TECHNICAL NOTE

Low Voltage Dry Type Transformers

Transformer percent impedance

The question of transformer impedance often comes up during an engineering evaluation. There are several factors to understand. This tech note relates to the US Federal Regulation known as 10 CFR 431 Subpart K (DOE), and the other is around the short circuit current at the terminals of the transformer secondary. Also included is information on UL and NEMA standards and impedance tolerances.

DOE-2016

The 10 CFR 431 Subpart K (aka DOE-2016) is a federal regulation around distribution transformers of which the low-voltage dry-type transformers (LVDTT) from ABB fall under. Transformers that are shipped into and installed in the US must meet this regulation (a few exceptions apply). This regulation supersedes the efficiency values and testing of the NEMA TP-1 standard. TP-1 requirements should not show up on transformer specifications unless those transformers meet the exceptions (like drive isolation types) called out in the federal regulation. One of the definitions in the DOE 2016 is, "what constitutes a distribution transformer", and one of those variables is transformer impedance. The ranges below are from the regulation and transformers that are manufactured outside of the ranges are not required to meet the efficiency values in the regulation; however, the manufacturer *may* meet those efficiency values and offer that model as a DOE 2016 efficient model.

10 CFR 431.192			
Table 2 - Normal Impedance Ranges for Dry-Type Transformers			
Single-phase transformers		Three-phase transformers	
kVA	Impedance (%)	kVA	Impedance (%)
15	1.5 - 6.0	**15**	1.5 - 6.0
25	1.5 - 6.0	**30**	1.5 - 6.0
37.5	1.5 - 6.0	**45**	1.5 - 6.0
50	1.5 - 6.0	**75**	1.5 - 6.0
75	2.0 - 7.0	**112.5**	1.5 - 6.0
100	2.0 - 7.0	**150**	1.5 - 6.0
167	2.5 - 8.0	**225**	3.0 - 7.0
250	3.5 - 8.0	**300**	3.0 - 7.0
333	3.5 - 8.0	**500**	4.5 - 8.0
500	3.5 - 8.0	**750**	5.0 - 8.0
667	5.0 - 8.0	**1000**	5.0 - 8.0
833	5.0 - 8.0	**1500**	5.0 - 8.0
		2000	5.0 - 8.0

Percent Impedance

Transformer impedance plays an important part in calculating incident energy and short circuit currents. However, there is a misconception that higher impedance values are always better. Higher impedances will provide lower short circuit currents and incident energy, but the values may not be necessary to match upstream connected electrical equipment.

As an example, a 45 kVA, 3-phase transformer with 3.6% impedance is well within the range shown in the table above and will provide a short circuit current (SCC) (*at the transformer terminals*) of 3.5 kA which is well below the typical 10 kAIC rating of typically connected lighting panels. Using a 5.75% impedance, also within the above ranges, will provide 2.2 kA (*at the transformer terminals*). This is also well below the 10 kAIC rating of the lighting panel and its breakers. Actual short circuit currents at the lighting panel will be even less due to connecting cables and connections. So, the added cost to create the transformer impedance of 5.75% holds no tangible value. Arc Flash incidence levels are very low at these short circuit currents. The incident energy calculations are not run for this tech note, but it would be surprising if the results were higher than 1 Cal/cm^2 meaning a Hazard Risk Category (HRC) level 0 applies. This is especially true with lower kVA values like this 45 kVA example.

Concerning the 75 kVA 3-phase transformer, ABB provides a 6.4% impedance slightly higher in the range in the above table, but ABB has decided to design this transformer with the DOE efficiency requirements and offers it as a DOE efficient model. Calculating the SCC at 5.75% we get 3.6 kA and the calculation at 6.4% we get 3.3 kVA which is lower, but both will likely again provide incident energy levels below 1 Cal/cm^2.

The remaining higher kVA transformers have similar stories, but the incident energy may possibly increase higher than 1 Cal/cm^2 but likely below 4 Cal/cm^2, the professional engineer of record can calculate and determine the applicable incident energy and HRC level.

Please remember that the SCC of the transformers is not the SCC that will be seen at the panel as cables and connections must be added to the calculation which will make the actual SCC at the panel even lower.

Here is a little table with the four transformers in question requesting a 5.75% impedance:

$I_{sc}=I_{FLA\ secondary} * (100/\%Z)$ [FLA = Full Load Amps]

	requested Imp	SCC @ terminal	ABB %Z	ABB SCC
45 kVA	5.75	2.2 kA	3.6	3.5 kA
75 kVA	5.75	3.6 kA	6.4	3.3 kA
225 kVA	5.75	10.8 kA	5.0	12.5 kA
300 kVA	5.75	14.5 kA	4.5	18.5 kA

Percent Impedance Tolerances

For LVDTTs, percent impedances are typically nominal values with this value being determined during design verification tests. Percent impedance is not typically run as a production routine test.

UL 1561 in section 22 and NEMA ST-20 in section 4.2.8.3b state that the tolerance for a 3 winding or zig-zag transformer is +/- 10% from its nominal value. NEMA ST-20 states that for 2 winding transformers (think single phase transformer), the tolerance is +/-7.5% from its nominal value. The IEEE C57.12.01 Section 9.2 matches the tolerances of the NEMA ST-20 in +/- 10% for 3-phase and +/- 7.5% for single phase.

It would be beneficial to run short circuit and incident energy calculations using the tolerances above as a guide to determine best case, worst case, and nominal case.

Frank Basciano
Global Product Manager, LVDTT
NEMA GPG