Total Solution Services for Advanced Maintenance of Thermal Power-generation Plants

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OVERVIEW: As a result of the tougher global competition brought on by the liberalization and deregulation of power generation, power-generation companies and new entrants into the power market such as IPPs (independent power producers) must meet strong demands to reduce maintenance and repair costs if they are to gain the upper hand over the competition. Furthermore, it is becoming increasingly necessary to guarantee plant reliability and economic efficiency in order to improve plant utilization rates. In response to these demands, Hitachi Group is offering "total solution services" for optimizing the life cycle of an entire power-generation plant. In place of the conventional maintenance work performed separately on each machine throughout a plant, our new "solution services" provide completely integrated maintenance coverage — including equipment maintenance, management, and operation — for the whole plant.

INTRODUCTION

IN recent times, maintenance engineering for thermal-power-plant facilities has been undergoing a transition from time-based management to condition-based management and risk-based management that take into account long-term benefits. At the same time, the business model for maintenance engineering has been moving rapidly away from the conventional way of selling one-off items toward so-called retrofitting of other companies' equipment and long-term service

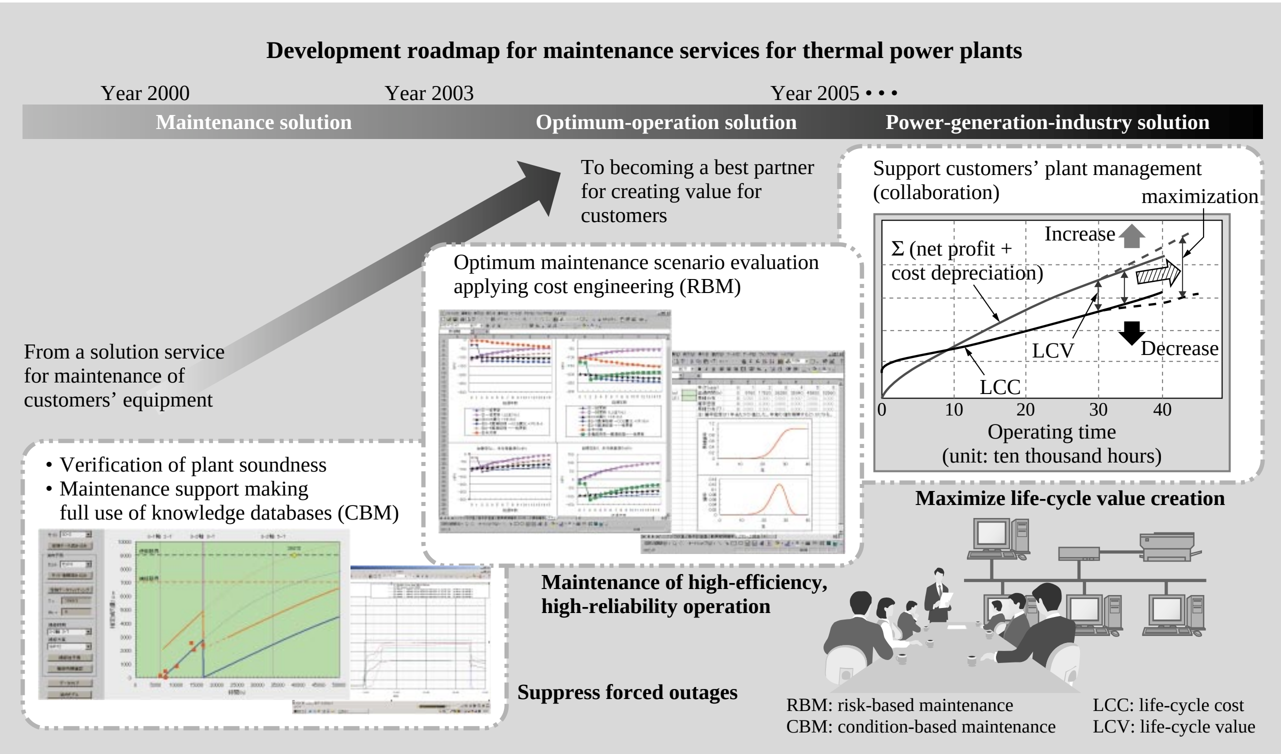

Fig. 1—Hitachi Group's "Total Solution Services" for Preventative Maintenance of Thermal Power Plants.
Making full use of IT combined with our technical skills fostered by manufacturing, Hitachi is aiming at becoming a "Best Solutions Partner" of customers.

agreements as well as toward maintenance and repair services outside their usual scope. Moreover, on top of tougher global competition, demands for machinery and services providing outstanding economic efficiency, reliability, and environmental sustainability are growing stronger.

