



# PQSoft Case Study

## Commercial Facility Harmonic Evaluation

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### Abstract:

Utility power system harmonic problems can often be solved using a comprehensive approach including site surveys, harmonic measurements, and computer simulations.

This case study presents the results for a commercial facility harmonic evaluation. The simulations were completed using the PSCAD program. The analysis evaluates the effects of transformer connections to determine the harmonic current distortion levels on both the primary and secondary sides of the customer transformers. The simulation results show the third harmonic neutral current and a K-Factor transformer derating analysis.

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## RELATED STANDARDS

IEEE Std. 519-1992  
IEEE Std. 1159-1995

## GLOSSARY AND ACRONYMS

ASD	Adjustable-Speed Drive
CF	Crest Factor
DFT	Discreet Fourier Transform
DPF	Displacement Power Factor
PCC	Point of Common Coupling
PF	Power Factor
PWM	Pulse Width Modulation
TDD	Total Demand Distortion
THD	Total Harmonic Distortion
TPF	True Power Factor

# INTRODUCTION

A commercial facility harmonic evaluation was completed for the system shown in Figure 1. The case study was completed using the PSCAD program. The accuracy of the simulation model was verified using three-phase and single-line-to-ground fault currents and other steady-state quantities.

The circuit model for the case involved a 25.56kV customer substation with two 1,000 kVA step-down transformers supplying HVAC loads and one 100 kVA transformer supplying switch-mode power supply (SMPS) loads.

