ABSTRACT

The growths and declines of transformer market through the decades have been driven by grid expansions, global economic crises and in recent years by emerging distributed generation, energy efficiency initiatives, and sophisticated control through smart grid and FACT systems. Every aspect of transformer design and use has evolved and will continue to evolve over the coming decades. Due to price pressure and competition, transformers are nowadays built more compactly with reduced usage of materials which consequently gives rise to quality issues. Sophisticated network management complicates the definition of requirements placed on the transformer and the definition based solely on the lowest price is no longer sufficient.

KEYWORDS

transformer market, efficiency standards, smart grids, product specification, duty requirements

Steve AUBERTIN

Soft market issues

1. Introduction

Previous editions of this column have lead heavily on hard statistical data and market metrics covering production values, trade values and the resulting changes in markets that have been substantive in nature. In this edition we take a look at the softer issues that impact upon markets and market development.

Broadly these issues are:

- Price and competitive pressures
- Efficiency standards and requirements
- Product specification
- Manufacturing build quality
- Operational duty requirements

Since the global industry adopted an Alternating Current (AC) system rather than a Direct Current (DC) system for electricity transmission and distribution, transformers have been at the heart of the networks. In fact, one of the major reasons why George Westinghouse – proponent of AC systems – prevailed over Thomas Edison – proponent of the DC – in the 1880s was the fact that electricity can be easily transformed from one voltage level to another, and thus be transmitted over long distances at high voltage and low currents whilst keeping losses low.

The basic design concept of two sets of windings on an iron core, which held true in 1880, is just about the only thing that has remained unchanged since those times. The expectations of a transformer in a modern network, whether it be for generator step-up, transmission or distribution use, have resulted in technically advanced highly engineered products, operating at voltages and efficiency levels that would not have been dreamed of nearly 140 years ago.

Does that mean that we now have reached the pinnacle of transformer design – a product that is 100 % failsafe, efficient, reliable and cost effective? Even the most bullish of commentators would accept that this is far from the case. Designs are still evolving; improvements are being made and evermore things are being expected of the transformers.

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Cyclic grid expansions lead to imbalance between the demand and transformer production capacities

Even the advent of HVDC systems, which would have given enormous pleasure to Thomas Edison, has resulted in an even greater demand for transformers and other wound products in the form of reactors, phase shifting transformers and other auxiliary and conditioning products.

So, in broad terms, transformers will continue to be at the very heart of the worlds' transmission and distribution networks, but nearly every aspect of their design and use has evolved and will continue to evolve over the coming decades.

2. Price and competitive pressures

The transformer manufacturing industry was dogged by overcapacity for the entire twenty year period of time between 1980 and 2000. The re-building and grid expansion work worldwide that occurred during the thirty year period of time up to the 1980s had fuelled manufacturers worldwide to increase their capacities; orders were plentiful and margins were good. Transformers, and particularly distribution transformers were a mature product and in many countries the number of manufacturers increased. Often entrepreneurial ex-employees of established manufacturers would set up their own companies separate from, but near to their former employers where they had access to local skilled employees and established local suppliers. Technical and capital barriers to a market entry by this method were low; competition increased and because of the low overhead nature of the competition, margins were eroded.

By the mid-1980s, as demand was easing,

The positives which emerged after the global crisis in 2008 are rationalization of transformer production capabilities, energy efficiency initiatives, and increased spend on smart grids

the oversupply in the market place was becoming a problem and profits were declining. There began a period of contraction, some smaller and more vulnerable manufacturers ceased trading, there were mergers and larger competitors acquired smaller companies by way of buying up competition. What emerged by about 2000 was an industry that was in capacity terms smaller, much leaner, but much more consolidated. This coincided with a period of global economic growth, utility companies were again investing as was industry and furthermore the four BRIC countries – Brazil, Russia, India and China were booming.

There followed a sustained period of time when business was plentiful and returns were good. Manufacturers were able to increase prices on the back of increasing raw material costs, which enabled them to pass on these increased costs – plus a bit more. Everything looked very good and the future prospects for the industry looked very comfortable; until 2008. The global crash that followed in truth did not hit the transformer industry until 2009 and 2010, but it did eventually hit and hit hard.

Distribution transformer orders began to dry up, as did investment capital; projects involving power transformers were either cancelled or phased back and business became very tough. It became a buyers-market; lead times were reduced; manufacturers entered a round of cost cutting and rationalisation; the only immediate positive aspect of the recession was that raw material prices fell back.

There were three not quite so clearly evident positives that can be taken from this global disaster from which the industry is still recovering. Firstly, this period has allowed manufacturers to rationalize their production capabilities to more effectively meet purchasers' needs. Secondly, the whole industry – users and suppliers – have seized on, and actively embraced the energy efficiency initiatives that are being rolled out worldwide and the attendant price increases are most welcome. Thirdly, in these more austere times, utility companies have focussed more on "sweating the assets", which has led to ever increasing spend on smart grids, which has in turn led to greater spend on wound components and control equipment rather than on pylons, lines, etc.

