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# Safety and Availability - RAM Analysis in Power Plants

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ABSTRACT
The global competitiveness of providers is getting harder. Safety and availability of plants and systems are key factors influencing product quality and operating costs. With a simulative RAM Analysis (Reliability, Availability, Maintainability) an integral approach which takes into account the factor man, technology and organization is available. The results of these simulations show the significance of individual influencing parameters and/or individual components vis-à-vis system availability as well as the probability of system failures. Thus we are enabled to quantitatively assess the influence of maintenance on availability, safety and on-going costs. With the help of this procedure, the operational behavior of plants and systems is realistically simulated. This offers the possibility of integral plant assessments.

## 1 INTRODUCTION

The global competitiveness of providers depends on achieving maximum product quality with minimum costs. Safety and availability of plants and systems are key factors influencing product quality and operating costs. Maintenance ensures that design-based availability and safety are retained and can be adjusted to current requirements. Maintenance, therefore, is a service that adds a lot of value to your plant. It can be the decisive key to the optimization of operating costs and thus to ensuring international competitiveness.

## 2 SIGNIFICANCE OF MAINTENANCE FOR AVAILABILITY AND SAFETY

We know from experience, for example, that the failure probability of many technical systems or components starts at a specific design-based minimum value and then increases more or less linearly with time (Fig. 1). After the completion of maintenance measures, servicing and corrective maintenance, the particular component or, if applicable, the system in question can be largely considered as fully operational again. As a result, failure probability decreases again to the specific minimum value. This example shows that plant availability and safety vary with time and are mainly determined by maintenance measures.

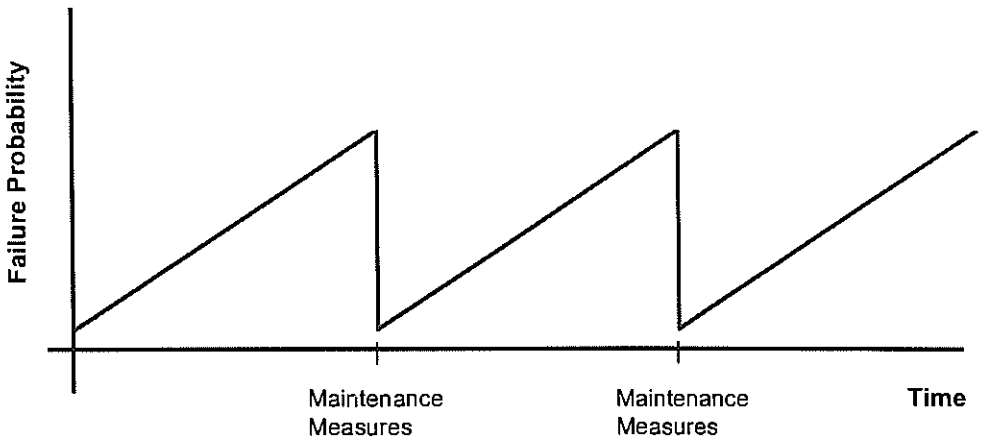



Fig. 1 Influence of maintenance measures on failure probability

In order to avoid risks, the question of plant safety is dominated by the principle of preventive maintenance. The scope and frequency of these maintenance measures depend on the test object's risk potential.

The situation concerning plant availability is slightly different. Depending on the requirements pertaining to availability, a combination of corrective and preventive maintenance is applied. Plant design is crucial in this context. In the case of operational systems of redundant design, preventive maintenance can often be dispensed with, since failure of a duplicated component does not considerably affect availability and there is sufficient time for repair or replacement.

In the age of growing competition, the question: how much maintenance is necessary to achieve the required level of safety and availability is becoming increasingly common. The development of a well-balanced and practicable maintenance strategy consisting of preventive and corrective maintenance for complex plants is a very difficult task. An optimum maintenance strategy requires an integral approach. that takes into account all influencing variables and thus optimizes both safety and availability simultaneously.