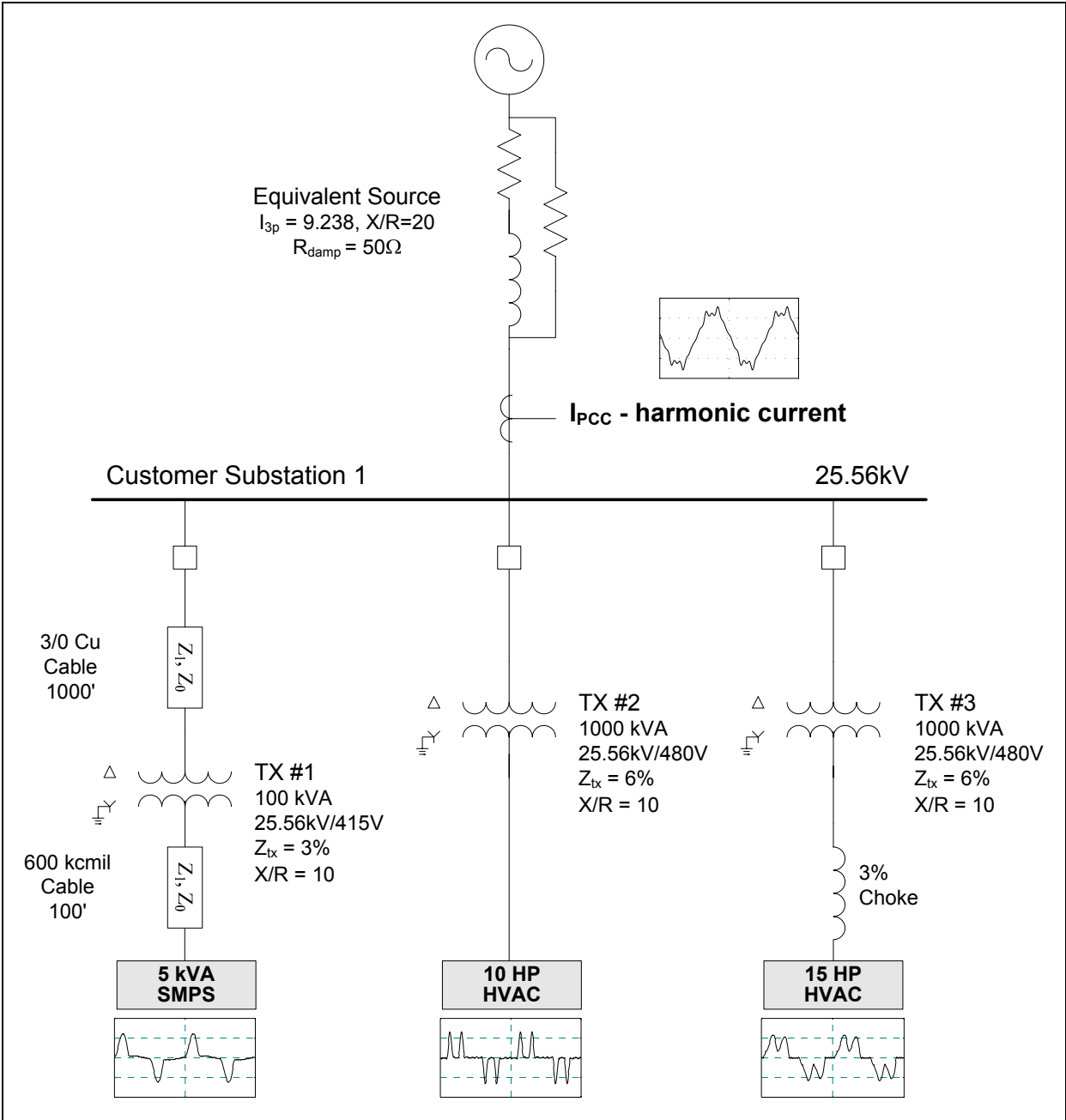


Figure 1 - Illustration of Oneline Diagram for Commercial Facility Harmonic Evaluation

Switch-mode power supplies use dc/dc conversion techniques for maintaining constant dc voltage output. In the absence of a large ac-side inductance, input current to the power supply becomes positive and negative current pulses, characterized by high crest factors (peak to rms ratio) and high harmonic content. A high third harmonic current content is especially typical of switch-mode power supplies. Since third harmonic current components do not cancel each other in the neutral of a three-phase system, increasing application of switch-mode power supplies has created a concern for overloading of neutral conductors, especially in older buildings where an undersized neutral may have been utilized.

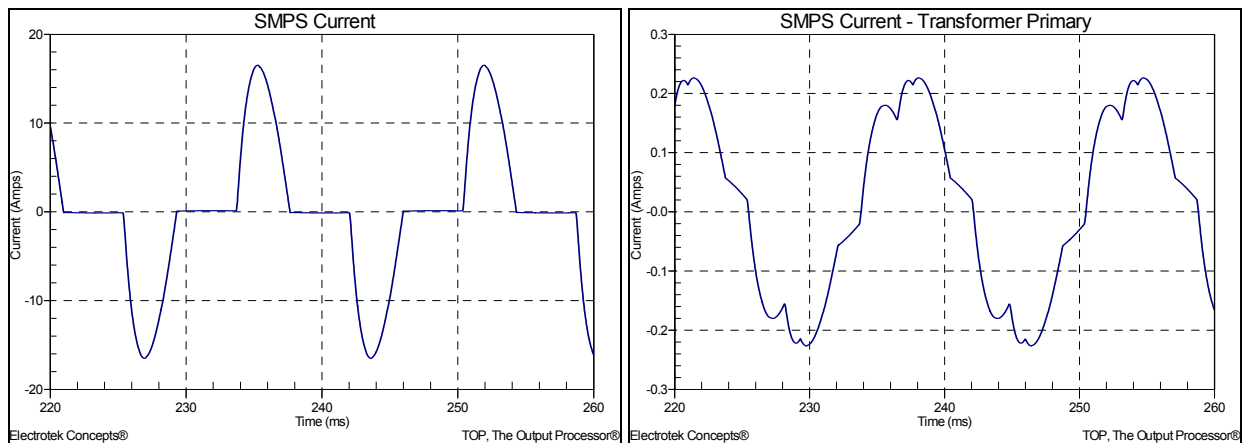
## SIMULATION RESULTS

The case study evaluates the effects of transformer connections to determine the harmonic current distortion levels on both the primary and secondary sides of the customer transformers. Figure 2 shows the simulated power supply current and the resulting current on the transformer primary due to the delta/wye connection that traps the zero sequence harmonics in the primary delta winding.

