This article discusses the industry basis and value of performing an insulation power-factor test on dry-type transformers, specifically the cast-coil design. The basis for performing this test as outlined in the industry standards is discussed. The value of performing the test based on the transformer application, site conditions, and customer objectives is presented. The intent is to provide insight into when it is prudent to apply insulation power-factor testing to dry-type transformers.

The Institute of Electrical and Electronic Engineers (IEEE) publishes a voluntary consensus standard, IEEE Std. C57.12.01 (2015), IEEE Standard for General Requirements for Dry-Type Distribution and Power Transformers. This standard was first published in 1979, and its purpose is to provide a basis for establishing performance and interchangeability requirements for dry-type transformers. This standard describes electrical and mechanical requirements of single- and poly-phase as well as ventilated, non-ventilated, and sealed dry-type distribution and power transformers or autotransformers with a voltage of 601 volts or higher in the highest voltage winding. This standard applies to all dry-type transformers, including those with solid cast and/or resin-encapsulated windings.

Section 8 of the C57.12.01 standard addresses testing. Specifically, paragraph 8.3 addresses routine, design, and other tests for transformers. Dry-type transformer tests are summarized in Table 16. The insulation power-factor test is listed under “other” tests. The standard implies that other tests are those that are specified individually as deemed appropriate. Thus, the standards recognize it is common practice to consider insulation power-factor testing for dry-type transformers.

A companion standard to IEEE C57.12.01 is IEEE C57.12.91 (2011), IEEE Standard Test Code for Dry-Type Distribution and Power Transformers. This standard provides
information regarding procedures for testing dry-type transformers. It identifies that transformer requirements and specific test criteria are not part of this standard but are contained in appropriate standards such as IEEE C57.12.01 or in other user-developed specifications. Thus, there is some basis that applications vary, and as such, different testing may be applicable for different conditions.

Within IEEE Std. C57.12.91, the following commentary is noted:

While the real significance that can be attached to the insulation power factor of dry-type transformers is still a matter of opinion, experience has shown that insulation power factor is helpful in assessing the probable condition of the insulation when good judgment is used. In interpreting the results of insulation power-factor test values, the comparative values of tests taken at periodic intervals are useful in identifying potential problems rather than an absolute value of insulation power factor. A factory insulation-power-factor test is of value for comparison with field insulation-power-factor measurements to assess the probable condition of the insulation. It has not been feasible to establish standard insulation-power-factor values for dry-type transformers because experience has indicated that little or no relation exists between insulation power factor and the ability of the transformer to withstand the prescribed dielectric tests.

Another factor cited for the inability to establish a standard insulation-power-factor test value is the wide variation in size, type, and quantity of insulating materials used in large dry-type transformers. However, practice has proven the value in trending the insulation power factor over time as a predictor of overall insulation quality. Such trend test data is helpful in identifying degradation or verifying insulation quality improvement from drying/cleaning. Such testing is also helpful in identifying potential issues (insulation voids/carbonization) that may not be observed externally.

Large (>500 kVA) cast-coil transformers (stand-alone or unit substation types) are generally applied (in lieu of open-wound or encapsulated types) where additional strength and protection is required. These units are intended for harsh environments and/or outdoor applications and are applied for their superior short-circuit strength and short-duration overloads as are typically experienced in industrial process applications.

One noted disadvantage when applying or using a cast-coil transformer is that the coefficient of expansion of the epoxy insulation is less than that of the copper (or aluminum) windings. If the transformer is exposed to environmental or operating conditions that create cyclical expansion and contraction by heating and cooling the coils, this can lead to cracking of the cast-coil epoxy-resin insulation over time.

General Electric published a service bulletin titled Test Application Data for Secondary Substation Transformers. In this test application guide, the insulation power-factor test is listed as an optional test; however, it is noted that this test is useful for checking the condition of the insulation. This service guide identifies that comparative measurements made at periodic (i.e., maintenance) intervals are useful in identifying potential problems rather than the absolute test value. Thus, GE is one manufacturer that readily acknowledges
the value of using the insulation power-factor test trend data as a maintenance test.


