth

Burial depth is another interesting parameter, which is often overlooked during coating review. Although most of the pipeline section is buried in the standard depth of 900mm, there are certain cases, for example, road crossing, the burial depth of the pipeline section is significantly different to other sections. It is shown as

$$\%IR = C \cdot \left(\frac{1}{H} - \frac{1}{\sqrt{H^2+l^2}}\right) \cdot r_0 \qquad \text{(eq.10)}$$

Figure 4 Impact of local soil resistivity on %IR for the same coating defect
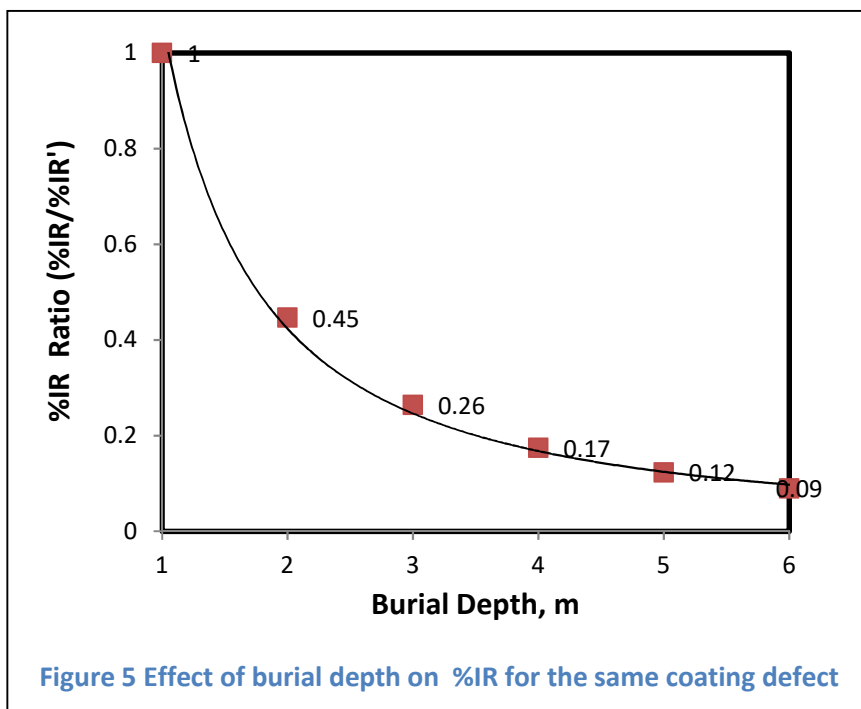
For the same defect size, the deeper the pipeline buried, the less %IR can be measured.

This is illustrated in Figure 5. For 5 m burial depth, the %IR of the same size defect is equivalent to 12% of %IR at 1 m depth, which is easily overlooked during the review if the only %IR is of concern. This is also important for coating assessment of large diameter, say 42 inches, pipeline. The normal burial depth is around 1 m. However, the engineer should aware of burial depth for coating defects locate at 12 o'clock and 3 o'clock is significant. The same size defects may cause more than double in %IR due to the defects locating in the significantly different burial depth.

Figure 5 Effect of burial depth on %IR for the same coating defect

Summary

While DCVG %IR is a useful tool for pipeline coating defect assessment, Engineer should be aware of burial depth, local soil resistivity other than defect size also have a great impact on %IR. This should be analysed carefully in pipeline coating risk assessment

Reference

[1] Von Baeckmann Handbook of Cathodic Corrosion Protection Gulf Professional Publishing
[2] Tony J.A. Richardson Shreir's Corrosion Volume 4, Elsevier Ltd.
[3] AS 4827.1 Coating defect surveys for buried pipelines Part 1: Direct current voltage gradient (DCVG)
[4] Gabriella Bolzon Integrity of Pipelines Transporting Hydrocarbons Corrosion, Mechanisms, Control, and Management, Springer, 2011
[5] TM0109-2009 Aboveground Survey Techniques for the Evaluation of Underground Pipeline Coating Condition

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