Decision model for End of Life management of switchgears

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Abstract - Due to a wave of investment in the 1960's-70's, a large amount of switchgear in W-Europe is now 30-45 years old. The number of ageing phenomena is increasing, and indicates that for certain types the end of service-life is showing up. Theoretically then, the switchgear should be replaced. In practice, however, service-life extension can be an option to reduce the required investment cost. Minimum Long Term Cost of Ownership should be the drive for the final decision. Based on case studies, a financial model has been developed that compares future costs for use-up, retrofit, re-conditioning, and full replacement. The model performs a financial analysis of the different scenarios, and provides the Net Present Value of Additional Investments versus the Minimum Investment. A variety of factors representing financial value, are observed, such as power availability, safety, knowledge-management, resource allocation and risk on economical catastrophes. The data is derived from Asset Management strategies, Field experiences, Literature, Historical manufacturer data, Workshop experiences and Case Studies. The financial indicators of this method can validate the technical recommendations, and provide the required input to make a rational replacement decision for circuit breakers and switchgear.

Index Terms — Switchgear, Life, Extension, Asset Management

I. INTRODUCTION

Switchgear represents a significant capital investment in the grid. A major part of the current electrical infra structure in W-Europe is from the 1960's-1970's and will have exceeded projected service-life within the near future. The reliable performance of low & medium voltage distribution switchgear within industries is a basic requirement for overall reliability of the plant. The lifecycle of the process plant equipment will often be in a different phase than the power systems lifecycle. A traditional equipment management strategy, which is often followed by plant management, is to replace switchgear when it has reached the end of its economic life. This choice provides maximum equipment lifespan whilst incorporating the latest technology and safety features upon replacement; however, it usually requires high economic investment. Conscious end of life decisions often mean a struggle to balance both a minimum investment and economic life cycle costs. The traditional replacement strategy does not necessarily fit with the overall needs of a particular plant. For example, the life expectancy of the plant as a whole may not match that of the new switchgear. The downtime of the plant to enable replacement of the switchgear may not fit with operational and production commitments. The timing of the switchgear replacement may not match the capital expenditure plans of the business. The replacement strategy may not necessarily represent the optimal lifetime costs. In this paper several possible solutions for switchgear systems are compared in order to gain the required safety & reliability at minimum long-term cost of ownership (MLTCO) for the remaining life of the plant.

II. DRIVERS

Switchgear in industrial plants must safely and reliably fulfill their basic functionalities of closing and opening electrical circuits and carrying a certain load, at MLTCO. In remaining-life assessments for plants, two main drivers are defined that can lead to replacement planning of switchgear.

A. Technical

When there are signs that the reliability & safety of equipment will run out of control within a relatively short time, a remaining-life assessment may be done, in order to prevent forced outages or failures. End of service-life usually means that there is risk of failure, where the switchgear does not open or close on command, does not break the current or there are insulation failures etc. Often there is a sense of urgency to reduce the risk of accidents or unplanned outages. End of life usually is introduced by:

a) Physical ageing effects such as oil leakage, wear of mechanical parts, cracks or moisture in insulation materials, dangerous or unreliable situations to be found during Inspections, or mechanical failures.

b) Necessary spare parts or critical maintenance support are not available any more.

c) Increased requirements due to new safety aspects.

B. Economical

Besides managing the safety and reliability of the main functions of switchgear, there can be an opportunity to improve the MLTCO, with an investment. It is important to validate any projected solution.

a) Old breakers are more complicated than newer designs. Old breakers have no low-maintenance design, but have, for example, a lot of mechanical parts that have to be serviced. Life extension scenarios can reduce maintenance labour cost and negate the high prices and long lead times of old or obsolete spare parts, even if the breakers are in an acceptable condition. For small populations of differing types of switchgear especially, there can be relatively high costs for maintaining knowledge and spare parts, which will contribute to high maintenance costs.

b) Increased availability requirements due to technical improvements in new process equipment may reduce the economical life of the existing infra equipment. Maintenance of electrical infra might cause production losses if the overall process plant outage time is reduced or inspection intervals are less frequent and production losses decreased. Many plant infra designs contain enough redundancy to subordinate the maintenance of electrical infra to other maintenance activities. Increasing the electrical power availability is therefore not a frequently identified value driver.

c) Increased load ability requirements due to the de-bottlenecking of the production process.

