ESTABLISHING MAINTENANCE STANDARDS FOLLOWING A RISK BASED MAINTENANCE STRATEGY

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ABSTRACT

The paper reports on how risk based approaches have been used for establishing a maintenance strategy and maintenance standards for distribution companies.

The experience from this has shown the usefulness of risk assessment when dealing with maintenance management, giving increased understanding and better basis for maintenance decisions in distribution systems.

INTRODUCTION

Since the deregulation of the electricity sector and the introduction of the income cap regulation, there has been a period of much focus on cost cutting among the Norwegian grid companies. The regulatory regime has given strong economic incentives towards extending lifetime of old components and postponing new investments, [1]. The postponement of investments put increasing importance on maintenance of the existing infrastructure.

There is an increasing awareness among the distribution companies on developing holistic strategies for the maintenance of the grid in an adequate way, [5]. In this setting it is important that the emphasis on cost effectiveness must be balanced with the aspects of operating the grid in a safe manner; seeking solutions where all risk aspects are being sufficiently taken care of. Handling this task is the basic and complex challenge the network companies are facing under the existing regulatory regime. Risk management has been found to be the key approach to face this challenge, [2-4, 6].

This paper reports on the process and results from establishing a common framework for maintenance and maintenance management, elaborated by the distribution companies in the Statkraft-alliance.

The companies in question cover approximately 25 % of all grid customers in Norway, and close to 20 % of assets such as overhead lines and cables and MV/LV substations.

MAINTENANCE STRATEGY

As a basis for working with new approaches for maintenance management, a maintenance strategy has been developed. The principles stated in the maintenance strategy are the basis for the process of establishing specific maintenance standards for network components.

The strategy shall give an efficient maintenance management to meet goals within:

> **Economy** – by contributing to keeping a technical condition in the distribution grid which ensures an optimal economic payback from the grid capital.
>
> **HSE** (*health, security, environment*) – by contributing to keeping the distribution grid assets in a technical condition which in a good manner ensures the aspects of safety, working environment and environmental impact.
>
> **Quality of supply** – by contributing to keeping the technical condition of the distribution grid at an appropriate level so that the quality of service delivered to the customers is sufficient.
>
> **Reputation** – by maintaining the assets in such a manner that it contributes to building a positive image of the company.

These goals are further described in the following.

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Goals within economy

The goal for maintenance with respect to economy is to contribute to maximum rate of return for the grid company. With a given income cap this is equivalent to minimising cost.

The economic target for the grid maintenance is thus minimising the net present value sum of investments cost, operation and maintenance costs, interruption costs, *and* costs of losses - keeping within relevant framework condition. The framework conditions constitutes of demands within the other goal areas. From this it can be seen that there is no target in itself that the maintenance costs should be as low as possible – as long as one obtains the minimum total cost.

The chosen way of handling the economy goal is through using net present value (NPV) calculations, and also applying a risk matrix to take into account the risk aversion towards large economic losses.

Goals within HSE

The goal for maintenance with respect to HSE is to:

- Have an acceptable safety level, by not having injuries as consequence of operating the network
- Have a good working environment
- Have a good environmental profile by no having severe environmental impacts as a consequence of operating the network.

The way of handling this goal is by risk assessment using risk matrices for safety and environmental impact respectively.

Goals within quality of supply

The goal for maintenance with respect to quality of supply is to:

- Contribute to appropriate quality of supply for the customers
- Contribute to keeping within the boundary values for voltage quality

The first bullet point is regulated though the Norwegian CENS-arrangement for economic compensation for long interruptions (>3 min), and will hence be handled by the economic criterion. The second bullet point is regulated through boundary values given in Quality of supply regulations. Other impacts on Quality of supply – such as short interruptions – are included as a part of the reputation criterion.

Goals within reputation

The goal for maintenance with respect to company reputation is to take considerations so that relevant stakeholders have a positive impression of the company.

