How to Select the Right Energy-Efficient Dry Type Transformer

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As fuel costs continue to rise and power outages become more prevalent around the country, the necessity of utilizing energy-efficient products of all types is becoming universally recognized. Additionally, today's globally competitive business environment is causing businesses to cut costs in order to remain competitive. Of particular interest are products like distribution transformers that remain energized and consume energy 24 hr per day.

For years, electric utilities have been evaluating transformers for losses when making purchase decisions on medium- and high-voltage power transformers. However, in the commercial arena, the losses—and efficiencies—of 600V class dry type distribution transformers have received relatively little attention, due in part to the fact that the initial cost of a low-voltage distribution transformer is the primary driver in determining which transformer to purchase. The total operating cost of the transformer, over the life of the transformer, is rarely taken into consideration. As the need to consider energy efficiency in these applications grows, it's your job to educate yourself and your customers on the most cost-effective solution to a variety of applications.

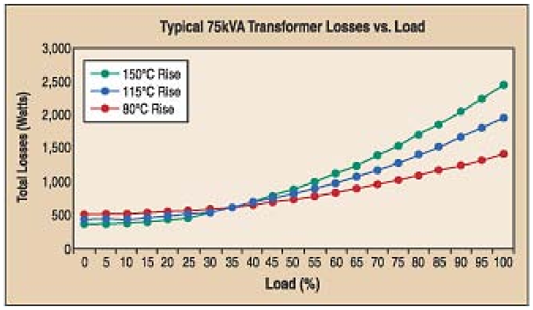
The meaning of the term "energy-efficient transformer" has changed significantly in the past several years. Today, energy-efficient 600V class distribution transformers fall into three different categories: Low temperature rise, NEMA TP-1 compliant, and harmonic mitigating. Depending on the specific application, any one of these may be the best option.

It's important to understand a few basic items before discussing energy-efficient transformers.

Transformer losses. Transformers aren't perfect devices; they don't convert 100% of the energy input to useable energy output. The difference between the energy input and that which is available on their output is quantified in losses. Transformer losses fall into two categories: no-load losses and load losses. No-load losses—commonly referred to as core losses or iron losses—are the amount of power required to magnetize, or energize, the core of the transformer. Since most distribution transformers are energized 24/7, no-load losses are present at all times, whether a load is connected to the transformer or not. When lightly loaded, no-load losses represent the greatest portion of the total losses.

Load losses, on the other hand, are those losses incident to carrying a load, and include winding losses (I2R losses), stray losses due to stray fluxes in the windings and core clamps, and circulating currents in parallel windings. Because load losses are a function of the square of the load current, they increase quickly as the transformer is loaded. Load losses represent the greatest portion of the total losses when a transformer is heavily loaded. Transformer loss data is readily available from most manufacturers.

Insulation system. The insulation system is another important characteristic of distribution transformers. The insulation system is the maximum internal temperature a transformer can tolerate before it begins to deteriorate and eventually fail. Most ventilated transformers manufactured today use a Class 220°C insulation system. This temperature rating is the sum of the winding rise temperature, normally 150°C, the maximum ambient temperature, 40°C, and the hot spot allowance inside the coils, 30°C. For ventilated transformers, 80°C and 115°C are common low temperature rise transformer ratings. The standard winding temperature is 150°C for a ventilated transformer. However, all three of these temperature rise ratings utilize the 220°C insulation system.



Low temperature rise energy-efficient transformers. Low temperature rise—80°C and 115°C—energy-efficient transformers have been available for more than 40 years. Until recently, the term “energy-efficient transformer” referred exclusively to these transformers. Low temperature rise transformers also use the 220°C insulation system and are designed to have lower load losses than equivalent rated 150°C rise transformers. As previously mentioned, load losses are most critical at high load levels. This means that when a transformer is loaded in excess of half its full load capacity, low temperature rise transformers provide better energy efficiency than standard 150°C rise transformers. Typical efficiencies of 150°C, 115°C, and 80°C rise transformers are shown in **Fig. 1**.

