INVESTMENT STRATEGIES BASED UPON ASSET SIMULATION

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ABSTRACT

An important task of the asset management process is the definition of strategies for long term investments to ensure the required functionality and quality of the complete system. This definition is performed by using a dynamic asset simulation tool, which represents the statistical behavior of the complete asset group over a time range of 40 to 60 years. A more sophisticated approach includes the actual condition distribution of the asset group into the simulation method. The final result is the evaluation of the total investments and operational expenditures as well as the comparison of different investment and maintenance strategies.

1 INTRODUCTION

The Asset Management Process can be divided into different steps, which start with the evaluation of the long term strategy and end with a concrete maintenance activity of certain equipment [1], [2]. In the following report the initial step is described: The derivation of the capital as well as the operational expenditures of a fleet of power transformers over the total life time. The goal of this analysis is to develop a long-term plan for the maintenance and investment strategy of a system by suitable equipment models. The main questions which can be answered by usage of the long term resource planning are:

- Evaluation of long term strategies,
- impact on system reliability,
- estimation of capital and operational costs,
- calculation of the yearly budget,
- identification of investment peaks to allocate the necessary resources.

Finally the procedure is described how to select the appropriate pieces of equipment which have to be replaced, if the yearly budget is confirmed.

2 ASSET SIMULATION

2.1 Equipment model for the operational level

Different models can be used for the presentation of different groups of equipment to develop the long-term plan for the maintenance as well as the investment strategy for the strategic corporate level. The main task of this procedure is to prepare the long-term decision in the asset management process. In general several model reproductions are possible in order to solve the task:

- statistical model (e.g. normal distribution, chapter 2.3),
- reproduction under consideration of the survival function (chapter 2.4).

The two models mentioned are briefly discussed in the following. Thereby the usage of the statistical model is mainly dealt with considering the application of the normal distribution of a population of assets. Whereas the last model described in [3] takes into consideration the actual condition of the asset. A lot of data are required to perform the asset simulation and these are described in chapter 2.2 considering the asset group of 10/0.4-kV-power transformers.

In general the asset simulation covers two financial aspects: the capital investment expenditure (CAPEX) and operational expenditure (OPEX). In this report the calculation of the investment costs are evaluated.

2.2 Considered asset group

The data base used to evaluate the principles of the long term resource planning in this report consists of 1000 power transformers (10 kV/0.4 kV) and the age distribution of the asset group under investigation is presented in Fig. 1.

Furthermore the following data have to be used, to perform the simulation:

- Number of pieces of equipment,
- maximum life time,
- statistical behavior of the group or condition assessment,
- age distribution of the asset fleet (Fig. 1),
- investment costs,
- renewal rate of old components (≤ 1),
- additional investments depending on the system development.

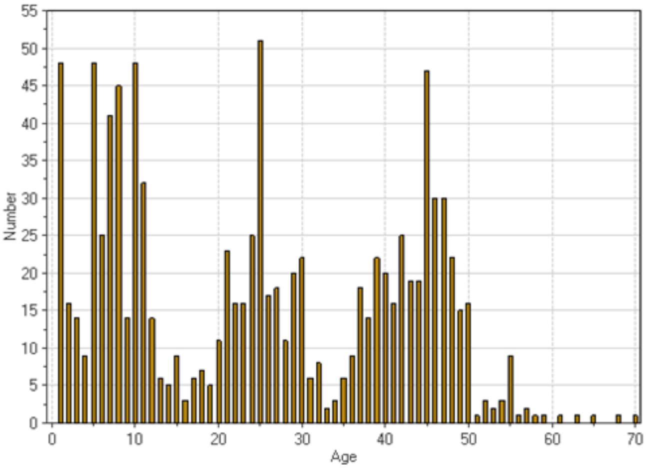

Fig. 1: Age distribution of the population

According to Fig. 1 most of the power transformers are installed between 1960 and 2010 with some investment peaks in the sixties, eighties of the last century and during the last decade**.**

2.3 Statistical method (normal distribution)

In case of the usage of the statistical method to calculate the number of components which have to be replaced it has to be assumed, that a density function of the replacement rate can be applied. The basic principle is that a sufficient population is available, so that for example a normal distribution can be presupposed. In general various types of statistical functions can be used, e. g. Weibull distribution, to achieve the asymmetrical shape of the distribution to simulate the different age behavior of the asset. If for example according to Fig. 2 a mean value μ = 52 years of power transformers (10 kV/ 0.4 kV) is assumed with a standard deviation σ = 6 years, the number of renewed power transformers can be determined, which should be exchanged in each year within a fixed time range. In addition it should be considered that all components have to be replaced which exceed a maximum technical life time, for example t_{max} = 70 years. The used replacement rate according Fig. 2 depends on the experience of the distribution system operator.

