TECHNICAL PAPER

Reverse Feeding Low Voltage Dry Type Transformers

An old practice with modern issues

Transformers have been part of our electrical distribution systems from the late 1800's after the alternating current vs. direct current battle. One installation practice has been to reverse feed a transformer, and this practice requires careful thought and preparation before installation and operation.

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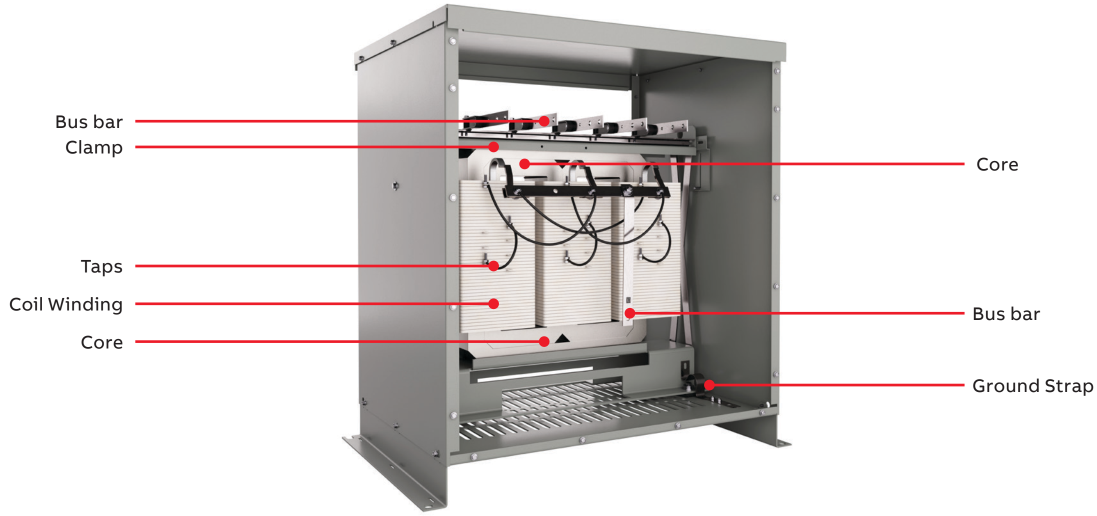
Abstract – Reverse feeding transformers has been a practice in the electrical industry for many years. While possible and to a point, successful, reverse feeding a transformer presents technical issues that should not be overlooked. Several key transformer attributes are compromised when reverse-feeding a dry type transformer. Therefore, the most reliable installation is to install a transformer designed for its application. Nevertheless, the quick restoration of interrupted power may lead toward the installation of a transformer by reverse feeding. This paper presents some technical issues that must be considered with reverse feeding a low-voltage dry type transformer.

Introduction

General-purpose dry type transformers rated 600 volts and below are used for supplying appliance, lighting, and various linear and/or non-linear loads within an electrical distribution system. These transformers are used to convert the facility distribution voltage to the load's utilization voltage. Most general-purpose transformers are used in step-down applications. The most used polyphase transformer in the United States has a 480 volt three-phase delta primary and a 208/120 volt three-phase, four-wire, wye secondary. This is known as a Delta-Wye transformer. Step-up transformers are available, but because step-up applications are rare these transformers are not typically stocked. So, step-up transformers are mostly built-to-order and construction can take six weeks or longer.

When there is an immediate need for a non-stock step-up transformer, it has been a common practice to use an in-stock step-down transformer and install it in reverse fashion (reverse feed). If permitted by local codes and allowed by the authority having jurisdiction, it is generally acceptable to reverse feed (or back-feed) a transformer. Considering the complexities of a reverse-feed transformer installation, the electrical contractor owns the complete installation.
Nevertheless, there are several issues that must be considered before reverse feeding a step-down transformer. This paper discusses a reverse-feed application and presents the technical challenges from reverse feeding a low-voltage dry type transformer.



Structural Integrity
As an electromagnetic machine, the transformer "machine" has no moving parts to transfer energy, this energy transfer is accomplished through electromagnetism using the magnetic flux that is inherent in the transformer core. The magnetic flux has a limit or saturation point of its flux density. When the flux density exceeds or "saturates", the magnetic properties of the transformer core degrade exponentially causing excessive energy loss, higher core vibrations that presents greater stress on the insulation system which could cause premature failure, appreciable audible noise from those vibrations will be easily heard and the entire core & coil of the transformer will experience higher than designed operating temperatures. All these factors alone should be a concern as the expected transformer life of 20-30 years of operation could be dramatically reduced.

