EVALUATION OF THE REPLACEMENT OF A DISTRIBUTION SUBSTATION

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ABSTRACT

Regarding the development in distribution networks in the regulated sector of electricity supply, the Asset Management has gained more and more importance in the past years. The renewal of a group of equipment forming a technical unit can be done stepwise depending on the remaining lifetime of the components or at once at a certain point of time.
Taking as an example the replacement of a distribution substation (MV/LV) with the adjacent network different replacement scenarios are analysed from a primarily economic point of view. Also possible influences of the remuneration of network use are discussed.

INTRODUCTION

ewz is a Swiss utility, which operates distribution networks in the city of Zurich and parts of the Grisons. In Switzerland the activities relating to distribution networks have been unbundled following the Electricity Supply Act [1] and the associated Ordinance [2], which entered into force on 1 January 2008 and 1 April 2008 respectively. This means, that network operation has to be run independently and separated from the other activities of the electricity supply companies at least in terms of accounting [3].
As the Electricity Supply Act specifies the maximum remuneration for network use, investment decisions of the Asset Management of the distribution net operator (DNO) are analysed more and more under this focus.
Regarding a technical installation, it is often the case that a part of the components is up for replacement whereas the rest have not yet reached the end of their lifetime. This results in the question, which replacement strategy should be pursued. On the one hand the renewal of the individual components at the end of their lifetime leads to a multitude of measures, whereas the replacement of all components at once means, that a part of the components has to be replaced at a suboptimal point of time.
In this article the above problem is analysed from a mainly economic point of view using the example of a distribution substation and the adjacent network including cable duct, MV cable, LV cable, supply connections and street lightning cable.

REPLACEMENT STRATEGY

In the following it is analysed for a distribution substation and its adjacent network, which replacement strategy is to be preferred from an economic point of view, when a part of the equipment has reached the anticipated life time and the rest could still stay in operation for several years.
For ewz this question is especially important, as the voltage of the MV grid is being changed from 11 kV to 22 kV. This means, that with the replacement of a distribution substation the upcoming changes in the adjacent network have to be taken into account.

Economic calculation

In economic calculation an investment is valued based on the effective free cash flow in the period under concern. The respective series of incoming and outgoing payments is discounted to the starting point and totalised in one value, which is called capital value of the investment. The length of the period will be generally chosen depending on the expected lifetime of the investment. For investments in the public grid the planning horizon is typically between 30 – 40 years. If there is a choice between several investment alternatives, the relative profitability of the different variants can be compared by their capital value at the starting point.

Renewal variants

Four variants for the replacement of a distribution substation with the adjacent network (connection to next node) are compared. These four variants differ in the investment point for the different components and the respective supplementary costs. Due to the voltage change from 11 kV to 22 kV it is especially important, that the MV equipment can be operated at 22 kV, so that ring feeders can be switched to 22 kV successively. At a first step the operational costs are assumed to be equal for all variants. It should be pointed out however, that outage probability tends to rise with the age of the equipment, particularly, when components are operated beyond their expected lifetime. Figures 1 and 2 show the situation in the network for an exemplary distribution substation. For the further analysis it is assumed, that all components were installed in 1970, the lifetime of the components however varies between 35 and 60 years (see Table 1).

Figure 1 Scheme of Distribution Substation and adjacent MV-network

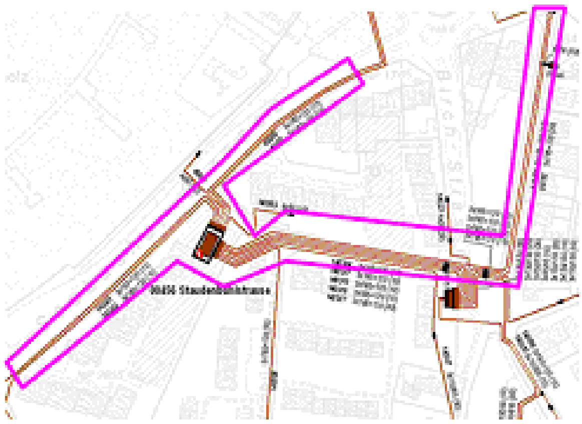

Figure 2 Scheme of Distribution Substation and adjacent LV-network

Equipment	Lifetime/[Years]
Distribution Substation	35
MV-Cables	40
LV-Cables	40
Supply Connections	35
Street Lightning Cable	40
Cable Duct	60

