The Basics of Large Dry-Type Transformers

What you need to know when selecting a transformer for a critical electrical distribution system

Photo 1. This 12,470V to 480V, 3-phase vacuum pressure encapsulated (VPE) transformer serving a large data center is dual rated at 2,000kVA and fan assisted to 2,666kVA. The right-hand side of the enclosure contains the medium-voltage switches, the middle section is the transformer, and the far left section contains the secondary 480V breakers.

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Like all of the electrical distribution equipment serving critical systems, transformers are a key component. That's why it's crucial to evaluate your decision from every angle before choosing a unit. To help you narrow the playing field, let's take a look at some of the most important factors to consider when specifying or purchasing primary dry-type transformers, which typically feed a large industrial plant, data center, or other critical facility.

1) *Capacity* — The kVA rating of the transformer.

2) *Voltage rating* — Primary and secondary voltage of the transformer.

3) *Insulation system* — The sum of the maximum ambient temperature, plus the average winding temperature rise, plus the differential between the average winding

Photo 2. Two 45kVA open wound dry-type transformers in a stacked configuration.

temperature rise and the highest temperature of the winding.

4) *Core and coils* — Wound cores or stacked laminations (copper or aluminum conductors).

5) *Winding insulation system* — Open-wound, vacuum pressure impregnation, vacuum pressure encapsulated, encapsulated, and cast coil.

Large dry-type distribution transformers are typically fed by medium-voltage power systems (12.47kV, 13.3kV, or 13.8kV) and feature a secondary voltage rating of 480V, 3-phase (**Photo 1** on page C24). Some of the larger common sizes of dry-type transformers available today include 500kVA, 750kVA, 1,000kVA, 1,500kVA, 2,000kVA, 2,500kVA, 3,000kVA, 3,750kVA, 5,000kVA, and 7,500kVA.

As noted above, there are several different construction methods used in the manufacture of dry-type transformers, resulting in various designs that make installation in many different environments possible. The key difference in the design of these units is in the insulation of the windings. Dry-type transformers can have their windings insulated in a number of different ways.

• *Open wound.* The standard dry-type transformer follows a "dip-and-bake construction" method. This is accomplished by preheating the conductor coils and then, when heated, dipping them in varnish at an elevated temperature. The coils are then baked to cure the varnish (**Photo 2**).

• *Vacuum pressure impregnation (VPI)*. This technique applies the varnish coating in interchanging cycles of pressure and vacuum. The VPI process uses polyester resin. The coils are then cured in an oven. The VPI process is better than the standard dry-type transformer because it includes pressure in addition to vacuum. This process allows better penetration of the varnish in the transformer coil. These units offer an increased resistance to corona.

• *Vacuum pressure encapsulated (VPE)*. This method is usually superior to the VPI process. Several dip processes are added to the construction process to encapsulate the coil assembly after which the coatings are cured in the oven. These transformers feature better protection from harsh and wet environments than their VPI type counterparts (Photo 1).

• *Encapsulated (sealed)*. Encapsulated transformers are standard open-wound distribution transformers encased in an electrical-grade silica and epoxy, and totally enclosed in a heavy-duty style enclosure.

• *Cast coil (molded epoxy sealing).* These units incorporate coils encapsulated in epoxy by a molding process. The transformer coils are solidly cast in resin under a vacuum in a mold. The manufacturing process locks the windings in a strong epoxy resin with high dielectric strength, protecting the transformer from severe operating environments (**Figure** on page C28).

Each of the winding insulations noted above is specifically suited for particular environments. Therefore, it's important for you to understand where best to use each type. For example, it costs approximately 50% more to specify a cast coil transformer over a VPE or VPI type unit. Therefore, your final selection can have a significant impact on the overall cost of a project.

When improved resistance to corona (i.e., electrical discharges caused by the field intensity exceeding the dielectric strength of the insulation) and increased mechanical strength of the windings are required, you should use a VPI-type transformer.

Use a cast coil transformer when additional coil strength and protection is needed, such as in unforgiving environments like chemical process plants, construction material factories, and for outdoor installations. These types of harsh environments include substances that can devastate the windings of other dry-type transformers, including salt, dust, caustic gases, moisture, and metal particles. Additionally, cast coil transformers have improved abilities to withstand heavy electrical surges, such as recurring but short-duration overloads experienced by transformers serving industrial processes. Cast coil transformers typically have the same increased levels of BIL as oil-filled transformers, while still providing ample protection of the transformer coils. Cast coil transformers are also being used in some harsh locations that were previously thought best served by liquid-filled transformers.

The engineer has a choice between a VPI/VPE transformer or cast coil transformer for critical environments and harsh environments. The cast coil is typically accepted as the best transformer in these types of environments. Some manufacturers, however, indicate that the cast resin in the cast coil transformers can be detrimental to the life of the transformer. The coefficient of expansion of the epoxy is less than the copper windings. The cyclical expansion and contraction with the heating and cooling of the coils can eventually crack the resin. These manufacturers indicate that the epoxy encapsulation in the VPI transformer can better deal with this expansion and contraction; therefore, if offers longer life. In the end, the final choice is left to the design engineer.

