UTILISATION OF RELIABILITY AND ASSET MANAGEMENT TOOL IN STRATEGIC PLANNING

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ABSTRACT

Strategic planning has become a significant element in the electricity distribution. Requirements and commitments to distribution system operators (DSOs) have increased and ageing distribution infrastructure causes its own challenges. At the same time the efficiency of computers has increased and software development has been quick that has provided utilisation of computer aided distribution system analysis and development. Nevertheless, there are some deficiencies in the utilisation of analysis tools in strategic planning from the basis of creating alternative scenarios. This paper presents results of utilisation of reliability and asset management tool in the strategic planning. With the network analysis tool that is developed to strategic planning purposes it is possible to efficiently compare network development strategies.

INTRODUCTION

Computer aided electricity network design software have been developed several decades. At the beginning the aim of design software development was to create tools to compute network planning tasks, such as define reliability of network [1] and allocate new line routes and size conductors optimally. Since then, there have been implemented numerous features to computer systems to facilitate network planning, such as different optimisation task (placing of automation devices [2], [3], reliability) and asset management using network information systems and other required assisting programs. However, the usability for purposes of strategic planning has not been the basis of the systems. In addition, electricity distribution business is guided by economic regulation that has not traditionally been taken into account in network analysing systems. It is common for all the optimisation tasks that they can be written as cost minimisation function that is a traditional way to define planning task in distribution network planning

$$\min C = \int_0^T C_{\text{capex}}(t) + C_{\text{opex}}(t) + C_{\text{outage}}(t) dt, \qquad (1)$$

where C are total costs, C_{capex} are costs of capital expenditures, C_{opex} are costs of operational expenditures, C_{outage} are customer outage costs and T is lifetime of network.
Utilisation of computer based design system needs a lot of data that requires network information system and customer information system. For instance, load flow calculation needs quite detailed information of the distribution system and the loads. The same network information can also be used in reliability based analyses, but in reliability analysis it is also required extensive fault statistics to assess state of future that can be compared with present state.
Electricity distribution sector faces challenges from several directions. The infrastructure is ageing, reliability of supply should be improved and distribution fees should be decreased. The requirements indicate the need of good strategy for the next years. For instance, evaluation of ageing combined with reliability needs diversified analyses where the reliability question is studied at the same time as the question of the old networks. The toolbox of the distribution system operators has enlarged since the computers have become common. It makes easier to exploit the computer software in strategic planning. A good strategy takes into account the age of network, reliability, electro-technical and mechanical condition of the network and environmental factors [5]. The strategy provides keys for the distribution system operator to manage the state of change and guidelines to network development in the long time scale.
Figure 1 illustrates the strategy process that includes the strategic analyses, strategic decisions and assessment of the strategy. At first, strategic analyses have to be carried out for the basis of the strategic decisions to select the long term strategy that can be, for instance, underground cabling in any network circumstances, such as rural areas in difficult ground conditions. The last phase is to assess the best ways to implement the strategy that is decided to be applied. However, it has to be borne in mind that underground cabling is only one of the possible strategies that is a result from several analysis.

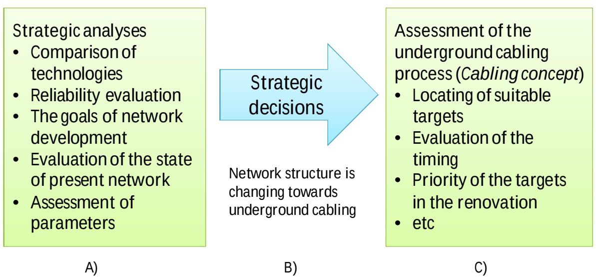

Figure 1. Simplified description of strategy process in network development where underground cabling is the chosen strategy.

For the strategy, a lot of analyses have to be carried out. At the beginning, the information of the analysed system has to be gathered. The goal is to process exploitable results from the initial information of the network, but there has to be many algorithms between the phases. A rough chart of the phases is presented in Figure 2.