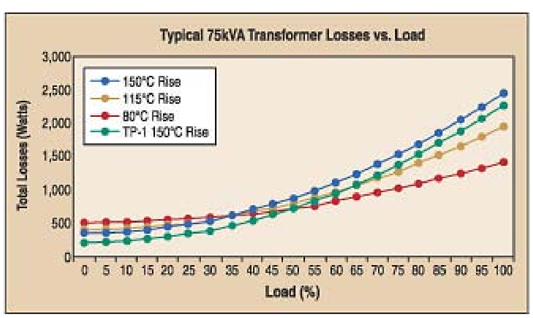
The 80°C rise transformer has the lowest total losses of the transformers in this group, when the load is 50% or greater. In addition to being more energy-efficient, low temperature rise transformers also run cooler. This not only extends the life of the transformer, but also means less cooling capacity is required to cool them.

The winding temperature rise is a key component used to arrive at the 220°C insulation system rating. For example, 115°C rise transformers have a continuous thermal overload capacity of 15% (35°C), and 80°C rise 75kVA transformers have a 30% (70°C) continuous overload capacity.

When transformers are loaded in excess of 50% of their full load capacity, low temperature rise transformers may offer greater savings over the life of a transformer than standard 150°C rise transformers.

NEMA TP-1 compliant energy-efficient transformers. In 1996, the National Electrical Manufacturers Association (NEMA) introduced NEMA Standard TP-1-1996 Guide for Determining Energy Efficiency for Distribution Transformers, which it had developed in coordination with the U.S. Environmental Protection Agency (EPA). It sets minimum efficiency levels for distribution transformers that were also incorporated by the EPA in their Energy Star program. The minimum efficiency levels in NEMA TP-1 are about 98%, depending on kVA rating, and are higher than the efficiencies of standard 150°C rise transformers.

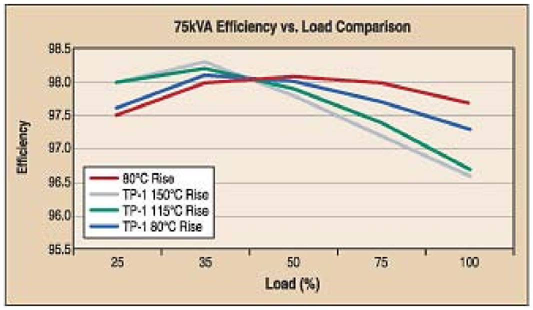
Surveys conducted at commercial and industrial facilities have shown the typical loading of low-voltage distribution transformers over a 24-hr period averages only 35% of the full-load capacity of the transformer. The goal of NEMA TP-1 is to reduce energy consumption, particularly when a transformer is lightly loaded. With the survey results in mind, NEMA Standard TP-1 sets minimum efficiency levels at 35% of a transformer’s full load rating.



NEMA TP-1 compliant transformers have lower no-load losses than standard transformers and are therefore more efficient when the transformers are lightly loaded. **Fig. 2** shows the losses of a 150°C rise NEMA TP-1 75kVA transformer compared to those of standard transformers and low temperature rise 75kVA transformers.

As you would expect, at the NEMA TP-1 conditions—35% loading—the NEMA TP-1 transformer is the most efficient transformer. In fact, due to its reduced no-load losses, the NEMA TP-1 transformer is the most efficient transformer for all loadings up to and slightly higher than 35%.

Fig. 3 shows the relative efficiency of a standard low temperature rise 80°C transformer compared to 150°C, 115°C, and 80°C rise NEMA TP-1 transformers. The reduced no load losses of the NEMA TP-1 transformers cause all three ratings of TP-1 transformers to be more efficient than the standard 80°C rise transformer. However, notice what happens when the transformer is loaded to 50% of capacity and higher, where the load losses have a greater impact on the overall efficiency of the transformer: the 80°C low temperature rise transformer is more efficient than the NEMA TP-1 rated transformers at high-load levels.



