Power System Studies

Measurements and Analysis of the Pepsi Cola Portland Bottling Plant 480 V Main With EP2000 Installation

for

Environmental Potentials

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by:

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1.0 Executive Summary

1.1 Introduction and Scope of Work

The measurements discussed in this report, were made to determine the effect of adding EP2000 devices to one of the plants 480 Main switchgear panels. The measurements were made at the Pepsi Cola Bottling Facility in Portland, Oregon on two separate occasions. Initial measurements (March 2, 2000) were made to document the 480 Main present power quality, and the follow-up measurements (November 17, 2000) were made after installation of EP2000 devices on the main buses.

The location for measurement was first chosen since it was the "obvious" plant main connection location with the most significant load. However, upon inspection of the initial measurements, it was found to be an ideal location to test the EP2000. This author, during discussion with the devices inventor, was informed of the high frequency absorption capability of the EP2000. It was designed to absorb high frequency transients and noise, with a roll-off frequency set around 10 kHz. This can be tuned differently during construction, however, the stock devices installed at Pepsi Cola were known to have the 10 kHz roll-off.

1.2 Observations and Conclusions

1. The EP2000 is supplying a great benefit in reducing high frequency noise on the plants main 480 V Panel. For this facility, we would recommend continuing operation with the EP2000s installed. Returning to the Initial voltage conditions with high frequency noise content would be returning to a poor voltage quality condition.

2. The EP2000 shows repeatable signs that it is absorbing the high frequency currents flowing in the plant that are causing the excessive noise on the Initial voltage.

3. This report was not conducted to demonsrate energy usage, to do so would necessitate a completely repeatable condition for Initial and Follow-Up measurements. This would be a plant constraint that would interfere with production, and is most likely not to even be considered by the plant's management. The testing performed here is most likely the best that can be done under profit controlled circumstances.

4. Reports heard by this author of metering "ratcheting" under transient and noise voltage conditions would be an additional valid reason to continue use of the EP2000. If such conditions are causing an increase in plant billing (as has been reported in several instances of EP2000 installations), then the EP2000 can create a plant voltage condition that would reduce such "ratchets" and a reduction in energy charges. Actual use of energy is most likely remaining the same, but the

use of that energy is being recorded more accurately, and in favor of the power user. A reduction in losses in motors or other equipment due to reduced transient voltages and noise seems a valid suggestion, however, the author believes that the energy component (as compared to a typical plants total energy consumption) would require longer monitoring periods for both before and after.

5. The EP2000 appears to be performing transient and noise voltage reduction on a continual basis, which is better than traditional transient voltage surge suppressors. Such devices only operate during an extremely high surge voltage condition. They supply no "general" high frequency filtering. Thus the EP2000 is supply two functions: high frequency noise filtering and transient voltage surge suppression.

1.3 Recommendations

1. We recommend that additional testing be performed on the EP2000 with actual metering equipment under controlled laboratory conditions. That equipment should be exposed to similar noise voltage and transient voltage conditions while measuring a known load. A with and without noise (and transient voltage) case will prove conclusively the benefits that have been seen in the field, in regard to reduced energy charges.

2. We would recommend that the EP2000 carry an energy rating similar to a transient voltage surge suppressor. In this way, it can be retrofit into existing installations as a one-for-one replacement with failed surge suppressors, or where new installations have surge arrestors already specified but not installed.

3. We that the technology of the EP2000 be expanded to include high current capability for active front end active harmonic filters and drive systems. Both of these new technologies produce high levels of high frequency noise at the carrier and integer multiples of the carrier. There is a great need in the industry at this time for such a filter device, as conventional filtering is expensive and only partially effective.

2.0 Introduction and Scope

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Measurements are discussed in the following section by figure. Note that the figures included in this report represent only a portion of the captured data. To include all captured data would necessitate several hundred pages of report, and so only the most important items are included. We believe that these figures with discussion represent the full database well, and provide excellent insight into the EP2000 performance.

3.0 Measurements

3.1 Introduction

Plots are supplied in this section for measurements that reveal items of interest for this analysis. We have not included a detailed discussion of all measurements taken. For each plot a discussion is supplied highlighting the critical observations as well as any results that can be concluded.

3.2 Measurement Consistency

One of the most important items to consider for a comparison measurement is whether the measurements were taken under similar plant loading conditions. We address this issue by comparing the system supply voltage, and the plant current, power and reactive power draw. If the initial and follow-up conditions are similar, and there have been no other major plant modifications (which is understood to be true by the author) then a before-after comparison can be made with an assurance of repeatability

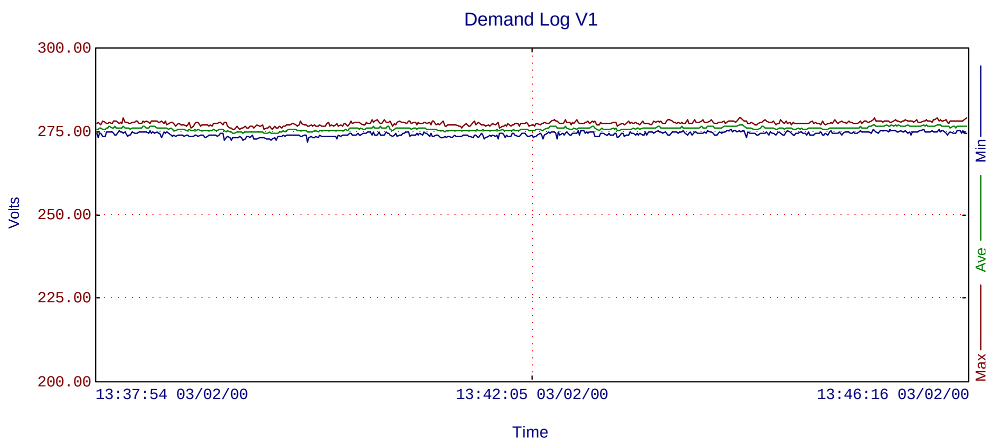

Figure 1. 480 V Main Phase 1 Voltage - Initial.

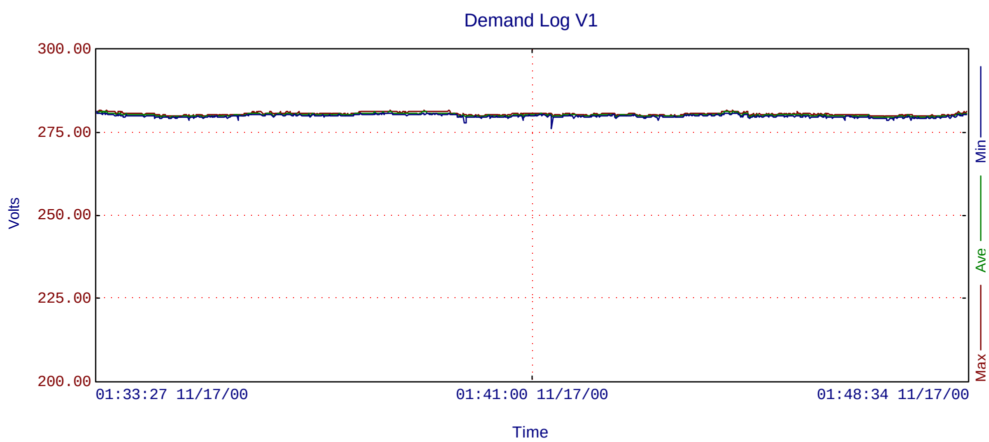

Figure 2. 480 V Main Phase 1 Voltage - Follow-Up.

