DEVELOPMENT OF TARGET GRID STRATEGIES SUPPORTED BY THE ASSET SIMULATION OPTIMIZATION CORE HAVING REGARD TO TARGET COSTING

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ABSTRACT

The requirements on the asset management of a distribution system operator in the regulated market are increasing further. Beside coping with intensely changing feeding-scenarios the balance between regulatory cost imposed targets and aging equipment inventory must be found and kept. This requires advanced methods to develop target grid strategies that meet these competing demands. A promising approach is the use of the asset simulation model for distribution systems with the integration of evolutionary optimization algorithms. In this way the asset manager receives an indication to control the actions of replacement in the target grid planning with regard to improving the grid quality in compliance with cost limits.

INTRODUCTION

Currently the target grid planning is mainly based on optimizing the network structure for future technical requirements and the asset base concerning the degree of amortisation. The necessary measures are collected year-related in a master action plan so as to comply the current medium- and long-term planning with the resulting investment and operation expenses [1].

Due to the regulatory framework currently available budgets are more and more subjected to a target costing. Simplified there can be spent only as much capital on the operation of the distribution network as remains of the grid usage fee less the return of investor requirements amongst others.

At the same time an increasing budget has to be spent for reinforcement and expansion of the distribution grid related to the connection of “Renewable-Energy-Law”-feed-ins.

In general both factors stress the budget for the replacement measures and also consequentially to some degree the availability of the grid. Therefore a subsequent temporal extension of already from the target grid planning derived measures is necessary to comply with the available replacement budget. This step is usually executed manually and offers potential for improvement.

One approach to the development and adaptation of the target grid strategies, which considers the reduced replacement budget and the network availability, is the inclusion of the asset simulation tool ASIM containing the optimization core in the target grid planning process. The asset simulation is an established tool in asset management. It maps the dynamic relationships and interdependencies of the considered assets to a strategy and allows a long-term prognosis for certain target values such as costs, supply reliability or replacement requirements.

The optimization core is attached to the asset simulation. It provides an automatic, target oriented development of a strategy considering target values and restrictions. The applied evolutionary optimization algorithms find solutions by mutation and recombination of the strategy parameters. After subsequent comparison the best strategy regarding to target and restriction values is followed up. This process is performed iteratively. As a result of this approach also very erratic, nonlinear high and low points are found with many variables in compliance with numerous restrictions [2].

SIMULATION AND OPTIMIZATION

Basis for optimization in the context of the target grid planning is a “normal replacement strategy”. This has been parameterized in such a way that the resources considered in the target grid planning are replaced at the end of their life cycle. This is defined as a functional relationship in the asset simulation. The amount specification of the equipment to be replaced annually is described for each resource as the ratio of equipment stock and technical lifetime. The simulation simply regards the older assets at the end of technical lifetime for the reservoir of measures.

The normal replacement strategy is a simplified model of a linear replacement renewing facilities and equipment after their technical life cycle without considering budget constraints. The resulting costs of the renovation measures consisting of the elements "renewal", "conversion" and "shutdown" exceed the available funds from the target costing in general. At this point the optimization core tries to identify a strategy that meets the budget in the field of replacement. In the process the packages of measures of the normal replacement strategy for renewal and conversion are changed by the optimizer so that the total replacement costs comply with the budget targets.

To execute an optimization successfully, some basic considerations are necessary in particular with regard to the optimized target value and cost objectives, which have to be met in addition to the restrictions.

Target Value

Objective of an optimization is always either the minimizing or maximizing of a target value of the asset simulation target value portfolio.

Since only one target value can be chosen for an optimization run, this value should have a good significance for secure grid operation. For this purpose only very few target values are possible to be selected. Two commonly cited are the replacement requirements (target value "percentage of the actual replacement value of older assets") and the network quality (target value "unavailability").

Sensitivity analysis indicate that the network quality / non-availability can be minimized only in very narrow limits considering the planning period and the available budget. In contrast the percentage of the actual replacement value of older assets reacts considerably stronger to changes in the replacement amount for specific equipment and is therefore selected as the target value which is to be minimized by the optimization core.

Restrictions

The restriction values provide general conditions for the optimization and must be followed by a valid optimized strategy.

