EXPERIENCES FROM IMPLEMENTING A RISK BASED MAINTENANCE STRATEGY USING AN INTEGRATED NETWORK INFORMATION AND MAINTENANCE SYSTEM

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ABSTRACT

Maintenance and renewal are important parts of distribution system asset management, as means to control risk. Distribution companies are hence increasingly recognising risk assessment and risk management as important tools in this context.

This paper reports on experiences from implementing a risk based maintenance strategy using a maintenance management system. The paper illustrates benefits which can be achieved through implementing a risk differentiated maintenance strategy on a company portfolio of MV/LV substations, resulting in better risk control in addition to lower overall cost for the distribution network company.

INTRODUCTION

Electricity distribution is a vital part of the infrastructure of modern society. In industrialized countries, the electricity distribution systems are already a mature infrastructure which has been developed during the 20th century. Hence, electricity distribution companies are now faced with the challenges associated with managing a generally ageing infrastructure, see e.g. [1].

During the last 10 to 15 years electricity distribution companies throughout the world have been ever more focused on *asset management* as the guiding principle for their activities, [2]. Within asset management, *risk* is a key issue, balanced together with overall cost and performance.

There is an increased awareness of including risk analyses into the companies' decision making and planning processes [3, 4], such as maintenance and renewal of network assets. The risk assessment gives a basis for differentiation between network components due to different probabilities for and consequences of undesired events. The consequences cover a variety of risk categories – e.g. economy, safety and environmental impact [5].

This paper reports on experiences from implementing a risk based maintenance strategy at a Norwegian network company, TrønderEnergi Nett (TEN). It illustrates the outcome of a risk differentiated maintenance strategy compared to a conventional uniform maintenance approach for TEN's population of MV/LV substations, showing differences and benefits of the risk differentiated approach.

BACKGROUND

In the core of asset management lies balancing the aspects of cost, performance and risk, in order to ensure an optimal utilization of the physical network assets [6]. It is important that the emphasis on cost effectiveness is balanced with the aspects of operating the grid in a safe manner; seeking solutions where all risk aspects are being sufficiently taken care of. This motivates for using methods for risk analysis to support asset management decision making, and to make the foundation for maintenance strategies [7].

Risk based 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 type of assets (or group of assets) shall be maintained taking into account different risk aspects. Such a differentiation leads to a set of *archetypes,* which are established through identification of risk differentiating factors. (Examples of archetypes are given in the case later in the paper.) The maintenance standards are the basis for establishing a maintenance program, [8].

The process of establishing maintenance standards and their implementation is illustrated in Figure 1.

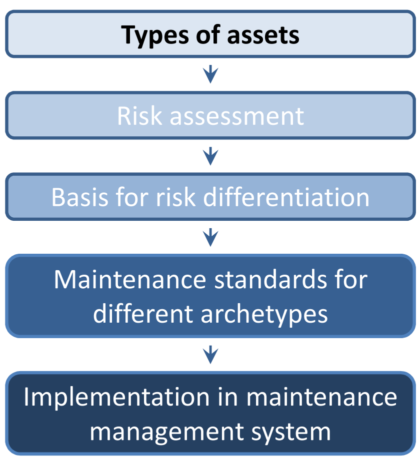

Figure 1 Establishing and implementing maintenance standards

The maintenance standard states the chosen maintenance activities for archetypes of network components, and their corresponding intervals (*e.g. Calendar-time, events, number of operations or condition based)*.

Network Information and Maintenance System

Risk differentiated maintenance standards should be implemented in a Network Information and Maintenance Management System (Powel Maintenance) through a set of risk differentiated decision rules, where each of the components in the asset data base is assigned a maintenance regime (for inspections, overhauls, etc.) based on the given set of risk differentiating factors.

Maintenance rules are either defined for groups of components (e.g. switchgear types) or for individual components. Maintenance rules can be based upon asset documentation or based on results from grid calculations. The latter means that e.g. calculation of CENS (cost of energy not supplied) can be used as a differentiation criterion for the risk based maintenance strategy. Simulations are performed to evaluate the consequences from different risk based strategies and thus enabling studies of quantitative and qualitative consequences in order to choose preferred maintenance strategy.

The Network Information and Maintenance Management System supports work order management, field data support (e.g. inspections) and decision support for management of observations from inspection routines. Figure 2 shows the maintenance process.

