Economic decision model for End of Life management of distribution switchgear

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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 is an option to reduce the required investment cost. The described method is a dedicated life cycle cost tool in order to compare the economical value of 4 possible scenarios:

- *Use-up*
- *Refurbishment*
- *Retrofit*
- *Replacement*

Lifetime assessment and review of operation strategies are important inputs to the decision process. The spreadsheet tool is filled with several default settings, derived from: literature, asset management strategies, field experiences, data mining, and case studies.
The tool facilitates fast and rational decision-making by providing:

- *Total Investment Costs*
- *Minimum Long Term Cost of Ownership*
- *Net Present Value*
- *Return of Additional Investment*

Case studies show that the most logical scenario is not necessarily the most valuable one.

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 distribution switchgear is a basic regulatory requirement. A traditional equipment management strategy within industrial and electrical companies is to replace switchgear when it has reached the end of its technical lifecycle [1]. This choice provides maximum equipment lifespan whilst incorporating the latest technology and safety features upon replacement, but usually implies high economic investment. The outage time required to enable replacement of switchgear may not fit with delivery commitments. Also this replacement strategy does not necessarily represent the optimal life cycle costs. Conscious end of life decisions often mean a struggle to balance both minimum investment and life cycle costs. The methodology described in this paper compares several solutions for aging switchgear in order to gain the required safety & reliability at consciously chosen optimal economical conditions.

DRIVERS

Switchgear must safely and reliably fulfill its basic functionality of closing and opening electrical circuits and carrying a certain load. Two sorts of drivers can lead to the replacement planning for switchgear:

A. <u>Technical Condition</u>

End of service-life usually means an increasing risk of failure in switchgear, such as: does not open or close on command, does not break the current, insulation failures etc. Signs that reliability & safety of the equipment will run out of control within a relatively short time can be found through 'remaining lifetime assessment' or by 'trend analyzing'. Some populations show typical end of life signs, such as ageing plastic. End of life signs can also be related to a specific application, such as frequent operation, or an extremely moist environment. End of life is usually introduced by:

a) Physical ageing effects such as oil leakage, wear of mechanical parts, cracks or moisture in insulation materials, dangerous or unreliable situations found during inspections, or mechanical failures
b) Necessary spare parts or critical maintenance support are not available any more.

B. <u>Grid Optimization</u>

Optimization and modification of the grid operation can require increased equipment performance.

a) Old breaker designs are more complicated than newer designs. Old breakers have no low-maintenance design, and, for example, a lot of mechanical parts to service. Life extension scenarios can reduce maintenance intervals and labour cost.
b) Small populations of differing types of switchgear cause relative high cost for maintaining knowledge and spare parts.
c) Increased availability requirements. Year over year increasing consumption of electrical power, and technical improvements in the grid may reduce the economical lifetime of existing switchgear, as the

overall outage time of a substation/grid section is reduced or inspection intervals are less frequent.

d) Increased load ability requirements due to the bottlenecking in the grid.

LIFE TIME ASSESSMENT

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

a) Required Future Service-Life

Based on 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 requested safety level.

b) Estimated Remaining Life of the Switchgear

The first step is a review if the current general design is acceptable according to known future requirements, with regard to safety, reliability & functionality. The second step is to review prospected spare part availability for the future. Thirdly, review the physical health of the switchgear. The most practical approach to this is to look at failures or problems that specifically occur to a certain population, and investigate if there are any reasonable grounds to expect failures in the extended lifetime.

Following this, the current physical health and eventually ageing trends could be validated by visual inspection, analysis of maintenance history from proven methods such as visual inspection, tangent delta measurement, discharge measurement, speed measurement and analysis from historic load indications.

c) GAP analysis

The gap between requested and estimated extended life dictates the minimum required investment to reach the expected lifetime. The calculation method will show if the minimum investment is also the scenario with the lowest total cost of ownership during future service life.

SCENARIOS

A few manufacturers are tending to develop alternatives for complete switchgear replacement. The following scenarios and combinations apply at end of service-life:

a) Use-up

Use-up means using the equipment until the End of Economical Service Life; the time from installation to a situation where annual maintenance and equipment-caused outage costs exceed the discounted annual cost for new equipment. Maintenance cost, reliability and safety have to be investigated carefully due to old design, ageing effects and risk for maintenance-induced failures.

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 risk 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 components of the panel are replaced to enhance the safety of the equipment. Retrofit of protection and control, where protection and control devices are replaced - providing increased functionality, data communication and safety. A type tested “form fit function” replacement of the breakers developed by the manufacturer provides a fast re-conditioning of switchgear. The outage time is minimised, as the only on-site activities are those of racking-out, removing the old breakers and inserting the new retrofits.

c) Refurbishment

Refurbishment of switchgear provides 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, but acceptable performance needs to be maintained over the short to medium term. Refurbishment is possible as long as spare parts, support, services and knowledge of the switchgear is available. Complete panel refurbishment, which is not applicable in our case studies, provides the possibility to re-use panels of disused systems. Switching devices such as circuit breakers, contactors and switches are typically candidates for refurbishment. The devices are removed from the switchgear, sometimes on a rotational basis in order to maintain continuity of supply, and returned to a reconditioning centre. Manufacturer specifications are required to bring the breaker up to the original quality standards.

