POWER QUALITY INTERNATIONAL

Exclusive e-Rated® Provider

Transformer kVA Ratings and Efficiency Considerations

New Construction

A *Load Factor* survey, undertaken by The Cadmus Group Inc.in 1999, found that the average loading of low voltage, dry-type distribution transformers in commercial, industrial and public buildings was in a range between 9% and 17% FL. They also found that loading, for at least 12 hours a day, was only 10% of the average. More recent surveys have shown much lower *Load Factors*, the result of upgrading to more energy efficient loads.

Transformer oversizing is a typical outcome when meeting the requirements of national and local electrical codes in the USA and Canada. To maximize energy conservation, the optimum transformer kVA rating can be determined by referring to CSA C802.4-2013 *(A Guide for kVA Sizing of Dry-Type Transformers).* Where there is a conflict between a code's requirements and the guide's recommendations, we recommend the application of the lowest allowable kVA rating.

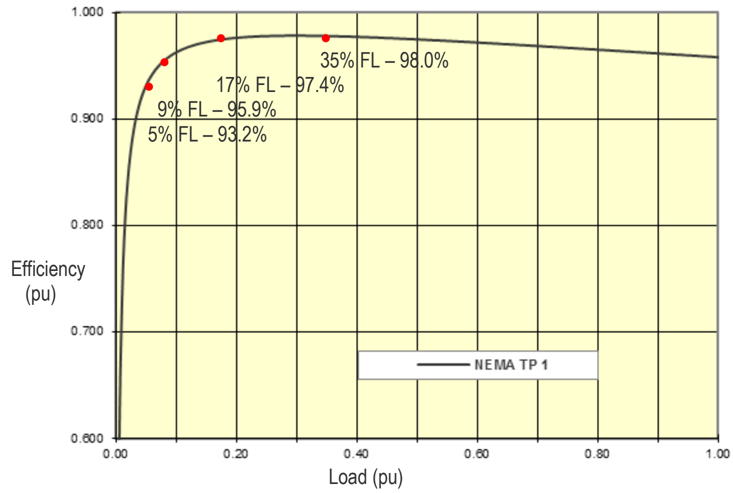
In addition to the higher capital cost of oversizing, the cost of operating a lightly loaded transformer is also higher. Using the Cadmus survey findings, *Figure 1* shows that the efficiency of a typical 75kVA, NEMA TP 1 transformer, with a required efficiency of 98.0% at 35% FL, is 97.4% at 17% FL, but only 95.9% at 9% FL. However, based on the more recent surveys, and our own experience, average loading is often much lower. For example, at 5% FL the transformer's efficiency is only 93.2%. Rightsizing a transformer, as recommended in CSA C802.4, can result in a substantial reduction in losses, increase in efficiency and reduction in energy costs.

Since the recommendations given in CSA C802.4 are for a transformer under *linear* loading, before proceeding with a final selection, its nonlinear efficiency, under anticipated loading and harmonic current profiles, can be determined by referring to CSA C802.5-2015 *(Guide for Selection of a Distribution Transformer for Nonlinear Applications.)*

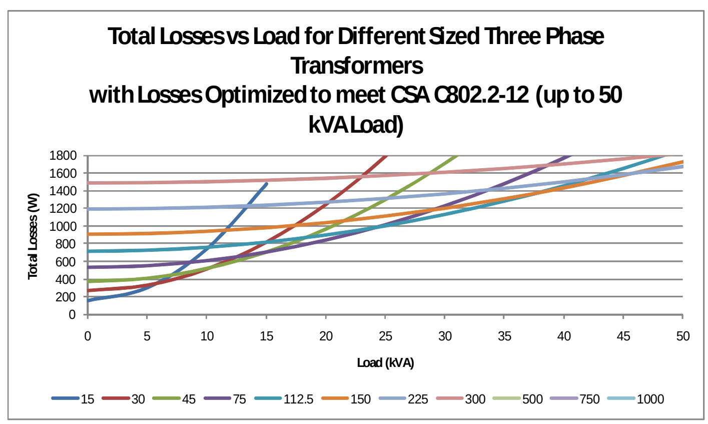
Based on these efficiency outcomes, one can then compare the energy savings, payback, return-on-investment (ROI) and EPA environmental outcomes for each alternative, some of which may include downsizing. A comparison of the total losses in a downsizing scenario, under linear loading, may be found in *Figure 2*.

