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There is no 'Off-The-Peg' Solution

As part of the energy transition, managers of thermal power stations are facing significant cost pressures that sometimes lead to serious impacts on plant safety. Many of the recently reported incidents can be attributed to insufficient maintenance, for example. New strategies that are customised to the case at hand and ensure an ideal cost-benefit ratio and maximum plant safety are in high demand.

Thermal power station managers are facing a dilemma. The energy transition has resulted in rising cost pressures, which, in turn, tighten the screws on maintenance budgets from year to year. Plant managers are less willing to invest, postponing modernisation measures and new purchases. At the same time, they are less and less frequently able to run their power stations in profitable full-load operation. Instead, power stations must withstand frequent load changes during startup and shutdown operations, and manage steep load ramps in order to respond flexibly to fluctuations in the feed-in of electricity from renewable sources. This has impacts including reduced service life of individual plant components.

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Higher wear also calls for new maintenance strategies. Otherwise, as shown by recent incidents, it may result in malfunctions and downtime. In the Staudinger power plant in Hesse, Germany, for example, an explosion caused steam to be blown off under high pressure, penetrating the outer façade of the building. Experts determined that the incident had been caused by cracking in the boiler circulating pump, which was exposed to high cyclic loads. The costs of repair alone amounted to millions. On top of this the plant suffered losses in profit caused by several months of downtime.

No two faults are the same

However, not every crack requires immediate repair upon discovery. Instead, plant

Figure 1. Slag formation in the combustion chamber of a wood-fired boiler caused by temperatures above the deformation temperature.

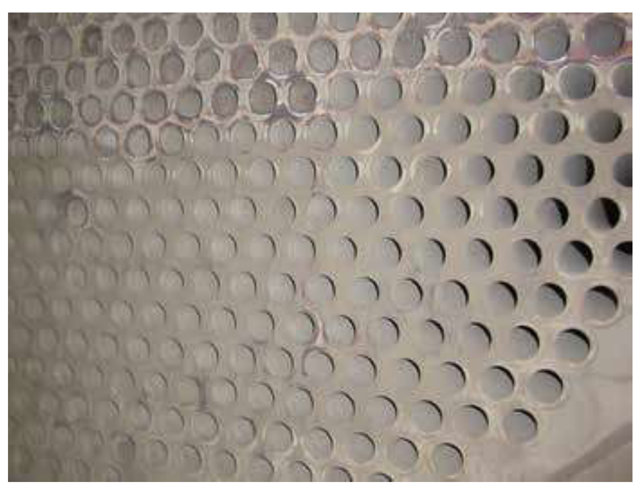

Figure 2. View of a clean heat exchanger.

professionals must determine whether the crack may be tolerable for a certain period to be defined. This may be the case if risk analyses and modern test methods show that continued crack propagation is not expected for the stresses on hand. However, the component concerned should be monitored continuously. Generally, it can be said that no power plant is completely free from faults. Given this, the principle of "having to live with faults" forms a legitimate part of a qualified overall assessment.

Individual strategies instead of silver bullets

Maintenance differs fundamentally from remediation and repair. Every maintenance strategy aims at maximising plant availability and ensuring high levels of operational and process safety. This requires timely identification and evaluation of any weaknesses in the plant before they cause operational interruptions. However, which is the right strategy? Which strategy offers the best cost/benefit ratio? And how to reliably determine the actual risk and the acceptable tolerance limits? There is no silver bullet for these challenges. In addition, even developed strategies cannot be simply transferred from one plant to the next because power stations are complex systems and differ too much in terms of their age, condition and mode of operation.

Fundamental maintenance strategies

These approaches are developed on the basis of various established and new maintenance strategies. In the field, none of the strategies outlined below will be used on its own. Instead, the measures will be coordinated and aligned to the plant's state of repair and mode of operation.

Conventional maintenance strategies include failure recovery as well as preventive, condition-based and predictive maintenance. In *failure recovery,* the plant will be operated until one of the machines fails. While this purely reactive strategy with no conceptual framework admittedly keeps maintenance efforts and costs to a minimum, it involves a high risk of unforeseeable plant failure, and the downtime associated therewith may prove very expensive.

Preventive maintenance means that maintenance staff will carry out standardised maintenance activities at pre-defined intervals, during which plant components will be replaced as planned and sometimes even before reaching their wear limit. This maintenance strategy largely prevents unscheduled downtimes. However, premature replacement of spare parts may cause "excessive maintenance" and the additional costs associated therewith. These drawbacks can be avoided by opting for *condition-based maintenance*, in which plant components are monitored for their condition and examined for the damage potential. However, this again generates higher costs incurred by the implementation of appropriate monitoring options and the organisation of staff training.

