

Case Study

Advanced Power Quality Analyzer diagnoses - the reason for cable overheating and power transformer failure



Espec's advanced portable power quality analyzer, the G4500, identified the root cause of cable overheating and transformer failure in a major hospital in the MENA region.

Medical apparatus and other equipment in critical healthcare facilities are highly vulnerable to power quality and EMC problems. Any downtime or equipment failure can have critical consequences.

The Challenge

The contractor on the new facility experienced cable overheating and a power transformer failure. The contractor could not identify the cause. Therefore, he approached a renowned PQ expert who was also the Elspec agent to undertake an in-depth investigation.

The equipment under the test included a number of "low harmonic drives" comprising 6 pulse variable frequency drives (VFD) and an active filter (AF) in one enclosure, connected to switchboards.

Power Quality Analysis

The test utilized three Elspec G4500 [Class A analyzers](#) and [power quality analysis software](#), the PQSCADA Sapphire.

According to open data, there are known cases when IGBT-based products (e.g., VFDs and active filters) were responsible for transformers and other equipment failures. Therefore, it was required to use a power quality analyzer with the capability to measure high-frequency harmonics.

The G4500 [portable power quality analyzer](#) continuously records waveform signals at 1,024 samples/cycle, from which it calculates 5,000 power parameters at ½ cycle resolution, including harmonics up to the 511th. In addition, it fully complies with the IEC 61000-4-30 Class A standard and is equipped with a built-in Wi-Fi and mobile application for real-time view and configuration.

The Results

The analysis determined the voltage THDu when the filters were operating and when they were switched off, as shown below in Figure 1.

