Actual Kvar Output Versus Installed Kvar for Harmonic Filter Banks

Introduction

When specifying, purchasing, or evaluating harmonic filter banks, it is important to understand the difference between the actual kvar output of a perspective harmonic filter bank versus its installed kvar. This technical note provides background information to engineers to aid in the evaluation and design of harmonic filter banks.

Background

Capacitors utilized in harmonic filter banks need to have their voltage ratings increased beyond normal system voltage levels due to the following reasons:

- The harmonic filter reactor causes a fundamental voltage rise (i.e. A 60-Hertz voltage rise on a 60- Hertz system) on the capacitors. The 60-Hertz voltage rise can be calculated utilizing the following formula:

$V_{rise} = N^2 / (N^2-1)$

Where –

V_{rise} = Fundamental Voltage Rise Due to Filter Reactor

N = Tuning point of Filter Bank

For a typical 5th harmonic filter, the 60-Hertz voltage rise is on the order of 4.1%. The voltage rise will increase as the tuning point is decreased. This inherent voltage rise on the capacitor requires that the capacitors used in the harmonic filter bank be rated higher than the nominal system voltage. Although capacitors have an over voltage capability by ANSI Standard 18, this capability or allowed voltage margin should not be used as part of the design criteria for the harmonic filter bank since these margins are for voltage variations due to system regulation.

- The harmonic voltage rise on the capacitors due to the flow of harmonic currents into the harmonic filter bank.

Since the kvar output of a capacitor varies with the square of the applied voltage, and the applied voltage on the filter capacitor is below its nameplate rating (due to the reasons as noted above), the output kvar of the filter bank will be less than the total kvar installed in the bank. For most 5th harmonic filter banks, the installed kvar can be as high as 25% to 40% more than the actual output kvar of the filter bank. For this reason, it is essential to understand the difference between installed kvar and actual kvar output of a filter bank. In many specifications the following terms are commonly used:

Effective kvar – This value is defined as the fundamental kvar output of the harmonic filter bank at rated system voltage. This value should always be specified when evaluating or specifying harmonic filter banks.

Actual kvar/Installed – This value is defined as the actual kvar that is installed in the filter bank at the rated voltage of the capacitors. Typically this value may not be specified as it may be left up to the filter manufacturer. The capacitor kvar and voltage rating, however, is very important in determining the maximum filtering capability of the perspective filter and should be considered when evaluating competing bids.

Effective Kvar Calculation

The effective kvar of a filter bank can be calculated utilizing the following formula:

$Kvar_{out} = N^2V^2_{sys}kvar_{cap} / [(N^2-1)V^2_{cap}]$

Where –

$Kvar_{out}$ = The output kvar (or effective kvar) of the filter bank at rated system voltage.

N = The tuning point of the harmonic filter bank.

$kvar_{cap}$ = The total installed nameplate kvar (all three phase) of the filter bank.

V_{cap} = The line-to-line Nameplate Voltage Rating of the Capacitors.

For wye-connected banks, V_{cap} would be equal to the product of 1.73 and the Nameplate voltage rating of the capacitor.

The following example shows how a harmonic filter kvar requirement can be misinterpreted and lead to a lack of desired kvar output.

A customer desiring 3,000 kvar at 13.8kV issues a specification stating that a 3,000 kvar 4.7th harmonic filter bank is required. A perspective vendor's quote states a 4.7th harmonic filter bank is being supplied and that it consists of 3000 kvar (as requested in an RFQ). To further evaluate the quotation, the customer request the voltage rating and kvar rating of the capacitors installed in the filter bank. The vendor informs the customer that the bank consists of 15 200-kvar 9.96kV double bushing capacitors connected in an ungrounded-wye configuration (Five 200 kvar capacitors per phase). The customer calculates the voltage utilizing the formula as stated above and determines the kvar output of the filter bank at 13.8kV would only be 2,015 kvar, a value that is much lower than the customer requires to correct their power factor.

The above example shows the importance of distinguishing between effective kvar and installed kvar. To achieve an effective kvar of 3,000 kvar, the vendor would need to install 4,465 kvar at 9.96kV into the filter bank.

Conclusion

When specifying or evaluating harmonic filters, it is important to distinguish between effective kvar (output kvar of filter bank) and installed kvar. To fully compare competing filter bank quotes, the following key questions should be asked and confirmed:

- What is the tuning point of the harmonic filter bank?
- What is the effective kvar output of the filter bank at your rated system voltage?
- What is the voltage and kvar rating of the capacitors utilized in the proposed harmonic filter bank?
- What justification was utilized in determining the required capacitor voltage?

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