Figure 3: Heat exchanger similar to Figure 2 with major fouling and slag formation caused by the fly ash in the flue gas due to excessive temperatures (same effect as in Figure 1).

Companies are increasingly relying on risk-based strategies to evaluate whether defects and their associated risks can be tolerated. The two main forms of risk-based strategies are *risk-based maintenance (RBM)* and *reliability-centred maintenance (RCM)*

Predictive maintenance is an active maintenance strategy with a conceptual framework. Plants are inspected in a targeted manner to identify potential defects, which are then remedied promptly. However, the measures involved are very time-consuming and make high demands on the maintenance staff. As in condition-based maintenance, experts must check on a case-by-case basis whether the benefits delivered will cause the scheme to break even within a reasonable period and thus justify the higher costs.

Risk assessment and evaluation

Companies are increasingly relying on risk-based strategies to evaluate whether defects and their associated risks can be tolerated. The two main forms of risk-based strategies are *risk-based maintenance (RBM)* and *reliability-centred maintenance (RCM)*. Risk-based maintenance aims at reducing maintenance efforts while taking into account and complying with defined safety standards. To do so, the experts identify and prioritise the possible failure risks of the entire plant and/or individual components. On the basis of an "importance analysis", the areas and components of the plant that involve the highest risk of failure are then addressed with the highest priority. However, in thermal power stations the interactions between the individual units and components are complex in nature and require a systematic and practice-focused approach. Field experience shows that not all companies adopt such an approach.

Reliability-centred maintenance (RCM) focuses not on determining the risk of failure, but on identifying possible malfunctions and their consequences. The results will then be used to determine which maintenance strategies are the most suitable for increasing plant reliability and under which framework conditions, while reducing the costs incurred by maintenance processes.

Detailed view of the heat exchanger shown in Figures 2 and 3.

Maintenance as a continuous improvement process

Total productive maintenance (TPM) was developed in Japan. Going beyond conventional maintenance, it covers the entire production process in the sense of a continuous improvement process. The TPM system is reviewed on the basis of performance indicators, with the key performance indicator being total plant efficiency as a benchmark of value-added. Another essential element of TPM concerns the continuous involvement of production staff who independently carry out routine maintenance activities in their plant areas. In addition, the production staff is instructed to identify component wear independently and initiate preventive actions, if necessary, to avoid malfunctions and quality losses. This *continuous improvement process (CIP)* eases the workload of the actual maintenance team, so that the persons in charge have more time for addressing focal problems and strategic issues. However, for the TPM approach to function, management must implement it as a top-down change management process and must act as a role model, exemplifying this approach in practice.

HR management – a key success factor

Irrespective of the approaches included in a company's maintenance strategy, qualified human resources and well-functioning organisational structures are paramount for achieving the objectives the company has set itself. Maintenance has evolved from a mere support service to a modern system-related service. It has become a value-adding process for companies, which involves high demands and growing responsibility. Correct HR management is one of the success factors for meeting this responsibility. Creativity and a solution-oriented approach are as much in demand as are engineering expertise and profound knowledge of the plant. Lead engineers must keep their staff motivated by implementing measures such as a defined scope for independent decision-making. Also they have to be able to accept risks and take on responsibility.

Future-oriented strategies

A maintenance strategy customised to a company and a plant requires system-related knowledge and an integrated approach. It must take operating conditions and the plant's state of repair into consideration, but also potential sources of faults and defects. Maintenance experts support companies within the scope of an overall assessment and assist in determining the key influencing parameters and damage mechanisms. For this assessment, they rely on both deterministic and probabilistic tools. In addition, they use non-destructive testing during ongoing operation, fracture mechanics and the finite element method. Based on qualified data, they can make reliable statements as to how long the operation of certain plants and components may be continued without interruption, and thus determine the best maintenance strategy for realising safe and profitable plant operation at maximum availability ◂◂

Deterministic or Probabilistic?

A frequent question in maintenance is whether the approach should be deterministic or probabilistic. A deterministic approach is based on the assumption that there are clear causal, "if-then" relationships. If x happens, y will result. These approaches, while having proved their worth from the perspective of safety technology, have repeatedly resulted in excessive maintenance measures because of the safety factors that must be observed in design.

Probabilistic approaches, by contrast, are based on probabilities, and quantify risks on the basis of their frequency of occurrence and their consequences. These approaches allow for prioritisation of measures and reduction of consequences. However, the downside includes uncertainties concerning the quality of the input data, and the high costs and efforts involved in complex events and fault-tree analyses.