DEVELOPING A MAINTENANCE AND REPLACEMENT CABLEING STRATEGY FOR MEDIUM AND LOW VOLTAGE OVERHEAD LINES – A PRACTICAL APPROACH

Walter SCHAFFER  
Salzburg Netz GmbH – Austria  
walter.schaffer@salzburgnetz.at

Manfred ARMELLINI  
Salzburg Netz GmbH – Austria  
manfred.armellini@salzburgnetz.at

Thomas RIEDER  
Salzburg Netz GmbH – Austria  
thomas.rieder@salzburgnetz.at

ABSTRACT

The specific maintenance costs of medium and low voltage overhead lines with wood poles are up to ten times higher compared to cables. A way of estimating the costs for the replacement cabling and the maintenance as accurate as possible for the economic appraisal as well as the economic appraisal itself is shown in this paper. The cost estimation is automated based on the maintenance software tool and the geographic information system. Since improvements of the supply situation are achieved with replacement cabling they have to be evaluated and taken into account.

INTRODUCTION

When comparing the specific maintenance costs of overhead lines and underground cables for medium and low voltage distribution networks it can be seen that overhead lines are up to ten times more expensive. This applies especially to lines where it is necessary to replace wood poles or to clear and maintain vegetation as it can be seen in fig. 1. Hence at least the actual conditions of the wood poles and the demand to clear the right of way are required.

Fig. 1: Cost drivers of low voltage overhead lines

For the economic appraisal the costs of overhead line maintenance and replacement cabling have to be estimated as accurate as possible. To get a sufficient accuracy it is necessary to do this for each overhead line section.

In Salzburg about 1,700 km low voltage overhead lines and 2,200 km medium voltage overhead lines were appraised automatically, by analyzing information and data from existing and fully serviced data bases and systems. Hence a carefully managed maintenance software tool and a geographical information system containing the right data are needed. It is a big advantage when these systems are linked, since database errors are avoided.

COST ESTIMATION

While it is relatively easy to estimate the maintenance cost from historic data, important uncertainties are the costs of the replacement cabling, since they vary depending on parameters like the surface and the underground.

Maintenance Costs

The maintenance costs of overhead lines are split into five classes, as shown in fig. 1:

- Vegetation Maintenance
- Inspection
- Wood Pole Replacement
- Fault Clearance
- Miscellaneous Maintenance

The cost drivers of medium and low voltage overhead lines are the vegetation maintenance and the wood pole replacement. For the wood pole replacement it is important to know the condition of the wood poles. This is essential to estimate the residual lifetime and the time of replacement. At Salzburg Netz GmbH the wood pole replacement is done based on the condition. Therefore the condition of wood poles is in principal monitored by internal experts in a ten years period. The condition is classified in five clusters. The classes 1, 2 and 3 mean that it is not necessary to replace the wood pole within the next ten years. The classes 4 and 5 mean that the pole has to be replaced within the next years respectively the following year.

Within the principal monitoring period of ten years the poles are briefly checked during the yearly inspection of the overhead lines. This inspection is carried out by members of staff.

The vegetation maintenance is in general time based with a period of four years taken as basis. But it can also be triggered by the yearly inspections. Hence there is a smaller part of the vegetation maintenance which is condition based. The overhead lines requiring vegetation maintenance and the corresponding lengths where determined with the help of the geographic information system (GIS), see fig. 2. The specific costs were determined based on historic data.
**Cost of Cabling**

The costs of cabling depend on parameters like the surface and the underground. To estimate the costs more accurate three classes of a so called “habitat density” were defined in case of low voltage lines.

\[
\text{HabitatDensity (LV)} = \frac{\text{Number of Private Connections}}{\text{Number of Poles}}
\]

In this case the private connections connected to the overhead line are counted. This ration was chosen because the focus is on low voltage overhead lines and the cost estimation of replacement cabling for these overhead lines. The classes which are an indicator for the costs of cabling are:

- S1: Single Buildings (farmsteads)
- S2: Low Density (villages)
- S3: High Density (communities, towns)

In case of the low voltage network each line leaving the secondary transformer station was defined as one overhead line section. Each single section was classified according to S1, S2 and S3.

