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Maintenance and Risk Management for Hydro Generators

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INTRODUCTION

For a save and reliable operation of rotating electric machines the maintenance strategy and condition evaluation is a sufficient part for the utility. Within the maintenance program diagnostic measurements should be evaluated carefully. Only the results of both, diagnostic measurements and analysis of the machine operating dates can give a view to the actual condition of the power equipment. For this reason the measurements and data analysis has to be treated independent and carefully. Based on failure statistics and the results of diagnostics and condition evaluation the reliability of the machines can be determined. For the risk assessment the different kinds of risks and their probability so as the magnitude of damage have to be analyzed.

Risk in general is defined as the product of probability and its amount. Therefore the basis for the risk assessment is the knowledge about the probability of any kind of risk and the size of its damage. By the means of statistical methods the reliability and failure probability can be calculated. To gain a realistic statistic reliability function the data quality is essential. The risk size is dependant on contractual and public law constellations or official conditions so as consequential damages. For the risk analysis any tools which were well known from quality management can be helpful and give the possibility to cover all possible risks. As an example for a management tool the risk matrix should be mentioned, with it risks can be recognized and classified. The applied risk strategy can result in a reduction, prevention or transfer of each single risk.

Maintenance

Maintenance is a combination of all technical and administrative measures and all measures of management during lifetime period to prevent the functional condition or recirculation to this condition, that the demanded functions were ensured.

Maintenance			
planned, preventive, condition oriented		failure incident	
Inspection	**Servicing**	**Reconditioning**	
Detection and evaluation of actual condition	Measures to keep desired condition	Measures to restore desired condition	
Condition control, diagnostic of damage to remove faults, trending	Delay or prevent time relevant faults	Time dependant reconditioning	Damage dependant reconditioning
Selective tests and measurements	lubricating, cleaning, adjusting, exchanging, conservation	Overhaul from functional condition	Repair after breakdown or failure
Revision			
Combined measures consisting from components: inspection, servicing and reconditioning			

Figure 1: Visual inspection of a generator winding
Table 1: Terms of Maintenance

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.

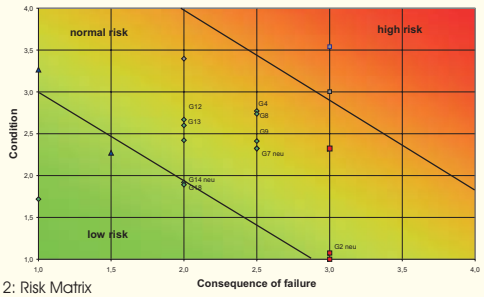

Figure 2: Risk Matrix

- High risk:
red area, the risk due to failure probability and damage is not acceptable
- Normal risk:
the yellow fields show equipment under normal operational behavior, not immediate measures were necessary
- Low risk:
at all green fields the equipment is new a save and reliable operation is present

Statistical Analysis

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 and the reliability R(t) and failure rate λ(t) can be calculated.

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

with: η … characteristic Lifetime
β … Weibull Exponent

$$R(t) = 1 - F(t)$$

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

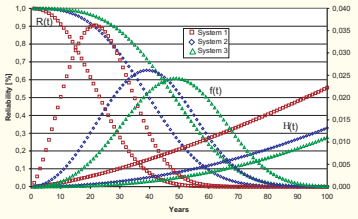

Figure 3: Statisitcal evaluation of different generator insulation systems:
- System 1: Resin
- System 2: Shelac
- System 3: Asphalt

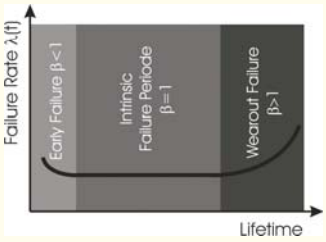

Figure 4: Interpretation of Weibull-Exponent β
"Bathtub Curve"

Risk Handling

The task of risk handling is to prevent, reduce, transfer or finally to accept the risk. 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 of a full exchange.

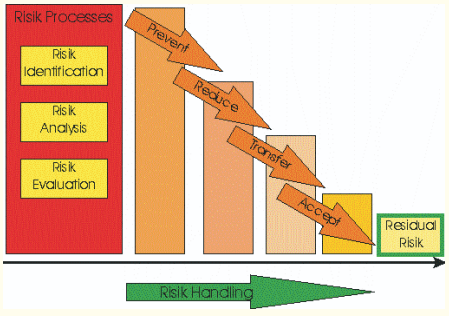

Figure 5: Schematic process of risk handling

Summary

In this paper the theory and practice of maintenance for rotating machines and the strategy for the operation were discussed. To evaluate the condition technical diagnostic measurements have to be evaluated carefully but also operational dates and other qualitative criterions should be observed.

The knowledge base of risk management was investigated and the main steps in risk evaluation were shown. The risk matrix is one of the most popular tools in risk management and enables a general view to the actual situation of the machine park. Handling and controlling the risk is a