UTILIZATION OF GRID CONDITION DATA FOR EFFICIENT MAINTENANCE PLANNING

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ABSTRACT

Large scale utility management is facing conflicting requirements from shareholders and management on one side and regulatory authorities and customers on the other side. The challenge for the utilities is therefore to reduce cost levels without reducing customer service and quality of supply. Decisions need to be based on holistic, detailed technology knowledge of assets instead of subjective and local judgements.

This paper describes a method, developed by SINTEF Energy Research, and implemented in a Network Information System to represent and evaluate the technical condition on components in a grid system. The paper further describes practical experiences from a utility that has used the method as a basis for improved maintenance strategies.

BACKGROUND

With ever stronger emphasis on cost efficiency, modern grid operators must apply their maintenance resources where the benefits are the greatest. This requires a complete overview of the grid's condition and its utilization at any time. Utilities spend much time and effort on inspection activities in order to collect crucial information about the condition of poles, insulators, overhead lines, vegetation hazards, and electrical components. Unfortunately, this information is often recorded in written reports filled in different manual archives, and vital information is kept as "undocumented knowledge" locked in the heads of experienced employees. Information based on people's habits and preferences may allow for planning and decision-making at a local level, but will not be sufficient for company-wide maintenance planning.

In a professional maintenance management system, it is essential to have easy access to structured information describing the maintenance procedures, results of previous inspections and the technical condition of all components. This requires new methodology which enables calculation of condition on assets based on results from inspections.

Furthermore, as utilities' assets are distributed over large geographical areas, any effective maintenance management system should also include GIS (Geographical Information System) functionality in order to display and understand the relatively vast amount of complex information resulting from inspection activities and from analyses of condition on components.

Knowledge of asset condition, supported by the methodology described in this paper, is an important source for maintenance decisions. However, detailed and accurate maintenance plans need to be based upon a composite set of information and calculations such as:

- Voltage levels in grid
- Utilization of components in grid
- Outage data (including CENS)
- Criticality and reliability data
- Load data
- Customer data

This requires representation and calculation of condition data to be a part of an integrated Network Information System, allowing decisions makers to continuously improve their maintenance program based on a broad knowledge of grid condition and grid information.

METHODOLOGY

The method developed enables calculation of a Technical Condition Index (TCI), which is used to describe the condition of an asset based on results from inspections. The intended use of TCI is to serve as decision support when developing maintenance plans and renewal programs. The method also provides calculation of Technical Condition Index on aggregated asset levels, thus enabling evaluation of maintenance and renewal for whole grid areas.

Maintenance Objects

A maintenance object is a component or an item suitable for description of maintenance activities, e.g. inspections or overhauls. It must also be possible to calculate technical condition on also aggregated component levels. This can only be achieved if a hierarchic structure is used to describe relation between components.

Component weighting

In the calculations above on technical condition relative component weight is used. Relative component weight is used to differentiate the importance of condition contribution of each maintenance object when calculating technical condition for an aggregated component level

Inspection Points

Inspection points represent conditions that may be checked or assessed on maintenance objects. There may be several inspection points on each maintenance object.

The table below shows practical examples on inspection points.

Maintenance object	Inspection Point
Distribution station (DS)	Door/access
	Roof
	Dust
Load-break switch (BL)	Connectors
	Ground Rod
	HV Sign
Distribution Transformer (TD)	Oil Leak
	Corrosion
	HV Sign

Inspection points shall serve two basis purposes:

- Basis for definition of condition on maintenance objects
- Definition of deviation on maintenance objects

This is achieved by relating a status profile to each inspection point. Status profiles describe how each inspection point shall be evaluated when doing inspections. One practical approach is to have more than one profile, using one profile on inspection points where deviations may be represented. On inspection points where deviations shall not be identified another profile is used. One example is a standard profile with predefined levels {0,1,2,3,4} and threshold for deviation is set to >= 3.

Deviations are used to identify issues that need to be corrected, either immediately or at a later stage. This could be due to several conditions, such as:

- Safety
- Authority requirements
- Quality and reliability requirements

Technical Condition Index on Maintenance Objects

A Technical Condition Index is a number that indicates the technical condition on a maintenance component. TCI is processed information in order to support decisions regarding maintenance or replacement. In principle TCI may be based on different kinds of information, such as:

- Deviations
- Measures
- Attribute data
- Operational data
- Environmental data

In this approach it chosen to use a system where the technical condition of a maintenance object is described by values between 0 and 100 where 100 points represents technical condition for a new component and 0 points represent a component which is likely to fail under normal operation.

Technical condition index P for a component is calculated using the following formula:

$$P = 100 - P_t - \sum_f P_f$$

where

P - Technical Condition Index for Maintenance object

P_t - Reduction of technical condition due to component age

P_f - Reduction of technical condition due to failures and defects

P_t is calculated as a linear reduction over component lifetime.

UTILIZING TECHNICAL CONDITION IN MAINTENANCE PLANNING

Utility status

The utility launched the maintenance system implementation project in 2004. The software application has been adopted and implemented in cooperation with the system vendor. The utility experience is limited to distribution network level.