Table 1 Equipment and Lifetime in Years

Variant 1: The distribution substation and the adjacent network are replaced in the starting year in one building measure. Afterwards the MV equipment can be operated at 22 kV.

Variant 2: The distribution substation is replaced in the starting year and the adjacent network is replaced after 10 years. This causes supplementary costs of 100 kEUR for the backfitting of the distribution substation in the starting year. The MV cable can only be operated at 22 kV 10 years after the starting year.

Variant 3: The distribution substation is replaced in the starting year together with MV cable, which is drawn in provisorily. The provisional MV cable can be operated at 22 kV. The supplementary costs for this measure add up to 270 kEUR. The complete adjacent network including the provisional MV cables is replaced 15 years after the starting point.

Variant 4: Option for variant 3. The renewal of the adjacent network is postponed for another 5 years and is thus executed 20 years after the starting point.

Figure 3 shows the investment and additional costs for the four variants (with price increase of 1.5 %).

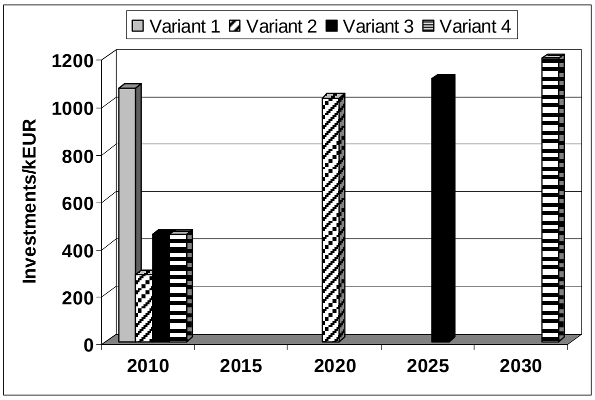

Figure 3 Investment Costs incl. Supplementary Costs for Variants 1-4

ANALYSIS AND MODEL CALCULATIONS

For the model calculation the capital value is calculated for each of the four variants. For investment calculation the technical components are now seen as "facilities" with their respective depreciable life. Components, which are to be replaced by "new components" will be called "existing components" in the following.

The replacement of a distribution substation with its adjacent network causes payments, which make up the profitability of the project. These are particularly:

- investment costs,
- operational costs,
- revenues from network use remuneration.

As basic settings for the calculation the planning period is set to 35 years and the price increase to 1.5 % (mean value of PIP over the last 50 years).

Assumptions

In order to make the four variants comparable, the following assumptions are made.

- For all four variants the year 2010 is chosen as starting point and the planning period is assumed to be 35 years.
- For the depreciable life or amortisation period of the components the values in Table 1 are applied in accordance with the regulations (Electricity Supply Ordinance [2]).
- Supply quality and associated costs are not regarded in this analysis.

Investment calculation based on cost

To begin with only the payouts or expenses are taken into account and the variants are compared by juxtaposing the capital value of the investment costs relating to the starting year. The capital value of a series of outgoing payments will always be negative. The variant with the largest capital value (smallest norm for negative values) is preferable from an economic point of view. Figure 4 shows the results for the four variants under consideration.