## 3 INTEGRAL APPROACH

Plant availability and safety do not only depend on the observation of technical rules and codes or specifications. Basically, plant availability and plant safety are influenced by the factors man, technology and organization. These in turn, are interdependent. This means that all influencing factors must be taken into account when optimizing the maintenance strategy to increase availability and safety. This can only be achieved by an integral approach.

## 4 PROCEDURES FOR THE OPTIMIZATION OF PLANT OPERATION

Today, efficient quantitative procedures are available for integral optimization of the maintenance strategy. They make it possible to compute the effects of maintenance and safety-related measures on plant availability and reliability and to develop optimum solutions.

4.1 Use Of Operational Experience

In almost all plants data is collected in the individual subsections and processed in heterogeneous computer environments. The data collected include information about system structure and components as well as operational experience. In the past, the traditional approach based on the division of labor and insufficiently integrated EDP systems have prevented the centralized collection and evaluation of operational experience.

Today's EDP systems allow processing of almost unlimited information, thus making it possible to realize and optimize integral plant monitoring and plant management based on systematic and supra plant data recording and evaluation. For this purpose, all the know-how, the plant data and the operational experience available in the plant are interlinked and made accessible to all authorized employees. Thus a basis of know-how is created which can form the foundation of an optimized maintenance scheme. The fundamental approach to evaluating and utilizing operational experience is shown in Figure 2 (1).

By means of an example, I would like to show how just the consistent use of operational experience can help to optimize the maintenance strategy.

An in-company energy supplier had to ensure a high availability of electrical energy for certain power consumers. For this purpose, use was made of both external and internal electricity. Most of the electricity was generated by means of a gas and a steam turbine within the company. The energy generated was supplied to a central distribution station and from there supplied to the individual consumers.

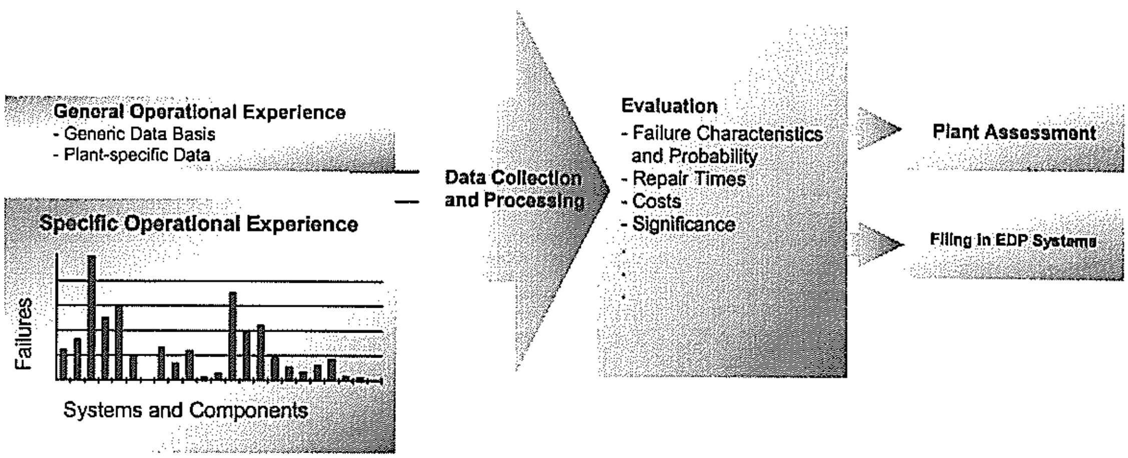



Fig. 2 Fundamental approach to evaluating and utilizing operational experience

The losses in production caused by power failures led to the failure records of recent years being evaluated. Evaluation showed clearly that the failures were caused primarily by the distribution of electrical energy (Fig. 3) and here mainly by human errors in maintenance and the required switching operations.

