Profitability analysis as a part of medium voltage underground cable network condition management in the distribution network company

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Abstract

The condition management of underground networks is based on electrical measurements. The objective of the measurements is to provide information for the networks' operator on the condition of the network and helps to make the right maintenance and investment decisions.

The condition management of the cable network requires good knowledge of the structure of the network and its state for networks operator, which is based on the cable database construction and its exploitation. One foundation of the cable database is the information, which cable measurements and testing produce. By using information from cable database the condition of the cable network can be assessed. Combining this with the reliability-based network analysis, which allows carrying out different kind of analysis, the maintenance actions can be prioritized and allocated correctly. In this way, the important economic aspect has been taken into account too.

The purpose of this paper is to define the profitability of the measurements and testing considering the above-mentioned economical aspect together with the current network structure. In addition, there are different kinds of factors which may have an impact on the profitability of the measurements which also will be described.

1. Introduction

In the year 2006 Vattenfall Verkko Ltd. (later VFV) started developing a weatherproof network. For this reason, cabling has become a prevailing construction method. The cabled medium voltage network has formed only a small part of the whole network earlier, but the situation will be changing quickly in the future. This creates the need for systematic condition management of the cable network.

The purpose of this study has been to analyse and bring forth suitable methods, which can be used in the cable network's condition management, from inside the Vattenfall concern and elsewhere in the world. The suitable methods have been examined by benefit calculations. The profitability analyses have been implemented through the network business result's formation, when it has been possible to verify a straight connection between cable diagnostic and result of the network business.

In the case of VFV, the distribution network is located within quite a large area in geographical aspect and this causes challenges for the development of the cable network condition management strategy. The geographical factor has been taken into account in the benefit calculations, and the analysis has been made for different type of areas. The division of these areas is based on the reliability criteria which can be regarded as a meter for the customized reliability and which give planning criteria in the future. The construction of the network, construction conditions, customers and their placing depends a lot on the area, as the condition management strategy establishment has to be based on the prevailing conditions of the each area.

2. Construction strategy

VFV has chosen large scale cabling its building strategy of the network. The new installation methods, cheaper prices of the components and installation work have brought the costs of cabling and overhead lines construction closer to each others. Figure 1 presents the cumulative length of the medium voltage cable network from the year 2005 to the year 2010, and in addition shows a prediction of the coming years' developments in the case of VFV.

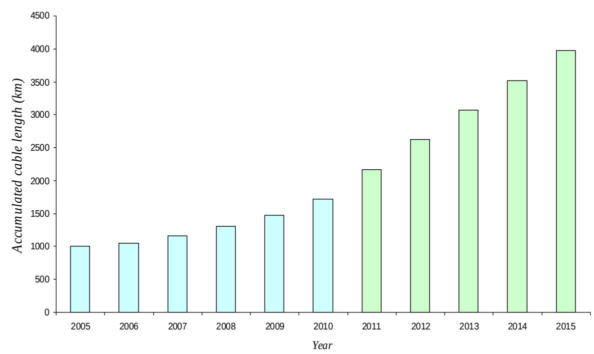

Fig. 1 - VFV's accumulative medium voltage cable length each year and estimation of the future.

The total length of the medium voltage cable network was about 1470 km in the end of year 2009. The strategic construction decision and the old cables' location create the biggest input for the condition management strategy development for the medium voltage cable network.

3. Cable networks' failure profile

3.1. Medium voltage cables accessories

Joints and terminations are very often the weakest points in a cable network, because the stress of electric field is bigger than elsewhere or not as evenly distributed as in the cable itself. Joints and terminations are also likely sources of defects leading to cable system failures. Even if the manufacturing process of joints and terminations are high quality, their failure rate is still high, due to their manual assembling. [1] In figure 2 below are presented joints and terminations portion of MV cable network failures.

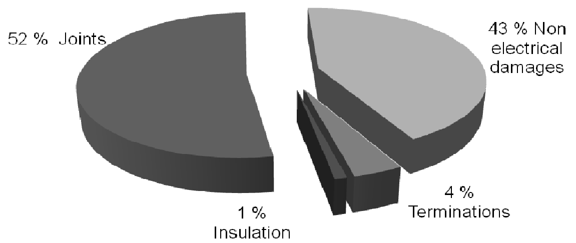

Fig. 2 – Failure profile of the MV cable network. [2]

Consequently, improper stress control is the main reason which leads to failures in cable termination. Other risk factors may be tracking, erosion or weathering of external leakage insulation and ingress of moisture. The joints have almost the same factors as termination, but voids in insulation and inadequate insulation may be added to the list. [3]

3.2. Installation and installation methods

A large part of cable damages occur in the cables' installation situation. Another risk factor is the challenging and variable soil in Finland. In the past there was only one installation method and it was normal digging. Trench digging by using an excavator is quite slow and the growing interest in cabling has caused the need to find new alternative installation methods such as ploughing. In figure 2 non electrical damage portion of MV cable network failures are presented.

