# AGE PROFILE ANALYSIS FOR HV ASSETS

Jelica POLIMAC
Polimac Ltd – United Kingdom
jelica@polimac.net

## ABSTRACT

*Replacements of HV circuit breakers are analysed for different methods, as Age Replacement, Average Age Replacement and Extended Life Replacement. Those three methods are described, analysed, and assessed.*

## 1. INTRODUCTION

Major developments in Europe in electrical transmission and distribution networks happened in 60s and 70s of the twentieth century when many assets were installed. Some of those assets are now at the end of their service life, ready for replacement.

Historically, the old assets were replaced at the end of their service life. Following that utilities are facing replacement of a large quantity of aged assets which require unfeasible outage programs, a considerable number of resources and large investments for replacements are required.

## 2. ASSET LIFE

### 2.1 Asset Life

Transmission and distribution companies define asset service life in technical specifications as a fixed number of years, presenting a pre-defined commercial life. It is considered that after the service life, the capitalized cost of equipment continuing to be in service would exceed the cost of a new asset.

In reality assets can perform satisfactorily until they reach the end of their technical life. The asset's technical life is the asset age when it cannot perform according to its technical characteristics or operational and maintenance costs exceed the capitalized cost of a new asset. Asset technical life is dependent on the asset itself, on the asset's position in the network, operational conditions, maintenance, environmental & safety aspects, etc.

The asset's technical life may not be equal to the commercial service life. Assets may last longer after their theoretical service life expired, performing well. However, some assets may require earlier replacement, before the end of their service life, due to their poor condition.

### 2.2 Asset Extended Life

Asset life may be extended if the asset's performance and condition are satisfactory, and if operational and maintenance costs are below the defined limits. When extending asset life the following points are to be considered:

- Asset condition
- Performance records
- Failure rates
- Maintenance records
- Availability of spare parts
- Safety and environmental aspects.

The asset's condition has an impact on asset performance and asset failure rate. Regular maintenance checks support good asset condition. Availability of spare parts has a direct impact on repair time and reliability. Records show that a certain number of failures are related to asset age, and that older age may cause poor condition and performance. However, other factors contribute to the condition as well, such as the asset's location in the network, exposure to abnormal conditions, etc. Assets with very low failure rates, good performance, in good condition, with good maintenance records and available spare parts can be considered for extension of their service life.

When an asset in service may cause safety incidents leading to asset(s) damage, injury and/or death of person(s), the asset is not recommended for extended life. Also, if continuous service of a considered asset may cause impact on the environment, the impact may lead to environmental damage and extremely high costs for countering the damage.

How much to extend the service life for?

Each network owner has to consider, analyse and decide what the optimum extended life for the assets is [1], considering factors relevant for the assets.

### 2.3 Asset Groups

Assets are in general classified in several groups; transformers, High Voltage (HV) switchgear & circuit breakers, HV cables, Low Voltage (LV) switchgear, LV power cables, protection systems, control systems, etc.

From a replacement aspect, each of these groups has to be considered separately because of its specific performance requirements, commercial life, reliability, safety and environmental issues.

This paper will analyse 1880 HV circuit breakers, installed in a medium voltage network. Replacement will be considered within a period of 40 years starting from 2007.

## 3. ASSET REPLACEMENT ANALYSIS

### 3.1 General

In general terms the following different methods can be used for asset replacement:

- Age Replacement
- Average Age Replacement
- Extended Life Replacement
- Condition Based Replacement
- Replacement on failure

Age Replacement has been used in the past for replacement at the end of service life.

Average Age Replacement requires replacement of assets before the asset average age reaches the agreed limit. In this way, an asset's age across the network is managed, allowing more freedom for deciding on assets requiring replacement and a replacement program.

Extended Life Replacement proposes asset replacement after reaching the extended life.

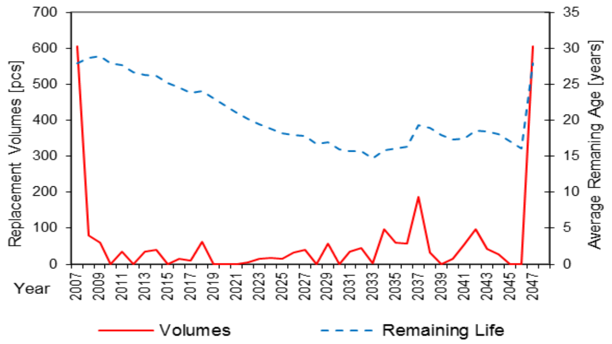
Condition Based Replacement considers analysis of asset condition to advocate replacement of assets. This method of replacement will not be considered further in this paper.

Replacement on failure is carried out after a failure when no repair is possible or economically acceptable. This method, sometimes used for low reliability equipment available for purchase from shelf, will not be considered further.