In Figures 1 and 2, we see that the supply voltage is very near the same (275 to 277 Volts) for both initial and follow-up measurements. In the initial measurements we see a wider spread of voltage that we believe is caused by the additional noise on the supply voltage. This noise will be discussed further in later figures.

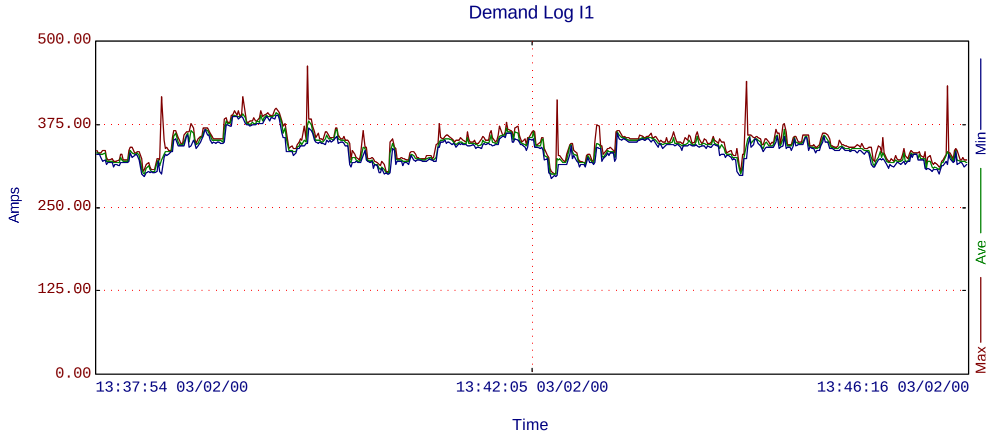

Figure 3. 480 V Main Phase 1 Current - Initial.

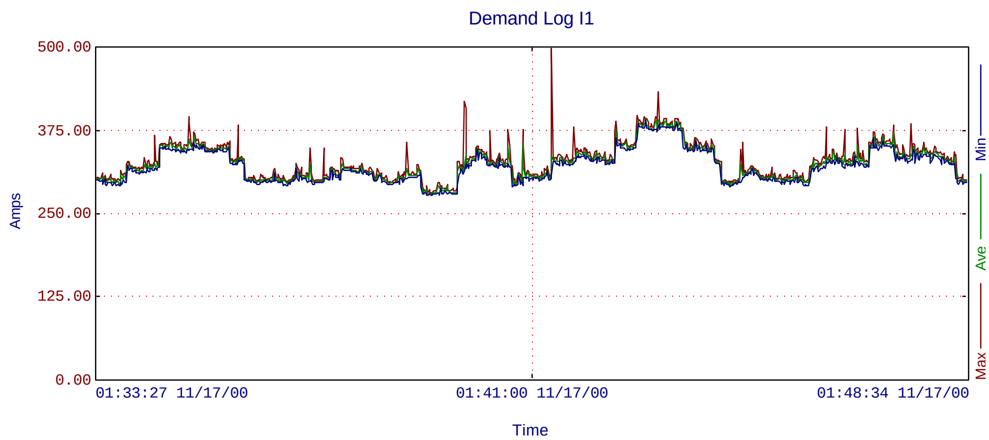

Figure 4. 480 V Main Phase 1 Current - Follow-Up.

As with the supply voltage above, the load current drawn by the facility is very near the same. Yes, the fluctuations are not identical, but the average level of current is very comparable. Note that we are only showing phase 1. Review of the measurements on the other phases showed identical loading patterns, which correspond to a plant with well balanced loading, and mostly 3-phase loads. Because of this, we do not need to review phases 2 and 3.

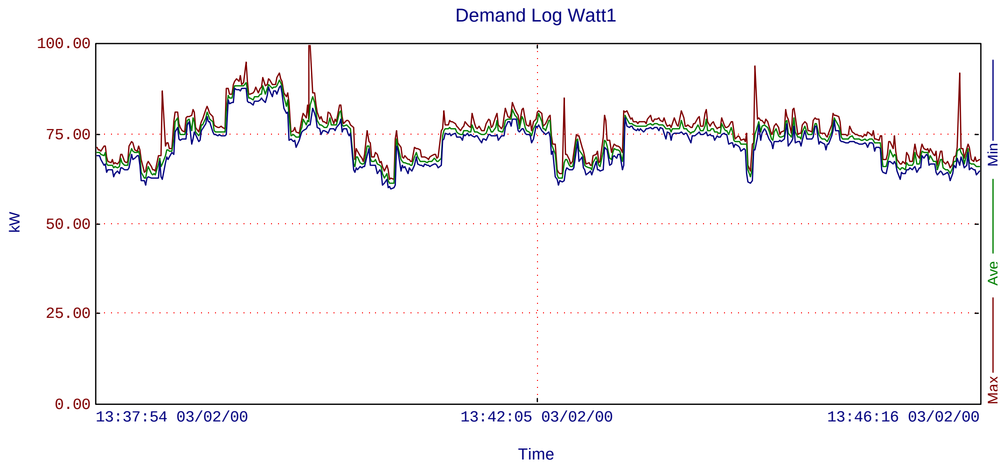

Figure 5. 480 V Main Phase 1 kW - Initial.

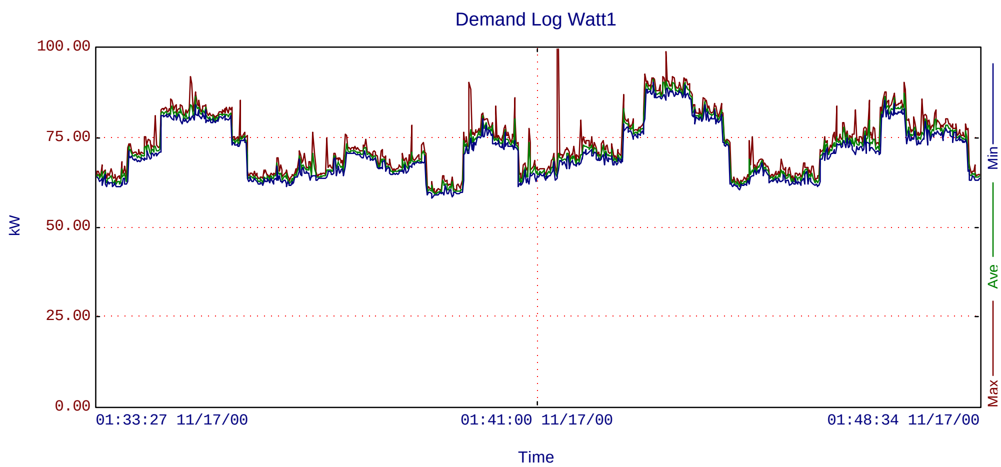

Figure 6. 480 V Main Phase 1 kW - Follow-Up.

The kW loading of the facility again shows nearly the same load level. Fluctuations are again slightly different, but the average loading is very comparable.