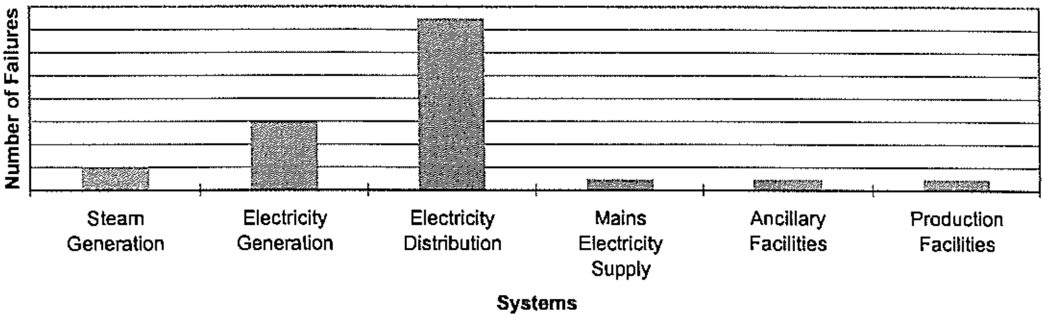
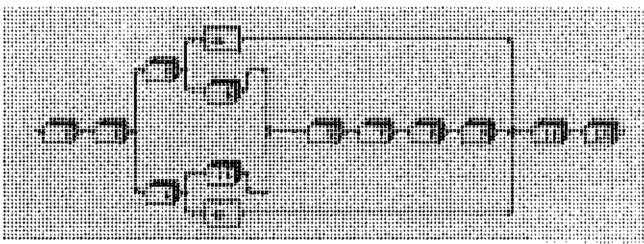



Fig. 3 Example: causes of failures in an energy generating plant

## 4.2 Simulation Analysis

System simulation is a procedure for maintenance optimization that is now successfully applied on an international scale. With the help of this procedure, the operational behavior of plants and systems is realistically simulated.

**Block Wiring Diagram**
**System Structure**



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**Rules**
**Processes**
**Instructions**

```
3.1 If subsystem 7 in current system is failed no
   Passivate subsystem 5 in current system
   Do nothing
3.1 End Of If
3.2 If subsystem 7 in current system is repaired
   3.3 If subsystem 5 in current system is intern
      Activate subsystem 5 in current system
      Do nothing
   3.3 End Of If
   Do nothing
3.2 End Of If
```

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MTBF: Mean time between failure
MTTR: Mean time to repair

**Data**

| | Failures | λ | MTBF | Dauer | MTTR |
|---|---|---|---|---|---|
| Compressor | 5 | 3,5E-02 | 266 | 10 | 30 |
| Turbine | 4 | 5,00E-02 | 20 | 321 | 405 |
| Combustion Chamber | 29 | 1,2E-01 | 8 | 247 | 123 |
| Bearings | 3 | 2,0E-02 | 40 | 19 | 44 |

Fig. 4 Simulation model

All factors that influence safety and availability and result from man, technology and organization are presented within one mathematical model. The basic approach is shown schematically in Figure 4. This approach takes interface problems implicitly into account.

Availability and safety are calculated for each point in time within the defined period by means of simulation (2) (Fig. 5).

