PROACTIVE NETWORK PLANNING IN MEDIUM VOLTAGE LEVEL

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1. Overview

Due to the expansion of supply-dependent generation plants and the integration of flexible loads such as electric cars and energy storage systems the infrastructure in the medium- and low-voltage networks reaches its limit of operation. Distribution system operators face the difficult challenge to provide a reliable, secure and yet cost-effective energy supply network within their area of responsibility. This paper introduces a proactive two-step network planning approach for the medium voltage level which will support distribution system operators in their network planning process. This is achieved by taking into consideration the courses of existing lines in order to establish a more realistic reference network in the first step. In the second step, the reference network is divided into individual expansion measures and optimal realisation times by using the Discounted-Free-Cash-Flow (DFCF)-method under consideration of the regulatory framework.

2. Methods

The planning process is divided into the reference network planning and the expansion network planning each of them representing an individual step during the proactive network planning approach.

2.1 Reference network planning

During the frist step a street-graph for the relevant network area is determined based on the geographical raw data which includes the current network and additional line routings. The relevant street and network data is filtered and transformed into a weighted adjacency matrix in a node-branch model, which represents the degrees of freedom in the reference network planning process. The geographical position of the network nodes, representing the future supply task, are amalgamated with the available realistic routes of lines by determining the closest point in a route of the line for every network node using k-nearest neighbour search [1].

To limit the degrees of freedom to a manageable amount, particularly long line routings are eliminated by using the Dijkstra algorithm [2]. In addition, dead end streets without substations are deleted from the street-graph, as these are not relevant for potential line routings. This results in a reduced street graph which minimises the lengths of the connections between the substations and neglects economically cost-inefficicent line routings. Thus, a network of all possible functional connections between the substations is generated in which the nodes of the network represent the substations and the branches of the network describe possible connections.

Using the Delaunay triangulation [3] and ant optimisation [4], a reduced network of functional connections in ring topology is determined to reduce the degrees of freedom within the network development. Subsequently, an amalgamation of the reduced street-graph and the graph with functional connections of the substations in ring topology is performed. The nodes of the triangulation are weighted by projecting the shortest paths of the street graph to the triangulation. This enables a back calculation of the utilised streets for realistic line routing.

2.2 Expansion planning

In context of the expansion planning a herusitic development of expansion plans is implemented. Thus, expansion measures are assigned to different realisation times. If the developed expansion plan fulfils the technical requirements of a secure and reliable network operation, an economic evaluation is applied. This evaluation is based on the shareholder value concept and uses the DFCF-method in order to quantify the influence of the expansion plan on the markt value of the company. The method is continued until a technically permissible and economically optimal plan is identified.

3 Results

The exemplary investigations show that a consideration of the current network structure and additional geographical data provides significant advantages for reference network planning. First of all, realistic and practical line routings in the reference network are ensured. On this basis it is possible to point out cost reduction potentials by considering a multiple use of trenches within the optimisation process. By using the current network structure as input data a high correlation between the line routings of the current and the reference network is obtained. Thus, the reference network can be reached from the current network structure with a few changes. In Firgure 1 the line routing of the current network and the reference network is presented. Every route where the two networks do not overlap represents an expansion or a reduction planning measure.

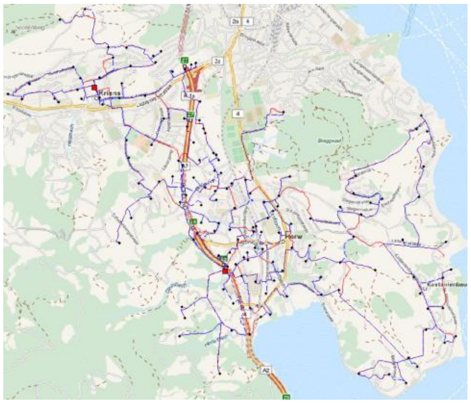

Figure 1: Line routing of current and reference network

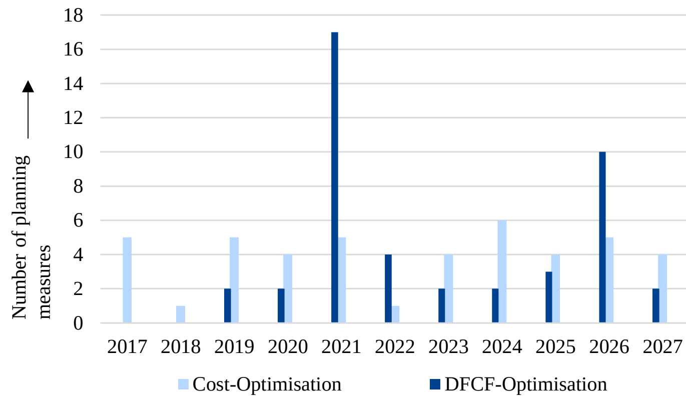

Figure 2: Realisation times of planning measures

In the following step, the expansion planning was applied on different optimisation strategies. Cost-Optimisation, as state of the art approach, which assumes a perfect regulatory framework [5], whereas DFCF-Optimisation considers imperfections of the regulatory framework for optimising according to the shareholder value. Both optimisation strategies were evaluated by the resulting DFCF, because of its racial relevance in order to determinate the shareholder value. The investitgations show that the Optimisation under consideration of the regulatory framework results in higher DFCF. This can be explained by present imperfections in the regulatory framework, which causes that specific realisation dates result in higher revenues than others. Figure 2 shows that the imperfections lead to an increased amount of planning measures in specific years, especially 2016 and 2026, within the planning horizon.

4 Conclusions

For todays and future urbanisation, alongside with the flexibility of load as well as the ongoing electrification and the possibility of curtailment of renewables, a proactive network planning becomes necessary. In times where these changes apply in even higher paces, network planning has to cope with more geographical and technical restrictions.

The refence planning process enables a more detailed analysis of security and reliablility of the grid operation already in the optimisation process. As especially the voltage stability depends strongly on the resulting length of lines, taking specific geographical restrictions per area into account simplifies the remaining effort for the network planner in the expansion planning. Additionally, due to the realistic routes of lines and the consideration of the current network, the multiple use of lines can be considered within the economic assessment.

For the expansion planning it can be concluded, that under consideration of practical regulation frameworks an optimisation of the DFCF is strategically more useful for investment planning of distribution network operators. The investigation shows that the shareholder value is effected by specific realisation dates within the regulatory framework.

5 References

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