POWER QUALITY INTERNATIONAL

APPLICATION GUIDE

Type ‘EY’ *e-Rated*® Distribution Transformer
Ultra-Efficient, Low Voltage, Dry-Type Isolation Transformer

Product Description

Type EY ***e-Rated***® low voltage dry-type isolation transformers provide an ultra-efficient alternative to conventional or K-Rated distribution transformers. Type EY transformers are ideally suited for new construction or when replacing older transformers with historically low efficiencies as part of a power system optimization and energy reduction plan.

Efficiency

With reference to *Table 1,* Type EY ***e-Rated***® transformers, with *standard* ‘Z3’ efficiencies, exceed the energy efficiency requirements of NEMA TP 1-2002, CSA C802.2-12, NEMA Premium™, US DOE Candidate Standard Levels (CSL) 3 and 4 and pending US DOE 2016. With reference to the table, optional ‘Z3+’ and ‘Z4’, with progressively higher levels of energy efficiency, are available when their selection can produce a financial benefit.

Efficiency Confirmation

The efficiencies of Type EY ***e-Rated***® transformers are confirmed using NEMA TP 2-2005 *(Standard Test Method for Measuring the Energy Consumption of Distribution Transformers)*. When necessary, these results can be subjected to CSA C802.5 *(Guide for Selection of Efficient Dry-Type Transformers for Nonlinear Loading)* calculations to determine their *nonlinear* efficiencies, at any load level, with any defined or measured harmonic current profile.

kVA Sizing and Efficiency Considerations for 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% of their full load ratings. 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. Selecting the optimum transformer kVA can be determined by referring to CSA Standard C802.4-13 *(Guide for kVA Sizing of Dry-Type Transformers).*

In addition to the high capital cost of oversizing, the cost of operating a lightly loaded transformer will be high. Using the Cadmus survey findings, *Figure 1* displays the efficiencies of a typical 75kVA NEMA TP 1 transformer and a Type EY ***e-Rated***® transformer with the same kVA rating. Their efficiencies at 9% and 17% FL are shown.

At 9% FL the efficiency of the NEMA TP 1, with a required efficiency of 98% at 35% FL, is now only 95.94%. However, based on more recent surveys, average loading is often much lower. For example, at 5% FL the efficiency of the NEMA TP 1 transformer is only 93.21%. Rightsizing a transformer, as recommended by CSA C802.4, can result in a substantial reduction in losses and operating costs.

Since the recommendations given in CSA C802.4 are for transformer efficiencies under *linear* loading, before proceeding with a final selection, CSA C802.5 should be used to determine a transformer’s *nonlinear* losses and efficiencies under the anticipated loading and harmonic current profiles.

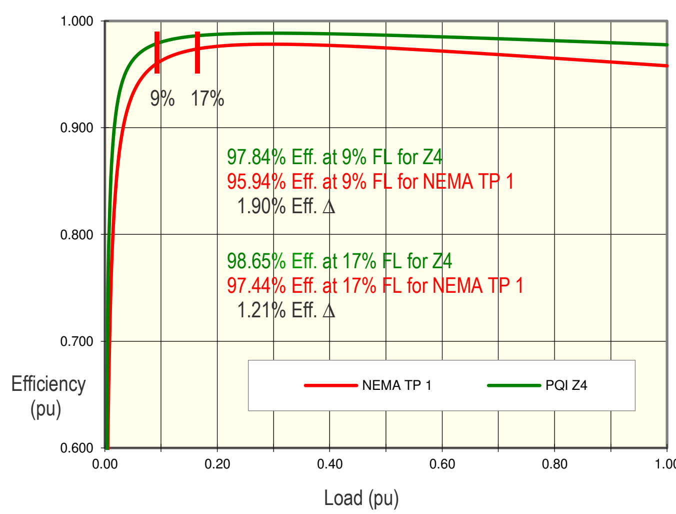
Table 1

Required vs. PQI Energy Efficiencies [1]

