CAN WE DELAY THE REPLACEMENT OF THIS COMPONENT? – AN ASSET MANAGEMENT APPROACH TO THE QUESTION

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Summary:

Asset management is emerging as a new approach on how to exploit the physical asset in the most profitable way. One of the major questions to answer by the asset management staff is when to do replacements?

An asset management approach has been developed, and incorporated in a software tool VefoNet, where the problem is addressed in direct economic terms.

The model is capable of evaluating the consequences of replacing today or later, and point out the component which should be replaced first. Hereby ensuring the most cost-efficient solution.

To solve the stated optimisation problem the following parameters are considered and weighted against each other:

• Energy not supplied due to interruptions
• Need for corrective maintenance (repair)
• Need for preventive maintenance
• Operating costs
• Energy losses (for transformers etc.)
• Non-ideal technical conditions of the asset
• Non-ideal constructions of the asset

Furthermore, the replacement costs is included as a parameter.

The model is based on a financial calculation of the present value (the sum of the cost during a period of e.g. 20 years carried out at a certain discount rate) for different options of replacement times. Direct economic costs as well as indirect costs are included in the calculations.

The VefoNet system includes the described model as well as other asset management models. VefoNet also includes a data collection system based on Windows CE handheld PCs. A systemised data collection system is important to establish good input data in a cost-effective way for advanced asset management models like the one described.

Figure 1. Example of result from the present value model for a 10 kV switchgear.

Figure 2. Example of a Windows CE industrial terminals fulfilling the requirements to a handheld device for use in the utility.
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Abstract

Asset management is emerging as a new approach on how to exploit the physical asset in the most profitable way. One of the major questions to answer by the asset management staff is when to do replacements?

This is a difficult question, which require weighting of several parameters of totally different nature – e.g. reliability data, operating cost and condition information.

This paper presents an asset management approach which answer the question “When to replace a component?”.

The presented model address the problem in direct economic terms, and the model is capable of evaluating consequences of replacing today or later, so the most cost-efficient solutions can be reached.

A software system, VefoNet, has been developed in a common Nordic project. The system includes the described model as well as other asset management models. The system also includes a data collection system based on Windows CE handheld computers which will be presented in this paper. The calculations showed in the paper are based on this tool, and the software system is today available and used by Danish electric utilities.

Introduction

Asset management has emerged as a hot topic in the electric utility industry as well as in many other types of industries in the past years. But what is really the basic of this emerging approach? A tripartite definition made by a group from New Zealand describes this very well [1]:

**Infrastructure Asset Management**: “The combination of management, financial, economic, engineering and other practices applied to physical assets with the objective of providing the required level of service in the most effective manner.”

**Basic Asset Management**: “Asset management which relies primarily on the use of an asset register, maintenance management system, job/resource management, inventory control, condition assessment and defined levels of service, in order to establish alternative options and long-term cash-flow predictions.”

**Advanced Asset Management**: “Asset management which employs predictive modelling, risk management and optimised renewal decision making techniques to establish asset lifecycle options and related long-term cash-flow predictions.”

In other words, asset management is the ability to model and compare operational, maintenance and capital options with the goal, to find the overall most cost-efficient solutions that provide the required capability over time. Asset management is how to exploit the asset most profitable.

The foundation of a well-driven asset management is to get control of the basic asset management (according to the definition above). For an electric utility company this includes an up to date asset register and implemented routines and systems for managing the planning of everyday activities. Today software systems exist which can support the basic asset management.

When it comes to the advanced asset management the utilities are poorly supported with regards to recommendations and software tools. Advanced asset management is therefore not very widely used in a systematic frame, in spite of a large potential of increasing cost-efficiency.

One of the major questions – if not the most important – to be answered by persons responsible for the asset management of an electric utility network – or any other system – is when to do a replacement; or as it is often expressed in a quite loaded form: “The replacement is due now – can we delay it?”. This optimisation problem clearly belongs to the advanced asset management.

This question, and other questions regarding optimal decision making is becoming more and more important concurrently with the increased focus on cost minimisation and economic profitability within the electric utility sector. But the type of problems dealt with is also very complex of nature, and the questions are therefore difficult to answer in a simple way. The majority of decisions today are therefore based on limited calculations and a large amount of subjective assessment done with great care.

Tools and systematic approaches, as described here, which support the advanced asset management, are therefore needed in the future.
Nature of the problem

System considerations
When we want to decide when to replace a component, e.g. a switch-gear in a 10/0.4 kV substation, we first have to do some system considerations.