The secondary power supply current has a fundamental frequency value of 6.76 amps, an rms value of 8.10 amps, and a THD value of 66.12%. The highest component was the 3<sup>rd</sup> harmonic with a value of 62.30%. The resulting primary transformer current has fundamental frequency value of 0.15 amps, an rms value of 0.16 amps, and a THD value of 14.89%. The highest components were the 5<sup>th</sup> harmonic with a value of 12.93% and the 7<sup>th</sup> harmonic with a value of 6.39%.

Figure 3 shows the transformer derating and K-Factor calculations. The assumed eddy current loss factor ( $P_{EC-R}$ ) for the dry type 100 kVA transformer was 8%. A K-Rating of four would be sufficient for this application.

Figure 4 shows the transformer neutral current when supplying the power supply loads. The phase A power supply current is also shown for reference. The triplen harmonics add in the neutral to create a waveform that consists of mostly 3<sup>rd</sup> harmonic (180 Hz) frequency. The rms value of the neutral current was 12.72 amps, with the highest components being the 3<sup>rd</sup> at 12.63 amps, the 9<sup>th</sup> at 1.41 amps, and the 15<sup>th</sup> at 0.25 amps. One mistake commonly made with this type of waveform is to use a THD value in percent. This is because the fundamental frequency component of the neutral current in a balanced system approaches zero amps, which leads to a THD value that approaches infinity.