Many states, including Massachusetts, Minnesota, New York, and California, have passed legislation mandating the use of distribution transformers that meet or exceed the NEMA TP-1 efficiency standards. Installations in these states where the average loading of the transformer exceeds 50%, the use of NEMA TP-1 compliant transformers may actually cost building owners more in electricity costs than if they had installed a standard transformer with a 80°C low temperature rise.

In applications where the anticipated average daily loading of a distribution transformer is about 40% or less of the full load capacity of the transformer, NEMA TP-1 compliant transformers may be the most economical choice. Operations that run a single shift and are vacant overnight and on weekends should reap the long-term benefits of installing NEMA TP-1 compliant, energy-efficient transformers. In addition to the energy savings companies may receive by installing NEMA TP-1 compliant transformers, they may be able to take advantage of rebates offered by many local utilities and government agencies to customers who install energy saving products in their facilities. In many cases, the rebate is nearly equal to the difference in price between a NEMA TP-1 transformer and a standard 150°C rise transformer.

Harmonic mitigating transformers. The harmonic mitigating transformer is a relative newcomer to the world of energy-efficient transformers. The previous analysis regarding low temperature rise and NEMA TP-1 transformers assumes the transformers are feeding linear loads. However, it's a fact of life in today's world that many loads are nonlinear in nature, and the number of these loads is growing. The impact of nonlinear loads on distribution transformers is a separate topic itself and can't be adequately covered here. However, nonlinear loads reduce the efficiency of distribution transformers, including K-factor rated transformers. The higher the content of nonlinear loads, the lower the efficiency of the transformer. Most harmonic mitigating transformers are at least 98% efficient, even when the load is 100% nonlinear in nature. Under normal loading conditions, the life expectancy of a transformer is at least 20 years. Over the lifetime of the transformer, even a minor improvement in efficiency can result in significant energy savings.

If your distribution system is rich in harmonic loads, particularly single-phase harmonic loads like laptop computers, lighting ballasts, and office equipment, energy-efficient harmonic mitigating transformers may offer the greatest overall benefit and energy savings.

Examples of energy savings using different transformers. One way to evaluate which transformer is best for a specific application is to look at the costs associated with the transformer losses. **Table 1** shows the losses, in watts, of low temperature rise energy-efficient transformers previously discussed. These are typical losses. Actual losses will vary from one manufacturer to another.

But what is really important are the dollar costs of these losses. The following equation was applied to the values from **Table 2**, then used to calculate the annual operating cost.

$ Cost/yr = ($/kWh)(1kW/1000W)(losses in watts)(24 hr/1 day)(365 day/1 yr)

The price of electricity varies across the country. In Table 2, a price of $0.08/kWh was used to determine the operating cost of these four transformers.

When operated at full load 24/7, the 80°C rise transformer costs $729 less to operate than a standard 150°C rise 75kVA transformer.

If the transformer is loaded at 35% of its capacity, the NEMA TP-1 150°C rise transformer is the least costly transformer to operate. The NEMA TP-1 transformer costs $98 less per year than a standard 150°C rise transformer, at $0.08/kWh. As the cost of electricity increases, the savings become even greater.

There are several different energy-efficient transformer options available in the market today. To determine which is the most cost effective for a specific application, it's important to have a reasonably accurate idea of how the transformer is going to be loaded. When a transformer is going to be lightly loaded, a NEMA TP-1 compliant or 115°C low temperature rise model is likely the best option. On the other hand, when the anticipated load on the transformer is going to be in excess of about 50% percent of its capacity, an 80°C low temperature rise model is likely the better choice. However, local ordinances, building codes, energy codes, and legislation may limit the available options by mandating the use of a specific type of transformer.

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