

Get the transformer you expect: Beyond standards and specifications



Executive summary

The need for utilities and industrial companies to lower initial costs has forced many power transformer buyers to look beyond their national borders. This causes new challenges in creating specifications that will provide low, first-cost manufacturers clear direction regarding the desired performance and features. Standards provide baseline parameters but don't fully describe all of the buyer's requirements. When shopping in a global market, buyers need to provide broader levels of detail and increased specificity to ensure that they get the transformer they expect.

Transformer buyers in search of low first-cost equipment are increasingly turning to suppliers outside their geographic region, taking their business to lower-cost labor markets. Given the constant pressure to tightly control costs and the large capital investment represented by a transformer purchase, many buyers are forced to look at alternatives to lower first

cost including sourcing outside of North America. However, buyers need to take appropriate precautions to ensure that the transformer they want is the transformer they get.

Anyone who's travelled internationally and visited a local store knows that the shopping and buying experience can be confusing. Different languages, cultures and customs combine to make communication and negotiation a challenge.

What's true of shopping for toys or ties is just as true for transformers. When dealing in unfamiliar markets and with new and untested suppliers, the buyer must truly beware. It's essential to clearly define the device requirements, something that may be simplified by accepted standards such as IEEE, ANSI, CSA or IEC. But even for the active parts of the transformer, the standards don't cover all the special cases or specific parameters. Clarification is suggested for all agreements between builders and buyers.

Beyond the transformer itself, the specification needs to clearly describe system requirements and interfaces with the existing or future infrastructure and the requirements regarding delivery.

This white paper describes some of the information that transformer buyers must consider beyond the standards, requirements that must be included in the specification to ensure that buyers get the transformer they expect. Special considerations will be defined in three broad areas: functionality, safety and serviceability.

Before delving into some of the specific items to be considered in specification, we will explore some of the broader topics related to buying transformers in a global market and end with some items to consider adding to purchasing specifications (although the reader should be cautioned that these recommendations in this paper should not be viewed as an exhaustive list).

Standards don't cover everything

The process of specifying a transformer is, in some ways, like planning to build a home. It's easy to buy basic plans for a house that will be structurally sound and functional in every way. However, the builder needs to provide additional information to the architect to assure it suits the maintenance capabilities of the client and meets all local building codes and site requirements. For example, a special-needs homeowner might require low-maintenance or hypo-allergenic building materials – and if the house is to be built on the Florida coast, plans must be modified to withstand hurricane-force winds.

Just as blueprints provide most of the information needed to build a new house, the standards provide most of the information needed to build a transformer.

“In any specification, the buyer will reference one or more standards as the basis for the electrical parameters of the transformer,” according to Krzysztof Kulasek, Vice President of Power transformer Engineering at ABB. “The standards establish the fundamental performance expectations related to the electrical design of the active part, such as the rated power, test voltages, and so on. Beyond electrical parameters and testing, we can also find basic information regarding control, cooling and auxiliary equipment, as well as some of the mechanical requirements. The standards provide the framework for a good specification, defining the majority of the parameters for what the manufacturer will deliver.”

Still, to ensure that the buyer receives the transformer they expected, additional clarification – beyond what's described in the standard – must be provided to the manufacturer. This is especially true when buyers are sourcing from unfamiliar builders in distant countries.

The buyer must also be aware of the need to manage the complexity of dealing with multiple standards from around the world, clearly stating which elements of each are to be followed. In the absence of clear and complete specifications, problems can begin before the transformer even arrives at

the installation site because standards don't address transportation requirements.

“The manufacturer will build, test and then disassemble the unit for shipment,” says Robert Latrendesse, ABB Power transformer Logistics Manager. “At that point, 90 percent of the value is already in the transformer. You need to specify your expectations regarding transportation to ensure the unit will arrive safely after being hoisted on and off ships, trains and trailers. It is a long and difficult journey. Some buyers are increasing their comfort level by specifying that the manufacturer must equip the transformer with a self-contained GPS-enabled tracking device. These new sensors monitor impacts, can transmit alerts and allow the buyer to log onto a website and personally track the progress of their transformer as it makes its way to the final destination.”

Once safely arriving at the site, the installation crew may discover that re-engineering or adaptations are required to get the transformer situated on the pad. Issues may also arise related to compliance with buyer or local requirements related to quality, safety and sustainability practices. Problems could continue when maintenance or repairs are needed. Routine maintenance activities turn into a major undertaking when fasteners are the wrong type, and technicians are faced with design features that are foreign to them. Without proper documentation, another item that must be part of the spec, both service and operation activities will be hampered. And, if replacement parts are required, there may be no ready, local supplier. Instead, the buyer must go on a scavenger hunt or wait for parts to arrive from the country of origin.