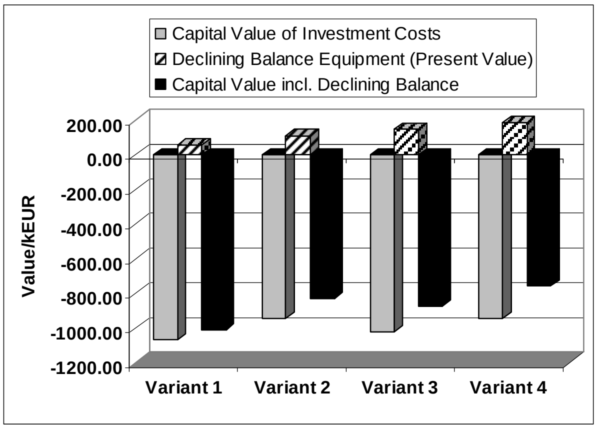

Figure 4 Results of Investment Calculation: Capital Value and Declining Balance at Present Value

It can be seen, that variant 4 is favourable with regard to the capital value of cost under the assumptions made. As for variant 4 investments are postponed, the declining balance of the equipment is higher. If other factors of influence (i.e. operational cost, supply quality) are neglected, postponing an investment leads to a lower capital value. Variant 2 and variant 3 are nearly on a par, the difference between the capital value being 5 %. Variant 1 is the most unfavourable choice.

Influence of network remuneration

As a consequence of unbundling the distribution grid the revenues resulting from investments can be calculated according to the Electricity Supply Ordinance [2].
The network use remuneration comprehends particularly operating and capital costs as "recoverable costs". The operational costs cover the expenses for network operation, i.e. inspections, maintenance and network control. Operational costs are recompensed at same cost (one-to-one). The capital costs reflect the costs for the renewal and extension of the network. They consist of the amortisation and the interest costs.
For distribution networks with a similar supply task these costs could be taken by an external observer as an indicator for cost-effectiveness. Therefore the development of these costs within the planning period is analysed for the four variants as well. Figure 5 shows the network recoverable cost for the four variants.
The curves show, that costs rise significantly, as soon as the distribution substation is replaced. The rise is steeper in those years, when components are dismounted and replaced before the end of life and the complete residual value is amortised one-time. After the investment year the capital costs get lower over the years, as the interest costs are calculated in proportion to the declining balance of the facilities.

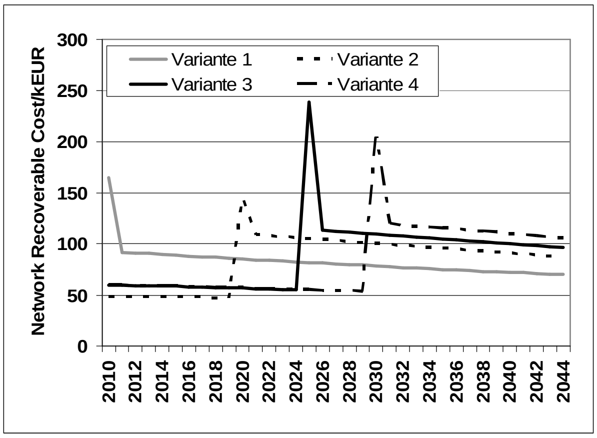

Figure 5 Time Line of Network Recoverable Cost

The amortisation however is usually distributed linearly over lifetime and falls away afterwards.
Regarding the remunerable costs over the planning period it is obvious, that the ranking of the variants changes with time. In the beginning until 2020 variant 2 leads to the least costs, variant 3 and variant 4 are favourable until 2025 and 2030 respectively, afterwards variant 1 has the lowest costs. This is partly due to the fact, that the planning period is limited to 35 years and part of the components has a lifetime exceeding this span. It can be deducted furthermore, that the operation of the distribution substation may appear most efficient for an external observer, if no renewal at all is made. This observation changes, as soon as outages of equipment due to delayed renewal appear.
In order to make the final investment decision the efficiency of the network is a very important parameter. Furthermore the following facets should be considered:

- structural optimisation of the network
- technical feasibility
- supply quality
- customer satisfaction.

