Aging and Degradation, Their Detection and Monitoring & Asset Management

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INTRODUCTION

In this paper gives an overview about asset and risk management. The terms of aging and degradation and the methods for the detection and condition evaluation by the means of technical diagnostics and monitoring were discussed. Asset, risk and maintenance management were the most important methods in electric power utilities to gain an effective electric power production and to operate the electric grid. The monitoring of the condition is a necessary method to know about the technical status of the equipment. To evaluate the technical risk and the priority of network components often statistical analysis methods were applied.

Keywords: Aging, Degradation, Asset Management, Condition Evaluation, Diagnostics, Monitoring, Risk Management, Statistical Analysis

ASSET MANAGEMENT

The goal of asset management is designed to align the management of asset-related spending to corporate targets. The objective of asset management is to make all infrastructure-related decisions according to single set of stakeholder-driven criteria. The payoff is a set of spending decisions capable of delivering the greatest stakeholder value from the investment money available. Electric utilities typically adopt an asset management approach to either reduce spending, more effectively manage risks, or drive corporate objectives throughout an organization [1].

Asset management consists of different core processes according to Figure 1:

- investment decisions
- planning
- project decision
- project realization
- maintenance
- operation

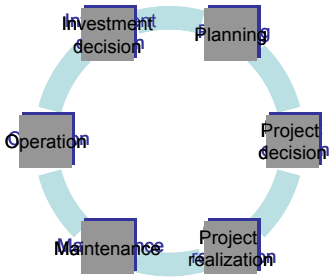


Figure 1: Core Processes of Asset Management

The structure of asset management can be explained as a process of three parts, where the asset owner puts the asset manager and other service provider in charge. Different service level agreements (SLA) were arranged between the asset owner and each service provider. The principle of this structure is displayed in Figure 2.

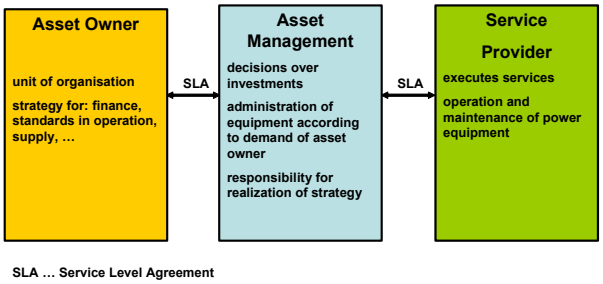


Figure 2: Structure of Asset Management

Beside this structure several assisting tools are available for the asset manager. The most important tools were the maintenance management, the technical controlling and the risk management.

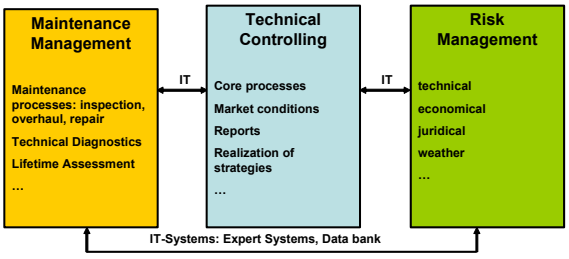


Figure 3: Assisting Tools for Asset Management

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AGING AND DEGRADATION

Aging is defined as the irreversible change of the properties of an electric insulation system (EIS) due to action by one or more factors of influence. Aging stresses may cause either intrinsic or extrinsic aging. In most EIS extrinsic predominates because, in practice, they include some imperfections and contaminations.

The acceleration of aging can result in an irreversible condition, deterioration. Following different types of accelerated aging were important for electric power equipment [2]:

Electrical aging is effected by:

- partial discharges, when local electric field strength exceeds the breakdown strength in the liquid or gaseous dielectric medium
- tracking , treeing or electrolysis
- increased temperatures produced by high dielectric losses
- space charges

Thermal aging is caused by:

- the progress of chemical and physical changes as consequences of chemical degradation reactions, polymerization, depolymerization, diffusion, etc.
- thermomechanical effects caused by the force due to thermal expansion and/or contraction

Mechanical stress can cause:

- fatigue failure of insulation components by a large number of low-level stress cycles
- thermomechanical effects caused by thermal expansion and/or contraction
- rupture of insulation by high levels of mechanical stress such can be caused by external forces or operating condition of the equipment
- abrasive wear caused by relative motion between equipment components
- insulation creep or flow under electrical, thermal or mechanical stress

Each insulation system shows characteristic defects due to its type of load. The aging of a transformer is dominated by the thermal load; the solid insulating material consists of oil impregnated paper. The mechanical and also the electrical breakdown strength is dependant to the length of the cellulose molecules. If the transformer has a high percentage of water content the degradation process is accelerated. At generators the degradation of the insulation system is a multiple process of electrical, mechanical and thermal load [3].