III. LIFE ASSESSMENT

Before evaluating replacement or any other end of service-life scenario, a life assessment should be executed. Such assessment contains the following steps:

a) Required Remaining Lifetime

Based on the forecasted plant life and the forecasted grid development, the required future reliability should be determined, depending on how critical the switchgear is within the grid and including prospected future load and maximum safety level. The condition requirements are determined from there.

b) Estimated Remaining Lifetime of the switchgear

The first step to determine the remaining life of the switchgear is to review if the design is still acceptable according current practices. With regard to safety requirements and prospected reliability, general design properties such as fixed or withdrawable, oil, gas or air insulated, accessibility, operator knowledge, maintenance practises, average repair time must be evaluated. For example the majority of installed MV switchgear in European industries have panel designs that are not arc flash resistant. This is acceptable under certain operating conditions and with additional safety precautions.

The second step is the investigation of the prospected spare part availability for the remaining life.

Thirdly, the physical health of the switchgear has to be determined by proven methods such as visual inspection, tangens delta measurement, discharge measurement, and speed measurement of breakers. Finally ageing trends can be determined from maintenance history and past loading.

c) GAP analysis

The GAP analysis (i.e. the gap between required and estimated remaining life) dictates the minimum required investment to reach the required safe and reliable life with the MLTCO.

IV. SCENARIOS

A few manufacturers are tending to develop alternative solutions that provide the safest and most cost effective extended life for installed equipment. Looking at more choices, each with different advantages and costs, it becomes possible and normally more profitable to select the specific solution that best fits the overall business strategy of the plant. Alternative choices are:

- Use-up
- Retrofit
- Re-conditioning
- Replacement.

a) Use-up

Use-up means using the equipment until the End of Economical Life; the time from installation to a situation where annual maintenance and equipment caused outage costs exceed the discounted annual cost for new equipment. Especially for economically driven investigations, use-up is an alternative that cannot be ignored. Beside maintenance though, reliability and safety have to be investigated carefully due to old designs, ageing effects and the increasing risk of maintenance induced failures.

At the same time, experiences with use-up scenarios can be used as basis/reference to review the financial value that can be generated by investment in other life extension scenarios.

b) Retrofit

In general, Retrofit means that one or more of the main components of the switchgear are replaced with modern equivalents. Components with the highest maintenance cost and failure risks can be targeted specifically. Retrofit of the switchgear can take many forms: Retrofit of switching devices, where the existing device is replaced by a more modern equivalent. Retrofit of the switchgear panel, where panel components are replaced to enhance the safety of the panel. Retrofit of protection and control, where protection and control devices are replaced - providing increased functionality, reliability, data communication, and safety.

The identified drivers as described in chapter II, lead to a focus mainly on Form / Fit / Function replacement of breakers. Retrofit of a circuit breaker involves complete replacement of the original circuit breaker with a modern vacuum circuit breaker on existing truck, or with a complete new roll in replacement. Form / Fit / Function means that the retrofit includes all interlocking facilities supplied with the original panel design, as well as racking mechanisms for the breakers. The interface for secondary control is also maintained to enable simple swapping of the old breaker with the new retrofit. This retrofit option provides a fast life extension of the switchgear. The down time is minimised as the only on-site activities are racking out the old breakers and inserting the new retrofits along with minor modifications. This can be performed during a normal shutdown of the switchgear.

c) Re-conditioning

Re-conditioning of switchgear provides a life extension for equipment at a low investment cost. The existing switchgear is fully overhauled and restored to an “as new” condition, but with old technology. This option is especially attractive if there is no need for modernization; however, acceptable performance of the switchgear needs to be maintained over the short to medium term.

Re-conditioning is possible as long as spare parts, support, services and knowledge of the switchgear are available. Re-conditioning of switchgear can take place in a number of ways, from Re-conditioning of the switching devices to Re-conditioning of the complete panel. Switching devices such as circuit breakers, contactors and switches are typically candidates for re-conditioning. The devices are removed from the switchgear, sometimes on a rotational basis in order to maintain continuity of supply, and returned to a re-conditioning centre. Manufacturer specifications are preferred to bring the breaker up to the original quality standards. When such a refurbished breaker leaves the reconditioning centre, eventually with a full new warranty, a new life with a new reliability factor starts.