The grid owner acts as a buyer of maintenance work and doesn’t employ staffs that perform the maintenance work. Grid owner has developed inspection sets containing control points. The inspection sets are tailor made for different types of assets, e.g substations, overhead lines, cables and poles and the content is differentiated for different kinds of inspections and controls. Examples are annual inspections, which aim to ensure that requirements from regulators, health and safety are fulfilled. Such inspections contain from five to ten control points for each component, whereas inspection sets for more detailed controls contain more control points.

In all cases control points contain an explanation which explains how scores shall be given. There are only two possible values; OK and NOT OK. This approach is chosen in order to achieve as objective judgements as possible. The utility has experienced this to be an effective solution. Today contractors use PDA when working in field to register data for inspections and controls. Data is transferred to the maintenance system upon completion of field work.

Decision support

Implementation of the system has provided the utility with new decision processes. In general terms decisions have moved from local levels to a central level. When doing inspections in field the contractor will only correct problems that are critical with respect to personnel safety and environment. No other problems are corrected when doing inspections. Data are instead collected in the maintenance system and evaluated holistically with a perspective for the whole grid. This ensures the right prioritisation based on profitability, criticality and safety.

Observations are displayed in a geographical interface using colours and symbols to differentiate different levels of technical condition, criticality and other vital information. The quality of decision processes is significantly improving quality of decisions to be made.

Organisational consequences

The new decentralised decision processes have also caused organisational changes in the utility.

Responsibility for maintenance strategy, including routines for time based inspections and controls, and order of repair work based on inspection data are made on the operative level in the organisation. More extensive technical and economical analyses, where technical condition on components is a part of decision criteria, are performed by another, non-operative, level in the organisation.

Two main maintenance processes are used in the utility:

<u>Process 1</u>
Grid owner orders maintenance work, inspections and control, according to maintenance plans. The orders are directed to selected contractors. The content of inspections and controls is predefined and applied in the field. Based on reports from the contractors, maintenance work to correct problems and to improve technical condition is ordered upon judgements made by grid owner.

<u>Process 2</u>
Grid owner uses collected inspection data in decision processes where reinvestment plans are made. Technical condition on components and aggregated technical condition for collection of components (e.g. lines and radials) is the basis for such decisions. Other premises, such as CENS, investment cost, failure and interruption data, is also taken into consideration together with technical condition.

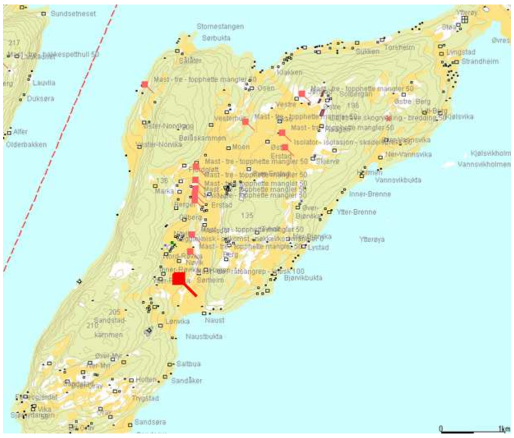

Figure 1 – Observations from inspections in grid shown in Network Information System

EXPERIENCES

After applying the system and method for one year within a utility, experiences show that new work practices with new ways of managing maintenance decisions in the grid has been successfully supported by new methods in the Network Information System. Former subjective judgements have been replaced by more precise objective decisions. Maintenance actions to correct all kinds of problems are now defined and ordered upon inspection data collected in field. Another benefit is the ability to document failures that need to be corrected due to authority requirements and due to internal quality requirements.

Training of field crew is necessary in order to obtain proper quality when evaluating technical condition on control points. "Hand-books" that describe criteria for judgements to be made on control points have been developed and this is strongly recommended. Use of digital images has been used successfully, both as explanation and illustrations for judgements to be made on components and to document observations (failures) found on some components.

Experiences also show data quality on data collected in field remain a major challenge. Proper data quality is crucial for making the right decisions. One example is when a control points addresses a question whether substation cleaning is necessary. The answer given may be NO (only Yes or No can be selected) whilst the optional user comment provided says "the substation should be cleaned". What decision is the right one to make upon this feedback from the field? Order cleaning now, wait another year or don't do it? Experience shows that control points addressing measurable, exact values are easy to deal with. Such data is seldom or never wrong. The reason for uncertainty in data quality is caused by several factors, the most important ones are:

- Control points are not precise, too much room for individual judgements
- Too many control points
- Guide to control points is too general
- Guide to control points is too complex
- Guide to control points is not available on Contractor's PDA (field application)
- Limited use of measurable data in control points

Attention should therefore be paid to definition of control points before putting the method into operation. Control points will certainly reflect the same technical issues as covered by former manually systems, but data implementation provides many new possibilities. These possibilities can only be achieved if the moments mentioned above are taken into account.

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