COMCAST OF NEW JERSEY

800 RAHWAY AVE., UNION, NEW JERSEY

MIRUS NEUTRAL CURRENT ELIMINATOR PERFORMANCE REPORT

OCT. 16, 2001

MIRUS PROJECT # 1992-01

Prepared for:
JOHN DUANE
CHIEF ENGINEER
COMCAST OF NEW JERSEY

Prepared by:
TONY HOEVENAARS
VICE PRESIDENT
MIRUS INTERNATIONAL INC.

EXECUTIVE SUMMARY

On Oct. 3, 2001 a 400 amp Neutral Current Eliminator™ (NCE™) was put into service at the Comcast Cable facility in Union, New Jersey. The NCE™ is a triplen harmonic filter and had been purchased to address harmonic concerns within the facility. These concerns included:

- An 80 kVA EPS 2000 UPS System supplying critical power to computer systems and broadcasting equipment within the facility that was running excessively hot while being loaded at about 85%. External fans had been installed to remove heat and cool down the UPS.
- Voltage distortion downstream of the UPS System was in excess of 10%.
- Harmonic currents, more specifically the 3rd harmonic, were creating high neutral current at the main power panel downstream of the UPS.
- Neutral-ground voltage was above the commonly accepted maximum limit of 2 volts.

The NCE™ was connected in parallel at the main power panel downstream of the UPS. By providing a low impedance path for the 3rd harmonic and other triplen harmonic currents, the NCE™ offloaded the neutral conductor and upstream electrical equipment. The NCE™ was extremely effective as demonstrated by the following improvements:

1. Neutral current returning from the main power panel back to the UPS was reduced from 144 amps to 18 amps, an almost 90% reduction.
2. Voltage distortion was reduced from over 13% to less than 3%, an over 80% reduction.
3. The reduction in harmonic currents reduced the loading on the UPS system from 85% to 78%. This resulted in a noticeable reduction in the UPS's operating temperature.
4. Neutral-to-ground voltage at the main power panel was lowered from 2.4V to 0.4V.
5. Phase current imbalance at the main panel was substantially improved.

By achieving the principle goals of reducing neutral current and offloading the UPS system, the NCE™ installation was extremely successful. Evidence of further benefits are expected to appear as improved equipment operation results from the dramatically lower voltage distortion and neutral-to-ground voltage at connected equipment.

BACKGROUND

Computer systems and audio/video equipment, like most of today's electronic equipment which utilize switch-mode power supplies, produce troublesome amounts of harmonic currents. By drawing current in a non-sinusoidal manner, these non-linear loads create harmonics which circulate through the electrical distribution system. The most common problems which result are:

- Overheating neutrals, transformers and other electrical distribution equipment
- Excessive voltage distortion and neutral-ground voltage which can cause equipment malfunctions, component damage and shortened equipment life span
- Ground currents which, among other things, can cause video noise problems.

Over heating due to harmonics: The 3rd and other triplen harmonic currents are additive as they return in the neutral conductor. Because of this, neutral conductors will often carry very heavy currents when non-linear loads are present. These currents have been known to cause overheating and failures of the neutral conductor.

In addition, harmonics will increase I^2R and eddy current losses in transformers and other distribution equipment such as UPS systems. These excessive losses can cause transformers to overheat even when they are relatively lightly loaded.

High voltage distortion and neutral-ground voltage: Harmonic problems which have been less well documented, but are potentially even more troublesome, are the heavy voltage distortion and high neutral-ground voltages (common mode noise) that are common where high densities of non-linear loads exist. Most of the distortion is the result of the interaction of the harmonic currents with the impedance of the electrical distribution system. That is, as the harmonic currents circulate through the electrical distribution, they produce voltage drops at each harmonic frequency in relation to Ohm's law - $V_h = I_h \times Z_h$. The combined effect of the voltage drops at each harmonic frequency is what creates the overall voltage distortion. This problem becomes even more serious when the distribution system is serviced by a weak source, such as an UPS system or diesel generator. Distortion levels are higher when system impedance is higher. System impedance is generally high when fairly long cable runs are serviced from a supply with high source impedance, such as a UPS.

Voltage flat-topping is the most common form of voltage distortion. Flat-topping results from the fact that non-linear loads draw currents in pulses at the peak of the voltage waveform.

