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Part 3: Life management and extension

Power Transformer

ABSTRACT

This article closes the *Transformer Life* series by looking at various ways that a transformer owner can extend the life of their investment.

From the initial stages of specifying and purchasing a transformer to the management of the transformer throughout its useful life, we explore which options have the best cost to benefit ratio and why.

Keywords

power transformer, life, asset management, condition assessment, life extension, paper, insulation, cellulose

HOW LONG IS A TRANSFORMER SUPPOSED TO LAST?

In the first article in this series we defined what life means for a power transformer. In the second article we looked at the factors that most influence a power transformer's life.

In this, the third and last, article of this series we explore what options we have to manage and, as far as possible, extend the life of these important assets in your system.

Before we delve into what you can do to extend the life of a transformer, we need to agree on how long it is supposed to last.

As we have discussed, the life of a particular transformer depends on many factors, some of which are unpredictable in nature. In most circumstances there is not enough information to accurately predict the remaining life of a particular unit with any significant confidence. Current national and international standards and publications [1],[2],[3] and [4] favour the definition of life in "per unit" terms.

However, enough statistical data might be available in a particular system to be able to ascertain an estimated "average" life for a transformer in that system. In my own experience an average life of 35 to 40 years is a reasonable number to be expected for transformers manufactured before the 90s and working under nominal conditions with some transformers, in very isolated cases, reaching into the 70 to 100 years of age mark [5].

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So, if a transformer is to last 40 or more years of active service, what can you do to give it the best chances to do so?

Life

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THE LIFE CYCLE VIEW OF LIFE EXTENSION

We might be tempted to think of the term *life extension* as something that is executed towards the end of the life of the asset in an attempt to extend its life.

In my opinion this would be a very short-sighted view of the topic. In my view, life extension starts before the transformer is even manufactured. A holistic view of the complete life cycle of the unit will allow making the right decisions and putting the appropriate measures in place at every step of the way, from purchasing to disposal of the asset.

Just as with our own life and health, the most effective way of preventing a premature death is with prevention more than remediation. In the case of transformers this is not only logical, but considerably less costly.

On a dollar (or the applicable currency used in your country) per year of service of a particular asset, investing in prevention is almost always the wisest decision.

In the remaining sections of this article I will lay out what I think are the most important actions you can take to maximise the benefit that you get for your investment.

SPECIFYING AND PURCHASING

A good start in life leads to a good performing transformer during operation. By investing the time and resources in correctly specifying and sourcing the transformer most suitable for your application, you will save an incredible amount of money in the long run and a lot of headaches to your operations and maintenance team.

A properly documented specification that adequately reflects your needs is essential to ensure that you are getting the right asset for the intended function. In many instances I have seen asset owners and buyers contempt with buying transformers that merely stick to the existing standards. While standards should be the starting point of any specification, they are certainly not sufficient in most cases. In my opinion, standards are just the bare minimum that a transformer should comply with. By their very nature, standards cannot cater for the specific requirements that you might have in your specific operational context and circumstances.

Buying a transformer that simply meets the standards is like buying a car only specifying that you want it with an engine, a body and four wheels. Well, maybe I am exaggerating a little bit, but my point is that you are likely to require certain characteristics in your transformers that are not listed or spelled out in the standards and that you will need to be explicit about when requesting a new unit. Things like specific types of bushing terminals, connection boxes, control wiring and protective devices are but a few of the elements of your transformer design that you might want to stipulate to ensure compatibility with your environment.

A well crafted specification will also allow you to compare apples to apples when evaluating offers from various manufacturers. The best way to avoid unexpected outcomes is to be explicit about what you want.

MANUFACTURING

You have now ordered a new unit with a proper specification and from a manufacturer you feel comfortable with. Well, the next step is building the transformer.

Life extension starts before the transformer is even manufactured

A good manufacturer is made up of many small details that add up to a properly built and good quality finished transformer. From the quality of the raw materials, to the expertise and skill of the people manufacturing these machines, to the attention to detail on every step of the manufacturing process, it all counts.

The process of building a transformer is complex and hand-labour intensive where a lot of things can go wrong. In fact, almost always something will not go exactly as planned. In essence you will want to associate with a manufacturer that is not shy in acknowledging and correcting the issues that will inevitably arise during the manufacturing process. When I was working as a service engineer for a transformer factory, a client once told me that he measured the manufacturer's quality not only by the number of issues they had but also by how they responded to them.

In the realm of client to manufacturer relations each company will have its own preference in how these are handled and I do not intend to give you an opinion one way or the other. Some customers prefer a pre-approval process to select the manufacturer or manufacturers with whom they plan to establish a long term relationship. Others prefer to witness key milestones at the factory during the manufacturing process like tanking or final testing.

My point is simply that it is in your best interest to ensure that you have a mechanism to guarantee that the manufacturing quality of your transformer is adequate and the final product fulfils with your expectations.

INSTALLATION AND COMMISSIONING

Most power transformers of a certain size and above are like flat-packed furniture - some assembly is required.