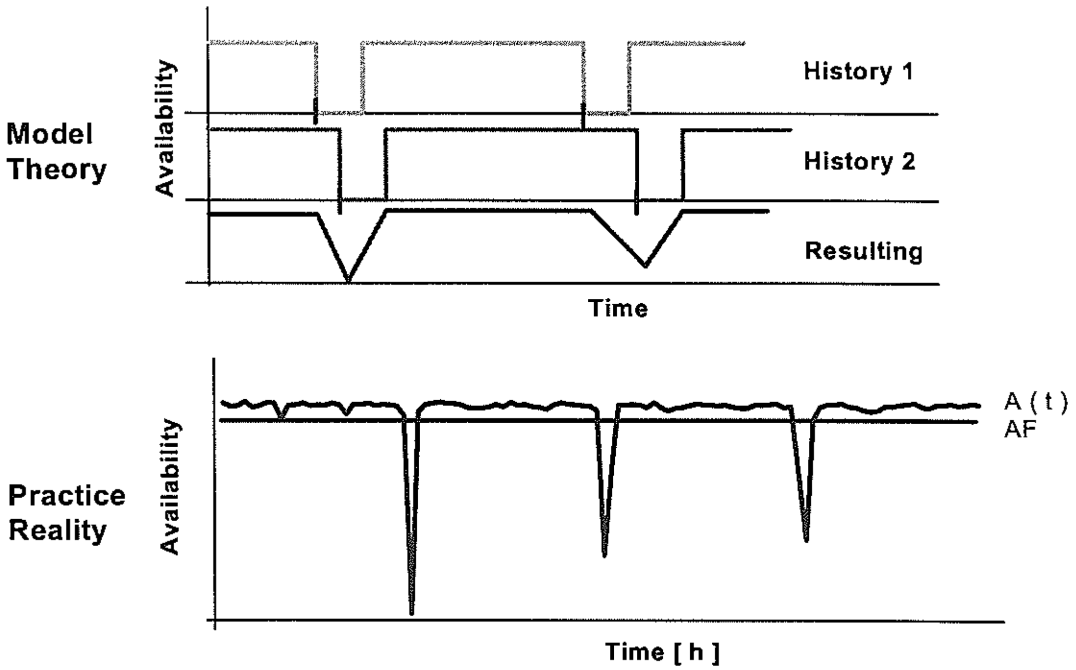


Fig. 5 Simulation of the operation

The results obtained in this analysis show the significance of individual influencing parameters and/or individual components vis-à-vis system availability as well as the probability of system failures. Thus a tool is provided which makes it possible to quantitatively assess the influence of maintenance measures on availability, safety and on-going costs and to optimize the maintenance strategy. Safety and availability are thus optimized at the same time. In detail, this method has the following advantages:

- determination of the key variables influencing availability and safety
- determination of the priority of individual measures
- cost transparency for individual measures
- prediction of the effects of planned measures on safety, availability and costs.

Please allow me to present the advantages of this procedure by means of the development of an optimum maintenance strategy for a combined power station. In the first step various possible inspection and revision variants were compiled based on the overhaul time, the manpower required, the number of replacements and the costs (Fig. 6).

| Name of inspection | Relative duration of inspection | Relative costs |
|---|---|---|
| Minor | 3 | 11 |
| Main I | 43 | 10 |
| Main II | 29 | 10 |
| Main III | 19 | 33 |
| Intermediate I | 14 | 9 |
| Intermediate II | 11 | 10 |

| | |
|---|---|
| Inspection 1 (Basis) | Minor + Main I + Intermediate I |
| Inspection 2 | Minor + Main II + Intermediate I |
| Inspection 3 | Minor + Main III + Intermediate II |

Fig. 6 Inspection and revision variants, example combined power station

In the second step, the combined power station was disaggregated to such an extent that it was possible to present the various inspection and revision variants in a simulated computer model. Figure 7 shows the basic analytical model.