The same Ohm's Law relationship is what creates high neutral-ground common mode noise voltages. Heavy neutral currents, resulting from the additive effect of the triplen harmonic currents, 3rd, 9th, 15th, etc., in the neutral will produce a voltage drop along the neutral conductor. This voltage drop will appear as a potential difference between neutral and ground near the harmonic generating loads (ie. at the power panels and power receptacles). Commonly referred to as common mode noise, this voltage can have a very adverse affect on the operation of equipment which is subjected to it.

An effective strategy for harmonic mitigation is to isolate the harmonic currents near the loads themselves through phase shifting and zero sequence filtering. By reducing the current harmonics, the voltage distortion, neutral-ground voltage and overheating that these harmonic currents produce will be dramatically reduced.

Ground Currents*:* Most electronic equipment which utilize switch-mode power supplies are equipped with π-Filters to reduce the high frequency EMI emissions. These filters are effective at reducing EMI but may allow some low frequency harmonic leakage currents (ie. 180 Hz) to pass through to the ground wire. This can result in troublesome ground currents circulating through the power system.

PERFORMANCE MEASUREMENTS

Measurements taken Oct. 3rd on a Fluke 41 meter confirmed that the NCE™ was very effective in addressing the harmonic concerns at Comcast. Figure 1 shows measurements taken on the neutral conductor before and after the installation of the NCE™. Neutral current was reduced by almost 90% (from 144 amps to 18 amps). The largest reduction was in the 3rd harmonic which went from 134 amps to 15 amps. This has offloaded the neutral conductor and the upstream UPS system allowing them to run much cooler. Also, by reducing the neutral current, neutral-to-ground voltage dropped from 2.4V to 0.4V.