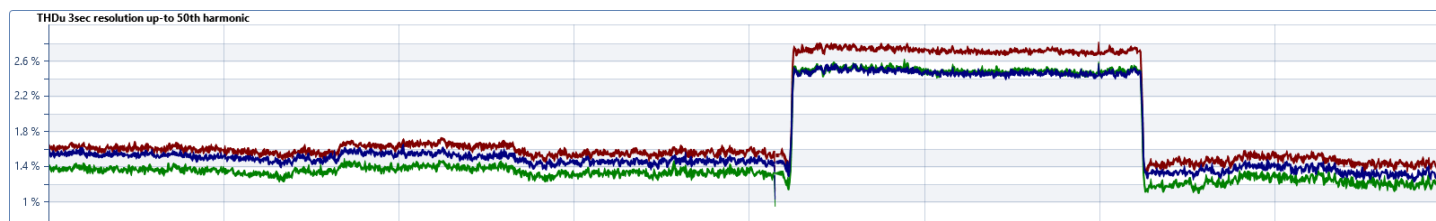


Figure 1: voltage THDu at 3-sec resolution with harmonics up to the 50th

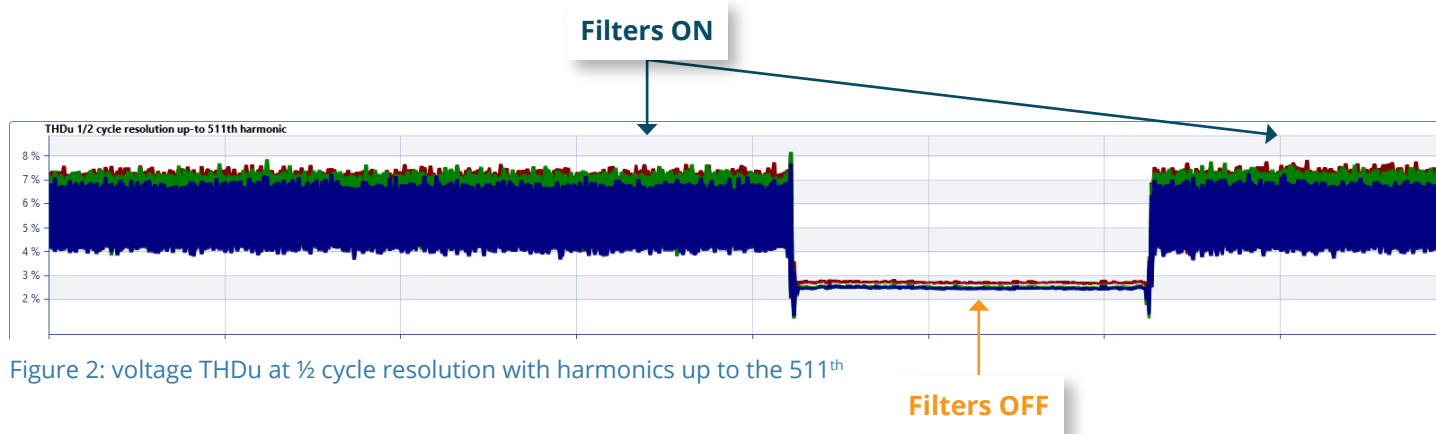


Figure 2: voltage THDu at 1/2 cycle resolution with harmonics up to the 511th

Figure 1 (above) illustrates the voltage THDu up to the 50th harmonics at 3-second resolution as per IEEE 519 standards require. It can be observed that when the filters are switched off, the THDu level increases from 1.6% to 2.8%, as expected.

However, looking at the voltage THDu at 1/2 cycle resolution up to the 511th harmonic (Figure 2 above) reveals a different picture. When the filters are switched off, the THDu level decreases to 2.5% from 7.5%, the THDu level apparent when the filters were operated. That meant that the switching operation of the active filters contributed approximately 70% of the total THDu. This is the opposite of what was expected.

To further analyze this unexpected result, we looked at the individual harmonics in two 'on' and 'off' periods. Figure 3 below illustrates the THDu when the two filters were operating.

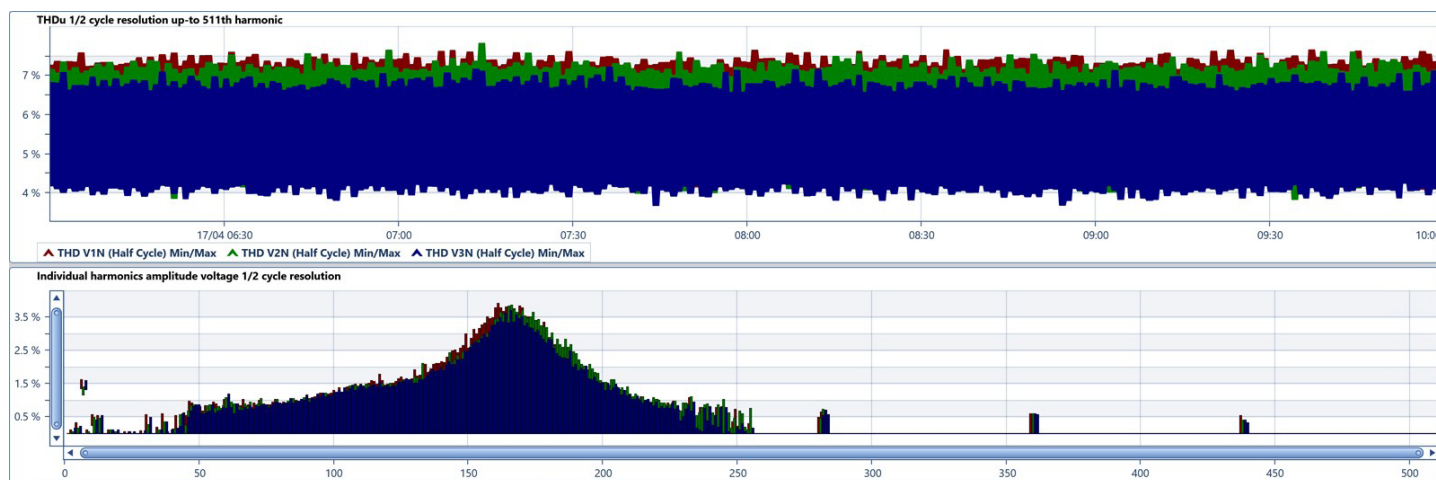


Figure 3: voltage THDu and individual harmonic spectrum at 1/2 cycle resolution while filters are switched on

Figure 3 (above) indicates an unexpected, significant harmonic activity in the range of 2.5–12.5kHz when the filters are operating. However, while filters are switched off (figure 4) below, the high frequency harmonics are barely discernable or not present at all.