3. Efficiency standards and requirements

Without going into the specifics of the different regulatory requirements in each of the major countries and regions of the world, it is fair to say that most of the major markets have enacted energy efficiency standards for transformers. Requirements for increased efficiency levels have been enacted starting with voluntary codes in 2006, and began to have an impact in 2008 through to 2016 and, certainly in Europe, will finally be fully implemented in 2021.

The case is always made that total cost of ownership should be the true measure of a transformer cost, and the figure is widely quoted that the EU losses due to "low efficiency" transformers equates to some 100 TWh annually. There is no doubt that these increased efficiency requirements will save energy and hence costs over their lifetime; however, it is still the bottom line effect of the purchase price that impacts more directly on the purchaser, not the total savings over a 30 or 40 year service life.

However, this trend is good news for the transformer manufacturers. There is a healthy premium to be demanded for transformers designed to comply with the latest efficiency standards. The size of that premium varies not only on the duty cycle of the transformer, but also as to whether the supplier or the user is making the calculation. There can certainly be a premium of between 20 % and 40 % comparing a unit compliant with the latest regulations and a "high loss" industrial type unit. Any increase in sales price will be welcomed by the transformer manufacturing industry because of the attendant increase in margins.

Amorphous metal core technology has been heralded as the answer to all low loss requirements, but although its use has been included in the relevant standards, it is fair to say that the speed of uptake has been glacial. Whilst the technology has been embraced in China (and to a lesser extent in India and the USA) the usage is measured in the low hundreds of ktonnes (thousand tonnes) compared with grain oriented steel for which the demand is in the order of 2.5 to 3.0 million tonnes. There is no doubt that on the plus side the technology does deliver high efficiency transformers; on the down side, it is expensive, difficult to work and there have

Increased efficiency standards are driven by total cost of ownership which should be the true measure of a transformer cost

been reported noise problems with some pilot installations. It must also been born in mind that with the material only being produced in Japan, China and to a lesser extent in the USA, many transformer manufacturers will be reluctant to commit to a material with such a monopolistic supply structure.

As a result, it would be surprising if the market penetration rate of amorphous metal remains anything other than glacial and the biggest fillip to market value growth will be mandatory efficiency requirements.

4. Product specification

On an initial examination, product specification should be the most straightforward aspect in producing, selling and purchasing transformers. There are clearly written national and international specifications which give detailed requirements that a transformer, its component parts, raw materials and sub-assemblies must be designed, built, and ultimately tested and accepted to meet. The problem is that it is very difficult to specify quality; and hence difficult, even given the uniform standards, to be sure that as a purchaser you are comparing like for like. At a recent congress on Insulators and Bushings (INMR Congress 2017 Sitges Spain), a paper given on behalf of KEMA Laboratories [1] covered exactly that point. KEMA have noted that approximately 25 % of all MV and HV components submitted for type testing initially failed the test; 22 % of power transformers initially failed short-circuit tests and that the distribution transformer failure rates were very comparable. Furthermore, the results have been consistent over the period 1996 to 2016. The paper concluded that:

"Failure rate stays stable over the year, despite better materials, knowledge, modelling and production techniques

Business tendencies that drive this are: Build more compactly, reduce usage of materials and market competition and price pressure

Quality of a component is difficult to describe in specification and tendering procedures "normalize" to ease the bidding process that may result in delivery of components with questionable quality"

The point is that in previous generations a utility engineer would calculate the maximum load that a transformer would be subjected to, he would add 20 % to 30 % to this to allow for future load growth, call for three or four tenders, and would probably select not the cheapest, but the bidder that he knew would supply reliable products – because they had a proven track record – and because they would add a further 10 % to 20 % overload capability to their design. Thus a 1,000 kVA transformer would happily cope with a load of up to 1,500 kVA without any problems.

Competitive bids are now often won on price and price alone – providing they meet the specification. As a result, the transformers are designed down to the bone to win the bid. Counter-intuitively efficiency standards and improved modelling and production techniques have actually exacerbated this problem. An overdesigned bulky transformer would probably not meet efficiency requirements and without the advanced modelling and production techniques, it would not be possible to design down to the limits and hence "minimize" the product.

So, whilst designing down to a specification depresses market prices, this may not be the most optimal approach.

5. Manufacturing build quality

This topic follows on quite logically from the last. Given the pre-condition that products all meet the relevant standards, norms, etc., how can a purchaser (a) ascertain adequate build quality, and (b) guarantee this in individual products?

For power transformers, with high unit values, periodic site inspections throughout the manufacturing process and quality auditing of sites together with witnesses acceptance testing is the ultimate solution. However, this is time consuming, costly, and is not applicable to small distribution transformers.

