POWER QUALITY INTERNATIONAL

CASE STUDY

Johns Hopkins University
School of Medicine
The Bunting Blaustein Cancer Research Building
Baltimore, MD

Facilities Description

The Bunting Blaustein Cancer Research building was completed in 2000. This 122,000 square-foot mission-critical facility, which includes numerous laboratories and offices, accommodates more than 400 researchers and staff.

Existing Conditions

- Nineteen inefficient pre-NEMA TP 1 distribution transformers
- 7.4% 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. Since completion in 2000, there has been a significant increase in single-phase nonlinear electronic laboratory, office and lighting loads. The existing system was not designed to operate efficiently in this nonlinear environment.

Pre-NEMA TP 1 distribution transformers had higher losses and lower efficiencies than DOE 2016 compliant units. At an average daytime loading of only 7.4%, 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, Bunting Blaustein Cancer Research building 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.

Impact

- **606,934 kWh a**nnual savings
- **$60,693** annual utility savings
- **$37,322** calculated energy savings due to transformer replacements
- **$23,371** calculated energy savings due to voltage distortion improvement at the loads and harmonic current reduction in the 480/277-volt circuits
- **5.8%** reduction in energy costs
- **$86,250 u**tility rebate
- **1.7 years** project payback