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13. How do Harmonic Mitigating Transformers reduce voltage distortion?

Delta-wye transformers, even those with a high K-factor rating, generally present high impedance to the flow of harmonic currents created by the non-linear loads. Question 8 showed that the non-linear loads are current sources that push the harmonic currents through the impedances of the system. Any voltage drop across the impedance of the transformer at other than the fundamental frequency (60 Hz) is a component of voltage distortion.

Because of its higher impedance to harmonic currents, the voltage distortion at the output of a delta-wye transformer often reaches the 5% maximum voltage distortion limit recommended by IEEE Std. 519-1992 by the time that the secondary side load has reached just one-half of full-load RMS current. At closer to full-load, these transformers can produce critically high levels of voltage distortion and flat-topping at their outputs and at the downstream loads.

To minimize the voltage distortion rise due to the transformer itself, Harmonic Mitigating Transformers (HMTs) are designed to reduce the impedance seen by the harmonic currents. This is accomplished through zero sequence flux cancellation and through phase shifting - a combined strategy pioneered by MIRUS. The secondary winding configuration of the HMT cancels the zero sequence fluxes (those produced by the 3rd, 9th, 15th (triplen) current harmonics) without coupling them to the primary windings. This prevents the triplen current harmonics from circulating in the primary windings as they do in a delta-wye transformer. The flux cancellation also results in much lower impedance to the zero sequence currents and hence lower voltage distortion at these harmonics. In addition, the reduced primary winding circulating current will lower losses and allow the transformer to run cooler.

The remaining major harmonics (5th, 7th, 11th, 13th, 17th & 19th) are treated to varying degrees through the introduction of phase shifts in the various HMT models.

Single output HMTs are offered in 0° and 30° models to provide upstream cancellation of 5th, 7th, 17th and 19th harmonic currents on the primary feeder.

In a dual output HMT, 5th, 7th, 17th and 19th harmonic current fluxes are cancelled by the 30° phase shift between the secondary windings so that only residual amounts of 5th, 7th, 17th, and 19th current harmonics will be found in the primary side windings.

A three output HMT is configured such that the relative phase shift between the three sets of secondary windings will cancel 5th, 7th, 11th and 13th harmonic fluxes without coupling them to the primary windings.