With reference to *Figure 2*, using the 9% and 17% load levels described in *Figure 1,* one can examine the 'rightsizing' possibilities. For example, if a 75kVA transformer was initially considered, but the anticipated load was only 9% FL or 6.75kVA, the best alternative may be a 30kVA transformer, with an average equivalent load of 22.5% FL. Based on the graph, a 15kVA unit at 45% FL may also qualify, since its calculated average *Load Factor* would not exceed 50% FL, a nationalgrid® transformer replacement program recommendation. Before proceeding with this alternative, however, one must consider the possible addition of future loads, keeping in mind that existing loads may be replaced with more energy efficient loads over time.

Applying the same logic, if a 75kVA transformer was initially considered, but the anticipated load was only17% FL or 9kVA, a 45kVA unit at 20% FL or a 30kVA unit at 30% FL could be considered.



75kVA NEMA TP 1 Distribution Transformers under Linear Loading
Figure 1



Graph taken from CSA C802.4
Standard for kVA Sizing of Dry-Type Transformers
Figure 2

Based on the 75kVA transformer at 9% FL example, *Figures 3 and 4* detail the difference in losses and efficiencies, when comparing a 75kVA, NEMA TP 1 transformer and a 30kVA, DOE CSL 4 transformer. With 1864W lower losses and 2.8% higher efficiency, the 30kVA transformer will provide a significant energy saving.

Existing Facilities

The motivation to replacing an existing transformer is usually based on its questionable reliability and/or a need to reduce energy consumption and utility costs. Based again on the *Load Factor* survey undertaken by The Cadmus Group, the higher excitation losses and lower efficiencies of pre-NEMA TP 1 transformers, particularly at low *Load Factors,* provides an even greater opportunity to save energy and reduce utility costs.

With reference to *Figure 5,* a typical pre-NEMA TP 1, 75kVA transformer has an efficiency of only 92.8% at 9.0% FL, whereas a DOE CSL 4, 30kVA transformer has an efficiency of 98.5% at a 22.5% FL equivalent, a 5.7% efficiency improvement and subsystem energy cost reduction.

Again, based on more recent surveys, average loading is often much lower. For example, at 5% FL, the efficiency of the 75kVA, pre-NEMA TP 1 unit is only 88.2%, whereas a DOE CSL 4, 15kVA transformer has an efficiency of 98.4% at a 25.0% FL equivalent, a 10.2% efficiency improvement.

Rightsizing a transformer, as recommended in CSA C802.4 and national**grid**® *(Transformer Replacement Program for Low-Voltage Dry-Type Transformers,)* can result in a substantial reduction in operating costs.

The national**grid**® program recommends that downsizing should only be considered if:

1. The measured *Load Factor* of the existing transformer never exceeds 35% FL or
2. The calculated *Load Factor* of the replacement transformer never exceeds 50% FL.

Based on these criteria, the *Load Factor* for the replacement transformer can be calculated as follow:

$$LF_{NEW} = LF_{OLD} \times (kVA_{OLD} / kVA_{NEW})$$

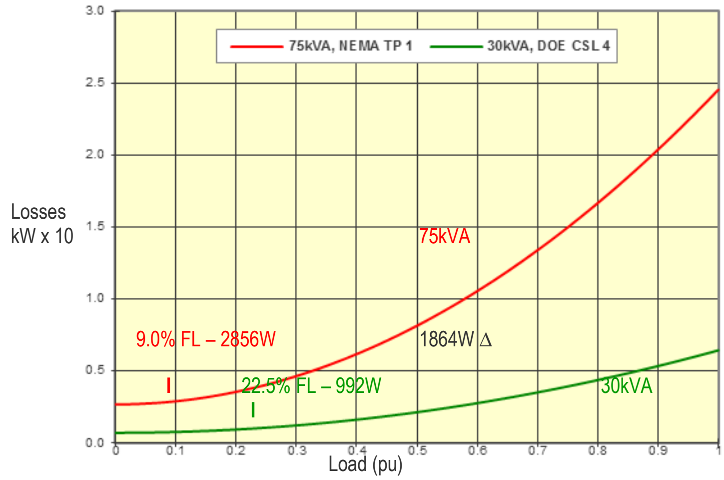
To determine the replacement transformer's potential energy savings, payback, ROI and EPA environmental outcomes, CSA C802.5 must first be used to calculate the efficiency of the existing and proposed replacement transformers, under their measured or calculated *Load Factors.* At low *Load Factors*, the national electrical codes are somewhat more flexible regarding downsizing, if the load profiles can be verified. Since even an ultra-efficient transformer's efficiency begins to falls off below 20% FL, downsizing with a smaller, more efficient transformer will also provide an attractive capital cost reduction

