The following is an analysis of the earthing resistance for surge arresters on the distribution network. The simplified analysis is based on lumped parameter circuit impedance values for a lightning strike.

Assume lightning strikes a phase conductor of an overhead line. Refer to Figure 1 for an equivalent circuit. $Z_s$ is the surge impedance of the overhead line which is typically 400 to 450 ohms for a single wire above ground. Assume 400 ohms for calculation. $I_1$ is the lightning current magnitude. Assume $I_1$ is 30 kA which is the 50% probability magnitude for lightning. Therefore, $I_2$ and $I_3$ are each 15 kA.

![Figure 1 – Equivalent circuit for lightning striking an overhead line](image)

Lightning current $I_3$ of 15 kA magnitude travels along the overhead line until it comes to the arrester branch circuit. Refer to Figure 2. This lightning current then splits between the arrester branch and the surge impedance of the line, $Z_s$. 
The surge arrester is connected across the plant with short leads to minimise inductance $L_L$. Typically, the arrester is directly mounted on the equipment tank. $L_D$ is the inductance of the downlead. Typically this ranges between 1.2 and 2uH/m. Assume a downlead inductance of 15uH (i.e. 1.5uH/m and 10m length). $R_e$ is the earthing resistance for the surge arrester.

Refer to Figure 3 for an equivalent circuit of the arrester branch in parallel with the surge impedance of the line which is 400ohms. $Z_A$ is the impedance of the arrester when conducting lightning current. It is assumed to be 10ohms. $Z_D$ is the impedance of the downlead. AS1768 – 2007 gives a 50% probability value for lightning rise time of 25kA/us. Assuming some sloughing off of the rise time as lightning travels along the phase conductor, a rise time of 15kA/us has been assumed for calculation. This gives a voltage drop of 225kV across the downlead (i.e. 15us x 15kA/us). The downlead impedance is 500ohms (i.e. 15uH/0.03us, where the travel time for the downlead is 0.03us assuming 10m lead and the transient speed is that of light, 300m/us). $R_e$ is the earthing resistance for the surge arrester. Assume a value of 30ohms for the earthing resistance which is the maximum value allowable by Energex’s current standard.
The arrester branch impedance is then 540ohms (i.e. 10+500+30). Lightning current $I_3$ of 15kA magnitude splits into $I_4$, 6.4kA, down the arrester branch and $I_5$, 8.6kA, continues along the surge impedance of the overhead line. The arrester will clamp the voltage across the plant to 64kV (i.e. 6.4 x 10) which is within its rating. The BIL of the insulators for 11kV systems is 95kV and for 33kV insulation is 170kV.

The voltage rise of the phase conductor above ground due to the lightning strike is therefore approximately 481kV (i.e. 225 + 10 x 6.4 + 30 x 6.4). This applied lightning impulse of 481kV will flash over adjacent insulators as it is much larger than their BIL. In summary, a 50% probability lightning stroke amplitude and rise time will not cause damage to the plant protected by the surge arrester but the phase conductor voltage rise will cause impulse flashover of adjacent insulators probably resulting in a fault with power frequency follow current.

Now consider the effect of varying the earthing resistance from 5 to 100ohms. Assuming the arrester conducting impedance is 10ohms and the downlead voltage drop is 225kV in all cases, the currents and voltages have been calculated and are given in Table 1. Note that for all cases considered, the arrester clamps the voltage across the plant to less than its BIL.
Table 1 – Summary for different arrester earthing resistance values

Note from Table 1 that increasing arrester earthing resistance increases the phase conductor voltage to earth. At large arrester earthing resistances, the higher conductor impulse voltage rise will put more voltage stress on adjacent insulators and also insulators further away. Another way of looking at this is that for low arrester earthing values more energy is shunted to earth through the arrester branch and less energy continues along the phase conductor. While a low value of say 5ohms gives better performance it will be more expensive to achieve than 30ohms. It is recommended that the current standard value of 30ohms maximum for arrester earthing resistance be continued.