RISK MANAGEMENT

Risk management is classically divided into four steps as shown in Figure 4. With the knowledge of statistical functions the basis for the technical risk management is given. The first step “identification of the risk” can exemplarily be done with the risk matrix.

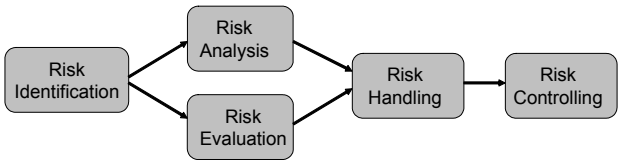


Figure 4: Risk management

For the next steps in risk management, the different kinds of risk have to be considered. Risk can be divided into following aspects [4]:

- technical risk
- economical risk
- judicial risk (laws, contracts)
- management, financial and trading risks
- ecological and environmental risk
- other risks

Depending on the politics and philosophy of the operator, further decisions relating to the analysis, evaluation and handling of the risk could also occur.

Risk Analysis

To analyze the risk of operation and of a failure and to evaluate the damage and costs several management tools can be used. One of the most popular is the risk matrix. The risk matrix displays the probability of a fall out in dependence of the consequential damage. The determination of the failure probability can be done by the statistical relation between technical condition of the power equipment or with a database of the statistical lifetime. The evaluation of damage has to be done for each power equipment separately under the consideration of the economical consequences for the company.

In Figure 5 an example for a risk matrix is given. Eight transformers (T1 to T8) with a different condition level and importance were displayed. On the x-axis the consequences respectively the importance of a damage and on the y-axis the probability of failure occurrence respectively the condition is quantified for eight apparatus. The position of the equipment can be interpreted as:

- High risk: dark grey area, the risk due to failure probability and damage is not acceptable
- Normal Risk: the medium grey fields show equipment under normal operational behavior, not immediate measures were necessary

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- Low Risk: bright grey field, equipment is new or not consequences in case of fall out

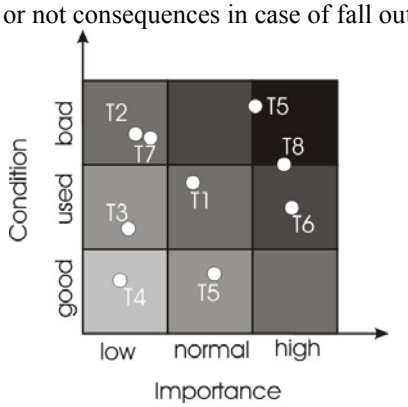


Figure 5: Risk matrix and risk assessment

Detection and Monitoring of Aging and Defects

For the quantification of condition the means of technical diagnostics and condition evaluation can be applied. For generators normally following test methods were applied: insulation resistance (PI), dissipation factor (tan δ TIP-UP), Partial Discharges (PD) as well as operational dates and the results of a visual inspection [5, 6, 7].

For power transformers normally different oil parameters represent deciding factors: electrical chemical analysis (breakdown voltage, acidity, tan δ, etc.) as well as Dissolved Gas Analysis (DGA) and for the determination of the solid insulation system the DP is measured (Furan analysis). Only if a fault is detected additional electrical tests (PD-measurement) are applied [8, 9, 10].

To determine the consequential damage respectively the importance of the possible claim following facts have to be taken into account: noncompliance of contracts, costs of repair/spare parts of machine, additional costs, danger for people or properties, as well as juridical consequences.

Risk Evaluation by the Means of Statistical Analysis

The risk evaluation can also be done by using statistical databases. For electric power equipment and in high voltage engineering normally the two parametric Weibull distribution is applied for statistical evaluations and calculations. Through the characteristic lifetime and the Weibull exponent the failure probability F(t) is given, see equation (1).

$$F(t) = \int_0^t f(t).dt = 1 - e^{-\left(\frac{t}{\eta}\right)^{\beta}} \quad (1)$$

with: η … characteristic Lifetime
β … Weibull Exponent

The first deviation in time in equation (1) results in the density function f(t), which is given by gradient of the failure probability. The reliability R(t) is a very important quantity for maintenance strategy and renewal program of the utility, which is defined in equation (2).

$$R(t) = 1 - F(t) \quad (2)$$

Dividing the density function through the reliability, the failure rate λ(t) results in equation (3). The failure rate gives the number of failures at the present time by the total number of failures.

$$\lambda(t) = \frac{f(t)}{1 - F(t)} = \frac{f(t)}{e^{-\left(\frac{t}{\eta}\right)^{\beta}}} \quad (3)$$

The curves of Figure 6 were calculated with the results of the Weibull analysis and equations (1) through (3). In this Figure the failure probability, reliability and failure rate of different generator insulations systems are shown [11].