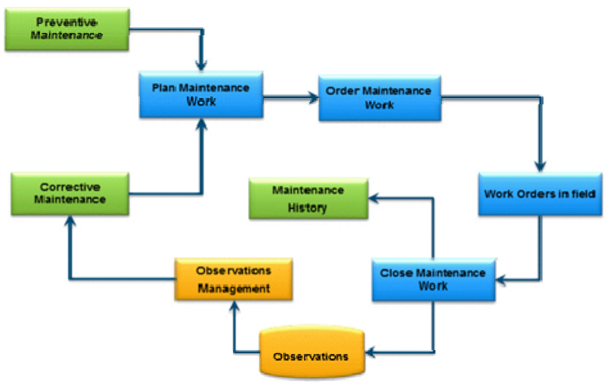

Figure 2 Maintenance process supported by Powel Maintenance

The maintenance process is integrated with ERP-system and system for dispatch support of contracting enterprise. Geographical Information System (GIS) functionality (Esri/ArcGIS technology) is used to present data and for risk based decisions support of observations management.

CASE - MV/LV SUBSTATIONS

To illustrate the implementation of the risk based maintenance strategy, the population of MV/LV substations as TrønderEnergi Nett has been chosen.
TrønderEnergi Nett is a grid company supplying 125.000 customers in the middle of Norway. The network consists of 2.000 km HV, 3.000 km MV and 6.000 km LV power lines and cables, 50 HV/MV and 3.500 MV/LV sub stations with installed transformer capacity of 1,7 TW.

The area of supply stretches from a stressed corrosive climate at the Atlantic coast to a dry and cold inland climate near the border to Sweden, and covers both the city of Trondheim and sparsely populated areas. During the last 10 years the company has put a strong effort in developing and implementing a risk based maintenance strategy.

TrønderEnergi Nett has 2546 MV/LV substations located on the ground. These substations are of different types and brands.

The MV/LV substations are grouped in 7 archetypes characterized by the type of switchgear and their age, and the encapsulation:

- New AIS[1], fully encapsulated
- New AIS, semi encapsulated
- Old AIS, semi encapsulated
- AIS with wire fence encapsulation
- Epoxy insulated switchgear
- New GIS[2]
- Old GIS.

Old is used for equipment ≥ 25 years, while *New* is equipment < 25 years. *Fully encapsulated* switchgear denotes a cubicle covered by steel plates with pressure release in safe directions, while *semi encapsulated* is used for steel-plated cubicles where the top and bottom of the cubicle is open. The differentiation in archetypes represents the main types of MV/LV substations, based on a generic risk assessment.

The preventive maintenance activities for MV/LV substations are categorized in:

- Light inspections
- Inspections
- Functional control
- Overhaul, and
- Replacement

The list represents an increasing order of effort and comprehensiveness.
The following case focuses on an analysis of *Inspection*, an activity which involves a thorough check of the MV/LV substations, and which conventionally has been performed every 5 years for all substations, regardless of make or condition.
Table 1 shows the risk differentiated inspection intervals. The time intervals are chosen based on a risk analysis performed in cooperation with experts from five other Norwegian distribution companies, [8].

1 AIS - Air Insulated Switchgear
2 GIS – Gas Insulated Switchgear (SF_6)

Table 1 Risk differentiated inspection intervals [years]

Voltage level	12 kV		24 kV	
Strain / Switchgear type	Low	High	Low	High
New AIS encapsulated	10	3	8	2
New AIS semi encapsulated	4	2	5	3
Old AIS semi encapsulated	5	2	3	2
AIS wire fence	2	1	2	1
Epoxy insulated	5	3	4	2
GIS	10	3	8	3
Old GIS	5	2	5	2

Comment: Some of the inspection frequencies may seem counter-intuitive - e.g. Old AIS semi encapsulated have lower inspection frequency than New AIS semi encapsulated. This is due to the fact that Inspection is only one part of the maintenance regime; the total maintenance activities include also light inspections and functional controls which in total give a higher maintenance activity for MV/LV substations with old AIS switchgear.

Figure 3 shows the population distributed over the archetypes. The majority of MV/LV substations have new GIS (almost 1400 units). AIS with wire fence encapsulation is represented with only 7 units.