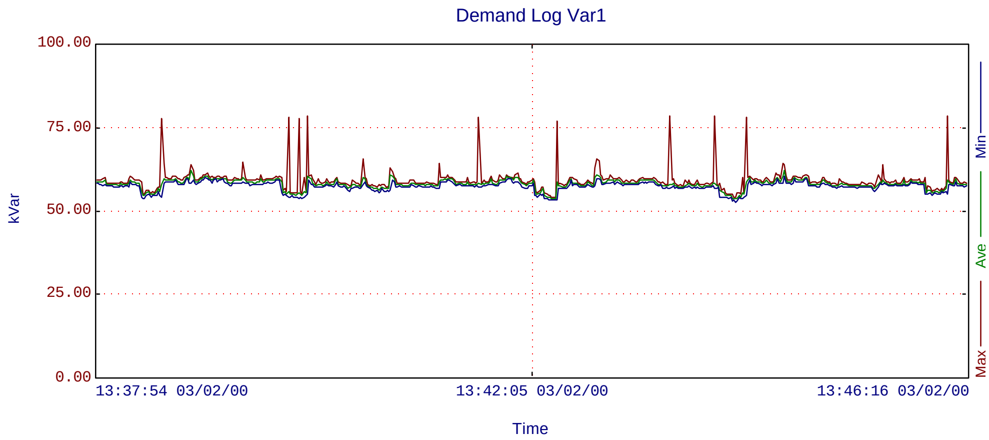

Figure 7. 480 V Main Phase 1 kVar - Initial.

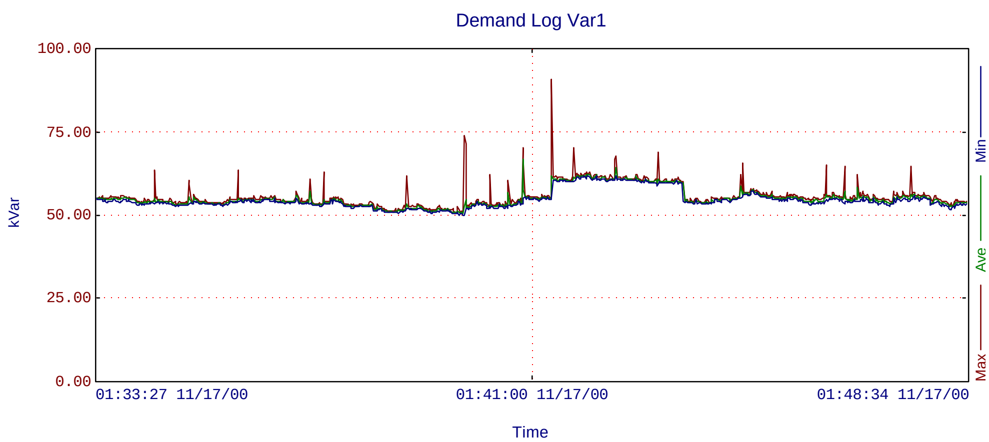

Figure 8. 480 V Main Phase 1 kVar - Follow-Up.

Var loading again is very comparable, with differences seen in the fluctuations. It could be stated that the Follow-Up measurement shows an average kVar demand lower than the Initial. However, given the short measurement period and seeing that the Follow-Up measurement does for a short interval reach the same kVar level as the initial, this cannot be concluded without question.

We thus conclude that the load conditions of the Initial and Follow-Up measurements are very comparable, and thus lead to an accurate comparison of before and after measurements.

3.3 Voltage Quality

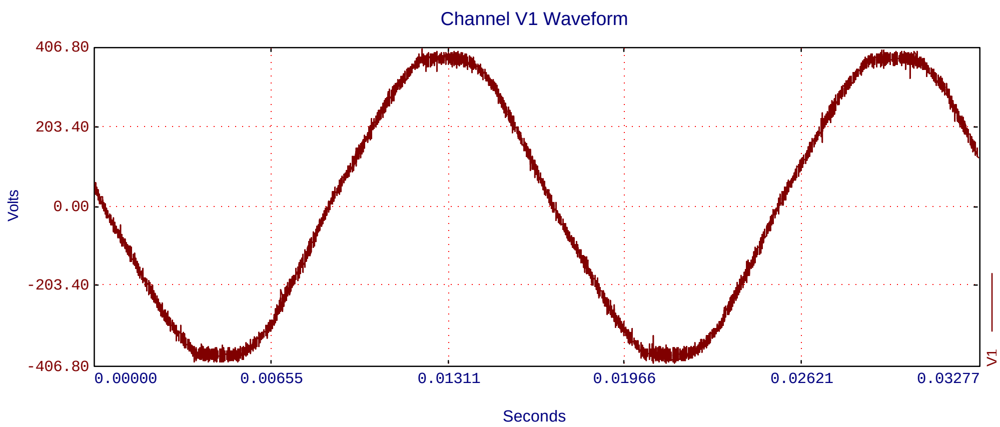

Figure 9. 480 V Main Phase 1 LG Voltage - Initial.

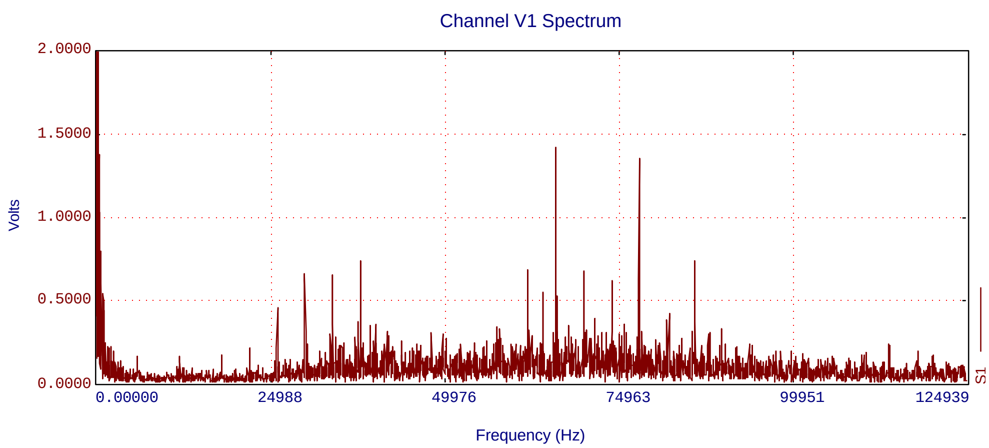

Figure 10. 480 V Main Phase 1 LG Voltage - Spectral Content - Initial.

As can be seen in Figures 9 and 10, Initial measurements show a significant noise component riding on the voltage wave. We believe this is being caused by an internal plant load that includes non-linear switching. This noise is not a healthy plant condition, even though it appears to not be causing any equipment failures. The highest noise component is around 66 kHz, but we do see a significant spread of noise across the spectrum. Volts on the spectrum plot are RMS, where the highest single frequency component is only 1.5 V. However, we can see clearly that the peak-to-peak noise voltage is in excess of 40 Volts.

