Eaton Electrical Inc.
1000 Cherrington Parkway
Moon Township, PA 15108
United States
tel: 1-800-525-2000
www.EatonElectrical.com

The HMT as a Substitute for K Factor Transformers

Executive Summary

While the K-rated dry-type transformer can still be used in today's electrical environments, there have been advancements in transformer design that provide improved performance when dealing with power quality concerns, and provide the additional benefit of energy savings.

Origins and Impact

The K-rated dry-type transformer was the industry's response to the introduction of harmonics into our electrical systems at levels that were beginning to show detrimental effects (circa 1980). Harmonics introduced additional currents and higher-order frequencies (mathematically characterized as multiples of the 50 or 60 Hz fundamental frequency) to the entire electrical infrastructure.

It's important to understand how these aspects impact the operation of our standard electrical equipment. Within a transformer, the additional currents and frequencies increase the losses and decrease the nameplate capacity of operation. A transformer's losses and capacity are normally only measured with a 60 Hz linear load. This effect, impact, and suggested changes to the operation and construction of electrical transformers are discussed in many publications, including IEEE Standard C57.110-1998, UL® 1561, and UL 1562.

These standards go into detail about the specifics of the additional losses due to the additional currents and frequencies of today's non-linear loading. The primary impact is transformers need to be derated, or increased in size, to maintain the rated nameplate kVA output capacity when supplying non-linear loads. The idea of K-rating, or K-factor, was one of the initial attempts by transformer manufacturers to design a transformer that would cope with the side effects of harmonics in an electrical system.

After additional investigation, it appears that K-rated transformers may not be an adequate solution. Instead of just coping with harmonics, the transformer needs to be redesigned to deal with the root issue — harmonic currents and frequencies generated by their loads. The original attempt by transformer manufacturers to sell an already designed, larger kVA size, with a derated nameplate, didn't take in to account the other issues of transformer operation; specifically increased operational energy losses. These increased losses translate into additional monthly energy expense and increased pollution.

Using a K-rated transformer in an electrical system is like driving an 18-wheeler to the corner store instead of driving a small car. Both will accomplish your goal, but which one do you want to pay the fuel bill for? Additionally, contrary to common thought, K-rated transformers do not provide any improvement in the power quality of an electrical system. In fact, voltage distortion is normally increased due to the larger size and impedance of the transformer.

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The Importance of 'Loading Levels'

Another question that should be asked, since the K-rating of a transformer deals with the maximum kVA output of the transformer, is "At what levels of capacity are distribution transformers normally operated?" Legislation in the form of the Energy Policy Act of 1992 provided an avenue to investigate the feasibility of improving transformer efficiency, resulting in lower energy consumption and reduced pollution. Studies showed that distribution transformers installed in a typical commercial building are loaded an average of 35% over a normal 24-hour period.

In 1996, the National Electrical Manufacturers Association (NEMA®), in its Standard TP-1-1996, established minimum efficiency levels of around 98 percent (dependent on kVA size) for low voltage, dry-type distribution transformers at the 35% loading level, when feeding linear, resistive loads. Linear, resistive loads are not representative of the non-linear nature of today's loads. The U.S. Environmental Protection Agency (US EPA) and Department of Energy (DOE) adopted NEMA Standard TP-1 as part of their ENERGY STAR® Program for transformer performance.

In 1999, the Northeast Energy Efficiency Partnership, Inc. (NEEP) contracted the Cadmus Group to measure transformer loading and harmonic levels in a variety of commercial and industrial installations. In the 89 buildings that were analyzed (comprised of a collection of universities, health care facilities, manufacturing facilities, office buildings and retail facilities) the average loading factor was found to be 15.9% (varying between 14.1% to 17.6%). (Northeast Energy Efficiency Partnerships (NEEP) — "Metered Load Factors for Low-Voltage, Dry-Type, Transformers in Commercial, Industrial, and Public Buildings," 12/7/99 — owned by The Cadmus Group, Inc.).

This leads us to conclude that from a practical standpoint, a transformer typically does not reach the loading levels that are required for K-rating derating to become necessary. As a result, in commercial and industrial facilities, the negative effects of K-rated transformers remain, without attaining the loading levels necessary to realize the benefits of reduced heating due to the K-rating of the transformer These negative effects include reduced energy efficiency, increased energy loss, increased expenditures on maintenance, increased pollution, increased footprint size, and lack of power quality cleaning ability.

From a theoretical, engineering design standpoint, a transformer must have the ability to supply the full designed capacity of the electrical equipment over the designed lifetime of the electrical system. This leads to a dilemma. How can you offer the best of both worlds; the ability to supply non-linear loads to the full nameplate rating of the transformer and be energy efficient? The solution comes in the form of a transformer that has been specifically designed to deal with the root issues, harmonic currents and higher order frequencies, and not suffer the negative challenges faced by the K-rated transformer.

The Solution

Eaton Corporation's energy-efficient Harmonic Mitigating Transformer (HMT) is designed to handle the challenges of today's electrical infrastructures. The construction of the HMT is such that it utilizes electromagnetic mitigation to deal specifically with the triplen (3rd, 9th, 15th,...) harmonics through changes to its secondary windings. Additionally, by using a system approach called phase shifting, the 5th and 7th harmonics in an electrical system are also addressed.

Employing these two electromagnetic techniques, the Eaton HMT allows the loads to operate the way their manufacturer designed them, while minimizing the impact of the harmonics to energy losses and distortion. Eaton HMTs exceed the NEMA TP-1 efficiency standards, even when tested with 100% non-linear loads, and bring the transformer into the performance realm of the more stringent Candidate Standard Level 3 (Federal Register — 10 CFR Part 430, Energy Conservation Program for Commercial and Industrial Equipment: Energy Conservation Standards for Distribution Transformers: Proposed Rule, July 29, 2004).

In conclusion, wherever a K-rated transformer is specified within an electrical system, it is apparent that the design team and/or the customer have realized the need for harmonic treatment within their electrical infrastructure. The HMT is a direct substitute for the K-rated transformer in this situation as it:

- Allows the loads to operate the way they were designed;
- Minimizes the impact of the harmonic currents and frequencies;
- Maintains a high energy efficiency, even when feeding non-linear loads;
- Reduces electrical consumption;
- Reduces pollution as a result of its higher energy efficiency;
- Doesn't allow the triplens to circulate in the delta winding of the transformer, which results in an increase in usable transformer capacity.

For additional information, please contact Eaton's electrical business or visit us on the Web at EatonElectrical.com

Printed in USA
Publication No. IA00904002E / Z4846
September 2006