TARGET PLANNING OF ELECTRICAL DISTRIBUTION GRIDS
AS A FUNDAMENTAL MODULE FOR A SUCCESSFUL ASSET MANAGEMENT

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ABSTRACT
The field of duties and responsibilities of the asset management of electrical distribution grids has increased in recent years. Long-term oriented target grid planning forms an essential base of these assignments. This paper describes the actual and future demands of this fundamental planning process. Besides a detailed explanation of individual methods and used tools selected key figures and case studies will be imparted.

INTRODUCTION
Demands on electrical distribution grids are getting more and more complex and multifaceted. Regulatory requirements, the present age distribution and increasingly growing dynamics of load and supply scenarios create a contradictory context where the asset management has to find the mandatory balance between all challenging requirements. A fundamental module for a successful asset management is provided by a holistic target planning of distribution grids considering the described demand portfolio as a whole.

OBJECTIVE
In this context a self-contained view to future target grid structures of the higher voltage levels of a large german distribution network operator has been developed. Different demands are considered equally including economics, a dedicated investment catalogue, technical grid capabilities, utilisation of geographical possibilities of the supply area and as a matter of course supply reliability (see ill. 1).

Both large special contract customers and larger municipal utilities are embedded in an integrated concept in equal measure. Regional specific developments like the industrial change of structure demand a spacious examination of the complete supply area. Long-term replacement and refurbishment programs considering the supply area as a whole are integrated in the best possible way.

Within the scope of target grid planning the best possible network structure is developed and evaluated in technical and economical scales. Due to the entire size the complete grid should normally be divided into smaller regional units; for instance independent high voltage network groups. The process of target grid planning can comprehend a mid- resp. long-term range of about 10 to 15 years.

Technical View
From a technical point of view the aim of this planning process is a „young and lean“ distribution grid excellently positioned for all further demands. The mentioned criteria „young“ and „lean“ are evaluated by means of the development of both the asset base and the quantity structure (see ill. 2).

The degree of amortisation calculated for different equipment classes represents a fundamental indicator for the age distribution. Hence this indicator yields an approach for dedicated allocation options of investment budgets. Regarding existing strategies to optimise network access fees asset base segments as well as life cycle costs are excellent optimisation parameters for comparisons between target and actual grid structure. Sophisticated conclusions concerning supply reliability will be possible by the use of probabilistic methods.

III. 1: Growing demands towards distribution grid structures

III. 2: Economical evaluation of target grid structures
Besides the described target grid structure the planning process yields a master catalogue of concrete individual projects facilitating the transfer from actual structures towards target structures. This project catalogue is provided with both a selected investment volume and an approximate time schedule. This essential documentation component serves as a „road map“ to attain the target grid structures.

**Process View**

Among the described technically oriented aims the master project catalogue provides further process-related improvements. Essential coordination between planning, construction and operation can be kept to a minimum. Decisions will be transparent and comprehensible. All involved parties can share a common view towards the future layout of distribution grid structures. The direct responsibility concerning the individual work of all persons in charge will be increased considerably and hence strengthens the common direct responsibility of the entire process.

**TOOL COLLECTION**

Target grid planning works with a set of different tools which enable the development of grid structures from the perspective of technical grid capabilities, economics and supply reliability. The evaluation of the technical grid capability requires information about the future supply tasks and the existing grid structure. The long-term economic efficiency is closely connected to targeted investments that strongly reduce annual operating costs. Formerly used versions of the (n-1)-criterion for the determination of supply reliability are supplemented with probabilistic methods. Ill. 3 gives an overview of the close connection between the tools.

**Geographical Representation**

The development of target grids in higher voltage levels considers the subordinate medium voltage grids which take local distribution functions. Therefore a geographical representation containing many different information has been designed. This includes among others the spatial and topological extent of the supplied medium voltage grids and their load centres, information about the years of construction and long-term refurbishment programs as well as the feeding from the overlaid transport systems. The whole distribution grid was divided in 16 so-called target grid areas. Ill. 4 shows exemplarily the existing structure of one of these target grid areas.

![Ill. 4: Exemplary target grid area](image)

Based on these geographical representations useful substation positions are determined. For this purpose the existing medium voltage grids, the position of major clients and the distance to existing positions of the substations are considered. Especially for old substation positions a displacement makes sense if the supplied load centres have moved. Typical reasons are the declaration of new commercial areas or the discontinuation of a single major consumer. Such a relocation usually takes place at a time when the existing substation has reached the technical durability and a complete refurbishment or a new construction is necessary. On the economic side all costs including the activities for reorientation of the subordinate medium voltage grids have to be considered.

Using existing development prognoses the actual load data are forecasted to a range of about 10 to 15 years. Demographic studies which consider the change of population for every administrative district provide a basis. For example the declining population in the northern part of the Ruhrgebiet in the mentioned period can be estimated. Also an increasing population in parts of the Münsterland which is located approximately 50 km north can be found. This means that there will be no increasing population and loads in total, but there will be a considerable reallocation in the whole supply area.

**Technical Grid Capability**

The technical evaluation of the identified substation positions and the assigned forecasted loads is executed by established network calculation tools (Load flow, Short circuit). The main focus is the arrangement of a capable supply network which is sufficiently dimensioned especial
under fault conditions. As boundary conditions the determined faults and the tolerance band of technical criteria in the strategic planning principles have to be mentioned.

