CHAUVIN ARNOUX

TECHNICAL ARTICLE

Neutral Current Crisis – When Harmonics Turn the Neutral into the Hottest Conductor

What This Technical Article is About

Monitoring at a resort facility showed neutral currents reaching more than 400A, exceeding the phase conductor currents by almost double and indicating severe harmonic loading. This technical article describes a neutral current overload problem caused by harmonic currents in a modern electrical installation. It explains how monitoring at a resort site identified the issue and why neutral conductors can become the most heavily loaded conductors in harmonic rich systems.

Why There is a Story to Tell

Power quality issues are increasingly common in commercial and industrial installations. Modern facilities use large numbers of non-linear loads such as LED lighting, computer power supplies, and variable speed drives. These loads generate harmonic currents that do not cancel each other out in the neutral.

This can cause very high neutral currents, overheating, equipment damage and safety risks. Many installations are not designed for this condition, making neutral overheating a hidden but serious problem.

How the Issue Was Identified and Addressed

Power quality monitoring was carried out at a resort site to measure phase currents, neutral currents, and voltages. The logged data showed a very high neutral current caused by harmonics.

This allowed the issue to be quantified and corrective actions to be planned. Elliot Ajose, Regional Sales and Technical Manager for CA UK, reviewed the monitoring results and confirmed the harmonic induced neutral load condition as he explains below.

Monitoring Data from a Resort Site

Monitoring was carried out at a resort site. Phase currents, neutral current, and voltages were recorded using a Chauvin Arnoux power and energy logger installed at the main distribution board supplying guest rooms, lighting, HVAC, and common facilities.

Average currents recorded on site:

Phase 1 (I1): 90.79 A
Phase 2 (I2): 74.30 A
Phase 3 (I3): 86.23 A
Neutral (IN): 173.9 A

Maximum recorded currents were:

I1: 230.0 A
I2: 213.0 A
I3: 238.2 A
IN: 410.3 A

The neutral current averaged nearly double the typical phase current and peaked at 410.3 A, higher than any individual phase maximum. This pattern, shown in Figure 1, is a classic sign of harmonic-induced neutral overload, common in modern setups where most equipment is non-linear and draws current in small, abrupt pulses.

The data shows that the neutral conductor was heavily loaded even when phase currents were moderate - indicating significant Triplen harmonics in the system.

Current RMS - Session MIN/MAX/AVG								
Name	MIN	MIN date	MIN time	MAX	MAX date	MAX time	AVG	Units
I1 (5 min)	27.59	01/05/2025	02:47:23	230.0	03/05/2025	07:37:33	90.79	A
I2 (5 min)	22.14	01/05/2025	22:30:14	213.0	03/05/2025	12:31:31	74.30	A
I3 (5 min)	30.33	03/05/2025	05:30:43	238.2	04/05/2025	12:19:06	86.23	A
IN (5 min)	70.88	06/05/2025	05:01:19	410.3	27/04/2025	18:11:05	173.9	A

Figure 1 - Monitoring chart and panel photo.

Harmonic Multiplication Effect on the Neutral Conductor

The green fundamental currents at 50Hz are separated by 120 degrees and cancel in the neutral. The red harmonic alignment effect as seen in Figure 2., harmonic currents at 150Hz (3rd harmonic) align in phase and add in the neutral. The same effect occurs for the 9th,15th 21st and all other triplet harmonics.

This harmonic multiplication effect on the neutral can overload the neutral conductor. Many neutral conductors are the same size as phase conductors, which are no longer suitable in harmonic rich environments. In older installations, the neutral was sometimes reduced in size, which is dangerous in modern systems.

If the neutral overheats, insulation can fail, connections can burn, and the neutral can be lost. This can cause serious problems for the entire electrical system and connected equipment.

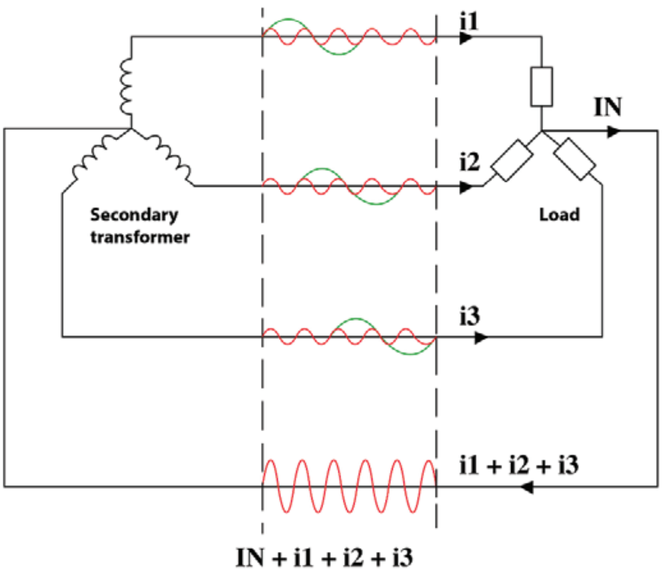

Figure 2 - Harmonic waveform showing Triplen harmonics adding in the neutral.