The way of handling this goal is by risk assessment using risk matrices for reputational impact.

The goals are hence handled by a combination of NPV calculations and risk assessment for different aspects of risk.

Principles of the maintenance strategy

The following four principles have been established for the maintenance strategy based on the goals defined:

Maintenance shall be based on risk evaluations. The need for maintenance activities shall be evaluated from the probability and consequences of the unwanted events it is meant to prevent.

Maintenance shall be economically evaluated on how it affects the sum of future costs of investments, operation/maintenance, interruptions and losses.

Maintenance shall be closely coordinated with renewal evaluations. The choice of maintenance activities must be adapted to the process of renewal of the grid.

Maintenance shall be in compliance with existing rules and regulations. Explicit demands in regulations shall be followed. The network companies must have a risk based strategy regarding demands which are not explicit.

To make these principles operative within the companies, it is important that the maintenance is a part of a targeted maintenance management process, where experience is used to follow performance trends and to improve routines and work tasks. The maintenance management process is illustrated in Figure 1.

The overall goals and the process of establishing the maintenance strategy is found in the upper left corner of Figure 1.

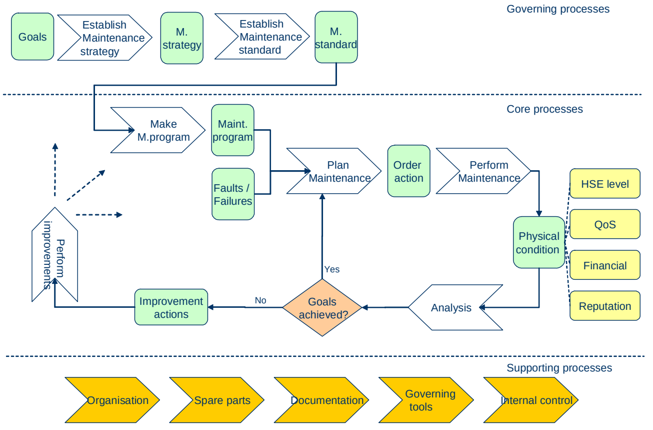

Figure 1 Maintenance management process

MAINTENANCE STANDARDS

To make the maintenance strategy operational, maintenance standards are chosen as the tool. A *maintenance standard* is a general guideline for how a component (or group of components) shall be maintained taking into account different risk aspects. The maintenance standards are the basis for establishing a maintenance program.

Establishing maintenance standards has been performed as collaboration workshops where experts from the participating companies meet, discussing the different aspects of maintenance approaches based on the principles of the maintenance strategy.

The process of establishing maintenance standards is performed though the following steps, as can be seen in Figure 2:

Identification of maintenance objects. For each of the families of components a split into recognisable maintenance objects have bee performed.

Mapping of existing practice. For each of the participating companies a job was done to document the present maintenance level. Even though the companies are relatively comparable, there are quite many differences in how maintenance has been handled:

Risk analysis of different components.
The risk analysis have been performed through identifying undesired events, quantifying probabilities for and consequences of the events, and estimating risk based on this. Finding possible actions to reduce risk is also a part of this.

Evaluation and adaptation of results
Through discussions of existing practice and the results from the more formalised risk analysis, a common description of maintenance activities and level is established.

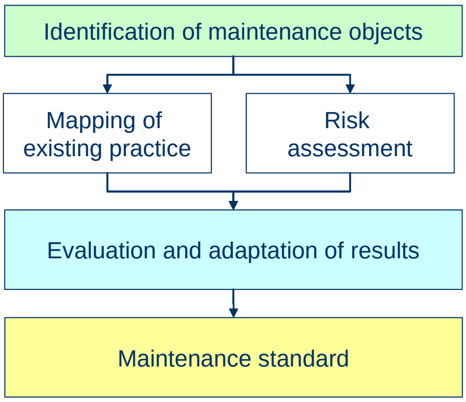

Figure 2 Process of establishing maintenance standards

The maintenance standard contains information about the chosen maintenance activities, and their corresponding frequencies (*e.g. Calender-time, events, number of operations or condition based).*

The overall challenge in this work is finding the optimal mix of activities and their frequencies.

