RELIABILITY-BASED PLANNING IN RURAL AREAS; GOALS, METHODS, PRIORITIZATION, AND FOLLOW-UP AT FORTUM DISTRIBUTION

Per BENGTSSON, Lars-Åke PERSSON, Kjell OBERGER, and Jörgen HASSELSTRÖM

Fortum Distribution AB – Sweden

per.bengtsson@fortum.com, lars-ake.persson@fortum.com, kjell.oberger@fortum.com, jorgen.hasselstrom@fortum.com

ABSTRACT

In 2005 Fortum Distribution initiated a reliability improvement program in Sweden, denoted SäkraNät. Since then, more than 3000 km of mainly medium voltage overhead lines has been converted to aerial and/or underground cable. In addition, feeder automation and remotely controlled disconnectors has been installed in order to quickly sectionalize faults and restore power upon an interruption. The goal of this paper is to describe the approach Fortum has been using in Sweden to improve reliability in rural and semi-rural areas. The planning process, beginning with goal-formulation, identification of optimal solutions and methods to improve reliability, prioritization and follow-up is described. All finalized reliability projects are followed up and its effect on, e.g., System Average Interruption Duration Index (SAIDI) is measured by comparing recent interruption statistics from historical. The benefit and cost-efficiency of the investments are evaluated and knowledge is transferred back to the planning department for consideration into future projects.

INTRODUCTION

From the late 90’ies the distribution system reliability has been debated in the Nordic countries. There are many reasons for this. Firstly, there have been unusual hard weather conditions. Major storms have, for example, affected parts of the Swedish service areas of Fortum Distribution in 2003, 2005, and 2007. Secondly, customer expectations are different. Traditionally customers in rural areas have experienced more power interruptions than other customers. However, nowadays rural customers expect similar reliability as those living in more dense areas. Thirdly, the energy cost as experienced from the customer point of view has increased the last years following an initial decrease in cost of energy after the Swedish deregulation in 1996. This has put the utilities under pressure to provide some additional value to the customers in the form of increased service (e.g., invoicing alternatives, efficient call-centers etc.) and/or better reliability of supply.

When the concern about reliability issues began to grow in the late 90’ies the initial response from the utilities was to modify their reinvestment strategies to whenever possible move away from open-wire networks in favor of insulated systems. The renewal rate of overhead lines is however anywhere from 40-60 years so the gradual improvement in reliability hardly became noticeable for most customers. Since the utilities shifted re-investment strategy, several big storms have struck Sweden. In more or less every year up until 2006 wide-spread outages occurred resulting in massive interruptions ranging from 12-72 hrs. The worst storm (named Gudrun) hit southern Sweden in January 2005. The effect was devastating and led to power interruptions of over 300’000 customers on a national level. After one week still 65’000 customers were without power. It took an additional 5 weeks to get all customers back.

After Gudrun, the Swedish regulator almost immediately began working on a new model to penalize utilities for long interruptions. Among other things, a target was set that no customers should experience interruptions longer than 24 hours in 2011. Penalties should be paid to affected customer after 12 hours ranging from 12,5 % (12 hours) to 300 % (>12 days) of the average annual network fee for the customer [1]. The larger utilities in Sweden also responded by announcing that simply changing the re-investment strategy will not be sufficient. Targets were established, e.g., within 5-6 years a significant part of all overhead lines through forest and mixed areas should be cabled, isolated by tree-wire and/or secured by other actions to avoid long interruptions. In September 2005 Fortum Distribution launched a major investment program specifically aimed at improving reliability performance on distribution feeders in rural and semi-rural areas.

The goal of this paper is to describe the approach Fortum Distribution is using in Sweden to plan, execute and follow-up the reliability program. The paper describes the whole planning process beginning with goal-formulation, identification of optimal solutions and methods to improve reliability, network planning, prioritization and follow-up. The program has only been run a limited time so statistical variations in weather make it difficult to evaluate the efficiency of the program on a system basis. However, when comparing SAIDI and SAIFI for the feeders included in the program up until 2008 an improvement (about 40 %) is observed.

GOAL FORMULATION

Fortum Distribution has operations in Sweden, Norway, Finland and Estonia. Figure 1 shows the geographical areas in which Fortum Distribution is responsible for distribution of power. It is one of the largest utilities in the Nordic
market serving more than 1.4 million customers.