Thermal Stress and Cable Damage

High neutral current causes thermal stress in cables and terminations. Continuous heating increases conductor resistance and accelerates insulation aging. Loose terminations can develop hot spots, which increases the likelihood of arc flash events.

In distribution boards, neutral bars and terminals are often not rated for such high currents. Overheating can cause melting of insulation and plastic components. This increases fire risk in LV Panels switchboards and cable trays. Thermal imaging surveys often show neutral conductors running hotter than phase conductors in harmonic rich installations. This is a clear indicator of harmonic overload.

In some documented cases, neutral conductors have been found burnt open circuits or melted due to sustained harmonic currents. This represents a major safety concern in commercial facilities and industries today.

The Danger of a Lost Neutral

If the neutral is lost upstream of the neutral bar, the system becomes unbalanced, and single-phase loads can be exposed to phase-to-phase voltage. This is one of the most dangerous failures in low voltage distribution systems.

For example, with 20A on Phase 1 and no load on Phase 2 and Phase 3, the voltage on the loaded phase could rise to around 400V potential in a 230V system. Kirchhoff's Current Law makes this fact – in other words, the total current flowing into any point where wires connect must equal the total current flowing out of that point and since the neutral is open circuit upstream of the neutral bar the only return path is through the neutral bar.

This neutral loss voltage imbalance is shown in Figure 3. This can damage equipment connected to Phase 1 instantly.

Balanced loads might maintain normal voltage, but imbalanced loads can lead to destructive overvoltage depending on load impedance. Sensitive equipment such as IT equipment, LED drivers, HVAC controllers, automation systems, communication devices, virtually most household equipment, especially anything with a power supply, can fail immediately during a neutral loss event.

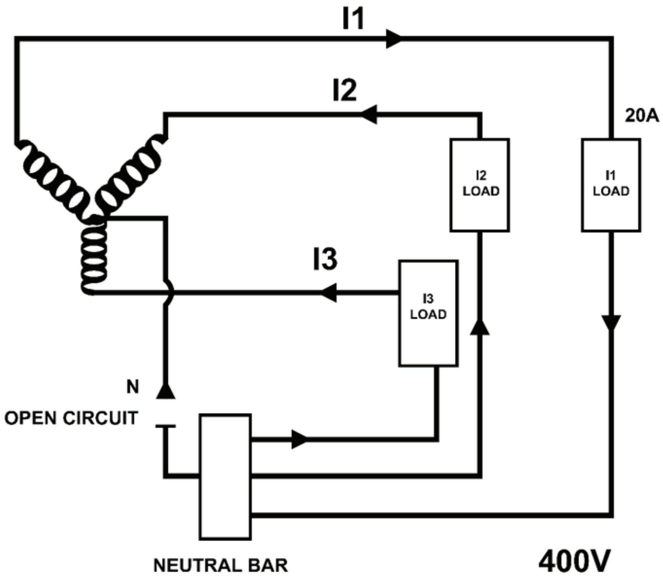

Figure 3 – Voltage imbalance example when the neutral is lost.

Voltage Monitoring Results

Site data showed stable phase to neutral voltages with averages of:

V1: 241.7 V
V2: 244.3 V
V3: 241.6 V

Phase-to-Neutral Voltage RMS - Session MIN/MAX/AVG

Name	MIN	MIN date	MIN time	MAX	MAX date	MAX time	AVG	Units
V1 (5 min)	234.5	06/05/2025	02:54:58	248.5	30/04/2025	11:45:37	241.7	V
V2 (5 min)	237.6	07/05/2025	04:27:18	251.0	28/04/2025	22:25:23	244.3	V
V3 (5 min)	232.6	06/05/2025	02:54:58	248.6	28/04/2025	22:25:24	241.6	V

Figure 4 – Stable Phase to Neutral Voltages.

Although voltage was stable during monitoring, the high neutral current indicates a potential failure risk. Without monitoring, a neutral failure could go undetected until equipment damage occurs. Continuous monitoring is required to detect abnormal neutral current and voltage imbalance conditions.

Harmonic Observations

Analysis of consumption showed a strong third harmonic component on all three phases, with ninth and fifteenth harmonics also present but at lower levels. The third harmonic was clearly the dominant component, which explains why the neutral current was so high.

The captured waveforms were heavily distorted, with sharp current peaks. This is typical of LED drivers, switched-mode power supplies, and other electronic loads. Harmonic distortion was not constant and increased during the evening period, when lighting and guest room loads were at their highest.

Daily Load Profile and Neutral Behavior

Load trends showed that phase currents followed expected daily patterns, with peaks during morning HVAC operation and evening guest activity. Neutral current followed a different pattern. Neutral current remained high even when phase currents were moderate, indicating that neutral loading was driven by harmonic content rather than fundamental load imbalance.