The ANSI/NETA MTS-2015 test specifications identify the insulation power-factor test as a standard (routine) test. Additionally, the specifications identify an insulation power-factor tip-up test as an option. Industry practice has established the value of performing this additional test when the standard insulation-power-factor test results are suspect.

The industry body of knowledge referenced herein provides guidance on transformer testing by considering the type of insulation system: dry-type or liquid-filled. There is some distinction with respect to size. Transformers larger than 500 kVA (three-phase) are generally considered significantly more critical to business operations. The standards make no distinction with respect to the test specifications based on the various types of dry-type insulation system designs such as cast coil, resibloc, vacuum-pressure impregnated (VPI), or vacuum-pressure encapsulated (VPE). Industry standards further guide the user toward good engineering judgment and apply reasonable economic justification based on additional factors such as reliability, criticality, environment, and service-aged conditions.

Having data on the frequency and magnitude of through-faults experienced by a transformer are criteria that warrant consideration with respect to specifying more or less testing. In facilities and plant sites that have high available fault currents, and in situations where a transformer has been subjected to a through-fault, it is prudent to perform insulation power-factor testing to verify the insulation quality.

Doble Engineering Company suggests the following as acceptable, stand-alone insulation-power-factor test values:

1. Ventilated Dry-Type
   - CHL (high-to-low) 2 percent
   - CL (low-to-ground) 4 percent
   - CH (high-to-ground) 3 percent

2. Epoxy Encapsulated Dry-Type
   - CHL 1 percent
   - CL 2 percent
   - CH 3 percent

It is important to note that CL power factors as high as 8 percent have been noted in some manufacturers’ transformers, and these levels may be considered acceptable. Thus, having trend data is very helpful in monitoring/identifying normal and degraded conditions. Literature published by electrical test instrument manufacturer Megger Group Ltd. provides the following insight: “Higher overall power-factor results may be expected on dry-type transformers; however, the majority of test results for PF are found to be below 2.0 percent, but can range up to 10 percent.”

The test community universally recognizes applying the insulation power-factor test periodically for maintenance and using the trend-test data to validate the quality of dry-type transformer insulation as an established industry best practice. This practice is also recommended by ANSI/NETA as a routine maintenance test.

The insulation power-factor tip-up test is an additional test recognized in the ANSI/NETA MTS-2015 industry standard. This test is performed to further clarify what the insulation power-factor test results may be indicating. When performed, this optional test is useful in evaluating and discriminating whether moisture or corona are present in the insulation system. To perform the tip-up test, the applied test voltage starts at about 1 kV and increases in intervals up to 10 kV or the line-to-ground rating of the winding insulation. If the insulation power-factor does not change as the test voltage is increased, moisture is suspected as a probable cause. If the insulation power-factor increases as the voltage is increased, carbonization of the insulation or ionization in voids is a probable cause.-
CONCLUSION

It is reasonable to perform the insulation power-factor test on dry-type transformers, including cast-coil designed units. The insulation power-factor test may add two to four hours to the testing scope; thus, it can be significant in the price of the work. It is important to understand how to prioritize the value of this test with customer economic expectations.

In some aspects, this is akin to the mindset that transformers only need to be tested on the applied tap setting. However, turn-to-turn winding shorts are found often enough to justify testing a transformer on all of its available tap positions, and time added for this testing is minimal. Understanding the value of the test, the added scope/cost, and when it may provide the best value to the customer are all things to consider when specifying testing for dry-type cast coil transformers.

Bruce Rockwell is the Director of Engineering for American Electrical Testing, Inc., Boonton, New Jersey. Bruce has more than 35 years of engineering and operations experience spanning industrial and utility power systems in transmission, distribution, substation, generation, and rail transit from low voltage to 500 kV. He has a Bachelor of Science in Electrical Engineering from the New Jersey Institute of Technology and an MBA from Monmouth University. Bruce is a licensed Professional Engineer in 22 states, a licensed Electrical Contractor in New Jersey, and a New Jersey State-Certified Continuing Education Instructor for electrical contractors. He is a senior member of IEEE and has been recognized many times for his contributions to various publications and as a speaker at various electric power industry conferences. Bruce was recently appointed as an alternate to the NEC - Code Panel 10.