A complete, clear and carefully written specification fills in the white spaces and ensures that transformer buyers have a painless installation, trouble-free maintenance, and long and



reliable transformer life. Without a well-written specification, buyers are setting themselves up for many headaches and unexpected costs in the future.

Buying in a global market

Precisely specifying a transformer being purchased in the local market is a complex undertaking. The challenge increases greatly as transformer buyer's purchase from manufacturers located in low-cost labor markets.

"People have been buying offshore for a good 10 years," says Kulasek. "They've learned a lot and invented creative workarounds to overcome the difficulties and problems. The question is how much it costs them. There's no doubt that the transformer sticker price will be lower, but they aren't seeing the total cost. It will often be higher than if they'd made their purchase closer to home."

For example, it is standard practice for transformer buyers to make occasional visits to the manufacturing facility to check on the progress of their build, verify that the equipment is being manufactured according to expectations and will be delivered as promised. What is the cost to have several engineers spend weeks overseas? With new or unproven manufacturers, more frequent and longer visits may be required.

Manufacturers won't intentionally shortcut specifications. However, without a clear understanding of the specification and standards, they may use materials or processes that are typical in their region or local market, but are not what will be expected in the destination market.

In the US for example, the IEEE standard requires the use of thermally upgraded paper for windings, capable of taking higher temperatures. In China, if produced to IEC standards, the limit is

lower and thermally upgraded paper is not required. US-based transformer owners often run these units at relatively higher hot spot temperatures than other global users. It is important that the upgraded paper be used not only on the windings, but on winding exits, cables connecting leads and bushings as well. Without upgraded paper, material degradation accelerates and transformer life is shortened.

There are also potential discrepancies regarding cables, connections to bushings and dozens of other production details.

"Everyone in North America is accustomed to receiving transformers equipped with IEEE bushings," says Randy Williams, ABB Components Account Executive – Bushings. "They are astonished when they receive a new transformer that does not properly fit or meet interchangeability requirements of bushings per IEEE standards. These are the kind of details you can't take for granted when preparing the spec."

"We can't ignore the fact that there are individuals at both ends of the process," says Kulasek. "There is the customer writing the spec and the manufacturer building the equipment. Anytime humans are involved, there is room for misinterpretation, especially when buying globally. The manufacturing team won't necessarily get to the same meaning from the standard or specification language as the buyer intended when writing the spec. The difficulties here are magnified when working with manufacturers on a different continent. You can have a perfect standard but still have different interpretations or implementations."

Some manufacturers overcome these obstacles by ensuring that engineers and experts local to the North American market are available to oversee each step of the process and act as the local liaison.



“We see the value in having engineers in both the country supplying transformers and in the country of installation,” says Scott Curley, Vice President and General Manager of ABB’s Power transformer business. “Besides local engineering expertise, we have project managers in the local time zone with the ability to work effectively with local customers. We also have transport people in the local market with the ability to effectively get the transformer from the factory to the pad. When you consider the potential problems and regulations of getting the device off the boat and then onto one or more rail cars and truck trailers, it’s a tremendous advantage to have someone with local expertise to react if something goes wrong.”

Now, let’s look at three areas to be considered when creating a specification, beginning with functionality.

Functionality

“As organizations merge and grow geographically, transformer buyers are increasingly put in the position of specifying equipment for installations in geographies or environments outside of what they’ve typically done in the past,” says Williams. “They don’t realize that what works fine in one geographic location may not be appropriate somewhere else.”

When specifying bushings, the job may seem relatively clear cut: select the needed bushing style and size. However, that doesn’t provide all the information needed.

A basic, but sometimes overlooked, consideration is the bushing orientation or inclination. It can be installed vertically, horizontally or at some angle.

“If they put a bushing at the wrong inclination, the oil doesn’t cover the condenser body; and it’s possible that the whole

condenser body could be uncovered, with disastrous results,” Williams says.

Two potentially critical bushing specifications related to environment are the creep and strike distances. Creep distance is measured from the point of the incoming connection at the head of the bushing to the metal flange where it’s mounted to the transformer. Imagine an ant walking between those two points, around any sheds on the bushing, and that is the creep distance. If you drew a string between those two points, on the other hand, that is the strike distance.

“The appropriate distances, as well as the treatment applied to the bushing porcelain, must be specified based on the transformer’s environment,” says Williams. “Will it be in a dirty manufacturing facility, a chemical or petroleum facility with airborne contaminants, or a coastal facility where salt or humidity is present? These environmental factors have to be considered when specifying a transformer if you expect to get the full, rated life.”