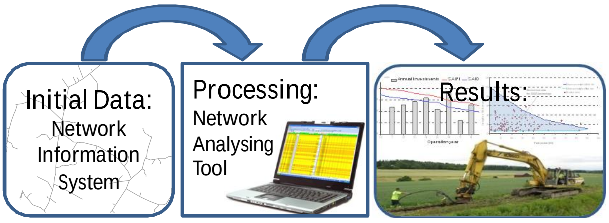

Figure 2. Process from raw information to useful results that can realize in the network as implementation of chosen strategy such as underground cabling.

This paper introduces results of developed reliability and asset management analysis tool for strategic planning. The development work is carried out in cooperation with Lappeenranta University of Technology and Asset Vision Ltd.

ASSET MANAGEMENT

Electricity distribution is a capital intensive business, and therefore asset management plays a key role in the operation of an electricity distribution company. Electricity distribution networks have been constructed within several decades, and in several cases the networks are mainly over 30 years old. This means that the networks have to be renovated soon. A typical lifetime for overhead line is 40 years because of the lifetime of wood poles. The ageing problem is illustrated in Figure 3 that discusses the age of wood poles in a Finnish distribution network utility. At present, 65 % of the poles are over 30 years old that is a signal that approximately 65 % of the network have to be renovated during next two decades if the age of poles is not allowed to exceed 50 years age.

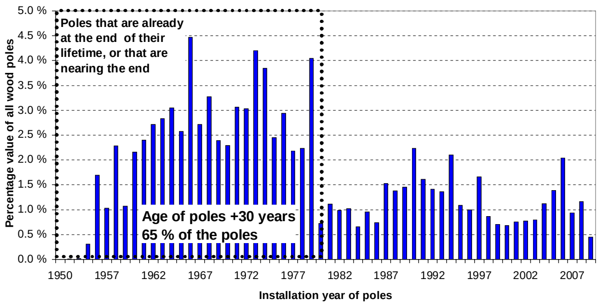

Figure 3. Age structure of medium-voltage network wood poles from a Finnish distribution network.

The difficulty in the renovation is the question of how it should be made. Replacement of the original overhead lines with similar components would be easy and often a cheap solution, but requirements for the maintenance and reliability do not support this alternative. Often old lines are located to fault vulnerable forest areas and possibly far away from the roads, which makes it difficult to locate faults, and at the same time, increases faulting probability. In addition, economic regulation affects asset management when the regulator defines the guidelines for the network development such as valuation of aged line sections.

RELIABILITY ASSESSMENT

Reliability evaluation of the networks is an important factor in the strategic planning. DSOs have to assess the performance of the network because of commitments, customer satisfaction, and economy, and possibly because of tight limitations by authorities or law. For instance, low reliability may cause external pressure against the DSO. In Finland there is a recent example after winter storms, when two week outages occurred in large areas in the electricity networks. A result of publicity is that the authority clarifies if there are enough incentives to avoid long interruptions [6].
Assessment of reliability requires good fault statistics. This means for the DSOs that statistics have to be gathered from a long period of time because annual variation in the fault statistics can be significant. With sufficient statistics, reliable fault rates can be formed for the future evaluation of the system. In Figure 4 permanent fault statistics are presented from a Finnish distribution network.

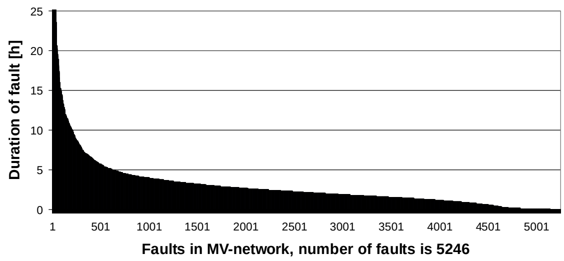

Figure 4. Distribution of faults in medium-voltage network from eight year period (2000-2008).

ECONOMIC REGULATION

Economic regulation is typically arranged nation widely. However, there are similarities in the regulatory models. For instance, reliability is included almost without exception in the model. Some countries have connected profits of distribution system operators to supply reliability. In Finland and Norway interruptions are valued to monetary costs that effect on the profit that is a straight incentive to invest in reliable network. In addition, in many countries other mechanisms of reliability are implemented in regulation. For instance, standard compensations can be paid to customers, when the duration of interruption exceeds a certain time limit. Even the reliability issues have high importance in the regulation, they are just a piece of the model; for instance, the profit of the operator is dependent on the network valuation. Thus, the effects of economic regulation should be taken into account as an entity in strategic planning that has also been the idea in the developed asset management tool [5].

