CASE STUDY

Johns Hopkins University
School of Medicine, Preclinical Building

Facility Description

The Preclinical Building is located in a relatively small four-story building that was completed in 1981. This preclinical building consists mainly of small medical offices.

When compared to the facility's combined 277-volt lighting and 480-volt HVAC loads, its 120-volt office loads actually consume more energy. This load group's harmonic current-generating switch-mode power supplies create the facility's best energy-saving opportunity.

Existing Conditions

- Two large inefficient pre-NEMA TP 1 distribution transformers
- 14.9% daytime loading of the transformers
- Unacceptable levels of positive-, negative- and zero-sequence harmonic currents
- Unacceptable zero-sequence harmonic impedances at 208/120-volts

The existing distribution transformers were installed before the imposition of US DOE transformer efficiency legislation. In 1981, single-phase nonlinear electronic office and lighting loads did not exist. K-Rated or harmonic mitigating low voltage distribution transformers had not yet been developed.

Pre-NEMA TP 1 distribution transformers had higher losses and lower efficiencies than DOE 2016 compliant units. At an average daytime loading of only 14.9%, the pre-NEMA TP 1 transformers' excitation losses were extremely high, resulting in unacceptably low energy efficiencies. Light distribution transformer loading was typical when complying with the requirements of the National Electrical Code.

Compared to all other nonlinear load types, single-phase switch-mode power supplies generate the highest levels of positive- and negative-sequence harmonic currents (≈ 3.5X higher than a three-phase power rectifier). When connected phase-to-neutral, single-phase switch-mode power supplies also generate extremely high levels of zero-sequence harmonic currents (i.e. $I_3 \approx 82\%$ of I_1).

In an Ohm's Law relationship with the existing transformers' high zero-sequence impedances, zero-sequence harmonic

currents generate high levels of zero-sequence harmonic voltages ($E_0 = I_0 \times Z_0$) and voltage distortion. Distortion of the 60Hz sinusoidal waveform, which is always highest at the loads, will produce significant load 'penalty losses', reduce the switch-mode power supplies' efficiencies and reduce the 208/120-volt system's power factor.

Challenge

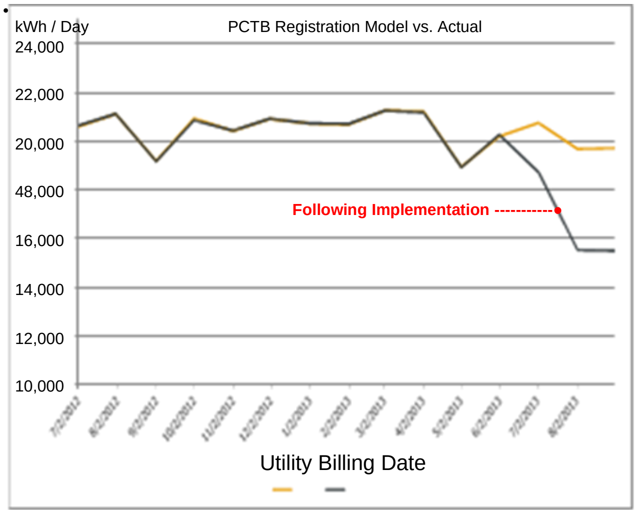
PQI's challenge was to improve transformer efficiency, reduce the subsystems' zero-sequence impedances, improve load efficiencies, increase load power factors and reduce the 480-volt system's harmonic current-generated 'penalty losses', while ensuring system-load compatibility.

Solution

PQI was contracted by Johns Hopkins University School of Medicine to develop a distribution system solution that would reduce 'penalty losses', increase efficiency and power factor, improve overall power quality and ensure system-to-load compatibility.

After confirming each transformer's maximum and average load factors, and harmonic current load profile, PQI's engineers optimized the system by replacing the two large oversized, inefficient transformers with rightsized, ultra-efficient harmonic mitigating transformers. The transformer downsizing was made in accordance with CSA C802.4, national**grid**® guidelines, and NEC requirements.

To maximize payback and return-on-investment we were limited in downsizing to one standard kVA rating. This limitation, which was far less than recommended by CSA or national**grid**® guidelines, was necessary to avoid the need to change existing transformer and circuit protection and conductors.



- 1,587,332 kWh annual power saving
- $158,733 annual utility saving
- 21.3% reduction in annual energy cost
- 3.1 months projected payback