An essential restriction in this study is the total cost of replacement. Here the amount, which is corresponding to the budget target in the medium and long term strategy in accordance with the target costing, is defined as an upper annual limit.

Regarding the practicability of a strategy further restrictions are still necessary after the optimization. Due to the given resource stock and the aging models the optimization core usually identifies optimized strategies by a preferred replacement in years with a high proportion of older asset. On the other side the tool partly reduces other resources with a low replacement proportion. An optimization without limiting the amount of changes leads to a strategy with significant yearly fluctuations in the prescribed amounts, which are not operationally executable by a network service provider. Strategies with uncapped fluctuations in the targeted amounts can therefore hardly improve the very operational action plans of the target grid planning. Therefore the annual volume changes in the replacement are limited by restriction requirements.

Optimization parameters

The simulation begins with the current planning year. Because of different contractual relationships and agreements there is no option to make an operational change of measure quantities in this year. Therefore the optimization core must not vary the targeted amounts in the current year. Hence the amounts of the base year are fixed by a specific parameter setting.

The asset simulation includes equipment, which can not be renewed in the original technology and has to be rebuilt in newer technology. This equipment must be excluded from the optimization of the renewal amounts. This leads to an exact resource related release of the renewal amount optimization. The conversion is generally allowed for the optimization in all cases the simulation model permits a conversion.

The study handles a complete network of a large German distribution system operator including all active resources of the voltage levels from 110 kV to 0.4 kV. To find valid results within such a complex model concerning the mentioned restrictions and requirements, the search step sizes of the optimizer must be set large enough. However they may not be too large otherwise very discontinuous high and low points of the target value can not be found.

STRATEGY COMPARISON

Afterwards the optimized strategy is examined using the analysis tools built in the asset simulation. Qualitative information is derived to renewal and conversion quantities in terms of size and timing.

In the following some individual particularly striking examples are explained which are representative for all assets included in the asset simulation. The curves are made anonymous in their height, but the form will match the real results. For both the "normal replacement strategy" and the optimal strategy the amounts for renewal or conversion are compared with each other.

110-kV overhead lines - non-galvanized towers

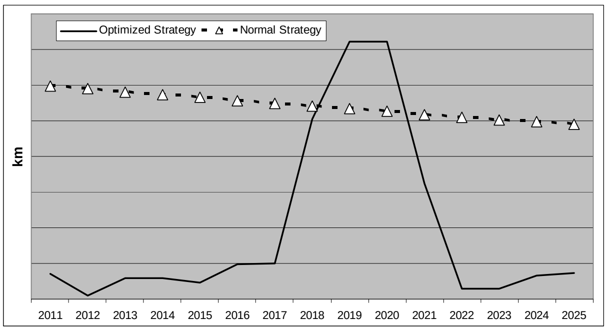

Fig. 1: Conversion of non-galvanized 110-kV towers

The result of the optimization is a reduced conversion activity in galvanized towers compared to the normal replacement strategy (see fig. 1). Only in years 2018 to 2021 some sections reaching the end of their life cycle will be rebuilt nearly with the normal replacement amount. This approach leads to lower costs in the first seven years. So other resources which are already in a worse condition in this period can preferably be renewed.

110-kV oil and external gas pressure cables

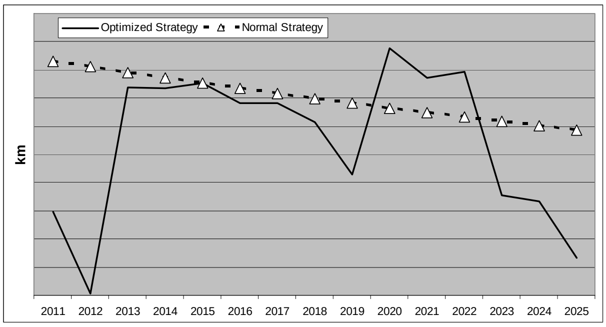

Fig. 2: Conversion of 110-kV cables

The optimization shows a delayed conversion of the oil and external gas pressure cables in modern XLPE cables until 2012 (see fig. 2). From 2013 the conversion amount will rise to the "normal" conversion amount. After 2022 the amount decreases again to a lower level. Therefore in the first years the optimizer follows the age distribution of the oil and external gas pressure cables. The decline towards the end is a compensation in favour of other older equipment.

