EATON | Cutler-Hammer

The Power Sheet

Consulting Engineer Edition

HARMONIC BLOCKING FILTERS

INTRODUCTION

Power quality issues are becoming a concern as facilities become more sophisticated. Microprocessor and computer equipment are especially sensitive to power quality. This newsletter deals specifically with harmonics and harmonic blocking filters.

NON-LINEAR LOADS

Linear loads are those loads which draw the full sine wave of current. In contrast, non-linear loads draw current in pulses at the sine wave minimum and maximum points, not consuming the full sine wave. The loads are named "non-linear" because these devices draw only parts of electric current wave rather than consuming the full sine wave of current. Non-linear loads cause harmonics.

The most common non-linear load is switch-mode power supply (SMPS). SMPS use AC power and convert to DC power by pulsing (opening/closing) IGBTs. This pulsing action only draws the peak of the current sine wave rather than the full wave, hence the term non-linear load.

Figure 1 shows balance single phase, non-linear loads. As the figure shows, little or no current flows in the neutral conductor when the loads are non-linear and balanced.

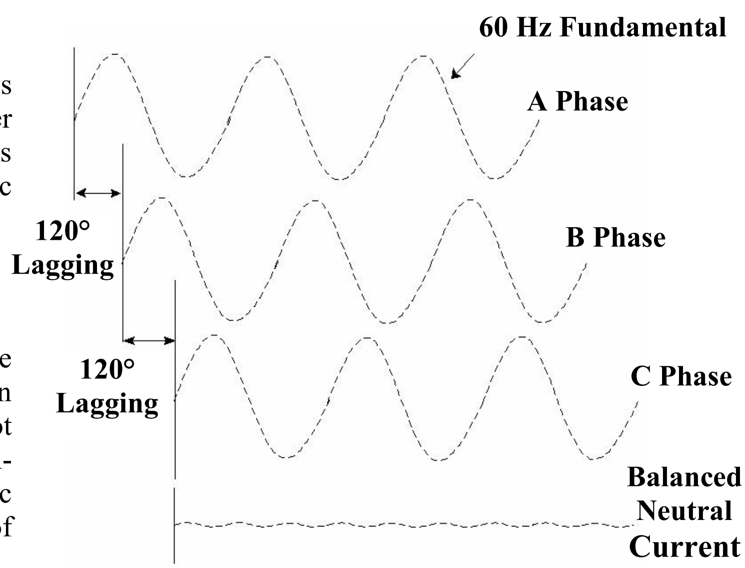

FIGURE 1 - Balanced Single Phase Loads without Triplen Harmonics

TRIPLEN HARMONICS

In commercial buildings, most non-linear (harmonic generating) loads are single phase caused by electronic lighting ballast, copying machines, uninterruptible power supplies and personal computers. Triplen harmonics are those which are the 3rd, 9th, 15th harmonic.

Triplen harmonics are the most damaging to an electrical system because these harmonics on the A-phase, B-phase and C-phase are in sequence with each other. Meaning, the triplen harmonics present on the three phases add together in the neutral rather than cancel each other out.

In general, harmonics present on a distribution system can have the following deleterious effects:

- Overheating of transformers & rotating equipment
- Increased Hysteresis losses
- Decreased kVA capacity
- Overloading of Neutral
- Unacceptable neutral-to-ground voltages
- Distorted voltage and current waveforms
- Failed capacitor banks
- Breakers and fuses tripping