Complete panel refurbishment, which is not applicable in our case studies, provides the possibility to re-use panels of disused systems.

d) Replacement

Replacement can include the entire switchgear or even the entire substation. Additional work is engineering, spec. writing, evaluation of several suppliers, cable modifications, welds and connections, civil modification, secondary installation and commissioning. Replacement usually has a long execution time, especially if there is a lot of extra cable work, or if space is limited, the existing switchgear has to be removed first before installation of the new one. If no field preparation can be done, Replacement is an extensive and expensive solution.

V. RATIONALIZATION

Technical knowledge and experience are a prerequisite for safe and reliable operation, but careful economical validation of technical recommendations provides MLTCO. The investment costs of replacement scenarios are often compared to each other without accounting for any significant additional costs, or without weighing up the different lifetimes from each scenario. The total investment cost must include all necessary expenditures such as installing, cabling, commissioning, civil modifications and conversion costs, before a scenario can be feasibly chosen.

Reference to financial literature reveals that value is defined as: the sum of all future cash flows, calculated to today. A cash flow is the difference between income and expenditure. This is not the same as the difference between revenues and costs, as revenues and costs can be greatly influenced by accounting practices. The value of a cash flow is related to time. The definition of value can be represented by the following formula:

$$PV = \Sigma \{C_t /(1+r)^t\}$$

Where: PV = value (present value)

C_t = cash flow in year t (cash flow)

r = discount rate

The decision model for end of life management of switchgear validates the five main value drivers for lifetime extension of switchgear, in order to review investments. The influence of every value driver differs for every case and as such should be given a weighting for each new review situation. Case studies show much variety there is in the value potential of the five value drivers depending on individual situations.

a) Value of Depreciation

Different scenarios can have different lifetimes, and for that reason can have different periods for depreciation. Interest to pay over the book value should also be included. The 'rest value' is a typical factor that is different for every scenario. For example 15 years after replacement, the switchgear can have a rest value of 25% but cabling and civil costs, which are often a major part of the investment, have no rest value. Refurbishment has no rest value, whereas for a retrofit the rest value of almost the complete investment can be 25% as long as it is suitable for use in another substation.

b) Value of Maintenance Cost

Maintenance cost is dependent on application and choice of maintenance strategies such as traditional reliability centred maintenance, risk based maintenance or reactive maintenance. In all case the cost of maintenance and repair will not be similar for all scenarios. For example modern replacement and retrofit designs require a lower maintenance effort than existing 30 years old designs and for every scenario one should question if the required knowledge for operation and maintenance is still available within the company, or with a contractor. According to the predicted inspection and maintenance intervals, the spreadsheet transfers the maintenance cost to the correct moments in time.

Fig.1 Maintenance of 30 years old minimum-oil breaker.

c) Value of Availability

In a market where demand exceeds supply, planned and unplanned outages have huge cost implications. Greater process availability results in more products, more income and thus higher value. The consequence of a failure can result in damage to the substation, and the ensuing downtime of one or more switchgear. In plants running continuous processes, unplanned downtime and the subsequent loss of production can be of significant cost. All available information about the risk of failure is exceptionally situation specific, and also generally conflicting. Even in the unique situation that there should be reliable historic failure rates for a certain replacement scenario, these rates will be valid for the past, but not for the future.

The practical approach that is used here, is a simple question; Is it most likely that alternative a, b or c will cause failures leading to more production losses and possible damage to the infra than a replacement would in the foreseen extend lifetime? If the answer is yes, what would be the expected production losses? Unless there is a realistically larger risk of failure or specific data is available, a very small variety of failure rates from the IEC Gold book will be used.

d) Value of Allocations

Inventory management of spare parts can increase value for a company. So does standardization, and proper knowledge management. The annual inventory allocation cost in most companies will be between 12% and 25% of the inventory value. For spare parts the total inventory value for a certain old type of switchgear shall be divided by the number of this type of switchgear that are still in service. Especially for small populations reduction of spare parts and knowledge management can be a value driver.

e) Value of Safety Health & Environment (SHE)

Accidents tend to necessitate substantial expenditure, with resulting negative cash flows. Due to the growing body of laws and regulations covering safety health & environment, skilled technicians, OEM (original equipment manufacturer) spare parts, and applicable operating standards have to be used.

Similar to unplanned availability, a lack of very clear and specific information about failure chances and consequences makes it impossible to weigh up the total economical consequences in every unique end of service life decision. Instead, the practical approach that is used, is again a simple question: Is it most likely that alternative a, b or c will cause failures leading to accident/injury/fatally more often than a replacement would in the foreseen extend lifetime? Owing to insurance conditions several companies have standard economical values for these accidents. Unless there is a realistically larger risk on failure or specific data is available, a very small variety of failure rates from the IEC Gold book will be used.

