Q. Further to the response to PUB-NLH-238, explain how the pre-insertion resistor is used to discharge the dc cable prior to connection of the cable to the other pole.

A. For discussion purposes, assume that the spare cable had been connected in parallel to the positive pole cable and is operating at +350 kV when there is a requirement to switch the spare cable to the negative pole due to a loss of the negative pole cable. The first step of the cable-switching scheme requires that the spare cable be disconnected from the positive pole. When the switches connecting the spare cable to the positive pole are opened and the spare cable is isolated, the effect of the cable capacitance is to result in a trapped charge being maintained on the spare cable, similar to a shunt capacitor that has just been switched out of a circuit. For discussion purposes, the spare cable can be assumed to have a +350 kV voltage on it despite being isolated from the positive pole. Before the spare cable can be connected to the negative pole operating at -350 kV, the trapped charge on the spare cable must be dissipated such that the spare cable voltage is brought to zero voltage (i.e., discharge the cable). This is accomplished by connecting the spare cable to ground through a resistor as shown in Figure 1.

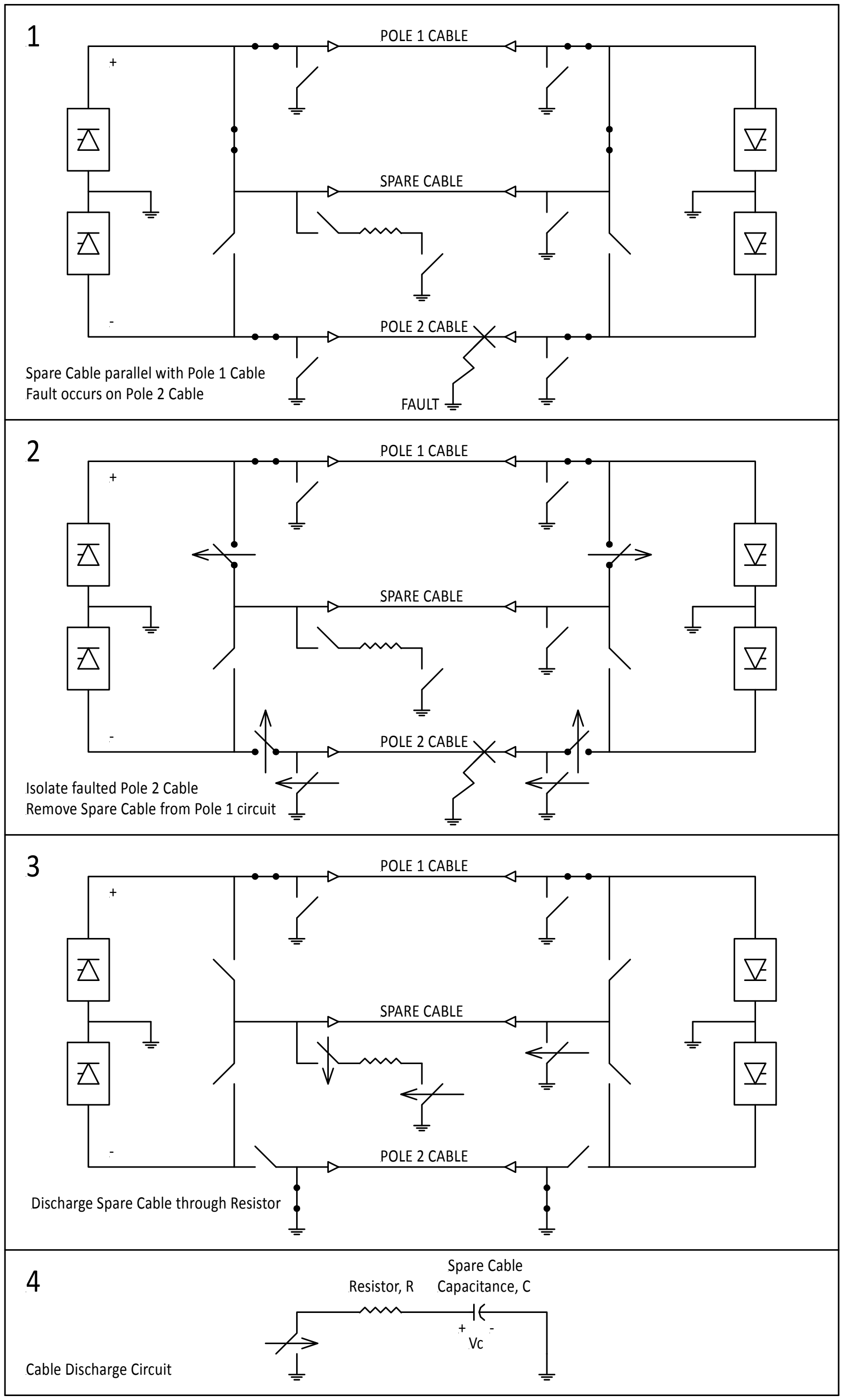

Figure 1 – Simplified Spare Cable Discharge Scheme

The connection provides an RC circuit in which the voltage on the cable is calculated by the equation:

$$Vc = Vco * e^{\frac{-t}{R*C}}$$

Where,

Vc is the cable voltage in kV

Vco is the initial cable voltage at the time the ground switches are closed

t is the time in seconds

R is the pre-insertion resistor resistance in ohms, Ω

C is the cable capacitance in Farads, F

Given a total spare cable capacitance of 16.72 µF (16.72 x 10^{-6} F), one can calculate the cable voltage versus time for varying pre-insertion resistor ohmic values during the spare cable discharge sequence.

Figure 2 provides a plot of the spare cable voltage versus time for both a 100 Ω and a 400 Ω pre-insertion resistor. One notes that the lower pre-insertion resistor value results in a faster discharge time for the spare cable.

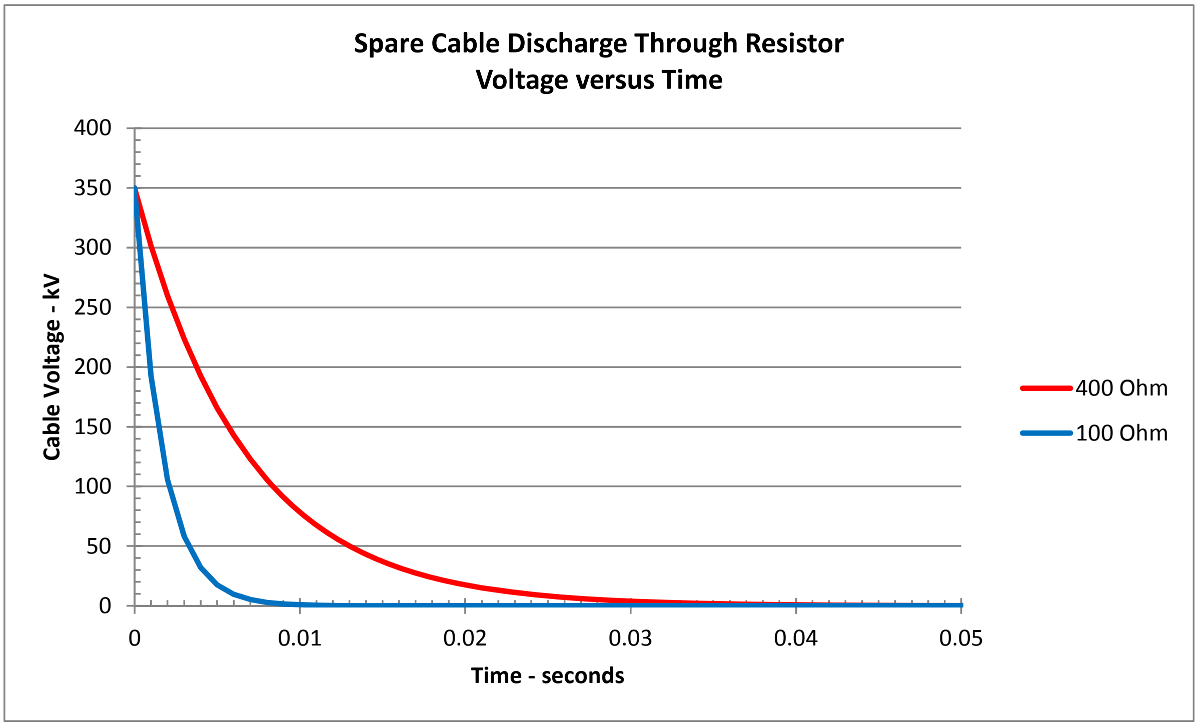

Figure 2 – Spare Cable Voltage versus Time for Discharge Through a 100Ω and a 400Ω Pre-insertion Resistor