**Figure 2 - Simulated Power Supply and Transformer Primary Currents**

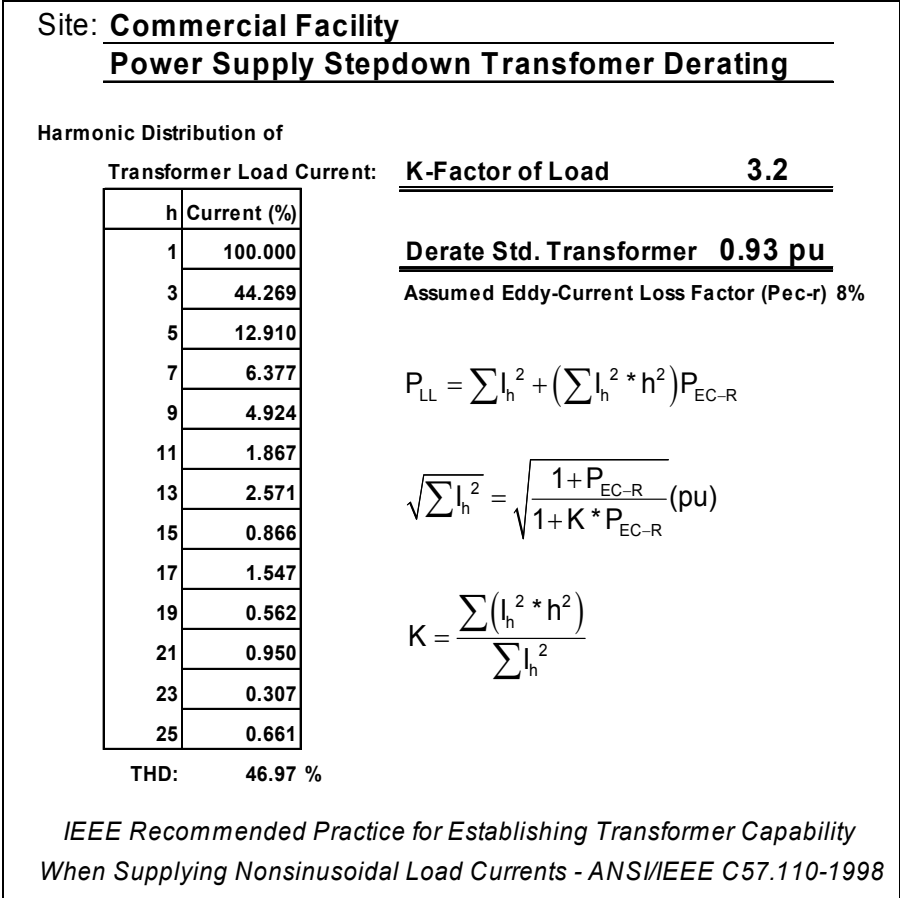


Figure 3 - Power Supply Transformer Derating Calculation

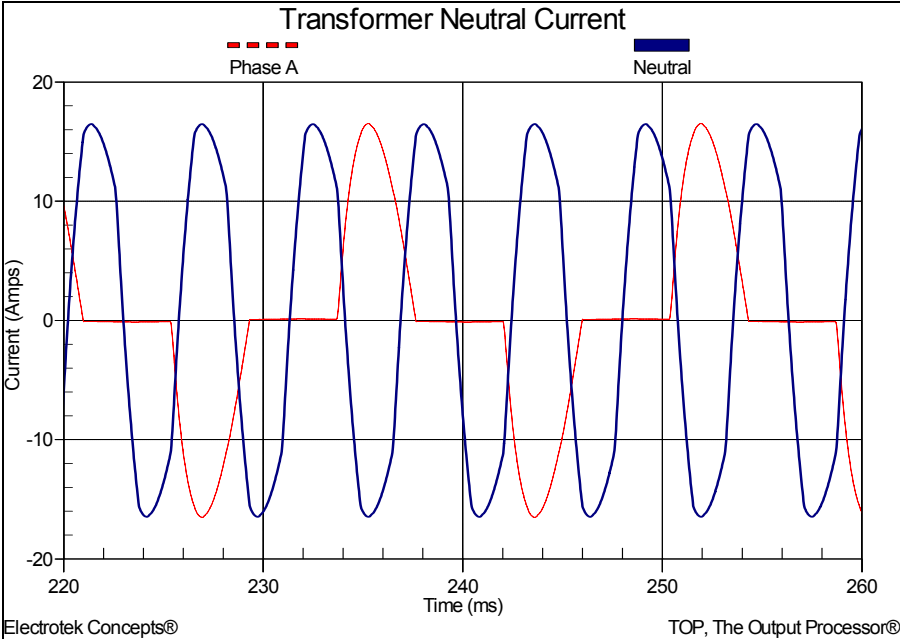
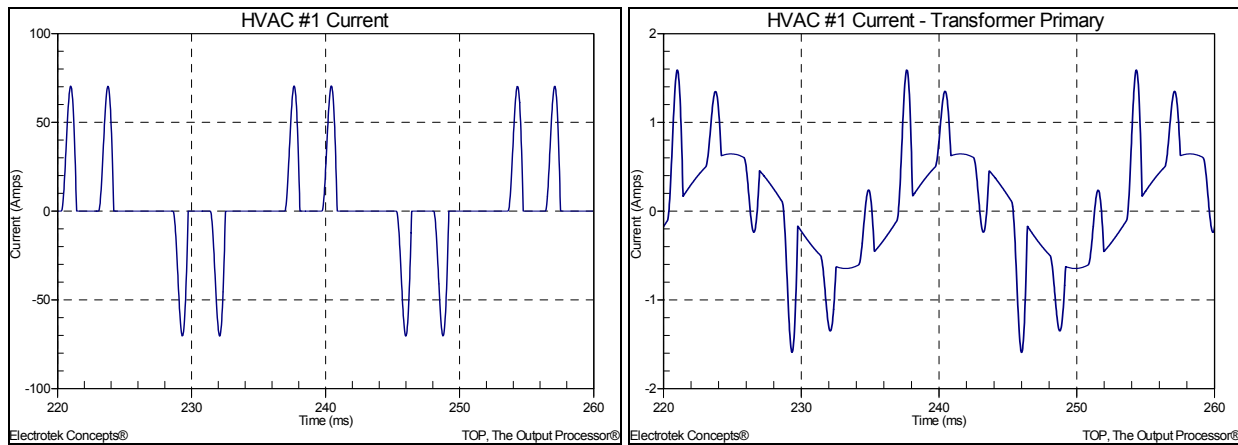