As a first step the following have to be considered:

- Are there any future network-changes, which can result in replacement or elimination of the component?
- Are any connected components (e.g. the rest of the components in a substation) reaching the end of their lifetime, and is a collective replacement relevant due to cost saving or technical benefits?
- Are new more simple system layouts possible by making a collective replacement of several components?

If the answer is yes to one or more of the above questions, the replacement of the component can not be considered isolated. If a replacement of several components (e.g. the whole substation) is an option the described model can be used for collective replacement of the group of components instead of replacement of the single component. In fact it is possible by the use of this model to determine the best alternative: collective replacement of the group of component at one time or replacement of the components separately.

If the replacement is dependent on network-changes e.g. due to load increase, network analysis tools have to be included in the decision process of determining the optimal replacement time. In this paper the case of changed network layout is not considered. It is assumed that the replacement can be considered insulated and consist of one or more old components that should be replaced by one or more new components.

Technical requirements
Next step is to consider any absolute technical requirements which can force the replacement. This could be a requirement of environmental, customer supply or personal safety character. Examples are public regulations that require elimination of components containing PCB, or company requirement to remove components which due to the construction make up a safety problem for the staff.

If such absolute requirements exist, the time of replacement will be restricted. Technical-economical optimisation can have no or little relevance in such cases, and deeper considerations can possibly be avoided.

Technical-economical optimisation
On the other side, if no network-changes are relevant and no absolute requirements regarding environment or safety exist in near future, the question “When to replace” is a difficult optimisation problem.

The optimisation regards on the one side the cost of replacement and on the other side the deterioration of the component. If the replacement is postponed replacement costs can be saved, but the utility has to live with a more deteriorated component for a longer time.

Figure 1 illustrate the shape of the problem. The present asset (component) is kept in operation for a number of years R while it becomes more and more deteriorated.
deteriorated. At the year R the component is replaced with a new component with low deterioration.

The optimisation problem is to calculate the time R which result in the minimal overall cost and deterioration over a timespan of the asset. This is a difficult task due to the incompatibility of cost and deterioration. Furthermore, the deterioration consists of several properties of very different nature.

**Weighting of parameters**

To solve the stated optimisation problem the maintenance strategy of the utility company has to be well defined, so weighting of different parameters can be determined. It has to be considered which parameters should determinate the deterioration and how should the parameters be weighted against each other.

To express the deterioration, the following parameters are here used:
- Energy not supplied due to interruptions
- Need for corrective maintenance (repair)
- Need for preventive maintenance
- Operating costs
- Energy losses (for transformers etc.)
- Non-ideal technical conditions of the asset
- Non-ideal constructions of the asset

Furthermore, the replacement costs is included as a parameter.

Weighting is done by normalising all parameters to a common cost unit. This is no problem for the real cost elements (e.g. investments, preventive and corrective maintenance, and losses), while it is a more challenging task to convert elements which normally are not directly connected with costs, e.g. interruptions, technical condition, and construction. In the following each parameter is treated.

**Replacement cost**

The replacement cost is expressed in direct economic terms, and the parameter consists of direct cost of the new component, cost of the civil work (manpower and equipment), and cost of dispose of the old component. The costs take place at the replacement time.

**Energy not supplied (ENS)**

Energy not supplied due to interruptions of the component express the importance of the supply to the consumers. The energy not supplied can be capitalised by the use of the following expression:

\[ C_{\text{ENS}} = [\text{Specific costs for ENS (DKK/MWh)}] \cdot [\text{Yearly interruption (h/year)}] \cdot [\text{Power flow (MW)}] \]

The yearly energy not supplied depends primarily on the type of component, the age of the component, and its location in the network. A fault and interruption statistic can be used for calculation of the yearly interruption.

For a discussion regarding specific cost for not delivered energy see e.g. [2].

**Repair**

The repair parameter includes the yearly cost of repair of failures. The costs are highly correlated with the cost of energy not supplied and they can in most cases be assumed proportional.

**Energy losses**

Cost of energy losses in transformers etc. can be calculated by the cost of the energy and the yearly losses in kWh.

**Operating, cost preventive maintenance costs, and energy losses**

Operating and preventive maintenance costs as well as energy losses are direct economic costs elements. Typically these cost elements are smaller for the new asset compared to the old.

**Technical condition and construction properties of the asset**

Technical condition and construction properties of an asset include information on non-ideal technical conditions (e.g. rust and defects) and non-ideal construction (e.g. constructions with environmental or personal hazards). A pre-defined list of possible non-ideal technical condition and construction properties can be made in accordance with the priorities of the utility company. For a given asset a number of these properties can be present. The information is normally based on inspections of the component.