VI. PRACTICES

A software tool provides a quick review of the applicable scenarios. Though there is a lot of data and research available, getting the right input is the hardest part of the investigation. For that reason the spreadsheet contains explanations and default data from recognized [2,3,6] sources.

It is important to be aware of both investment costs and long term costs of ownership, however the weight of each may be influenced by the companies policy with respect to how out-of-pocket costs (components, parts, external labour cost) are weighted against internal costs (internal labour cost, internal overhead cost). Limitations of the investment budget can also influence the decision. For electrical infrastructure equipment, the Net Present Value (NPV) is rarely positive, for that reason the minimum necessary investment is proposed to use as a reference value, from which to calculate the NPV of additional investment costs from which to evaluate the most valuable solution. High NPV scores are normally found where there is more than one value driver.

Modernization can protect an investment by extending the equipment life while raising safety, reliability and performance standards. The integration of advanced sensors, protection and controls improve reliability and safety. The shorter downtime required compared to total replacement ensures greater productivity. However although the need for additional functionalities could also be viewed as contributing causes for replacement, they are seldom a driver. Sole replacement of Control and Protection devices/equipment does not, in most cases, heavily interrupt the uptime. Many modernization options can be executed at any given moment during the life cycle of switchgear. For that reason, whilst minor upgrades can be included in a use-up, retrofit or re-conditioning scenario, they are not a driver.

Within different replacement scenarios, opportunities can be found to optimize present value. For example if the incomers and couplers of a switchgear run out of technical life, but the feeders will last for at least another 5 years, both the refurbishment and retrofit scenarios would allow for a delay of a significant part of the investment over 5 years.

However, although some of the extended life scenarios will have non-identical depreciation periods and different technical lifetimes, it is possible to review NPV, initial investment and annual cost, in the same timeframe, and choose the most valuable scenario.

In general the backbone of the existing switchgear usually will not bottleneck the extended life, as bus-bar and steel construction are static components. For certain kinds of bus-bar insulation, the use of materials like plastics, paper or bulk oil, may raise legitimate concerns, as it is known that the applied materials are sensitive to physical ageing. Unfortunately, there is Insufficient research data about ageing available to correctly quantify this currently.

In general the reliability of retrofits and replacements have a shorter lifetime compared to the old equipment because modern design is less oversized mechanically and electrically.

A practical approach for reviewing the prospected reliability for the extended service-life is to gather data from typical problems found among older populations using the same technology. The exchange of failure data between users and manufacturers supports a reliable condition assessment.

VII. USER BENEFITS

Retrofit or Re-conditioning over Replacement is especially valuable when:

- Special shut down of the plant to replace switchgear cannot take place due to operational commitments.
- Physical constraints of the existing space limits replacement.
- To disturb and re-terminate old existing cable systems to new switchgears is not preferred
- Where a type tested retrofit design, developed by the manufacturer, is available

VIII. CONCLUSION

The investment costs for replacements are substantial, especially if several switchgears of the same age have to be replaced at the same time. Replacement needs to be well planned. Late replacement can lead to an increased risk of failures but at the same time, early replacement can cause unnecessarily high investment cost

Retrofit and Re-conditioning techniques provide a range of options for economically improving safety and extending the life of switchgear. The best option depends on several parameters. Analytical comparison of the options allows plant management to identify the most suitable way of improving the performance of their electrical assets.

Case studies have identified important value potential for switchgear and proved that the most logical scenario is not necessary the most valuable one and as such, lifecycle extension investments should be decided on an individual basis.

Fig.2 An example of a retrofit solution: The minimum-oil breaker in fig.1 can be replaced by a new truck; including a modern vacuum breaker actuated by an electro-mechanical drive.

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XI. VITA

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APPENDIX A

CASE STUDY 1

CURRENT SITUATION/DRIVERS

DOW Chemical Company want to assure the future reliable performance of their 11kV, 750MVA, SUBSTATION-52, which was built in the 1960's. As well as this, the company wants to ensure a reliable power supply in the future; therefore the substation should meet the growing load and availability requirements. In particular, the MV switchgear, HVP52-1, which has exceeded projected service life already, is still a critical component in the power supply chain.