The level of assembly required varies with the size and manufacturer of the transformer. In some cases it is only necessary to fit a few of the components like radiators and conservator tank and then "top up" the oil. In other cases a full assembly is required that finishes with the vacuum dry-out and hot oil-fill process.

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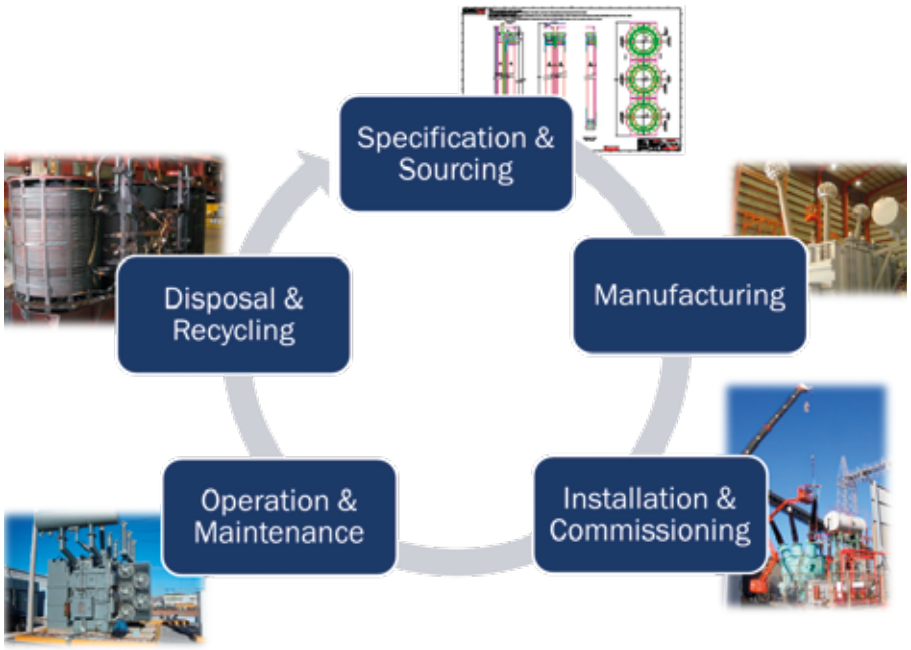

Figure 1: Typical transformer life cycle

In any case, executing the assembly procedure according to the manufacturer's recommendations will not only insure the unit is put together properly but also ensure your warranty is in full effect by the time the unit is placed in service. There are many factors that need to be taken care of during the final field assembly of the unit. You would want to ensure that a qualified team of techni-

Figure 3: Good quality coils are essential to ensure the longevity of your transformer



Figure 2: Different environments require different specifications

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cians perform this assembly. Investing in the right service provider at this stage will increase your chances to avoid issues like oil leaks or any other type of assembly related malfunctions after energising the transformer.

It is at this stage in the life of a transformer that the initial moisture level in the insulation system is established. It might be tempting to take shortcuts in this process. Sometimes the dry-out might take days to bring down the moisture to acceptable levels (typically 0.5% by dry weight). But if you remember from the second article in this series, water is one of the main catalysts that accelerate the ageing processes of the solid insulation of the transformer. Saving a few days or even a few hours of work at this stage has the potential to reduce the life by years in the long run. The economy is simply not there unless you want to operate your plant on a very short term basis.

OPERATION AND MAINTENANCE

Since this stage in the life of a transformer is the longest (or at least it is supposed to be) much of your attention and day-to-day efforts will be spent in maintaining the unit in an adequate condition.

If I attempted to summarise what I think you should focus your preventive maintenance efforts on during this period, I would point out the following:

- Keep the transformer dry. As we have mentioned a few times already, water is one of the main ageing accelerating factors. In order to keep the transformer dry, you would want to ensure that there are no oil leaks (if oil can come out, moisture can come in). You will want to make sure that whatever the oil preservation system is, it is operating as the design intended. If silica gels are used, they should be dry and with enough capacity to dry the air that the transformer breathes. If diaphragms are used to separate the oil in the conservator tank from the ambient air, you want to make sure they are in good condition and free of ruptures. If automatic nitrogen equipment is used, it should be kept in good working order, with sufficient nitrogen in the supply and with the regulating system always ensuring the adequate positive pressure in the nitrogen chamber. In summary, ensure that water does not find its way into the coils of the unit.

- Keep the oxygen to a minimum. Similar to the point above, you would want to minimise the exposure of the oil to oxygen which obviously accelerates the oxidation processes in the transformer. The same recommendations given above to keep the water out of the unit are applicable to keep the oxygen out, although in some cases, like a conservator tank without diaphragm, it is not always possible.

- Ensure nominal operating conditions. As we also talked about, temperature plays a major role in the ageing processes. The unit is designed to operate within a certain temperature range and the more you can do to keep it within that range, the better chances you are giving the unit for a long useful life. Situations like overloading are sometimes unavoidable and in these cases, there are clear guidelines available in the technical literature to allow you to estimate the impact of overloading in the life of a particular transformer. On maintenance basis, you can help by ensuring that the cooling system is operating adequately and that the top oil or

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winding hot spot temperature has not reached alarm levels. If you find that this has happened, you need to investigate the root cause so you can address it as soon as possible.