In addition to the capacities noted earlier, the electrical design engineer can specify a fan-assisted transformer that can add significant capacity to the rating of the transformer. For a cast coil transformer, the addition of the fans to cool the transformer during heavy loading can add another 50% to the rating of the transformer. For a VPE or VPI transformer, an additional 33% kVA capacity can be added to the rating of the transformer. For instance, a standard cast coil dry-type transformer rated for 3,000kVA can have a second rating when fan assisted to 4,500kVA (a 50% increase in the standard rating). On the other hand, a VPE or VPI transformer rated 2,500kVA can have a second rating when fan assisted to 3,333kVA (a 33% increase in the standard rating).

Remember: When using the fan-assist rating of a transformer, you are relying on moving parts to supply the rated capacity. For critical installations, you may only want to rely on the fan-assist rating for unusual overloads that may occur under certain operations, including:

1) The extra current required to recharge UPS batteries after the UPS system has been used during a power outage before the generators begin to come online.

2) Planned maintenance bypass that placed a short-term condition of extra load on a specific transformer.

3) Other short-term overloads of the electrical distribution system.

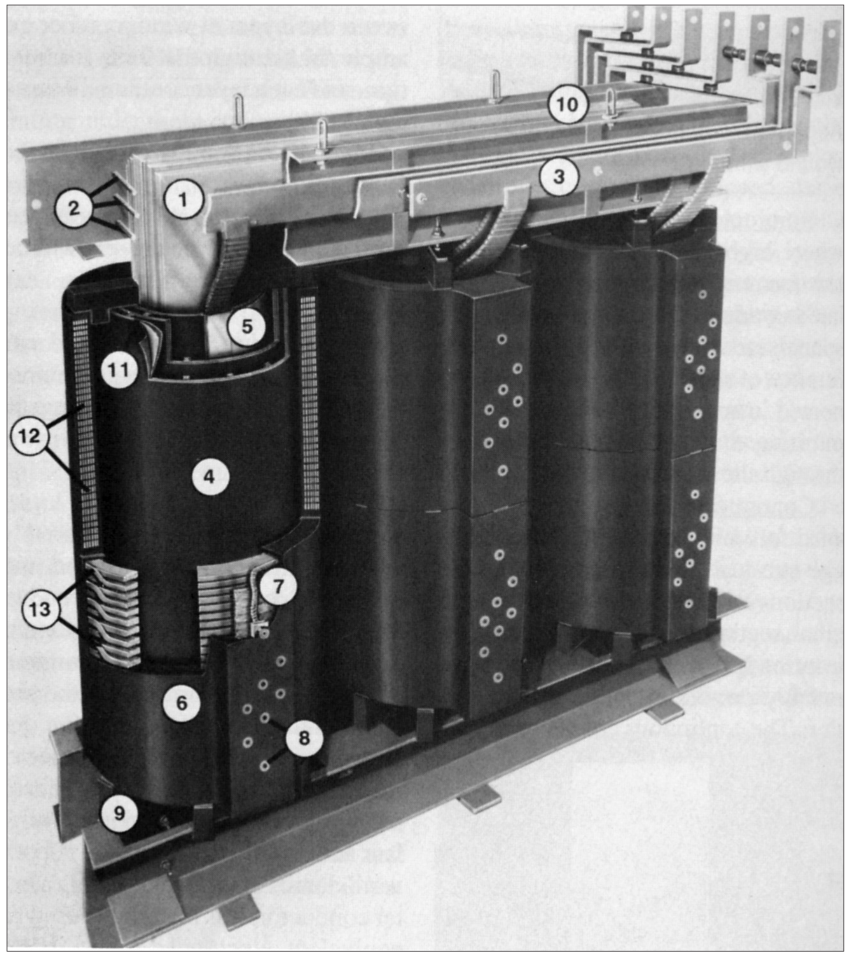

Illustration courtesy of *EC&M Books*

A typical cast coil transformer consists of the low-voltage bus (1), clamp bolts (2), high-voltage bus (3), low-voltage winding (4), core (5), high-voltage winding (6), tap (7), tap terminals (8), transformer base (9), lifting channels (10), air channel (11), high-voltage winding conductors (12), and low-voltage conductors (13).

For critical environments where uptime is essential, a system that relies on the fan-assisted rating for normal operation may reduce overall system reliability.

Dry-type transformers can have their windings insulated in a number of different ways.

The electrical design engineer must always evaluate cost implications and system reliability when designing electrical distribution systems. This type of evaluation becomes even more important in critical environments. The transformer is only one component in complex electrical distribution systems. As you can see, the design engineer must be armed with the most accurate information in order to make the proper transformer selection. **EC&M**

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