Need for circular economy

Refurbishment of large power transformers

ABSTRACT

Why, what, which and when of power transformer maintenance

As transformer maintenance costs continuously increase, new approaches to optimize all life cycle decisions are becoming the focus of electrical utilities. Determining the optimal maintenance choice on the right unit at the right time is by itself a complex science. One approach to look at this problem is to optimize the total life cycle cost of a transformer. Mainly there are two main intervention actions in a life of a transformer: maintenance which can be regrouped under corrective and preventive maintenance, and replacement. Between the two, there are targeted actions on certain transformers, such as targeted maintenance or refurbishment.

KEYWORDS:

prioritization of maintenance, refurbishment, decarbonisation.

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Introduction

The active part of a transformer can be defined as the magnetic core, the windings, and the solid insulation in and around the windings, and it represents about 70 % of the total cost of the transformer. For utility substation applications, the life expectancy of an active part can vary between 70 to 80 years and maybe more. However, historically, the replacement of a power transformer is often performed way before the end of life of its active part due to severe degradation of its critical components, such as bushings and tap changers and its accessories, even if they represent only approximately 30 % of the total cost of a new transformer. And if the transformer is not replaced or refurbished when these critical components and accessories are getting to their end of life, the total lifetime maintenance cost and offline duration will increase significantly, and the transformer reliability will decrease substantially.

Many industrialised countries have built their main infrastructures from the mid-fifties to the mid-seventies. In the following 40 to 50 years, their utilities had an easy life to maintain the condition and reliability of their power transformers. But now, those days are over, and the maintenance of a good proportion of their transformer fleet is more and more difficult. Utilities that believe that the old transformers should simply be replaced by new ones are facing supply chain and investment budget limitation issues.

Concerns for the environment and climate change forced governments and utilities to take into consideration new strategies to reduce their carbon footprints. Knowing that more than 60 % of tons of CO_2e is generated during the transformers' manufacturing, refurbishment methodologies of power transformers could help utilities reduce their carbon emission.

Maintenance cost and refurbishment

The life extension of a power transformer after 40–50 years in service can be considered an asset investment if the active part is in fairly good shape and if the refurbishment is cost-effective. Strictly using the maintenance cost that includes the cost of material, labour, offline time and capitalization fees, it can be demonstrated that it can be cost-effective to refurbish a transformer, but if we add the other advantages such as the carbon footprint decrease, environmental impact reduction due to oil leeks reduction, reduction in preventive maintenance workforce required, downtime reduction and others, it then becomes evident that transformer refurbishment is unavoidable.

A power transformer refurbishment usually implies replacing: the bushings, all supervision accessories and their wiring, the connection cabinet, the cooling fans, and other similar accessories. It also implies replacing all the gasket material and valves and redoing all the pipe works. Tap changers and cooling radiators can be eighter replaced or refurbished. Tank and accessories paint can be optional depending on the original paint condition.

But implementing a transformer refurbishment program involves many challenges:

Candidate selection and prioritization

Aged power transformer fleets would have many candidates for life extension decisions. Candidate selection and prioritization can be performed using health indicators developed to choose the ones that represent the highest interest for the