Therefore the feeding substations from the overlaid transport system, the complete 110-kV- and 30-kV-grids as well as maybe existing reserves in the medium voltage grids are considered. This is to satisfy the demand of calculating the whole distribution network including the medium voltage level. Ill. 5 shows exemplarily a part of the network calculation.

Ill. 5: Exemplary part of the network calculation

Especial in the 110-kV-level an unconditional reorientation of the line system is normally not possible because the constructed overhead lines are tied to approved routes. So often the only opportunity is the construction of a new wire on empty positions on the overhead line poles as well as the change of the wire to a wire with a larger profile or high temperature wires.

An important planning step is the configuration of the feeders from the transport system. Due to the focus of supply reliability the subordinated 110-kV-grids are usually operated in ring structures and at a high intermeshed level. Hence these grids naturally provide reserves in case of a breakdown of certain connections to the transport system. In consequence of the integrated consideration of both voltage levels the abandonment of intrinsically safe feeding points from the maximum voltage level can be compensated efficiently by the existing or expanded distribution capacity in the high voltage level. The fact that different network operators take responsibility for both voltage levels has to be considered. Therefore an aggregated solution must not lead to an single-sided cost burden, e.g. the distinct expansion of the high voltage grids and the abandonment of intrinsically safe feeding points. Rather a well balanced solution which distributes the advantages and costs equally among all concerned parties has to be aspired.

Economical Evaluation
Besides the geographical options and the technical boundary conditions the economical evaluation of the grid structures as the third column of target grid planning has to be mentioned. The life-cycle costs are estimated by the necessary investments and the operating costs during the technical durability. These portions of costs have been determined for different equipment groups and compressed for typical network structures, e.g. target structure of a substation.

Based on these specific costs the quantity structure of the existing grid as well as the established quantity structure of the target grids are evaluated. The quantity structures are calculated on the detailed level of a single equipment. Differences from valid target substation structures according to the strategic planning principles are considered per equipment.

A comparison of costs between the existing grid and possible target grid options gives an indication of the development of the asset base and the annual operating costs.

Supply Reliability
As a further step the established network calculations have been completed with the determination of supply reliability by means of probabilistic methods. Additional results are for instance the probability of failure or the omitted amount of energy not supplied to the subordinated medium voltage grids. This addendum to the conventional (n-1)-criterion offers the possibility of an additional distinction between otherwise similar planning alternatives.

In particular, grid areas can be identified which show a supply reliability level varying significantly upwards or downwards. These outliers can be restored to average levels by use of selected individual projects. Representative project examples are the modified grid connection of particular substations or an enhanced automation level.

This method of calculation is generally implemented as an additional module of network calculation tools. The essential identification of failure areas and rebuilding strategies require the additional acquisition of all circuit breaker positions and the present automation level (remote control vs. hand operated equipment).

Documentation
The process of target planning yields a detailed master catalogue of concrete individual projects permitting the transfer from actual structures towards target structures.

The individual projects are provided with according investments calculated by the above-mentioned economical evaluation tools. The temporal distribution of the individual projects results in an overview of all annual investment budgets. The adjustment with the existing investment possibilities subsequently yields a fine setting of the temporal project distribution. Against the background of regulatory requirements the temporal extension will be the normal case in future.
Besides a comprehensive demand analysis all essential individual projects are substantiated and described in detail. This documentation provides a basis for the subsequent process of concept planning.

Furthermore this consistent grid planning process gives the opportunity of regarding additional long-term programs. The occupation situation of grid service providers will become more transparent especially for longer periods and hence provides a basis for own optimisation approaches.

SELECTED EXAMPLES

The examination of actual replacement values identifies a wide variety of the asset base in different capital assets. Typically the main individual positions are the high voltage line system, the switchgear and the high voltage transformers (see ill. 6).

Due to this distribution the investment allocation has to be balanced between the line system, the substations and the transformation section. Deviations from a proportional investment allocation are motivated by various additional parameters.

The individual capital assets feature different asset depreciation ranges and technical optimum degrees of amortisation. Exemplarily ill. 7 shows the current and the technical optimum degree of amortisation of the considered capital assets.

Generally capital assets with small differences between the two values tend to require a lower level of investment than capital assets with a current value exceeding the technical optimum.

Ill. 7: Degrees of amortisation of different capital assets

The selective allocation of investment budgets differentiated by the capital asset classes leads to a complex but easy to apply controlling tool influencing even the concrete individual projects. For instance technical and economical similar planning alternatives can be evaluated in the scope of an additional decision criterion optimising the investment allocation between different voltage levels.

Besides these consequences towards the investment aspects the impact on operational costs always has to be regarded concerning the sustainability of life-cycle costs. Ill. 8 shows a regional developed planning alternative which abandons the subordinate medium voltage grid in favour of the high voltage level. This specific reduction of the quantity structure yields to a sustainable reduction of operational costs amounting to more than 20%.

Ill. 8: Regional planning alternative

CONCLUSION

This paper describes the current demands on the long-term oriented target planning of electrical distribution grids. Besides the well-known technical implications on future grid structures the processual advantages of this process are accentuated in particular. The developed controlling tools offer enhanced possibilities to manage investment budgets as well as concrete individual projects.