Fig.1 Current configu-retion of switchgear HVP52-1

The switchgear HVP52-1 contains air-insulated busbar and 6 panels with minimum oil circuit breakers and 1 spare breaker. DOW only has 2 switchgears of this type left, and beside the spare breaker; there are no spare parts. In the past Dow has had some repairs on the switchgear and the cost of current maintenance activities is still acceptable.

LIFE TIME ASSESMENT

The required remaining switchgear lifetime, based on the forecasted plant life time is more then 20 years. Based on the forecasted grid development, it is not expected that the switchgear should be extended with additional feeders in the remaining life. The current 750 MVA system configuration is sufficient for the expected future load. In the configuration of the power supply chain, the switchgear is required to have 100% availability.

The estimated remaining lifetime of the 40 years old switchgear is limited. The safety and reliability of the panel design and the breaker design are acceptable according current practices, but its necessary 5-year maintenance interval does not match with the 8-year plant maintenance interval planned in the future. The long-term product support and availability of replacement parts for the remaining lifetime is also in doubt. The manufacturer is still able to carry out maintenance and re-conditioning but has made no clear statement regarding maintenance support for the future.

Inspection of the switchgear shows minor oil leakage, some wear of mechanical parts, and no visible reasons for insulation failures. The present condition of the switchgear causes no immediately safety risk, but the reliability of the breakers will decrease in the future. The busbar is in good condition. The protection equipment was replaced 10 years ago, and is in good condition. The protection relays are located separately in a control panel. The system can be operated remotely.

To close the identified gaps, the circuit breakers have to be returned to an 'as new' condition, and must offer reliable power supply on an 8 years maintenance interval cycle.

INVESTMENT

A quick scan shows that various life extension scenarios can be considered with the exception of "use up" because for reliable service at least the mechanisms of the breakers need re-conditioning.

There is no standard retrofit solution available, but replacement of the breakers including the truck is possible. The total investment cost for dimensional measurement, engineering, breakers, trucks, connection materials, switching and installation is € 176k. There is no fieldwork required for secondary changes in the panel. The required outage time for life extension of the system would be 8 hours for maintenance of the busbar. Each feeder would be switched off for 3 hours to install the new breaker and to perform testing procedures.

Re-conditioning of the complete truck can be done on a rotational basis in order to maintain continuity of supply. The investment for re-conditioning by the manufacturer would be € 86k including shipments, switching, installing, and testing. The required outage time for life extension of the system would be 8 hours for the busbar, and 5 hours per feeder, 2 hours for installing the spare breaker and later on 3 hours for installing the re-conditioned breaker including testing procedures.

In the case of total replacement, the investment would be € 377k for a new power distribution system including all secondary equipment, specification writing, quotation review, project meetings, new joints and sleeves for 50% of the cables, transferring of cable holes, transport, installing and commissioning. The prospected technical life of new equipment is longer than the prospected remaining plant life, however, after 20 years the equipment can probably be used elsewhere. For that reason a rest value of 20% of the equipment cost is calculated. Replacement would take more then 3 weeks, and the required outage would not fit within a maintenance shutdown which is maximal 1 week. The slight movement of the older cables in order to connect them to the terminals of the new system could cause cracking and failure, which considerably reduce the lifetime of the cables.

In all cases the decommissioning costs are minor.

VALUE DRIVERS

The depreciation cost of re-conditioning is the most favourable, but it has to be considered that this solution is not expected to last another 20 years.

The prospected maintenance cost for a re-conditioned system is much higher than for both alternatives options (retrofitted system or replaced system), for several reasons. Maintenance on minimum oil breakers is more labour intensive than maintenance of modern breakers. In many cases, improper circuit breaker operations are caused by faulty cleaning practices or inadequate re-lubrication and adjustments. For that reason the maintenance of old design breakers has to be executed by specialists from the manufacturer, or authorised partners. For modern breakers, the end users technical staff or the local E-contractor can carry out the maintenance. Specialists not only have higher hour rates but also additional administration cost for outsourcing on an incidental order base, along with travel costs. They need to be guided around the plant, and also accompanied for switching. For eventual unplanned repairs after the warranty period, high prices for out phased spare parts are taken into account.

The 5-year maintenance interval for re-conditioned switchgear, according current design, does not match with the 8-year plant maintenance interval. This could be problematic, particularly as lubrication and inspection of the level and quality of oil within the proper maintenance interval are vitally important. Although the process has redundant power supply, there will be only production commitments for scheduled switchgear service activities during a major plant shut down. The risk to rely on 1 feeder chain during maintenance, and the risk of maintenance-induced failures, are, in general, not acceptable. An unforeseen power outage of just a few minutes could result in days of work to re-start and fine-tune a production process. In practise the maintenance interval of the breaker would be enlarged, which decreases the reliability of the re-conditioning scenario. Due to this enlarging of the maintenance interval the authors assumed an increase to the failure rate of 25%.