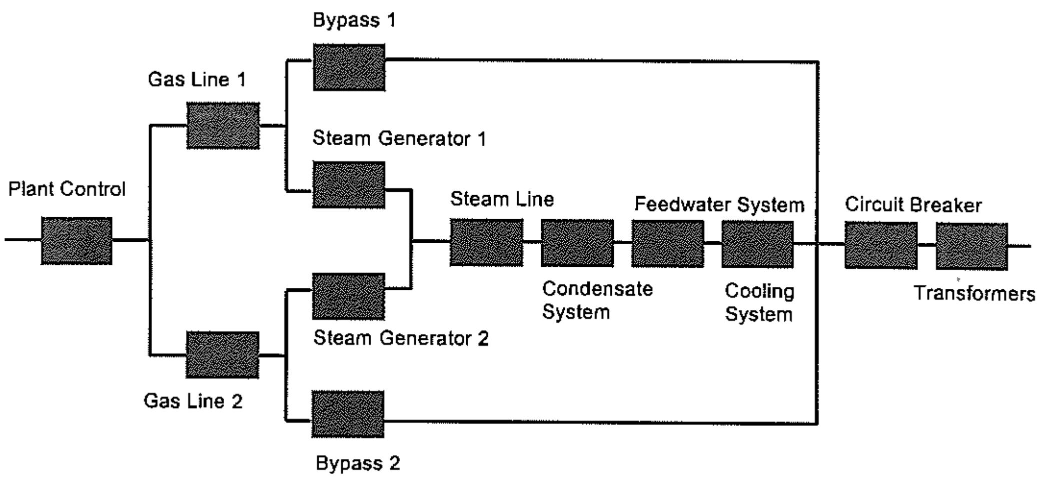


Fig. 7 Analytical model / basic model

In the third step, the operational experience gathered in comparable plants was evaluated in order to obtain reliable information on the failure behavior of components (MTBF) and the mean time for repairs. The fundamental approach has already been shown in Figure 2. As shown by the analytical results (Fig. 8), information for optimizing the maintenance strategy is already obtained at this stage of the analysis. It becomes clear, for example, that failure of individual components in systems of redundant design does not result in the failure of the overall system.

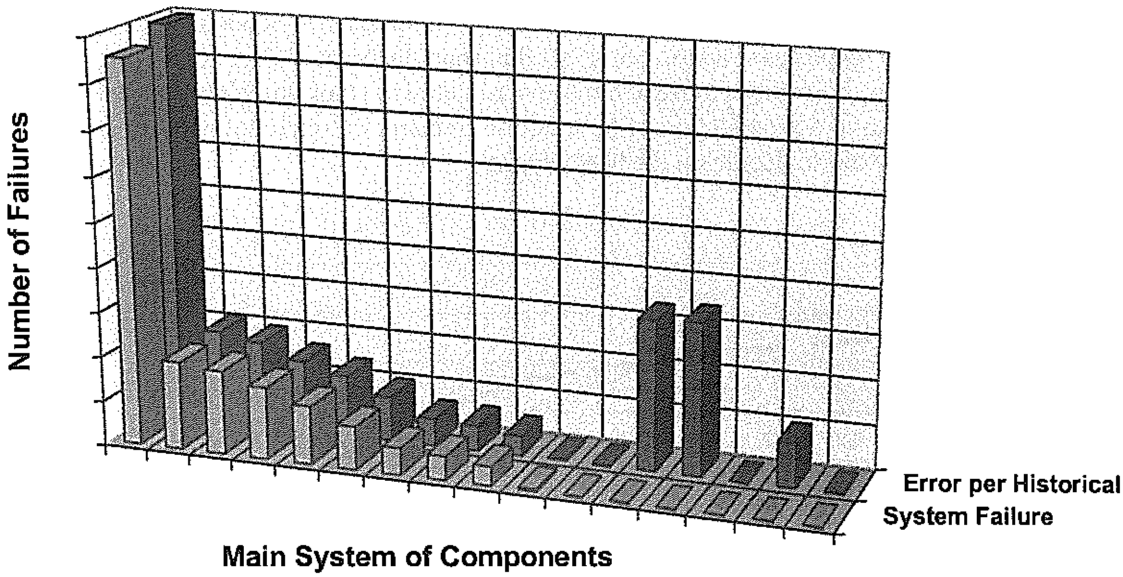


Fig. 8 Failure behavior of the main components in a combined power station

Finally, in the fourth step, the operational behavior of the plant was simulated and the influences of the various inspection variants quantified. The results are presented in Figures 9 and 10. Figure 9 shows the specific availability and the costs connected with the various inspection variants.