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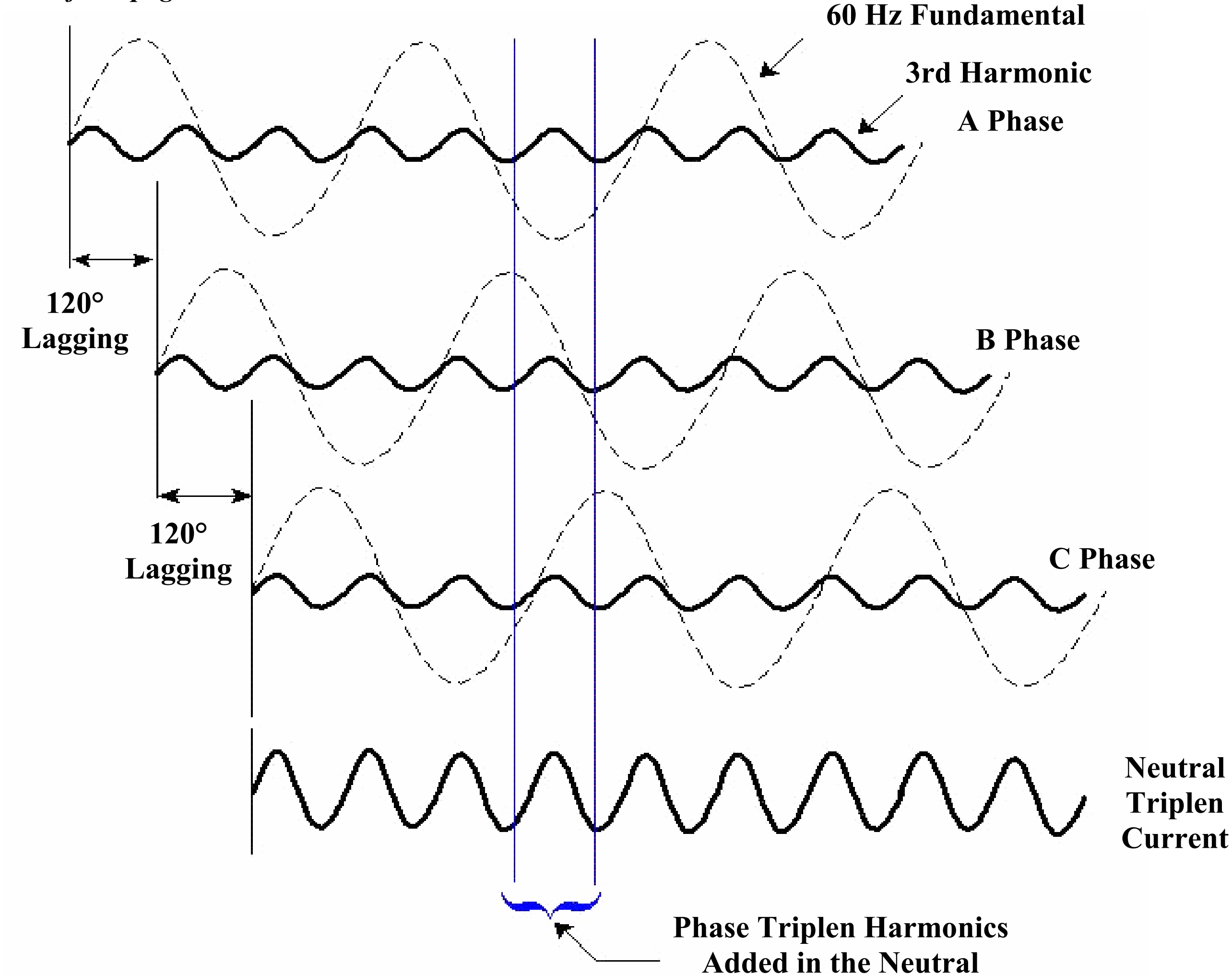

FIGURE 2 - Unbalanced Single Phase Loads with Triplen Harmonics

- Interference on phone and communications systems
- Unreliable operation of electronic equipment
- Erroneous registering of electric meters
- Wasted energy / higher electric bills - kW & kWh
- Wasted capacity - Inefficient distribution of power

The result can be overheating and failure of electrical components. Further, harmonic current is wasted electrical power.

Figure 2 shows single phase loads with the triplen harmonic currents adding in the neutral. Note the effect of the triplen (3rd) harmonic currents adding together in the neutral and increasing in magnitude.

TREATMENT of HARMONICS

Traditionally, harmonics were accommodated rather than prevented. By accommodating the harmonics, electrical distribution gear is designed and manufactured to ***withstand*** harmonic disturbances.

Harmonic Mitigating transformers only *accommodate* harmonic and do not solve the harmonic damage and harmonic losses in the electrical distribution system. Below are several ways harmonics are accommodated:

- Oversizing distribution switchgear to compensate for harmonic losses
- De-Rating transformers, again, to compensate for harmonic losses

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- Double or ever triple sized neutrals to defy the negative effects of triplen harmonics

Further, harmonic currents are electrical power that performs no work. Harmonics are wasted electrical energy that over burden the distribution system. This electrical overcrowding prevents an existing electrical distribution system from serving additional future loads. When designing a new electrical distribution system, future electrical loads and expansion must be considered. Future non-linear loads require forethought to account for possible extra distribution capacity due to energy wasted by harmonics.