## 3.2 Age Replacement

Age Replacement for a group of 1880 HV circuit breakers is shown in Figure 3.2. Replacement volume over a period of 40 years is 2485 circuit breakers, while annual volumes vary with big initial spike, a small spike in 2037 year, and another big spike at the end of this period.

Figure 3.2: Age Replacement




Average remaining age for the whole period is 20.8 years. However, annual average age varies. The minimum is 14 years (in 2033), while the maximum is 29 years (in 2009), caused by a large initial replacement of 605 breakers.

With this replacement method utilities will face a similar replacement problem again after 40 years.

## 3.3 Average Age Replacement

Another way of replacing assets would be to maintain the average asset age within the asset group above the agreed limit for the average asset age. Although the oldest assets require replacement first, this method enables replacement of the most critical assets (which are not at the end of their service life) in the network, while managing good asset health conditions within the group. The assets with most problems may be those with a high failure rate or without available spare parts, causing high maintenance and long repair time. It may also be assets with a potential to negatively affect safety or the environment.

In order to determine the most appropriate average asset age limit an analysis has been carried out and the results are presented in Table 3.3a, Figure 3.3b and Figure 3.3c.

Table 3.3a: Average age replacement

| Average age limit | Average remain age | | | | Max asset age |
|---|---|---|---|---|---|
| | | Total | Annual | Initial | |
| 20% | 8 years | 1039 | 25.3 | 0 | 66 years |
| 25% | 10 years | 1155 | 28.2 | 0 | 63 years |
| 30% | 12 years | 1287 | 31.4 | 0 | 60 years |
| 35% | 14 years | 1436 | 35.0 | 2 | 57 years |
| 40% | 16 years | 1601 | 39.0 | 79 | 54 years |
| 45% | 18 years | 1788 | 43.6 | 161 | 51 years |
| 50% | 20 years | 2010 | 49.0 | 247 | 48 years |
| 55% | 22 years | 2262 | 55.2 | 335 | 45 years |
| 60% | 24 years | 2558 | 62.4 | 424 | 43 years |

Replacement volume and average remaining life for different average age limits, listed in Table 3.3a, show that the higher the limit, larger the replacement volume is and higher the average remaining age. On the other hand, higher average life limit will provide smaller maximum asset age. The limit of 60% requires more replacements than Age Replacement, and because of that it is not recommended for further consideration.

Figure 3.3b: Average Age Replacement – Volumes

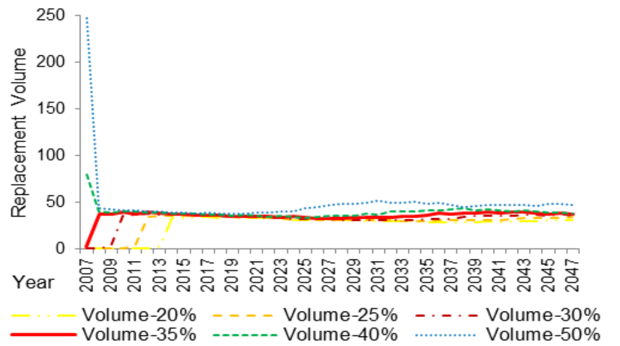
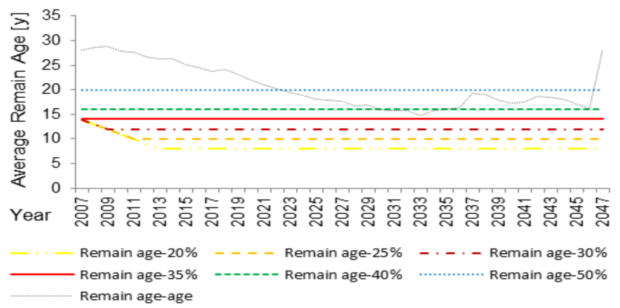



Figure 3.3b shows that replacement will be staggered for different limits. Replacement for an average age limit of 35-60% had begun in 2007, and for limits below 35%, replacement is staggered (for 20% in 2013, for 25% in 2011, and for 30% in 2009). From this aspect the limits of 35% and 40% are the most suitable methods offering continuous replacement throughout the considered period without initial high volume.