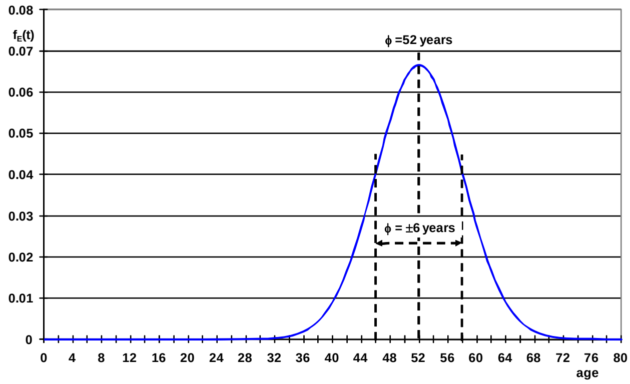

Fig. 2: Replacement rate of 10/0.4 kV power transformers (density function f(t), normal distribution)

In general three different equations are available which describe the statistical behavior of statistical functions:

- Density function f(t), Fig. 2,
- distribution function F(t),
- hazard or replacement rate λ(t).

The other two functions F(t) and λ(t) can be derived by the density function, so that with the help of the mean value μ and the standard deviation σ the replacement of an asset population can be calculated depending on the given time interval. If the number of replaced components and assets, which are in service, can be calculated for every year, the related investment expenditure (CAPEX) can be derived.

Fig. 3 shows the result of the asset simulation and it can be expected, that investment peaks will arise in about 7 and 47 years due to the age population of the considered power transformers.

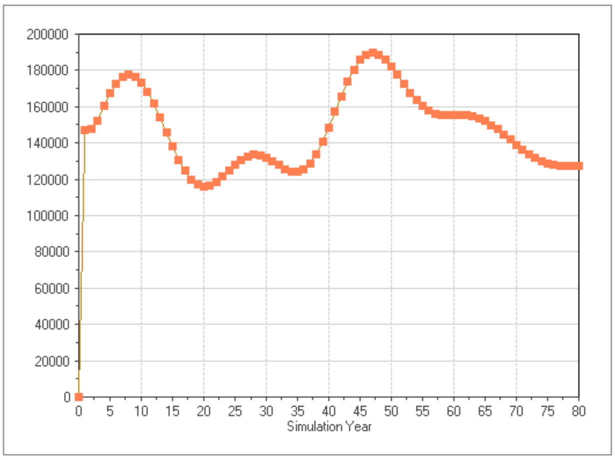

Fig. 3: Yearly investment costs of the replaced power transformers (CAPEX in Euros), normal distribution

The average number of power transformers which has to be replaced within five years is about 19 each year. On the basis of the exact age distribution of the asset fleet the behavior of the entire group of asset is analyzed by the application of the statistical model, thus an allocation of the exact equipment which has to be changed is in principle not possible.

2.4 Reproduction of the survival function under consideration of the actual condition

Whereas the described method according to chapter 2.3 uses the statistical functions, which for example are published in technical journals, in this chapter it is the task of the asset simulation to apply the simulation by usage of the actual condition of the asset group. This approach is described in detail, see [3].

The total process can be divided in different steps, which can be described as follows:

- Evaluation of the condition of the asset group,
- representation of the condition depending on the age,
- derivation of the survival function,
- asset simulation.

The condition of the total asset group can be evaluated depending on various criteria, which describe the condition as well as the importance of the assets according to [4]. After the parameters *c* (condition) and *i* (importance) have been calculated, the results (crosses) can be listed in an X, Y system of coordinates, as shown in Fig. 4. The c and i axes are scaled in such a way that the *c* and *i* values can at maximum assume the value 100. A large value for *i* signifies that the equipment concerned is of high importance in the network. The vertical axis represents the condition of the power transformer concerned, while the horizontal axis reflects its importance in the network. A cross in the top left-hand corner corresponds to a power transformer which, although in a poor technical condition, would not cause any major consequences if it fails. Depending on the condition three different areas for maintenance activities can be distinguished: replacement (red area) – service (yellow area) – inspection (green area). The consequence is that the components with a higher condition level of $c \geq 60$ should be replaced.

