



Challenge

Rambam Health Care Hospital and Campus in Haifa, Israel, is a 1,000-bed academic hospital serving more than two million people in northern Israel. Rambam Hospital is also the backup referral center for twelve district Hospitals, the Israel Defense Forces Northern Command, the US Navy Sixth Fleet and the UN Peacekeeping Forces posted in the region.

In an effort to save energy the hospital purchased two new Chillers at 240kW each for their cooling system. The new Chillers were to replace an aging and inefficient single 600kW Chiller which was part of the 5000 ton cooling array. The new Chillers were equipped with VFD's which consume far less energy per cooling ton but draw current from the electrical supply in nonlinear pulses instead of linear sine waves due to their construction (Fig. 1).

As nonlinear pulsing currents (Fig. 2) reached higher values their interaction with the system impedance caused the hospital's supply voltage to become increasingly distorted. The distorted system voltage affected the reliable operation of sensitive equipment in the hospital that any interruption, even extremely short, may lead to loss of life. Due to the importance of this issue, the IEEE 519 1992 Standards specify < 3% Total Harmonic Voltage Distortion (THD (V)) for hospitals and airports compared to other applications where THD (V) of <5% is acceptable.

In addition to the problems created by higher levels of THD (V) the nonlinear pulsing currents (Fig. 2) were made up of a spectrum of higher frequency sine wave currents ranging from the 5th ($5 \times 50 = 250$ HZ), 7th, ($7 \times 50 = 350$ HZ) 11th $11 \times 50 = 550$ HZ) 13th ($13 \times 50 = 650$ HZ) etc.

These higher frequency harmonic currents caused over heating of cables, transformers and generators due to increased I²R losses and eddy current losses. Over heating will lead to nuisance operation of overload devices and increased risk of fire in transformers, cables and generators.

The harmonic frequencies (Fig. 2) are reflected onto the system voltage waveform. Some of the frequencies have a positive sequence, but those that have a negative sequence actually create counter torque on AC motors that are running directly across the line.

After the new 240kW Chillers were installed the Hospital maintenance team noted that the power transformer feeding the Chillers were severely damaged and caused unplanned interruptions until it had to be replaced. In addition, it was not possible to operate both new Chillers simultaneously, as the overheating activated the overload protection. Even while running a single Chiller, it was hotter than expected and the HVAC plant manager was afraid that the new transformer would fail.

Even though the Chiller VFD's were supplied complete with series connected input AC line reactors, a common practice for basic harmonic filtration, the reactors did not lower the harmonic current distortion low enough. Series AC line reactors can only lower the current harmonics to about 35%.

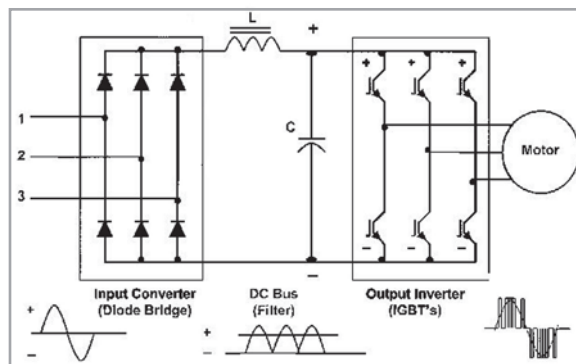


Fig. 1: Variable Frequency 6-Pulse Drive Structure

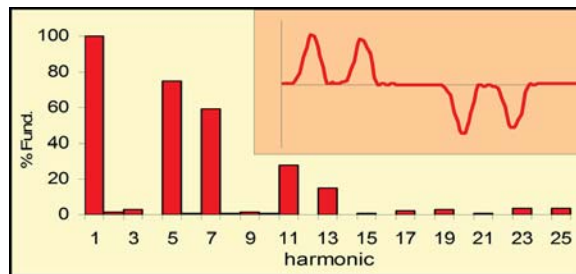


Fig. 2: Variable Frequency 6-Pulse Input Current Waveform

Solution

Several harmonic mitigation methods were researched by the hospital maintenance team and management team and were considered as possible solutions (Table 1).

After much review the hospital's management team selected the LINEATOR™ Passive Harmonic Filter

by Mirus International to solve their harmonic challenge. There were several key advantages the LINEATOR™ provided over the other methods:

- Maintenance-free passive filtering
- Series connected to the grid
- One single magnetic core construction with multiple windings
- Provides the lowest losses
- Very small capacitor bank <15% of the kVA of the load allows compatible operation with diesel generators
- Guaranteed compliance to IEEE 519-1992 at the input terminals of the filter
- Three (3) year standard warranty

P.Q. Tech, a company specialized in analyzing and correcting power quality issues installed two 300HP LINEATORs (Fig. 3) with each unit connected to one drive for maximum filtration and flexibility.