The historical reliability performance (SAIDI = System Average Interruption Duration Index) of the Swedish distribution networks is given in Figure 2. Note that Hälsingland, Värmland, and Västkusten are different rural/semi-rural sub-regions of Fortum Distribution in Sweden. As can be seen from the graph storms struck the areas of Hälsingland in 2001 and Värmland in 2003. The storm Gudrun mainly affected the area of Västkusten (and part of Värmland) in 2005 (not shown). In 2006 another big storm hit Värmland. The baseline SAIDI level, excluding major storms, was approximately 160 min for rural and semi-rural areas prior to 2006.

The targets were established based on an optimization of the cost-benefit level from a regulatory standpoint, on customer expectations, and on practical considerations, e.g., control centre congestion issues and number of available contracting resources on the market. In line with the Swedish regulation the planning target was also set so that no customers will experience any interruptions exceeding 24 hours in the future. All the targets should be met for all voltage levels in the entire system and include both planned and unplanned interruptions.

**METHODS TO INCREASE RELIABILITY**

Fortunately when trying to reduce weather related interruptions there are many methods to choose from. One can try to reduce the effect of outages once it occurs by remotely controllable disconnectors or network automation. In almost all energy regulator schemes around the world addressing network reliability this action has proven to be most cost-efficient. The second approach is to try to reduce the outages from happening in the first place. This requires the bare-wire overhead lines to be cablified and/or changed to some kind of insulated conductor type. The second approach is more expensive and only in certain situations provides sufficient financial return from the regulators.

Remotely controlled disconnectors and automation has proven most useful in obtaining SAIDI = 60 minutes during normal weather conditions [2]. However, when it comes to the 24 hour target remotely controlled disconnections are still very useful but have certain drawbacks. During severe storms there tend to be numerous trees fallen over the power lines in many sections of the feeder. Isolating the fault and restoring power is thus not easy; repair works are first needed. There will also be congestion issues in the dispatch center during major storms. Even though a disconnector can be operated remotely the operator still needs to analyze the feeder layout and plan his or her action carefully prior to operating the switches safely. To balance the two reliability targets, Fortum has chosen to accept bare-wire power lines located in open areas and on adjacent to roads. The main portions of the power lines that run through forest areas will be insulated in some way, either through cablification where the ground conditions are favorable for plowing or through the installation of covered overhead conductors or aerial cable. Widening the line corridors is also an option. Presently around 80% of Fortum’s lost customer outage minutes can be attributed to weather related faults in forest areas.

Table 1 shows the analysis done on methods to improve reliability for the service areas in Sweden. In all areas, the Table 1. Main solutions used to mitigate weather related outages and their respective benefit and cost.
use of remotely controlled disconnectors has been proven very cost-effective; approximately 2-3 disconnectors will be used on outage-prone feeders. In addition, voltage transformation to 1 kV low voltage (LV) systems instead of conventional 10 or 20 kV on longer lightly loaded spur lines has been analyzed. In the Nordic countries spur lines are normally not fused; 1 kV LV system enables simple breakers to be used at the interconnection to the MV network protecting the main line [3]. Finally, the use of pole-mounted reclosers was also considered in the analysis.

**PROJECT PRIORITIZATION**

In Fig. 3 the reliability performance of Fortum’s approximately 1400 rural distribution feeders is shown for a given year. The feeders reliability performance have been normalized to that of the worst performing feeder. Contributions from major storms are excluded. Approximately 200 feeders (or 15% of the feeders) correspond to the vast majority of all customer outage minutes. 50% of the feeders had no customer interruptions at all. The graph highlights the importance of the network planning; proper feeder selection is most crucial.

<table>
<thead>
<tr>
<th>Method</th>
<th>Effectiveness</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cablification</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Aerial cable</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Covered overhead conductor</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>1 kV, LV systems</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Feeder automation</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Pole mounted reclosing switches</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Widening of line corridors</td>
<td>Medium</td>
<td>Low</td>
</tr>
</tbody>
</table>

The network planning is performed in a few consecutive steps.

- Review of historical feeder reliability performance including where (position) and why (cause) the faults have occurred. Metrological data is studied. In addition discussions with field crews to get their feedback on the planned modifications. The reliability analysis begins from the feeder breaker and downstream.