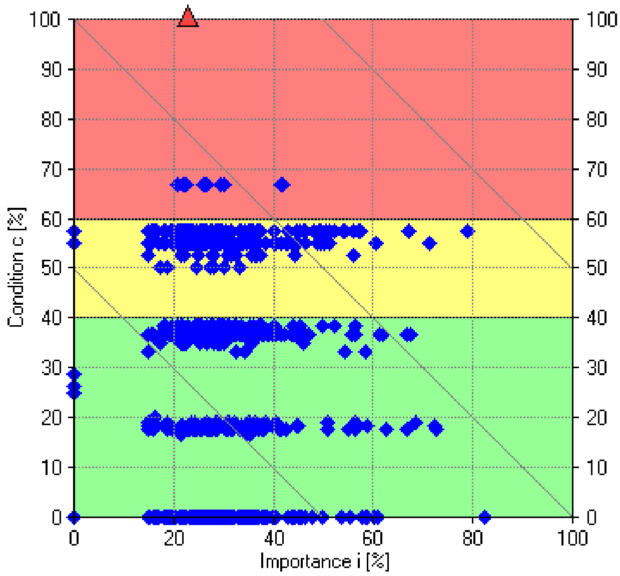

Fig. 4: Condition and importance asset of power transformers

The evaluation of the condition of the asset group is done by calculating the values of the artificial age in addition to the given real age. If the power transformer behaves as old as it is, the real and artificial age are equal, otherwise when the asset behaves older than it really is, the artificial age is higher than the real age. This can be seen in Fig. 5, where the envelope is a frequency polygon through the transformers with the best condition states. The artificial age of the individual equipment can be seen from the chart by using a horizontal line through the coordinate of the power transformers until the frequency polygon is cut [3], [5].

Due to the age behavior of the asset group the year of replacement can be evaluated taking the maximum possible life time into consideration (in this case t_{max} = 70 years). Furthermore it is assumed that the future condition performance is comparable to the performance in the past. The final conclusions will lead to the distribution function (survival function) of the total asset group, which can be used for the simulation.

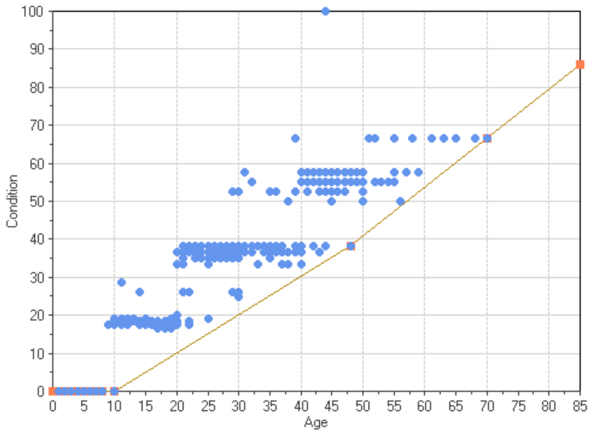

Fig. 5: Condition of power transformers depending on age

Finally the yearly replacement rate can be evaluated, if the survival function is correlated with the age distribution of the asset population. The result is listed in Fig. 6, if the number of components is multiplied by the investment costs of a new equipment.

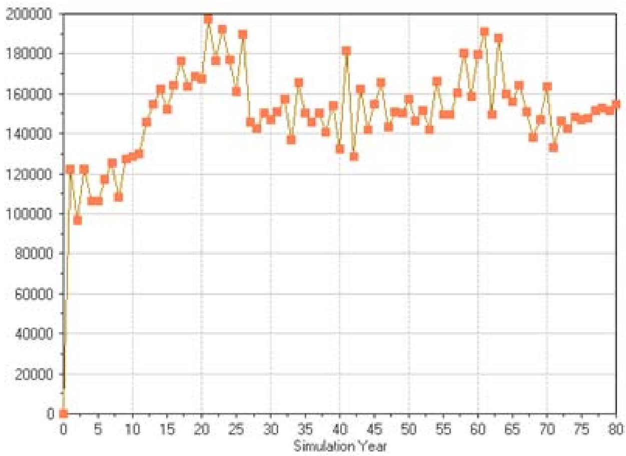

Fig. 6: Yearly investment costs of the replaced power transformers (CAPEX in Euros), condition assessment