Now, what if you are not the person that has watched the transformer its entire life and you just got handed over a fleet of old transformers to maintain? (Hard to imagine right?). In this case you are in corrective maintenance territory and the best course of action, in my opinion, would be:

- Establish the condition of each unit in your fleet. You have many tools at your disposal for this purpose. Try to gather as much information as possible on each unit and establish an effective information storage and retrieval mechanism. Include oil analysis history and any other test and inspection performed on each transformer. This information will allow you to establish a preliminary condition ranking for each asset in the fleet.

- Once the above has been established, you will have a clearer idea of which units are priorities and which units can wait.

- Depending on the state of each unit, a number of actions can be taken in order to ameliorate the current condition or remove some of the agents that might be causing the accelerated ageing.

- The oil can be processed to remove water and acids, which contribute to the ageing processes.

- If any, more serious, failure modes are suspected, these need to be addressed on a case by case basis until you have satisfied the risk management policies of your company and you are aware of the situation of each unit.

Last but not least, an adequate condition monitoring programme is essential to give you as much reaction time as possible if a failure mode starts to affect any particular transformer.

The condition monitoring method most commonly used is oil sampling and analysis. The analysis of the oil is a well established technique that allows the early detection of incipient failures in the transformers.

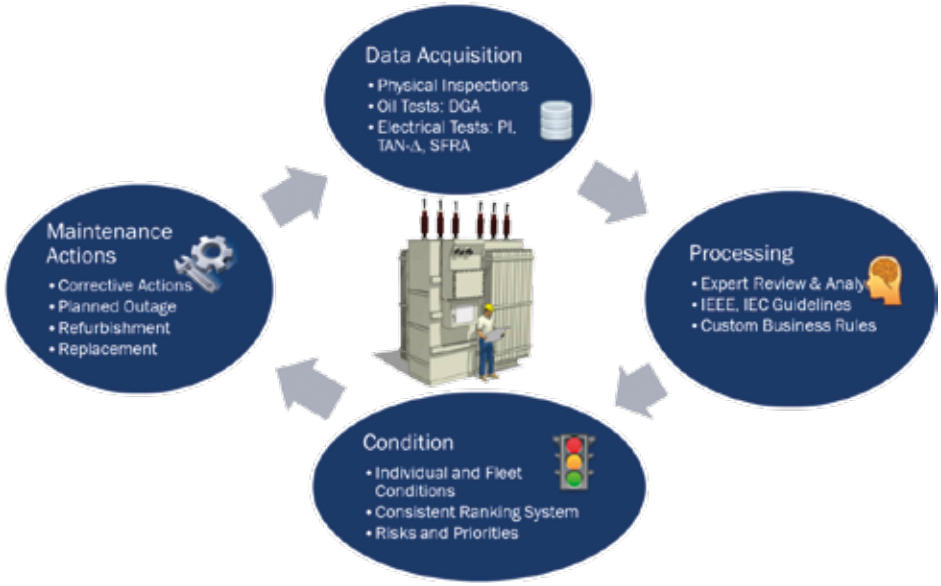

Figure 4: Example of a condition monitoring and maintenance programme

A suitable condition monitoring strategy will minimise the probability of unexpected failures occurring and therefore minimise the overall operational risk of your transformer fleet.

CONCLUSION

This brings this article series to a conclusion. Through the series we discussed some of the concepts that help to understand what transformer life is, what determines its duration and what actions you can take to extend it as much as possible. The topics covered in this series are vast and I have inevitably had to reduce them to their fundamental concepts. I hope that in doing so I have not made them unintelligible, boring or too simplistic.

For the readers who are interested, there is plenty of literature to consult to become acquainted in depth with each of the subjects covered here.

Our industry is a specialised one and it is a great privilege to have the opportunity to communicate some of my experiences and ideas to my colleagues and friends around the world.

I now will start thinking about an interesting topic for the next article. I hope that you have enjoyed reading this series as much as I have enjoyed writing it.

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> **Preventive maintenance efforts should be focused on keeping the transformer dry, keeping the oxygen to a minimum, and ensuring nominal operating conditions.**

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Author

After graduating in Electrical and Mechanical Engineering in 1996, Carlos started working as a Transformer Design Engineer at PROLEC-GE, the biggest transformer factory for General Electric on the American continent.
Over the course of the following years, he gained expertise working in various roles such as Product Development, Manufacturing Improvements, Technology and Software Development, Field Engineering and Customer Service.
In early 2007, Carlos was seconded by General Electric to move to Perth, WA to start up the Transformer Division to provide field and workshop maintenance and repair services to customers across Australia.
Having fulfilled this mission, in early 2011, Carlos accepted a Principal Consultant position with Assetivity, a consultancy firm leader in Asset Management.
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