The specific costs for each class [€/m] were estimated as an average value from realized projects. The aim of the partitioning was to find three approximately equal partitions for the classes as well as the specific costs (fig 3 and fig 4).

For the medium voltage overhead lines the definition of a section follows the node model of the network calculation, i.e. each transformer station or branch defines a new overhead line section.

\[
\text{HabitatDensity (MV)} = \frac{\text{Area (LV network)}}{\text{Number of Private Connections}}
\]

In case of medium voltage lines the habitat density was defined a different way long to estimate the cost of cabling as accurate as possible. Hence for each low voltage network the ratio of the area covered by the low voltage network [m²] and the number of private connections of the network was calculated. The area covered by the low voltage network is assumed to be equivalent to the occupied area.

Once again three classes were defined. Yet another class (S0), for overhead lines in unoccupied areas, is required. The cabling costs of this class were assumed to be equal with the costs of class S1, for rural areas. The overhead line lengths within the different habitat density classes as well as the one outside of the low voltage network areas were determined with the help of GIS as shown in fig. 5. Green areas correspond to the class S1, yellow ones to S2 and red ones to S3. White areas are unoccupied areas, i.e. S0.
In case of estimating the costs of medium voltage replacement cabling the kind of connection to the existing grid has to be taken into account. This is essential because the costs of setting up a new secondary substation or to be able to connect to an existing cable or overhead line vary within a wide band. Therefore all nodes were classified with respect to the required type of joint:

- Secondary substation required
- Connect with existing substation
- Joint with existing cable
- Joint with overhead line without modification
- Joint with overhead line with modification

The connection to an existing overhead line with modification means that it is necessary to replace the joining wood pole by a new one. The classification was once again done with the help of GIS.

When the overhead line crosses a street it is assumed that the street has to be crossed by the cable as well. Since this is equivalent to additional costs the street crossings where determined with GIS and classified in two categories, i.e.

- motorway crossings and
- main road crossings.

Another point that has to be taken into account is the length of the replacement cable, since this length won’t be the same as the one of the replaced overhead line section. Hence a factor describing the additional length of the cable was established. For low voltage overhead lines the factor was determined from realized projects. For the medium voltage network this factor was calculated as the difference of the average ration of the linear distance to the effective distance between two nodes for all cables and all overhead lines of the medium voltage network.

The following factors were determined:

- 1.12 for the low voltage level and
- 1.24 for the medium voltage level.

The connection to an existing overhead line with modification means that it is necessary to replace the joining wood pole by a new one. The classification was once again done with the help of GIS.

When the overhead line crosses a street it is assumed that the street has to be crossed by the cable as well. Since this is equivalent to additional costs the street crossings where determined with GIS and classified in two categories, i.e.

- motorway crossings and
- main road crossings.

Another point that has to be taken into account is the length of the replacement cable, since this length won’t be the same as the one of the replaced overhead line section. Hence a factor describing the additional length of the cable was established. For low voltage overhead lines the factor was determined from realized projects. For the medium voltage network this factor was calculated as the difference of the average ration of the linear distance to the effective distance between two nodes for all cables and all overhead lines of the medium voltage network.

The following factors were determined:

- 1.12 for the low voltage level and
- 1.24 for the medium voltage level.

Now the costs of the replacement cabling can be estimated with a sufficient accuracy. This was checked with actually calculated and realized projects. The accuracy was within five percent.

**COST EFFICIENCY CALCULATION**

In case of the cost efficiency calculation it is necessary to discuss the period to be considered. For the low voltage network the period was set to 8 years with respect to

- the uncertainty of the wood pole condition assessment,
- the uncertainty of the vegetation maintenance periods,
- the turnover of the low voltage network and
- the duration of a regulation period.