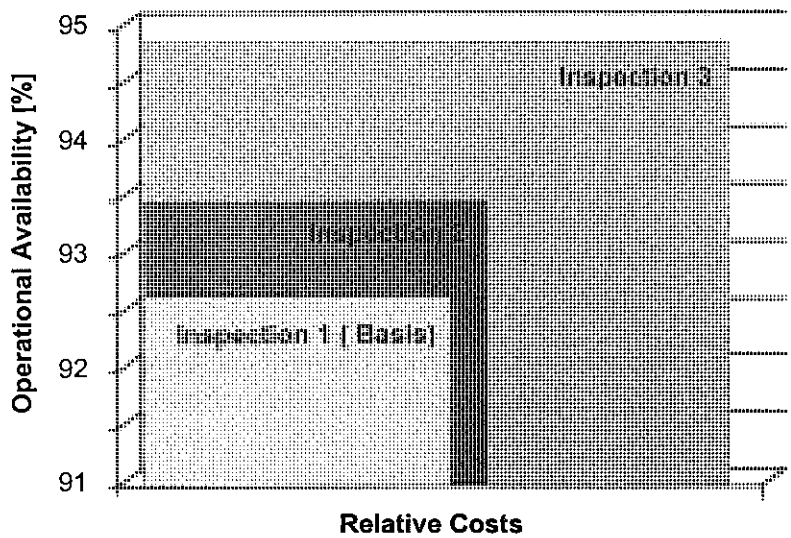


Fig. 9 Availability and costs in relation to inspection variants

Figure 10 shows how failure frequency affects the spare part scheme. If a plant has a low failure frequency which in turn is determined by the maintenance scheme it is more cost effective to store expensive spare parts at the manufacturer. With increasing failure frequency, however, it becomes more and more reasonable to stock spare parts directly at the plant. The quantitative determination of how failure frequencies relate to inspection variants provides a valuable aid to decide on the best variant.

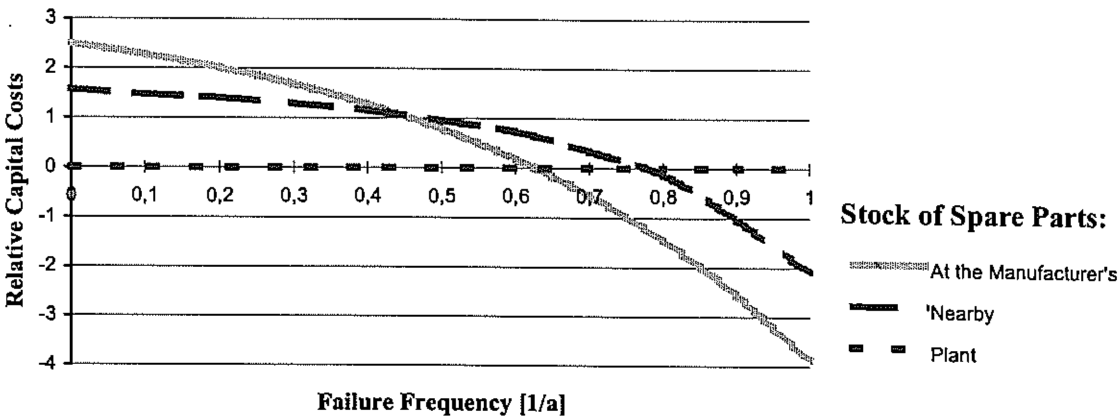


Fig. 10 Storage alternatives, example combined power station - strategic spare part

## 5 SUMMARY

RAM Analysis to optimize plant availability and safety must take into account a large number of factors. Without mathematical aids it is hardly possible to assess the effects of individual measures in the case of complex plants. The procedures presented here offer the possibility of integral plant assessments in which all variables influencing plant availability and safety are taken into account. This allows the development of a maintenance scheme that makes it possible to simultaneously optimize both plant safety and availability.

Bibliography


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