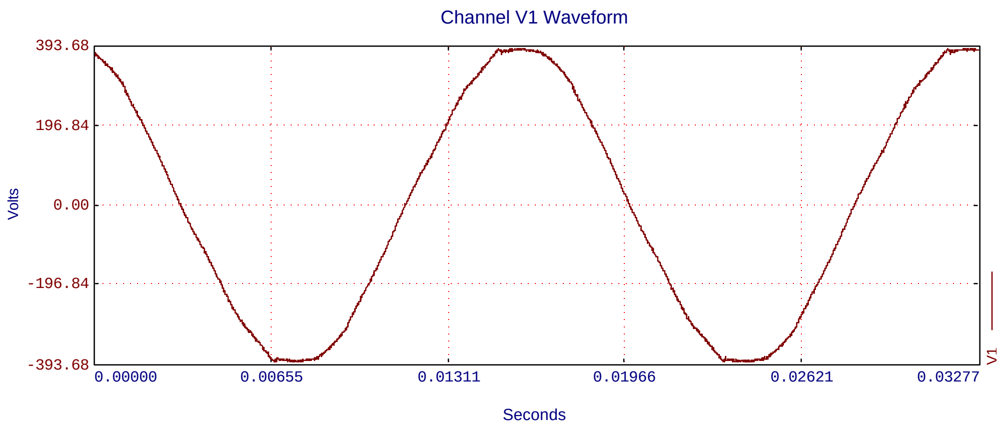

Figure 11. 480 V Main Phase 1 LG Voltage - Follow-Up.

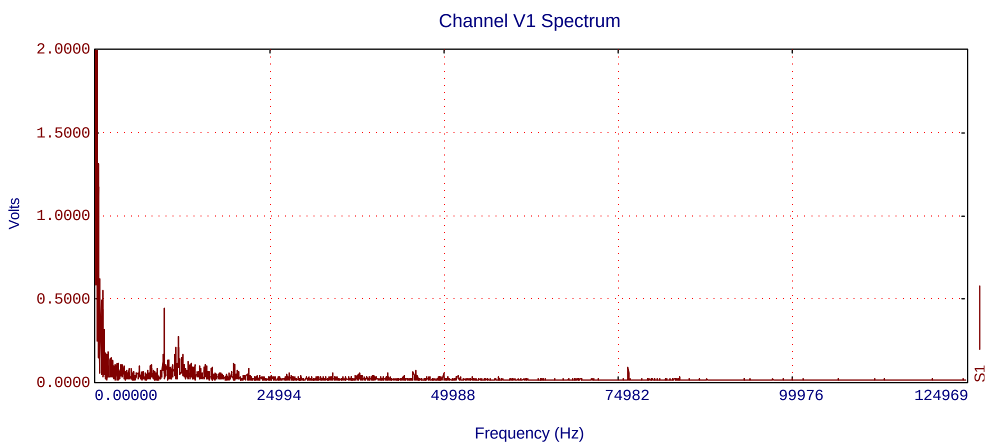

Figure 12. 480 V Main Phase 1 LG Voltage - Spectral Content - Follow-Up.

Measurements shown here in Figures 11 and 12 after installation of an EP2000, have illustrated most clearly the benefit of the EP2000. The hash on the main panel voltage is clearly evident before (Figures 9 and 10). After installation, the voltage is drastically "cleaned up". To prove that the EP2000 is creating this clean up, current transducers were connected around the EP200 leads, and showed significant amounts of high frequency current being absorbed (see Figures below). This falls directly in line with the 10kHz roll-off of the EP2000 as discussed with its inventor. Any high frequency transient or "hash" caused by drives systems or any other for of static load should be absorbed significantly by the EP2000. The higher the frequency, the greater the absorption. Note how the spectrum shows less and less residual noise as we move above 10 kHz, where the filtering action appears clearly evident.

3.4 EP2000 Absorption

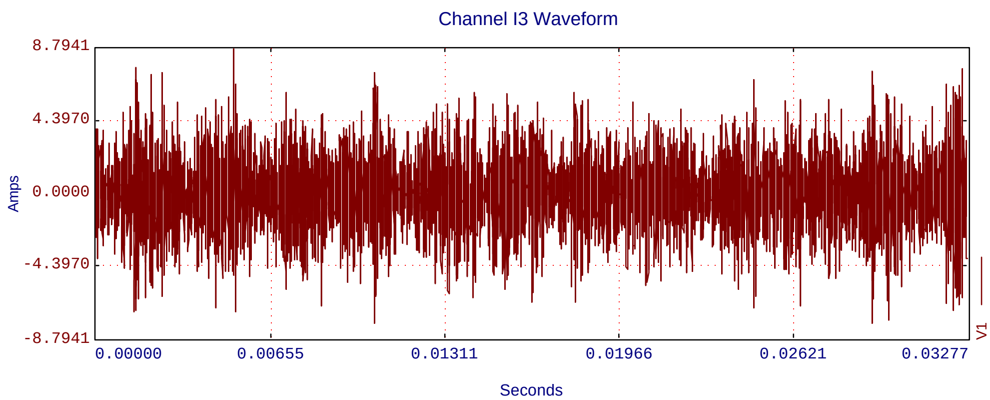

Figure 13. Current into Phase 3 of EP2000.

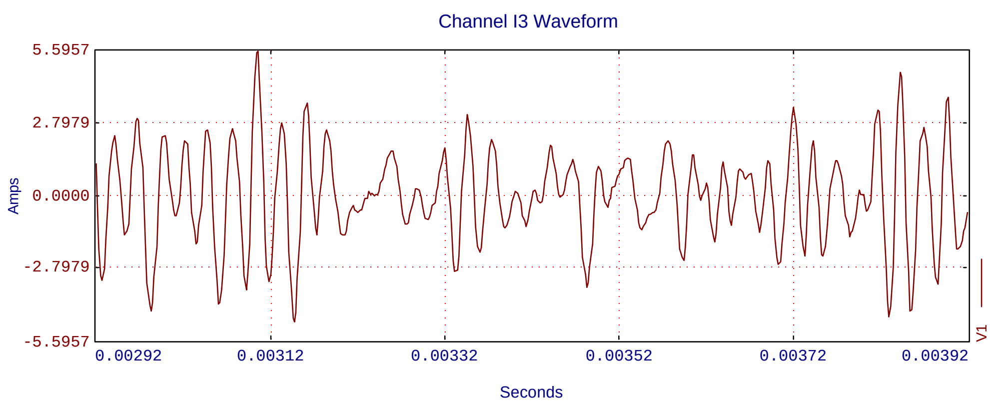

Figure 14. Zoom in of Phase 3 Current into EP2000.

Figures 13 and 14 show the significant high frequency current being absorbed by the EP2000. Figure 14 is supplied to show that the noise does actually have visibly apparent frequency content. In Figure 15 below, the spectral content of the current is shown, and reveals the spectral character of the noise. Please note that around 40 to 50 kHz and above, that the frequency response of the clamps causes little to no noise to be seen, and thus does not duplicated the noise spectrum seen on the voltage. This is due solely to the frequency response of the current clamps used during measurements. We believe that the noise component of the current is significant even above 50 kHz, as was seen in the voltage. Such a high frequency component in a current is difficult to measure without very expensive test equipment.

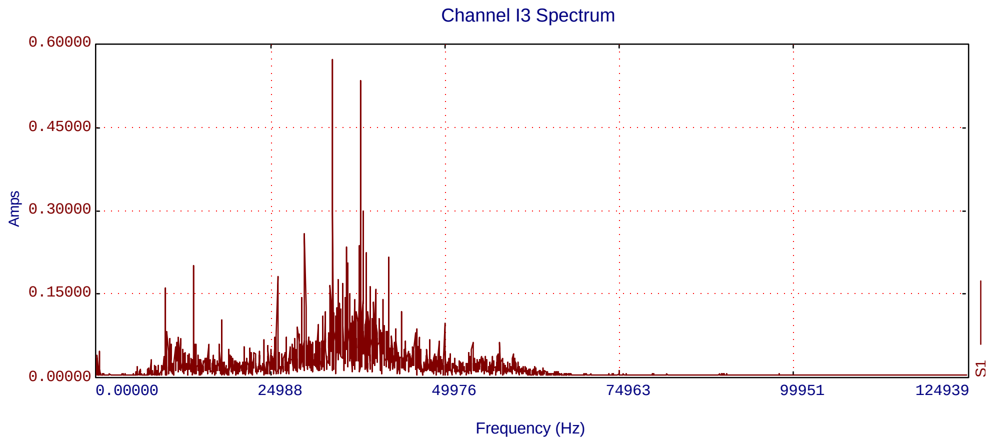

Figure 15. Current into Phase 3 of EP2000 - Spectral Content.

