Influence of lightning on a magnetic anchor point

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Versioning

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Lightning magnetic anchor point

Introduction
Scaffold anchor points can be used in an outdoor installation. This means lightning can occur. The question is how the magnet will react to this. This document will identify what the expected impact will be in a worst case scenario to be determined.

Descriptive summary
A scaffold is always applied next to a metal object, like a tank. For safety, this object is always connected with the local electrical ground using a PE protective conductor connection with sufficient low impedance.
The scaffold will also be connected to the ground with its own connection. This is a standard procedure. No problems are known with this approach. If lightning strikes, everything will remain intact.
The anchor magnets are not intentionally electrically connected to the object or the scaffold. If a coating has been applied to the object, the electrical impedance between the scaffold pipe and the object will be relatively high: several ohms will not be unlikely. The coating can also be of a nature and quality that it provides an insulating layer. It will have a dielectric strength that will not be above several kV/mm (note any field increase as a result of spots and obstacles).
If the magnetic anchor point is located on an untreated object, the electrical connection between the object and the magnet will be relatively good. A tightened bolt connection that connects two bare metal strips to each other has an electrical impedance of at least several μΩ.
The connection of a magnet and an object will therefore have an impedance that ranges from several μΩ to isolator values with a dielectric strength of several kV/mm.

Drawing:

Object
Ground point
Scaffold
Ground point
Anchor points in red

Figure 1: Scaffold with anchor points attached to an object

In the situation that lightning strikes the scaffold, (a part of) the current can run to the object through a magnet.

<u>Characterization of the lightning</u>
In this case we assume a standardized lightning pulse rise time of 1 μs and an end time of 250 μs (e-power). This means a frequency content of at least 4 kHz.
Lightning current size with very good conductivity: 40 kA.
Lightning voltages are typically around 5 MV.
At these rise times no conductivity occurs because of the solid material. The current is limited to the surface. This is called penetration depth. At faster occurrences (higher frequencies) the penetration depth will be smaller. The penetration depth is determined by:

$$d = 1/\sqrt{(\pi.\mu_0.\mu_r.\sigma.f)}$$

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where:
d – penetration depth in m
μ_0 - absolute permeability in H/m
μ_r. - relative permeability
σ - conductivity (= 1/resistivity) in S/m
f - frequency in Hz
For carbon steel and 4 kHz the penetration depth is approximately 0.1 mm.

<u>Elaboration</u>
Lightning can strike at two fundamentally different locations:

point A – the object
point B – the scaffold

Electrically, a parallel connection exists from the resistance of the object parallel to the resistance of the scaffold. At first, the DC resistance is determined, then the HF impedance. This will first be done for the object and then for the scaffold. The phase shift will not be taken into account.

Resistance and impedance of object
As an example, we choose a steel tank of 7 mm thick steel, 35 m high and 30 meters in diameter. Essentially, this is a short tube with a large diameter.
The resistivity of carbon steel is: 0.18 10^{-6} Ω.m (DC value). For the lightning a penetration depth of 0.1 mm must be taken into account.
This tank will have a DC resistance of approximately 5.10^{-6} Ω. At a DC current of 40 kA when the full diameter joins in, a voltage is created of U = IxR = $40.10^{3}.5.10^{-6}$ = 200 mV.

For a lightning pulse, however, only the outer 0.1 mm shares in the conductivity (outer wall and inner wall each 0.1 mm). Furthermore, not the entire circumference of the tank takes part in an impact, which occurs at one point. It is assessed that the time it takes to get the voltage wave down from the top edge of the tank is also related to expanding in width.
Folded out in a flat surface, it looks as follows.

Figure 2: Result tank wall with lightning trajectory

The HF behavior creates an impedance of 35 times higher than the DC resistance. Since a part of the tank wall joins in, the resistance is increased by the ratio of the surfaces: 3290/1225 = 2.7 times higher. The DC resistance will in total be increased 35 x 2.7 = 94.5 times from 5 10^{-6} to 472.5 10^{-6} Ω. The voltage will also be 94.5 times higher. This provides a maximum of 18.9 V between the top and bottom of the tank, which will not lead to problems.

Resistance and impedance of scaffold
The electrical impedance consists of four parallel scaffold pipes with a height of 35 meters. A scaffold pipe of 4 meters weighs 19.1 kg. With a special gravity of $7.8x10^{3}$ kg/m^{3} the steel section of the scaffold pipe is $0.6x10^{-3}$ m^{2} = $0.6x10^{3}$ mm^{2} . This results in a wall thickness of 3 mm.

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The electrical resistance at 35 meters high will than be approximately 10 m Ω (DC value) per pipe. Four parallel pipes have a DC resistance of 2.5 m Ω. When a current of 40 kA runs through, a voltage of 100 V is created.
For a lightning current that only passes through the outer 0.1 mm (outside and inside tube) the impedance will be 15 times bigger: 37.5 mΩ. This also creates a 15 fold voltage: 1500 V. Even this is not problematic in itself.

Power distribution at lightning
It is important to determine how big the current through an anchor point can become in worst case when lightning strikes in B. Here the worst case scenario will occur when one of the top anchor points is electrically correctly connected to the object and all the other anchor points are not. This is a highly unlikely situation. At a voltage difference between the scaffold and the object of 1500 – 18.9 V the lightning will blow through from the magnet sole to the object at more than one magnet. We are now considering a very worst case, however. The wiring diagram will in this situation be as follows:

Impact
R object = 472.5 μΩ
Ground
R scaffold = 37.5 mΩ

Figure 3: Electric view scaffold with one conductive anchor point on an object

Electrically, the ratio of the currents at an impact in B will be the reversed ratio of the resistances. This means that the ratio of current through an object and current through a scaffold will be 79:1. Nearly the entire lightning current that strikes at B will go to the object through the anchor point.

This current will run along the outside of the anchor point and will be distributed over the outer surface. The corresponding magnetic field will also remain on the outside of the magnet. Roughly after every penetration depth a factor e (natural log base) attenuation of the magnet field will be provided. For a characteristic distance of 10 mm between the current path and the magnet, a factor of approximately e_{10} = 22,000 attenuation will occur.
For demagnetization of Neodymium a field of approximately 1 MA/m is required. When the permanent magnets are at a distance of 1 cm from the current path of the lightning and if massive steel exists between them, the current on the outside must generate a field that is 22,000 times as great.
Maxwell shows that H = I/(2.π.d) where d is de distance between the current path and the magnet.
A lightning current concentrated on 1 line creates a field at a distance of 1 cm of:
H = 40 kA/(2x3.14x0.01) = 640 kA/m= 0.64 MA/m. This is a factor of 34000 too small to be able to demagnetize. In this case the behavior of the steel is completely neglected.
In practice, the current will not follow one line, but will be distributed over the entire surface of the magnet. This will lead to lower current densities and therefore lower fields at the location of the permanent magnets in the magnet.

Conclusion
Even in a worst case scenario where one anchor point would carry the full lightning current of 40 kA, no demagnetization of the Neodymium magnets in the anchor point is to be expected.