Under these circumstances, as well as working toward increasing the performance of individual machines, Hitachi is providing “total solution services” to cover the maintenance, management, and operation of these machines. These are new services that utilize recent advances in IT to optimize the life-cycle cost of power-plant machinery. As the “Best Solutions Partner” of customers, Hitachi is currently promoting these services on a global scale (see Fig. 1).

The rest of this paper first describes our solution-services-oriented maintenance technologies and systems developed for power-plant machinery, and then outlines the future developments of these technologies.

RISK-BASED MAINTENANCE SATISFYING BOTH IMPROVED RELIABILITY AND ECONOMIC EFFICIENCY

Over recent years, maintenance methods that decrease costs while ensuring reliability have become strongly demanded. As a response to this demand, RBM (risk-based maintenance) is being applied. RBM — based on failure risk defined as the product of the degrees of failure probability and influence of failure — is a process that analyzes equipment conditions and dictates exact maintenance measures.

By approaching maintenance of equipment through “life cycles,” Hitachi has been engaged in optimization of maintenance that combines reliability with economic efficiency. As a result, we have developed a maintenance-planning procedure that introduces a financial-engineering-type technique into RBM, and applied this procedure to the low-pressure rotor of an aged steam turbine.

A low-pressure turbine — which contains numerous long blades in a large main body rotating at high speed — is a important piece of equipment that dominates the overall performance of a steam turbine. In recent years, however, cases of damage to aged low-pressure rotors caused by corrosion fatigue have been increasing. Accordingly, the damage is inspected, and loading factors and environmental factors are examined. It can be understood from these examination findings that changes in blade vibration response caused by aging and growth of corrosion pits increase the probability of crack initiation.

Procedures for evaluation of reliability based on the probability of failure of a steam-turbine low-pressure rotor and for risk assessment considering economic efficiency of maintenance are shown in Fig.