For distribution transformers, purchasers rely on conformity with the relevant specifications and then batch testing every "n^{th}" item to ensure that the final product output meets the criterion.

However, the bottom line is that ensuring build quality is one of the most difficult aspects of the purchasing process to assess. Ultimately, the answers only become clear some years after units

have been in the field and a forensic examination of failures can be made. It is only then that the full consequences of purchasing the lowest price option may become clear.

Increasingly, purchasers are going down the route of pre-qualifying suppliers and furthermore pre-qualifying individual production plants for specific types of transformers as a way of overcoming this problem. Indirectly this may be a way of excluding the lowest price option before even receiving the bid, but it does for individual purchasers put down a floor beneath which they will not go.

Does this practice drive up the market price for transformers? The answer is probably by a small amount, but ultimately there will always be a purchaser somewhere that will accept the risk of purchasing from an unknown or untested supplier for a good price – every new entrant has to start somewhere. If the product is good, then the entrant will win more business and as the maxim goes – cream will always rise to the top of the milk.

Competitive bids are often won on price alone, resulting in transformers designed down to the limits

In summary, purchasers are falling back on old fashioned values, being guided by the reputation of a supplier and building relationships with their suppliers. These are values that have remained unchanged over the entire history of the industry.

6. Operational duty requirements

At the start of this column the point was made that the basic design concept of a transformer is just about the only thing that has not changed. At the other end of the spectrum, the operational duty requirements of transformers is the facet that has most changed.

Purchasers are being guided by old fashioned values, the reputation of a supplier and their mutual relationship

At some point in time towards the end of the last century it became clear – through brownouts and blackouts in various countries – that the load had outstripped the capacity of the grid systems in many instances. The grid owners being fully commercialised businesses were reluctant to invest the huge sums of money and time necessary to reinforce their grid systems and looked for other solutions. Fortunately, advanced engineering came to the rescue and rather than increase the general capacity, the industry went down the route of increasing the efficiency of the existing hardware. Smart grid and FACT systems were implemented to make this happen. A neat solution, but one that by definition puts a heavier load on the networks and components. On top of this another complication was added, the philosophy of distributed generation; the move away from centralised generating stations fuelled by fossil fuels and nuclear towards smaller greener solutions such as wind, solar, hydro, etc. began. This placed another layer of complicated operational duty requirements on the network; including an entirely new concept of making a transformer work backwards.

This trend has continued and we are now entering the age of the "intelligent transformer".

So far, advances in engineering have kept pace with increased demand, and by and large, the concept of sweating the assets and increasing the overall efficiency of the grid has worked; however, it has to be acknowledged that the grid in some countries is now so finely balanced that the control has to be first class, otherwise the whole edifice will come tumbling down.

No longer is a transformer an inert piece of kit that is installed in a field somewhere and occasionally checked for leaks and to top up the oil level. It is a highly engineered active component that is expected to work under the extremes of full load and no load and ever point in between, and to do this at efficiency levels exceeding 99 % for 30 or 40 years.

This situation suits the commercial needs of the utility companies, but in their drive for commercial success they have lost the engineering ability to specify what they need when they buy key components such as transformers. Engineers can build pretty much whatever is asked of them, but the design brief has to be accurate and comprehensive, and the correct purchasing decision will not be made on the lowest price option.

At the risk of being nostalgic, in the UK before the privatization of the electricity supply industry, the former CEGB (Central Electricity Generating Board) was a monopolistic generating transmission and distribution entity; the following is from a history of the company [2]:

Transformers in modern grids are active components expected to work at every point between full load and no load, at efficiency levels exceeding 99 %, for 30 or 40 years

"Despite big increases in the demand for electricity, the years also saw a fall in the number of staff. In 1958/59 the CEGB employed 53,128 staff to meet a peak demand of 20,889 megawatts. Thirty years on, demand had increased to 46,875 megawatts and staff numbers had dropped to 47,201. Over the same period manpower productivity, expressed in units of electricity sold per employee, had risen from 1.59 million to 5.14 million."

The point of quoting those figures is that within the nearly 50,000 staff, the CEGB possessed expertise in every single aspect of T&D systems and component design. Their skill base was equal to, if not in excess of the manufacturing companies; they knew what they needed and how to specify the products.

The ground rules now in the 21st century are obviously very different, but nevertheless, it does remain a problem to be overcome if in the future the customer does not know how to specify the equipment that is being ordered and the suppliers have to guess at the requirements. Does that mean that the customer base will pay for that expertise, probably only very reluctantly and it may take a disaster or two to focus minds on the problem.

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Author

Steve Aubertin is the Managing Director of Goulden Reports and following a first career in electrical engineering has spent the last 30 years researching and reporting on the global market for electrical products in both published and in the form of tailored research for specific clients.