3 COMPARISON OF DIFFERENT APROACHES

Due to the different approaches of the asset simulation (chapter 2.3 and 2.4), the yearly investment costs are different regarding the considered asset population, if the Figures 3 and 6 are compared. Whereas the usage of the density function according Fig. 2 takes the statistical behavior of the asset fleet, derived from overall experiences, into consideration, the second approach uses the condition assessment of the actual system components which are installed in the system. The result is demonstrated by Table 1, if the number of components are compared which have to be replaced in the first years.

Year	Number Fig. 3	Number Fig. 6
1	18	15
2	18	12
3	19	15
4	20	13
5	21	13
average	19	14

Table 1: Comparison of the replaced transformers, depending on the simulation approach

4 FINAL REPLACEMENT STRATEGY

The result of the asset simulation is to evaluate the yearly budget for the investment costs of the asset group. Due to the different steps of the asset management process [1], the next step is to fix the equipment which should be replaced. The solution is the comparison of the asset simulation (Fig. 6) with the condition assessment (Fig. 4) and the last figure mirrors the actual condition of the total asset group depending on the importance in the system. The investment costs which are derived from the simulation define the number of transformers which should be replaced (Fig. 7, right) and the sequence which individual components have to be replaced can be taken from the condition assessment (Fig. 7, left) starting from right to left in the red replacement area.

5 CONCLUSION

The investment and maintenance costs can be evaluated with the help of an asset simulation for different years under the today's boundary conditions. By a change of the boundary conditions, e.g. extension of the possible life time, the influence on the financial requirement and the system reliability can be derived.

It is possible in a second step to identify the equipment, which should be maintained or replaced under knowledge of the annually necessary budget to identify with the help of the RCM procedure according to [4].

The substantial advantage of a dynamic asset simulation is, besides from the knowledge of the financial requirements under consideration of the current maintenance and renewal strategy, to evaluate the influence of different strategies on the final result, e.g. the shift of a renewal measure or extension of a maintenance activity. This will be of special interest in case of the discussion with the appropriate national authorities regarding the investment strategy and the financial expenditures deriving from this.

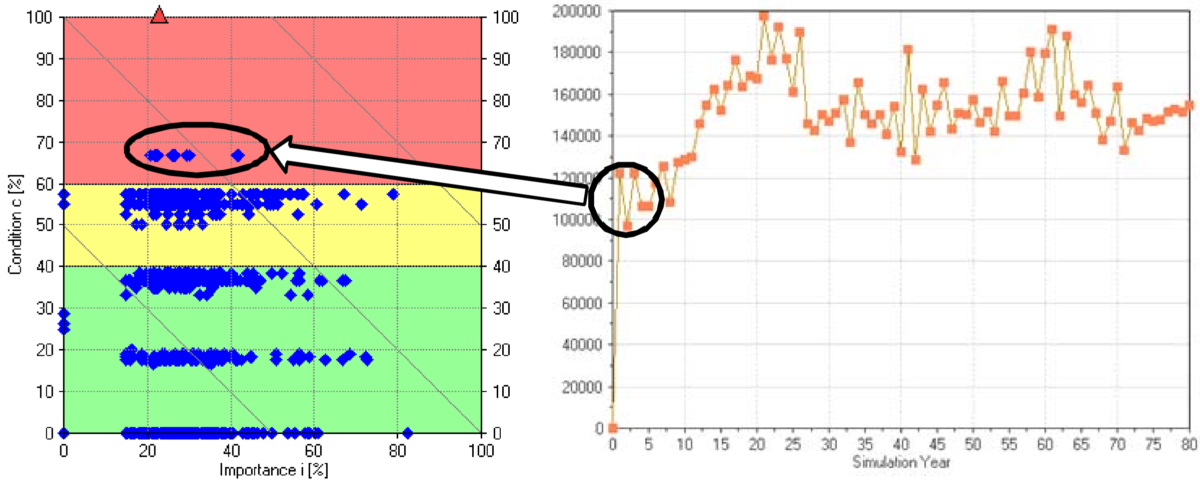

Fig. 7: Final replacement strategy for the asset group

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