Voltage Taps
A standard step-down transformer usually contains taps on the input (primary) side, placing the taps on the primary side is called out in the NEMA ST-20 (sec. 2.1) transformer standard. Lowering the primary side taps will increase secondary voltage and raising the primary taps will lower the secondary voltage. When a transformer is reverse fed, the taps move to the output side and so their operation is reversed. For reverse fed applications, raising the taps will increase output voltage and lowering the taps will lower output voltage.

The primary purpose of these taps is to match the input rating of the transformer to the actual voltage applied to the primary terminals to provide the output (secondary) voltage that most closely matches the load requirement. The taps must be used with care since no-load or low-load conditions combined with variance in the utility service voltage can cause an over-excitation of the winding, resulting in higher than rated core loss and excitation current. This is generally not a serious concern unless the over-voltage exceeds 5%. For reverse feed applications, the taps are positioned at the output side and so cannot be used to correct for over-excitation.

There is a fine line with the voltage taps and reverse feeding which should arise a concern as misapplication could cause premature transformer failure or other adverse effects such as over-heating and excessive vibration that causes noise and excessive wear on the insulation system.

Compensated Windings
Voltage drop across transformers increases with load. At no-load a transformer's primary: secondary voltage ratio may exactly match the winding turns ratio. At full-load the same transformer's secondary voltage could be 3- 4% less than the turns ratio would dictate. The transformer winding turns ratio can be compensated to correct for this phenomenon. Smaller (less than 3 kVA) transformers commonly have compensated windings. Winding turns ratios are compensated so that a 3-4% over-voltage exists at no-load, but nominal secondary voltage is available at full load. Some manufacturers build larger transformers (>10 kVA) with compensated windings, although this is not a common practice due to the extra costs involved in manufacturing such a transformer.

When transformers with compensated windings are reverse fed, the compensation is reversed. As a result, the transformer voltage drop will be 3- 4% at no-load and 6-8% at full load. The transformer's taps may be able to correct for this additional voltage drop, but extra caution is required to have a transformer installation that provides the correct voltages.

Inrush Currents
Upon energization, transformers will draw a high inrush current for a brief period (typically 0.1 seconds or less). The inrush current can be on the order of eight to twelve times the rated full load current of the transformer. For a specified input voltage and VA rating, the inrush current for a reverse fed step-down transformer will be greater than the inrush current for a transformer specifically designed and installed as a step-up transformer.

To illustrate, assume that a standard ABB 9T10A1004 step-down transformer will be used in a step-up application. This transformer is rated 75 kVA, 60 Hz, 480 volt three-phase delta primary and 208/120 volt three-phase, four-wire, wye secondary. This transformer also contains six (6) 2.5% voltage taps on the primary (480 volt) side, 2 taps above nominal and 4 taps below nominal. For reverse feeding application, the secondary is to be operated step-up (208 VAC input to 480 VAC output).

The installer may discover that the primary side overcurrent protection, having been properly selected and applied per Article 450 (Table 450.3) of the National Electrical Code, nevertheless operates (trips) when attempting to energize the reverse operated transformer.

This tripping phenomenon can occur because the low impedance winding (the 208Y/120 VAC winding) that was intended by design to be the secondary winding, now serves as the primary and the value of the magnetizing inrush current (Mag-I) is much greater than expected.

The Mag-I experienced when energizing transformers is like the inrush current associated with motor starting. The primary and secondary full load amps of the above referenced transformer are 90 amps @ 480 VAC and 208 amps @ 208 VAC. When connected as the intended design as a step-down transformer and energized at 480 VAC, the maximum peak inrush current is approximately 990 amps or 11 times the rated 90 amp primary winding full load current.
But when connected in reverse and energized at 208 VAC, the maximum peak inrush current can reach 7700 amps or 37 times the rated 208 amp secondary winding full load current ($7700/208 \approx 37$). To accommodate this high inrush current without the nuisance tripping of the overcurrent protective device, the input (208 VAC side) overcurrent protective device must be sized at a higher value than the allowed National Electric Code Article 450.
Clearly, in this case, a National Electric Code violation (adopted by most state electrical codes), would occur creating a potential fire hazard at best and safety concern at worst.