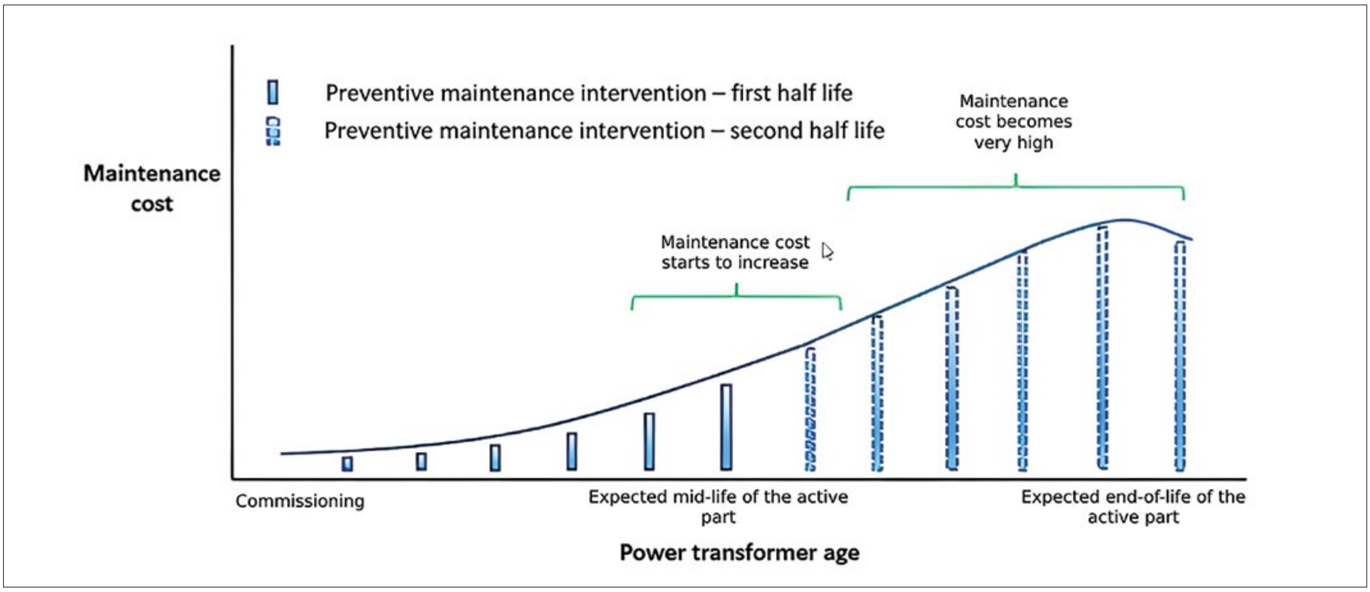

Figure 1. Maintenance cost without refurbishment

investment. The health indicators are using system data and information such as active part and accessories condition, age, grid impact and many others.

Candidate evaluation

When a short list of candidates has been established, a refurbishment qualification tree can be developed using specific criteria. This tree will, however, have to be used by a transformer specialist because of the complexity and the diversity of the information that needs to be processed. Anyway, the investment decision should not rely strictly on automated data processing because the data quality could easily lead to a false qualification. The critical point is to correctly evaluate the active part condition to invest in candidates that will have a good life expectancy after the refurbishment is performed. The main tool to make that evaluation is oil analysis (dissolved gas analysis (DGA) and chemical markers (furan and methanol)).

Intervention planning, engineering, and procurement

The success of a refurbishment project relies heavily on performing the work, detailed engineering and procurement ahead of time because many of these accessories have a very long delivery lead time. With the great diversity of the transformers present in these fleets, there is no one size fits all receipt. A lot of case-to-case solutions will have to be developed.

Refurbishment candidate selection and prioritization can be performed using health indicators developed to choose the ones that represent the highest interest for the investment

Intervention mode

The refurbishment work mode scenario will depend on many factors, such as the size and weight of the transformer, its location and the downtime allowed by the grid. For cases in which downtime needs to be reduced to the minimum, a rotation scenario should be evaluated. And generally, the bigger transformers located in remote areas are a good candidate to perform the refurbishment work on-site, while smaller units could well be refurbished more efficiently in a service shop.

Intervention efficiency

And the last challenge may well be dictated by the labour shortage that strikes many countries these days. To perform a transformer refurbishment project with the expected efficiency and quality, you absolutely need a highly specialised workforce at all levels, going from the engineer to the labourer that performs the work. Many utilities could have great difficulty choosing between using their workforce or a contractor. But one way or the other, a specialized workforce in that technical field might well be difficult to find in the next years.

Benefits of refurbishment

Circular economy

In order to determine whether a targeted intervention, such as the refurbishment of a large power transformer, is economically reasonable, a business case must be evaluated. Approximately the cost of all critical components and accessories represents 30 % of the total cost of a new transformer, excluding all the engineering and related project costs. In a case where the active part is in good condition, replacement of all accessories would result in a potential circular economy volume of more than 70 % of the value of a new transformer while reusing the raw materials such as copper and core steel that have seen their highest prices per unit of weight in 2022.