3.5 Additional Trend Plot Comparisons

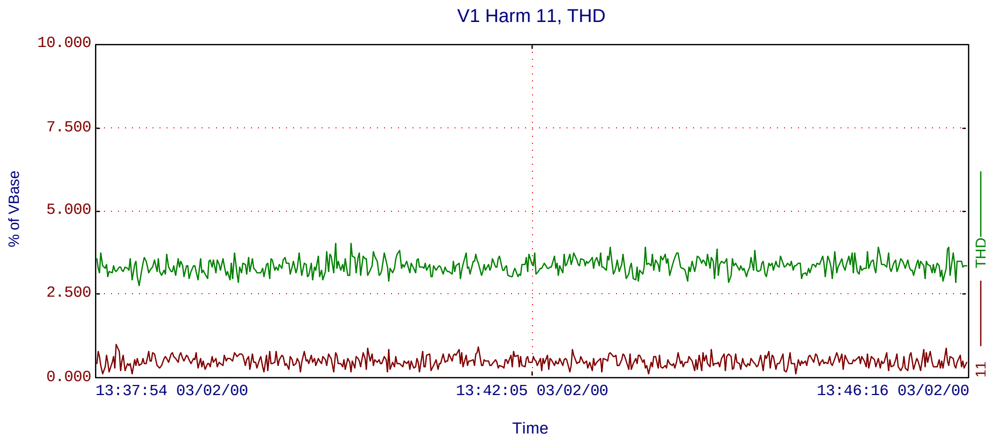

Figure 16. 480 V Main Phase 1 Voltage THD (Green) - Initial.

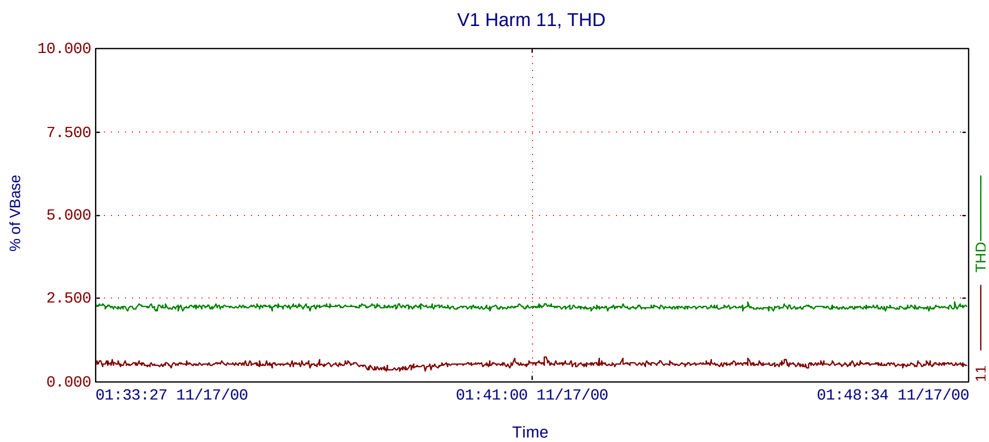

Figure 17. 480 V Main Phase 1 Voltage THD (Green) - Follow-Up.

As expected, the decrease in noise shows decreased voltage distortion.

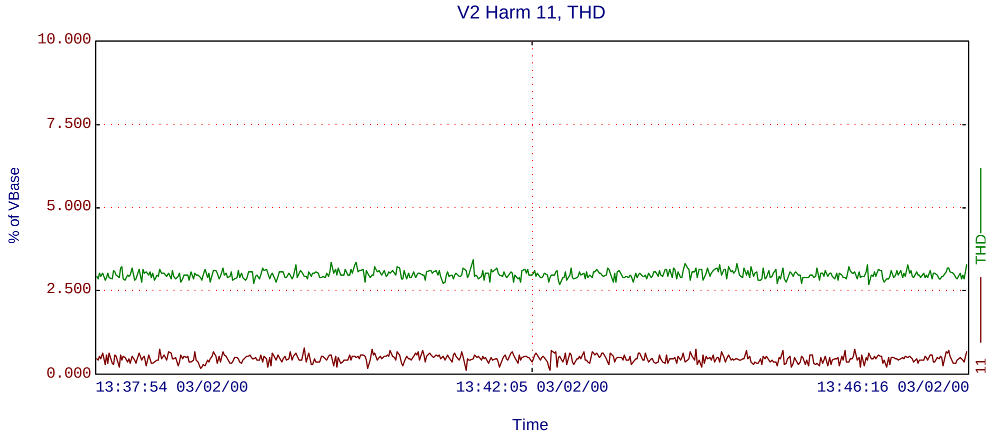

Figure 18. 480 V Main Phase 2 Voltage THD (Green) - Initial.

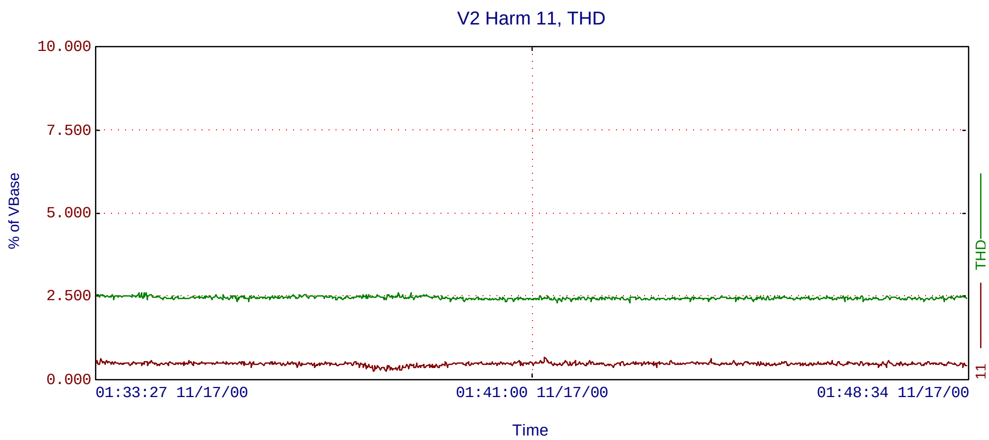

Figure 19. 480 V Main Phase 2 Voltage THD (Green) - Follow-Up.

As expected, the decrease in noise shows decreased voltage distortion.