Similarly, the spare cable discharging current can be calculated for the RC circuit using the following equation:

$$ic = \frac{Vco}{R} * \left(e^{\frac{-t}{R*C}}\right)$$

Where

ic is the cable current in kA

Vco is the initial cable voltage at the time the ground switches are closed in kV

t is the time in seconds

R is the pre-insertion resistor resistance in ohms, Ω

C is the cable capacitance in Farads, F

Figure 3 provides a plot of the spare cable discharge current versus time for both a 100 Ω and a 400 Ω pre-insertion resistor[1]. One notes that the lower pre-insertion resistor value results in a greater discharge current for the spare cable. For the 100Ω resistor value the peak discharge current equals 3.5 kA versus a peak discharge current of 0.9 kA for the 400Ω resistor.

Consequently, the selection of the pre-insertion resistor size is a balance between the discharge time and the peak discharge current. The pre-insertion resistor size will be selected during the final design stage.

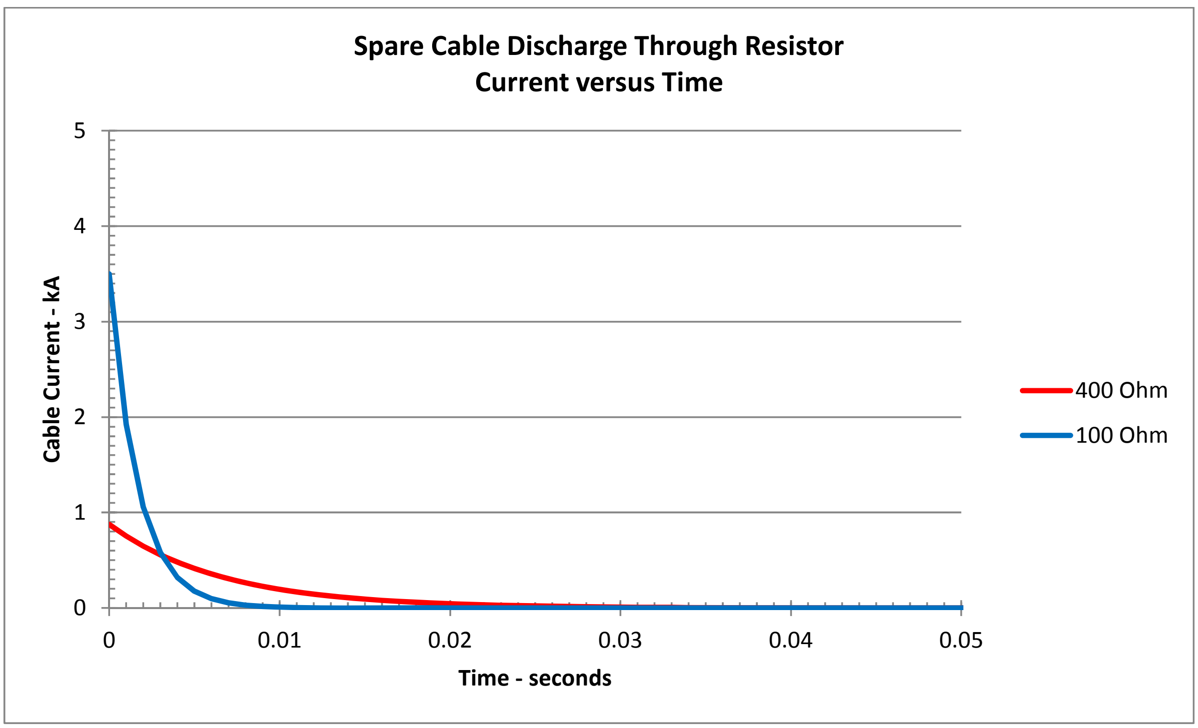

Figure 3 – Spare Cable Discharge Current versus Time for Discharge Through a 100Ω and a 400Ω Pre-insertion Resistor

[1] The cable current is depicted in Figure 3 as a positive current for clarity despite the current flow being out of the cable, and therefore by convention, considered negative in value.