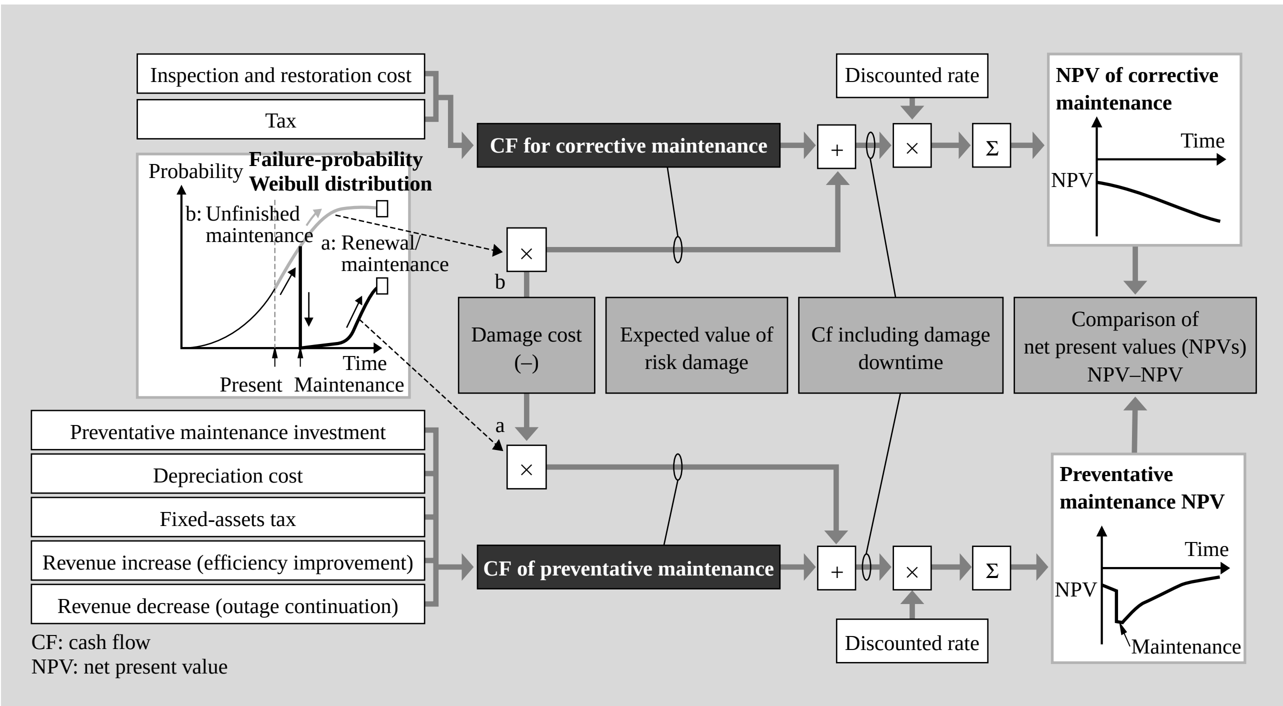

Fig. 2—Overview of RBM Procedure for Optimizing Economical Efficiency and Reliability of Maintenance.
RBM applies risk-assessment procedures considering reliability evaluation and economical efficiency.

2. This figure expresses the NPV (net present value) defined as the difference between the cost and the benefit in the case that preventative maintenance is carried out and in the case that it is not carried out (i.e. corrective maintenance). Risk is quantified by defining it as the product of failure probability and the amount of damage caused by failure. This value is equivalent to the amount of damage that can be expected. NPV is calculated by integrating benefits concerning target machines in each maintenance period, loss in respect to failure rate, and CF (cash flow) — made up from maintenance investment — divided by a discount rate. By using this calculation, optimum maintenance measures can be chosen in response to the different operation plans for each generator set and operating condition, and the appropriate implementation period for such measures can be assured. The effect of the maintenance is worked out on the basis of the cost and the gain, and expressed quantitatively as a risk in terms of NPV. This result is then used in the decision-making process for determining the capital investment in preventative maintenance for machine repairs and renewal so that an optimum maintenance plan can be drawn up.

There are three possible scenarios regarding the maintenance of an aged low-pressure rotor:
(1) complete renewal of the rotor;
(2) refitting with a new blade configuration — i.e. CCB (continuous cover blade) — and skin-cut treatment to parts of interest as repairs;
(3) maintenance measures determined according to the amount of risk, i.e. NPV.

In scenario (3), the cost and gain are evaluated on the basis the failure probability and loss (which depends on fuel cost, power unit cost, utilization ratio, restoration cost, etc.) from scenarios (1) and (2), and the amount of risk (NPV) — including a time value — is determined. The change in NPV against time (in years) for each maintenance scenario is plotted in Fig. 3. According to this figure, since the failure probability is high in the case of an aged low-pressure rotor, compared to maintenance by repairs, complete rotor renewal is a more effective maintenance measure from the viewpoint of risk assessment.

This quantitative risk assessment based on NPV can also be applied to evaluate the risk when selecting maintenance scenarios for aged equipment. That is, in the case that maintenance measures are delayed when a failure occurs, two model scenarios can be evaluated: a retroactive scenario (i.e. complete renewal after a failure) or a preventative scenario (i.e. complete renewal before a failure). In this manner, the advantages of preventative maintenance scenarios for aged equipment can also be economically ascertained.