High K-Factor Nonlinear Loading

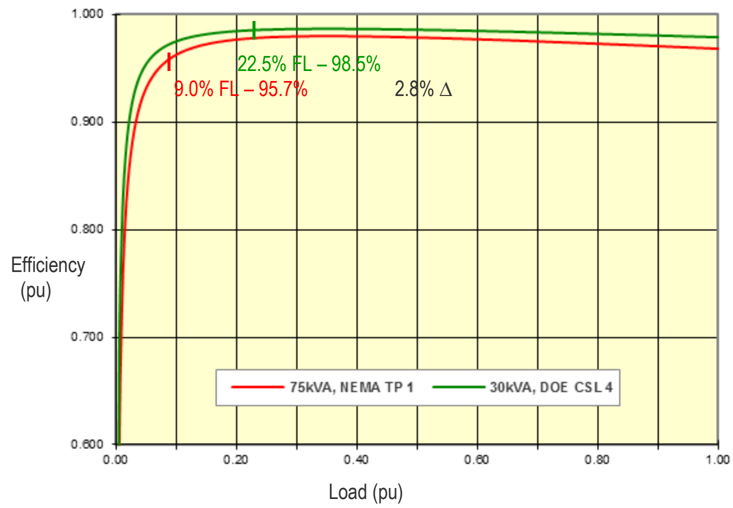
Under high K-Factor loading, with voltage distortion that exceeds 5% THD_V at the subsystem's loads, a power quality analysis may reveal the need for a harmonic mitigating transformer and/or harmonic filter(s).

The FES Solution™

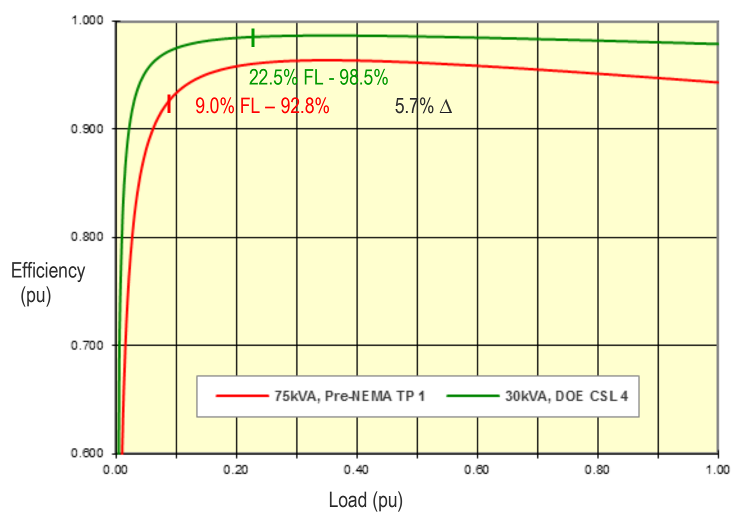
FES International uses IEEE Std. C57.110 and CSA C802.5 compliant engineering software to quickly and accurately compare the losses and efficiencies of any two transformers, under any anticipated or measured harmonic and loading profile. Given the cost of each transformer, or a single transformer in a replacement scenario, and utility rates, the software can also calculate the annual energy savings, including A/C costs, payback on incremental costs, return-on-investment and EPA environmental benefits. An FES solution includes this analysis with recommendations. To discuss our Power System Optimization services, please contact FES International at (727) 478-7288.



Distribution Transformers Losses
75kVA, NEMA TP 1 vs. 30kVA, DOE CSL 4, under 6.75kVA Linear Loading
Figure 3



Distribution Transformers Efficiency
75kVA, NEMA TP 1 vs. 30kVA, DOE CSL 4, under 6.75kVA Linear Loading
Figure 4



Distribution Transformers Efficiency
75kVA, Pri-NEMA TP 1 vs. 30kVA, DOE CSL 4, under 6.75kVA Linear Loading
Figure 5