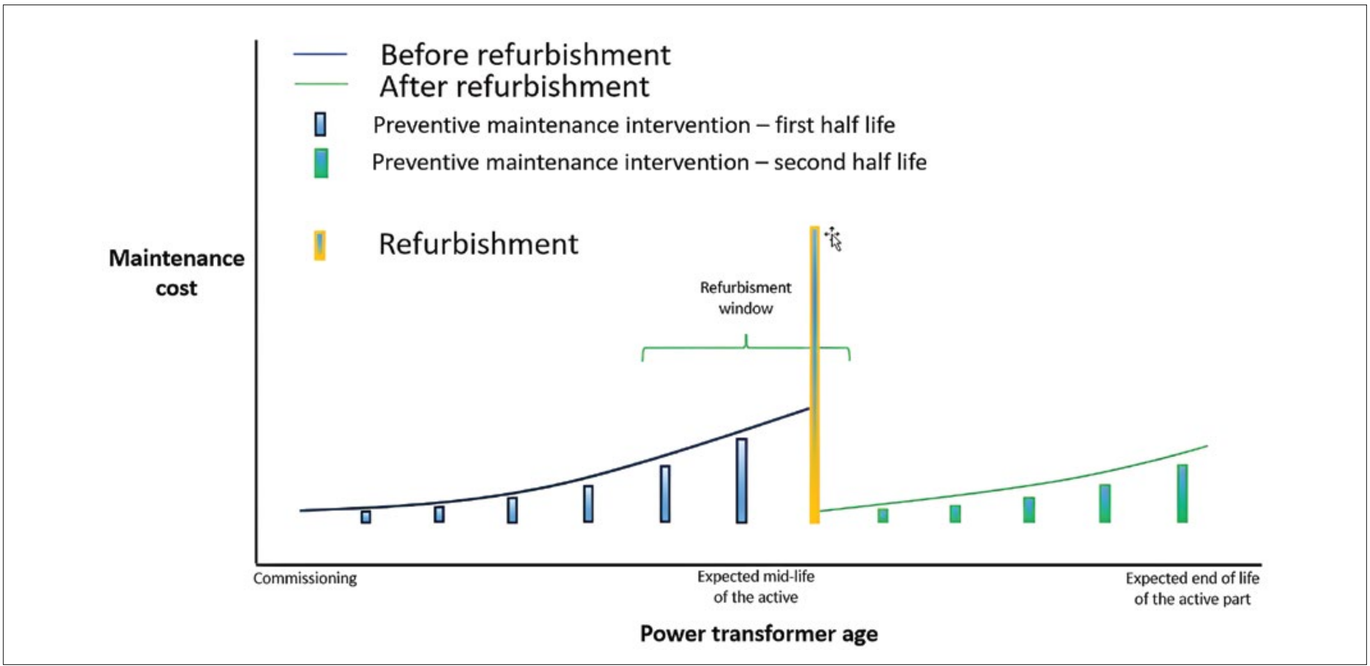

Figure 2. Maintenance cost with refurbishment

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Resilience of network

Ageing power transformer fleets represent a particularly significant issue for the ability to perform as required, without failure, for a given time interval, under given conditions. As the complexity and interdependencies in the electrical transmission industry increase, power networks may become more vulnerable, creating conditions for cascading, system-level failures. Therefore, resilience-based asset management approaches are gaining importance in the context of deep uncertainties and various possible future disruptive events. For a complex power network, having a robust redundancy plan is very crucial to reduce the recovery time. A refurbished reserve fleet would increase the ability to effectively manage operations after many failures after extreme events while reducing the cost of the redundancy bank investments.

Carbon footprint

Electrical networks play a crucial role in delivering the Net Zero targets and the transition to a more sustainable future. The challenges to achieving such environmental targets will have an impact on every industry, with electrical networks at the heart of the solution. More than 60 % of greenhouse gas emission in a whole life of a transformer is generated during the manufacturing of the active part, excluding the carbon footprint of copper cables and core steel manufacturing and transport. Implementing refurbishment strategies would have a significant impact on reducing the carbon footprint of a large transformer fleet as well as the number of oil leaks that are related to the natural ageing of the transformer structure.