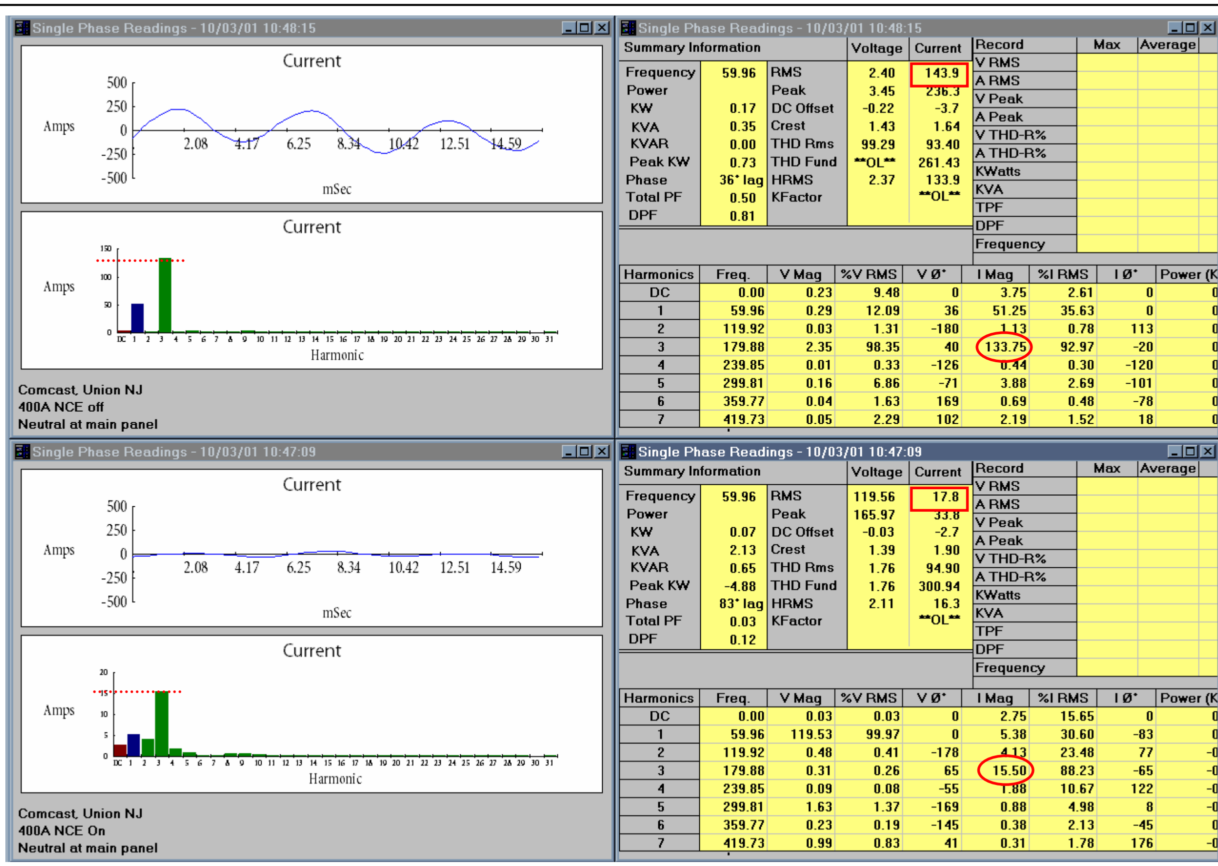

Figure 1: NCE Performance – Neutral Conductor

Other improvements can be seen in the phase current measurements shown in Figure 2. Voltage and current measurements on Phase B are shown both before and after the installation of the NCE™. Removal of the 3rd harmonic current in the phase conductor has reduced the overall current distortion from 35% to 25%. With fewer harmonics in the current, voltage distortion which is caused by these harmonics, was dramatically reduced (13% to 2%). The improvement in voltage distortion is also demonstrated by the elimination of the voltage flat-topping. The NCE™ increased the peak voltage to 165V from 150V (a 10% improvement) . This reduction in current harmonics is reflected in the lower current peak.

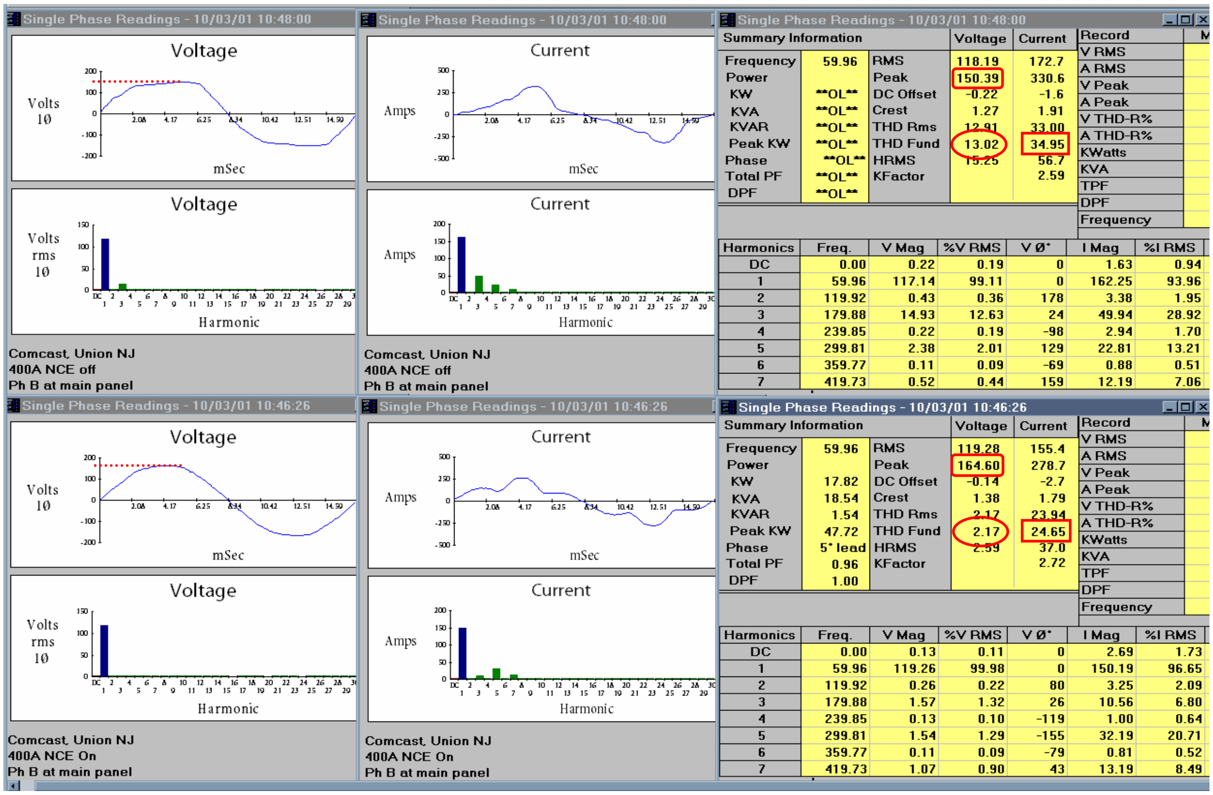

Figure 2: NCE Performance – Ph B