110/30-kV transformers

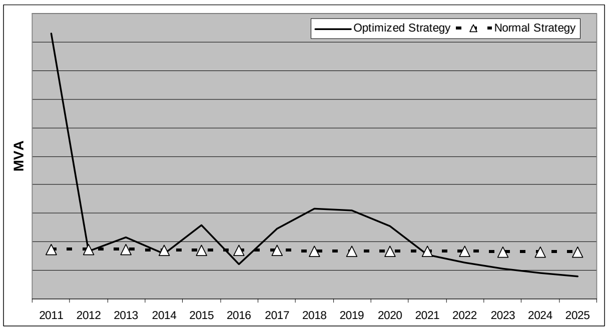

Fig. 3: Renewal of 110/30-kV transformers

The result of the optimization (see fig. 3) has a special significance for the 110/30-kV transformers. Here the optimization shows that a focussed renewal of the old transformers in the first year is necessary and appropriate.

Although this approach is associated with a significant burden of the available renewal budgets, it is important from the point of view of replacement requirements as the target dimension. A detailed examination of the inventory data of the 110/30-kV transformers shows that some transformers are renewed even before they reach the end of their technical life cycle.

The background of this solution is that the renewal of the transformers at the end of their life cycle collide with other resources considering the declining budgets and the aging of the assets in total. This leads to a non-compliance of the budget. To minimize the amount of older assets, the renewal of the old transformers is absolutely essential. Therefore the optimization core has reduced the renewal of other resources in favour of the renewal of the old transformers. So the overall renewal requirements can be reduced.

30-kV overhead lines

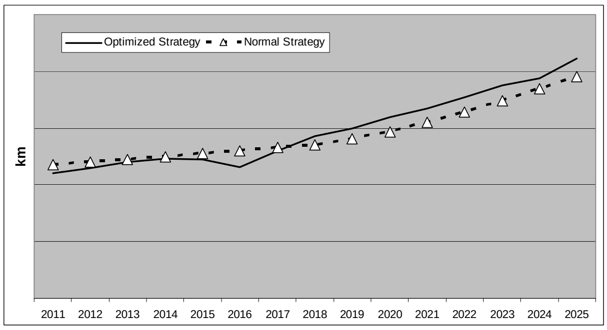

Fig. 4: Conversion of 30-kV overhead lines

Fig. 4 shows that the linear replacement has also a right to exist. Here the normal renewal strategy is confirmed by the optimization. The conversion amount of 30-kV overhead lines into 30-kV XLPE cables is nearly equivalent for each strategy. The slow increase in the amount reflects the age distribution of the 30-kV overhead lines.

Due to a high proportion of assets in good or moderate condition the target amount for replacement in the normal strategy is higher than the amount of old overhead lines with a bad condition. Therefore less assets are replaced as specified by the linear strategy in the early years. Only at the end of the period under consideration more and more overhead lines come to the end of their life-cycle and form the reservoir of measures for conversion.

10-kV oil cables

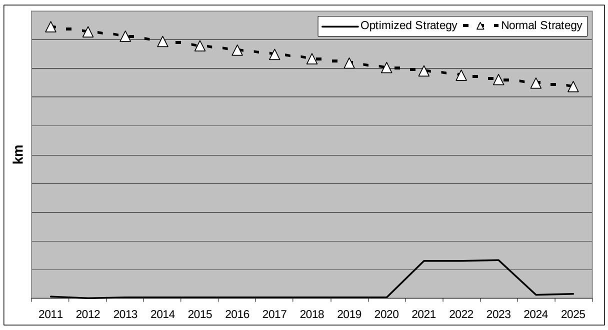

Fig. 5: Conversion of 10-kV oil cables

The optimization reduces the conversion of oil cables into 10-kV XLPE cables almost to zero in the period of consideration (see fig. 5). Again the age distribution of the assets is responsible for the decision made by the optimizer. A significant length of 10-kV oil cables reaches the end of their life cycle just after the period of consideration. Therefore the optimizer reduces the effort for conversion in favour of older assets. The replacement requirements of the entire network are improved by this approach.