Figure 3.3c: Average Age Replacement – Remaining Age



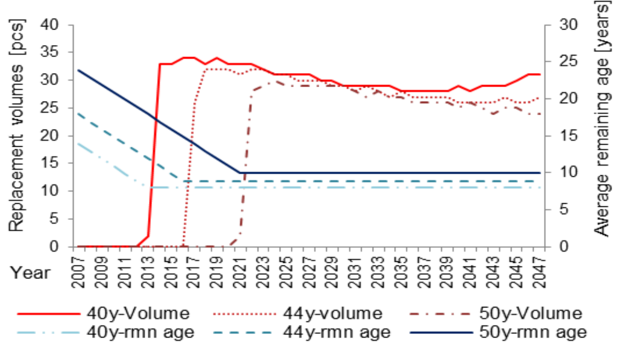
Annual replacement volume will be up to 35 breakers for average age limit up to 35%. Initial annual replacement is 2 breakers for 35% limit, 79 breakers for 40% limit, 247 breakers for 50% limit, and 424 breakers for 60% limit. Figure 3.3c illustrates that for limits up to and including 35% the average remaining asset age is below the minimum average age of the Age Replacement. The remaining asset age for 50% limit is well above that minimum age, and for period 2022-2046 provides even higher average age than the average age of the Age Replacement. The average remaining age is the smallest for the age limit of 20% (8 years), while it is biggest for limit of 60% (24 years). From the average asset age aspect, the limit of 40% is the best method within the Average Age Replacement.

There is a question what would happen if average age is applied to assets with extended service life. For that purpose analysis has been carried out for the Average Age Replacement with limit of 20% and service lives of 40, 44 and 50 years. The results are shown in Table 3.3d and Figure 3.3e.

Table 3.3d: Average Age with Extended Life Replacement

| Life | Average age limit | Average remain age | Replace Volume | Max asset age |
|---|---|---|---|---|
| 40 | 20% | 8 | 1039 | 66 y |
| 44 | 20% | 8.8 | 885 | 71 y |
| 50 | 20% | 10 | 702 | 78 y |

Figure 3.3e: Average Age with Extended Life Replacement




The Figure shows that for longer extended service life (50) replacement will start later (2021) resulting in smaller replacement volume (702). However, Table 3.3d shows that some assets become very old (78 years) when the service life is extended (50 years), although the average age will be kept above 20%.
It can be concluded that it is better to apply either the average age replacement or extended life replacement, and not combine those two methods together.

Another issue is replacing newer assets within a group due to their bad performance or some serious asset issues. To define what would be the impact of earlier replacement analysis of earlier replacement of ten circuit breakers within the considered group of 1880 breakers has been carried out. The breakers installation dates are listed in Table 3.3f.
The results show that earlier replacement of ten breakers installed in 2004 would slightly increase the replacement volume from 1436 to 1445, while the average remaining age of the group is changed from 14.02 to 14.01 years, while the maximum asset age within group remains at 57.

Table 3.3f: Average Age Replacement–Earlier Replacement

| Install year | Replacement Volume | Annual volume | Average remain age | Maximum asset age |
|---|---|---|---|---|
| 1967 | 1436 | 35.05 | 14.02 | 57 |
| 1977 | 1438 | 35.07 | 14.02 | 57 |
| 1997 | 1442 | 35.17 | 14.02 | 57 |
| 2002 | 1444 | 35.22 | 14.01 | 57 |
| 2004 | 1445 | 35.24 | 14.01 | 57 |

This indicates a small impact of earlier replacement of 10 out of 1880 assets in the Average Age Replacement method. However, it has to be highlighted that 10 assets presents 0.53% of 1880. If a larger quantity is for earlier replacement, the impact will be bigger.

## 3.4 Extended Life Replacement

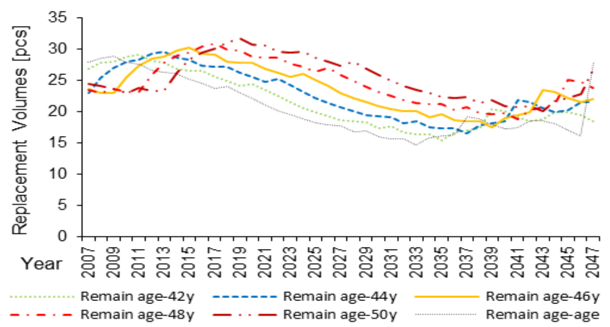
When the asset service life can be extended after careful consideration of certain factors discussed in Section 2.2, Extended Life Replacement may be applied as a method for asset replacement.
Analysis has been performed for the circuit breakers when their service life is extended to 42, 44, 46, 48 or 50 years. Assets are replaced after reaching the extended service life. Results are presented in Table 3.4a and Figure 3.4b.

Table 3.4a: Extended Life Replacement - Volume

| Extended life | Average remain age | Replacement volume | Initial volume |
|---|---|---|---|
| 42 | 21.6 | 1880 | 463 |
| 44 | 22.7 | 1853 | 203 |
| 46 | 23.6 | 1712 | 146 |
| 48 | 24.6 | 1640 | 61 |
| 50 | 25.4 | 1608 | 19 |

Extending the service life causes reduction of the replaced volume; the longer the service life the fewer assets will be replaced. For the extended life to 42 years initial replacement in volume is very high (463 assets), which indicate that that extended life is not recommended.