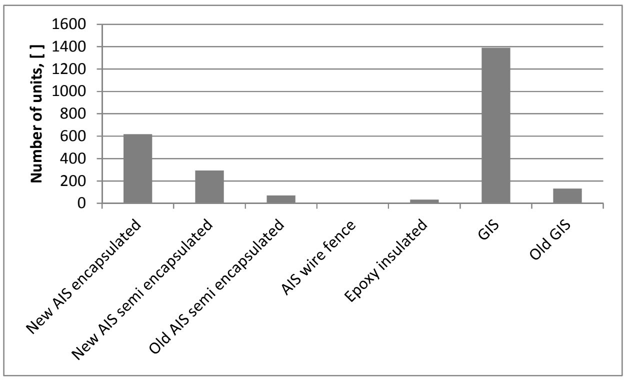

Figure 3 Number of MV/LV substations in the different archetypes

The risk differentiated inspection frequencies are compared to a conventional regime with uniform 5 year intervals. *For the analysis of the portfolio of MV/LV substations a uniform cost of NOK 1018 (~ € 150) per inspection is assumed, based on TrønderEnergi Nett's own estimates.*

The overall results with respect to annual inspection costs for the substation portfolio are illustrated in, showing a 16 % decrease in total annual costs related to inspections using a risk differentiated regime compared to the conventional approach.

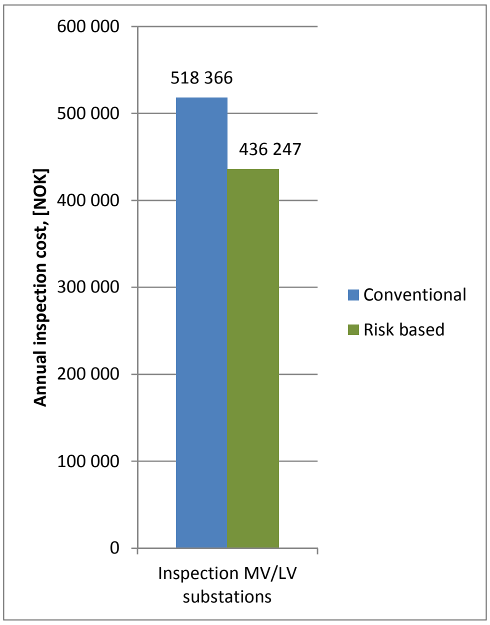

Figure 4 Annual inspection costs [NOK] for 2546 MV/LV substations [1€ ≈ 7.5 NOK]

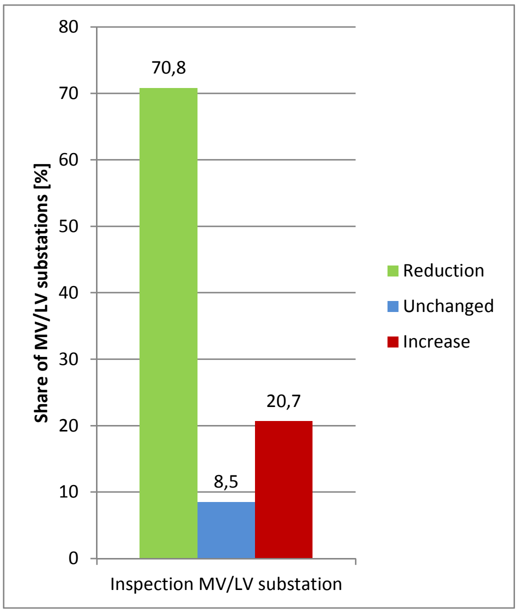

Figure 5 Changes in maintenance intensity for the population of MV/LV substations

Figure 5 shows that 70.8 % of the MV/LV substations will have a decrease in maintenance activities, while 20.7 % will experience an increase in inspection activities. This shows that in addition to a lower overall maintenance cost, the substations with higher risk will be subject to a more intensive maintenance regime – giving better risk control for the substations where the need is most prominent.

Figure 6 shows how the changes in inspection intensities vary among the MV/LV substation archetypes.