- Estimation of impact of the investment to system reliability. Presently Fortum Distribution is implementing methods for probabilistic reliability calculations in Sweden. As of today, a combination of various Geographical Information System (GIS) tools, fault statistics, and manual reliability improvement calculations are used to evaluate the projects.

- Prioritization of projects based on benefit-to-cost ratios. The ratio cost per reduced customer outage minute (COM) is used. Also marginal benefit-to-cost ratios are used to evaluate projects aimed to be carried out in steps on the same feeder; i.e., in each project the additional COM savings delivered by moving up from one option to the next is evaluated.

- Review and update of current long-term plan for the feeder under consideration and neighboring feeders.

![SAIDI Benefit / Cost of the project](image)

Fig. 4. Ranking and estimated SAIDI benefit of proposed projects based on benefit-to-cost ratios (MCOM = COM x 10^6).

Each individual project carried out is ranked based on its contribution to the corporate reliability targets. Figure 4 shows an example of the cumulative estimated improvement in COM as a function of the total cost of the projects. Each data point on the graph represents one project. The effectiveness of the first 100 MSEK spent is thus indicated in the graph to about 7 MCOM. The next 100 MSEK spent will only provide an additional 2 MCOM improvement A threshold level of effectiveness of the investments is also indicated in the graph. This level may be set differently.
depending, e.g., on the overall budget level. Projects that do not meet the criterion will be sent back to the planner for further motivation, for change of solution or will be postponed/cancelled.

FOLLOW UP
The progress of the reliability program is followed closely by Fortum internally as well as by our customers and media. Fortum is using a three year follow up cycle whereas in year one projects are identified, prioritized and the expected contribution to the corporate targets are calculated, in year two the projects are executed and in year three (and onwards) the actual improvements are measured and compared to plan (year one base level).

Externally, Fortum use its webpage and news briefings to communicate where work is planned, under progress and concluded. Most often whenever bigger projects on a feeder are launched an information meeting is organized for media and customers in the area. Internally, a corporate steering group is governing the project. On a quarterly basis (or upon demand) this group receives status information regarding the progress of the program (e.g., reliability performance, effectiveness of investments, project economy etc.). As mentioned above, for concluded projects follow up measurements are started and each projects anticipated reliability improvement is followed up. If necessary the comparison between planned and actual improvement may lead to a review of the principles used to estimate the effect in the first place. In addition a comparison between planned and actual cost may lead to a review of the principles used to estimate cost of the future projects.

FIRST RESULTS
In order to obtain accurate reliability statistics several years of data are needed. It is thus somewhat early to draw any major conclusion regarding the effectiveness of the reliability program. What can be done is to investigate the feeders that were selected for renewal in 2006. For those feeders Fortum has two years of statistics available that can be compared, e.g., to the previous five years performance prior to 2007. In total the data set includes about 50 feeders. These feeders were among the worst performing ones and the SAIDI value for them was higher than the average of about 160 min for the entire system. The reliability actions on these feeders are mainly replacement of overhead line by cable on outage prone sections of the feeder. The results are given in Fig. 5. In the figure the base reliability performance have been separated from those of major storms.

Best statistics is available for the reliability performance during non-storm years. Here a reduction of SAIDI by 42 % is observed. The corresponding number for storm years is 39 %. The result is satisfactory since the action done in 2006 quite often were only the first step; for the most outage prone feeders actions are divided into several projects of which the first project was done within the first three years of the reliability program an the latter steps in the final three years of the program. Once all steps have been finalized a better performance is expected. Also, the program aims at correcting for weather related outages and the reduction in this category of fault is much higher than the 42 % reduction that is obtained for all types of faults.

SUMMARY
The goal of this paper has been to describe and show some results from the approach Fortum has been using to improve reliability in rural and semi-rural areas. The planning process, beginning with goal-formulation, identification of optimal solutions, prioritization and follow-up has been described. First results from the reliability program for about 50 feeders selected for renewal in 2006 have been shown. The results indicate an approximately 40 % reduction in SAIDI; once these feeders have been rebuilt according to plan the corporate target of SAIDI improvement of > 50 %, while maintaining high cost-effectiveness, seems very possible to achieve.

REFERENCES