Figure 3.4b: Extended Life Replacement-Remaining age




After initial period the average remaining asset age is almost always above the average remaining age of the Age Replacement.

The optimum extended service life, dependent on various factors as per Section 2.2, is to be defined for a particular assets group. Extended Life Replacement will be based on the optimum extended service life.

## 4 REPLACEMENT ASSESSMENT

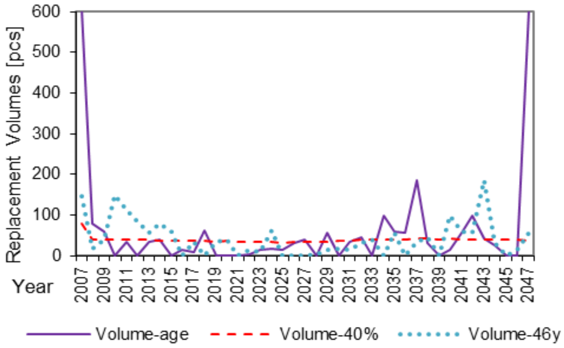
For comparison purposes results for replacement volumes for the Age Replacement, Average Age Replacement with 40% average age limit, and Extended Life Replacement (46years) are listed in Table 4a and Figure 4b.

Table 4a: Replacement Assessment - Volume

| Replacement Method | Volume | Initial volume | Annual volume |
|---|---|---|---|
| Age (40y) | 2485 | 605 | 60 |
| Average Age (40%) | 1601 | 79 | 39 |
| Extended Life (46y) | 1712 | 146 | 42 |

From Table 4a it is obvious that the largest number of asset replacements is required for the Age Replacement, while the smallest number of replacements is for the Average Age Replacement. The biggest initial replacement volume is for the Age Replacement, while the smallest initial volume is for the Average Age Replacement. The biggest average annual replacement of 60 breakers is for the Age Replacement, while the Average Age and the Extended Life Replacements have similar annual volume of 39 and 42 breakers respectively.

Figure 4b: Replacement Assessment – Volumes




Average remaining age for those three replacement methods is shown in Table 4c and on Figure 4b.

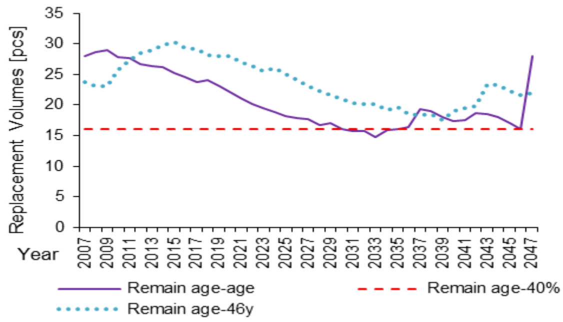
Table 4c: Replacement Assessment – Age

| Replacement method | Initial average age | Remain average age | Max asset age |
|---|---|---|---|
| Age (40y) | 28 years | 20.8 years | 40 years |
| Average Age (40%) | 16 years | 16 years | 54 years |
| Extended Life (46y) | 24 years | 24 years | 46 years |

The Extended Life Replacement provides the biggest average remaining age of 24 years, followed by the Age Replacement (20.8 years), while the smallest remaining age of 16 years is related to the Average Age method.

The Age Replacement and the Extended Life Replacement offer maximum asset age of 40 and 46 years, while Average Age Replacement would allow some assets to age to 54 years before being replaced.

Figure 4d: Replacement Assessment – Age




From the replacement volume the Average Age Replacement is the best replacement method, followed by the Extended Life Replacement.

From the remaining asset age the Extended Life Replacement is the best replacement method.

From the asset maximum life the Age Replacement is the best method, followed by the Extended Life Replacement, while the Average Age Replacement is the worst method.

## 5 CONCLUSION

HV circuit breakers can be replaced using different methods, such as Age Replacement at the end of their service life, Average Age Replacement replacing breakers and managing the average age of all breakers to be above the agreed limit, or Extended Life Replacement replacing breakers at the end of their extended service life.

The largest replacement volume and annual replacement volume is required by the Age Replacement, while Average Age Replacement provides the smallest volume.

Considering the asset remaining age the Average Age Replacement offers the smallest asset remaining age, allowing age of certain assets across the network to reach the value well above the service life. The Extended Life Replacement provides the best asset remaining age.

Choosing asset replacement method for a power network has to be considered from the assets point of view, their condition, performance, failure rate, maintenance records, safety and environmental aspects. These factors will indicate that it is appropriate to apply extended service life, or which limit for average age to be used when considering method replacement different from the Age Replacement, usually applied in the past.

## REFERENCES

[1] J Reid, U Bryan: ‘Measurement of Life and Life Extension: A Utility View by National Grid UK’, CIGRE, Group 13, 2002