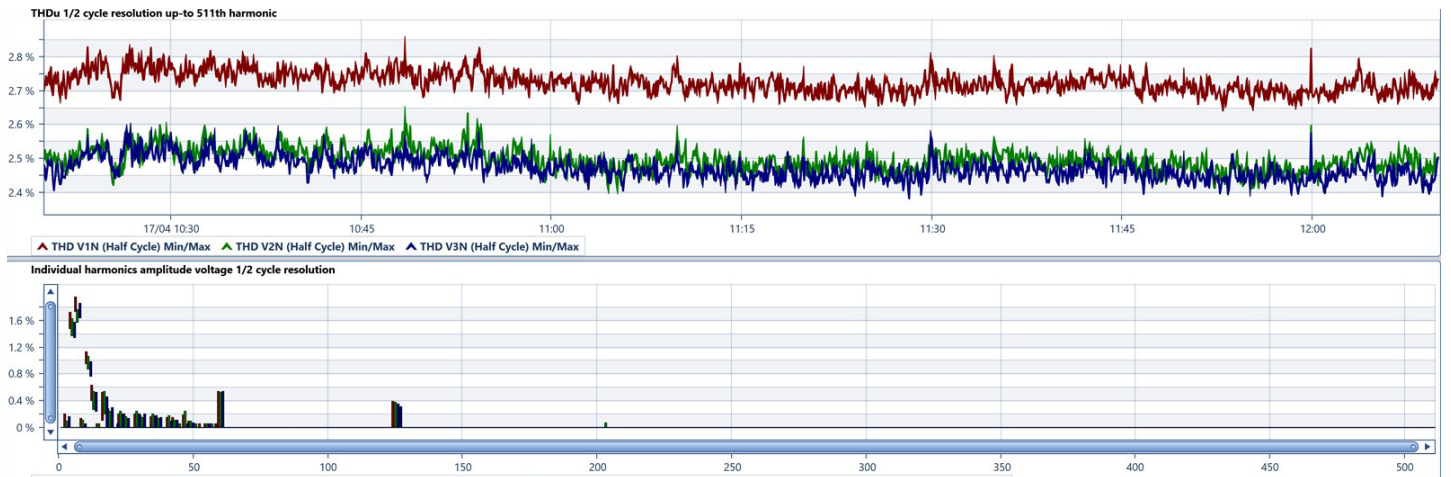


Figure 4: voltage THDu and individual harmonic spectrum at $\frac{1}{2}$ cycle resolution while filters are switched off

Furthermore, high frequency harmonic currents were also produced during the operation of the active filters, as can be observed in Figure 5 below:

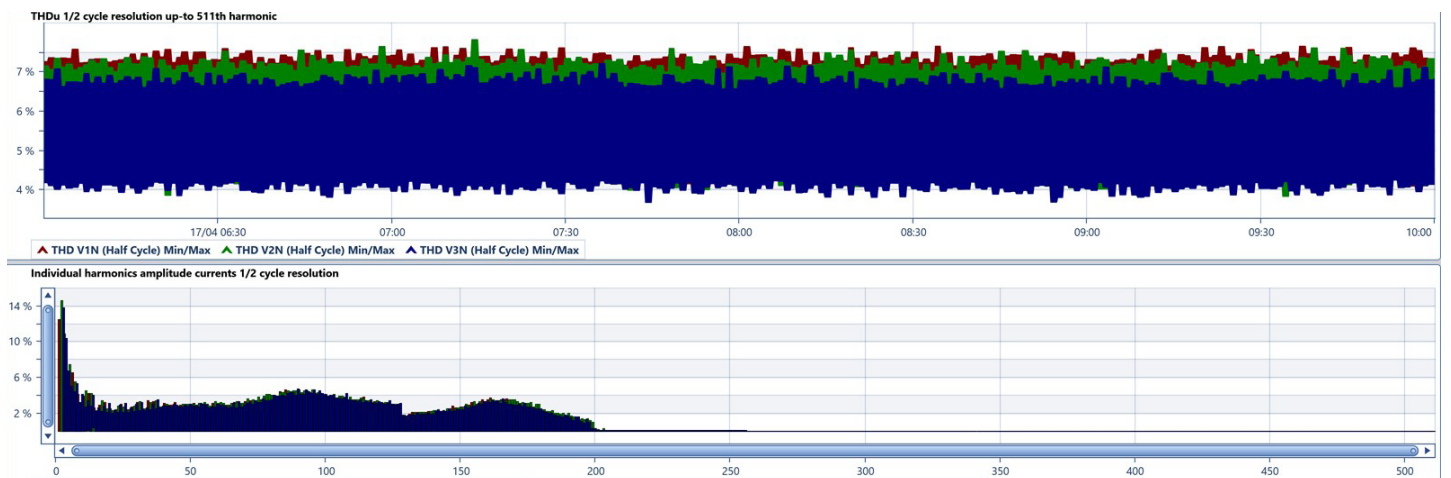


Figure 5: voltage THDu and individual current harmonic spectrum at $\frac{1}{2}$ cycle resolution while filters are on

From Figure 1 to Figure 2, the extent of high-frequency voltage components can be seen. The project's harmonic specification is based on recommendation IEEE-519-1992, for harmonics below the 50th order. Within IEEE-519-1992, there is also 'Special Applications' criteria for hospitals and airports with a limit of 3% THDu. Figures 3 and 4 illustrate high frequency voltage emissions, which also extended to the common mode (i.e., between three phases and ground). Note that common mode voltage and current are EMC issues, not PQ issues. Excessive common mode voltage can be very damaging and disruptive to other equipment, including sensitive medical equipment connected to the same ground, whereas the accompanying high frequency common mode current is responsible for motor bearing failure).

Apart from causing transformer failure, high-frequency voltage emissions can affect motors and generators, and cause the overheating of electric power cables. These effects are primarily due to excessive copper and iron losses plus proximity effect and skin effect on the cables carrying the current.

The currents above the 127th order, as shown in Figure 5, were similar to those found in induction heating systems. These high frequency currents, when combined with the resultant additional losses and heating effects, were a direct or contributory factor in the recent failure of the 2000kVA transformer and the overheating of cables and switchboard.



Conclusions

IEEE 519-1992 was the basis of the hospital specification in this instance, which recommended that THDu should be <3%. However, generally and outside of special applications, IEEE-519-1992 requires a maximum of 5% of the total harmonic voltage distortion, whereas [IEEE-519-2014](#) and IEEE-519-2022 both require <8% THDu. However, all IEEE-519 recommendations require measuring the harmonics only up to the 50th harmonic. In addition, the required resolutions are 3sec and 10min only.

In this case, the measurement results show that despite the active filters treated the harmonic current as expected, their switching voltage harmonics increased the THDu to almost three times that of the observed on the 6 pulse VFDs without mitigation. The reason for this unusual phenomenon was never disclosed publicly by the vendor.

Conventional analyzers that only comply with the IEEE-519 harmonics standard would not reveal such a phenomenon as their recording is limited to the 50th harmonic. However, in the United Kingdom, Engineering Recommendation G5/5 specifies measurements to the 100th order. This 100th-order requirement may soon be commonplace across utilities worldwide.

Elspec's G4500 analyzer measures and records the waveform continuously at 1,024 sample/cycle resolutions. As a result, it provides the ability to analyze harmonics up to the 511th at ½ cycle resolution. This capability allowed for the identification of the root cause of the problems, such as higher frequency PQ and other types of distortion, including high frequency harmonics caused by the active filters, AFE VFDs, and other equipment with a harmonic footprint >50th.

About the writer

Ian C Evans is Principal Electrical Engineer with Sentinel Power Quality Group FZE (SPQ) is based in the UAE. SPQ and its dedicated divisions, Harmonic Solutions Oil & Gas and Harmonic Solutions Marine, specialized in harmonics, power quality, and aspects of EMI pertaining to VFDs and electric drives, active filters, and other fast switching devices. They provide consulting and site harmonic PQ/EMI site services, harmonic, and other types of mitigation, plus portable and continuous PQ monitoring systems.

Ian has written many technical papers on diverse subjects such as harmonics and PQ, VFD/explosion-proof motor interaction and safety, marine and offshore PQ and EMC, marine electrical propulsion, Resonant Link technology applications et al. He has published over forty editorials on a range of subjects.

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