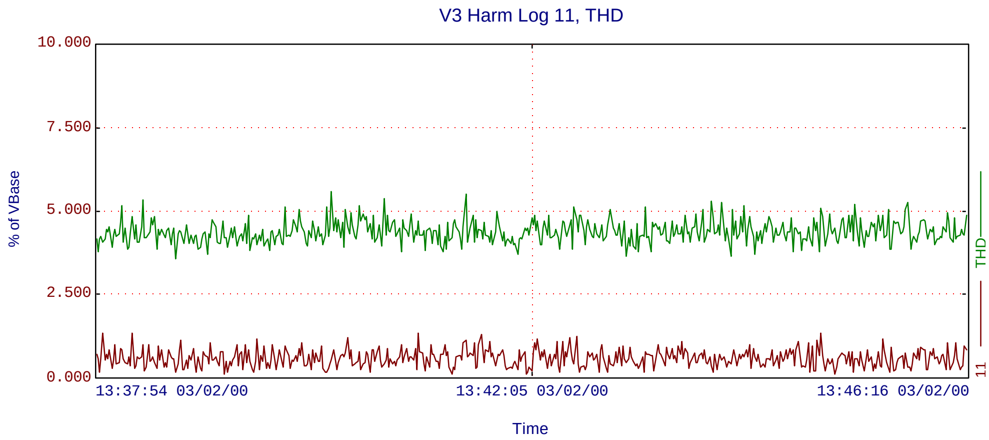

Figure 20. 480 V Main Phase 3 Voltage THD (Green) - Initial.

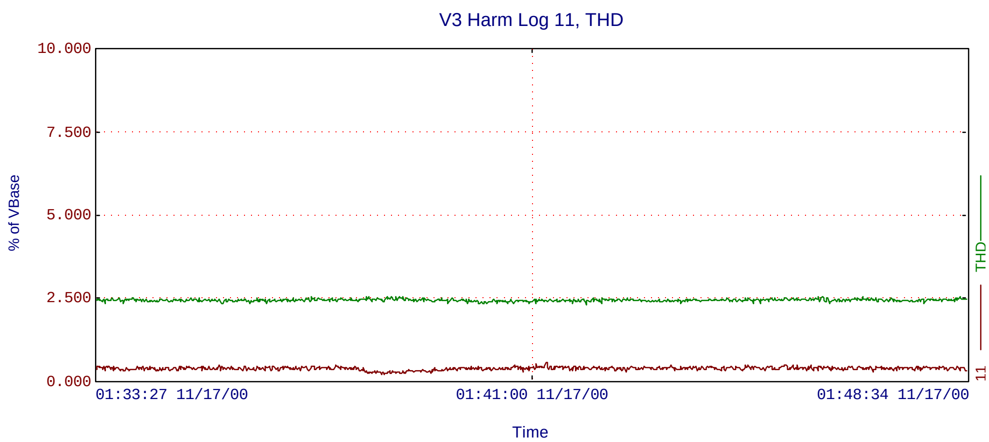

Figure 21. 480 V Main Phase 3 Voltage THD (Green) - Follow-Up.

As expected, the decrease in noise shows decreased voltage distortion. Notice also, that after the EP2000 was installed, that the voltage distortion is balanced, i.e. it is the same on each of the phases. The noise on the voltage was not balanced, and thus caused the Initial voltage THD to appear significantly different on each phase.

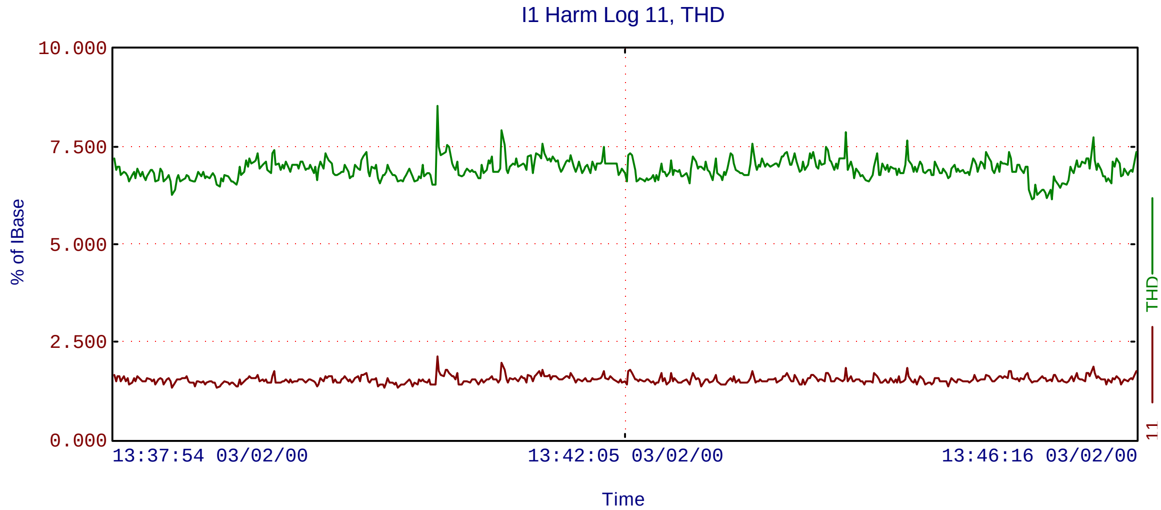

Figure 22. 480 V Main Phase 1 Current THD (Green) - Initial.

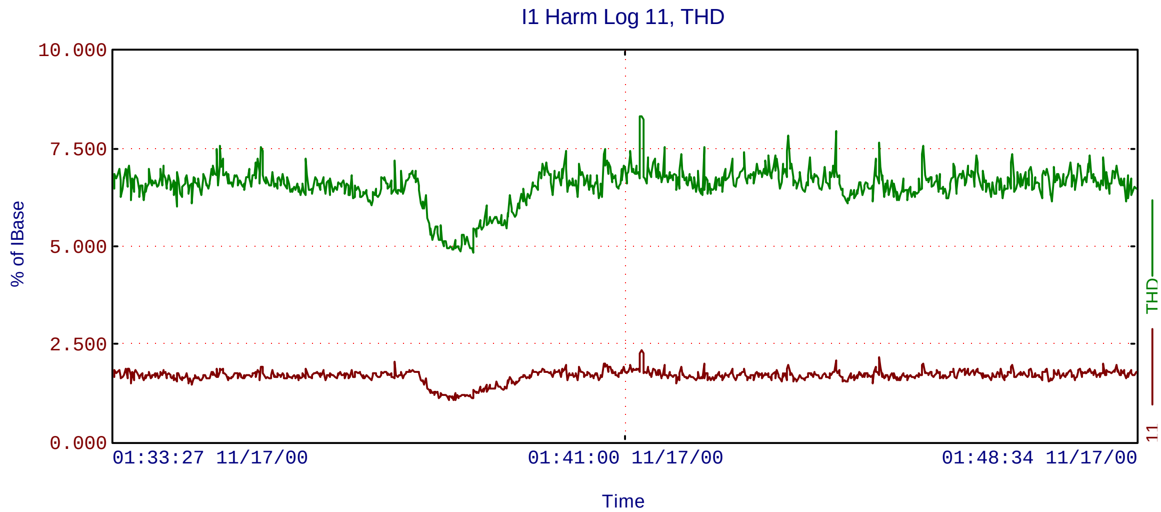

Figure 23. 480 V Main Phase 1 Current THD (Green) - Follow-Up.

Current distortion shows similar load patterns from Initial to Follow-Up measurements.