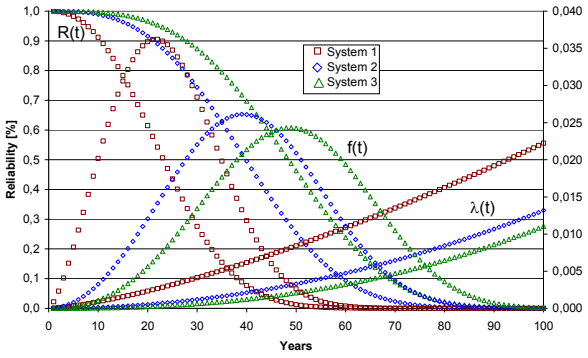


Figure 6: Reliability, failure density and failure rate of three different insulation systems

Risk Handling

The task of risk handling is to prevent, reducing, transferring or finally to accept the risk, see Figure 7. If a high and therefore not acceptable risk is present measures to reduce the risk have to be applied immediately. The reduction of risk can be achieved by maintenance, replacement of parts of the machine or in the most expensive way a full exchange.

In case of a transformer the IEC standards 60422 (Table 4) recommends measures to improve the condition of a transformer. This recommendation can be interpreted as measures of risk handling. If the results of the technical diagnostics of the oil shows a low breakdown voltage, a high water content, a high concentration of particles or a clouding of the oil a filtration, a drying or degassing of the oil. In the case that the oil shows a low interfacial tension (IFT), high

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acidity, high tan δ, low inhibitor level or sludge formation a total regeneration or exchange of the oil is recommended.

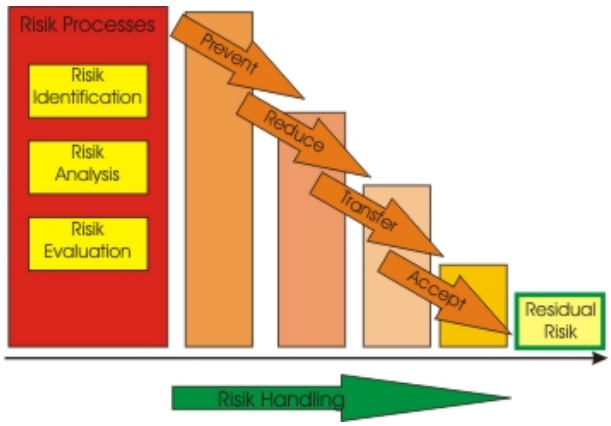


Figure 7: Risk handling

There are no general rules for ideal measures of risk handling; always economical aspects have to be fulfilled. The costs of the risk measures have to be opposed to the profit; in many cases it will be useful to accept a residual risk. In some cases also a transferring of the risk can be done, e.g. maintenance services can transferred by outsourcing to a service provider.

Risk Controlling

Finally the controlling of the risk has the same priority as the other measures in risk management. After the risk measures were implemented and finished the risk should be evaluated again to see if the desired success resulted.

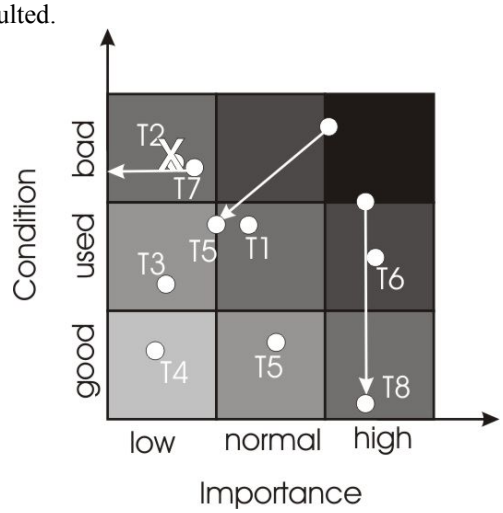


Figure 8: Risk handling and controlling

Above some examples for the possible risk handling measures and the effect in the risk matrix are shown. The transformer T8 was replaced by a new one, for this reason it moves from high risk to low risk area – the risk is reduced. At the transformer T5 the oil was regenerated, so that the condition is acceptable again and therefore the risk decreased. The transformer T2 was set out of operation because the customer does not exist longer, the risk is prevented totally. At transformer T7 the maintenance was sourced out to an external service provider so that the risk could be transferred.

SUMMARY

In this paper the basic management tools for asset and risk management were discussed. The structure and processes of asset management were shown. By the means of a risk matrix a good overview about the structure of the observed network is possible. For the equipment of high risk different measures can be applied to handle the risk. Besides preventing also reducing, transferring and finally accepting were usual methods to manage the demands of risk.

The failure probability can be determined by technical diagnostics and condition evaluation as well as statistical lifetime estimation. For the statistical analysis the bathtub curve and Weibull distribution is applied.

Within risk controlling the success of each measure can be observed. Equipment of high risk should be shifted to areas of better condition or lower failure impact.

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