During low occupancy periods, neutral current remained elevated due to continuous electronic loads such as servers, networking equipment, security systems, and control systems. This behavior is typical in modern commercial facilities where electronic loads operate continuously.

To be noted – the CA 6117 multifunction tester is a good alternative to run harmonic analysis. It was recently used at a large manufacturing plant, where the maintenance team noticed overheating of the neutral conductor in one of the main distribution boards.

- Voltage and current harmonics up to the 50th order were measured.
- 56% of the load profile was identified on the 3rd harmonic adding in the neutral conductor.
- The 9th and 15th harmonics were found at a smaller magnitude but still present, causing significant neutral overload.
- Harmonics issues pinpointed towards the UPS system, and a passive harmonic filter was fitted.

Impact on Cable Sizing and Design Assumptions

Traditional cable sizing assumes neutral current is small. This assumption is no longer valid in harmonic-rich systems today! Neutral conductors may require the same or larger cross-sectional area compared to phase conductors.

Some standards require oversized neutrals when third harmonic content exceeds specific thresholds. Designers must consider harmonic current when selecting cable size, neutral bar rating, and distribution board capacity. Transformer neutral points must also be rated for harmonic current. In some cases, K-rated transformers are required to handle harmonic heating.

Protection and Monitoring Limitations

Most protective devices are installed on phase conductors only. Neutral conductors often have no overcurrent protection. Residual current devices detect leakage but not neutral overload. Overcurrent relays typically do not measure neutral current.

This means neutral overload can exist without triggering alarms or trips. Monitoring equipment is required to measure neutral current directly. Permanent monitoring systems or a Chauvin Arnoux PEL113 Power and Energy Logger can provide alarms when neutral current exceeds thresholds and help prevent failures.

Operational and Fire Safety Risks

In hospitality facilities, electrical reliability is critical. Guest comfort depends on lighting, air conditioning, and IT systems. Neutral failure can cause widespread equipment damage. Guest rooms can experience overvoltage. Lighting drivers and electronics can fail. HVAC controllers can trip or reset.

Overheated neutral conductors present a fire risk. Cable insulation can degrade and ignite nearby materials. Switchboards and cable trays can accumulate heat from overloaded neutrals. Fire risk is increased in ceiling voids and cable risers where combustible materials may be present.

Long Term Reliability and Asset Life

High harmonic currents reduce equipment lifespan. Transformers experience additional heating. Cables age faster. Switchgear contacts degrade. Continuous thermal stress accelerates insulation breakdown and dramatically reduces the service life of assets.

Monitoring data can be used to plan maintenance and equipment upgrades. Predictive maintenance improves reliability and reduces unplanned outages. Facilities with continuous monitoring can identify deteriorating conditions before catastrophic failure.

Future Load Growth Considerations

Electronic load density is increasing. LED lighting upgrades, EV chargers, automation systems, and digital infrastructure will increase harmonic levels in future installations. Future expansions should consider harmonic impact on neutral conductors.

New installations should include oversized neutrals and harmonic mitigation measures. Designers should consider permanent monitoring for critical facilities to manage future harmonic risks.

Mitigation Options

Several mitigation options exist for harmonic induced neutral overload. These include increasing neutral conductor size, installing passive or active harmonic filters, using K-rated transformers, and redistributing loads across phases.

Passive and active harmonic filters can reduce triplen harmonic currents. Proper load balancing can reduce fundamental imbalance but does not eliminate triplen harmonics. In some installations, dedicated neutrals for high nonlinear loads may be required. Cable derating factors should be applied when harmonics are present.

Field Lessons

This site analysis demonstrated that neutral conductors can be the most heavily loaded conductors in modern installations. Visual inspection alone cannot detect harmonic loading, measurement is required.

Engineers should not assume neutral current is low. Harmonic analysis should be part of commissioning for commercial facilities. Early monitoring avoids costly failures and retrofits

What Was Done

Power and energy monitoring was carried out at the resort site to measure phase currents, neutral current and voltages. The monitoring identified very high neutral current caused by harmonics. The data confirmed that the neutral conductor was overloaded and at risk of overheating or even worse a lost neutral.

How Customers Can Benefit

Identifying high neutral current allows corrective actions such as increasing neutral conductor size, installing harmonic filters, balancing loads and upgrading transformers. This reduces the risk of equipment damage, fire hazards and unplanned downtime, monitoring also improves system reliability and asset life.

Who should be doing this and how easy is it?

Commercial and industrial facilities should monitor power quality and neutral current. Harmonic data can be collected without interrupting operations. Electricians and engineers can quickly identify harmonic problems and plan mitigation measures. A small investment in monitoring today can prevent warm cables, cold outages and a hot conversation tomorrow.

Access more resources and technical guides on our website: www.cauk.net