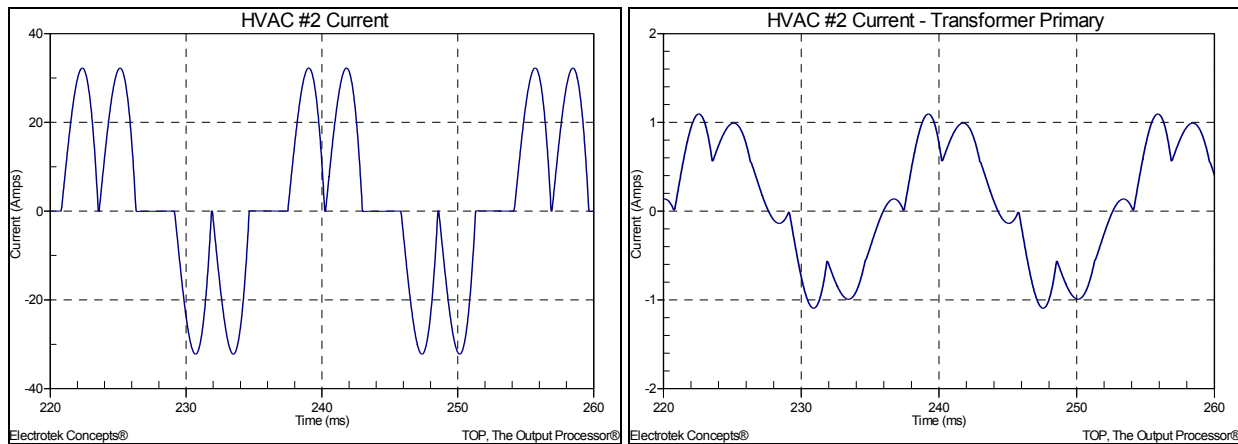
Figure 4 - Simulated Transformer Neutral

Figure 5 shows the simulated HVAC #1 current and the resulting current on the transformer primary. The secondary current has a fundamental frequency value of 13.10 amps, an rms value of 24.12 amps, and a THD value of 154.58%.