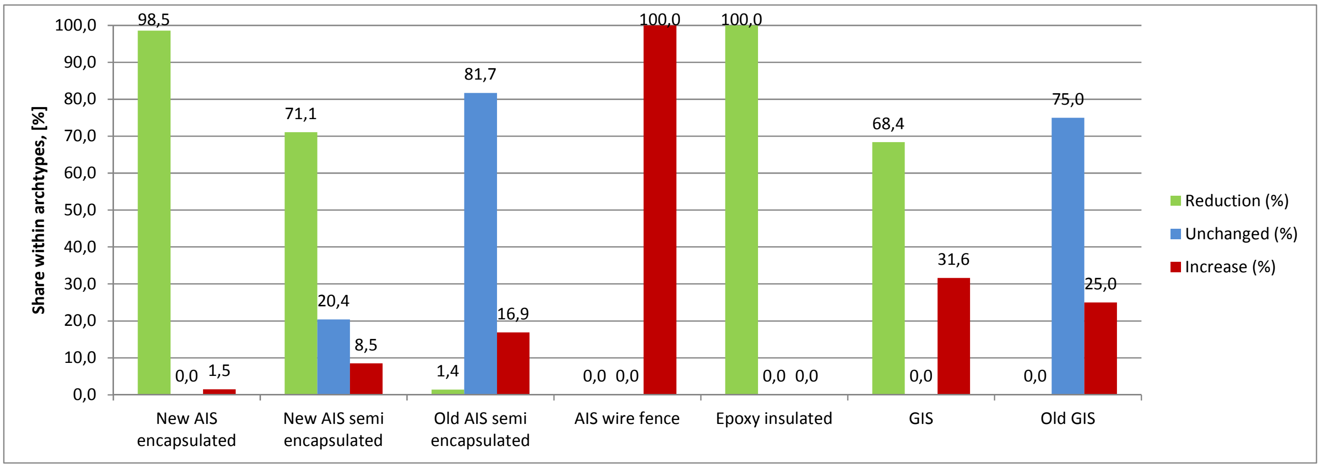

Figure 6 – Changes in maintenance intensity for the MV/LV substation archetypes

The figure shows that for archetypes with presumably higher risk archetypes (AIS with wire fence encapsulation, and old equipment) there will be a more intensive maintenance, while for substations which is considered to be of lower risk there is a significant decrease in inspection intensity, e.g. for new fully encapsulated AIS where almost the entire population (98.5 %) will have reduced activity.

CONCLUDING REMARKS

This paper has described the overall motivation for a risk based maintenance strategy – in order to use company resources where it is needed the most. TrønderEnergi Nett has established risk differentiated maintenance standards for all of their assets, dividing the thousands of assets into a limited number of archetypes which are treated differently because of different risk.

A case is presented for the population of MV/LV substations to show how the differentiation will work in practice. The overall results for this specific portfolio show both a decrease in overall maintenance cost related to inspections, and an increase in maintenance intensity for the assets with presumably higher risk.

The risk differentiated maintenance strategy will require a more advanced handling of grid maintenance. This is supported by the Netbas Maintenance System, where the rules for risk differentiation are implemented in the system, and then applied to any distribution system asset which is represented in the Maintenance system database. In this way, changes in the database will automatically result in updated maintenance activities – which in turn can be issued in work orders for TrønderEnergi Nett's maintenance crews.

REFERENCES

[1] J. Sinclair, "ENARD Annex III: Infrastructure asset management. Final report for ENARD ExCo," EA Technology, November 2009.
[2] PAS 55-1: Asset Management. Part 1: Specification for the optimized management of physical assets, 2008.
[3] D. E. Nordgård, "Risk analysis for decision support in electricity distribution system asset management : methods and frameworks for analysing intangible risks," PhD thesis 2010:54, NTNU, Trondheim, 2010.
[4] D. Hughes, P. Pschierer-Barnfather, and T. Pears, "Condition Based Risk Management (CBRM): Bringing excellence in asset management into the boardroom," presented at the CIRED, Prague, 2009.
[5] D. E. Nordgård, O. Gjerde, K. Sand, M. D. Catrinu, J. Lassila, J. Partanen, S. Bonnoit, and J. Aupied, "A risk based approach to distribution system asset management and a survey of perceived risk exposure among distribution companies," presented at the CIRED Vienna, 2007.
[6] R. E. Brown and J. H. Spare, "Asset Management, Risk, and Distribution System Planning," presented at the IEEE PES Power System Conference and Exposition, New York, 2004.
[7] D. E. Nordgard, "A framework for risk-informed decision support in electricity distribution companies utilizing input from quantitative risk assessment," International Journal of Electrical Power & Energy Systems, vol. 43, pp. 255-261, 2012.
[8] D. E. Nordgård, G. Solum, L. Heggdal, A. B. Sjursø, J. I. Fjellsbø, and E. Omdal, "Establishing maintenance standards following a risk based maintenance strategy," presented at the CIRED, Vienna, 2007.