ANALYSIS TOOL IN STRATEGIC PLANNING

Strategic planning consists of several subtasks that can be, for instance, profitability analysis of increase of automation such as circuit reclosers [7], potential survey of targets to apply 1000 V low-voltage technology [8], exploitability of roadsides in the line installations and consideration of load growth. Usually, the subtasks have to be carried out before the proper network strategy process can be studied because the subtasks are often an outline for the deeper strategy analysis, that is, for instance, the situation with the study of automation and 1000 V technology. There is no sense to consider large-scale strategy that is based on utilisation of 1000 V technology in medium-voltage network, if the network does not contain suitable branch lines. Figure 5 describes the potential of 1000 V technology in a Finnish distribution system. It can be observed that potential is significant in this particular network, because significant amount of all medium-voltage branch lines are operated with suitable power.

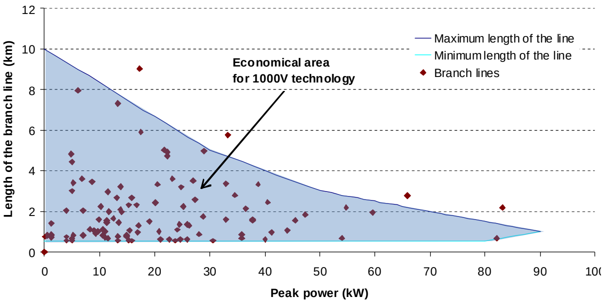

Figure 5. Profitability of 1000V technology for branch line targets in a Finnish distribution network [8].

Potential analysis of recloser placing is based on profitability analysis that considers possible recloser locations with selected criteria. Usually the criterion is ecomimic profitability but it can also be reliability. Figure 6 illustrates profitability of recloser installations in a medium-voltage feeder, where the best installations provide over 25% reducing in outage costs that are 10000 €/year in the feeder. This indicates good profitability in the recloser installations in the analysed feeder, because the annuity of recloser investment is under 3000 €/year. However, there has to be studied a larger network area for the potential survey of

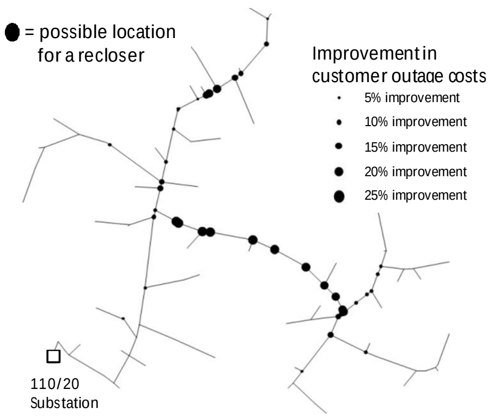

Figure 6. Improvement in customer outage costs in a studied medium-voltage feeder.

recloser installations of the whole system.

Managing the age structure is one of the key elements in strategic planing as well as development and maintaining the reliable electricity supply. Therefore, for the purposes of strategic planning in the analysis the age structure of the network should be simultaneously monitored when network renovation strategies are studied. Network strategies that can be evaluated in the analysis are, for instance, traditional overhead line strategy, covered conductor overhead line to roadside strategy, underground cable strategy and utilisation of 1000V technology in low loaded medium-voltage lines. In addition, there is an opportunity to vary the strategies by changing the order of renovation, such as from where the network renovation is started. An example of assessment of age, reliability and costs of investments are presented in Figure 7 and Figure 8, where the development of ages of wood poles during investment program with different renovation strategies and average estimated reliability related to investments during a selected renovation strategy are presented. However, it has to be noticed that average reliability indices cannot be used to measure the supply security of a single customer. For this matter there have to be separate evaluation methods such as stochastic risk assessment that provides an opportunity to define the worst performing network sections.

