Air core inductors in low-voltage capacitor banks

Some project specifications call for the use of air-core type inductors per NEMA® ICS-2 to limit the capacitor in-rush current to a value equal to or less than the capacitor switching rating of the contactor. This is addressed specifically in Paragraphs 9.3.2 and 9.3.3 of NEMA ICS-2.

The Eaton LV AutoVAR uses contactors specially designed for capacitor switching, which use pre-make contactors and resistors to greatly reduce the inrush current. The rated inrush current of these contactors is such that they do not require inductors. Capacitors brought online using a traditional contactor results in a significant current spike because of the voltage differential between the capacitor and the system. The pre-make contactors close for a duration of 5–10 ms bringing the capacitor between 90% and 95% of the system voltage, reducing the current spike when the capacitor is brought online. Figure 1 and Figure 2 show the difference between the magnitude of inrush current with and without pre-make contactors.

Figure 2. Without pre-make contactors (B&J Oszi 12)
- K3-18NK
- 12.5 kvar (18 A/400 V)
- Vertical: 250 A/div
- Horizontal: 0.5 ms/div

Figure 2 shows a make current peak without pre-make contactors with about 1200 A with high power opposite to 280 A with low power (power = integrated area). Of course, the contactors endure a few switches without pre-make contactors.

In addition to the use of pre-make contactors to mitigate transient levels, the AutoVAR uses small wire coil inductors to provide additional mitigation. In Paragraph 9.3.2, the NEMA standard states “In many installations, the impedance of connecting conductors may be sufficient for this purpose.” Paragraph 9.3.3 of that standard provides an example of how to provide inductance if installed wire levels are insufficient by creating a wire coil of 6 inches in diameter with eight turns for voltages greater than 250 V and less than 600 V.

Using the equation below, the inductance of the coil can be calculated.

$$L_{coil} = \frac{N^2 \mu \mu_r (\frac{D}{2}) \left[\ln \left(\frac{8D}{d}\right) - 2\right]}{2}$$

- $L_{coil}$ = inductance of the coil in henries (H)
- $N^2$ = number of turns
- $\mu$ = permeability of free space = $4\pi \times 10^{-7}$
- $\mu_r$ = relative permeability
- $D$ = loop diameter
- $d$ = wire diameter

The coils used in the AutoVAR 600 have a 6-inch loop, are 1 turn, made with 4 AWG copper wire, and have an inductance of 3.31 µH.