PREVENTIVE MEASURES – HARMONIC BLOCKING FILTERS

Another alternative to the above problems is preventive measures – preventing harmonics, especially triplen harmonics, before these are an issue.

The advantage to preventing harmonics rather than merely accommodating harmonics, is *ability to expand and modify* the existing system. In contrast, preventive measures look toward the future and compensate for harmonics not only now, but for the future electrical loads.

Harmonic Blocking Filters do as the name implies; block the specific harmonic currents. Typically, harmonic blocking filters are built to eliminate a specific harmonic value. In this newsletter, the 3rd harmonic is specifically discussed as this harmonic is the most troublesome and potentially the most damaging.

As shown in Figure 3, a Delta/Wye transformer serving single phase, non-linear loads with triplen harmonics in the neutral. These harmonic currents overload the neutral conductor.

In addition, the harmonic current causes a circulating current in the Delta windings of the transformer. Because the high side of the transformer does not have a neutral, the harmonics in the low side neutral will induce a circulating current between the A, B, and C phase windings in the Delta.

This circulating current is wasted electrical energy and can overheat the transformer, thus shortening the transformer life.

HOW TO APPLY HARMONIC BLOCKING FILTERS

A harmonic blocking filter is a static device. Meaning, the filter is designed to eliminate a specific harmonic value and a specific magnitude of that harmonic value. In contrast, an active harmonic filter will measure the magnitude and harmonic values then adjust to eliminate those har-

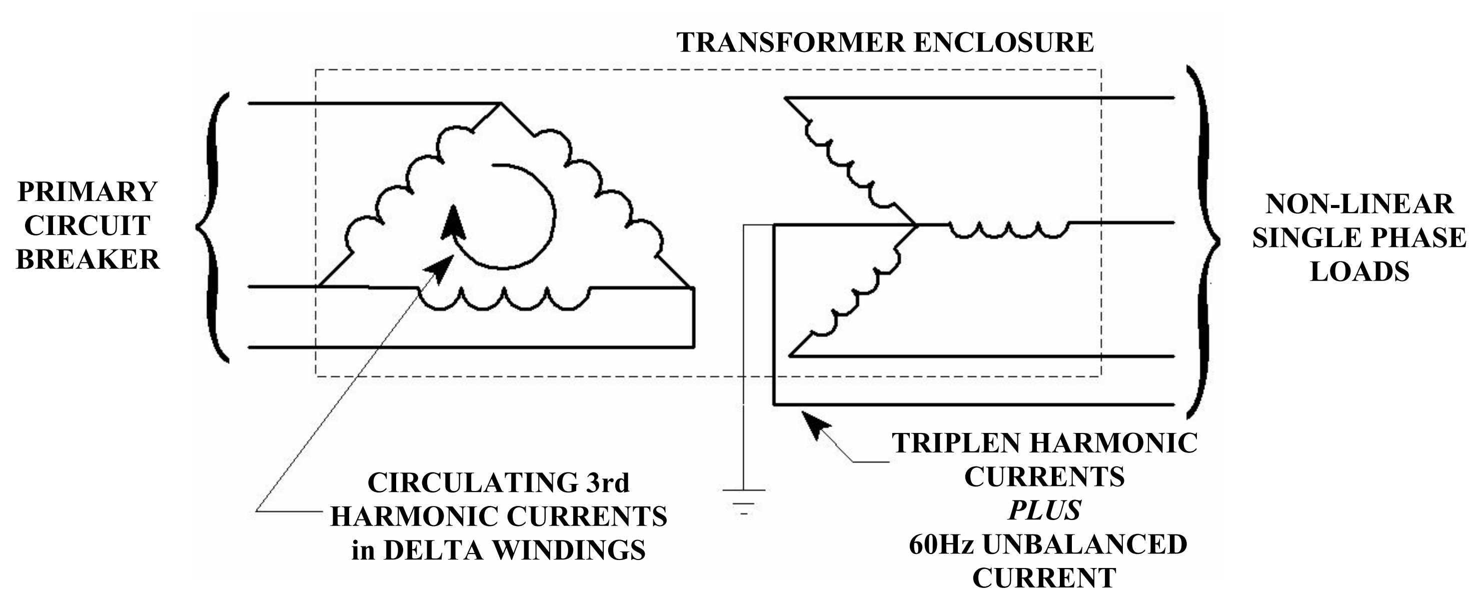

FIGURE 3 - Delta/Wye Transformer without Harmonic Blocking Filter

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monics values.