Solution	Pros	Cons
Do Nothing	Low price	Does not work
Series Reactor	Simple low cost	THD(I) reduced to only 35%
Improved Drives (12/18 pulses, AFE)	Low harmonic pollution	Expensive, 2 to 3% extra losses. Need maximum floor space.
Traditional LC Trap Filters	Low harmonics	Capacitor banks must be 40% of the kVA of the load
Active Harmonic Filter	Suitable for any load and variable conditions	Very expensive 1% extra losses. Not reliable. Needs large floor space.
Passive Harmonic Filter (LINEATOR™)	Excellent filtration guaranteed to meet IEEE 519 at the input terminals of the filter. Very small capacitor bank < 15% of the kVA of the load. Most efficient solution.	Requires some floor space but less than other options.

Table 1: Solutions for Harmonic Mitigation

Results

The installation of the LINEATORS enabled the simultaneous operation of the two Chillers by reducing the harmonic pollution by more than 2/3 and lowering voltage distortion from almost 4% to <1.5%, well below the IEEE 519-1992 requirements. The operation temperature of the drives and Chillers was reduced by more than 10°C, increasing their life time and reliability.

Figure 4 shows the current waveform without and with the filtration; Figures 5 and 6 shows the voltage harmonics and the current harmonics respectively. It can be clearly seen that the harmonic pollution exceeded the IEEE 519-1992 levels before the installation of the filters and are well below afterwards.

Installation of the LINEATOR™ Advanced Universal Harmonic Filter on the new Chiller VFD's ensures compliance to harmonic pollution levels and smooth operation of the Chillers. The no-setup approach, requiring just fitting the filter to the drive rating and motor type, provides the best solution for reduced harmonics in this retrofit system and is also ideal for application at the design stage for new construction. Specifying LINEATOR™ on VFD applications will ensure that harmonic pollution limits are met.

Study conducted by: Mr. Menachem Bercholz, Mr. Al Archambault, Mr. Amir Broshi



Fig. 3: Two 300HP LINEATORS at Rambam Hospital

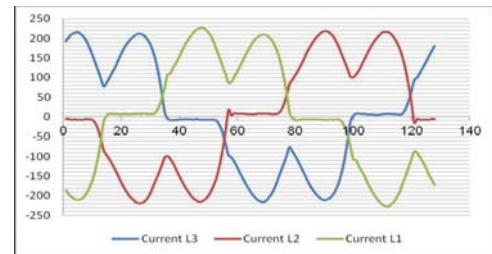


Fig. 4a: Current Waveform without Filtration

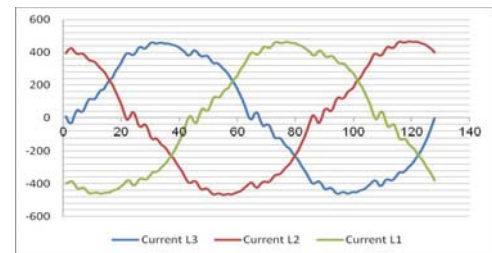


Fig. 4b: Current Waveform with Filtration

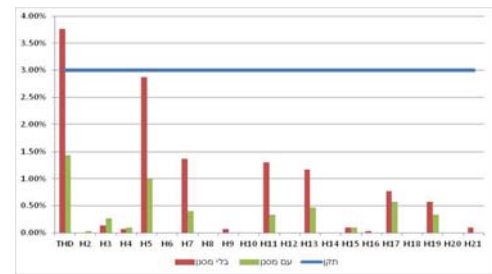


Fig. 5: Voltage Harmonics with and without Filtration and IEEE 519-1992 Level

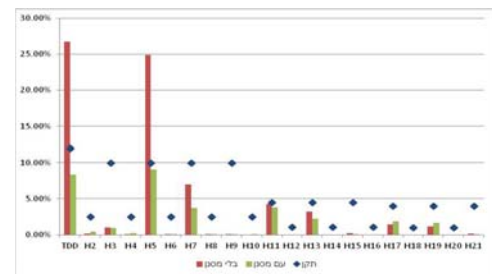


Fig. 6: Current Harmonics with and without Filtration and IEEE 519-1992 Level

About Mirus International

Mirus designs and develops world class power quality improvement products for mission critical operations. Their uniquely specialized product line includes highly efficient harmonic filters, transformers, autotransformers and Data Center power distribution equipment. Comprised of a leading team of power quality experts, Mirus' solutions minimize disruption to the power supply, improve reliability and adhere to the strictest of regulatory requirements while also saving energy. Proven to perform, Mirus products are available globally and are real-world tested in its own Harmonics & Energy (H&E) Lab.