From IEEE Goldbook there are no different failure rates for old and modern designs. The old minimum oil breakers are very robust and reliable, as long as they have been properly maintained. Modern vacuum breakers have fewer moving parts, all components are new, and modern mechanisms exert less force resulting in reduced component wear. Modern breakers are designed for many operations. In a three phase three wire system, arc interruption will occur, even if only one bottle lost vacuum. Several causes of failure can be prevented through the self control functions of modern breakers. For that reason the failure rates are the same, but in the retrofit and replacement scenarios the chance on unexpected failures is more unlikely. Production losses due to equipment failures are therefore unlikely in this case, because the complete plant has redundant feeders

Allocation costs for spare parts are approximately the same for all scenarios. Due to early retirements there has been a decline in knowledge and expertise among users. Maintaining the old technology means that at least 2 members of the technical staff need to be trained in the operation of the equipment.

All solutions have an acceptable (high) level of safety. Nevertheless from SHE (Safety, Health & Environmental) point of view, re-conditioning is not the most favourable solution. Due to the decline in knowledge and expertise among the users, and some operators are not aware of the risks when closing onto circuits that could be faulty. The re-conditioned breakers also still contain a minimum quantity of oil and in the case of major switchgear failure there will be an increased chance of damage or injury due to fire. It is hard to find out what percentage of equipment failures result in officially reported injuries and also what percentage of failures are due to human causes. Investigation in the US showed that 1 out of 14 reported electrical injuries are fatal. 55% of these happen between 601V-15.000V range, however, in this case the chance on injury is negligible, in all scenarios, the equipment is operated remotely.

Depreciation Cost	RETROF	RE-CON	REPLACE
Investment	€ 176.400	€ 85.575	€ 377.234
Project Life (breaker) technical (yrs)	20	10	20
Project Life (breaker) depreciation (yrs)	7	7	15
Restvalue as % of initial investment	5%	0%	20%
Interest to pay over bookvalue	10%	10%	10%
Inflation (%)	2%	2%	2%
Decomissioning costs end of lifetime	€ -	€ -	NA
Depreciation method	liniair	liniair	liniair
Total depreciation cost lifetime			
Preventive Maintenance Cost	RETROF	RE-CON	REPLACE
Recurrent inspection interval (yrs)	5	5	5
Recurrent inspection interval costs	-	-	-
Recurrent maintenance interval (yrs)	8	8	8
Recurrent maintenance interval costs	5.000	10.000	5.000
Total internal preventive maintenance cost lifetime			
Corrective Maintenance Cost	RETROF	RE-CON	REPLACE
Q	☐ ☑	☑	☑
Unplanned repaircosts expected enduring lifetim	8.000	16.000	8.000
Faillure chance a year	0,303%	0,379%	0,303%
Total corrective maintenance cost lifetime			
Cost of Non Availibility	RETROF	RE-CON	REPLACE
Question…..	☐ ☐	☐	☐
Productionlosses	30.000	30.000	30.000
Faillure chance a year	0,227%	0,284%	0,227%
Total Cost of NonAvailibility per lifetime			
Allocation costs	RETROF	RE-CON	REPLACE
Cost of keeping parts stock / knowledge p.yr.	3.000	3.500	2.500
Total Cost of NonAvailibility per lifetime			
Safety Health Environment (SHE)	RETROF	RE-CON	REPLACE

Fig.2. *Screendump of value drivers input screen*

CONCLUSION

The average cost a year is €16k for retrofit, €17k for re-conditioning and €37k for replacement. Re-conditioning is the option with the lowest capital investment today, but it is unlikely that the breakers will last another 20 years and the long-term availability of replacement parts and maintenance support is in doubt. After about 10 to 15 years the reliability will decrease, and further investment will be required.

