# Tech Byte 13: A True High-Efficiency Transformer

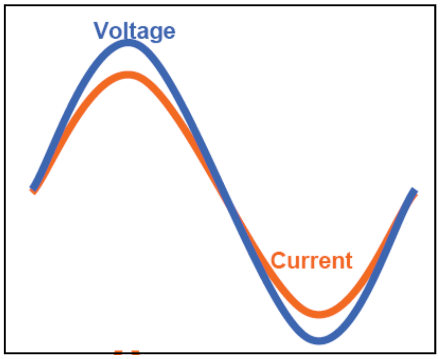
## Designing a Transformer to Achieve High Efficiency in the Real World

**~ Abstract ~**

*Penalty losses, associated with powering common electronic equipment such as computers, VFDs, electronic ballast lighting, and everyday office equipment, result in achieving lower than anticipated operating efficiency of electrical distribution systems—especially distribution transformers. This paper aims to provide a general overview of how the electrical distribution landscape has been affected by these "non-linear" loads, and how most transformer manufacturing and industry focused entities have failed to address the problem. Discussion will also include the present ineffectiveness of today's energy efficiency legislation on mandating minimum transformer operating efficiencies. The paper will conclude with an overview of how a properly designed transformer can achieve operating efficiencies in excess of the requirements of current legislation, even when supporting the typical non-linear load profiles of nearly every facility in today's world.*

In today's world, significant efforts are being made by property owners, facility managers, and design engineers to find ways to increase the operating efficiency of energy consuming equipment and processes. By doing so, on-going operating costs can be reduced, profitability can be increased, and in some cases a facility can qualify for utility or federal rebates for their success in reducing or eliminating wasteful use of energy.

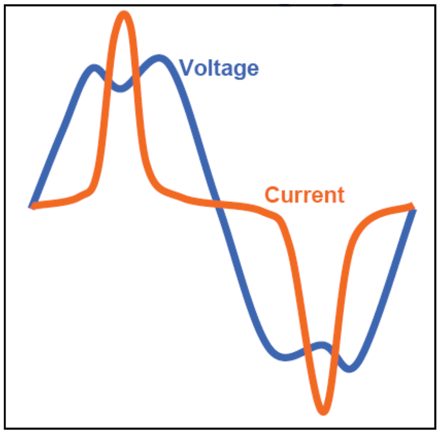
On the electrical side of the discussion, high efficiency lighting has been a focal point for some time, and some exciting products and technology have evolved from this industry interest. But what other options are out there for consideration, that can lend themselves to increasing the electrical utilization efficiency of a given building or facility? One area of focus should be on transformers. Transformers are a necessary element in the distribution of power from the point of generation to the point of utilization. They are required to convert distribution level voltages down to utilization voltages for a given consumer. But transformers are transformers, right? Has the transformer design or manufacturing process really changed over the past 50 years, and if so, why? Do these changes warrant re-evaluation of transformer products and how they are applied? The answer is yes. There are very good reasons to re-consider the transformer product that you are currently purchasing or specifying. The reason is that even today, many manufacturers are designing and building transformers very much the same way they did many decades ago. But these transformers are now supporting facility equipment that is very different than that of the past. What impact does this have on the operational effectiveness and efficiency of the legacy transformer? Conversely, what options exist and how do they differ in design, operational effectiveness, and efficiency? The fact is, legacy transformer designs are not ideal in supporting today's commercial and industrial buildings in an effective, efficient manner. This paper will offer a high level glimpse into the design and operational benefits of transformers that are designed to support today's ***real*** world.




***Voltage and Current Waveforms When Feeding Linear Loads***

Transformers have been around for many decades. The first three-phase transformer was developed in 1889 by Russian engineer Mikhail Dolivo-Dobrovolsky and has been an instrumental piece of AC power distribution ever since. For many decades after the transformer invention, the landscape of electrically powered equipment, such as incandescent lighting and motors (with no VFDs), exhibited predictable, linear-load behavior. Linear load behavior means that the current and voltage waveforms drawn by the equipment are purely sinusoidal, and the current waveform follows the voltage waveform. Electrical distribution systems, including transformers, were optimized very effectively in design and construction for this type of connected load and therefore, the electrical distribution industry was quite happy and content for many, many years. Then something happened. Things began to change and problems that had previously never been encountered began occurring and sent the conventional laws of electrical distribution into a tail spin….

The decade of the 1980's brought about the boom of the personal computing age, and with it the introduction of associated power quality problems in electrical distribution systems, as a resulting impact of their operation The culprit responsible for these problems was the computer's internal switching mode power supply. The problem that the switching mode power supply posed was a function of how it operated. The AC main input of the switching mode power supply is directly rectified without the use of a transformer, to obtain a DC voltage. This voltage is then sliced into small pieces by a high-speed electronic switch. The size of these slices grows larger as power output requirements increase. By slicing up the sinusoidal AC wave into very small discrete pieces, the portion of the alternating current not used stays in the power line as very small spikes of power that cannot be utilized and results in waste heating of the electrical distribution—especially transformers. Hundreds of switched mode power supplies in a building can result in poor power quality for other customers surrounding that building, and high electric bills for the company if they are billed according to their power factor in addition to the kilowatts used. Graphically described, the impact of many electronic devices in a building changes the linear load AC waveform shown on page 1, to that shown in the image to the right. This is what happens to the AC waveform in every building or facility that utilizes electronic equipment. ***The legacy transformer was never designed to handle this kind of load profile***, yet they are continuously installed, even today, to support this type of equipment.




***Voltage and Current Waveforms When Feeding NON-Linear Loads***

A key discussion in the progression of electronic equipment technology was the industry response to this wide-sweeping problem back in the 1980's and 1990's. The transformer manufacturing community and associated industry advisors began to see a common side effect of these non-linear loads. When transformers were sized for a certain duty, as they were in the past, they experienced excessive heating problems when connected to electronic loads. This heating effect would later be recognized as a problem caused by harmonic distortion, caused by the operation of the switching mode power supply.

Instead of moving in the direction of identifying and rectifying the problem, the direction the industry took was to compensate for a ***symptom*** of the problem. Since overheating was a concern, the directive was to de-rate, or over-size transformers to accommodate the heating effects of non-linear load profiles. So in essence, if an application required a 75kVA transformer, the new design practice would be to utilize a 112.5 kVA transformer. Thus, the transformer would be larger and therefore serve as a better heat-sink to better survive the heating effects of non-linear loading. What is the problem with this response? The underlying problem still existed. Harmonics continued to proliferate and cause a myriad of power quality problems and significantly reduce the operational efficiency of the electrical distribution system. ***The worst part of this problem is that these design practices, in some form or fashion, are still present today***. The root problem is still not being universally addressed.

# Tech Byte 13: A True High-Efficiency Transformer

## *Designing a Transformer to Achieve High Efficiency in the Real World*

It is important to remember as well, that for any compensation for a given problem, a different problem can present itself. Additional problems are caused by over-sizing, including:

- Decreased electrical operating efficiency
- Increased equipment footprints
- Increased installation and capital costs

Also, derating of electronic equipment has created a false perception of a given facility's power quality. Oversizing of transformers, breakers, and feeders can solve the ***symptom*** of excessive heating, due to the presence of non-linear loads, and because of this, many are led to believe that this has somehow "solved" the harmonic ***problem***. Other's believe that harmonics are a problem of the past. This is in fact, not true. Harmonics very much still exist and are a significant cause of operational problems, such as computer lock-ups, breakers tripping for seemingly no reason, and reduced operating efficiency. Yet they continue to escape blame.