Reverse Feeding Dry-Type Transformers

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Introduction

General-purpose dry-type transformers rated 600 volts and below are used for supplying appliance, lighting, and power loads in electrical distribution systems. These transformers are used to convert the facility distribution voltage to the load's utilization voltage.

The majority of general-purpose transformers are used in step-down applications. The most commonly built 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. Step-up transformers are available, but because step-up applications are rare these transformers are not stocked. Instead, step-up transformers are 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 is common practice to use an in-stock step-down unit and operate it in reverse. If permitted by local codes and allowed by the authority having jurisdiction, it is generally acceptable to reverse feed (or back-feed) a transformer.

There are several issues that should be considered before reverse feeding a step-down transformer. This paper discusses reverse-feed application issues and the appropriate corrective actions.

Inrush Current

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 as a step-up transformer.

To illustrate, assume that a standard General Electric 9T23B3874 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) 2-1/2% voltage taps on the primary (480 volt) side. 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 of the National Electrical Code, nevertheless operates (trips) when attempting to energize the reverse operated transformer.

This 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 actually much greater than expected.

The Mag-I experienced when energizing transformers is similar to 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 step-down 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 step-up and energized at 208 VAC, the maximum peak inrush can reach 7700 amps or 37 times the rated 208 amp secondary winding full load current. The input overcurrent protective device must be sized at the higher range allowed by NEC Article 450 to accommodate these higher inrush currents.

Voltage Taps

A standard step-down transformer may contain taps on the input (primary side). 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 its terminals. 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 exciting 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.

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. Some manufacturers also build larger transformers with 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.

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 can be used to correct for this additional voltage drop.

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. 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.

Fan Cooled Transformers

Specialty general-purpose transformers are available with cooling fans. Fan cooled transformers are smaller than standard air cooled transformers and are often used where space is limited. If the transformer nameplate VA rating can only be achieved with the use of cooling fans, then UL requires winding temperature sensors connected to an integral primary side switch. This switch will open if the transformer windings exceed the design temperature threshold. Since UL requires this switch on the input (primary) side, these specialty transformers cannot be reverse fed.

Conclusion:

Standard step-down transformers may be reverse fed for step-up applications but there are several precautions that should be considered:

1. Higher inrush currents dictate that the input overcurrent protection must be sized at the higher range allowed by NEC Article 450.

2. Transformers with 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 can be used to correct for this under-voltage condition.

3. Taps can be used to adjust output voltage but cannot be used to correct for over-excitation. Tap operation is reversed, so raising taps increases the output voltage.

4. The neutral on the input side of the transformer should not be tied to ground and should not be bonded to the transformer enclosure.

5. Never reverse feed a fan cooled transformer.

6. Always review applicable codes and standards and consult with the local authority having jurisdiction before reverse-feeding transformers.

Additional Reference Material:

ANSI/IEEE C57.96: Distribution and Power Transformers, Guide for Loading Dry-Type (Appendix to ANSI C57.12 Standards)

NEMA ST-20: Dry-Type Transformers for General Applications

IEEE C57.12.01: General Requirements for Dry-Type Distribution and Power Transformers (Including Those with Solid Cast and / or Resin-Encapsulated Windings)

GE Publication GEP-1100R: General Electric BuyLog - Section 8 (transformer definition used with permission).