Example

In the following section an example and some experiences from the maintenance standard for MV overhead lines are presented.

Identification of maintenance objects
When analysing MV overhead lines the following sub-components were chosen:

- Poles (including traverse, insulators, ..)
- Phase conductor
- Line trace
- Pole-mounted switches
- Cable terminations
- Pole-mounted MV/LV sub-stations

Mapping of existing practice
For each of the components, a mapping is performed to establish the status of existing practice for the different companies. This mapping showed an obvious need for establishing a common terminology for distribution system maintenance.

Risk analysis of different components
For each of the categories of components risk estimation has been performed with regards to the following consequence categories:

- Safety
- Environmental impact
- Reputational impact
- Economy

In the following we are looking closer into the component *poles.*

- Unwanted events related to poles
Though brainstorming and discussions in the maintenance standard work group the following unwanted events were identified:

1. Pole breakage
2. Pole askew
3. Fire damage of pole
4. Insulator flashover
5. Conductor falls on traverse / burnt traverse
6. Broken traverse
7. Flashover / discharge of insulator chain
8. Displaced traverse
9. (Partially) defect discharger
10. Fall down from (and / or with) pole

11. Person climbing in pole and touching live MV parts
12. Poor earthing connections
13. Insulators destroyed by vandalism
14. Creosote impregnation run-off to water and/or soil

The events are chosen based on their presumed impact on four consequence categories.

- Risk estimation

The following scales of probability and consequence have been used for estimation for these events.

Table 1 Probability and consequence scales for risk estimation

Probability scale	*Consequence scale*
P5 – Highly Probable – More often than once a year	C5 – Catastrophic - One or more deaths – many injuries
P4 – Very Probable – Once every 1-10 years	C4 – Serious – More than one person with serious injury
P3 – Probable – Once every 10-100 years	C3 – Medium – Medium to serious injuries
P2 – Less probable – Once every 100-1 000 years	C2 – Small – Minor injuries
P1 – Improbable – Less than once every 1 000 years	C1 – Negligible – No injuries

As sources of estimation of probabilities and consequences there are little (if any) statistical material to rely on. Expert judgement has therefore been used as qualified input to the risk analyses regarding maintenance standards.
An example of using risk matrices for risk estimation is shown in Figure 3.

	Consequence				
Probability	C1 Negligible	C2 Small	C3 Medium	C4 Serious	C5 Catastrophic
P_5: Highly probable					
P_4: Very probable					
P_3: Probable					
P_2: Less probable					
P_1: Improbable			8 12	1 6	10 11

Figure 3 Example: Risk matrix for *safety* for the unwanted events

Not all of the initial 14 unwanted events are placed in the risk matrix for safety, because some of them are regarded as not relevant for this consequence category.
Similar risk matrices have been established for the other three consequence categories.

Events 10 and 11 are identified as being the most critical with regards to *safety* in our risk mapping.

- Evaluation and adaptation of results

Based on the risk analysis of safety issues – the maintenance standard gives emphasis on maintenance activities controlling occurrence of rot in poles, inspection of traverses and top inspections. The frequencies of maintenance activities are established based on existing practice and the experience and knowledge of the company experts.

Through the process of establishing maintenance standards the companies get a documentation of what risk is evaluated and what measure have been chosen to meet the risk challenges.

CONCLUSIONS

The paper shows how risk based approaches can be used for a structured analysis and handling of distribution system maintenance management. Including risk based approaches in maintenance management requires new knowledge and thinking among the distribution companies.

Experience has shown the usefulness of the structure and logic of risk assessment, giving increased understanding and better basis for maintenance decisions in distribution systems.

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