For the medium voltage network the same period was used to be able to compare the results.

Obviously the change of material prices and wages as to be considered. This is done by using the so called “network operator index”, which is part of the Austrian regulation formula.

Taking the given period of 8 years into account leads to the following costs for maintenance work and pole replacement. This values refer to the replacement of one compound mast (“A-shaped pole”).

<table>
<thead>
<tr>
<th>Cost Comparison</th>
<th>Class 4, 5</th>
<th>Class 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-shaped pole Replacement (£/pole)</td>
<td>1.00</td>
<td>0.75</td>
</tr>
<tr>
<td>Single Pole Replacement (£/pole)</td>
<td>0.47</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Tab 1: Overview of the referenced LV maintenance costs

Therefore it is now possible to compare the overall maintenance costs including the costs of pole replacements with the costs of an eventual replacement cabling. The result is that it can be seen if it is economic to do a replacement cabling instead of the maintenance work for each single overhead line section.

The replacement cabling is the economic solution when the costs of maintenance are high. This is given in case of low voltage overhead lines when either vegetation maintenance for the main part of the overhead line section is required or when most of the poles have to be replaced. In case of medium voltage overhead lines nearly no sections could be
determined where replacement cabling is the economic solution. Although the actual maintenance costs and the maximum maintenance costs where used for the economic appraisal.

![Fig. 7: Results of the MV cost efficiency calculation](image)

In case of the maximum maintenance costs it is assumed that all poles of the overhead line sections have to be replaced immediately. A value smaller than 1 means that replacement cabling is the economic solution. It can be seen that for most of the medium voltage overhead line sections replacement cabling is in average up to ten times more expensive than the maintenance work.

At this point it has to be considered, that improvements of the supply situation are not taken into account since this is not part of the Austrian regulation regime until today.

**TAKING ENHANCEMENTS INTO ACCOUNT**

Since improvements of the supply situation are achieved with replacement cabling it is necessary to evaluate the improvements and consider them. At low voltage level the improvements are mainly archived in the field of power quality. While at medium voltage level the improvements are mainly in the field of reliability. Therefore reliability calculation of the network is necessary. One way to weight the reliability monetarily is to use the Norwegian approach of quality regulation, the socioeconomic optimization. Also this method differentiates between customer groups.

**LOW VOLTAGE NETWORK RESULTS**

![Fig. 8: Visualized result for the low voltage network (GIS)](image)

For the low voltage network the result of the cost efficiency appraisal is a list of overhead lines which indicates if the line should be replaced by an underground cable or not within the next few years. This result of the cost efficiency calculation can be compared or weighted with the improvements of the power quality, i.e. the minimum short circuit power and registered power quality complaints of customers or with the failure statistics referring to single overhead line sections.

**MEDIUM VOLTAGE NETWORK RESULTS**

In case of the medium voltage network it was not possible to estimate overhead lines for replacement cabling without taking technical improvements into account. Using the socioeconomic optimization has the disadvantage that the customer groups are weighted. This will lead to reliability levels depending on the customer groups connected. Another way is to take soft facts like stakeholder values and customer views into account. These are for example the number and duration of outages, matters of nature conservation, the number of houses in view of an overhead line or the building land in the right of way. All of these date were determined by using the geographic information system.

An important point that has to be taken into account is, that the interests of the network operator do not automatically correspond with the interests of the shareholders and the customers.

**CONCLUSION**

In case of the low voltage network it was possible to identify overhead lines where replacement cabling is the economic solution without taking enhancements into account. Therefore a low voltage replacement cabling program is already under progress at Salzburg Netz GmbH.

When considering the medium voltage network at least technical improvements have to be taken into account to find overhead line sections where replacement cabling is less expensive than the required maintenance work. The monetary weighting of the improvements implies the risk of different interpretations of the result. Therefore soft facts like shareholder values will be considered when setting up a replacement cabling strategy.

**REFERENCES**
