# Condition Based and Risk Informed Management for Power Plant Efficiency

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## 1. Introduction

The efficiency management of power plants is an obvious and tedious topic, but it is still one of the most important pending issues. Efficiency management is not a difficult discipline in terms of academic standard. However, we can realize how we are lack of knowledge from the viewpoint of field practice. Nowadays, utilities are trying to strictly manage plant efficiency because of cost competitiveness with other energy resources. Efficiency management can be widely characterized from the replacement of hardware to the optimization of operation and maintenance using the advanced IT technologies.

In this paper, we will overview the advanced efficiency management strategy, which is based on the IT technologies. We named the strategy as condition-based risk-informed efficiency management. This strategy aims at the implementation of predictive as well as proactive maintenance considering the risk in terms of cost.

## 2. Methods

For the success of a condition-based risk-informed maintenance, we suggest three modules: Monitoring, Diagnosis, Prediction and Decision Module. Figure 1 shows relations between modules.

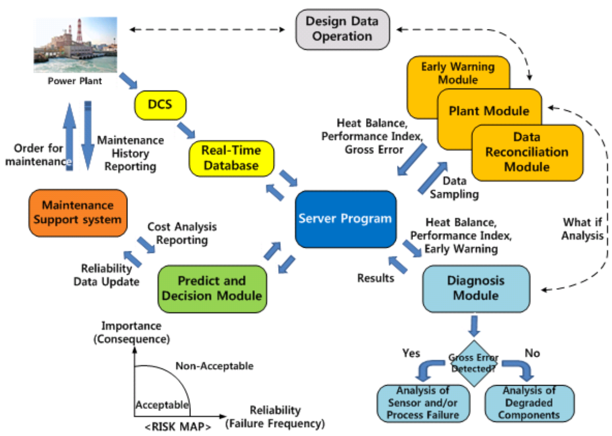


**Figure 1. Framework of plant efficiency management strategy**

### *2.1 Monitoring Module*

The monitoring module calculates system-and/or component-level performance indices and associated heat balance employing reconciled data for noticing to users what significant changes take place in major performance indices. This module is composed of three parts: Data Reconciliation, Plant Model and Early warning.

#### *2.1.1 Data Reconciliation*

The data from sensors can have random and/or gross errors. These errors make results incorrect. To solve problems, the data should be filtered by reconciliation process. Physical models and empirical models can be considered for this process. However, in our experience, the physical model method is better because it is deterministic and can be also used in performance calculations. After reconciliation, gross errors are be reported to the server if exists.

#### *2.1.2 Plant Model*

In a plant model, a heat balance diagram and plant performance indices are evaluated by the ASME(American Society of Mechanical Engineers) PTCs(Performance Test Codes), the heat exchanger institute codes, industrial codes and standards, and the first principles used in industry fields. All of necessary data come from the real-time database through the server.

#### *2.1.3 Early Warning*

The early warning module observes the difference, called residual, between an anticipated normal condition and an operational condition. In any situations, it is important that operators should recognize the malfunction of processes before unexpected shutdowns, which is the concept of early warning shown in Figure 2.

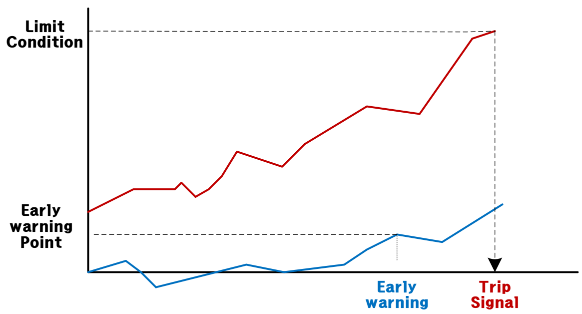


**Figure 2. Difference between early warning and trip signal**

To achieve accurate warning, it is important to accurately predict the anticipated normal conditions. In order to get the anticipated normal conditions, it seems reasonable to apply empirical and physical models together to compensate the disadvantages of each one [1].

### *2.2 Diagnosis Module*

The purpose of the diagnosis module is to detect (1) sensor failures, (2) component failures, and (3) component degradation. The diagnosis works when early warnings are reported to the server module. Under a warning, sensor and/or component failures imply the existence of gross errors, which means the governing equations for mass & energy balance are changed. Otherwise, component degradation represents any other malfunctions while mass & energy balance is keeping.

#### *2.2.1 Sensor and/or Process Failure Detection*

The detection of sensor and/or component failures implies the existence of gross errors, which means the governing equations for mass & energy balance are changed, for instance, due to leak, rupture, significant failure, and so on. It is very hard to recognize the origin of failure; either sensor or process unless enough information is provided. At this time, the decision by operator's knowledge and field oversight seems reasonable from practical viewpoint.

#### *2.2.2 Degraded components detection*

To find degraded components, we suggested a combinational method referred 'What-If' and 'Inverse What-if' method [2]. The what-if method stands for the sensitivity study upon the variation of failure modes for individual component. For this process, we need a plant model that can simulate off-design conditions. The plant model in the monitoring module can be utilized.

The inverse what-if method is a kind of expert system to search the probable root cause using the results of the what-if method and the system- or component-level performance indices. Since the search algorithm is not matured, we are investigating this topic in the separate R&D project.

### *2.3 Prediction and Decision Module*

In this module, the residual life time of components is estimated and the risk map is determined for individual component, which ultimately supports the maintenance support system.

#### *2.3.1 Prediction of Residual Life Time*

This is strongly associated with proactive maintenance for material degradation. Recently the attempts for the information fusion of deterministic degradation mechanism and statistical condition monitoring have been proposed and being conducted. From practical viewpoint, there still seems no commercialized solution for power plants, so it is expected to study more.

#### *2.3.2 Risk Map*

The risk map helps operators to decide maintenance tasks which are associated with, what components should be replaced or maintained upon risk; the leverage between the cost for maintenance and profit from efficiency increase.

The maintenance support system works with prediction and decision module. The function of the maintenance support system is to deliver maintenance orders informed from the prediction and decision module and to update the risk map after maintenance crews' key in about maintenance information.

## 3. Conclusions

This study was motivated by the need of an advanced efficiency management strategy for power plants. In 2002, IAEA has already noticed the streamlined reliability-centered and condition-based maintenance would be the major technical trend in maintenance practice. Recently, many of utilities have begun to develop their own efficiency management systems. However, we have concerns on overlapping investment, adoption of immature technologies, misunderstanding the capability of methodologies. We expect the paper can be a guideline to those who have interest in developing an efficiency management strategy regardless of system's category.

## ACKNOWLEDGEMENT

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