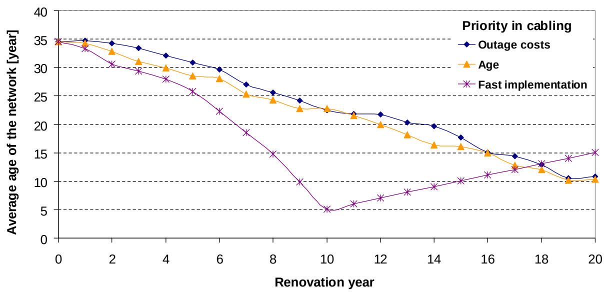

Figure 7. Development of average age of wood poles in Finnish medium-voltage network feeder in three different underground cabling strategies.

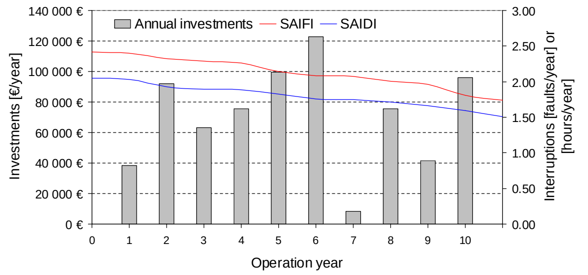

Figure 8. Annual amount of investments and development of general reliability numbers of SAIFI (System Average Interruption Frequency Index) and SAIDI (System Average Interruption Duration Index) after the investments.

Strategic planning answers to the question; what is the long-term strategy that fulfils the goals in the future. It can be defined in the strategy that security of supply should be at a certain level in the year 2025 that acts as boundary in the strategic planning. In this kind of analysis the performance of the network is measured with the worst performing section. Thus, reliability assessment has to provide information of the areas where the risk to experience most interruptions is most significant, and how long interruptions will the customers experience [9]. Figure 9 presents an interruption risk assessment of a rural area distribution company where three parallel development strategies (1st *pole renovation* of existing overhead line network, 2nd utilisation of *1000 V* technology in low loaded medium-voltage branch lines and changing poles in the other line sections and 3rd full scale *underground cabling*) are compared with each other in the annual interruption time with 25 % exceeding probability. 25 % exceeding probability means that every fourth year the marked interruption duration is realised. For instance, customers of substation that locates in the worst performing network section experiences in pole renovated network at least 8.5 hour annual interruption time every fourth year.

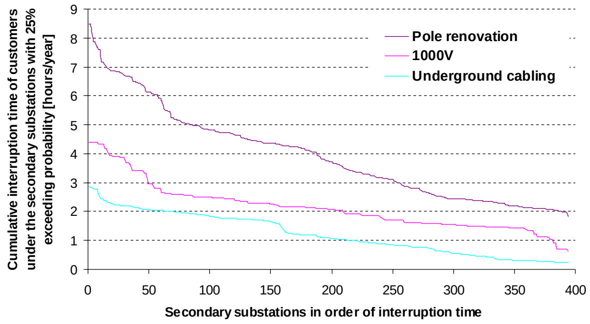

Figure 9. Interruption time of customers under secondary substations with exceeding probability 25% in the considered distribution network.

CONCLUSIONS

Strategic planning plays a key role in the preparation for the future in electricity distribution sector. Asset management and reliability analyses are an essential part of the strategy of distribution system operators. For the purposes of strategy concept an analysis system that contains the main tasks of strategic planning has been developed. The analysis tool can be used to assist the operator to evaluate the strategy options and support decision-making. The key elements in the analysis tool are:

1. Potential and profitability surveys (for instance, survey of branch lines, potential of circuit reclosers)
2. Age monitoring
3. Reliability analysis
4. Comparison of strategy options

Even the paper presents results of strategy analyses that focus in several cases on underground cabling, it has to be borne in mind that there are no universal development technology (strategy) that provides best result in every case. This requires case specific studies where suitable development technologies are analysed carefully. Strategic planning assistant tool is a suitable instrument to this. It provides opportunity to analyse the network development effectively. Reliability analyses and asset management can be combined with the tool, which is important in strategy making.

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