4. Studied cable diagnostic methods

The cable diagnostic methods in this study consisted of three different kind of concepts. The first one was the portable online diagnostic process, which consists of partial discharge screening and monitoring measurements. The second one was the permanently installed continuous online PD monitoring unit. The last one was off-line diagnostic method which based on the combination of PD and dissipation factor measurements. The online PD diagnostic methods are described in more detail in [4].

5. Results formation and regulation in the network business in Finland

The electricity network business is a monopoly business and due to this character it is under supervision of an authority. The supervision is designed to encourage the network owners to develop operational efficiency and to keep the pricing of electricity transmission reasonable at the same time.

The creation of the allowed return affects different kinds of factors. In the figure 3 is presented a supervising model which is in use at the moment and includes the supervising period 2008-2011.

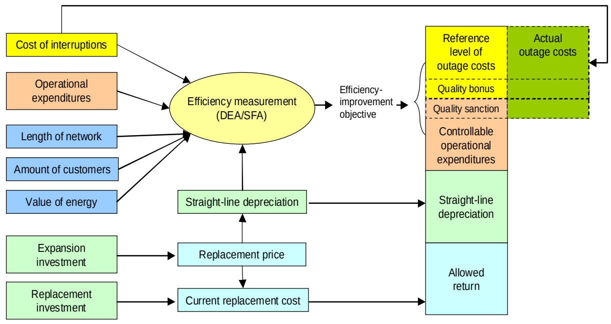

Fig. 3 - Supervising model 2008-2011. [5]

Considering the cable diagnostic, the sections of the supervising model which the cable diagnostic have an impact on can be easily identified. Commissioning of the measurements and the installation of the monitoring systems require operations which cause operational expenditures. Some of these operations, especially off-line diagnostic need planned outages which have an influence on the costs of interruptions. The normal failures also have an influence on the actual outage costs.

Table 1 - The one part of the principle of calculating actual adjusted return. [6]

Operating profit (or loss) *+ 0.5* Actual outage costs* *+ Actual controllable operational costs* *- 0.5* reference level of outage costs* *- Controllable operational costs in accordance with the efficiency target* **= Adjusted operating profit/loss**
= Imputed profit +/- Other adjustment items
= Profit before taxes - Imputed corporation tax for the enterprise
= Actual profit (adjusted)

The profitability of the cable diagnostic can be also considered from the point of view of the principle of calculating actual adjusted return. In the table 1 the one part of calculation of the actual adjusted return after the computational entity taxes have been described [6]. As can be seen from the principle of calculating actual adjusted return, half of the actual outage costs and the reference level of the outages costs have been taken into account. In addition, there are also included the actual controllable operational costs and as a benchmark, controllable operational costs in accordance with the efficiency target. Thus from the operationally aspect, it is profitable to try to reduce the actual adjusted income, when the risk for exceeding the allowable return decreases.

6. Change factors in the profitability of cable diagnostic

As always, the calculations which are directed far in the future contain a lot of assumptions. It is important to take into account the reliability and the effect of these assumptions when the decisions are made. The versatile tool which could help the interpretation of the results is known as “nine boxes” [7]. The nine boxes where the cable diagnostic is integrated are presented in the figure 4.

There can be seen that the factors which have the biggest influence on the cable diagnostic profitability are located on the upper right and left corners. It should be also noticed that both of these factors contains uncertainty. However, the calculation can be regarded as relatively reliable, because probability of the incipient fault detecting is assumed quite low in the benefit calculation. On the other hand, one important factor which may affect on the profitability of the cable diagnostic is the behaviour of the cable failure frequency in the future. The ageing of cable network in urban and city areas, and increased length of constructed cable network together with new contractors and installation methods may change the failure frequency. The estimation is that outage costs valuation increases which makes the cable diagnostic more profitable than earlier. The second valuable result, which the benefit calculation gave, was that the operational expenditures have quite small influence on the profitability.

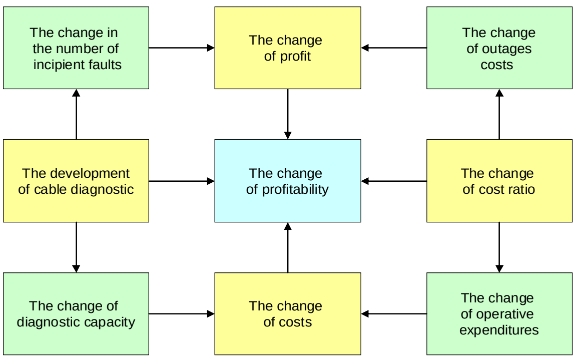

Fig. 4 - The change factors of the profitability in the case of cable diagnostic [7].