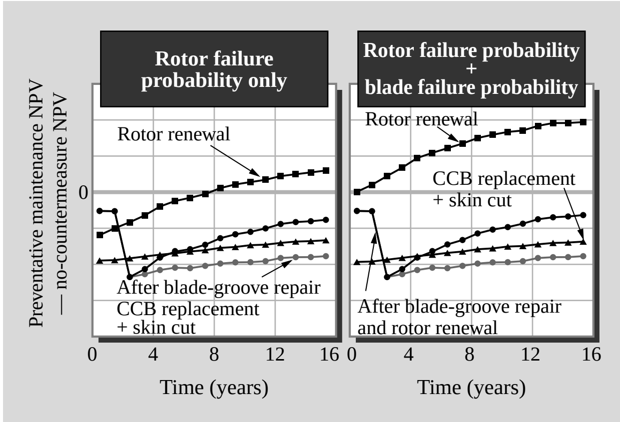

Fig. 3—Example of RBM Evaluation for Maintenance Scenarios Involving Low-pressure Rotor of Aged Steam Turbine.
By means of risk assessment for a maintenance scenario, effectiveness of maintenance can be quantitatively evaluated.

To sum up this section, as regards maintenance of aged thermal-power-generation equipment, preventative maintenance — i.e. preventing losses before they occur — that rationalizes risk in terms of reliability and economic efficiency was demonstrated. Moreover, as a concrete example of risk assessment applying financial-engineering-like procedures to determine optimum preventative measures and their appropriate timing, scenarios concerning a low-pressure rotor of a steam turbine were presented.

STEAM-TURBINE RETROFIT TECHNOLOGY FOR IMPROVED EFFICIENCY AND INCREASED POWER OUTPUT

In recent years, from the viewpoint of the global environment, it is not only necessary to focus on lowering fuel costs but also to address the needs to improve efficiency and increase power output of existing thermal-power-generation facilities that have arisen in response to tougher CO_2 emission regulations and liberalization of power generation.

In response to these needs, Hitachi has been developing high-efficiency turbine blades and diaphragm nozzles. That is to say, we have developed a blade for use as a low-pressure last-stage blade — called a CCB — with high reliability and high efficiency, and by expanding the application of our "retrofit technology" (i.e. reconstruction applying the latest high-efficiency, high-reliability technologies), we are also applying CCB technology to blades other

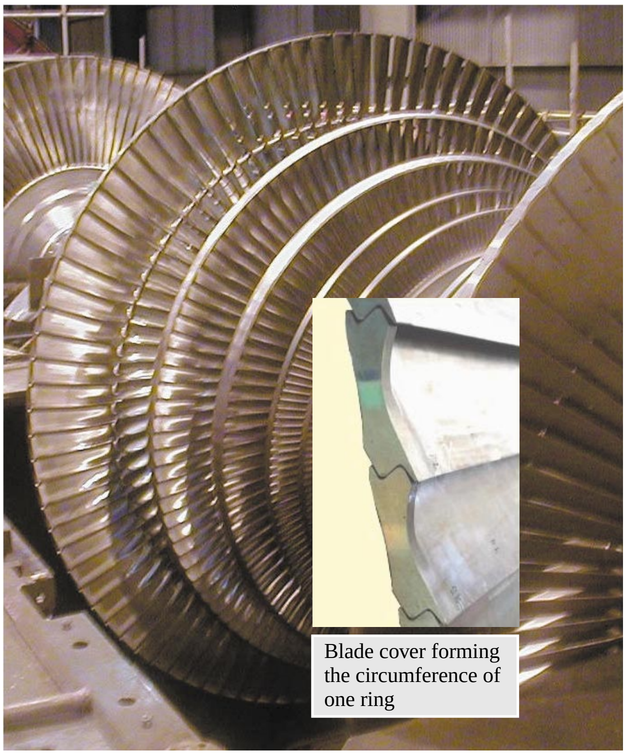

Fig. 4—External View of Low-pressure Rotor Utilizing CCBs for All Blade Stages.
It shows an example of reverse engineering using retrofit technology for a non-OEM (original equipment manufacturer) machine.

than last-stage ones — namely, early- and mid-stage blades.

In the case of existing thermal-power-generation facilities in countries where liberalization of power generation is advancing, the demands for improved efficiency and power output are growing strongly; for example, we recently reconstructed an existing 500-MW low-pressure turbine (50 Hz).