To utilise the technical condition and construction properties in the model, the properties have to be normalised by attaching each property to an economic cost representing the weighting of the property. The unit of the value is cost per year corresponding to the yearly cost the company is willing to invest to avoid the property.

The capitalised costs associated with technical condition and construction of the component are fictive costs representing the importance of the registered, non-ideal technical conditions and non-ideal construction.

**Economic calculation model**

The developed model which can addresses the question “When to replace a component?” is based on a number of cost calculations for different replacement times.
For each possible replacement time (year) the total costs during a calculation period (e.g. 20 years) are calculated. The total costs are calculated as a present value (the sum of cost during a period taking account of the compound interest). The calculation of present value, PV, is based on the following formula:

\[ PV = C_0 + C_1(1 + r)^{-1} + C_2(1 + r)^{-2} + \ldots + C_N(1 + r)^{-(N-1)} \]

\( C_i \) is the total costs in year no. \( i \) (\( i=0 \) correspond to the present year), \( r \) is the rate of interest per year, and \( N \) is the calculation period in years.

The total cost per year, \( C_i \), includes:
- Cost of replacement (only if replacement in year \( i \))
- Cost of energy not supplied
- Corrective maintenance cost (repair)
- Preventive maintenance cost
- Operating costs
- Cost of energy losses
- Cost associated with technical condition properties
- Cost associated with construction properties

The model will use information about the old component for computation of annual costs before the replacement time, and information about the new component for computation of annual costs after the replacement time. The replacement cost is included in the total costs at the replacement time.

Figure 2 summarises the calculation result from the model as it is presented in the developed software program. The illustrated example is an analysis of a 10 kV switchgear. The calculation is made with basis in 2001 and the calculation period covers 2001-2025.

The showed model gives in direct terms guidance for the replacement time of an asset. Consequences of postponement of the replacement are expressed in direct economic terms.

The economic model has been incorporated into the software tool, VefoNet, together with a number of other models for replacement and maintenance. The core of the software system has been developed within the framework of a Danish-Norwegian-Swedish project in the period 1996-1998.

The system consist of the following elements: asset register with asset management relevant information regarding maintenance and replacement, several models dealing with different advanced asset management questions and a data collection system for easy collection of data in the field. By use of the system, the user is supplied with an overview of the assets and their condition, and the asset manager is supported in decision-making processes.

For an overview of the software tool see [3].

Data collection

One of the conclusions from the users of the developed software system is the need for an easy to use data collection system.

For this reason a handheld pc system has been added to the VefoNet program. By the use of handheld pc’s the most beneficial. The optimum is quite flat though, and replacement within a 2-4 year period is not critical.

As it is seen from the numbers in Table 1, the saving by postponing the replacement from 2001 to 2005 is a present value of 2,600 DKK. If the replacement is postponed further the costs saving will be less or turn to a cost increase.

<table>
<thead>
<tr>
<th>Replacement year</th>
<th>Capitalised costs 2001-2025 in 2001-DKK</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>80,800 DKK</td>
</tr>
<tr>
<td>2005</td>
<td>78,200 DKK</td>
</tr>
<tr>
<td>2010</td>
<td>81,400 DKK</td>
</tr>
<tr>
<td>2015</td>
<td>90,100 DKK</td>
</tr>
</tbody>
</table>

Table 1. Capitalised costs calculated by the model for different replacement years.
staff easily can collect information regarding technical condition and construction of the assets.

Industrial devices based on Windows CE have turned out to fulfill the requirements set by the Danish utilities. Windows CE was therefore selected as the software platform. Examples of hardware used by the data collection system is seen in Figure 3.

The layout of the system is quite simple. Data is read from the VefoNet system and transferred to the handheld device. Then the data can be maintained in the field by use of the keyboard or by clicking on the touch-sensitive screen. After an inspection data is uploaded back to the VefoNet system and data is updated.

An example of a screen dump from the user interface on the handheld pc is showed in Figure 4.

Figure 3. Example of two type of Windows CE industrial terminals fulfilling the requirements to a handheld device for use in the utility.

Figure 4. Screen dump from the application on the handheld pc’s (in Danish). In this window the user can check different technical conditions for the asset.

Conclusion

A method has been developed which can address the question “When to replace a component?”. The results from the model are expressed in direct economic terms.

The model is based on a financial calculation of the present value (the sum of the cost during a period of e.g. 20 years carried out at a certain discount rate) for different options of replacement times. The calculations include direct economic costs as well as indirect costs.

The model - as well as other models - have been included in an asset management software tool. The tool includes a data collection system based on Windows CE handheld PC’s. A systemised data collection system is important to establish good input data in a cost-effective way for advanced asset management models like the one described.

References