Transformer buyers don’t always specify that the bushings will be housed in a bus duct, what maintenance people sometimes refer to as a “dog house.” The bus duct protects the interface between the bushing and the transformer from the elements and other contaminants, but they are unventilated and therefore contain heat that would otherwise dissipate naturally.

“The standard bushing hot spot temperature is 105°C (220°F), but the high-temperature gaskets for use in a bus duct are rated 125°C (250°F) to tolerate the higher heat levels,” says Williams. “At temperatures >105°C, standard gaskets typically deteriorate much faster than their expected 30-40 year lifespan. If high-temperature gaskets aren’t specified and the discrepancy isn’t



detected, the gasket will allow moisture to enter or oil to leak; the power factor can rise, and the result could be a catastrophic failure.”

Another parameter not always clearly defined is impedance.

“The majority of units purchased in North America are replacements,” observes Kulasek. “Although it’s a critical consideration, buyer specifications sometime lack the detail that the impedance has to change in a certain way from the nominal value. The standard is your tolerance. It says the impedance can be different, for example, in a three-winding transformer or an autotransformer plus/minus 10 percent. You can imagine that one supplier might be plus and the other minus. That could give you a 20 percent variation. Does that create a problem for you? Are you willing to accept that difference? Or do you need to tighten your specification to ensure that the impedance is as-required?”

To ensure that the transformer output will precisely meet the application requirements, it may be appropriate to specify the quality of the testing lab certifying transformer performance. Consider possible variations on load loss.

Power transformers have a very low power factor and that requires special consideration when measuring load losses and impedance voltage. Careful selection of measurement method and test system equipment is essential for accurate and repeatable results. The phase-angle errors in the instrument transformers and measuring instruments will affect load loss test results.

In the majority of commercial applications, transformer users put a penalty on the losses that occur in the load and no-load



conditions. The loss accurateness measurement is of primary economic importance for any power transformer project. Also of critical import is the comparative measured loss with calculated and guaranteed values in the quality check process prior to delivery to ensure safe operation.

“The bottom line is you want to get the losses you paid for,” Kulasek explains. “How accurate will the measurements be? Transformer buyers can specify their expectations regarding the testing labs.”

Another test requirement to be considered relates to hot spot limits.

When designing transformers, engineers use thermal models and run complex calculation of temperatures including hot spots. These models are based on theoretical assumptions and are sometimes modified by empirical factors. Correct hot spot calculations need knowledge and tools that ensure the necessary accuracy. IEEE guide 1538 lists requirements for mathematical models and recommendations for determining the maximum winding temperature rises.

It is important to remember that the final result will depend not only on the calculations accuracy but also will be influenced by materials and shop assembly tolerances. Even a small difference of two to three degrees will reduce insulation life when a unit is fully loaded in service.

Fiber optics should be put in windings at multiple locations to measure hot spot temperatures on prototype transformers. The direct hot spot measurement gives the most objective validation of the thermal model and checks the quality of manufacturing.

Every user will specify or refer to IEEE to set winding hot spot limits. However, to ensure proper operation in service, other hot spots in the transformer are equally important for trouble free service operation. Metal parts like tanks and core frame parts are heated by stray flux. Metallic parts with a hot spot may lead to gassing problems, unplanned outages or failures.

Cooling of the core has to be checked, making sure that the hot spot temperature inside of the core and core surface temperature are calculated. Hot spots in the windings should be validated in a prototype unit by a direct measurement.

During a design review all hot spots locations must be reviewed and manufacturers must be able to provide data to support their calculation models.

Serviceability

There is an old proverb that poetically describes how a horse losing a horseshoe nail in battle could be responsible for the loss of a battle and, therefore, the entire kingdom. The same scenario can play out with transformers; but substitute a fuse for the nail, and substitute the power grid for the kingdom.

“Something as small as a fuse in a low-voltage control cabinet can take the transformer off line and create an outage,” Kulasek explains. “When relays and breakers in the cabinet fail, you have no voltage regulation and the transformer goes off-line. Because of a \$5.00 part, your \$2 million transformer is out of service.”

The solution is not to assume that basic replacement or service parts will be available locally. Instead, include in the specification that locally available parts should be included in the control cabinet and other positions supporting the transformer. If not currently available locally, then specify that replacements should be included for the short term and a local supply chain be created for the long term.

Buyers in the United States should include in their specification that NEMA-standard fans, motors, and related devices be included so that replacements can be locally sourced. There are standards coming along for control cabinets, interfaces, connections and related parts for power transformers; but for now, it’s an area that requires special attention by the buyer.