Grounding
When the secondary (wye) of a delta- wye transformer is energized instead of the primary (delta), then the wye side of the transformer is not a separately derived service according the National Electric Code Article 250. As such, the neutral should not be connected to building ground nor should it be bonded to the transformer enclosure. The delta side of the transformer becomes the output, which is the separately derived system. The output delta “B” phase should be tied to ground unless the facility distribution system utilizes a different grounding scheme. As with compensation taps, extra caution is required as a wrong installation could prove to become a safety hazard.

Corner grounding a delta transformer presents different overcurrent protection device challenges. The IEEE 3004.5 standard Sec. 5.4.2 (Fig 13) should be referenced along with the National Electric Code Art. 450 to understand the overcurrent protection challenges and requirements.

CONCLUSION
Standard step-down transformers may be reverse fed for step-up applications but there are several significant precautions that must be considered (not all inclusive):

Structural Integrity – by reverse feeding the step down transformer, extra stresses will be applied to the transformer for which it was not designed to handle. Great care is needed to assure that these thermal and mechanical compromises are worth the reverse feed installation.

Voltage Taps – the over-excitation with its extra core loss (lower efficiency rating) must be considered if a reverse feed application is required. Lower installed efficiency values could violate the US Federal Regulation 10 CFR 431 (DOE) or the CSA 802.2 (NRCan) laws. The function of the taps becomes a greater challenge as the taps no longer match the primary voltage to the secondary, rather it does this voltage matching in reverse. (the nameplate does not provide guidance to this usage).

Higher Inrush Current – the higher inrush currents that will occur in reverse feeding, will likely violate the overcurrent protection device requirements of the National Electric Code Article 450. Proper overcurrent protection is a requirement in most municipalities, a properly sized overcurrent protective device will likely trip each time the transformer is energized.

Compensated Windings - Transformers with compensated windings (most do not have compensated windings) will have output voltage 3-4% below nominal at no-load and 6-8% below nominal at full load. The transformer's taps may be able to correct for this under-voltage condition, but extra caution is required to have a transformer installation that provides the correct voltages.

Grounding – an essential installation requirement. The reverse feed of a Delta-Wye transformer no longer allows the neutral of the Wye portion of the transformer to be used as a grounding means as a separately derived source. The separately derived source becomes the Delta side and extra caution needs to be considered when grounding a delta transformer to prevent imbalances and short circuit currents issues.

Local Codes – always review applicable codes and standards along with consulting the local authority having jurisdiction (AHJ) before reverse feeding transformers.

Considering the explanation and for permanent installations, ABB recommends that transformers be specified and installed to match the installation requirements. However, in temporary installations to resolve immediate power issues, a step-down transformer can be successfully installed in reverse. The specifier, installer and inspector must understand the technical challenges and compromises presented, the potential code related issues, and the potential safety concerns of the installation. ABB manufactures step-up transformers and these are available from ABB as made-to-order items. Critical factors (but not all possible) to consider when specifying a low-voltage dry type transformer are:

- Primary (supply) voltage and system (Delta or Wye) – most common is Delta 480 V.
- Secondary (Load) voltage and system (Wye or Delta) – most common is Wye 208/120
- Load profile – linear and/or non-linear loads (50% or more of non-linear loads, consider a K-Factor transformer)
- Amount of energy required for the loads – (kVA) – also known as the transformer's capacity
- The acceptable temperature rise – 150 °C being the most common, lower temperatures are available
- The maximum ambient temperature – 40 °C being the most common, equatorial, or desert areas may require a higher ambient temperature, usually 50 °C.
- Coil Material – Copper or Aluminum
- Special Requirements, such as installation location, impedance, presence of harmonics, electrostatic shielding, lower audible noise required, special approvals, etc.

Reference materials
IEEE C57.96: IEEE Guide for Loading Dry Type Distribution and Power Transformers

NEMA ST-20: Dry Type Transformers for General Applications

IEEE C57.12.01: IEEE Standard for General Requirements for Dry Type Distribution and Power Transformers

IEEE C57.105: IEEE Guide for Application of Transformer Connections in Three-Phase Electrical Systems

NFPA 70 – National Electric Code

IEEE 3004.5: IEEE Recommended Practice for the Application of Low-Voltage Circuit Breakers in Industrial and Commercial Power Systems

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1TQC193900E0005 REV.A DECEMBER 2021