In the case of existing turbines, defects in low-pressure rotors (disk-thermal-shrinkage type) due to SCC (stress corrosion cracking) and reduction of efficiency and output power due to aging can be seen, and problems are occurring from the viewpoints of both reliability and operability. For these reasons, a low-pressure rotor utilizing low-pressure-stage CCBs for all stages and a single-body rotor without the thermal-shrinkage configuration were modified by applying retrofit technology utilizing a high-efficiency diaphragm (i.e. low-pressure section modification). The relative performance after the modification was improved by 4.8%; in other words, the efficiency of low-pressure turbine modified by retrofit technology significantly exceeded that achieved up till now, thereby gaining full customer satisfaction (see Fig. 4).

Since the unit in Fig. 4 is not an OEM (original equipment manufacturer) machine, when devising the modification design and installation plan, actual measurements of dimension and confirmation of machine conditions were performed at the site. Reverse engineering of the unit was then performed according to the results of these investigations. In the future, aiming at better measurement precision and shorter on-site measurement periods, we are striving for further improvements in on-site technologies.

"SOLUTION SERVICES" UTILIZING IT FOR OPTIMIZATION OF MAINTENANCE

Focusing on our overseas customers, Hitachi is already providing solutions to technical problems over the Internet. This "answer service" — set up to cover all preventative maintenance departments of thermal power plants — provides information concerning the latest operation and maintenance conditions.

Moreover, new entrants into the power-generation market, such as IPPs (independent power producers) and power producers and suppliers, as well as overseas customers are increasingly entering into LTSAs (long-term service agreements) lasting for 10 to 15 years. Such LTSAs state that operation records must be kept and monitoring, examination, and management of maintenance data must be performed for a target plant over the specified period. To meet these requirements, Hitachi is establishing a monitoring center, and operation of part of this facility has already started (see Fig. 5).

Regarding normal operation of this service, analog and digital data from control devices in a power plant are sent to the monitoring center over the Internet, and the diagnosis function of the center-side server automatically monitors and diagnoses signs of abnormalities. Plant soundness is confirmed by sending the diagnosis results to client PCs set up in the customer's relevant departments. The results are then compiled as a periodic report by our quality assurance department and sent to the client at a later date.

In the event that a defect or fault is detected, a full-time connection is requested from the center side, and restoration support is given on-line while the site conditions are checked out. In this way, the reduction in the utilization ratio of the client's facilities is curbed.

As security measures to ensure secure data transmission, firewalls are set up on both the plant side and monitoring center side, and data is transmitted and received by means of an artificial exclusive-use circuit

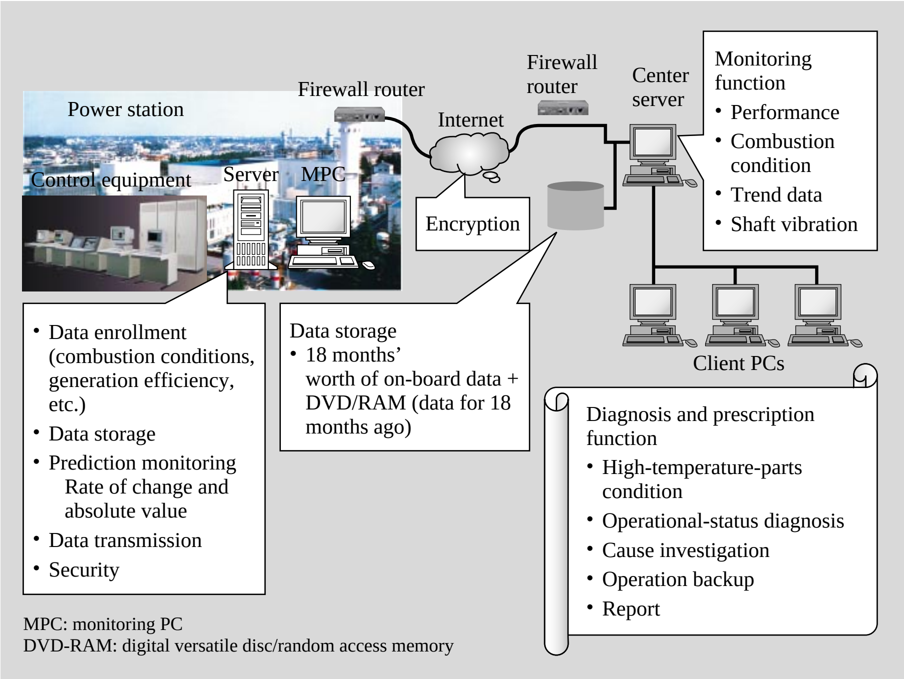

Fig. 5—Overview of Remote-monitoring System.
Analog and digital data from control devices are accumulated at the Hitachi Monitoring Center via the Internet and used to monitor and diagnose plant soundness and abnormalities.