These parameters are taken into account by ewz in order to make the decision between the variants in a specific case. At ewz variant 3 and variant 4 are the chosen replacement strategy. From an economic point of view regarding investment costs, variant 4 is favourable and variant 3 is slightly less economic than variant 2. Taking into account the voltage change however, variants 3 and 4 are more flexible than variant 2 as both enable the change-over from the starting year on. The choice between variant 3 and 4 is made depending on operational criteria. Further investigations are planned to analyse the investment optimum for the grid.

Sensitivity to parameter changes

The sensitivity of the results to parameter changes was analysed for: price increase, planning period, amortisation period and year of construction of the existing facilities.
For the analysis one parameter was varied and the other parameters were set to the basic values.

A parameter change within the chosen limits affects the relative position in case of a price increase above 3.5 % or a price decrease below 8 % (see Figure 6).

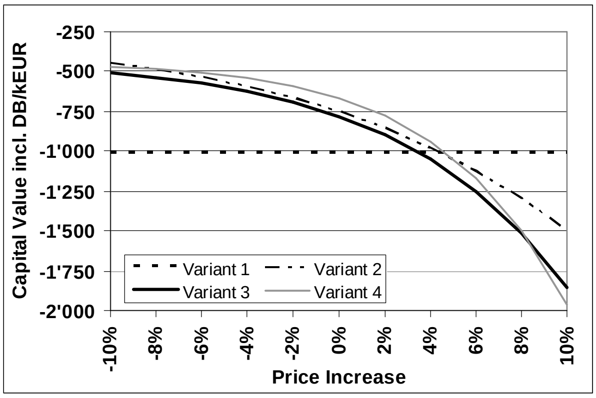

Figure 6 Sensitivity of Capital Value to Price Increase

For the capital value incl. declining balance, there are mainly three effects, which influence the relative ranking of the variants:

- Postponing an investment leads to a lower capital value due to discounting to the starting point (other things being equal).
- A higher initial investment leads to a higher capital value of cost (other things being equal).
- A steeper price increase leads to a higher capital value due to the rise of investment costs in following years (other things being equal). Postponing investment gets less attractive the higher the price increase is.

As these effects affect the capital value in different direction, the price increase should be included in the calculation, even though it will not lead to another ranking order of the variants within the usual long-time valuation.

DISCUSSION AND CONCLUSIONS

In the framework of a long-term investment strategy under regulation it is especially important to watch the efficiency of the grid. The simplest method to assess the efficiency is to compare the costs for similar distribution networks and supply tasks.

It has to be taken into account here, that the recoverable costs as the basis for network remuneration comprise operating and capital costs.

As capital costs diminish during the lifetime of a technical facility and go down to zero after the amortisation period, for amortised facilities only operating costs occur.

This means, that a network with delayed renewal, which is technically out-of-date, may appear to be more efficient for an external observer at a certain point of time, than an adequately modernised network, if only the cost base is regarded.

As operating costs for the network with delayed renewal will not rise instantaneously but within a certain period, the adequately modernised network will not always appear to be more efficient.

When renewal has to be caught up due to a significant increase of outages in the network with delayed renewal however, the costs will then rise significantly [4, 5]. In this case the measures will tend to be event-driven and not strategic.

As capital costs are about 6-7.5% of the investment costs at the beginning of the investment with the actual interest rate, it is a very difficult task to compensate them by a reduction of the operating costs, even if structural optimisation measures are taken into account.

Looking at the liberalisation this means, that under incentive regulation incentives for an adequate renewal of the distribution network are important. If an unspecific revenue cap is set, the unintended incentive to postpone network renewal may be the consequence. Therefore a revenue cap should take into account an adequate renewal of the network.

For the DNO a strategic planning of renewal, taking into account optimisation of the network as well as the age structure of the components, is required to keep the network efficiently working within a long-term perspective.

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