# Filtration of Harmonics in Lighting Fixtures

The Sami Ofer Stadium in Haifa, which opened in 2014, is used for soccer matches of the Israeli national team, the Israeli League, and also for other events/cultural performances. A catwalk built along its stadium roof (largest of its type in Israel) has 200 lamps for field illumination.
The fixtures are metal halide (MH) type, each consisting of a capacitor installed in its ballast to improve the power factor and reduce the operating current. The bulbs are high-intensity discharge (HID) type, which produce current harmonics, which were being amplified by the capacitors. The dominant harmonic created by these lamps is the fifth (250 Hz), and the total harmonic distortion in the current (THDi) exceeds 50%, resulting in frequent damage and unreliable operation. Figure 1 shows the waveform and spectrum of harmonics.

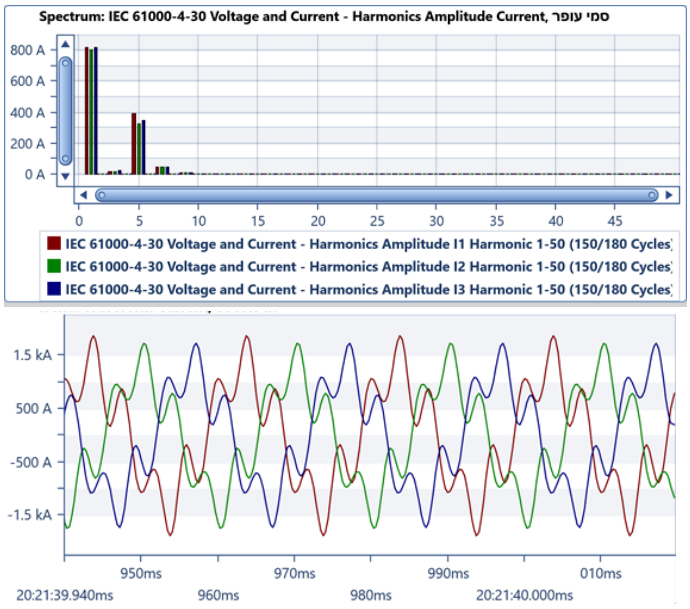

Figure 1 - Harmonic spectrum and waveform without filter

## The Problems Caused by the Harmonics

The high level of harmonics created a number of problems:

- Vibration of the panelboards, resulting in an increased need to tighten terminals.
- Major stress on the capacitors installed in the lighting fixtures requiring a thorough inspection after each game and replacement of faulty capacitors
- Increased energy losses in the facility both due to the harmonics and the unnecessary operation of the lights during capacitor testing

## Possible Solutions

Several alternatives were examined:

- **Replacing the fixtures with LED lights.**
  This alternative was found to be uneconomical, given the relatively low number of hours the lighting was on (beyond the fact that LED lighting also produces harmonics)
- **Installing an active harmonic filter.**
  By examining the impedances and measuring the harmonics during generator operation, the engineers raised concerns that an active filter would be affected by the resonance and would not be able to resolve the problems.
- **Installation of a passive harmonic filter in the sub-panels of the lighting fixtures.**
  This solution would provide maximum filtration, including the reduction of current harmonics along the long cable runs. Although this alternative is technically the best, it was not chosen for cost and logistics (consideration of installing equipment on the roof construction).
- **Installation of a central passive series harmonic filter.**
  This solution removes the majority of harmonic currents from the upstream panelboard, reducing the voltage distortion, while also significantly reducing harmonics downstream.


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Figure 2 – Harmonic filter

## Solution

The solution chosen and characterized by engineers Ariel Segal and Amir Broshi was a MIRUS International LINEATOR series passive harmonic filter. The filter was installed in the main electrical room (Fig. 2).

The filter has several unique features that were among the reasons for choosing it:

- High filtering ability - the results below corresponded to the simulations performed
- Being sized properly to the load, the filter cannot be overloaded regardless of the amount of harmonics
- The coils are wound on a common core to take advantage of mutual coupling
- Low losses (only 0.6%)
- Low capacitance that allows compatibility with a generator (Fig. 3)
- Creating a buffer between the source and the load, which reduced the voltage harmonics and resulted in savings in conductor losses.


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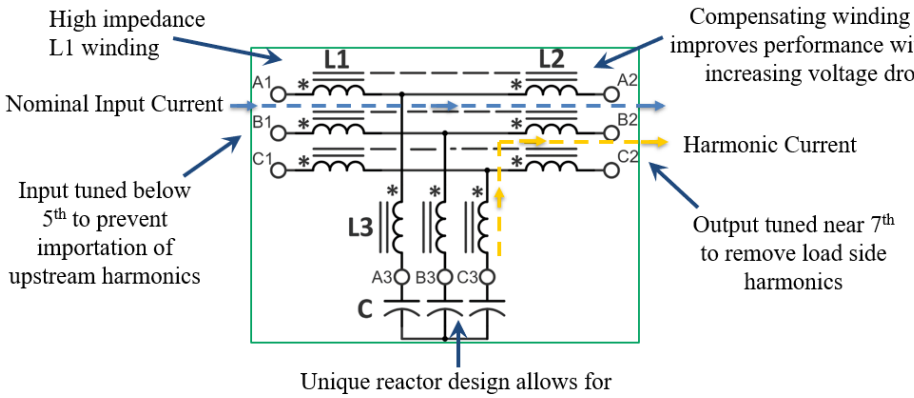

Figure 3 – LINEATOR harmonic filter schematic

## Results

Table 1 summarizes the data measured at the filter entry/feeder input, and compares with data before installation of the filter.