Bushings are the single-most common failure mode in transformers, and bushing issues are a common source of serviceability problems.

“One of the biggest problems we see is on bushings, where the connection point to the top terminal – the termination to their line – can become loose,” Williams states. “This creates localized overheating that can quickly erode the quality of the gaskets, leading to water or contaminant ingress to the transformer and/or bushing. The customer needs to pay particular attention to ensuring tight connections at the top terminal of the bushing.”

When it becomes necessary to replace a bushing, maintenance managers are often dismayed to discover that the connection method for the replacement bushing doesn’t match the original equipment. Bushings can be connected to the transformer winding in one of three ways: draw lead, bottom-connected or draw rod. Each has benefits that may better fit with the buyer’s application. The critical factor is to include the connection type in the specification.

“The connection method and size vary between manufacturers,” Williams says. “If the buyer intends to always rely on their transformer manufacturer for replacements, this isn’t an issue. If they want the flexibility to rely on a different supplier for replacement bushings, they need to specify the desired connection method and size.”



Even something as simple as the drawings and instruction documents warrant mention in the specification. Indicate the expectation that they be provided in the local language and the local measurement system (English vs. metric), not the country of origin.

Safety

To ensure the operational safety of the transformer, buyers need to be assured that the design of their transformer has been tested and proven. While some aspects of testing are included in various standards, a careful buyer will expand on their testing-related expectations in the standard.

Short circuit testing, while optional, is a highly reliable indicator of design safety, and it is an area where buyers should lay out expectations of their manufacturer.

“Buyers should be wary of purchasing from a supplier that is unable to show third-party testing of some of their designs,” Curley says.

“Transient events can be very destructive to your transformer as they create electromagnetic forces that deform the windings and may not be evident immediately. Short circuit testing demonstrates how the unit will react to transients in the field such as faults or lightning strikes. It is recommended that customers ask for the manufacturer’s KEMA results for all short circuit tests in the last 10 years. If they can’t produce results to show the integrity of the design system they use, then there’s no third-party verification of the safety of the design process or standards. Absent that,” Curley says, “there’s no confidence that the buyer won’t have a catastrophic failure when a fault hits their transformer. Better to know the design safety margins from test data rather than field failures. Call out testing and documentation requirements in the specification. Without it, buyers have no proof of the integrity of the transformer’s design stability and safety.”

The specification should also describe requirements regarding the safe transportation of the transformer to the site. If the unit is dropped or experiences shock loads during transportation, the core and coil can actually be knocked out of position. Damage to the active components can create a safety risk to anyone in the area when the transformer is energized.

“Ask for a frequency response analysis to verify the geometry of the active part of the transformer before and after transport,” advises Curley. “This should provide buyers the confidence that nothing internally has shifted during shipping. It is the best way to know the integrity of the transformer and minimize risk of catastrophic failure when the unit is energized.”

Another consideration is the safety performance of the plant and its manufacturer’s representatives during installation. The safety practices of the crew that position, connect and commission the transformer will affect the buyer’s safety record. Is the supplier OHSAS 18001 compliant and can they produce safety records to show a commitment to safe working and operating conditions.

“The specification can describe the qualifications, experience or training of the on-site technicians,” says Graham Stalling, ABB Marketing Manager – Transformer Remanufacturing and Engineering Services. “Don’t allow them to identify an unproven local vendor without data that shows they can be trusted to safely bring the transformer online. Ask about the installing firm’s Experience Modification Rate (EMR). Specify expectations and non-performance penalties. Require that they have a factory representative on site for the installation.”

Installation and training become critical issues as the buyer begins to specify all of the accessories for their transformer. How do they ensure that everything they need – valves and fans, piping and connections, and control cabinet wiring – will be included and that it will all come together correctly at the time of installation on site? The specification should address all of these issues. However, because the standards provide little or no help in this area, difficulties may arise when the erection crew puts the transformer on the pad and begins to install it.

Conclusion

Cost pressures are forcing many power transformer buyers to look beyond their national borders to lower the initial purchase price. It is crucial that buyers stipulate detailed technical and non-technical parameters or risk taking delivery of a unit that fails to meet functional, safety and/or serviceability expectations. Over the expected lifecycle of the transformer, failure to factor these issues into the up-front specification can obliterate any initial cost advantage.

Standards provide an excellent foundation for power transformer specifications, but are only the starting point.

To minimize the future risk of transformer performance issues and/or unanticipated higher operational costs, buyers need to rethink how their initial purchase specification is written – especially when purchasing from new and distant manufacturers. In the end, it is all about ensuring that the transformer that arrives on the pad is the transformer the buyer expects.

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