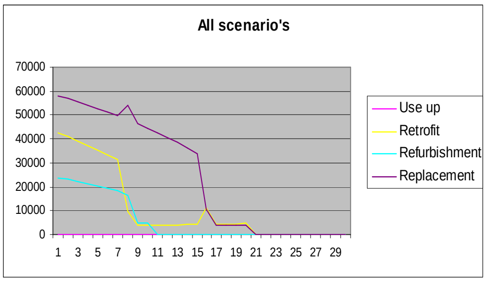

Fig.3 Average cost

With about the same average cost a year, the retrofit option, is by far the most cost-effective alternative, enabling the substation to be operated for another 20 years or more. Retrofit offers a reliable performance with significantly lower capital expenditure than replacement, and has a more favourable minimum long term cost of ownership. The overall cost of implementing will also be kept to a minimum, as the substation will need to be de-energized for only a short period, which will fit within the plant's operational planning.

CASE STUDY 2

CURRENT SITUATION

DOW's main distribution panel 52-1 and 2 has been installed in 1970. A maintenance outage during one week is scheduled for the next plant turnaround. The switchgear has 2 incomers,1 coupler and 16 feeders. The incomer circuit breakers have had some problems in the past and previous experiences with a similar system indicate that several repairs can be expected. Six of the feeders show mechanical wear due to frequent switching. Taking the applicable expected reliability into account, in this case the cost of switchgear replacement is compared to life extension, and to use up.

LIFE TIME ASSESMENT

The required remaining lifetime of the plant is at least 15 years.

The estimated remaining lifetime of the switchgear, after maintenance and repair is 5-10 years. Eventual extension of the system is still possible, but for the circuit breakers the support and spare parts from the manufacturer will no much longer be available. The current design is considered acceptable according to current practices. No particular safety risk is expected, but future reliability will be substantial lower than in the first 35 years of service.

The breakers must be kept in a reliable condition. A cost of ownership calculation must turn out if replacement should be postponed 5 years, till the next major planned outage. The arc chambers of the incomers and the coupler contain Asbestos which is a relevant issue.

INVESTMENT

Use up involves maintenance of the existing switchgear, including expected necessary repairs of the circuit breakers, and including cleaning up asbestos, and replacement of the arc chambers. The total investment cost of this scenario is € 89k. The maintenance and repair can be provided by the original manufacturer, with field engineers from abroad.

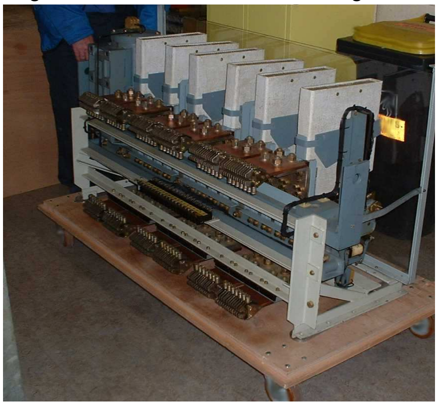

Fig.1 Existing spare breaker

The retrofit solution is provided by a third party. The total investment cost of retrofit is € 118k, including removal from asbestos of the existing switchgear. Like use-up, this scenario can be performed within the next scheduled maintenance outage.

The cost of re-conditioning, € 137k, is slightly higher than retrofit. Re-conditioning is possible within the workshop of the original manufacturer. The lead time for re-conditioning doesn't fit into the maintenance schedule. For that reason it has to be done in a rotating schedule. Limited spare breakers are available. Nevertheless the total investment required for re-conditioning is high, as the rotating schedule results in high additional cost for switching, (de-)installation and transport. Beside the clean arc chambers are expensive.

Full replacement demands a relative great investment, due to high equipment cost, civil adjustments, approval procedures and expenditure on infrastructure. The total investment cost would be € 440k. With an adequate project planning, replacement is possible within the next major plant stop. Due to limited space in the substation, the old switchgear would have to be removed before the new switchgear could be carried in. Lack of possibilities to prepare and test the new system just before exchange, is an extra risk.

VALUE DRIVERS

The only identified value drivers in this case are; depreciation and maintenance..