kVA Rating	*NEMA TP 1 2002* [2] *CSA C802.2*	*NEMA Premium* [2]	*DOE 2016* [3]	***PQI Z3*** *exceeds CSL 3* [4]	***PQI Z3+***	***PQI Z4*** *exceeds CSL 4* [4]
15	97.00	97.90	97.89	**98.23**	**98.25**	**98.43**
30	97.50	98.25	98.23	**98.29**	**98.52**	**98.68**
45	97.70	98.39	98.40	**98.45**	**98.66**	**98.81**
75	98.00	98.60	98.60	**98.64**	**98.82**	**98.95**
112.5	98.20	98.74	98.74	**98.77**	**98.93**	**99.05**
150	98.30	98.81	98.83	**98.86**	**99.01**	**99.12**
225	98.50	98.95	98.94	**98.97**	**99.10**	**99.20**
300	98.60	99.02	99.02	**99.04**	**99.16**	**99.26**
500	98.70	99.09	99.14	**99.16**	**99.26**	**99.35**
750	98.80	99.16	99.23	**99.24**	**99.33**	**99.41**
1000	98.90	99.23	99.28	**99.29**	**99.38**	**99.45**

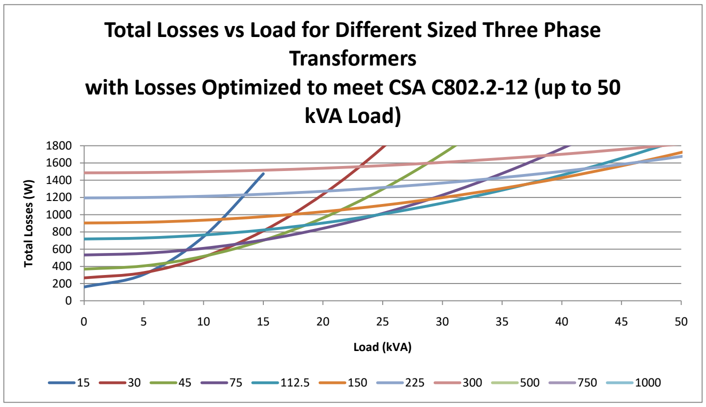
Table 1 Notes:

[1] Efficiency values are measured at 35% of nameplate rating.
[2] The efficiency of transformers manufactured after January 1, 2007, but before January 1, 2016 must meet the efficiency requirements of NEMA TP1 2002.
[3] The efficiency of transformers manufactured after January 1, 2016 must meet the efficiency requirements of US DOE 2016
[4] PQI Z3 & Z4 efficiencies exceed the requirements of DOE Candidate Standard Level 3 & 4 (CSL 3 & CSL 4) respectively



75kVA Distribution Transformers under Linear Loading
NEMA TP 1 vs. PQI Z4 Efficiencies at 9% & 17% FL
Figure 1

Based on these efficiency outcomes, one can then compare the energy savings, payback, return-on-investment (ROI) and EPA environmental outcomes for all alternatives, which may also include downsizing per C802.4. A comparison of total losses in a downsizing scenario may be found in *Figure 2,* which may be found in CSA Standard C802.4.



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

With reference to the *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 exceeds 50% FL, a national**grid**® transformer replacement program recommendation. Before proceeding with this alternative, however, one must consider the possible addition of future loads.

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.

Based on the 75kVA, 9% FL average load example, *Figures 3* & *4* details the differences in losses and efficiencies, when comparing the 75kVA vs. 30kVA transformers. With 1863W lower losses and 2.6% higher efficiency, the 30kVA ultra-efficient transformer will provide a significant energy saving.

kVA Sizing and Efficiency Considerations when Replacing Existing Transformers

The motivation to replacing an existing transformer is usually based on its questionable reliability and/or a need to reduce energy consumption and 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 operating costs.

As demonstrated in *Figure 5,* at 9% FL the efficiency of the pre-NEMA TP 1 transformer is only 92.84%. Based on more recent surveys, average loading is often much lower. At 5% F,L the efficiency of the pre-NEMA TP 1 unit is only 88.11%. 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.

