

Triplen harmonics

a look at a very effective low cost solution

Following Nigel Bird's article 'What is triplen harmonics' (September / October 2006) Ian Evans outlines a very effective low cost solution to this growing problem.

Ian C Evans, an acknowledged expert in the field, has been heavily involved in harmonic mitigation, both passive and active, since 1996. His company, Harmonic Solutions, supplies harmonic mitigation and associated services (e.g. training, surveys, investigations and consultancy) throughout the world to industrial, commercial, marine and offshore sectors. In 2005 he wrote the highly successful 240 A4 page harmonics guide 'Guidance Notes for the Control of Harmonics in Electrical Power Systems' for the American Bureau of Shipping.

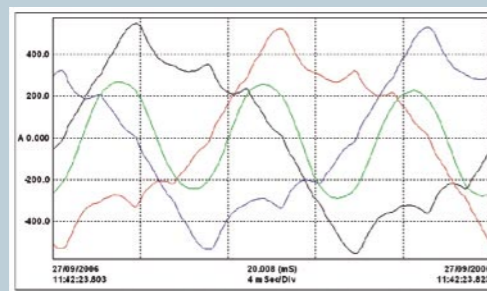
Multiple single-phase non-linear loads (e.g. computers, fluorescent lighting, single-phase AC drives, etc.) can be problematic on four wire systems (i.e. three-phase and neutral) because of excessive triplen harmonics, (i.e. 3, 9, 15, 21...), which add cumulatively in the neutral conductor. This results in:

- Overloaded and overheating neutral conductors (up 173% phase current).
- Overheated delta windings in distribution transformers.
- High earth to neutral voltages.
- Distortion of voltage waveform (including 'flat topping').
- Poor power factor.

In a four-wire system (i.e. three-phase + neutral), the phase currents' return path is via the neutral conductor. In a distribution system with only linear loads, the 120 deg phase shift between linear phase currents results in their balanced portions instantaneously cancelling out in the neutral.

However, in distribution systems with non linear, or mixed linear and non linear loads, the current on one phase does not have a 'pulse' on either of the two other phases with which to cancel. These current pulses add together in the neutral conductor, which can result in up to 173% of phase current levels, even if all phases are completely balanced. The frequency of the neutral current is predominately 150hz (for 50hz supplies) and mainly 3rd harmonic and other triplens.

Fig 1: Road tunnel lighting distribution board in Ireland. Phase and neutral current waveforms - note 150Hz neutral current



Figs 1 and 2 illustrate, as an example, the phase and neutral current waveforms, and neutral current harmonic spectrum respectively, measured on a four-wire distribution board feeding a large number of fluorescent lights in a large Irish road traffic tunnel.

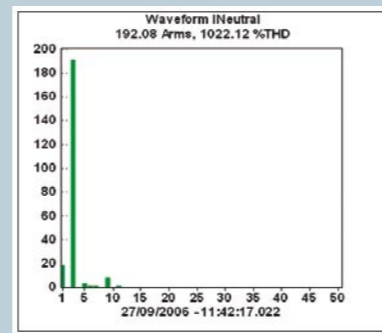


Fig 2: Tunnel lighting system distribution board. As can be seen the harmonic spectrum of neutral current is almost entirely 3rd harmonic therefore, the neutral current waveform will appear as 150Hz.

Note that in Fig 2, the third harmonic current was 191A and lthd 1022 % (the latter can be a little artificial as measured in neutral currents as lthd is measured against the fundamental which is only the imbalanced portion of the phase currents and therefore, quite small).

In the majority of cases, four-wire active filters (which inject on the neutral conductor as well as on three phases) have been used in the UK to address this issue. Whilst they can be very effective in isolating the source from the load(s), they are also very, very expensive, especially for the majority of applications where the triplen harmonics and the resultant high neutral currents are the salient problems. In addition, because of their very low source impedance (<1%), the voltage distortion on the load side is higher than without the filter in the circuit - a downside which can effect the performance and reliability of sensitive loads.

In North America, four-wire active filters are rarely used as they are simply deemed far too

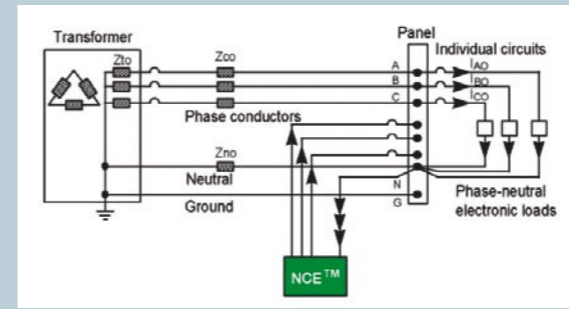


Fig 3: NCETM (neutral current eliminator) offloads up to 85% of triplen harmonics

expensive. What are widely used are 'neutral current eliminators', (NCETM) manufactured by Mirus International Inc. These patented, zero phase sequence transformers are a very effective, simple and inexpensive method of reducing the neutral currents in four-wire systems and are available to 1200A (and any number can be used in parallel).

The NCETM is connected as illustrated in Fig 3 and comprises of multiple windings on a common core. The windings of at least two phases are wound in opposition around each core leg in order that the magnetic fluxes created by the zero sequence currents will oppose, and therefore cancel out, providing an alternative low impedance path when connecting in parallel on a four-wire system.

Note that the positive and negative sequence fluxes (e.g. due to 5th, 7th, 11th, 13th harmonics, etc.) remain 120 degrees out of phase and are not cancelled out. In practical terms, the NCETM removes the majority of the triplen harmonics (also called zero sequence harmonics) from the neutral current and returns them to the three phases. It also balances the phase currents.

For larger power systems which require multiple NCETM units or where the total neutral current exceeds the rating of an individual NCETM, the 'field adjustable impedance' (FAI) can be specified. In the 'high impedance position' the neutral current drawn by any single unit is minimised. Once all NCETM units are brought on line, this can be switched to 'low impedance' for normal operation. Without this feature, a single unit may become overloaded before the other NCETM units can be connected. Note that not all zero sequence transformers have this feature.

Neutral current eliminator design can also be combined with phase shifting techniques to provide effective harmonic attenuation from 3rd to up to 19th harmonics depending on the number and current ratings of discrete loads. The use of a CNCETM (combined phase shift and neutral current eliminator) with 30 degrees phase shift treats both the triplens (3rd, 8th, 15th, 21st) and the 5th, 7th, 17th, 19th...harmonics within the system. Fig 4 illustrates a system with an NCE and CNCE in circuit.

In summary, the application of appropriate 'magnetics' can offer a very economical and cost-effective solution for the growing problem of high neutral currents due to triplen harmonics generated by modern single-phase non-linear loads and at a fraction of the cost currently spent on active solutions.

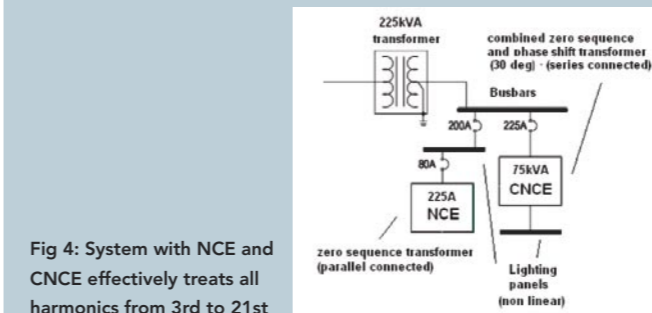


Fig 4: System with NCE and CNCE effectively treats all harmonics from 3rd to 21st