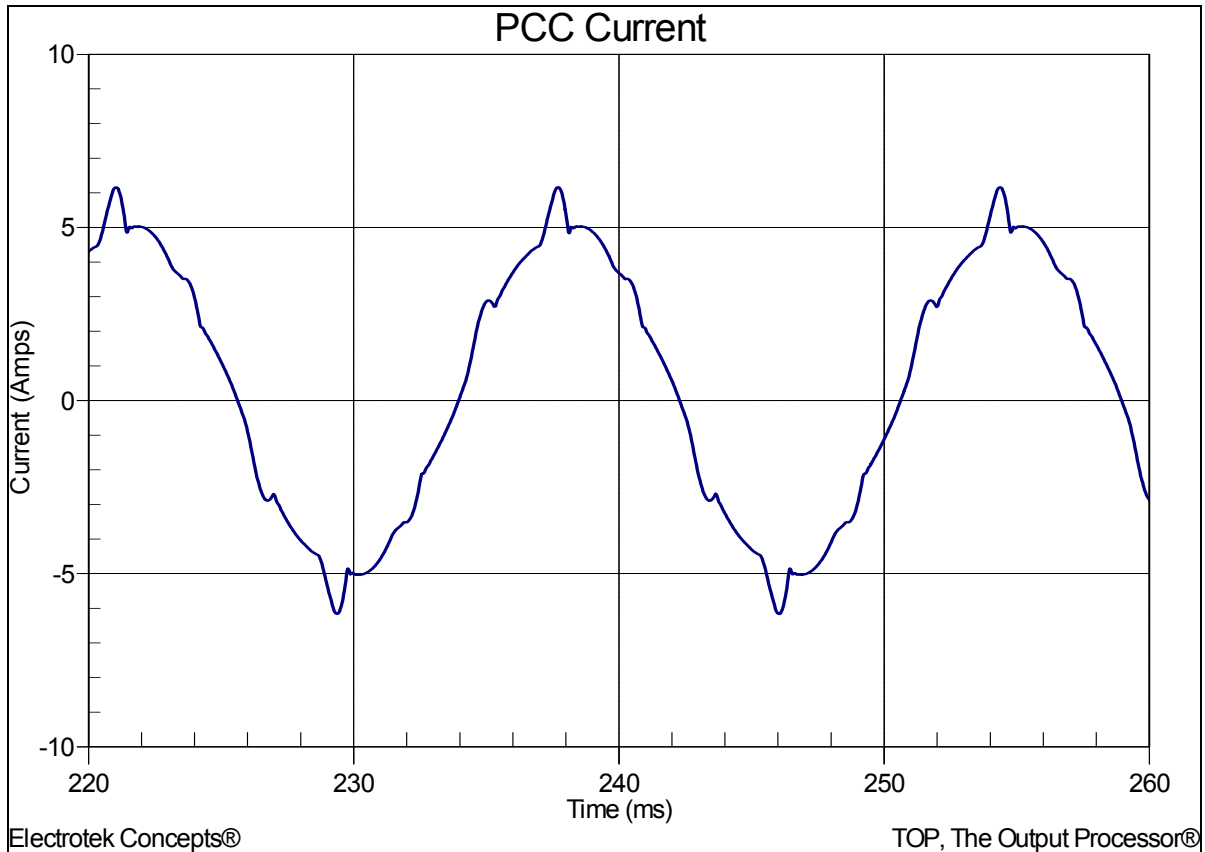
**Figure 5 - Simulated Drive #1 and Transformer Primary Currents**

Figure 6 shows the simulated HVAC #2 current and the resulting current on the transformer primary. The secondary current has a fundamental frequency value of 16.18 amps, an rms value of 18.57 amps, and a THD value of 56.44%.



**Figure 6 - Simulated Drive #2 and Transformer Primary Currents**

Figure 7 shows the simulated point of common coupling (PCC) current at the utility/customer interface. The current has a fundamental frequency value of 3.73 amps, an rms value of 3.74 amps, and a THD value of 8.18%. The highest components were the 5<sup>th</sup> harmonic with a value of 3.99%, the 7<sup>th</sup> harmonic with a value of 4.30%, the 11<sup>th</sup> with a value of 4.05%, and the 13<sup>th</sup> with a value of 2.89%. The values of the triplen harmonics (e.g., 3<sup>rd</sup>, 9<sup>th</sup>, 15<sup>th</sup>, etc.) were negligible due to the fact that all of the transformers supplying the nonlinear customer loads have delta connected primary windings and also that all of the customer loads were balanced.



**Figure 7 - Simulated Point of Common Coupling Current**

## SUMMARY

This case study summarizes the results for a commercial facility harmonic evaluation. The case study evaluates the effects of transformers connections to determine the harmonic current distortion levels on both the primary and secondary sides of the customer transformers. The simulation results show the third harmonic neutral current and a K-Factor transformer derating analysis. The simulation results also highlight the effect of harmonic current cancellation that may occur in a facility which results in lower distortion at the point of common coupling.

## REFERENCES

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2. IEEE Recommended Practice for Monitoring Electric Power Quality," IEEE Std. 1159-1995, IEEE, October 1995, ISBN: 1-55937-549-3.
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