Evaluation of Risk Based Maintenance Procedures and Best Practice Guidelines for Power Industry

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EXECUTIVE SUMMARY

The electricity generation industry has changed significantly in the past two decades or more. There has been an increase in shareholder demand for higher profits and more stringent statutory requirements. There is also considerable financial risk because of the possibilities of major plant failures due to the change in the mode of operation from base load to cycling. This underscores the need for power plants to focus their efforts on areas of high risk within their business. As a result, there has been increased interest in a 'risk-based management' approach to address these challenges and avoid market penalties.

Risk-based maintenance/management (RBM) is a useful tool for understanding plant issues and potential consequences of various risks. It is necessary for plant management to know the potential risk of future incidents in various power plant areas (e.g., boiler tubes, headers, main steam line systems, steam turbines, gas turbines, etc.). Numerous methods for addressing risks in the power industry have been developed. This study critically reviews and assesses the current status of the risk-based management approach for the optimisation of maintenance in thermal power plants (both conventional and combined cycle) to understand the potential application areas, the limitations and the benefits offered by these methodologies. The fundamental concept behind risk-based inspection, testing and maintenance is that the effort and cost devoted to these activities should in some way be regulated according to the benefit gained and that benefit should be measured in terms of the likely cost of the events which these activities are designed to avert. It is thus a cost-benefit analysis which allows various strategies to be compared.

The operation of a fossil power plant to deliver market needs involves considerable risks. Balancing inspection costs with safety and regulatory compliance can only be achieved by understanding the financial and physical risks that equipment poses to a plant and its operating staff. The report begins by presenting an overview of various existing maintenance ideologies, such as reactive, preventative, predictive and proactive maintenance. Reactive maintenance is an unplanned maintenance activity that is a response to sudden failure or breakdown. All other maintenance types fall within the planned maintenance category as the maintenance activities can be planned in advance according to the specific programme requirements. One of the main objectives of a power plant is to avoid reactive or unplanned maintenance in the event of failure or serious damage to components as this will result in significant losses in plant productivity due to the unplanned shutdown.

At the beginning of a plant's commissioning period, the OEM staff is often involved in the major maintenance activities. Sometimes there may be a long-term agreement with the OEM for maintenance (with or without warranty conditions) for perhaps five to ten years after commissioning. In some cases, smaller power companies may rely on the manufacturers' support for the whole life of a plant, if they do not have sufficient maintenance expertise within their organisation. This type of maintenance is mainly time-based and is known as *preventative maintenance.* This approach can be costly as it can result in over-maintenance. There are other types of maintenance programmes. For example, a plant may need to perform *reactive maintenance* (unplanned) when there is a sudden failure or breakdown. Reactive maintenance can be very costly as serious damage can occur to nearby equipment with the risk to life; it can

also result in very costly lost production during the peak period of demand. The other two types of maintenance are *predictive* and *proactive maintenance*, which are more beneficial, as this type of maintenance can predict failures from the equipment's true condition and thus one can carry out repair, replacement, or other palliative measures during a planned shutdown. For this type of maintenance, some sort of inspection or monitoring of the critical equipment is necessary in order to be able to forecast an imminent incident. A relatively recent trend is to monitor the performance of the plant equipment continuously through digital monitoring and diagnostic centres.

During the first few years of power plant operation, the general maintenance programme is often governed by the requirements to keep the plant condition within the terms of warranty offered by the original equipment manufacturer (OEM). This type of maintenance is known as preventative maintenance and can be performed as the monthly, quarterly, semi-annual, or annual maintenance programme as recommended by the OEM or as decided by the utilities. The advantages of preventative maintenance include controlled maintenance activities, improved equipment performance and reliability, reduced failures and reduced safety risks. The main disadvantages are that it does not consider the equipment's true condition and cannot enable early detection of failures as the maintenance is mostly time-based. Predictive and proactive maintenance programmes can also be planned in advance and have advantages similar to the preventative maintenance programme. Additionally, in these maintenance programmes, early detection of failures is possible and the maintenance activities are mostly condition-based and therefore more cost effective. Risk-based maintenance (RBM) and reliability-centred maintenance (RCM) fall under proactive maintenance as these maintenance programmes determine the root causes of the problems or issues.

In a power plant there are various types of equipment operating under a variety of conditions. Some pose a very low threat to business and safety, while others pose a very high risk. The concept of *risk-based maintenance* takes the level of risk into account. Risk-based management programmes for utilities have generally been prepared to achieve higher plant availability and reliability targets by identifying and managing potential events that may affect equipment operation. The modern approach used by most utilities is to manage risk rather than avoid risk at all cost on the basis that there is a correlation between risk and reward. The main objective of RBM is to provide a framework to identify the risk areas, quantify the levels of risk and thereby optimise the use of available resources. The pros and cons of various RBM procedures and tools are discussed in Sections 3 and 4 of the report, with a brief of some practical case studies in Section 5. Various established risk assessment procedures are available in the existing market such as API 580 and 581, European RIMAP (European Standard EN16991:2018), ASME PCC-3-2017, and ASME CRTD Vol. 41. The basic concepts (the basis of a risk assessment procedure) of all of these procedures are more or less similar, such as the determination of probability and consequence of failure and the use of a risk matrix for the evaluation of the risk assessment results. The only differences are in the actual analysis process and/or in the risk assessment results presentation or sometimes in the assumptions of acceptable risk and the size of the risk matrix. In all of these procedures, risk can be shared, accepted, or treated using appropriate mitigation plans. Section 3 also discusses ETD's 'RiskFit' RBM procedure that was specifically developed for power plants. The 'RiskFit'

procedure follows all processes of a best practice RBM programme including the application of ‘management level’ and ‘implementation level’ steps.

In terms of power plant maintenance and management, the most popular methodology is the ‘risk-based management’ (RBM) approach as it puts a value on each risk and lets the plant operator/owner determine which component needs the most attention at any given time. Successful implementation of an RBM programme can be achieved by managements’ commitments, regular monitoring and updating of the programme. Section 6 provides a detailed discussion of a best practice RBM programme with a step-by-step process for its development and implementation. The main steps of a well-developed RBM programme are to establish business goals, identify and categorise risk, analyse risk, evaluate and mitigate risk.

A recommended best practice risk-based management (RBM) programme has been summarised in Section 7. A well-developed RBM programme should include important steps such as specifying business goals and objectives, identifying all potential risks, categorising and analysing risk, evaluating and mitigating risk, and monitoring the performance of the RBM programme. The formation of a multidisciplinary team with the necessary qualifications and skills is a key step for the control and successful implementation of an RBM programme. This recommendation can be used to develop a complete RBM programme for utilities that do not have one, or to improve an existing programme.

It is established from the overall report contents that risk-based inspection as well as maintenance is an integrated, data-based methodology that factors risk into inspection decision making. It includes progressive qualitative and quantitative processes for managing plant assets on the basis of risk, thus including consideration of both the probability and consequences of failure. The process is fully systemic, establishing and prioritising risk levels for each piece of equipment. It is also ‘evergreen’, allowing continuous updating of risk levels as circumstances alter or understanding or knowledge is improved. By considering both probability and consequence, the risk drivers are clearly identified, thus enabling appropriate strategies for risk reduction to be identified and implemented.

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