Supply chain disruptions

Over the past two years, many supply chain disruptions have affected electrical utility operations across the planet. However, supply chain resilience has never been tested as it was in 2022. These disruptions, such as raw material and labour shortages, transport bottlenecks and low probability high-impact events, have resulted in rising costs and longer delivery timelines for major equipment. Power transformers have been affected the most due to the diversity of raw materials used in manufacturing.

The ability to manage disruption is an important resilience capacity of an electrical utility company. Most North American utilities are facing or will likely face a replacement wave due to their fleet profile. Utilities must develop more secure and sustainable supply chains while managing the risk of a high-impact event to ensure reliability. Refurbishment offers a buffer to utilities from such major supply chain disruptions.

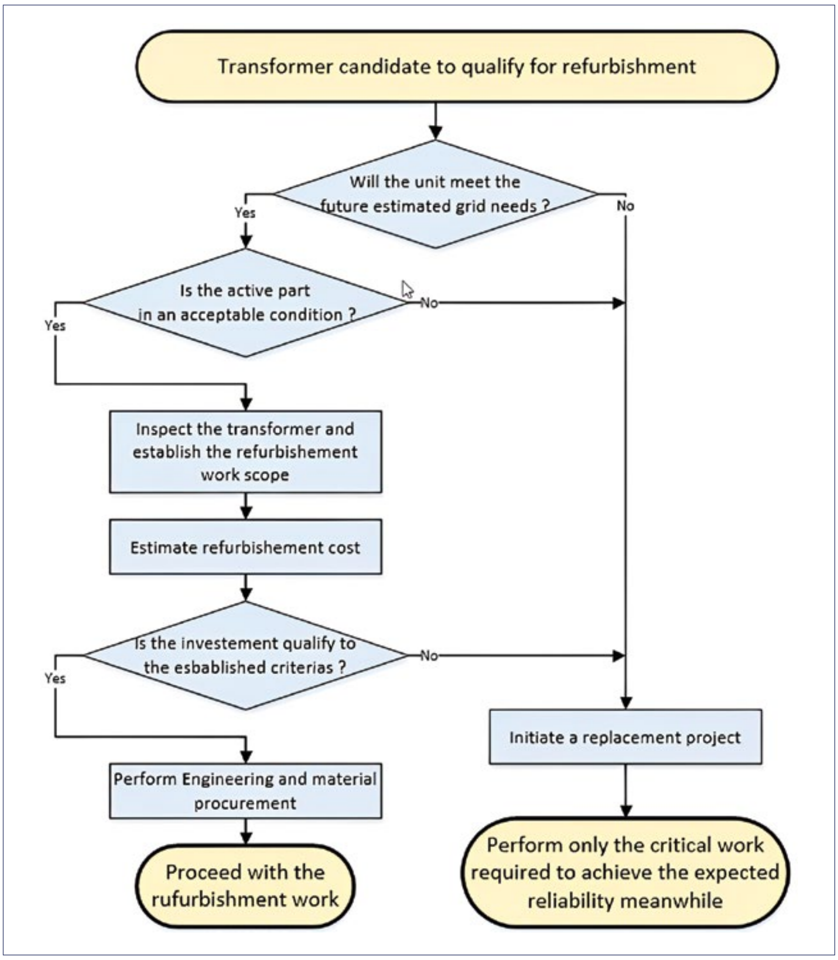

Figure 3. Example of a transformer refurbishment qualification tree

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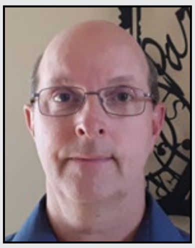

Denis Gosselin graduated from École de Technologie Supérieure (E.T.S.) in 1990 as an Electrical Engineer, and has been involved in repairing and remanufacturing different types of electrical apparatus for more than 25 years. He has been the Service department Engineer of the General Electric Montréal facility for 14 years and has been a transformer specialist for Hydro-Québec since 2010. He is currently involved with the Hydro-Québec repair facility in Trois-Rivières (CEE) and in many transformer repair and refurbishment projects.