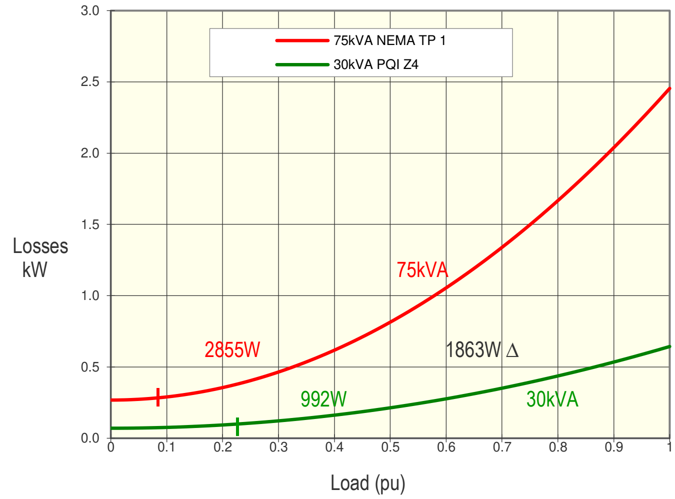
The national**grid**® program recommends that downsizing should only be considered if:

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.

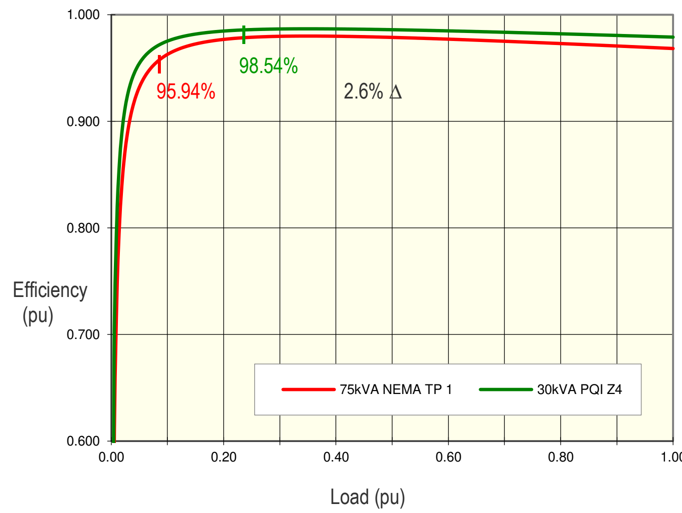
Based on these criteria, the *Load Factor* for the replacement transformer can be calculated as follow:

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

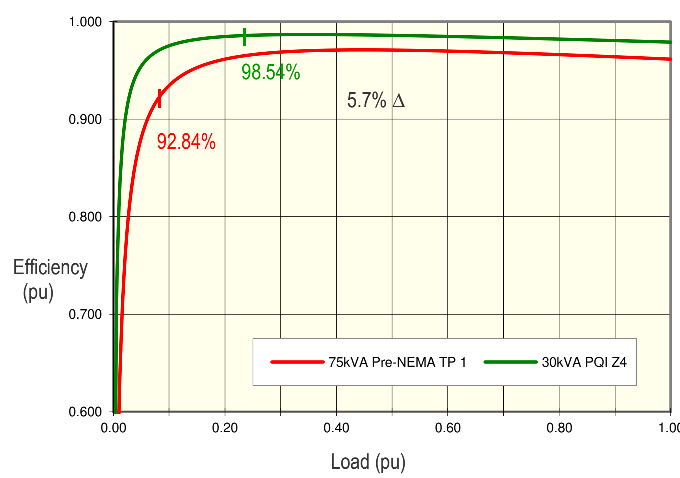
To determine the replacement transformer’s potential energy savings, payback, ROI and EPA environmental outcomes, CSA C802.5 must first be



75kVA & 30kVA Distribution Transformers Losses
75kVA NEMA TP 1 vs. 30kVA PQI Z4 under 6.75kVA Linear Loading
Figure 3



75kVA & 30kVA Distribution Transformers Efficiency
75kVA NEMA TP 1 vs. 30kVA PQI Z4 under 6.75kVA Linear Loading
Figure 4



75kVA & 30kVA Distribution Transformers Efficiency
75kVA Pri-NEMA TP 1 vs. 30kVA PQI Z4 under 6.75kVA Linear Loading
Figure 5

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 confirmed. Since even an ultra-efficient transformer's efficiency begins to falls off below 15% 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 PQI Solution™

Power Quality 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 also calculates the annual energy savings, including A/C costs, payback on incremental costs, return-on-investment and EPA environmental benefits. PQI offers these analytical services, with recommendations, on a 'no charge' basis. To access this service, please contact PQI at (888) 539-7712 or engineering@PowerQualityInternational.com.

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