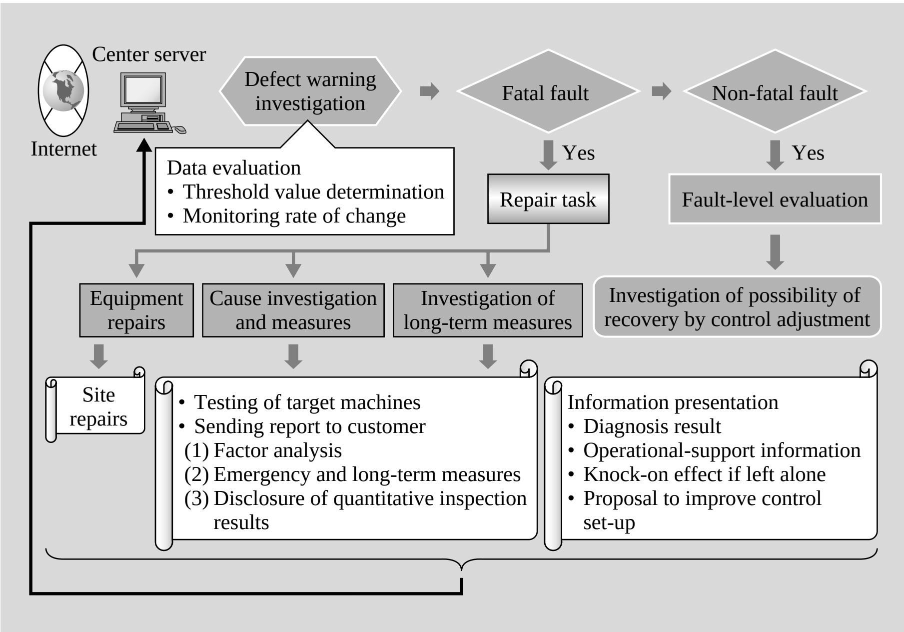

Fig. 6—Process Flow of Monitoring and Diagnosis.
Based on plant information obtained by monitoring devices, the system diagnoses soundness and abnormalities, and when it detects warning signs, it assists cause investigation and fault restoration.

— provided by a VPN (virtual private network) — in conjunction with data encryption.

In regards to remote-monitoring systems, as well as monitoring of plant status during operation, status monitoring during test operations of facilities and test-operation coordination assistance after major inspections are provided. As a result of these services, the test-operation period is shortened, and the time required for producing test-result reports becomes less.

Furthermore, applying our basic know-how concerning stable operation of Hitachi's established power-generation equipment and our abundant test results from factory testing, we are devising rules for cause investigation. In particular, we are preparing a diagnostic function that uses a statistical simulator applying design tools developed by Hitachi and a dynamic-characteristics simulator including implementation control logic. This function enables actual data to be directly retrieved from the monitoring system's database and compared with the simulation results (see Fig. 6).

From now on, by combining our high-temperaturecomponent lifetime-evaluation technology, our know-how gained up till now concerning repair technology and materials development, and our database of results gathered from previously developed plants, we plan to supplement our plant-monitoring services with a drafting function that will provide optimum preventative-maintenance plans for minimizing the life-cycle cost of power plants.

CONCLUSIONS

Focusing our efforts on meeting the changing needs of customers in line with the liberalization, deregulation, and globalization of power generation, we have developed “solution services” — namely, maintenance technologies and systems — for preventative maintenance of power-generation facilities. From now on, Hitachi Group will strive to make further qualitative improvements to our “total solution services” — by fusing IT and our core technologies for manufacturing.

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