The blocking filter is constructed of capacitors, reactors and transformers. Again, designed only to eliminate a specific harmonic value.

Figure 4 shown how a harmonic blocking filter is applied. The filter is installed between the load side neutral conductor and the transformer neutral connection. In the specific case shown in Figure 4, the blocking filter is tuned to the 3rd harmonic.

When the 3rd harmonic is eliminated, the circulating current in the Delta windings of the transformer stop. The reason is the harmonic currents in the neutral pull through current from the Delta windings. Because a neutral is not present on the high side (Delta) of the transformer, the current circulates through the phase windings to feed the harmonic current demand.

As an analogy, think of a garden hose where the faucet is open feeding water through the hose. If the end of the hose is plugged, water will not flow even though the faucet is open. In the case of a harmonic blocking filter, the filter is the plug at the end of the hose and the water is the current in the Delta windings of the transformer.

Because a properly size and selected blocking filter eliminates the harmonic current, the neutral conductor does not need over sizing and the need for a "K" rated transformer is not needed.

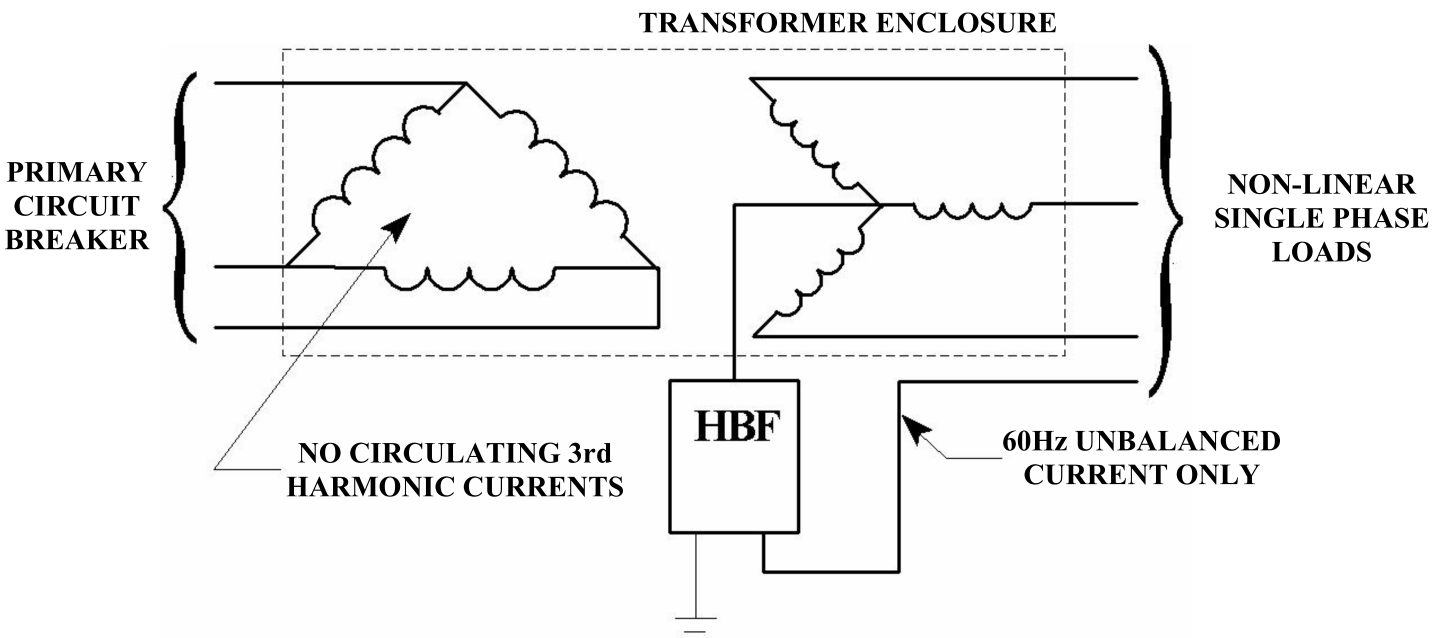

FIGURE 4 - Delta/Wye Transformer with Harmonic Blocking Filter