7. Operations management

In order for the maintenance actions to be directed correctly, the cables need to be able to be set in the right order based on their condition and interruption risks. In the figure 5 one model of the evaluation process is presented. In this model, maintenance operations have tried to be presented as condition based as possible, which aims to take into account different factors which may have an effect on the need of maintenance actions. The main purpose of the model is to behave as a tool, which could be carried out on the whole cable networks analysis at fixed intervals, by performing calculations and simulations. However, this requires an updated cable database, condition assessment algorithm and reliability based network analysis integration.

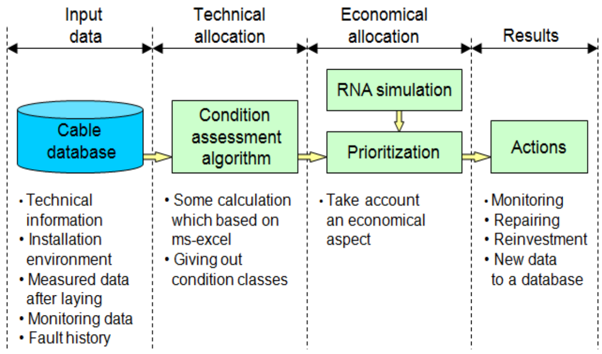

Fig. 5 - The maintenance actions allocation [9].

7.1. Prioritization with the economical aspect

The technical allocation and classification of the cables is not a sufficient way to direct maintenance operation in a sensible way. The economical aspect is also needed. The prioritization can be made by considering the factors which have influence on the network operations in the economical aspect. Some main drivers which could allow the implementation of prioritization are following; the strategic location of the cable in the distribution network (does this cable form the frame, is it a branch or frame line between two primary substations), if the cable section fails, which is the cost of unplanned outages (i.e., how large is the area where the fault in cable causes harm. What kind of customers are there? What is the possibility to limit the fault and how long does it takes?), the costs of forthcoming operations (The cost of organization and planned outages? Can this be done without interruption of the supply?).

If the economical prioritization is not carried out, it could lead e.g. to the following situations; the contractor resources are directed to less valuable targets which can cause undesirable costs, funding problem of the repairing/replacement operations, yearly budgets exceeding which causes that the valuable targets replacement have to be postponed in the future.

After the technical and economical allocation, it is possible to organize all the cable sections in the risk matrix, which is presented in the figure 6 and analyse the state of whole network. The closer the upper right corner the cable sections are located in the matrix, the greater is the need of their maintenance. When the age of the cable network increases, so does the probability of the failure. The points which represent the cable in the risk matrix move upwards all the time. The cable diagnostic and maintenance operations can drop these points lower in the risk matrix. The cross-sectional movement of the points cannot be influenced by cable diagnostic or maintenance operations. It depends on the physical location of the cable. This can be only influenced by the constructional changes of the cable network.

8. Conclusions

At the moment, the cable network part of the total length of the medium voltage network is about 7 % in the case of VFV, but the change through the higher cabling rate is fast. This is due to continued replacement investments, which the age structure and the mechanical condition of the network cause. In addition, the need of replacement investment causes the objectives, which are set in reliability criteria.

At the moment cable diagnostic exploitation as a part of condition management of the cable network is quite new in Finland and there is not a lot experience measurement results' interpretation. The lack of above-mentioned is the one main factor which increases the importance of the prioritization in an economically aspect.

The second reason which supports the profitability analysis is that the single approach of the condition management strategy for the cable network is not possible to establish, because the condition of the cable network may be affected by many different factors. Mainly can be said that the geographically location, the moment of cable life-cycle and role of the cable section determines profitability of the operations.

Based on the study [9], there are no economic justifications for cable diagnostics in the rural areas. It is almost impossible to affect the life-cycle costs of the cable, by the cable diagnostic. Then the only way to affect these costs is the structure of the network. In the urban and city areas the situation is different, when the operations management can be implemented the way as described in chapter 7. Then the measurements which are performed in the condition management purposes based on the limit values of the profitability and the structure of the network.

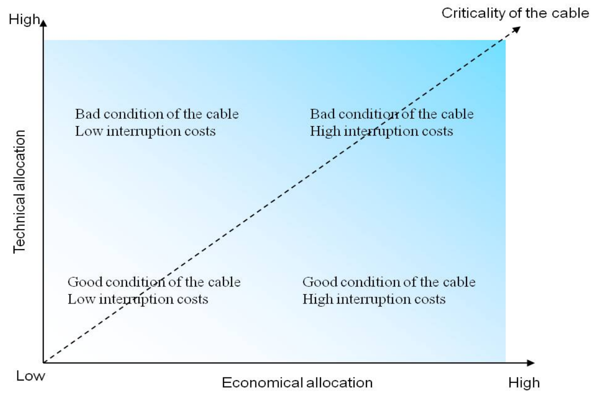

Fig. 6 - Risk matrix for cables. [8]

As the final result of the study can be concluded, that by successfully implemented cable network condition management and cable diagnostic exploitation relating to it, the results of the network business can be influence in a positive way.

9. References

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