**Reliability:** The main purpose of filtering harmonics in general, and in this project in particular, is to improve the reliability of the facility. The board vibrations were completely eliminated which spared the need to tighten the loosening terminals/fasteners, as well as a reduction of over 95% in the wear and tear of the fixture and the number of capacitors required to be replaced.

**Harmonics:** A significant decrease can be seen in both current and voltage harmonics. The decrease in voltage harmonics is both due to the decrease in current harmonics and also due to the buffer between the input and output.

**Current:** Filtering the harmonics resulted in a significant decrease in the total current. At the output of the filter the current is higher than at the inlet (although still lower without filtration), because current harmonics drawn by the lighting flow to the parallel component of the filter and do not reach the transformer.

**Power:** Harmonic filtering saves electricity, but usually the savings alone do not justify the investment (over 3% without calculating the losses of the filter itself). In addition, the reduction of harmonics is expected to lead to an additional saving of about 5% in the transformer itself (estimated).

| Parameter | Before | After | |
|---|---|---|---|
| | At Incoming Feeder | At Incoming Feeder (Filter Input) | At Lighting Panel (Filter Output) |
| Voltage Harmonics | 7% | 2% | 3% |
| Current Harmonics | 50% | 7% | 21% |
| Current (A) | 940 | 840 | 900 |
| Power (kW) | 574 | 560 | 556 |

Table 1 – Comparison of data with and without filter


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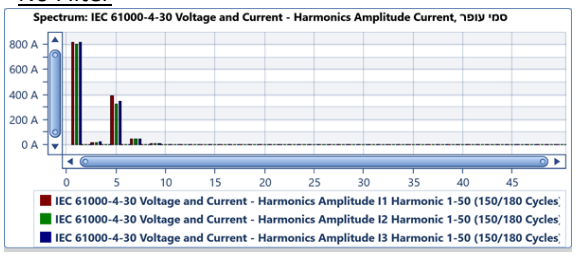
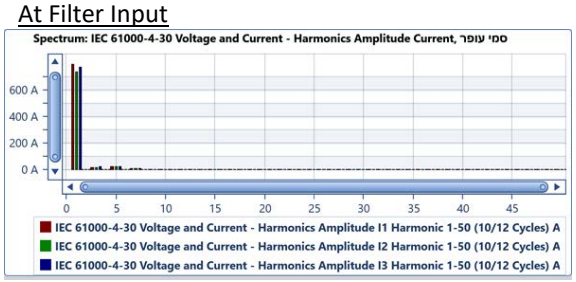
No Filter




At Filter Input




At Filter Output (To Lighting)

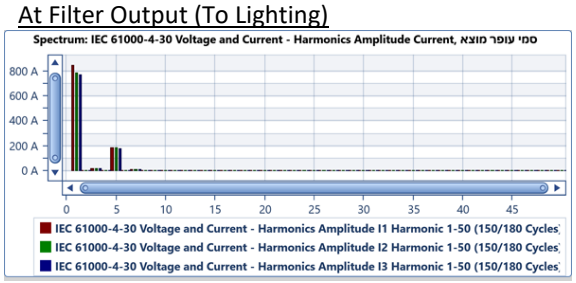
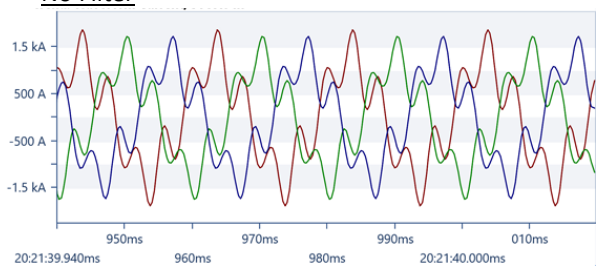
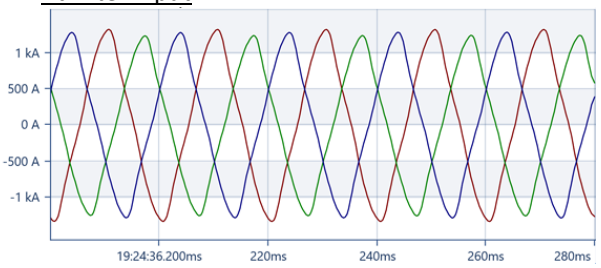



Figure 4 – Harmonic spectrum (in amperes) with and without filter

No Filter




At Filter Input




At Filter Output (To Lighting)

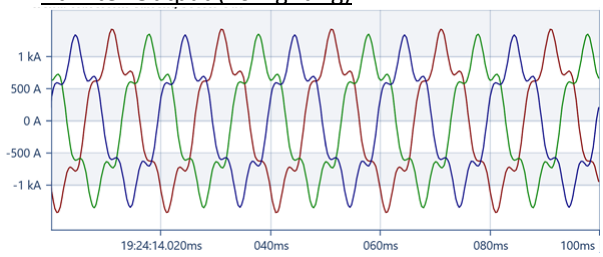



Figure 5 – Waveforms with and without filter

## Summary and Conclusion

Installing the harmonic filter solved the reliability and maintenance issues for the stadium, and also led to financial savings. The choice of a wide spectrum passive filter has proven once again that it is the best solution for filtering harmonics when the dominant harmonic is of the fifth order and higher. It allows for simplicity in the design (only the maximum current value is required to be determined), without requiring any complicated settings, minimal maintenance requirements and high performance.