d) Upgrade

Increased requirements due to new safety aspects, modifications in the grid, or changes in operating strategy, are usually not the driver for replacement planning. Sole replacement of Control and Protection devices/equipment is in many cases not heavily interruptive to grid uptime. However these are important contributing causes for the selection of the optimal life extension scenario. Modernization can protect an investment by extending the equipment lifespan while raising load ability, safety, reliability and performance standards. Retrofits and new switchgear are usually well prepared for modernisation. The minimum required functionalities should be included in the calculation of all scenarios.

e) Replacement

Replacements can include the entire switchgear or even the entire substation. The investment cost for this can be huge, especially if multiple switchgear of the same age has to be replaced at the same time. Replacement has to be planned well. Late replacement induces an increased risk of failures and early replacement can cause unnecessary investment cost. In case of replacement, the investment cost for the specifications, quotation review, work instructions, civil modifications, cable modifications, welds, connections, secondary installation etc. are far above the cost of the actual switchgear. Replacement usually requires a long outage period, especially if there is a lot of cable transferring, or if existing switchgear has to be removed because of limited space.

RATIONALIZATION

The investment cost of the above 5 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 contain all necessary expenditures such as installing, cabling, commissioning, civil modifications and conversion costs, before a scenario can be chosen. A quick practical analysis of the possible scenarios provides tangible data. Standard values for these costs are not reliable though, because every project is different and an individual situation.

To prevent us for becoming blinded by technical recommendations or a focus on minimum investment; end of service-life decisions require an economical validation. Using a definition from current financial literature [2], value is defined as the sum of all future cash flows, discounted 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 these 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:

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

where: PV = value (present value)

C_t = cash flow in year t (cash flow)

r = discount rate

Our calculation model provides five value drivers that are applicable for the review of the financial value of investments in lifecycle extension of electrical infrastructure. 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 in the value potential of the five value drivers depending on individual situations.

a) Value of Depreciation

Different scenarios can have different life times, and for that reason 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. 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 maintenance strategies such as traditional reliability centred maintenance, risk based maintenance and 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 lower maintenance effort than existing 30 years old designs and for every scenario one should wonder if the required knowledge is available within the company, or with a contractor. According the predicted inspection and maintenance intervals, the spreadsheet transfers the maintenance cost to the right moments in time.

c) Value of Availability

Maintenance intervals can cause outages, and occasionally extra cost for timely power supplies should be calculated. Calculating the cost of unplanned availability can be hard to define. All available information about failure chances and MTBF is very situation specific, and 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 yes what will the production losses probably be. Unless there is a realistic larger risk of failure, we use a very small variety of failure rates from the IEC Goldbook.

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 about 25% of the inventory value. For spare parts we look at the total inventory value for a certain old type of switchgear and divide it 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)

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. 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 realistic larger risk on failure, we use a very small variety of failure rates from the IEC Goldbook.

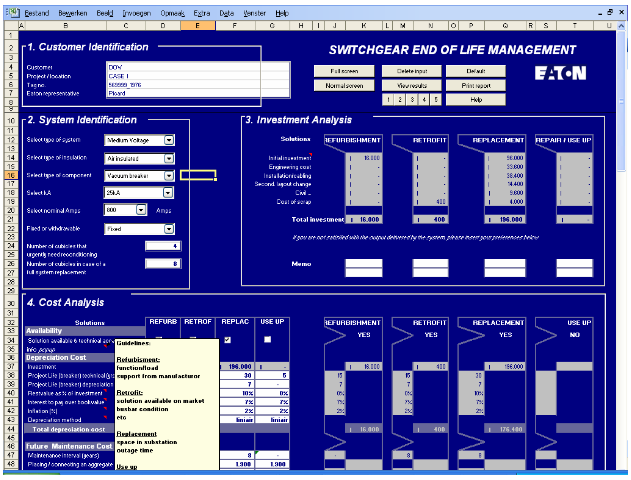

Fig 1: Input screen of spreadsheet

PRACTICES

A sophisticated spreadsheet (Fig. 1) 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 [4,5,6,7] sources.

It is important to be aware of both investment cost and long term cost of ownership, however the weight of each may be influenced by the companies policy with respect to the way 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 we propose the minimum necessary investment as a reference value, from which to calculate the NPV of additional investment costs for a eventually more valuable solution. High NPV scores are found where there is more then one value 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 scenario allow to delay a significant part of the investment over 5 years.

However 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 time, as bus bar and steel construction are static components. For certain kinds of bus bar insulation, using plastics, paper or bulk oil, some suspicion is legitimate, as it is known that the applied materials are sensitive to physical ageing. Insufficient research data about ageing is available.

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.

The best way to review the prospected reliability for the extended service life, is to gather typical problems from older populations using the same technology. The exchange of failure data between users and manufacturers supports a reliable condition assessment.

CONCLUSION

Refurbishment and retrofit 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 allow grid managers to identify the most suitable way of improving the performance of their electrical assets.

Case studies 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 accordingly.

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