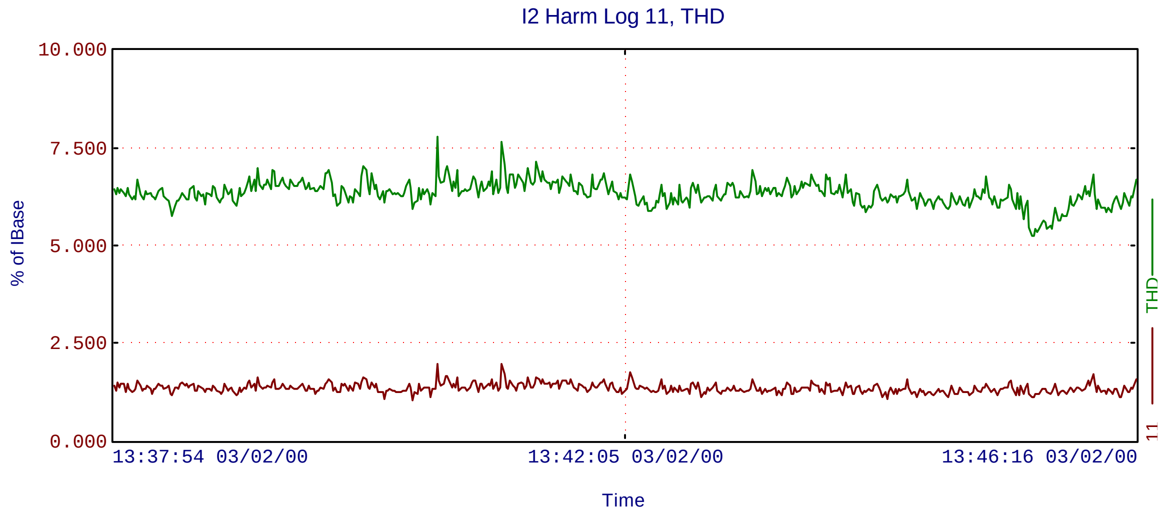

Figure 24. 480 V Main Phase 2 Current THD (Green) - Initial.

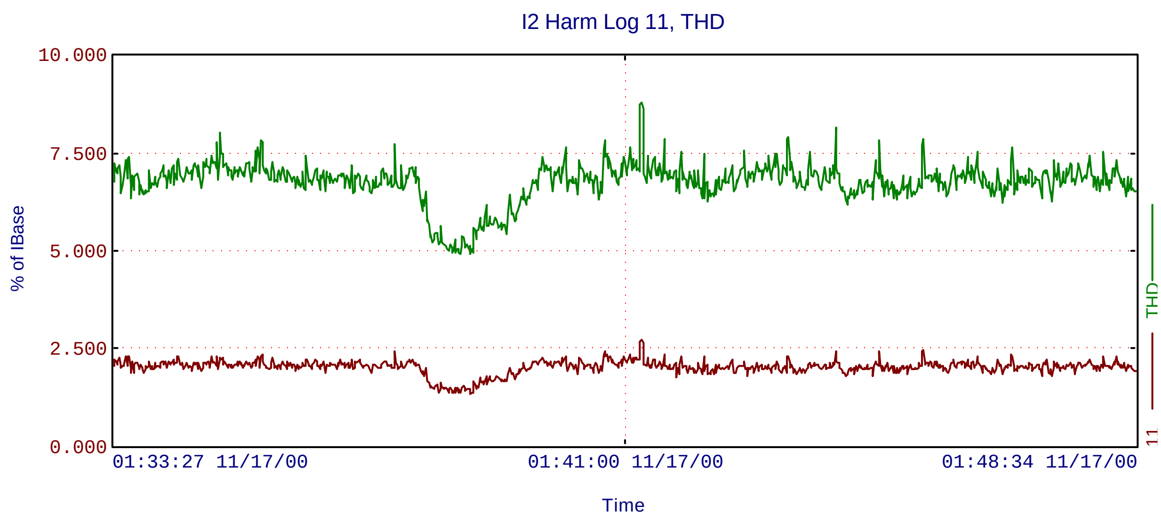

Figure 25. 480 V Main Phase 2 Current THD (Green) - Follow-Up.

Current distortion shows similar load patterns from Initial to Follow-Up measurements. We do see here however, a small increase in current THD. Since the EP2000 is constructed to handle only high frequency noise issues, without a doubt, we can conclude that the var increase seen here is not caused by the EP2000. This is mostly a small difference in equipment loading.

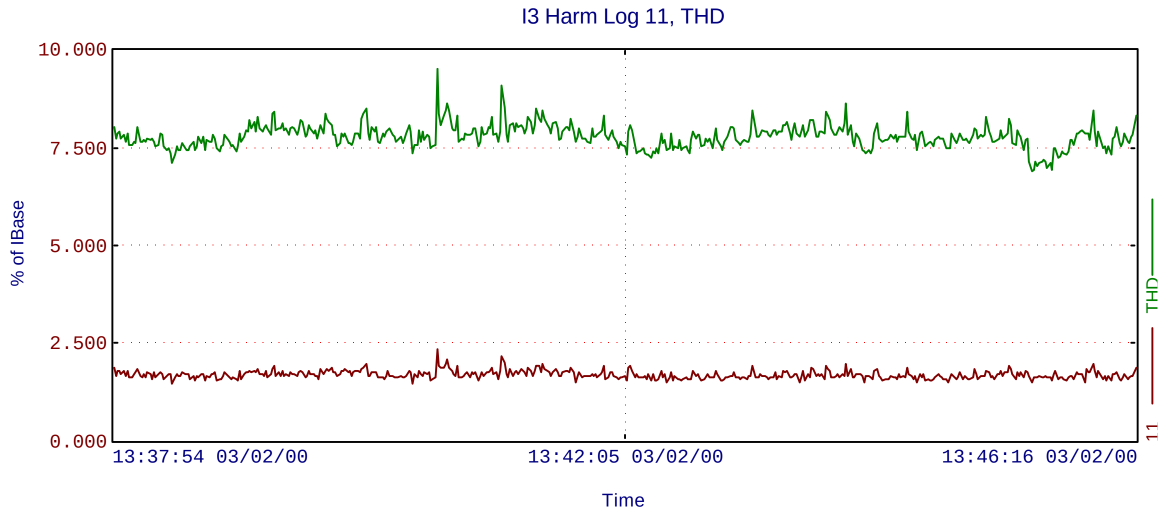

Figure 26. 480 V Main Phase 3 Current THD (Green) - Initial.

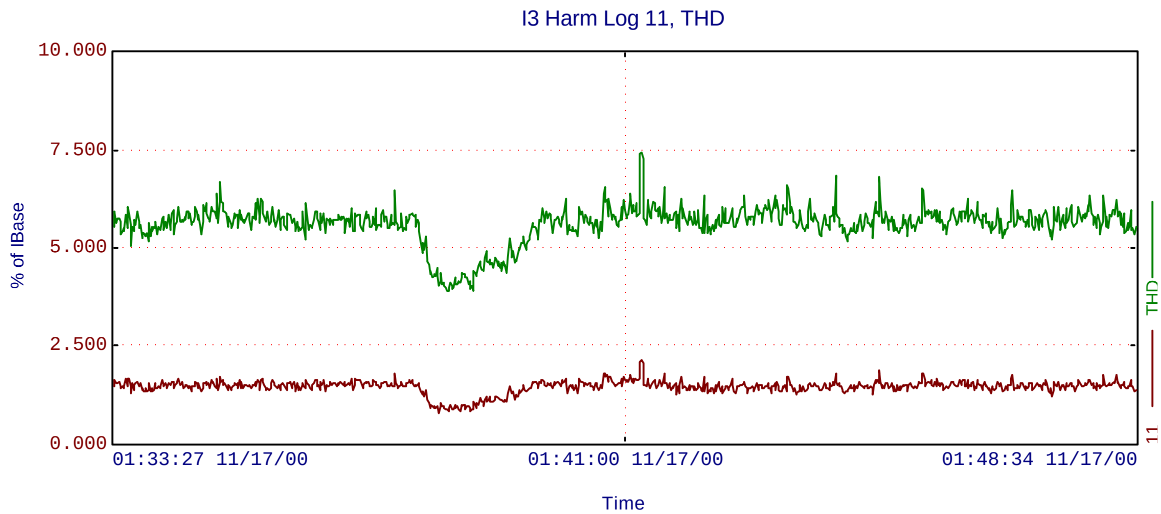

Figure 27. 480 V Main Phase 3 Current THD (Green) - Follow-Up.