Solutions	REP./USE UP	RETROF	RE-CON	REPLACE
Availability				
Solution available?	☑	☑	☑	☑
Depreciation Cost	REP./USE UP	RETROF	RE-CON	REPLACE
Investment	€ 88.935	€ 118.230	€ 137.041	€ 440.213
Project Life (breaker) technical (yrs)	5	15	10	15
Project Life (breaker) depreciation (yrs)	1	3	1	7
Restvalue as % of initial investment	0%	20%	0%	20%
Interest to pay over bookvalue	7%	10%	10%	10%
Inflation (%)	2%	2%	2%	2%
Decomissioning costs end of lifetime	€ -	€ -	€ -	NA
Depreciation method	liniair	liniair	liniair	liniair
Total depreciation cost lifetime				
Preventive Maintenance Cost	REP./USE UP	RETROF	RE-CON	REPLACE
Recurrent inspection interval (yrs)	4	4	4	4
Recurrent inspection interval costs	-	-	-	-
Recurrent maintenance interval (yrs)	6	6	6	6
Recurrent maintenance interval costs	4.800	3.600	4.800	3.000
Total internal preventive maintenance cost lifetime				
Corrective Maintenance Cost	REP./USE UP	RETROF	RE-CON	REPLACE
Question.....	☑	☑	☑	☑
Unplanned repaircosts expected enduring lifetim	2.000	1.500	4.000	1.500
Faillure chance a year	0,006%	0,002%	0,004%	0,002%
Total corrective maintenance cost lifetime				
Cost of Non Availibility	REP./USE UP	RETROF	RE-CON	REPLACE
Question.....	☐	☐	☐	☐
Productionlosses	25.000	25.000	25.000	25.000
Faillure chance a year	0,006%	0,002%	0,004%	0,002%
Total Cost of NonAvailibility per lifetime				
Allocation costs	REP./USE UP	RETROF	RE-CON	REPLACE
Cost of keeping parts stock / knowledge p.yr.	-	-	-	-
Total Cost of NonAvailibility per lifetime				
Safety Health Environment (SHE)	REP./USE UP	RETROF	RE-CON	REPLACE
Question....	☐	☐	☐	☐
Fatally injury	10.000.000	10.000.000	10.000.000	10.000.000
Injury	25.000	25.000	25.000	25.000
Nearly accident	5.000	5.000	5.000	5.000
Faillure chance a year	0,002%	0,002%	0,002%	0,002%
Total Safety Health Environment per lifetime				

Fig2 Screendump of value drivers input screen

Use-up has the lowest level of depreciation for the next 5 years. From the long term solutions, retrofit has the favourite level of depreciation

In case of use-up or re-conditioning, the maintenance of the breakers would have to be carried out by the manufacturer, accompanied by the DOW employee who maintains the other cubicles. In the case of unplanned repair, out phased spare parts would have longer lead-times and higher prices than for new breakers. For retrofit breakers, maintenance is slightly less expensive because own technical staff and local contractors are skilled to maintain the modern types of breakers. In case of full replacement of the system, maintenance strain and cost shall be least.

By lack of suitable statistic data, the reliability of the replacement and retrofit are assumed to be 2x better than re-conditioning and 3 times better than use-up. Because of the redundant feeder chains, reliability percentages on this minimal scale have no cost impact at all. Due to the re-conditioned spare breaker, eventual failures of old design breakers are not expected to require longer repair times than the newer ones.

All scenarios have the same allocation costs, and there is no difference regarding Safety Health & Environment issues, as long as the asbestos is cleaned up.

Fig.4 Current switchgear configuration

CONCLUSION

The average cost a year is € 18k for use-up, € 8k for retrofit, € 15 k for re-conditioning and € 37k for replacement. Use-up requires the lowest capital investment, but is only a short term solution. Because of the relative high yearly cost, use-up is not a beneficial way to postpone the investment.

Retrofit is the most attractive alternative to replacement as it offers a reliable performance during entire estimated remaining plant life, at a significantly lower capital expenditure. Retrofit offers the lowest minimum long time cost of ownership.

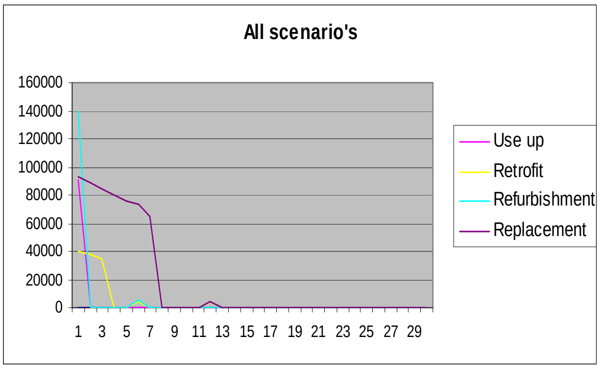

Fig.3 Average cost

Even with a calculated project life of 15 years for a retrofit and 30 years for a replacement, both without rest value, the average cost (€ 10k) of retrofit is much lower than the annual average cost (€ 21k) of replacement. Thus postponing the replacement investment by the retrofit option, saves money.