This indicates what has to be considered always in a time-limited optimization: The optimizer does not analyze the impacts of his decisions after the optimization period. Like in the given example it's possible that a sharp increase of replacement requirements is generated by the time-displacement of large quantities of older assets at the end of the period of consideration.

EFFECT ON MEASURES OF THE TARGET GRID PLANNING

In conjunction with target grid planning the obtained insights can be used for the preparation or revision of the master action plan. The measures are timed in the action plan based on the optimized strategy and taking into account network-wise boundary conditions. This proceeding gives a sequence of actions which reflects both the technical requirements of a target network topology and the compliance with the budget from target costing.

110-kV overhead lines - non-galvanized towers

As far as renewal is not necessary in the context of network-wise optimization the age-related remodelling of non-galvanized towers is considerably reduced and moved to the time frame of 2018-2021.

110-kV oil and external gas pressure cables

The reconstruction measures in the target grid planning for old 110-kV oil and external gas pressure cables, which were in recent years repeatedly delayed due to budget cuts, are fixed with a "normal" conversion amount in the master action plan from 2013 and increasingly from 2020 with high priority. The conversion projects are part of a package of measures to optimize network topology also leading to a reduction of cable lengths and thus further relieving the renovation budget.

110/30-kV transformers

Due to the possibility of swapping transformers the renewal process of transformers is relatively independent of the remaining measures of the target grid planning. Hence the number of old 110/30-kV transformers which are identified for renewal in the next two to three years will significantly increase. Furthermore the rising use of three-coil-transformers will also minimize the number of old transformers at the same time.

30-kV overhead lines

Various measures to switch from overhead lines to cables in the 30-kV level are timed in the master action plan starting in 2013. Also different 30-kV overhead lines can be shut down through network-wise optimization (e.g. by means of the new construction of a 110 kV primary substation to replace two 30-kV primary stations and corresponding 30-kV overhead lines, see fig. 6). Additionally these measures provide a relief of the replacement budget.

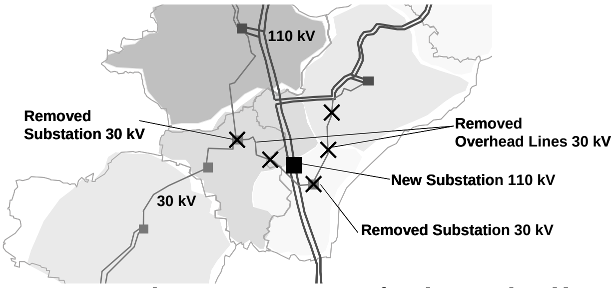

Fig. 6: Network-wise optimization of 30-kV overhead lines

10-kV oil cables

In the next few years there will be no major cable conversion programs in the target network planning. Sole exception will be interrupt- or load-related conversion.

SUMMARY

Under the given budget of target costing an overall increase in the need for replacement and thus the risk of age-related loss of network equipment can be barely avoided (see fig. 7). The "manual strategy" shows the results for a manually adjusted action plan considering a limited total cost of replacement.

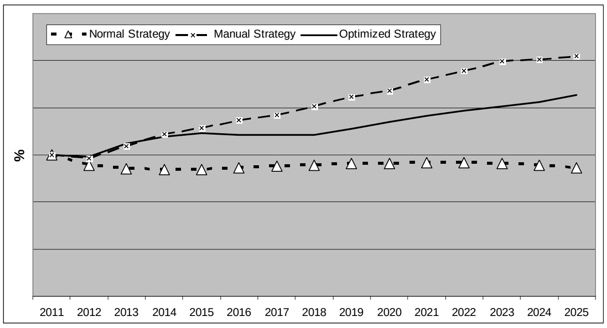

Fig. 7: Proportion of actual repl. value on older assets

However with the choice of smart timing the replacement actions provides the ability to the asset manager to deflate this increase to a more acceptable level which is represented by the "optimized strategy". In the long run this approach is not sufficient to maintain the current network state. Nevertheless in the context of target grid planning the presented optimization helps gaining time in order to further optimize network structures and minimize the costs for renovation, maintenance and operation.

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