Current distortion shows similar load patterns from Initial to Follow-Up measurements. We do see here however, a small reduction in current THD. Without a well documented completely repeatable test, it cannot be concluded that the EP2000 is causing this improvement. This is mostly a small difference in equipment loading.

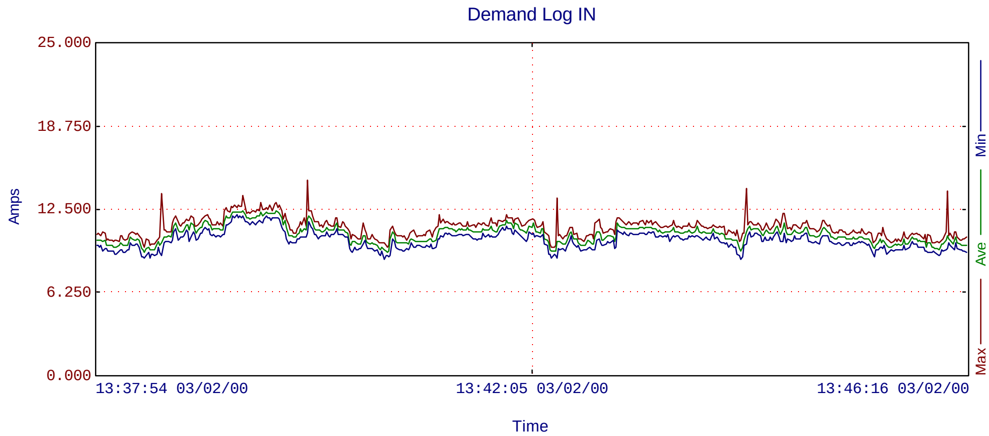

Figure 28. 480 V Main Neutral Current - Initial.

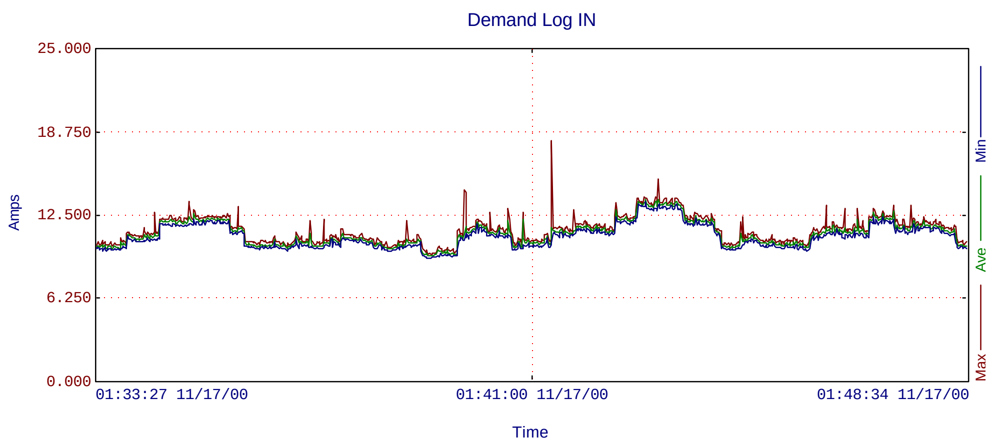

Figure 29. 480 V Main Neutral Current - Follow-Up.

There are no significant changes seen in the neutral current. This means that the slight imbalance in loading that existed in the Initial measurements also existed in the Follow-Up measurements.

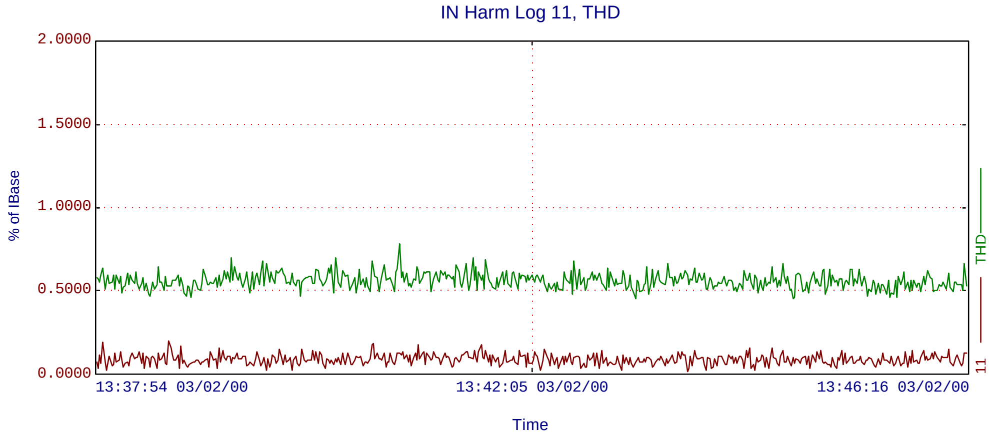

Figure 30. 480 V Main Neutral Current THD (Green) - Initial.

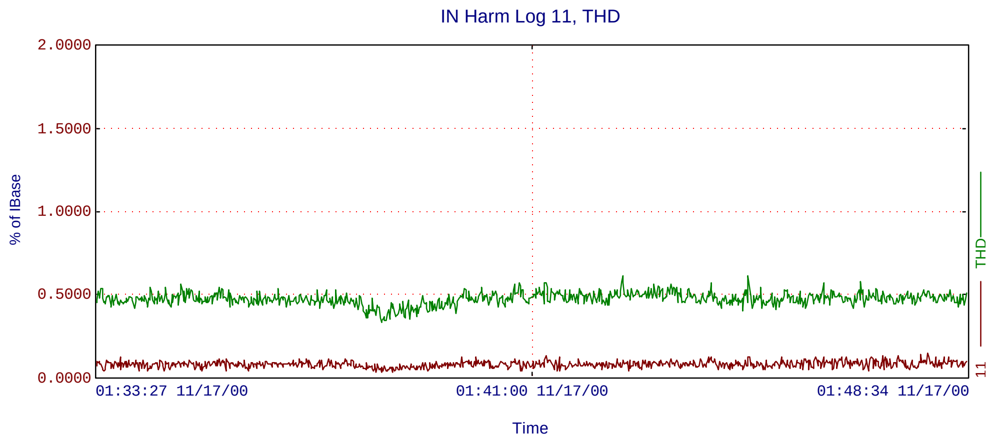

Figure 31. 480 V Main Neutral Current THD (Green) - Follow-Up.

There are no significant changes seen in the neutral current THD. This means that the slight imbalance in loading and its associated harmonic current content that existed in the Initial measurements also existed in the Follow-Up measurements.